Middle and Lower Big Hole Planning Area TMDLs and Water Quality Improvement Plan

September 3, 2009

Montana Department of Environmental Quality

Montana Department of Environmental Quality
P.O. Box 200901
Helena, MT 59620-0901

Darrin Kron, Project Coordinator, Nutrient and Temperature Project Manager
Lisa Kusnierz, Sediment and Metals Project Manager
Kyle Flynn, Water Quality Modeling Assistance

Cooperators:
Big Hole Watershed Committee
Big Hole River Foundation

Significant Contributors:
Big Hole Watershed Committee
PBS&J Corp.

TABLE OF CONTENTS

Executive Summary 17

Section 1.0 Introduction 21

1.1 Background 21
1.2 303(d) List Summary and TMDLs Written 22
1.3 Document Description 27

Section 2.0 Watershed Characterization 29

2.1 Physical Characteristics 29
2.1.1 Location 29
2.1.2 Climate 29
2.1.3 Hydrology 30
2.1.4 Geology, Soils, and Slope 30
2.2 Social Characteristics 31
2.2.1 Land Ownership 31
2.2.2 Land Use, Land Cover, and Vegetation 31
2.2.3 Irrigation 31
2.2.4 Mineral Extraction and Mining 32
2.3 Fish and Aquatic Life 33

Section 3.0 Application of Montana's Water Quality Standards for TMDL Development 35

3.1 Classification and Beneficial Uses 35
3.2 Standards 38

Section 4.0 Description of TMDL Components 41

4.1 Target Development 42
4.2 Quantifying Pollutant Sources 42
4.3 Establishing the Total Allowable Load 43
4.4 Determining Allocations 44
4.5 Margin of Safety 44

Section 5.0 Sediment 47

5.1 Mechanism of Effects of Excess Sediment on Beneficial Uses 47
5.2 Stream Segments of Concern 47
5.3 Information Sources and Assessment Methods 50
5.3.1 Modeled Upland Erosion 51
5.3.2 Unpaved Road Sediment Assessment 51
5.3.3 Eroding Streambank Sediment Assessment 52
5.4 Water Quality Targets and Comparison to Existing Conditions 52
5.4.1 Water Quality Targets 52
5.4.2 Existing Condition and Comparison to Water Quality Targets 60

5.4.3 TMDL Development Summary 140
5.5 Source Quantification 141
5.5.1 Upland Erosion 142
5.5.2 Unpaved Roads 143
5.5.3 Streambank Erosion 144
5.5.4 Source Assessment Summary 144
5.6 TMDL and Allocations 145
5.6.1 Big Hole River, Middle Segment 146
5.6.2 Birch Creek, Upper Segment 147
5.6.3 Birch Creek, Lower Segment 148
5.6.4 California Creek 149
5.6.5 Camp Creek 150
5.6.6 Corral Creek 151
5.6.7 Deep Creek 152
5.6.8 Delano Creek 153
5.6.9 Divide Creek 154
5.6.10 Elkhorn Creek 155
5.6.11 Fishtrap Creek 156
5.6.12 French Creek 157
5.6.13 Gold Creek 158
5.6.14 Grose Creek 159
5.6.15 Jerry Creek 160
5.6.16 Lost Creek 161
5.6.17 Moose Creek 162
5.6.18 Oregon Creek 163
5.6.19 Pattengail Creek 164
5.6.20 Rochester Creek 165
5.6.21 Sawlog Creek 166
5.6.22 Sevenmile Creek 167
5.6.23 Sixmile Creek 168
5.6.24 Soap Creek 168
5.6.25 Trapper Creek 169
5.6.26 Wise River 170
5.7 Seasonality and Margin of Safety 171
5.7.1 Seasonality 171
5.7.2 Margin of Safety 172
5.7.3 Uncertainty and Adaptive Management 173

Section 6.0 Nutrients 175

6.1 Introduction 175
6.2 Background Information 175
6.3 Information Sources and Assessment Methods 177
6.4 Nutrient Water Quality Targets 177
6.4.1 Nutrient Concentrations and Chlorophyll *a* 177
6.4.2 Riparian Vegetation 179
6.4.3 Biological Indicators 180

6.4.4 Summary of Targets and Supplemental Indicators for Nutrients 180
6.5 Existing Condition and Comparison to Water Quality Targets 180
6.5.1 Camp Creek 180
6.5.2 Divide Creek 183
6.5.3 Grose Creek 186
6.5.4 Jerry Creek 187
6.5.5 Lost Creek 189
6.5.6 Soap Creek 191
6.5.7 Other Streams 193
6.6 Nutrient Source Assessment Techniques 193
6.6.1 Initial Nutrient Assessment Planning 193
6.6.2 Watershed Source Assessment Modeling and Supporting Information 194
6.7 Nutrient Source Assessments, TMDLs and Allocations 194
6.7.1 Nutrient TMDLs 194
6.7.2 Nutrient Source Assessment and Allocations 195
6.8 Uncertainty and Adaptive Management for Nutrient TMDLs 216
6.9 Margin of Safety and Seasonal Considerations for Nutrient TMDLs 217
6.10 Nutrient Monitoring Strategies 217

Section 7.0 Metal TMDL Components 219

7.1 Mechanism of Effects of Excess Metals to Beneficial Uses 219
7.2 Stream Segments of Concern 219
7.3 Information Sources and Assessment Methods 220
7.3.1 Natural Background Loading 221
7.3.2 Atmospheric Deposition 221
7.3.3 Abandoned Mines 221
7.4 Water Quality Targets 223
7.4.1 Targets 223
7.4.2 Supplemental Indicators 224
7.4.3 Summary of Targets and Supplemental Indicators for Metals 225
7.4.4 Existing Condition and Comparison to Water Quality Targets 226
7.4.5 TMDL Development Determination Summary 251
7.4.6 Additional Exceedances of Water Quality Targets or Supplemental Indicators 252
7.5 TMDLs 254
7.6 Loading Summary and Allocations 259
7.6.2 Oregon Creek/California Creek/French Creek 259
7.6.3 Elkhorn Creek/Wise River 264
7.6.4 Jerry Creek (MT41D003_020) 268
7.6.5 Big Hole River, Middle Segment (MT41D001_020) 269
7.6.6 Wickiup Creek (MT41D002_120) 271
7.6.7 Lost Creek (MT41D002_180) 272
7.6.8 Rochester Creek (MT41D002_160) 273
7.6.9 Trapper Creek (MT41D002_010) 276
7.7 Seasonality and Margin of Safety 277
7.7.1 Seasonality 278
7.7.2 Margin of Safety 278

7.8 Adaptive Management 279

SECTION 8.0 Temperature 281

8.1 Thermal Impacts upon Sensitive Uses 281
8.2. Stream Segments of Concern 281
8.3 Temperature Targets 281
8.3.1 Surrogate Targets 282
8.3.2 Impact to Fish 284
8.4 Existing Conditions Summary 285
8.4.1 Big Hole River - Middle Segment (between Pintlar Creek and Divide Creek) 285
8.4.2 Big Hole River, Lower Segment (from Divide Creek to mouth) 289
8.4.3 Divide Creek 292
8.5 Temperature TMDLs 294
8.5.1 Big Hole River, Middle Segment (Pintlar Creek to Divide Creek) 297
8.5.2 Big Hole River, Lower Segment 300
8.5.3 Divide Creek 302
8.6 Margin of Safety and Seasonal Considerations 302
8.7 Adaptive Management 303
8.8 Monitoring Plan 303

Section 9.0 Framework Water Quality Restoration Strategy 305

9.1 Summary of Restoration Strategy 305
9.2 Role of DEQ, Other Agencies, and Stakeholders 305
9.2.1 Coordinated Effort between Fishery and Water Quality Restoration 306
9.3 Watershed Restoration Goals 306
9.4 Overview of Management Recommendations 307
9.4.1 Sediment Restoration Approach 308
9.4.2 Nutrient Restoration Approach 315
9.4.3 Metals Restoration Approach 316
9.4.4 Temperature Restoration Approach 317
9.4.5 Pollution Restoration Approach 318
9.5 Restoration Approaches by Source 319
9.5.1 Grazing 319
9.5.2 Animal Feeding Operations 321
9.5.3 Cropland 322
9.5.4 Irrigation 323
9.5.5 Riparian Vegetation Removal 325
9.5.6 Unpaved Roads 325
9.5.7 Bank hardening/riprap/revetment/floodplain development 326
9.5.8 Forestry and Timber Harvest 327
9.5.9 Mining/Smelter Fallout -Related 327

Section 10.0 Monitoring Strategy 331

10.1 Introduction 331
10.2 Adaptive Management Approach 331

10.3 Follow-up Monitoring ... 331
10.3.1 Hydrology ... 332
10.3.2 Sediment ... 332
10.3.3 Nutrients ... 334
10.3.4 Metals ... 335
10.3.5 Temperature ... 337
10.4 Implementation and Restoration Effectiveness Monitoring ... 337
10.4.1 Road BMPs ... 337
10.4.2 Agricultural BMPs ... 338
10.4.3 Abandoned Mine Reclamation ... 339
10.5 Watershed-Scale Monitoring ... 340

Section 11.0 Stakeholder and Public Comments ... 341

Section 12 References ... 343

Appendices

Appendix A: Maps
Appendix B: Regulatory Framework and Reference Condition
Approach Appendix C: Sediment Contribution from Roads
Appendix D: Sediment Contribution from Hillslope Erosion
Appendix E: Sediment Contribution from Streambank Erosion
Appendix F: Daily TMDLs for Sediment and Temperature
Appendix G: Nutrient Model
Appendix H: Sediment/Metals Data
Appendix I: Big Hole River Temperature Model
Appendix J: Divide Creek Temperature Model
Appendix K: Response to Public Comments

TABLE OF TABLES

Table E-1. List of Water Bodies, Impairment Causes, and Pollutant Categories in the Middle and Lower Big Hole TPA for Which TMDLs Were Completed...................................... 19
Table 1-1. Impairment causes and TMDL development status 23
Table 2-1. High Priority Abandoned Hardrock Mine Sites in the Middle and Lower Big Hole River TPA. 33
Table 3-1. Water Bodies in the Middle and Lower Big Hole River TPAs from the 2006 303(d) List and their Associated Level of Beneficial Use-Support....................................... 36
Table 5-1. Water body segments with sediment listings and possible sediment-related listings on the 2006 303(d) List.. 48
Table 5-2. Targets and Supplemental Indicators for Sediment in the Middle and Lower Big Hole TPA. 53
Table 5-3. Beaverhead Deerlodge National Forest Reference Dataset 75th Percentiles for Individual Rosgen Stream Types. 55
Table 5-4. Middle Segment of the Big Hole River Sediment Data Compared to Targets and Supplemental Indicators.. 62
Table 5-5. Biological Metrics for Middle Segment of the Big Hole River. 63
Table 5-6. Lower Segment of the Big Hole River Sediment Data Compared to Targets and Supplemental Indicators.. 66
Table 5-7. Macroinvertebrate Metrics for Lower Segment of the Big Hole River...................... 66
Table 5-8. Upper Segment of the Birch Creek Sediment Data Compared to Targets and Supplemental Indicators.. 69
Table 5-9. Biological Metrics for the upper segment of Birch Creek. 69
Table 5-10. Lower Segment of Birch Creek Sediment Data Compared to Targets and Supplemental Indicators.. 71
Table 5-11. Biological Metrics for the lower segment of Birch Creek. 71
Table 5-12. California Creek Sediment Data Compared to Targets and Supplemental Indicators. 73
Table 5-13. Biological Metrics for California Creek.. 74
Table 5-14. Camp Creek Sediment Data Compared to Targets and Supplemental Indicators..... 77
Table 5-15. Biological Metrics for Camp Creek. 77
Table 5-16. Canyon Creek Sediment Data Compared to Targets and Supplemental Indicators.. 79
Table 5-17. Biological Metrics for Canyon Creek.. 79
Table 5-18. Charcoal Creek Sediment Data Compared to Targets and Supplemental Indicators.81
Table 5-19. Biological Metrics for Charcoal Creek.. 81
Table 5-20. Corral Creek Sediment Data Compared to Targets and Supplemental Indicators. ... 83
Table 5-21. Biological Metrics for Corral Creek.. 84
Table 5-22. Deep Creek Sediment Data Compared to Targets and Supplemental Indicators...... 86
Table 5-23. Biological Metrics for Deep Creek.. 87
Table 5-24. Delano Creek Sediment Data Compared to Targets and Supplemental Indicators... 89
Table 5-25. Biological Metrics for Delano Creek. 90
Table 5-26. Divide Creek Sediment Data Compared to Targets and Supplemental Indicators. .. 93
Table 5-27. Biological Metrics for Divide Creek. 93
Table 5-28. Elkhorn Creek Sediment Data Compared to Targets and Supplemental Indicators. 96
Table 5-29. Biological Metrics for Elkhorn Creek. 96

