E. coli, Phased Benthic, and Phased Total PCB TMDL Development for Levisa Fork, Slate Creek, and Garden Creek

Levisa Fork:
E. coli, Benthic, PCBs

Slate Creek:
E. coli, Benthic

Garden Creek:
PCBs

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Submitted by:

MapTech, Inc.
3154 State Street
Blacksburg, VA 24060

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PREFACE FOR VIRGINA'S PHASED RESOURCE EXTRACTION TMDLS: LEVISA FORK

Phased Benthic and Phased Total PCBs

In order to meet the U.S. Environmental Protection Agency's (EPA) May 1, 2010 deadline, Virginia agencies have been working diligently to complete Total Maximum Daily Load (TMDL) studies for the Levisa Fork watershed. The following draft report represents the product of the state's efforts to date. During development, uncertainties regarding data and predictive tools were identified and help with the TMDL solicited. The U.S. Office of Surface Mining, EPA, and private contractors provided assistance, but some concerns regarding the sufficiency of the available data's ability to determine pollution load reductions and the adequacy of the predictive tools being utilized remain. Therefore, the report is being presented as a "Phased" TMDL in accordance with EPA guidance and the state will utilize an adaptive management approach.

A revised TMDL document is planned for submittal to EPA two years from the date that both the EPA Region III has approved and the Virginia State Water Control Board (SWCB) has adopted the "phased" TMDL. Virginia Department of Mines, Minerals, and Energy's Division of Mined Land Reclamation (DMLR) will take the lead role with the revisions.

Adaptive implementation is an iterative implementation process that moves toward achieving water quality goals while collecting, and using, new data and information. It is intended to provide time to address uncertainties with TMDLs and make necessary revisions while interim water quality improvements are initiated.

A monitoring plan and experimentation for model refinement will be implemented by the Virginia Department of Environmental Quality (DEQ) and DMLR during the period of time beginning with the submittal to EPA of this DRAFT until the preparation of the revised TMDL submittal to EPA.

The follow interim actions will be implemented immediately upon both the approval of the TMDL by EPA and adoption of the TMDL by the SWCB:

DMLR will utilize its existing TMDL processes and software to maintain or decrease existing pollution wasteloads from active mining for sediment (TSS). DMLR will also restrict additional mining, through the use of offset requirements, to collective pollution loads equal to or below current wasteloads.

All Waste Load Allocations in this TMDL will be effective and implemented by DMLR. EPA regulations require that an appropriate TMDL include individual WLAs for each point source. According to 40 CFR §122.44(d)(1)(vii)(B), Effluent limits developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, shall be consistent with assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA pursuant to 40 CFR §130.7.

Although additional monitoring data, modeling refinements, allocations for pollutants, and long term implementation actions will be part of the revised TMDL, on-going, long-term efforts to improve the watershed as described below will continue.

The elimination or reduction of pollution loads from abandoned coal mined lands (AML) is typically necessary for the state to meet the allocations prescribed in Virginia's resource extraction TMDLs. DMLR's efforts to eliminate and reduce pollution from AML will continue in the TMDL watershed.

DMLR will utilizes AML Program Funding, including the U. S. Office of Surface Mining's annual AML grants, Clean Streams Initiative, and Acid Mine Drainage set-aside provisions, to remediate AML problems within the watersheds.

DMLR recognizes that assistance is needed with AML reclamation and will encourage assistance from Virginia's active coal mining industry. Several approaches, consistent with this recognition, will be implemented including re-mining, Rahall permits, AML enhancements, and TMDL offsets.

TMDL offsets will provide for mine discharge permit applicants to reclaim existing AML features within the watershed to create a water pollution offset for proposed coal mining activity. The offsets will be required to contain a positive ratio for pollution reduction and to eliminate permanent pollutant sources for temporary pollution credit.

CONTENTS

ACKNOWLEDGEMENTS i

PREFACE FOR VIRGINA'S PHASED RESOURCE EXTRACTION TMDLs: Levisa Fork iii

CONTENTS v

FIGURES xiii

TABLES xxiii

EXECUTIVE SUMMARY xxxi

Background and Applicable Standards xxxi

TMDL Endpoint and Water Quality Assessment xxxi

Modeling Procedures xxxii

Hydrology xxxii

Fecal Coliform xxxii

Sediment xxxiii

tPCBs xxxiii

Load Allocation Scenarios xxxiii

Implementation xxxiv

Public Participation xxxv

1. INTRODUCTION 1-1

1.1 Regulations Background 1-1

1.2 Levisa Fork Watershed Characteristics 1-2

1.3 Levisa Fork Watershed Impairments 1-4

1.3.1 Slate Creek 1-4

1.3.2 Garden Creek 1-5

1.3.3 Levisa Fork 1-5

2. BACTERIAL TMDL ENDPOINT AND WATER QUALITY ASSESSMENT 2-1

2.1 Applicable Water Quality Standards 2-1

2.2 Applicable Criteria for Fecal Bacteria Impairments 2-1

2.3 Selection of a bacteria TMDL Endpoint 2-3

2.4 Discussion of In-stream Water Quality 2-3

2.4.1 Inventory of Water Quality Monitoring Data 2-3

2.4.2 Trend and Seasonal Analyses 2-13

3. BACTERIAL SOURCE ASSESSMENT 3-1

3.1 Assessment of Permitted Sources 3-1

3.2 Assessment of Nonpoint Sources 3-5

3.2.1 Private Residential Sewage Treatment 3-5

3.2.2 Biosolids 3-7

3.2.3 Pets 3-7

3.2.4 Livestock 3-8

3.2.5 Wildlife 3-10

4. BACTERIAL MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT 4-1

4.1 Modeling Framework Selection 4-2

4.2 Model Setup 4-2

4.2.1 Subwatersheds 4-3

4.2.2 Land uses 4-5

4.2.3 Stream Characteristics 4-8

4.3 Selection of a TMDL Critical Condition 4-10

4.4 Hydrology Modeling 4-12

4.4.1 Selection of Representative Hydrologic Modeling Periods 4-12

4.4.2 Hydrology Calibration 4-15

4.4.3 Hydrologic Validation 4-19

4.5 Bacterial Source Tracking Results 4-22

4.6 Bacteria Source Representation 4-22

4.6.1 Permitted Sources 4-23

4.6.2 Private Residential Sewage Treatment 4-24

4.6.3 Livestock 4-26

4.6.4 Biosolids 4-27

4.6.5 Wildlife 4-28

4.6.6 Pets 4-29

4.7 Water Quality Modeling - Bacteria 4-29

4.7.1 Selection of Representative Modeling Periods 4-29

4.7.2 Water Quality Calibration - Bacteria 4-30

4.7.3 Water Quality Validation - Bacteria 4-35

4.8 Existing Conditions - Bacteria 4-38

5. BACTERIAL ALLOCATION 5-1

5.1 Margin of Safety (MOS) 5-2

5.2 Waste Load Allocations (WLAs) 5-2

5.3 Load Allocations (LAs) 5-2

5.4 Bacterial Total Maximum Daily Loads (TMDLs) 5-3

5.4.1 Levisa Fork 5-4

5.4.2 Slate Creek 5-11

6. BENTHIC WATER QUALITY ASSESSMENT 6-1

6.1 Applicable Criterion for Benthic Impairment 6-1

6.2 Benthic Assessment – Levisa Fork 6-2

6.3 Benthic Assessment – Slate Creek 6-8

6.4 Habitat Assessments 6-13

6.4.1 Habitat Assessment at Biological Monitoring Stations – Levisa Fork 6-14

6.4.2 Habitat Assessment at Biological Monitoring Stations – Slate Creek 6-17

6.5 Discussion of In-stream Water Quality 6-19

6.5.1 Inventory of Water Quality Monitoring Data 6-19

7. BENTHIC TMDL ENDPOINT: STRESSOR IDENTIFICATION – LEVISA FORK 7-1

7.1 Stressor Identification – Levisa Fork 7-1

7.2 Non-Stressors 7-3

7.2.1 Low Dissolved Oxygen 7-3

7.2.2 Nutrients 7-5

7.2.3 Toxics (ammonia, tPCBs, Pesticides, and PAHs) 7-9

7.2.4 Metals 7-9

7.2.5 Temperature 7-9

7.2.6 Field pH 7-11

7.3 Possible Stressors 7-13

7.3.1 Sediment metals (copper, lead, nickel and zinc) 7-13

7.3.2 Sulfate and chlorides 7-17

7.3.3 Organic matter (Total organic solids, total organic suspended solids, total Kjeldahl nitrogen, and chemical oxygen demand) 7-23

7.3.4 Conductivity/Total dissolved solids (TDS) 7-31

7.3.5 Toxics (unknown) 7-37

7.4 Most Probable Stressor 7-38

7.4.1 Sediment 7-38

8. BENTHIC TMDL ENDPOINT: STRESSOR IDENTIFICATION – SLATE CREEK 8-1

8.1 Stressor Identification – Slate Creek 8-1

8.2 Non-Stressors 8-1

8.2.1 Low Dissolved Oxygen 8-2

8.2.2 Nutrients 8-2

8.2.3 Toxics (ammonia, Pesticides, tPCBs and PAHs) 8-4

8.2.4 Metals 8-4

8.2.5 Temperature 8-4

8.2.6 Total chloride 8-5

8.3 Possible Stressors 8-6

8.3.1 pH 8-6

8.3.2 Sulfate 8-7

8.3.3 Organic matter (Total organic solids and total dissolved organic solids) 8-8

8.3.4 Conductivity/Total dissolved solids (TDS) 8-10

8.4 Most Probable Stressor 8-13

8.4.1 Sediment 8-13

9. REFERENCE WATERSHED SELECTIONS 9-1

9.1 Reference Watershed Selection for Levisa Fork 9-1

9.2 Reference Watershed Selection for Slate Creek 9-6

10. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT- SEDIMENT 10-1

10.1 Modeling Framework Selection - GWLF 10-1

10.2 GWLF Model Setup 10-2

10.2.1 Sediment Source Assessment 10-3

10.2.2 Sediment Source Representation – Input Requirements 10-4

10.2.3 Selection of Representative Modeling Period - GWLF 10-11

10.3 GWLF Sensitivity Analyses 10-11

10.4 GWLF Hydrology Calibration 10-13

10.4.1 Levisa Fork – Impaired Stream 10-13

10.4.2 Dry Fork – Reference Stream 10-16

10.5 Sediment Existing Conditions 10-19

11. SEDIMENT ALLOCATION 11-1

11.1 Margin of Safety 11-1

11.2 Future Growth Considerations 11-2

11.3 Slate Creek Sediment TMDL 11-2

11.4 Levisa Fork Sediment TMDL 11-8

12. TOTAL PCB (tPCB) WATER QUALITY ASSESSMENT 12-1

12.1 Introduction to PCBs 12-1

12.2 Levisa Fork Impairments 12-2

12.3 PCB Standards 12-4

12.4 PCB Monitoring Data Inventory 12-6

12.4.1 Fish Tissue Data 12-7

12.4.2 Sediment Sampling Analysis and Summary 12-10

12.4.3 Water Column Sampling Analysis and Summary 12-13

13. TOTAL PCB (tPCB) SOURCE ASSESSMENT 13-1

13.1 Permitted Discharges 13-2

13.2 Nonpoint PCB Sources 13-4

13.2.1 Atmospheric Deposition 13-4

13.2.2 Streambed Sediments 13-4

13.2.3 Known Contaminated Sites 13-4

13.2.4 General Data Trends that show Potential Unknown Contaminated Sites 13-6

14. TOTAL PCBS (tPCBs) MODELING PROCEDURE AND ALLOCATION 14-1

14.1 Model Selection, Model Setup, and Hydrology Modeling 14-1

14.2 PCB transport 14-1
14.2.1 Known and Unknown PCB Spill Sites 14-2
14.2.2 Permitted PCB point sources 14-2
14.2.3 TSS calibration 14-2
14.2.4 tPCB water column calibration 14-7
14.3 Margin of Safety 14-14
14.4 Wasteload Allocations 14-14
14.5 Load Allocations 14-15
14.6 Garden Creek tPCB TMDL 14-15
14.7 Levisa Fork tPCB TMDL 14-19
15. TMDL REASONABLE ASSURANCE 15-1
15.1 Continuing Planning Process and Water Quality Management Planning 15-1
15.2 Staged Implementation 15-2
15.3 Implementation of Waste Load Allocations 15-2
15.3.1 tPCBs 15-2
15.3.2 Stormwater 15-4
15.3.3 TMDL Modifications for New or Expanding Discharges 15-5
15.4 Implementation of Load Allocations 15-6
15.4.1 tPCBs 15-6
15.4.2 Implementation Plan Development 15-7
15.4.3 Staged Implementation Scenarios 15-8
15.4.4 Link to Ongoing Restoration Efforts 15-10
15.4.5 Implementation Funding Sources 15-10
15.5 Follow-Up Monitoring 15-11
15.6 Attainability of Designated Uses 15-13

16. PUBLIC PARTICIPATION 16-1
GLOSSARY G-1
REFERENCES R-1
APPENDIX A A-1
APPENDIX B B-1
APPENDIX C C-1
APPENDIX D D-1

FIGURES

Figure 1.1 Location of the Levisa Fork watershed. 1-2

Figure 1.2 The impaired segments within the Levisa Fork watershed included in this project. 1-9

Figure 2.1 Location of VADEQ water quality monitoring stations in the Levisa Fork watershed. 2-5

Figure 2.2 Location of BST water quality monitoring stations in the Levisa Fork watershed. 2-12

Figure 3.1 Location of VADEQ permits in the Levisa Fork watershed (SW=stormwater; WWT=wastewater treatment). 3-4

Figure 4.1 Subwatersheds delineated for HSPF modeling in the Levisa Fork watershed. 4-4

Figure 4.2 Land uses in the Levisa Fork watershed (combined 2001 MRLC, DMME, DRG data; does not include Active Mining and Reclaimed Mining). 4-7

Figure 4.3 Stream profile representation in HSPF. 4-9

Figure 4.4 Fecal coliform concentrations at 6ALEV130.00in Levisa Fork versus discharge at USGS Gaging Station #03207800. 4-11

Figure 4.5 Annual disturbed and reclaimed land by mining operations in the Levisa Fork watershed. 4-13

Figure 4.6 Hydrology modeling time periods, annual historical flow (USGS Station 03207800), and precipitation (NCDC Stations in Grundy, Hurley, Richlands, Virginia) data. 4-14

Figure 4.7 Hydrology modeling time periods, seasonal historical flow (USGS Station 03207800), and precipitation (NCDC Stations in Grundy, Hurley, Richlands, Virginia) data. 4-14

Figure 4.8 Levisa Fork modeled flow duration for the calibration period 10/1/2000 through 9/30/2003 versus USGS Gaging Station 03207800. 4-17

Figure 4.9 Calibration results for the HSPF model during calibration period 10/1/2000 through 9/30/2003 versus USGS Gaging Station 03207800. 4-18

Figure 4.10 Levisa Fork modeled flow duration for the validation period 10/1/1996 through 9/30/1999 versus USGS Gaging Station 03207800. 4-20

Figure 4.11 Calibration results for the HSPF model during validation period 10/1/1996 through 9/30/1999 versus USGS Gaging Station 03207800. 4-21

Figure 4.12 Example of raccoon habitat layer in the Levisa Fork watershed, as developed by MapTech. 4-28

Figure 4.13 Fecal coliform calibration results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Fork impairment. 4-32

Figure 4.14 Fecal coliform calibration results at VADEQ station 6ASAT000.03 in subwatershed 10 in the Slate Creek impairment. 4-32

Figure 4.15 Fecal coliform quality validation results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Creek impairment. 4-37

Figure 4.16 Fecal coliform quality validation results at VADEQ station 6ASAT000.03 in subwatershed 10 in the Slate Creek impairment. 4-37

Figure 4.17 Monthly geometric mean of *E. coli* concentrations for existing conditions at the Slate Creek impairment outlet (subwatershed 10). 4-38

Figure 4.18 Monthly geometric mean of *E. coli* concentrations for existing conditions at the Levisa Fork impairment outlet (subwatershed 8). 4-39

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 8, Levisa Fork impairment outlet. 5-6

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 10, Slate Creek impairment outlet. 5-13

Figure 6.1 VADEQ water quality monitoring stations on Levisa Fork. 6-3

Figure 6.2 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV130.29 on Levisa Fork. 6-4

Figure 6.3 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV138.19 on Levisa Fork. 6-5

Figure 6.4 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV143.80 on Levisa Fork. 6-6

Figure 6.5 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV151.90 on Levisa Fork. 6-7

Figure 6.6 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV152.46 on Levisa Fork. 6-8

Figure 6.7 Biological, ambient and special study water quality monitoring stations on Slate Creek. 6-9

Figure 6.8 VASCI biological monitoring scores for VADEQ benthic monitoring sweep on Slate Creek in June 1998. 6-10
Figure 6.9 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT000.05 on Slate Creek. 6-11
Figure 6.10 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT000.26 on Slate Creek. 6-12
Figure 6.11 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT007.71 on Slate Creek. 6-13
Figure 6.12 DMME ambient water quality monitoring stations on Levisa Fork. 6-26
Figure 7.1 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV131.52. 7-4
Figure 7.2 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV143.86. 7-4
Figure 7.3 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV152.46. 7-5
Figure 7.4 Total phosphorus concentrations at VADEQ station 6ALEV131.52. 7-6
Figure 7.5 Total phosphorus concentrations at VADEQ station 6ALEV143.86. 7-6
Figure 7.6 Total phosphorus concentrations at VADEQ station 6ALEV152.46. 7-7
Figure 7.7 Nitrate-nitrogen concentrations at VADEQ station 6ALEV131.52. 7-7
Figure 7.8 Nitrate-nitrogen concentrations at VADEQ station 6ALEV143.86. 7-8
Figure 7.9 Nitrate-nitrogen concentrations at VADEQ station 6ALEV152.46. 7-8
Figure 7.10 Temperature measurements at VADEQ station 6ALEV131.52. 7-10
Figure 7.11 Temperature measurements at VADEQ station 6ALEV143.86. 7-10
Figure 7.12 Temperature measurements at VADEQ station 6ALEV152.46. 7-11
Figure 7.13 Field pH measurements at VADEQ station 6ALEV131.52. 7-12
Figure 7.14 Field pH measurements at VADEQ station 6ALEV143.86. 7-12
Figure 7.15 Field pH measurements at VADEQ station 6ALEV152.46. 7-13
Figure 7.16 Sediment copper VADEQ station 6ALEV131.52. 7-14
Figure 7.17 Sediment nickel VADEQ station 6ALEV131.52. 7-15
Figure 7.18 Sediment zinc at VADEQ station 6ALEV131.52..... 7-15

Figure 7.19 Sediment copper at VADEQ station 6ALEV143.86. 7-16
Figure 7.20 Sediment lead at VADEQ station 6ALEV143.86..... 7-16
Figure 7.21 Sediment zinc at VADEQ station 6ALEV143.86..... 7-17
Figure 7.22 Sulfate concentrations at VADEQ monitoring station 6ALEV131.52. 7-18
Figure 7.23 Sulfate concentrations at VADEQ monitoring station 6ALEV143.86. 7-19
Figure 7.24 Sulfate concentrations at VADEQ monitoring station 6ALEV152.46. 7-19
Figure 7.25 Total chloride concentrations at VADEQ monitoring station 6ALEV152.46. 7-21
Figure 7.26 Total chloride concentrations at VADEQ monitoring station 6ALEV143.86. 7-22
Figure 7.27 Total chloride concentrations at VADEQ monitoring station 6ALEV131.52. 7-22
Figure 7.28 Total organic solids concentrations at VADEQ monitoring station 6ALEV131.52. 7-24
Figure 7.29 Total organic solids concentrations at VADEQ monitoring station 6ALEV143.86. 7-24
Figure 7.30 Total organic solids concentrations at VADEQ monitoring station 6ALEV152.46. 7-25
Figure 7.31 Total organic suspended solids concentrations at VADEQ monitoring station 6ALEV131.52. 7-25
Figure 7.32 Total organic suspended solids concentrations at VADEQ monitoring station 6ALEV143.86. 7-26
Figure 7.33 Total organic dissolved solids concentrations at VADEQ monitoring station 6ALEV131.52. 7-26
Figure 7.34 Total organic dissolved solids concentrations at VADEQ monitoring station 6ALEV152.46. 7-27
Figure 7.35 Total Kjeldahl nitrogen concentrations at VADEQ monitoring station 6ALEV143.86. 7-28
Figure 7.36 Total Kjeldahl nitrogen concentrations at VADEQ monitoring station 6ALEV152.46. 7-28
Figure 7.37 Chemical oxygen demand concentrations at VADEQ monitoring station 6ALEV131.52. 7-29
Figure 7.38 Chemical oxygen demand concentrations at VADEQ monitoring station 6ALEV143.86. 7-30

Figure 7.39 The relationship between % Ephemeroptera and conductivity from reference and mined sites (Pond, 2004). 7-31
Figure 7.40 Conductivity measurements at VADEQ station 6ALEV131.52..... 7-32
Figure 7.41 Conductivity measurements at VADEQ station 6ALEV143.86..... 7-33
Figure 7.42 Conductivity measurements at 6ALEV152.46. 7-33
Figure 7.43 TDS concentrations at VADEQ station 6ALEV131.52. 7-34
Figure 7.44 TDS concentrations at 6ALEV143.86. 7-35
Figure 7.45 TDS concentrations at 6ALEV152.46. 7-35
Figure 7.46 TSS concentrations at VADEQ station 6ALEV131.52 on Levisa Fork. 7-39
Figure 7.47 TSS concentrations at 6ALEV143.86 on Levisa Fork..... 7-39
Figure 7.48 TSS concentrations at 6ALEV152.46 on Levisa Fork..... 7-40
Figure 8.1 Dissolved oxygen concentrations at VADEQ monitoring station 6ASAT000.26. 8-2
Figure 8.2 Total phosphorus concentrations at VADEQ station 6ASAT000.26. 8-3
Figure 8.3 Nitrate-nitrogen concentrations at VADEQ station 6ASAT000.26. 8-3
Figure 8.4 Temperature measurements at VADEQ station 6ASAT000.26. 8-5
Figure 8.5 Total chloride concentrations at VADEQ station 6ASAT000.26..... 8-6
Figure 8.6 Field pH measurements at VADEQ station 6ASAT000.26..... 8-7
Figure 8.7 Sulfate concentrations at VADEQ station 6ASAT000.26..... 8-8
Figure 8.8 Total organic solids concentrations at VADEQ monitoring station 6ASAT000.26. 8-9
Figure 8.9 Total dissolved organic solids concentrations at VADEQ monitoring station 6ASAT000.26..... 8-9
Figure 8.10 The relationship between %Ephemeroptera and conductivity from reference and mined sites (Pond, 2004). 8-11
Figure 8.11 Conductivity measurements at VADEQ station 6ASAT000.26..... 8-12
Figure 8.12 TDS concentrations at VADEQ station 6ASAT000.26..... 8-12
Figure 8.13 Total suspended solids concentrations at VADEQ station 6ASAT000.26. 8-14
Figure 9.1 Location of selected and potential reference watersheds for Levisa Fork. 9-2
Figure 9.2 Location of selected and potential reference watersheds for Slate Creek. 9-7

Figure 10.1 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Levisa Fork. 10-14

Figure 10.2 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Levisa Fork. 10-15

Figure 10.3 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Dry Fork. 10-17

Figure 10.4 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Dry Fork. 10-18

Figure 12.1 Chemical structure of a PCB molecule. 12-1

Figure 12.2 Virginia Institute Marine Science (VIMS) laboratory fish tissue tPCB data collected throughout Virginia from 1995-2006. 12-3

Figure 12.3 VADEQ streambed sediment and fish tissue monitoring for tPCBs in the Levisa Fork watershed. 12-7

Figure 13.1 Levisa Fork fish tissue sample tPCB results organized downstream to upstream. 13-7

Figure 13.2 The locations and average concentrations of tPCBs in fish tissue samples in the Levisa Fork watershed and extending downstream into Fishtrap Lake, KY. 13-8

Figure 13.3 High flow tPCB loadings in the Levisa Fork watershed, March 5, 2008. 13-9

Figure 13.4 The locations and average concentrations of tPCBs in sediment samples in the Levisa Fork watershed. 13-10

Figure 14.1 TSS calibration results at VADEQ station 6AGAR000.16 in subwatershed 12 in the Garden Creek impairment. 14-4

Figure 14.2 TSS calibration results at VADEQ station 6ALEV152.46 at the outlet of subwatershed 12 in the Levisa Fork impairment. 14-4

Figure 14.3 TSS calibration results at VADEQ station 6ADIS001.24 at the outlet of subwatershed 11 in Dismal Creek. 14-5

Figure 14.4 TSS calibration results at VADEQ station 6ASAT000.03 at the outlet of subwatershed 10 in Slate Creek. 14-5

Figure 14.5 TSS calibration results at VADEQ station 6ALEV143.86 at the outlet of subwatershed 5 in the Levisa Fork impairment. 14-6

Figure 14.6 TSS calibration results at VADEQ station 6ALEV131.52 at the outlet of subwatershed 8 in the Levisa Fork impairment. 14-6

Figure 14.7 PCB calibration results at VADEQ station 6ALEV156.82 in subwatershed 2 in the Levisa Fork impairment. 14-9

Figure 14.8 PCB calibration results at VADEQ station 6AGAR000.16 in subwatershed 12 in the Garden Creek impairment. 14-9

Figure 14.9 PCB calibration results at VADEQ station 6ALEV152.46 in subwatershed 3 in the Levisa Fork impairment. 14-10

Figure 14.10 PCB calibration results at VADEQ station 6ADIS001.24 in subwatershed 11 in Dismal Creek..... 14-10

Figure 14.11 PCB calibration results at VADEQ station 6ABIP000.18 in subwatershed 13 in Big Prater Creek. 14-11

Figure 14.12 PCB calibration results at VADEQ station 6ASAT000.26 in subwatershed 10 in Slate Creek. 14-11

Figure 14.13 PCB calibration results at VADEQ station 6ALEV143.80 in subwatershed 5 in the Levisa Creek impairment. 14-12

Figure 14.14 PCB calibration results at VADEQ station 6ABLC002.30 in subwatershed 14 in Bull Creek. 14-12

Figure 14.15 PCB calibration results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Creek impairment. 14-13

Figure 14.16 Existing and allocated monthly geometric mean in-stream PCB concentrations in subwatershed 12, Garden Creek impairment outlet. 14-16

Figure 14.17 Existing and allocated monthly geometric mean in-stream PCB concentrations in subwatershed 8, Levisa Fork impairment outlet. 14-19

Figure A. 1 Frequency analysis of fecal coliform concentrations at station 6ALEV130.00 in the Levisa Fork Watershed impairment for the period from February 1980 to October 1991. ..... A-2

Figure A. 2 Frequency analysis of fecal coliform concentrations at station 6ALEV131.52 in the Levisa Fork Watershed impairment for the period from June 1992 to November 2006. ..... A-3

Figure A. 3 Frequency analysis of fecal coliform concentrations at station 6ALEV143.86 in the Levisa Fork Watershed impairment for the period from June 1992 to March 2001..... A-4

Figure A. 4 Frequency analysis of fecal coliform concentrations at station 6ALEV152.46 in the Levisa Fork Watershed impairment for the period from January 2000 to June 2003..... A-5

Figure A. 5 Frequency analysis of fecal coliform concentrations at station 6ALEV156.82 in the Levisa Fork Watershed impairment for the period from July 2001 to June 2003. ..... A-6

Figure A. 6 Frequency analysis of fecal coliform concentrations at station 6ASAT000.03 in the Levisa Fork Watershed (Slate Creek)

impairment for the period from February 1980 to February 2001 ..... A-7

Figure A. 7 Frequency analysis of *E. coli* concentrations at station 6ALEV131.52 in the Levisa Fork Watershed impairment for the period from July 2002 to November 2005. ..... A-8

Figure A. 8 Frequency analysis of *E. coli* concentrations at station 6ALEV152.46 in the Levisa Fork Watershed impairment for the period from March 2007 to September 2007. ..... A-9

Figure A. 9 Frequency analysis of *E. coli* concentrations at station 6ALEV156.82 in the Levisa Fork Watershed impairment for the period from March 2007 to September 2007. ..... A-10

Figure A. 10 Frequency analysis of *E. coli* concentrations at station 6ASAT000.26 in the Levisa Fork Watershed (Slate Creek) impairment for the period from July 2005 to November 2006. ..... A-11

Figure B.1 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV131.25 and discharge at USGS Station #03207800 for Levisa Fork. B-2

Figure B.2 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV143.86 and discharge at USGS Station #03207800 for Levisa Fork. B-3

Figure B.3 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV152.46 and discharge at USGS Station #03207800 for Levisa Fork. B-3

Figure B.4 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV156.82 and discharge at USGS Station #03207800 for Levisa Fork. B-4

Figure B.5 Relationship between fecal coliform concentrations at VADEQ Station 6ASAT000.03and discharge at USGS Station #03207800 for Slate Creek. B-4

Figure B.6 Relationship between *E. coli* concentrations at VADEQ Station 6ALEV130.00 and discharge at USGS Station #03207800 for Levisa Fork. B-5

Figure D. 1 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in the in-stream first-order decay rate (FSTDEC). D-7

Figure D. 2 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in maximum fecal accumulation on land (MON-SQOLIM). D-8

Figure D. 3 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in the wash-off rate from land surfaces (WSQOP). D-9

Figure D. 4 Results of total loading sensitivity analysis for Levisa Fork (subwatershed 8). D-10

Figure D. 5 Results of sensitivity analysis on monthly geometric-mean concentrations in Levisa Fork (subwatershed 8) as affected by changes in land-based loadings. D-11

Figure D. 6 Results of sensitivity analysis on monthly geometric-mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in loadings from direct nonpoint sources. D-12

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TABLES

Table ES.1 Average annual in-stream cumulative pollutant loads modeled after allocation in the Levisa Fork impairments. xxxiv

Table 1.1 Impairments within the Levisa Fork watershed. 1-10

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1980 – December 2006. 2-6

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from May 2002 – November 2007. 2-7

Table 2.3 Summary of bacterial source tracking results from water samples collected in Big Prater Creek (6ABIP000.18). 2-9

Table 2.4 Summary of bacterial source tracking results from water samples collected in Dismal Creek (6ADIS001.24). 2-9

Table 2.5 Summary of bacterial source tracking results from water samples collected in Slate Creek (6ASAT000.26). 2-10

Table 2.6 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV156.82). 2-10

Table 2.7 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV152.46). 2-11

Table 2.8 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV143.80). 2-11

Table 2.9 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV131.52). 2-12

Table 3.1 Summary of VPDES permitted point sources in the Levisa Fork watershed. 3-2

Table 3.2 Single family home permits in the Levisa Fork watershed. 3-3

Table 3.3 Carwash, concrete, industrial, and construction permits in the Levisa Fork watershed. 3-4

Table 3.4 Human population information for 2008 in areas contributing to impaired segments in the Levisa Fork watershed. 3-6

Table 3.5 Domestic animal population density, waste load, and fecal coliform density. 3-7

Table 3.6 Estimated domestic animal populations in areas contributing to impaired segments in the Levisa Fork watershed. 3-7

Table 3.7 Livestock populations (2008) in areas contributing to impaired segments in the Levisa Fork watershed. 3-8

Table 3.8 Average fecal coliform densities and waste loads associated with livestock. 3-8

Table 3.9 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day for the Levisa Fork watershed. 3-9

Table 3.10 Wildlife population densities for the Levisa Fork watershed. 3-10

Table 3.11 Estimated wildlife populations in the Levisa Fork watershed. 3-10

Table 3.12 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife. 3-11

Table 3.13 Wildlife fecal production rates and habitat. 3-12

Table 4.1 Impairments and subwatersheds within the Levisa Fork watershed. 4-3

Table 4.2 Consolidation of MRLC/NLCD 2001 land use categories for the Levisa Fork watershed used in HSPF modeling. 4-6

Table 4.3 Land use acerages in the Levisa Fork HSPF model. 4-7

Table 4.4 Summary of Manning's roughness coefficients for channel cells*. 4-9

Table 4.5 Example of an F-table calculated for the HSPF model. 4-10

Table 4.6 Comparison of modeling time period (calibration and validation) data to historical data for the Levisa Fork watershed. 4-15

Table 4.7 Model parameters utilized for hydrologic calibration. 4-16

Table 4.8 Hydrology calibration model performance for period 10/1/2000 through 9/30/2003 at USGS Gaging Station 03207800 on Levisa Fork. 4-16

Table 4.9 Hydrology validation model performance for Levisa Fork for the period 10/1/1996 through 9/30/1999. 4-19

Table 4.10 Isolate-streamflow-concentration weighted average proportions of fecal bacteria originating from four source categories using all data. 4-22

Table 4.11 Flow rates and bacteria concentrations used to model active VADEQ permits in the Levisa Fork watershed. 4-24

Table 4.12 Estimated failing septic systems and straight pipes for 2008 in the Levisa Fork watershed. 4-26

Table 4.13 Model parameters utilized for water quality calibration. 4-31

Table 4.14 Mean standard error of the calibrated model for the Levisa Fork watershed (10/1/1999 to 9/30/2002). 4-34

Table 4.15 Comparison of modeled and observed fecal bacteria calibration results for the Levisa Fork watershed. 4-34

Table 4.16 The average *E. coli* concentrations compared between modeled (HSPF) and observed (BST) bacteria sources. 4-35

Table 4.17 Mean standard error of the fecal coliform validation model for impairments in the Levisa Fork watershed. 4-35

Table 4.18 Comparison of modeled and observed fecal coliform validation results for the Levisa Fork watershed. 4-36

Table 5.1 Allocation scenarios for reducing current bacteria loads in Levisa Fork (subwatershed 1,2,3,4,5,6,7,8,11,13,14). 5-5

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Levisa Fork impairment. 5-7

Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Levisa Fork impairment. 5-8

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Levisa Fork impairment. 5-10

Table 5.5 Allocation scenarios for reducing current bacteria loads in Slate Creek (subwatershed 9,10). 5-12

Table 5.6 Estimated existing and allocated *E. coli* in-stream loads in the Slate Creek impairment. 5-14

Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Slate Creek impairment. 5-15

Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Slate Creek impairment. 5-16

Table 6.1 Components of the Virginia Stream Condition Index (VASCI). 6-1

Table 6.2 VADEQ water quality monitoring stations on Levisa Fork. 6-2

Table 6.3 VASCI biological monitoring scores for station 6ALEV130.29 on Levisa Fork. 6-4

Table 6.4 VASCI biological monitoring scores for station 6ALEV138.19 on Levisa Fork. 6-5

Table 6.5 VASCI biological monitoring scores for station 6ALEV143.80 on Levisa Fork. 6-6

Table 6.6 VASCI biological monitoring scores for station 6ALEV151.90 on Levisa Fork. 6-7

Table 6.7 VASCI biological monitoring scores for station 6ALEV152.46 on Levisa Fork. 6-8

Table 6.8 VADEQ monitoring stations on Slate Creek. 6-9

Table 6.9 VASCI biological monitoring results for VADEQ benthic monitoring sweep on Slate Creek on July 20, 1998. 6-10

Table 6.10 VASCI data for VADEQ station 6ASAT000.05 on Slate Creek. 6-11

Table 6.11 VASCI data for VADEQ station 6ASAT000.26 on Slate Creek. 6-12

Table 6.12 VASCI data for VADEQ station 6ASAT007.71 on Slate Creek. 6-13
Table 6.13 Classification of habitat metrics based on score. 6-14
Table 6.14 Habitat scores for VADEQ monitoring station 6ALEV130.29 on Levisa Fork. 6-15
Table 6.15 Habitat scores for 6ALEV138.19 on Levisa Fork. 6-15
Table 6.16 Habitat scores for 6ALEV143.80 on Levisa Fork. 6-16
Table 6.17 Habitat scores for 6ALEV151.90 on Levisa Fork. 6-16
Table 6.18 Habitat scores for 6ALEV152.46 on Levisa Fork. 6-17
Table 6.19 Habitat scores at VADEQ benthic monitoring stations on Slate Creek on July 20, 1998. 6-18
Table 6.20 Habitat scores for 6ASAT000.05 on Slate Creek. 6-18
Table 6.21 VADEQ ambient water quality monitoring stations on Levisa Fork. 6-19
Table 6.22 In-stream water quality data at 6ALEV131.52 in Levisa Fork (1/1997 – 3/2008). 6-20
Table 6.23 In-stream water quality data at 6ALEV143.86 in Levisa Fork (1/1997 - 7/2007). 6-21
Table 6.24 In-stream water quality data at 6ALEV152.46 in Levisa Fork (7/2000 - 12/2007). 6-22
Table 6.25 In-stream water quality data at 6ALEV156.82 in Levisa Fork (7/2001 - 11/2007). 6-23
Table 6.26 VADEQ monitoring station on Slate Creek. 6-24
Table 6.27 In-stream water quality data at 6ASAT000.26 on Slate Creek (7/2005 – 11/2007). 6-25
Table 6.28 Monitoring stations on Levisa Fork from data supplied by DMME. 6-26
Table 6.29 In-stream water quality data at MPID 5684669 (2/2000—8/2001). 6-27
Table 6.30 In-stream water quality data at MPID 5784675 (1/1996-4/1997). 6-27
Table 6.31 VADEQ fish tissue and in-stream sediment water quality monitoring stations on Levisa Fork. 6-28
Table 6.32 Fish tissue sampling results for tPCB from six VADEQ monitoring stations on Levisa Fork. 6-29
Table 6.32 Fish tissue sampling results for tPCB from six VADEQ monitoring stations on Levisa Fork (cont). 6-30
Table 6.33 In-stream sediment sampling results for tPCB from 18 VADEQ monitoring stations on Levisa Fork. 6-31

Table 6.34 In-stream sediment sampling results for pesticides and other organic chemicals from 12 VADEQ monitoring stations on Levisa Fork. 6-32

Table 6.35 Special study sediment PAH results from 6ALEV130.00 on Levisa Fork (July 1997 and August 2002). 6-33

Table 6.36 In-stream sediment sampling results for metals from seven VADEQ monitoring stations on Levisa Fork. 6-35

Table 6.36 In-stream sediment sampling results for metals from seven VADEQ monitoring stations on Levisa Fork (cont.). 6-36

Table 6.37 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV131.52 on Levisa Fork. 6-37

Table 6.38 Dissolved metal concentrations at VADEQ special study monitoring station 6ALEV138.19 on Levisa Fork (March 28, 2007). 6-37

Table 6.39 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV143.80 on Levisa Fork (September 25, 2007). 6-38

Table 6.40 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV152.46 on Levisa Fork. 6-38

Table 6.41 Sediment metal sampling results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002). 6-39

Table 6.42 Sediment PAH results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002). 6-40

Table 6.43 Sediment tPCB and pesticide results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002). 6-41

Table 6.44 Sediment metals results from VADEQ ambient monitoring station 6ASAT000.26 on Slate Creek (9/4/2007). 6-41

Table 6.45 Dissolved metal concentrations at VADEQ ambient monitoring station 6ASAT000.26 on Slate Creek (9/4/2007). 6-41

Table 7.1 Non-Stressors in Levisa Fork. 7-3

Table 7.2 Possible Stressors in Levisa Fork. 7-13

Table 7.3 Levisa Fork August 2007 Toxicity Testing Results. 7-37

Table 7.4 Probable stressors in Levisa Fork. 7-38

Table 8.1 Non-Stressors in Slate Creek. 8-1

Table 8.2 Possible Stressors in Slate Creek. 8-6

Table 8.3 Probable stressors in Slate Creek. 8-13

Table 9.1 Reference watershed selection for Levisa Fork – Part1. 9-3

Table 9.2 Reference watershed selection for Levisa Fork – Part2. 9-4
Table 9.3 Reference watershed selection for Levisa Fork – Part3. 9-5
Table 9.4 Reference watershed selection for Slate Creek – Part1 9-8
Table 9.5 Reference watershed selection for Slate Creek – Part2 9-9
Table 10.1 Land use areas used in the GWLF model for the Levisa Fork and area-adjusted Dry Fork watersheds. 10-6
Table 10.2 Land use areas used in the GWLF model for the Slate Creek and area-adjusted Lick Creek watersheds. 10-7
Table 10.3 Permitted Sources in the Levisa Fork watershed excluding the Slate Creek and Bull Creek areas. 10-10
Table 10.4 Permitted Sources in the Slate Creek watershed. 10-11
Table 10.5 Base parameter values used in GWLF sensitivity analysis. 10-12
Table 10.6 Sensitivity of GWLF model response to changes in selected parameters for Levisa Fork. 10-13
Table 10.7 GWLF flow calibration statistics for Levisa Fork. 10-13
Table 10.8 GWLF flow calibration statistics for Dry Fork. 10-16
Table 10.9 GWLF watershed parameters in the calibrated impaired and reference watersheds. 10-19
Table 10.10 Calibrated GWLF monthly evaporation cover coefficients. 10-19
Table 10.11 The GWLF curve numbers and KLSCP values for existing conditions in the Levisa Fork and Dry Fork watersheds. 10-20
Table 10.12 The GWLF curve numbers and KLSCP values for existing conditions in the Slate Creek and Lick Creek watersheds. 10-21
Table 10.13 Existing sediment loads for Levisa Fork and area-adjusted Dry Fork watersheds. 10-22
Table 10.14 Existing sediment loads for Slate Creek and area-adjusted Lick Creek watersheds. 10-23
Table 11.1 Final TMDL allocation scenario for the impaired Slate Creek watershed. 11-3
Table 11.2 Existing and allocated annual sediment loads for DMME mining permits within the Slate Creek watershed. 11-4
Table 11.3 Average annual sediment TMDL for Slate Creek. 11-5
Table 11.4 Required sediment load reductions for Slate Creek. 11-6
Table 11.5 Average daily sediment TMDL for Slate Creek. 11-7
Table 11.6 Final TMDL allocation scenario for the impaired Levisa Fork watershed. 11-9

Table 11.7 Existing and allocated annual sediment loads for DMME mining permits within the Levisa Fork watershed. 11-10

Table 11.8 Required sediment reductions for Levisa Fork. 11-13

Table 11.9 Average annual sediment TMDL for Levisa Fork. 11-14

Table 11.10 Average daily sediment TMDL for Levisa Fork. 11-18

Table 12.1 Applicable water quality, fish tissue, and sediment criteria/guidelines for PCBs. 12-6

Table 12.2 Fish tissue tPCB sampling results from six VADEQ monitoring stations on Levisa Fork. 12-8

Table 12.2 Fish tissue tPCB sampling results from six VADEQ monitoring stations on Levisa Fork (continued). 12-9

Table 12.3 Fish tissue sampling results for tPCB from three VADEQ monitoring stations on Levisa Fork tributaries. 12-10

Table 12.4 Streambed sediment tPCB results from VADEQ monitoring. 12-12

Table 12.5 tPCB concentrations in the Levisa Fork watershed. 12-14

Table 13.1 Total PCB (tPCB) data from permitted sources in the Levisa Fork watershed. 13-3

Table 14.1 Model parameters utilized for TSS calibration. 14-3

Table 14.2 Comparison of modeled and observed TSS calibration results for the Levisa Fork watershed. 14-7

Table 14.4 Comparison of modeled and observed PCB calibration results for the Levisa Fork watershed. 14-14

Table 14.5 Final average annual in-stream PCB loads (mg/year) modeled after TMDL allocation in the Garden Creek impairment. 14-17

Table 14.6 Final average daily in-stream PCB loads (mg/day) modeled after TMDL allocation in the Garden Creek impairment. 14-18

Table 14.7 Final average annual in-stream PCB loads (mg/year) modeled after TMDL allocation in the Levisa Fork impairment. 14-20

Table 14.8 Existing and allocated annual PCB loads for DMME mining permits within the Levisa Fork watershed. 14-21

Table 14.9 Final average daily in-stream PCB loads (mg/day) modeled after TMDL allocation in the Levisa Fork impairment. 14-22

Table 16.1 Public participation during TMDL development for the Levisa Fork study area. 16-1

Table B. 1 Summary of the Mood's Median Test on monthly total precipitation from combined NCDC stations #443640 Grundy, #444180 Hurley4S, #447174 Richlands (p=0.065). B-5

Table B. 2 Summary of fecal coliform data trends at VADEQ stations with adequate data. B-6

Table C.1 Current conditions of land applied fecal coliform load for Levisa Fork by land use (all subwatersheds). C-2

Table C.2 Monthly, directly deposited fecal coliform loads in Levisa Fork by land use (all subwatersheds). C-2

Table C.3 Existing annual fecal coliform loads from land-based sources for Levisa Fork by land use (all subwatersheds). C-3

Table C.4 Existing annual fecal coliform loads from direct-deposition sources for Levisa Fork by land use (all subwatersheds). C-4

Table C.5 Current conditions of land applied fecal coliform load for Levisa Fork by land use (subwatersheds 9,10). C-5

Table C.6 Monthly, directly deposited fecal coliform loads in Levisa Fork by land use (subwatersheds 9,10). C-5

Table C.7 Existing annual fecal coliform loads from land-based sources for Levisa Fork by land use (subwatersheds 9,10). C-6

Table C.8 Existing annual fecal coliform loads from direct-deposition sources for Levisa Fork by land use (subwatersheds 9,10). C-7

Table D. 1 HSPF base parameter values used to determine hydrologic model response. D-3

Table D. 2 HSPF sensitivity analysis results for hydrologic model parameters for Levisa Fork. D-4

Table D. 3 Base parameter values used to determine water quality model response. D-5

Table D. 4 Percent change in average monthly *E. coli* geometric mean for the years 2000-2003 for Levisa Fork (subwatershed 8). D-6

EXECUTIVE SUMMARY

Background and Applicable Standards

Slate Creek (VAS-Q07R_SAT01A00) was first listed as impaired for the General Standard (benthic) according to the *1996 303(d) TMDL Priority List* (VADEQ, 1997). A primary contact (recreational) use impairment was added on the 1998 Section 303(d) list.

Two segments of Levisa Fork were originally listed for aquatic life use impairments on the 1996 303(d) list. Many new segments of Levisa Fork were listed on the 2002 303(d) list as impaired for the fish consumption use for high levels of Total Polychlorinated Biphenyls (tPCBs) in fish tissue. The 2004 303(d) listed the Levisa Fork as impaired for not meeting the primary contact (recreational) use.

The mainstem of Garden Creek from the Right Fork Garden Creek confluence to the Levisa Fork confluence (1.80 miles) was first listed as impaired for the fish consumption use for high levels of tPCBs in fish tissue in 2006.

TMDL Endpoint and Water Quality Assessment

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. A translator developed by VADEQ was used to convert fecal coliform values to E. coli values.

The General Standard states that waters should be free of substances that are harmful to aquatic life. The stressor determined to be impacting the aquatic life in Levisa Fork and Slate Creek is sediment. The sediment endpoints were calculated from reference watersheds.

Virginia's water quality standards for the maintenance of designated uses include numeric Aroclor PCB criteria for the protection of aquatic life and a tPCBs criterion for the protection of human health. The value of 640 pg/L will be used as the tPCB endpoint for the PCB modeling.

Modeling Procedures

Hydrology

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform loads in the riverine segments. For purposes of modeling the Levisa Fork watershed, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into 14 subwatersheds.

The historical stream flow at USGS gage #03207800 in Levisa Fork and precipitation from NCDC stations in Grundy, Hurley, and Richlands, Virginia were used to model the hydrology of the Levisa Fork watershed. Data representing the period 10/1/2000 to 9/30/2003 were used to calibrate the HSPF hydrologic model used in this study. To validate that the HSPF can accurately simulate other time periods, a validation time period of 10/1/1996 to 9/30/1999 was selected.

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct sources of uncontrolled discharges, direct deposition by wildlife, direct deposition by livestock, and direct inputs from sewer overflows. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

The fecal coliform calibration was conducted using monitored data collected at VADEQ monitoring stations. The water quality calibration was conducted from 10/1/1999 to 9/30/2002; the validation period 10/1/1996 to 9/30/1999. The 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 throughout the impaired watersheds.

Sediment

The model used in this study was the *Visual Basic*™ version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The target TMDL load for Slate Creek is the average annual load in metric tons per year (t/yr) from the area-adjusted Lick Creek watershed under existing conditions. To reach the TMDL target goal (1,770.63 t/yr), different scenarios were run with GWLF.

The target TMDL load for Levisa Fork is the average annual load in metric tons per year (t/yr) from the area-adjusted Dry Fork watershed under existing conditions. To reach the TMDL target load (17,547.48 t/yr), different scenarios were run using GWLF.

tPCBs

Polychlorinated bi-phenyls (PCBs) are hydrophobic compounds that tend to attach to organic matter, fatty tissue or become dissolved in an organic solvent rather than dissolve in water. These compounds are much more likely to be found in streambed sediments and in fish tissues within a contaminated channel. For this reason, total suspended sediment (TSS) was modeled as the vehicle on which PCBs travel to the surface water, become suspended in the water column, and settle out in streambed sediments. TSS concentrations were calibrated, and then PCBs were attached to the TSS in order to model total PCB concentrations in the stream. This modeling was done using HSPF with an endpoint of 640 pg/L.

Load Allocation Scenarios

The next step in the TMDL processes was to reduce the various source loads to levels that would result in attainment of the water quality standards or endpoints. Because Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL information is shown in Table ES.1.

The final bacterial TMDLs for Levisa Fork and Slate Creek include 100% reductions in straight pipes and sewer overflows.

Table ES.1 Average annual in-stream cumulative pollutant loads modeled after allocation in the Levisa Fork impairments.

Pollutant	Units	Impairment	WLA[1]	LA	MOS	TMDL	Existing Load	Percent Reduction
E. coli	cfu/yr	**Levisa Fork**	7.69E+12	1.93E+14	*Implicit*	2.00E+14	6.20E+14	67.7%
E. coli	cfu/yr	**Slate Creek**	5.29E+11	5.03E+13	*Implicit*	5.08E+13	1.59E+14	68.0%
Sediment	t/yr	**Levisa Fork**	729.66	16,817.78	1,949.76	19,497.20	53,272.75	63.4%
Sediment	t/yr	**Slate Creek**	31.46	1,738.14	197.77	1,967.37	8,321.71	76.4%
tPCBs	mg/yr	**Levisa Fork**	5,009.30	3,421.12	443.71	8,874.14	161,713.44	94.51%
tPCBs	mg/yr	**Garden Creek**	319.10	632.61	50.09	1001.80	2643.93	62.11%

[1] WLA by permit can be found in the corresponding allocation chapters.

Implementation

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in Levisa Fork watershed. The next step will be more monitoring to better establish the sources of PCBs (see Preface). The next step is to develop TMDL implementation plans (IP). The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned, a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

During development of the TMDL for the impairments in the Levisa Fork study area, public involvement was encouraged through a technical advisory committee (10/9/2008, 13 attendees), a first public meeting (10/9/2008, 14 attendees), and a final public meeting (1/14/2010, 34 attendees). An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the Levisa Fork TMDLs were presented at the first of the public meeting. Public understanding of and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting. Written comments were addressed in the final document.

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1. INTRODUCTION

1.1 Regulations Background

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the state of Virginia has found that many stream segments do not meet state water quality standards for protection of the six beneficial uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, the stream is "listed" in the current Section 303(d) report as requiring a Total Maximum Daily Load (TMDL). Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a stream; that is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *"Board shall develop and implement a plan to achieve fully supporting status for impaired waters"*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

1.2 *Levisa Fork Watershed Characteristics*

The majority of the Levisa Fork watershed (USGS Hydrologic Unit Code 05070202) is located in Buchanan County, Virginia with a small portion in Pike County, Kentucky. Levisa Fork flows northwest from the headwaters at the Tazewell and Russell County boundaries into Kentucky. The impairments addressed here end at the Virginia state line. This watershed is a part of the Tennessee/Big Sandy River basin, which drains via the Mississippi River to the Gulf of Mexico. The location of the watershed is shown in Figure 1.1.

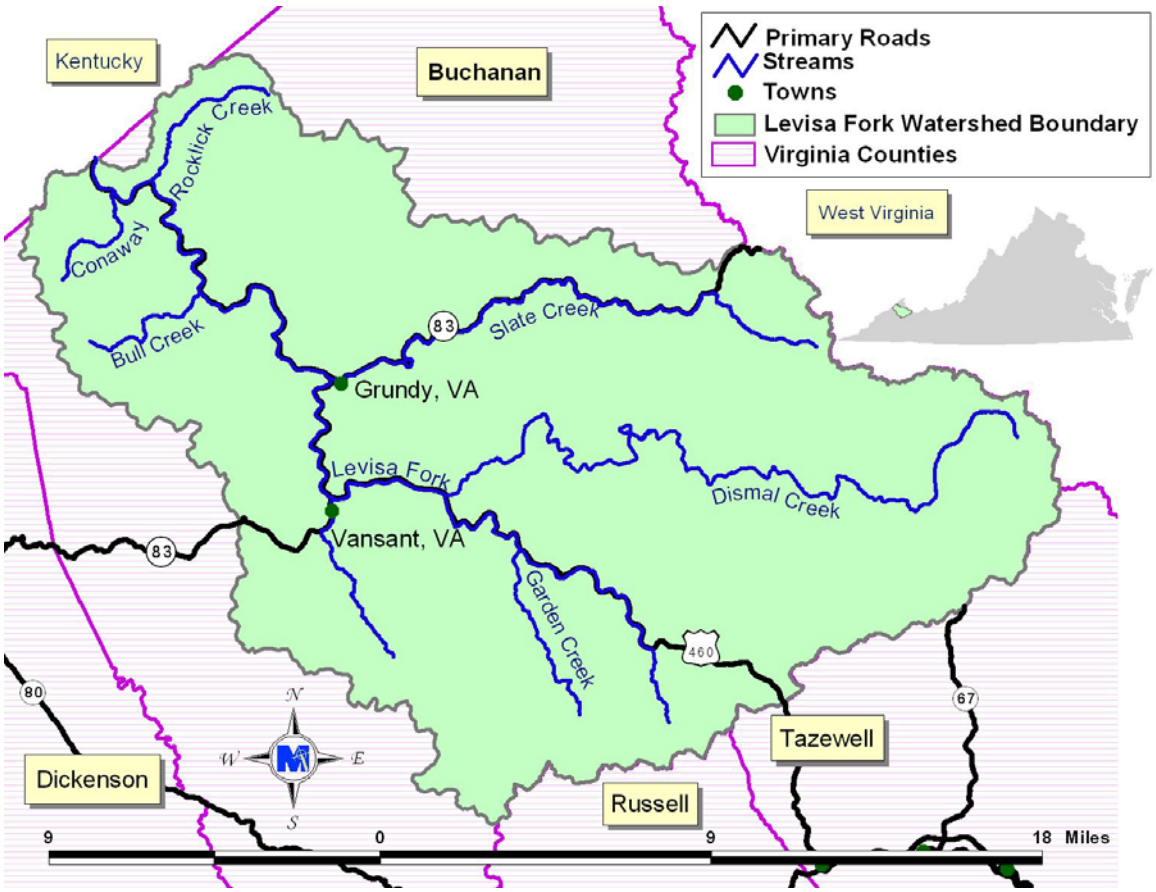

Figure 1.1 Location of the Levisa Fork watershed.

The Levisa Fork watershed is entirely located within the level III Central Appalachian ecoregion in the subset level IV Dissected Appalachian Plateau ecoregion. The level IV ecoregion is described by Purdue University quite well: "The Central Appalachian

ecoregion, stretching from central Pennsylvania to northern Tennessee, is primarily a high, dissected, rugged plateau composed of sandstone, shale, conglomerate, and coal. The rugged terrain, cool climate, and infertile soils limit agriculture, resulting in a mostly forested land cover. The high hills and low mountains are covered by a mixed mesophytic forest with areas of Appalachian oak and northern hardwood forest." (www.hort.purdue.edu/newcrop/cropmap/ecoreg/descript.html).

The National Land Cover Database 2001 (NLCD) was initially utilized to characterize the land use for this study. Knowing that this dataset commonly misclassifies surface mining, gas well, and abandoned mine land (AML) areas as barren, pasture, and other types, the NLCD data was modified using spatial AML information, current permitted surface mining, and gas well locations. More details about land uses are in Section 4.2.2.

The Levisa Fork watershed is comprised of many different SSURGO (Soil Survey Geographic) soils. The majority of the area is comprised of four soil complexes: Highsplint-Shelocta complex, Matewan-Gilpin-Rock outcrop complex, Cloverlick-Shelocta complex, and Marrowbone-Gilpin complex (NRCS, 2008). The Highsplint series (18% of the watershed) consists of deep, well-drained, moderately permeable, mountain soils. This stony-loamy soil was formed from weathered sandstone, siltstone and shale. The dominant land with this series slopes from 35 to 75 percent (NRCS, 2008). The Matewan series (16% of the watershed) consists of moderately deep, well-drained, moderately rapid permeable soils. This soil was formed from weathered gray and brown acid sandstone with siltstone and shale present. The land with this series ranges from a 3 to 80 percent slope. Rock outcrops are common (NRCS, 2008). The Cloverlick series (12% of the watershed) consists of deep, well-drained, moderately permeable, stony-loamy mountain soils which were formed from weathered sandstone, siltstone and shale. The land with this series ranges from a 5 to 90 percent slope (NRCS, 2008). The Marrowbone series (8% of the watershed) consists of moderately deep, well-drained, moderately permeable, loamy mountain soils was formed from weathered sandstone and siltstone. The dominant land with this series slopes from 30 to 90 percent (NRCS, 2008).

As for the climatic conditions in the Levisa Fork watershed, during the period from 1948 to 2007 Grundy, Virginia (NCDC station# 443640) received an average annual precipitation of approximately 44.31 inches, with 53% of the precipitation occurring during the May through October growing season (SERCC, 2008). Average annual snowfall is 16.9 inches, with the highest snowfall occurring during January (SERCC, 2008). The highest average daily temperature of 86.9 ºF occurs in July, while the lowest average daily temperature of 45.8 ºF occurs in January (SERCC, 2008).

1.3 Levisa Fork Watershed Impairments

1.3.1 Slate Creek

Separate TMDLs will be calculated for Slate Creek for the different impaired uses: aquatic life use (benthic) and recreation/swimming (*E. coli*). Descriptions of the different impaired segments of Slate Creek are grouped by listing year below.

Slate Creek (VAS-Q07R_SAT01A00) was first listed as impaired for the General Standard (benthic) according to the *1996 303(d) TMDL Priority List* (VADEQ, 1997). The 4.8-mile segment from Elkins Branch to the Levisa Fork yielded three moderately impaired ratings and one severely impaired rating (December 1991) during the biological monitoring. Low habitat scores were noted due to embeddedness, few riffles, channel alterations, and the lack of bank vegetative stability.

Slate Creek remained impaired and was listed again on the 1998 Section 303(d) list and a recreational/swimming use impairment was added. Slate Creek violated the fecal coliform standard in 3 out of 14 samples. Slate Creek was listed on all subsequent 303(d)/305(b) lists (2002, 2004, and 2006) for not meeting the aquatic life use and the recreation/swimming use.

In the 2002 Section 303(d) list, the length of the aquatic life use impaired segment was increased to 9.08 miles, representing the mainstem of Slate Creek from the Upper Rockhouse Branch confluence to the Levisa Fork confluence. The impaired segment was extended upstream due to monitoring results from a special study conducted in 1998. During this study, biological monitoring was conducted at stations 6ASAT000.00,

6ASAT000.05, 6ASAT004.52, and 6ASAT007.71 resulting in moderately impaired ratings. Slate Creek was still listed on the 2002 list for recreation/swimming use impairment because 4 of 24 fecal coliform samples violated the standard at station 6ASAT000.03.

Slate Creek was again listed on the 2004 Section 303(d) list for aquatic life use and recreation/swimming use impairments. The fecal coliform monitoring resulted in 6 out of 18 violations.

In the 2006 Section 303(d) list, the length of the Slate Creek swimming/recreation use impairment was updated to 9.10 miles. At station 6ASAT000.03, 6 out of 18 samples violated the current *E coli* bacteria standard. The benthic and *E. coli* TMDLs will be calculated for the 9.10-mile segment as it appears in Figure 1.2. The stream runs through Stacy, Virginia and meets Levisa Fork in downtown Grundy, Virginia. Figure 1.2 and Table 1.1 show more details about the Slate Creek impairments.

1.3.2 Garden Creek

The mainstem of Garden Creek from the Right Fork Garden Creek confluence to the Levisa Fork confluence (1.80 miles) was first listed as impaired for the fish consumption use for high levels of Total Polychlorinated Biphenyls (tPCBs) in fish tissue in 2006. This segment was again listed in 2008. Figure 1.2 and Table 1.1 show more details about the Garden Creek tPCB impairment.

1.3.3 Levisa Fork

Separate TMDLs will be calculated for Levisa Fork for the different impaired uses: aquatic life use (benthic), recreation/swimming (*E. coli*), and fish consumption (tPCBs in fish tissue). Descriptions of the different impaired segments of Levisa Fork are grouped by listing year below.

Two segments of Levisa Fork were originally listed for aquatic life use impairments on the 1996 303(d) list. A 4.10-mile segment of Levisa Fork from the Garden Creek confluence to the Dismal Creek confluence showed poor aquatic habitat due to embeddedness, lack of canopy, and poor bank stability. Three biological monitoring

samples resulted in moderately impaired ratings and one sample concluded with a severely impaired rating. A 1.52-mile segment from Conaway Creek to the Kentucky state line was also listed for impaired biological ratings. Four samplings resulted in moderately impaired ratings and three samplings have classified this segment as severely impaired. Benthic organism habitat and density were low in this segment. These segments were again listed on the 1998 303(d) list.

Many new segments of Levisa Fork were listed on the 2002 303(d) list. From the headwaters to Garden Creek, 9.85 miles was listed as impaired for the fish consumption use for high levels of tPCBs in fish tissue. Total PCBs exceeded the VADEQ screening value detected in two samples of one fish species at station 6ALEV151.26 in August of 2000. The segment of Levisa Fork from Garden Creek to Dismal Creek was again listed in 2002 for not supporting the aquatic life use, and was also listed as impaired for the fish consumption use for high levels of tPCBs in fish tissue. A new segment of Levisa Fork, from Dismal Creek to Slate Creek was listed in 2002 for not supporting the aquatic life use and for the fish consumption use for high levels of tPCBs. At station 6ALEV143.80, Levisa Fork was rated as moderately impaired for the aquatic life use. tPCBs exceeded VADEQ's screening value in three species of fish at station 6ALEV145.86 in October 2000. A new segment, which overlaps a portion of the previous segment, was also listed for high tPCB levels in fish in the 2002 303(d) list. From river mile 142.00 to the Rocklick Creek confluence, Levisa Fork was listed as impaired for fish consumption (tPCBs). Fish tissue sampling in July 1997 found in tPCBs in three species of fish exceeded the Virginia Department of Health's (VDH) action level at station 6ALEV130.00. Fish tissue samples were collected again at station 6ALEV130.00 in August and October 2000 and two species of fish exceeded the VDH action level. The most downstream Levisa Fork impaired segment, from Rocklick Creek to the Kentucky State line, was first listed in 2002. This segment includes the 1.52-mile segment from Conaway Creek to the Kentucky state line first listed in 1996. The updated 2.66-mile segment was listed for not supporting the aquatic life use and fish consumption (tPCBs). Levisa Fork at biological monitoring station 6ALEV130.29 was moderately impaired.

The 2004 303(d) list contained many of the same Levisa Fork impaired segments as the 2002 list. One exception is the Levisa Fork segment from the headwaters to Garden Creek was not listed as impaired for the fish consumption use (tPCBs). This segment was listed as impaired for the recreation/swimming use for 3 violations out of 9 samples at 6ALEV156.82. The Levisa Fork segment from Garden Creek to Dismal Creek was, once again, listed for both not supporting the aquatic life use and for the fish consumption use (tPCBs). This segment was also listed for recreation/swimming use for bacteria violations at 6ALEV152.46 (9 out of 24 samples violated the bacteria standard) and at 6ALEV156.82. The next downstream segment of Levisa Fork, from Dismal Creek to Slate Creek, was again listed for both not supporting the aquatic life use and for the fish consumption use (tPCBs). This segment was also listed for recreation/swimming use for bacteria violations at 6ALEV143.86 (5/38). The Levisa Fork segment from river mile 142.00 to the Rocklick Creek confluence was listed again in 2004 as impaired for fish consumption (tPCBs). The most downstream Levisa Fork segment, from Rocklick Creek to the Kentucky State line, was again listed as impaired for not supporting the aquatic life use and fish consumption (tPCBs). Fish tissue sampling in August 2002 found tPCBs in three species of fish exceeded the VDH action level at station 6ALEV130.00, and tPCBs in sediment exceeded the consensus probable effect concentration (PEC). This segment was also listed for recreation/swimming use impairment for 10 violations out of 56 samples at station 6ALEV131.52.

Segments of Levisa Fork were again listed on the 2006 303(d)/305(b) integrated report for various impairments. The most upstream segment, Levisa Fork headwaters to Garden Creek, was listed as impaired for not supporting both the fish consumption use (tPCBs) and the recreation/swimming use (3 out of 12 samples violated the bacteria standard). The next downstream segment, from Garden Creek to Dismal Creek, remained impaired for not supporting the aquatic life use, the fish consumption use (tPCBs), and the recreation/swimming use (9 out of 27 samples violated the bacteria standard). This segment of Levisa Fork was also listed for chloride in the 2006 list. This impairment will not be specifically addressed in this study. The next downstream segment, from Dismal Creek to Slate Creek, remained impaired for not supporting the aquatic life use, the fish consumption use (tPCBs), and the recreation/swimming use (5 out of 38 samples violated

the bacteria standard). Four biological monitoring samples collected at station 6ALEV143.80 resulted in moderately impaired ratings for Levisa Fork. The Levisa Fork segment, river mile 142.00 to the Rocklick Creek confluence, was broken into two separate segments during the 2006 listing and the overlapping section was dropped. The Levisa Fork segment from Slate Creek to Bull Creek was listed as impaired for not supporting the fish consumption use (tPCBs). Fish tissue samples collected at 6ALEV141.28 in October 2000 had high levels of tPCBs that exceeded the VADEQ screening value. This newly defined segment was also listed as impaired for not supporting the aquatic life use. Biological monitoring results at station 6ALEV143.80 indicated a moderate impairment rating. The second section of the newly defined segments is Levisa Fork from Bull Creek to Rocklick Creek. This segment is listed as impaired for not supporting the fish consumption use (tPCBs) only. The final Levisa Fork segment, from Rocklick Creek to the Kentucky State line, was again listed as impaired for not supporting the aquatic life use, the fish consumption (tPCBs), and the recreation/swimming use (8 out of 20 samples violated the bacteria standard).

Figure 1.2 shows the impaired segments in the Levisa Fork watershed as they are described in the 2006 list. Table 1.1 describes the segment name and identification number, the impairments, the initial 303(d) listing year, the length of the impairment in river miles as it was listed in 2006, the listing number of bacteria violations over the total samples, the number of bacteria violations over the total samples for the 2006 assessment time period, and the segment description.

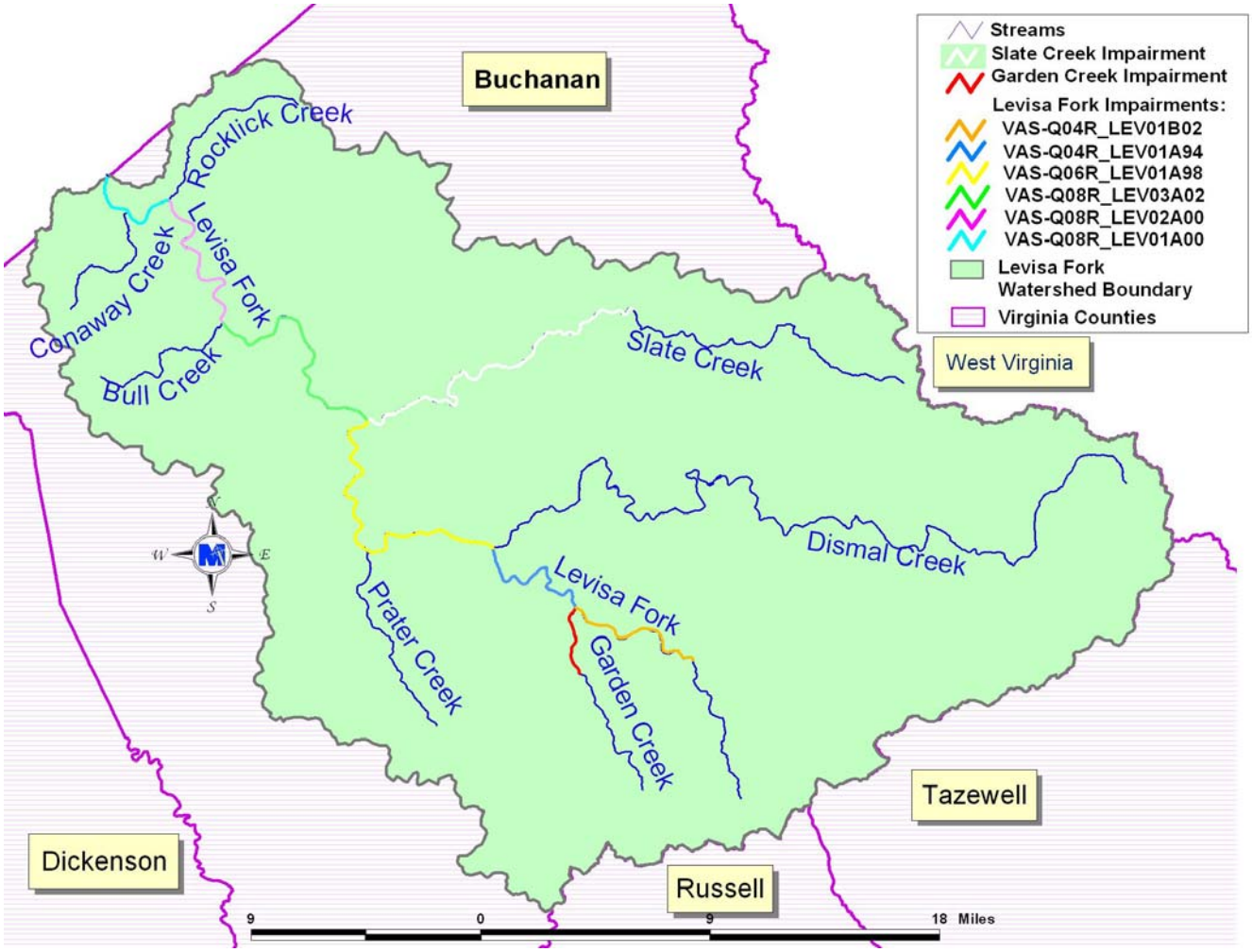

Figure 1.2 The impaired segments within the Levisa Fork watershed included in this project.

Table 1.1 Impairments within the Levisa Fork watershed.

Stream Name Impairment Id	**Impairment(s) Contracted**	**Initial Listing Year(s)**	**2006 River Miles**	**Listing year Fecal Violations[1]/ Total Samples**	**2006 Listing Fecal Violations[2]/ Total Samples**	**Impairment Location Description**
Slate Creek VAS-Q04R_SAT01A00	Benthic, *E. coli*	1996, 1998	9.10	6/18	6/18 FC	Upper Rockhouse Branch conf. to Levisa Fork conf.
Garden Creek VAS-Q04R_GAR01A98	tPCBs	2006	1.80	NA	NA	Right Fork Garden Creek to Levisa Fork conf.
Levisa Fork VAS-Q04R_LEV01B02	tPCBs, *E. coli*	2002, 2004	3.80	3/9	3/12 FC	Downstream of Contrary Creek conf. to Garden Creek conf.
Levisa Fork VAS-Q04R_LEV01A94	Benthic, tPCBs, *E. coli*	1996, 2002, 2004	3.95	12/33	9/27FC	Garden Creek conf. to Dismal Creek conf.
Levisa Fork VAS-Q06R_LEV01A98	Benthic, tPCBs, *E. coli*	2002, 2002, 2004	8.10	5/38	1/15 FC	Dismal Creek conf. to Slate Creek conf.
Levisa Fork VAS-Q08R_LEV03A02	tPCBs, Benthic	2002, 2006	6.19	NA	NA	Slate Creek conf. to Bull Creek conf.
Levisa Fork VAS-Q08R_LEV02A00	tPCBs	2002	4.69	NA	NA	Bull Creek conf. to Rocklick Creek conf.
Levisa Fork VAS-Q08R_LEV01A00	Benthic, tPCBs, *E. coli*	1996, 2002, 2004	2.66	10/56	10/47 FC 8/20 *E. coli*	Rocklick Creek conf. to KY state line

FC = Fecal Coliform; EC=*E. coli*; conf=confluence

[1] Based on the interim instantaneous fecal coliform standard of 1000 cfu/100mL for samples collected during the assessment period.

[2] Based on the instantaneous fecal coliform standard of 400 cfu/100mL or the instantaneous *E. coli* standard of 235 cfu/100mL for samples collected during the assessment period.

2. BACTERIAL TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 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.*

2.2 Applicable Criteria for Fecal Bacteria Impairments

Virginia adopted its current *E. coli* and *enterococci* standard in January 2003 and was updated in 2009. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

The criteria which were used in developing the bacteria TMDL in this study are outlined in Section 9 VAC 25-260-170 (Bacteria; other recreational waters) and read as follows:

A. The following bacteria criteria (colony forming units (cfu)/100mL) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:

E. coli bacteria shall not exceed a monthly geometric mean of 126 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 35 cfu/100mL in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there [are] insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E. coli cfu/100mL.*
4. *If there [are] insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 cfu/100mL.*
5. *For beach advisories or closures, a single sample maximum of 235 E. coli cfu/100mL in freshwater and a single sample maximum of 104 enterococci cfu/100mL in saltwater and transition zones shall apply.*

B. The following bacteria criteria per 100mL (cfu/100mL) of water shall apply to protect secondary contact recreational uses in surface waters:

E. coli bacteria shall not exceed a monthly geometric mean of 630 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 175 cfu/100mL in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there [are] insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 1173 E. coli cfu/100mL.*
4. *If there [are] insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 519 cfu/100mL.*
5. *Where the existing water quality for bacteria is below the geometric mean criteria in a water body designated for secondary contact in subdivision 6 of this subsection that higher water quality will be maintained in accordance with 9VAC25-260-30 A 2.*

2.3 Selection of a bacteria TMDL Endpoint

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 bacteria impairments in the Levisa Fork watershed, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard.

Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using the geometric mean standard. Therefore, the in-stream *E. coli* target for the TMDLs in this study was a monthly geometric mean not exceeding 126 cfu/100 ml.

2.4 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the watershed of the Levisa Fork watershed. An examination of data from water quality stations used in the 303(d) assessment was performed. Sources of data and pertinent results are discussed.

2.4.1 Inventory of Water Quality Monitoring Data

The primary sources of available fecal bacteria information are:

- Bacteria enumerations from 15 VADEQ in-stream monitoring stations with date from February 1980 to November 2007, and
- Bacterial source tracking at seven VADEQ stations.

2.4.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from February 1980 to December 2006 (Figure 2.1) were analyzed for fecal coliform (Table 2.1). Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting fecal coliform concentrations to 400 cfu/100 mL or

less. As a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.*, 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values.

E. coli samples were also collected to evaluate compliance with the state's current bacterial standard. Table 2.2 summarizes the *E. coli* samples collected at the in-stream monitoring stations. Information in the tables is arranged in alphabetical order by stream name then from downstream to upstream station location.

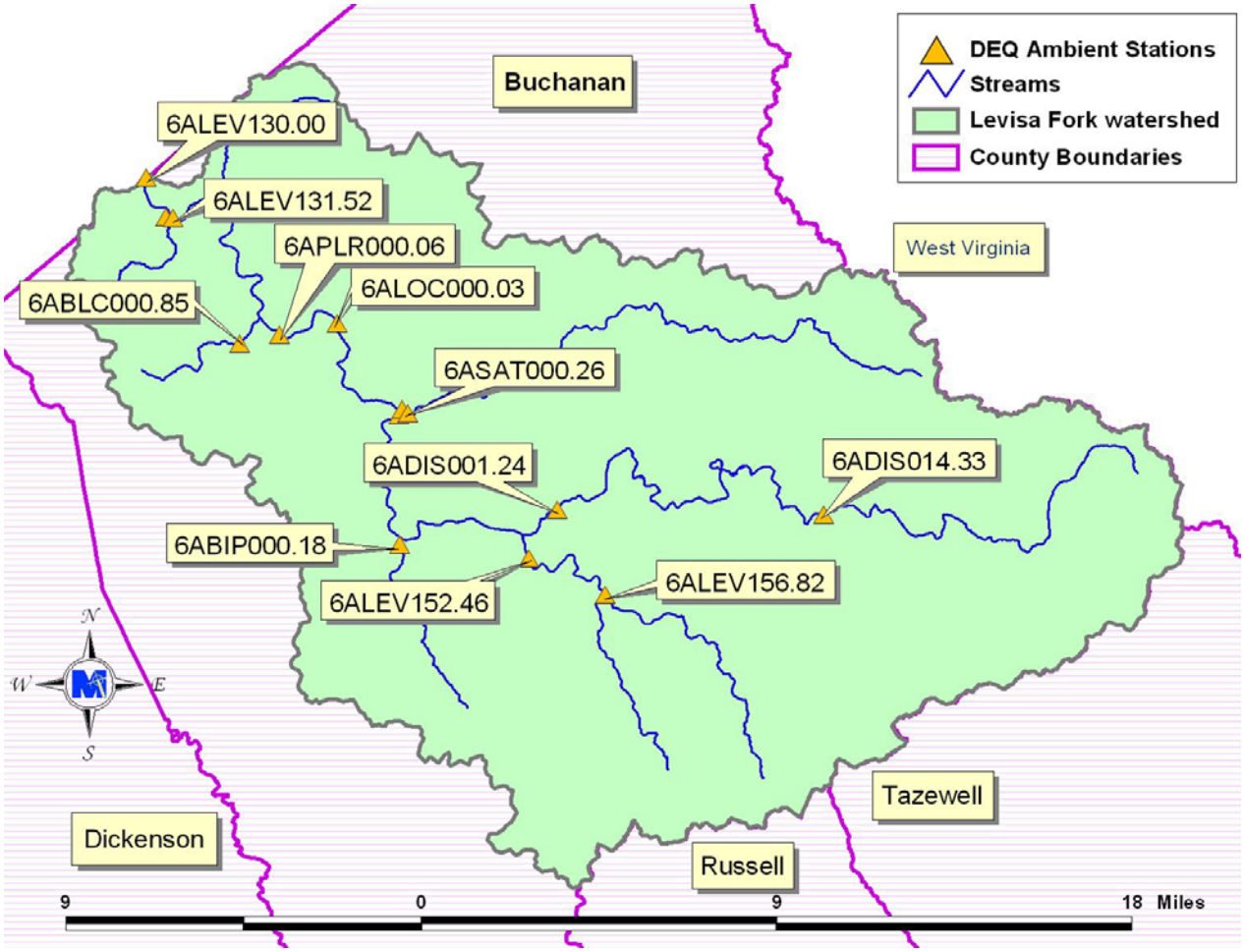

Figure 2.1 Location of VADEQ water quality monitoring stations in the Levisa Fork watershed.

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1980 – December 2006.

Stream	VADEQ Station	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Standard Deviation	Violations[1] %	Violations[2] %
Dismal Creek	6ADIS001.24	151	0	20,000	689	100	1,910	15%	28%
Dismal Creek	6ADIS013.73	1	25	25	25	25	NA	0%	0%
Home Creek	6AHME002.16	1	400	400	400	400	NA	0%	0%
Levisa Fork	6ALEV130.00	116	0	20,000	1,529	550	2,470	37%	53%
Levisa Fork	6ALEV131.52	127	0	8,000	502	190	1,040	11%	22%
Levisa Fork	6ALEV143.86	87	0	3,300	403	140	667	10%	24%
Levisa Fork	6ALEV152.46	27	100	8,000	985	200	1,927	19%	33%
Levisa Fork	6ALEV156.82	12	100	8,000	1,025	100	2,285	25%	25%
Slate Creek	6ASAT000.03	149	0	20,000	2,733	1,400	3,155	52%	64%

NA – Not applicable

[1] Based on the interim instantaneous fecal coliform standard of 1000 cfu/100mL.

[2] Based on the instantaneous fecal coliform standard of 400 cfu/100mL.

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from May 2002 – November 2007.

Stream	VADEQ Station	Count (#)	Minimum (cfu/100mL)	Maximum (cfu/100mL)	Mean (cfu/100mL)	Median (cfu/100mL)	Standard Deviation	Violations[1] %
Big Prater Creek	6ABIP000.18	12	25	1,200	269	38	404	33%
Bull Creek	6ABLC000.85	13	25	2,000	460	280	583	69%
Conway Creek	6ACNW000.23	9	25	250	97	75	81	11%
Dismal Creek	6ADIS001.24	12	25	350	77	25	108	17%
Dismal Creek	6ADIS013.73	1	10	10	10	10	NA	0%
Dismal Creek	6ADIS014.33	12	25	1,000	141	25	283	17%
Home Creek	6AHME002.16	1	300	300	300	300	NA	100%
Levisa Fork	6ALEV131.52	33	10	800	218	100	254	30%
Levisa Fork	6ALEV152.46	7	10	510	117	28	180	14%
Levisa Fork	6ALEV156.82	7	14	2,001	516	260	700	71%
Looney Creek	6ALOC000.03	9	25	400	131	75	123	11%
Poplar Creek	6APLR000.06	9	25	2,000	633	220	787	44%
Slate Creek	6ASAT000.26	9	25	580	203	150	180	33%

NA – Not applicable

[1] Based on the current instantaneous *E. coli* standard of 235 cfu/100mL.

2.4.1.2 Bacterial Source Tracking

MapTech, Inc. was contracted to perform an analysis of *E. coli* concentrations, as well as bacterial source tracking (BST) for ten samples at seven locations during 2007. BST is intended to aid in identifying sources (*i.e.,* human, pets, livestock, or wildlife) of fecal contamination in water bodies. Data collected provided insight into the likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions.

Several procedures are currently under study for use in BST. Virginia has adopted the Antibiotic Resistance Analysis (ARA) methodology implemented by MapTech's Environmental Detection Laboratory (EDL). This method was selected because it has been demonstrated to be a reliable procedure for confirming the presence of human, pet, livestock and wildlife sources in watersheds in Virginia. The results were reported as the percentage of isolates acquired from the samples that were identified as originating from either humans, pets, livestock, or wildlife.

The BST results of water samples collected at seven stations in the Levisa Fork watershed are reported in Tables 2.3 through 2.9. The locations of these stations are shown in Figure 2.2. The *E. coli* enumerations are given to indicate the bacteria concentrations at the time of sampling. Bold values in this column represent samples that exceeded the current instantaneous (single sample) standard of 235 cfu/100mL. In the EPA procedure used, colony forming units are counted up to 200. A count of 200 from a 10 mL sample equates to 2,000 cfu/100mL. Therefore, any colonies greater than 200 are not counted, and the value in the database is recorded as above detection limit (>2,000 cfu/100mL).

The proportions (%) reported are formatted to indicate statistical significance (*i.e.*, bold numbers indicate a statistically significant result). The statistical significance was determined through two tests. The first test 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.

These results show that all four categories of fecal bacteria were detected in waters of the Levisa Fork watershed. Overall at each station, human sources were the most predominate contributor. This observation of the data is reasonable, as it is known that this watershed has many straight pipes and sanitary sewer overflows (Section 3.2.1).

Table 2.3 Summary of bacterial source tracking results from water samples collected in Big Prater Creek (6ABIP000.18).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	24	82	12%	**71%**	17%	0%
04/23/07	13	24	0%	**69%**	**31%**	0%
05/23/07	15	80	7%	**73%**	**20%**	0%
06/18/07	10	60	0%	**70%**	**30%**	0%
07/24/07	24	99	**96%**	0%	0%	4%
08/28/07	24	50	**50%**	**17%**	**29%**	4%
09/24/07	23	74	9%	**69%**	**22%**	0%
10/23/07	24	120	**47%**	8%	12%	**33%**
11/27/07	24	110	29%	**29%**	8%	**34%**
12/18/07	23	60	17%	**79%**	4%	0%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.4 Summary of bacterial source tracking results from water samples collected in Dismal Creek (6ADIS001.24).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	10	16	0%	**90%**	10%	0%
04/23/07	16	22	12%	**51%**	**31%**	6%
05/23/07	18	30	17%	**38%**	**28%**	**17%**
06/18/07	13	70	23%	**23%**	**23%**	**31%**
07/24/07	23	**370**	**35%**	**52%**	13%	0%
08/28/07	21	42	29%	**38%**	0%	**33%**
09/24/07	23	42	**39%**	**44%**	0%	**17%**
10/23/07	9	18	22%	**67%**	0%	11%
11/27/07	5	10	80%	0%	0%	20%
12/18/07	2	4	0%	50%	50%	0%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.5 Summary of bacterial source tracking results from water samples collected in Slate Creek (6ASAT000.26).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	24	104	21%	**58%**	17%	4%
04/23/07	21	52	24%	**66%**	0%	10%
05/23/07	19	221	11%	**73%**	11%	5%
06/18/07	16	36	25%	**19%**	**37%**	**19%**
07/24/07	22	**>2,000**	27%	**27%**	**32%**	**14%**
08/28/07	10	**460**	0%	**80%**	20%	0%
09/24/07	4	**620**	25%	50%	25%	0%
10/23/07	19	**730**	16%	**26%**	16%	**42%**
11/27/07	24	84	25%	**29%**	4%	**42%**
12/18/07	24	62	21%	**29%**	**46%**	4%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.6 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV156.82).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	9	14	0%	**56%**	**44%**	0%
04/23/07	24	46	8%	**67%**	**25%**	0%
05/23/07	22	**260**	9%	**77%**	5%	9%
06/18/07	13	**260**	**31%**	8%	**38%**	**23%**
07/24/07	24	**>2,000**	**46%**	**50%**	0%	4%
08/28/07	24	**770**	**67%**	**33%**	0%	0%
09/24/07	16	**260**	0%	**94%**	6%	0%
10/23/07	23	**380**	26%	**48%**	0%	**26%**
11/27/07	24	235	8%	**84%**	0%	8%
12/18/07	23	58	0%	**74%**	13%	**13%**

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.7 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV152.46).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	16	24	25%	**56%**	**19%**	0%
04/23/07	13	22	0%	**70%**	15%	15%
05/23/07	24	152	21%	**42%**	**29%**	8%
06/18/07	6	70	0%	17%	66%	17%
07/24/07	24	**510**	**88%**	0%	8%	4%
08/28/07	19	28	**64%**	5%	5%	**26%**
09/24/07	7	10	0%	71%	0%	29%
10/23/07	3	20	33%	67%	0%	0%
11/27/07	2	4	100%	0%	0%	0%
12/18/07	8	22	0%	88%	0%	12%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.8 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV143.80).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	3	4	0%	67%	0%	33%
04/23/07	13	30	0%	**84%**	8%	8%
05/23/07	20	**260**	10%	**60%**	**25%**	5%
06/18/07	15	230	20%	7%	**40%**	**33%**
07/24/07	24	**>2,000**	**54%**	4%	17%	**25%**
08/28/07	10	58	0%	**100%**	0%	0%
09/24/07	12	**240**	0%	**33%**	**67%**	0%
10/23/07	17	**1,390**	6%	**64%**	12%	**18%**
11/27/07	24	82	21%	0%	**41%**	**38%**
12/18/07	11	22	9%	**64%**	18%	9%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

Table 2.9 Summary of bacterial source tracking results from water samples collected in Levisa Fork (6ALEV131.52).

Date	Number of Isolates	*E. coli*[1] (cfu/100 ml)	Percent Isolates classified as[2]:			
			Wildlife	Human	Livestock	Pet
03/28/07	8	12	0%	50%	25%	25%
04/23/07	12	28	0%	**83%**	0%	17%
05/23/07	21	46	5%	**43%**	**38%**	**14%**
06/18/07	3	10	33%	0%	67%	0%
07/24/07	24	**>2,000**	**46%**	8%	**25%**	**21%**
08/28/07	12	26	0%	**75%**	8%	17%
09/24/07	4	12	0%	75%	0%	25%
10/23/07	7	18	29%	29%	13%	29%
11/27/07	12	18	8%	17%	**67%**	8%
12/18/07	24	72	0%	**46%**	**46%**	8%

[1]**Bold** type indicates this sample violates the instantaneous standard (235 cfu/100mL).
[2]**Bold** type indicates a statistically significant value.

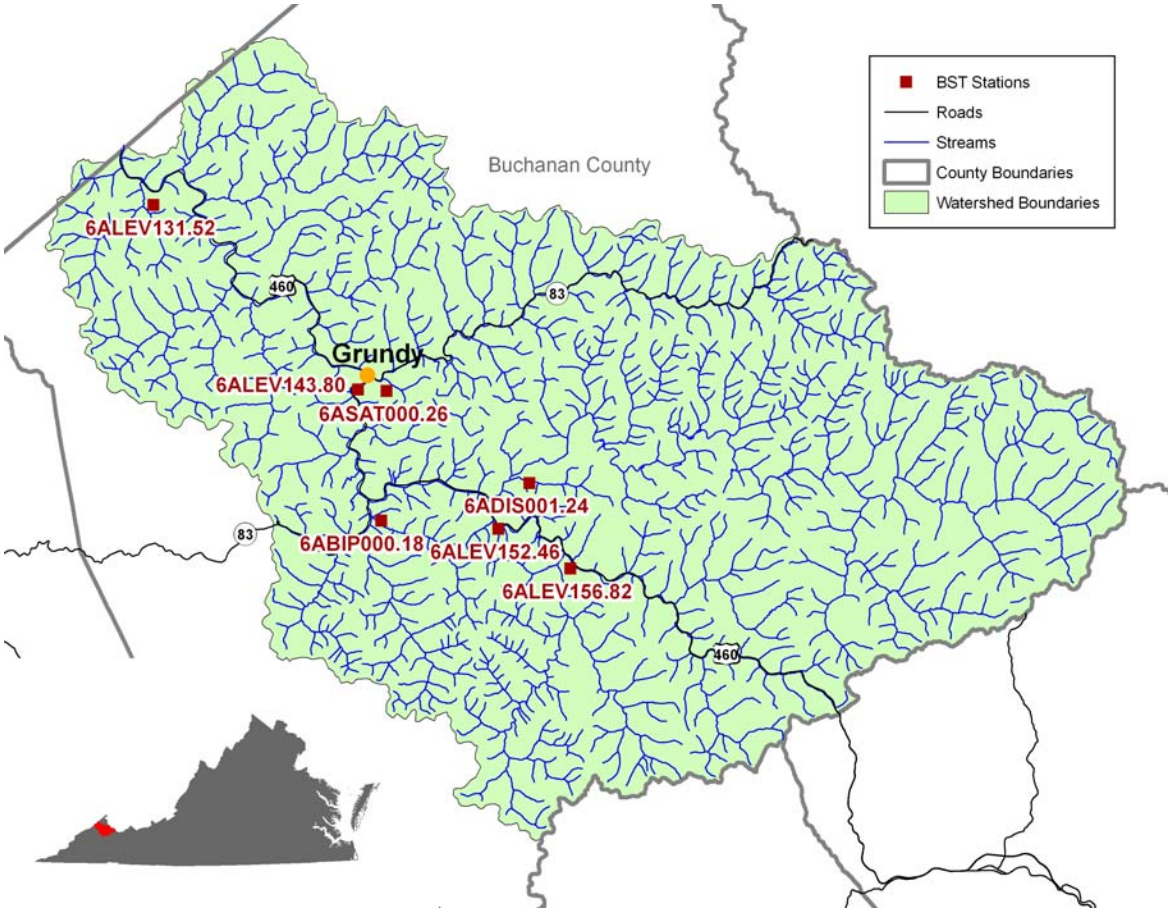

Figure 2.2 Location of BST water quality monitoring stations in the Levisa Fork watershed.

2.4.2 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 fecal bacteria data and precipitation data. Trend and seasonal analyses were performed on bacteria concentration data at VADEQ stations. A Seasonal Kendall Test, which ignores seasonal cycles, was used to examine long-term trends. This test improves the chances of finding existing trends in data that are likely to have seasonal patterns.

Significant trends were observed in the fecal coliform concentrations at VADEQ stations 6ADIS001.24 in Dismal Creek, 6ALEV130.00 in Levisa Fork, and at 6ASAT000.03 in Slate Creek (Appendix B, Table B.2). The trends were all negative indicating statistically significant decreases in fecal coliform concentrations over time. The other stations did not have enough data to perform the analysis. There was not enough data to perform the trend analysis on *E. coli* concentration data.

A seasonal analysis of precipitation and fecal coliform concentration data were conducted using the Mood's Median Test (Minitab, 1995). This test was used to compare monthly total precipitation and monthly average fecal coliform concentrations in each month. Significant differences between months within years were reported. Significant seasonality effects were found in the precipitation values. Differences in mean monthly precipitation are indicated in Table B.1 (Appendix B). Precipitation values in months with the same median group letter are not significantly different from each other. July was grouped in the high precipitation group; February, October and November were grouped into the low precipitation group. All other months were not statistically significantly different from either group.

The use of a Mood's Median test showed that none of the bacteria data from VADEQ stations on Levisa Fork or Slate Creek had statistically significant seasonality.

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3. BACTERIAL SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal coliform in the Levisa Fork. The source assessment was used as the basis of 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 management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into permitted and nonpoint sections. The representation of the following sources in the model is discussed in Chapter 4.

3.1 Assessment of Permitted Sources

Sixty-five point sources, some with multiple outfalls, are permitted to discharge to surface water bodies in the Levisa Fork watershed. These are listed in Tables 3.1, 3.2 and 3.3. The use of "UT" refers to unnamed tributaries. Eight of the VPDES permits are permitted for fecal bacteria control. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 ml. Currently, these permitted discharges are expected not to exceed the 126 cfu/100mL *E. coli* standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill pathogens. 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 concentrations) are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, bacteria concentrations are reduced to levels well below the standard. The remaining two VPDES permits are not permitted for fecal bacteria control, but they do discharge water to the streams. Permit locations are shown in Figure 3.1. The Conaway WWTP discharged into Conaway Creek before the outfall was moved to Levisa Fork around 1999.

Table 3.3 shows the single family home permits within the Levisa Fork watershed. These permits allow treated residential wastewater to be discharged to surface waters. All of these housing units discharge water and bacteria to the streams.

There are no VPDES Confined Animal Feeding Operations (CAFO), Virginia Pollution Abatement (VPA) facilities, Municipal Separate Storm Sewer Systems (MS4), or surface water and ground water withdrawal permits in the watershed.

Table 3.1 Summary of VPDES permitted point sources in the Levisa Fork watershed.

Permit	Receiving Stream	Facility Name	Permitted for FC Control
VA0026999	Slate Creek	Buchanan County Public Schools - J M Bevins Elementary	Yes
VA0050351	Levisa Fork	Jewell Coke Company Coke Plants 2 and 3	No
VA0052639	Levisa Fork	Norfolk & Western Railway Co -Weller Yard Terminal	No
VA0065536	Dismal Creek	Island Creek Coal Company - VP Mine 1 STP	Yes
VA0065625	Big Prater Creek	Island Creek Coal Company - VP Mine 8 Deskins STP	Yes
VA0066907*	Garden Creek	Consolidation Coal Company - Buchanan Mine STP	Yes
VA0068438	Dismal Creek	Buchanan County Public Schools - Twin Valley High School STP	Yes
VA0089907	Mill Branch	Buchanan County PSA - Mill Branch STP	Yes
VA0090239	Big Prater Creek	Buchanan County PSA - Deskins STP	Yes
VA0090531	Levisa Fork	Buchanan County PSA - Conaway WWTP	Yes

*Accounted for during separate reports on the Garden Creek TMDLs

Table 3.2 Single family home permits in the Levisa Fork watershed.

Permit	Receiving Stream	Facility Type
VAG400064	White Oak Branch	Single Family Home
VAG400087	Big Lick Branch	Crigloo Properties LLC STP
VAG400096	Lick Branch	Single Family Home
VAG400108	Russell Fork	Appalachian Air Incorporated
VAG400129	Linn Camp Branch	Single Family Home
VAG400190	Rocklick Creek	Single Family Home
VAG400191	Levisa Fork	Thompson Enterprises STP
VAG400192	Home Creek	Single Family Home
VAG400200	Cranesnest Branch	Wade Property STP
VAG400211	Grassy Creek	Single Family Home
VAG400342*	Right Fork Garden Creek	Knox Creek Coal Corp - Tiller No 1 Mine Bathhouse
VAG400404	Slate Creek	Single Family Home
VAG400405	Dry Fork	Single Family Home
VAG400413	Straight Fork	Matney Construction Company Shop STP
VAG400445	Slate Creek	Pilgrims Knob Community Park STP
VAG400465	Home Creek, Left Fork	R & J Properties STP
VAG400515	Poplar Creek, UT	Buchanan County Animal Shelter STP
VAG400549	Slate Creek	Single Family Home
VAG400557	Big Prater Creek	Cardinal Development Inc STP No 1
VAG400558	Slate Creek	Cardinal Development Inc STP No 2
VAG400573**	Bull Creek	Single Family Home
VAG400589**	Bull Creek	Single Family Home
VAG400613	Dismal Creek, UT	Poplar Gap Gymnasium STP
VAG400613	Dry Fork	Poplar Gap Gymnasium STP
VAG400619	Hobbs Branch	Harman Memorial Baptist Church
VAG400634	Poplar Creek	Single Family Home
VAG400643	Poplar Creek, UT	Single Family Home
VAG400663	Dismal Creek	Single Family Home
VAG400664	Big Prater Creek	Single Family Home
VAG400668	Levisa Fork	Single Family Home
VAG400678	Upper Mill Branch	Carl L Harman Apartments STP
VAG400680	Licklog Branch	Single Family Home
VAG400681	Smith Branch	Single Family Home
VAG400682	Stonecoal Branch, UT	Single Family Home
VAG400686	Elkins Branch	Single Family Home
VAG400697	Little Prater Creek	Single Family Home
VAG400698	Prater Creek, UT	Single Family Home
VAG400710	Dry Fork	Single Family Home
VAG400727	Stilner Creek	Matney Construction Office Complex STP
VAG400729*	Little Garden Creek	Single Family Home
VAG400730	Home Creek	Whitewood Vol Fire Dept and Community Center STP
VAG400731	Home Creek	Single Family Home
VAG400735	Dry Fork	Single Family Home
VAG400741	Left Fork Home Creek	Single Family Home
VAG400809	Hobbs Branch	Photo Classics Inc
VAG400812	Stilton Branch	Single Family Home

* Accounted for in separate reports on the Garden Creek TMDLs
** Accounted for in a separate report on the Bull Creek TMDL

Table 3.3 Carwash, concrete, industrial, and construction permits in the Levisa Fork watershed.