Table 5-30. Fishtrap Creek Sediment Data Compared to Targets and Supplemental Indicators. 99
Table 5-31. Biological Metrics for Fishtrap Creek. 99
Table 5-32. French Creek Sediment Data Compared to Targets and Supplemental Indicators. 101
Table 5-33. Biological Metrics for French Creek. 102
Table 5-34. Gold Creek Sediment Data Compared to Targets and Supplemental Indicators 104
Table 5-35. Biological Metrics for Gold Creek. 104
Table 5-36. Grose Creek Sediment Data Compared to Targets and Supplemental Indicators. 106
Table 5-37. Biological Metrics for Grose Creek. 106
Table 5-38. Jerry Creek Sediment Data Compared to Targets and Supplemental Indicators 108
Table 5-39. Biological Metrics for Jerry Creek. 109
Table 5-40. Lost Creek Sediment Data Compared to Targets and Supplemental Indicators. 111
Table 5-41. Biological Metrics for Lost Creek. 111
Table 5-42. Moose Creek Sediment Data Compared to Targets and Supplemental Indicators 113
Table 5-43. Biological Metrics for Moose Creek. 114
Table 5-44. Oregon Creek Sediment Data Compared to Targets and Supplemental Indicators. 115
Table 5-45. Biological Metrics for Oregon Creek. 116
Table 5-46. Pattengail Creek Sediment Data Compared to Targets and Supplemental Indicators. 118
Table 5-47. Biological Metrics for Pattengail Creek. 118
Table 5-48. Rochester Creek Sediment Data Compared to Targets and Supplemental Indicators. 120
Table 5-49. Biological Metrics for Rochester Creek. 120
Table 5-50. Sawlog Creek Sediment Data Compared to Targets and Supplemental Indicators. 122
Table 5-51. Biological Metrics for Sawlog Creek. 122
Table 5-52. Sevenmile Creek Sediment Data Compared to Targets and Supplemental Indicators. 124
Table 5-53. Biological Metrics for Sevenmile Creek. 125
Table 5-54. Sixmile Creek Sediment Data Compared to Targets and Supplemental Indicators. 127
Table 5-55. Biological Metrics for Sixmile Creek. 127
Table 5-56. Soap Creek Sediment Data Compared to Targets and Supplemental Indicators. 129
Table 5-57. Biological Metrics for Soap Creek. 130
Table 5-58. Trapper Creek Sediment Data Compared to Targets and Supplemental Indicators. 132
Table 5-59. Biological Metrics for Trapper Creek. 132
Table 5-60. Willow Creek Sediment Data Compared to Targets and Supplemental Indicators. 135
Table 5-61. Biological Metrics for Willow Creek. 136
Table 5-62. Wise River Sediment Data Compared to Targets and Supplemental Indicators. 138
Table 5-63. Biological Metrics for Wise River. 139
Table 5-64. Summary of TMDL development determinations. 140
Table 5-65. Middle Segment of the Big Hole River Sediment Source Load Allocations. 147
Table 5-66. Upper Segment of Birch Creek Sediment Source Load Allocations. 148
Table 5-67. Lower Segment of Birch Creek Sediment Source Load Allocations. 149
Table 5-68. California Creek Sediment Source Load Allocations. 150
Table 5-69. Camp Creek Sediment Source Load Allocations. 151
Table 5-70. Corral Creek Sediment Source Load Allocations. 152
Table 5-71. Deep Creek Sediment Source Load Allocations. 153
Table 5-72. Delano Creek Sediment Source Load Allocations. 154

Table 5-73. Divide Creek Sediment Source Load Allocations. 155
Table 5-74. Elkhorn Creek Sediment Source Load Allocations. 156
Table 5-75. Fishtrap Creek Sediment Source Load Allocations. 157
Table 5-76. French Creek Sediment Source Load Allocations. 158
Table 5-77. Gold Creek Sediment Source Load Allocations. 159
Table 5-78. Grose Creek Sediment Source Load Allocations. 160
Table 5-79. Jerry Creek Sediment Source Load Allocations. 161
Table 5-80. Lost Creek Sediment Source Load Allocations. 162
Table 5-81. Moose Creek Sediment Source Load Allocations. 163
Table 5-82. Oregon Creek Sediment Source Load Allocations. 164
Table 5-83. Pattengail Creek Sediment Source Load Allocations. 165
Table 5-84. Rochester Creek Sediment Source Load Allocations. 166
Table 5-85. Sawlog Creek Sediment Source Load Allocations. 167
Table 5-86. Sevenmile Creek Sediment Source Load Allocations. 167
Table 5-87. Sixmile Creek Sediment Source Load Allocations. 168
Table 5-88. Soap Creek Sediment Source Load Allocations. 169
Table 5-89. Trapper Creek Sediment Source Load Allocations. 170
Table 5-90. Wise River Sediment Source Load Allocations. 171
Table 6-1. Impaired streams with identified nutrient related causes in the Middle and Lower Big Hole TMDL Planning Areas. 176
Table 6-2. Targets for Nutrients in the Middle and Lower Big Hole River TPAs. 179
Table 6-3. Nutrient Concentrations in Camp Creek. 182
Table 6-4. Chlorophyll a Concentrations in Camp Creek. 182
Table 6-5. Nutrient Concentrations in Divide Creek. 184
Table 6-6. Nutrient Concentrations in East Fork Divide Creek and North Fork Divide Creek. 185
Table 6-7. Chlorophyll a Concentrations in Divide Creek. 185
Table 6-8. Nutrient Concentrations in Grose Creek. 186
Table 6-9. Nutrient Concentrations in Jerry Creek. 188
Table 6-10. Chlorophyll a Concentrations in Jerry Creek. 188
Table 6-11. Nutrient Concentrations in Lost Creek. 190
Table 6-12. Chlorophyll a Concentrations in Lost Creek. 190
Table 6-13. Nutrient Concentrations in Soap Creek. 192
Table 6-14. Chlorophyll a Concentrations in Soap Creek. 192
Table 6-15. Camp Creek Total Nitrogen Load Assessment. 197
Table 6-16. Camp Creek Total Phosphorus Load Assessment. 197
Table 6-17. Camp Creek Total Nitrogen Allocations 199
Table 6-18. Camp Creek Total Phosphorus Allocations 200
Table 6-19. Divide Creek Total Nitrogen Load Assessment. 201
Table 6-20. Divide Creek Total Phosphorus Load Assessment. 201
Table 6-21. Divide Creek Total Nitrogen Allocations. 203
Table 6-22. Divide Creek Total Phosphorus Allocations 204
Table 6-23. Grose Creek Nitrogen Load Assessment. 205
Table 6-24. Grose Creek Phosphorus Load Assessment. 205
Table 6-25. Grose Creek Total Nitrogen Allocations 207
Table 6-26. Grose Creek Total Phosphorus Allocations 208
Table 6-27. Lost Creek Nitrogen Load Assessment. 209

Table 6-28. Lost Creek Phosphorus Load Assessment. 209
Table 6-29. Lost Creek Total Nitrogen Allocations 211
Table 6-30. Lost Creek Total Phosphorus Allocations 212
Table 6-31. Soap Creek Nitrogen Load Assessment. 213
Table 6-32. Soap Creek Phosphorus Load Assessment. 213
Table 6-33. Soap Creek Total Nitrogen Allocations 215
Table 6-34. Soap Creek Total Phosphorus Allocations 216
Table 7-1. Water body segments in the Middle and Lower Big Hole TPA with metals listings on the 2006 303(d) List. 219
Table 7-2. Summary of Potentially Contributing Source Areas for Metals to 303(d) Listed Streams 222
Table 7-3. Screening level criteria for sediment metals concentrations that will be used as supplemental indicators in the Middle and Lower Big Hole TPA. 225
Table 7-4. Targets and Supplemental Indicators for Metals in the Middle and Lower Big Hole TPA. 226
Table 7-5. Copper and Lead Concentrations in the Middle Segment of the Big Hole River. 227
Table 7-6. Metals Concentrations in the Lower Big Hole River. 229
Table 7-7. Arsenic and Copper Concentrations in California Creek. 231
Table 7-8. Arsenic Concentrations in Camp Creek. 232
Table 7-9. Metals Concentrations in Elkhorn Creek. 234
Table 7-10. Arsenic and Copper Concentrations in French Creek. 236
Table 7-11. Metals Concentrations in Jerry Creek. 237
Table 7-12. Arsenic Concentrations in Lost Creek. 238
Table 7-13. Metals Concentrations in Oregon Creek. 240
Table 7-14. Metals Concentrations in Rochester Creek from DEQ sites. 242
Table 7-15. Metals Concentrations in Rochester Creek during BLM reclamation investigation. 243
Table 7-16. Arsenic Concentrations in Sassman Gulch. 244
Table 7-17. Arsenic Concentrations in Sawlog Creek. 245
Table 7-18. Metals Concentrations in Trapper Creek in 2005 and 2006. 247
Table 7-19. Metals Concentrations in Wickiup Creek. 249
Table 7-20. Metals Concentrations in the Wise River. 251
Table 7-21. Streams Requiring a TMDL for Metal Pollutants. 252
Table 7-22. Example Metal TMDLs for the Middle and Lower Big Hole TPA. 257
Table 7-23. Metals TMDLs and load allocation example for Oregon Creek. 261
Table 7-24. Metals TMDLs and load allocation example for California Creek. 262
Table 7-25. Metals TMDLs and load allocation example for French Creek. 264
Table 7-26. Equation for computing the WLA for each metal. 266
Table 7-27. Metals TMDLs and load allocation example for Elkhorn Creek. 266
Table 7-28. Metals TMDLs and load allocation example for the Wise River. 268
Table 7-29. Metals TMDLs and load allocation example for Jerry Creek. 269
Table 7-30. Loading example illustrating that meeting the Wise River TMDLs will result in attainment of TMDLs in the middle segment of the Big Hole River 270
Table 7-31. Metals TMDLs and load allocation example for the middle segment of the Big Hole River. 271
Table 7-32. Copper TMDL and load allocation example for Wickiup Creek. 272

Table 7-33. Arsenic TMDL and load allocation example for Lost Creek. 273
Table 7-34. Arsenic, copper, and lead TMDLs and load allocation example for Rochester Creek. 275
Table 7-35. Mercury TMDL and load allocation example for Rochester Creek. 275
Table 7-36. Metals TMDLs and load allocation example for Trapper Creek. 277
Table 8-1. Targets for Temperature in the Middle and Lower Big Hole River TPA. 283
Table 8-2. Estimated Temperature Reductions Achievable via Restoration Approach in the Middle Segment of the Big Hole River for Selected Locations Identified Using the Heatsource v7.0 Model. 287
Table 8-3. Temperature Data Summary for the Middle Segment of the Big Hole River, Summer 2006... 288
Table 8-4. Land Cover Densities along the Middle Segment of the Big Hole River. 288
Table 8-5. Estimated Temperature Reductions Achievable via Restoration Approach in the Lower Segment of the Big Hole River for Selected Locations Identified Using the Heatsource v7.0 Model 291
Table 8-6. Temperature Data Summary for the Middle Segment of the Big Hole River, Summer 2006... 291
Table 8-7. Land Cover Densities along the Middle Segment of the Big Hole River. 292
Table 8-8. Estimated Temperature Reductions Achievable via Restoration Approach in Divide Creek for Selected Locations Identified Using the Heatsource v7.0 Model............. 293
Table 8-9. Temperature Data Summary for Divide Creek, Summer 2006. 294
Table 8-10. Temperature TMDL and allocations for the Middle Segment of the Big Hole River. 299
Table 8-11. Temperature TMDL and allocations for the Lower Segment of the Big Hole River. 301
Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed 309
Table 9-2. Restoration Recommendations for Nutrient Impaired Streams................................ 316
Table 9-3. General grazing/wildlife BMPs and management techniques (from NRCS 2001; DNRC 1999). 320
Table 9-4. Priority Abandoned Mine Sites Identified as Potential Sources of Metals Impairments. 328
Table 9-5. Facilities on the CECRA priority list within the Middle and Lower Big Hole TPA. 329
Table 10-1. Water bodies segments recommended for 303(d) reassessment and/or additional monitoring prior to reassessment 334
Table 10-2. Metals Monitoring Recommendations 336
Table 10-3. Monitoring Recommendations for Road BMPs 338
Table 10-4. Effectiveness Monitoring Recommendations for Grazing BMPs by Restoration Concern. 339
Table 10-5. Effectiveness monitoring recommendations for abandoned mine reclamation sites. 339

TABLE OF FIGURES

Figure 4-1. Schematic example of TMDL development. 42
Figure 4-2. Schematic diagram of TMDL and allocations. 44
Figure 5-1. Existing Annual Sediment Load (tons/year) from Upland Erosion by 303(d) listed subwatersheds within the Middle and Lower Big Hole TPA. 143
Figure 5-2. Existing Annual Sediment Load (tons/year) from Unpaved Roads in 303(d) listed Sub-watersheds within the Middle and Lower Big Hole TPA. 143
Figure 5-3. Existing Annual Sediment Load (tons/year) from Streambank Erosion by 303(d) listed Sub-watersheds within the Middle and Lower Big Hole TPA........................ 144
Figure 6-1. Riparian Zone Runoff and Groundwater treatment pathways 196
Figure 6-2. Camp Creek Nutrient Source Assessment Results... 198
Figure 6-3. Divide Creek Nutrient Source Assessment Results 202
Figure 6-4. Grose Creek Nutrient Source Assessment Results... 206
Figure 6-5. Lost Creek Nutrient Source Assessment Results 210
Figure 6-6. Soap Creek Nutrient Source Assessment Results 214
Figure 7-1. Arsenic TMDL curve that illustrates how the TMDL changes with flow. 255
Figure 7-2. Mercury TMDL curve that illustrates how the TMDL changes with flow............. 256

EXECUTIVE SUMMARY

This document presents Total Maximum Daily Loads (TMDLs) and a framework water quality improvement plan for the Middle and Lower Big Hole TMDL Planning Area (**Appendix A, Figure A-1**). The plan was developed by the Montana Department of Environmental Quality (DEQ).