Permit	Receiving Stream	Facility Name	Facility Type
VAG750020	Levisa Fork	Vansant Car Wash	Carwash
VAG750149	Slate Creek	Chads Zip In	Carwash
VAR101038	Levisa Fork	Grundy Nonstructural Project Redevelopment Site E	Construction Stormwater
VAR104503	Laurel Creek	Mountaineer 1 Land Clearing	Construction Stormwater
VAR102495	Road Branch	VDOT Lebanon Residency 0703 013 P52 N501	Construction Stormwater
VAR104799	Grassy Creek	Grassy Creek Impoundment Maintenance	Construction Stormwater
VAR050018	Little Prater, UT	Grundy Municipal Airport	Industrial Stormwater
VAR050059	Levisa Fork/Home Creek/Bull Creek	Excello Oil Company Incorporated - Grundy	Industrial Stormwater
VAR050102	Home Creek	Excel Mining Systems LLC - Grundy	Industrial Stormwater
VAR051686	Levisa Fork	Leetown Railsiding	Industrial Stormwater
VAG110243	Laurel Branch/Fork	Buchanan County Ready Mix	Concrete

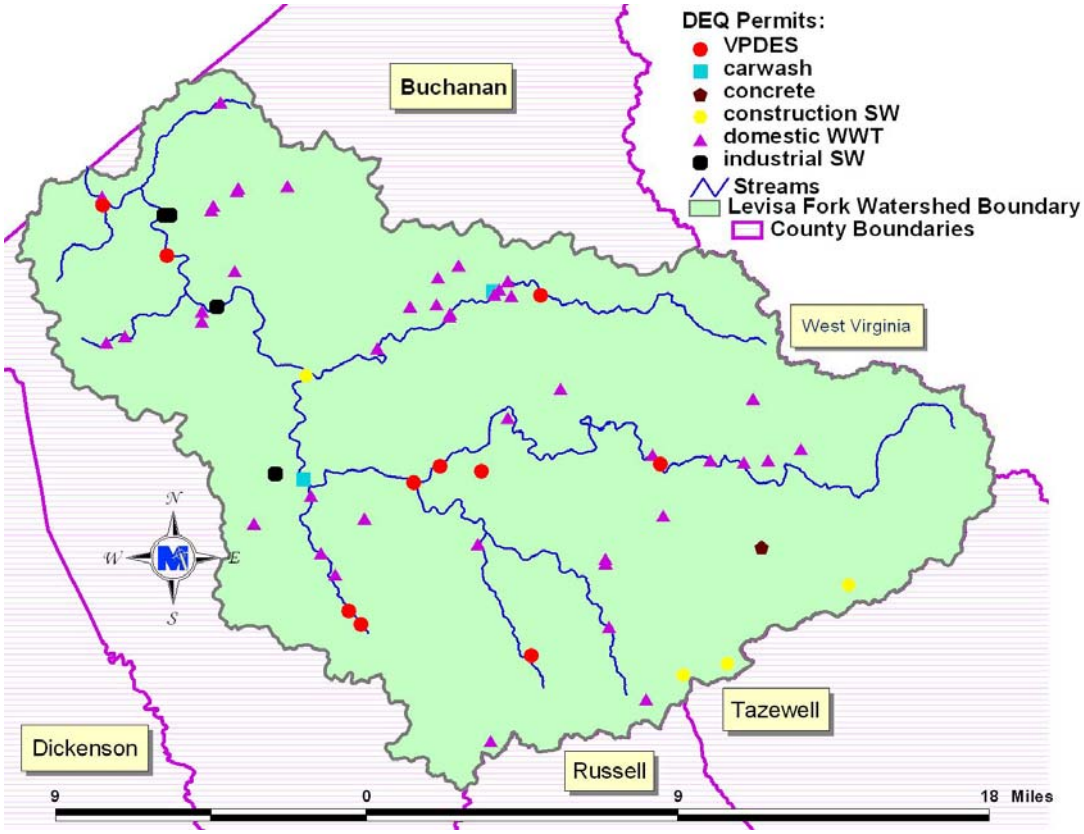

Figure 3.1 Location of VADEQ permits in the Levisa Fork watershed (SW=stormwater; WWT=wastewater treatment).

3.2 Assessment of Nonpoint Sources

In the Levisa Fork watershed, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. MapTech previously collected samples of fecal coliform sources (*i.e.,* wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria. This analysis was used to support the modeling process for the current project and to expand the database of known fecal coliform sources for purposes of bacterial source tracking (Section 2.3.1.3). Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Population, housing units, and type of sewage treatment data from the U.S. Census Bureau were determined using GIS (Table 3.4). In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool, or the sewage is disposed of in some other way. The Census category “Other Means” includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via a straight pipe (uncontrolled discharge).

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity or the capacity is reduced by a blockage, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows.

Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

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 are 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, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal bacteria is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal bacteria to surface waters.

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 available to be washed into waterways during runoff events. A survey of septic pump-out contractors, previously performed by MapTech, showed that failures were more likely to occur in the winter-spring months than in the summer-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 in the yard.

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml (MapTech, 2001). An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.4 Human population information for 2008 in areas contributing to impaired segments in the Levisa Fork watershed.

Impaired Segment	Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
Slate Creek	3,424	1,443	290	1,083	70
Levisa Fork	16,775	7,676	1,162	6,023	487

* Houses with sewage disposal systems other than sanitary sewer and septic systems.

3.2.2 Biosolids

The Conaway Wastewater Treatment Plant (WWTP) (VA0090531) produces biosolids that are both periodically land applied and disposed of in a landfill. Of the two areas allowed to land apply the biosolids from this source; only one area is within the Levisa Fork watershed. This area is within subwatershed 2 (Figure 4.1), high on a mountain, and maintained with appropriate vegetated buffers around the treated area. Applications are infrequent, no more than once every three years. Due to these facts, it is assumed that the contribution of fecal bacteria and other possible pollutants is negligible from biosolids in the Levisa Fork watershed.

3.2.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the Levisa Fork watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured by MapTech. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech. A summary of the data collected is given in Table 3.5. Table 3.6 lists the domestic animal populations for impairments in the Levisa Fork watershed.

Table 3.5 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 3.6 Estimated domestic animal populations in areas contributing to impaired segments in the Levisa Fork watershed.

Impaired Segment	Dogs	Cats
Slate Creek	771	862
Levisa Fork	4,100	4,589

3.2.4 Livestock

The predominant types of livestock in the Levisa Fork watershed are beef cattle and horses, although all types of livestock identified were considered in modeling the watersheds. Table 3.7 gives a summary of livestock populations in the Levisa Fork watershed for 2008, organized by impairment. Animal populations were based on communication with Big Sandy Soil and Water Conservation District (BSWCD) and verbal communication with citizens at the first public meeting.

Table 3.7 Livestock populations (2008) in areas contributing to impaired segments in the Levisa Fork watershed.

Impaired Segment	Beef Adult	Beef Calves	Dairy Milkers	Horse	Sheep	Hog
Slate Creek	51	12	2	17	3	1
Levisa Fork	498	119	9	121	26	4

Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999a). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.8.

Table 3.8 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Dairy milker (1,400 lb)	120.4	271,329	0.5
Dairy heifer (850 lb)	70.0	271,329	0.25
Dairy calf (350 lb)	29.0	271,329	0.5
Hog (135 lb)	11.3	400,000	0.8
Hog Lagoon	N/A	95,300[1]	NA
Horse (1,000 lb)	51.0	94,000	NA
Sheep (60 lb)	2.4	43,000	NA
Goat (140 lb)	5.7	15,000	NA
Poultry (1 lb):			
Broiler	0.17	586,000	0.5
Layer	0.26	586,000	0.5

[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 drainage systems that divert wash-water and waste directly to drainage ways or streams. No confined animal facilities were identified in the Levisa Fork watershed, so only the second and third pathways were considered.

All livestock were expected to deposit some portion of waste on land areas. The percentage of time spent on pasture for beef cattle was verified by BSSWCD (Table 3.7). Horses and sheep were assumed to be in pasture 100% of the time. The average amount of time spent by beef cattle in stream access areas (*i.e.*, within 50 feet of the stream) for each month is given in Table 3.9.

Table 3.9 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day for the Levisa Fork watershed.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.2.5 Wildlife

The predominant wildlife species in the Levisa Fork watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), United States Fish and Wildlife Service (FWS), and source sampling. Population densities were calculated from data provided by VDGIF and FWS and are listed in Table 3.10 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987; Mayhorn, 2005).

Table 3.10 Wildlife population densities for the Levisa Fork watershed.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)
0.0037	0.0079	0	0.0027	0.0487	0.0133	3.8

The numbers of animals estimated in the Levisa Fork watershed are reported in Table 3.11.

Table 3.11 Estimated wildlife populations in the Levisa Fork watershed.

Impaired Segment	Raccoon	Muskrat	Deer	Goose	Turkey	Duck	Beaver
Slate Creek	341	335	96	0	179	19	145
Levisa Fork	2,277	2,532	627	0	1,174	132	1,100

Where available, fecal coliform densities were based on sampling of wildlife scat performed previously by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999a). Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in Table 3.12.

Table 3.12 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

Table 3.13 summarizes the habitat and waste production information for wildlife. Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; Weiskel et al., 1996, and Yagow, 1999b). Habitat was determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999).

Table 3.13 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	**Primary** = region within 600 ft of perennial streams **Secondary** = region between 601 and 7,920 ft from perennial streams **Infrequent/Seldom** = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Beaver[1]	200	**Primary** = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) **Infrequent/Seldom** = rest of the watershed area
Deer	772	**Primary** = forest, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, livestock access, wetlands, transitional land, reclaimed mine land **Secondary** = low density residential, medium density residential, gas wells, abandoned mine land **Infrequent/Seldom** = water, barren, high-density residential, commercial/industrial/transportation, active mine land, developed
Turkey[2]	320	**Primary** = forest, harvested forest land, grazed woodland, orchards, wetlands, transitional land, reclaimed mine land **Secondar**y = cropland, pasture **Infrequent/Seldom** = water, barren, residential, developed, abandoned mine land, commercial/industrial/transportation, active mine land, gas wells
Goose[3]	225	**Primary** = waterbodies, and land area within 66 ft from the edge of water **Secondary** = region between 67 and 308 ft from water **Infrequent/Seldom** = rest of the watershed area
Mallard (Duck)	150	**Primary** = waterbodies, and land area within 66 ft from the edge of water **Secondary** = region between 67 and 308 ft from water **Infrequent/Seldom** = rest of the watershed area

[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, 2003)

4. BACTERIAL MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the bacteria 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 in the Levisa Fork watershed, the relationship was defined through computer modeling, based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. 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. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality. In this section, the selection of modeling tools, source assessment, selection of a representative period, 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 streamflow, existing conditions, and to perform bacteria TMDL allocations. 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 land uses 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.

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.

4.2 Model Setup

Daily precipitation data was available within the watershed at the Grundy NCDC Coop station #443640. Missing values were filled using daily precipitation from the Hurley 4S NCDC Coop station #444180 and the Richlands NCDC Coop station #447174. The resulting daily rainfall was disaggregated into hourly data using hourly rainfall data from Hurley 4S NCDC Coop station #444180.

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 previously 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.

4.2.1 Subwatersheds

To adequately represent the spatial variation in the watershed, the Levisa Fork watershed was divided into fourteen subwatersheds (Figure 4.1 and Table 4.1) for the purpose of modeling hydrology and bacteria transport. 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 (fecal coliform and *E. coli* concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with monitoring stations, when appropriate, since output from the model can only be obtained at the modeled subwatershed outlets. Table 4.1 notes the subwatersheds containing the impaired stream segments and the all contributing subwatersheds for each impairment.

Table 4.1 Impairments and subwatersheds within the Levisa Fork watershed.

Impairment	Bacteria Impaired Subwatershed(s)	Contributing Subwatersheds
Slate Creek	10	9, 10
Levisa Fork	2-8	1-14

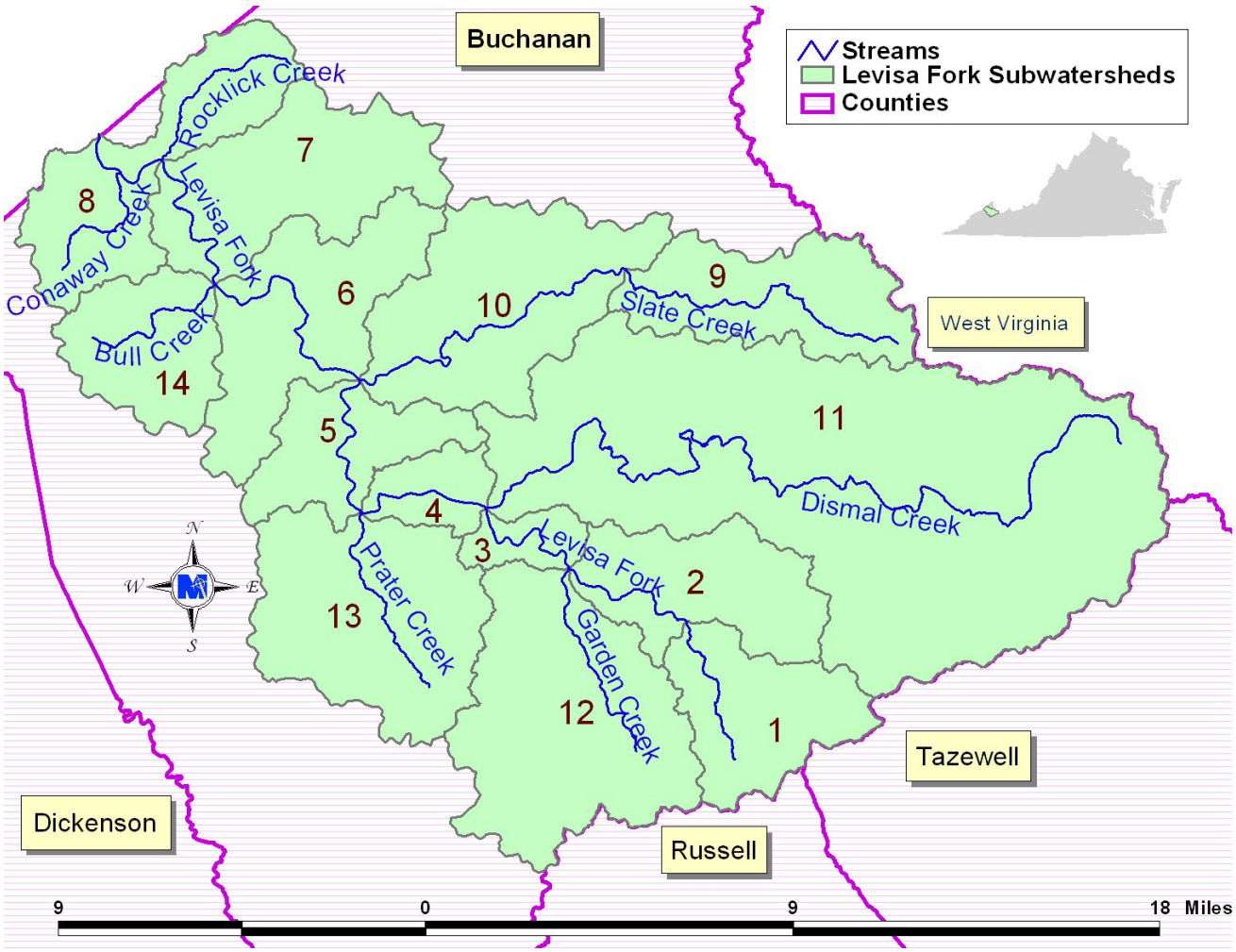

Figure 4.1 Subwatersheds delineated for HSPF modeling in the Levisa Fork watershed.

In an effort to standardize modeling efforts across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

4.2.2 Land uses

The 2001 MRLC/NLCD land use grid identified 13 land use types in the watershed. The 13 land use types were consolidated into categories based on similarities in hydrologic and waste application/production features (Table 4.2). Within each subwatershed, up to ten land use types were represented. Each land use in each subwatershed has hydrologic parameters (*e.g.,* average slope length) and pollutant behavior parameters (*e.g.,* fecal coliform accumulation rate) associated with it. Table 4.2 shows the consolidated land use types in the watershed. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in three IMPLND types, while there are eleven PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with the season (*e.g.,* upper zone storage) to account for plant growth, die-off, and removal. Figure 4.2 shows the land uses in the watershed. Table 4.3 shows the breakdown of land uses within the drainage area of each impairment.

The "Active Mining" and "Reclaimed Mining" land use acreages were determined using DMME mine permit ledger information. For every year of each mining permit a total acres of disturbed and revegetated land were noted. The cumulative areas were calculated as a running tally from each permit. The final value for each subwatershed was determined based on the average annual cumulative acres during the modeling time periods of 1996 to 2003 (see Section 4.4.1) for each permit within the boundary of the subwatershed. These values represent an average disturbed and reclaimed for a stable time period. The "Active Mining" and "Reclaimed Mining" land uses are not shown in Figure 4.2 because the acre values were not determined spatially. These acres were entered into the HSPF model directly and were subtracted from the forest land use.

The "Active Gas Well" land use was created using data from DMME and the 2001 MRLC data. Each active well point was assumed to have half and acre of land associated with it. In addition to this area, any pasture or grassland that touched these points were assigned to "Active Gas Well" also. The remaining grassland was grouped with forest; the remaining pasture was modeled as "Pasture Hay".

Digital Raster Graphics (DRG) maps show mining in purple that was active before 1975. The areas that did not fall within the boundaries of current mine permitted areas were delineated and named abandoned mine land (AML). It was assumed that any AML within a permit boundary would have to be reclaimed before the permit would be released.

Table 4.2 Consolidation of MRLC/NLCD 2001 land use categories for the Levisa Fork watershed used in HSPF modeling.

HSPF Land use Categories	Pervious/Impervious (Percentage)	2001 MRLC Land use Classifications (Class Number)
Active Gas Well	Pervious (100%)	DMME data points - assumed 0.5 acre per well; Grassland (71) and Pasture/Hay (81) that touch these points
Active Mining	Pervious (70%) Impervious (30%)	Average annual cumulative disturbed area from DMME ledgers for 1996 – 2003 Barren Land (31)
AML	Pervious (100%)	DRG and DMME area that were not in current permitted mining
Developed	Pervious (80%) Impervious (20%)	Developed, Medium Intensity (23) Developed, High Intensity (24)
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Scrub/Shrub (52) Remaining Grassland (71)
Open Water	Pervious (100%)	Open Water (11)
Pasture Hay	Pervious (100%)	Remaining Pasture/Hay (81)
Reclaimed Mining	Pervious (100%)	Average annual cumulative revegetated area from DMME ledgers for 1996 - 2003
Residential	Pervious (90%) Impervious (10%)	Developed, Open Space (21) Developed, Low Intensity (22)
Row Crops	Pervious (100%)	RowCrop (82)

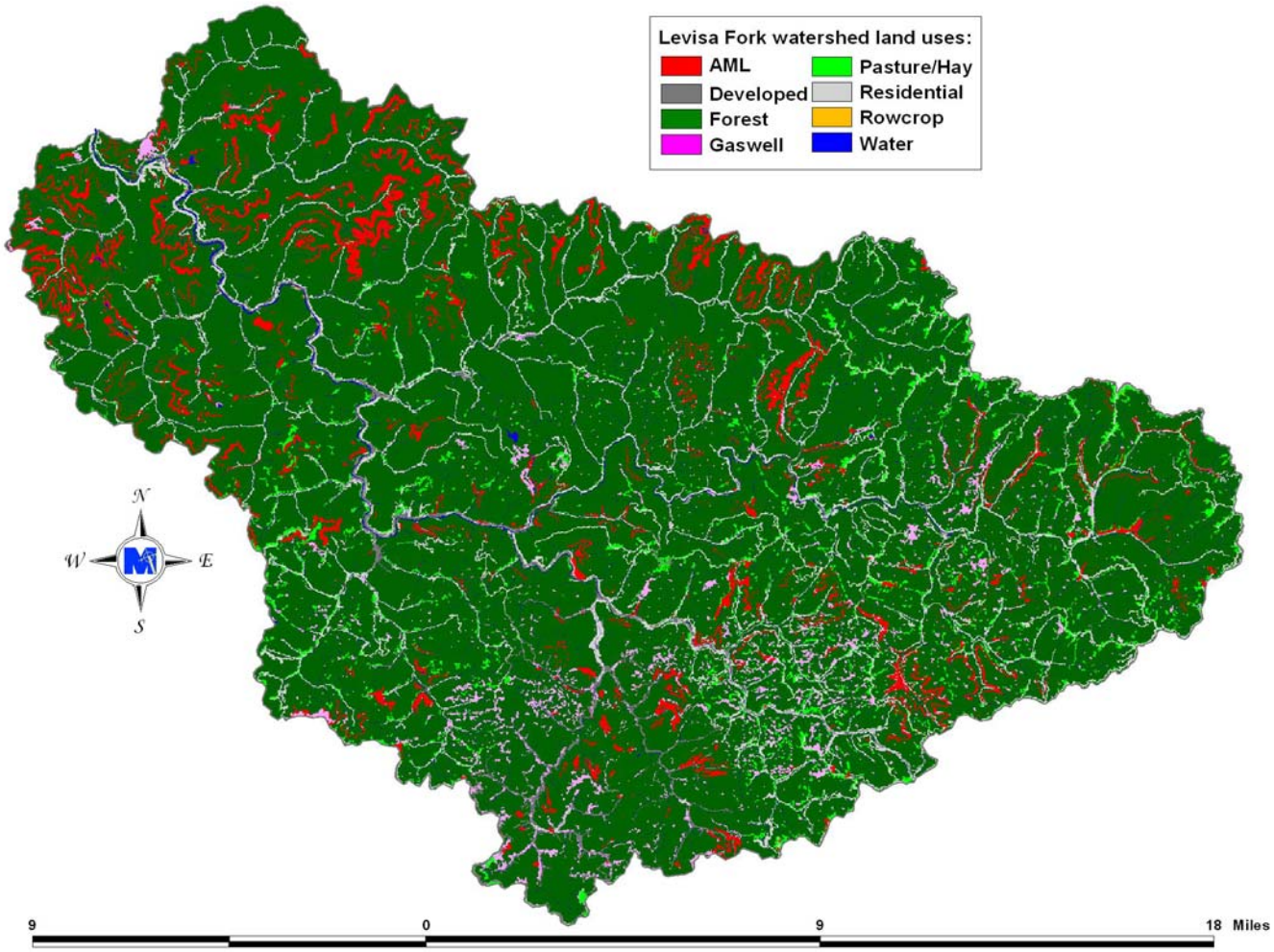

Figure 4.2 Land uses in the Levisa Fork watershed (combined 2001 MRLC, DMME, DRG data; does not include Active Mining and Reclaimed Mining).

Table 4.3 Land use acerages in the Levisa Fork HSPF model.

Impaired Segment	Active Gas Well	Active Mining	AML	Barren	Developed	Forest	Open Water	Pasture/Hay	Reclaimed Mining	Residential	Row Crops	Total
Slate Creek	63	89	1,134	0	107	22,231	283	452	52	1,694	0	**26,105**
Levisa Fork*	4,694	3,873	9,973	14	2,345	155,802	2,516	4,526	1,585	10,938	31	**196,297**

*Includes the Garden Creek area (subwatershed 12), which was modeled in separate bacterial and benthic TMDL projects.

4.2.3 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.,* stream geometry and resistance to flow). These data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (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 in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2008) and Digital Elevation Models (DEM) were used. The NRCS has developed empirical formulas for estimating stream width, cross-sectional area, average depth, and flow rate at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the Levisa Fork watershed. The NRCS equations developed from data in the Hydrologic Region 5 in Central New York were implemented. Levisa Fork and this area in New York are in the same physiographic region (Appalachian Plateau). Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with distance for each subwatershed outlet (Figure 4.3). Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile.

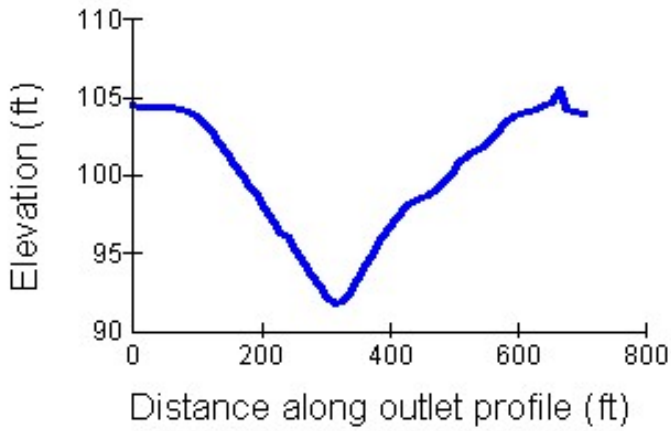

Figure 4.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with values for resistance to flow (Manning's *n*) assigned based on recommendations by Brater and King (1976) and shown in Table 4.4. The conveyance was calculated for each of the two floodplains and the main channel; these figures were then added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from DEMs and a stream-flow network based on National Hydrography Dataset (NHD) data. The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (in ft^3/s) at a given depth. An example of an F-table used in HSPF is shown in Table 4.5.

Table 4.4 Summary of Manning's roughness coefficients for channel cells*.

Section	Upstream Area (ha)	Manning's *n*
Intermittent stream	18 - 360	0.06
Perennial stream	360 and greater	0.05

*Brater and King (1976)

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	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

4.3 Selection of a TMDL Critical Condition

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Levisa Fork watershed 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 will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the Levisa Fork watershed are attributed to both point and non-point sources. Critical conditions for waters impacted by land-based non-point 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 non-point sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A description of the data used in these analyses is shown in Table 2.1 and Table 2.2 in Chapter 2. Data at the VADEQ monitoring station 6ALEV130.00 in Levisa Fork shown in Figure 4.10 is an example of a stream with fecal coliform standard violations (>400 cfu/100mL) during all flow regimes. Levisa Fork also had fecal coliform standard violations during all flow regimes at an upstream station, 6ALEV131.25. Figure 4.4 shows an example of a critical flow regime graph. The remaining concentration versus

stream flow graphs are shown in Appendix B. The flow levels in which water quality violations occur are considered "critical conditions".

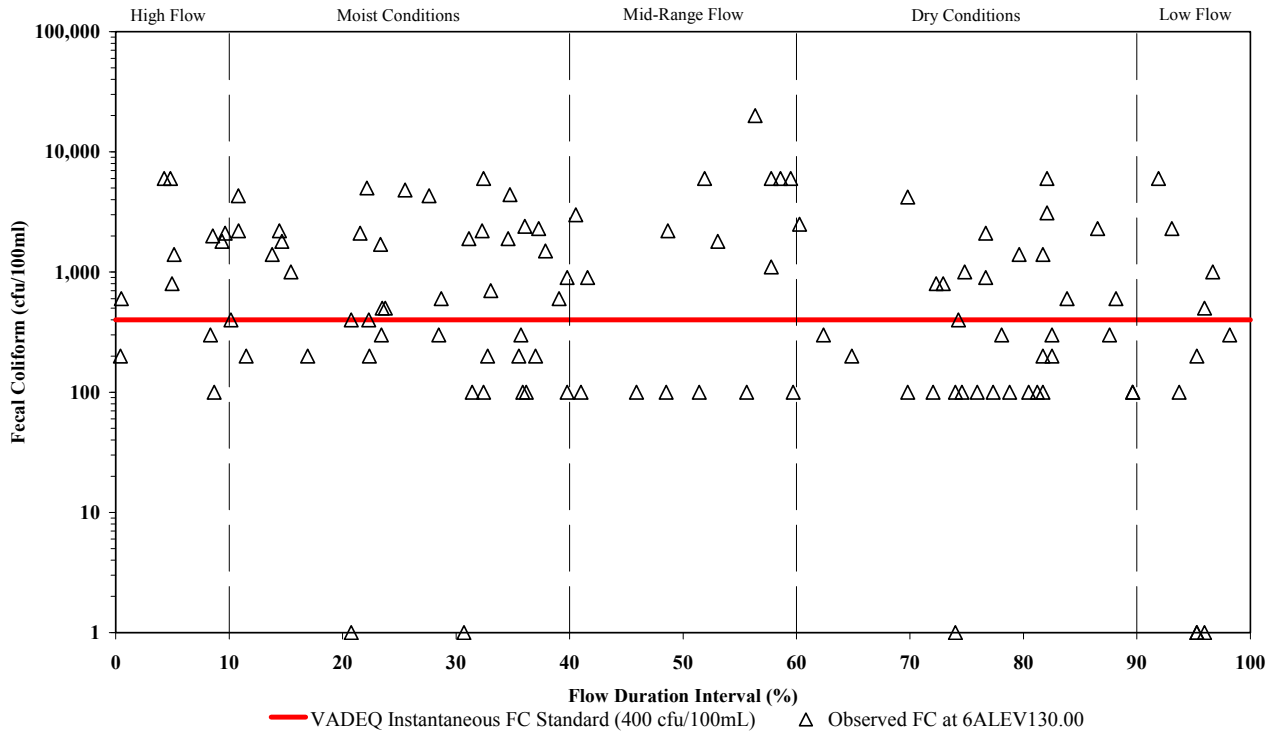

Figure 4.4 Fecal coliform concentrations at 6ALEV130.00in Levisa Fork versus discharge at USGS Gaging Station #03207800.

Graphical analyses of fecal coliform concentrations and flow duration intervals showed that there were different critical flow levels for different segments of Levisa Fork (Figures B.1 to B.4 and B.6). The data from the stations in the Levisa Fork show fewer violations at low and dry flows, which can indicate that, even when the flow in the Levisa Fork is low, there is enough water to dilute contributions from point sources and directly deposited sources. Violations were observed during all flow regimes in Levisa Fork; therefore, the allocation model should use representative rainfall and flow data relating to all recorded historical data.

The graph for Slate Creek at VADEQ station 6ASAT000.03 shows fecal coliform standard violations during all flow regimes (Figure B.5 in Appendix B). Violations were observed during all flow regimes on Slate Creek; therefore, the allocation model should use representative rainfall and flow data relating to all recorded historical data. The

resulting modeling periods for hydrology calibration and validation are presented in Section 4.4.1.

4.4 Hydrology Modeling

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, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.4.1 Selection of Representative Hydrologic Modeling Periods

Selection of the modeling periods was based on three factors: the degree of land-disturbing activity, availability of data (stream flow and water quality), and the need to represent critical hydrological conditions. Using these criteria, modeling periods were selected for hydrology calibration and validation.

Much of the data used to develop the inputs for modeling hydrology is time-dependent due to land use changes and resulting hydrologic changes. Based on a review of mine permit anniversary reports, it was evident that surface coal mining has occurred in this watershed for many decades. An observation of the cumulative disturbed acres per year showed a relatively stable time period from 1994 to 2003 (Figure 4.5). During this time period the average disturbed acreage was 3,921 acres.

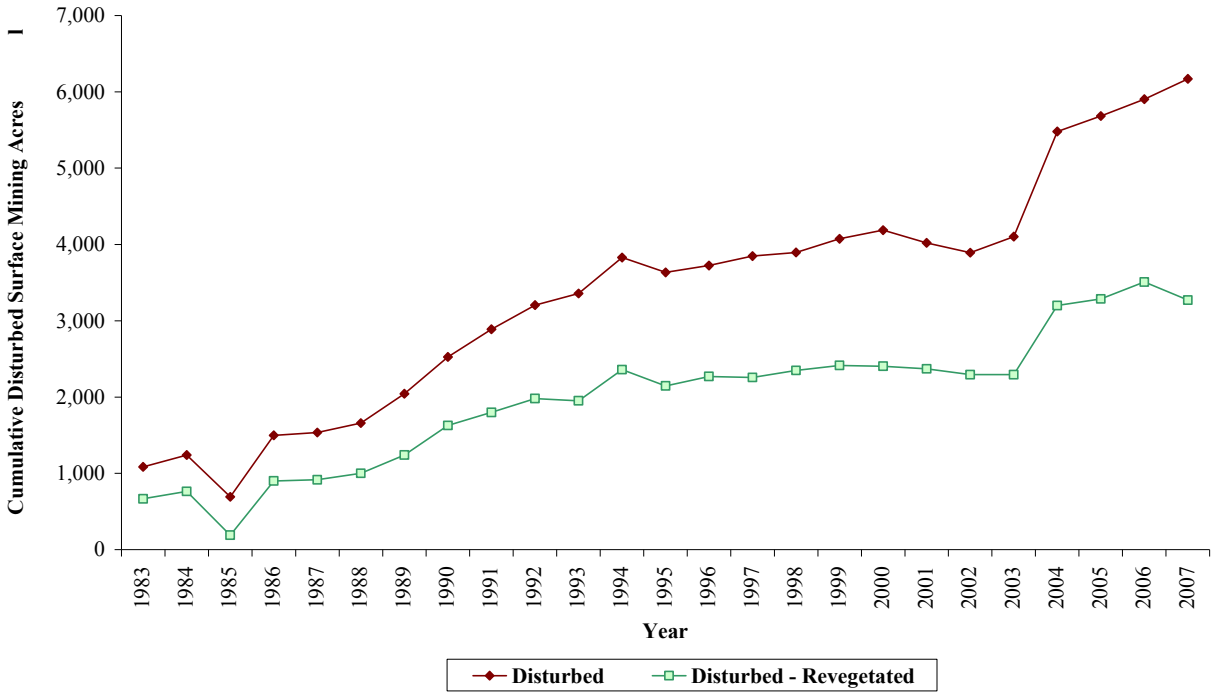

Figure 4.5 Annual disturbed and reclaimed land by mining operations in the Levisa Fork watershed.

As explained in the critical conditions section (Section 4.3), all flow levels had bacteria violations at VADEQ stations in Levisa Fork and Slate Creek. This indicates that the modeling time periods must include all flow regimes to account for critical conditions.

The selection of hydrologic modeling period was based on representative streamflow and precipitation during the stable time period (1994 to 2003). The historical stream flow at USGS gage #03207800 in Levisa Fork and precipitation from NCDC stations in Grundy, Hurley, and Richlands, Virginia were compared to shorter time periods within the stable time period to determine two representative periods for modeling. Data representing the period 10/1/2000 to 9/30/2003 were used to calibrate the HSPF hydrologic model used in this study. To validate that the HSPF can accurately simulate other time periods, a validation time period of 10/1/1996 to 9/30/1999 was selected. A comparison between the two modeling time periods and historical data is shown in Figure 4.6 and 4.7 and in Table 4.6.

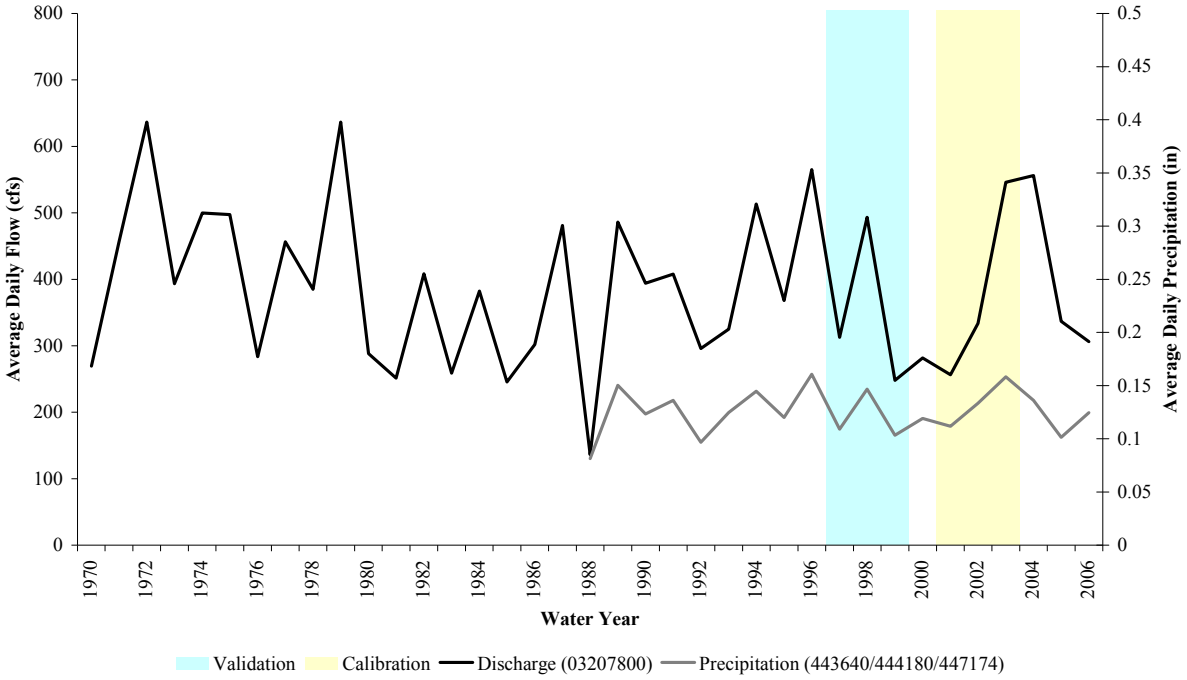

Figure 4.6 Hydrology modeling time periods, annual historical flow (USGS Station 03207800), and precipitation (NCDC Stations in Grundy, Hurley, Richlands, Virginia) data.

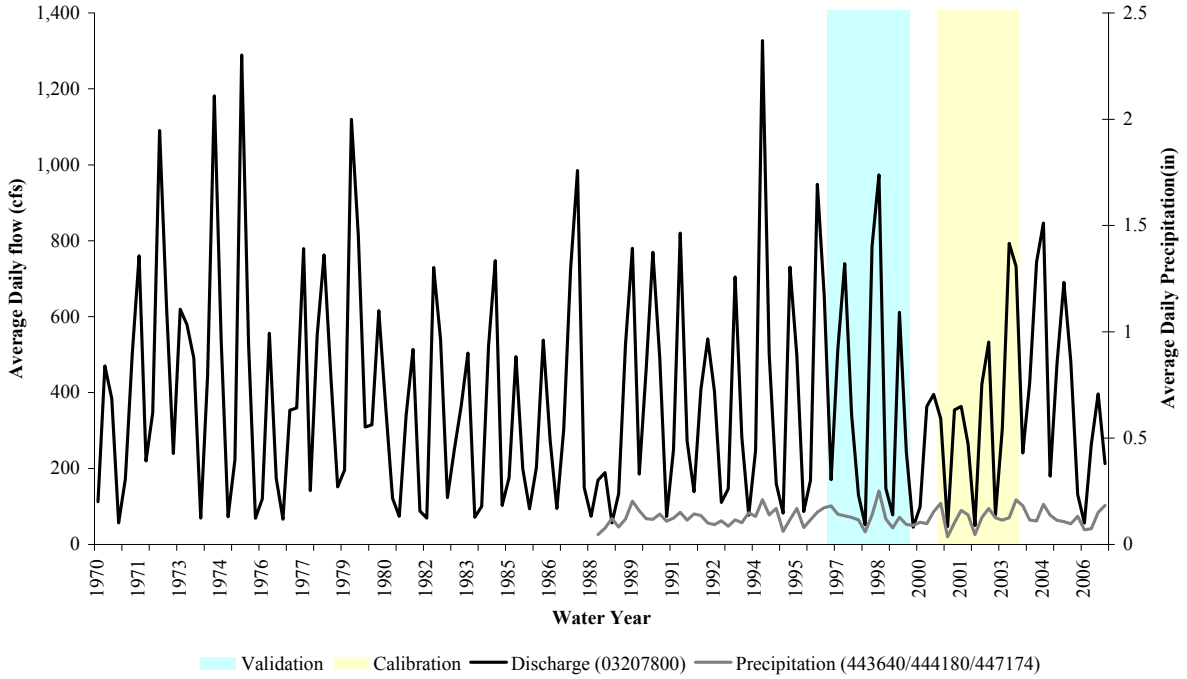

Figure 4.7 Hydrology modeling time periods, seasonal historical flow (USGS Station 03207800), and precipitation (NCDC Stations in Grundy, Hurley, Richlands, Virginia) data.

Table 4.6 Comparison of modeling time period (calibration and validation) data to historical data for the Levisa Fork watershed.

	Discharge (USGS Station #03207800)				Precipitation (443640/444180/447174)[1]			
	Fall	Winter	Summer	Spring	Fall	Winter	Summer	Spring
	Historical Data (1950 - 2005)				Historical Data (1904 - 2006)			
Mean	229	645	504	131	0.096	0.117	0.146	0.138
Variance	25,421	76,307	45,720	5,363	0.001	0.001	0.002	0.001
	Modeling Time Period Data				Modeling Time Period Data			
Mean	120	545	468	157	0.069	0.120	0.158	0.134
Variance	15,494	39,229	45,093	12,421	0.001	0.0001	0.002	0.001
	p-values				p-values			
Mean	0.055	0.181	0.377	0.322	0.082	0.382	0.325	0.427
Variance	0.387	0.325	0.591	0.091	0.292	0.055	0.367	0.263

[1] Subsequent stations utilized in order when preceding stations were off-line.

4.4.2 Hydrology Calibration

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), deep groundwater inflow fraction (DEEPFR), and baseflow PET (BASETP). Table 4.10 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions. The hydrology sensitivity analysis shows how changes in these parameters change the overall stream flow in the model (Appendix D). The model was calibrated for hydrologic accuracy using daily average flow data from USGS Gaging Station 03207800 on the Levisa Fork for the period 10/1/2000 through 9/30/2003. Table 4.7 and 4.8 show the results of the hydrologic modeling. Figures 4.8 through 4.9 display comparisons of modeled versus observed data for the entire calibration period.

All hydrologic parameters in the HSPF model were calibrated within the possible ranges of values. Any value of zero in Table 4.7 was for the water land use. The percent error values in Table 4.8 show the difference between the observed data from the USGS station

and the modeled values from HSPF. These percentages were within the recommended 10 to 30%.

Table 4.7 Model parameters utilized for hydrologic calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
AGWRC	l/day	0.85 – 0.999	0.955	0.997
BASETP	---	0.0 – 0.20	0.0 – 0.01	0.0 – 0.168
CEPSC	in	0.01 – 0.40	0.0 – 0.20	0.0 – 0.40
DEEPFR	---	0.0 – 0.50	0.01 – 0.04	0.16 – 0.64
INFILT	in/hr	0.001 – 0.50	0.10 – 0.1547	0.11 – 0.1702
IRC	l/day	0.30 – 0.85	0.60	0.12
LZETP	---	0.1 – 0.9	0.0 – 0.80	0.0 – 0.9
LZSN	in	2.0 – 15.0	3.731 – 11.848	8.395
UZSN	in	0.05 – 2.0	0.30 – 1.18	0.19 – 2.00

Table 4.8 Hydrology calibration model performance for period 10/1/2000 through 9/30/2003 at USGS Gaging Station 03207800 on Levisa Fork.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	47.60	43.42	-8.77%
Upper 10% Flow Values:	22.18	20.95	-5.53%
Lower 50% Flow Values:	5.28	5.75	9.01%
Winter Flow Volume	17.69	15.97	-9.68%
Spring Flow Volume	18.57	14.76	-20.53%
Summer Flow Volume	6.71	7.27	8.29%
Fall Flow Volume	4.63	5.42	17.12%
Total Storm Volume	43.35	39.28	-9.41%
Winter Storm Volume	16.64	14.95	-10.17%
Spring Storm Volume	17.51	13.72	-21.65%
Summer Storm Volume	5.64	6.23	10.43%
Fall Storm Volume	3.56	4.38	22.84%

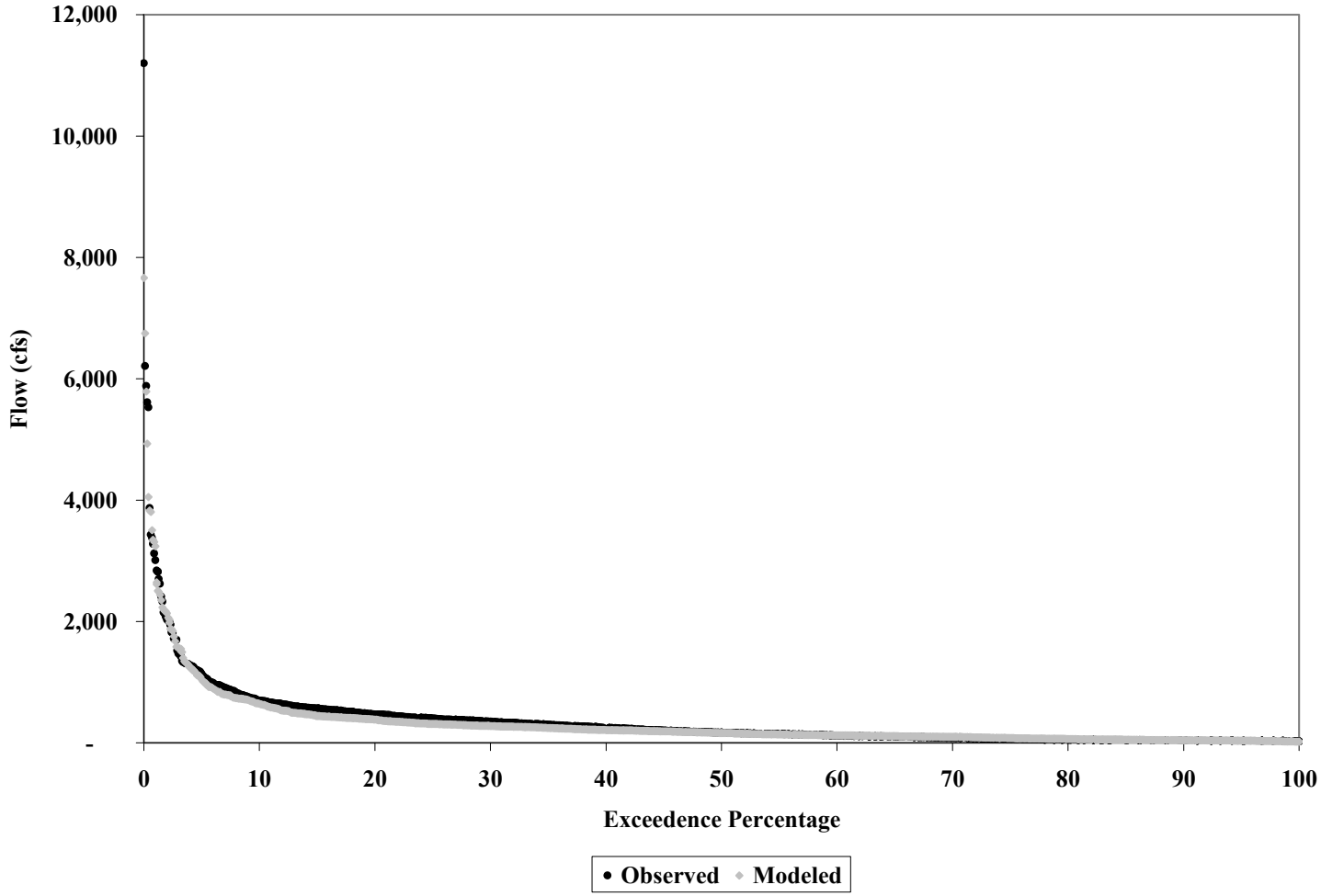

Figure 4.8 Levisa Fork modeled flow duration for the calibration period 10/1/2000 through 9/30/2003 versus USGS Gaging Station 03207800.

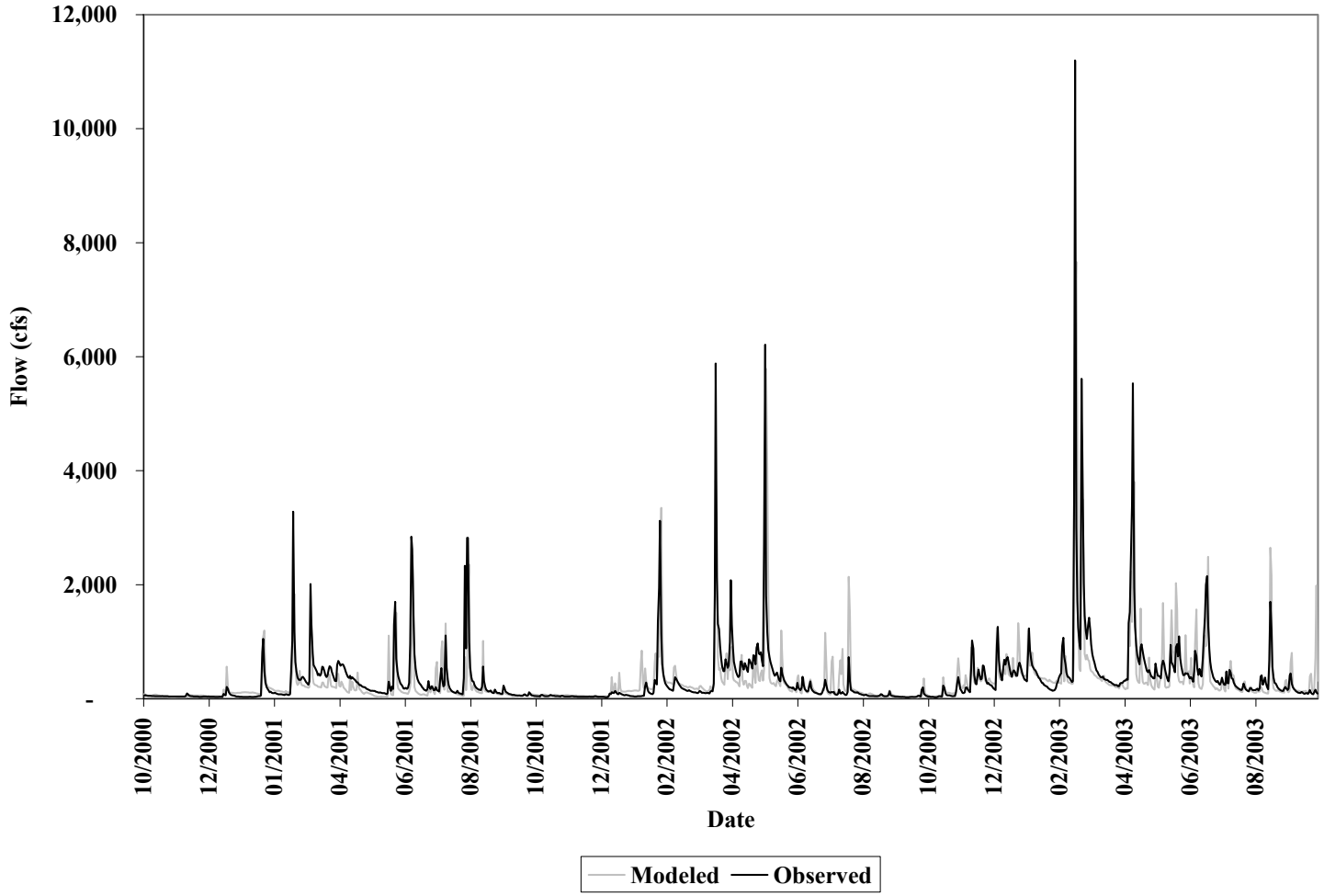

Figure 4.9 Calibration results for the HSPF model during calibration period 10/1/2000 through 9/30/2003 versus USGS Gaging Station 03207800.

4.4.3 Hydrologic Validation

The hydrologic model was verified using stream flow data from 10/1/1996 to 9/30/1999. The resulting statistics are shown in Table 4.9. The percent error is within acceptable ranges for model validation. The hydrology validation results are shown in Figures 4.10 and 4.11.

Table 4.9 Hydrology validation model performance for Levisa Fork for the period 10/1/1996 through 9/30/1999.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	52.99	45.90	-13.38%
Upper 10% Flow Values:	22.47	21.66	-3.59%
Lower 50% Flow Values:	5.59	5.19	-7.29%
Winter Flow Volume	24.09	20.89	-13.26%
Spring Flow Volume	17.77	14.34	-19.28%
Summer Flow Volume	3.72	2.45	-34.08%
Fall Flow Volume	7.42	8.21	10.71%
Total Storm Volume	49.45	42.63	-13.80%
Winter Storm Volume	23.21	20.08	-13.46%
Spring Storm Volume	16.88	13.53	-19.88%
Summer Storm Volume	2.84	1.63	-42.63%
Fall Storm Volume	6.52	7.39	13.30%

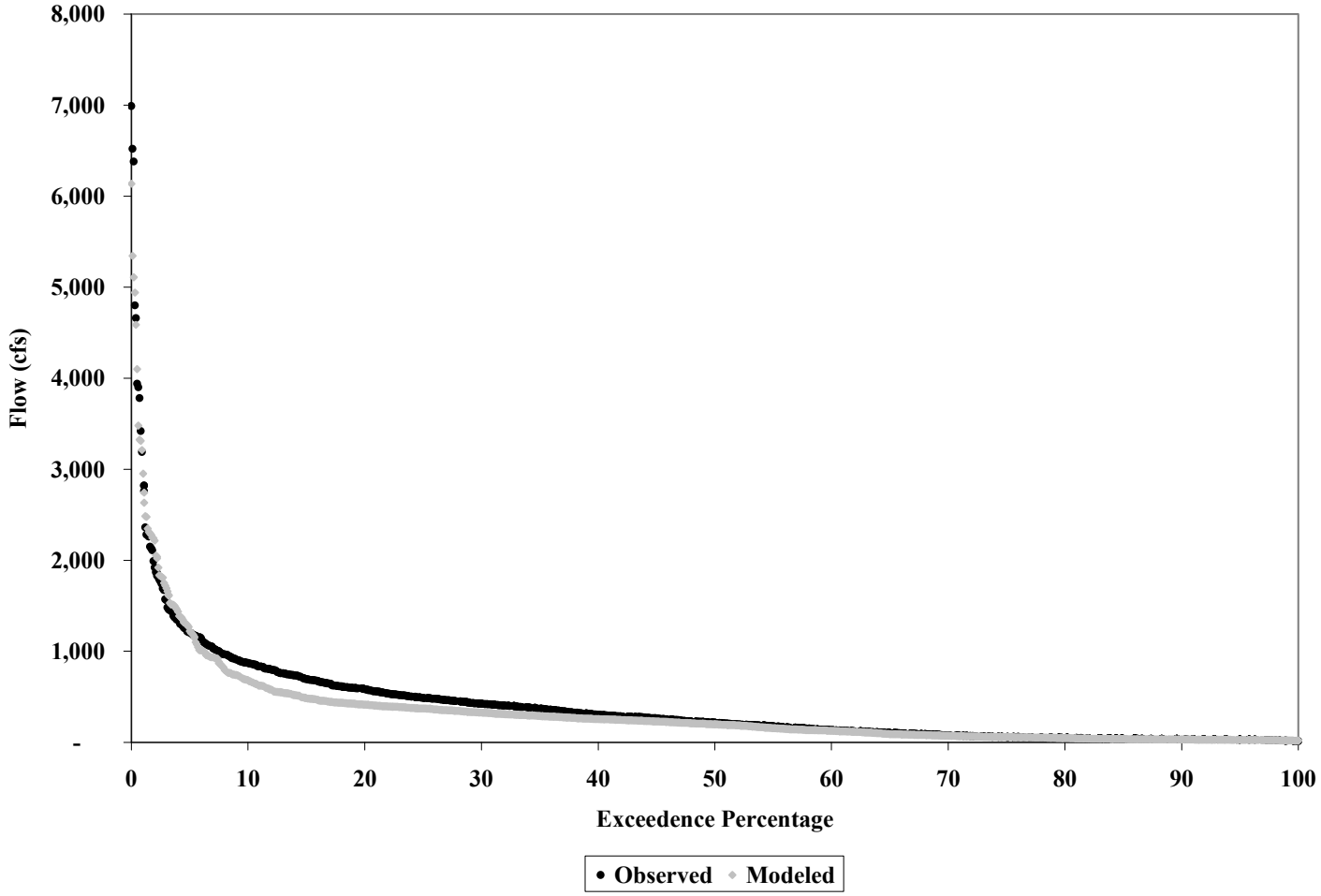

Figure 4.10 Levisa Fork modeled flow duration for the validation period 10/1/1996 through 9/30/1999 versus USGS Gaging Station 03207800.

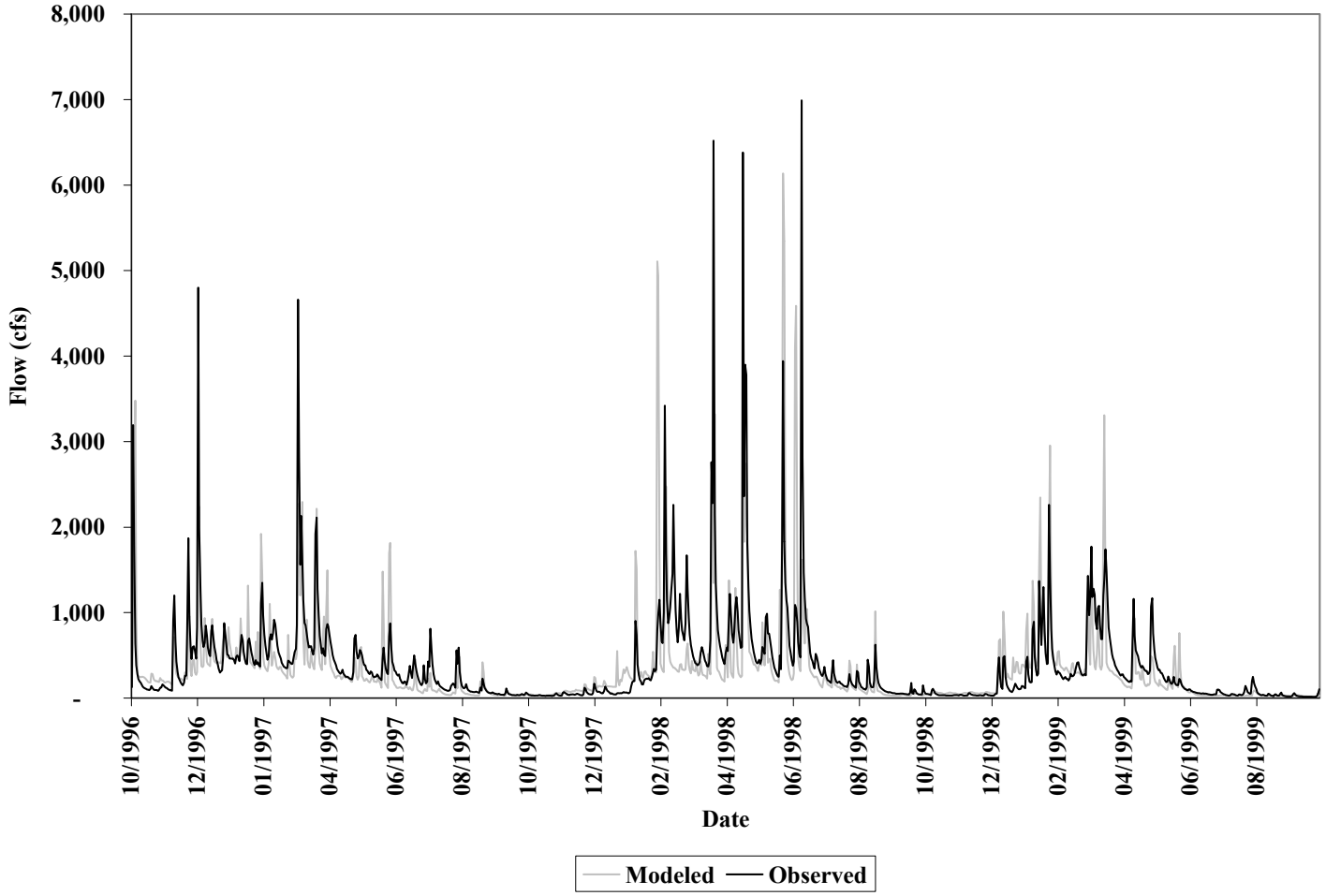

Figure 4.11 Calibration results for the HSPF model during validation period 10/1/1996 through 9/30/1999 versus USGS Gaging Station 03207800.

4.5 Bacterial Source Tracking Results

MapTech, Inc. was contracted to perform an analysis of bacterial source tracking (BST) for 24 samples at seven locations during 2007. BST is intended to aid in identifying sources (*i.e.,* human, pets, livestock, or wildlife) of fecal contamination in water bodies. More information is shown in Section 2.3.1.3.

Table 4.10 summarizes the results for each station with isolate-weighted average proportions of bacteria originating from the four source categories. The isolate-weighted average considers the concentration of *E. coli*, the number of bacterial isolates analyzed, streamflow at the USGS gage #03207800, and the percent contributions from each bacteria source. The anthropogenic (human + livestock + pet) bacteria proportion is also shown in this table. This gives an estimation of the overall bacteria load reduction percentage attainable without addressing wildlife loads, which may be useful during implementation plan development. The anthropogenic percentage is the majority of the fecal bacteria at all stations except 6ALEV152.46 on Levisa Fork.

Table 4.10 Isolate-streamflow-concentration weighted average proportions of fecal bacteria originating from four source categories using all data.

Stream Name	Station	Weighted Averages of all data:				
		Wildlife	Human	Livestock	Pet	Anthropogenic (H+L+P)
Big Prater Creek	6ABIP000.18	27	54	15	4	73
Dismal Creek	6ADIS001.24	29	51	16	4	71
Levisa Fork	6ALEV131.52	42	13	25	20	58
Levisa Fork	6ALEV143.80	42	17	19	22	58
Levisa Fork	6ALEV152.46	60	19	15	6	40
Levisa Fork	6ALEV156.82	37	54	4	5	63
Slate Creek	6ASAT000.26	24	38	25	13	76

4.6 Bacteria 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 land use 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 wildlife 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 were used. Data representing 2002 were used for the water quality calibration period and data representing 1997 were used for validation period. Data representing 2008 were used for the allocation runs in order to represent current conditions.

4.6.1 Permitted Sources

Sixty-five point sources, some with multiple outfalls, are permitted to discharge to surface water bodies in the Levisa Fork watershed (Table 3.1). Section 3.2 discusses these permits in more detail. Three of these VPDES permits are permitted for fecal bacteria control. For calibration and validation condition runs, recorded flow and Total Residual Chlorine (TRC) levels documented by the VADEQ were used as the input for each permit (Table 4.11). The TRC data was related to fecal colifrom concentrations using a regression analysis. Table 4.11 shows the minimum and maximum discharge rate in million gallons per day (MGD) and the minimum and maximum fecal coliform (FC) bacteria load in colony forming units per 100 milileters (cfu/100mL). The design flow capacity was used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu per 100 ml to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. The design flow rates and fecal coliform bacteria loads are shown in Table 4.11.

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

Table 4.11 Flow rates and bacteria concentrations used to model active VADEQ permits in the Levisa Fork watershed.

		Calibration/Validation				Allocation	
		Flow Rate (MGD)		Bacteria Conc. (cfu/100mL)		Flow Rate (MGD)	Bacteria Conc. (cfu/100mL)
VADEQ Permit Number	Facility Name	Min	Max	Min	Max	Design Flow	FC Geo. Mean Standard
VA0026999	Buchanan County Public Schools - J M Bevins Elementary	0.0	0.005	0.0	4.3	0.006	200
VA0050351	Jewell Coke Company Coke Plants 2 and 3	0.0	0.576	0.0	0.0	0.200	0
VA0052639	Norfolk & Western Railway Co -Weller Yard Terminal	0.0	0.009	0.0	0.0	0.001	0
VA0065536	Island Creek Coal Company - VP Mine 1 STP	0.0	0.0	0.0	0.0	0.02	200
VA0065625	Island Creek Coal Company - VP Mine 8 Deskins STP	0.0	0.005	0.0	4.3	0.025	200
VA0068438	Buchanan County Public Schools - Twin Valley High School STP	0.0	0.003	0.0	4.3	0.0072	200
VA0089907	Buchanan County PSA - Mill Branch STP	0.0	0.004	0.0	4.3	0.0075	200
VA0090239	Buchanan County PSA - Deskins STP	0.0	0.0031	0.0	4.3	0.0032	200
VA0090531	Buchanan County PSA - Conaway WWTP	0.121	1.873	2.8	4.3	2.000	200
VAG******	Each of the 46 Domestic Waste Treatment Permits	0.0001	0.0001	200	200	0.0001	200

Conc. = Concentration; FC = Fecal Coliform; Geo. Mean = Geometric Mean; MGD = Million Gallons per day

4.6.2 Private Residential Sewage Treatment

The number of septic systems in the Levisa Fork watershed was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the subwatersheds. During allocation runs, the number of households was projected to 2008, based on current

growth rates (USCB, 2000) resulting in 2,088 failing septic systems and 487 straight pipes (uncontrolled discharges) (Table 4.12).

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. from 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 Levisa Fork watershed. 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 failing 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 to account for more frequent failures during wet months. The total number of failing septic systems was refined after discussion with Buchanan County VDH personnell by limiting failing septics to within 100 feet from a stream. This analysis resulted in a total of 264 failing septic systems for the entire watershed and 59 in the Slate Creek drainage area (Table 4.12).

Uncontrolled discharges (straight pipes) 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 sewage via uncontrolled discharges. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the wasteload 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.

Table 4.12 Estimated failing septic systems and straight pipes for 2008 in the Levisa Fork watershed.

Impaired Segment	Septic Systems	Failing Septic Systems	Uncontrolled Discharges
Slate Creek	1,083	59	70
Levisa Fork	6,023	264	487

During the HSPF water quality calibration/validation period, (October 1996 to September 2002) there were 14 total reported sewer overflows. It was assumed that additional occurrences of sewer overflows were likely undetected; therefore a statistical analysis of meteorological events and sewer overflows was determined and a projection of undetected sewer overflows was performed. This analysis involved using the daily total precipitation and the 3-day prior rainfall for each day an overflow was reported due to high rainfall and not due to mechanical issues. The sewer overflow event reports contained an estimate of the volume of sewage discharged, so the model includes these discharges. The concentration of fecal bacteria discharged was considered 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 per subwatershed. As some biodegradation occurs in a septic system, it is felt that the estimate of concentration is conservative. The following subwatersheds have sewer overflows and the projected undetected sewer overflows in the model: 2, 4, 5, 6, 7, 8, 10, and 13.

4.6.3 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. Due to the lack of confined animal facilities in this watershed, only deposition on land and direct deposition to streams are 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 populations from 2002 were used for calibration, 1997 for validation, and 2008 allocation. The numbers are based on Virginia Agricultural Statistics with verification by the Big Sandy SWCD. Growing and declining

population rates were taken into account in Buchanan County as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1995 and VASS, 2002). The fecal coliform density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.8).

4.6.3.1 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, sheep, and hog) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land use type was area-weighted.

4.6.3.2 Direct Deposition to Streams

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. The nature of this watershed is not highly agricultural; therefore, the "stream access" land use was not created for this project. All cattle waste was modeled as deposited directly to the stream or onto pasture land.

4.6.4 Biosolids

Investigation of DEQ data indicated that biosolids applications have occurred within the Levisa Fork area. However, the applications seldom occur and are on high mountain areas away from streams. All applicable best management practices (BMPs) are followed on the areas of application. Therefore, it is assumed that no fecal bacteria originating from biosolids enters a Levisa Fork stream and no biosolids source was modeled in HSPF.

4.6.5 Wildlife

For each species of wildlife, 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 4.12. This layer was overlaid with the land use layer, and the resulting area was calculated for each land use 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 wasteload, fecal coliform densities, and number of animals for each species.

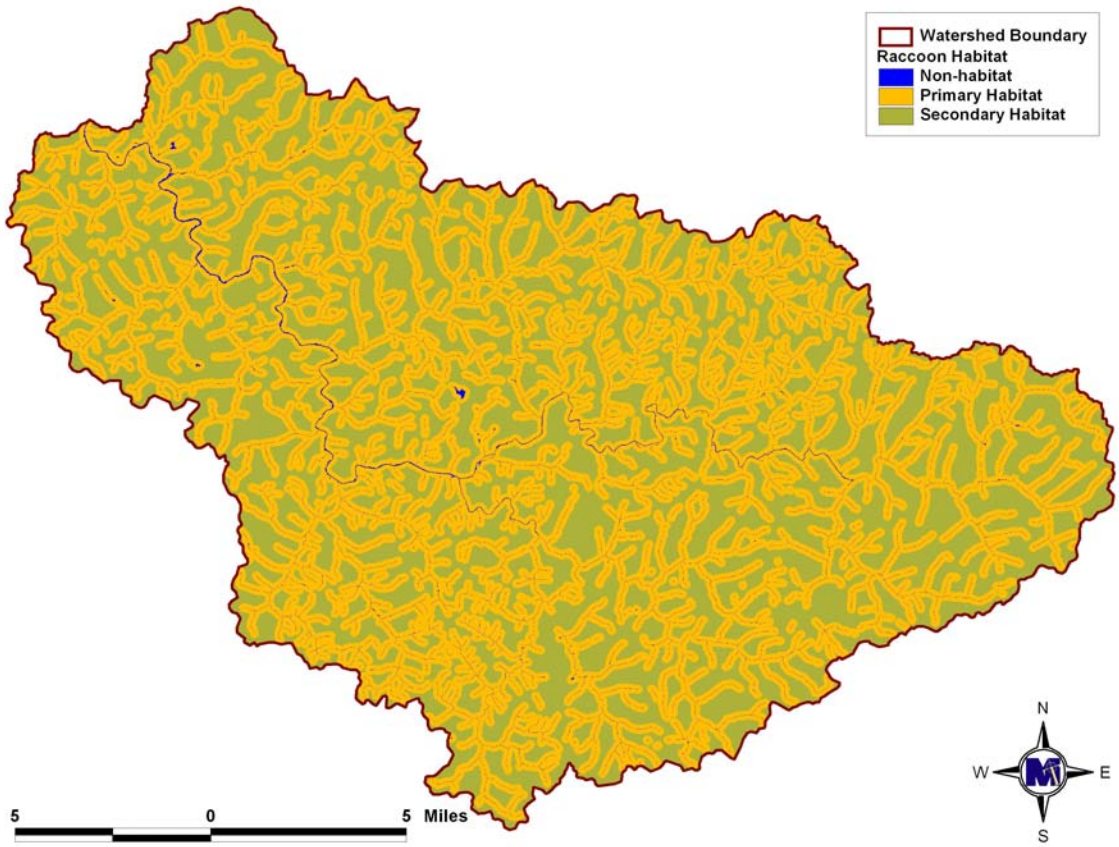

Figure 4.12 Example of raccoon habitat layer in the Levisa Fork watershed, as developed by MapTech.

For each species, a portion of the total wasteload was considered 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 3.12). It was estimated that, for all animals other than beaver, 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 adjustments were made to wildlife populations, as there was no available data to support such adjustments.

4.6.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2008.

4.7 Water Quality Modeling - Bacteria

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, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

4.7.1 Selection of Representative Modeling Periods

The critical flow regime study (Section 4.3) showed that all flow regimes, but most critically high flows, should be represented in the modeling time periods of the impaired streams in this study. The water quality calibration (10/1/1999 to 9/30/2002) and validation time periods (10/1/1996 to 9/30/1999) have some of the highest and lowest daily average streamflow and precipitation, which represent the high and low flow critical regimes (Figures 4.5 and 4.6). The year 1999 was a dry year, whereas 1998 and 2002 were wet years. Having modeling time periods that encompass these years for

calibration and validation will ensure the HSPF model can predict bacteria concentrations in different flow regimes. These time periods were also chosen because together they encompass the most fecal coliform samples taken in the watershed (195 fecal coliform samples and 4 *E. coli* samples) than different combinations of years between 1994 and 2003.

4.7.2 Water Quality Calibration - Bacteria

There are no set criteria for water quality calibration set forth for a TMDL. Water quality observations are sparse with different amounts of data per stream. This makes it difficult to set standard criteria that must be met for all streams with different number of observations at different times during the day. Water quality calibration acceptance is evaluated based on four separate evaluations of the differences between observed and modeled bacteria concentrations. Evaluating and observing all four separate evaluations as a whole determines the acceptance of the calibration. The evaluations include: observed versus modeled bacteria concentration graphs, mean standard error calculations, observed versus modeled geometric mean calculations, and observed versus modeled single sample standard percent violations.

Water quality calibration is complicated by a number of factors. First, water quality (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. 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 re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the VADEQ data were censored at 8,000 cfu/100ml at times and at 16,000 cfu/100ml at other times. Limited amounts of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

The water quality calibration was conducted from 10/1/1999 to 9/30/2002. Four parameters were utilized for model adjustment: in-stream first-order decay rate

(FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), the rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP), and the temperature correction coefficient for first-order decay of quality (THFST). The sensitivity analysis shown in Appendix D aided the water quality calibration by determining how the modeled bacteria concentrations reacted to changes in these values. 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 4.13).

Table 4.13 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0 – 5.10E+08	0 – 1.0E+11
WSQOP	in/hr	0.05 – 3.00	0 – 2.5	0 – 0.63
FSTDEC	1/day	0.01 – 10.00	1.0	1.25 – 5.0
THFST	none	1.0 – 2.0	1.07	1.07

During calibration it was noted that the initial graph of the modeled output seemed muted as adjusting parameters did not affect the look of the graph. Furthermore, since the model was overpredicting the bacteria concentrations, the input for direct human bacteria was reduced as the comparison between the BST results and modeled results suggested the contribution from humans was excessive. This is shown in more detail in Section 4.7.2.1. The final calibrated values are shown in Figures 4.13 and 4.14.

Although the range of modeled daily average values may not reach every instantaneous monitored value, the daily minimum and maximum range does include the monitored extremes. Monitored values are an instantaneous snapshot of bacterial level, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at a high flow at the highest concentration of the day and thus correctly appear above the modeled daily average.

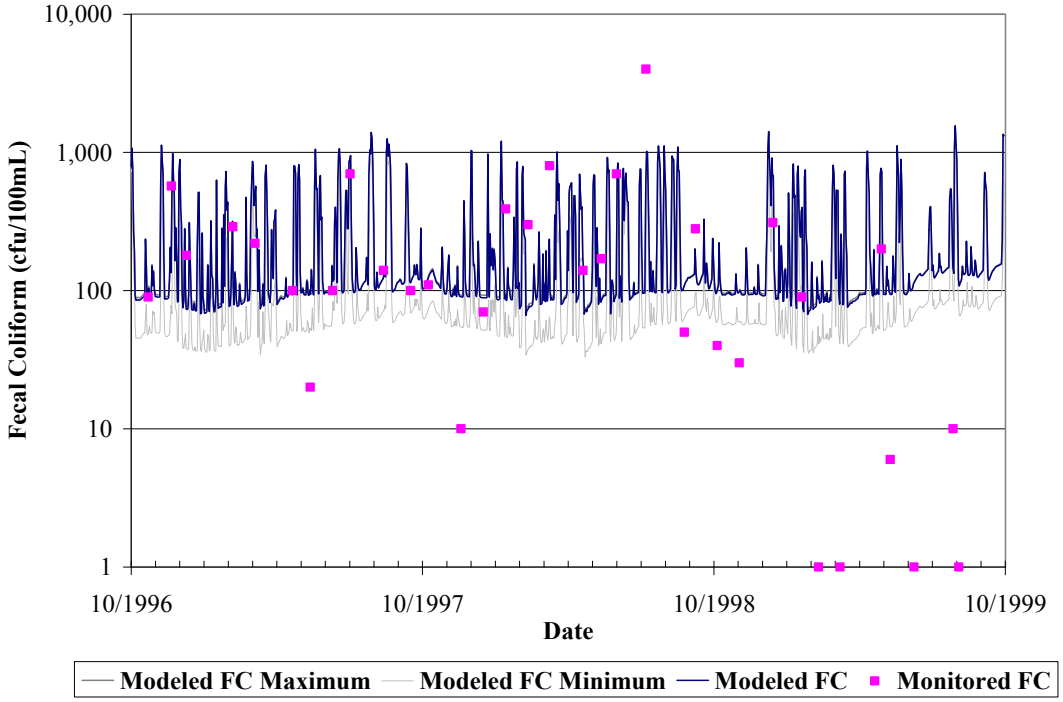

Figure 4.13 Fecal coliform calibration results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Fork impairment.

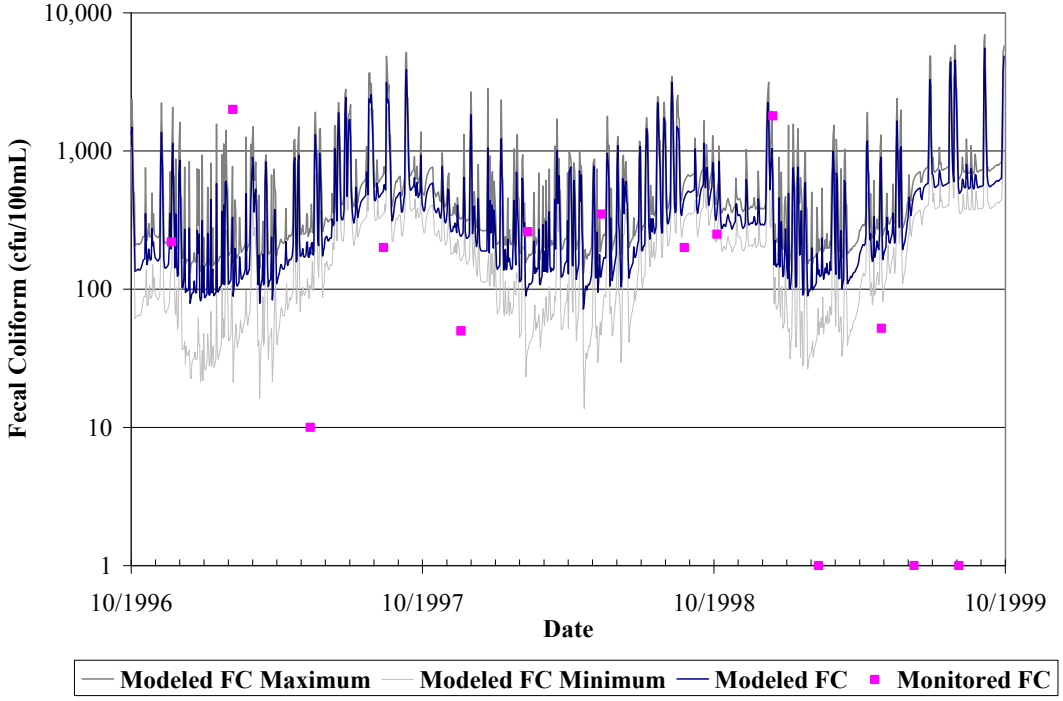

Figure 4.14 Fecal coliform calibration results at VADEQ station 6ASAT000.03 in subwatershed 10 in the Slate Creek impairment.

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. Standard error in each observation window was calculated as follows:

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

where

$$\begin{aligned} observed &= \text{an observed value of fecal coliform} \\ modeled_i &= \text{a modeled value in the 2-day window surrounding the observation} \\ n &= \text{the number of modeled observations in the 2-day window} \end{aligned}$$

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. The standard errors in Table 4.14 range from a low of 37.5 to a high of 96.3. Even the highest value in this range can be considered quite reasonable when one takes into account the censoring of maximum values that is practiced in the collection of actual water quality samples. The standard error will be biased upwards when an observed high value censored at 8,000 or 16,000 cfu/100mL is compared to a simulated high value that may be an order of magnitude or more above the censor limit. Thus, the standard errors calculated for these impairments are considered an indicator of strong model performance.

Table 4.14 Mean standard error of the calibrated model for the Levisa Fork watershed (10/1/1999 to 9/30/2002).

Stream	Subwatershed	Station ID(s)	Mean Standard Error	Maximum Simulated Value	Maximum Monitored Value
				-------(cfu/100 mL)-------	
Slate Creek	10	6ASAT000.03	204	5,796	7,800
Levisa Fork	8	6ALEV131.52	37.5	1,113	8,000

Table 4.15 shows the predicted and observed values for the geometric mean and single sample (SS) instantaneous violations for the appropriate stream segments. The maximum percent difference between modeled and monitored geometric means and instantaneous violations are within the standard deviation of the observed data at each station and, therefore, the fecal coliform calibration is acceptable.

Table 4.15 Comparison of modeled and observed fecal bacteria calibration results for the Levisa Fork watershed.

Stream	Subwatershed	Modeled Fecal Bacteria 10/1/99 to 9/30/02			Monitored Fecal Bacteria 10/1/99 to 9/30/02		
		n	Geometric Mean (cfu/100ml)	SS % violations (cfu/100ml) [1]	*n*	Geometric Mean (cfu/100ml)	SS % violations (cfu/100ml) [1]
Slate Creek	10	1,096	367.30	35.13%	9	592.40	55.56%
Levisa Fork	8	1,096	98.34	14.14%	33	213.70	15.15%

[1] SS = single sample instantaneous standard violations

4.7.2.1 HSPF Model Results Compared to BST Results

In an effort to compare the HSPF model bacteria concentration results with the Bacterial Source Tracking results (Section 2.3.1.2), the model was run for the year 2007. This comparison was needed to ascertain if the model was indeed overpredicting the human bacteria contribution as originally thought during calibration.

Table 4.16 shows the final model comparison with the BST results for each station. The averages of all ten dates are shown with the minimum and maximum values shown in parentheses.

Table 4.16 The average *E. coli* concentrations compared between modeled (HSPF) and observed (BST) bacteria sources.

Stream	Station	Sub		Wildlife	Human	Livestock	Pets
				Average *E. coli* cfu/100mL			
Levisa Fork	6ALEV152.46	2	BST	39%	53%	3%	5%
			HSPF	35%	41%	10%	14%
Levisa Fork	6ALEV152.46	3	BST	61%	17%	16%	7%
			HSPF	42%	30%	12%	15%
Levisa Fork	6ALEV143.80	5	BST	32%	28%	20%	21%
			HSPF	35%	37%	14%	14%
Levisa Fork	6ALEV131.52	8	BST	40%	14%	26%	20%
			HSPF	31%	36%	16%	17%
Slate Creek	6ASAT000.26	10	BST	21%	41%	24%	14%
			HSPF	28%	36%	17%	19%
Dismal Creek	6ADIS001.24	11	BST	28%	48%	17%	7%
			HSPF	25%	57%	11%	7%
Big Prater Creek	6ABIP000.18	13	BST	37%	42%	11%	9%
			HSPF	28%	45%	14%	13%

4.7.3 Water Quality Validation - Bacteria

The water quality model validation time period used was 10/1/1996 to 9/30/1999. The results are shown in Tables 4.17 and 4.18 and in Figures 4.15 and 4.16.

Table 4.17 Mean standard error of the fecal coliform validation model for impairments in the Levisa Fork watershed.

Stream	Subwatershed	Station ID(s)	Mean Standard Error	Maximum Simulated Value	Maximum Monitored Value
Slate Creek	10	6ASAT000.03	25.4	5,543	2,000
Levisa Fork	8	6ALEV131.52	16.9	1,556	4,000

Table 4.17 shows the predicted and observed values for the geometric mean and single sample (SS) instantaneous violations for the appropriate stream segments. The maximum percent difference between modeled and monitored geometric means and instantaneous violations are within the standard deviation of the observed data at each station and, therefore, the fecal coliform validation is acceptable.

Table 4.18 Comparison of modeled and observed fecal coliform validation results for the Levisa Fork watershed.

Stream	Subwatershed	Modeled Fecal Bacteria 10/1/96 to 9/30/99			Monitored Fecal Bacteria 10/1/96 to 9/30/99		
		n	Geometric Mean (cfu/100ml)	SS % violations (cfu/100ml) [1]	*n*	Geometric Mean (cfu/100ml)	SS % violations (cfu/100ml) [1]
Slate Creek	10	1,096	309.37	38.08%	14	198.39	14.29%
Levisa Fork	8	1,096	156.00	16.62%	34	130.76	14.71%

[1] SS = single sample instantaneous standard violations

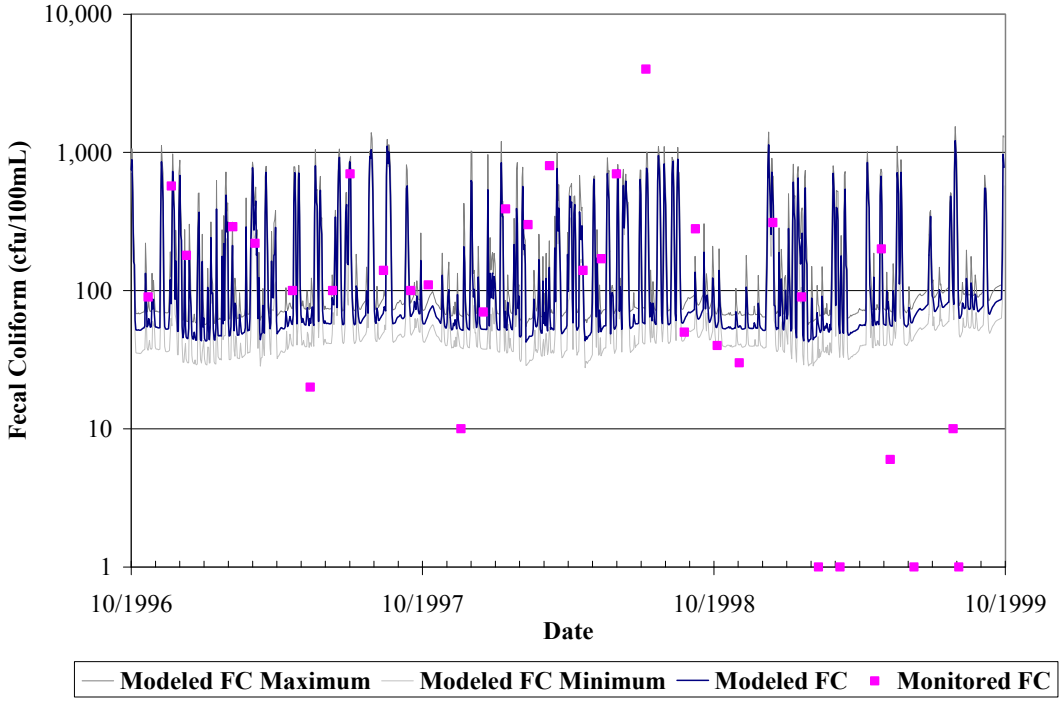

Figure 4.15 Fecal coliform quality validation results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Creek impairment.

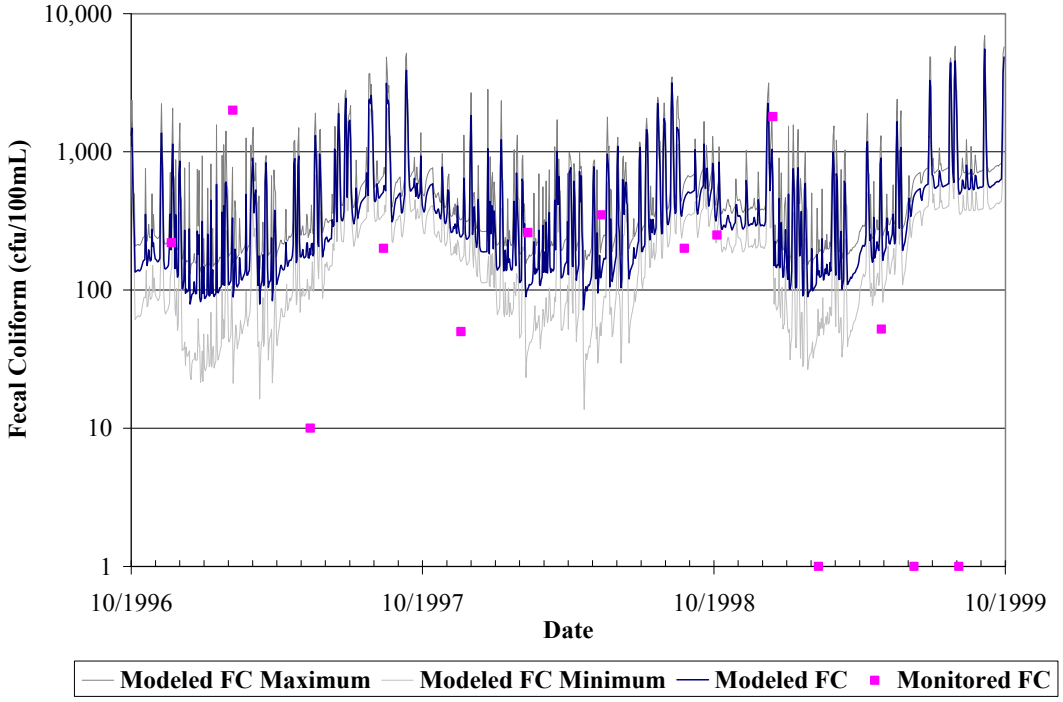

Figure 4.16 Fecal coliform quality validation results at VADEQ station 6ASAT000.03 in subwatershed 10 in the Slate Creek impairment.

4.8 Existing Conditions - Bacteria

All appropriate inputs were updated to current conditions. Figure 4.17 shows the monthly geometric mean of *E. coli* concentrations in relation to the 126-cfu/100mL standard at the outlet of the Slate Creek impairment (subwatershed 10). Figure 4.18 shows the monthly geometric mean of *E. coli* concentrations in relation to the 126-cfu/100mL standard at the outlet of the Levisa Fork impairment (subwatershed 8).

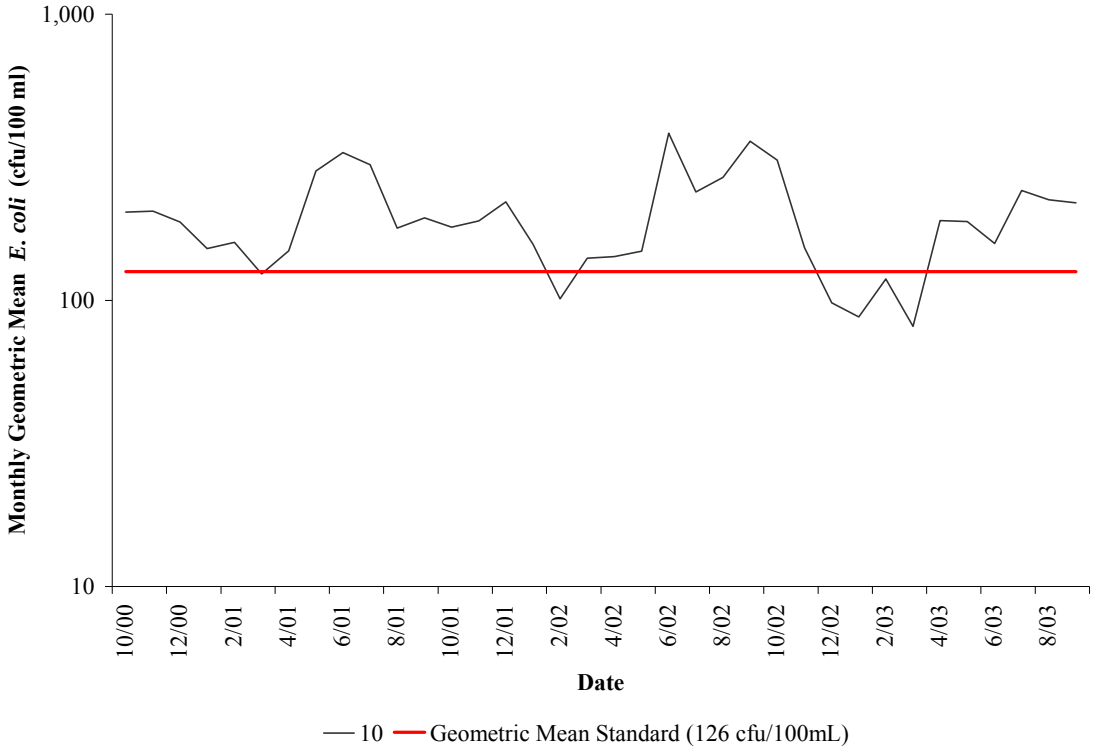

Figure 4.17 Monthly geometric mean of *E. coli* concentrations for existing conditions at the Slate Creek impairment outlet (subwatershed 10).

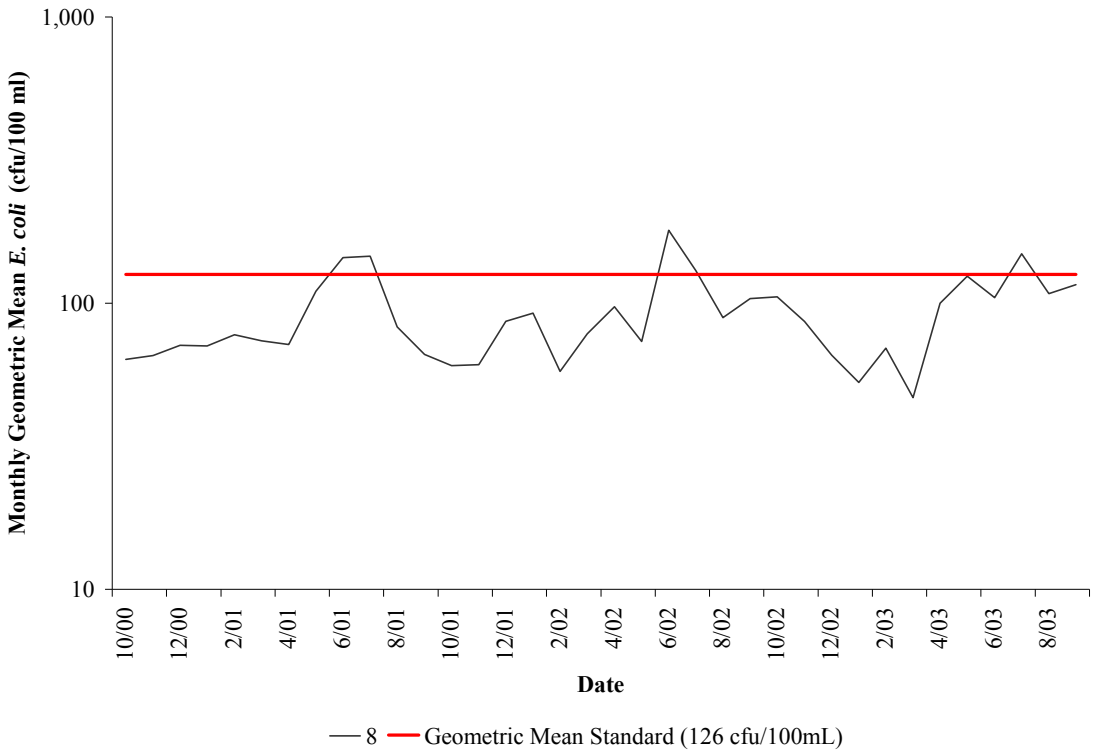

Figure 4.18 Monthly geometric mean of *E. coli* concentrations for existing conditions at the Levisa Fork impairment outlet (subwatershed 8).

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5. BACTERIAL ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, non-permitted 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:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For these impairments, the TMDLs are expressed in terms of colony forming units (or resulting concentration).

Allocation scenarios were modeled using the HSPF model. Scenarios were created by reducing direct and land-based bacteria until the water quality standards were attained. The TMDLs developed for the impairments in the Levisa Fork watershed were based on the *E. coli* riverine Virginia State standards. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standards state that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml.

According to the guidelines put forth by the VADEQ (VADEQ, 2003) for modeling bacteria 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 data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc}) \qquad \textit{E. coli}$$

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 standards were met. 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 applicable water quality standards.

5.1 Margin of Safety (MOS)

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 MOS 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 an MOS in the development of a bacteria TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of these TMDLs. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of these TMDLs are:

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

Using the critical hydrologic conditions as the modeling allocation time period, ensures that the TMDL accounts for the range of hydrologic conditions (droughts to floods) that contribute to violations of the bacteria water quality standards.

5.2 Waste Load Allocations (WLAs)

There are currently no Municipal Separate Storm Sewer System (MS4) permits in the Levisa Fork watershed.

5.3 Load Allocations (LAs)

Load allocations to nonpoint sources are divided into land-based loadings from land uses (nonpoint source, NPS) and directly applied loads in the stream (livestock, wildlife,

straight pipes, and sewer overflows). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads most significantly impact bacteria concentrations during high-flow conditions, while direct deposition NPS most significantly impact low flow bacteria concentrations. The BST results confirmed the presence of human, livestock, pet, and wildlife contamination in all impairments. Nonpoint source load reductions were performed by land use, as opposed to reducing sources, as it is considered that the majority of BMPs will be implemented by land use. Reductions on agricultural land uses (pasture and cropland) include reductions required for land applied livestock and wildlife wastes. Appendix C shows tables of the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds to each impairment.

5.4 Bacterial Total Maximum Daily Loads (TMDLs)

Allocation scenarios were run sequentially, beginning with headwater impairments, and then continuing with downstream impairments until all impairments were allocated to 0% exceedances of all applicable standards. The first table in each of the following sections represents a small portion of the scenarios developed to determine the TMDLs. The first five scenarios were run for all impairments simultaneously; subsequent runs were made after upstream impairments were allocated. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. In each table, Scenario 2 eliminated direct human sources (straight pipes and unpermitted sewer overflows). Further scenarios in each table explore a range of management scenarios, leading to the final allocation scenario that contains the predicted reductions needed to meet 0% exceedance of all applicable water quality standards.

The two graphs in the following sections depict the existing and allocated daily average in-stream bacteria concentrations, and the existing and allocated monthly geometric mean in-stream bacteria concentrations.

The second table in the following sections shows the existing and allocated *E. coli* loads that are output from the HSPF model. The third table shows the final in-stream allocated loads for the appropriate bacteria species. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. The final table is an estimation of the in-stream daily load of bacteria.

The tables and graphs in the following sections all depict values at the corresponding impairment outlet. The impairment outlet is the mouth of the impaired segment as the segments are described in Section 1.2. It is the point at which the impaired stream flows out of the most downstream subwatershed or segment. The impairment outlets are shown in the "Outlet" column of Table 4.1.

5.4.1 Levisa Fork

Table 5.1 shows allocation scenarios used to determine the final TMDL for Levisa Fork. Because Virginia's standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational (swimming) use geometric mean standard. The existing condition, Scenario 1, shows 66.7% violations of the geometric mean standard. Scenario 2 (eliminating illicit residential discharges or straight pipes) showed dramatic improvement. Scenario 3 showed that eliminating straight pipes and unpermitted sewer overflows would benefit water quality and allows Levisa Fork to have a 0% violation rate of the GM swimming use standard.

An appropriate Stage I scenario would be a 50% reduction in both the straight pipe bacteria load and the unpermitted sewer overflow load. This reduction scenario gets Levisa Fork to a 25% violation rate of the GM standard.

Table 5.1 Allocation scenarios for reducing current bacteria loads in Levisa Fork (subwatershed 1,2,3,4,5,6,7,8,11,13,14).

	Percent Reductions to Existing Bacteria Loads							
		Wildlife Land Based		Agricultural Land Based	Human Direct	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren, Commercial, Forest, HIR, Wetlands	Livestock Direct	Cropland, Pasture, LAX	Straight Pipes	Sewer Overflows	LMIR	>126 GM
1	0	0	0	0	0	0	0	66.67
2	0	0	0	0	100	0	0	30.56
3[1]	0	0	0	0	100	100	0	0.00

[1]Final TMDL Scenario

Figure 5.1 shows the existing and allocated monthly geometric mean *E. coli* concentrations, respectively, from Levisa Fork impairment outlet. This graph shows existing conditions in black, with allocated conditions overlaid in blue.

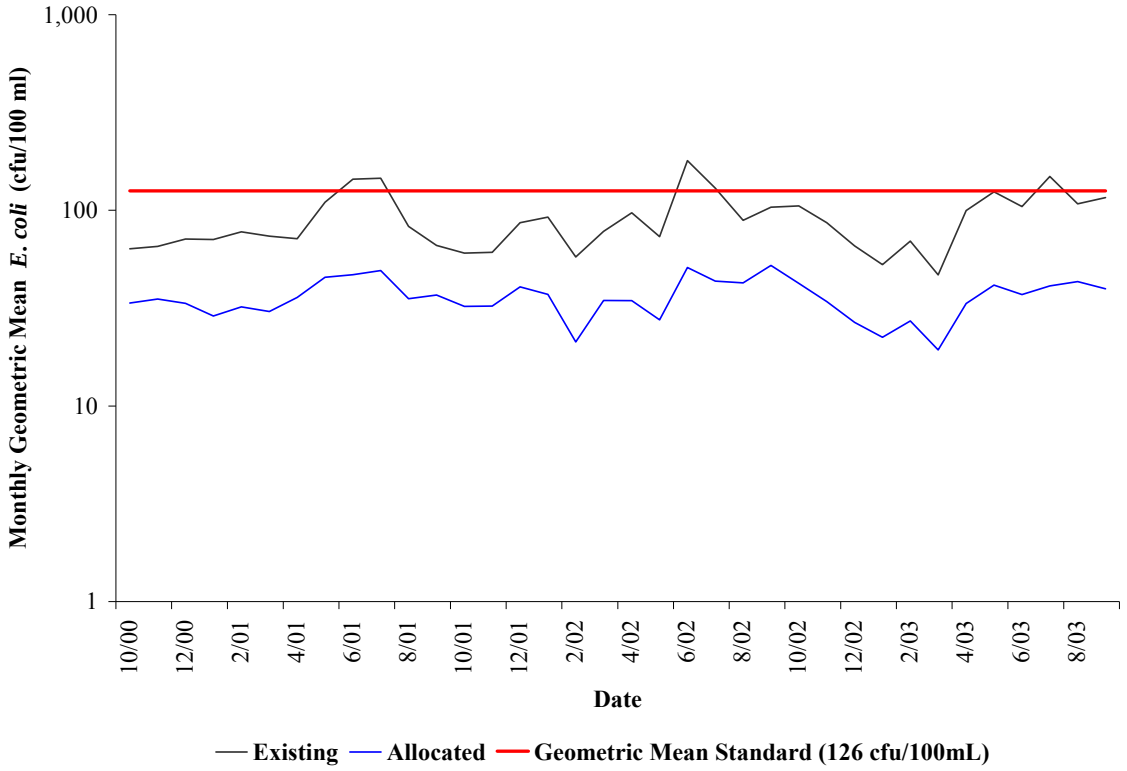

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 8, Levisa Fork impairment outlet.