The Montana Water Quality Act requires DEQ to develop TMDLs for streams and lakes that do not meet Montana water quality standards. TMDLs are the maximum amount of a pollutant a water body can receive and still meet water quality standards, or the level of reduction in pollutant loading that is needed to meet water quality standards. The goal of TMDLs is to eventually attain and maintain water quality standards in all of Montana's streams and lakes, and to improve water quality to levels that support all state-designated beneficial water uses.

The DEQ has divided the Big Hole River watershed into three planning areas for the purposes of developing framework water quality plans. This report focuses on the Middle and Lower Big Hole River TMDL Planning Areas (TPAs). The Middle Big Hole River extends 43.8 miles from the confluence of Pintlar Creek downstream to the confluence with Divide Creek, while the Lower Big Hole River extends 51.4 miles from Divide Creek to the mouth, where the Big Hole River meets the Beaverhead River to form the Jefferson River. Thus, the TPA encompasses 95.2 miles of the 150.7 mile long Big Hole River. The combined TPA covers approximately 1,021,021 acres (1,596 square miles) and encompasses Beaverhead, Deer Lodge, Madison, and Silver Bow counties.

The scope of the TMDLs in this document address sediment, nutrients, metals, and temperature related water quality impairments in the Middle and Lower Big Hole TPA (**Table E-1**). This document only addresses pollutants on the 2006 303(d) List. Future assessments may require additional TMDLs in this TPA.

<u>Sediment</u> **–** Sediment TMDLs are provided for twenty six water body segments in the Middle and Lower Big Hole TPA. Sediment impacted beneficial water uses in these streams by altering aquatic insect communities, reducing fish spawning success, filling pool habitat, or increasing levels of turbidity. Water quality targets for sediment in these stream segments were established on the basis of fine sediment levels in trout spawning areas, fine sediment in riffles where many aquatic insects reside, and the stability of streambanks. Attainment of these targets is believed to be capable of restoring all water uses presently impacted by sediment.

Sediment loads were quantified for natural background conditions and for the following sources: bank erosion, hillslope erosion, and roads. The most significant sources included upland erosion associated with grazing, streambank erosion related to roads and riparian vegetation removal associated with agriculture, unpaved roads, and natural sources. The sediment TMDLs completed for the Middle and Lower Big Hole TPA indicate that reductions in sediment loads ranging from 8 percent to 40 percent will result in meeting the water quality targets.

<u>Nutrients</u> **–** Nitrogen and Phosphorus TMDLs are provided for five water body segments in the Middle and Lower Big Hole TPA. Nutrient conditions were above thresholds which are linked to

nuisance algae growth. Nutrient targets for these streams relate to nutrient conditions which will control algal growth. Nutrient loads were estimated from bank erosion, grazing systems, cropping systems, suburban areas, and natural conditions. The most significant sources of nutrients were from natural and agricultural conditions, which include livestock grazing and hay/alfalfa production. The most easily implemented restoration approaches include streamside natural vegetation restoration in range areas, fertilizer and irrigation management on fields, moving corrals away from streams.

Metals – Twenty eight metals TMDLs are provided for eleven water body segments within the Middle and Lower Big Hole TPA. The metals of concern include arsenic, copper, cadmium, lead, mercury, and zinc. Metals TMDLs are based on target concentrations, and stream flow. Water quality targets for metals were established based on the numeric water quality criteria as defined in DEQ Circular DEQ-7. Abandoned mines and atmospheric deposition from the Anaconda Smelter were the most significant sources.

Water Temperature – Temperature TMDLs are provided for three water body segments in the Middle and Lower Big Hole TPA. Temperature impacted beneficial water uses in these streams by causing stress to fish during warm summer days. Water quality targets for temperature relate to conditions that influence temperature such as streamside shade-producing vegetation, in stream flow, and channel shape. Attainment of these targets is believed to be capable of restoring all water uses presently impacted by temperature.

Heating was quantified for naturally occurring background conditions, and for the following sources: human activities which influence stream shading, and shifts in stream channel shape. The human influences on the capacity of the stream to provide buffering capacity are diversions from the river for irrigation, and domestic uses. The most significant sources included riparian vegetation removal associated with agriculture, natural sources, and loss of thermal buffering capacity due to decreased streamflow.

Recommended strategies for achieving the pollutant reduction goals of the Middle and Lower Big Hole TMDLs are also presented in this plan. They include the application of riparian grazing, unpaved road, timber harvest, suburban development best management practices (BMPs), improved stream shading and expanded riparian buffer areas, and the use of other land, soil and water conservation practices capable of improving condition of stream channels and associated riparian vegetation.

Implementation of most measures described in this plan will be based on voluntary cooperation by watershed stakeholders, and proposed actions will not conflict with water rights or private property rights. Flexible, adaptive management approaches may become necessary as more knowledge is gained through implementation, and future monitoring. The plan includes an effectiveness monitoring strategy that is designed to track future progress towards meeting TMDL objectives and goals, and to help refine the plan during its implementation. Ideally, the TMDL and associated documentation will be used by a local watershed group and/or other watershed stakeholders as a tool to help guide, and prioritize local water quality improvement activities. These improvement activities can ultimately be documented within a watershed restoration plan consistent with DEQ and EPA recommendations.

Table E-1. List of Water Bodies, Impairment Causes, and Pollutant Categories in the Middle and Lower Big Hole TPA for Which TMDLs Were Completed

Water body & Stream Description	Impairment Cause	TMDL Pollutant Category Completed
Big Hole River between Divide Cr and Pintlar Cr (Middle segment) MT41D001_020	Copper Lead Temperature	Metals Temperature
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment) MT41D001_010	Temperature	Temperature
Birch Creek headwaters to the National Forest Boundary MT41D002_090	Sedimentation/ Siltation	Sediment
Birch Creek from National Forest Boundary to mouth (Big Hole R) MT41D002_100	Sedimentation/ Siltation	Sediment
California Creek from headwaters to mouth (French Cr-Deep Cr) MT41D003_070	Arsenic Sedimentation/ Siltation Turbidity	Metals Sediment
Camp Creek from headwaters to mouth (Big Hole R) MT41D002_020	Phosphorus (Total) Sedimentation/ Siltation Solids (suspended/bedload)	Nutrients Sediment
Corral Creek from headwaters to mouth (Deep Cr) MT41D003_130	Sedimentation/ Siltation	Sediment
Deep Creek from headwaters to mouth (Big Hole R) MT41D003_040	Sedimentation/ Siltation	Sediment
Delano Creek from headwaters to mouth (Jerry Cr) MT41D003_030	Sedimentation/ Siltation	Sediment
Divide Creek from headwaters to mouth (Big Hole R) MT41D002_040	Sedimentation/ Siltation Temperature Phosphorus (Total) Total Kjeldahl Nitrogen (TKN)	Sediment Temperature Nutrients
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R) MT41D003_220	Arsenic Cadmium Copper Zinc Sedimentation/ Siltation	Metals Sediment
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole) MT41D003_160	Sedimentation/ Siltation	Sediment
French Creek from headwaters to mouth (Deep Cr) MT41D003_050	Arsenic	Metals
Gold Creek from headwaters to mouth (Wise R) MT41D003_230	Sedimentation/ Siltation	Sediment
Grose Creek from headwaters to mouth (Big Hole R) MT41D002_060	Phosphorus (Total) Sedimentation/ Siltation	Nutrients Sediment
Jerry Creek from headwaters to mouth (Big Hole R) MT41D003_020	Copper	Metals
Lost Creek MT41D002_180	Nitrogen (Total) Phosphorus (Total) Sedimentation/ Siltation	Nutrients Sediment
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep) MT41D003_080	Arsenic Copper Sedimentation/ Siltation	Metals Sediment
Pattengail Creek from headwaters to mouth (Wise R) MT41D003_210	Sedimentation/ Siltation	Sediment

Table E-1. List of Water Bodies, Impairment Causes, and Pollutant Categories in the Middle and Lower Big Hole TPA for Which TMDLs Were Completed

Water body & Stream Description	Impairment Cause	TMDL Pollutant Category Completed
Rochester Creek from headwaters to mouth (Big Hole R) MT41D002_160	Arsenic Copper Lead Mercury Sedimentation/ Siltation	Metals Sediment
Sawlog Creek tributary to Big Hole R MT41D004_230	Phosphorus (Total) Sedimentation/ Siltation	Sediment
Sevenmile Creek from headwaters to mouth (Deep Cr) MT41D003_110	Sedimentation/ Siltation	Sediment
Sixmile Creek from headwaters to mouth (California Cr) MT41D003_090	Sedimentation/ Siltation	Sediment
Soap Creek from headwaters to mouth (Big Hole R) MT41D002_140	Phosphorus (Total) Sedimentation/ Siltation	Nutrients Sediment
Trapper Creek from headwaters to mouth (Big Hole R) MT41D002_010	Copper Lead Zinc Sedimentation/ Siltation	Metals Sediment
Wickiup Creek Tributary to Camp Cr (Big Hole R) MT41D002_120	Copper	Metals

New data collected during this project indicated the need for sediment TMDLs for five other water body segments and additional metals TMDLs for four water body segments in addition to the TMDLs identified as needed by Montana's impaired waters list. The additional TMDLs completed within this document address aquatic life and cold water fishery impacts of sediment to the middle segment of the Big Hole River, lower segment of Birch Creek, French Creek, Jerry Creek, and Moose Creek. The additional metals TMDLs include copper for California Creek, copper for French Creek, arsenic and cadmium for Trapper Creek, and copper, cadmium, and lead for the Wise River. TMDLs were developed for both nitrogen and phosphorus for all water bodies with any nutrient TMDL category listing, regardless of the specific nutrient listing (e.g. total phosphorus or total nitrogen).

SECTION 1.0
INTRODUCTION

1.1 Background

This document describes the Montana DEQ's present understanding of sediment, temperature, metals, and nutrient-related water quality problems in rivers and streams of the Middle and Lower Big Hole TPA (**Appendix A, Figure A-1**), and presents a general framework for resolving them. Guidance for completing the plan is contained in the Montana Water Quality Act and the federal Clean Water Act.

Congress passed the Water Pollution Control Act, more commonly known as the Clean Water Act, in 1972. The goal of this act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The Clean Water Act requires each state to set water quality standards to protect designated beneficial water uses, and to monitor the attainment of those uses. Fish and aquatic life, wildlife, recreation, agriculture, industrial, and drinking water are all types of beneficial uses. Streams and lakes (also referred to as water bodies) not meeting the established standards are called *impaired waters*. These waters are identified on the 303(d) List, named after Section 303(d) of the Clean Water Act which mandates the monitoring, assessment, and listing of water quality limited water bodies. The 303(d) List is contained within a biennial integrated water quality report.

Both Montana state law (Section 75-5-703 of the Montana Water Quality Act) and section 303(d) of the federal Clean Water Act require the development of total maximum daily loads (TMDLs) for impaired waters where a measurable pollutant (for example, sediment, nutrients, metals or temperature) is the cause of the impairment. A TMDL is a loading capacity and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards.