Table 5.2 contains estimates of existing and allocated in-stream *E. coli* loads at the Levisa Fork impairment outlet reported as average annual cfu per year. The estimates in Table 5.3 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

In Appendix C, Tables C.1 through C.4 include the land-based fecal coliform load distributions and offer more details for specific implementation development and source assessment evaluation.

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Levisa Fork impairment.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
AML	6.88E+11	6.88E+11	0%
Developed	8.44E+10	8.44E+10	0%
Cropland	7.32E+08	7.32E+08	0%
Forest	2.60E+13	2.60E+13	0%
Active Mine	7.88E+05	7.88E+05	0%
Residential	7.24E+12	7.24E+12	0%
Reclaimed Mine	4.26E+06	4.26E+06	0%
Pasture Hay	4.14E+12	4.14E+12	0%
Active Gas Well	9.26E+10	9.26E+10	0%
Direct			
Human	4.22E+14	0.00E+00	100%
Livestock	7.59E+13	7.59E+13	0%
Wildlife	7.85E+13	7.85E+13	0%
Permitted Sources	5.69E+12	5.69E+12	0%
Future Growth	0.00E+00	2.00E+12	NA
Total Loads	**6.20E+14**	**2.00E+14**	**67.7%**

Table 5.3 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Levisa Fork impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Levisa Fork	**7.63E+12**	**1.93E+14**		**2.00E+14**
VAG400200	*1.74E+09*			
VAG400573	*1.74E+09*			
VAG400405	*1.74E+09*			
VAG400741	*1.74E+09*			
VAG400809	*1.74E+09*			
VAG400404	*1.74E+09*			
VAG400697	*1.74E+09*			
VAG400589	*1.74E+09*			
VAG400192	*1.74E+09*			
VAG400129	*1.74E+09*			
VAG400681	*1.74E+09*			
VAG400682	*1.74E+09*			
VAG400698	*1.74E+09*			
VAG400830	*1.74E+09*			
VAG400190	*1.74E+09*			
VAG400191	*1.74E+09*			
VAG400515	*1.74E+09*			
VAG400211	*1.74E+09*		*Implicit*	
VAG400445	*1.74E+09*			
VAG400549	*1.74E+09*			
VAG400613	*1.74E+09*			
VAG400413	*1.74E+09*			
VAG400686	*1.74E+09*			
VAG400727	*1.74E+09*			
VAG400730	*1.74E+09*			
VAG400825	*1.74E+09*			
VAG400087	*1.74E+09*			
VAG400108	*1.74E+09*			
VAG400663	*1.74E+09*			
VAG400729	*1.74E+09*			
VAG400710	*1.74E+09*			
VAG400619	*1.74E+09*			
VAG400680	*1.74E+09*			
VA0090531	*5.39E+12*			
VA0026999	*1.62E+10*			
VA0065536	*5.39E+10*			
VA0068438	*1.94E+10*			

Impairment	WLA[1]	LA	MOS	TMDL[2]
VA0089907	*2.02E+10*			
VA0065625	*6.74E+10*			
VA0090239	*8.63E+09*			
Future Load	*2.00E+12*			

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

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for Levisa Fork are shown in Table 5.4. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Levisa Fork impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Levisa Fork	**2.09E+10**	**1.49E+13**		**1.49E+13**
VAG400200	*4.77E+06*			
VAG400405	*4.77E+06*			
VAG400741	*4.77E+06*			
VAG400809	*4.77E+06*			
VAG400404	*4.77E+06*			
VAG400697	*4.77E+06*			
VAG400192	*4.77E+06*			
VAG400129	*4.77E+06*			
VAG400681	*4.77E+06*			
VAG400682	*4.77E+06*			
VAG400698	*4.77E+06*			
VAG400830	*4.77E+06*			
VAG400190	*4.77E+06*			
VAG400191	*4.77E+06*			
VAG400515	*4.77E+06*			
VAG400211	*4.77E+06*			
VAG400445	*4.77E+06*			
VAG400549	*4.77E+06*		*Implicit*	
VAG400613	*4.77E+06*			
VAG400413	*4.77E+06*			
VAG400686	*4.77E+06*			
VAG400727	*4.77E+06*			
VAG400730	*4.77E+06*			
VAG400825	*4.77E+06*			
VAG400087	*4.77E+06*			
VAG400108	*4.77E+06*			
VAG400663	*4.77E+06*			
VAG400729	*4.77E+06*			
VAG400710	*4.77E+06*			
VAG400619	*4.77E+06*			
VAG400680	*4.77E+06*			
VA0090531	*1.48E+10*			
VA0026999	*4.43E+07*			
VA0065536	*1.48E+08*			
VA0068438	*5.32E+07*			
VA0089907	*5.54E+07*			
VA0065625	*1.85E+08*			

Impairment	WLA[1]	LA	MOS	TMDL[2]
VA0090239	*2.36E+07*			
Future Load	*5.49E+09*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

5.4.2 Slate Creek

Table 5.5 shows allocation scenarios used to determine the final TMDL for Slate Creek. Because Virginia's standard does not permit any exceedances, modeling was conducted for a target value of 0% exceedance of the VADEQ riverine primary contact recreational (swimming) use geometric mean standard. The existing condition, Scenario 1, shows 83.3% violations of the geometric mean standard. Although the existing conditions had violations, Scenario 2 (eliminating illicit residential discharges or straight pipes) showed dramatic improvement. Scenario 3 showed that eliminating straight pipes and unpermitted sewer overflows would benefit water quality and allows Slate Creek to have a 0% violation rate of the GM swimming use standard.

An appropriate Stage I scenario would be a 50% reduction in both the straight pipe bacteria load and the unpermitted sewer overflow load. This reduction scenario gets Slate Creek to a 2.8% violation rate of the GM standard.

Table 5.5 Allocation scenarios for reducing current bacteria loads in Slate Creek (subwatershed 9,10).

	Percent Reductions to Existing Bacteria Loads							
		Wildlife Land Based		Agricultural Land Based	Human Direct	Human Direct	Human and Pet Land Based	VADEQ *E. coli* Standard percent violations
Scenario	Wildlife Direct	Barren, Commercial, Forest, HIR, Wetlands	Livestock Direct	Cropland, Pasture, LAX	Straight Pipes	Sewer Overflows	LMIR	>126 GM
1	0	0	0	0	0	0	0	83.33
2	0	0	0	0	100	0	0	11.11
3[1]	0	0	0	0	100	100	0	0.00

[1]Final TMDL Scenario

Figure 5.2 shows the existing and allocated monthly geometric mean *E. coli* concentrations, respectively, from Slate Creek impairment outlet. This graph shows existing conditions in black, with allocated conditions overlaid in blue.

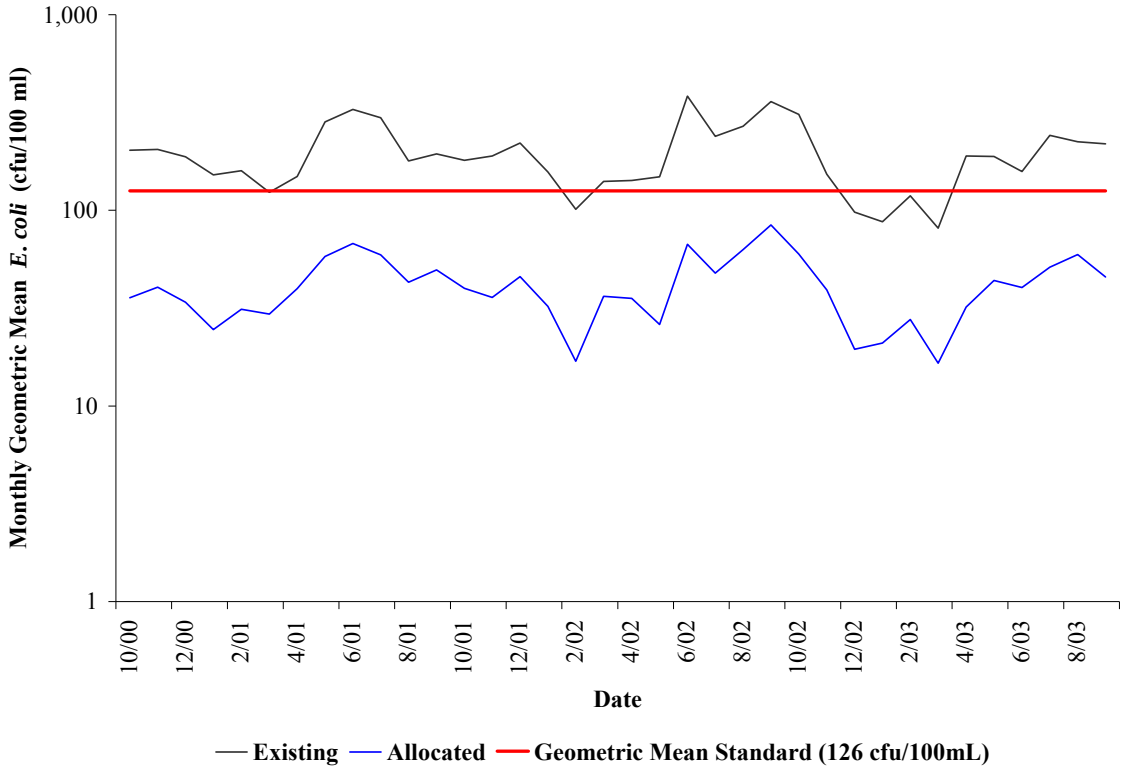

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 10, Slate Creek impairment outlet.

Table 5.6 contains estimates of existing and allocated in-stream *E. coli* loads at the Slate Creek impairment outlet reported as average annual cfu per year. The estimates in Table 5.7 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of all applicable water quality standards are given in the final column.

Tables C.5 through C.8 in Appendix C include the land-based fecal coliform load distributions and offer more details for specific implementation development and source assessment evaluation.

Table 5.6 Estimated existing and allocated *E. coli* in-stream loads in the Slate Creek impairment.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
AML	2.48E+11	2.48E+11	0%
Developed	3.96E+10	3.96E+10	0%
Cropland	0.00E+00	0.00E+00	0%
Forest	1.29E+13	1.29E+13	0%
Active Mine	1.61E+04	1.61E+04	0%
Residential	3.56E+12	3.56E+12	0%
Reclaimed Mine	4.96E+03	4.96E+03	0%
Pasture Hay	1.60E+12	1.60E+12	0%
Active Gas Well	1.79E+10	1.79E+10	0%
Direct			
Human	1.08E+14	0.00E+00	100%
Livestock	1.63E+13	1.63E+13	0%
Wildlife	1.56E+13	1.56E+13	0%
Permitted Sources	2.09E+10	2.09E+10	0%
Future Growth	0.00E+00	5.08E+11	NA
Total Loads	**1.59E+14**	**5.08E+13**	**68.0%**

Table 5.8 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet existing water quality standards. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.7 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Slate Creek impairment.

Impairment	WLA[1]	LA	MOS	TMDL
Slate Creek	**5.29E+11**	**5.03E+13**		**5.08E+13**
VAG400096	*1.74E+09*			
VAG400064	*1.74E+09*			
VAG400465	*1.74E+09*			
VAG400557	*1.74E+09*			
VAG400558	*1.74E+09*		*Implicit*	
VAG400643	*1.74E+09*			
VAG400668	*1.74E+09*			
VAG400664	*1.74E+09*			
VAG400634	*1.74E+09*			
VAG400731	*1.74E+09*			
VAG400735	*1.74E+09*			
VAG400812	*1.74E+09*			
Future Load	*5.08E+11*			

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

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for Slate Creek are shown in Table 5.8. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100ml. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.8 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Slate Creek impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Slate Creek	**1.45E+09**	**2.68E+12**		**2.69E+12**
VAG400096	4.77E+06			
VAG400064	4.77E+06			
VAG400465	4.77E+06			
VAG400557	4.77E+06			
VAG400558	4.77E+06		*Implicit*	
VAG400643	4.77E+06			
VAG400668	4.77E+06			
VAG400664	4.77E+06			
VAG400634	4.77E+06			
VAG400731	4.77E+06			
VAG400735	4.77E+06			
VAG400812	4.77E+06			
Future Load	1.39E+09			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

6. BENTHIC WATER QUALITY ASSESSMENT

6.1 Applicable Criterion for Benthic Impairment

The General Standard**,** as defined in Virginia state law 9 VAC 25-260-20, 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 used to be implemented by VADEQ through application of the modified Rapid Bioassessment Protocol II (RBP II) (Barbour, 1999). However, in January 2008, VADEQ moved to a multimetric index approach called the Virginia Stream Condition Index (VASCI) (Burton, 2003). The health of the benthic macroinvertebrate community is assessed through measurement of eight biometrics statistically derived from numerous reference sites in the non-coastal regions of Virginia (Table 6.1). Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. All eight biometrics in Table 6.1 are measured during all benthic surveys and the total VACSI score is the sum of the eight individual scores. The VADEQ benchmark for a "not impaired" status is a VASCI total score of 60 (if a stream scores less than 60 it is considered impaired).

Table 6.1 Components of the Virginia Stream Condition Index (VASCI).

Biometric	Abbreviation	Benthic Health [1]
Total Taxa Score	Richness Score	↑
EPT Taxa Score	EPT Score	↑
% Ephemeroptera Score	% Ephem. Score	↑
% Plecoptera plus Trichoptera less Hydopschyidae Score	% P+T-H Score	↑
% Scraper Score	% Scraper Score	↑
% Chironomidae Score	% Chironomidae Score	↓
% Two Dominant Families Score	% 2 Dom. Score	↓
Modified Family Biotic Index (MFBI) Score	% MFBI Score	↓

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

6.2 Benthic Assessment – Levisa Fork

Levisa Fork was initially listed on the *1996 303(d) TMDL Priority List* as not supporting the aquatic life use. All VADEQ biological water quality monitoring (benthic survey), ambient water quality monitoring and special study stations on Levisa Fork are shown in Table 6.2 and Figure 6.1.

Table 6.2 VADEQ water quality monitoring stations on Levisa Fork.

Station	Type	Descriptive Location	River Mile
6ALEV130.00	Special Study	Kentucky/VA State line	130.00
6ALEV130.25	Special Study	Bridge near State line	130.25
6ALEV130.29	Benthic	Levisa Fork at KY-VA line on 460	130.29
6ALEV130.52	Special Study	Upstream from Buckeye Branch	130.52
6ALEV130.79	Special Study	Below Conaway Creek	130.79
6ALEV131.14	Special Study	Just downstream from Conaway Creek	131.14
6ALEV131.27	Special Study	Just above Conaway Creek	131.27
6ALEV131.52	Special Study/Ambient	Wellmore Coal Dock	131.52
6ALEV131.88	Special Study	Below unnamed tributary	131.88
6ALEV132.16	Special Study	Above unnamed tributary	132.16
6ALEV132.31	Special Study	Between unnamed tributary and Rocklick Creek	132.31
6ALEV132.62	Special Study	Below Rocklick Creek	132.62
6ALEV132.91	Special Study	Below Harper Branch	132.91
6ALEV134.82	Special Study	Below Weller	134.82
6ALEV138.19	Benthic	Harman Junction	138.19
6ALEV141.28	Special Study	Above Twentymile Creek	141.28
6ALEV143.80	Benthic	Off U.S. 460 / Rt. 83 at Grundy	143.80
6ALEV143.86	Ambient/Special Study	Railroad Ave. off Rt 83	143.86
6ALEV145.86	Special Study	Downstream of Tookland	145.86
6ALEV151.26	Special Study	Just below Dismal Creek	151.26
6ALEV151.90	Benthic	Dismal Creek confluence	151.90
6ALEV152.46	Benthic/Special Study	Near Janey, VA 0.5 mi. Upstream of Dismal Creek	152.46
6ALEV155.45	Special Study	Near Oakwood	155.45
6ALEV156.82	Ambient	Garden Creek Elem. School	156.82

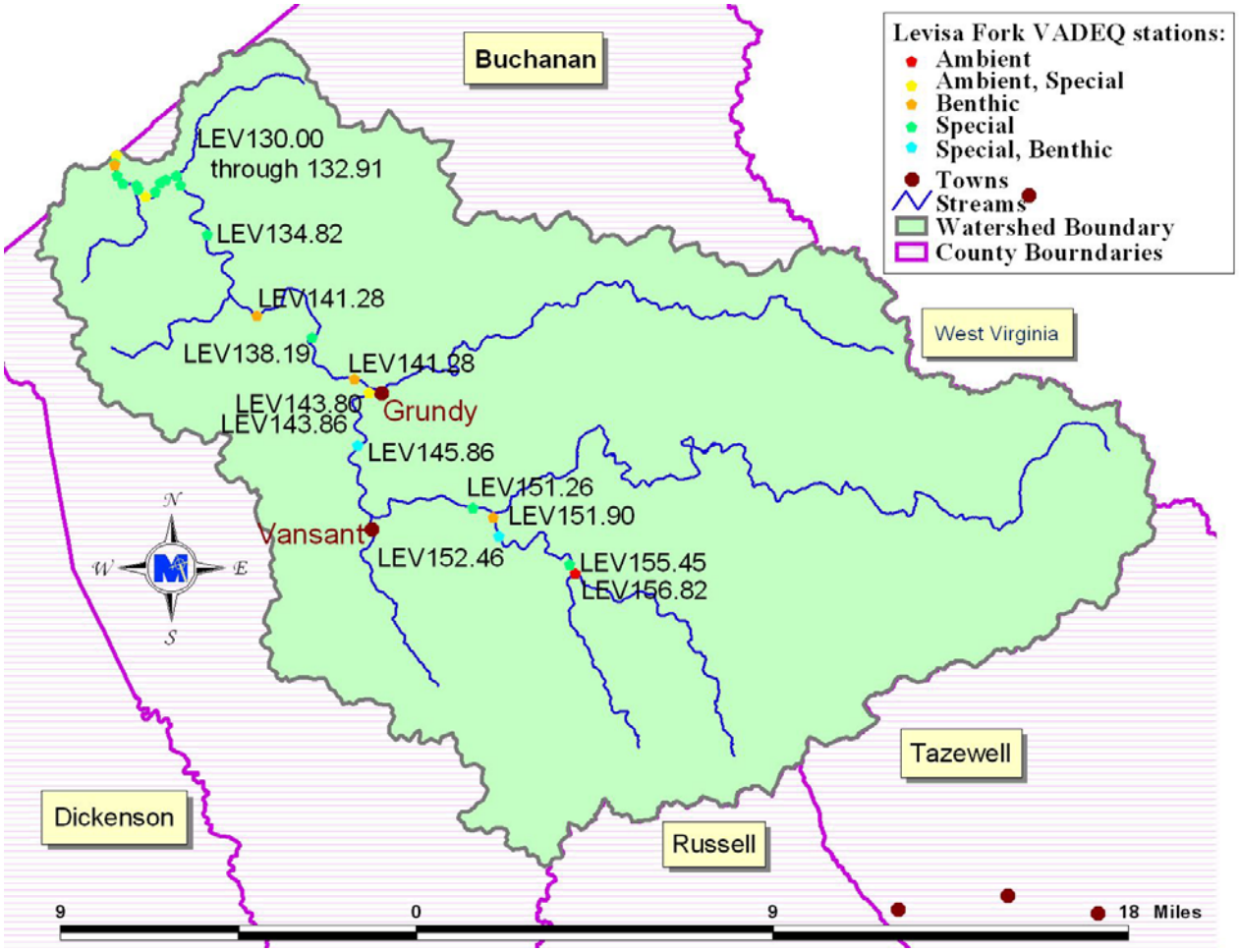

Figure 6.1 VADEQ water quality monitoring stations on Levisa Fork.

Five benthic surveys were performed by the VADEQ from December 1994 through September 2007 at benthic monitoring station 6ALEV130.29. The VASCI scores are presented in Table 6.3 and Figure 6.2. The results indicate that the surveys found impaired conditions.

Table 6.3 VASCI biological monitoring scores for station 6ALEV130.29 on Levisa Fork.

Metric	12/07/94	04/04/96	11/12/97	05/24/07	09/25/07
Richness Score	41	23	32	32	45
EPT Score	27	0	18	18	45
% Ephem. Score	7	0	1	74	59
% P+T-H Score	0	0	0	0	0
% Scraper Score	17	36	15	18	56
% Chironomidae Score	62	44	62	64	96
% 2 Dom. Score	24	36	20	26	56
% MFBI Score	64	60	61	75	77
VASCI Score	**30**	**25**	**26**	**38**	**54**
Assessment	**Impaired**	**Impaired**	**Impaired**	**Impaired**	**Impaired**

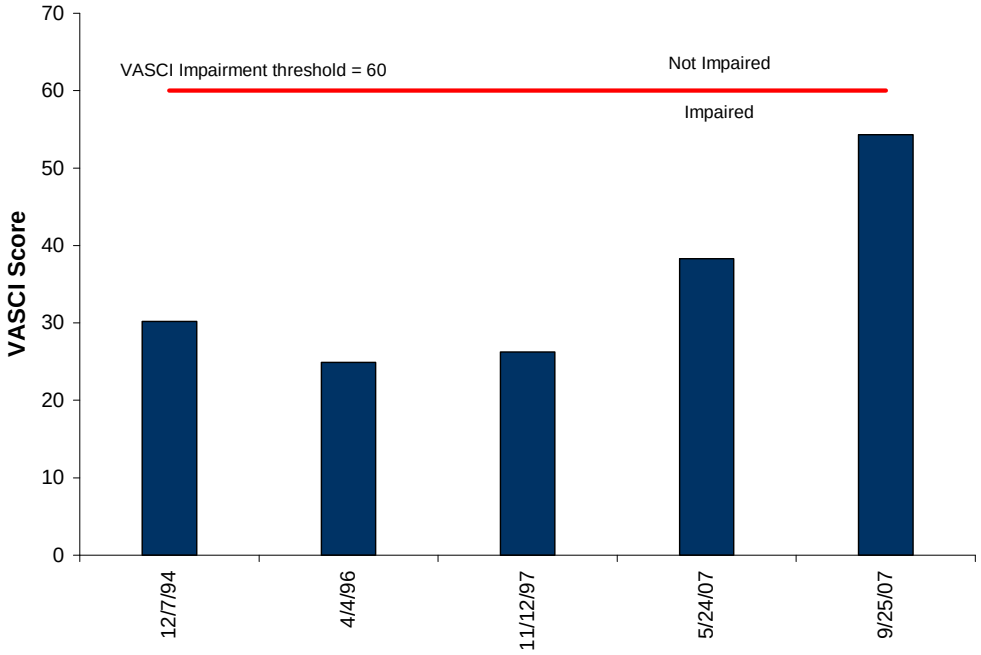

Figure 6.2 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV130.29 on Levisa Fork.

Two benthic surveys were performed by the VADEQ in March and October of 2007 at benthic monitoring station 6ALEV138.19. The VASCI scores are presented in Table 6.4 and Figure 6.3. The results indicate that the surveys found an impaired condition in the spring and not impaired in the fall of 2007.

Table 6.4 VASCI biological monitoring scores for station 6ALEV138.19 on Levisa Fork.

Metric	3/28/07	10/3/07
Richness Score	55	86
EPT Score	45	82
% Ephem. Score	16	28
% P+T-H Score	0	39
% Scraper Score	24	37
% Chironomidae Score	83	92
% 2 Dom. Score	36	88
% MFBI Score	48	75
VASCI Score	**39**	**66**
Assessment	**Impaired**	**Not Impaired**

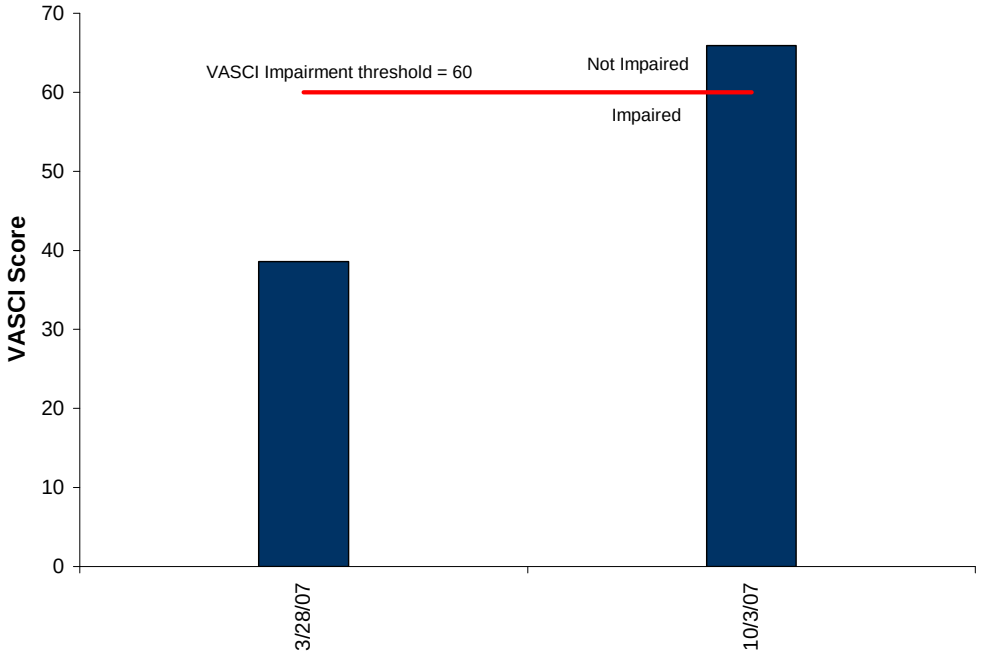

Figure 6.3 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV138.19 on Levisa Fork.

Two benthic surveys were performed by the VADEQ in May and September of 2007 at benthic monitoring station 6ALEV143.80. The VASCI scores are presented in Table 6.5 and Figure 6.4. The results indicate that the surveys found an impaired condition in the spring and an impaired condition in the fall of 2007.

Table 6.5 VASCI biological monitoring scores for station 6ALEV143.80 on Levisa Fork.

Metric	5/30/07	9/25/07
Richness Score	59	45
EPT Score	55	36
% Ephem. Score	88	43
% P+T-H Score	3	0
% Scraper Score	20	49
% Chironomidae Score	94	96
% 2 Dom. Score	58	61
% MFBI Score	74	75
VASCI Score	**56**	**51**
Assessment	**Impaired**	**Impaired**

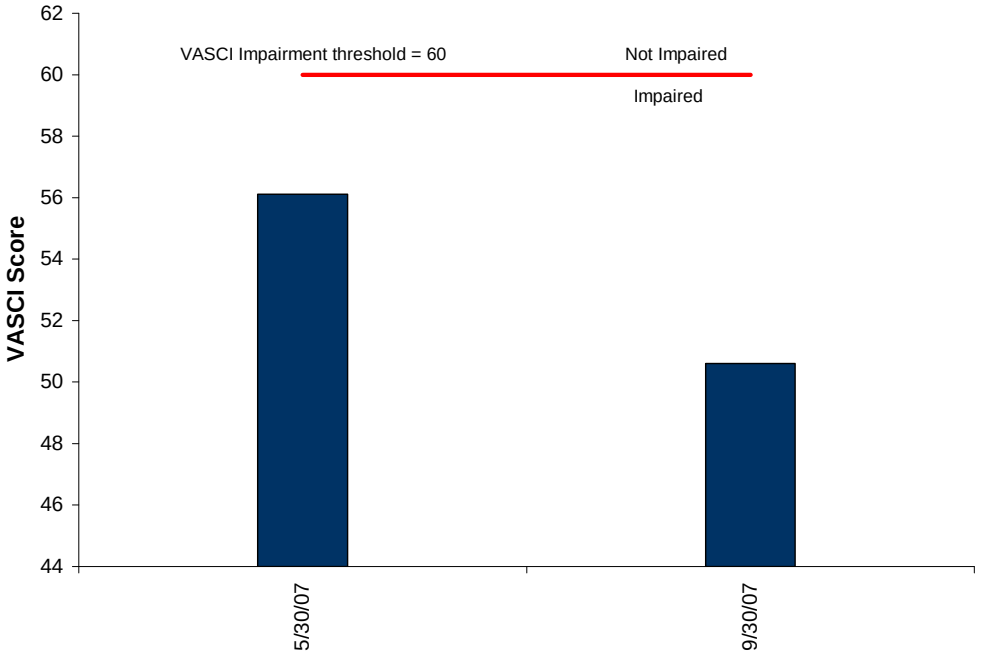

Figure 6.4 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV143.80 on Levisa Fork.

Two benthic surveys were performed by the VADEQ in December of 1992 and 1993 at benthic monitoring station 6ALEV151.90. The VASCI scores are presented in Table 6.6 and Figure 6.5. Both surveys found an impaired condition in Levisa Fork.

Table 6.6 VASCI biological monitoring scores for station 6ALEV151.90 on Levisa Fork.

Metric	12/09/92	12/14/93
Richness Score	50	59
EPT Score	36	27
% Ephem. Score	11	2
% P+T-H Score	11	45
% Scraper Score	31	55
% Chironomidae Score	97	86
% 2 Dom. Score	31	72
% MFBI Score	67	77
VASCI Score	**42**	**53**
Assessment	**Impaired**	**Impaired**

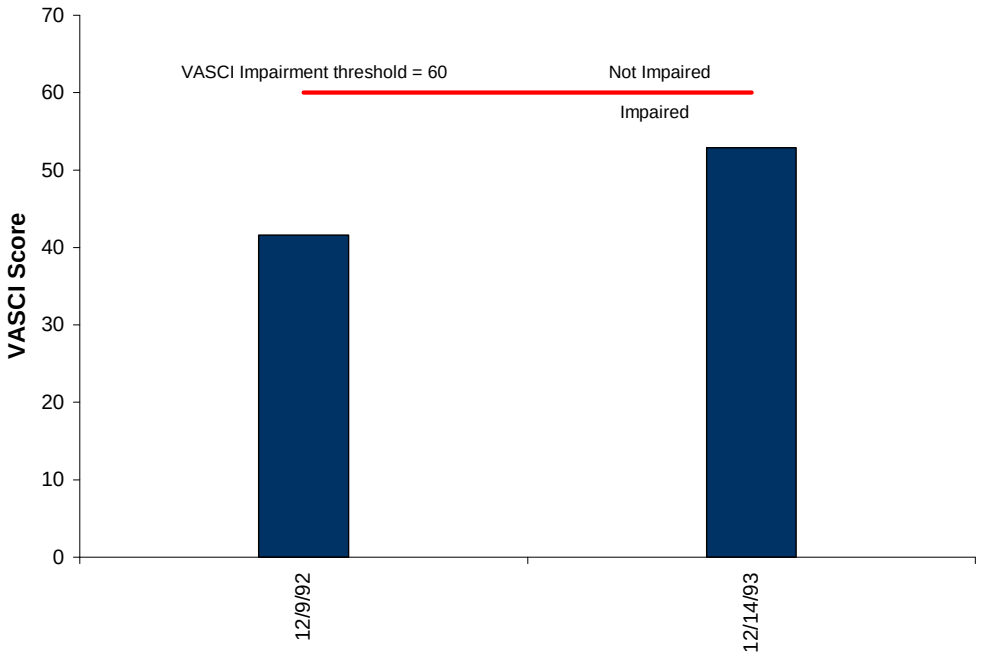

Figure 6.5 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV151.90 on Levisa Fork.

Two benthic surveys were performed by the VADEQ in May and September of 2007 at benthic monitoring station 6ALEV152.46. The VASCI scores are presented in Table 6.7 and Figure 6.6. The results indicate that the surveys found an impaired condition in the spring and a slightly impaired condition in the fall of 2007.

Table 6.7 VASCI biological monitoring scores for station 6ALEV152.46 on Levisa Fork.

Metric	5/30/07	9/26/07
Richness Score	41	55
EPT Score	18	64
% Ephem. Score	57	26
% P+T-H Score	0	17
% Scraper Score	14	79
% Chironomidae Score	96	93
% 2 Dom. Score	41	52
% MFBI Score	62	74
VASCI Score	**41**	**57**
Assessment	**Impaired**	**Impaired**

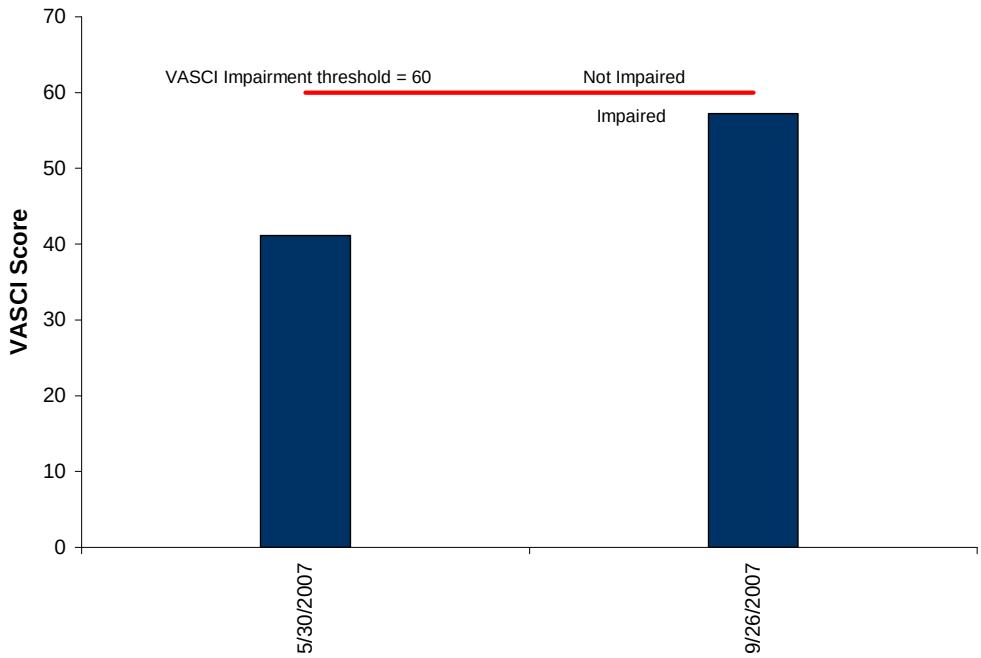

Figure 6.6 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ALEV152.46 on Levisa Fork.

6.3 Benthic Assessment – Slate Creek

Slate Creek was initially listed on the *1996 303(d) TMDL Priority List* as not supporting the aquatic life use. All biological and ambient water quality monitoring stations on Slate Creek are shown in Table 6.8 and Figure 6.7.

Table 6.8 VADEQ monitoring stations on Slate Creek.

Station	Station Type	River Mile
6ASAT000.00	Benthic	0.00
6ASAT000.03	Ambient	0.03
6ASAT000.05	Benthic	0.05
6ASAT000.26	Ambient/Benthic	0.26
6ASAT004.52	Benthic	4.52
6ASAT004.56	Special Study	4.56
6ASAT007.71	Benthic	7.71

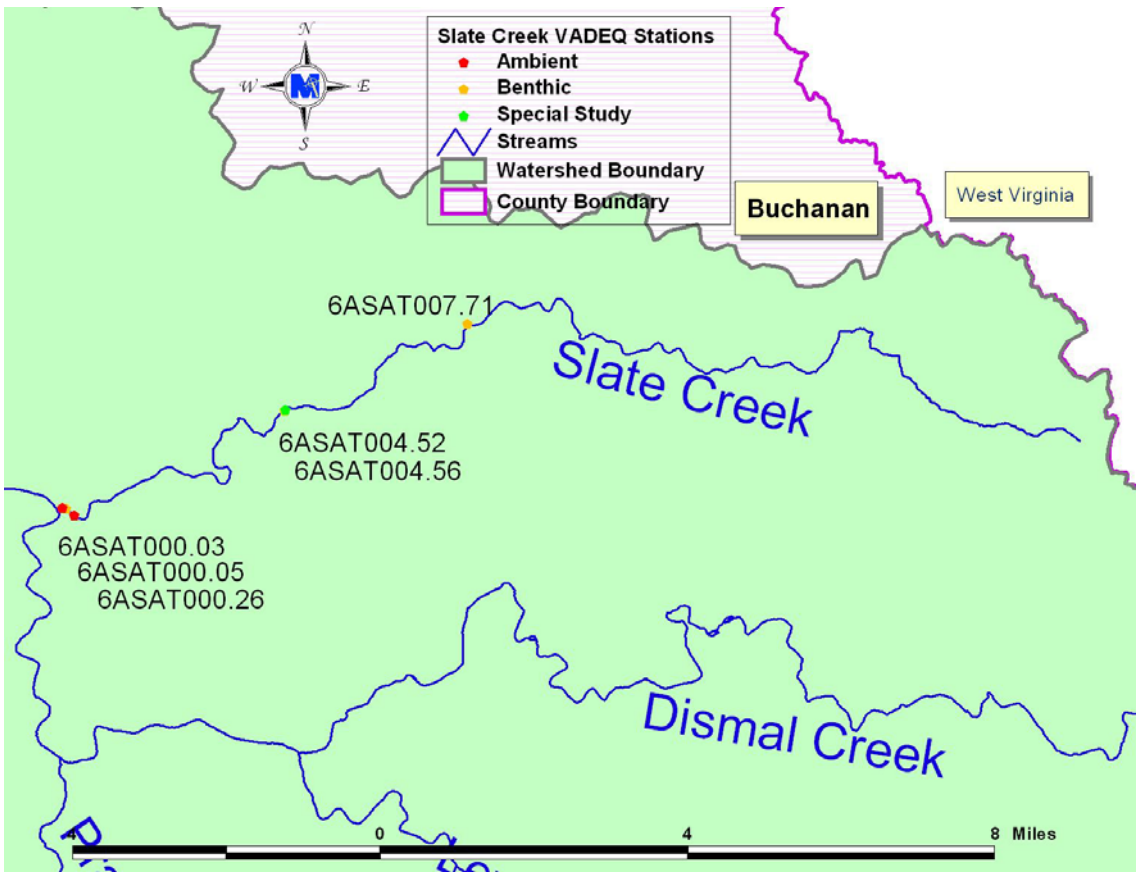

Figure 6.7 Biological, ambient and special study water quality monitoring stations on Slate Creek.

VADEQ performed a benthic monitoring sweep at three stations on Slate Creek in June 1998. The VASCI scores are presented in Table 6.9 and Figure 6.8. The results indicated moderate impairment at all three monitoring stations.

Table 6.9 VASCI biological monitoring results for VADEQ benthic monitoring sweep on Slate Creek on July 20, 1998.

Metric	6ASAT000.05	6ASAT004.52	6ASAT007.71
Richness Score	55	41	45
EPT Score	45	36	45
% Ephem. Score	100	100	100
% P+T-H Score	3	0	0
% Scraper Score	17	21	17
% Chironomidae Score	82	88	96
% 2 Dom. Score	42	51	32
% MFBI Score	83	82	86
VASCI Score	**53**	**52**	**53**
Assessment	**Impaired**	**Impaired**	**Impaired**

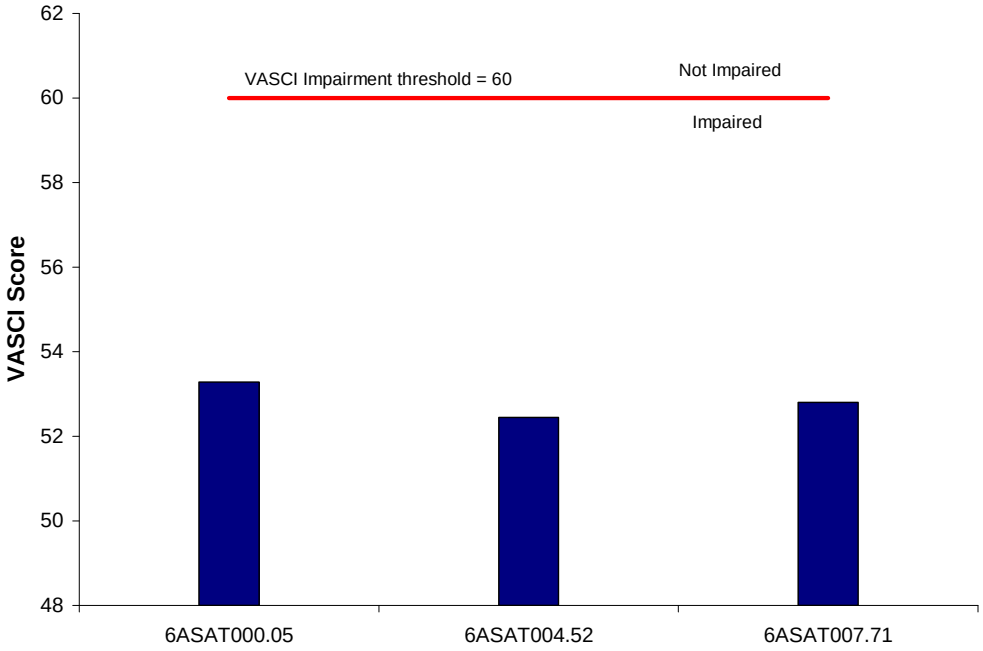

Figure 6.8 VASCI biological monitoring scores for VADEQ benthic monitoring sweep on Slate Creek in June 1998.

Two benthic surveys were performed by the VADEQ in May and November of 2006 at benthic monitoring station 6ASAT000.05. The VASCI scores are presented in Table 6.10 and Figure 6.9. The results indicate that both surveys found an impaired condition.

Table 6.10 VASCI data for VADEQ station 6ASAT000.05 on Slate Creek.

Metric	5/15/06	11/27/06
Richness Score	36	59
EPT Score	36	55
% Ephem. Score	81	44
% P+T-H Score	0	11
% Scraper Score	0	24
% Chironomidae Score	67	53
% 2 Dom. Score	29	63
% MFBI Score	73	70
VASCI Score	**40**	**47**
Assessment	**Impaired**	**Impaired**

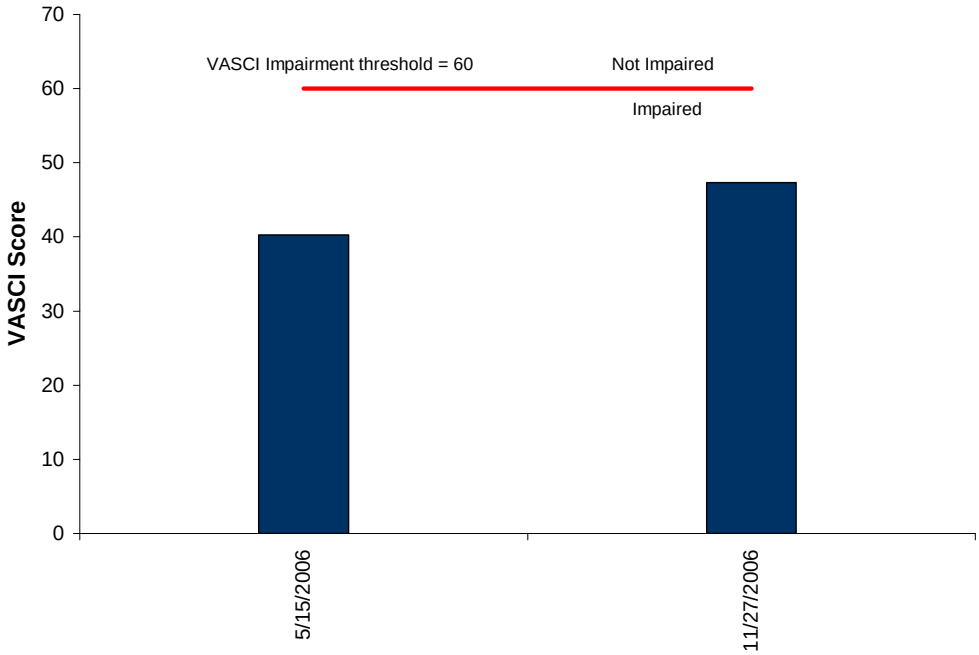

Figure 6.9 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT000.05 on Slate Creek.

Two benthic surveys were performed by the VADEQ in May and September of 2007 at benthic monitoring station 6ASAT000.26. The VASCI scores are presented in Table 6.11 and Figure 6.10. The results indicate that the surveys found an impaired condition in the spring and not impaired condition in the fall.

Table 6.11 VASCI data for VADEQ station 6ASAT000.26 on Slate Creek.

Metric	5/30/07	9/26/07
Richness Score	50	59
EPT Score	45	73
% Ephem. Score	79	26
% P+T-H Score	3	14
% Scraper Score	24	80
% Chironomidae Score	86	98
% 2 Dom. Score	59	50
% MFBI Score	78	79
VASCI Score	**53**	**60**
Assessment	**Impaired**	**Not Impaired**

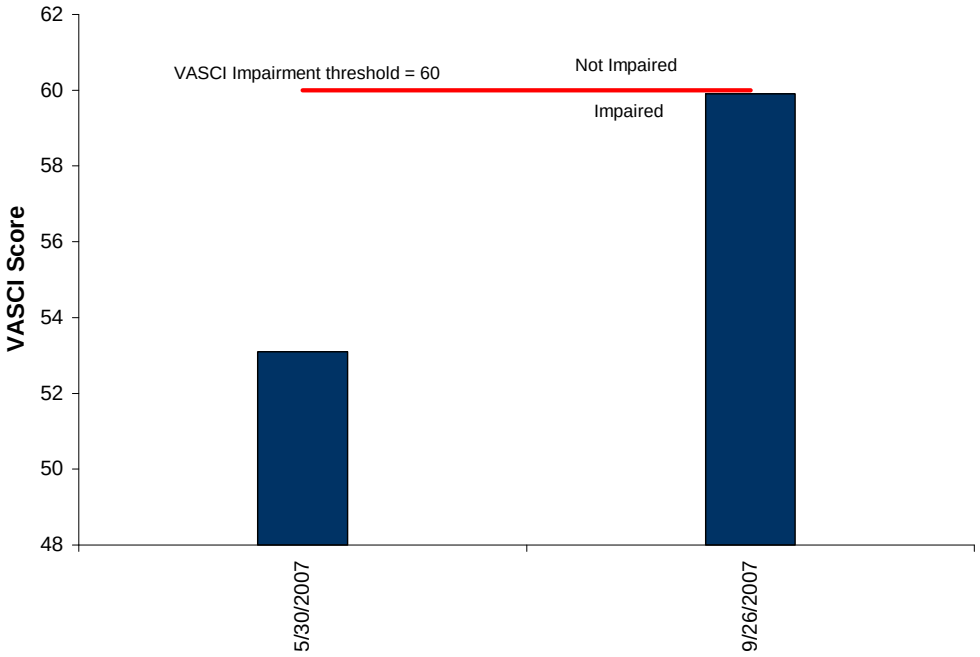

Figure 6.10 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT000.26 on Slate Creek.

Two benthic surveys were performed by the VADEQ in May and September of 2007 at benthic monitoring station 6ASAT007.71. The VASCI scores are presented in Table 6.12 and Figure 6.11. The results indicate that the surveys found an impaired condition in the spring and a not impaired condition in the fall.

Table 6.12 VASCI data for VADEQ station 6ASAT007.71 on Slate Creek.

Metric	5/30/07	9/26/07
Richness Score	36	55
EPT Score	27	55
% Ephem. Score	84	47
% P+T-H Score	0	12
% Scraper Score	27	100
% Chironomidae Score	94	98
% 2 Dom. Score	51	63
% MFBI Score	75	87
VASCI Score	**49**	**64**
Assessment	**Impaired**	**Not Impaired**

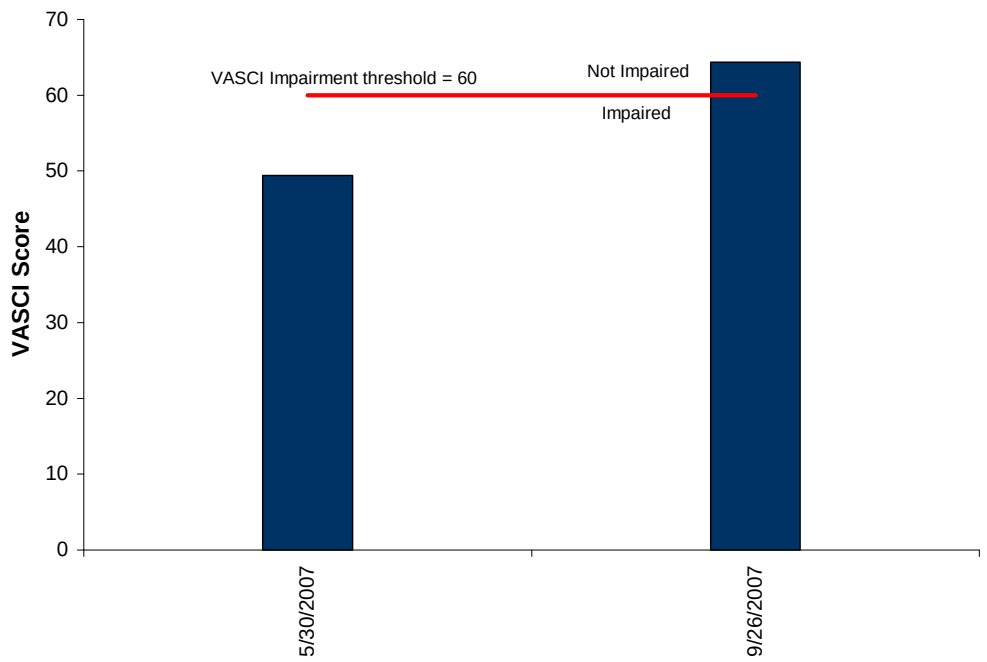

Figure 6.11 VASCI biological monitoring scores for VADEQ benthic monitoring station 6ASAT007.71 on Slate Creek.

6.4 Habitat Assessments

Benthic impairments have two general causes: input of pollutants to streams and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.,* by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.,* due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of ten individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 6.13.

Table 6.13 Classification of habitat metrics based on score.

Habitat Metric	Optimal	Sub-optimal	Marginal	Poor
Embeddedness	16 - 20	11 – 15	6 - 10	0 - 5
Epifaunal Substrate	16 - 20	11 – 15	6 - 10	0 - 5
Pool Sediment	16 - 20	11 – 15	6 - 10	0 - 5
Flow	16 - 20	11 – 15	6 - 10	0 - 5
Channel Alteration	16 - 20	11 – 15	6 - 10	0 - 5
Riffles	16 - 20	11 – 15	6 - 10	0 - 5
Velocity	16 - 20	11 – 15	6 - 10	0 - 5
Bank Stability	18 - 20	12 – 16	6 - 10	0 - 4
Bank Vegetation	18 - 20	12 – 16	6 - 10	0 - 4
Riparian Vegetation	18 - 20	12 – 16	6 - 10	0 - 4

6.4.1 Habitat Assessment at Biological Monitoring Stations – Levisa Fork

Habitat assessment for Levisa Fork includes an analysis of habitat scores recorded by the VADEQ biologist at the four benthic monitoring stations. The VADEQ habitat assessments for 6ALEV130.29 are displayed in Table 6.14. Riparian Vegetation is a measure of the width of the natural riparian zone. A healthy riparian zone acts as a buffer for pollutants running off the land, helps prevent erosion, and provides habitat. The Riparian Vegetation around this monitoring station consistently scored in the marginal category. Embeddedness is a measure of the silt, sand or mud that surrounds the rocks on the stream bottom. Less habitat is available to benthic macroinvertebrates the deeper the layer of sediment becomes. The average Embeddedness score at station 6ALEV130.29 was in the marginal category meaning the rocks on the stream bottom are between 50 to 70% surrounded by sediment. The Pool Sediment metric assesses the amount of sediment that collects in pool areas of the stream. The average Pool Sediment score at this station was in the marginal category, indicating that 30 to 50% of stream bottom was covered with sediment.

Table 6.14 Habitat scores for VADEQ monitoring station 6ALEV130.29 on Levisa Fork.

Habitat Metric	12/7/1994	4/4/1996	11/12/1997	5/24/2007	9/25/2007	Average
Embeddedness	9	12	7	13	11	10
Epifaunal Substrate	14	14	15	16	17	15
Pool Sediment	13	10	6	10	9	10
Flow	14	19	11	15	9	14
Channel Alteration	14	13	14	15	14	14
Riffles	12	12	7	11	12	11
Velocity	17	17	15	16	14	16
Bank Stability	14	10	12	12	16	13
Bank Vegetation	18	15	16	11	12	14
Riparian Vegetation	7	6	6	11	9	8
Total	**132**	**128**	**109**	**130**	**123**	**125**

Table 6.15 shows the habitat scores for the two benthic surveys at station 6ALEV138.19 in March and October 2007.

Table 6.15 Habitat scores for 6ALEV138.19 on Levisa Fork.

Habitat Metric	3/28/2007
Embeddedness	11
Epifaunal Substrate	19
Pool Sediment	13
Flow	18
Channel Alteration	15
Riffles	8
Velocity	10
Bank Stability	12
Bank Vegetation	9
Riparian Vegetation	11
Total	**126**

Table 6.16 shows the habitat scores for the two benthic surveys at station 6ALEV143.80 in May and September 2007. Bank Stability is a measure of stream bank erosion. Both the fall and spring scores for this metric were in the poor category, which means that 60 - 100% of the stream bank has erosion scars. In addition, the Bank Vegetation metric scored in the poor category in both surveys. A poor score for this habitat metric means that less than 50% of the stream bank is covered by vegetation. Both the Embeddedness and Pool Sediment metrics scored in the marginal category during the spring survey, indicating that sediment is periodically a problem at this monitoring station.

Table 6.16 Habitat scores for 6ALEV143.80 on Levisa Fork.

Habitat Metric	5/30/2007	9/25/2007	Average
Embeddedness	8	13	11
Epifaunal Substrate	16	16	16
Pool Sediment	10	12	11
Flow	12	13	13
Channel Alteration	7	13	10
Riffles	14	16	15
Velocity	17	10	14
Bank Stability	10	17	14
Bank Vegetation	2	2	2
Riparian Vegetation	2	2	2
Total	**98**	**114**	**108**

Table 6.17 shows the habitat scores for the December 1993 VADEQ benthic survey at 6ALEV151.90 (habitat scores for the December 1992 survey were not available). Both the Embeddedness and Pool Sediment parameters scored in the marginal category and Bank Stability was in the poor category. A total habitat score of 94 is considered very low.

Table 6.17 Habitat scores for 6ALEV151.90 on Levisa Fork.

Habitat Metric	12/14/1993
Embeddedness	7
Epifaunal Substrate	18
Pool Sediment	8
Flow	7
Channel Alteration	13
Riffles	12
Velocity	16
Bank Stability	4
Bank Vegetation	5
Riparian Vegetation	4
Total	**94**

Table 6.18 shows the habitat scores for the two benthic surveys at station 6ALEV152.46 in May and September 2007. Both the fall and spring scores for the Bank Stability metric were in the marginal category. The Riffles metric scored in the marginal category in both surveys. A marginal score for this habitat metric means that riffle areas in the stream are infrequent; and, therefore, suitable habitat for many benthic macroinvertebrates does

exist. In addition, the Flow habitat metric scored in the marginal category during the fall survey, indicating that 25 – 75% of the riffle habitat was exposed.

Table 6.18 Habitat scores for 6ALEV152.46 on Levisa Fork.

Habitat Metric	5/30/2007	9/26/2007	Average
Embeddedness	13	16	15
Epifaunal Substrate	16	18	17
Pool Sediment	11	13	12
Flow	12	8	10
Channel Alteration	11	12	12
Riffles	9	10	10
Velocity	16	15	16
Bank Stability	9	8	9
Bank Vegetation	12	11	12
Riparian Vegetation	13	12	13
Total	**122**	**123**	**126**

6.4.2 Habitat Assessment at Biological Monitoring Stations – Slate Creek

Habitat assessment for Slate Creek includes an analysis of habitat scores recorded by the VADEQ biologist at the three benthic monitoring stations. The VADEQ habitat assessments for benthic monitoring sweep on July 20, 1998 are shown in Table 6.19. The Flow habitat metric was in the marginal category at all three monitoring stations, indicating that 25 – 75% of the riffle habitat was exposed. Bank Stability scored in the marginal category at all three monitoring stations. Riparian Vegetation scored in the poor category at monitoring stations 6ASAT000.05 and 6ASAT007.71. This indicates that the width of the vegetation zone in the riparian area is less than 6 meters. The Velocity habitat metric was in the marginal category at station 6ASAT007.71, indicating that there were only two out of the four possible habitat regimes present. Both the Embeddedness and Pool Sediment habitat metrics scored in the marginal category at monitoring station 6ASAT007.71, indicating that excessive sediment is a problem at this monitoring station.

Table 6.19 Habitat scores at VADEQ benthic monitoring stations on Slate Creek on July 20, 1998.

Metric	6ASAT000.05	6ASAT004.52	6ASAT007.71
Embeddedness	15	18	10
Substrate	16	15	17
Pool Sediment	11	11	9
Flow	10	10	10
Channel Alteration	11	15	14
Riffles	13	11	13
Velocity	12	11	9
Bank Stability	10	10	10
Bank Vegetation	16	16	16
Riparian Vegetation	5	16	7
Total	**119**	**133**	**115**

Table 6.20 shows the habitat scores for benthic surveys at Slate Creek monitoring stations 6ASAT000.05, 6ASAT000.26 and 6ASAT007.71.

Table 6.20 Habitat scores for 6ASAT000.05 on Slate Creek.

Habitat Metric	6ASAT000.05 5/15/2006	6ASAT000.05 11/27/2006	6ASAT000.26 5/30/2007	6ASAT000.269/26/2007	6ASAT007.71 5/30/2007	6ASAT007.71 9/26/2007
Embeddedness	10	7	13	16	5	9
Epifaunal Substrate	16	17	16	18	14	16
Pool Sediment	8	11	10	13	9	8
Flow	11	18	13	7	13	7
Channel Alteration	12	9	7	8	14	13
Riffles	18	16	15	12	16	3
Velocity	8	9	10	10	10	9
Bank Stability	12	17	8	14	16	9
Bank Vegetation	12	1	3	3	12	9
Riparian Vegetation	6	1	2	3	9	6
Total	**113**	**106**	**97**	**104**	**118**	**89**

The Embeddedness and Pool Sediment metrics at benthic monitoring stations 6ASAT000.05 and 6ASAT007.71 scored in the marginal and poor categories. In addition, the Pool Sediment metric scored in the marginal category in a least one survey at all three benthic monitoring stations. This indicates that sediment is a problem at these

monitoring stations. Several other metrics such as Riparian Vegetation, Bank Vegetation and Channel Alteration also scored in the marginal and poor categories during some of the surveys at these three monitoring stations.

6.5 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream water quality data throughout the Levisa Fork and Slate Creek watersheds. An examination of data from water quality stations used in the Section 305(b) assessment and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

6.5.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information for Levisa Fork are:

- Data collected at three VADEQ ambient monitoring stations, and
- Special study fish tissue and sediment data collected at six VADEQ stations.

6.5.1.1 VADEQ Water Quality Monitoring – Levisa Fork

VADEQ has monitored water quality recently at four stations on Levisa Fork in the vicinity of the benthic monitoring stations (Table 6.21). The locations of these stations are shown in Figure 6.1. The conventional data is summarized in Tables 6.22 through 6.25.

Table 6.21 VADEQ ambient water quality monitoring stations on Levisa Fork.

Station	Type	Data Record	Descriptive location
6ALEV131.52	Ambient	1/1997 – 11/2007	Wellmore Coal Co. dock #14 Bridge off 460
6ALEV143.86	Ambient	1/1997 – 3/2001, 2/2007 – 7/2007	Steel Bridge on Railroad Ave off Rt. 83
6ALEV152.46	Ambient	1/2000 – 6/2003, 1/2007 – 12/2007	Near Janey 0.5 mi. upstream of Dismal Creek
6ALEV156.82	Ambient	7/2001 – 6/2003, 1/2007 – 12/2007	At Garden Elem. School

Table 6.22 In-stream water quality data at 6ALEV131.52 in Levisa Fork (1/1997 – 3/2008).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Acid Neutralizing Capacity	132	41	186	61	141	11
Acidity, Total (mg/l)	3.13	1.16	4.48	1.97	3.02	7
Alkalinity (mg/L)	104	40	186	30	109	60
Ammonia + Ammonium (mg/L as N)	0.08	0.03	0.10	0.04	0.09	3
Bicarbonate, Dissolved (mg/L)	132	41	186	61	141	11
BOD5 (mg/L)	1.50	0.58	2.00	1.00	1.50	4
Calcium, dissolved (mg/l)	44.57	11.41	62.30	23.90	46.95	13
Carbon, Total Organic (mg/l)	7.22	6.34	11.70	2.73	NA	2
Chloride, dissolved (mg/L)	23.90	11.61	43.40	9.31	23.40	11
Chloride,Total (mg/L)	46.66	41.44	233	7.33	32.85	64
COD (mg/L)	11.95	10.30	46.00	5.00	8.00	19
Conductivity (µmhos/cm)	658	266	1,465	214	620	88
Dissolved Inorganic Solids (mg/L)	403	134	520	177	472	10
Dissolved Organic Solids (mg/L)	45.70	16.04	68.00	25.00	47.00	10
DO_Probe (mg/L)	10.43	1.94	15.98	6.55	10.30	103
Field_pH (std units)	8.00	0.32	8.66	6.53	8.04	109
Hardness (mg/L)	242	25	259	224	NA	2
Iron (mg/kg)	21,265	2,357	23,700	18,995	21,100	3
Nitrate Nitrogen (mg/L as N)	0.37	0.24	1.09	0.04	0.33	56
Nitrate Nitrogen, Dissolved (mg/L as N)	0.31	0.20	0.57	0.11	0.29	6
Nitrite Nitrogen (mg/L)	0.01	0.01	0.05	0.01	0.01	15
Nitrite Plus Nitrate, Total (mg/L as N)	0.32	0.18	0.54	0.08	0.32	10
Nitrogen, Kjeldahl, Total, (mg/L As N)	0.22	0.16	1.00	0.10	0.20	76
Nitrogen, Total (mg/L As N)	0.47	0.45	2.72	0.10	0.40	35
Phosphorus (Total Ortho P, mg/L)	0.02	0.01	0.05	0.01	0.02	43
Phosphorus, Total (mg/L As P)	0.02	0.04	0.34	0.01	0.01	87
Potassium, Dissolved (mg/L)	2.49	0.73	3.41	1.00	2.60	11
Sodium, Dissolved (mg/L)	69.79	34.14	117.00	23.80	77.80	11
Sulfate, dissolved (mg/L)	179	56	237	80	206	11
Sulfate, Total (mg/L)	163	61	274	59	156	61
Temp_Celsuis	14.29	7.73	27.60	0.10	13.30	109
Total Dissolved Solids (mg/L)	422	178	853	135	419	68
Total Hardness (CaCO3 mg/L)	180	61	297	54	179	73
Total Inorganic Solids (mg/L)	379	158	798	108	363	84
Total Inorganic Suspended Solids (mg/L)	28.40	38.12	160.00	3.00	11.00	40
Total Organic Solids (mg/L)	64.45	27.69	173.00	15.00	57.50	84
Total Solids (mg/L)	429	191	1,316	169	404	101
Total Suspended Organic Solids (mg/L)	9.62	6.84	24.00	3.00	7.00	21
Total Suspended Solids (TSS) (mg/L)	39.34	138	1,165	3.00	6.50	74
Turbidity Lab (ntu)	36.01	148	900	0.89	3.10	38

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 6.23 In-stream water quality data at 6ALEV143.86 in Levisa Fork (1/1997 - 7/2007).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Acid Neutralizing Capacity	121	32	163	78	128	5
Acidity, Total (mg/l)	2.16	0.79	3.02	1.48	1.97	3
Alkalinity (mg/L)	107	40	166	31	110	55
Ammonia + Ammonium (mg/L as N)	0.05	0.00	0.05	0.05	NA	2
Bicarbonate, Dissolved (mg/L)	121	34	165	78	128	5
BOD5 (mg/L)	2.00	NA	2.00	2.00	NA	1
Calcium, dissolved (mg/l)	29.34	4.76	33.60	21.40	30.80	5
Carbon, Total Organic (mg/l)	16.80	NA	16.80	16.80	NA	1
Chloride, dissolved (mg/L)	21.64	7.31	31.00	13.80	19.20	5
Chloride,Total (mg/L)	82.09	82.37	380	5.90	65.60	55
COD (mg/L)	13.12	16.79	73	5.00	7.00	24
Conductivity (µmhos/cm)	696	348	1,775	194	662	56
Dissolved Inorganic Solids (mg/L)	307	93	408	192	310	5
Dissolved Organic Solids (mg/L)	32.00	13.73	48.00	21.00	23.00	5
DO (mg/L)	10.66	2.16	16.70	6.99	10.46	53
Field_pH (std units)	7.98	0.38	8.68	6.54	8.01	55
Iron (mg/kg)	22,550	6,435	27,100	18,000	NA	2
Magnesium, dissolved (mg/l)	11.40	1.96	13.60	8.49	12.20	5
Nitrate Nitrogen (mg/L as N)	0.34	0.21	0.91	0.05	0.30	32
Nitrate Nitrogen, Dissolved (mg/L as N)	0.25	0.19	0.45	0.07	0.24	4
Nitrite Nitrogen (mg/L)	0.01	0.00	0.02	0.01	0.01	9
Nitrite Plus Nitrate, Total (mg/L as N)	0.24	0.17	0.41	0.08	0.24	4
Nitrogen, Kjeldahl, Total, (mg/L As N)	0.31	0.25	1.50	0.10	0.20	45
Nitrogen, Total (mg/L As N)	0.39	0.23	0.75	0.19	0.26	5
Phosphorus (Total Ortho P, mg/L)	0.02	0.01	0.04	0.01	0.02	36
Phosphorus, Total (mg/L As P)	0.03	0.10	0.65	0.01	0.02	45
Potassium, Dissolved (mg/L)	1.94	0.57	2.50	1.07	2.03	5
Sodium, Dissolved (mg/L)	49.62	15.77	68.50	29.90	48.70	5
Sulfate, dissolved (mg/L)	104	30	144	72	100	5
Sulfate, Total (mg/L)	111	39	231	43	111	55
Temp_Celsuis	13.52	8.01	26.30	0.00	11.40	55
Total Dissolved Solids (mg/L)	409	195	1,010	123	397	55
Total Hardness (CaCO3 mg/L)	155	52	296	44	155	50
Total Inorganic Solids (mg/L)	383	196	925	96	361	55
Total Inorganic Suspended Solids (mg/L)	49.22	131	564	3.00	8.00	18
Total Organic Solids (mg/L)	53	25	140	15	48	55
Total Solids (mg/L)	437	212	1,026	155	416	55
Total Suspended Organic Solids (mg/L)	11.64	18.28	66.00	3.00	5.00	11
Total Suspended Solids (TSS) (mg/L)	38	119	630	3.00	7.00	28
Turbidity Lab (ntu)	236	524	1,173	1	3	5

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 6.24 In-stream water quality data at 6ALEV152.46 in Levisa Fork (7/2000 - 12/2007).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Acid Neutralizing Capacity	131.8	41.3	186.0	60.5	141.0	11
Acidity, Total (mg/l)	3.13	1.16	4.48	1.97	3.02	7
Alkalinity (mg/L)	104	40	186	30	109	60
Ammonia + Ammonium (mg/L as N)	0.08	0.03	0.10	0.04	0.09	3
Bicarbonate, Dissolved	131.7	41.4	186.0	60.5	141.0	11
BOD5 (mg/L)	1.50	0.58	2.00	1.00	1.50	4
Calcium, dissolved (mg/l)	44.6	11.4	62.3	23.9	47.0	13
Carbon, Total Organic (mg/l)	7.22	6.34	11.70	2.73	NA	2
Chloride, dissolved (mg/L)	23.9	11.6	43.4	9.3	23.4	11
Chloride,Total (mg/L)	46.7	41.4	233.0	7.3	32.9	64
COD (mg/L)	11.95	10.30	46.00	5.00	8.00	19
Conductivity (µmhos/cm)	658	266	1465	214	620	88
Dissolved Inorganic Solids (mg/L)	402.6	133.7	520.0	177.0	472.0	10
Dissolved Organic Solids (mg/L)	45.70	16.04	68.00	25.00	47.00	10
DO_Probe	10.43	1.94	15.98	6.55	10.30	103
Field_pH	8.00	0.32	8.66	6.53	8.04	109
Hardness	242	25	259	224	NA	2
Iron (mg/kg)	21,265	2,357	23,700	18,995	21,100	3
Nitrate Nitrogen (mg/L as N)	0.37	0.24	1.09	0.04	0.33	56
Nitrate Nitrogen, Dissolved (mg/L as N)	0.31	0.20	0.57	0.11	0.29	6
Nitrite Nitrogen (mg/L)	0.01	0.01	0.05	0.01	0.01	15
Nitrite Plus Nitrate, Total (mg/L as N)	0.32	0.18	0.54	0.08	0.32	10
Nitrogen, Kjeldahl, Total, (mg/L As N)	0.22	0.16	1.00	0.10	0.20	76
Nitrogen, Total (mg/L As N)	0.47	0.45	2.72	0.10	0.40	35
Phosphorus (Total Ortho P, mg/L)	0.02	0.01	0.05	0.01	0.02	43
Phosphorus, Total (mg/L As P)	0.02	0.04	0.34	0.01	0.01	87
Potassium, Dissolved (mg/L)	2.49	0.73	3.41	1.00	2.60	11
Sodium, Dissolved (mg/L)	69.8	34.1	117.0	23.8	77.8	11
Sulfate, dissolved (mg/L)	179.0	55.6	237.0	79.7	206.0	11
Sulfate, Total (mg/L)	163	61	274	59	156	61
Temp_Celsuis	14.29	7.73	27.60	0.10	13.30	109
Total Dissolved Solids (mg/L)	422	178	853	135	419	68
Total Hardness (CaCO3 mg/L)	180	61	297	54	179	73
Total Inorganic Solids (mg/L)	379.23	157.89	798.00	108.00	363.50	84
Total Inorganic Suspended Solids (mg/L)	28.4	38.1	160.0	3.0	11.0	40
Total Organic Solids (mg/L)	64.5	27.7	173.0	15.0	57.5	84
Total Solids (mg/L)	429.5	191.5	1,316.0	169.0	404.0	101
Total Suspended Organic Solids (mg/L)	9.6	6.8	24.0	3.0	7.0	21
Total Suspended Solids (TSS) (mg/L)	39.3	137.9	1165.0	3.0	6.5	74
Turbidity Lab (ntu)	36.0	147.6	900.0	0.9	3.1	38

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 6.25 In-stream water quality data at 6ALEV156.82 in Levisa Fork (7/2001 - 11/2007).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Acid Neutralizing Capacity	136	43	191	68	144	10
Acidity, Total (mg/l)	3.81	1.90	7.43	2.10	3.45	6
Alkalinity (mg/L)	133	43	189	68	137	10
Ammonia + Ammonium (mg/L as N)	0.14	0.06	0.18	0.09	NA	2
Bicarbonate, Dissolved (mg/L)	135	43	191	68	139	10
calcium, dissolved (mg/l)	43.12	11.08	59.10	24.20	44.75	10
Carbon, Total Organic (mg/l)	11.50	NA	11.50	11.50	NA	1
Chloride, dissolved (mg/L)	17.83	5.33	26.60	12.20	17.15	10
Chloride,Total (mg/L)	17.75	5.41	26.60	12.20	17.25	10
COD (mg/L)	10.50	7.72	22.00	6.00	7.00	4
Conductivity (µmhos/cm)	627	181	997	353	554	23
Dissolved Inorganic Solids (mg/L)	373	106	498	190	393	10
Dissolved Organic Solids (mg/L)	40.00	15.02	54.00	20.00	47.00	10
DO (mg/L)	10.11	1.36	12.48	8.20	9.80	21
Field pH (std units)	8.02	0.27	8.60	7.48	8.00	23
Magnesium, dissolved (mg/l)	15.91	4.03	20.80	8.22	16.90	10
Nitrate Nitrogen (mg/L as N)	0.43	0.20	0.72	0.04	0.41	12
Nitrate Nitrogen, Dissolved (mg/L as N)	0.28	0.18	0.57	0.10	0.24	8
Nitrite Nitrogen (mg/L)	0.02	0.02	0.04	0.01	0.01	3
Nitrite Plus Nitrate, Total (mg/L as N)	0.23	0.17	0.54	0.04	0.19	10
Nitrogen, Kjeldahl, Total, (mg/L As N)	0.28	0.26	1.00	0.10	0.20	13
Nitrogen, Total (mg/L As N)	0.36	0.23	0.75	0.13	0.28	10
Phosphorus (Total Ortho P, mg/L)	0.02	0.01	0.04	0.02	0.02	5
Phosphorus, Total (mg/L As P)	0.03	0.05	0.19	0.01	0.01	16
Potassium, Dissolved (mg/L)	2.07	0.33	2.61	1.60	2.14	10
Sodium, Dissolved (mg/L)	61.93	26.73	114.00	27.20	51.50	10
Sulfate, dissolved (mg/L)	165	52	233	88	176	10
Sulfate, Total (mg/L)	167	50	233	89	177	10
Temp_Celsuis	13.86	5.20	22.50	5.13	15.05	23
Total Dissolved Solids (mg/L)	413	119	552	216	440	10
Total Hardness (CaCO3 mg/L)	193	59	287	124	173	12
Total Inorganic Solids (mg/L)	374	122	616	190	345	22
Total Inorganic Suspended Solids (mg/L)	26.20	45.36	107.00	3.00	5.00	5
Total Organic Solids (mg/L)	56	17	102	35	55	22
Total Solids (mg/L)	431	136	718	228	397	22
Total Suspended Organic Solids (mg/L)	11.50	9.19	18.00	5.00	11.50	2
Total Suspended Solids (TSS) (mg/L)	13.92	33.63	125.00	3.00	3.00	13
Turbidity Lab (ntu)	13	34	119	1.00	2.95	12

[1]SD: standard deviation, [2]N: number of sample measurements.

6.5.1.2 VADEQ Water Quality Monitoring– Slate Creek

VADEQ has monitored water quality recently at one site on Slate Creek (Table 6.26). The location of this station is shown in Figure 6.7. The data for this station is summarized in Table 6.27.

Table 6.26 VADEQ monitoring station on Slate Creek.

Station	Type	Data Record	Descriptive location
6ASAT000.26	Ambient	7/2005 – 11/2007	Walk Bridge #9000 across from Law School

Table 6.27 In-stream water quality data at 6ASAT000.26 on Slate Creek (7/2005 – 11/2007).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Acid Neutralizing Capacity	88.64	40.63	139.00	28.50	89.75	10
Acidity, Total (mg/l)	3.65	1.62	6.44	1.58	3.48	6
Alkalinity (mg/L)	86.83	40.32	138.00	28.50	86.75	10
Ammonia + Ammonium (mg/L as N)	0.04	0.00	0.04	0.04	NA	2
Bicarbonate, Dissolved (mg/L)	88.64	40.63	139.00	28.50	89.75	10
Calcium, dissolved (mg/l)	43.38	17.67	65.20	15.70	49.10	10
Carbon, Total Organic (mg/l)	4.00	NA	4.00	4.00	NA	1
Chloride, dissolved (mg/L)	17.06	11.21	41.50	6.42	12.60	9
Chloride,Total (mg/L)	15.67	11.42	41.50	3.72	12.00	10
COD (mg/L)	7.33	1.53	9.00	6.00	7.00	3
Conductivity (µmhos/cm)	476	240	853	202	384	20
Dissolved Inorganic Solids (mg/L)	330	148	500	113	358	10
Dissolved Organic Solids (mg/L)	44.00	19.75	74.00	19.00	51.00	10
DO (mg/L)	10.27	1.13	12.10	8.97	10.08	18
Field pH (std units)	8.21	0.21	8.60	7.80	8.20	20
Iron (mg/kg)	16,000	NA	16,000	16,000	NA	1
Nitrate Nitrogen, Dissolved (mg/L as N)	0.34	0.23	0.62	0.06	0.30	7
Nitrite Plus Nitrate, Total (mg/L as N)	0.32	0.24	0.79	0.04	0.31	16
Nitrogen, Kjeldahl, Total, (mg/L As N)	0.28	0.18	0.70	0.10	0.20	8
Nitrogen, Total (mg/L As N)	0.40	0.26	0.87	0.11	0.36	19
Phosphorus, Total (mg/L As P)	0.02	0.01	0.07	0.01	0.01	18
Potassium, Dissolved (mg/L)	2.32	0.79	3.36	0.90	2.56	10
Sodium, Dissolved (mg/L)	39.46	32.13	89.80	7.12	29.25	10
Sulfate, dissolved (mg/L)	170	76	253	57	188	10
Sulfate, Total (mg/L)	171	76	253	57	190	10
Temp_Celsuis	15.21	6.40	25.90	5.30	15.40	20
Total Dissolved Solids (mg/L)	312	172	574	129	212	17
Total Inorganic Solids (mg/L)	331	147	503	113	340	10
Total Inorganic Suspended Solids (mg/L)	23.50	26.16	42.00	5.00	NA	2
Total Organic Solids (mg/L)	63.60	24.93	108.00	32.00	68.00	10
Total Solids (mg/L)	394	171	611	145	409	10
Total Suspended Organic Solids (mg/L)	7.00	NA	7.00	7.00	NA	1
Total Suspended Solids (TSS) (mg/L)	9.44	14.96	49.00	3.00	3.00	9
Turbidity Lab (ntu)	4.05	8.44	38.50	0.58	1.90	19

[1]SD: standard deviation, [2]N: number of sample measurements.

6.5.1.3 Mine Permit Application/Compliance Monitoring – Levisa Fork

There is ambient water quality monitoring data associated with two coal-mining sites on Levisa Fork with monitoring data. DMME requires in-stream monitoring from coal mining related permittees throughout the watershed. Sample timing varied based on the permit that the sample was intended to support. DMME requires their permittees to

monitor pH, acidity, total iron, total suspended solids and temperature. Stations on the mainstem of Levisa Fork where monitoring data was supplied by the DMME are shown in Table 6.28 and Figure 6.12. The data from these stations were used in the stressor identification in Chapter 7.

Table 6.28 Monitoring stations on Levisa Fork from data supplied by DMME.

MPID	River Mile	Data Record	
		Begin	End
5684669	143.12	2/2000	8/2001
5784675	157.44	1/1996	4/1997

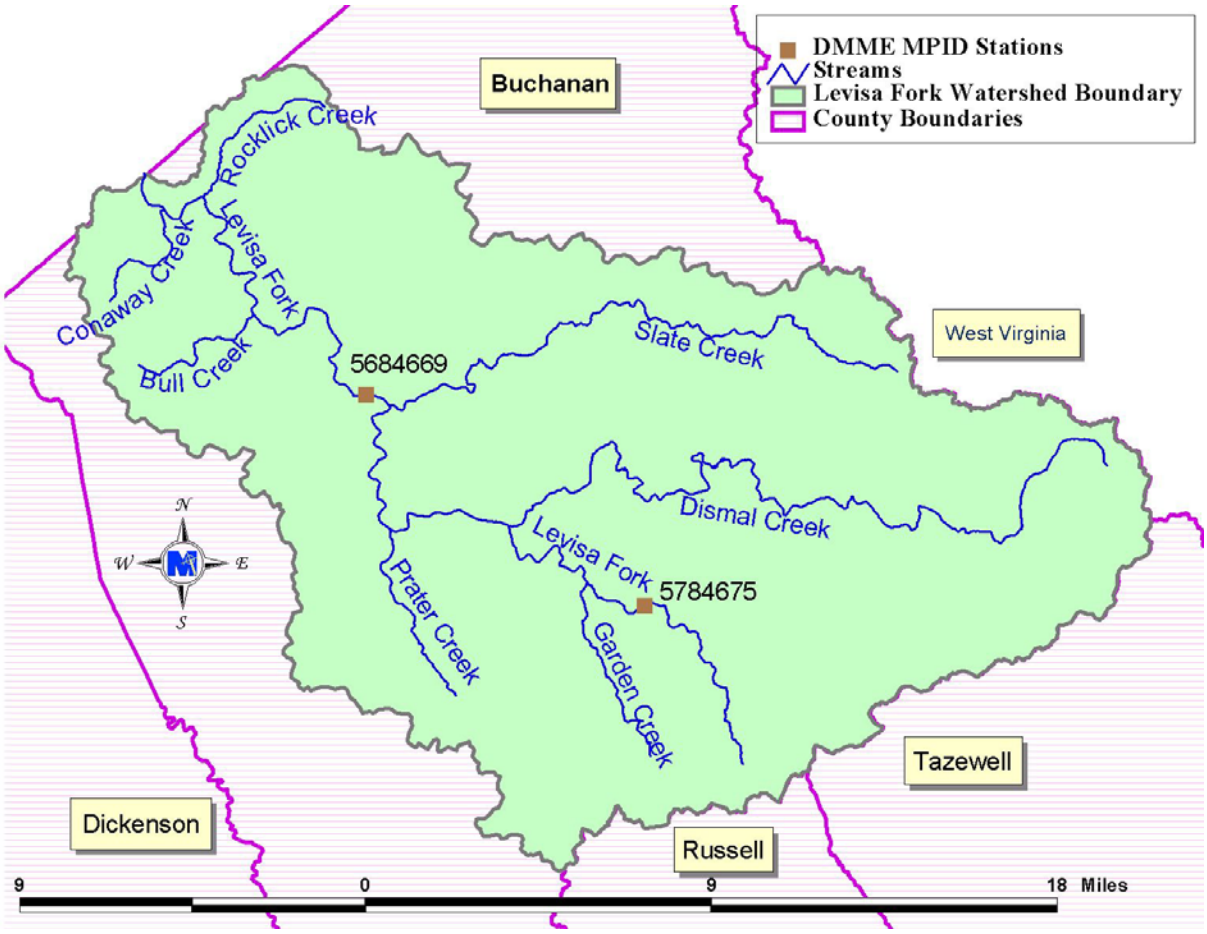

Figure 6.12 DMME ambient water quality monitoring stations on Levisa Fork.

Tables 6.29 and 6.30 show summaries of the water quality data collected at the two in-stream MPIDs.

Table 6.29 In-stream water quality data at MPID 5684669 (2/2000—8/2001).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Iron (mg/L)	0.17	0.08	0.30	0.10	0.20	7
Field pH (std units)	7.18	0.48	8.20	6.70	7.00	9
Temp (Celsius)	5.83	2.86	9.00	2.00	6.00	6
TSS (mg/L)	9.11	7.01	22.00	1.00	9.00	9

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 6.30 In-stream water quality data at MPID 5784675 (1/1996-4/1997).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Iron (mg/L)	0.23	0.24	1.20	0.10	0.15	24
Manganese (mg/L)	0.17	0.17	0.60	0.10	0.10	24
Field pH (std units)	7.70	0.17	8.00	7.40	7.70	25
Temp (Celsius)	12.00	0.71	13.00	11.00	12.00	5

[1]SD: standard deviation, [2]N: number of sample measurements.

6.5.1.4 Fish Tissue and Sediment Sampling Results – Levisa Fork

VADEQ performed special study fish tissue sampling at six sites and in-stream sediment sampling at 19 sites on Levisa Fork. These stations are described in Table 6.31 and shown in Figure 6.1. The fish tissue was collected from different species and is shown in Table 6.32. Sediment samples were tested for tPCBs, various pesticides and organic chemicals, and metals.

Table 6.31 VADEQ fish tissue and in-stream sediment water quality monitoring stations on Levisa Fork.

Station	Type	Data Records	Descriptive location
6ALEV130.00	Fish Tissue, Sediment tPCBs, Sediment Pesticides, Sediment Organics, Sediment PAHs, Sediment Metals	7/97, 8/00, 8/02, 7/07 7/97, 8/00, 8/02 7/97 8/02 7/97, 8/02 7/97, 8/02	Levisa Fork at KY-VA line on 460
6ALEV130.25	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork last bridge near KY-VA line
6ALEV130.52	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork upstream of Buckeye Branch
6ALEV130.79	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork between Buckeye Branch and Conaway Creek
6ALEV131.14	Sediment tPCBs, Sediment Pesticides, Sediment Metals	10/00	Levisa Fork just downstream of Conaway Creek
6ALEV131.27	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork just upstream of Conaway Creek
6ALEV131.52	Sediment tPCBs, Sediment Metals	7/97, 6/93, 6/94 (tPCB only), 7/95, 7/96, 5/97, 5/99	Wellmore Coal Co. dock #14 Bridge off 460
6ALEV131.88	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork downstream of Unamed Trib
6ALEV132.16	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork upstream of Unamed Trib
6ALEV132.31	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork between Unamed Trib and Rocklick Creek
6ALEV132.62	Sediment tPCBs, Sediment Pesticides	10/00	Levisa Fork just downstream of Rocklick Creek
6ALEV132.91	Sediment tPCBs	10/00	Levisa Fork downstream of Harper Branch
6ALEV134.82	Fish Tissue, Sediment tPCBs, Sediment Pesticides	8/00	Levisa Fork downstream of Weller
6ALEV141.28	Fish Tissue, Sediment tPCBs	10/00	Levisa Fork upstream of Twentymile Creek
6ALEV143.86	Sediment tPCBs, Sediment Metals	7/92, 6/93, 6/94 (tPCB only), 8/95, 7/96, 9/97, 5/99	Steel Bridge on Railroad Ave off Rt 83
6ALEV145.86	Fish Tissue, Sediment tPCBs	10/00	Levisa Fork downstream of Tookland
6ALEV151.26	Fish Tissue, Sediment tPCBs	8/00, 7/07 8/00	Levisa Fork downstream of Dismal Creek
6ALEV152.46	Sediment Metals	9/07	Near Janey, VA 0.5 mi. Upstream of Dismal Creek
6ALEV155.45	Fish Tissue, Sediment tPCBs, Sediment Pesticides	8/00	Levisa Fork near Oakwood, VA

The fish tissue, sediment, and water column tPCB data is discussed at length in Chapter 12 tPCB Water Quality Assessment. Some data is shown here in order to draw conclusions about benthic health regarding toxics in Chapter 7 and Chapter 8. All metals, pesticides, and other organic compounds (except tPCBs) in fish tissue were below VDH, VADEQ, and EPA screening and action levels at the six fish tissue monitoring stations and are therefore not shown. Fish tissue data sampling results did exceed VDH and VADEQ levels of concern for tPCBs and are shown in Table 6.32.

Table 6.32 Fish tissue sampling results for tPCB from six VADEQ monitoring stations on Levisa Fork.

Station	Date	Fish species name	VDH Action Level[1]	Total tPCB wet weight basis, ppb[2]
6ALEV130.00	07/22/97	Gizzard Shad	50	**1,182**
	07/22/97	Golden Redhorse Sucker	50	**1,448**
	07/22/97	Northern Hogsucker	50	**102**
	07/22/97	Rock Bass	50	**735**
	08/08/00	Channel Catfish (A)	50	**414**
	08/08/00	Channel Catfish (B)	50	**1,332**
	08/08/00	Northern Hogsucker (A)	50	**321**
	08/08/00	Northern Hogsucker (B)	50	20
	08/08/00	Rock Bass	50	**328**
	10/03/00	Gizzard Shad	50	**7,584**
	08/6/02	Rock Bass	50	**2,148**
	08/6/02	Rock Bass	50	**531**
	08/6/02	Channel Catfish	50	**1,244**
	08/6/02	Channel Catfish	50	**2,158**
	08/6/02	Northern Hogsucker	50	**5,403**
	07/17/07	Redhorse Sucker	50	**3,009**
	07/17/07	Channel Catfish	50	**1,868**
	07/17/07	Channel Catfish	50	**1,028**
	07/17/07	Northern Hogsucker	50	**908**
	07/17/07	Rock Bass	50	**325**
	07/17/07	Smallmouth Bass	50	**274**
	07/17/07	Smallmouth Bass	50	**214**
	07/17/07	Stoneroller	50	**155**
6ALEV134.82	08/08/00	Channel Catfish	50	**61**
	08/08/00	Gizzard Shad	50	**609**
	08/08/00	Redhorse Sucker	50	**151**
	08/08/00	Rock Bass (A)	50	44
	08/08/00	Rock Bass (B)	50	5

[1]VDH lower level of concern, ppb; **bold** values exceed the VDH lower level of concern; [2]ppb = parts per billion (µg/kg), wet weight basis edible fillet

Table 6.32 Fish tissue sampling results for tPCB from six VADEQ monitoring stations on Levisa Fork (cont).

Station	Date	Fish species name	VDH Action Level[1]	Total tPCB wet weight basis (ppb)[2]
6ALEV141.28	10/03/00	Channel Catfish	50	**280**
	10/03/00	Northern Hogsucker	50	22
	10/03/00	Rock Bass	50	42
	10/03/00	Smallmouth Bass (A)	50	**69**
	10/03/00	Smallmouth Bass (B)	50	37
6ALEV145.86	10/03/00	Channel Catfish	50	**54**
	10/03/00	Gizzard Shad	50	**413**
	10/03/00	Northern Hogsucker	50	6
	10/03/00	Redhorse Sucker	50	**67**
	10/03/00	Rock Bass	50	3
	10/03/00	Smallmouth Bass	50	**59**
6ALEV151.26	08/09/00	Gizzard Shad (A)	50	**119**
	08/09/00	Gizzard Shad (B)	50	**499**
	08/09/00	Rock Bass	50	8
	07/17/07	Channel Catfish	50	**110**
	07/17/07	Redhorse Sucker	50	**50**
	07/17/07	Northern Hogsucker	50	4
	07/17/07	Rock Bass	50	3
6ALEV155.45	08/09/00	Northern Hogsucker	50	27
	08/09/00	Rainbow Trout	50	29
	08/09/00	Rock Bass (A)	50	22
	08/09/00	Rock Bass (B)	50	29
	08/09/00	Smallmouth Bass (A)	50	12
	08/09/00	Stoneroller	50	9

[1]VDH lower level of concern, ppb; **bold** values exceed the VDH lower level of concern; [2]ppb = parts per billion (µg/kg), wet weight basis edible fillet

Of the 18 stations sampled, only two sediment samples exceeded the PEC values for tPCBs in sediment (676 ppb). PEC is the Probable Effects Concentration (MacDonald et al., 2000) which is a consensus based threshold value where a noted relationship between a specific contaminant concentration and an adverse effect to the benthic community has been observed. These values were obtained in 1990 and 1992. Subsequent samples collected at these two locations on Levisa Fork tested below the PEC for tPCBs in sediment (Table 6.33).

Table 6.33 In-stream sediment sampling results for tPCB from 18 VADEQ monitoring stations on Levisa Fork.

Station	Station Location	Date	Sediment tPCB (ppb)
6ALEV130.00	Levisa Fork near KY-VA line	7/17/1990	**1,000**
6ALEV130.00	Levisa Fork near KY-VA line	8/20/1990	500
6ALEV130.00	Levisa Fork near KY-VA line	7/22/1997	0
6ALEV130.00	Levisa Fork near KY-VA line	8/8/2000	1.32
6ALEV130.25	Levisa Fork last bridge near KY-VA line	10/3/2000	17.93
6ALEV130.52	Levisa Fork upstream of Buckeye Branch	10/3/2000	9.24
6ALEV130.79	Levisa Fork between Buckeye Branch and Conaway Creek	10/3/2000	6.26
6ALEV131.14	Levisa Fork just downstream of Conaway Creek	10/3/2000	49.98
6ALEV131.27	Levisa Fork just upstream of Conaway Creek	10/3/2000	306.34
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	7/16/1992	**2,400**
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	6/9/1993	440
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	6/9/1994	10
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	7/18/1995	140
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	7/9/1996	30
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	5/13/1997	50
6ALEV131.52	Wellmore Coal Co. Dock #14 Bridge off 460	5/10/1999	20
6ALEV131.88	Levisa Fork downstream of Unnamed Trib	10/3/2000	6.97
6ALEV132.16	Levisa Fork upstream of Unnamed Trib	10/3/2000	0.77
6ALEV132.31	Levisa Fork between Unnamed Trib and Rocklick Creek	10/3/2000	5.43
6ALEV132.62	Levisa Fork just downstream of Rocklick Creek	10/3/2000	4.89
6ALEV132.91	Levisa Fork downstream of Harper Branch	10/3/2000	2.31
6ALEV134.82	Levisa Fork downstream of Weller	8/8/2000	3.35
6ALEV141.28	Levisa Fork upstream of Twentymile Creek	10/3/2000	1.05
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	7/16/1992	500
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	6/9/1993	500
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	6/9/1994	30
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	8/14/1995	210
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	7/9/1996	40
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	9/2/1997	60
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	5/10/1999	30
6ALEV145.86	Levisa Fork downstream of Tookland	10/3/2000	1.29
6ALEV151.26	Levisa Fork downstream of Dismal Creek	8/9/2000	4.54
6ALEV155.45	Levisa Fork near Oakwood	8/9/2000	4.53

PEC value for tPCB in sediment = 676 ug/kg

In-stream sediment samples were tested for pesticides and organic chemicals at 12 stations on Levisa Fork. All sediment results were below PEC values (Table 6.34).

Table 6.34 In-stream sediment sampling results for pesticides and other organic chemicals from 12 VADEQ monitoring stations on Levisa Fork.

Station	Date	Pesticides and other Organic Chemicals (ppb)									
		Total Chlordane	Sum DDE	Sum DDD	Sum DDT	Total DDT	Total BDE	HCB	PCA	OCDD	Cl-NAP
	PEC Values:	*17.6*	*31.3*	*28*	*62.9*	*572*	*NA*	*NA*	*NA*	*NA*	*NA*
6ALEV130.00	7/22/1997	ND				ND					
6ALEV130.00	8/6/2002	0.83		4.52	10.24	14.76	4.49	0.06	0.14	0.13	0.39
6ALEV130.25	10/3/2000	0.72	0.46		1.34	1.8	1.56	0.28	0.27		
6ALEV130.52	10/3/2000				0.46	0.46					
6ALEV130.79	10/3/2000	0.48			0.26	0.26	0.58				
6ALEV131.14	10/3/2000					15.29					
6ALEV131.27	10/3/2000	1.32	0.58		0.58		82.39				
6ALEV131.88	10/3/2000	0.59	0.35		0.35						
6ALEV132.16	10/3/2000		1.24		1.24						
6ALEV132.31	10/3/2000				0.30						
6ALEV132.62	10/3/2000	2.44									
6ALEV134.82	8/8/2000	1.96			1	1					
6ALEV155.45	8/9/2000	0.37			1.48	1.48					

PEC = Probable Effect Concentration (McDonald, 2000); NA= None specified; ND = None detected; Sum DDE = sum of dichlorodiphenyl dichloroethylene isomers; sum DDD denotes sum of dichlorodiphenyl dichloroethane isomers, Sum DDT = sum of dichlorodiphenyl trichloroethane isomers; Total DDT = sum of isomers of DDE, DDD, and DDT; Total BDE = sum of polybrominated diphenyl ether congeners; HCB = Hexachlorobenzene; PCA = Pentachloroanisole; OCDD = Octachlorodibenzodioxin; Cl-NAP = Chloronaphthalene

VADEQ collected sediment samples at 6ALEV130.00 and analyzed the samples for PAHs in 1997 and 2002. Both samples resulted in low values for all PAHs tested and none of the values were above PEC values (Table 6.35). PAHs originate from petroleum products that travel into a waterbody and breakdown over time.

Table 6.35 Special study sediment PAH results from 6ALEV130.00 on Levisa Fork (July 1997 and August 2002).

Parameter	PEC[1] or VADEQ 99th Percentile (ug/Kg)	6ALEV130.00 07/22/97 (ug/Kg)	6ALEV130.00 08/06/02 (ug/Kg)
Total PAH[2]	22,800	2,283	1,257
High MW[3] PAH	NA	732	855
Low MW PAH	NA	169	402
NAP[4]	561	7.86	19.30
NAP 1-Me[5]	NA		52.45
biphenyl	NA	11.70	16.07
NAP d-Me[6]	NA	21.29	48.38
Naphthylene ace	NA	3.57	0.83
NAP t-Me[7]	NA		8.52
fluorene	536	12.61	10.43
PHH[8]	1,170	128.19	116.64
ATH[9]	845	17.15	6.53
PHH 1-Me	NA	56.19	47.84
FTH[10]	2,230	199	88
Pyrene	1,520	133	79
ATH benz(a)	1,050	120	54
chrysene	1,290	177	104
FTH benzo(b)	NA	100	120
FTH benzo(k)	NA	49.81	56.76
Pyrene benzo(e)	NA	83.41	91.75
Pyrene benzo(a)	1,450	82.28	94.30
perylene	NA	24.18	30.24
pyrene IND[11]	NA	54.37	51.63
ATH db(a,h)[12]	318	20.34	24.62
perylene benzo(ghi)	NA	47.77	60.37

[1]PEC = Probable Effect Concentration (McDonald, 2000); VADEQ 99th percentile = VADEQ screening value, [2]PAH = Polyaromatic hydrocarbon, also polynuclear aromatic hydrocarbons (PNAs); [3]MW = Molecular Weight; [4]NAP = Naphthalene; [5]1-Me Methyl; [6]d-Me = 2,6-Dimethyl; [7]t-Me = 2,3,5-Trimethyl; [8]PHH = Phenanthrene; [9]ATH = Anthracene; [10]FTH = Fluoranthene; [11]IND = indeno(1,2,3-cd); [12]db(a,h) dibenzo(a,h); NA = None specified

VADEQ collected sediment metals samples on six occasions during its routine monitoring from July 1992 through May 1999 at 6ALEV131.52 and 6ALEV143.86 (Table 6.36). Copper, lead, nickel and zinc exceeded the PEC screening values in 1992

and 1993 at these two stations. Subsequent sampling events resulted in values well below the PEC values and were low at the four other stations sampled in 1997, 2000, 2002, and/or 2007 (6ALEV130.00, 6ALEV131.14, 6ALEV138.19, and 6ALEV152.46).

Table 6.36 In-stream sediment sampling results for metals from seven VADEQ monitoring stations on Levisa Fork.

		Sediment Metals (mg/kg)												
Station	**Date**	**Aluminum**	**Antimony**	**Arsenic**	**Cadmium**	**Chromium, Total**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Zinc**
PEC Values or VADEQ 99th Percentile:		***NA***	***NA***	***33***	***4.98***	***111***	***149***	***128***	***1.06***	***48.6***	***NA***	***2.6***	***NA***	***459***
6ALEV130.00	3/6/1990		4.7		0.5	8	9.8	9.4		15	4.7			
6ALEV130.00	7/17/1990			4.7		17	22	15		27				83
6ALEV130.00	4/22/1991			9		5		9		16				52
6ALEV130.00	7/22/1997	0.56	<0.5	4.1	0.068	5.2	6	15	0.11	0.85	<0.5	<0.02	<0.3	52
6ALEV130.00	8/6/2002	0.47	<0.5	7.2	0.2	10	18	18	0.03	19	<0.5	<0.02	<0.3	51
6ALEV131.14	10/3/2000	0.76	<0.5	14	0.43	26	56	16	0.044	46	<0.5	0.45	<0.3	141
6ALEV131.52	7/16/1992			13		12	38	20		**143**				**821**
6ALEV131.52	6/9/1993			9		20	**170**	110		87				
6ALEV131.52	7/18/1995	8,840	10	8		12	33	13		33	1.3			112
6ALEV131.52	7/9/1996	9,550	6	9		15	30	23		37				128
6ALEV131.52	5/13/1997	9,618				9	12	9		27				126
6ALEV131.52	5/10/1999	6,990		6.2		11.6	27.6	51		24.3				85
6ALEV138.19	3/27/2007	4,400				9.11	8.52	8.5		14.2				49.6
6ALEV143.80	9/25/2007	5,180		15.2	1.32	17.4	21.4	21.3		25.4	1.22			147
6ALEV143.86	7/1/1992			6		8	17	10		17				86
6ALEV143.86	6/1/1993			12		49	**150**	**230**		22				**550**
6ALEV143.86	8/1/1995	16,300		12		22	48	31		51				228
6ALEV143.86	7/1/1996	7,410		8		11	28	19		26				101

Bold values exceed a screening value

Table 6.36 In-stream sediment sampling results for metals from seven VADEQ monitoring stations on Levisa Fork (cont.).