The development of TMDLs and water quality improvement strategies in Montana include several steps that must be completed for each impaired or threatened water body, and for each contributing pollutant (i.e. each "pollutant/water body combination"). These steps include:

- Characterizing the existing water body conditions and comparing these conditions to water quality standards. During this step, measurable targets (as numeric values) are set to help evaluate the stream's condition in relation to the standards
- Quantifying the magnitude of pollutant contribution from sources
- Establishing allowable loading limits (or total maximum daily loads) for each pollutant
- Comparing the current pollutant load to the loading capacity (or maximum loading limit/TMDL) of the particular water body, and
- Determining the allowable loads or the necessary load reduction for each source (these are called pollutant allocations)

In Montana, restoration strategies and recommendations are also incorporated to help facilitate TMDL implementation.

The above four TMDL steps are further defined in **Section 4.0** of this document. Basically, TMDL development for an impaired water body is a problem solving exercise. The problem is excess pollutant loading negatively impacting one or more designated beneficial uses. The solution is developed by identifying the total acceptable pollutant load to the water body (the TMDL), characterizing all the significant sources contributing to the total pollutant loading, and then identifying where pollutant loading reductions should be applied to one or more sources to achieve the acceptable load.

1.2 303(d) List Summary and TMDLs Written

On the 2006 303(d) List, there are thirty three stream segments listed as impaired in the Middle and Lower Big Hole TPA (**Appendix A, Figure A-2**). Four of the stream segments from the 2006 303(d) List were determined to lack "sufficient credible data" to assess support of the fisheries and aquatic life beneficial uses during the 303(d) assessment process. The segments include French Creek, Canyon Creek, Moose Creek, and Willow Creek. Because fisheries and aquatic life are typically the most sensitive uses related to sediment, those four water body segments were included in the sediment and habitat data collection effort during TMDL development. Although beneficial use support determinations occur separately from the TMDL development process, existing data from those water body segments are discussed within this document.

Water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and from pollutants (e.g. nutrients, sediment, and metals). However, because only pollutants are associated with a load, the EPA restricts TMDL development to pollutants. Pollution is commonly, but not always, associated with a pollutant and a TMDL may be written (but is not required) for a water body that is only on the 303(d) for pollution. Based on the 2006 303(d) List and a review of existing data for the Middle and Lower Big Hole TPA, sixty two TMDLs were written for various pollutants within twenty nine water body segments (**Table 1-1**). The TMDL breakdown by pollutant is as follows:

- 26 TMDLs for sediment; 6 of which were listed for pollution or not previously assessed for support of all beneficial uses
- 5 TMDLs for nutrients
- 28 TMDLs for metals
- 3 TMDLs for temperature

The causes and sources of water quality impairments within the Middle and Lower Big Hole TPA vary from stream to stream. Listings include a mix of pollutant-related impairments from sediment, nutrients, metals, and elevated temperatures and pollution-related impairment from excess algal growth, substrate alterations, alterations in stream-side or littoral vegetative cover, and low flow alterations. The majority of the pollutants identified on the 2006 303(d) List are addressed within this water quality restoration plan, though a few are not addressed at this time due to project timeframe constraints. These listings will be identified in a follow up monitoring strategy (**Section 10.0**), and addressed within a timeframe identified in Montana's law (MCA 75-5-703). A review of the relevant existing data will be provided for stream segments on the 2006 303(d) List in **Sections 5-8**.

Table 1-1. Impairment causes and TMDL development status

Water body & Stream Description	Probable Cause of Impairment	2006 Integrated Report	2008 TMDL Review Completed	TMDL Completed	Further Review Needed*
Big Hole River between Divide Cr and Pintlar Cr (Middle segment) MT41D001_020	**Copper**	Yes	Yes	Yes	No
	Lead	Yes	Yes	Yes	No
	Temperature	Yes	Yes	Yes	No
	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	No	Yes	Yes	Yes
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment) MT41D001_010	**Cadmium**	Yes	Yes	No	Yes
	Copper	Yes	Yes	No	Yes
	Lead	Yes	Yes	No	Yes
	Zinc	Yes	Yes	No	Yes
	Temperature	Yes	Yes	Yes	No
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
Birch Creek headwaters to the National Forest Boundary MT41D002_090	**Sedimentation/ Siltation**	Yes	Yes	Yes	No
	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
Birch Creek from National Forest Boundary to mouth (Big Hole R) MT41D002_100	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Other anthropogenic substrate alterations	Yes	N/A	N/A	N/A
	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation		Yes	Yes	Yes
California Creek from headwaters to mouth (French Cr-Deep Cr) MT41D003_070	**Arsenic**	Yes	Yes	Yes	No
	Iron	Yes	Yes	No	Yes
	Copper	No	Yes	Yes	Yes
	Dewatering	Yes	N/A	N/A	N/A
	Bank erosion	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
	Riparian degradation	Yes	N/A	N/A	N/A
	Turbidity	Yes	Yes	Yes	No
	Fish habitat degradation	Yes	N/A	N/A	N/A
Camp Creek from headwaters to mouth (Big Hole R) MT41D002_020	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Arsenic	Yes	Yes	No	Yes
	Low flow alterations	Yes	N/A	N/A	N/A
	Phosphorus (Total)	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
	Solids (suspended/bedload)	Yes	Yes	Yes	No

Table 1-1. Impairment causes and TMDL development status

Water body & Stream Description	Probable Cause of Impairment	2006 Integrated Report	2008 TMDL Review Completed	TMDL Completed	Further Review Needed*
Canyon Creek from headwaters to mouth (Big Hole R) MT41D002_030	Low flow alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	No	Yes	No	Yes
Charcoal Creek tributary of the Big Hole R MT41D003_010	**Nitrogen (Total)**	Yes	No	No	Yes
	Phosphorus (Total)	Yes	No	No	Yes
	Sedimentation/ Siltation	Yes	Yes	No	Yes
Corral Creek from headwaters to mouth (Deep Cr) MT41D003_130	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Deep Creek from headwaters to mouth (Big Hole R) MT41D003_040	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Delano Creek from headwaters to mouth (Jerry Cr) MT41D003_030	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Divide Creek from headwaters to mouth (Big Hole R) MT41D002_040	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Phosphorus (Total)	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
	Temperature	Yes	Yes	Yes	No
	Total Kjeldahl Nitrogen (TKN)	Yes	Yes	Yes	No
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R) MT41D003_220	**Arsenic**	Yes	Yes	Yes	Yes
	Cadmium	Yes	Yes	Yes	No
	Copper	Yes	Yes	Yes	No
	Lead	Yes	Yes	Yes	Yes
	Zinc	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole) MT41D003_160	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Phosphorus (Total)	Yes	No	No	Yes
	Sedimentation/ Siltation	Yes	Yes	Yes	No
French Creek from headwaters to mouth (Deep Cr) MT41D003_050	**Arsenic**	Yes	Yes	Yes	No
	Copper	No	Yes	Yes	Yes
	Sedimentation/ Siltation	No	Yes	Yes	Yes

Table 1-1. Impairment causes and TMDL development status

Water body & Stream Description	Probable Cause of Impairment	2006 Integrated Report	2008 TMDL Review Completed	TMDL Completed	Further Review Needed*
Gold Creek from headwaters to mouth (Wise R) MT41D003_230	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Phosphorus (Total)	Yes	No	No	Yes
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Grose Creek from headwaters to mouth (Big Hole R) MT41D002_060	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Other flow regime alterations	Yes	N/A	N/A	N/A
	Phosphorus (Total)	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Jerry Creek from headwaters to mouth (Big Hole R) MT41D003_020	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Copper	Yes	Yes	Yes	No
	Excess algal growth	Yes	Yes	No	Yes
	Lead	Yes	Yes	No	Yes
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation		Yes	Yes	Yes
Lost Creek MT41D002_180	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Arsenic	Yes	Yes	Yes	No
	Nitrogen (Total)	Yes	Yes	Yes	No
	Phosphorus (Total)	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock) MT41D002_050	Low flow alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	No	Yes	Yes	Yes
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep) MT41D003_080	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Arsenic	Yes	Yes	Yes	No
	Copper	Yes	Yes	Yes	No
	Lead	Yes	Yes	No	Yes
	Other anthropogenic substrate alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Pattengail Creek from headwaters to mouth (Wise R) MT41D003_210	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Pintlar Creek	Addressed in the Upper and North Fork TPA Document, 2008, Section 5.13. No TMDLs completed.				

Table 1-1. Impairment causes and TMDL development status

Water body & Stream Description	Probable Cause of Impairment	2006 Integrated Report	2008 TMDL Review Completed	TMDL Completed	Further Review Needed*
Rochester Creek from headwaters to mouth (Big Hole R) MT41D002_160	**Arsenic**	Yes	Yes	Yes	No
	Copper	Yes	Yes	Yes	No
	Lead	Yes	Yes	Yes	No
	Mercury	Yes	Yes	Yes	No
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Sassman Gulch from headwaters to mouth (Big Hole R) MT41D002_070	**Arsenic**	Yes	Yes	No	Yes
Sawlog Creek tributary to Big Hole R MT41D004_230	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Arsenic	Yes	Yes	No	Yes
	Phosphorus (Total)	Yes	No	No	Yes
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Sevenmile Creek from headwaters to mouth (Deep Cr) MT41D003_110	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Sixmile Creek from headwaters to mouth (California Cr) MT41D003_090	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Soap Creek from headwaters to mouth (Big Hole R) MT41D002_140	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Nitrogen (Total)	No	Yes	Yes	Yes
	Phosphorus (Total)	Yes	Yes	Yes	No
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Trapper Creek from headwaters to mouth (Big Hole R) MT41D002_010	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Copper	Yes	Yes	Yes	No
	Lead	Yes	Yes	Yes	No
	Zinc	Yes	Yes	Yes	No
	Arsenic	No	Yes	Yes	Yes
	Cadmium	No	Yes	Yes	Yes
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	Yes	Yes	Yes	No
Twelvemile Creek from headwaters to mouth (Deep Cr) MT41D003_120	**Sedimentation/ Siltation**	Yes	No	No	Yes

Table 1-1. Impairment causes and TMDL development status

Water body & Stream Description	Probable Cause of Impairment	2006 Integrated Report	2008 TMDL Review Completed	TMDL Completed	Further Review Needed*
Wickiup Creek Tributary to Camp Cr (Big Hole R) MT41D002_120	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Bottom deposits	Yes	N/A	N/A	N/A
	Copper	Yes	Yes	Yes	No
	Lead	Yes	Yes	No	Yes
	Mercury	Yes	Yes	No	Yes
	Phosphorus (Total)	Yes	No	No	Yes
Willow Creek from headwaters to mouth (Big Hole R) MT41D002_110	Low flow alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	No	Yes	No	Yes
Wise River from headwaters to mouth (Big Hole R) MT41D003_200	Alteration in stream-side or littoral vegetative cover	Yes	N/A	N/A	N/A
	Low flow alterations	Yes	N/A	N/A	N/A
	Physical substrate habitat alterations	Yes	N/A	N/A	N/A
	Sedimentation/ Siltation	No	Yes	Yes	Yes
	Copper	No	Yes	Yes	Yes
	Lead	No	Yes	Yes	Yes
	Cadmium	No	Yes	Yes	Yes

*Indicates if an additional 303(d) assessment is recommended based on data collected during the TMDL development process. Additional monitoring may be necessary.

All 303(d) Listing probable causes shown in **bold** in **Table 1-1** are associated with pollutants and will be addressed within this document. Although TMDLs address pollutant loading, implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some pollution impairments in the listed water bodies above.

1.3 Document Description

Water quality impairments affecting the Middle and Lower Big Hole TPAs that are addressed by this plan include sediment, nutrients, metals, and elevated water temperatures. These pollutants have been shown to impair some designated uses of these streams, including aquatic life, and cold water fisheries, drinking water, swimming and recreation, and industrial uses (See **Table 3-1**). Because TMDLs are completed for each pollutant/water body combination, one framework water quality improvement plan, such as this, is likely to contain several TMDLs.