		Sediment Metals (mg/kg)												
Station	**Date**	**Aluminum**	**Antimony**	**Arsenic**	**Cadmium**	**Chromium, Total**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Selenium**	**Silver**	**Thallium**	**Zinc**
PEC Values or VADEQ 99th Percentile:		***NA***	***NA***	***33***	***4.98***	***111***	***149***	***128***	***1.06***	***48.6***	***NA***	***2.6***	***NA***	***459***
6ALEV143.86	9/1/1997	4,920		6		9	13	14		17				79
6ALEV143.86	5/1/1999	11,500		6.9		15.4	34.5	22.2		33.7	1.0			137
6ALEV152.46	9/1/2007	5290				8.69	11.4	10.3		14.1				70

Bold values exceed a screening value

6.5.1.5 Dissolved Metals Sampling Results – Levisa Fork

Dissolved metals were collected at four VADEQ monitoring stations on the Levisa Fork and all of the values were below the chronic water quality standards. The results are shown in Table 6.37 through 6.40.

Table 6.37 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV131.52 on Levisa Fork.

Metal	8/16/2000 (ug/L)	Chronic WQS (ug/L)[1]	6/16/2002 (ug/L)	Chronic WQS (ug/L)[1]	9/25/2007 (ug/L)	Chronic WQS (ug/L)[1]
Cadmium	0.1	2.32	0.1	2.40	0.1	2.14
Chromium (III)	0.1	356	0.35	452	0.8	401
Copper	0.8	20.81	1.43	26.69	1.5	23.59
Lead	0.1	31.35	0.14	45.44	0.1	37.80
Nickel	2.1	35.57	1.91	45.52	2.8	40.28
Silver	0.1	NA	0.1	NA	0.1	NA
Zinc	1.5	186	1.01	238	1.4	210

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal

Table 6.38 Dissolved metal concentrations at VADEQ special study monitoring station 6ALEV138.19 on Levisa Fork (March 28, 2007).

Metal	(ug/L)	Chronic WQS (ug/L)[1]
Cadmium	0.10	1.30
Chromium (III)	0.80	239.55
Copper	0.60	13.77
Lead	0.10	16.95
Nickel	1.30	23.64
Silver	0.10	NA
Zinc	2.30	123.29

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal

Table 6.39 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV143.80 on Levisa Fork (September 25, 2007).

Metal	(ug/L)	Chronic WQS (ug/L)[1]
Cadmium	0.10	1.70
Chromium (III)	0.80	315.02
Copper	1.10	18.33
Lead	0.10	25.95
Nickel	2.40	31.37
Silver	0.10	NA
Zinc	1.00	163.67

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal

Table 6.40 Dissolved metal concentrations at VADEQ ambient monitoring station 6ALEV152.46 on Levisa Fork.

Metal	8/16/2000 (ug/L)	Chronic WQS (ug/L)[1]	9/14/2007 (ug/L)	Chronic WQS (ug/L)[1]
Cadmium	0.1	1.31	0.1	1.75
Chromium (III)	0.1	240	2.4	326
Copper	0.4	13.82	0.8	18.98
Lead	0.1	17.04	0.1	27.34
Nickel	0.5	23.72	3	32.48
Silver	0.1	NA	0.1	NA
Zinc	1	124	1.4	169

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal

6.5.1.6 Fish Tissue and Sediment Sampling Results – Slate Creek

VADEQ performed special fish tissue sampling at six sites and sediment sampling at 6ASAT004.56 on Slate Creek. All fish tissue concentrations from three species of fish were below VDH levels of concern and VADEQ screening levels. All sediment values were below the consensus PEC values (Tables 6.41 through 6.44). Sediment metals were also collected at the ambient monitoring site 6ASAT000.26 in September 2007 (Table 6.44).

Table 6.41 Sediment metal sampling results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002).

Metal	PEC[1] or VADEQ 99th Percentile (mg/Kg)	07/22/97 (mg/Kg)	08/07/00 (mg/Kg)
Aluminum	NA	1.20	0.40
Silver	2.6	0.09	<0.02
Arsenic	33	11.00	4.45
Cadmium	4.98	0.14	0.10
Chromium, Total	111	13.00	6.97
Copper	149	0.57	13.89
Mercury	1.06	0.15	0.01
Nickel	48.6	0.78	11.37
Lead	128	15.00	12.04
Antimony	NA	<0.5	<0.5
Selenium	NA	<0.5	<0.5
Thallium	NA	<0.3	<0.3
Zinc	459	51	35

[1]PEC = Probable Effect Concentration (McDonald, 2000); VADEQ 99th percentile screening value; NA = None specified

Table 6.42 Sediment PAH results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002).

Parameter	PEC[1] (ug/Kg)	07/22/97 (ug/Kg)	08/07/02 (ug/Kg)
Total PAH[2]	22,800	1,144.49	577.01
High MW3 PAH	NA	226.18	469.62
Low MW PAH	NA	69.59	107.39
NAP[4]	561		2.15
NAP 2-Me[5]	NA		8.29
NAP 1-Me[5]	NA		7.50
biphenyl	NA		3.56
NAP d-Me[6]	NA	13.52	12.60
Naphthylene ace	NA	3.49	0.78
naphthene ace	NA		2.27
NAP t-Me[7]	NA	16.28	8.86
fluorene	536	6.80	2.59
PHH[8]	1170	53.53	39.43
ATH[9]	845	5.77	2.53
PHH 1-Me	NA	78.16	16.83
FTH[10]	2,230	58.83	53.04
Pyrene	1,520	45.15	45.06
ATH benz(a)	1,050	26.32	32.71
chrysene	1,290	61.68	42.02
FTH benzo(b)	NA	34.76	58.09
FTH benzo(k)	NA	20.01	37.25
Pyrene benzo(e)	NA	30.11	41.75
Pyrene benzo(a)	1,450	24.96	61.43
perylene	NA	12.31	20.49
Pyrene IND[11]	NA	23.60	31.67
ATH db(a,h)[12]	NA	9.24	13.87
perylene benzo(ghi)	NA	21.81	32.24

[1]PEC = Probable Effect Concentration (McDonald, 2000); [2]PAH = Polyaromatic hydrocarbon, also polynuclear aromatic hydrocarbons (PNAs); [3]MW = Molecular Weight; [4]NAP = Naphthalene; [5]Me = Methyl, [6]d-Me = 2,6-Dimethyl; [7]t-Me = 2,3,5-Trimethyl; [8]PHH = Phenanthrene; [9]ATH = Anthracene, [10]FTH = Fluoranthene; [11]IND = indeno(1,2,3-cd); [12]db(a,h) = dibenzo(a,h); NA = None specified

Table 6.43 Sediment tPCB and pesticide results at VADEQ fish tissue monitoring station 6ASAT004.56 on Slate Creek (July 1997 and August 2002).

Parameter	PEC[1] (ug/Kg)	07/22/97 (ug/Kg)	08/07/02 (ug/Kg)
Total tPCB[2]	676	0.69	2.51
Total Chlordane	17.6	0.18	0.36
Sum DDE[3]	31.3		0.20
Sum DDT[4]	62.9	0.10	0.35
Total DDT	572	0.10	0.55
Total BDE[5]	NA	0.58	1.95
OCDD[6]	NA		0.07

[1]PEC = Probable Effect Concentration (McDonald, 2000); [2]Total tPCB = sum of polychlorinated biphenyl congeners; [3]Sum DDE = sum of dichlorodiphenyl dichloroethylene isomers; [4]Sum DDT = sum of dichlorodiphenyl trichloroethane isomers; [5]Total BDE = sum of polybrominated diphenyl ether congeners; [6]OCDD = Octachlorodibenzodioxin, NA = None specified

Table 6.44 Sediment metals results from VADEQ ambient monitoring station 6ASAT000.26 on Slate Creek (9/4/2007).

Parameter	PEC[1] (mg/Kg)	(mg/Kg)
Aluminum	NA	5,520
Chromium, Total	111	6.78
Copper	149	9.24
Lead	128	9.89
Nickel	48.6	11.4
Zinc	459	87.3

[1]PEC = Probable Effect Concentration (McDonald, 2000); NA = None specified

6.5.1.7 Dissolved Metals Sampling Results – Slate Creek

Dissolved metals were collected at VADEQ monitoring station 6ASAT000.26 on Slate Creek and all of the values were below the chronic water quality standard. The results are shown in Table 6.45.

Table 6.45 Dissolved metal concentrations at VADEQ ambient monitoring station 6ASAT000.26 on Slate Creek (9/4/2007).

Metal	Concentration (ug/L)	Chronic WQS (ug/L)[1]
Cadmium	0.1	2.32
Chromium (III)	0.5	436.49
Copper	1.5	25.75
Lead	0.1	43.08
Nickel	2	43.93
Silver	0.1	NA
Zinc	2.6	229.36

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal

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7. BENTHIC TMDL ENDPOINT: STRESSOR IDENTIFICATION – LEVISA FORK

7.1 Stressor Identification – Levisa Fork

Levisa Fork begins in sourthern Buchanan County and flows northwest to the Virginia/Kentucky state line (river mile 129.19). There are three impaired benthic segments on the mainstem of Levisa Fork. The first begins at the Virginia/Kentucky state line and continues upstream to the Levisa Fork/Rocklick Creek confluence (2.66 stream miles). The second segment begins at the Levisa Fork/Bull Creek confluence and continues upstream to the Levisa Fork/Dismal Creek confluence (14.29 stream miles). The third segment begins at the Levisa Fork/Dismal Creek confluence and continues upstream to the Levisa Fork/Garden Creek confluence (3.95 stream miles).

For a water quality constituent without an established standard, criteria, or screening value, a 90th percentile screening value was used. The 90th percentile screening values were calculated from 49 monitoring stations in southwest Virginia on third and fourth order streams that were used as benthic reference stations or were otherwise non-impaired based on the most recent benthic sampling results. The 90th percentile screening values were used to develop a list of possible stressors to the benthic community in Levisa Fork. For a parameter to become a probable stressor, additional supporting information was required (*e.g.,* benthic habitat, metrics, and scientific references documenting potential adverse effects for aquatic life). Graphs are shown for parameters that exceeded the screening value in more than 10% of the samples collected within the impaired segment or if the parameter had extreme values. Graphs for parameters with more than one but less than nine data points are not shown in this section unless there are extreme values. The presence of nine values was selected as a cutoff in order to avoid using limited data from stations that were not sampled during different seasons of the year or different flow regimes in Levisa Fork. However, all data were reviewed to ensure consistency with typical value ranges for a parameter in streams in Virginia. There are four water quality monitoring stations with recent data collected in the vicinity of the impaired benthic monitoring stations. Ambient water quality monitoring station 6ALEV152.46 is co-located with the most upstream impaired benthic

monitoring station. Ambient monitoring station 6ALEV156.82 is located approximately four miles upstream. Both the data record and values for the various parameters that were examined are very similar. Therefore, in the interest of redundancy, only the data from ambient monitoring station 6ALEV152.46 is discussed in the Levisa Fork stressor analysis. The ambient data for both monitoring stations can be found in Tables 6.24 and 6.25.

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 they usually do not provide enough information to determine the cause(s) of the impairment when organisms are not classified beyond the family level. The process outlined in the Stressor Identification Guidance Document (EPA, 2000b) was used to separately identify the most probable stressor(s) for Levisa Fork. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data 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). Land use data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for Levisa Fork are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors. Non-stressors are listed in Table 7.1.
>
> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors. Possible stressors are listed in Table 7.2.
>
> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s). Probable stressors are listed in Table 7.4.

7.2 Non-Stressors

Table 7.1 Non-Stressors in Levisa Fork.

Parameter	Location in Document
Low dissolved oxygen	Section 7.2.1
Nutrients	Section 7.2.2
Toxics (ammonia, pesticides, tPCBs and polycyclic aromatic hydrocarbons (PAHs))	Section 7.2.3
Metals (Except sediment copper, lead, nickel and zinc)	Section 7.2.4
Temperature	Section 7.2.5
Field pH	Section 7.2.6

There is always a possibility that conditions in the watershed, available data, and the understanding of the natural processes may change beyond what was revealed in this stressor analysis. If additional monitoring shows that different most probable stressor(s) exist or water quality target(s) are protective of water quality standards (WQS), then the Commonwealth will make use of the option to refine the TMDLs for re-submittal to EPA for approval.

7.2.1 Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations were well above the water quality minimum standard at all three VADEQ monitoring stations (6ALEV131.52, 6ALEV143.86 and 6ALEV152.46; Figures 7.1, 7.2 and 7.3). Low dissolved oxygen is considered a non-stressor.

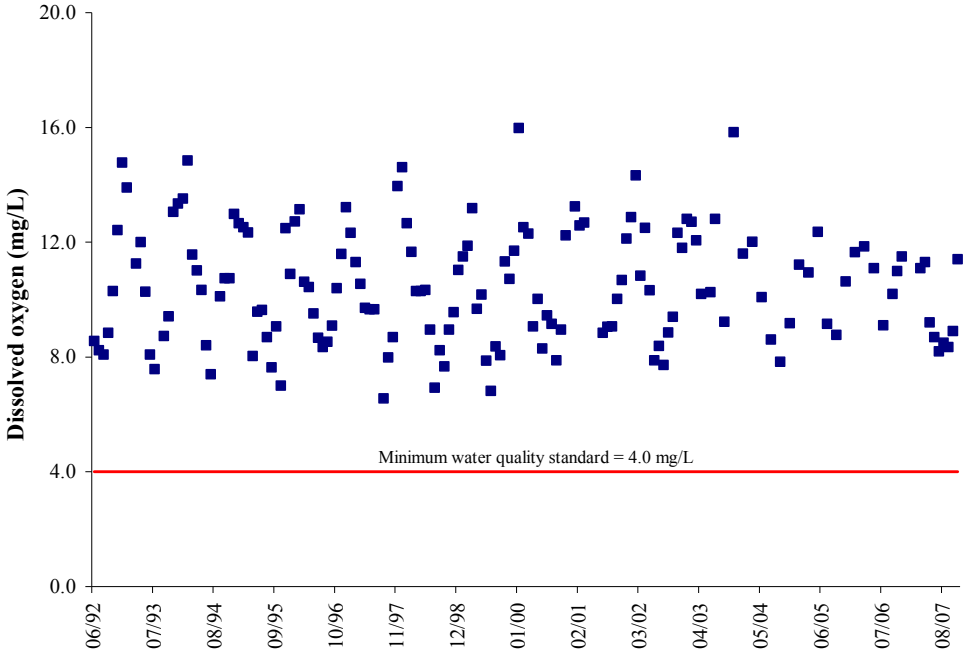

Figure 7.1 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV131.52.

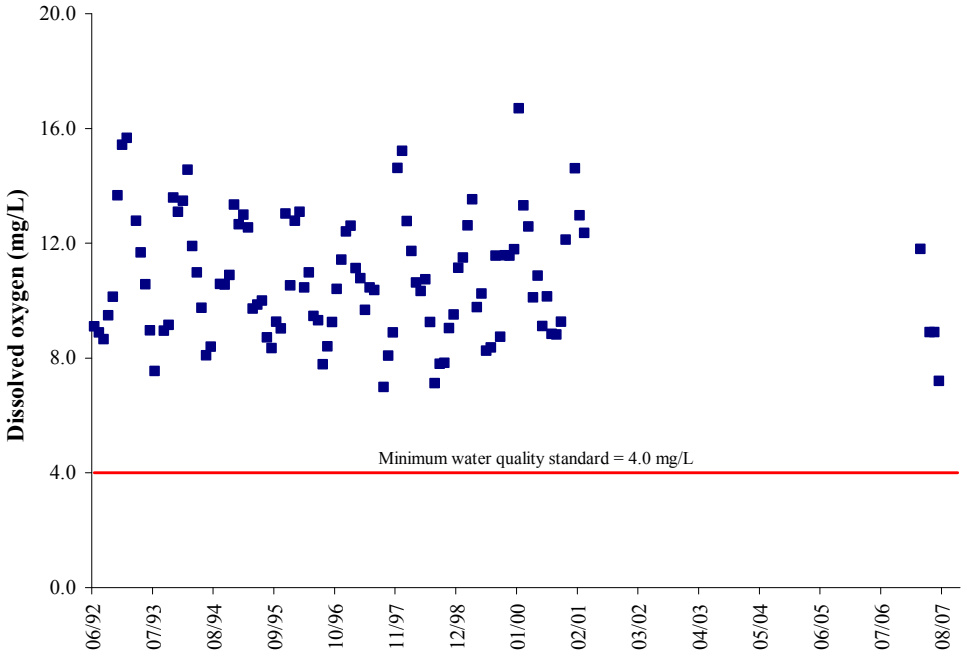

Figure 7.2 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV143.86.

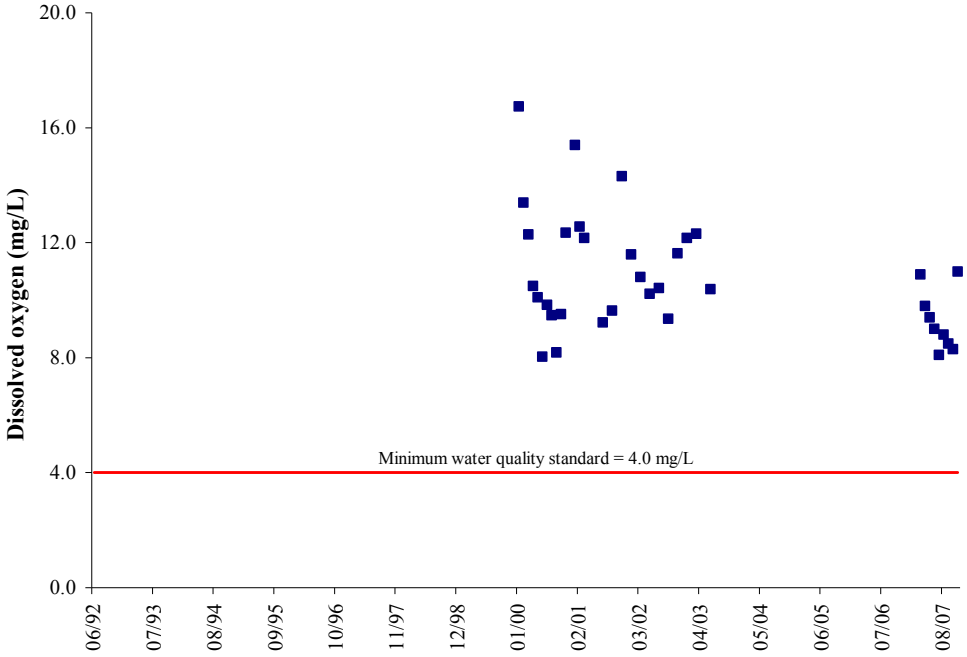

Figure 7.3 Dissolved oxygen concentrations at VADEQ monitoring station 6ALEV152.46.

7.2.2 Nutrients

Total phosphorus (TP) concentrations were generally very low at all three VADEQ ambient monitoring stations. Only three values out of 238 samples exceeded the VADEQ screening value of 0.2 mg/L (Figures 7.4, 7.5 and 7.6). Nitrate nitrogen concentrations were also low with 99% of the values at all three monitoring stations below 1.0 mg/L (Figures 7.7, 7.8 and 7.9). Nutrients are considered non-stressors.

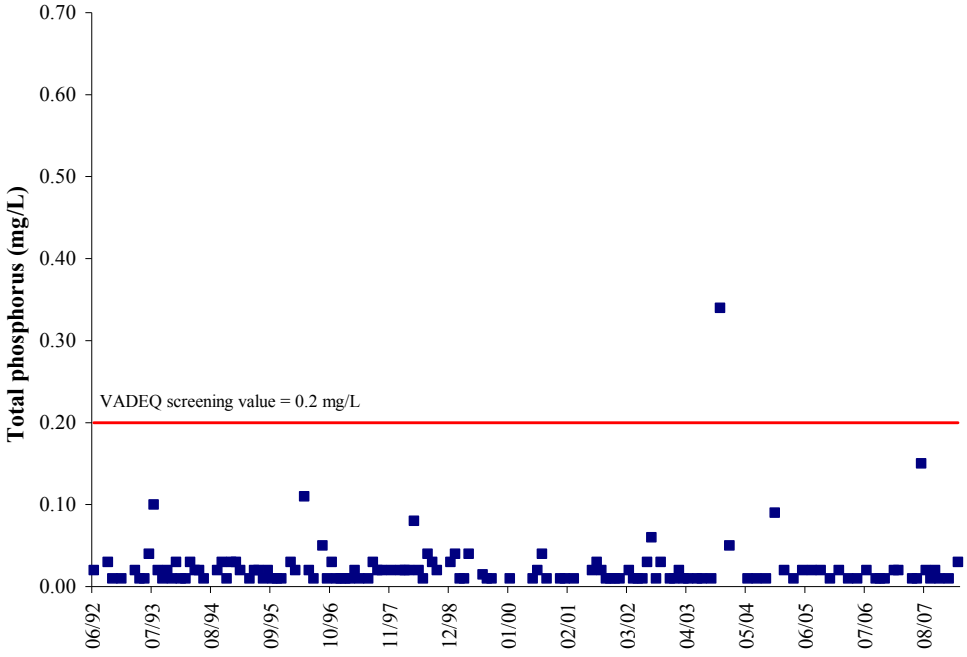

Figure 7.4 Total phosphorus concentrations at VADEQ station 6ALEV131.52.

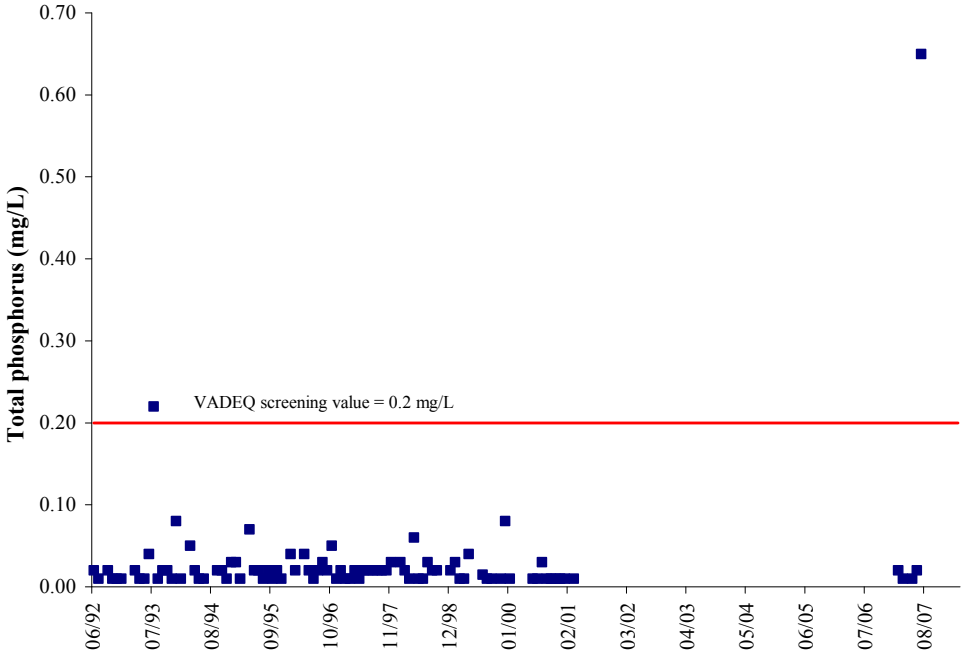

Figure 7.5 Total phosphorus concentrations at VADEQ station 6ALEV143.86.

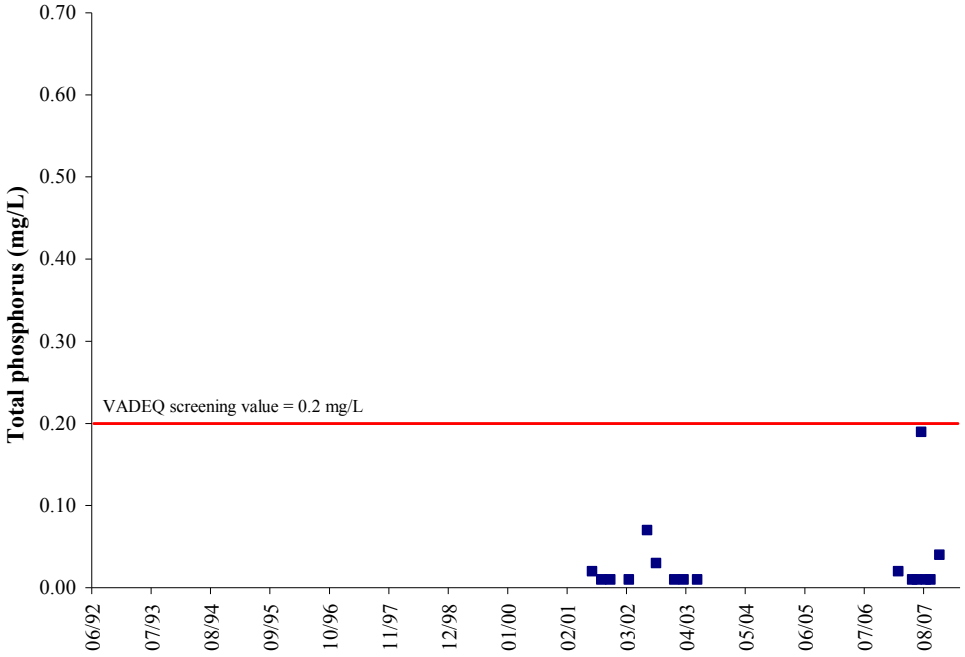

Figure 7.6 Total phosphorus concentrations at VADEQ station 6ALEV152.46.

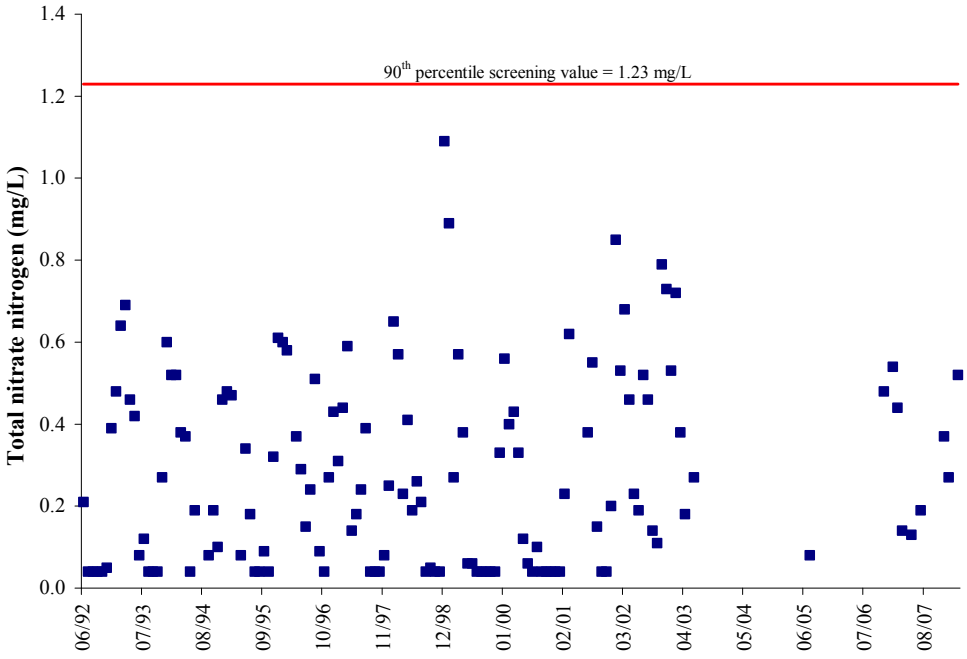

Figure 7.7 Nitrate-nitrogen concentrations at VADEQ station 6ALEV131.52.

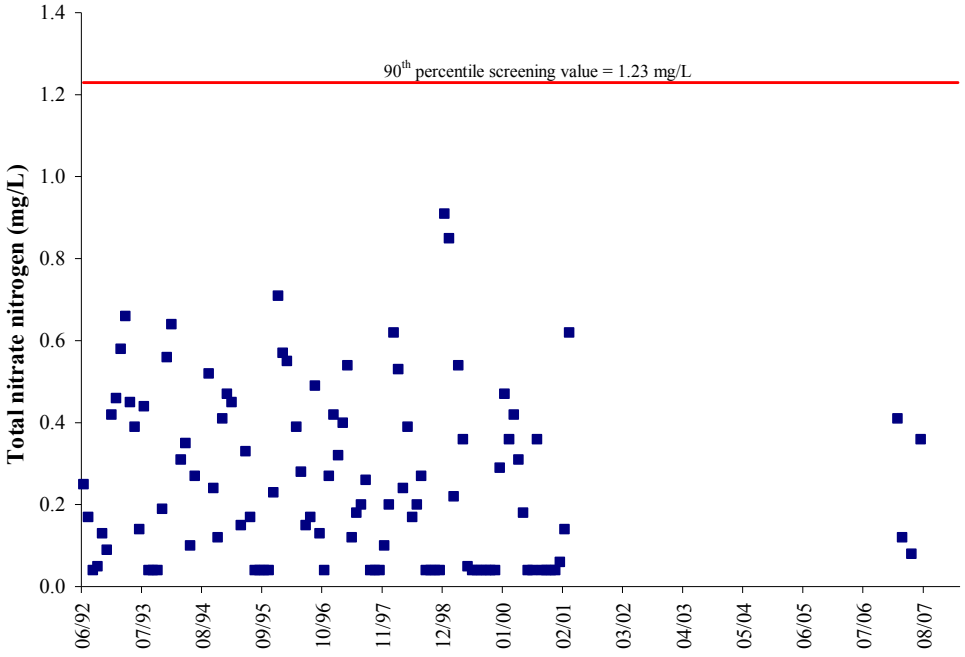

Figure 7.8 Nitrate-nitrogen concentrations at VADEQ station 6ALEV143.86.

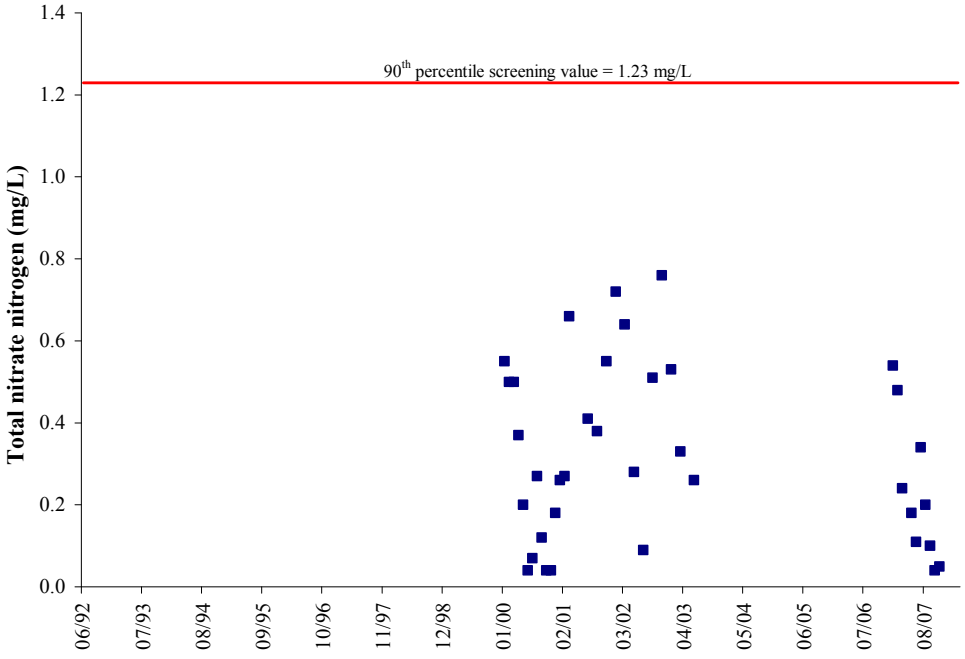

Figure 7.9 Nitrate-nitrogen concentrations at VADEQ station 6ALEV152.46.

7.2.3 Toxics (ammonia, tPCBs, Pesticides, and PAHs)

The majority of the ammonia (NH_3/NH_4) samples collected in Levisa Fork were below the minimum laboratory level of detection (0.04 mg/L). Only eight ammonia (NH_3/NH_4) samples collected at VADEQ station 6ALEV131.52, seven samples collected at 6ALEV143.86 and five samples collected at 6ALEV152.46 were above the minimum laboratory detection level; and they were all well below the chronic WQS (chronic and acute ammonia water quality standards vary, depending on the pH and temperature of the stream at the time of sample collection).

Sediment pesticides, PAHs, and tPCBs were all below established screening levels (Tables 6.34 through 6.36). Ammonia, Pesticides, tPCBs and PAHs are considered non-stressors in Levisa Fork.

7.2.4 Metals

This section discusses VADEQ water quality monitoring for metals dissolved in the water column, metals in the sediment, and metals in fish tissue. All sediment metal values were below the PEC values with the exception of copper, lead, nickel, and zinc in 1992 and 1993 (discussed in Section 7.3.1). All recent sediment metals concentrations have been below PEC values. Table 6.37 shows the sediment metals compared to the PEC values.

Water column dissolved metals were sampled at four VADEQ monitoring stations on Levisa Fork and all results were below the appropriate water quality standard (Tables 6.38 through 6.41). Not all of the metals listed have established VADEQ or USEPA water quality standards.

Based on the results of the dissolved metals, sediment metals, and fish tissue metals data, metals are considered non-stressors with the exceptions of sediment copper, lead, nickel and zinc (Section 7.3.1).

7.2.5 Temperature

The maximum temperature standard for Levisa Fork is 31.0°C. The maximum temperature recorded at the three VADEQ monitoring stations on Levisa Fork was

29.5°C (Figures 7.10, 7.11 and 7.12). Temperature is considered a non-stressor in Levisa Fork.

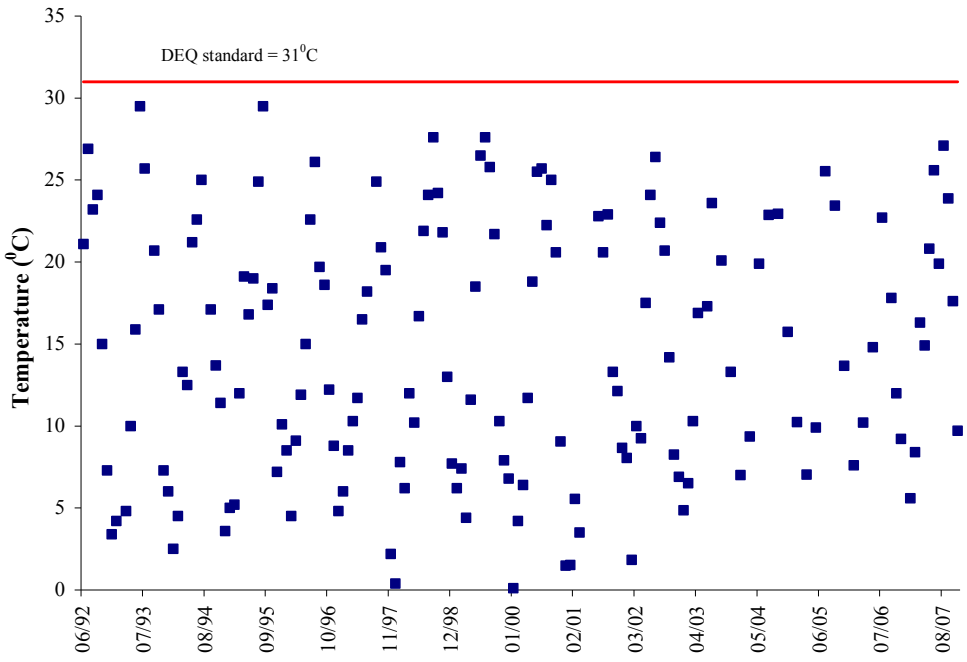

Figure 7.10 Temperature measurements at VADEQ station 6ALEV131.52.

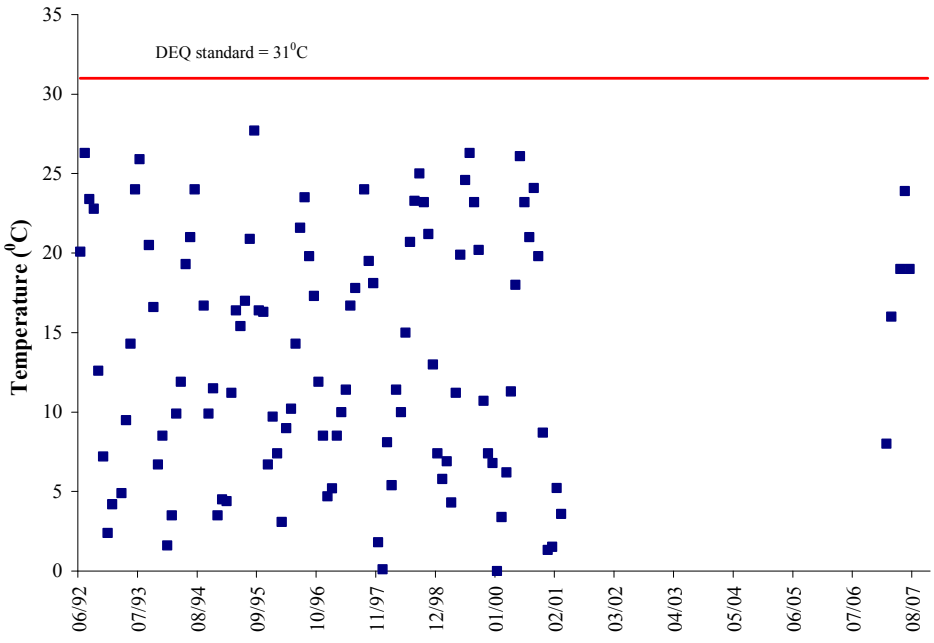

Figure 7.11 Temperature measurements at VADEQ station 6ALEV143.86.

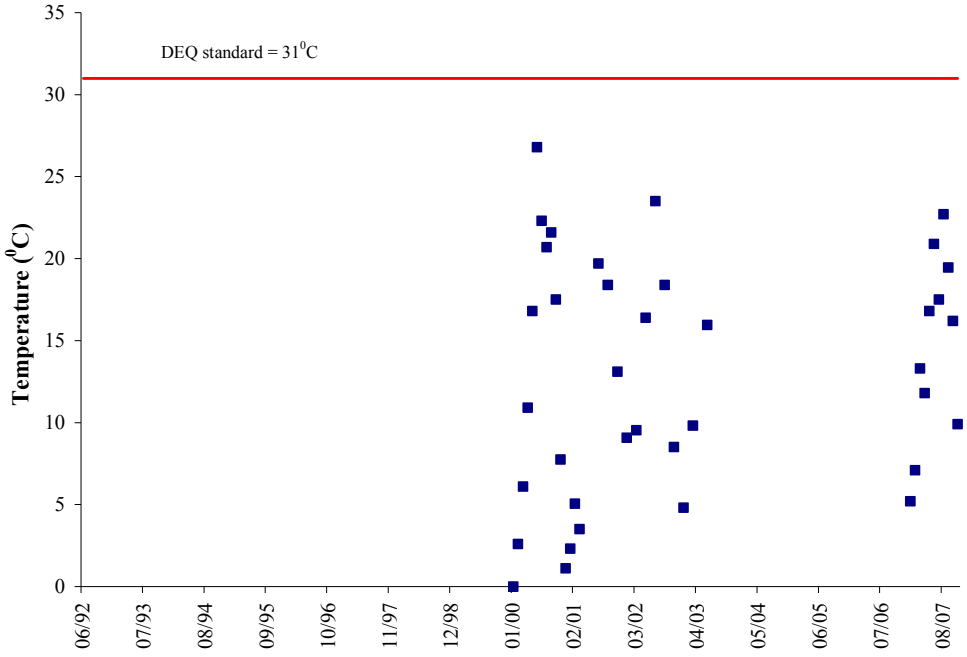

Figure 7.12 Temperature measurements at VADEQ station 6ALEV152.46.

7.2.6 Field pH

Field pH values were within the minimum and maximum water quality standards at all three VADEQ monitoring stations on Levisa Fork (Figures 7.13, 7.14 and 7.15). Therefore, field pH is considered a non-stressor in Levisa Fork.

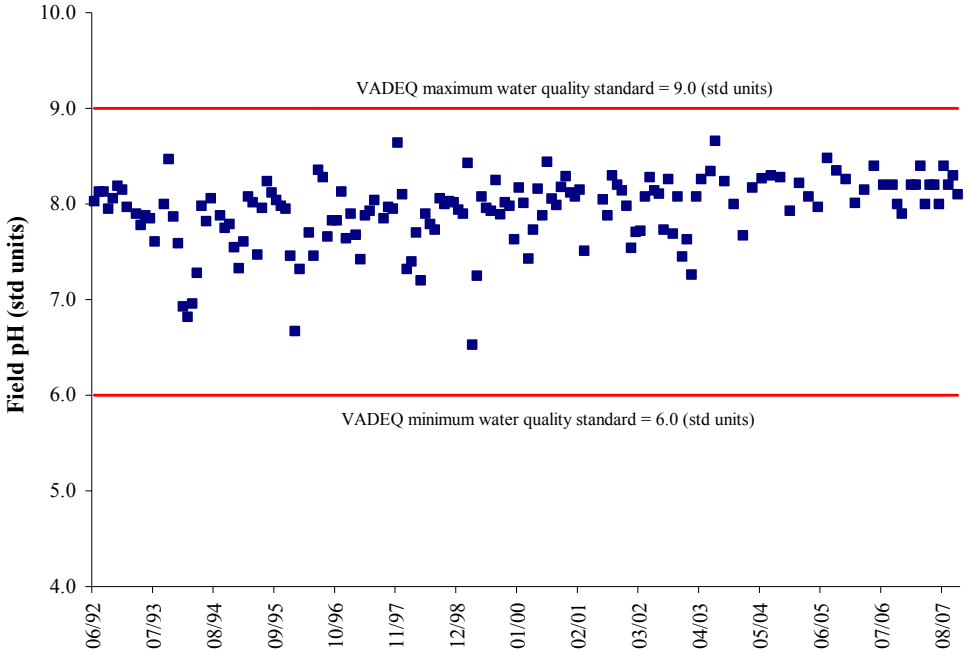

Figure 7.13 Field pH measurements at VADEQ station 6ALEV131.52.

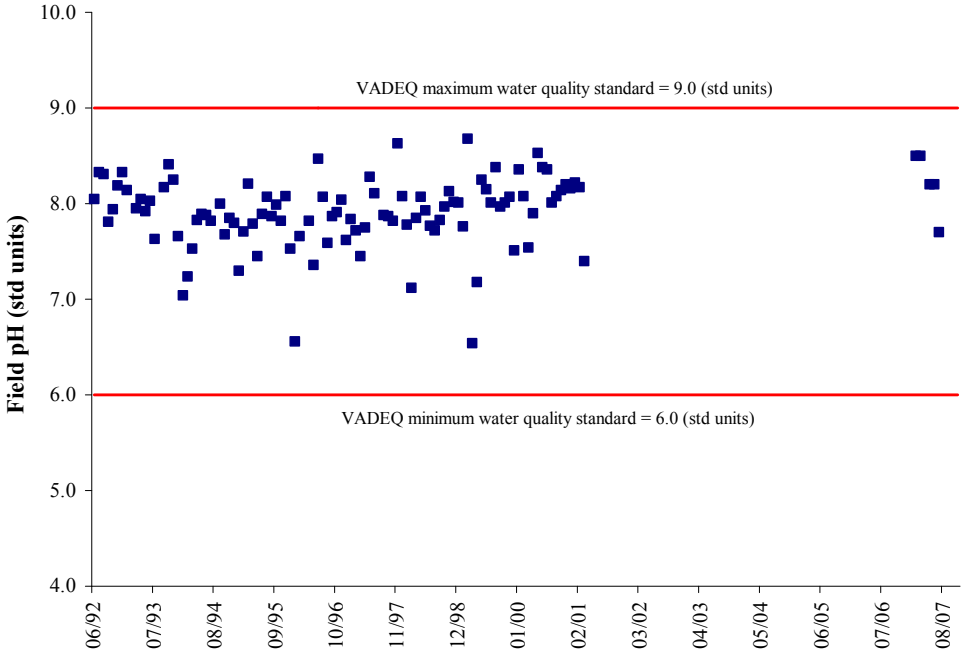

Figure 7.14 Field pH measurements at VADEQ station 6ALEV143.86.

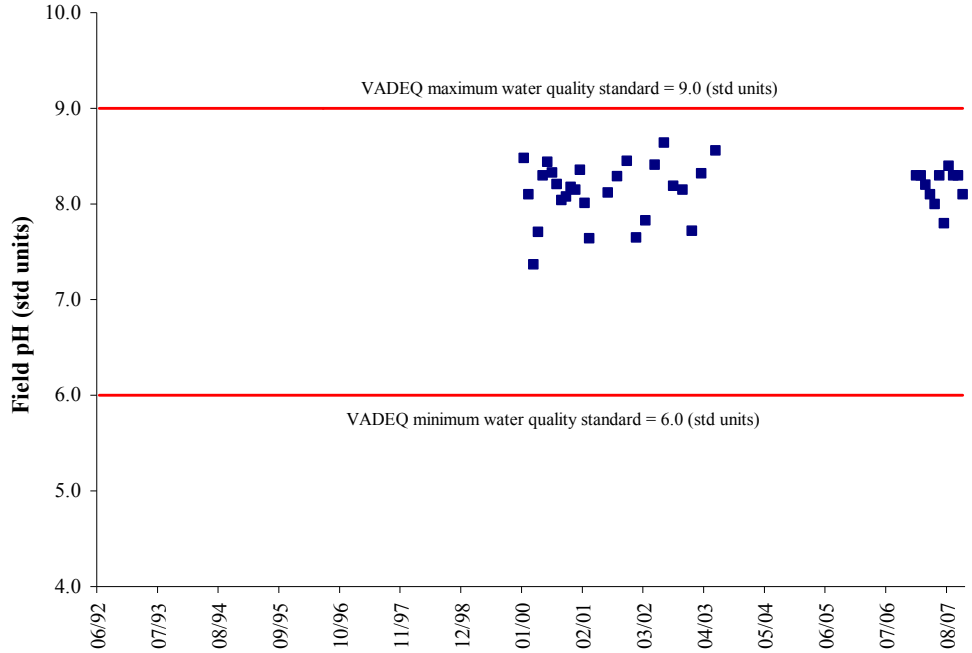

Figure 7.15 Field pH measurements at VADEQ station 6ALEV152.46.

7.3 Possible Stressors

Table 7.2 Possible Stressors in Levisa Fork.

Parameter	Location in Document
Sediment copper, lead, nickel and zinc.	Section 7.3.1
Sulfate and Chlorides	Section 7.3.2
Organic matter (total organic solids, organic suspended solids, total organic dissolved solids, total Kjeldahl nitrogen (TKN) and chemical oxygen demand (COD)	Section 7.3.3
Conductivity/total dissolved solids (TDS)	Section 7.3.4
Toxics (unknown)	Section 7.3.5

7.3.1 Sediment metals (copper, lead, nickel and zinc)

Sediment metals were collected nine times between July 1992 and September 2007 at three VADEQ ambient monitoring stations on Levisa Fork (6ALEV131.52, 6ALEV143.86, and 6ALEV152.46). Copper exceeded the consensus PEC values in 1993 at stations 6ALEV131.52 and 6ALEV143.86. Lead exceeded the consensus PEC value at station 6ALEV143.86 in 1993. Nickel exceeded the consensus PEC value at

6ALEV131.52 in 1992 and 1993 and at 6ALEV143.86 in 1995. Zinc exceeded the consensus PEC value at 6ALEV131.52 in 1992 and at 6ALEV143.86 in 1993. All subsequent sampling after these resulted in values lower than the PEC values. The sediment metals results are shown in Figures 7.16 through 7.21.

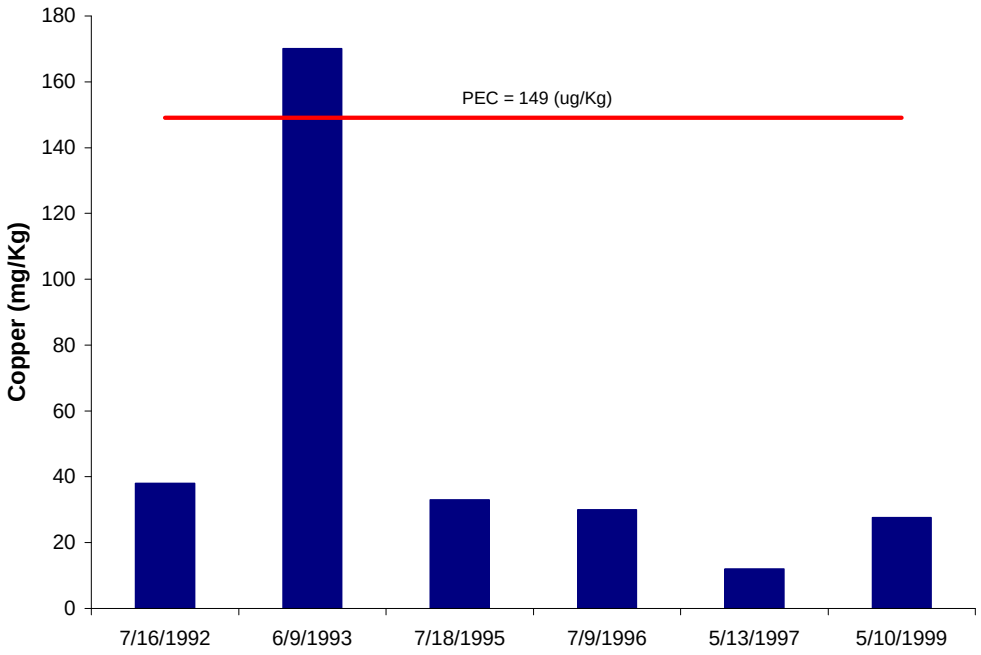

Figure 7.16 Sediment copper VADEQ station 6ALEV131.52.

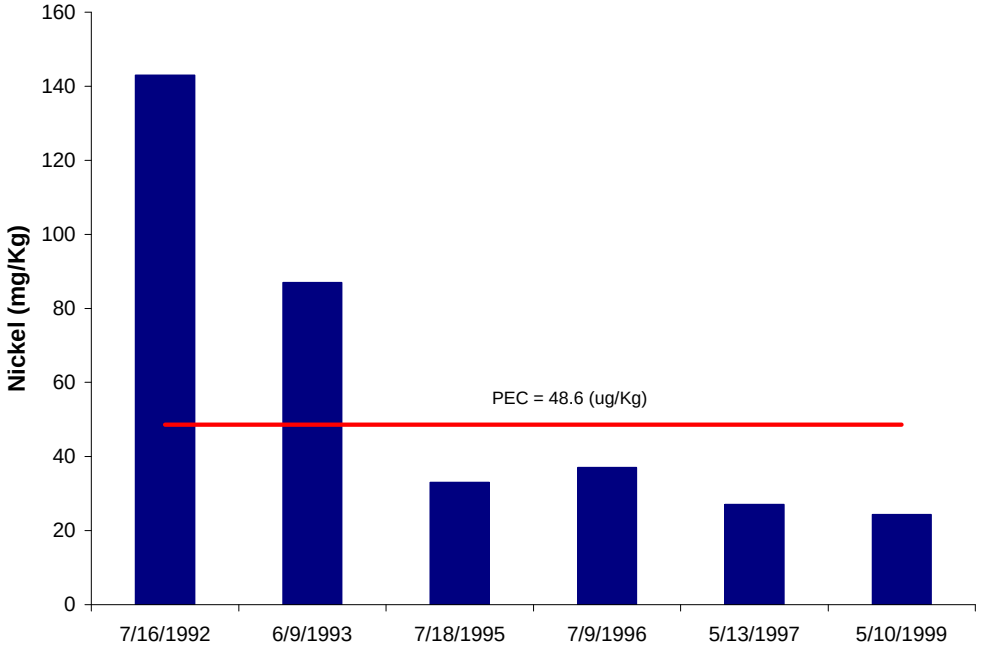

Figure 7.17 Sediment nickel VADEQ station 6ALEV131.52.

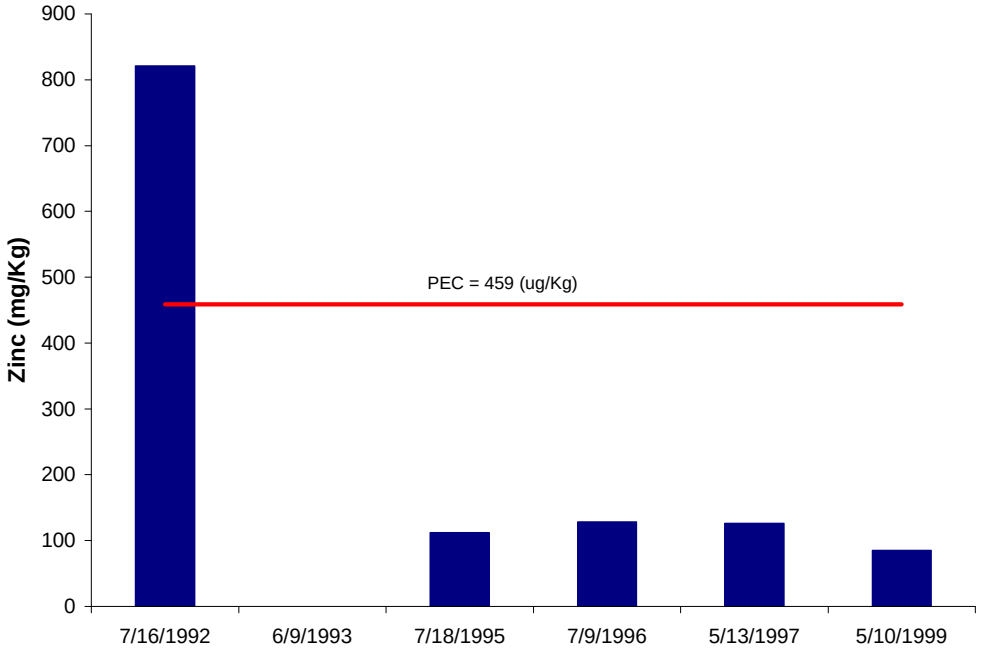

Figure 7.18 Sediment zinc at VADEQ station 6ALEV131.52.

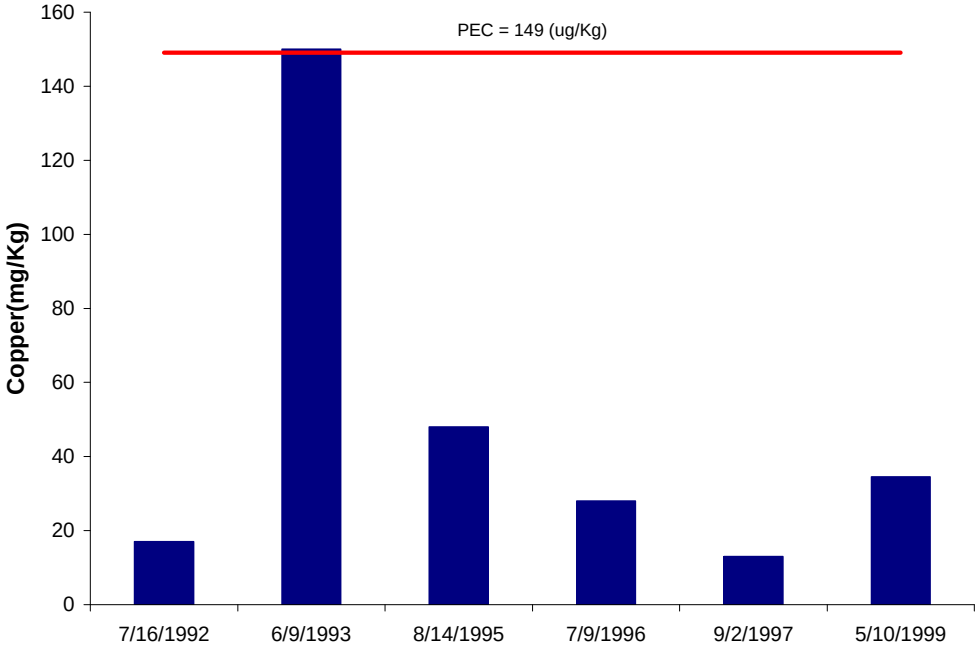

Figure 7.19 Sediment copper at VADEQ station 6ALEV143.86.

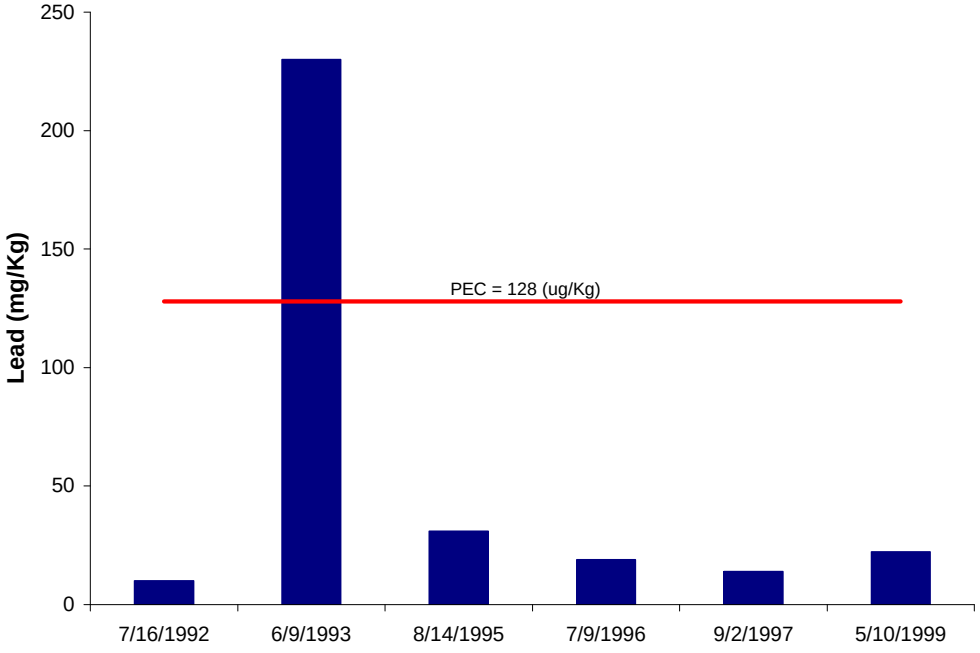

Figure 7.20 Sediment lead at VADEQ station 6ALEV143.86.

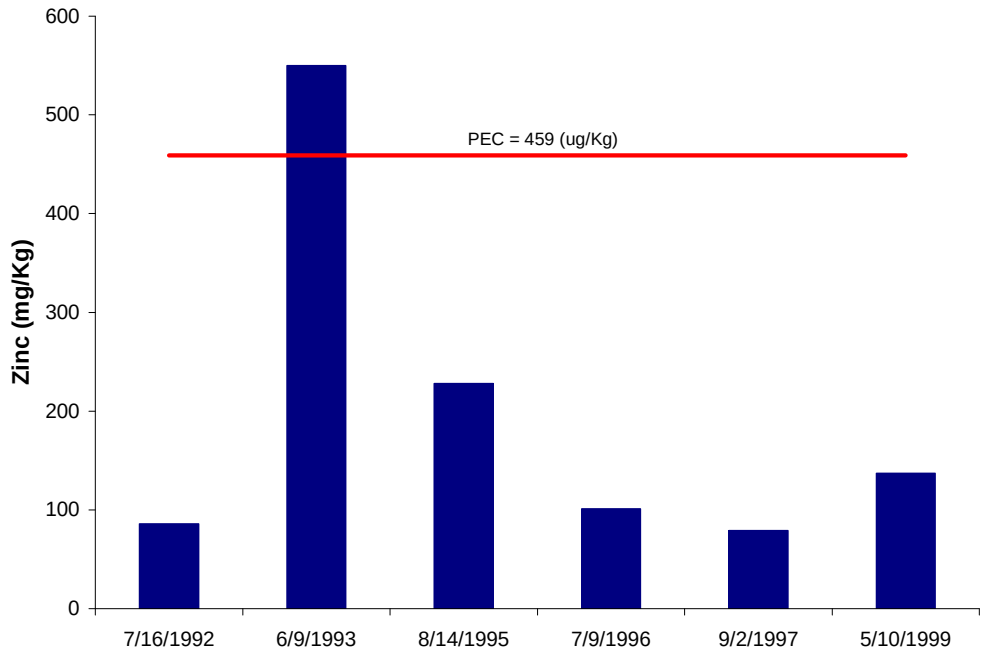

Figure 7.21 Sediment zinc at VADEQ station 6ALEV143.86.

Sediment sampling in Levisa Fork during 1992 and/or 1993 show high values of copper, lead, nickel and zinc. However, sediment sampling at two VADEQ stations (6ALEV130.00 and 6ALEV131.14) in 1997 and 2002 found all sediment metals well below their consensus PEC values. Based on the results of the more recent sediment sampling sediment copper, lead, nickel and zinc are considered only possible stressors in Levisa Fork.

7.3.2 Sulfate and chlorides

Sulfate concentrations exceeded the 90th percentile screening value (76 mg/L) in more than 10% of the samples collected at three VADEQ ambient monitoring stations evaluated on Levisa Fork (Figures 7.22, 7.23 and 7.24). There is a public water supply water quality standard of 250 mg/L, but this is for taste and odor control and does not apply to aquatic life. The USEPA used sulfate concentrations as an indicator of impaired macroinvertebrate communities in mid-Atlantic highland streams (Klemm et al., 2001). Other studies note that sulfate is a reliable indicator of mining activity and is often linked to depressed benthic health, but, by itself, has not been shown to actually cause a reduction in the health of benthic communities (Merricks, 2003). Sulfate is, however, a

principle component of total dissolved solids, which have been shown to impair benthic macroinvertebrate communities. Therefore, sulfate is considered a possible stressor.

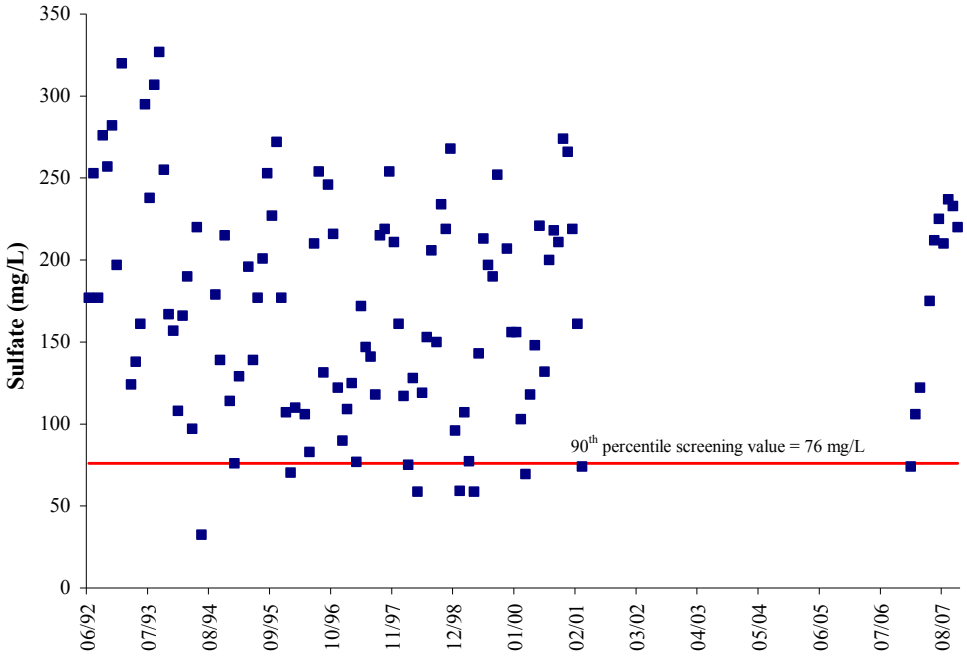

Figure 7.22 Sulfate concentrations at VADEQ monitoring station 6ALEV131.52.

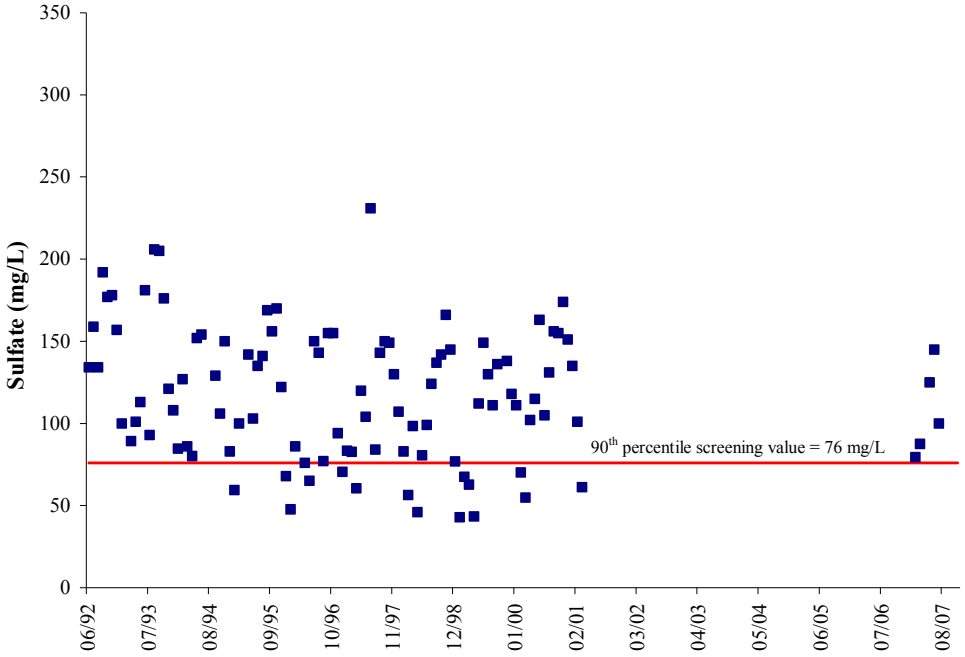

Figure 7.23 Sulfate concentrations at VADEQ monitoring station 6ALEV143.86.

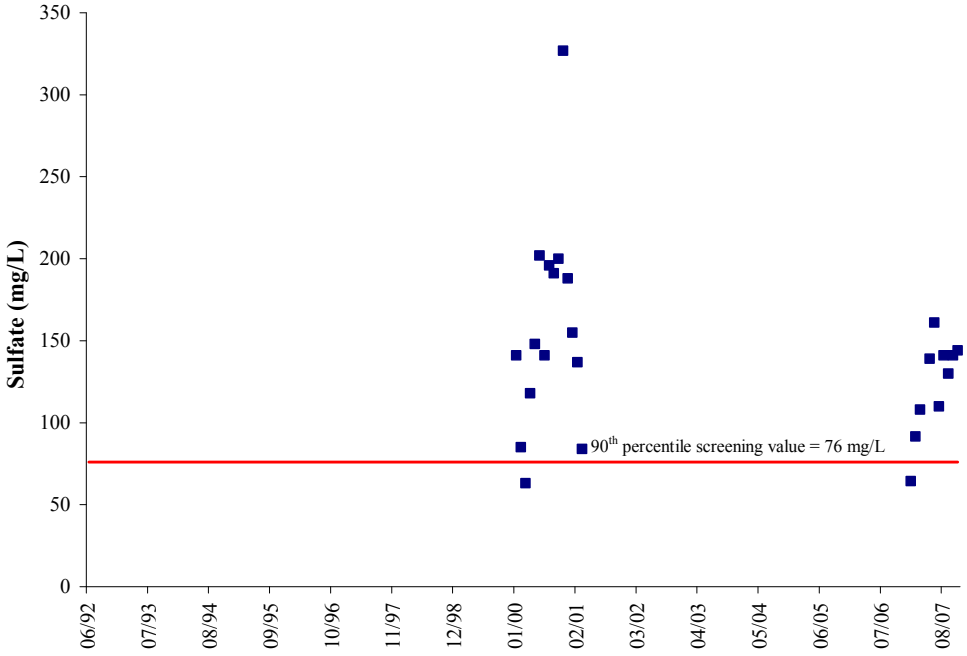

Figure 7.24 Sulfate concentrations at VADEQ monitoring station 6ALEV152.46.

Both the USEPA and the VADEQ consider chloride to be a potentially toxic parameter and both have an acute and a chronic water quality standard criterion. The acute water quality standard of 860 mg/L is based on a one-hour average concentration that is not to be exceeded more than once every three years. The chronic water quality standard of 230 mg/L is based on a four-day average concentration not to be exceeded more than once every three years (9 VAC 25-260-140). Monthly chloride concentrations exceeded the chronic water quality standard 27% of the time at VADEQ monitoring station 6ALEV152.46 (8/2000 – 2/2001) and 5% percent of the time at 6ALEV143.86 (9/1996 – 12/1997) (Figures 7.25 and 7.26). This monitoring station is located approximately 3 miles downstream from the confluence with Garden Creek. Historically, there have been deep mine discharges into Garden Creek watershed that had very high chloride concentrations. In addition to gravity flow discharges from drainage mines, the VP8 Mine and the Buchanan Mine have had pumped discharges from their underground mine area. The VP8 discharge was eliminated in November 2005. The pumped discharge from the Buchanan Mine to Pond No. 3 has been eliminated as well (but this outfall can still be used on an emergency basis). The only deep mine discharge, a gravity flow discharge, is still active is MPID 0002431 (Basin 025) from the Buchanan Mine. Basin 025 discharges to North Branch a tributary to the Right Fork of Garden Creek. The elimination and/or reduction in pumping in addition to the modified and improved operation of the sediment control basins have resulted in reductions in total chloride and total dissolved solids concentrations in the Right Fork of Garden Creek and in Garden Creek. In addition, a TMDL for total chlorides and total dissolved solids in the Garden Creek watershed was approved by the USEPA on November 4, 2007. Chloride concentrations at the most downstream VADEQ monitoring station (6ALEV131.52) did not exceed the chloride chronic water quality standard.

In 2007, the Department of Mines Minerals and Energy approved a permit application submitted by Consolidated Coal Company for a deep mine dewatering discharge to Levisa Fork from its Buchanan mine (outfall 033) because other options for the water were limited. The water from this deep mine is very high in chlorides, and the discharge required the establishment of a mixing zone on Levisa Fork based on the flow rate in the stream at the time of the discharge. The mixing zone begins at the point of the discharge,

less than one half mile downstream from the Levisa Fork/Slate Creek confluence in Grundy, Virginia. The downstream boundary of the mixing zone fluctuates with the flow in Levisa Fork, but the maximum distance downstream is approximately two miles. Discharges from the deep mine are periodic and on an as needed basis. The initial discharges did not begin until February 2008. As of March 2008 there had been no visible impact on chloride concentrations at VADEQ's downstream monitoring station (6ALEV131.52), Figure 7.27.

Based on the fact that the source of the high chloride concentrations measured at the VADEQ monitoring station 6ALEV152.46 were from Garden Creek and due to the recent changes in operations by Consolidated Coal and the approval of a total chloride TMDL for Garden Creek, chlorides are considered a possible stressor in Levisa Fork.

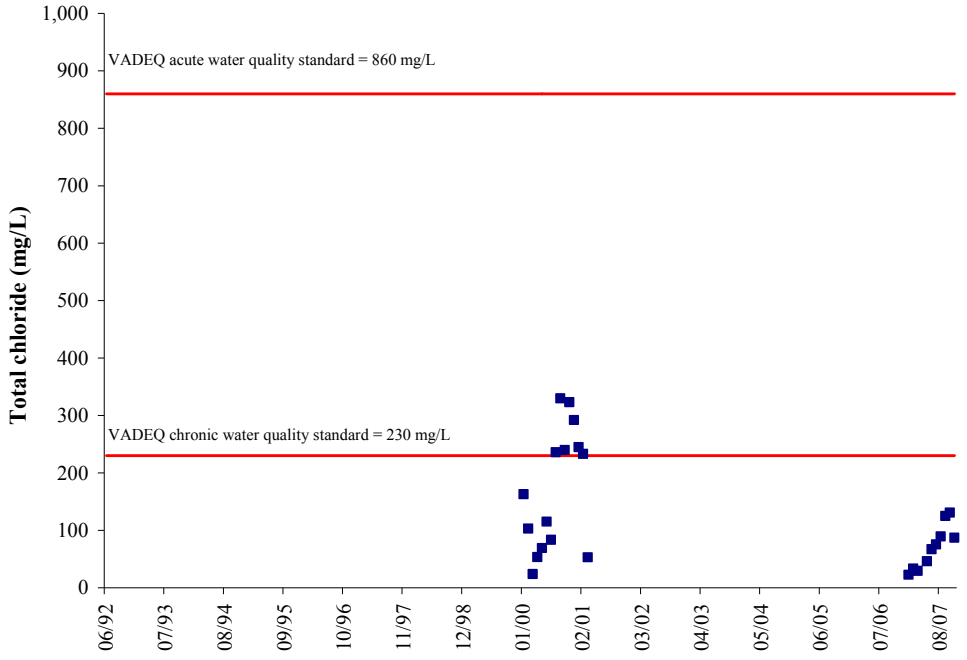

Figure 7.25 Total chloride concentrations at VADEQ monitoring station 6ALEV152.46.

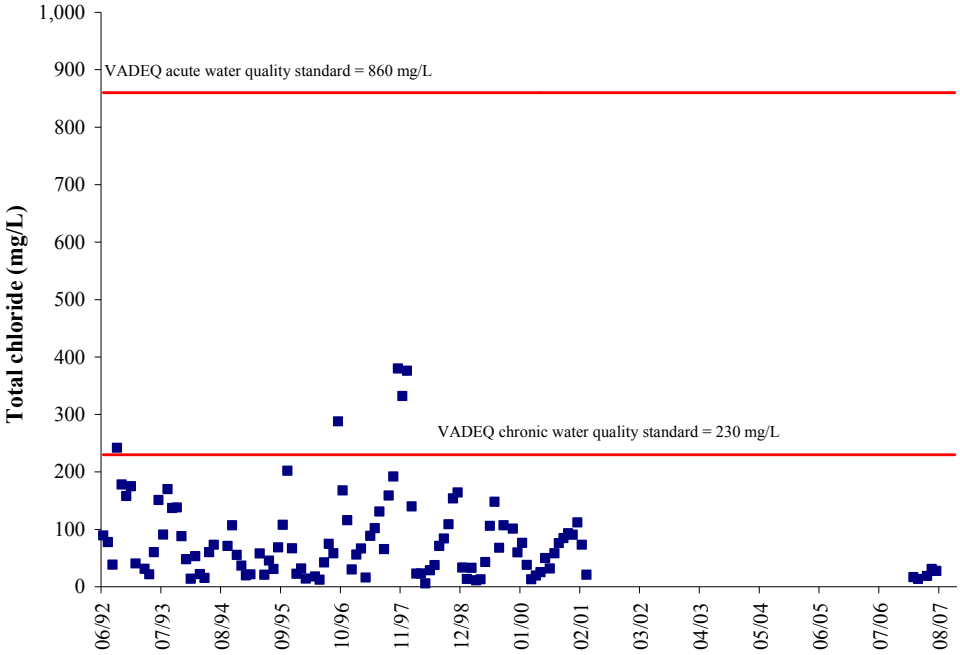

Figure 7.26 Total chloride concentrations at VADEQ monitoring station 6ALEV143.86.

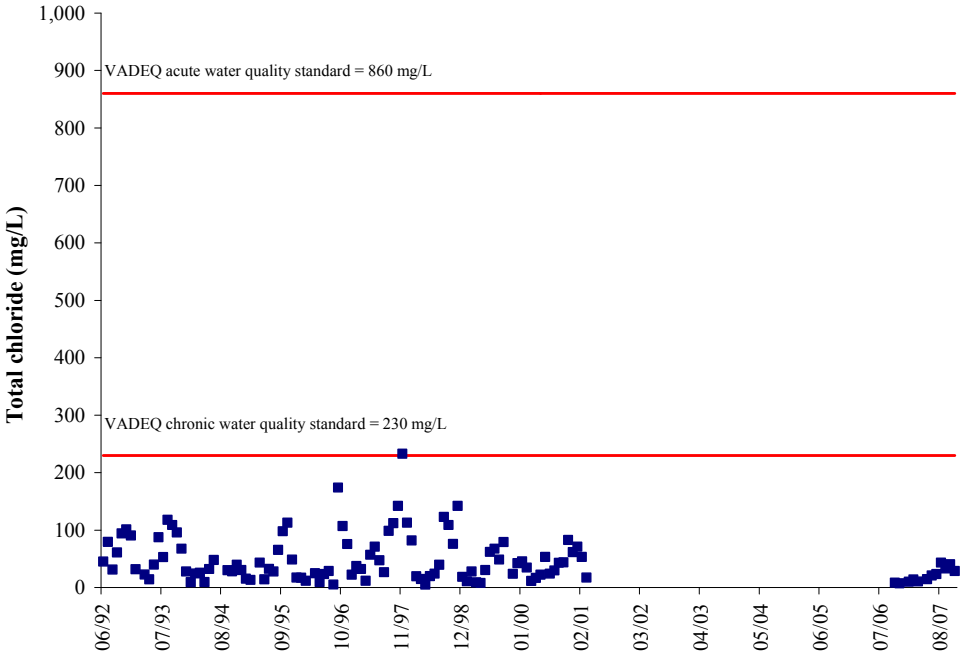

Figure 7.27 Total chloride concentrations at VADEQ monitoring station 6ALEV131.52.

7.3.3 Organic matter (Total organic solids, total organic suspended solids, total Kjeldahl nitrogen, and chemical oxygen demand)

Total organic solids (also called total volatile solids, TVS) provide an indication of dissolved and suspended organic matter. TVS concentrations exceeded the 90th percentile screening concentration (63 mg/L) in 49%, 26% and 30% of the samples collected at VADEQ monitoring stations 6ALEV131.52, 6ALEV143.86 and 6ALEV152.46, respectively (Figures 7.28, 7.29 and 7.30). Total organic suspended solids (also called total volatile suspended solids, TVSS) provide an indication of particulate organic matter in a stream. TVSS also exceeded the 90th percentile concentration (9 mg/L) in 24% and 21% of the samples collected at VADEQ monitoring stations 6ALEV131.52 and 6ALEV143.86, respectively (monitoring station 6ALEV152.46 had less than nine samples above the minimum laboratory detection level; Figures 7.31 and 7.32).

Total dissolved organic solids indicate how much of the organic matter in a stream is dissolved. The 90th percentile screening value for total organic dissolved solids is 54 mg/L and this value was exceeded in 40% and 20% of the samples collected at 6ALEV131.52 and 6ALEV152.46, respectively (6ALEV143.86 had less than 9 values above the minimum laboratory detection level; Figures 7.33 and 7.34).

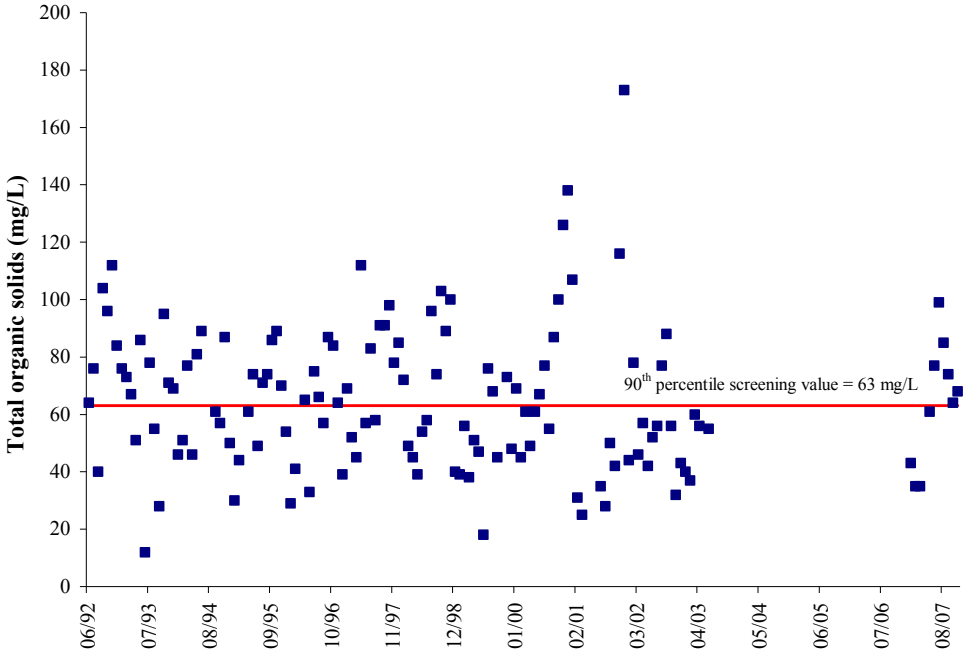

Figure 7.28 Total organic solids concentrations at VADEQ monitoring station 6ALEV131.52.

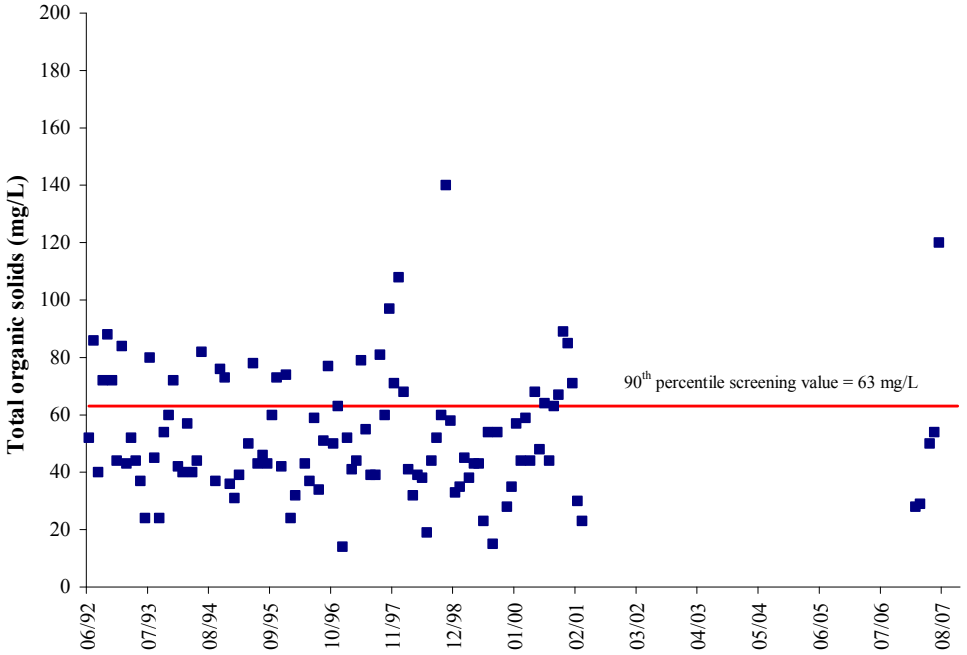

Figure 7.29 Total organic solids concentrations at VADEQ monitoring station 6ALEV143.86.

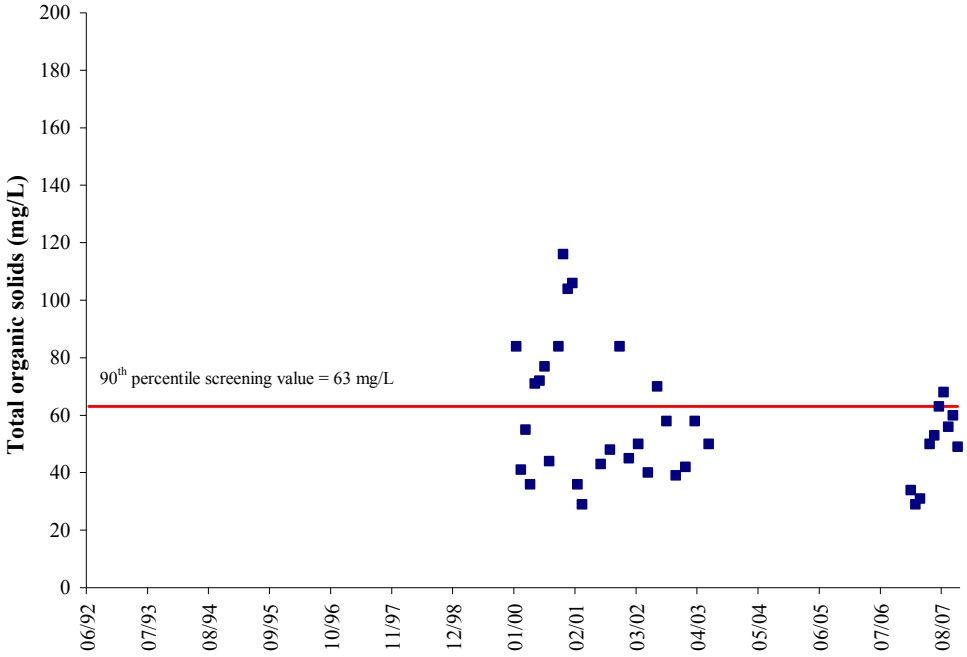

Figure 7.30 Total organic solids concentrations at VADEQ monitoring station 6ALEV152.46.

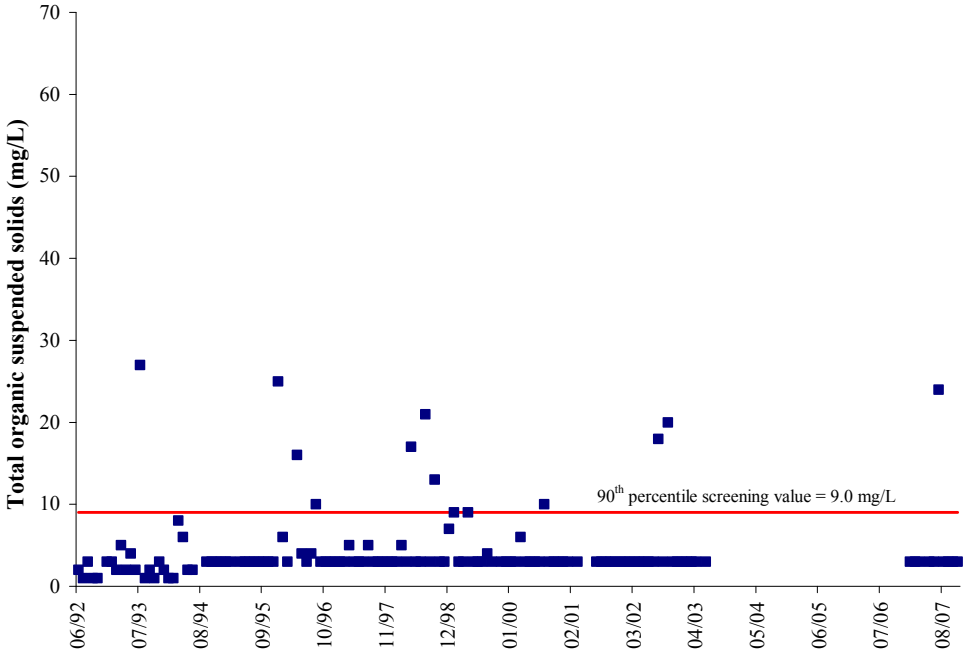

Figure 7.31 Total organic suspended solids concentrations at VADEQ monitoring station 6ALEV131.52.

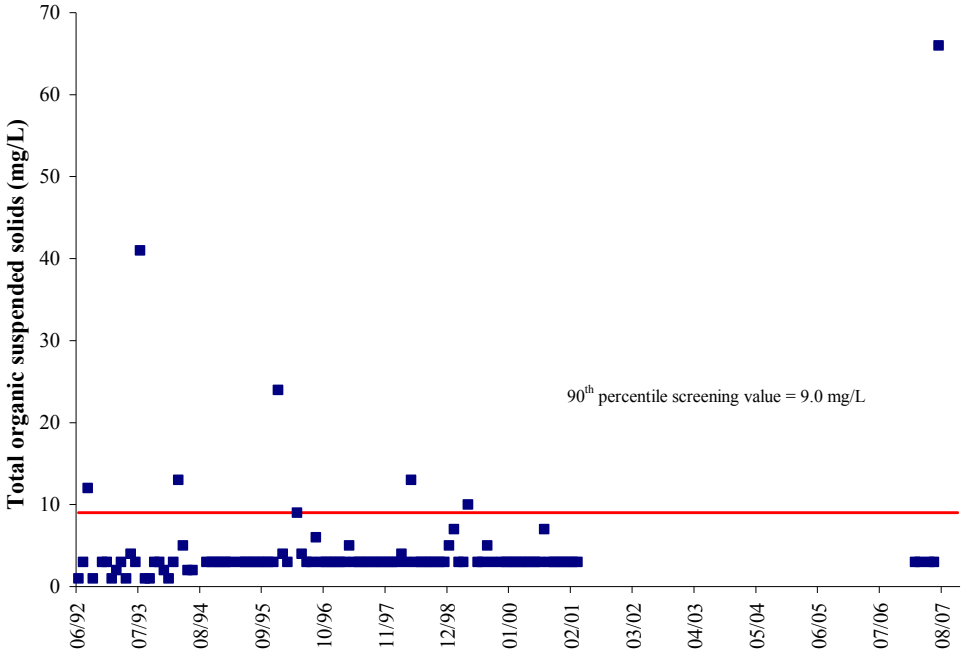

Figure 7.32 Total organic suspended solids concentrations at VADEQ monitoring station 6ALEV143.86.

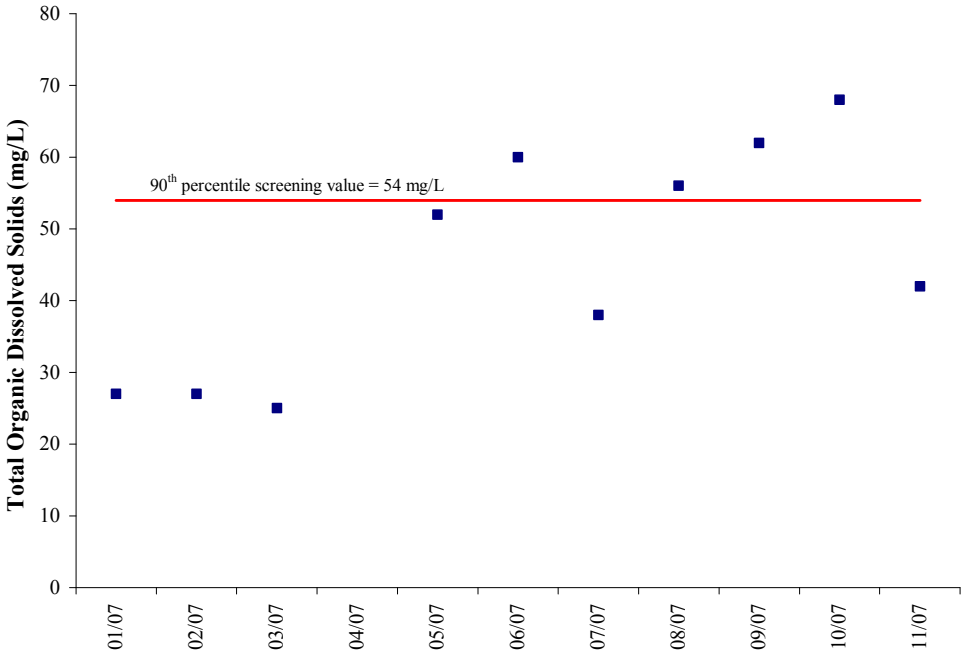

Figure 7.33 Total organic dissolved solids concentrations at VADEQ monitoring station 6ALEV131.52.

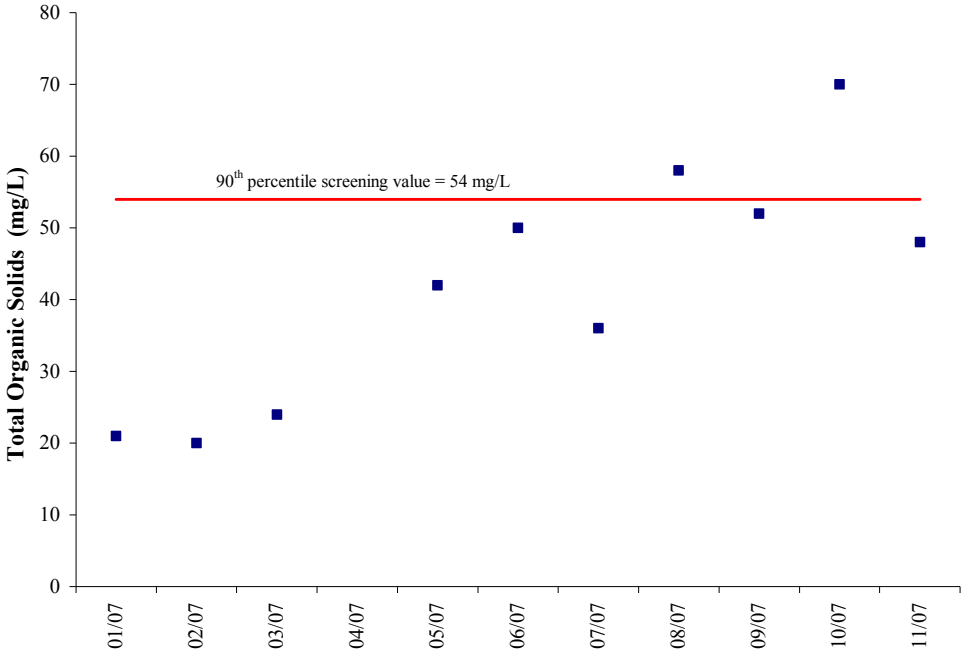

Figure 7.34 Total organic dissolved solids concentrations at VADEQ monitoring station 6ALEV152.46.

Total Kjeldahl nitrogen (TKN) is a measure of the amount of organic nitrogen present in the stream. TKN concentrations exceeded the 90th percentile screening value (0.4 mg/L) in 12% and 18% of the total number of samples collected at VADEQ monitoring stations 6ALEV143.86 and 6ALEV152.46 (Figures 7.35 and 7.36).

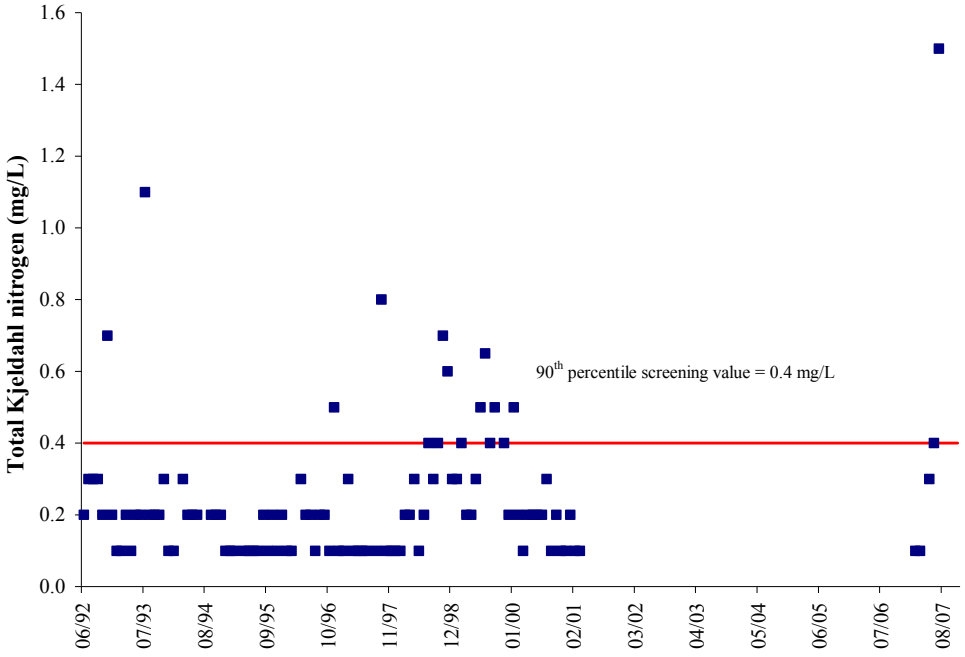

Figure 7.35 Total Kjeldahl nitrogen concentrations at VADEQ monitoring station 6ALEV143.86.

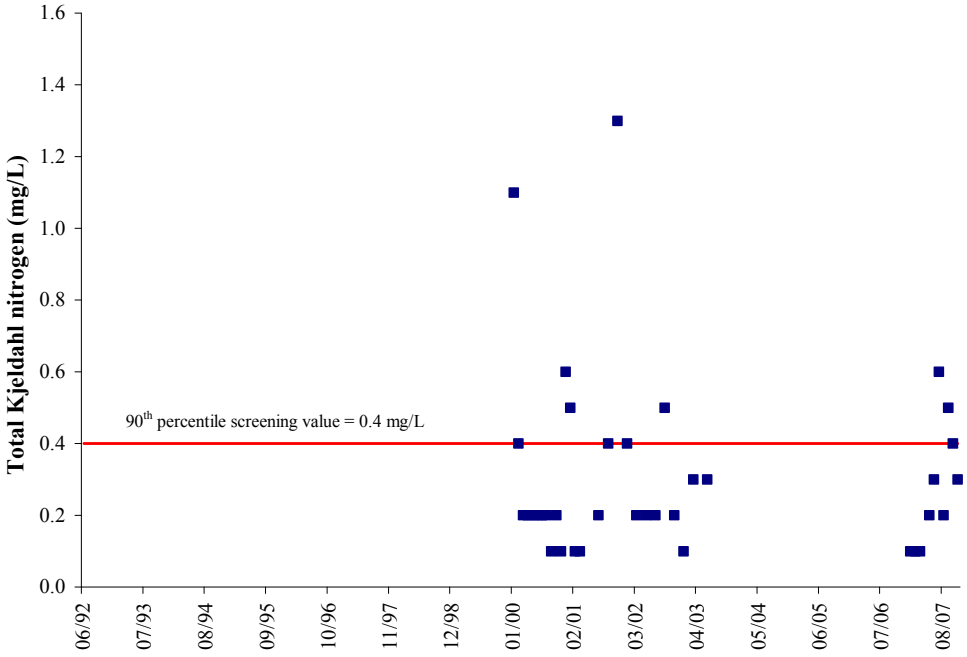

Figure 7.36 Total Kjeldahl nitrogen concentrations at VADEQ monitoring station 6ALEV152.46.

Chemical oxygen demand (COD) is used to indirectly measure the amount of organic pollutants in the stream. COD concentrations exceeded the 90th percentile screening value (14.0 mg/L) in 16% and 14% of the samples collected at VADEQ monitoring stations 6ALEV131.52 and 6ALEV143.86, respectively (monitoring station 6ALEV152.46 had less than nine samples above the minimum laboratory detection level; Figures 7.37 and 7.38).

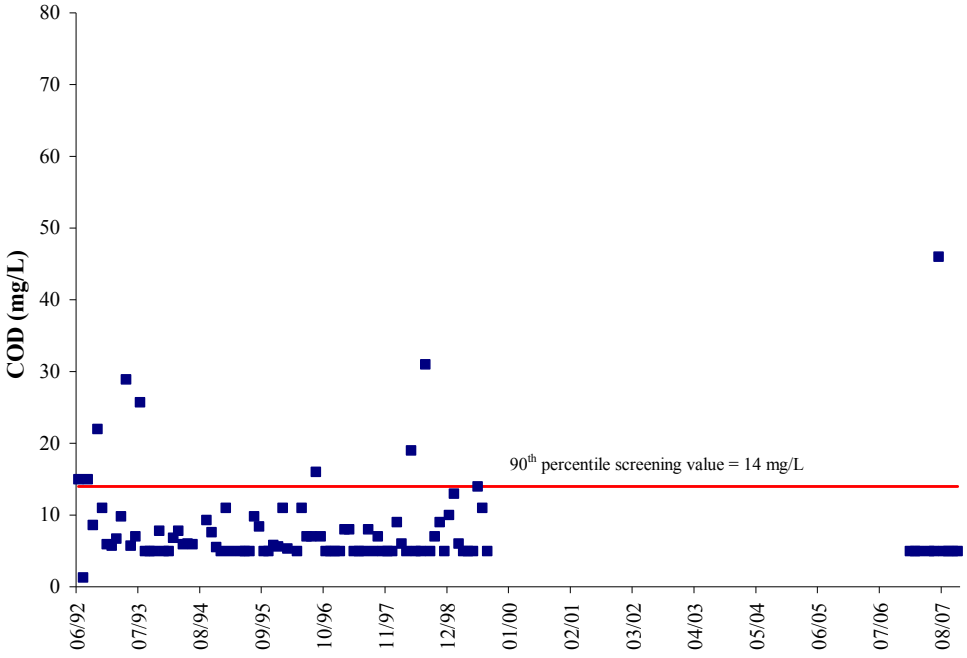

Figure 7.37 Chemical oxygen demand concentrations at VADEQ monitoring station 6ALEV131.52.

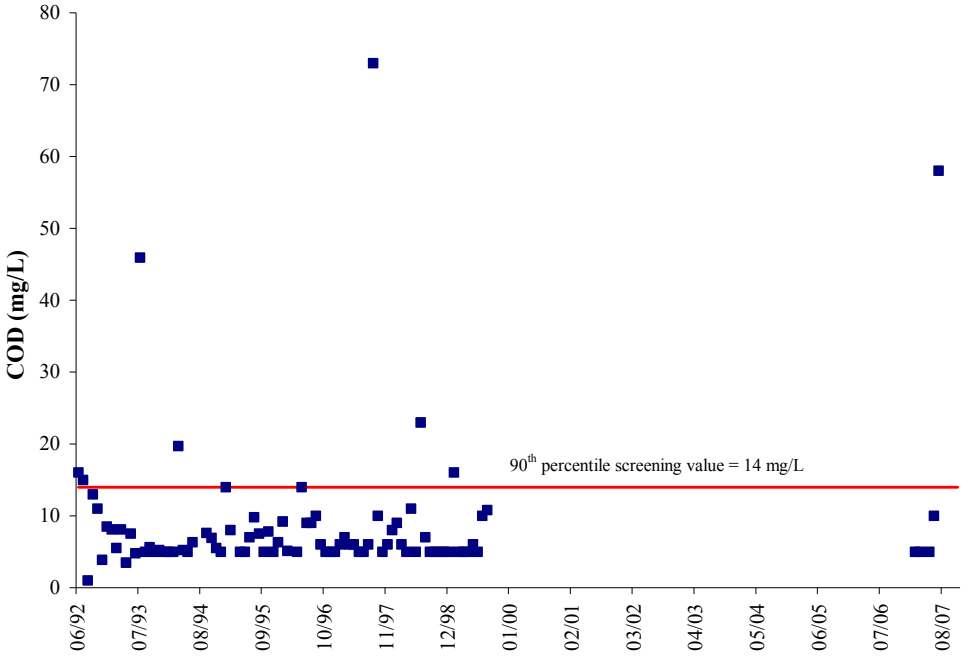

Figure 7.38 Chemical oxygen demand concentrations at VADEQ monitoring station 6ALEV143.86.

The assemblage for all five benthic stations on the Levisa Fork from the VADEQ Ecological Data Application System (EDAS) database were examined, and Hydropsychidae (netspinning caddisflies) were found to be the most dominant or a very significant family at each monitoring station (15% - 31%). According to Voshell (2002), "If common netspinners account for the majority of the community that is a reliable indicator of organic or nutrient pollution." Naididae (an aquatic worm) was the most dominant family at one of the stations 6ALEV138.19 (30%) and second most dominant at 6ALEV152.46 (20%). This type of organism is also often associated with polluted and degraded water quality. For the purposes of this stressor analysis, organic matter is considered a possible stressor because as part of this overall TMDL study an *E. coli* TMDL will be developed for the Levisa Fork watershed, which will require significant reductions to the sources of organic matter in the watershed (straight pipes, failing septic systems, and sewer overflows).

7.3.4 Conductivity/Total dissolved solids (TDS)

Conductivity is a measure of the electrical potential in the water based on the ionic charges of the dissolved compounds that are present. TDS is a measure of the actual concentration of the dissolved ions, dissolved metals, minerals, and dissolved organic matter in water. Dissolved ions can include sulfate, calcium carbonate, chloride, etc. Therefore, even though they are two different measurements, there is a direct correlation between conductivity and TDS. In the Levisa Fork data set, there was a Pearson Product Moment Correlation (a common statistical measure of the amount of correlation between two different variables) of 0.928 between conductivity and TDS.

High conductivity values have been linked to poor benthic health (Merricks, 2003) and elevated conductivity is common with land disturbance and mine drainages. A recent report on the effects of surface mining on headwater stream biotic integrity in Eastern Kentucky noted that one of the most significant stressors in these watersheds was elevated TDS (Pond, 2004). Elevated TDS concentrations impact pollution sensitive mayflies the most. Figure 7.39 from this report shows that "drastic reductions in mayflies occurred at sites with conductivities generally above 500 µmhos/cm" (Pond, 2004).

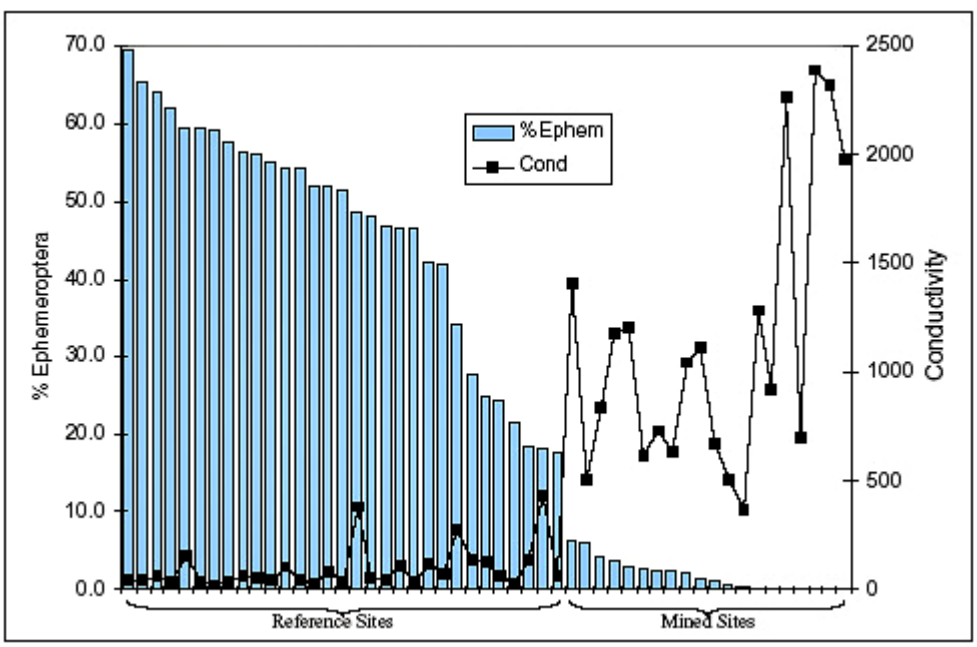

Figure 7.39 The relationship between % Ephemeroptera and conductivity from reference and mined sites (Pond, 2004).

Pond speculated that the increased salinity may irritate the gill structures on mayflies and inhibit the absorption of oxygen, but research has not confirmed this. A typical reference station in this part of the state can be expected to have at least nearly 50% mayflies out of the total assemblage. The results of a VADEQ benthic surveys in Levisa Fork at five monitoring stations indicated that sensitive mayflies made up between 2% - 5% of the total benthic assemblage. The members of the more pollution tolerant families (Caenidae, Baetidae, and Isonychiidae) were not included in this calculation. In the development of both the Virginia and West Virginia Stream Condition Indices, the reference streams used had conductivity levels that did not exceed 500 µmhos/cm. In the absence of a Virginia water quality standard, the 90th percentile screening value of 402 µmhos/cm was used. Conductivity values at all three VADEQ stations consistently exceeded the 90th percentile screening value in 83%, 78% and 95% at VADEQ monitoring stations 6ALEV131.52, 6ALEV143.86 and 6ALEV152.46 (Figures 7.40, 7.41 and 7.42).

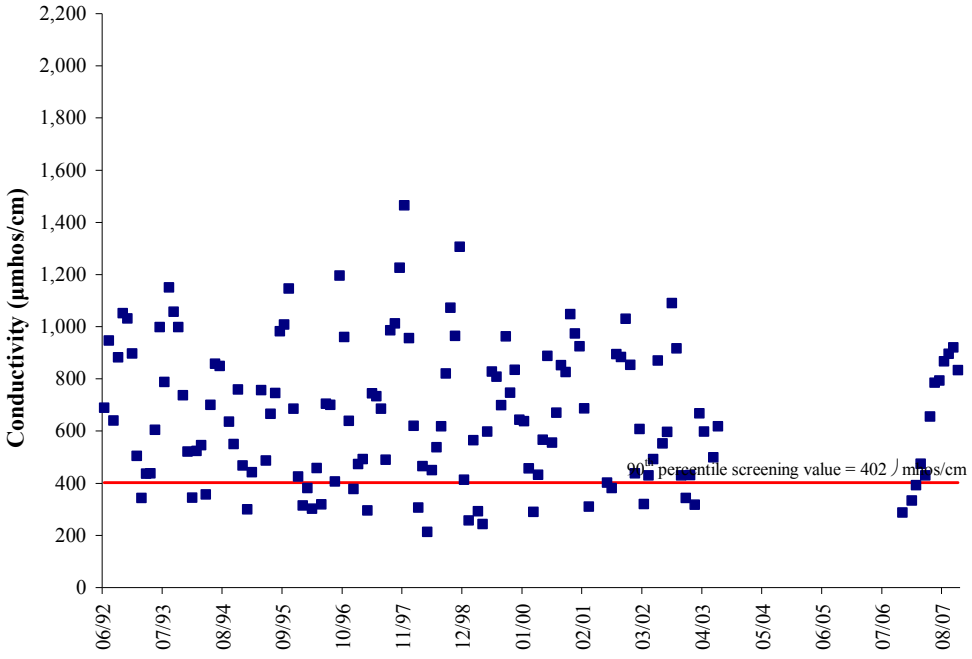

Figure 7.40 Conductivity measurements at VADEQ station 6ALEV131.52.

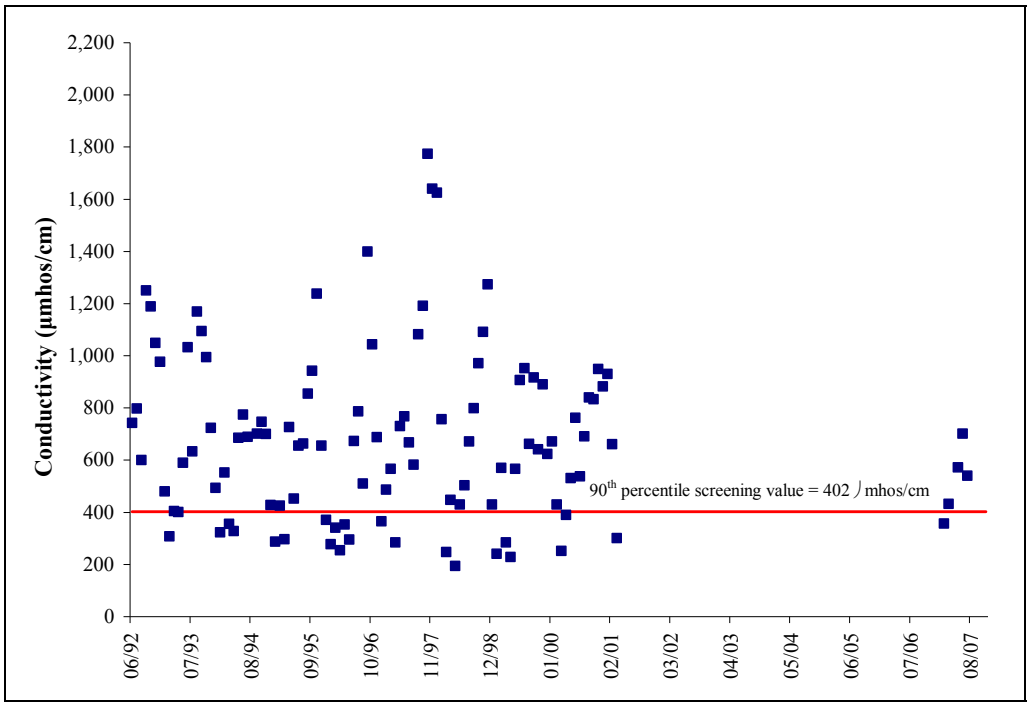

Figure 7.41 Conductivity measurements at VADEQ station 6ALEV143.86.

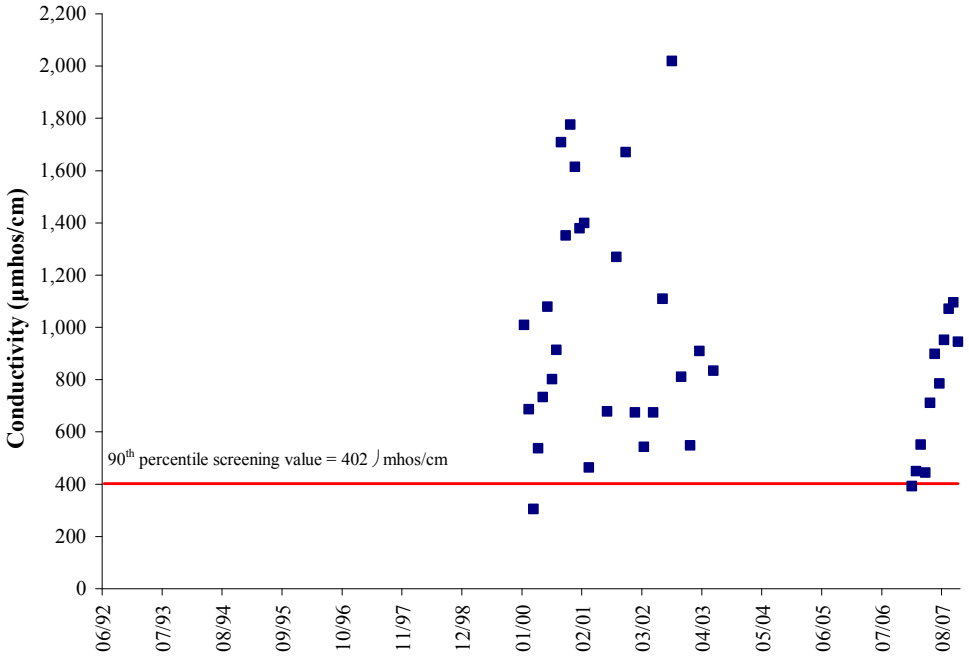

Figure 7.42 Conductivity measurements at 6ALEV152.46.

The TDS 90th percentile screening value was 260 mg/L. TDS concentrations consistently exceeded this value in 77%, 72% and 88% of the samples at all three VADEQ ambient monitoring stations 6ALEV131.52, 6ALEV143.86 and 6ALEV152.46, respectively (Figures 7.43, 7.44 and 7.45).

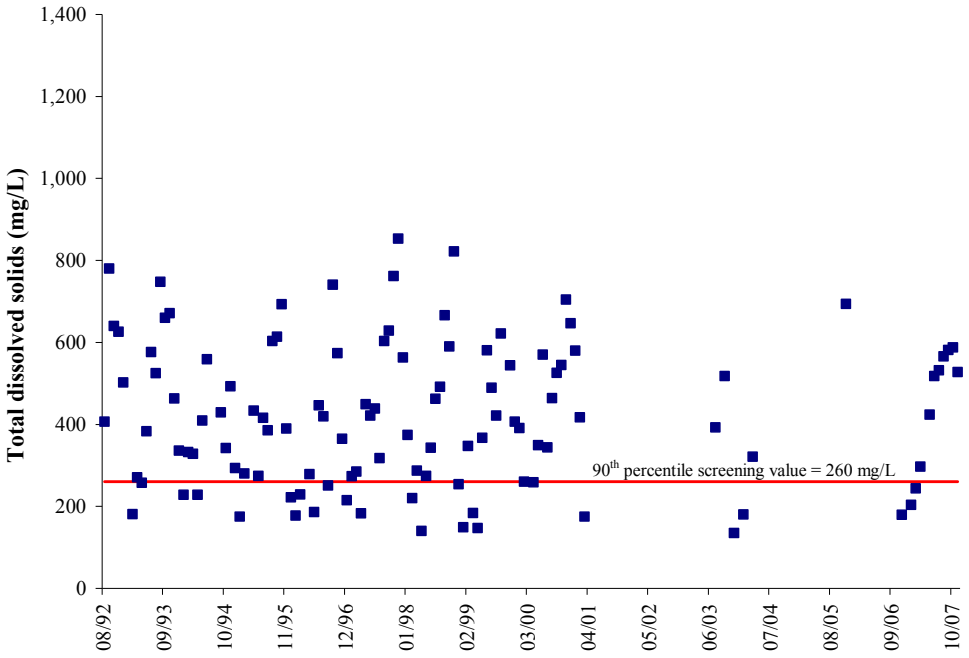

Figure 7.43 TDS concentrations at VADEQ station 6ALEV131.52.

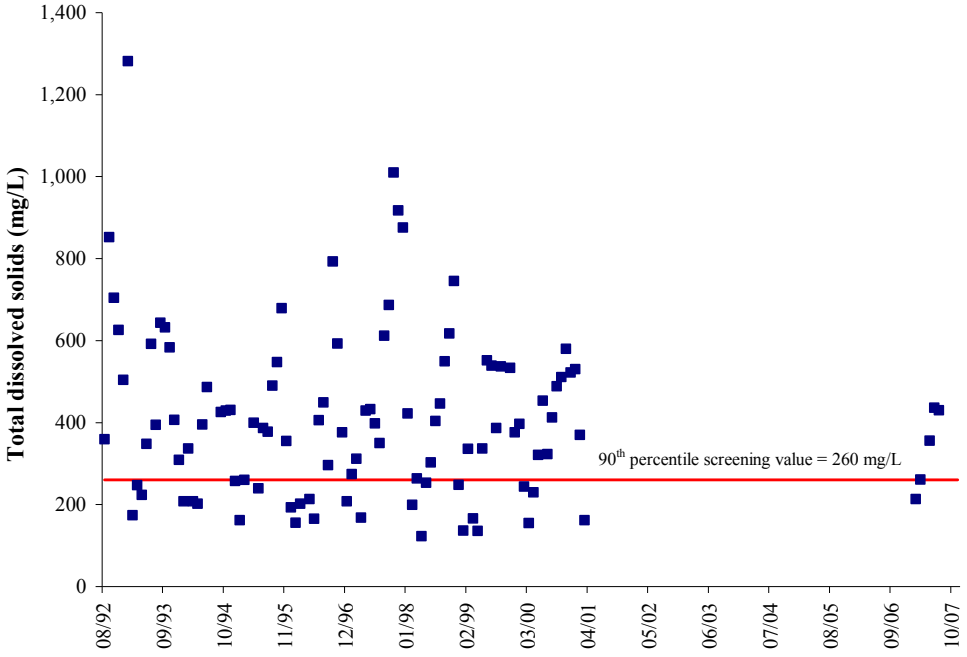

Figure 7.44 TDS concentrations at 6ALEV143.86.

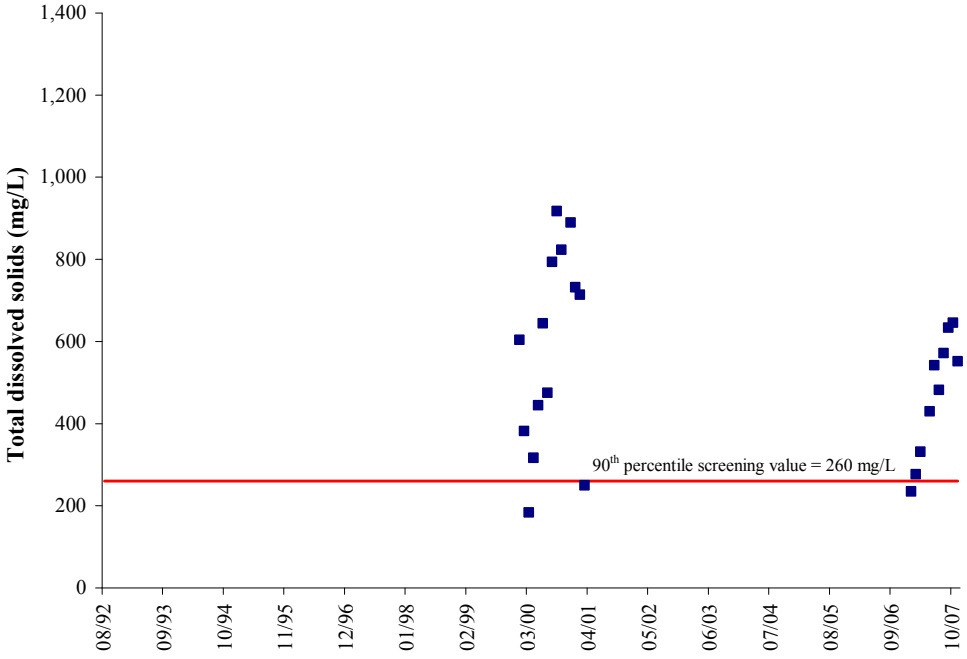

Figure 7.45 TDS concentrations at 6ALEV152.46.

TDS concentrations can be harmful to aquatic organisms without causing death. Aquatic organisms balance water and internal ions through a number of different mechanisms.

Therefore, high concentrations and significant changes in TDS over long periods of time can place a lot of stress on the organisms. The resulting chronic stress affects processes such as growth and reproduction. Sudden large spikes in TDS concentration can be fatal. A study of TDS toxicity in a coal-mining watershed in southeastern Ohio found the lowest observed effect concentration (LOEC) on the test organism *Isonychia bicolor* (a species of Mayfly) was 1,066 mg/L (Kennedy, 2002). The author carefully noted that this concentration was specific to the watershed studied, but noted that similar studies with the same test organism and TDS with varying ionic compositions were toxic between 1,018 and 1,783 mg/L (Kennedy, 2002). Kennedy also cited a study that suggested that aquatic organisms should be able to tolerate TDS concentrations up to 1,000 mg/L; however, the test organism used was *Chironomous tentans*, which is considerably more pollution tolerant than *Isonychia bicolor* (Kennedy, 2002). Research also indicates that the likely mechanism(s) of TDS benthic macroinvertebrate mortality is from gill and internal tissue dehydration, salt accumulation and compromised osmoregulatory function. In fact, the rate of change in TDS concentrations may be more toxic to benthic macroinvertebrates than the TDS alone (Kennedy, 2002).

It is clear from the data available that conductivity and TDS values are very high, and there have been significant fluctuations over the sampling period. Levisa Fork is considered by the VADEQ to be a fifth order stream at monitoring stations 6ALEV130.29, 6ALEV138.19 and 6ALEV143.80. Larger streams tend to be comprised of benthic organisms that are a little more facultative than lower order high gradient streams in the Central Appalachians. These organisms are generally somewhat more tolerant of higher TDS concentrations. In addition, a TDS TMDL is being developed for Bull Creek a tributary to Levisa Fork, and implementation of this TMDL will result in decreasing TDS concentrations in the downstream portion of Levisa Fork. The most upstream-impaired VADEQ benthic monitoring station is 6ALEV152.46 and Levisa Fork is a fourth order stream at this monitoring station. This station is just downstream from Garden Creek's confluence with Levisa Fork. Garden Creek has been a very significant source of high TDS concentrations in Levisa Fork due to the discharges from deep mines in the watershed. However, as previously discussed, there have been significant operational changes in the Garden Creek watershed resulting in some deep mine

discharges being taken out of service. Also, a TMDL requiring load reductions for total chlorides and TDS was approved by the USEPA in November of 2007. Implementation of the TMDL will result in further decreases in TDS concentrations to both Garden Creek and Levisa Fork. Therefore, conductivity and TDS are considered possible stressors in Levisa Fork.

7.3.5 Toxics (unknown)

A chronic water column toxicity study using fathead minnows (Pimephales promelas) and Ceriodaphnia dubia (water flea) was conducted using samples from three monitoring sties on Levisa Fork in August 2007 by the USEPA Freshwater Biology Team in Wheeling, West Virginia. The results shown in Table 7.3 indicated no acute toxicity at any of the monitoring stations, but chronic toxicity to *Ceriodaphnia dubia* at station 6ALEV152.46 was found.

Table 7.3 Levisa Fork August 2007 Toxicity Testing Results.

Station	Date	Toxicity Found	Result
6ALEV131.52	8/6/2007	No	No Toxicity
6ALEV143.86	8/6/2007	No	No Toxicity
6ALEV152.46	8/6/2007	Yes	*Ceriodaphnia dubia* Chronic toxicity

A single toxicity test is not enough to confirm a chronic toxics problem. As noted in the previous sections, sediment toxics sampling does not indicate a problem with a particular toxic parameter. The finding of chronic toxicity at station 6ALEV152.46 is not surprising given the number of homes that discharge household wastewater directly to the stream. The presence of household cleaners and other constituents in these discharges could cause toxicity problems in the stream. These discharges will be addressed by an *E. coli* TMDL for Levisa Fork being developed concurrently (Chapters 2 through 5). Therefore, because of the chronic toxic result at 6ALEV152.46, toxicity is considered a possible stressor.

7.4 Most Probable Stressor

Table 7.4 Probable stressors in Levisa Fork.

Parameter	Location in Document
Sediment	Section 7.4.1

7.4.1 Sediment

Total suspended solids (TSS) concentrations exceeded the 90th percentile screening value (30 mg/L) in 21%, 18% and 18% of samples collected at the three VADEQ ambient monitoring stations 6ALEV131.52, 6ALEV143.80 and 6ALEV152.46, respectively (Figures 7.46, 7.47 and 7.48). The highest concentration recorded in the dataset was 1,165 mg/L in November 2003 at station 6ALEV131.52. Clearly excessive solids are a problem in Levisa Fork.

The habitat data indicates marginal Embeddedness and Pool Sediment scores at benthic monitoring stations 6ALEV130.29 and 6ALEV143.80. Embeddedness and Pool Sediment scores were in the sub-optimal category at benthic monitoring station 6ALEV152.46, but the Bank Stability habitat metric scores were marginal indicating severe stream bank erosion, which contributes to sediment in Levisa Fork. Based on the high total suspended solids concentrations and Embeddedness and Pool Sediment habitat scores, sediment is considered a probable stressor in Levisa Fork. Modeling and subsequent allocations will focus on total sediment delivery (metric tons per year).

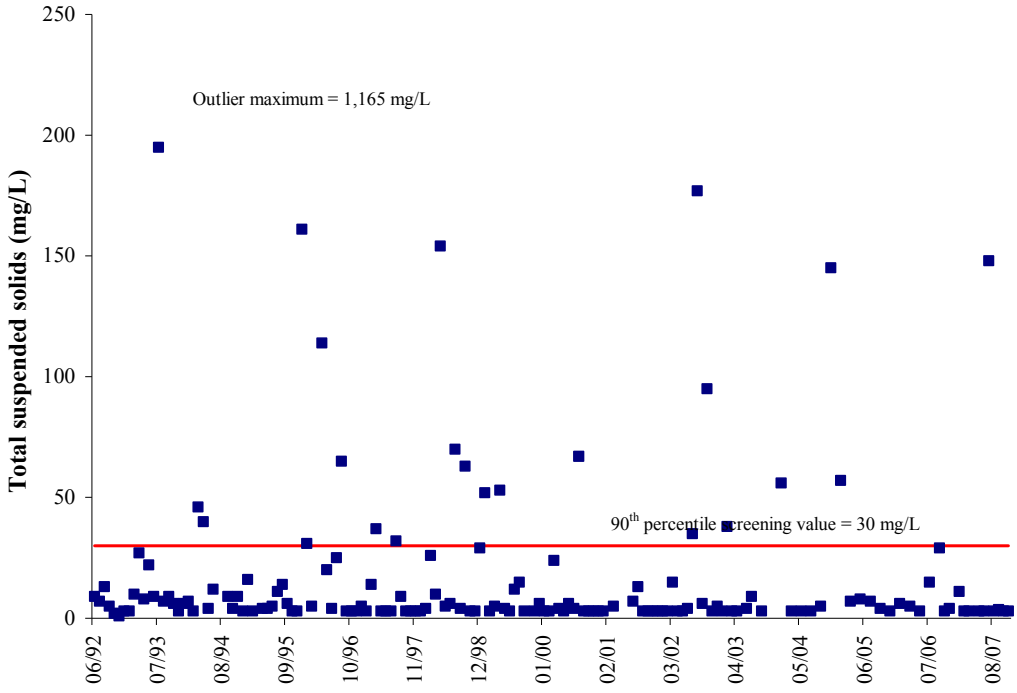

Figure 7.46 TSS concentrations at VADEQ station 6ALEV131.52 on Levisa Fork.

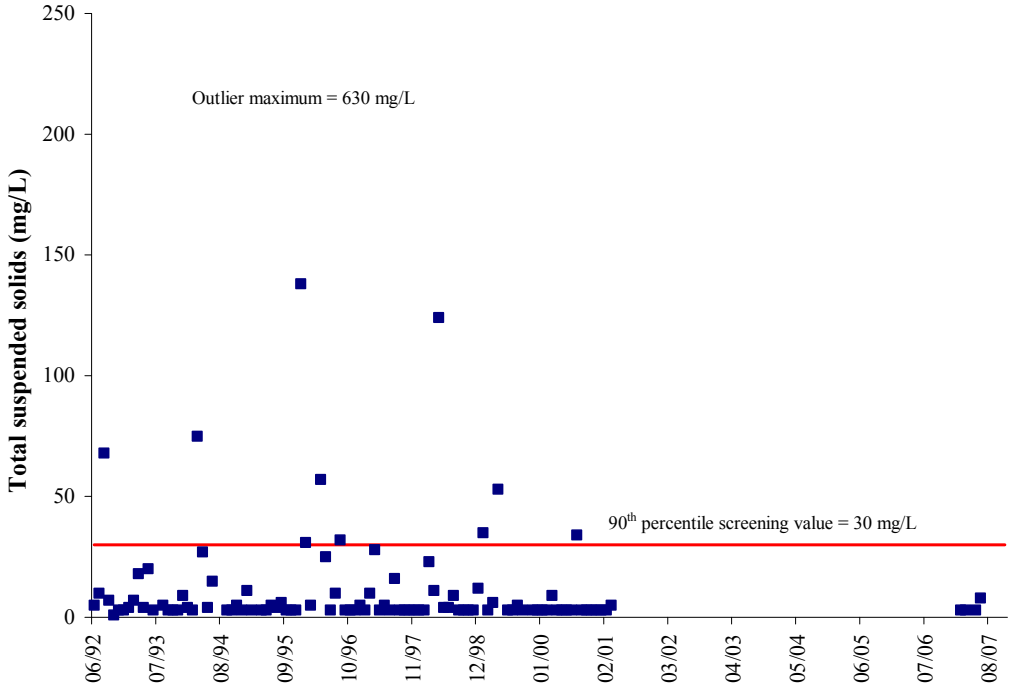

Figure 7.47 TSS concentrations at 6ALEV143.86 on Levisa Fork.

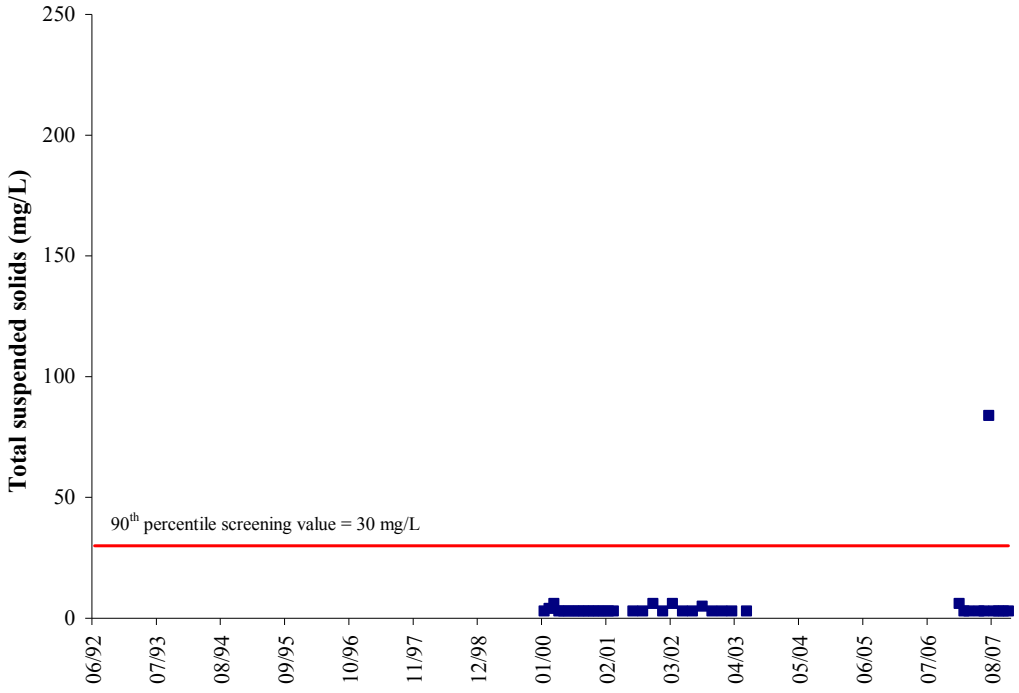

Figure 7.48 TSS concentrations at 6ALEV152.46 on Levisa Fork.

8. BENTHIC TMDL ENDPOINT: STRESSOR IDENTIFICATION – SLATE CREEK

8.1 Stressor Identification – Slate Creek

Slate Creek begins in northeastern portion of Buchanan County and flows southwest to its confluence with Levisa Fork at Grundy, Virginia. The impaired segment extends from Slate Creek's confluence with Upper Rockhouse Branch downstream to the Levisa Fork confluence (9.1 stream miles).

The stressor analysis procedure for Slate Creek was the same as the one used for Levisa Fork, described in Chapter 7 Section 7.1. A list of non-stressors is found in Table 8.1, possible stressors are shown in Table 8.2 and the most probable stressor in is Table 8.3.

8.2 Non-Stressors

Table 8.1 Non-Stressors in Slate Creek.

Parameter	Location in Document
Low dissolved oxygen	Section 8.2.1
Nutrients	Section 8.2.2
Toxics (ammonia, pesticides, tPCBs and polycyclic aromatic hydrocarbons (PAHs))	Section 8.2.3
Metals (Except sediment copper, lead, nickel and zinc)	Section 8.2.4
Temperature	Section 8.2.5
Total chloride	Section 8.2.6

There is always a possibility that conditions in the watershed, available data, and the understanding of the natural processes may change beyond what was revealed in this stressor analysis. If additional monitoring shows that different most probable stressor(s) exist or water quality target(s) are protective of water quality standards, then the Commonwealth will make use of the option to refine the TMDLs for re-submittal to EPA for approval.

8.2.1 Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations were well above the water quality standard VADEQ monitoring station 6ASAT000.26 (Figure 8.1). Low dissolved oxygen is considered a non-stressor.

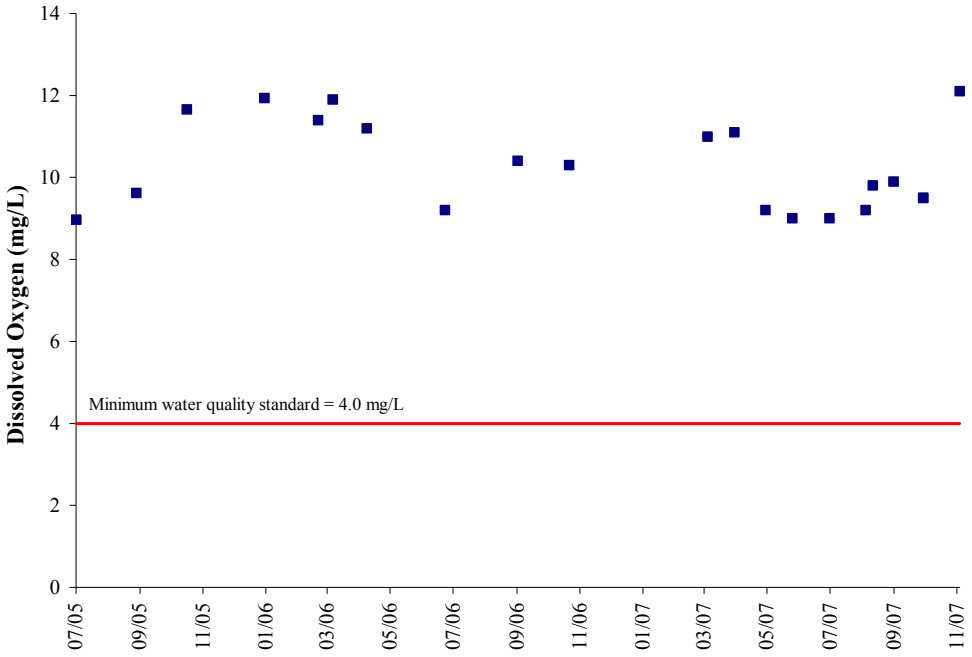

Figure 8.1 Dissolved oxygen concentrations at VADEQ monitoring station 6ASAT000.26.

8.2.2 Nutrients

Total Phosphorus (TP) concentrations were very low at VADEQ monitoring station 6ALEV000.26. No values exceeded the VADEQ screening value of 0.2 mg/L and the maximum value was 0.07 mg/L (Figures 8.2). Nitrate nitrogen concentrations were also low with the maximum value being 0.79 mg/L (Figure 8.3). Nutrients are considered non-stressors.

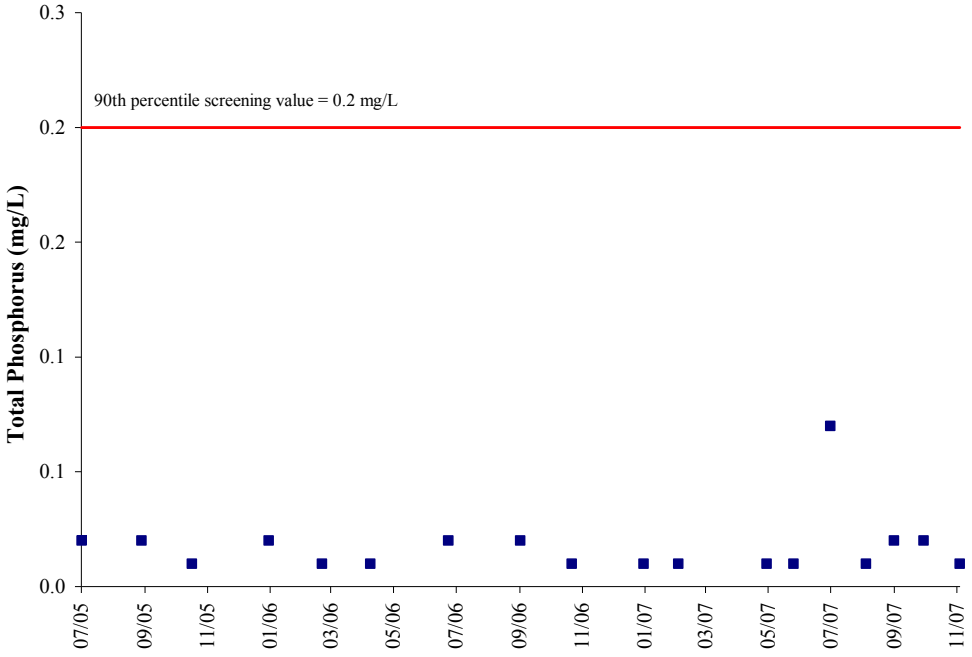

Figure 8.2 Total phosphorus concentrations at VADEQ station 6ASAT000.26.

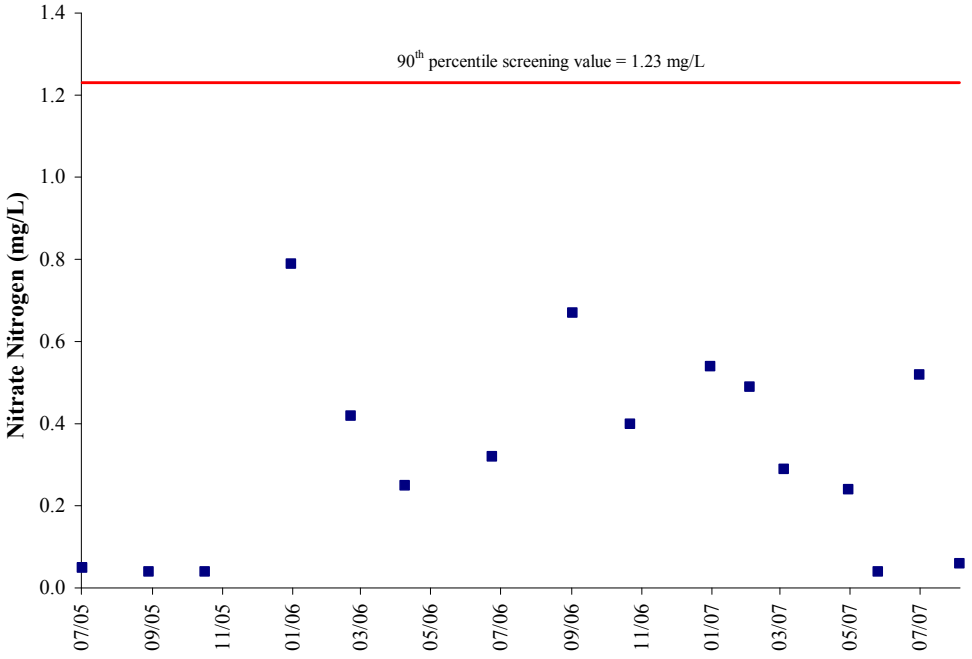

Figure 8.3 Nitrate-nitrogen concentrations at VADEQ station 6ASAT000.26.

8.2.3 Toxics (ammonia, Pesticides, tPCBs and PAHs)

All but two of the ammonia (NH_3/NH_4) samples collected in Slate Creek were below the minimum laboratory level of detection (0.04 mg/L), and both were well below the chronic WQS (chronic and acute ammonia water quality standards vary depending on the pH and temperature of the stream at the time of sample collection).

Sediment organics (PAHs), tPCBs and pesticides were collected at one VADEQ station on Slate Creek in July 1997 and August 2002. Fish tissue concentrations in three species of fish were below VDH levels of concern for pesticides and PAHs. In addition, all sediment PAHs and pesticides concentrations in Slate Creek were below established Consensus Probable Effect Concentrations (PEC) values (MacDonald et al., 2000) (Tables 6.43 and 6.44). Ammonia, pesticides and PAHs are considered non-stressors in Slate Creek.

8.2.4 Metals

This section discusses VADEQ water quality monitoring for metals dissolved in the water column, metals in the sediment, and metals in fish tissue. Sediment metal values were collected on September 4, 2007 and all were below the PEC values (Tables 6.41 and 6.44).

Water column dissolved metals were sampled at VADEQ monitoring station 6ALEV000.26 on September 4, 2007 and all results were below the appropriate water quality standards (Table 6.45). Not all of the metals listed have established VADEQ or USEPA water quality standards.

Based on the results of the dissolved metals and sediment metals data, metals are considered non-stressors in Slate Creek.

8.2.5 Temperature

The maximum temperature standard for Slate Creek is 31.0°C. The maximum temperature recorded at VADEQ monitoring station 6ASAT000.26 on Slate Creek was 25.9°C (Figure 8.4). Temperature is considered a non-stressor in Slate Creek.

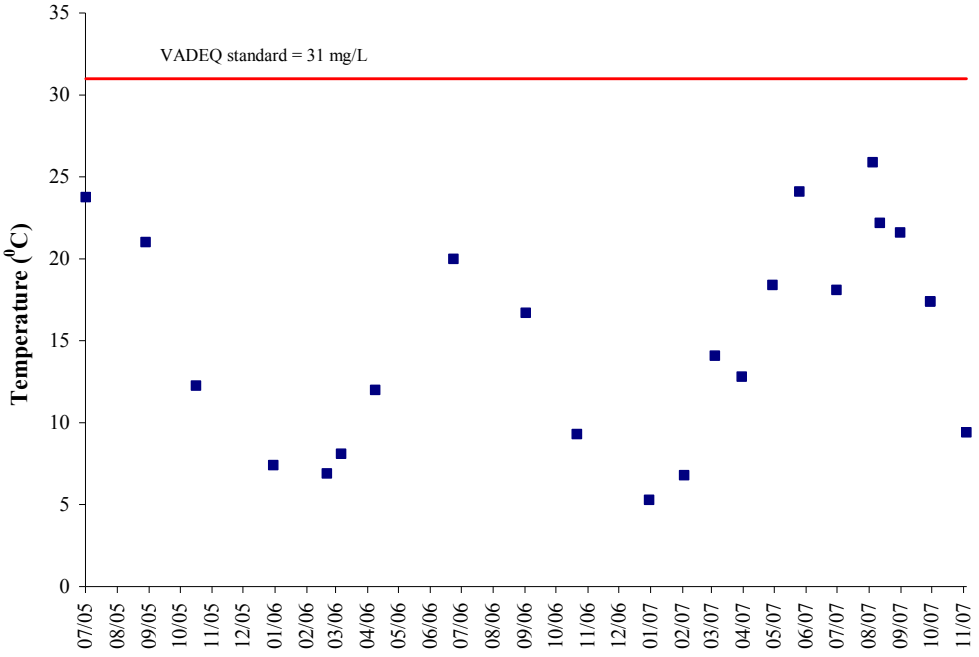

Figure 8.4 Temperature measurements at VADEQ station 6ASAT000.26.

8.2.6 Total chloride

Total chloride concentrations were well below the chronic water quality standard (230 mg/L) at 6ASAT000.26. The maximum concentration was 41.5 mg/L on August 28, 2007 (Figure 8.5). Total chloride is considered a non-stressor in Slate Creek.

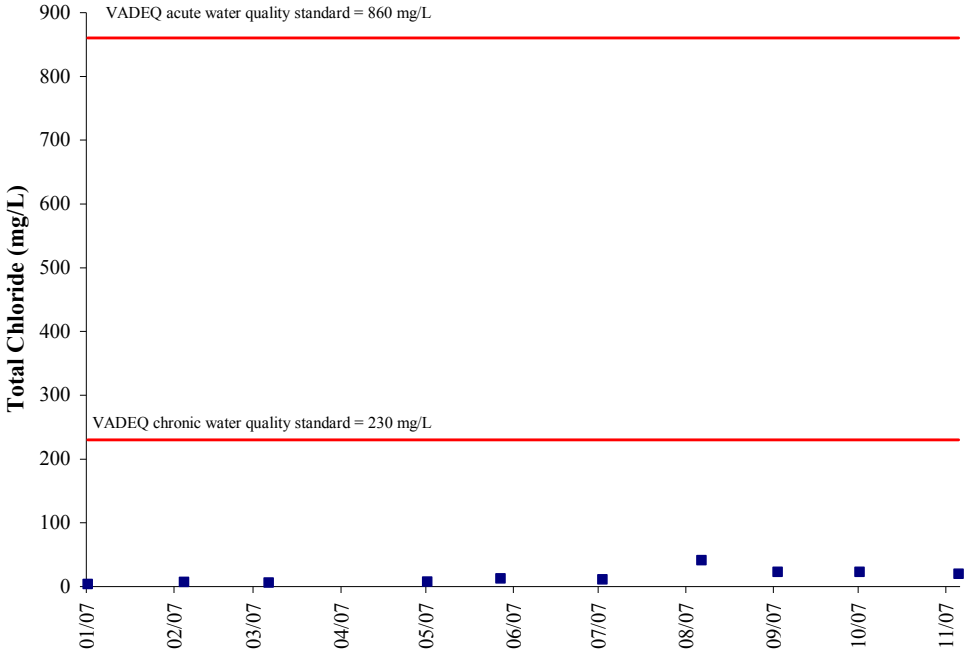

Figure 8.5 Total chloride concentrations at VADEQ station 6ASAT000.26.

8.3 Possible Stressors

Table 8.2 Possible Stressors in Slate Creek.

Parameter	Location in Document
Field pH	Section 8.3.1
Sulfate	Section 8.3.2
Organic matter (total organic solids and dissolved organic solids	Section 8.3.3
Conductivity/total dissolved solids (TDS)	Section 8.3.4

8.3.1 pH

Field pH values were within the minimum and maximum water quality standards with the exception of one maximum value of 9.6 std units at VADEQ monitoring station 6ASAT000.26 (Figure 8.6). Because high pH values have not been persistent or chronic in Slate Creek, high pH is considered a possible stressor.

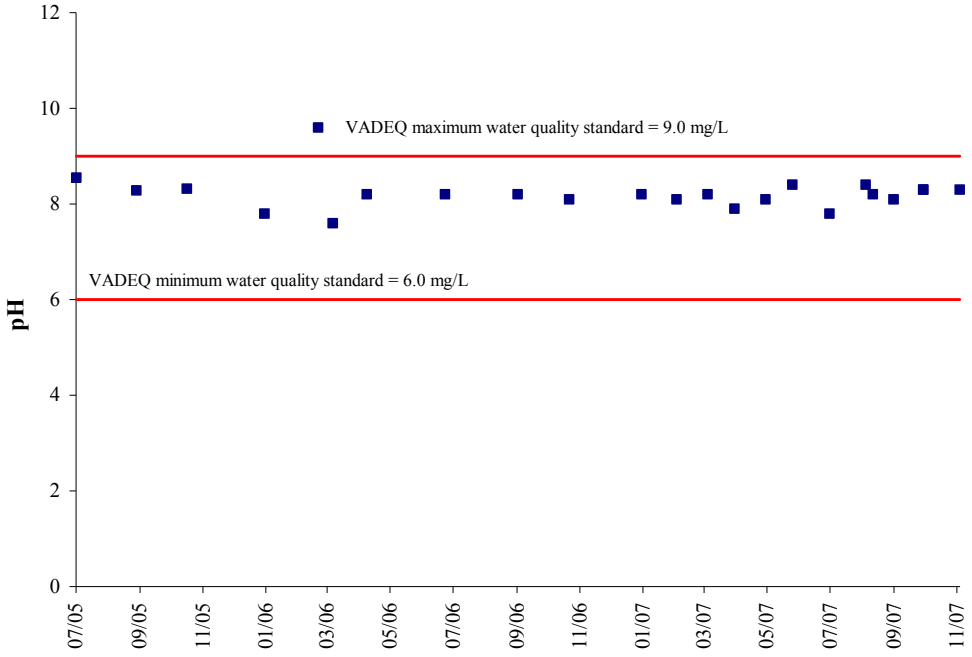

Figure 8.6 Field pH measurements at VADEQ station 6ASAT000.26.

8.3.2 Sulfate

Sulfate concentrations exceeded the 90th percentile screening value (76 mg/L) in more than 10% of the samples collected at VADEQ monitoring station 6ASAT000.26 (Figure 8.7). There is a public water supply water quality standard of 250 mg/L, but this is for taste and odor control and does not apply to aquatic life. The USEPA used sulfate concentrations as an indicator of impaired macroinvertebrate communities in mid-Atlantic highland streams (Klemm et al., 2001). Other studies note that sulfate is a reliable indicator of mining activity and is often linked to depressed benthic health but, by itself, has not been shown to actually cause a reduction in the health of benthic communities (Merricks, 2003). Sulfate is, however, a principle component of total dissolved solids, which have been shown to impair benthic macroinvertebrate communities. Therefore, sulfate is considered a possible stressor.

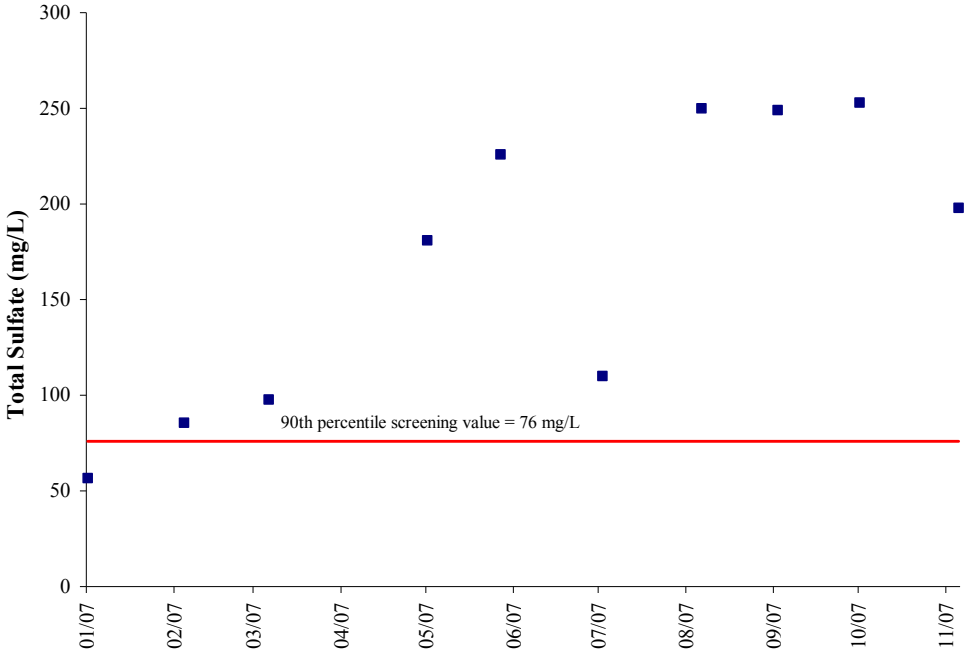

Figure 8.7 Sulfate concentrations at VADEQ station 6ASAT000.26.

8.3.3 Organic matter (Total organic solids and total dissolved organic solids)

Total organic solids (also called total volatile solids, TVS) provide an indication of dissolved and suspended organic matter. Observed TVS concentrations exceeded the 90th percentile screening concentration (63 mg/L) in 50% of the samples collected at VADEQ monitoring station 6ASAT000.26 (Figure 8.8). Total organic dissolved solids provide an indication of dissolved organic matter in a stream. Concentrations of dissolved organic matter also exceeded the 90th percentile concentration (54 mg/L) in 40% of the samples collected at VADEQ monitoring station 6ASAT000.26 (Figure 8.9).

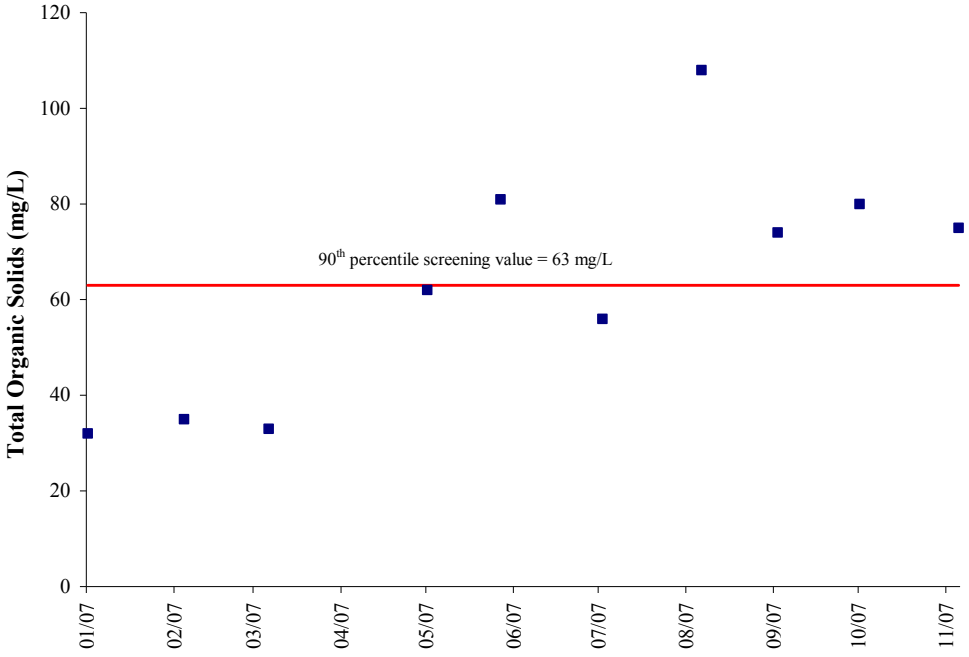

Figure 8.8 Total organic solids concentrations at VADEQ monitoring station 6ASAT000.26.

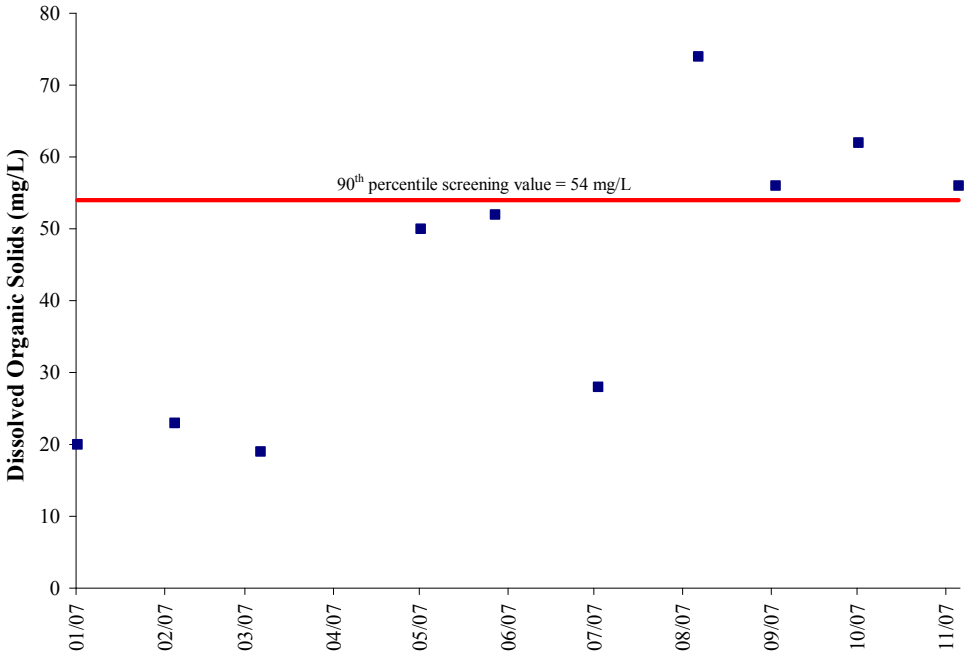

Figure 8.9 Total dissolved organic solids concentrations at VADEQ monitoring station 6ASAT000.26.

The assemblage for all four benthic stations on the Slate Creek from the VADEQ Ecological Data Application System (EDAS) database were examined, and Hydropsychidae (netspinning caddisflies) were not found to be as abundant in Slate Creek as they were in Levisa Fork; however, they were one of the dominant families at VADEQ benthic monitoring station 6ASAT000.26 (19%). The most dominant families were Baetidae, Elimdae and Chrionomidae (A). All three of these organisms are generally facultative to pollution tolerant. For the purposes of this stressor analysis organic matter is considered only a possible stressor because as part of this overall TMDL study an *E. coli* TMDL will be developed for the Slate Creek watershed, which will require significant reductions to the sources of organic matter in the watershed.

8.3.4 Conductivity/Total dissolved solids (TDS)

Conductivity is a measure of the electrical potential in the water based on the ionic charges of the dissolved compounds that are present. TDS is a measure of the actual concentration of the dissolved ions, dissolved metals, minerals, and dissolved organic matter in water. Dissolved ions can include sulfate, calcium carbonate, chloride, etc. Therefore, even though they are two different measurements, there is a direct correlation between conductivity and TDS. In the Slate Creek data set, there was a Pearson Product Moment Correlation (a common statistical measure of the amount of correlation between two different variables) of 0.998 between conductivity and TDS.

High conductivity values have been linked to poor benthic health (Merricks, 2003), and elevated conductivity is common with land disturbance and mine drainages. A recent report on the effects of surface mining on headwater stream biotic integrity in Eastern Kentucky noted that one of the most significant stressors in these watersheds was elevated TDS (Pond, 2004). Elevated TDS concentrations impact pollution sensitive mayflies the most. Figure 8.10 from this report shows that "drastic reductions in mayflies occurred at sites with conductivities generally above 500 μmhos/cm" (Pond, 2004).

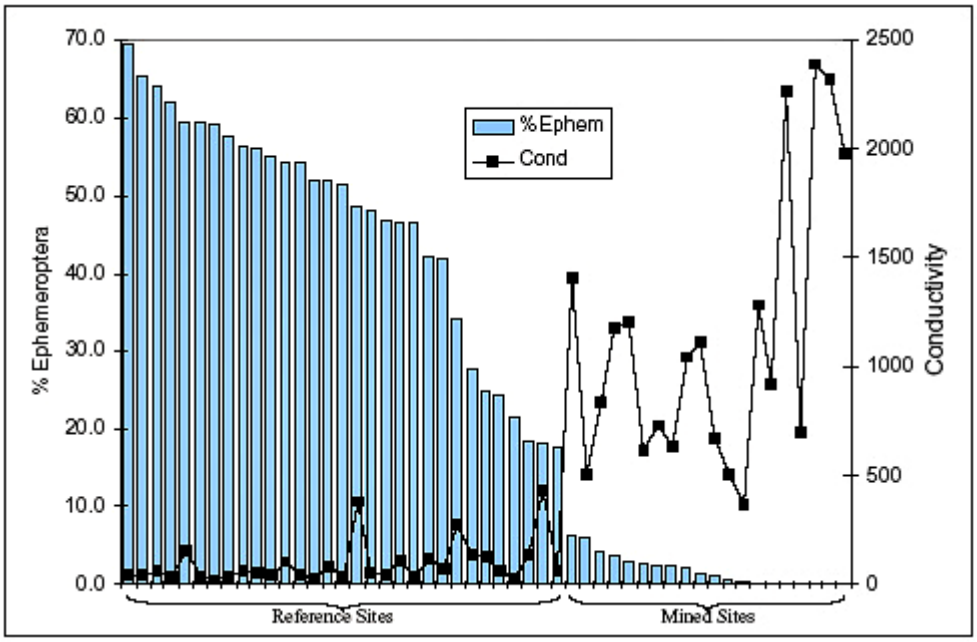

Figure 8.10 The relationship between %Ephemeroptera and conductivity from reference and mined sites (Pond, 2004).

Pond speculated that the increased salinity may irritate the gill structures on mayflies and inhibit the absorption of oxygen, but research has not confirmed this. A typical reference station in this part of the state can be expected to have at least nearly 50% mayflies out of the total assemblage. The results of a VADEQ benthic surveys in Slate Creek at four monitoring stations indicated that sensitive mayflies made up between 1% - 8% of the total benthic assemblage. The members of the more pollution tolerant families (Caenidae, Baetidae, and Isonychiidae) were not included in this calculation. In the development of both the Virginia and West Virginia Stream Condition Indices, the reference streams used had conductivity levels that did not exceed 500 µmhos/cm. In the absence of a Virginia water quality standard, the 90th percentile screening value of 402 µmhos/cm was used. Conductivity values at VADEQ monitoring station 6ASAT000.26 exceeded the 90th percentile screening value in 50% of the measurements (Figure 8.11).

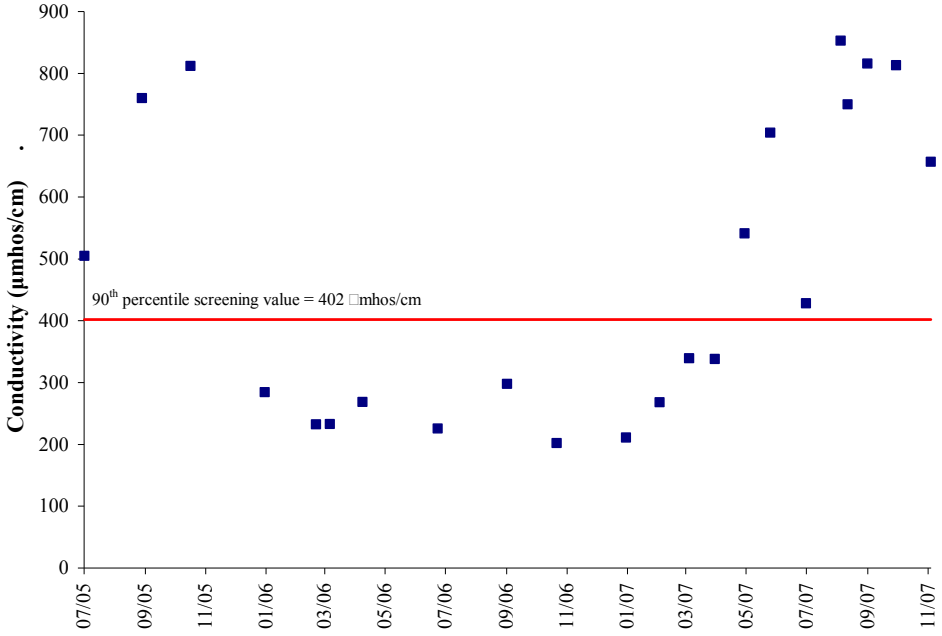

Figure 8.11 Conductivity measurements at VADEQ station 6ASAT000.26.

The TDS 90th percentile screening value was 260 mg/L. TDS concentrations exceeded this value in 47% of the samples at VADEQ monitoring station 6ASAT000.26 (Figure 8.12).

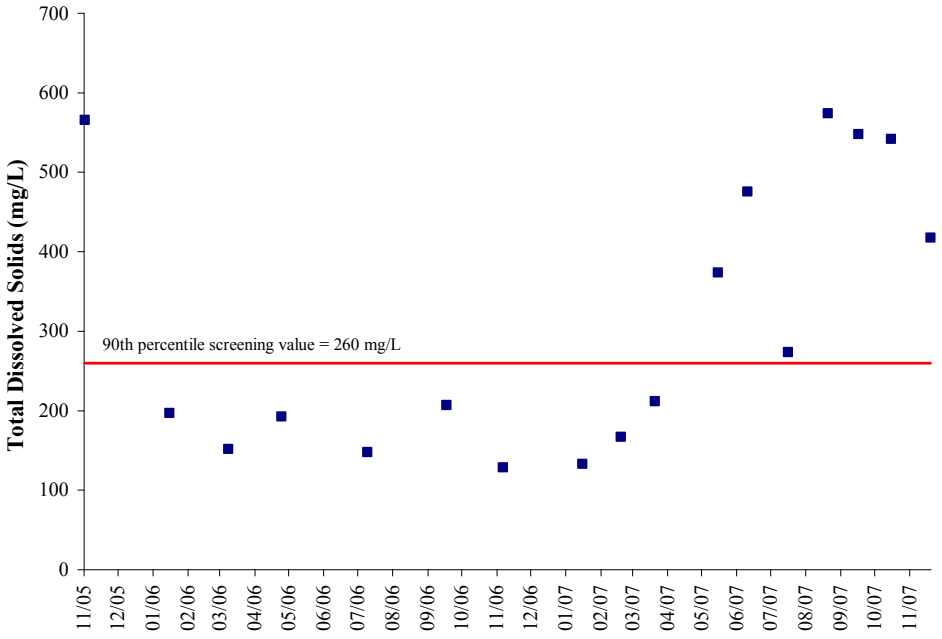

Figure 8.12 TDS concentrations at VADEQ station 6ASAT000.26.

TDS concentrations can be harmful to aquatic organisms without causing death. Aquatic organisms balance water and internal ions through a number of different mechanisms. Therefore, high concentrations and significant changes in TDS over long periods of time can place a lot of stress on the organisms. The resulting chronic stress affects processes such as growth and reproduction. Sudden large spikes in TDS concentration can be fatal. A study of TDS toxicity in a coal-mining watershed in southeastern Ohio found the lowest observed effect concentration (LOEC) on the test organism *Isonychia bicolor* (a species of Mayfly) was 1,066 mg/L (Kennedy, 2002). The author carefully noted that this concentration was specific to the watershed studied, but noted that similar studies with the same test organism and TDS with varying ionic compositions were toxic between 1,018 and 1,783 mg/L (Kennedy, 2002). Kennedy also cited a study that suggested that aquatic organisms should be able to tolerate TDS concentrations up to 1,000 mg/L; however, the test organism used was *Chironomous tentans*, which is considerably more pollution tolerant than *Isonychia bicolor* (Kennedy, 2002). Research also indicates that the likely mechanism(s) of TDS benthic macroinvertebrate mortality is from gill and internal tissue dehydration, salt accumulation and compromised osmoregulatory function. In fact, the rate of change in TDS concentrations may be more toxic to benthic macroinvertebrates than the TDS alone (Kennedy, 2002).

While TDS concentrations are high in Slate Creek, the median value is 212 mg/L at station 6ASAT000.26 and the maximum concentration found was 574 mg/L. Slate Creek would probably benefit from some reduction in conductivity and TDS concentrations; however, for the purposes of this TMDL they will be considered possible stressors.

8.4 Most Probable Stressor

Table 8.3 Probable stressors in Slate Creek.

Parameter	Location in Document
Sediment	Section 8.4.1

8.4.1 Sediment

Total suspended solids (TSS) concentrations exceeded the 90th percentile screening value (30 mg/L) in 11% of the samples at VADEQ monitoring station 6ASAT000.26 (Figure

8.13). The highest concentration recorded in the dataset was 49 mg/L in July 2007 indicating that excessive solids are a periodic problem in the watershed.

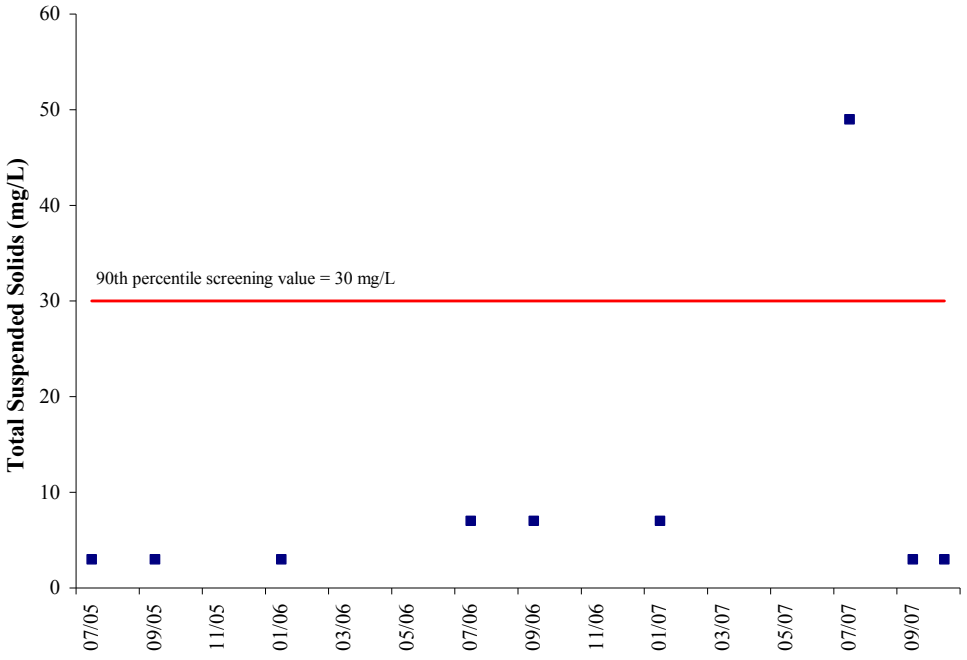

Figure 8.13 Total suspended solids concentrations at VADEQ station 6ASAT000.26.

The benthic macroinvertebrate habitat data indicates marginal Embeddedness and Pool Sediment scores at benthic monitoring stations 6ASAT000.05 and 6ASAT007.71. Pool Sediment scores were also in the marginal category at benthic monitoring station 6ASAT000.26. In addition, the Bank Stability habitat metric score at this monitoring station was marginal indicating stream bank erosion is present, which contributes to sediment in Slate Creek. Based on the high total suspended solids concentrations and Embeddedness and Pool Sediment habitat scores, sediment is considered a probable stressor in Slate Creek. Modeling and subsequent allocations will focus on sediment delivery (tons per year).

9. REFERENCE WATERSHED SELECTIONS

A reference watershed approach was used to estimate the necessary load reductions that are needed to restore a healthy aquatic community and allow Levisa Fork and Slate Creek to achieve their designated uses. This approach is based on selecting a non-impaired watershed that has similar land use, soils, watershed characteristics, area (not to exceed double or not to be less than half the size of the impaired watershed), and located in or near the same ecoregion as the impaired watershed. The modeling process uses load rates or pollutant concentrations 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 establish what reductions are necessary to meet the load rates of the non-impaired watershed.

9.1 Reference Watershed Selection for Levisa Fork

Six potential reference watersheds were selected from similar large watersheds for analyses that would lead to the selection of a reference watershed for Levisa Fork (Figure 9.1). The potential reference watersheds were ranked based on quantitative and qualitative comparisons of watershed attributes. Tables 9.1, 9.2 and 9.3 show Levisa Fork (highlighted green) and the potential reference streams and information used for comparison. The bold values are those that most closely match the value for Levisa Fork.

The Dry Fork watershed is a good choice as the reference watershed for the Levisa Fork watershed due to the similarities in ecoregion location, land use, soil characteristics, and size. The Levisa Fork watershed is completely within the Dissected Appalachian Plateau ecoregion, and the Dry Fork watershed is 96.12% within this region, which is the most out of the six candidate watersheds. This is important as the benthic communities should be comparable to similar order streams in the same ecoregion. Although the acreages of each land use are different as shown in Table 9.1, the percent of the total acres are very similar. Of the major land uses in Levisa Fork, 1% is Barren, 88% is Forest, 4% is Pasture, and 7% is Residential. Dry Fork is quite similar with 1% Barren, 89% Forest, 4% Pasture and 6% Residential. Land use is important because the GWLF model used to simulate sediment movement is influenced significantly by the curve number, which is assigned by land use. The soil and watershed characteristics are all similar between

Levisa Fork and Dry Fork. Also, the Dry Fork watershed meets the size limits for inclusion as a reference for the Levisa Fork watershed. Based on these comparisons and after conferring with state and regional VADEQ personnel, the Dry Fork watershed (highlighted yellow in Tables 9.1, 9.2 and 9.3) was selected as the reference watershed for the Levisa Fork watershed.

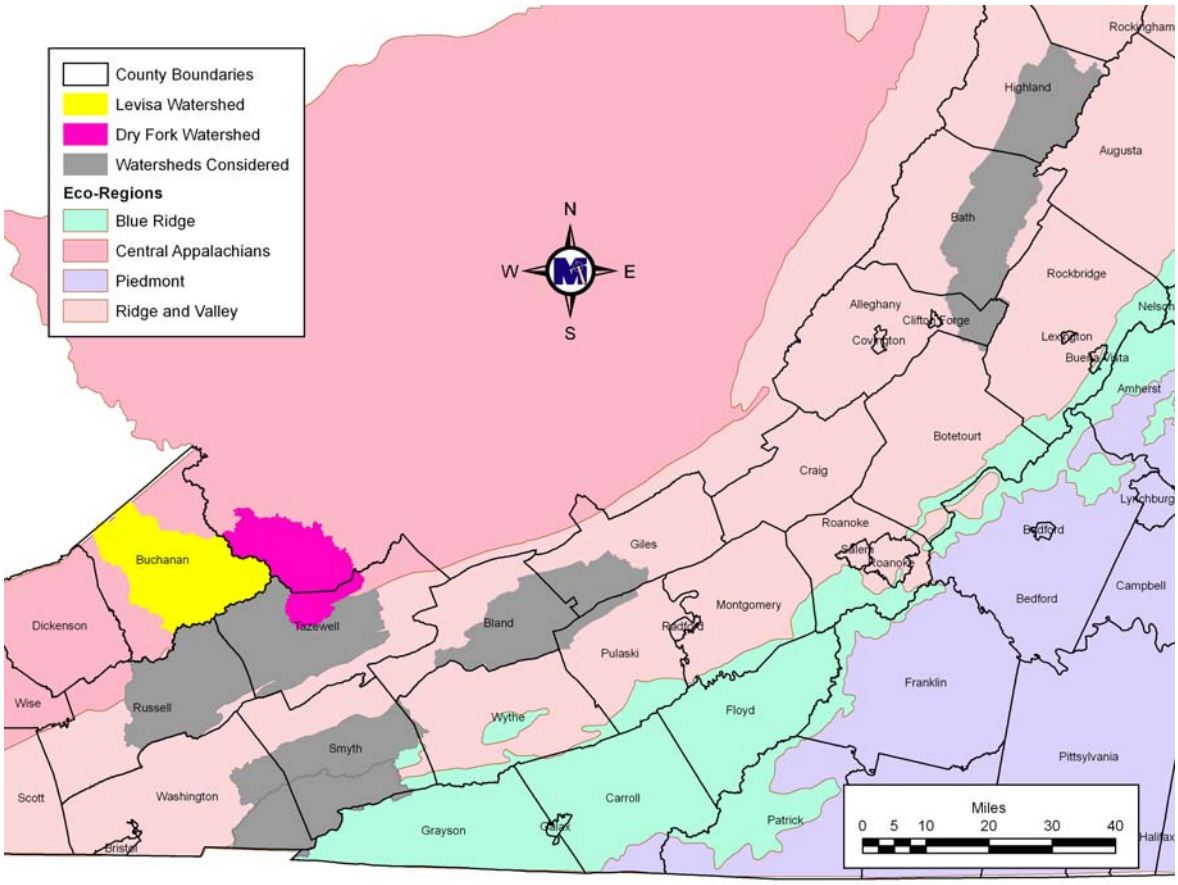

Figure 9.1 Location of selected and potential reference watersheds for Levisa Fork.

Table 9.1 Reference watershed selection for Levisa Fork – Part1.

Watershed Properties	Levisa Fork	Walker Creek	Dry Fork	Cowpasture River	Middle Fork Holston	South Fork Holston	Clinch River
Location:							
County*	Buchanan	Bland, Giles, Pulaski	Tazewell; McDowell, WV	Alleghany, Bath, Botetourt, Highland, Rockbridge	Smyth, Washington, Wythe	Grayson; Smyth; Washington; Johnson, NC	Russell, Tazewell
HUC	5070202	5050002	5070201	2080201	6010102	6010102	6010205
Land use:**							
Barren	1,140.22	104.47	859.96	55.87	83.43	125.70	910.43
Commercial	90.52	14.53	10.24	18,840.05	313.97	3.72	428.49
Crops	37.14	392.55	12.85	1,043.01	908.38	921.60	1,183.24
Forest	172,486	145,874	119,563	258,681	70,463	148,252	207,033
Pasture	8,109	39,221	5,019	23,444	48,729	37,742	102,829
Residential	14,366	5,238	8,143	10,555	11,091	6,635	26,582
Water	195.71	24.39	80.82	1,153.63	79.14	11.17	266.11
Wetlands	2.45	196.46	18.44	12.85	0.00	207.08	108.94
Total Acres	196,427	191,065	133,707	313,785	131,668	**193,897**	339,342
Watershed Characteristics:							
Stream Order	5	**5**	3	4	**5**	6	6
Slope (degrees)	21.71	12.85	19.92	13.9	11.27	13.94	13.72
Aspect (degrees)	188.23	186.81	**188.03**	181.69	190.02	195.83	189.52
Soil Characteristics:							
Hydrologic Group (avg)	2.660	2.533	**2.676**	2.939	2.479	2.473	2.394
Erodibility Kf factor	0.225	0.238	0.231	0.231	0.247	0.235	0.254
Available Water Capacity	0.091	0.100	**0.091**	0.092	0.112	0.112	0.119

*Virginia counties unless otherwise noted; **All land use is MRLC 2001 data only

Table 9.2 Reference watershed selection for Levisa Fork – Part2.

Watershed Properties	Levisa Fork	Walker Creek	Dry Fork	Cowpasture River	Middle Fork Holston	South Fork Holston	Clinch River
EcoRegion:				**% of area**			
Northern Sandstone Ridges				47.58			
Northern Dissected Ridges and Knobs				13.89			
Northern Shale Valleys				38.52			
Southern Sandstone Ridges		56.8		0.01	6.03		13.12
Southern Shale Valleys		11.35			8.03	6.24	6.16
Southern Limestone/Dolomite Valleys and Low Rolling Hills		31.85	3.88		54.06	28.88	43.45
New River Plateau						6.68	
Southern Sedimentary Ridges					13.38	51.31	
Southern Crystalline Ridges and Mountains						6.39	
Limestone Valleys and Coves						0.5	
Southern Dissected Ridges and Knobs					18.5		11.71
Dissected Appalachian Plateau	100		**96.12**				**25.56**

Table 9.3 Reference watershed selection for Levisa Fork – Part3.

Watershed Properties	Levisa Fork	Walker Creek	Dry Fork	Cowpasture River	Middle Fork Holston	South Fork Holston	Clinch River
Soil Type:				**% of area**			
VA001		38.99		33.92	28.07	10.09	2.8
VA003		26.15	1.29	0.01	46.07	16.78	40.49
VA004				0.16	2.96	2.89	1.8
VA005		9.49		51.34	7.25	1.63	2.25
VA007						0.03	
VA016	13.92	**25.38**		**12.52**	**8.01**	**8.33**	**0.12**
VA017					7.64	3.61	6.45
VA018						8.53	
VA047							20.38
VA056							
VA057	1						
VA059						1.05	
VA060						14.24	
VA072				2.05			
VA076			8.04				1.24
VA077			13.57				5.87
VA078	84.93		**0.4**				**18.6**
WV04			6.15				
WV05			70.55				
KY801	0.15						
NC097						0.08	
TN175						2.51	
TN183						2.18	
TN193						3.01	
TN194						4.9	
TN208						19.2	
TN224						0.94	

9.2 Reference Watershed Selection for Slate Creek

Six potential reference watersheds were selected from similar large watersheds for analyses that would lead to the selection of a reference watershed for Slate Creek (Figure 9.2). The potential reference watersheds were ranked based on quantitative and qualitative comparisons of watershed attributes. Tables 9.4 and 9.5 show Slate Creek (highlighted green) and the potential reference streams and information used for comparison. The bold values are those that most closely match the value for Slate Creek.

The Lick Creek watershed is a good choice as the reference watershed for the Slate Creek watershed due to the similarities in slope, soil characteristics, and size. The slope of a watershed is an important factor when evaluating sediment loads because a higher slope has the potential for higher erosion rates. Lick Creek has an average slope of 20.2% and Slate Creek has an average slope of 22.1%. The soil and watershed characteristics are all similar between Slate Creek and Lick Creek. The erodibility factor of the Lick Creek watershed is the most similar to the Slate Creek watershed. Also, the Lick Creek watershed meets the size limits for inclusion as a reference for the Slate Creek watershed. Based on these comparisons and after conferring with state and regional VADEQ personnel, the Lick Creek watershed (highlighted yellow in Tables 9.4 and 9.5) was selected as the reference watershed for the Slate Creek watershed.

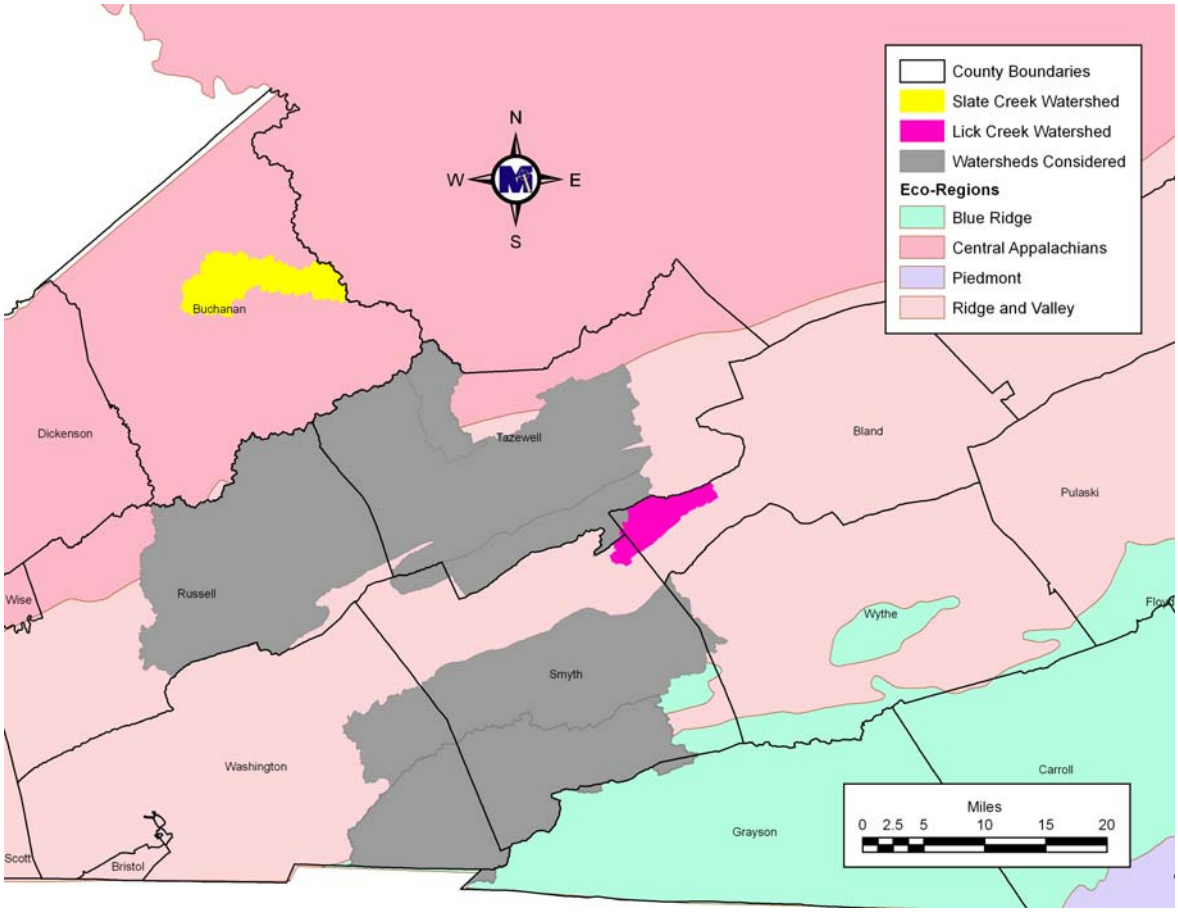

Figure 9.2 Location of selected and potential reference watersheds for Slate Creek.

Table 9.4 Reference watershed selection for Slate Creek – Part1.

Watershed Properties	Slate	Middle Fork Holston River	Clinch River	Laurel Creek	Lick Creek	South Fork Holston River	Indian Creek
Location:							
County*	Buchanan	Smyth, Washington, Wythe	Russell, Tazewell	Tazewell, Smyth	Bland, Smyth, Tazewell	Smyth; Johnson, NC; Washington; Grayson	Tazewell
HUC	5070202	06010102	06010206	06010101	06010101	06010102	06010206
Land use:**							
Barren	16.76	103.41	350.49	16.46	32.02	187.47	167.24
Commercial	112.85	591.34	316.24	1.11	0.00	163.23	0.89
Crops	0.00	390.52	614.24	403.86	95.41	247.52	406.53
Forest	23,720.59	36,055.65	11,728.85	33,630.48	14,434.00	40,237.02	19,081.06
Pasture	474.86		9,594.35	2,887.73	188.36	6,803.80	1,649.47
Residential	1,798.69		596.01	2.45		663.84	54.04
Water		8.01	38.25	4.67	6.01	4.89	13.79
Wetlands		32.69	22.91	63.16	14.90	20.24	14.01
Total Acres	*26,123.75*	*37,181.61*	***23,261.33***	*37,009.92*	*14,770.70*	*48,328.02*	*21,387.02*
Watershed Characteristics:							
Stream Order	3	3	3	3	3	3	3
Slope (degrees)	22.11	14.78	14.28	18.07	**20.18**	15.66	17.08
Aspect (degrees)	189.85	**192.69**	201.25	184.31	186.85	196.79	183.60
Soil Characteristics:							
Hydrologic Group (avg)	2.68	**2.70**	2.35	2.60	2.80	2.46	2.53
Erodibility Kf factor	0.22	0.23	0.25	0.21	**0.22**	0.23	0.27
Available Water Capacity	0.09	0.09	0.12	**0.09**	0.07	0.10	0.11

*Virginia counties unless otherwise noted; **All land use is MRLC 2001 data only

Table 9.5 Reference watershed selection for Slate Creek – Part2.

Watershed Properties	Slate	Middle Fork Holston River	Clinch River	Laurel Creek	Lick Creek	South Fork Holston River	Indian Creek
EcoRegion:				**% of area**			
Cumberland Mountains			3.39				68.22
Dissected Appalachian Plateau	100.00						
Southern Dissected Ridges and Knobs		23.51		0.53			
Southern Igneous Ridges and Mountains		30.25	70.36			20.63	31.78
Southern Limestone/Dolomite Valleys and Low		6.36	26.25	99.47	100.00		
Southern Sandstone Ridges		71.83				71.83	
Southern Sedimentary Ridges		20.17				7.51	
Soil Type:				**% of area**			
TN134		26.05	3.86	22.05	84.24	32.74	
TN151		29.96	63.44			11.87	24.07
TN164				13.47	3.30	6.97	0.65
VA001		10.92	1.86	60.07	12.46	6.57	
VA004		22.75		3.98		24.29	
VA005		10.33				4.32	
VA006						13.25	
VA016	7.57		**27.26**	**0.42**			
VA054			3.59				5.98
VA055							65.39
VA056							3.91
VA076							
VA078	92.43						
WV002							

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10. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT- SEDIMENT

10.1 Modeling Framework Selection - GWLF

A reference watershed approach was used in this study to develop a benthic TMDL for sediment for the Levisa Fork and Slate Creek watersheds. As noted in Chapter 6 and 7, sediment was identified as a probable stressor for these streams. A watershed model was used to simulate sediment loads from potential sources in these watersheds and in the reference watersheds. The model used in this study was the *Visual Basic*™ version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. 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 the reference watershed. The TMDL was then developed for the impaired watershed based on these endpoints and the results from load allocation scenarios. Parameters are described in the Glossary.

GWLF is a continuous simulation, spatially lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from 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. Land use 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 (USLE) (Schwab et al., 1981; 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 was based on a water year starting in October and ending in September. The transport file contains input data related to hydrology and sediment transport. The nutrient file contains nutrient values for the various land uses, point sources, and septic system types, and also urban sediment buildup rates.

10.2 GWLF 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. The watershed boundary for the Slate Creek and Levisa Fork drainage areas were the same used for the HSPF modeling (Chapter 4). Subwatersheds are not required to run the GWLF model. For the sediment TMDL development, the total area for the reference watersheds were equated to the area of impaired watersheds. To accomplish this, the area of land use categories in reference watershed was proportionately increased based on the percentage land use distribution. As a result, the watershed area for reference creek was increased to be equal to the watershed area of the impaired watersheds.

The GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept to estimate runoff and sediment from different pervious areas (HUs) in the watershed (Li, 1975; England, 1970). In the GWLF model, the nonpoint source load calculation for sediment is affected by land use activity (*e.g.,* farming practices), topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather. The model uses land use 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 land use 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 effect of varying soil-topographic conditions by land use entities. A description of model parameters is given in the Glossary and a description of how parameters and other data were calculated and/or assembled is below.

10.2.1 Sediment Source Assessment

Three source areas were identified as the primary contributors to sediment loading in Slate Creek and Levisa Fork 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 process. This section describes predominant sediment source areas, model parameters, and input data needed to simulate sediment loads.

10.2.1.1 Surface Runoff

During runoff events (natural rainfall or irrigation), sediment is transported to streams from pervious land areas (*e.g.,* agricultural fields, lawns, forest.). 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 (*e.g.,* along stream edge, uncontrolled access to streams), forest harvesting, and land disturbance due to mining and 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. The magnitude of sediment loading from this source is affected by various factors (*e.g.,* the deposition from wind erosion and vehicular traffic).

10.2.1.2 Channel and Streambank Erosion

An increase in impervious land without appropriate stormwater control increases runoff volume and peaks, which leads to greater channel erosion potential. 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, 1989; Kaufman and Kruger, 1984). Increasing the bank full width decreases

stream depth, increases sediment, and adversely affects aquatic habitat (USDI, 1998). Management practices that allow mowing, paving, building or material storage up to the edge of a stream or bank cause instability also. These practices do not allow natural stream migration along the floodplain and allow room for flood waters to dissipate. This makes banks and stream segments unstable and erosion from banks more prominent.

10.2.1.3 TSS Point Sources

Sediment loads from permitted wastewater, industrial, and construction stormwater dischargers, and mining operations are included in the WLA component of the TMDL, in compliance with 40 CFR§130.2(h). Fine sediments are included in TSS loads that are permitted for various facilities, industrial and construction stormwater, and VPDES permits within the Slate Creek and Levisa Fork watersheds. There are five types of discharges currently permitted within the Levisa Fork watershed: domestic sewage treatment permits, VPDES permits, construction stormwater permits, industrial stormwater permits, a concrete facility permit, carwash permits, and many DMME coal mining operation permits (Figure 3.2). There are no MS4 permits located in the Slate Creek and Levisa Fork watershed.

The TSS loading from uncontrolled discharges (straight pipes) was accounted for in the sediment TMDL. A TSS concentration from human waste was estimated as 320 mg/L (Lloyd, 2004) at 75 gal of waste water per day per person.

The existing annual load for active mining areas was calculated by multiplying the average annual runoff volume from active mining lands in permitted areas by the runoff-weighted TSS concentration from the active mining areas.

10.2.2 Sediment Source Representation – Input Requirements

As described in Section 10.2, the GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. The following sections describe required inputs for the GWLF program.

10.2.2.1 Streamflow and Weather data

Daily precipitation data was available within the Levisa Fork watershed at the Grundy NCDC Coop station #443640. Missing temperature and precipitation data were filled with values from the Hurley 4S NCDC Coop station #444180 and Richlands NCDC Coop station #447174.

Daily precipitation and temperature data was available for the Lick Creek and Dry Fork watersheds at the Burkes Garden NCDC Coop station #441209.

10.2.2.2 Land use and Land cover

Land use areas were estimated as described in Section 3.1. Land use distributions for Levisa Fork and the Slate Creek are given in Table 10.1 and 10.2. Land use acreage for the reference watersheds were adjusted up by the ratio of impaired watershed to reference watershed maintaining the original land use distribution. These areas were used for modeling sediment. The values in Table 10.1 for Levisa Fork do not include the Slate Creek drainage area.

Table 10.1 Land use areas used in the GWLF model for the Levisa Fork and area-adjusted Dry Fork watersheds.

Sediment Source	Levisa Fork - Slate Creek - Bull Creek (ha)[1]	Reference Watershed: Dry Fork (ha)	Reference Watershed: Area Adjusted Dry Fork (ha)
Pervious Area:			
Active Gas Well	1,863.55	0.00	0.00
Active Mining	1,017.38	274.51	332.48
AML	3,388.24	1,902.19	2,303.87
Barren	5.83	37.96	45.98
Developed	588.62	249.03	301.62
Disturbed Forest	1,211.98	1,065.79	1,290.85
Forest	50,202.98	44,147.64	53,470.08
Hay	181.31	993.96	1,203.85
Open Water	868.14	567.37	687.18
Pasture	1,448.68	1,494.00	1,809.48
Reclaimed Mine	614.23	521.79	631.97
Residential	3,215.77	2,447.92	2,964.84
Row Crop - High till	9.61	3.37	4.08
Row Crop - Low till	0.00	1.45	1.76
Impervious Area:			
Active Mining	443.00	117.65	142.49
Developed	178.73	62.26	75.41
Residential	357.31	271.99	329.42
Watershed Total	**65,595.36**	**54,158.88**	**65,595.36**

[1] 1ha = 2.47 ac

Table 10.2 Land use areas used in the GWLF model for the Slate Creek and area-adjusted Lick Creek watersheds.

Sediment Source	Slate Creek (ha)[1]	Reference Watershed Lick Creek (ha)	Reference Watershed Area Adjusted Lick Creek (ha)
Pervious Area:			
Active Gas Well	25.54	0.00	0.00
Active Mining	25.30	0.00	0.00
AML	458.74	0.00	0.00
Barren	0.00	11.93	21.08
Developed	34.60	0.00	0.00
Disturbed Forest	116.47	9.10	16.08
Forest	8,880.09	5,755.80	10,170.07
Hay	20.36	35.09	62.00
Open Water	114.60	47.03	83.10
Pasture	162.62	47.02	83.08
Reclaimed Mine	21.12	0.00	0.00
Residential	616.73	59.62	105.34
Row Crop - High till	0.00	1.95	3.45
Row Crop - Low till	0.00	4.69	8.29
Impervious Area:			
Active Mining	10.84	0.00	0.00
Developed	8.65	0.00	0.00
Residential	68.53	6.62	11.70
Watershed Total	**10,564.19**	**5,978.85**	**10,564.19**

[1] 1ha = 2.47 ac

10.2.2.3 Sediment Parameters

Sediment parameters include USLE parameters erodibility factor (K), length of slope (LS), cover crop factor (C), and practice factor (P), sediment delivery ratio, and a buildup and loss functions for impervious surfaces. The product of the USLE parameters, KLSCP, is entered as input to GWLF. Soils data for the watersheds were obtained from the Soil Survey Geographic (SSURGO) database for Virginia (SCS, 2004). The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field. The area-weighted K-factor by land use category was calculated using GIS procedures. Land slope was calculated from USGS National Elevation Dataset data using GIS techniques. The length of slope was based on VirGIS procedures given in

VirGIS Interim Reports (*e.g.,* Shanholtz et al., 1988). The area-weighted LS factor was calculated for each land use category using procedures recommended by Wischmeier and Smith (1978). The weighted C-factor for each land use category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992) and Kleene, 1995. Where multiple land use 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. The practice factor (P) was set at 1.0 for all land uses indicating no best management practices were being used.

10.2.2.4 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). The value used for the Levisa Fork and Dry Fork watersheds was 0.067. The Slate Creek Lick Creek watersheds had a SDR of 0.119.

10.2.2.5 SCS Runoff Curve Number

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

10.2.2.6 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, fraction of developed land, mean

stream depth, and watershed area. The animal density was calculated by dividing the number of animal units (beef and dairy) by watershed area in acres. The total length of the natural stream channel was estimated from USGS NHD hydrography coverage using GIS techniques. The mean stream depth was estimated as a function of watershed area.

10.2.2.7 Evapo-transpiration Cover Coefficients

Evapotranspiration (ET) cover coefficients were entered by month. Monthly ET cover coefficients were assigned each land use/land cover condition following procedures outlined in Novotny and Chesters (1981) and GWLF guidance. Area-weighted ET cover coefficients were then calculated for each sediment source class. These values were then adjusted during hydrology calibration.

10.2.2.8 TSS Permitted and Direct Sources

Construction stormwater permitted loads were calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/l. The modeled runoff for the construction stormwater discharge was estimated as equal to the annual runoff from the barren area. The modeled runoff for the industrial stormwater discharge was estimated as equal to the annual runoff from the developed area. For the construction and industrial permits, the average annual runoff (cm/yr) was multiplied by the permit area (ha), multiplied by the permitted TSS concentration (100 mg/L), and were multiplied by conversion factors to get a permit load in metric tons per year (t/yr). For the domestic wastewater treatment, carwashes, and VPDES permits, the design discharge was multiplied by the permitted TSS concentration and then multiplied by conversion factors to get a permit load in metric tons per year (t/yr). Each of the domestic wastewater treatment (DWT) permits were calculated separately as noted. All DWT permits are listed separately in Table 3.2. All permitted loads are shown in Tables 10.3 and 10.4.

The difference between the existing and allocated loads for the DMME mining permits is a result of the different way of estimating these loads. While the existing TSS concentration was estimated as the flow-weighted concentration from mining permits, the allocated TSS concentration was assumed to be the permitted concentration of 70 mg/L.