The document is structured to address all of the required components of a TMDL and also includes an implementation and monitoring strategy as well as a discussion on public involvement. The main body of the document provides a summary of the TMDL components. Additional technical details of these components are contained in the appendices of this report. The document is organized as follows:

- Watershed Characterization: **Section 2.0**
- Application of Montana's Water Quality Standards for TMDL Development: **Section 3.0**
- Description of TMDL Components: **Section 4.0**
- Sediment - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 5.0**
- Nutrients - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 6.0**
- Metals - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 7.0**
- Temperature - Comparison of Existing Data to Water Quality Targets, Sources and Loads, and TMDLs and Allocations: **Section 8.0**
- Water Quality Restoration Strategy: **Section 9.0**
- Monitoring Strategy: **Section 10.0**
- Stakeholder and Public Comments: **Section 11.0**

The supporting appendices include:

Appendix A: Maps
Appendix B: Regulatory Framework and Reference Condition Approach
Appendix C: Sediment Contribution from Roads
Appendix D: Sediment Contribution from Hillslope Erosion
Appendix E: Sediment Contribution from Streambank Erosion
Appendix F: Daily TMDLs for Sediment and Temperature
Appendix G: Nutrient Model
Appendix H: Sediment/Metals Data
Appendix I: Big Hole River Temperature Model
Appendix J: Divide Creek Temperature Model
Appendix K: Response to Public Comments

SECTION 2.0
WATERSHED CHARACTERIZATION

This section includes a summary of the physical and social characteristics of the Middle and Lower Big Hole River Watershed that has been excerpted from the *Watershed Characterization Report for the Middle and Lower Big Hole River Water Quality Restoration Planning Areas* (DEQ 2004).

2.1 Physical Characteristics

2.1.1 Location

The Middle and Lower Big Hole TPA covers approximately 1,021,021 acres (1,596 square miles) within Beaverhead, Deer Lodge, Madison, and Silver Bow counties (**Appendix A, Figure A-1**). The Middle Big Hole River extends 43.8 miles from the confluence of Pintlar Creek downstream to the confluence with Divide Creek, while the Lower Big Hole River extends 51.4 miles from Divide Creek to the mouth, where the Big Hole River meets the Beaverhead River to form the Jefferson River. Thus, the planning area encompasses 95.2 miles of the 150.7 mile long Big Hole River. The southern boundary of the planning area extends from Twin Bridges, Montana at the watershed's eastern extreme, along the Big Hole/Beaverhead hydrologic divide through the Pioneer Mountains. The western boundary separates the Middle and Lower Big Hole TPA from the Upper Big Hole River Planning Area, and extends through both the Pioneer Mountains and the Pintler Mountains of the Anaconda Range. The northern boundary runs along the Continental Divide, which separates the Big Hole River watershed from the upper Clark Fork River watershed. The eastern boundary of the planning area runs through the Highland Mountains, and separates the Big Hole River watershed from the Jefferson River watershed.

2.1.2 Climate

Climatic conditions vary widely throughout the watershed as elevation ranges from 4,595 feet in the Lower Big Hole River Valley to over 11,000 feet in the Pioneer Mountains and over 10,000 feet along the Continental Divide in the Pintler Mountains of the Anaconda Range. National Oceanic and Atmospheric Administration (NOAA) climate data are not available for the upper elevations in the watershed, so this summary does not fully represent meteorological conditions in the higher elevations of the watershed; however, most of the planning area (81 percent) is below 8,000 feet in elevation. July and August are the warmest months, while December and January are the coldest months. Average summertime highs are typically in the high-seventies to mid-eighties Fahrenheit. Average winter lows typically fall into the single digits. May and June are typically the two wettest months. Average annual precipitation ranges from about 9 inches at Glen to slightly less than 12 inches at both Divide and Wise River. Glen receives about 13 inches of snowfall on average, while Divide receives 40 inches and Wise River receives 25 inches. On average, measurable snowfall occurs in all months except June, July and August at Glen and Wise River, while Divide is only free from snowfall in June and July on average.

2.1.3 Hydrology

The U.S. Geological Survey (USGS) has current and historical daily streamflow data from 12 gaging stations in the Middle and Lower Big Hole River TPA (**Figure A-3**). There are currently three real-time sites on the mainstem: below Mudd Creek near Wisdom (6024540), near Melrose (6025500), and near Glen (6026210). Historical data include gages on the mainstem near Maiden Rock (6025250), on the Wise River (6024590), which is a major tributary of the Big Hole River that enters near the Town of Wise River, and on Birch Creek near Glen (602600). Spring high flows begin between April and May, peak in early June, and dissipate throughout July, reaching base flow conditions by August. A closer analysis of the stream flow data indicates peak stream flows tend to occur in late May and early June on the mainstem of the Big Hole River, while runoff tends to occur slightly later on the Wise River and Birch Creek. The average monthly stream flow at Glen is lower than the flow at Maiden Rock and at Melrose, which are both upstream of Glen. The mean annual stream flow in the watershed is 1,118 cubic feet per second (cfs) for the Big Hole River at Melrose, 189 cfs for the Wise River, and 29 cfs for Birch Creek. Stream flows in the fall and winter months remain fairly constant, ranging from approximately 400 to 500 cfs on the Big Hole River near Melrose, 40 to 60 cfs on the Wise River, and around 8 to 16 cfs on Birch Creek. Water is diverted from Willow Creek into Birch Creek, altering the natural flow regime and obscuring analysis of natural runoff rates. The Willow Creek diversion delivers a mean annual stream flow of 6 cfs to Birch Creek based on 5 years of data (1961-1965).

2.1.4 Geology, Soils, and Slope

Rocks in the Middle and Lower Big Hole TPA may be broadly divided into several groups (**Appendix A, Figure A-4**). The physiography of the TPA is largely related to the distribution, structure and composition of these rocks. The oldest rocks in the TPA are found in the Highland Mountains south of Divide. These are considered ‘basement’ rocks, and include highly metamorphosed gneisses, amphibolites, and schists of Precambrian age. These rocks occupy mid-elevation slopes on the southern half of the Highland Mountains, which are generally lower and less rugged than slopes underlain by Belt Series or igneous rocks. Precambrian Belt Series rocks are widespread within the TPA. These include metasedimentary rocks ranging from quartzite to shale and limestone. The rocks are generally lightly metamorphosed and largely undeformed, preserving their original sedimentary textures and structures. In the TPA, they are concentrated in the western Pioneer Range, west of the Wise River and south of the Big Hole River. The subdued physical expression of these mountains is similar to other ranges where these rocks are exposed at a similar elevation and orientation, such as the Sapphire and Garnet Ranges. Igneous rocks, both volcanic and intrusive, are widely distributed across the TPA. Intrusive rocks are volumetrically more significant than the volcanic rocks, and generally correspond to the higher elevations within the TPA. The “Pioneer Batholith” is located in the southern portion of the TPA, and includes the highest peaks of the Pioneers. This body of granitic rocks is similar in age and composition to the Boulder Batholith to the north. The southernmost portions of the Boulder Batholith extend into the TPA, north of Divide. Younger granitic rocks are found in the Anaconda Range, and uphold some of the higher peaks. Paleozoic and Mesozoic sedimentary rocks underlie the uplands in the rest of the TPA, essentially the area east and downstream of Wise River. These rocks include limestone, sandstone, and mudstone, and therefore vary widely in resistance to erosion. Poorly consolidated Tertiary rocks are present on broad inclined benches along the Big Hole River, and fill the intermountain basins to a considerable depth. These valley fill deposits include lithologies ranging from siltstone and ash to gravel. Tertiary benches tend to be well-drained and treeless. Quaternary deposits, including alluvium and glacial deposits are widespread. Glacial deposits are limited to higher elevations in the Pioneer and Anaconda Ranges. Alluvial plains of varying width are located along the Big Hole and Wise Rivers.

The Ovando-Elkner-Shadow soil series, which is a gravelly silty loam, is generally found at mid elevations of the Pintler Mountains in the Anaconda Range in the vicinity of LaMarche Creek and in the Pioneer Mountains above the Wise River. This roughly corresponds to areas mantled with glacial till. The Trimad-Kalsted-Crago is the predominant soil series in the lower portion of the TPA. The Trimad-Kalsted-Crago is found on benches and lower slopes from approximately Melrose downstream along both sides of the Big Hole River and surrounding McCartney Mountain. Slope in the Middle and Lower Big Hole TPA ranges from less than 1 percent to over 100 percent, with most of the watershed having steep slopes. Thirty seven percent of the watershed is within the 45 to 100 percent category, 29 percent has slopes greater than 100 percent, and only 8 percent of the TPA is comprised of lands with slopes less than 10 percent.

2.2 Social Characteristics

2.2.1 Land Ownership

The Middle and Lower Big Hole River TPA comprises approximately 1,021,021 acres. The U.S. Forest Service (USFS) is the dominate landowner with holdings that account for 58 percent of the TPA (**Figure A-1**). Of the remaining land, 20 percent is in private ownership, 16 percent is managed by the U.S. Bureau of Land Management (BLM), and 6 percent is owned by the State of Montana.

2.2.2 Land Use, Land Cover, and Vegetation

The Middle and Lower Big Hole TPA is predominately evergreen forest and grass rangeland (50 and 29 percent, respectively). Most of the evergreen forest is concentrated within the upper part of the watershed while most of the grass rangeland is concentrated in the lower part of the watershed (**Figure A-5**). About 5 percent of the TPA is crop/pasture and approximately 9 percent is brush and mixed rangeland. Residential and other urban cover only 258 acres in the planning area, which is approximately 0.025 percent of the TPA. The upper part of the watershed is dominated by Alpine Meadows and Mixed Xeric Forest, which cumulatively make up approximately 30 percent of the entire TPA. The lower part of the watershed is dominated by Mixed Xeric Shrubs and Irrigated Agricultural Lands, which cumulatively make up approximately 26 percent of the entire TPA.

2.2.3 Irrigation

In general, irrigation is supported by water withdrawals from the Big Hole River and its tributaries primarily through individual diversions in Silver Bow and Deer Lodge Counties and two major ditches in Madison County. In Deer Lodge County, tributaries important for irrigation within the Big Hole watershed are Pintlar, Mudd, Fishtrap, LaMarche, Seymour, Deep, and Bear creeks. Divide Creek is the only creek draining into the Big Hole River that provides significant irrigation to lands in Silver Bow County. In Madison County, the Big Hole Co-Op Ditch, which was originally a side channel of the Big Hole River called Owsley Slough, and the Pageville Canal are the principal diversions from the Big Hole River. Both of these ditches are located near the town of Twin Bridges.

Irrigation practices within the Big Hole watershed influence interactions between surface water and ground water in the basin. Marvin and Voeller (2000) found that most gains in aquifer storage occurred in May and June when 30,000 acre-feet were added to the aquifer in the lower basin, which the study defined as from Maiden Rock to Notch Bottom. This is equivalent to about 250 cfs entering storage throughout these months. Ground water storage reached its maximum, and was relatively stable in July. During this time, irrigation recharge of the aquifer was about equal to the ground water discharge to surface water streamflows. Ground water storage declined in August and September due primarily to evapotranspiration. Ground water storage continued to decline following the cessation of irrigation. However, surface water did not benefit from ground water storage declines in late summer while crops were actively growing. An average gain of 90 cfs in streamflow was directly attributed to irrigation return flows in October and November, with 25 cfs at Melrose and 55 cfs from the Glen valley. Increases in streamflows due to irrigation return flows are suspected to continue from October past November. Thus, it was concluded that irrigation water contributes significantly to ground water recharge, though evapotranspiration strongly influences contributions to streamflows (Marvin and Voeller 2000).

The Big Hole Drought Management Plan was adopted by the Big Hole Watershed Committee (BHWC) in partnership with Montana Department of Fish, Wildlife and Parks (FWP), Department of Natural Resources and Conservation (DNRC), and the U.S. Natural Resources Conservation Service (NRCS) in 1997. The plan has since been amended in 2000, 2002, 2004, 2005, and 2007. Its purpose is to mitigate the effects of low stream flows and lethal water temperatures for fisheries (particularly fluvial Arctic grayling) through a voluntary effort among agriculture, municipalities, business, conservation groups, anglers, and affected government agencies.

2.2.4 Mineral Extraction and Mining

Historic mining impacts are relatively minor in the Big Hole River watershed, although there are isolated areas in which intensive mining did occur during the later 1800's, including the Canyon Creek, Deep Creek, Trapper Creek, and Wise River watersheds. An industrial-scale placer operation located on French Gulch in the Deep Creek watershed began when gold was discovered 1864, with production peaking in 1867. In addition, French Gulch was dredged and "hydraulicked" along with neighboring tributaries in 1898. An 18-mile flume extending from the upper French Creek watershed over into the Mill Creek drainage transported logs to Anaconda from 1906 to 1911. Deforestation and erosion in this area lead President Roosevelt to create the Big Hole Forest Reserve in 1906, which eventually became the Deer Lodge National Forest (Munday 2001). In 1873, the Hecla Consolidated Mining Company made claims in the headwaters of Trapper and Canyon Creeks and founded the town of Glendale.