Table 10.3 Permitted Sources in the Levisa Fork watershed excluding the Slate Creek and Bull Creek areas.

					Permit	Existing Conditions	Future Conditions
Permit Number	**Abbreviated Name**	**Discharge (MGD)**	**Area (ha)**	**Runoff (cm/yr)**	**Conc. (mg/L)**	**Sediment (t/yr)**	**Sediment (t/yr)**
VAR101038	Grundy Nonstructural Project Site E	NA	25.5	18.4	100	4.69	4.69
VAR104503	Mountaineer 1 Land Clearing	NA	4.65	18.4	100	0.86	0.86
VAR102495	VDOT Lebanon Residency	NA	0.85	18.4	100	0.16	0.16
VAR104799	Grassy Creek Impt. Maint.	NA	1.01	18.4	100	0.19	0.19
VAR050018	Grundy Airport	NA	10.9	41.2	100	4.49	4.49
VAR050059	Excello Oil Company	NA	1.31	41.2	100	0.54	0.54
VAR050102	Excel Mining Systems	NA	1.51	41.2	100	0.62	0.62
VAR051686	Leetown Railsiding	NA	4.21	41.2	100	1.73	1.73
VAG110243	Buchanan County Ready Mix	NA	1.18	41.2	100	0.49	0.49
VAG750020	Vansant Car Wash	0.005	NA	NA	60	0.41	0.41
See Table 3.2	Domestic Wastewater Treatment	0.001	NA	NA	30	0.04 (*35)	0.04 (*35)
VA0050351	Jewell Coke Co. Plants 2 and 3	0.2	NA	NA	50	13.82	13.82
VA0052639	Norfolk & Western Railway Co	0.001	NA	NA	30	0.04	0.04
VA0065536	Island Creek Coal - VP Mine 1 STP	0.02	NA	NA	30	0.83	0.83
VA0065625	Island Creek Coal - VP Mine 8 Deskins STP	0.025	NA	NA	30	1.04	1.04
VA0066907	Consolidation Coal - Buchanan Mine STP	0.02	NA	NA	30	0.83	0.83
VA0068438	Twin Valley High School STP	0.0072	NA	NA	30	0.30	0.3
VA0089907	Mill Branch STP	0.0075	NA	NA	30	0.31	0.31
VA0090239	Buchanan Co. PSA - Deskins STP	0.0032	NA	NA	30	0.13	0.13
VA0090531	Conaway WWTP	2	NA	NA	30	82.95	82.95
various	DMME Mining Permits	NA	2,074.61	varies	70	208.39	418.86
NA	Future Growth	NA	NA	NA	NA	0	194.97
Total						**324.22**	**729.66**

Table 10.4 Permitted Sources in the Slate Creek watershed.

Permit Number	Abbreviated Name	Discharge (MGD)	Area (ha)	Total Runoff (cm/yr)	Permit Conc. (mg/L)	Existing Conditions Sediment (t/yr)	Future Conditions Sediment (t/yr)
VAG750149	Chads Zip In	0.005	NA	NA	60	0.41	0.41
See Table 3.2	Domestic Wastewater Treatment	0.001	NA	NA	30	0.04 (*12)	0.04 (*12)
VA0026999	J M Bevins Elementary	0.006	NA	NA	30	0.25	0.25
various	DMME Mining Permits	NA	57.26	varies	70	0.95	10.63
NA	Future Growth	NA	NA	NA	NA	0	19.67
Total						**2.09**	**31.44**

10.2.3 Selection of Representative Modeling Period - GWLF

As described in Chapter 4, an analysis of historic precipitation and streamflow in Levisa Fork was preformed to select a representative time frame (Figures 4.6 and 4.7 and Table 4.6). The time period chosen was water year 2000 through water year 2003. The GWLF hydrology calibration time period was selected to coincide with the time period used for HSPF modeling, 10/1/2000 to 9/30/2003.

10.3 GWLF Sensitivity Analyses

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 land disturbance, runoff curve number, etc.). Sensitivity analyses were run on the runoff curve number (CN), the combined erosion factor (KLSCP) that combines the effects of soil erodibility, land slope, land cover, and management practices, the recession coefficient, the seepage coefficient, the unsaturated available water capacity (AWC), and the Evapotranspiration (ET) Coefficient (Table 10.5).

Table 10.5 Base parameter values used in GWLF sensitivity analysis.

	Levisa Fork					
Land use	**CN**	**KLSCP**	**Recession Coefficient (1/d)**	**Seepage Coefficient (1/d)**	**Unsaturated Available Water Capacity (AWC)**	**Evapotrans-piration (ET) Coefficient**
Entire Watershed			0.052	0.0534	6.384	0.55 - 0.98
Pervious Area:						
Active Gas Well	83.71	0.005093				
Active Mining	86.79	0.012109				
AML	79.14	0.001707				
Barren	85.03	0.008978				
Developed	68.16	0.000159				
Forest	64.98	0.000043				
Open Water	100.00	0.000000				
Reclaimed Mine	73.65	0.004250				
Residential	68.89	0.000402				
Row Crop - High till	80.32	0.017876				
Disturbed Forest	73.32	0.003410				
Pasture	75.50	0.002204				
Hay	66.44	0.000382				
Impervious Area:						
Active Mining	98.00	0.012109				
Developed	98.00	0.000159				
Residential	98.00	0.000402				

For a given simulation, the model parameters in Table 10.8 were set at the base value except for the parameter being evaluated. The parameters were adjusted individually to -10% and +10% of the base value and then the output values from the base run and the adjusted run were compared. The results in Table 10.6 show that the parameters are directly correlated with runoff volume and sediment load. The relationships show fairly linear responses, with outputs being more sensitive to changes in CN than KLSCP. The hydrology model was most sensitive to changes in curve number values and evapotranspiration (ET) coefficient values. The sediment loading model was most sensitive to changes in curve number values. The results tend to reiterate the need to carefully evaluate conditions in the watershed and follow a systematic protocol in establishing values for model parameters.

Table 10.6 Sensitivity of GWLF model response to changes in selected parameters for Levisa Fork.

Model Parameter	Parameter Change (%)	Total Runoff Volume Percent Change (%)	Total Sediment Load Percent Change (%)
CN	10	6.15	4.59
CN	-10	-5.51	-5.01
KLSCP	10	0.00	0.31
KLSCP	-10	0.00	-0.35
Recession Coefficient	10	3.84	2.09
Recession Coefficient	-10	-4.23	-2.36
Seepage Coefficient	10	-3.80	-2.34
Seepage Coefficient	-10	4.20	2.55
ET Coefficient	10	-5.76	-3.72
ET Coefficient	-10	6.66	4.76
Unsaturated AWC	10	-0.29	-0.21
Unsaturated AWC	-10	0.29	0.29

10.4 GWLF Hydrology Calibration

Although the GWLF model was originally developed for use in ungaged watersheds, calibration was performed to ensure that hydrology was being simulated accurately. This process was performed in order to minimize errors in sediment simulations due to potential gross errors in hydrology. The model's parameters were assigned based on available soils, land use, and topographic data. Parameters that were adjusted during calibration included the recession constant, the monthly evapotranspiration cover coefficients, the unsaturated soil moisture storage, and the seepage coefficient.

10.4.1 Levisa Fork – Impaired Stream

The final GWLF calibration results for Levisa Fork are displayed in Figures 10.1 and 10.2 for the calibration period with statistics showing the accuracy of fit given in the Table 10.7. Model calibrations were considered good for total runoff volume (Table 10.7). Monthly fluctuations were variable but were still reasonable considering the general simplicity of GWLF.

Table 10.7 GWLF flow calibration statistics for Levisa Fork.

Watershed	Simulation Period	R^2 Correlation value	Total Volume Error (Sim-Obs)
Levisa Fork	10/1/2000 – 9/30/2003	0.9183	0.10%

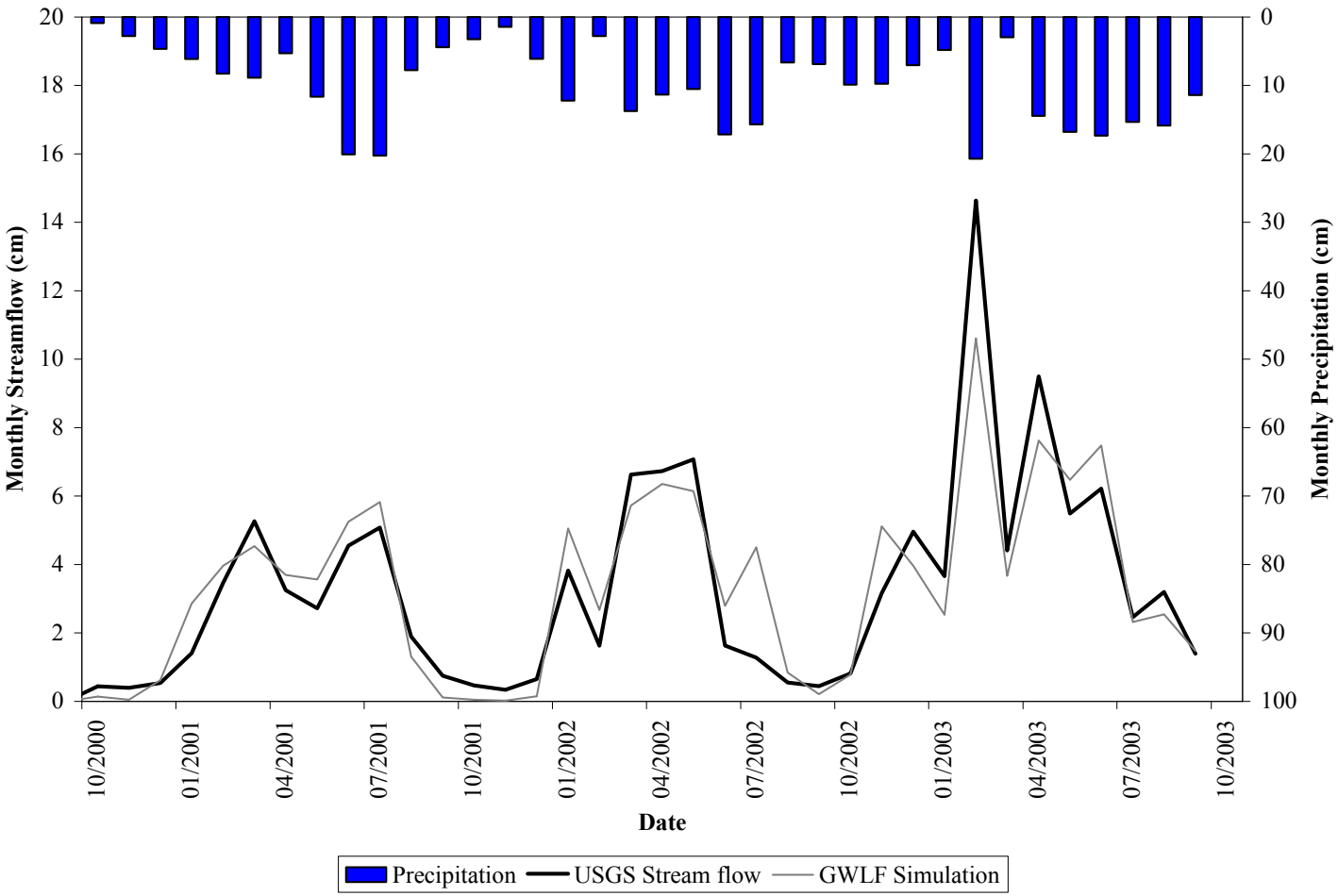

Figure 10.1 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Levisa Fork.

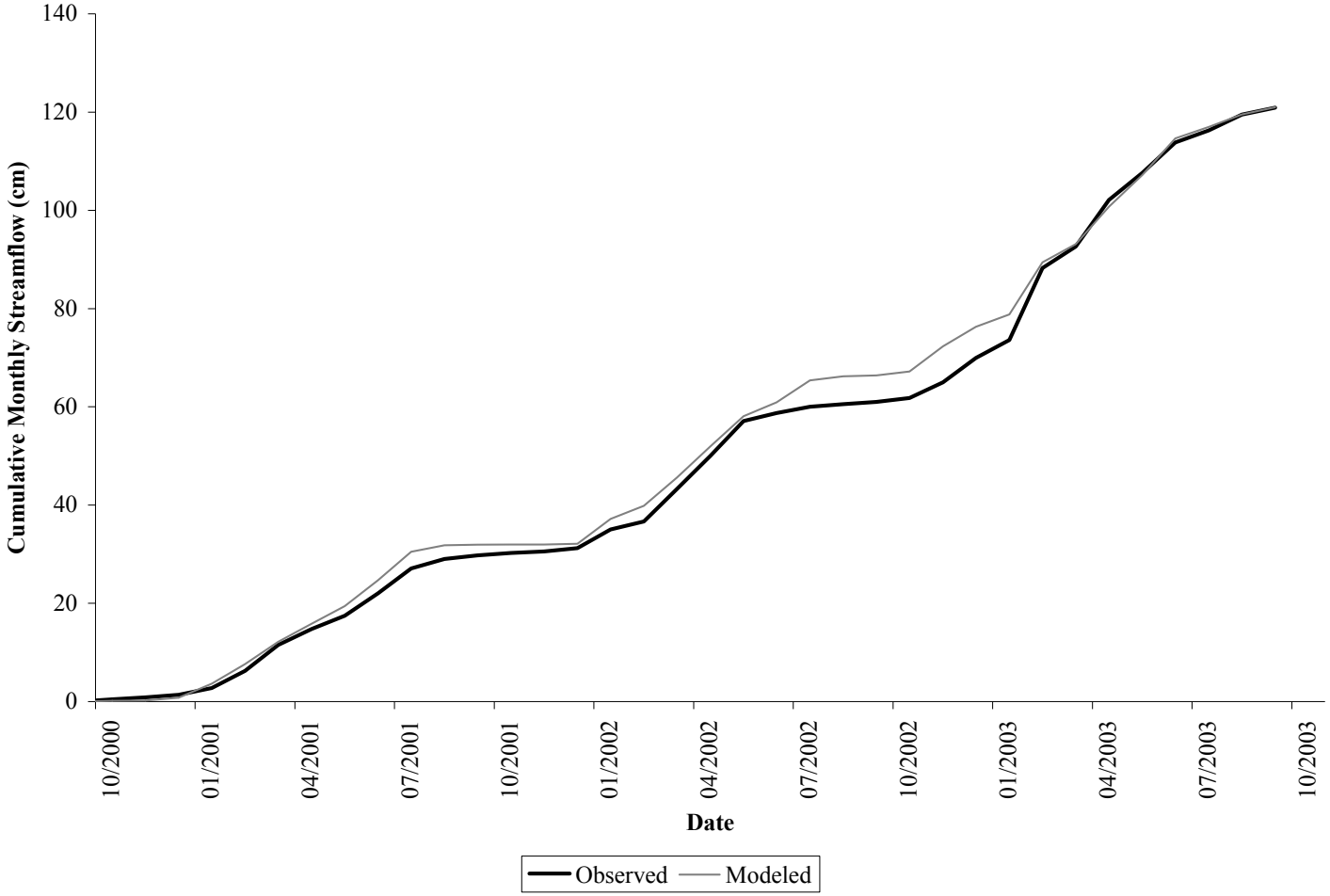

Figure 10.2 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Levisa Fork.

10.4.2 Dry Fork – Reference Stream

The final GWLF calibration results for Dry Fork are displayed in Figures 10.3 and 10.4 for the calibration period with statistics showing the accuracy of fit given in the Table 10.8. Model calibrations were considered good for total runoff volume (Table 10.8). Monthly fluctuations were variable but were still reasonable considering the general simplicity of GWLF.

Table 10.8 GWLF flow calibration statistics for Dry Fork.

Watershed	Simulation Period	R^2 Correlation value	Total Volume Error (Sim-Obs)
Dry Fork	10/1/2000 – 9/30/2003	0.8572	-0.65%

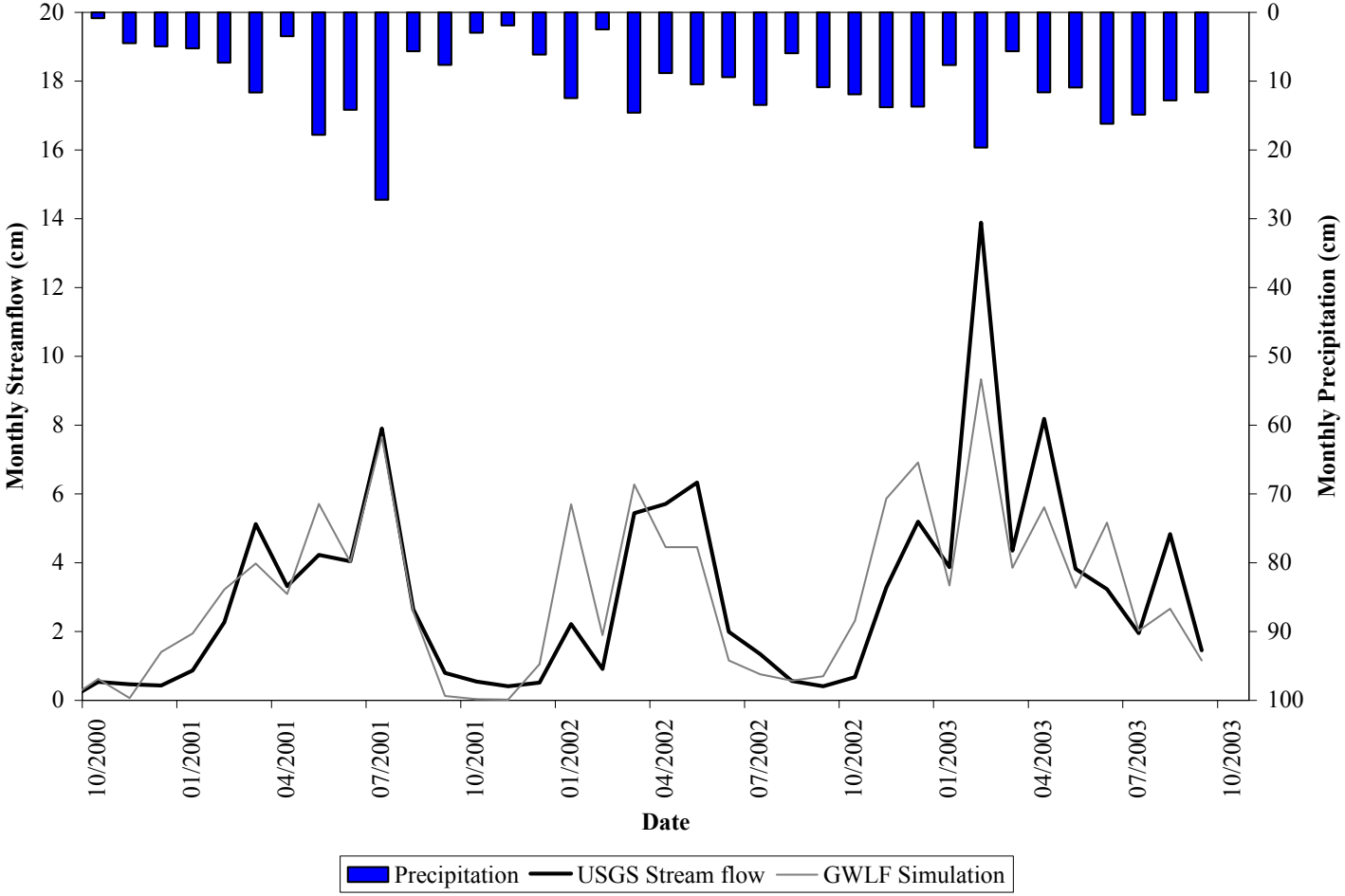

Figure 10.3 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Dry Fork.

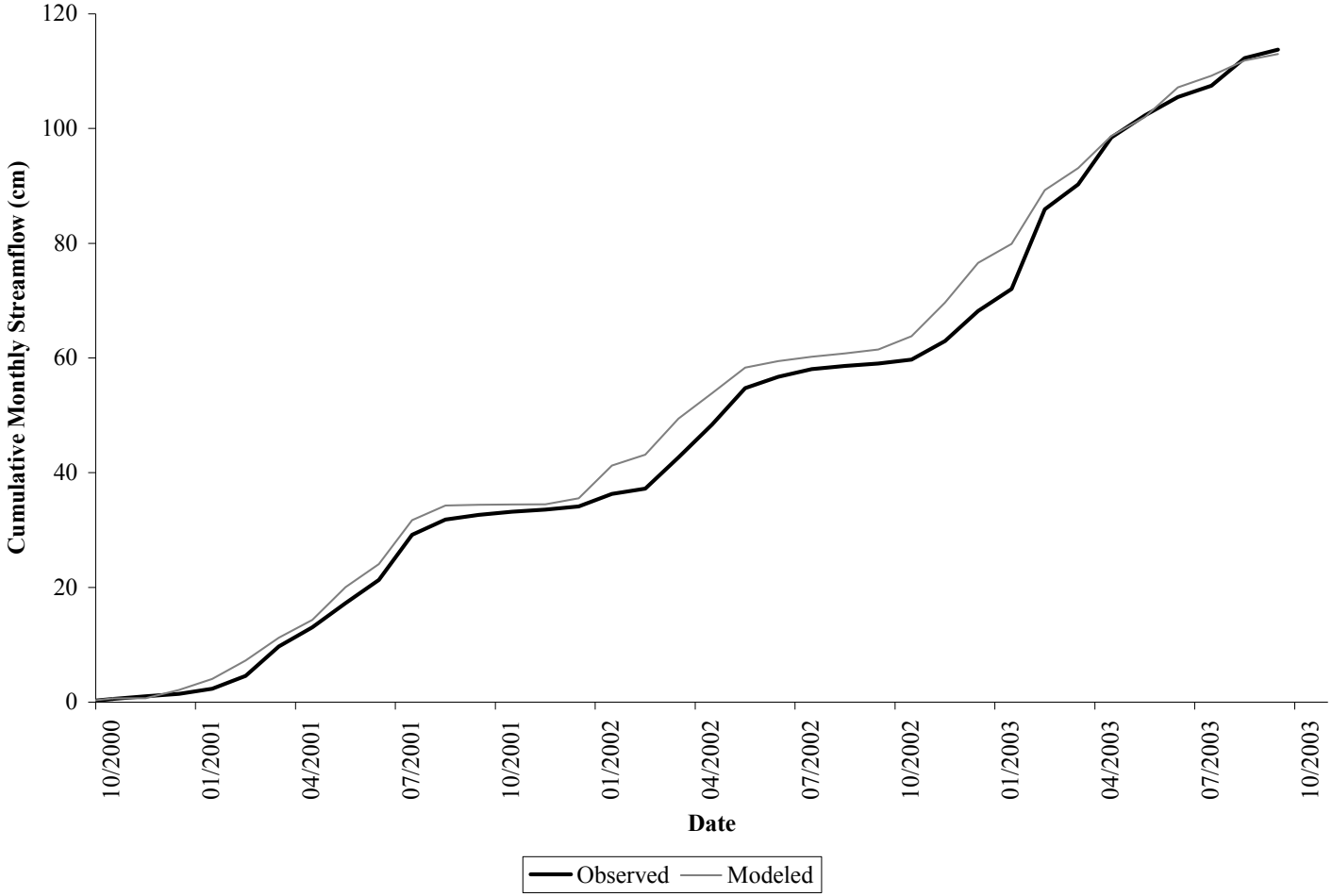

Figure 10.4 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Dry Fork.

10.5 Sediment Existing Conditions

A list of parameters from the GWLF transport input files that were finalized for existing conditions are given in Tables 10.9 through 10.10. Watershed parameters used for modeling existing conditions for each watershed are given in Table 10.9. Monthly evaporation cover coefficients are listed in Table 10.10.

Table 10.9 GWLF watershed parameters in the calibrated impaired and reference watersheds.

GWLF Watershed Parameter	Units	Levisa Fork	Dry Fork	Slate Creek	Lick Creek
Recession Coefficient	Day^{-1}	0.05512	0.05512	0.05512	0.05512
Seepage Coefficient	Day^{-1}	0.05012	0.075	0.05012	0.05012
Sediment Delivery Ratio	---	0.064	0.064	0.119	0.119
Unsaturated Water Capacity	(cm)	6.384	6.412	6.265	
Rainfall Erosivity Coefficient (Apr-Sep)	---	0.29	0.29	0.29	0.29
Rainfall Erosivity Coefficient (Oct-Mar)	---	0.10	0.10	0.10	0.10
% Developed land	(%)	0.065	0.056	0.069	0.011
Livestock density	(AU/ac)	0.00252	0.00863	0.00193	0.0526
Area-weighted soil erodibility (K)	---	0.2253	0.2324	0.2220	0.2169
Area-weighted Curve Number	---	68.17	67.36	67.10	67.49
Total Stream Length	(m)	207,078	278,715	176,578	71,836
Mean channel depth	(m)	0.5878	0.5878	0.5878	0.5878

Table 10.10 Calibrated GWLF monthly evaporation cover coefficients.

Watershed	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Levisa Fork	0.03	0.42	0.91	0.99	0.94	0.74	0.69	0.97	0.23	0.39	0.23	0.03
Dry Fork	0.01	0.25	0.91	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.01	0.03
Slate Creek	0.03	0.42	0.91	0.99	0.94	0.74	0.69	0.97	0.23	0.39	0.23	0.03
Lick Creek	0.03	0.42	0.91	0.99	0.94	0.74	0.69	0.97	0.23	0.39	0.23	0.03

Tables 10.11 and 10.12 list the area-weighted USLE erosion parameter (KLSCP) and runoff curve number by land use for each watershed. The curve number values are area weighted by land use for all subwatersheds.

Table 10.11 The GWLF curve numbers and KLSCP values for existing conditions in the Levisa Fork and Dry Fork watersheds.

	Levisa Fork		Dry Fork	
Sediment Source	**CN**	**KLSCP**	**CN**	**KLSCP**
Pervious Area:				
Active Gas Well	83.68	0.0052	NA	NA
Active Mining	86.79	0.0121	86.69	0.7479
AML	79.14	0.0017	79.10	0.1230
Barren	85.46	0.0083	85.41	0.5927
Developed	68.22	0.0002	69.98	0.0101
Disturbed Forest	73.32	0.0034	73.58	0.2613
Forest	64.99	0.0000	65.33	0.0033
Hay	66.39	0.0004	66.73	0.0272
Open Water	100.00	0.0000	100	0.0000
Pasture	75.46	0.0022	75.72	0.1570
Reclaimed Mine	73.65	0.0020	73.90	0.1113
Residential	68.89	0.0004	69.86	0.0289
Row Crop - High till	80.32	0.0179	81.56	0.9117
Row Crop - Low till	NA	NA	78.98	0.3611
Impervious Area:				
Active Mining	98.00	0.0121	98.00	0.7479
Developed	98.00	0.0002	98.00	0.0101
Residential	98.00	0.0004	98.00	0.0289

Table 10.12 The GWLF curve numbers and KLSCP values for existing conditions in the Slate Creek and Lick Creek watersheds.

	Slate Creek		Lick Creek	
Sediment Source	**CN**	**KLSCP**	**CN**	**KLSCP**
Pervious Area:				
Active Gas Well	83.84	0.5257	NA	NA
Active Mining	86.79	1.2109	NA	NA
AML	79.30	0.1673	NA	NA
Barren	NA	NA	85.50	0.6284
Developed	67.62	0.0178	NA	NA
Disturbed Forest	73.49	0.3395	74.81	0.2453
Forest	65.21	0.0042	67.01	0.0031
Hay	66.81	0.0367	68.83	0.0233
Open Water	100.00	0.0000	100.00	0.0000
Pasture	75.78	0.2119	77.33	0.1345
Reclaimed Mine	73.65	0.1998	NA	NA
Residential	69.44	0.0395	70.66	0.0264
Row Crop - High till	NA	NA	82.25	0.9137
Row Crop - Low till	NA	NA	79.95	0.3619
Impervious Area:				
Active Mining	98.00	1.2109	NA	NA
Developed	98.00	0.0178	NA	NA
Residential	98.00	0.0395	98.00	0.0264

The sediment loads were modeled for existing conditions in Levisa Fork and Slate Creek and the reference watersheds Dry Fork and Lick Creek. The existing condition is the combined sediment load, which compares to the area-adjusted reference watershed load (Tables 10.13 and 10.14).

Table 10.13 Existing sediment loads for Levisa Fork and area-adjusted Dry Fork watersheds.

Sediment Source	Levisa Fork		Reference Watershed Area-Adjusted Dry Fork	
	t/yr	t/ha/yr	t/yr	t/ha/yr
Pervious Area:				
Active Gas Well	3,476.01	1.87	0.00	0.00
AML	13,226.56	3.90	4,800.34	2.08
Barren	117.15	20.09	530.06	11.53
Developed	138.57	0.26	41.80	0.14
Forest	3,250.03	0.06	1,916.59	0.04
Open Water	0.00	0.00	0.00	0.00
Residential	2,174.94	0.68	1,177.25	0.40
Row Crop - High till	400.08	41.63	65.40	16.03
Row Crop - Low till	0.00	0.00	10.76	6.11
Disturbed Forest	8,312.09	6.86	5,107.77	3.96
Pasture	6,565.43	4.53	4,372.49	2.42
Hay	112.39	0.62	373.66	0.31
Impervious Area:				
Developed	37.84	0.21	16.63	0.22
Residential	75.66	0.21	72.63	0.22
Direct Sources:				
Streambank Erosion	671.77		838.82	
Straight Pipes	30.00		0.00	
Permitted Sources:				
DEQ - VPDES	115.83		0.00	
DMME - Mining	208.39	0.10	173.00	0.16
Slate Creek Existing Load	8,321.71	0.79	NA	
Bull Creek Future Load	6,038.30	1.92	NA	
Watershed Total	**53,272.75**	**0.81**	**19,497.20**	**0.30**

Table 10.14 Existing sediment loads for Slate Creek and area-adjusted Lick Creek watersheds.

Sediment Source	Slate Creek		Reference Watershed Area-Adjusted Lick Creek	
	t/yr	t/ha/yr	t/yr	t/ha/yr
Pervious Area:				
Active Gas Well	90.09	3.53	0.00	0.00
AML	3,244.44	7.07	0.00	0.00
Developed	18.73	0.54	0.00	0.00
Forest	1,100.08	0.12	701.97	0.07
Open Water	0.00	0.00	0.00	0.00
Residential	755.66	1.23	78.22	0.74
Disturbed Forest	1,472.33	12.64	112.76	7.01
Pasture	1,394.93	8.58	323.73	3.90
Hay	22.77	1.12	34.65	0.56
Row Crop - High till	0.00	0.00	107.72	31.22
Row Crop - Low till	0.00	0.00	97.85	11.80
Barren	0.00	0.00	486.10	23.06
Impervious Area:				
Developed	7.79	0.90	0.00	0.00
Residential	0.10	0.001	2.58	0.22
Direct Sources:				
Streambank Erosion	207.18		21.79	
Straight Pipes	5.50		0.00	
Permitted Sources:				
DEQ - VPDES	1.16			
DMME - Mining	0.95	0.15	0.00	0.00
Watershed Total	**8,321.71**	**0.79**	**1,967.37**	**0.19**

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11. SEDIMENT ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, nonpermitted 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. 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 annual load in metric tons per year (t/yr).

This section describes the development of TMDLs for sediment for Levisa Fork and Slate Creek using a reference watershed approach. The average annual sediment load from the Dry Fork reference watershed was used to define the sediment TMDL loads for the Levisa Fork watershed. The average annual sediment load from the Lick Creek reference watershed was used to define the sediment TMDL loads for the Slate Creek watershed.

This section describes the development of TMDLs for sediment for Levisa Fork and Slate Creek using a reference watershed approach. The models were run over the period of 10/1/2000 to 9/30/2003 for modeling both sediment allocations. The target sediment TMDL load for Levisa Fork is the average annual load in metric tons per year (t/yr) from the area-adjusted Dry Fork watershed under existing conditions minus a Margin of Safety (MOS). The target sediment TMDL load for Slate Creek is the average annual load in metric tons per year (t/yr) from the area-adjusted Lick Creek watershed under existing conditions minus a Margin of Safety (MOS). The Slate Creek sediment allocation is shown before the Levisa Fork results because Slate Creek flows into Levisa Fork and it is, therefore, a source of sediment included in the Levisa Fork existing condition.

11.1 Margin of Safety

In order to account for uncertainty in modeled output, an 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. For example, the typical method of assessing water quality through monitoring involves the collection and analysis of grab samples. The results of water quality analyses on grab samples collected from the stream may or may not reflect the "average" condition in the stream at the time of sampling. Calibration to observed data derived from grab samples introduces modeling uncertainty.

An MOS 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 MOS for the sediment TMDLs was explicitly expressed as 10% of the area-adjusted reference watershed load.

11.2 Future Growth Considerations

A review of the Buchanan County Comprehensive Plan (Buchanan County Board of Supervisors, 1994) indicated that land use is not expected to change significantly over the next 25 years. The Levisa Fork watershed is highly rural and it is assumed that residential and commercial growth in the watershed will not have an impact on future sediment loads. However, increased mining operations could have an impact if sediment control ponds exceed the permitted 70mg/L. Also, increase gas well installations may have an impact on sediment loads if access roads, sumps, line installation, and pump areas are not maintained or reseeded quickly.

A sediment load value for future growth was determined as 1% of the total TMDL. This was incorporated into the WLA for use as current discharges expand and for future permits that may discharge sediment.

11.3 Slate Creek Sediment TMDL

The target TMDL load for Slate Creek is the average annual load in metric tons per year (t/yr) from the area-adjusted Lick Creek watershed under existing conditions. To reach the TMDL target goal (1,770.63 t/yr), three different scenarios were run with GWLF (Table 11.1). Sediment loads from straight pipes were reduced 100% in all scenarios due to health implications and the requirements of the fecal bacteria TMDL for Levisa Fork. Scenario 1 shows reductions to sediment loads from abandoned mine land (98%), disturbed forest (98%), residential (82%), pasture (83%), and an 85% reduction to

streambank erosion. Scenarios 2 and 3 show different combinations of reductions from similar land uses. All three scenarios meet the TMDL goal at a total sediment load reduction of 79%. Scenario 1 was chosen to use for the final TMDL because it has similar reductions on different land uses with more emphasis on reducing streambank erosion.

Table 11.1 Final TMDL allocation scenario for the impaired Slate Creek watershed.

Sediment Source	Slate Creek Loads	Scenario 1 Reductions (Final)	Scenario 1 Allocated Loads	Scenario 2 Reductions	Scenario 2 Loads	Scenario 3 Reductions	Scenario 3 Loads
	t/yr	(%)	t/yr	(%)	t/yr	(%)	t/yr
Pervious Area:							
Active Gas Well	90.09	0	90.09	0	90.09	48	46.85
AML	3,244.44	98	64.89	94	194.67	95	162.22
Developed	18.73	0	18.73	0	18.73	0	18.73
Forest	1,100.08	0	1,100.08	0	1,100.08	0	1,100.08
Open Water	0.00	0	0.00	0	0.00	0	0.00
Residential	755.66	82	136.02	93	52.90	94	45.34
Disturbed Forest	1,472.33	98	29.45	93	103.06	95	73.62
Pasture	1,394.93	83	237.14	93	97.65	85	209.24
Hay	22.77	0	22.77	0	22.77	0	22.77
Impervious Area:							
Developed	7.79	0	7.79	0	7.79	0	7.79
Residential	0.10	0	0.10	0	0.10	0	0.10
Direct Sources:							
Streambank Erosion	207.18	85	31.08	76	49.72	75	51.80
Straight Pipes	5.50	100	0.00	100	0.00	100	0.00
Permitted Sources:							
DEQ - VPDES	1.16	0	1.16	0	1.16	0	1.16
DMME - Mining	0.95	0	10.63	0	10.63	0	10.63
Future Growth	0.00	0	19.67	0	19.67	0	19.67
Watershed Total	**8,321.71**	**78.74%**	**1,769.60**	**78.74%**	**1,769.02**	**78.73%**	**1,770.00**

The active mining permits issued by the Virginia DMME are shown in Table 11.2 with the existing and allocated loads. These loads were summed and entered into Table 11.1.

Table 11.2 Existing and allocated annual sediment loads for DMME mining permits within the Slate Creek watershed.

DMLR Mine Permits	DMLR Mine Permits	Existing Load t/yr	Allocated Load t/yr
1100470	Eagle Mining Corp.	0.13	0.4
1101823	Norton Coal Co. LLC	0	5.8
1200335	Wellmore Energy Co. LLC	0.04	0.16
1200342	Wellmore Energy Co. LLC	0.1	0.09
1200354	Dominion Coal Corp.	0	0.05
1201050	Jewell Smokeless Coal Corp.	0.01	0.09
1201097	The Black Diamond Co.	0.07	0.03
1201276	The Black Diamond Co.	0.13	0.05
1201345	Dominion Coal Corp.	0.13	0.51
1201484	Dominion Coal Corp.	0.25	0.29
1201508	Dominion Coal Corp.	0	0.01
1201539	The Black Diamond Co.	0.03	0.08
1201540	Dominion Coal Corp.	0	0.17
1201988	Wellmore Energy Co. LLC	0	0.07
1301640	The Black Diamond Co.	0.05	0.92
1400492	Island Creek Coal Co.	0.01	0.05
1401645	The Black Diamond Co.	0	0.05
1601816	The Black Diamond Co.	0	1.81
Total		**0.95**	**10.63**

The sediment TMDL for Slate Creek includes three components – WLA, LA, and the 10% MOS. 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 11.3).

Table 11.3 Average annual sediment TMDL for Slate Creek.

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
Slate Creek	**31.46**	**1,738.14**	**197.77**	**1,967.37**
VAG750149	0.41			
VAG400096	0.04			
VAG400064	0.04			
VAG400465	0.04			
VAG400557	0.04			
VAG400558	0.04			
VAG400643	0.04			
VAG400668	0.04			
VAG400664	0.04			
VAG400634	0.04			
VAG400731	0.04			
VAG400735	0.04			
VA0026999	0.25			
VAG400812	0.04			
Surface Coal Mining Transient Permits:				
1100470	*0.40*			
1101823	*5.80*			
1200335	*0.16*			
1200342	*0.09*			
1200354	*0.05*			
1201050	*0.09*			
1201097	*0.03*			
1201276	*0.05*			
1201345	*0.51*			
1201484	*0.29*			
1201508	*0.01*			
1201539	*0.08*			
1201540	*0.17*			
1201988	*0.07*			
1301640	*0.92*			
1400492	*0.05*			
1401645	*0.05*			
1601816	*1.81*			
Future Growth	*19.67*			

The final overall sediment load reduction required for Slate Creek is 79% (Table 11.4).

Table 11.4 Required sediment load reductions for Slate Creek.

Load Summary	Slate Creek (t/yr)	Reductions Required (t/yr)	(% of existing load)
Existing Sediment Load	8,321.71		
Target Modeling Load	1,770.63		
Final Allocated Load (WLA+LA)	1,769.60	6,552.11	78.74%

Starting in 2007, the USEPA has mandated that TMDL studies include a maximum daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach found in the 2007 document titled Options for Expressing Daily Loads in TMDLs (USEPA, 2007). The procedure involved calculating the MDL from the long-term average annual TMDL load in addition to a coefficient of variation (CV) estimated from the annual load for ten years. The annual sediment load had a coefficient of variation (CV) of 0.426. A multiplier was used to estimate the MDL from the long-term average based on the USEPA guidance. The multiplier estimated for the Levisa Fork was 2.88. In this case, the long-term average was the annual TMDL divided by 365 days (5.39 t/day) resulting in a MDL of 15.52 t/day. The daily WLA was estimated as the annual WLA divided by 365. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in Table 11.5.

Table 11.5 Average daily sediment TMDL for Slate Creek.

Impairment	WLA t/day	LA t/ day	MOS t/ day	TMDL t/ day
Slate Creek	**0.086**	**13.88**	**1.55**	**15.52**
VAG750149	0.0011			
VAG400096	0.0001			
VAG400064	0.0001			
VAG400465	0.0001			
VAG400557	0.0001			
VAG400558	0.0001			
VAG400643	0.0001			
VAG400668	0.0001			
VAG400664	0.0001			
VAG400634	0.0001			
VAG400731	0.0001			
VAG400735	0.0001			
VA0026999	0.0007			
VAG400812	0.0001			
Surface Coal Mining Transient Permits:				
1100470	*0.0011*			
1101823	*0.0159*			
1200335	*0.0004*			
1200342	*0.0002*			
1200354	*0.0001*			
1201050	*0.0002*			
1201097	*0.0001*			
1201276	*0.0001*			
1201345	*0.0014*			
1201484	*0.0008*			
1201508	*0.0000*			
1201539	*0.0002*			
1201540	*0.0005*			
1201988	*0.0002*			
1301640	*0.0025*			
1400492	*0.0001*			
1401645	*0.0001*			
1601816	*0.0050*			
Future Growth	0.0539			

11.4 Levisa Fork Sediment TMDL

The target TMDL load for Levisa Fork is the average annual load in metric tons per year (t/yr) from the area-adjusted Dry Fork watershed under existing conditions. To reach the TMDL target load (17,547.48 t/yr), three different scenarios were run (Table 11.6). Sediment loads from straight pipes were reduced 100% in all scenarios due to health implications and the requirements of the fecal bacteria TMDL. Scenario 1 shows similar reductions to sediment loads from row crop (72%), pasture (74%), residential (74%), developed land (71%), disturbed forest (74%), active gas wells (73%), abandoned mine land (AML, 74%), barren (74%), and a 74% reduction to streambank erosion. Scenario 2 shows reductions to loads from mining related and agricultural land uses. Scenario 3 shows reductions to loads from mining related and residential/urban land uses. All three scenarios meet the TMDL goal at a total sediment load reduction of 70.15%. Scenario 1 was chosen to use for the final TMDL because it has reasonable reductions on all types of land uses.

Existing and allocated loads from Bull Creek and Slate Creek were taken from the TMDLs for the two creeks since they fall within the current study area. No additional reductions were recommended from the two creeks since the percentage reductions called for in Table 11.6 are the same in the corresponding, previously developed TMDLs.

Table 11.6 Final TMDL allocation scenario for the impaired Levisa Fork watershed.

Sediment Source	Existing Levisa Loads t/yr	Scenario 1 Reductions (Final) (%)	Scenario 1 Allocated Loads t/yr	Scenario 2 Reductions (%)	Scenario 2 Loads t/yr	Scenario 3 Reductions (%)	Scenario 3 Loads t/yr
Pervious Area:							
ActiveGasWell	3,476.01	73	938.520	79	729.96	91	312.84
AML	13,226.56	74	3,438.91	80	2,645.31	92	1,058.12
Barren	117.15	74	30.46	76	28.12	91	10.54
Developed	138.57	71	40.19	0	138.57	91	12.47
Forest	3,250.03	0	3,250.03	0	3,250.03	0	3,250.03
OpenWater	0.00	0	0.00	0	0.00	0	0.00
Residential	2,174.94	74	565.48	0	2,174.94	91	195.74
RowCrop - High till	400.08	72	112.02	77	92.02	0	400.08
Disturbed Forest	8,312.09	74	2,161.14	79	1,745.54	93	581.85
Pasture	6,565.43	74	1,707.01	79	1,378.74	0	6,565.43
Hay	112.39	0	112.39	0	112.39	0	112.39
Impervious Area:							
Developed	37.84	69	11.73	0	37.84	89	4.16
Residential	75.66	71	21.94	0	75.66	91	6.81
Direct Sources:							
Streambank Erosion	671.77	74	174.66	77	154.51	92	53.74
Straight Pipes	30.00	100	0.00	100	0.00	100	0.00
Permitted Sources (WLA):							
DEQ - VPDES	115.83	0	115.83	0	115.83	0	115.83
DMME - Mining	208.39	0	418.86	0.00	418.86	0	418.86
Slate Creek Loads*	8,321.71	78.74	1,769.60	78.74	1,769.60	78.74	1,769.60
Bull Creek Loads*	6,038.30	58.87	2,483.70	58.87	2,483.70	58.87	2,483.70
Future Growth (WLA)	0.00	0	194.97	0	194.97	0	194.97
MOS	0.00	0	1,949.76	0	1,950.61	0	1,950.04
Watershed Target Total	**53,272.75**	**70.15**	**17,547.44**	**70.15**	**17,546.59**	**70.15**	**17,547.16**
TMDL (Target+MOS)			**19,497.20**				

*Existing and allocated loads were taken from the TMDLs for the two creeks since they fall within the current study area. No additional reductions were recommended since the percentage reductions called for in Table 11.6 are the same in the corresponding, previously developed TMDLs.

The active mining permits issued by the Virginia DMME are shown in Table 11.7 with the existing and allocated loads. These loads were summed and entered into Table 11.6.

Table 11.7 Existing and allocated annual sediment loads for DMME mining permits within the Levisa Fork watershed.

DMLR Mine Permits	DMLR Mine Permits	Existing Load t/yr	Allocated Load t/yr	DMLR Mine Permits	DMLR Mine Permits	Existing Load t/yr	Allocated Load t/yr	DMLR Mine Permits	DMLR Mine Permits	Existing Load t/yr	Allocated Load t/yr
1100470	Eagle Mining Corp.	1.03	2.37	1201532	Jewell Smokeless Coal Corp.	0.15	0.14	1401489	Island Creek Coal Co.	1.42	9.67
1101381	The Black Diamond Co.	8.75	18.87	1201574	The Black Diamond Co.	0.87	0.98	1401493	Dominion Coal Corp.	0.16	1.44
1101553	Jewell Smokeless Coal Corp.	5.16	11.11	1201698	Dominion Coal Corp.	0.10	0.14	1401531	Island Creek Coal Co.	22.41	10.46
1101752	Knox Creek Coal Corp.	11.57	24.95	1201716	Clintwood Elkhorn Mining Co,	11.32	0.96	1401598	Knox Creek Coal Corp.	0.46	4.66
1101792	Jewell Smokeless Coal Corp.	1.00	9.65	1201749	Calico Coal, Inc.	0.11	0.59	1401635	Knox Creek Coal Corp.	1.70	3.67
1101846	Paramont Coal Co. Va. LLC	23.94	7.81	1201753	The Black Diamond Co.	2.83	5.60	1500384	Consolidation Coal Co.	2.70	5.83
1101881	Highwall Mining Co. of Va.	0.16	0.35	1201902	Clintwood Elkhorn Mining Co,	0.12	0.79	1601787	The Black Diamond Co.	8.97	19.33
1101903	Paramont Coal Co. Va. LLC	0.00	1.47	1201906	Clintwood Elkhorn Mining Co,	0.04	0.09	1601816	The Black Diamond Co.	2.82	6.09
1101987	Jewell Smokeless Coal Corp.	2.67	5.75	1201907	Clintwood Elkhorn Mining Co,	0.04	0.20	1700864	Consolidation Coal Co.	5.29	5.88
1102001	The Black Diamond Co.	8.16	17.59	1300120	Jewell Smokeless Coal Corp.	2.00	1.26	1701300	The Black Diamond Co.	2.63	6.03

1102030	Norton Coal Co. LLC	1.74	3.76
1200194	Dominion Coal Corp.	0.14	1.68
1200235	Knox Creek Coal Corp.	1.98	1.03
1200282	Double L Coal Co.	0.05	0.24
1200308	Consolidation Coal Co.	1.20	2.59
1200335	Wellmore Energy Co. LLC	0.15	0.09
1200354	Dominion Coal Corp.	0.14	2.32
1200881	The Black Diamond Co.	0.16	0.28
1201015	Dominion Coal Corp.	0.35	0.75
1201050	Jewell Smokeless Coal Corp.	0.06	0.40
1201053	Jewell Smokeless Coal Corp.	0.08	0.17
1201091	Dominion Coal Corp.	0.22	2.13
1300359	Patrick Coal Corp.	4.76	5.88
1300378	Wellmore Energy Co. LLC	1.38	0.76
1300379	Wellmore Energy Co. LLC	1.34	3.44
1300398	The Black Diamond Co.	0.00	1.52
1300404	Jewell Smokeless Coal Corp.	2.88	1.15
1300417	Patrick Coal Corp.	0.20	1.24
1300425	Jewell Smokeless Coal Corp.	0.98	11.27
1300426	Jewell Smokeless Coal Corp.	2.74	18.02
1300451	The Black Diamond Co.	2.20	1.79
1300453	The Black Diamond Co.	12.98	14.55
1300454	The Black Diamond Co.	0.36	2.53
1300945	Jewell Smokeless Coal Corp.	0.05	0.25
1801821	Consolidation Coal Co.	0.00	0.02
Grand Total		**208.39**	**418.86**

1201131	The Black Diamond Co.	0.30	0.10	1301156	Knox Creek Coal Corp.	0.09	1.20
1201182	Dominion Coal Corp.	0.10	1.54	1301226	Jewell Smokeless Coal Corp.	3.08	13.46
1201230	Dominion Coal Corp.	0.03	0.36	1400047	Consolidation Coal Co.	17.11	79.28
1201273	Dominion Coal Corp.	0.06	0.97	1400345	The Black Diamond Co.	8.32	4.39
1201310	The Black Diamond Co.	0.00	0.19	1400419	Patrick Coal Corp.	0.44	0.95
1201345	Dominion Coal Corp.	0.50	0.56	1400492	Island Creek Coal Co.	3.18	16.16
1201348	Dominion Coal Corp.	0.59	3.20	1400493	Island Creek Coal Co.	1.31	8.27
1201373	The Black Diamond Co.	0.05	0.11	1400496	Island Creek Coal Co.	1.82	9.03
1201442	Dominion Coal Corp.	0.05	0.21	1400498	Island Creek Coal Co.	0.50	5.46
1201484	Dominion Coal Corp.	1.32	0.78	1401039	Dominion Coal Corp.	0.09	1.37
1201495	The Black Diamond Co.	0.19	0.45	1401167	Knox Creek Coal Corp.	3.31	2.61
1201508	Dominion Coal Corp.	0.09	0.52	1401181	Dominion Coal Corp.	0.06	0.69
1201523	Dominion Coal Corp.	0.02	0.31	1401232	Island Creek Coal Co.	1.06	5.10

The final overall sediment load reduction required for Levisa Fork is 54% (Table 11.8).

Table 11.8 Required sediment reductions for Levisa Fork.

Load Summary	Levisa Fork (t/yr)	Reductions Required (t/yr)	(% of existing load)
Existing Sediment Load	53,272.75		
Target Modeling Load	17,547.48		
Final Allocated Load (WLA+LA)	17,547.44	35,725.31	70.15%

The sediment TMDL for Levisa Fork includes three components – WLA, LA, and the 10% MOS. 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 11.9).

Table 11.9 Average annual sediment TMDL for Levisa Fork.

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
Levisa Fork	**729.66**	**16,817.78**	**1,949.76**	**19,497.20**
VAR101038	4.70			
VAR104503	0.86			
VAR102495	0.16			
VAR104799	0.19			
VAR050018	4.50			
VAR050059	0.54			
VAR050102	0.62			
VAR051686	1.73			
VAG110243	0.49			
VAG750020	0.41			
VAG400200	0.04			
VAG400573	0.04			
VAG400405	0.04			
VAG400741	0.04			
VAG400809	0.04			
VAG400404	0.04			
VAG400697	0.04			
VAG400589	0.04			
VAG400192	0.04			
VAG400129	0.04			
VAG400681	0.04			
VAG400682	0.04			
VAG400698	0.04			
VAG400830	0.04			
VAG400190	0.04			
VAG400191	0.04			
VAG400515	0.04			
VAG400211	0.04			
VAG400445	0.04			
VAG400549	0.04			
VAG400613	0.04			
VAG400413	0.04			
VAG400686	0.04			
VAG400727	0.04			
VAG400730	0.04			
VAG400825	0.04			
VAG400342	0.04			
VAG400678	0.04			
VAG400087	0.04			
VAG400108	0.04			
VAG400663	0.04			
VAG400729	0.04			
VAG400710	0.04			
VAG400680	0.04			
VA0050351	13.83			

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
VA0052639	0.04			
VA0065536	0.83			
VA0065625	1.04			
VA0066907	0.83			
VA0068438	0.30			
VA0089907	0.31			
VA0090239	0.13			
VA0090531	82.96			
Future Growth	*194.97*			
Surface Mining Transient Permits:	418.86			
1100470	*2.36*			
1101381	*18.85*			
1101553	*11.10*			
1101752	*24.92*			
1101792	*9.64*			
1101846	*7.80*			
1101881	*0.35*			
1101903	*1.47*			
1101987	*5.74*			
1102001	*17.57*			
1102030	*3.76*			
1200194	*1.68*			
1200235	*1.03*			
1200282	*0.24*			
1200308	*2.59*			
1200335	*0.09*			
1200354	*2.32*			
1200881	*0.28*			
1201015	*0.75*			
1201050	*0.40*			
1201053	*0.17*			
1201091	*2.13*			
1201131	*0.10*			
1201182	*1.54*			
1201230	*0.36*			
1201273	*0.97*			
1201310	*0.19*			
1201345	*0.56*			
1201348	*3.20*			
1201373	*0.11*			
1201442	*0.21*			
1201484	*0.78*			
1201495	*0.45*			
1201508	*0.52*			
1201523	*0.31*			
1201532	*0.14*			
1201574	*0.98*			

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
1201698	*0.14*			
1201716	*0.96*			
1201749	*0.59*			
1201753	*5.59*			
1201902	*0.79*			
1201906	*0.09*			
1201907	*0.20*			
1202036	*0.43*			
1300120	*1.26*			
1300359	*5.88*			
1300378	*0.76*			
1300379	*3.44*			
1300398	*1.52*			
1300404	*1.14*			
1300417	*1.24*			
1300425	*11.26*			
1300426	*18.00*			
1300451	*1.79*			
1300453	*14.53*			
1300454	*2.52*			
1300945	*0.25*			
1301156	*1.20*			
1301226	*13.44*			
1400047	*79.20*			
1400345	*4.38*			
1400419	*0.95*			
1400492	*16.14*			
1400493	*8.26*			
1400496	*9.03*			
1400498	*5.46*			
1401039	*1.37*			
1401167	*2.61*			
1401181	*0.69*			
1401232	*5.10*			
1401489	*9.66*			
1401493	*1.44*			
1401531	*10.45*			
1401598	*4.65*			
1401635	*3.67*			
1500384	*5.82*			
1601787	*19.31*			
1601816	*6.08*			
1700864	*5.87*			
1701300	*6.02*			
1801821	*0.02*			

Starting in 2007, the USEPA has mandated that TMDL studies include a maximum daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach found in the 2007 document titled Options for Expressing Daily Loads in TMDLs (USEPA, 2007). The procedure involved calculating the MDL from the long-term average annual TMDL load in addition to a coefficient of variation (CV) estimated from the annual load for ten years. The annual sediment load had a coefficient of variation (CV) of 0.388. A multiplier was used to estimate the MDL from the long-term average based on the USEPA guidance. The multiplier estimated for the Levisa Fork was 2.65. In this case, the long-term average was the annual TMDL divided by 365 days (53.42 t/day) resulting in a MDL of 141.56 t/day. The daily WLA was estimated as the annual WLA divided by 365. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in Table 11.10.

Table 11.10 Average daily sediment TMDL for Levisa Fork.

Impairment	WLA t/day	LA t/ day	MOS t/ day	TMDL t/ day
Levisa Fork	**1.999**	**125.40**	**14.16**	**141.56**
VAR101038	0.0129			
VAR104503	0.0024			
VAR102495	0.0004			
VAR104799	0.0005			
VAR050018	0.0123			
VAR050059	0.0015			
VAR050102	0.0017			
VAR051686	0.0047			
VAG110243	0.0013			
VAG750020	0.0011			
VAG400200	0.0001			
VAG400573	0.0001			
VAG400405	0.0001			
VAG400741	0.0001			
VAG400809	0.0001			
VAG400404	0.0001			
VAG400697	0.0001			
VAG400589	0.0001			
VAG400192	0.0001			
VAG400129	0.0001			
VAG400681	0.0001			
VAG400682	0.0001			
VAG400698	0.0001			
VAG400830	0.0001			
VAG400190	0.0001			
VAG400191	0.0001			
VAG400515	0.0001			
VAG400211	0.0001			
VAG400445	0.0001			
VAG400549	0.0001			
VAG400613	0.0001			
VAG400413	0.0001			
VAG400686	0.0001			
VAG400727	0.0001			
VAG400730	0.0001			
VAG400825	0.0001			
VAG400342	0.0001			
VAG400678	0.0001			
VAG400087	0.0001			
VAG400108	0.0001			
VAG400663	0.0001			
VAG400729	0.0001			
VAG400710	0.0001			
VAG400680	0.0001			
VA0050351	0.0379			

Impairment	WLA t/day	LA t/ day	MOS t/ day	TMDL t/ day
VA0052639	0.0001			
VA0065536	0.0023			
VA0065625	0.0028			
VA0066907	0.0023			
VA0068438	0.0008			
VA0089907	0.0008			
VA0090239	0.0004			
VA0090531	0.2273			
Future Growth	0.5342			
Surface Mining Transient Permits:	1.1476			
1100470	*0.0065*			
1101381	*0.0516*			
1101553	*0.0304*			
1101752	*0.0683*			
1101792	*0.0264*			
1101846	*0.0214*			
1101881	*0.0010*			
1101903	*0.0040*			
1101987	*0.0157*			
1102001	*0.0481*			
1102030	*0.0103*			
1200194	*0.0046*			
1200235	*0.0028*			
1200282	*0.0007*			
1200308	*0.0071*			
1200335	*0.0002*			
1200354	*0.0064*			
1200881	*0.0008*			
1201015	*0.0021*			
1201050	*0.0011*			
1201053	*0.0005*			
1201091	*0.0058*			
1201131	*0.0003*			
1201182	*0.0042*			
1201230	*0.0010*			
1201273	*0.0027*			
1201310	*0.0005*			
1201345	*0.0015*			
1201348	*0.0088*			
1201373	*0.0003*			
1201442	*0.0006*			
1201484	*0.0021*			
1201495	*0.0012*			
1201508	*0.0014*			
1201523	*0.0008*			
1201532	*0.0004*			
1201574	*0.0027*			

Impairment	WLA t/day	LA t/ day	MOS t/ day	TMDL t/ day
1201698	*0.0004*			
1201716	*0.0026*			
1201749	*0.0016*			
1201753	*0.0153*			
1201902	*0.0022*			
1201906	*0.0002*			
1201907	*0.0005*			
1202036	*0.0012*			
1300120	*0.0035*			
1300359	*0.0161*			
1300378	*0.0021*			
1300379	*0.0094*			
1300398	*0.0042*			
1300404	*0.0031*			
1300417	*0.0034*			
1300425	*0.0308*			
1300426	*0.0493*			
1300451	*0.0049*			
1300453	*0.0398*			
1300454	*0.0069*			
1300945	*0.0007*			
1301156	*0.0033*			
1301226	*0.0368*			
1400047	*0.2170*			
1400345	*0.0120*			
1400419	*0.0026*			
1400492	*0.0442*			
1400493	*0.0226*			
1400496	*0.0247*			
1400498	*0.0150*			
1401039	*0.0038*			
1401167	*0.0072*			
1401181	*0.0019*			
1401232	*0.0140*			
1401489	*0.0265*			
1401493	*0.0039*			
1401531	*0.0286*			
1401598	*0.0127*			
1401635	*0.0101*			
1500384	*0.0159*			
1601787	*0.0529*			
1601816	*0.0167*			
1700864	*0.0161*			
1701300	*0.0165*			
1801821	*0.0001*			

12. TOTAL PCB (tPCB) WATER QUALITY ASSESSMENT

12.1 Introduction to PCBs

Polychlorinated biphenyls (PCBs) are a group of synthetic chemicals that consist of 209 individual compounds (known as congeners), and when summed are defined as total PCBs (tPCBs). PCBs consist of either oily liquids or solids and are colorless to light yellow in color with no known smell or taste. Each of the 209 possible PCB compounds consists of two sigma bonded, chlorine substituted phenyl groups (Figure 12.1) and for each congener, the chlorine substitutes differ in their number and position. PCBs are relatively inert and non-reactive to heat and other chemicals, which provides excellent properties for applications of high heat exposure and flame resistance. When released to the environment, these same properties cause PCBs to break down slowly and to bioaccumulate in fatty tissue of biota. PCBs do not naturally occur.

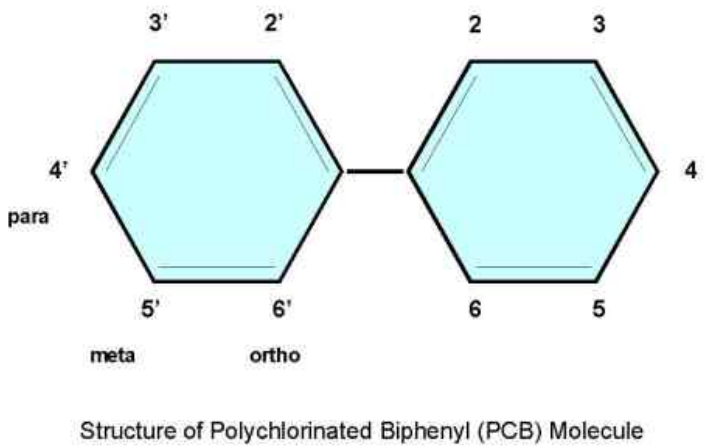

Figure 12.1 Chemical structure of a PCB molecule.
(from: http://www.epa.gov/hudson/pcbs101.htm available 6/20/2008)

Until the late 1970's, PCBs were manufactured and marketed in the United States under the trade name Aroclor. These compounds were used in many applications including capacitors, transformers, hydraulic fluid, plasticizers (sealants and caulk), adhesives, fire retardants, inks, lubricants, pesticide extenders, paints, mineral oil, carbonless copy paper, etc. By 1979, new PCB production was completely banned although continued

use of properly functioning PCB containing equipment such as transformers was allowed (EPA http://fn.cfs.purdue.edu/fish4health/HealthRisks/tPCB.pdf, 6/20/2008).

Historically, PCBs were introduced to the environment through discharges from point sources and through spills and releases. Although point source contributions should now be controlled, facilities could be unknowingly discharging PCB loads as a result of historical or inadvertent contamination. Sites with PCB-contaminated soils from past spills can also act as precipitation-driven nonpoint sources. In addition, the widespread use of PCBs before their ban coupled with their stable molecular structure has caused a generalized distribution of the pollutant in air, soil, and water at background concentrations. Once in a waterbody, PCBs become associated with sediment particles and since they are very resistant to breakdown, PCBs can remain in river sediments for decades. They are also available to aquatic life based on their lipophilic (fat loving) nature and will readily accumulate in the fatty tissues of the aquatic biota. When PCBs are present in the environment, all forms of aquatic life are exposed. When the higher organisms (i.e., fish) consume lower trophic levels, PCBs that have accumulated in the lower organisms concentrate in the higher trophic levels thus increasing their overall body burden. The process of PCBs transferring from lower to higher trophic levels within a food chain is known as biomagnification. This is important as the top trophic levels (i.e., sport fish) are sought by and consumed by humans and is the leading cause of PCB exposure (ATSDR, 2000).

PCB exposure has been shown to be detrimental to human health. Acute exposures to elevated concentrations have caused acne-like skin lesions, hearing/vision problems, and spasms. Chronic exposures have been linked to deleterious effects to the gastrointestinal, hematological (blood), dermal (skin), endocrine (hormonal), immunological, neurological, and reproductive systems. The EPA has classified tPCBs as a probable human carcinogen.

12.2 Levisa Fork Impairments

The Levisa Fork mainstem is under a (VDH) fish consumption ban due to tPCB contamination from the Virginia/Kentucky state line upstream to the Slate Creek

confluence (approximately 14 stream miles). In addition, a fish consumption advisory extends from the Levisa Fork's confluence with Slate Creek, upstream to the confluence with Contrary Creek (approximately 18 stream miles). A fish consumption advisory on Garden Creek extends from the confluence with Levisa Fork upstream to the confluence with the Right Fork of Garden Creek. Table 1.1 in Section 1.3 shows a full list of the impairments within the Levisa Fork watershed.

Of special note is the high degree of fish tissue contamination on Levisa Fork. When compared to a statewide fish tissue database, the tPCB concentrations (7,582 ppb wet weight basis) in fish samples collected from station 6ALEV130.00 near the Virginia/Kentucky state line are contained in the highest 1% of all tPCB samples in the Commonwealth (Figure 12.2).

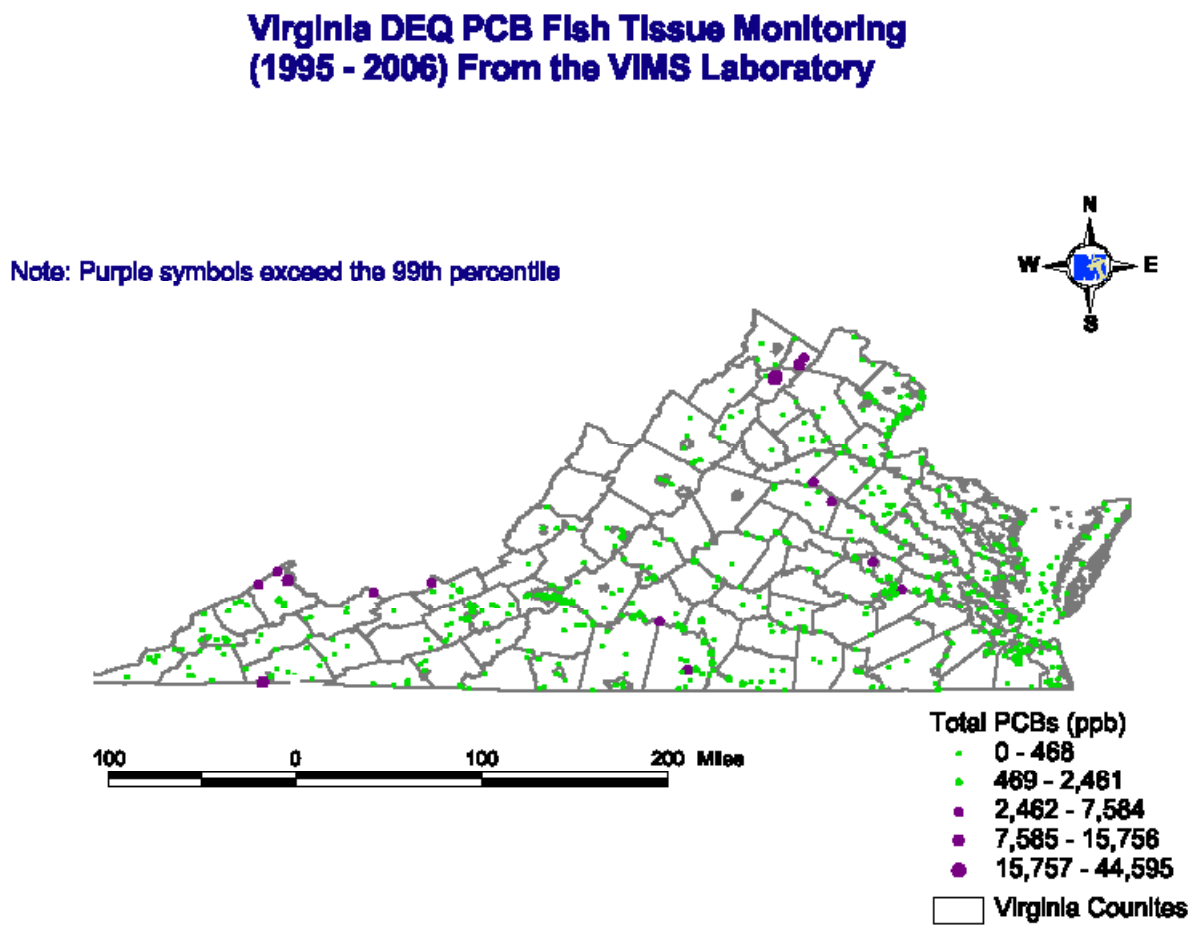

Figure 12.2 Virginia Institute Marine Science (VIMS) laboratory fish tissue tPCB data collected throughout Virginia from 1995-2006.

12.3 PCB Standards

As referenced in Section 2.1 (also see state regulation 9 VAC 25-260-10), Virginia's waters are to support the propagation of aquatic life, including game fish, and provide for edible fish. Virginia's water quality standards for the maintenance of designated uses include numeric Aroclor PCB criteria for the protection of aquatic life and a tPCBs criterion for the protection of human health (9 VAC-25-260-140.B). The state numeric values are based on criteria developed by EPA as issued in its 1999 Final Rule: *Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance—Revision of Polychlorinated Biphenyls (PCBs) Criteria* (USEPA 1999).

The 1999 final rule is an update to the human health criterion and a restatement of the aquatic life criteria both established as part of the National Toxics Rule (NTR) issued in 1992. The reassessment used revised PCB cancer study results and information on environmental processes, representative classes of environmental PCB mixtures, and different exposure pathways to develop a range of cancer slope factors—0.07 per milligram per kilogram per day (mg/kg-d) (lowest risk and persistence) to 2.0 per mg/kg-d (high risk and persistence)—that indicate the potency of a cancer-causing chemical. EPA determined that the major pathway of human exposure to PCBs is fish consumption and that bioaccumulated PCBs are the most toxic. As a result, the upper-bound cancer slope factor (2.0 per mg/kg-d) was selected to develop the 1999 human health criterion. The EPA criterion incorporates a bioconcentration factor (BCF) to account for the uptake and accumulation of PCBs in fish tissues from contaminated waters.

VADEQ has also developed a numeric criterion for tPCB concentrations in fish tissue [54 micrograms per kilogram (µg/kg)]. Called a screening value (SV), it was developed using the same toxicological, exposure, and risk data used to develop the human health PCB criterion. The SV represents the fish tissue concentration that the Virginia water quality criterion is designed to protect, and is considered by VADEQ to be its fish tissue concentration equivalent (VADEQ, 2001).

The hydrophobic properties of PCBs make them difficult to detect in water quality samples. As a result, VADEQ has historically used fish tissue monitoring data as a surrogate to determine whether a waterbody is attaining the human health PCB criterion. If a fish tissue composite sample exceeds the SV, the water is classified as threatened for fish consumption. Fish containing a contaminant at or below the screening value concentration are considered to pose minimal risk to the average consumer. Related VDH fish consumption advisory guidelines specify a *do not eat* PCB concentration threshold of 500 ppb and a limited consumption (not more than 2 meals a month) PCB concentration range between 50 and 500 ppb. Advisories limiting and prohibiting fish consumption define waters as not supporting the fish consumption use, respectively (VADEQ, 2007).

VADEQ uses sediment PCB contamination data to assess the likelihood of an observed effect on aquatic life. Sediment monitoring data are compared to the Probable Effects Concentration (PEC) SV for sediment (676 ppb from MacDonald et al. 2000). This SV is considered to be protective of aquatic organisms exposed to PCBs in the sediment.

Based on EPA recommendations, the water column Human Health Chronic Standard will be used in PCB modeling (Table 12.1). The endpoint used in PCB modeling is consistent with Virginia's Water Quality Criterion of 640 pg/L (9 VAC-25-260-140). This criterion, developed in accordance with EPA guidelines, was designed to prevent fish from bioconcentrating PCBs to levels that presents increased potential risk to consumers of the fish. Attainment of the "fishable" goal should be met upon meeting the endpoint in-stream.

Table 12.1 Applicable water quality, fish tissue, and sediment criteria/guidelines for PCBs.

Standard Type	Agency	Criteria description	Pollutant	Aquatic Life Chronic Standard (ppb)	Human Health Chronic Standard (ppb)
Water Column	VADEQ	State water quality criteria [a]	PCB-1260	0.014	
			PCB-1254	0.014	
			PCB-1248	0.014	
			PCB-1242	0.014	
			PCB-1232	0.014	
			PCB-1221	0.014	
			PCB-1016	0.014	
			tPCBs		0.00064
Fish Tissue	VADEQ	State screening value	tPCBs		54
	VDH	Limited consumption threshold [b]	tPCBs		50 – 500
		Do not eat threshold	tPCBs		> 500
Sediment	VADEQ	State screening value based on Probable Effects Concentration [c]	tPCBs	676	

[a] Source: Virginia State Code 9 VAC-25-260-140.B
[b] Source: (VADEQ, 2001)
[c] Source: (MacDonald et al. 2000)

12.4 PCB Monitoring Data Inventory

VADEQ collects fish tissue and sediment samples as part of the Virginia Fish Tissue and Sediment Contaminants Monitoring Program. Under the program, data are collected to assess the human health risks for individuals who might consume fish from state waters and to identify impaired aquatic ecosystems. The sampling program is charged with monitoring every major watershed in Virginia at least once within a 2–3 year cycling period. From 1997 to 2007, VADEQ performed fish tissue sampling at nine sites in the Levisa Fork watershed (Figure 12.3). Since PCBs have a strong affinity for solids, VADEQ performed sediment sampling at 18 sites on the Levisa Fork from 1990 to 2002 and at one site on Garden Creek during 1997 and again in 2002. Water column PCBs were monitored in Levisa Fork during fall 2007 and spring 2008 as a special study conducted by VADEQ.

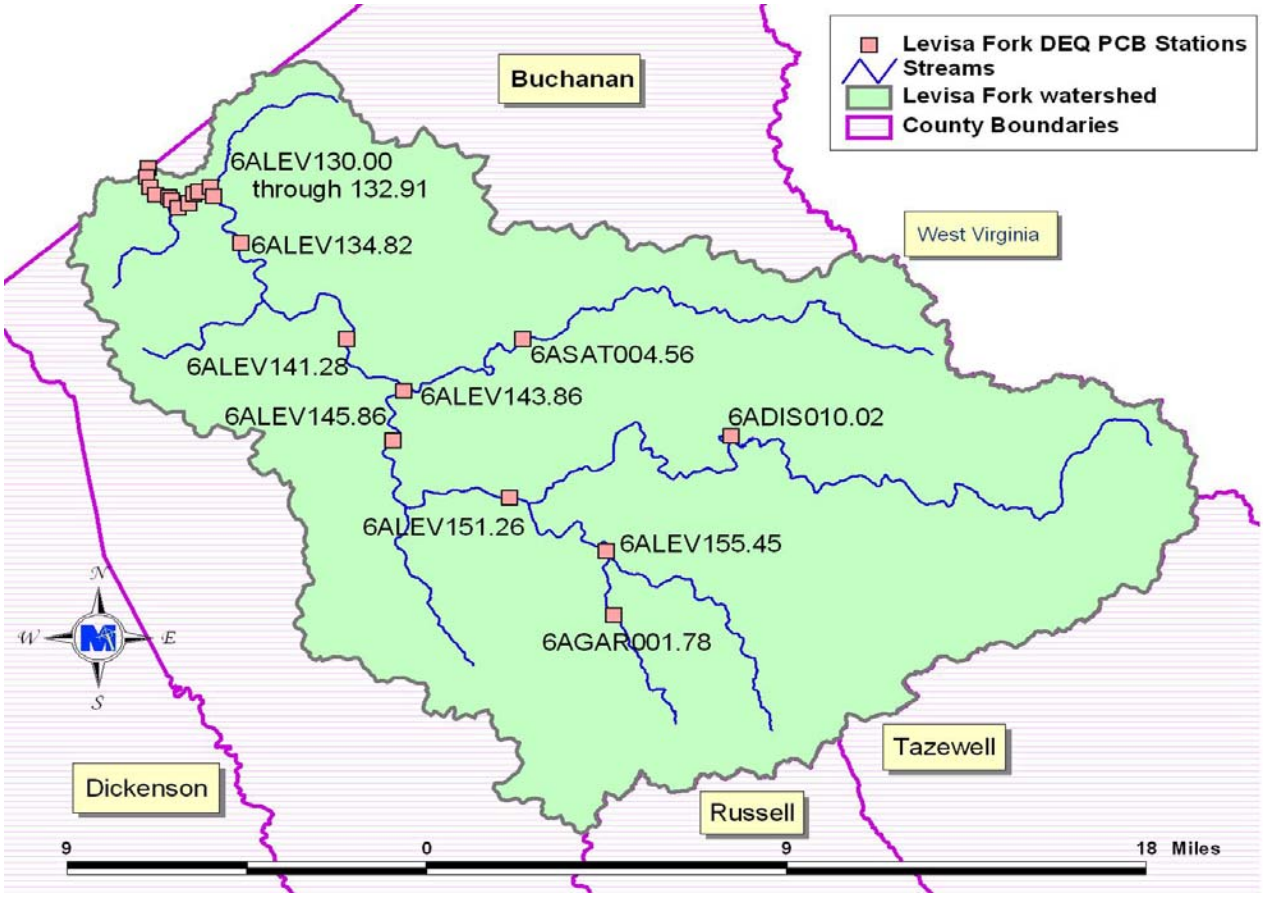

Figure 12.3 VADEQ streambed sediment and fish tissue monitoring for tPCBs in the Levisa Fork watershed.

12.4.1 Fish Tissue Data

Nine species of fish targeted for tissue samples include: Channel Catfish, Gizzard Shad, Golden Redhorse Sucker, Northern Hogsucker, Rainbow Trout, Redhorse Sucker, Rock Bass, Smallmouth Bass, and Stoneroller. These fish species are targeted since they represent different trophic levels as well as diverse feeding strategies.

12.4.1.1 Levisa Fork Mainstem

At the most downstream station (6ALEV130.00), 96% of the fish tissue samples were above the VDH limited consumption threshold (50 ppb) and 61% were above the VDH do not eat threshold (500 ppb) (Table 12.2). A gizzard shad sample collected at station 6ALEV130.00 during October 2000 yielded one of the higher PCB values (7,584 ppb wet weight) recorded from Virginia's Fish Tissue Monitoring Program. Tissue samples collected at station 6ALEV130.00 in 2007 suggest PCB levels may be on the decline

(mean PCB conc. 973 ppb, n = 8), but from the same sample set an individual redhorse sucker yielded a concentration of 3,009 ppb and two channel catfish samples averaged 1,448 ppb.

At the next upstream station (6ALEV134.82), 60% of the fish tissue samples were above the lower threshold while 20% were above the do not eat threshold. Moving upstream, river stations 6ALEV141.28, 6ALEV145.86 6ALEV151.26 resulted in greater than 55% (n = 18) exceedance of VDH's lower threshold. Fish tissue samples collected at the most upstream station (6ALEV155.45) were below the limited fish consumption threshold (50 ppb).

Table 12.2 Fish tissue tPCB sampling results from six VADEQ monitoring stations on Levisa Fork.

Station	Date	Fish species name	VDH Action Level[1]	Total tPCB wet weight basis, ppb[2]
6ALEV130.00	07/22/97	Gizzard Shad	50	**1,182**
	07/22/97	Golden Redhorse Sucker	50	**1,448**
	07/22/97	Northern Hogsucker	50	**102**
	07/22/97	Rock Bass	50	**735**
	08/08/00	Channel Catfish (A)	50	**414**
	08/08/00	Channel Catfish (B)	50	**1,332**
	08/08/00	Northern Hogsucker (A)	50	**321**
	08/08/00	Northern Hogsucker (B)	50	20
	08/08/00	Rock Bass	50	**328**
	10/03/00	Gizzard Shad	50	**7,584**
	08/6/02	Rock Bass	50	**2,148**
	08/6/02	Rock Bass	50	**531**
	08/6/02	Channel Catfish	50	**1,244**
	08/6/02	Channel Catfish	50	**2,158**
	08/6/02	Northern Hogsucker	50	**5,403**
	07/17/07	Redhorse Sucker	50	**3,009**
	07/17/07	Channel Catfish	50	**1,868**
	07/17/07	Channel Catfish	50	**1,028**
	07/17/07	Northern Hogsucker	50	**908**
	07/17/07	Rock Bass	50	**325**
	07/17/07	Smallmouth Bass	50	**274**
	07/17/07	Smallmouth Bass	50	**214**
	07/17/07	Stoneroller	50	**155**
	07/17/07	Redhorse Sucker	50	**3,009**
	07/17/07	Channel Catfish	50	**1,868**
6ALEV134.82	08/08/00	Channel Catfish	50	**61**
	08/08/00	Gizzard Shad	50	**609**
	08/08/00	Redhorse Sucker	50	**151**

	08/08/00	Rock Bass (A)	50	44
	08/08/00	Rock Bass (B)	50	5

[1]VDH limited consumption threshold , ppb; **bold** values exceed the VDH treshold; [2]ppb = parts per billion (µg/kg), wet weight basis edible fillet

Table 12.2 Fish tissue tPCB sampling results from six VADEQ monitoring stations on Levisa Fork (continued).

Station	Date	Fish species name	VDH Action Level[1]	Total tPCB wet weight basis (ppb)[2]
6ALEV141.28	10/03/00	Channel Catfish	50	**280**
	10/03/00	Northern Hogsucker	50	22
	10/03/00	Rock Bass	50	42
	10/03/00	Smallmouth Bass (A)	50	**69**
	10/03/00	Smallmouth Bass (B)	50	37
6ALEV145.86	10/03/00	Channel Catfish	50	**54**
	10/03/00	Gizzard Shad	50	**413**
	10/03/00	Northern Hogsucker	50	6
	10/03/00	Redhorse Sucker	50	**67**
	10/03/00	Rock Bass	50	3
	10/03/00	Smallmouth Bass	50	**59**
6ALEV151.26	08/09/00	Gizzard Shad (A)	50	**119**
	08/09/00	Gizzard Shad (B)	50	**499**
	08/09/00	Rock Bass	50	8
	07/17/07	Channel Catfish	50	**110**
	07/17/07	Redhorse Sucker	50	**50**
	07/17/07	Northern Hogsucker	50	4
	07/17/07	Rock Bass	50	3
6ALEV155.45	08/09/00	Northern Hogsucker	50	27
	08/09/00	Rainbow Trout	50	29
	08/09/00	Rock Bass (A)	50	22
	08/09/00	Rock Bass (B)	50	29
	08/09/00	Smallmouth Bass (A)	50	12
	08/09/00	Stoneroller	50	9

[1]VDH limited consumption threshold, ppb; **bold** values exceed the VDH threshold; [2]ppb = parts per billion (µg/kg), wet weight basis edible fillet

12.4.1.2 Levisa Fork Tributaries

Only one tissue sample from Dismal Creek (6ADIS010.02) in 1997 (50.13 ppb) and one sample from Garden Creek (6AGAR001.78) in 2002 (180.46 ppb) exceeded the VDH lower threshold level (50 ppb) (Table 12.3). A total of 6 tissue samples collected during 2002 and 2007 from Slate Creek (6ASAT004.56) were below VDH's lower threshold level (mean conc. = 16 ppb).

Table 12.3 Fish tissue sampling results for tPCB from three VADEQ monitoring stations on Levisa Fork tributaries.

Stream	Station	Date	Fish species name	VDH Lower Level[1], (ppb[2])	Total tPCB wet weight basis, (ppb[2])
Dismal Creek	6ADIS010.02	06/19/97	Rock Bass	50	7.76
	6ADIS010.02	06/19/97	Rock Bass	50	3.78
	6ADIS010.02	06/19/97	Smallmouth Bass	50	11.43
	6ADIS010.02	07/22/97	Channel Catfish	50	**50.13**
	6ADIS010.02	08/06/02	Northern Hogsucker	50	3.57
	6ADIS010.02	08/06/02	Rock Bass	50	1.68
	6ADIS010.02	07/18/07	Northern Hogsucker	50	1.77
	6ADIS010.02	07/18/07	Rainbow Trout	50	10.50
Garden Creek	6AGAR001.78	06/19/97	Northern Hogsucker	50	13.76
	6AGAR001.78	06/19/97	Rock Bass	50	11.74
	6AGAR001.78	06/19/97	Smallmouth Bass	50	14.59
	6AGAR001.78	08/07/02	Gizzard Shad	50	**180.46**
	6AGAR001.78	08/07/02	Northen Hogsucker	50	3.53
	6AGAR001.78	08/07/02	Rock Bass - 1	50	2.46
	6AGAR001.78	08/07/02	Smallmouth Bass	50	6.32
	6AGAR001.78	07/16/07	Northern Hogsucker-1	50	1.68
	6AGAR001.78	07/16/07	Rock Bass	50	0.81
	6AGAR001.78	07/16/07	Smallmouth Bass	50	4.69
	6AGAR001.78	07/16/07	Stoneroller	50	0.76
	6AGAR001.78	07/16/07	White Sucker	50	4.06
Slate Creek	6ASAT004.56	08/07/02	Rock Bass - 1	50	11.94
	6ASAT004.56	08/07/02	Smallmouth Bass	50	18.15
	6ASAT004.56	08/07/02	Northern Hogsucker	50	38.45
	6ASAT004.56	07/18/07	Northern Hogsucker-1	50	15.39
	6ASAT004.56	07/18/07	Rock Bass -1	50	5.96
	6ASAT004.56	07/18/07	Smallmouth Bass	50	7.6

[1]VDH limited consumption threshold, [2]ppb = parts per billion (µg/kg or ng/g); wet weight basis edible fillet; **bold** values exceed the VDH threshold.

12.4.2 Sediment Sampling Analysis and Summary

Since PCBs have a strong affinity for solids, VADEQ performed sediment sampling at 18 sites on the Levisa Fork from 1990 to 2002, at one station in Garden Creek during 1997 and 2002, and at one station in Slate Creek also during 1997 and 2002. Table 12.4 shows the results of these sampling efforts organized by year and moving from downstream to upstream stations. Given the prominent hydraulic gradient (steep slope) within the watershed, it is difficult, at many locations, to find depositional areas where sediments have settled to the streambed. During periods of elevated flow, the system is susceptible

to scouring of streambed sediments, which can impact the ability to bracket nearby upland PCB sources. The following conclusions have been drawn from the existing data set:

- These data suggest tPCBs in sediments may be decreasing over time at stations 6ALEV130.00 and 6ALEV131.52 as the highest observed values in the data set occurred in 1990 (1,000 ppb) and 1992 (2,400 ppb). However, this observation is made with the caveat that high PCB levels measured in sediment can be hit or miss in a system like Levisa Fork due to the hydraulic gradient.

- Elevated PCB concentrations found at the Kentucky/Virginia stateline indicates this area is likely pre-disposed to sediment deposition. High sediment concentrations provide an on-going source of PCBs to aquatic life through partitioning to the water column as well as through re-suspension.

- The 2000 sediment collection shows relatively low values throughout Levisa Fork with a spike upstream of the Conaway Creek and Levisa Fork confluence.

- All samples upstream of Rocklick Creek, including samples from Garden Creek and Slate Creek, were at or below 500 ppb.

Table 12.4 Streambed sediment tPCB results from VADEQ monitoring.

Station	Station Location	Date	Sediment tPCBs (ppb)
6ALEV130.00	Levisa Fork near KY-VA line	7/17/90	**1,000**
6ALEV130.00	Levisa Fork near KY-VA line	8/20/90	500
6ALEV130.00	Levisa Fork near KY-VA line	7/22/97	ND
6ALEV130.00	Levisa Fork near KY-VA line	08/08/00	1.32
6ALEV130.00	Levisa Fork near KY-VA line	08/06/02	**894.89**
6ALEV130.25	Levisa Fork last bridge near KY-VA line	10/03/00	17.93
6ALEV130.52	Levisa Fork upstream of Buckeye Branch	10/03/00	9.24
6ALEV130.79	Levisa Fork between Buckeye Branch and Conaway Creek	10/03/00	6.26
6ALEV131.14	Levisa Fork just downstream of Conaway Creek	10/03/00	49.98
6ALEV131.27	Levisa Fork just upstream of Conaway Creek	10/03/00	306.34
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	7/16/92	**2,400**
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	6/9/93	440
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	6/9/94	10
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	7/18/95	140
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	7/9/96	30
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	5/13/97	50
6ALEV131.52	Wellmore Coal Co.Dock #14 Bridge off 460	5/10/99	20
6ALEV131.88	Levisa Fork downstream of Unamed Trib	10/03/00	6.97
6ALEV132.16	Levisa Fork upstream of Unamed Trib	10/03/00	0.77
6ALEV132.31	Levisa Fork between Unamed Trib and Rocklick Creek	10/03/00	5.43
6ALEV132.62	Levisa Fork just downstream of Rocklick Creek	10/03/00	4.89
6ALEV132.91	Levisa Fork downstream of Harper Branch	10/03/00	2.31
6ALEV134.82	Levisa Fork downstream of Weller	08/08/00	3.35
6ALEV141.28	Levisa Fork upstream of Twentymile Creek	10/03/00	1.05
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	7/16/92	500
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	6/9/93	500
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	6/9/94	30
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	8/14/95	210
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	7/9/96	40
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	9/2/97	60
6ALEV143.86	Steel Bridge on Railroad Ave off Rt 83	5/10/99	30
6ALEV145.86	Levisa Fork downstream of Tookland	10/03/00	1.29
6ALEV151.26	Levisa Fork downstream of Dismal Creek	08/09/00	4.54
6ALEV155.45	Levisa Fork near Oakwood	08/09/00	4.53
6AGAR001.78	Garden Creek near Garden Creek Mission Church	06/19/97	105.68
6AGAR001.78	Garden Creek near Garden Creek Mission Church	08/07/02	6.42
6ASAT004.56	Slate Creek near Buchanan Co. Vocational School	07/22/97	0.69
6ASAT004.56	Slate Creek near Buchanan Co. Vocational School	08/07/02	2.51

Bold values are above the PEC value for tPCB in sediment = 676 ug/kg

On September 12, 2000, EPA and the Virginia Department of Emergency Management (VDEM) conducted soil and sediment sampling in Levisa Fork near the Virginia-Kentucky state line. Ten soil samples and 10 sediment samples were collected in Levisa Fork and along the streambank. Of these samples, one sediment sample collected from the western streambank contained an Arolcor-1260 concentration of 1,600 ppb. Three additional soil samples that contained Arochlor-1260 were obtained from the vegetation line on the western bank, a sandbar in the middle of Levisa Fork, and a sandbar near the eastern bank. The samples from these sites had 240 ppb, 150 ppb, and 38 ppb of Aroclor-1260, respectively.

During the Route 460/Grundy Flood Control project managed by the Virginia Department of Transportation (VDOT), soil samples were collected and analyzed for tPCBs. One sample, taken north of Slate Creek near the confluence with Levisa Fork, contained 428 ppb of total Arochlor.

12.4.3 Water Column Sampling Analysis and Summary

VADEQ conducted a special study in Levisa Fork during fall 2007 and spring 2008. The study was designed to augment the existing water quality record in support of TMDL development. Water quality samples were collected during low-flow and high-flow conditions at 11 monitoring locations throughout the watershed. The study design was to help bracket potential source areas. Because of the hydrophobic properties of PCBs and insensitive analytical methods, samples collected for prior monitoring studies routinely failed to detect measurable concentrations of PCBs. These special study results were analyzed using a high-resolution, low-detection level analysis method (1668A) specifically to account for PCBs' hydrophobic properties and are presented as picograms/Liter (pg/L or parts per quadrillion). The tPCB concentrations are shown in Table 12.5.

Under low flow conditions, tPCB concentrations are well below the WQC of 640 pg/L. This is consistent with low TSS levels, showing that PCBs were not washing off upland contaminated sites during sample collection.

Elevated tPCB concentrations (Table 12.5 and Fig. 12.8) are found during high flow on Levisa Fork at stations 6ALEV131.52 (986 pg/L) and 6ALEV143.80 (836 pg/L), and on Dismal Creek at station 6ADIS001.24 (1,140 pg/L). Elevated tPCB concentrations during high Levisa Fork flows is not surprising since PCBs are associated with resuspended particulates from streambed sediments and newly introduced particles associated with the erosion of PCB contaminated upland soils.

Table 12.5 tPCB concentrations in the Levisa Fork watershed.

Ambient Location	Sample Date Low Flow	Total tPCB (pg/L) *	Sample Date High Flow	Total tPCB (pg/L) *
6ALEV131.52 - Levisa Fork	9/27/2007	23	3/5/2008	986
6AHME000.42 - Home Creek	9/27/2007	11.3	3/5/2008	104
6ABLC002.30 - Bull Creek	10/1/2007	52.4	3/5/2008	148
6ASAT000.26 - Slate Creek	10/23/2007	133	3/5/2008	323
6ALEV143.80 - Levisa Fork	9/27/2007	35	3/5/2008	836
6ABIP000.18 - Big Prater Creek	9/26/2007	0	3/5/2008	132
6ADIS001.24 - Dismal Creek	9/26/2007	8.3	3/5/2008	1,140
6A LEV152.46 - Levisa Fork	9/26/2007	5.7	3/5/2008	372
6AGAR000.16 - Garden Creek	9/26/2007	40	3/5/2008	537
6AGRF000.56 - Rt. Fk. Garden Creek	9/26/2007	13.2	3/5/2008	218
6ALEV156.82 - Levisa Fork	9/26/2007	141	3/5/2008	428

*Results corrected to account for slight background PCB concentration.

13. TOTAL PCB (tPCB) SOURCE ASSESSMENT

Information presented in this section includes the best available to date on point and nonpoint sources of PCBs in the Levisa Fork watershed. The development of PCB TMDLs in the Levisa Fork watershed is subject to adaptive implementation and on-going source investigation whereby sources of PCB contamination are continuously being reviewed and updated based on the best available information. The following discussion of PCB sources, therefore, should be considered the most up-to-date information at the time of the development of this TMDL, rather than a complete and final characterization. The discussion that follows is limited to identification of the sources represented in the TMDL.

For the purposes of this TMDL, sources of PCB loadings to a waterbody are defined as either current or legacy. Current sources generate PCB loads that have a defined, disruptable pathway to a waterbody. Such sources, in theory, can be controlled either by eliminating the source of PCBs or by blocking the pathway. Examples of current sources include PCB-contaminated soils that wash off from upland areas, leachate from landfills and industrial disposal areas, leaking transformers and storage containers, discharges of PCB-contaminated effluent, local deposition of atmospheric PCBs accumulated from off-gassing contaminated sites, and a variety of other sources.

Legacy sources generate PCB loads to a waterbody that cannot be easily controlled because there is no disruptable pathway from the source to the affected waterbody. Control of the source requires its direct removal. In all cases, the source exists at an interface with the waterbody where there is continuous exchange of material. Examples of legacy sources include in-stream contaminated sediments, stream bank soils that are not part of a contaminated site, biota, and background atmospheric deposition to surface waters.

Both current and legacy sources are represented in the TMDL model framework.

13.1 Permitted Discharges

Three VPDES and twelve coal facility permitted dischargers in the Levisa Fork watershed provided Total Polychlorinated Biphenyls (tPCB) data for use in the source assessment and development of existing loads for the impending tPCB TMDL (Table 13.1). These data were voluntarily generated by the permitted dischargers, as requested by VADEQ during a December 2007 meeting held in Grundy, Virginia. It was requested that permittees use EPA Method 1668 to generate the results. Detailed information was disseminated on sample collection and the analytical requirements needed to generate meaningful data relative to Virginia's tPCB Water Quality Criterion (WQC) of 640 picograms per liter (pg/L).

VADEQ's experience with Method 1668 has resulted in several laboratories demonstrating the capability of quantifying tPCB congeners at low levels. Since the method is performance based, there is enough latitude for laboratories to make the necessary modifications to attain reporting levels (EMLs) well below those presented in the EPA method.

Table 13.1 Total PCB (tPCB) data from permitted sources in the Levisa Fork watershed.

Permit ID	Facility	Outfall	Precipitation Influence	tPCB (pg/L)	Receiving Stream
	Conaway STP				
VA0090531	Treated wastewater effluent	1	Wet	3,061	Levisa Fork
VA0090531	Treated wastewater effluent	1	Dry	706	Levisa Fork
VA0090531	Treated wastewater effluent	1	Dry	1,104	Levisa Fork
	Jewel Smokeless Coal				
1200354		1	Wet	7	Dismal Creek
1200354		1	Dry	92	Dismal Creek
1300425		4	Wet	135	Dismal Creek
1300425		4	Dry	145	Dismal Creek
1300426		7	Wet	1,009	Dismal Creek
1300426		7	Dry	117	Dismal Creek
1201532		B	Wet	18	Dismal Creek
1201532		B	Dry	79	Dismal Creek
	Norfolk Southern Railway Co				
VA0052639	Stormwater discharge	1	Dry	43,839*	Levisa Fork
VA0052639	Stormwater discharge	1	Wet	45,027*	Levisa Fork
	Consol Coal				
1400047	Underground mine water at diffuser	33	Wet	19.3	Levisa Fork
1400047	Underground mine water at diffuser	33	Wet	25.6	Levisa Fork
1400047	Coal processing plant	3	Wet	93.4	
1400047	Coal processing plant	18	Wet	31.0	
1400047	Coal processing plant	21	Wet	63.8	
1400047	Coal processing plant	27	Wet	96.5	
1400047	Coal processing plant	3	Dry	48.1	
1400047	Coal processing plant	18	Dry	40.7	
1400047	Coal processing plant	21	Dry	42.3	
1400047	Coal processing plant	21	Dry	52.3	
1400047	Coal processing plant	27	Dry	53.1	
	Wellmore Coal				
1200282	SW Runoff deep mine face-up areas	1		5.2	
1200335	SW Runoff deep mine face-up areas	S-3		4.1	Enoch Branch
1201988	SW Runoff deep mine face-up areas	3		3.4	Horse Branch
1300451	SW Runoff from coal processing plant & rail car loading	4		2.6	Hackney Creek
1101736	SW from surface mining mixed with underground mine drainage	1		1.2	Burnt Poplar
1201539	SW from surface mining mixed with underground mine drainage	1		13.0	Smith Branch
1301640	SW Runoff from coal processing plant & rail car loading	003-S		194.3	Rockhouse Creek

*All tPCB congeners reported as non-detect at elevated reporting level. tPCB values based on 1/2 Estimated Minimum Level.

13.2 Nonpoint PCB Sources

13.2.1 Atmospheric Deposition

The widespread use of PCBs before their ban in the 1970s, coupled with their stable molecular structure, has caused a generalized distribution of the pollutant in air, soil, and water at background concentrations. The net flux of gaseous PCBs between the atmosphere and the surface of a waterbody is a function of the dynamic concentration gradient between the two. Atmospheric deposition has been shown to be a significant pathway of PCB cycling in freshwater systems (PADEP 2001). The value used in this project is 1.6 $\mu g/m^2/yr$ (CBP, 1999).

13.2.2 Streambed Sediments

Streambed sediments can contain significant concentrations of PCBs from historical or current loadings or both. These PCBs can be released to the water column by the resuspension of streambed sediments, by the desorption of PCBs at the streambed-water column interface, and by the direct diffusion of PCBs from lower contaminated sediment layers.

In-stream processes govern the movement and accumulation of streambed sediments. Contaminated streambed sediments are available for consumption by aquatic biota, are transported downstream, and can be buried under additional sediments. Downstream transport can result in flushing sediments out of the system or trapping sediments behind downstream dams. In two existing PCB projects, the Hudson River project in New York and the Housatonic River project in Massachusetts, historical discharges have contaminated sediment, which have collected in slow river stretches or reservoirs. These contaminated sediments tend to remain in such depositional areas until they are removed by dredging or dislodged by storms.

13.2.3 Known Contaminated Sites

There are six sites in the Levisa Fork watershed where tPCBs were spilled or released and the Virginia Department of Emergency Management (VDEM) was notified. These areas have been identified, assessed and reported to the EPA. It is important to discuss

these incidents in this project, as similar tPCB spills are most likely occurring without the knowledge of local government and nearby citizens and are likely contributing on-going sources. If the following descriptions are familiar in an area not discussed here, please contact your local Hazardous Materials Officer (www.vaemergency.com/programs/hazmat/officers.cfm).

In March 1998, a local citizen contacted VDEM regarding an illegal dump with seven transformers and 75-100 batteries. The dump was located at the old Hobbs Grocery on Route 635 approximately 3.8 miles past the Dismal River Rescue Squad. The citizen reported that there was burning and breaking old mining equipment at this site. This site is in the Dismal Creek watershed (subwatershed 11). PCB soils or sediment data are unavailable.

A Virginia Department of Transportation (VDOT) staff member reported an illegal dump in October 1992. Along Route 610 off Route 460, at least three transformers were discovered. This site is in the Conaway Creek drainage area which empties into Levisa Fork near the Kentucky state line in subwatershed 8. PCB soils or sediment data are unavailable.