The U.S. Bureau of Mines Mineral Location database lists three hundred and twenty seven mines and prospects in the TPA, with 81 percent being in the lower part of the watershed (**Appendix A**, **Figure A-6**). Fourteen mines within the TPA have been identified by the State as High Priority Abandoned Hardrock Mine sites (**Table 2-1** and **Appendix A, Figure A-6**). Reclamation work is ongoing at the Elkhorn Mine under the CERCLA (National Superfund) program, including the design of constructed wetlands to trap metals and the relocation of the stream channel around tailings piles (D. Havig, pers. com., 2004). The BLM is currently developing a clean-up plan covering over four hundred abandoned mine site features, and four to five tailings ponds in the Rochester Creek and Nez Perce Creek watersheds, though new claims to rework the Rochester tailings have been submitted (M. Brown pers. com., 2004).

Table 2-1. High Priority Abandoned Hardrock Mine Sites in the Middle and Lower Big Hole River TPA.

Mine Site	Mining District	County	Sub Basin	Third Basin
Middle Fork Millsite	Moose Creek	Silverbow	Moose Creek	Middle Fk. Moose Creek
Clipper	Melrose	Silverbow	Camp Creek	Wickiup Creek
Old Glory	Melrose	Silverbow	Soap Gulch	Soap Gulch
Maiden Rock	Melrose	Silverbow	Big Hole River	Big Hole River
Watseca	Rochester	Madison	Rochester Creek	Rochester Creek
True Blue	Hecla/Vipond Park	Beaverhead	Trapper Creek	Spring Creek
Lower and Upper Cleve	Hecla	Beaverhead	Trapper Creek	Sappington Creek
Trapper	Hecla	Beaverhead	Trapper Creek	Sappington Creek
Silver King	Hecla	Beaverhead	Trapper Creek	Trapper Creek
Thistle Mine/Tailings	Rochester	Madison	Rochester Creek	Rochester Creek
Emma	Rochester	Madison	Nez Perce Creek	Nez Perce Creek
Tungsten Millsite	Lost Creek	Beaverhead	Big Hole River	Sassman Gulch
Indian Queen	Birch Creek	Beaverhead	Birch Creek	Birch Creek
Old Elkhorn	Elkhorn	Beaverhead	Wise River	Elkhorn Creek

2.3 Fish and Aquatic Life

Two fish species within the Middle and Lower Big Hole TPA, the westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and the Montana Arctic grayling (*Thymallus arcticus montanus*), are listed by the State of Montana as species of special concern. The Artic grayling population within the watershed is the last strictly fluvial population in the continental United States (DEQ 2003). Arctic grayling are primarily found in the upper part of the watershed (**Attachment A, Figure A-7**). They are rare in the mainstem, particularly between the mouth of the Big Hole River and Johnson Creek (approximately five miles upstream from the confluence with the Wise River), but are found in several tributaries. They are common in Deep Creek and rare in Fishtrap and LaMarche Creek (MFISH 2004). Westslope cutthroat trout are present in tributaries and will move into the mainstem of the Big Hole River near Melrose during a period of wet years (R. Oswald, pers. com., 2004). Tributaries with westslope cutthroat include, but are not limited to, Delano Creek, Divide Creek, Jerry Creek and tributaries to the Wise River (**Attachment A**, **Figure A-7**). While there are some genetically pure populations of westslope cutthroat trout left, they are faced with displacement by brook trout from downstream sources and hybridization with rainbow trout and Yellowstone cutthroat trout from upstream lakes (D. Downing, pers. com., 2004). Other species present in the Middle and Lower Big Hole TPA include brook trout, brown trout, burbot, common carp, longnose dace, longnose sucker, mottled sculpin, mountain sucker, mountain whitefish, rainbow trout, redside shiner, white sucker, and slimy sculpin.

SECTION 3.0
APPLICATION OF MONTANA'S WATER QUALITY STANDARDS FOR TMDL DEVELOPMENT

The goal of the federal Clean Water Act is to ensure that the quality of all surface waters is capable of supporting all designated uses. Water quality standards also form the basis for impairment determinations for Montana's 303(d) List, TMDL water quality improvement goals, formation of TMDLs and allocations, and standards attainment evaluations. The Montana water quality standards include four main parts: 1) stream classifications and designated uses, 2) numeric and narrative water quality criteria designed to protect the designated uses, 3) non-degradation provisions for existing high quality waters, and 4) prohibitions of various practices that degrade water quality. Pollutants addressed in this document include: metals, nutrients, sediment and temperature. This section provides a summary of the applicable water quality standards for each of these pollutants. More detailed descriptions of the Montana water quality standards that apply to Middle and Lower Big Hole TPA can be found in **Appendix B**.

3.1 Classification and Beneficial Uses

Classification is the designation of a single or group of uses to a water body based on the potential of the water body to support those uses. Designated uses or beneficial uses are simple narrative descriptions of water quality expectations or water quality goals. All Montana waters are classified for multiple beneficial uses. There are a variety of "uses" of State waters, including: growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; (primary) contact recreation; and wildlife. On the 2006 303(d) List, thirty one water bodies encompassing thirty three water body segments are listed as not supporting one or more beneficial uses (**Table 3-1**).

Streams in the Middle and Lower Big Hole River TPA are classified as either A-1 or B-1 by the State of Montana (**Table 3-1**). The mainstem of the Big Hole River is classified A-1 upstream of the Butte Water Company intake at Divide and B-1 downstream of Divide. All of the 303(d) Listed waters in the Middle Big Hole River watershed are assigned an A-1 water quality standard classification by the State of Montana, except for Seymour Creek, which is classified B-1. All of the 303(d) Listed waters in the Lower Big Hole River watershed are assigned a B-1 water quality standard classification. Waters classified as A-1 are to be "maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities, growth, and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and agricultural and industrial water supply." Waters classified B-1 are to be "maintained suitable for drinking, culinary and food processing purposes, after conventional treatment, bathing, swimming and recreation, growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and agricultural and industrial water supply." While some of the water bodies in the Middle and Lower Big Hole TPA might not actually be used for a specific use (e.g. drinking water supply), the quality of the water must be maintained at a level that can support that use to the best extent possible based on a stream's natural potential. More detailed descriptions of Montana's surface water classifications and designated beneficial uses are provided in **Section B.2.1** of **Appendix B**.

Table 3-1. Water Bodies in the Middle and Lower Big Hole River TPAs from the 2006 303(d) List and their Associated Level of Beneficial Use-Support.

Water body & Stream Description	Water body #	Use Class	Length (Miles)	Year	Aquatic Life	Coldwater Fishery	Drinking Water	Contact Recreation	Agriculture	Industry
Big Hole River between Divide Cr and Pintlar Cr (Middle segment)	MT41D001_020	A-1	43.8	2006	N	N	N	P	F	F
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment)	MT41D001_010	B-1	51.4	2006	N	N	N	P	F	F
Birch Creek headwaters to the National Forest Boundary	MT41D002_090	B-1	12.8	2006	P	P	F	F	F	F
Birch Creek from National Forest Boundary to mouth (Big Hole R)	MT41D002_100	B-1	10.4	2006	N	N	F	N	F	F
California Creek from headwaters to mouth (French Cr-Deep Cr)	MT41D003_070	A-1	7.9	2006	N	N	N	P	N	P
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	B-1	14.3	2006	P	P	N	P	P	P
Canyon Creek from headwaters to mouth (Big Hole R)	MT41D002_030	B-1	17.8	2006	X	X	X	P	X	F
Charcoal Creek tributary of the Big Hole R	MT41D003_010	A-1	3.8	2006	P	P	F	F	F	F
Corral Creek from headwaters to mouth (Deep Cr)	MT41D003_130	A-1	5.1	2006	P	P	F	F	F	F
Deep Creek from headwaters to mouth (Big Hole R)	MT41D003_040	A-1	7.9	2006	P	P	F	F	F	F
Delano Creek from headwaters to mouth (Jerry Cr)	MT41D003_030	A-1	2.3	2006	P	P	F	F	F	F
Divide Creek from headwaters to mouth (Big Hole R)	MT41D002_040	B-1	12.2	2006	P	P	F	P	F	F
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	MT41D003_220	A-1	7.2	2006	N	N	F	F	F	F
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	MT41D003_160	A-1	5.1	2006	P	P	F	P	F	F
French Creek from headwaters to mouth (Deep Cr)	MT41D003_050	A-1	9.4	2006	X	X	N	X	X	F

Table 3-1. Water Bodies in the Middle and Lower Big Hole River TPAs from the 2006 303(d) List and their Associated Level of Beneficial Use-Support.

Water body & Stream Description	Water body #	Use Class	Length (Miles)	Year	Aquatic Life	Coldwater Fishery	Drinking Water	Contact Recreation	Agriculture	Industry
Gold Creek from headwaters to mouth (Wise R)	MT41D003_230	A-1	4.8	2006	P	P	F	F	F	F
Grose Creek from headwaters to mouth (Big Hole R)	MT41D002_060	B-1	3.4	2006	P	P	F	P	F	F
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	A-1	12.3	2006	N	N	N	P	F	F
Lost Creek in the Lower Big Hole Watershed	MT41D002_180	B-1	7.8	2006	P	P	N	F	P	F
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock)	MT41D002_050	B-1	12.3	2006	X	X	X	P	X	F
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	MT41D003_080	A-1	1.8	2006	N	N	N	F	N	F
Pattengail Creek from headwaters to mouth (Wise R)	MT41D003_210	A-1	18.8	2006	P	P	F	F	F	F
Rochester Creek from headwaters to mouth (Big Hole R)	MT41D002_160	B-1	15.7	2006	P	P	N	F	F	F
Sassman Gulch from headwaters to mouth (Big Hole R)	MT41D002_070	B-1	6.5	2006	N	N	F	F	F	F
Sawlog Creek tributary to Big Hole R	MT41D004_230	A-1	5	2006	N	N	N	F	F	F
Sevenmile Creek from headwaters to mouth (Deep Cr)	MT41D003_110	A-1	6.3	2006	P	P	F	F	F	F
Sixmile Creek from headwaters to mouth (California Cr)	MT41D003_090	A-1	3.1	2006	P	P	F	F	F	F
Soap Creek from headwaters to mouth (Big Hole R)	MT41D002_140	B-1	8.3	2006	P	P	F	F	F	F
Trapper Creek from headwaters to mouth (Big Hole R)	MT41D002_010	B-1	17.4	2006	N	N	N	P	F	F
Twelvemile Creek from headwaters to mouth (Deep Cr)	MT41D003_120	A-1	8.9	2006	P	P	F	F	F	F
Wickiup Creek Tributary to Camp Cr (Big Hole R)	MT41D002_120	B-1	4.1	2006	N	N	N	F	F	F

Table 3-1. Water Bodies in the Middle and Lower Big Hole River TPAs from the 2006 303(d) List and their Associated Level of Beneficial Use-Support.

Water body & Stream Description	Water body #	Use Class	Length (Miles)	Year	Aquatic Life	Coldwater Fishery	Drinking Water	Contact Recreation	Agriculture	Industry
Willow Creek from headwaters to mouth (Big Hole R)	MT41D002_110	B-1	21	2006	X	X	X	P	X	X
Wise River from headwaters to mouth (Big Hole R)	MT41D003_200	A-1	25.7	2006	P	P	F	P	F	F

F = Full Support, P = Partial Support, N = Not Supported, T = Threatened, X = Not Assessed (Lacking Sufficient Credible Data)

3.2 Standards

In addition to the A-1 and B-1 use classifications described above, Montana's water quality standards include numeric and narrative criteria as well as a nondegradation policy. This section includes a brief summary of numeric and narrative standards.

Numeric standards apply to concentrations of pollutants that are known to have adverse effects on human health or aquatic life. Pollutants for which numeric standards exist include metals, organic chemicals, and other toxic constituents. Human health standards have been set at levels to protect against long-term (lifelong) exposure as well as short-term exposure through direct contact such as swimming. Aquatic life numeric standards include chronic and acute values. *Chronic* aquatic life standards are designed to prevent effects of long-term low level exposure to pollutants, while *acute* aquatic life standards are protective of short-term exposure to pollutants. Chronic standards are more stringent than acute standards, but they can be exceeded for short periods of time, while acute standards can never be exceeded.

Narrative standards have been developed for substances or conditions where sufficient data on the long and/or short-term effects do not exist, or for pollutants whose effects must be assessed on a site-specific basis. Narrative standards describe either the allowable condition or an allowable increase of a pollutant over "naturally occurring" conditions, or pollutant levels. DEQ uses a reference condition (naturally occurring condition) to determine whether or not narrative standards are being achieved.

Reference condition is defined as the condition a water body could attain if all reasonable land, soil, and water conservation practices were put in place. Reasonable land, soil, and water conservation practices usually include but are not limited to Best Management Practices (BMPs).

Appendix B contains additional details on determining reference conditions and the water quality standards, including relevant numeric criteria and complete definitions of applicable narrative standards for pollutants addressed in this document for the Middle and Lower Big Hole TPA. **Section B.2.2** describes the applicable narrative and numeric water quality standards for sediment, nutrients, metals, and temperature. **Section B.3** discusses primary and secondary approaches for determining reference conditions, and the use of statistics to develop reference values or ranges.

SECTION 4.0
DESCRIPTION OF TMDL COMPONENTS

A TMDL is the pollutant loading capacity for a particular water body and refers to the maximum amount of a pollutant a stream or lake can receive and still meet water quality standards. A TMDL is also a reduction in pollutant loading resulting in attainment of water quality standards. More specifically, a TMDL is the sum of the allowable loading from all sources to the water body. These loads are applied to individual sources, or categories of sources as a logical method to allocate water quality protection responsibilities, and overall loading limits within the contributing watershed(s). The allocated loads are referred to as waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources. Natural background loading is considered a type of nonpoint source, and therefore represents a specific load allocation. In addition, the TMDL includes a Margin of Safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream. The inclusion of a MOS results in less load allocated to one or more WLAs or LAs to help ensure attainment of water quality standards.

TMDLs are expressed by the following equation which incorporates the above components:

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

The allowable pollutant load must ensure that the water body being addressed by the TMDL will be able to attain and maintain water quality standards for all applicable seasonal variations in streamflow, and pollutant loading. **Figure 4-1** is a schematic diagram illustrating how numerous sources contribute to the existing load and how the TMDL is defined. The existing load can be compared to the allowable load to determine the amount of pollutant reduction needed.

The major components that go into TMDL development are target development, source quantification, establishing the total allowable load, and allocating the total allowable load to sources. Although the way a TMDL is expressed may vary by pollutant, these components are common to all TMDLs, regardless of pollutant. Each component is described in further detail below.

Each of the following four sections of the document (**Sections 5–8**) are organized by the four pollutants of concern in the Middle and Lower Big Hole TPA: sediment, nutrients, metals, and temperature. Each section includes a discussion on the water body segments of concern, how the pollutant of concern is impacting beneficial uses, the information sources, and assessment methods to evaluate stream health and pollutant source contributions, water quality target development along with a comparison of existing conditions to targets, quantification of loading from identified sources, the determination of the allowable loading (TMDL) for each water body, and the allocations of the allowable loading to sources.

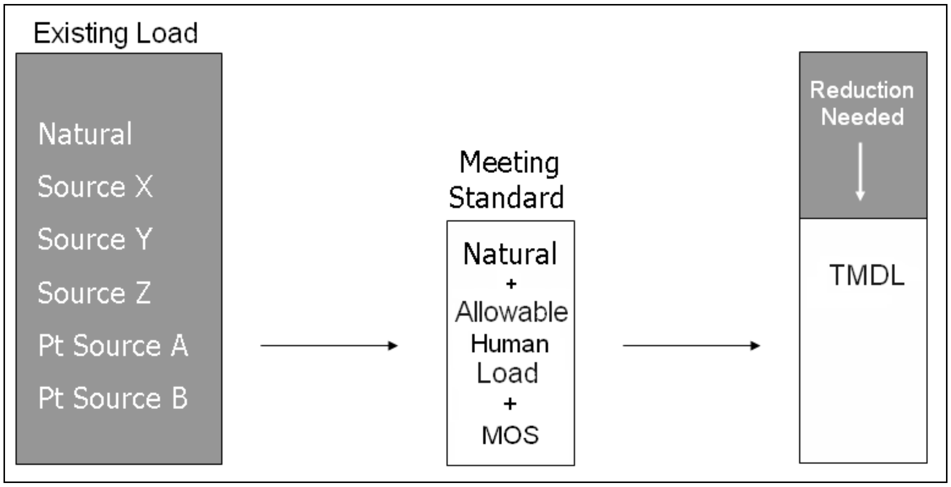


Figure 4-1. Schematic example of TMDL development.

4.1 Target Development

Because loading capacity is evaluated in terms of meeting water quality standards, quantitative water quality targets and supplemental indicators are developed to help assess the condition of the water body relative to the applicable standard(s), and to help determine successful TMDL implementation. This document outlines water quality targets for each pollutant of concern in the Middle and Lower Big Hole TPA. TMDL water quality targets help translate the applicable numeric or narrative water quality standards for the pollutant of concern. For pollutants with established numeric water quality standards, the numeric values are used as TMDL water quality targets. For pollutants with only narrative standards, the water quality targets help to further interpret the narrative standard, and provide an improved understanding of impairment conditions. Water quality targets typically include a suite of instream measures that link directly to the impacted beneficial use(s) and applicable water quality standard(s). The water quality targets help define the desired stream conditions and are used to provide benchmarks to evaluate overall success of restoration activities. By comparing existing stream conditions to target values, there will be a better understanding of the extent and severity of the problem.

4.2 Quantifying Pollutant Sources

All significant pollutant sources, including natural background loading, are quantified so that the relative pollutant contributions can be determined. Source assessments often have to evaluate the seasonal nature and ultimate fate of the pollutant loading since water quality impacts can vary throughout the year. The source assessment usually helps to further define the extent of the problem by putting human caused loading into context with natural background loading.

A pollutant load is usually quantified for each point source permitted under the MPDES program. Most other pollutant sources, typically referred to as nonpoint sources, are quantified by source categories such as unpaved roads and/or by land uses such as crop production or forestry. These source categories or land uses can be further divided by ownership such as Federal, State, or private. Alternatively, a sub-watersheds or tributaries approach can be used whereby most or all sources in a sub-watershed or tributary are combined for quantification purposes.

The source assessments are performed at a watershed scale, because all potentially significant sources of the water quality problems must be evaluated. The source quantification approaches may range from reasonably accurate estimates to gross allotments, depending on the availability of data, and appropriate techniques for predicting the loading (40CFR Section 130.2(I)). Montana TMDL development often includes a combination of approaches depending on the level of desired certainty for setting allocations and guiding implementation activities.

4.3 Establishing the Total Allowable Load

Identifying the TMDL requires a determination of the total allowable load over the appropriate and sensible time period necessary to comply with the applicable water quality standard(s). Although the concept of allowable daily load is incorporated into the TMDL term, a daily loading period may not be consistent with the applicable water quality standard(s), or may not be practical from a water quality management perspective. Therefore, the TMDL will ultimately be defined as the total allowable loading using a time period consistent with the application of the water quality standard(s) and consistent with established approaches to properly characterize, quantify, and manage pollutant sources in the watershed. For example, sediment TMDLs may be expressed as an allowable yearly load whereas the TMDL to address acute toxicity criteria for metals will include a near-instantaneous loading requirement calculated over a time period of one second (based on standard methods for evaluation flow in cubic feet per second).

Where numeric water quality standards exist for a stream, the TMDL or allowable loading, typically represents the allowable concentration multiplied by the flow of water over the time period of interest. This same approach can be applied for situations where a numeric target is developed to interpret a narrative standard, and the numeric value is based on an instream concentration of the pollutant of concern.

For some narrative standards such as those relating to sediment, there is often a suite of targets based on stream substrate conditions and other similar indicators. In many of these situations, it is difficult to link the desired target values to highly variable and often episodic instream loading conditions. In these situations, the TMDL is often expressed as a percent reduction in total loading based on source quantification results, and an evaluation of load reduction potential (**Figure 4-1**). The degree by which existing conditions exceed desired target values can also be used to justify a percent reduction value for a TMDL.

Even if the TMDL is preferably expressed using a time period other than daily, an allowable daily loading rate will also be calculated to meet specific requirements of the Clean Water Act. Where this occurs, TMDL implementation and the development of allocations will still be based on the preferred time period as discussed above.

4.4 Determining Allocations

Once the loading capacity (i.e. TMDL) is determined, that total must be divided, or allocated among the contributing sources. In addition to basic technical and environmental considerations, this step introduces economic, social, and political considerations. The allocations are often determined by quantifying feasible and achievable load reductions associated with the application of reasonable land, soil, and water conservation practices. Reasonable land, soil, and water conservation practices generally include BMPs, but additional conservation practices may be required to achieve compliance with water quality standards and restore beneficial uses. It is important to note that implementation of the TMDL does not conflict with water rights or private property rights. **Figure 4-2** contains a schematic diagram of how TMDLs are allocated to different sources using WLAs for point sources and LAs for natural and nonpoint sources. Although some flexibility in allocations is possible, the sum of all allocations must meet the water quality standards in all segments of the water body.

Under the current regulatory framework for development of TMDLs, flexibility is allowed for specifying allocations in that *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure."* Allocations are typically expressed as a number, a percent reduction (from the current load), or as a surrogate measure, such as a percent increase in canopy density for temperature TMDLs.

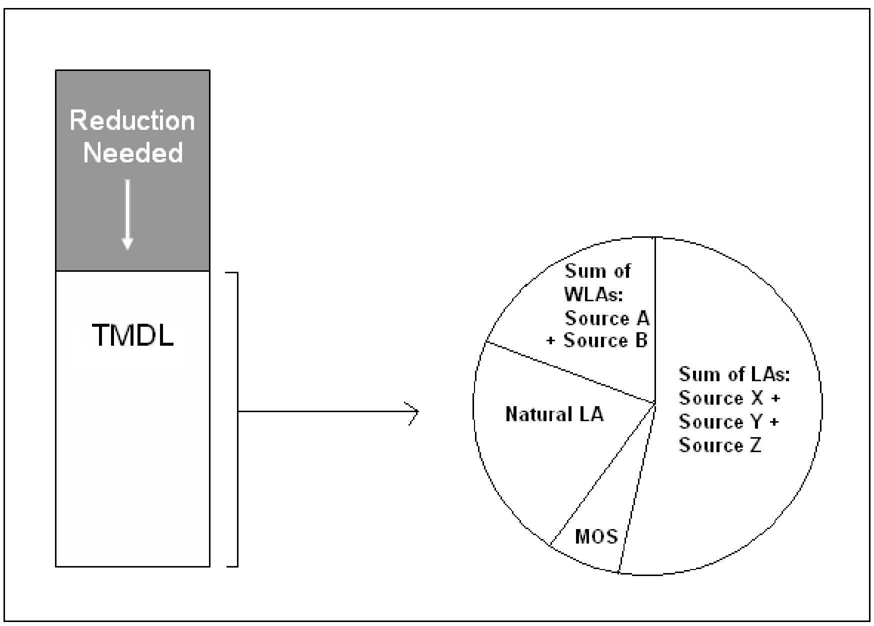


Figure 4-2. Schematic diagram of TMDL and allocations.

4.5 Margin of Safety

Incorporating a margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality, and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the

TMDL development process or explicitly by setting aside a portion of the allowable loading (USEPA 1999).

SECTION 5.0
SEDIMENT

This portion of the document focuses on sediment as an identified cause of water quality impairments in the Middle and Lower Big Hole TPA. It describes: 1) the mechanisms by which sediment impairs beneficial uses of those streams, 2) the specific stream segments of concern, 3) the presently available data pertaining to sediment impairments in the watershed, 4) the various contributing sources of sediment based on recent studies, and 5) the sediment TMDLs and allocations.

5.1 Mechanism of Effects of Excess Sediment on Beneficial Uses

The weathering and erosion of land surfaces and transport of sediment to and by streams are natural phenomena that are important in building and maintaining streambanks and floodplains. However, excessive erosion or the absence of natural sediment barriers and filters such as riparian vegetation, woody debris, beaver dams, and overhanging vegetation can lead to high levels of suspended sediment and sediment deposits in areas not naturally containing high levels of fine sediment.

Uncharacteristically high amounts of sediment in streams can impair the ability to support aquatic life, cold water fisheries, recreation, and drinking water beneficial uses. Potential effects of excess suspended sediment include increased filtration costs for water treatment facilities, decreased recreational use potential, and impaired aesthetic appreciation. Fish and other aquatic life are typically the most sensitive to excess sediment. High levels of suspended sediment can reduce light penetration through water, which may limit growth of algae and aquatic plants. This decline in primary producers may result in a decline in aquatic insect populations, which may also be affected if deposited sediment obscures sources of food, habitat, hiding places, and nesting sites. Excess sediment may also impair biological processes and reproductive success of individual aquatic organisms by clogging gills and causing abrasive damage, reducing availability of suitable spawning sites, and smothering eggs or hatchlings. An accumulation of fine sediment on stream bottoms can also reduce the flow of water through gravels harboring incubating eggs, hinder the emergence of newly hatched fish, deplete the oxygen supply to embryos, and cause metabolic wastes to accumulate around embryos, resulting in higher mortality rates.