In January 1992, an illegal dump was reported near Whitewood, Virginia off Route 690 near Harry's Branch Creek. An unknown number of transformers and batteries were reported at this site, which is in the Dismal Creek watershed (subwatershed 11). A soil sample from Upper Harry's Branch collected in November 1994 had 799 ppm Aroclor 1260. More recent soil samples (August 2008) yielded average and median concentrations of 54.5 ppm and 1.7 ppm, respectively. Nearby sediment samples had a mean concentration of 0.012 ppm, while PCBs were not detected in the water samples (method 1668). This site is currently (fall 2009) undergoing remediation by EPA with a target clean-up level of 0.277 ppm.

Acid and tPCB dumping was reported at Left Fork Mine and Brookie Coal Mine near Pilgrims Knob, Virginia in February 1990. These areas were abandoned coal mine sites and evidence of transformer stripping showed possible tPCB contamination to the nearby stream at one location. Charred and melted transformer parts were noted, as well as an

oil sheen on a nearby settling pond. Pictures, soil samples and water samples were collected. Three soil samples taken from the Left Fork Mine site ranged from Non Detected to 12 ppm tPCBs. The surface of the settling pond had 9.8 µg/L tPCBs. The Brookie Coal Mine site soil sample had 20 ppm tPCBs. This site is in the Dismal Creek watershed (subwatershed 11).

The final known site where tPCBs have been detected is in Grundy, Virginia at the R. C. Billards conveyer belt business. This location is off Route 460 near the Advance Auto Parts store. Aroclor 1254 was detected at 3,600 ppb in a water sample from a monitoring well on the business property. This sample was collected in August 1996.

These six sites are shown in subsequent maps as the approximate locations of known PCB spills.

13.2.4 General Data Trends that show Potential Unknown Contaminated Sites

The results of the fish tissue monitoring in Levisa Fork show a general trend toward higher tPCB values in fish near the watershed outlet where the river flows into Kentucky (Figure 13.1). The box and whisker plot shows the second quartile (Q2), third quartile (Q3), 10% of sample data, 90% of sample data, average (mean), minimum (min) and maximum (max) of all the fish tissue data collected from Levisa Fork by station. Even though fish are model in a stream system, this graph indicates the potential for a PCB source in between upstream station 6ALEV134.82 and downstream station 6ALEV130.00.

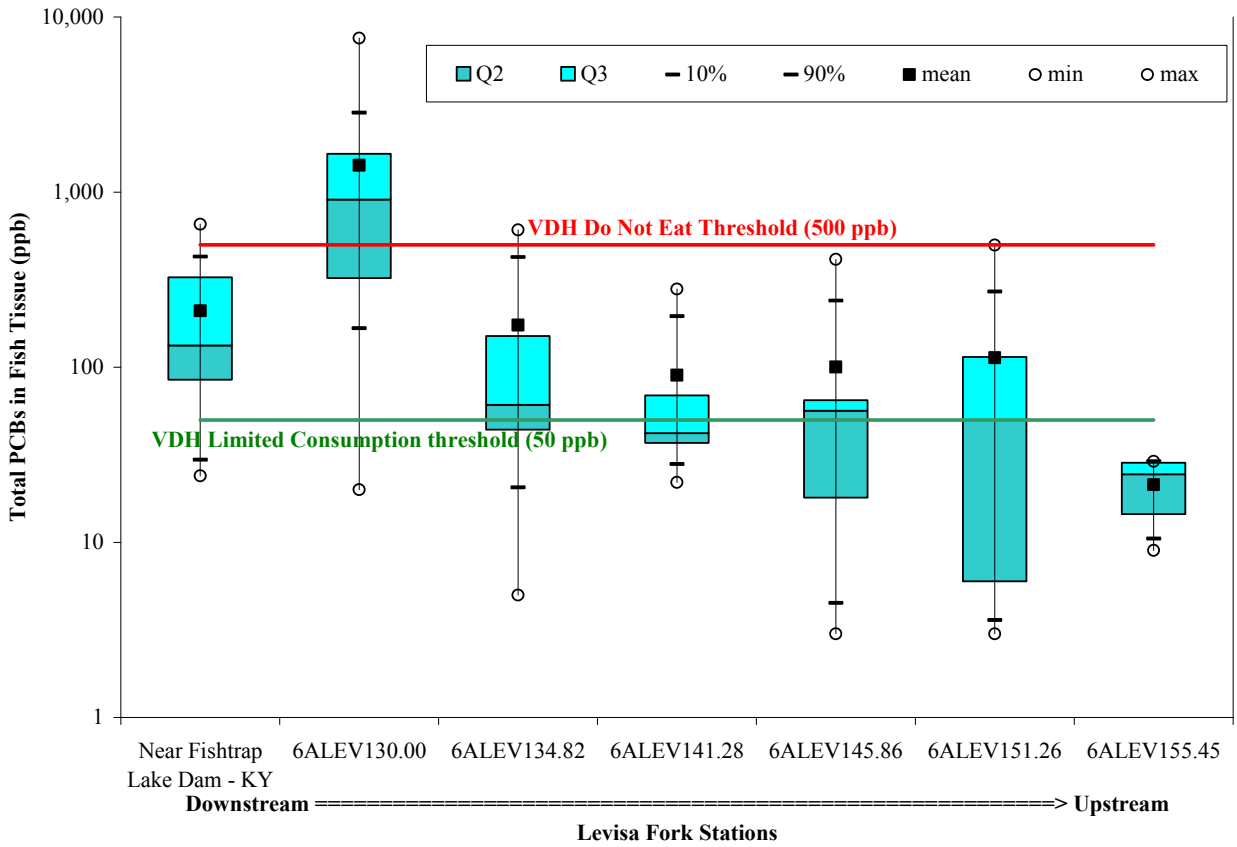

Figure 13.1 Levisa Fork fish tissue sample tPCB results organized downstream to upstream.

Since fish are mobile, it is difficult to pinpoint potential source areas based on these data. However, the data in Table 12.2 and Figure 13.2 both show there are elevated levels of tPCBs in the fish tissue of fish samples collected near the Kentucky-Virginia state line. The fish tissue tPCB concentrations are higher downstream of Dismal Creek starting at station 6ALEV151.26 and increase downstream to the outlet into Kentucky. Figure 13.2 shows the average fish tissue tPCB concentrations from all fish species from samples along the Levisa Fork and tributaries, as well as downstream of the project watershed. There is an obvious spike in the fish tissue tPCB data at station 6ALEV130.00 at the VA-KY state line. The tPCB concentrations in fish are also high downstream in Fishtrap Lake, but these levels are lower than at the state line, suggesting the contamination is not only from streambed sediments retained in Fishtrap Lake.

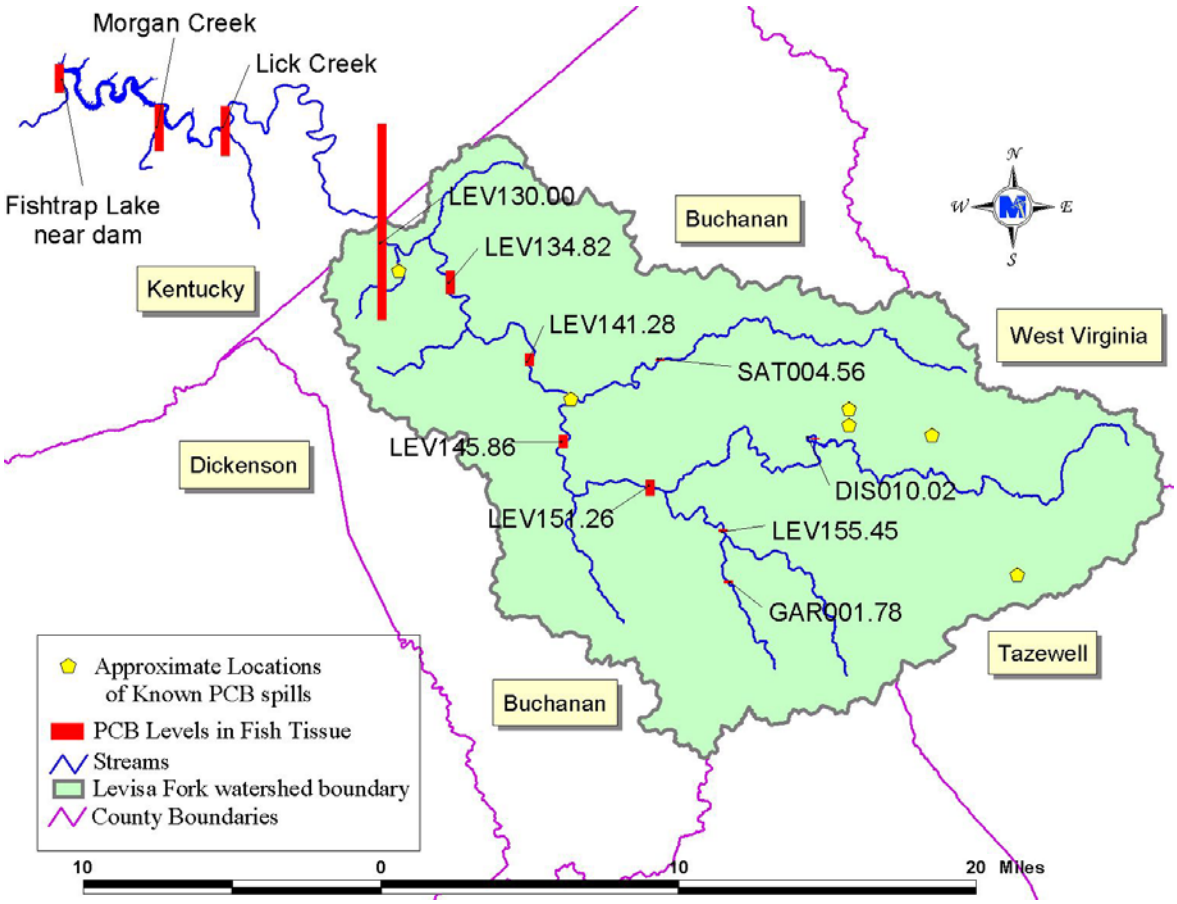

Figure 13.2 The locations and average concentrations of tPCBs in fish tissue samples in the Levisa Fork watershed and extending downstream into Fishtrap Lake, KY.

Another, less obvious, increase in the tPCB fish tissue data occurs between stations 6ALEV155.45 and 6ALEV151.26 on Levisa Fork. The average tPCB concentration jumps from 21 ppb at station 6ALEV155.45 to 113 ppb at downstream station 6ALEV151.26. The major tributary, Dismal Creek empties into Levisa Fork between these stations. Even though only one fish tissue sample was above the VDH lower level tPCB screening value (50 ppb) from the Dismal Creek station, this sampling station is 10.02 miles upstream. There may be sources of tPCBs in the downstream drainage area of Dismal Creek. There may also be a tPCB source along the Levisa Fork mainstem in between stations 6ALEV151.26 and 6ALEV155.45.

The VADEQ performed high and low flow water column PCB sampling sweeps in September and October 2007 and March 2008 to try and isolate areas of high tPCB contributions in the Levisa Fork watershed (Table 12.5). The high flow sampling sweep

followed a significant rainfall event. Sampling station 6ALEV131.52 is very close to the USGS flow gage 03207800 on the Levisa Fork At Big Rock, VA. Drainage area adjusted flows were determined for every monitoring station in the sweep and tPCB loadings were calculated for high flow samples collected on March 5, 2008 (Figure 13.3). This map is shown to demonstrate the relative differences between the tPCB loads during one sampling event.

The results indicate that Dismal Creek was a significant source of tPCBs at the time of the sampling. One third of the total loading at monitoring station 6ALEV131.52 can be attributed to Dismal Creek. In addition, much of the loading at station 6ALEV131.52 can be attributed to unknown sources downstream of station 6ALEV143.80.

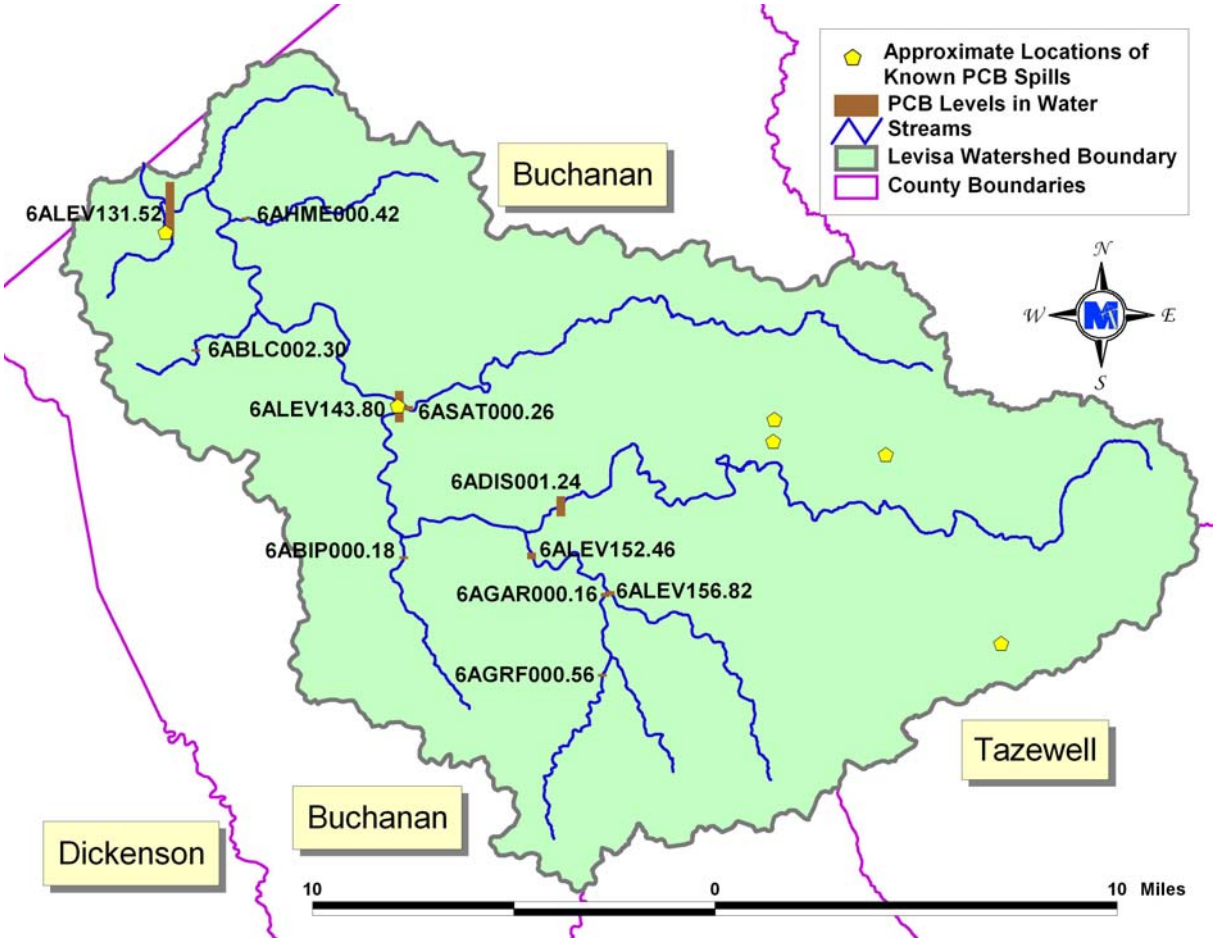

Figure 13.3 High flow tPCB loadings in the Levisa Fork watershed, March 5, 2008.

The tPCB in-stream sediment results are spotty. High values were detected in 1990, 1992, and 2002 at stations near the outlet of Levisa Fork. All samples upstream of Rocklick Creek, including samples from Garden Creek and Slate Creek, were at or below 500 ppb. Figure 13.4 shows the average tPCB concentrations in sediment for all data in the watershed. There is a PCB hot spot at the state line in the sediment data, ehich corresponds well to the higher fish tissue PCBs at the state line station (6ALEV130.00). There is a smaller spike in the sediment tPCB concentration at station 6ALEV143.86, which is near the outlet of Slate Creek where it empties into Levisa Fork.

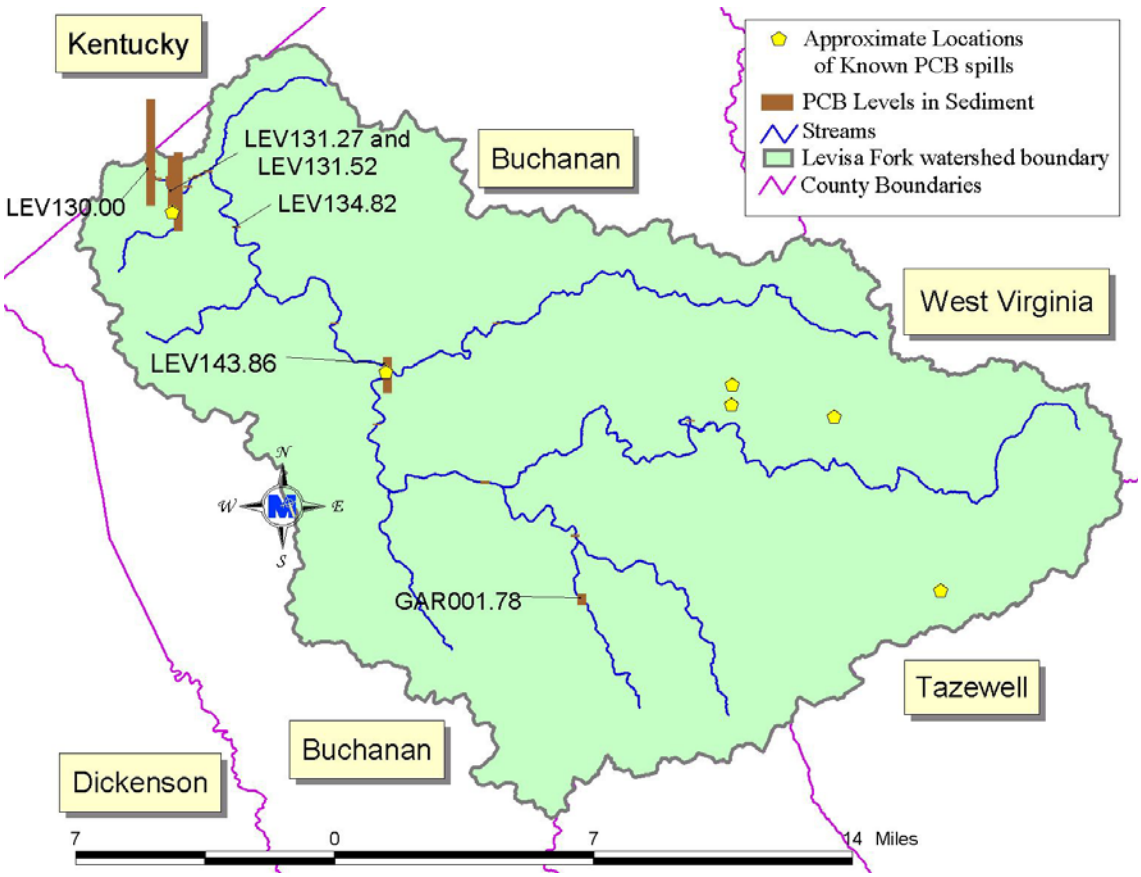

Figure 13.4 The locations and average concentrations of tPCBs in sediment samples in the Levisa Fork watershed.

The general PCB data trends discussed here show hot spots of higher PCB concentrations along Levisa Fork and its tributaries. Without a more intensive study of all potential sources/sites, the known contaminated sites, and streambed sediments of tributaries, it is difficult to pinpoint where all PCBs sources in this watershed are located. This chapter has provided a discussion of where potential sources may be by observing the data

currently available. Possible unreported areas that are contaminated with tPCBs could be illegal dumps of leaking tPCB containing items, current mining operations with leaking equipment or transformers, abandoned mine lands, deep mines used as dump sites for non-useable equipment, or contaminated soil from old spills.

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14. TOTAL PCBS (tPCBs) MODELING PROCEDURE AND ALLOCATION

14.1 Model Selection, Model Setup, and Hydrology Modeling

HSPF was used as the modeling framework for the PCB modeling. The modeling framework selection, model setup of rainfall data, subwatershed, land uses, stream characteristics and hydrology modeling were the same for the PCB HSPF model as the bacteria HSPF model. These are explained in Section 4.1, 4.2, and 4.4 of this report. All The HSPF hydrology modeling components of the PCB model were the same as the hydrology components of the bacteria model.

The PCB data that were available for model calibration were collected during the 2008 water year. Due to this constraint, modeling was restricted to this time period to maintain confidence in the modeled output. This data limitation is one of the reasons that this TMDL has been submitted as a "Phase I" of a phased TMDL. While the time frame for modeling was limited, it did include both baseflow conditions and storm events, which are considered to be the two hydrologically critical conditions for NPS pollutant delivery and impact.

14.2 PCB transport

Polychlorinated bi-phenyls (PCBs) are hydrophobic compounds that tend to attach to organic matter, fatty tissue or become dissolved in an organic solvent rather than dissolve in water. These compounds are much more likely to be found in streambed sediments and in fish tissues within a contaminated channel. For this reason, total suspended sediment (TSS) was modeled as the vehicle on which PCBs travel from the land to surface waters, become suspended in the water column, and settle out in streambed sediments. TSS concentrations were calibrated, and then PCBs were attached to the TSS in order to model total PCB concentrations in the stream. This modeling was done using HSPF. The model is explained in more detail in Chapter 4.

14.2.1 Known and Unknown PCB Spill Sites

Of the six sites in the Levisa Fork watershed that either have PCB containing found and documented or have documented PCB spills, none have enough data collected to model the site specifically.

14.2.2 Permitted PCB point sources

For existing conditions, permitted point sources that deliver water and PCBs to the streams were modeled using known flow discharges from DEQ data and an average PCB concentration from sampling efforts (Table 13.1). For mining land uses, the average of all sampling was used as the inflow and groundwater concentrations (92 pg/L).

14.2.3 TSS calibration

There are no set criteria for water quality calibration set forth for a TMDL. Water quality observations are sparse with different amounts of data per stream. This makes it difficult to set standard criteria that must be met for all streams with different number of observations at different times during the day. Water quality calibration acceptance is evaluated based on three separate evaluations of the differences between observed and modeled TSS concentrations. The evaluations include: observed versus modeled TSS concentration graphs, maximum, and percentage greater than 30mg/L as a screening value.

Water quality calibration is complicated by a number of factors. First, water quality (TSS) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of TSS is variable by sampling location in the stream and grab sampling, which lead to difficulty in measuring and modeling TSS concentrations.

The TSS calibration was conducted using data from 10/1/2000 to 9/30/2003. Ten parameters utilized for TSS model adjustment are shown in Table 14.1. 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 TSS concentrations was established (Table 14.2).

Table 14.1 Model parameters utilized for TSS calibration.

Parameter	Units	Description	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
DELTH	feet	Change in water elevation along reach	0 to any	30.0	26.25 – 472.44
LEN	miles	Length of reach	0.01 to any	1.0	0.50 – 27.70
TAUCS	lb/ft^2	critical shear stress for scour	1.0E-10 to any	0.03 – 0.3	0.03 – 0.50
KSER	complex	coefficient in the detached sediment wash-off equation	0 to any	0.6252 – 0.7288	0.3126 – 0.7288
EXPSAND	complex	exponent in the sand-load power function formula	0 to any	2.0	1.5
KEIM	complex	coefficient in the solids wash-off equation	0 to any	0.03	0.01 - 0.03
NVSI	lb/ac/day	sediment from atmospheric detached storage	any	1.0	0.1
ACCSDP	tons/(ac* day)	rate solids accumulate on land	0 to any	0.01	0.1 – 0.4
REMSDP	1/day	fraction of solids storage removed when there is no runoff, i.e. street sweeping	0 to 1	0.01	0.3 – 0.6
AFFIX	1/day	sediment storage decrease from soil compaction	0 to 1	0.05	0.03 - 0.05

The range of modeled daily average values reaches the instantaneous monitored values. Monitored values are an instantaneous snapshot of TSS concentration, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at a high flow at the highest concentration of the day and thus correctly appear above the modeled daily average. The final calibrated TSS values are shown in Figures 14.1 through 14.6. These figures are presented from upstream to downstream.

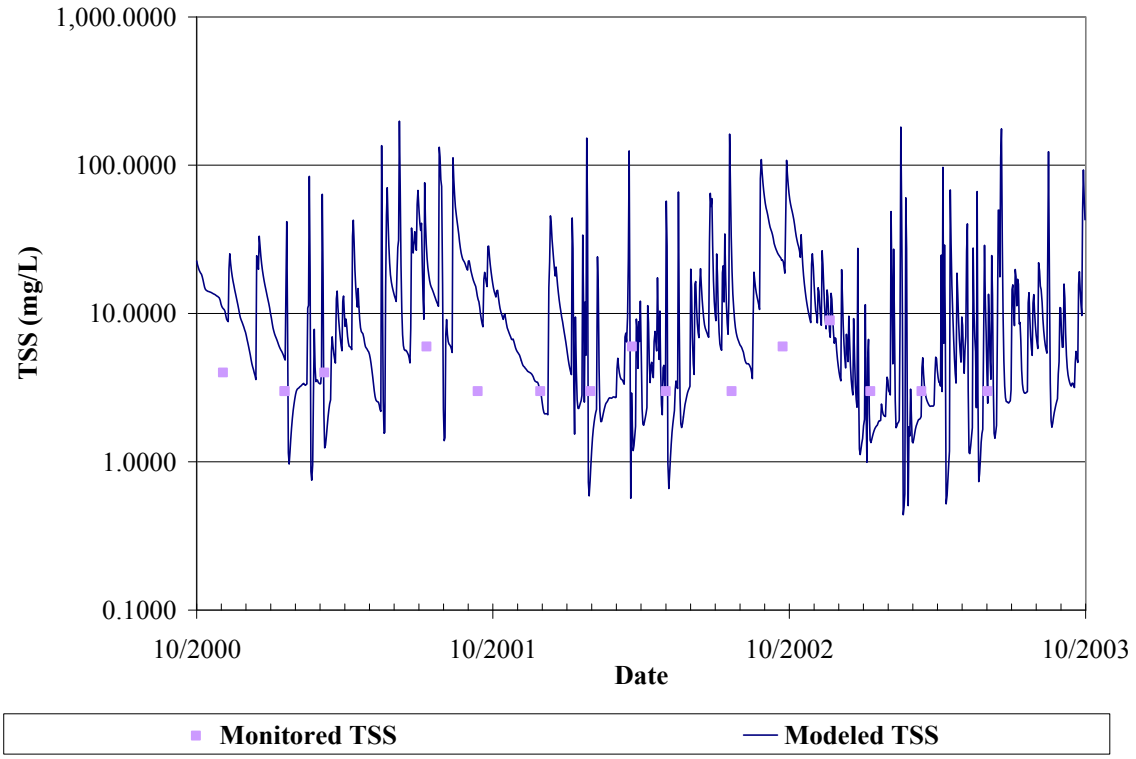

Figure 14.1 TSS calibration results at VADEQ station 6AGAR000.16 in subwatershed 12 in the Garden Creek impairment.

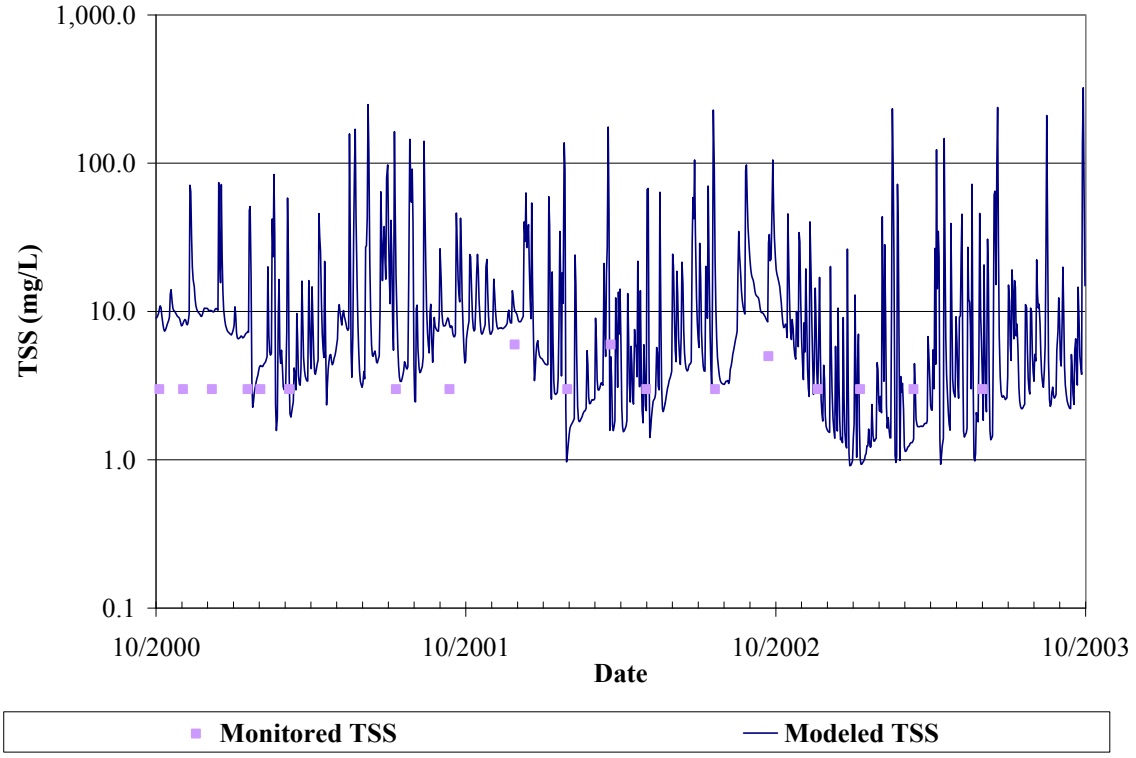

Figure 14.2 TSS calibration results at VADEQ station 6ALEV152.46 at the outlet of subwatershed 12 in the Levisa Fork impairment.

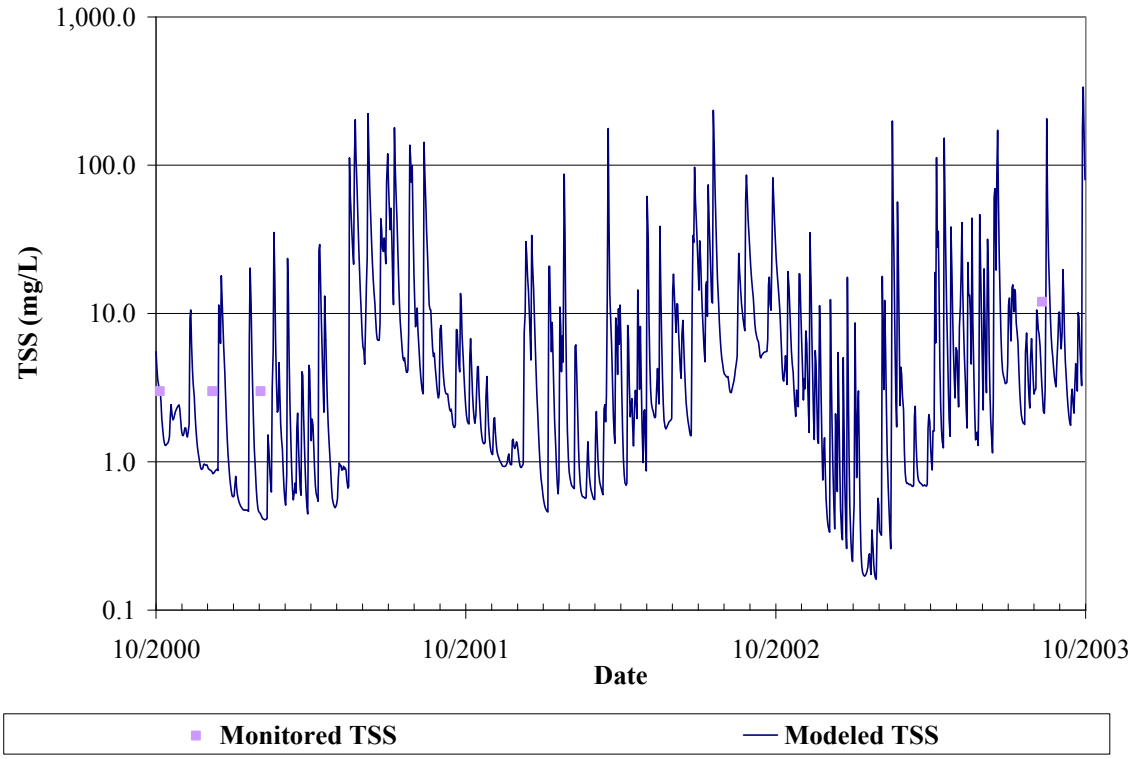

Figure 14.3 TSS calibration results at VADEQ station 6ADIS001.24 at the outlet of subwatershed 11 in Dismal Creek.

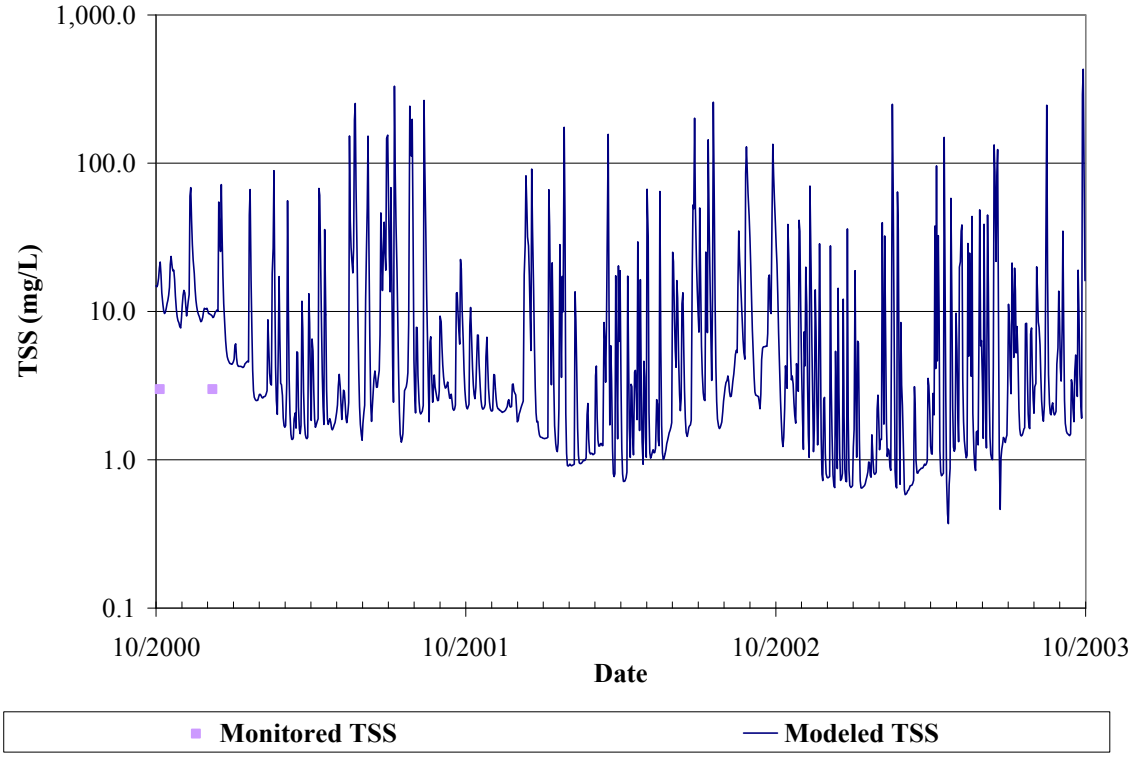

Figure 14.4 TSS calibration results at VADEQ station 6ASAT000.03 at the outlet of subwatershed 10 in Slate Creek.

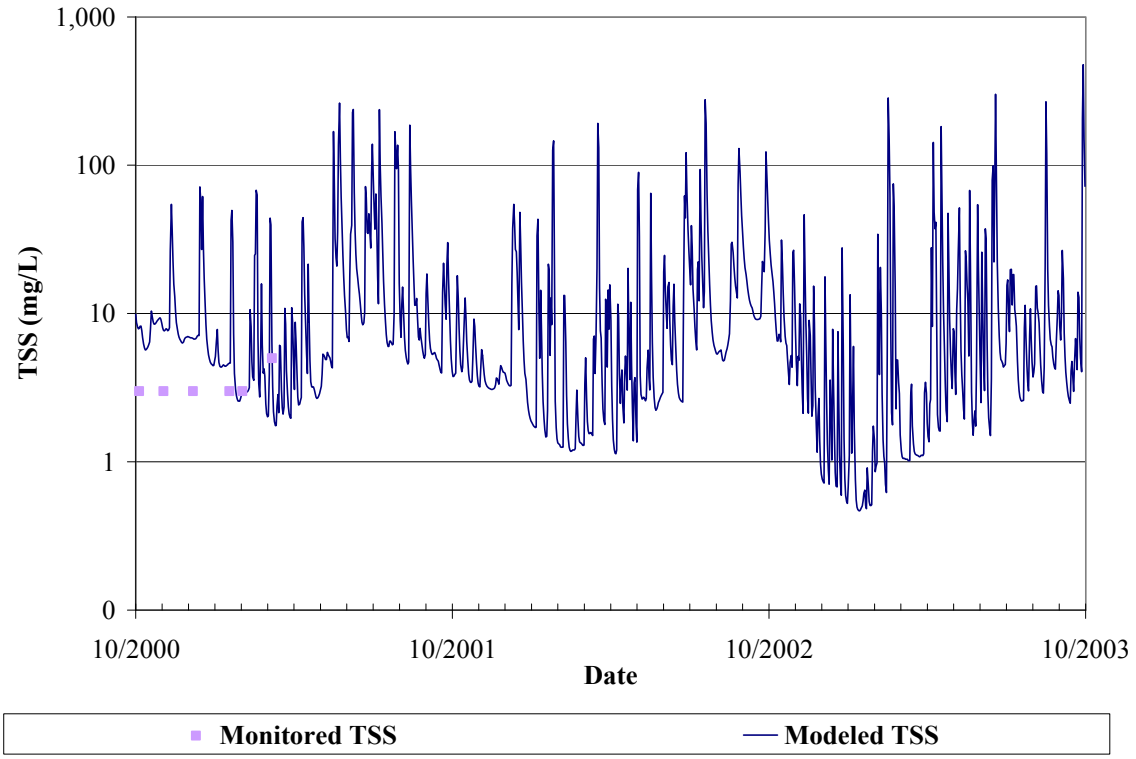

Figure 14.5 TSS calibration results at VADEQ station 6ALEV143.86 at the outlet of subwatershed 5 in the Levisa Fork impairment.

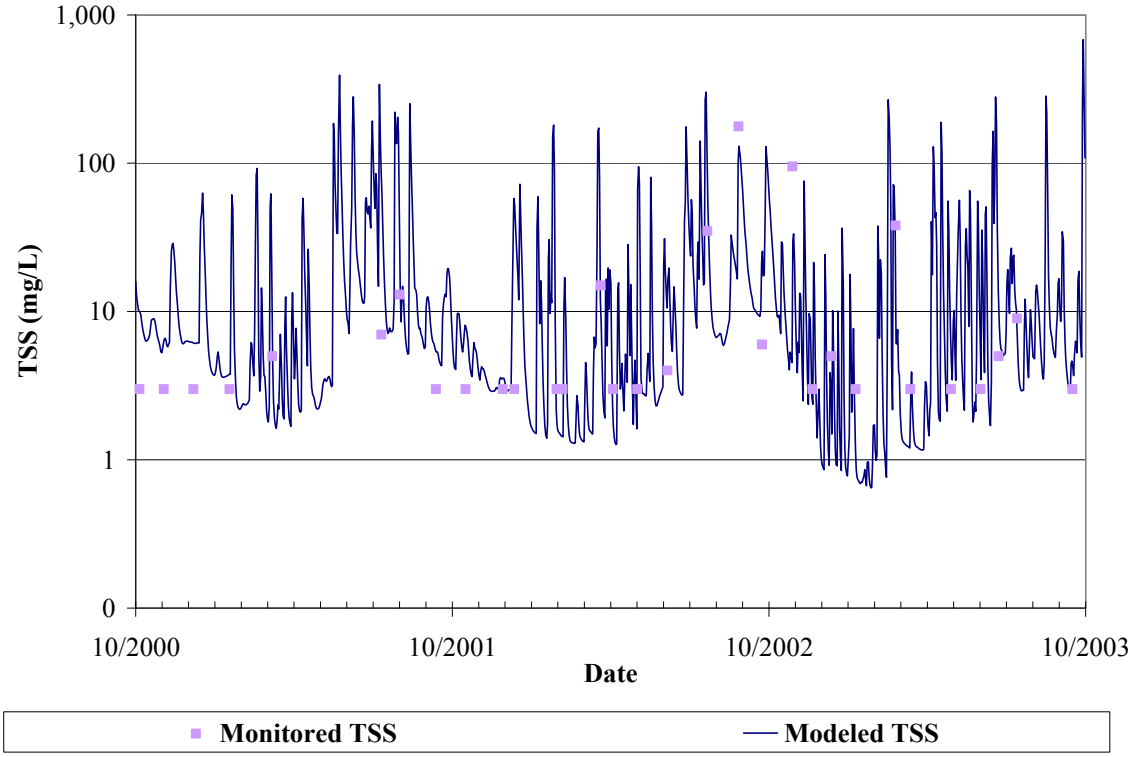

Figure 14.6 TSS calibration results at VADEQ station 6ALEV131.52 at the outlet of subwatershed 8 in the Levisa Fork impairment.

Table 14.2 shows the modeled and observed maximum values and the percentage higher than a 30mg/L TSS screening value. The differences between modeled and monitored values are within one standard deviation of the observed data at each station. The graphs above and the table below show that the results of the TSS calibration are acceptable.

Table 14.2 Comparison of modeled and observed TSS calibration results for the Levisa Fork watershed.

Stream	DEQ Station	Subwatershed	Modeled TSS 10/1/00 to 9/30/03			Monitored TSS 10/1/00 to 9/30/03		
			n	Maximum (mg/L)	% > 30 mg/L[1]	*n*	Maximum (mg/L)	% > 30 mg/L[1]
Garden Creek	GAR000.16	12	1095	198.45	9.68%	16	9.00	0.00%
Levisa Fork	LEV152.46	3	1095	321.82	8.86%	18	6.00	0.00%
Dismal Creek	DIS001.24	11	1095	336.81	8.31%	4	12.00	0.00%
Slate Creek	SAT000.03	10	1095	430.33	9.68%	2	3.00	0.00%
Levisa Fork	LEV143.86	5	1095	472.32	11.78%	6	5.00	0.00%
Levisa Fork	LEV131.52	8	1095	682.19	14.70%	31	177.0	12.90%

[1] 30mg/L is the TSS screening value

14.2.4 tPCB water column calibration

There are no set criteria for water quality calibration set forth for a TMDL. Water quality observations are sparse with different amounts of data per stream. This makes it difficult to set standard criteria that must be met for all streams with different number of observations at different times during the day. Water quality calibration acceptance is evaluated based on three separate evaluations of the differences between observed and modeled PCB concentrations. The evaluations include: observed versus modeled PCB concentration graphs, maximum, and percentage greater than 640 pg/L as the PCB endpoint.

Water quality calibration is complicated by a number of factors. First, water quality (PCB) concentrations are highly dependent on flow conditions and on sediment transport throughout the system. Any variability associated with the modeling of stream flow and

TSS compounds the variability in modeling water quality parameters. Second, the concentration of PCB is variable by sampling location in the stream and composite sampling, which lead to difficulty in measuring and modeling PCB concentrations.

The PCB calibration was conducted from 9/1/2007 to 9/30/2008. Seven parameters utilized for PCB model adjustment are shown in Table 14.3. All of these parameters were initially set at expected levels for the watershed conditions and adjusted until an acceptable match between measured and modeled PCB concentrations was established (Table 4.4).

Table 14.3 Model parameters utilized for TSS calibration.

Parameter	Units	Description	Possible Range	Initial Parameter Estimate	Calibrated Parameter Value
POTFW	pg/ton	Washoff potency factor	0 - any	0	0 – 6.32E09
POTFS	pg/ton	Scour potency factor	0 – any	0	0 – 6.32E09
IOQC	pg/ft^3	Interflow concentration	0 – any	0	0 – 2.80E7
AOQC	pg/ft^3	Groundwater concentration	0 - any	0	0 – 2.83E7
GQ-KD	L/mg	Adsorption coefficients of qual	1.0E-10 - any	0.0001 – 1.0	0.1 – 1.0
GQ-ADRATE	1/day	Adsorption/desorption rate	0.00001 - any	0.0001 – 25.0	0.000065 - 0.00026
GQ-SEDCONC	pg/mg	Initial concentrations on sediment	0 - any	0	1.05 – 19.26

The range of modeled daily average values reaches the instantaneous monitored values. Monitored values are an instantaneous snapshot of PCB concentration, whereas the modeled values are daily averages based on hourly modeling. The monitored values may have been sampled at a high flow at the highest concentration of the day and thus correctly appear above the modeled daily average. The final calibrated PCB values are shown in Figures 4.7 through 4.12. These figures are presented from upstream to downstream.

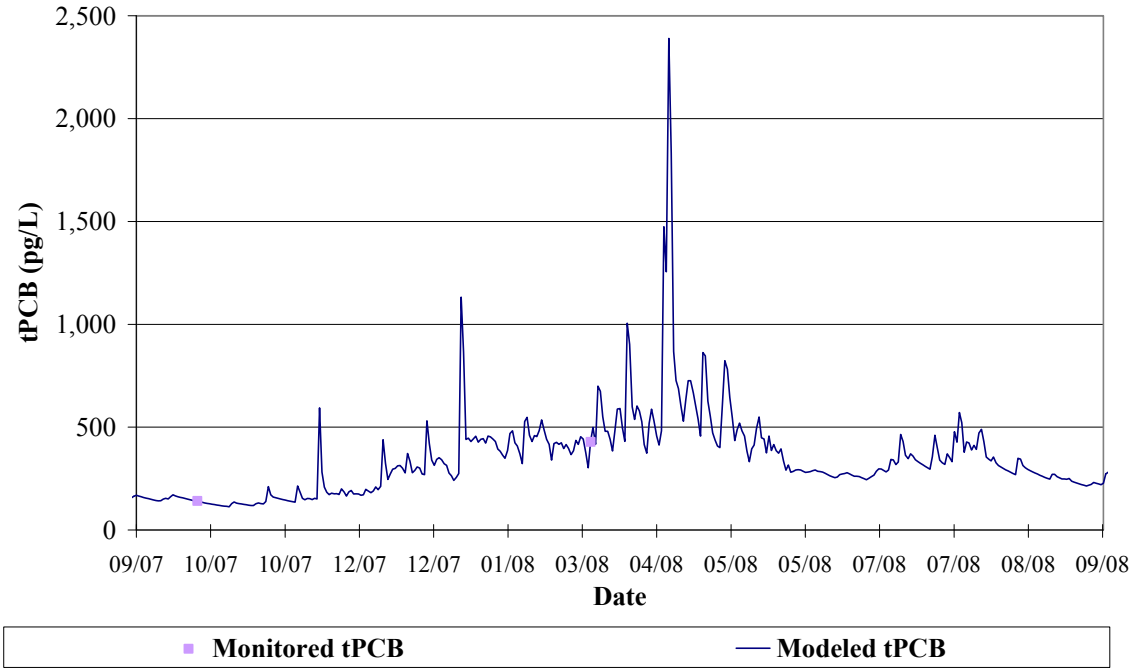

Figure 14.7 PCB calibration results at VADEQ station 6ALEV156.82 in subwatershed 2 in the Levisa Fork impairment.

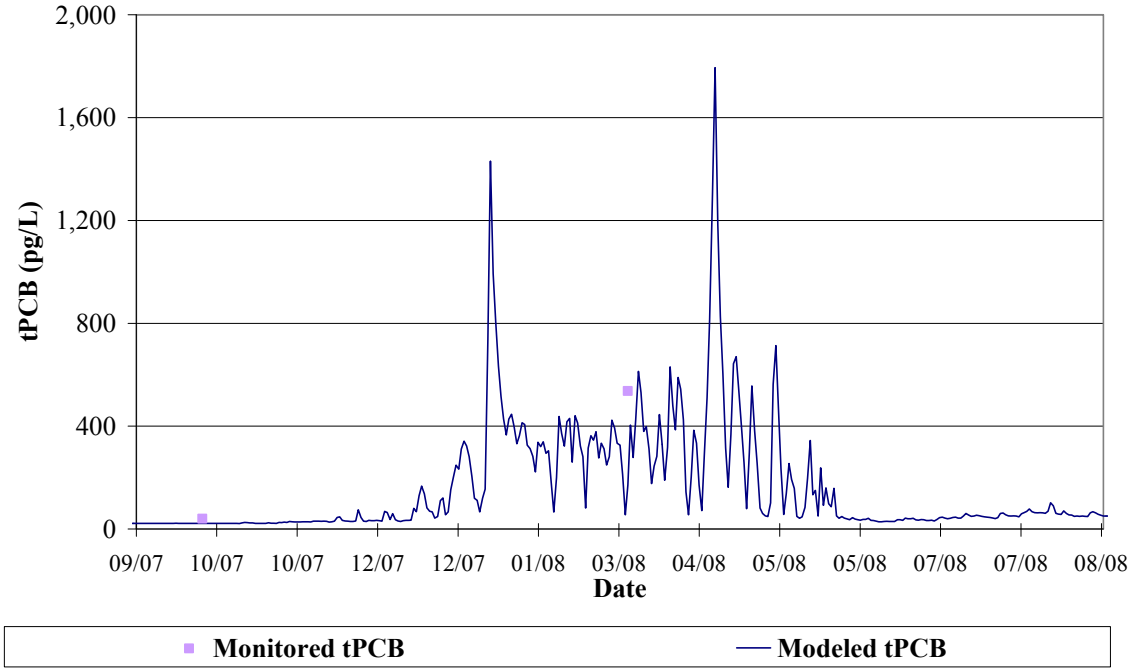

Figure 14.8 PCB calibration results at VADEQ station 6AGAR000.16 in subwatershed 12 in the Garden Creek impairment.

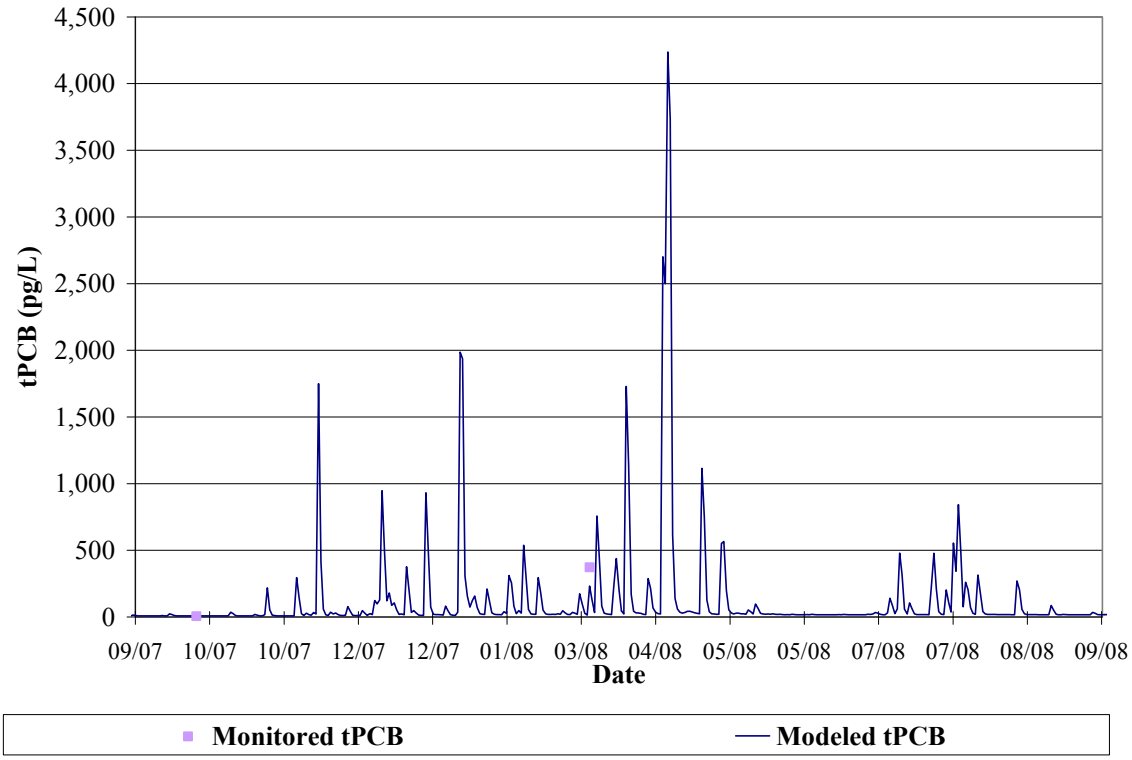

Figure 14.9 PCB calibration results at VADEQ station 6ALEV152.46 in subwatershed 3 in the Levisa Fork impairment.

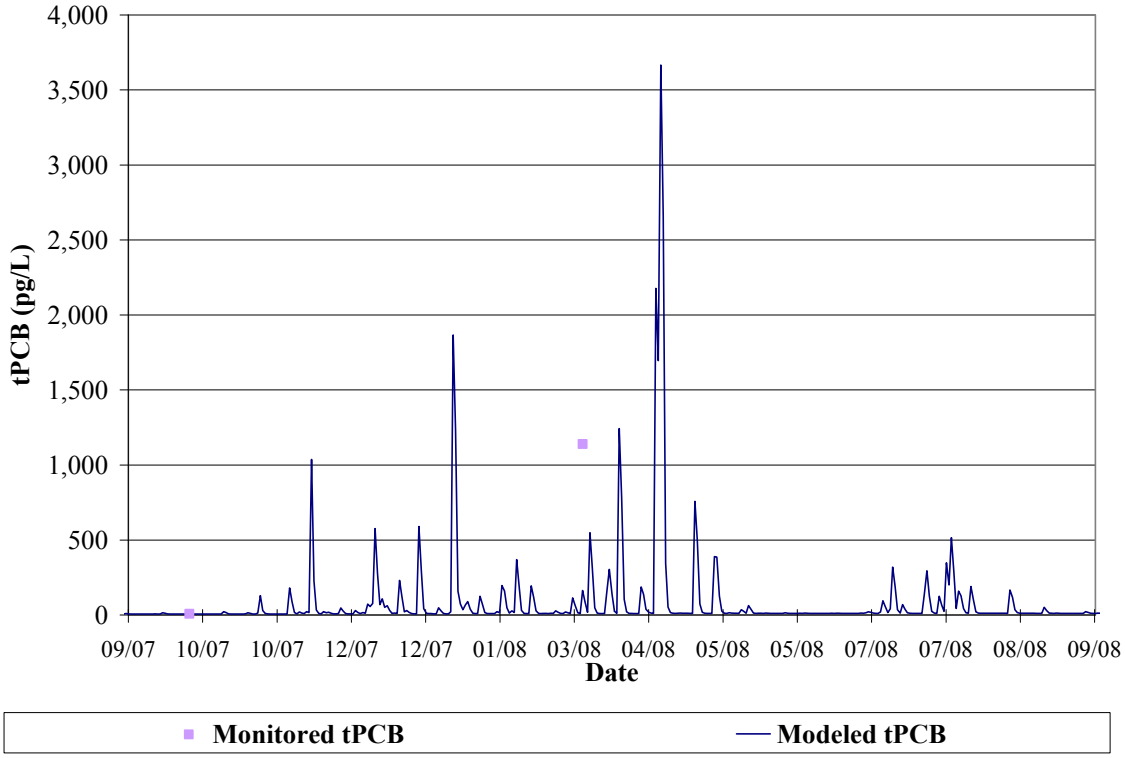

Figure 14.10 PCB calibration results at VADEQ station 6ADIS001.24 in subwatershed 11 in Dismal Creek.

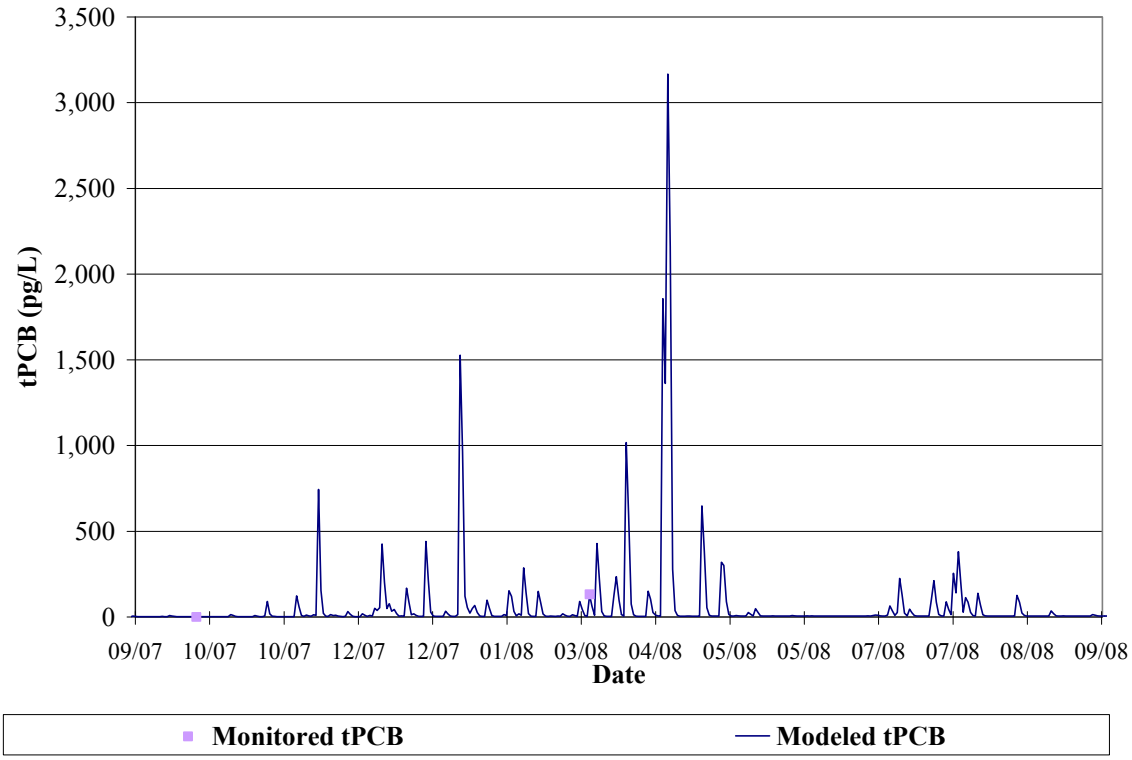

Figure 14.11 PCB calibration results at VADEQ station 6ABIP000.18 in subwatershed 13 in Big Prater Creek.

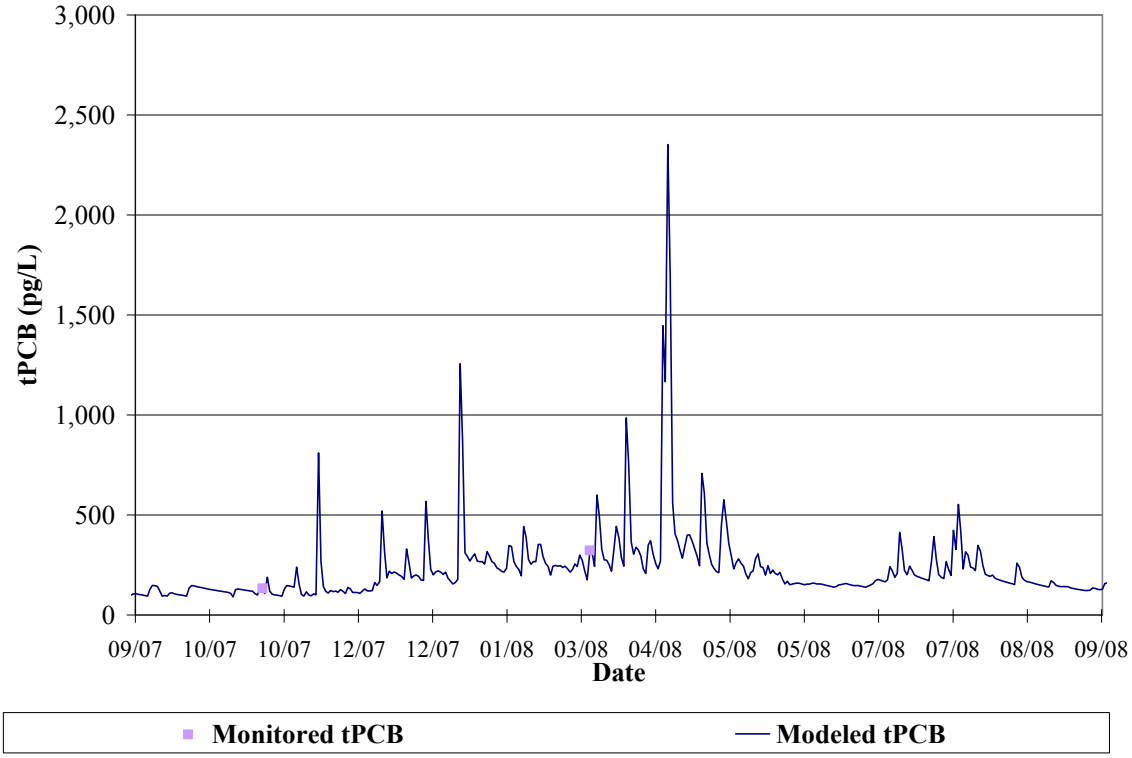

Figure 14.12 PCB calibration results at VADEQ station 6ASAT000.26 in subwatershed 10 in Slate Creek.

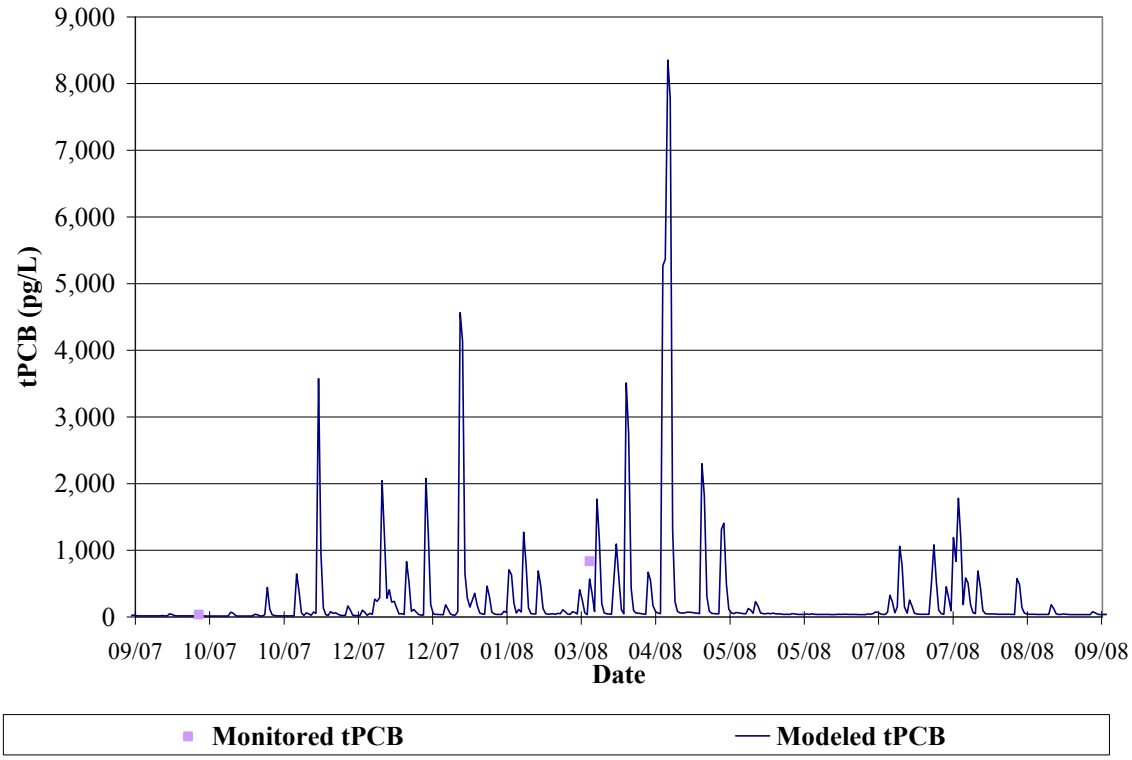

Figure 14.13 PCB calibration results at VADEQ station 6ALEV143.80 in subwatershed 5 in the Levisa Creek impairment.

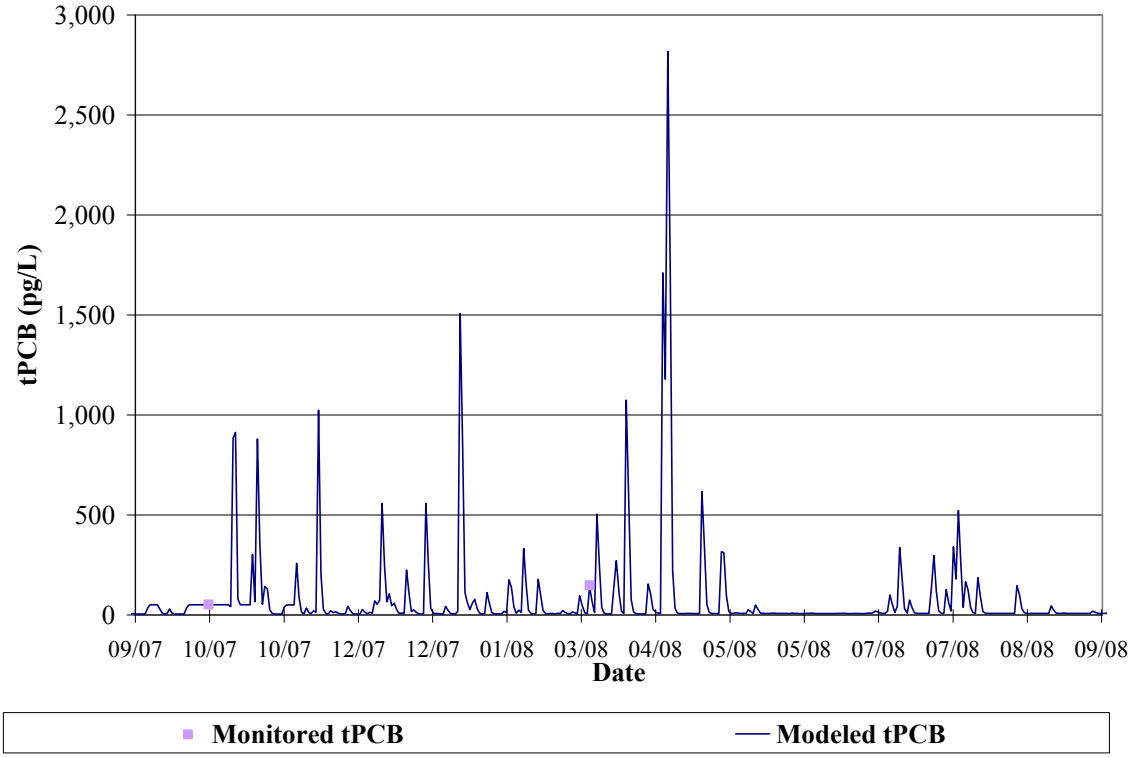

Figure 14.14 PCB calibration results at VADEQ station 6ABLC002.30 in subwatershed 14 in Bull Creek.

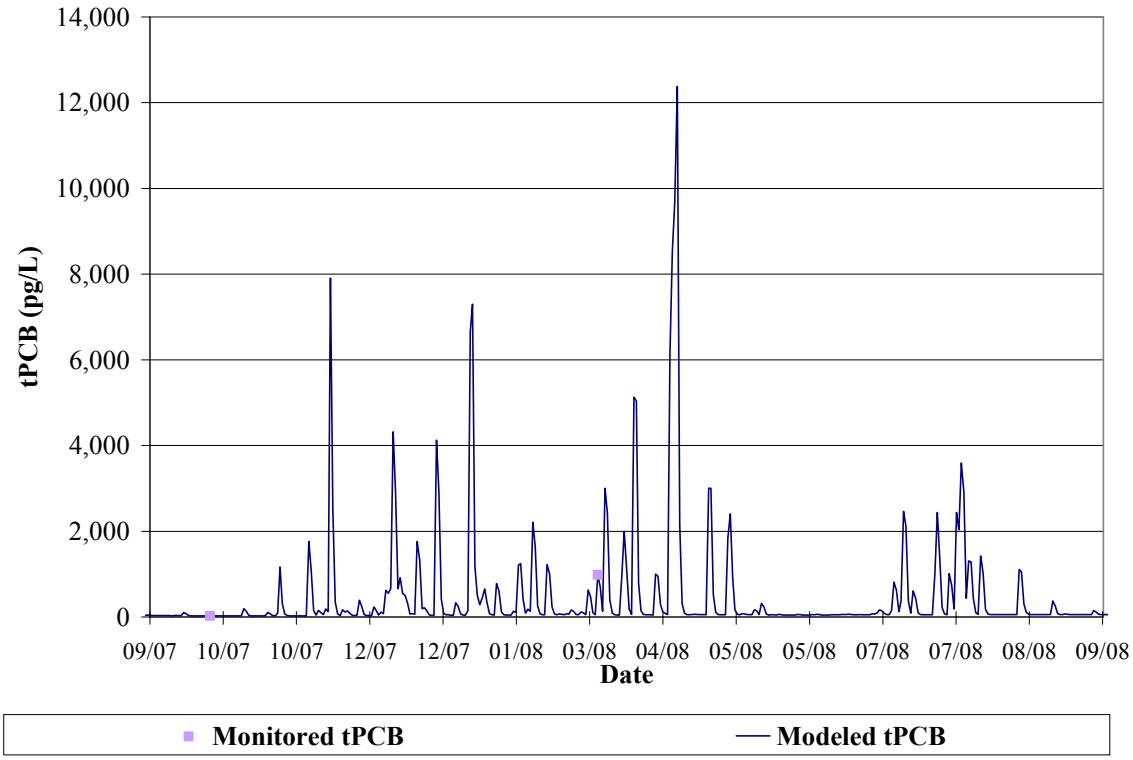

Figure 14.15 PCB calibration results at VADEQ station 6ALEV131.52 in subwatershed 8 in the Levisa Creek impairment.

Table 14.4 shows the modeled and observed maximum values and the percentage higher than the 640 pg/L PCB endpoint. The graphs above and the table below show that the results of the PCB calibration are acceptable.

Existing conditions for this project would be 2009, however, no other PCB water column or source data is available. Therefore, the 9/1/07 to 9/30/08 calibration modeling time period is as close to existing conditions as possible.

Table 14.4 Comparison of modeled and observed PCB calibration results for the Levisa Fork watershed.

Stream	DEQ Station	Subwatershed	Modeled PCB 9/1/07 to 9/30/08			Monitored PCB 9/1/07 to 9/30/08		
			n	Maximum (pg/L)	% > 640 pg/L[1]	*n*	Maximum (pg/L)	% > 640 pg/L[1]
Levisa Fork	LEV156.82	2	396	2,390	5.30%	2	428	0.00%
Garden Creek	GAR000.16	12	396	1,794	3.03%	2	537	0.00%
Levisa Fork	LEV152.46	3	396	4,237	3.79%	2	372	0.00%
Dismal Creek	DIS001.24	11	396	3,666	2.53%	2	1,140	50.00%
Big Prater Creek	BIP000.18	13	396	3,167	2.27%	2	132	0.00%
Slate Creek	SAT000.03	10	396	2,352	2.53%	2	323	0.00%
Levisa Fork	LEV143.86	5	396	8,354	9.60%	2	836	50.00%
Bull Creek	BLC002.30	14	396	2,816	2.78%	2	148	0.00%
Levisa Fork	LEV131.52	8	396	12,377	16.41%	2	986	50.00%

[1] 640pg/L is the PCB endpoint

14.3 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 MOS 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 an MOS in the development of this PCB TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An explicit load of 5% of the final TMDL was used as the MOS for the PCB TMDLs.

14.4 Wasteload Allocations

The PCB existing condition load from the mining land uses was calculated using the average sampled PCB concentration (92 pg/L) and the flow from the model. The PCB allocated load (WLA) from the mining land uses was calculated using the endpoint PCB concentration (640 pg/L) and the flow from the model Therefore, the WLAs for the

DMME surface mining permits were calculated as the average daily flow from the mining land uses multiplied by the endpoint and area-weighted to get the PCB load from each DMME permit. All other permits (DEQ) were modeled at their design flow times the endpoint.

14.5 Load Allocations

Atmospheric deposition loads in the LA were calculated using the value of 1.6 $\mu g/m^2/yr$ (Section 13.2.1; CBP, 1999). This value was multiplied by the entire area of the Levisa Fork drainage area and convert to become mg/yr in Table 14.5. The same procedure was used to calculate a value for Garden Creek using its' drainage area.

All non-mining land use PCB sources were reduced until the streams met the PCB endpoint.

14.6 Garden Creek tPCB TMDL

Modeling was conducted for a target value of 0% exceedance of the PCB endpoint 640 pg/L. The final scenario for Garden Creek was an overall 62.1% reduction of the estimated existing tPCB load.

Figure 14.16 shows the existing and allocated PCB concentrations from the Garden Creek impairment outlet. This graph shows existing conditions in black, with allocated conditions overlaid in blue.

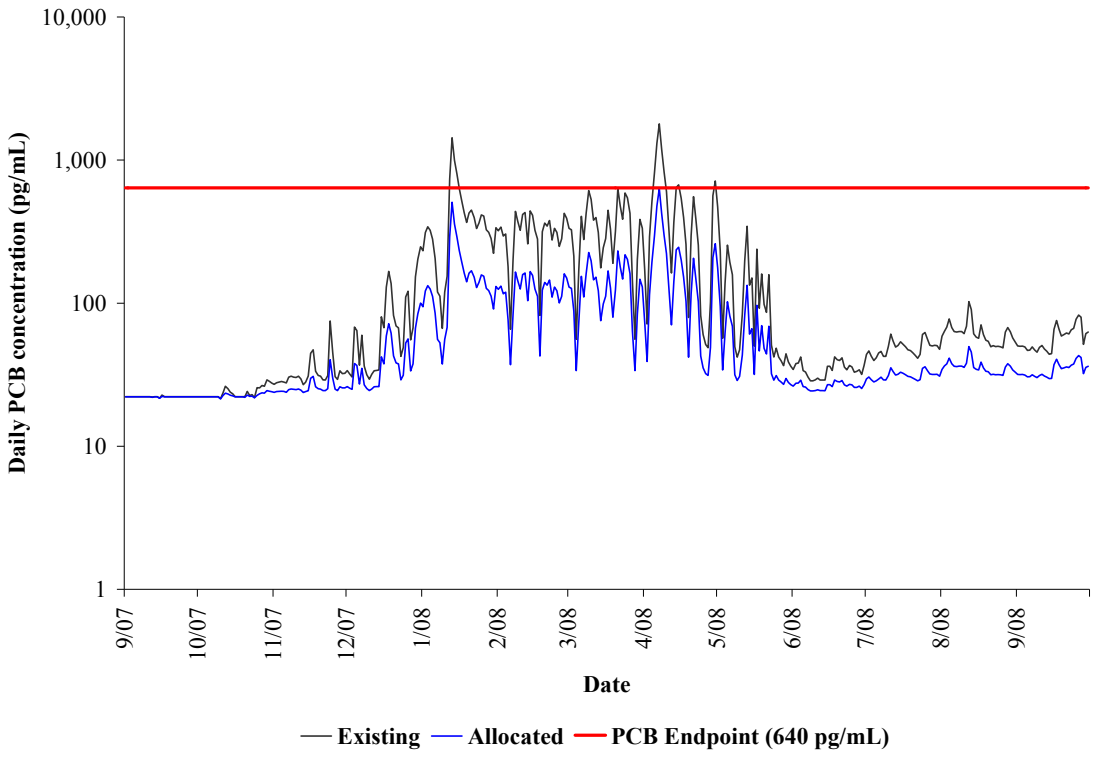

Figure 14.16 Existing and allocated monthly geometric mean in-stream PCB concentrations in subwatershed 12, Garden Creek impairment outlet.

Table 14.5 shows the average annual TMDL, which gives the average load of PCBs that can be present in the stream in a given year, and still meet the endpoint.

Table 14.5 Final average annual in-stream PCB loads (mg/year) modeled after TMDL allocation in the Garden Creek impairment.

Source	WLA (mg/yr)	LA (mg/yr)	MOS (mg/yr)	TMDL (mg/yr)	Existing (mg/yr)	% Reductions Needed
DMME permits:						
1201698	*0.57*				*0.08*	0%
1400047	*225.02*				*32.35*	0%
1400492	*1.07*				*0.15*	0%
1400493	*4.18*				*0.60*	0%
1401489	*0.48*				*0.07*	0%
1401531	*41.43*				*5.96*	0%
1500384	*23.07*				*3.32*	0%
1700864	*23.28*				*3.35*	0%
DMME permits total	**319.10**				**45.87**	0%
Nonpoint Source Land Loads[1]		**632.36**			**2597.81**	75.66%
Atmospheric Deposition		**0.25**			**0.25**	0%
MOS			**50.09**			0%
Total	**319.10**	**632.61**	**50.09**	**1001.80**	**2643.93**	62.11%

[1] includes the known contaminated sites and all other non-mining land uses

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration TMDLs. The daily average in-stream PCB loads for Garden Creek are shown in Table 14.6. The daily TMDL and WLAs were calculated as the annual value divided by 365. The LA is the difference between the TMDL and the WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 14.6 Final average daily in-stream PCB loads (mg/day) modeled after TMDL allocation in the Garden Creek impairment.

Source	WLA (mg/day)	LA (mg/day)	MOS (mg/ day)	TMDL (mg/ day)
DMME permits:				
1201698	*0.002*			
1400047	*0.62*			
1400492	*0.003*			
1400493	*0.01*			
1401489	*0.001*			
1401531	*0.11*			
1500384	*0.06*			
1700864	*0.06*			
DMME permits total	**0.87**			
Nonpoint Source Land Loads[1]		**1.73**		
Atmospheric Deposition		**0.001**		
MOS			**0.14**	
Total	**0.87**	**1.73**	**0.14**	**2.74**

[1] includes the known contaminated sites and all other non-mining land uses

14.7 Levisa Fork tPCB TMDL

Modeling was conducted for a target value of 0% exceedance of the PCB endpoint 640 pg/L. The final scenario for Levisa Fork was an overall 94.5% reduction of the estimated existing tPCB load.

Figure 14.17 shows the existing and allocated PCB concentrations from the Garden Creek impairment outlet. This graph shows existing conditions in black, with allocated conditions overlaid in blue.

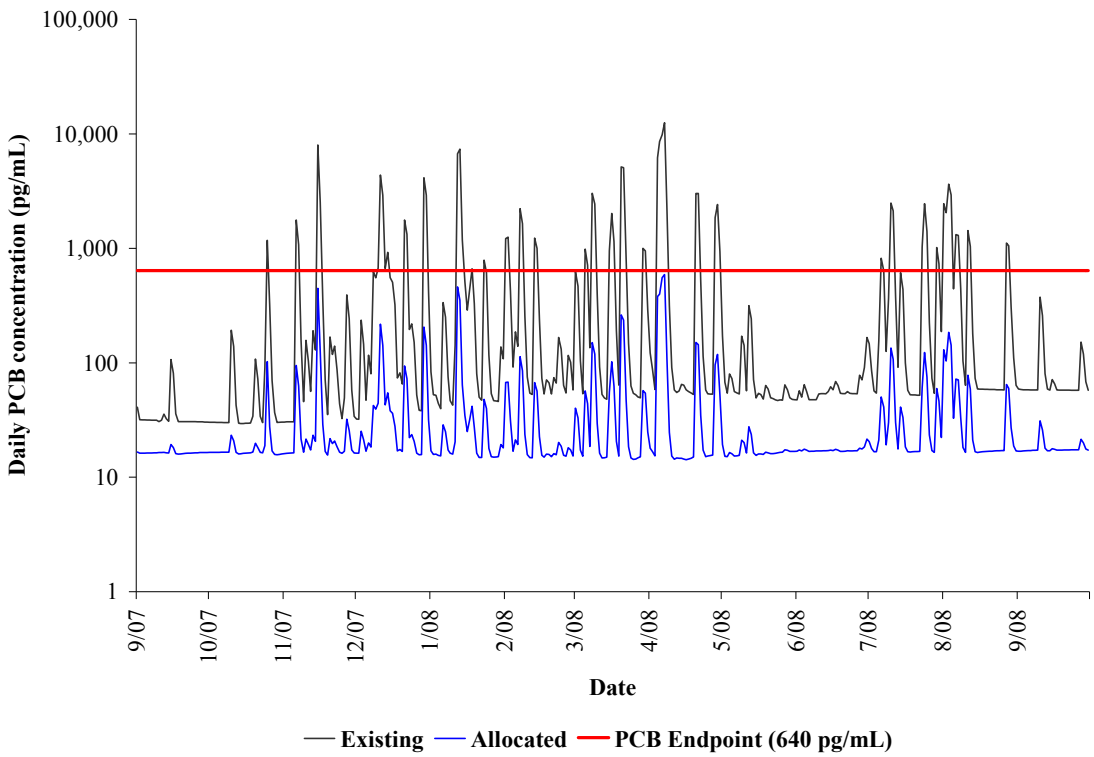

Figure 14.17 Existing and allocated monthly geometric mean in-stream PCB concentrations in subwatershed 8, Levisa Fork impairment outlet.

Table 14.7 shows the average annual TMDL, which gives the average load of PCBs that can be present in the stream in a given year, and still meet the endpoint. The Levisa Fork TMDL includes all reductions needed in the Garden Creek TMDL.

Table 14.7 Final average annual in-stream PCB loads (mg/year) modeled after TMDL allocation in the Levisa Fork impairment.

Source	WLA (mg/yr)	LA (mg/yr)	MOS (mg/yr)	TMDL (mg/yr)	Existing (mg/yr)	% Reductions Needed
VPDES permits:						
VA0090531	*1,769.76*				*4,489.85*	60.58%
VA0050351	*176.98*				*55.37*	0%
VA0052639	*0.88*				*61.43*	98.56%
VPDES permits total	**1,947.62**				**4,606.65**	57.7%
DMME permits total[1]	**3,061.68**				**440.12**	0%
Nonpoint Source Land Loads[2]		**3,419.73**			**156,665.28**	97.82%
Atmospheric Deposition		**1.39**			**1.39**	0%
MOS			**443.71**			0%
Total	**5,009.30**	**3,421.12**	**443.71**	**8,874.14**	**161,713.44**	94.51%

[1] DMME permits are shown individually in Table 14.8
[2] includes the known contaminated sites and all other non-mining land uses

Table 14.8 shows each DMME mining permits' estimated existing and allocated PCB load.

Table 14.8 Existing and allocated annual PCB loads for DMME mining permits within the Levisa Fork watershed.

DMME Permit	Existing mg/yr	Allocated mg/yr	DMME Permit	Existing mg/yr	Allocated mg/yr	DMME Permit	Existing mg/yr	Allocated mg/yr
1100470	3.26	22.70	1201348	2.72	18.93	1301640	2.86	19.90
1101381	16.04	111.55	1201373	0.09	0.66	1400047	67.40	468.85
1101553	9.45	65.72	1201442	0.18	1.24	1400345	3.73	25.95
1101701	2.37	16.46	1201484	1.55	10.78	1400419	0.81	5.61
1101736	6.06	42.14	1201495	0.38	2.65	1400492	13.88	96.54
1101752	21.20	147.50	1201508	0.46	3.21	1400493	7.03	48.92
1101792	8.21	57.08	1201523	0.27	1.85	1400496	7.68	53.42
1101823	17.94	124.77	1201532	0.12	0.85	1400498	4.64	32.29
1101846	6.63	46.15	1201539	0.25	1.72	1401039	1.16	8.09
1101881	0.30	2.08	1201540	0.51	3.56	1401167	2.22	15.43
1101903	17.08	118.84	1201574	0.84	5.81	1401181	0.59	4.10
1101979	3.19	22.20	1201678	0.13	0.91	1401232	4.34	30.17
1101987	4.89	33.98	1201698	0.12	0.85	1401489	8.22	57.21
1101999	1.21	8.42	1201716	0.82	5.70	1401493	1.22	8.51
1102001	14.95	104.02	1201749	0.50	3.48	1401531	8.89	61.86
1102030	8.07	56.17	1201753	4.76	33.10	1401598	3.96	27.53
1200194	1.43	9.92	1201902	0.67	4.66	1401635	3.12	21.70
1200235	0.88	6.10	1201906	0.07	0.47	1401645	0.16	1.11
1200281	0.30	2.09	1201907	0.17	1.19	1500384	4.95	34.45
1200282	0.21	1.43	1201922	0.46	3.18	1601787	16.43	114.31
1200308	2.21	15.34	1201940	0.28	1.97	1601788	15.90	110.64
1200335	0.56	3.90	1201988	0.21	1.47	1601816	10.77	74.95
1200342	0.27	1.85	1202036	0.37	2.56	1700864	5.00	34.77
1200343	0.27	1.87	1300120	1.07	7.48	1701300	5.13	35.66
1200354	2.11	14.70	1300359	5.00	34.79	1801821	0.00	0.01
1200881	0.24	1.67	1300378	0.65	4.51			
1201015	0.64	4.45	1300379	2.93	20.35			
1201050	0.61	4.22	1300398	1.29	8.99			
1201053	0.15	1.01	1300404	0.97	6.77			
1201091	1.81	12.61	1300417	1.05	7.32			
1201097	0.10	0.72	1300425	9.58	66.65			
1201131	0.09	0.61	1300426	15.32	106.57			
1201182	1.31	9.12	1300451	1.52	10.58			
1201230	0.30	2.12	1300453	12.36	86.01			
1201273	0.82	5.71	1300454	2.15	14.94			
1201276	0.15	1.03	1300945	0.22	1.50			
1201310	0.16	1.14	1301156	1.02	7.08			
1201345	2.07	14.43	1301226	11.44	79.57			

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration TMDLs. The daily average in-stream PCB loads for Levisa Fork are shown in Table 14.9. The daily TMDL and WLAs were calculated as the annual value divided by 365. The LA is the difference between the TMDL and the WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 14.9 Final average daily in-stream PCB loads (mg/day) modeled after TMDL allocation in the Levisa Fork impairment.

Source	WLA (mg/ day)	LA (mg/ day)	MOS (mg/ day)	TMDL (mg/ day)
VPDES permits:				
VA0090531	*4.85*			
VA0050351	*0.48*			
VA0052639	*0.002*			
VPDES permits total	**5.34**			
DMME permits total	**8.39**			
Nonpoint Source Land Loads[1]		**9.36**		
Atmospheric Deposition		**0.004**		
MOS			**1.22**	
Total	**13.72**	**9.36**	**1.22**	**24.31**

[1] includes the known contaminated sites and all other non-mining land uses

15. TMDL REASONABLE ASSURANCE

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. EPA requires that there is reasonable assurance that TMDLs can be implemented. TMDLs represent an attempt to quantify the pollutant load that might be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Commonwealth intends to use existing programs in order to attain water quality goals that support the recreational/primary contact use (bacteria), aquatic life use (sediment), and the fish consumption use (PCBs). Available programmatic options include a combination of regulatory authorities, such as the NPDES and Toxics Substances Control Act (TSCA), as well as state programs including the *Toxics Contamination Source Assessment Policy*, and the Virginia Environmental Emergency Response Fund (VEERF). The *PCB Strategy for the Commonwealth of Virginia*, published in October 2004, establishes the general strategy and outlines the regulatory framework and state initiatives that Virginia will use to address PCB impaired waterbodies. This document is available at: www.deq.virginia.gov/fishtissue/pcbstrategy.html.

The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

15.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in

accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ web site under www.deq.state.va.us/export/sites/default/tmdl/pdf/ppp.pdf.

15.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

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

15.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

15.3.1 tPCBs

VADEQ's TMDL Guidance Memo No. 09-2001 *Guidance for monitoring of point sources for TMDL development using low-level PCB method 1668* was signed March 6, 2009. This guidance specifies procedures for monitoring in support of TMDL development, as well as procedures for impaired waters with completed TMDLs.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process. The following provisions should be applied to all applicable permitted discharges:

- Permittees should review the history of activities on properties under their control for historical presence or known spills of PCBs.
- Requirements for testing of selected outfalls and/or receiving streams. Testing should be performed to better characterize stormwater loadings as well as for source tracking.
- Selection of test locations should be based on a review of current and historical land use. Testing for purposes of source tracking should be based on the location of historical activities such as outside storage areas and maintenance yards that may be PCB hotspots.
- If not already available, congener specific data should be collected using the most current version of EPA Method 1668 (currently, Method 1668, Revision A) or other equivalent methods capable of providing low-detection level, congener specific results, which are approved in advance by the permitting authority.
- The frequency of testing, quality control requirements, specific test conditions, and testing program termination shall be prescribed in the permit.
- Spill response programs should have policies and procedures to address spills when PCBs are expected to have been released.
- Permittees should develop and implement procedures based on historical activity and land use that identifies potential high-risk properties during the plan review phase for development and redevelopment projects. Potential high-risk sites should be reported to the appropriate regulatory agency for follow-up.

Non-numeric WQBELs (BMPs) will be used to comply with the WLA provisions of this PCB TMDL. While VPDES permits will be developed to be consistent with applicable regulations, this approach will not require specific WLA numbers in the permits. Additional PCB data will be collected from selected VPDES permitted facilities to better characterize dischargers. In establishing the necessity and extent of data collection, this approach will take into account data already available, and intake (or pass through) or other original sources of PCBs consistent with VPDES program "reasonable potential" determinations and the provisions of 9 VAC 25-31-230.G, for VPDES permitted facilities including regulated stormwater. Where warranted, development of pollutant minimization and reduction plans is recommended as the primary pollutant reduction

strategy. These plans, referred to as Pollutant Minimization Plans (PMP), may involve identifying known and potential PCB sources, provide strategies for identifying unknown sources, note previous minimization efforts, establish pollutant minimization measures (i.e. reducing runoff from urban areas, contaminated site remediation, reducing inputs to wastewater sewer systems, etc.), establish source prioritization, and determine a monitoring schedule and reporting criteria.

15.3.2 Stormwater

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

Reductions in sediment from construction sites and development areas will also be of benefit for reducing PCBs. The Virginia Erosion and Sediment Control and Virginia Stormwater Management Programs – administered by the Department of Conservation and Recreation and delegated to local jurisdictions – provides the framework for implementing sediment reduction BMPs throughout localities. More information regarding these programs can be found at http://www.dcr.virginia.gov/soil_&_water/e&s.shtml.

15.3.2.1 Municipal Separate Storm Sewer Systems – MS4s

There are currently no MS4 permits in the Levisa Fork watershed. Additional information on Virginia's Stormwater Program and a downloadable menu of Best

Management Practices and Measurable Goals Guidance can be found at www.dcr.virginia.gov/soil_&_water/vsmp.shtml.

15.3.2.2 Active Coal Mining Operations

In November 2005, the Department of Mines, Minerals and Energy, Division of Mined Land Reclamation issued Guidance Memorandum No. 14-05 to address the implementation of coal mining-related TMDL wasteload allocations. The memorandum can be accessed on DEQ's TMDL web page, http://www.deq.virginia.gov/tmdl. As of December 1, 2005 the Division of Mined Land Reclamation (Division) has been implementing the steps outlined in the memorandum regarding permit applications in watersheds with adopted benthic Total Maximum Daily Loads (TMDLs). A brief summary is provided below.

Generally, a BMP approach will be used in Virginia to meet WLAs in lieu of altered effluent limitations for permitted coal mine point source discharges. DMME's TMDL coordinator will track assigned and available WLAs. Prior to approval of new NPDES points within a TMDL watershed, the Division Water Quality staff will confer with the TMDL coordinator and/or consult the WLA information folder to determine that a WLA is available. Loadings for WLAs will be tracked using results of routine NPDES monitoring. When tracking indicates that WLAs are being exceeded, the Division will request the permittee to revise the BMPs to reduce waste loads.

15.3.3 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination

between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at www.deq.virginia.gov/waterguidance/.

15.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

15.4.1 tPCBs

LAs are assigned to nonpoint sources, including atmospheric deposition, known contaminated sites and contaminated streambed sediments. The HSPF model simulations predict that the re-suspension and desorption of PCBs and direct contributions from contaminated sediments are significant sources of PCB loading to waters. To mitigate such contributions, various approaches can be considered, including dredging streambed sediments and natural attenuation. Although the HSPF model simplistically represents water column-streambed sediment interaction, it has been shown that diffusion of PCBs from sediments, as well as desorption of PCBs from re-suspended contaminated sediments can be a significant contributor to water quality concentrations. These results are, therefore, consistent with available scientific evidence. The simplifications of HSPF, however, preclude the accurate simulation of PCBs accumulating in streambed sediments from direct interaction with the water column or the unavailability of PCBs in deep *inactive* sediments. In addition, the depth of PCB contamination in streambed sediments is unknown. Therefore, model results are an approximation of direct streambed sediment loadings and accumulation.

Mechanical or vacuum dredging would permanently remove PCBs from the system. These PCBs would no longer be available for diffusion from bed sediments or for desorption during resuspension events. Dredging might also cause habitat destruction

and unnecessary resuspension of PCBs, in addition to its high cost. These considerations must be taken into account when determining appropriate remedial action.

Burial rates throughout the majority of the watershed are considered negligible because of the flowing water characteristics of the Levisa Fork. Burial represents a process whereby deeper sediments become inactive, and any associated contamination is sequestered from the system. In addition, the processes of diffusion and the resuspension of contaminated sediments results in a *flushing* of sediments as PCBs are released into the water column and moved downstream. Natural attenuation can be considered an appropriate action alternative to ensure that the TMDL targets are met and water quality standards are achieved assuming upland sources of PCBs are rendered *de minimus*.

15.4.2 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". 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.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003. It is available upon request from the VADEQ and VADCR TMDL project staff or at www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

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

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

15.4.3 Staged Implementation Scenarios

15.4.3.1 Bacteria and Sediment

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient bacterial BMPs for both urban and rural watersheds are stream side fencing for cattle farms, pet waste clean-up programs, and government or grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis (UAA) may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under

§301b and §306 of Clean Water Act, and by implementing cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 6.6.

Stage I scenarios are discussed in Chapter 5. Correcting 50% of straight pipes and sewer overflows will benefit the water quality significantly for all the impairments.

15.4.3.2 tPCBs

As described in Wong (2006), adaptive implementation is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The focus of this approach is oriented towards increasingly efficient management and restoration and is not generally anticipated to lead to a re-opening of the TMDL. However, the TMDL and allocation scenarios can be changed if warranted by new data and information.

In the HSPF model of the Levisa Fork, PCB loadings from upland contaminated sites, the re-suspension of contaminated sediments, and direct contributions from contaminated sediments during low-flows were found to be contributors to water quality target exceedances in the baseline condition. The appropriate first step in an action plan to address PCB contamination would include the mitigation of known contaminated sites in addition to any point sources discharging PCBs. Although the known PCB dischargers are not a dominant source in the watershed, other contaminated dischargers might exist.

New data and information will be used to steer control strategies aimed to mitigate PCB loadings into the watershed and to better understand and characterize PCB loadings from key sources. It is suggested that monitoring of water column and streambed sediment PCB concentrations be continued to assess the progress made toward achieving this PCB TMDL. It is recommended that an increase in the frequency of monitoring would provide better feedback on maintaining the TMDL goal.

Atmospheric deposition sources of PCBs can be numerous and difficult to quantify. PCBs enter the air through a variety of pathways, and the deposition of PCBs from the atmosphere to the land surface and the volatilization of PCBs from the land to the

atmosphere are not well understood. Atmospheric deposition studies (recommended above) will help identify these pathways, and efforts to remediate contaminated sites will help reduce possible atmospheric contributions.

15.4.4 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality downstream in Levisa Fork, Slate Creek, Garden Creek, and tributaries to these streams. Water quality of Tug Fork downstream will also benefit from the completion of implementation of this TMDL.

15.4.5 Implementation Funding Sources

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

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF

projects and allocations can be found at www.deq.virginia.gov/bay/wqif.html and at www.dcr.virginia.gov/soil_&_water/wqia.shtml.

15.5 Follow-Up Monitoring

Because elements of this TMDL project (benthic and PCB impairments) are being developed using a phased approach, monitoring to support refinement of these aspects of the TMDL is required. However, follow-up monitoring is also performed during implementation of standard (non-phased) TMDLs. Monitoring to support refinement of the phased TMDLs will begin as soon as is feasible upon approval of the TMDLs, and will likely require a more intensive monitoring effort than that which is described below for non-phased TMDLs.

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

The objective of the Statewide Fish Tissue and Sediment Monitoring Program is to systematically assess and evaluate, using a multi-tier screening, waterbodies in Virginia in order to identify toxic contaminant(s) accumulation with the potential to adversely

affect human users of the resource. The details of the follow-up PCB monitoring will be outlined in the annual Fish Tissue and Sediment Monitoring Plan prepared by the VADEQ Water Quality Standards and Biological Monitoring Programs, Office of Water Quality Programs as well as the annual water monitoring plans prepared by the regional offices. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

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

The long term monitoring of fish tissue, sediment and, as resources allow, ambient water concentrations for PCBs will be used to evaluate trends in PCB concentrations in different environmental media, better characterize PCB loadings into the watershed and identify potential PCB hotspots for remedial activity. New information will be considered in light of the TMDL reduction goals. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

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

the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

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

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

15.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

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

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

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

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

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

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

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation is that all controllable sources would be reduced to the maximum extent possible using the implementation approaches described above. VADEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

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

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16. PUBLIC PARTICIPATION

Public participation during TMDL development for the Levisa Fork watershed was encouraged; a summary of the meetings is presented in Table 16.1. The first Technical Advisory Committee (TAC) meeting took place on October 9, 2008 at the Appalachian Law School in Grundy, VA. Thirteen people attended the meeting. The first public meeting was also held at the Appalachian Law School on October 9, 2008; 14 people attended. The meetings were publicized by placing notices in the Virginia Register, signs in the watershed, and emailing notices to local stakeholders and representatives.

Table 16.1 Public participation during TMDL development for the Levisa Fork study area.

Date	Location	Attendance[1]	Type
10/9/2008	Appalachian Law School, Grundy, VA	13	First TAC
10/9/2008	Appalachian Law School, Grundy, VA	14	First public
1/14/2010	Riverview Elementary School	34	Final public

[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 during the implementation plan development process will include the formation of a stakeholders' committees, with committee and public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. Stakeholder committees will have the express purpose of formulating the TMDL Implementation Plan. The committees will consist of, but not be limited to, representatives from VADEQ, VADCR, and local governments. This committees will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from USEPA (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.*

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.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

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.*

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).

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

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.*

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-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)

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.*

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.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

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 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.*

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.

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.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

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.*

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).*

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.

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.

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.

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.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

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.*

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 the 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.*

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.

Metric ton (Mg or t). A unit of mass equivalent to 1,000 kilograms. An annual load of a pollutant is typically reported in metric tons per year (t/yr).

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 land use, 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.

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.*

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 land use segment within a subwatershed (*e.g.*, pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the 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.

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.*

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 the 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 25th, 50th, and 75th 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 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II 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, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Re-mining. Extracting resources from land previously mined. This method is often used to reclaim abandoned mine areas.

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. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate 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.

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.*

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.

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).

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

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.

tPCBs- Total PCBs

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 wastewater 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.*

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

DMLR. Virginia Department of mine Land Reclamation.

DMME. Virginia Department of Mines, Minerals, and Energy.

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 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 the 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.

GWLF Hydrologic Parameters:

Watershed Related Parameter Descriptions

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

Recession Coefficient (/day): 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.

Seepage Coefficient (/day): The seepage coefficient represents the amount of flow lost to deep seepage.

Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone.

Initial saturated storage (cm): Initial depth of water stored in the saturated zone.

Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation.

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

Month Related Parameter Descriptions

Month: 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.

ET CV: Composite evap-transpiration cover coefficient, calculated as an area-weighted average from land uses within each watershed.

Hours per Day: mean number of daylight hours.

Erosion Coefficient: 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

Sediment Delivery ratio: 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).

Land use-Related Parameter Descriptions

USLE K-factor (erodibility): The soil erodibility factor was calculated as an area weighted average of all component soil types.

USLE LS-factor: This factor is calculated from slope and slope length.

USLE C-factor: The vegetative cover factor for each land use was evaluated following GWLF manual guidance and Wischmeier and Smith (1978).

Daily sediment build-up rate on impervious surfaces: 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)

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

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

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

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

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APPENDIX A

Frequency Analysis of Bacteria Data

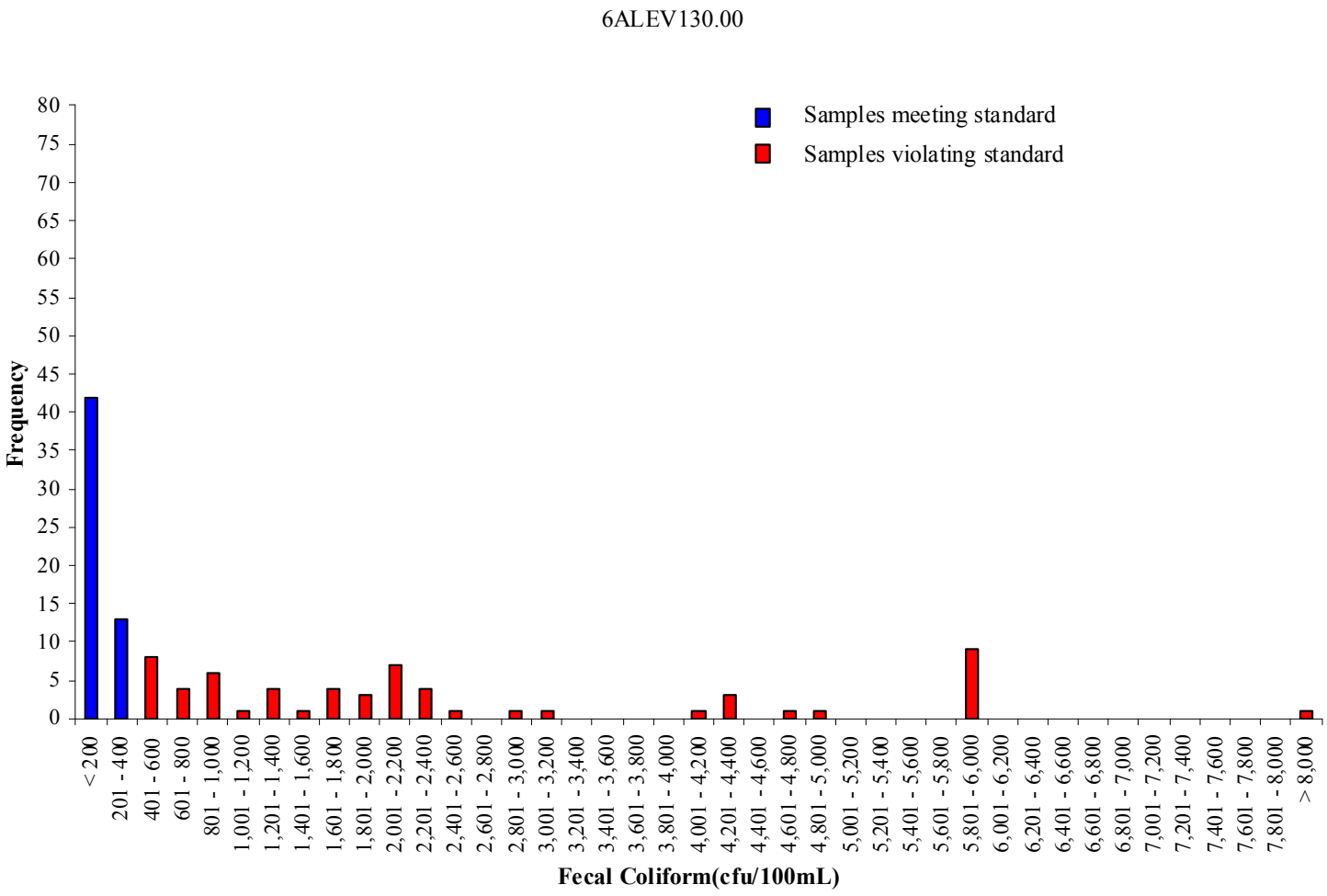

Figure A. 1 Frequency analysis of fecal coliform concentrations at station 6ALEV130.00 in the Levisa Fork Watershed impairment for the period from February 1980 to October 1991.

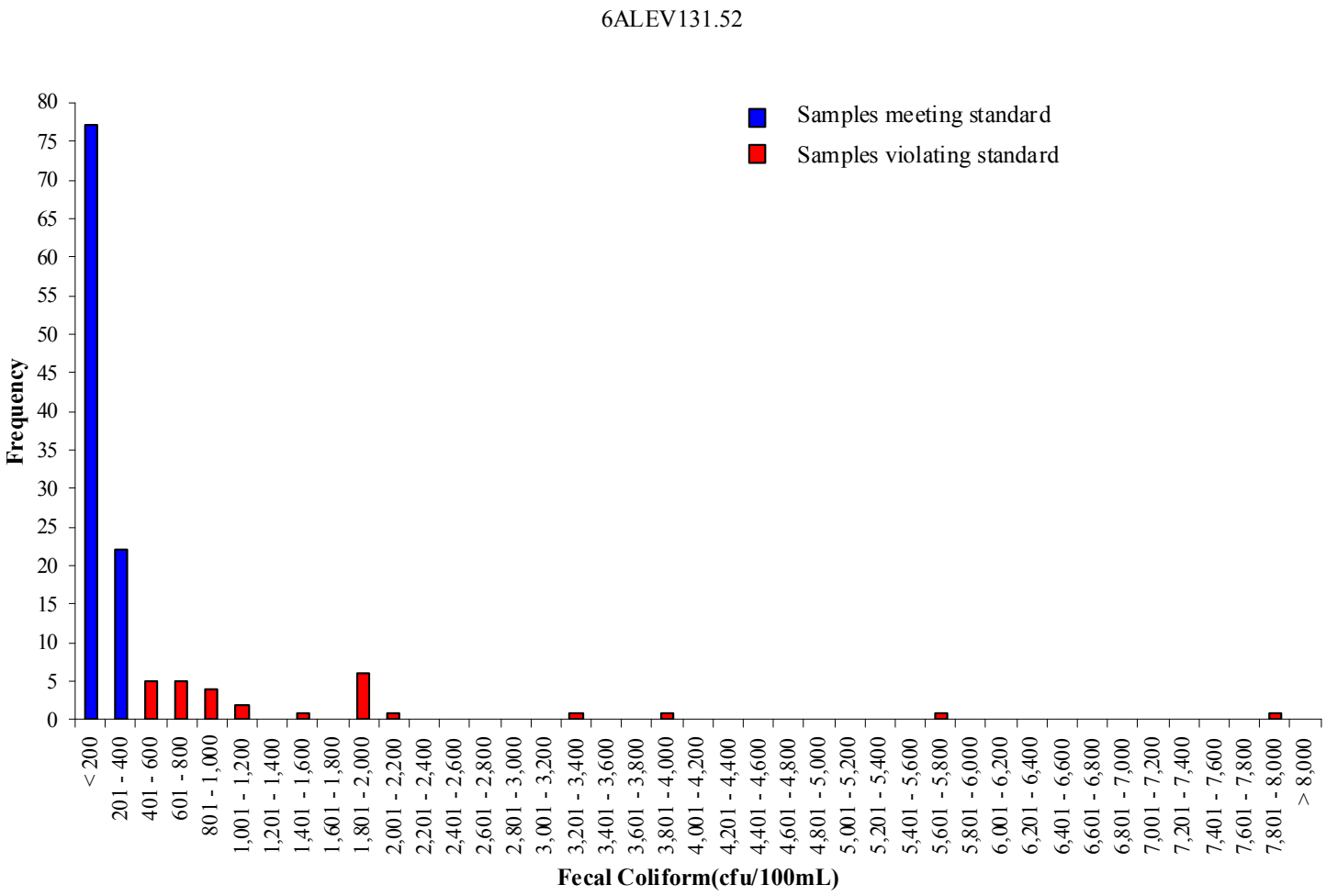

Figure A. 2 Frequency analysis of fecal coliform concentrations at station 6ALEV131.52 in the Levisa Fork Watershed impairment for the period from June 1992 to November 2006.

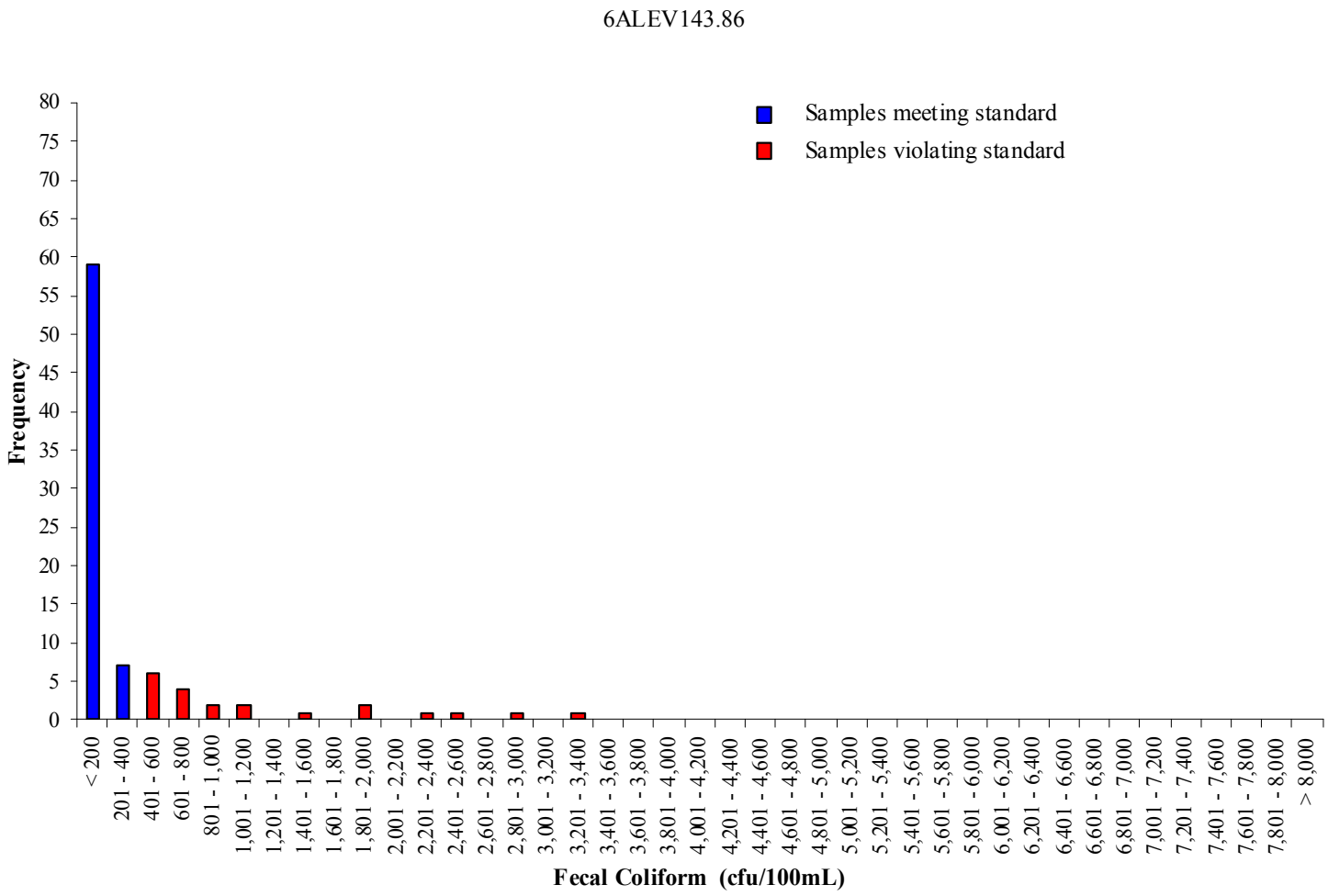

Figure A. 3 Frequency analysis of fecal coliform concentrations at station 6ALEV143.86 in the Levisa Fork Watershed impairment for the period from June 1992 to March 2001.

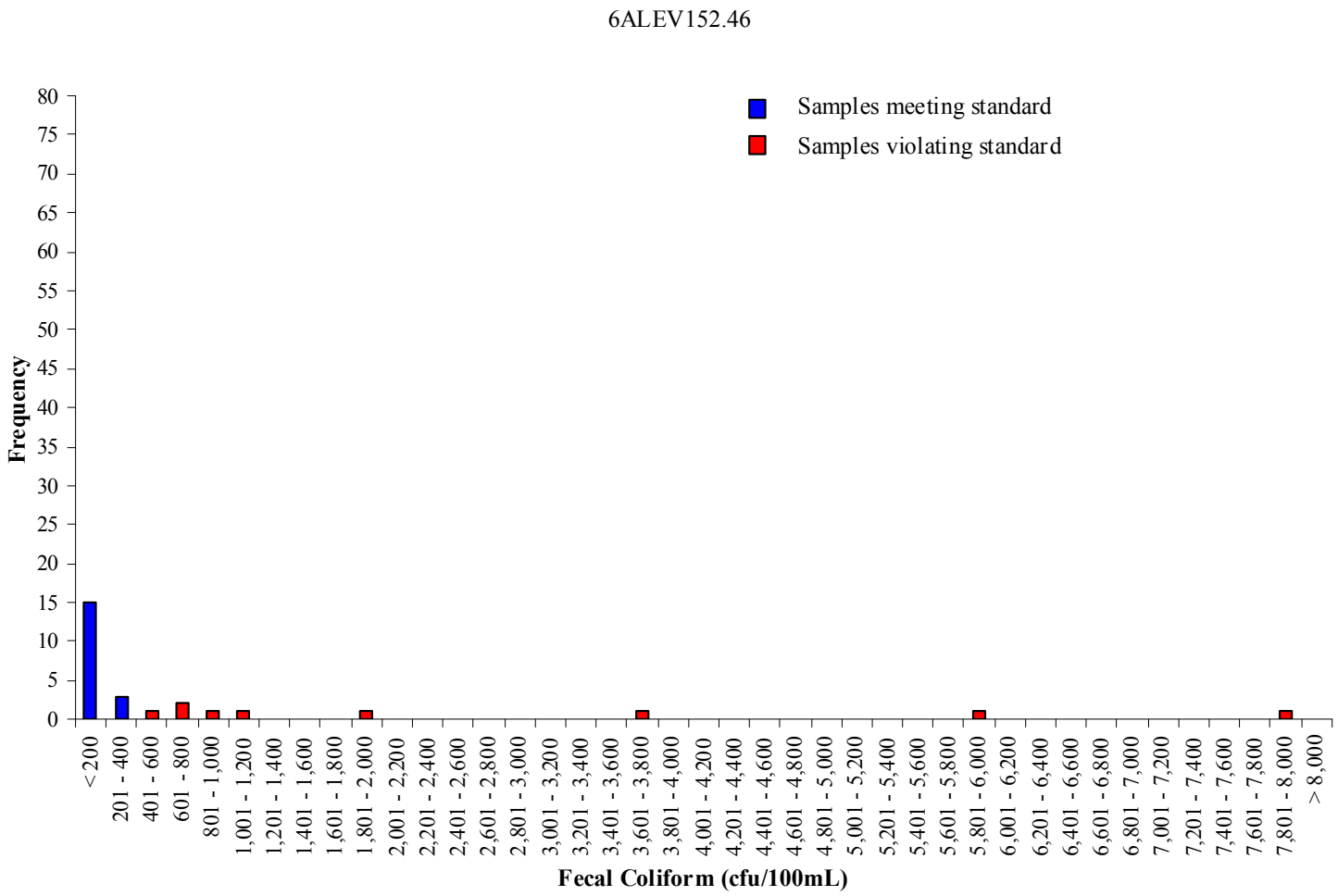

Figure A. 4 Frequency analysis of fecal coliform concentrations at station 6ALEV152.46 in the Levisa Fork Watershed impairment for the period from January 2000 to June 2003.

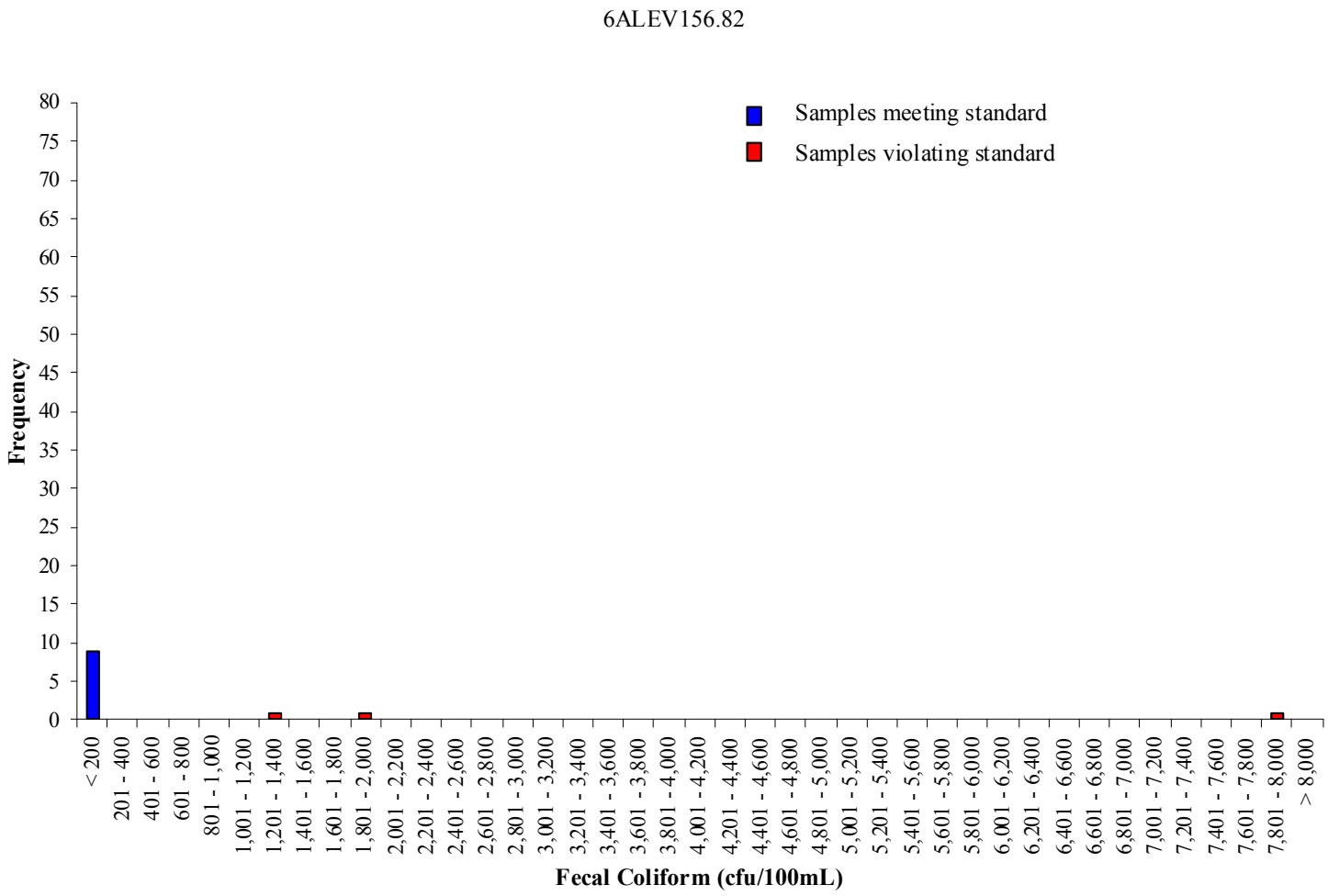

Figure A. 5 Frequency analysis of fecal coliform concentrations at station 6ALEV156.82 in the Levisa Fork Watershed impairment for the period from July 2001 to June 2003.

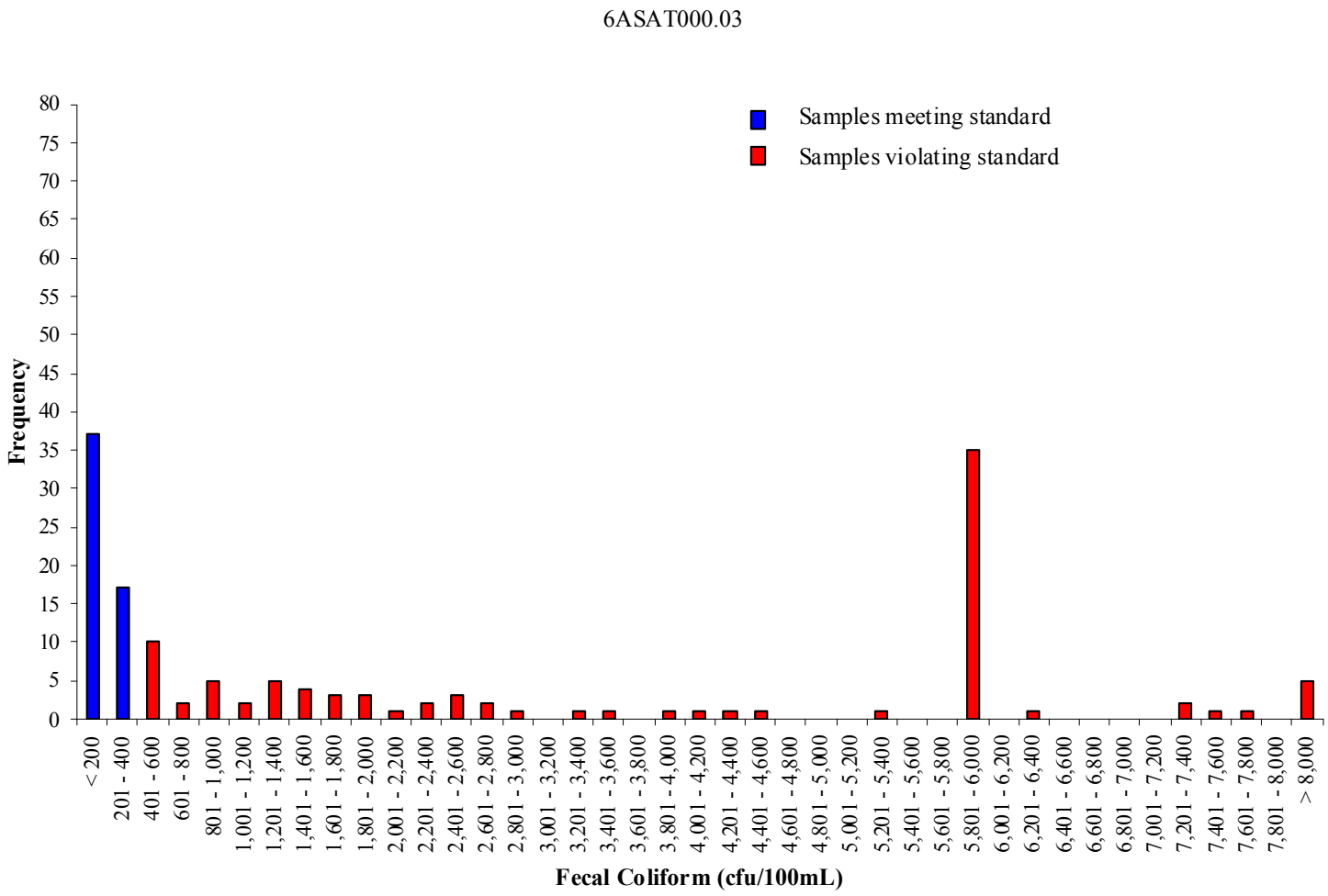

Figure A. 6 Frequency analysis of fecal coliform concentrations at station 6ASAT000.03 in the Levisa Fork Watershed (Slate Creek) impairment for the period from February 1980 to February 2001.

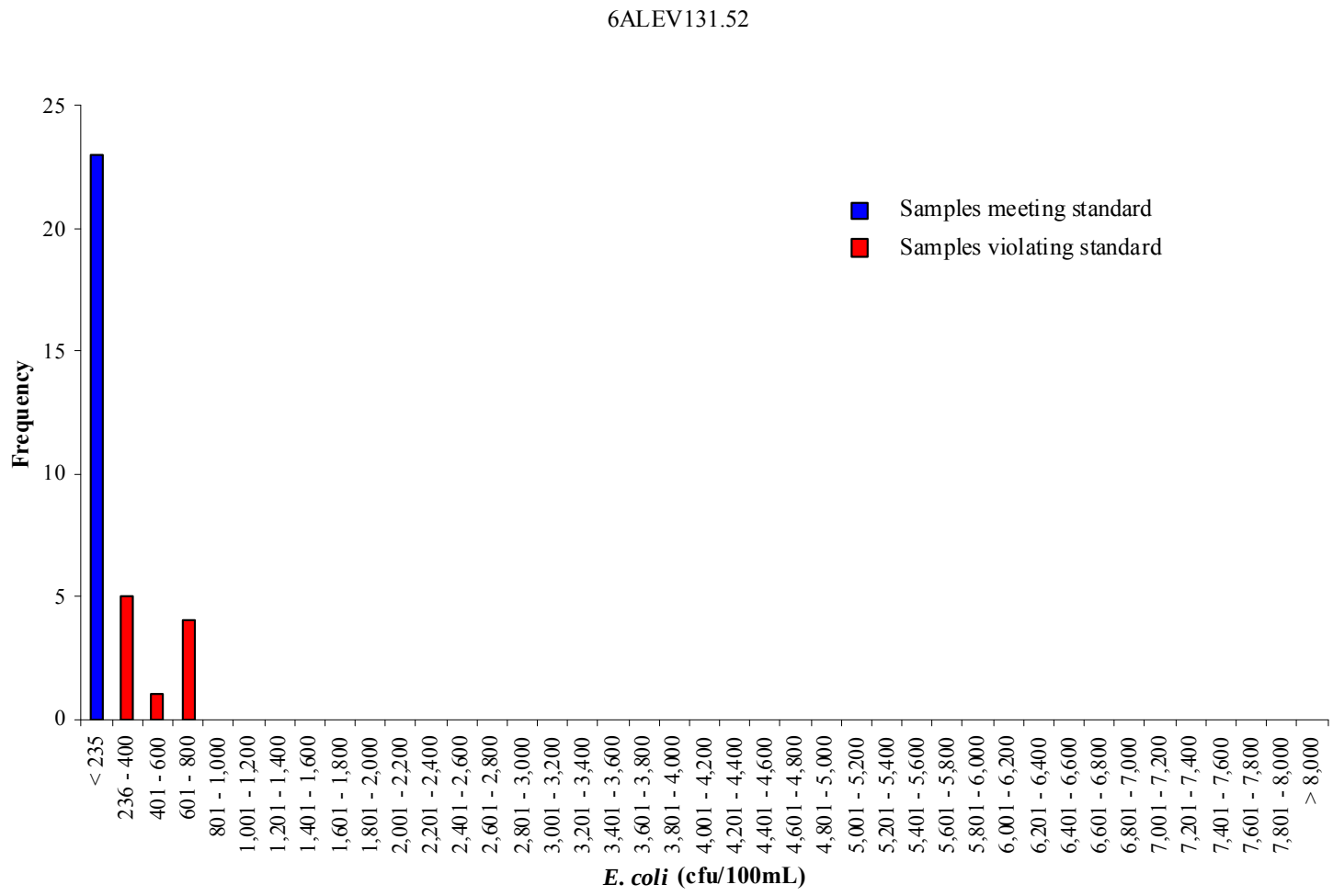

Figure A. 7 Frequency analysis of *E. coli* concentrations at station 6ALEV131.52 in the Levisa Fork Watershed impairment for the period from July 2002 to November 2005.

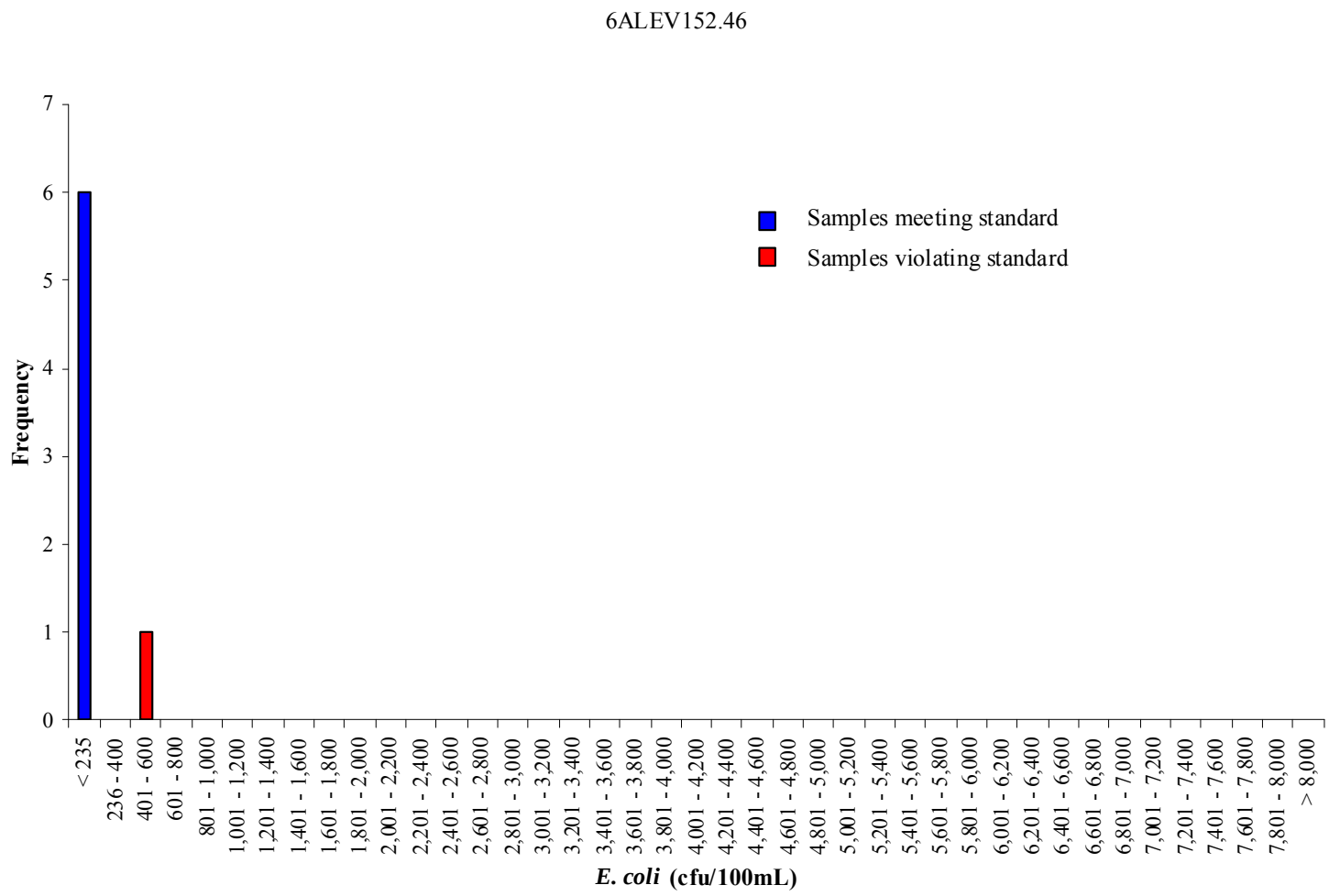

Figure A. 8 Frequency analysis of *E. coli* concentrations at station 6ALEV152.46 in the Levisa Fork Watershed impairment for the period from March 2007 to September 2007.

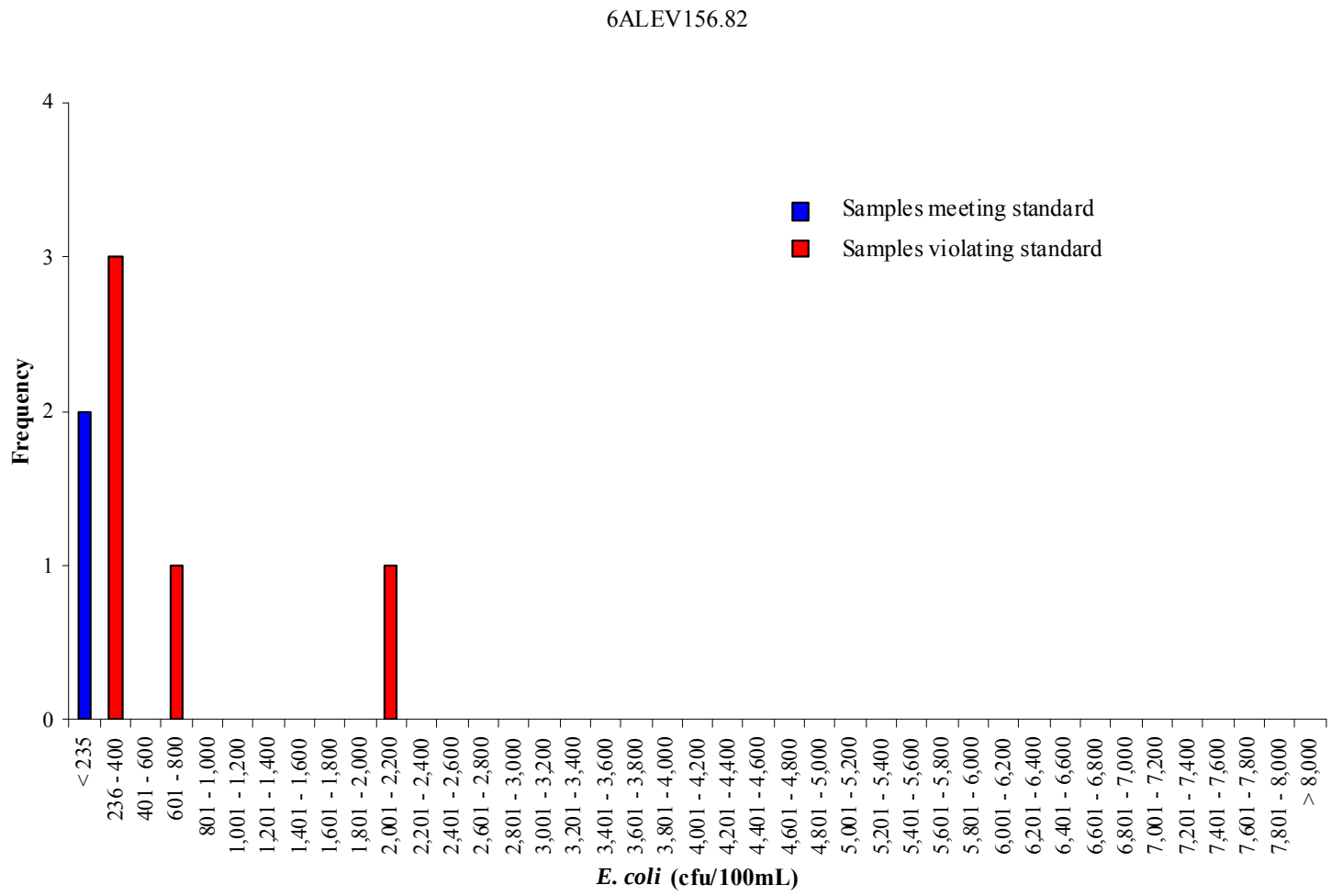

Figure A. 9 Frequency analysis of *E. coli* concentrations at station 6ALEV156.82 in the Levisa Fork Watershed impairment for the period from March 2007 to September 2007.

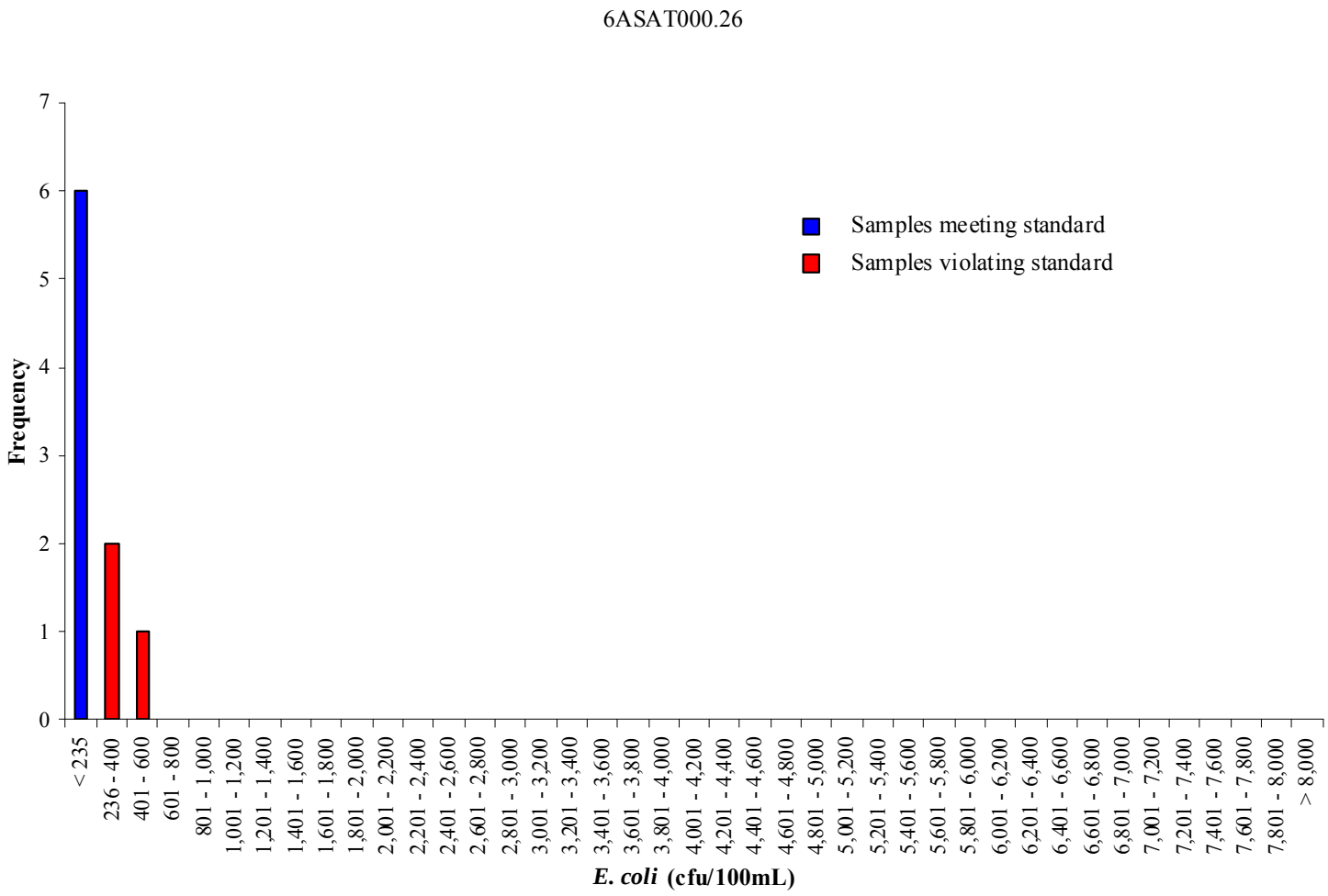

Figure A. 10 Frequency analysis of *E. coli* concentrations at station 6ASAT000.26 in the Levisa Fork Watershed (Slate Creek) impairment for the period from July 2005 to November 2006.

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APPENDIX B

Critical Period Analyses: Concentration versus Duration Graphs

Trends and Seasonal Analyses

Critical Period Analysis: Concentration versus Duration Graphs

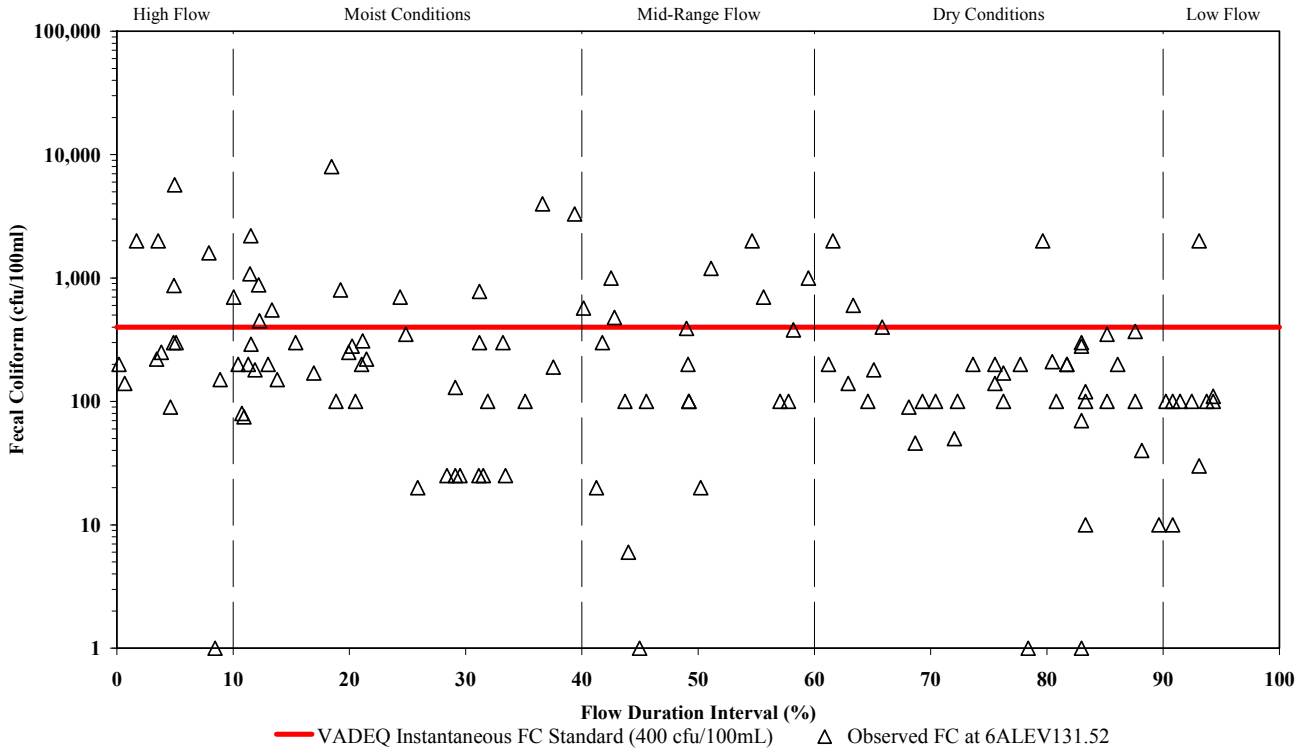

Figure B.1 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV131.25 and discharge at USGS Station #03207800 for Levisa Fork.

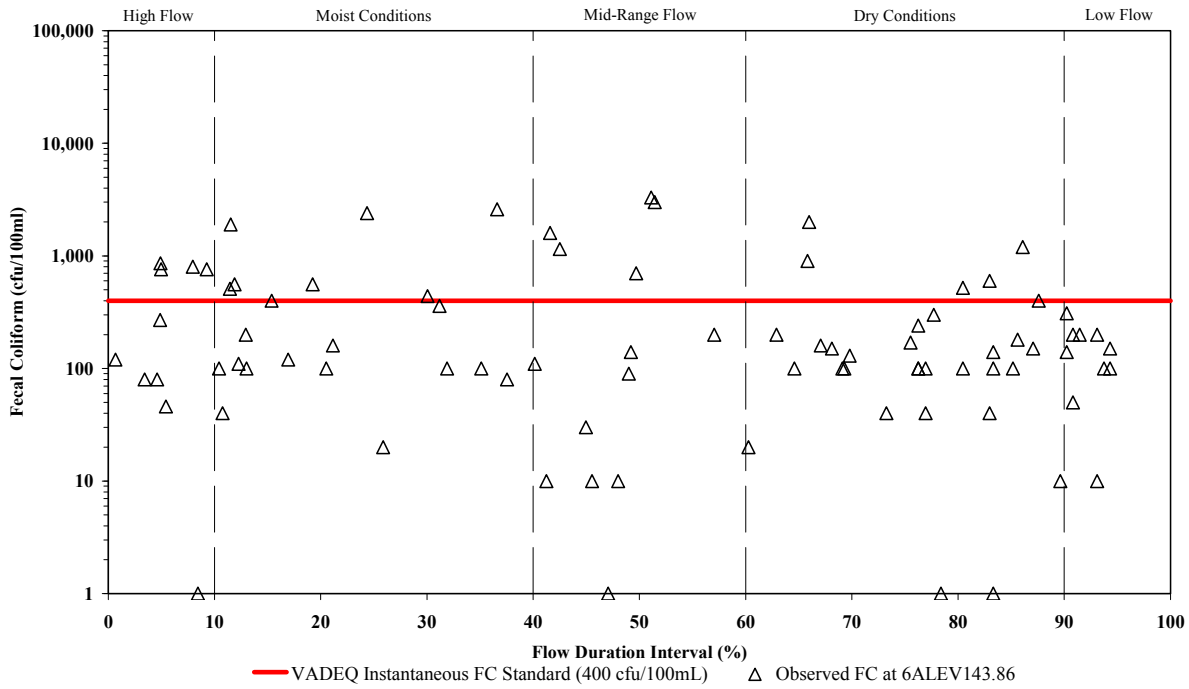

Figure B.2 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV143.86 and discharge at USGS Station #03207800 for Levisa Fork.

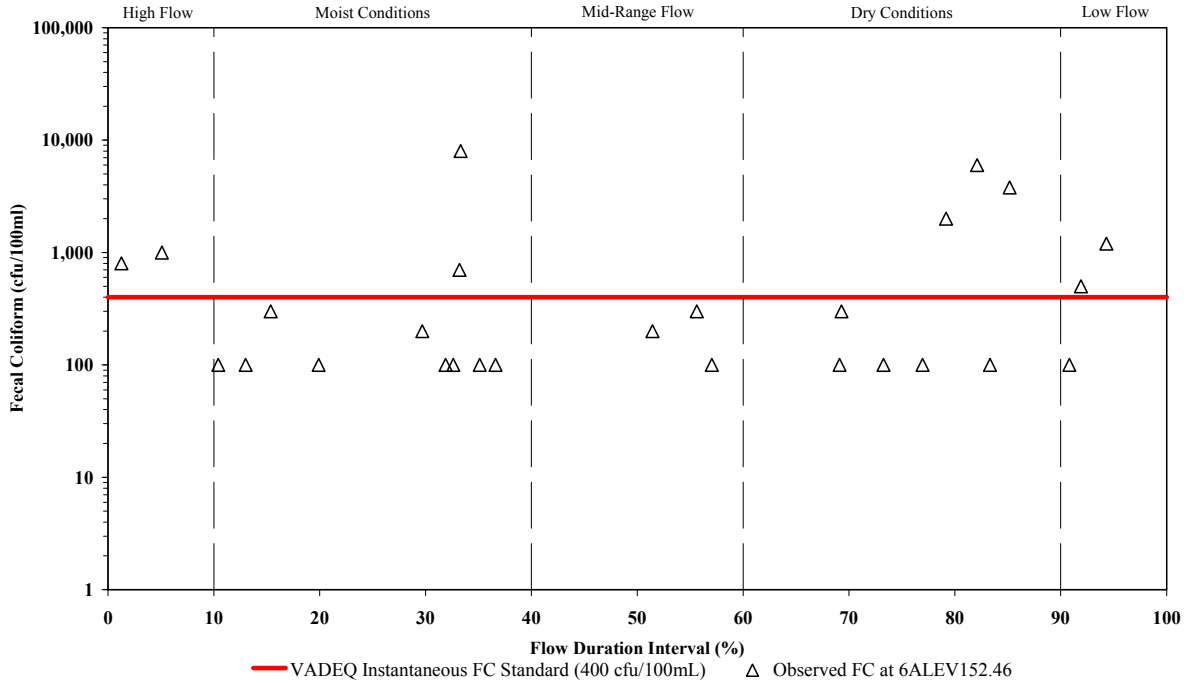

Figure B.3 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV152.46 and discharge at USGS Station #03207800 for Levisa Fork.

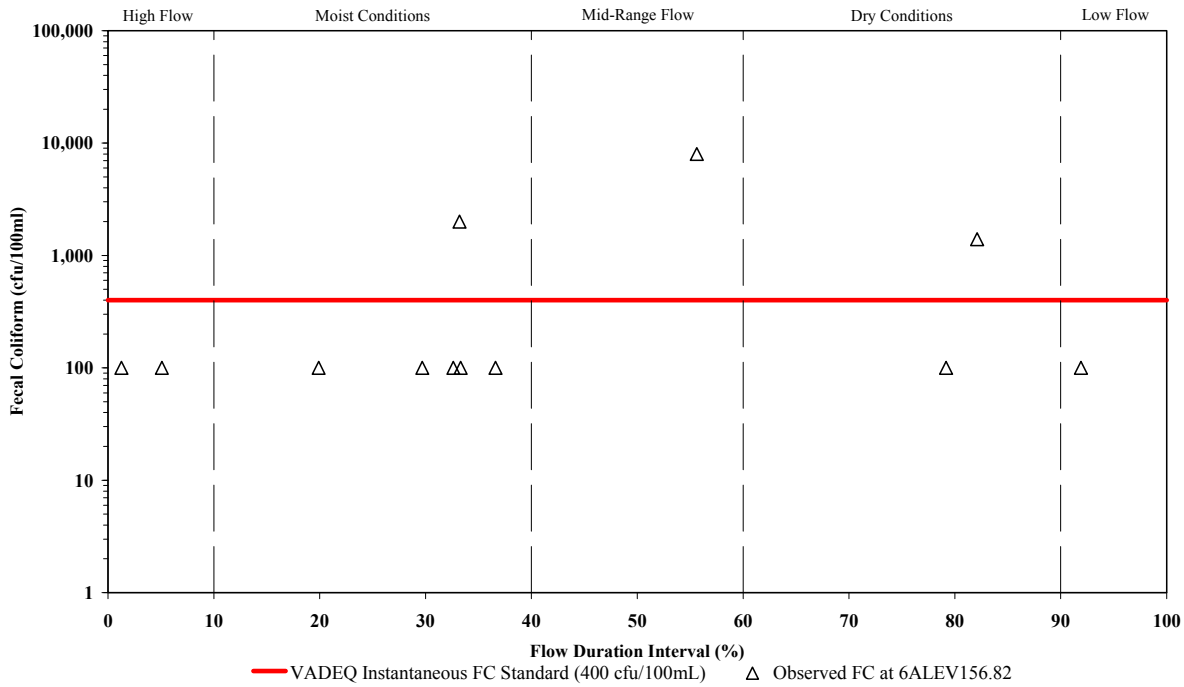

Figure B.4 Relationship between fecal coliform concentrations at VADEQ Station 6ALEV156.82 and discharge at USGS Station #03207800 for Levisa Fork.

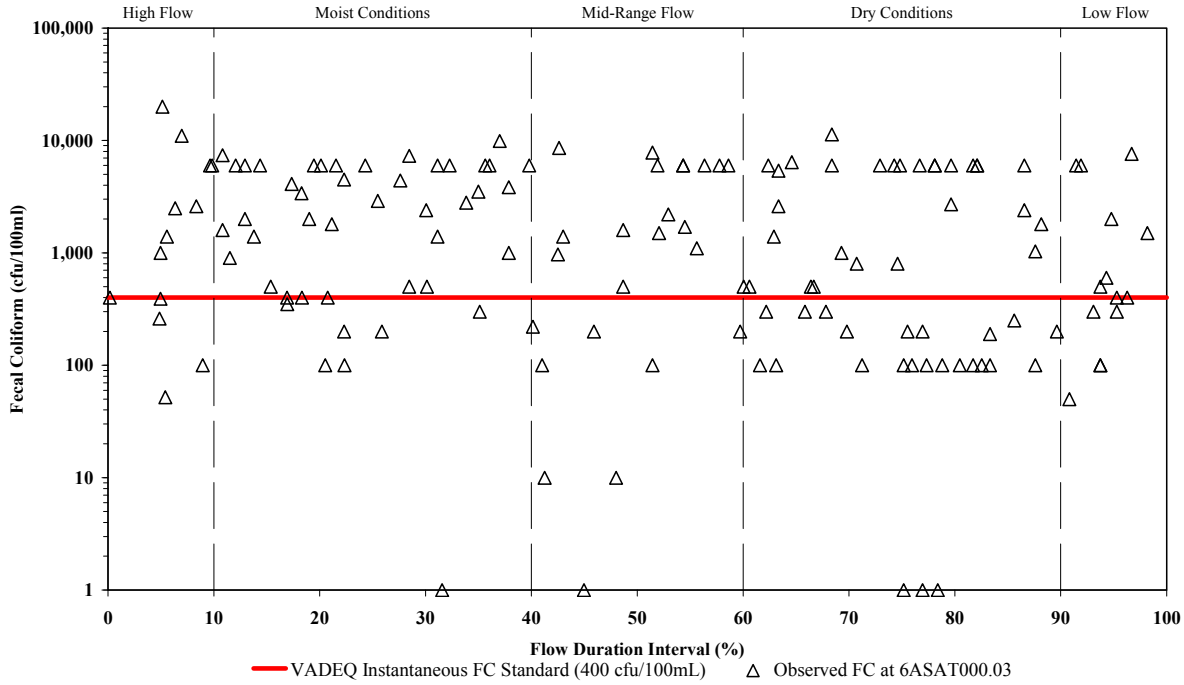

Figure B.5 Relationship between fecal coliform concentrations at VADEQ Station 6ASAT000.03and discharge at USGS Station #03207800 for Slate Creek.

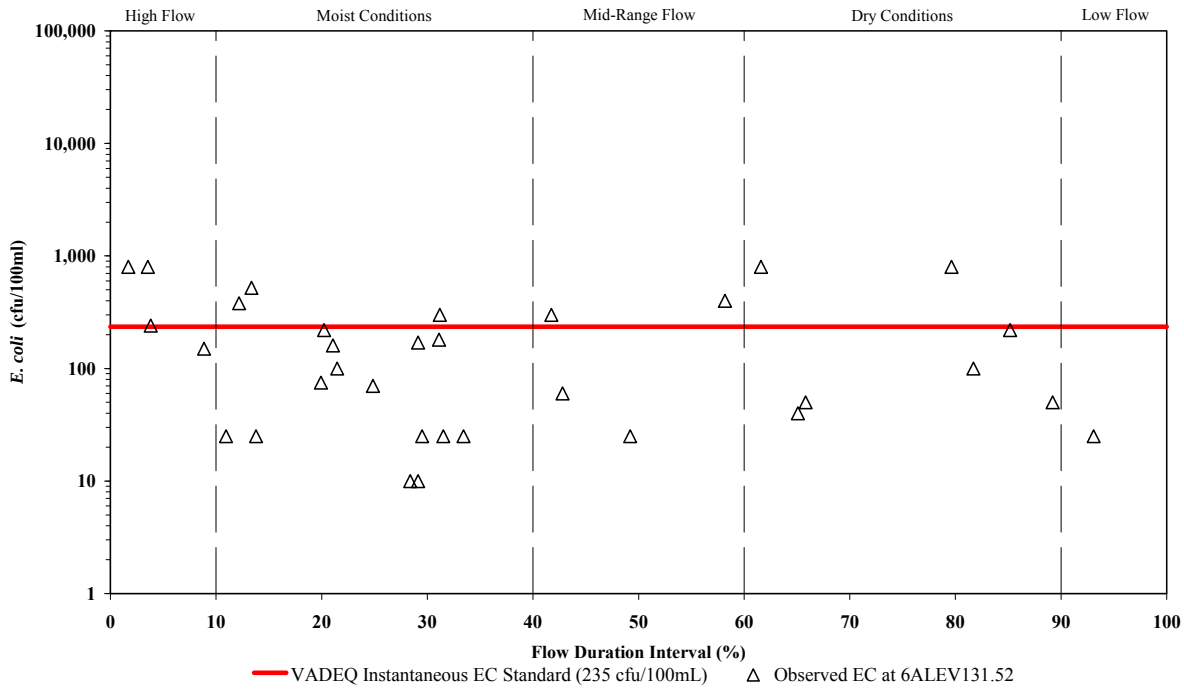

Figure B.6 Relationship between *E. coli* concentrations at VADEQ Station 6ALEV130.00 and discharge at USGS Station #03207800 for Levisa Fork.

Trends and Seasonal Analyses

Precipitation

Table B. 1 Summary of the Mood's Median Test on monthly total precipitation from combined NCDC stations #443640 Grundy, #444180 Hurley4S, #447174 Richlands (p=0.065).

Month	Mean	Min	Max	Median Group	
January	3.38	1.19	5.34	A	B
February	3.00	0.78	8.15	A	
March	3.99	1.18	8.20	A	B
April	4.14	1.30	7.00	A	B
May	4.48	1.64	8.70	A	B
June	4.68	1.22	8.28	A	B
July	5.32	2.08	8.22		B
August	3.94	1.46	6.37	A	B
September	3.40	1.14	6.32	A	B
October	2.90	0.35	6.65	A	
November	2.68	0.58	4.94	A	
December	3.25	1.36	7.78	A	B

VADEQ bacteria data

Table B. 2 Summary of fecal coliform data trends at VADEQ stations with adequate data.

Stream	VADEQ Station	Count (#)	Data Time Span	Trend	p-value	slope
Dismal Creek	6ADIS001.24	151	2/80 to 2/01	decreasing	0.0001	-25
Levisa Fork	6ALEV130.00	116	2/80 to 10/91	decreasing	0.0001	-55.7
Levisa Fork	6ALEV131.52	127	6/92 to 11/06	none	0.962	NA
Levisa Fork	6ALEV143.86	87	6/92 to 3/01	none	0.097	NA
Slate Creek	6ASAT000.03	149	2/80 to 2/01	decreasing	0.0001	-189

A number in the Slope column represents the Seasonal-Kendall estimated slope.

APPENDIX C

Land-Based Fecal Coliform Loads for Existing Conditions

Levisa Fork

Table C.1 Current conditions of land applied fecal coliform load for Levisa Fork by land use (all subwatersheds).

Land use	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
ActiveGasWell	1.38E+12	1.24E+12	1.38E+12	1.33E+12	1.38E+12	1.33E+12	1.38E+12	1.38E+12	1.33E+12	1.38E+12	1.33E+12	1.38E+12	1.62E+13
ActiveMining	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AML	3.74E+12	3.38E+12	3.74E+12	3.62E+12	3.74E+12	3.62E+12	3.74E+12	3.74E+12	3.62E+12	3.74E+12	3.62E+12	3.74E+12	4.41E+13
Developed	1.06E+12	9.61E+11	1.06E+12	1.03E+12	1.06E+12	1.03E+12	1.06E+12	1.06E+12	1.03E+12	1.06E+12	1.03E+12	1.06E+12	1.25E+13
Forest	6.74E+13	6.09E+13	6.74E+13	6.52E+13	6.74E+13	6.52E+13	6.74E+13	6.74E+13	6.52E+13	6.74E+13	6.52E+13	6.74E+13	7.93E+14
OpenWater	1.02E+14	9.20E+13	1.02E+14	9.87E+13	1.02E+14	9.87E+13	1.02E+14	1.02E+14	9.87E+13	1.02E+14	9.86E+13	1.02E+14	1.20E+15
PastureHay	2.20E+13	1.99E+13	2.20E+13	2.12E+13	2.19E+13	2.11E+13	2.18E+13	2.18E+13	2.12E+13	2.20E+13	2.13E+13	2.20E+13	2.58E+14
ReclaimedMine	5.20E+10	4.69E+10	5.20E+10	5.03E+10	5.20E+10	5.03E+10	5.20E+10	5.20E+10	5.03E+10	5.20E+10	5.03E+10	5.20E+10	6.12E+11
Residential	3.84E+13	3.44E+13	3.76E+13	3.62E+13	3.71E+13	3.57E+13	3.64E+13	3.64E+13	3.52E+13	3.61E+13	3.52E+13	3.74E+13	4.36E+14
RowCrop	2.81E+10	2.54E+10	2.81E+10	2.72E+10	2.81E+10	2.72E+10	2.81E+10	2.81E+10	2.72E+10	2.81E+10	2.72E+10	2.81E+10	3.31E+11
Total	**2.36E+14**	**2.13E+14**	**2.35E+14**	**2.27E+14**	**2.35E+14**	**2.27E+14**	**2.34E+14**	**2.34E+14**	**2.26E+14**	**2.34E+14**	**2.26E+14**	**2.35E+14**	**2.76E+15**

Table C.2 Monthly, directly deposited fecal coliform loads in Levisa Fork by land use (all subwatersheds).

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	9.94E+13	8.97E+13	9.94E+13	9.62E+13	9.94E+13	9.62E+13	9.94E+13	9.94E+13	9.62E+13	9.94E+13	9.62E+13	9.94E+13	1.17E+15
Livestock	1.43E+11	1.29E+11	2.04E+11	2.77E+11	2.86E+11	3.36E+11	3.48E+11	3.48E+11	2.77E+11	2.04E+11	1.98E+11	1.43E+11	2.89E+12
Wildlife	8.40E+11	7.59E+11	8.40E+11	8.13E+11	8.40E+11	8.13E+11	8.40E+11	8.40E+11	8.13E+11	8.40E+11	8.13E+11	8.40E+11	9.89E+12

Table C.3 Existing annual fecal coliform loads from land-based sources for Levisa Fork by land use (all subwatersheds).

Source	Active GasWell	Active Mining	AML	Developed	Forest	OpenWater	PastureHay	Reclaimed Mine	Residential	Row Crop
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.21E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.10E+12	1.38E+14	0.00E+00	0.00E+00	0.00E+00
Beef calf	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.92E+11	5.19E+13	0.00E+00	0.00E+00	0.00E+00
cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.64E+08	0.00E+00
Dairy milker	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.41E+12	0.00E+00	0.00E+00	0.00E+00
deer	1.50E+11	0.00E+00	1.37E+12	3.78E+10	5.85E+13	1.11E+11	5.30E+12	0.00E+00	1.44E+12	1.50E+10
dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.91E+14	0.00E+00
duck	1.18E+08	0.00E+00	6.72E+08	5.40E+08	1.42E+10	2.34E+09	1.87E+09	2.18E+07	3.53E+09	1.67E+07
Fail septic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E+13	0.00E+00
hog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.49E+12	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E+13	0.00E+00	0.00E+00	0.00E+00
muskrat	8.41E+11	0.00E+00	4.79E+12	3.85E+12	1.01E+14	1.67E+13	1.34E+13	1.55E+11	2.52E+13	1.19E+11
raccoon	1.52E+13	0.00E+00	3.79E+13	8.65E+12	6.34E+14	0.00E+00	2.09E+13	4.57E+11	6.31E+13	1.97E+11
sheep	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
Straight pipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+15	0.00E+00	0.00E+00	0.00E+00	0.00E+00
turkey	5.17E+08	0.00E+00	7.12E+08	9.78E+07	1.50E+11	2.63E+08	1.42E+09	0.00E+00	4.23E+08	9.67E+06
Total	**1.62E+13**	**0.00E+00**	**4.41E+13**	**1.25E+13**	**7.94E+14**	**1.19E+15**	**2.58E+14**	**6.12E+11**	**4.35E+14**	**3.31E+11**

Table C.4 Existing annual fecal coliform loads from direct-deposition sources for Levisa Fork by land use (all subwatersheds).

Source	Annual Total Loads (cfu/yr)
beaver	7.21E+10
beef	2.10E+12
Beef calf	7.92E+11
Dairy milker	0.00E+00
deer	3.35E+10
duck	9.08E+08
hog	0.00E+00
horse	0.00E+00
muskrat	7.82E+12
raccoon	1.96E+12
sheep	0.00E+00
straight pipe	1.17E+15
turkey	7.66E+07
Total	**1.18E+15**

Slate Creek

Table C.5 Current conditions of land applied fecal coliform load for Levisa Fork by land use (subwatersheds 9,10).

Land use	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
ActiveGasWell	3.28E+10	2.96E+10	3.28E+10	3.17E+10	3.28E+10	3.17E+10	3.28E+10	3.28E+10	3.17E+10	3.28E+10	3.17E+10	3.28E+10	3.86E+11
ActiveMining	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AML	4.46E+11	4.03E+11	4.46E+11	4.32E+11	4.46E+11	4.32E+11	4.46E+11	4.46E+11	4.32E+11	4.46E+11	4.32E+11	4.46E+11	5.25E+12
Developed	9.04E+10	8.17E+10	9.04E+10	8.75E+10	9.04E+10	8.75E+10	9.04E+10	9.04E+10	8.75E+10	9.04E+10	8.75E+10	9.04E+10	1.06E+12
Forest	1.11E+13	1.00E+13	1.11E+13	1.07E+13	1.11E+13	1.07E+13	1.11E+13	1.11E+13	1.07E+13	1.11E+13	1.07E+13	1.11E+13	1.30E+14
OpenWater	1.60E+13	1.44E+13	1.60E+13	1.55E+13	1.60E+13	1.55E+13	1.60E+13	1.60E+13	1.55E+13	1.60E+13	1.55E+13	1.60E+13	1.88E+14
PastureHay	3.84E+12	3.47E+12	3.83E+12	3.69E+12	3.81E+12	3.68E+12	3.80E+12	3.80E+12	3.69E+12	3.83E+12	3.71E+12	3.84E+12	4.50E+13
ReclaimedMine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Residential	6.86E+12	6.15E+12	6.71E+12	6.45E+12	6.61E+12	6.35E+12	6.46E+12	6.46E+12	6.25E+12	6.41E+12	6.25E+12	6.66E+12	7.76E+13
Total	**3.84E+13**	**3.45E+13**	**3.82E+13**	**3.69E+13**	**3.81E+13**	**3.68E+13**	**3.79E+13**	**3.79E+13**	**3.67E+13**	**3.79E+13**	**3.67E+13**	**3.82E+13**	**4.47E+14**

Table C.6 Monthly, directly deposited fecal coliform loads in Levisa Fork by land use (subwatersheds 9,10).

Source Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual Total Loads (cfu/yr)
Human	1.56E+13	1.41E+13	1.56E+13	1.52E+13	1.56E+13	1.52E+13	1.56E+13	1.56E+13	1.52E+13	1.56E+13	1.52E+13	1.56E+13	1.85E+14
Livestock	2.63E+10	2.38E+10	3.76E+10	5.10E+10	5.27E+10	6.18E+10	6.39E+10	6.39E+10	5.10E+10	3.76E+10	3.63E+10	2.63E+10	5.32E+11
Wildlife	1.31E+11	1.18E+11	1.31E+11	1.27E+11	1.31E+11	1.27E+11	1.31E+11	1.31E+11	1.27E+11	1.31E+11	1.27E+11	1.31E+11	1.55E+12

Table C.7 Existing annual fecal coliform loads from land-based sources for Levisa Fork by land use (subwatersheds 9,10).

Source	Active GasWell	Active Mining	AML	Developed	Forest	OpenWater	PastureHay	Reclaimed Mine	Residential	Row Crop
beaver	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
beef	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.84E+11	2.52E+13	0.00E+00	0.00E+00	0.00E+00
beefcalf	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E+11	9.68E+12	0.00E+00	0.00E+00	0.00E+00
cat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.74E+07	0.00E+00
dairymilker	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
deer	4.68E+09	0.00E+00	1.44E+11	0.00E+00	1.05E+13	0.00E+00	5.52E+11	0.00E+00	2.07E+11	0.00E+00
dog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.23E+13	0.00E+00
duck	6.69E+06	0.00E+00	5.86E+07	4.71E+07	2.40E+09	2.92E+08	2.61E+08	0.00E+00	5.79E+08	0.00E+00
failseptic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+13	0.00E+00
hog	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+12	0.00E+00	0.00E+00	0.00E+00
horse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.97E+12	0.00E+00	0.00E+00	0.00E+00
muskrat	4.77E+10	0.00E+00	4.18E+11	3.36E+11	1.71E+13	2.08E+12	1.86E+12	0.00E+00	4.13E+12	0.00E+00
raccoon	3.33E+11	0.00E+00	4.69E+12	7.29E+11	1.03E+14	0.00E+00	2.24E+12	0.00E+00	1.01E+13	0.00E+00
sheep	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
strtpipe	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.84E+14	0.00E+00	0.00E+00	0.00E+00	0.00E+00
turkey	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E+10	0.00E+00	1.43E+08	0.00E+00	0.00E+00	0.00E+00
Total	**3.85E+11**	**0.00E+00**	**5.25E+12**	**1.07E+12**	**1.31E+14**	**1.87E+14**	**4.50E+13**	**0.00E+00**	**7.76E+13**	**0.00E+00**

Table C.8 Existing annual fecal coliform loads from direct-deposition sources for Levisa Fork by land use (subwatersheds 9,10).

Source	Annual Total Loads (cfu/yr)
beaver	1.06E+10
beef	3.84E+11
Beef calf	1.48E+11
Dairy milker	0.00E+00
deer	5.72E+09
duck	1.42E+08
hog	0.00E+00
horse	0.00E+00
muskrat	1.22E+12
raccoon	3.03E+11
sheep	0.00E+00
Straight pipe	1.84E+14
turkey	1.41E+07
Total	**1.86E+14**

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APPENDIX D

HSPF Sensitivity Analyses

Sensitivity Analyses

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during a sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. 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).

HSPF - Hydrology Sensitivity Analysis

A hydrology sensitivity analysis was preformed during the development of the Levisa Fork TMDL. The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in Table D.1, with base values for the model runs given. The model was run for water years 2000-2003 and the parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, except for AGWRC. AGWRC was set at 0.98 initial and then changed to the values in Table 4.9, to show the hydrology changes when this parameter is at its minimum (0.85) and its maximum (0.999). Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used.

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 coliform from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), LZSN (Lower Zone Storage), and by UZSN (Upper Zone Storage), which governs surface transport, and LZETP (Lower Zone Evapotranspiration), which 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 were AGWRC (Groundwater Recession Rate), BASETP (Base Flow Evapotranspiration), LZETP, INFILT, DEEPFR (Groundwater Inflow to Deep Recharge), UZSN, CEPSC (Interception Storage Capacity), and LZSN. The responses of these and other hydrologic outputs are reported in Table D.2.

Table D. 1 HSPF base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	3.371-11.848
INFILT	Soil Infiltration Capacity	in/hr	0.1-0.1547
BASETP	Base Flow Evapotranspiration	---	0-0.01
INTFW	Interflow Inflow	---	2.0
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.01-0.04
AGWRC	Groundwater Recession rate	---	0.955
MON-NSUR	Monthly Manning's n coefficient	---	0.06-0.37
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.2
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.37-1.18
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.01-0.8

Table D. 2 HSPF sensitivity analysis results for hydrologic model parameters for Levisa Fork.

Model Parameter	Parameter Change (%)	Percent Change In: Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC	0.85	0.12	14.76	-40.18	0.95	0.40	-1.46	0.15	3.80
AGWRC	0.92	0.06	6.77	-19.71	0.58	0.16	-1.21	0.98	2.65
AGWRC	0.96	-0.01	-1.30	4.10	-0.19	-0.05	0.45	-0.42	-0.52
AGWRC	0.999	-13.32	-20.56	40.21	-22.72	-14.10	-1.81	-8.32	-23.18
BASETP	-50	0.07	-0.32	1.57	-0.27	0.15	0.53	-0.30	-0.32
BASETP	-10	0.01	-0.07	0.31	-0.05	0.03	0.11	-0.07	-0.08
BASETP	10	-0.01	0.06	-0.32	0.05	-0.03	-0.10	0.06	0.07
BASETP	50	-0.06	0.32	-1.53	0.26	-0.15	-0.52	0.29	0.47
DEEPFR	-50	0.35	0.27	0.37	0.35	0.31	0.37	0.47	0.36
DEEPFR	-10	0.07	0.05	0.07	0.07	0.06	0.07	0.09	0.07
DEEPFR	10	-0.07	-0.05	-0.07	-0.07	-0.06	-0.07	-0.09	-0.07
DEEPFR	50	-0.35	-0.27	-0.37	-0.35	-0.31	-0.37	-0.48	-0.36
INFILT	-50	-0.44	10.27	-12.27	2.48	0.65	-3.93	-5.25	0.05
INFILT	-10	-0.11	1.37	-1.73	0.39	0.08	-0.70	-0.95	-0.08
INFILT	10	0.11	-1.19	1.55	-0.35	-0.07	0.65	0.92	0.11
INFILT	50	0.61	-4.62	6.35	-1.33	-0.10	2.86	3.93	0.62
INTFW	-50	0.01	2.28	-0.76	0.13	0.23	-0.52	0.01	0.01
INTFW	-10	0.00	0.32	-0.09	0.02	0.05	-0.10	0.00	0.00
INTFW	10	0.00	-0.28	0.08	-0.01	-0.05	0.09	0.00	0.00
INTFW	50	-0.01	-1.10	0.32	-0.05	-0.22	0.40	-0.01	-0.01
LZSN	-50	2.92	6.01	-9.19	7.41	4.45	-1.06	-7.07	4.68
LZSN	-10	0.55	1.04	-1.12	1.17	0.84	0.07	-1.23	0.82
LZSN	10	-0.57	-1.00	0.86	-1.13	-0.81	-0.18	1.09	-0.72
LZSN	50	-3.18	-4.83	1.87	-5.62	-3.97	-1.54	3.23	-3.72
KVARY	-50	1.22	-0.62	4.57	-0.49	2.12	3.27	-1.58	1.03
KVARY	-10	0.20	-0.08	0.60	-0.03	0.37	0.65	-0.77	0.24
KVARY	10	-0.18	0.07	-0.59	0.06	-0.34	-0.67	0.78	-0.17
KVARY	50	-0.94	0.17	-3.63	0.62	-1.71	-3.03	1.89	-0.67
CEPSC	-50	10.81	9.73	18.18	13.10	4.61	7.47	34.01	10.48
CEPSC	-10	1.24	1.03	2.15	1.69	0.53	0.79	3.48	1.13
CEPSC	10	-0.98	-0.82	-1.59	-1.42	-0.40	-0.61	-2.56	-0.87
CEPSC	50	-7.12	-6.03	-10.61	-8.39	-3.06	-6.46	-19.53	-6.44
LZETP	-50	0.01	-0.04	-0.01	0.00	0.02	0.02	-0.03	0.01
LZETP	-10	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
LZETP	10	0.00	0.01	0.00	0.00	-0.01	0.00	0.00	0.00
LZETP	50	-0.01	0.06	0.01	0.00	-0.02	-0.03	0.01	-0.01
UZSN	-50	2.97	8.24	-3.08	0.82	4.73	6.68	-5.37	3.56
UZSN	-10	0.43	1.33	-0.59	0.20	0.65	0.98	-0.96	0.53
UZSN	10	-0.37	-1.17	0.56	-0.14	-0.58	-0.88	0.87	-0.43
UZSN	50	-1.56	-5.07	2.72	-1.00	-2.25	-3.33	3.27	-1.79

HSPF - Water Quality Parameter Sensitivity Analysis

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 2000 through 2003, and model parameters established for 2002 conditions (see Section 4.5 for a complete explanation of selected model time periods). The three HSPF parameters impacting the model's water quality response (Table D.3) were increased and decreased by amounts that were consistent with the range of values for the parameter. FSTDEC (First Order Decay) was the parameter with the greatest influence on monthly geometric mean concentration, although MON-SQOLIM and WSQOP also showed significant potential to influence this value (Table D.4, Figures D.1, D.2, and D.3).

Table D. 3 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 – 29E07
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	0 – 2.5
FSTDEC	In-stream First Order Decay Rate	1/day	5

Table D. 4 Percent change in average monthly *E. coli* geometric mean for the years 2000-2003 for Levisa Fork (subwatershed 8).

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly *E. coli* Geometric Mean for 2000-2003											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	111.63	107.23	105.05	101.23	114.79	118.31	104.44	116.53	129.84	132.86	132.23	127.36
FSTDEC	-10	13.25	12.99	12.82	12.58	13.42	13.60	12.77	13.51	14.24	14.41	14.36	14.16
FSTDEC	10	-10.92	-10.76	-10.65	-10.49	-11.02	-11.11	-10.60	-11.07	-11.50	-11.60	-11.57	-11.47
FSTDEC	50	-59.45	-59.25	-58.92	-58.69	-59.51	-59.55	-58.71	-59.61	-60.11	-60.27	-60.16	-60.27
SQOLIM	-50	0.02	0.01	0.02	0.03	0.02	0.03	0.04	0.01	0.01	0.01	0.01	0.01
SQOLIM	-25	0.06	0.03	0.06	0.06	0.04	0.08	0.10	0.04	0.02	0.01	0.02	0.03
SQOLIM	50	0.12	0.07	0.12	0.12	0.09	0.15	0.18	0.07	0.03	0.03	0.05	0.06
SQOLIM	100	0.25	0.13	0.24	0.23	0.16	0.30	0.36	0.14	0.07	0.06	0.10	0.12
WSQOP	-50	0.14	0.06	0.12	0.13	0.07	0.16	0.21	0.06	0.01	0.00	0.03	0.05
WSQOP	-10	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.01
WSQOP	10	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	0.00	0.00	0.00	0.00	-0.01
WSQOP	50	-0.05	-0.03	-0.05	-0.04	-0.03	-0.06	-0.09	-0.02	-0.01	0.00	-0.02	-0.02

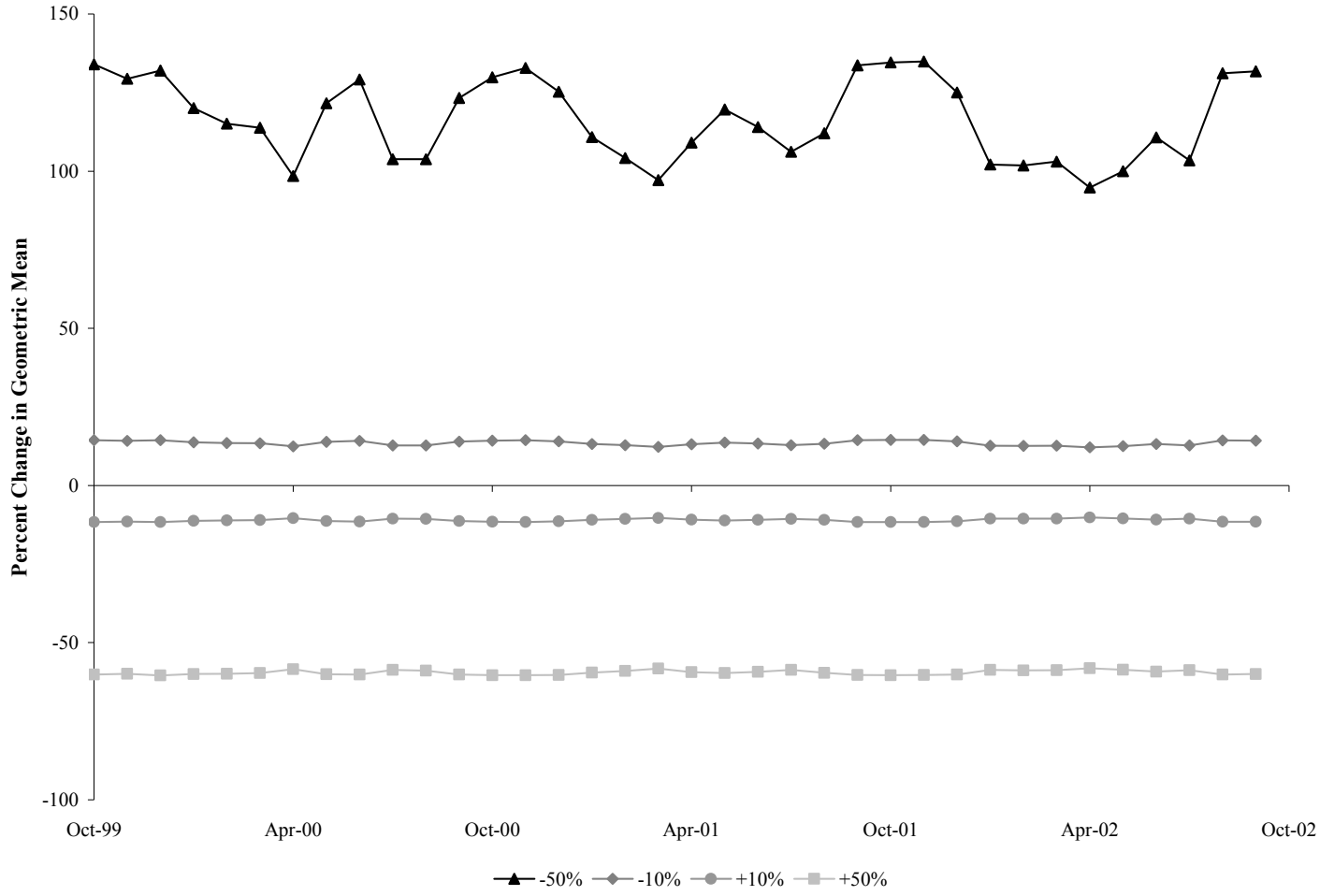

Figure D. 1 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in the in-stream first-order decay rate (FSTDEC).

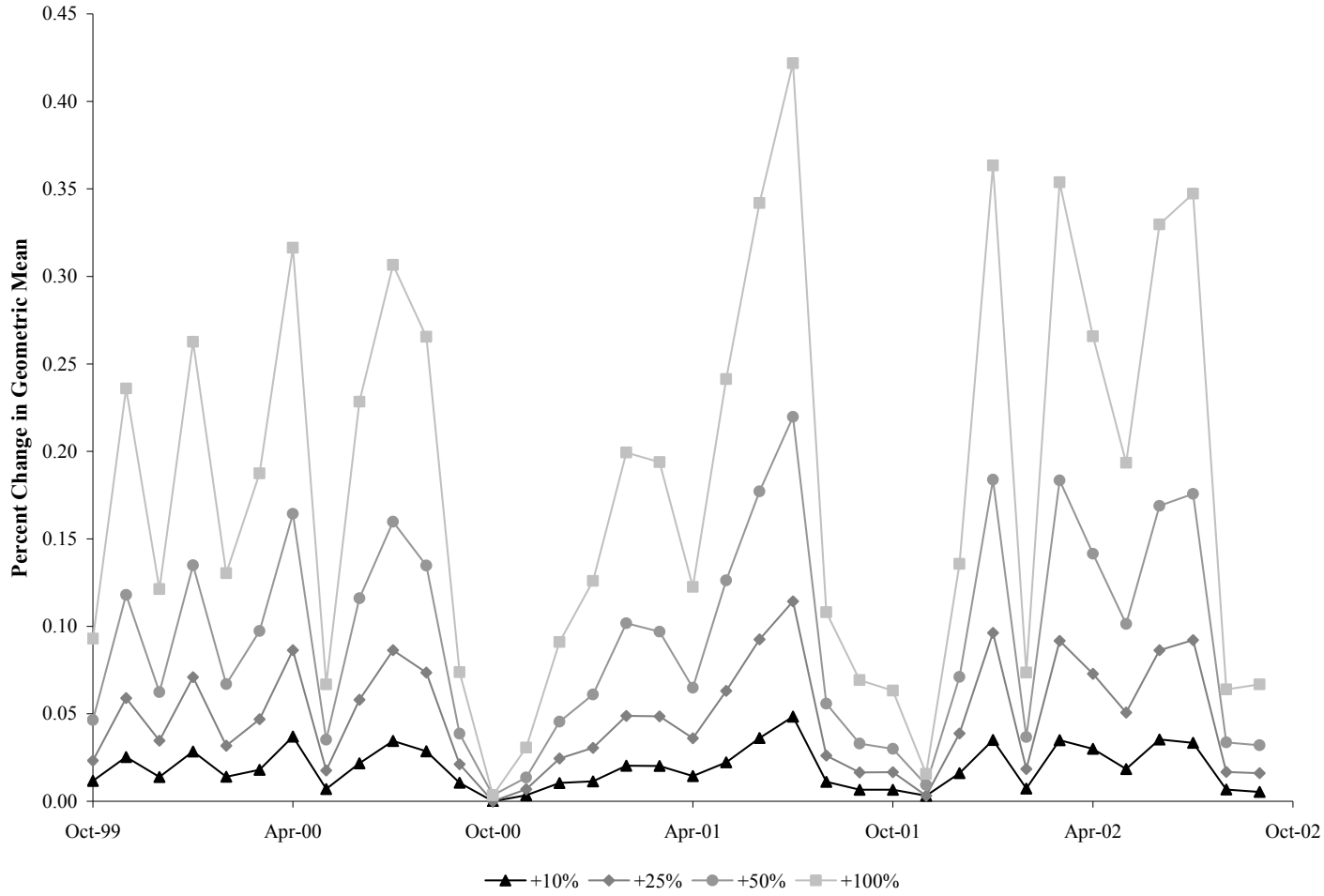

Figure D. 2 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).

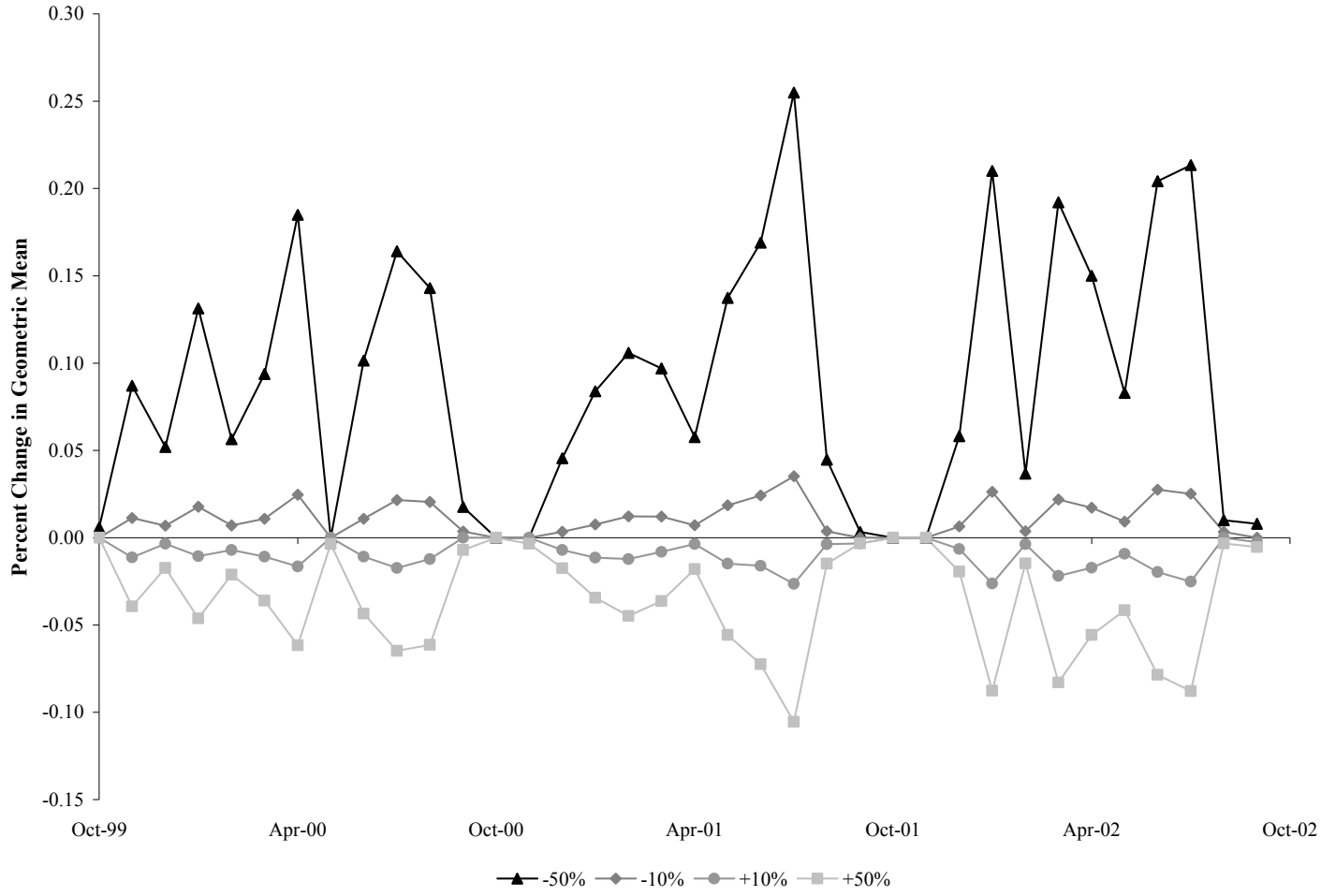

Figure D. 3 Results of sensitivity analysis on monthly geometric mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in the wash-off rate from land surfaces (WSQOP).

In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in Figure D.4 that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of 2% in stream loads, while a 100% increase in direct loads results in a 98% increase in stream loads. The sensitivity analysis of geometric mean concentrations also showed that direct loads and land based loads showed different impacts (Figures D.5 and D.6). These relationships are reasonable, as it is known there are numerous straight pipe direct bacteria sources to Levisa Fork.

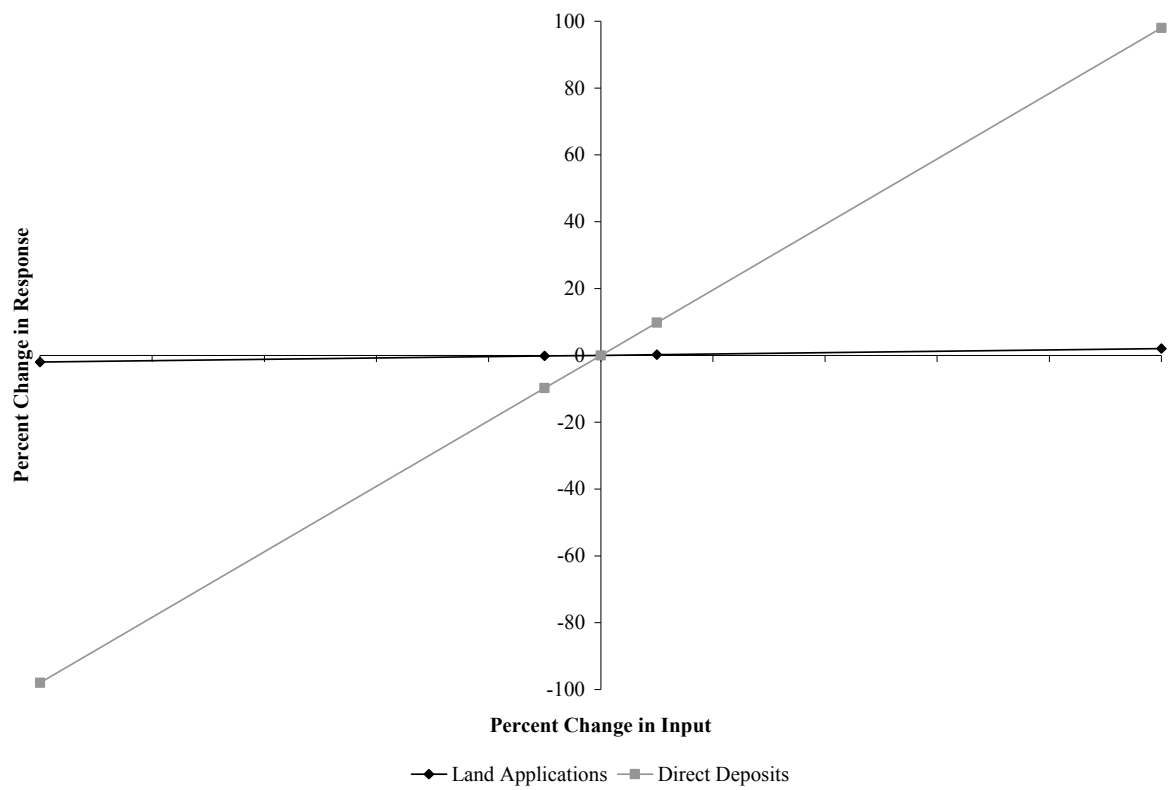

Figure D. 4 Results of total loading sensitivity analysis for Levisa Fork (subwatershed 8).

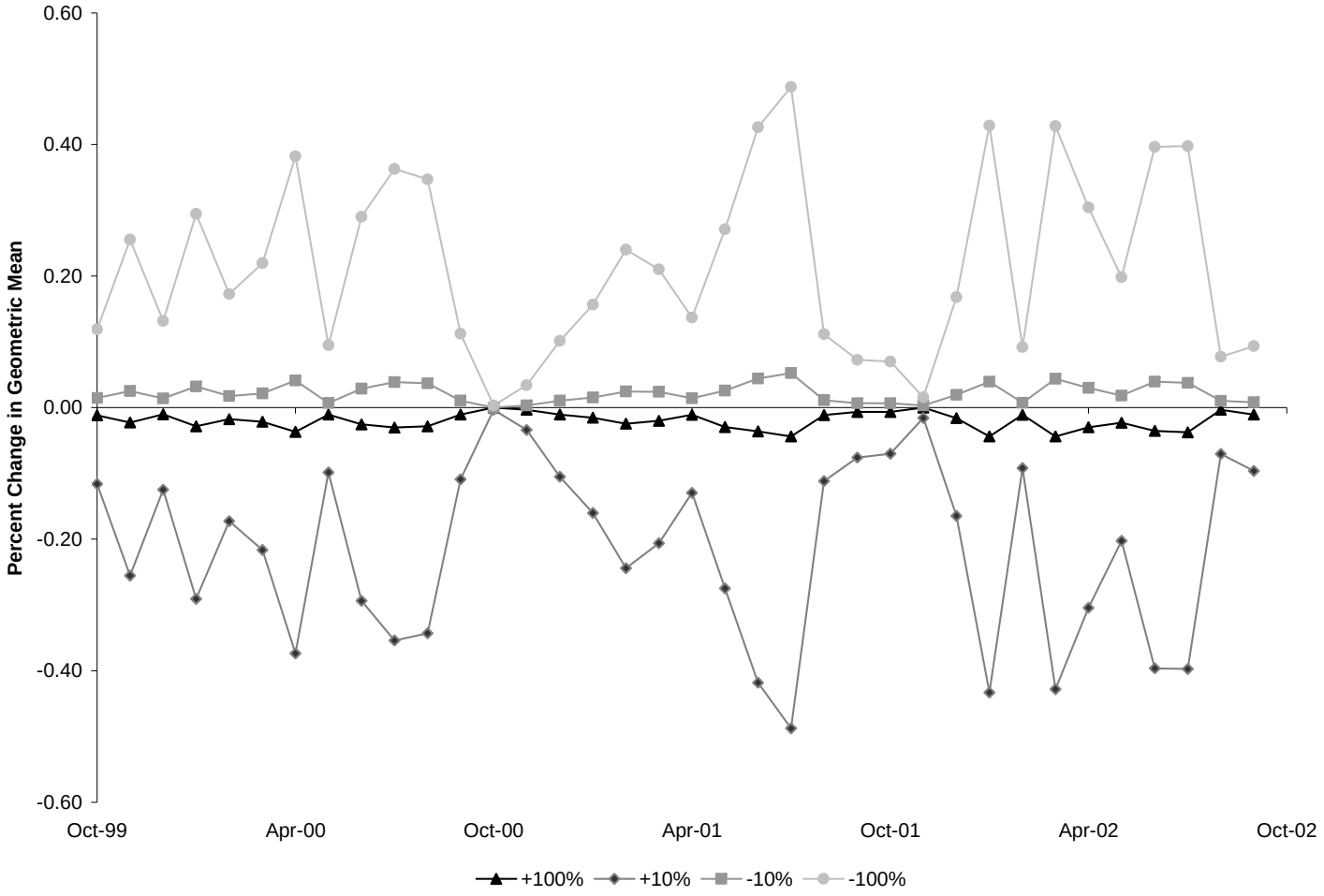

Figure D. 5 Results of sensitivity analysis on monthly geometric-mean concentrations in Levisa Fork (subwatershed 8) as affected by changes in land-based loadings.

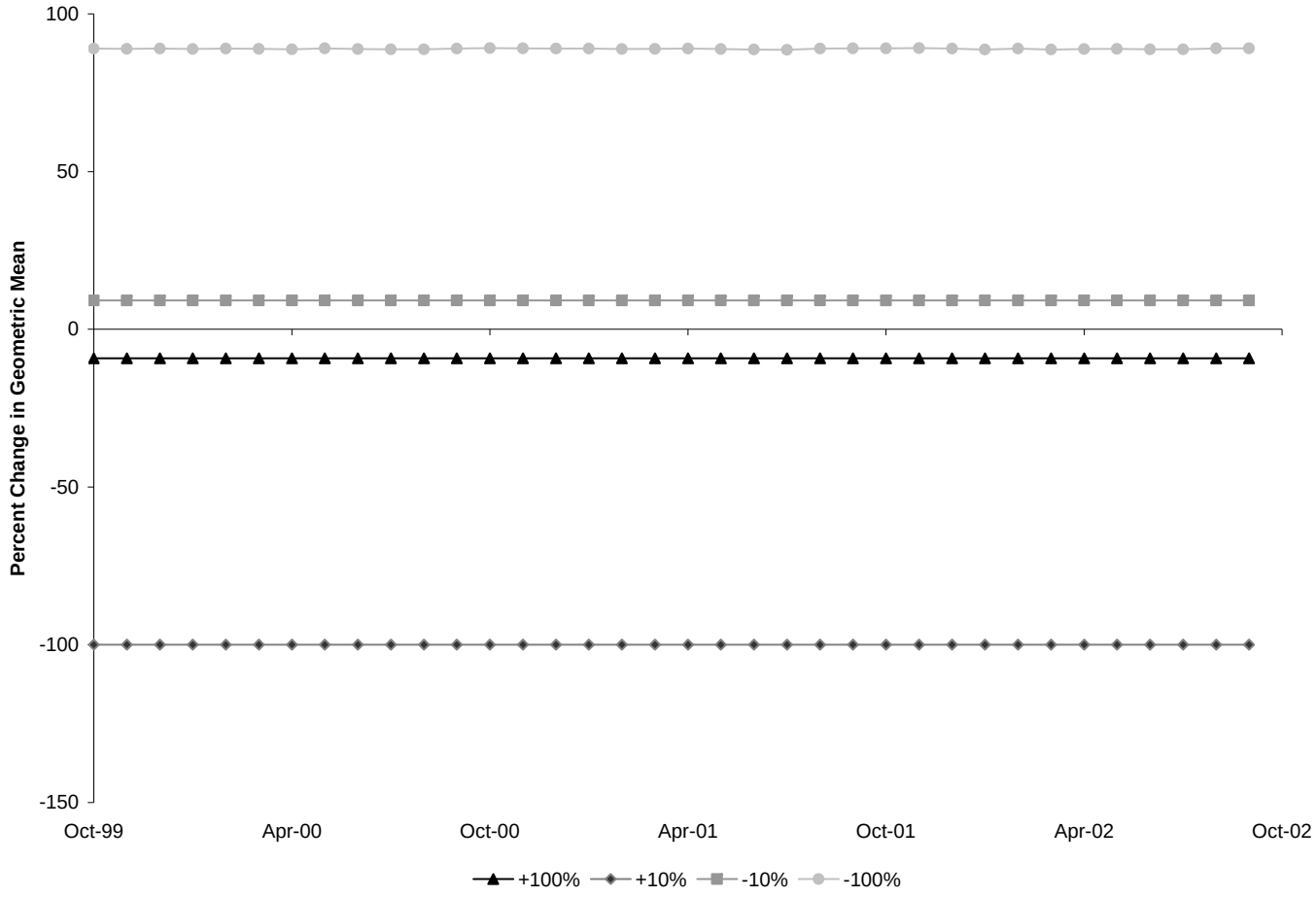

Figure D. 6 Results of sensitivity analysis on monthly geometric-mean concentrations in Levisa Fork (subwatershed 8), as affected by changes in loadings from direct nonpoint sources.