5.2 Stream Segments of Concern

A total of twenty three water body segments in the Middle and Lower Big Hole TPA appeared on the 2006 Montana 303(d) List due to sediment related impairments (**Table 5-1**). Listing causes include sedimentation/siltation, solids (suspended/bedload), bank erosion, turbidity, and bottom deposits. Although not shown in **Table 5-1** (see **Table 1-1**), many of the water bodies with sediment impairments are also listed for habitat and flow alterations, which are forms of pollution frequently associated with sediment impairment. TMDLs are limited to pollutants, but implementation of land, soil, and water conservation practices to reduce pollutant loading will inherently address some pollution impairments. Nine additional water body segments within the

Middle and Lower Big Hole TPA were either not assessed for the aquatic life and cold water fishery beneficial uses on the 2006 303(d) List and/or only on the 2006 303(d) List for habitat alterations or low flow alterations (**Table 5-1**). Because fish and aquatic life are typically the most sensitive uses to excess sediment and because of the common link between these forms of pollution and sediment impairment, these segments were identified as being potentially impaired for sediment and most are discussed within this section. The segments include the middle and lower segments of the Big Hole River, Birch Creek (lower segment), Canyon Creek, French Creek, Jerry Creek, Moose Creek, Willow Creek, and the Wise River. French Creek was the only water body that had not been assessed for all beneficial uses and did not have any sediment-related listings. However, sediment-related information was obtained for French Creek (MT41D003_050) during TMDL development because it was not assessed during the 2006 listing cycle for support of fish and aquatic life and is a major tributary to Deep Creek, which is listed for sedimentation/siltation (**Table 5-1**).

Due to the Integrated Report impairment listing timeframe being later than the TMDL project initiation timeframe, the sediment listings for Twelvemile Creek and Wickiup Creek will not be addressed within this document. These TMDLs will be addressed during future TMDL development.

Table 5-1. Water body segments with sediment listing and possible sediment related listings on the 2006 303 (d) List for sediment listings, only the sediment listings are shown. For water bodies with a possible sediment-related listing, all potentially related pollution causes are included.

Table 5-1. Water body segments with sediment listings and possible sediment-related listings on the 2006 303(d) List.

Stream Segment	Water Body #	Sediment and Potentially Related Causes of Impairment
Big Hole River between Divide Cr and Pintlar Cr (Middle segment)	MT41D001_020	Physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, low flow alterations[1]
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment)	MT41D001_010	Physical substrate habitat alterations, low flow alterations[1]
Birch Creek headwaters to the National Forest Boundary	MT41D002_090	Sedimentation/ Siltation
Birch Creek from National Forest Boundary to mouth (Big Hole R)	MT41D002_100	Physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, low flow alterations, other anthropogenic substrate alterations[1]
California Creek from headwaters to mouth (French Cr-Deep Cr)	MT41D003_070	Bank erosion, Siltation, Turbidity
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	Sedimentation/ Siltation, Solids (suspended/bedload)

Table 5-1. Water body segments with sediment listings and possible sediment-related listings on the 2006 303(d) List.

Stream Segment	Water Body #	Sediment and Potentially Related Causes of Impairment
Canyon Creek from headwaters to mouth (Big Hole R)	MT41D002_030	Low flow alterations[1, 2]
Charcoal Creek tributary of the Big Hole R	MT41D003_010	Sedimentation/ Siltation
Corral Creek from headwaters to mouth (Deep Cr)	MT41D003_130	Sedimentation/ Siltation
Deep Creek from headwaters to mouth (Big Hole R)	MT41D003_040	Sedimentation/ Siltation
Delano Creek from headwaters to mouth (Jerry Cr)	MT41D003_030	Sedimentation/ Siltation
Divide Creek from headwaters to mouth (Big Hole R)	MT41D002_040	Sedimentation/ Siltation
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	MT41D003_220	Sedimentation/ Siltation
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	MT41D003_160	Sedimentation/ Siltation
Gold Creek from headwaters to mouth (Wise R)	MT41D003_230	Sedimentation/ Siltation
Grose Creek from headwaters to mouth (Big Hole R)	MT41D002_060	Sedimentation/ Siltation
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	Physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, low flow alterations[1]
Lost Creek in the Lower Big Hole Watershed	MT41D002_180	Sedimentation/ Siltation
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock)	MT41D002_050	Low flow alterations[1, 2]
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	MT41D003_080	Sedimentation/ Siltation
Pattengail Creek from headwaters to mouth (Wise R)	MT41D003_210	Sedimentation/ Siltation
Rochester Creek from headwaters to mouth (Big Hole R)	MT41D002_160	Sedimentation/ Siltation
Sawlog Creek tributary to Big Hole R	MT41D004_230	Sedimentation/ Siltation
Sevenmile Creek from headwaters to mouth (Deep Cr)	MT41D003_110	Sedimentation/ Siltation
Sixmile Creek from headwaters to mouth (California Cr)	MT41D003_090	Sedimentation/ Siltation
Soap Creek from headwaters to mouth (Big Hole R)	MT41D002_140	Sedimentation/ Siltation

Table 5-1. Water body segments with sediment listings and possible sediment-related listings on the 2006 303(d) List.

Stream Segment	Water Body #	Sediment and Potentially Related Causes of Impairment
Trapper Creek from headwaters to mouth (Big Hole R)	MT41D002_010	Sedimentation/ Siltation
Twelvemile Creek from headwaters to mouth (Deep Cr)	MT41D003_120	Sedimentation/ Siltation[3]
Wickiup Creek Tributary to Camp Cr (Big Hole R)	MT41D002_120	Bottom deposits[3]
Willow Creek from headwaters to mouth (Big Hole R)	MT41D002_110	Low flow alterations[1, 2]
Wise River from headwaters to mouth (Big Hole R)	MT41D003_200	Physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, low flow alterations[1]

[1] Form of pollution frequently linked to sediment impairment.
[2] Not assessed for all beneficial uses on the 2006 303(d) List, including aquatic life and cold water fishery.
[3] This water body is not addressed within this document and will be addressed during future TMDL development.

5.3 Information Sources and Assessment Methods

Information sources used to develop the TMDL components include information from DEQ assessment files used to make impairment determinations and data collected and/or obtained during the TMDL development process. Biological, chemical, and habitat data were collected by DEQ on most water bodies between 1999 and 2003 (**Figure A-8**). Additionally, field measurements of channel morphology and riparian and instream habitat parameters were collected in 2005 and 2006 from forty nine reaches on thirty one water bodies to aid in TMDL development (**Appendix E, Figure 2-1**). Monitoring reaches were selected with the goal of collecting data that is representative of conditions within the listed water bodies and were based on the results of an aerial assessment that stratified listed stream segments into reaches based on physical parameters (e.g. valley length/slope, valley confinement, and geology) and land cover. The field parameters assessed in 2005/2006 include standard measures of stream channel morphology, stream habitat, riparian vegetation, and near stream land use. The aerial and field assessments are described in more detail in the Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (DEQ 2005). Field parameters are briefly described in **Section 5.4** and raw data tables and associated summaries of all field data are contained in the 2005 and 2006 Monitoring Summary reports (DEQ 2005b; DEQ 2006b). Additional data sources for this report include a wide range of chemical, physical and biological water quality monitoring results, fishery inventories, stream discharge data, GIS data layers, agency and university documents, and land use information.

Significant sediment sources identified within the Middle and Lower Big Hole TPA that were assessed for the purposes of TMDL development include:

- Upland erosion
- Unpaved roads
- Streambank erosion

For each impaired water body segment, sediment loads from each source category were estimated based on field surveys, watershed modeling, and load extrapolation techniques that are described below. Additional details about the source assessment approach are contained in the Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (DEQ 2005). The complete methods and results for source assessments for upland erosion, unpaved roads, and streambank erosion are located in **Appendices C, D,** and **E.**

5.3.1 Modeled Upland Erosion

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE) and sediment delivery to the stream was predicted using a sediment delivery ratio. The USLE results are useful for source assessment as well as determining allocations for human-caused upland erosion. This model provided an estimate of existing sediment loading from upland sources and an estimate of potential sediment loading reductions through the application of best management practices (BMPs). Because the plant canopy and type of tillage practices can influence erosion, potential load reductions are calculated by adjusting factors within the model that are associated with land management and cropping practices (C-factors). Additional information on the upland erosion modeling can be found in sediment contribution from hillslope Erosion, which is included as **Appendix C**.

5.3.2 Unpaved Road Sediment Assessment

Sediment loading from unpaved roads was assessed using GIS, field data collection and sediment modeling to estimate sediment inputs from the unpaved road network to streams in the Middle and Lower Big Hole watershed. Each identified unpaved road crossing and near-stream road segment was assigned attributes for road name, surface type, road ownership, stream name, subwatershed, and landscape setting (i.e. mountain, foothill, and valley). Fifty three crossings and thirty four near-stream segments that represented the range of conditions within the watershed were assessed in the field in 2006, and sediment loading was estimated using the Forest Road Sedimentation Assessment Methodology (FroSAM). The average sediment contribution from unpaved road crossings and near-stream road segments were extrapolated to all unpaved roads in the watershed based on landscape type. To address sediment from unpaved roads in the TMDLs and allocations that follow in **Section 5.6**, the FroSAM analysis was also run using BMPs to reduce the road contributing length. A more detailed description of this assessment can be found in the *Unpaved Road Runoff Sediment Assessment* (DEQ 2007), which is included as **Appendix D**.

5.3.3 Eroding Streambank Sediment Assessment

Sediment loading from eroding streambanks was assessed by performing Bank Erosion Hazard Index (BEHI) measurements and evaluating the Near Bank Stress (NBS) (Rosgen 1996, 2001) along monitoring reaches in 2005 and 2006. BEHI scores were determined at each eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle, and surface protection. In addition to BEHI data collection, the source of streambank erosion was evaluated based on observed anthropogenic disturbances and the surrounding land-use practices based on the following near-stream source categories:

- Transportation
- Riparian Grazing
- Cropland
- Mining
- Silviculture
- Irrigation-shifts in stream energy
- Natural Sources
- Other

Streambank erosion data from the monitoring in 2005/2006 was then extrapolated to the stream reach determined from the aerial reach stratification procedure, and then to the listed stream segment and watershed scale. The potential for sediment load reduction at the watershed scale was estimated as a percent reduction that could be achieved if all eroding streambanks could be reduced to a moderate BEHI score (i.e. moderate risk of erosion). A more detailed description of this assessment can be found in the *Streambank Erosion Source Assessment* (DEQ 2007b), which is included as **Appendix E**.

5.4 Water Quality Targets and Comparison to Existing Conditions

This section provides a summary of water quality targets and a comparison of targets to available data for the stream segments of concern in the Middle and Lower Big Hole TPA (**Table 5-1**). Although placement onto the 303(d) List indicates an impaired water quality, a comparison of water quality targets to existing data helps define the level of impairment and guide the development of TMDL allocations. It also establishes a starting point from which to measure future water quality restoration success.

5.4.1 Water Quality Targets

For the Middle and Lower Big Hole TPA, a suite of water quality targets and supplemental indicators are presented to assess the effect of sediment derived from anthropogenic sources on beneficial use support. Water quality targets and supplemental indicators for sediment impairments include measures of the width/depth ratio, entrenchment ratio, percent of fine sediment on the stream bed and in pool-tail outs, eroding banks, pool frequency, riparian condition, and biological metrics. Future surveys should document stable (if meeting criterion) or improving trends. The proposed water quality targets and supplemental indicators for sediment impairments are summarized in **Table 5-2** and are described in detail in the sections that follow. If the results are consistent with the existing impairment determination or there is strong evidence of a link between sediment and stream segments listed for pollution impairment only, a TMDL will be provided. Site-specific conditions such as recent wildfires, natural conditions, and flow alterations within a watershed may warrant the selection of unique indicator values that differ slightly from those presented below, or special interpretation of the data relative to the proposed sediment indicator values. Targets and supplemental indicators are based on the best available data, but may be adjusted in the future through the adaptive management process as more information becomes available.

Table 5-2. Targets and Supplemental Indicators for Sediment in the Middle and Lower Big Hole TPA.

Water Quality Targets	**Proposed Criterion**
Percentage of fine surface sediment <6mm based on the reach composite pebble count	Comparable with reference values based on Rosgen Stream type. [a]
Percentage of fine surface sediment <2mm based on the reach average riffle pebble counts	The reach average value must not exceed 15% for E channels and 13% for all other channels.
Width/depth ratio, expressed as the median of the channel cross-section measurements	Comparable with reference values. [a]
Entrenchment ratio, expressed as the median of the channel cross-section measurements	Comparable with reference values. [a] This target only applies to B, C, and E stream types. An entrenchment ratio >1.8 will be considered to meet the water quality target for B channels, >5.1 for C channels, and >3.7 for E channels.
% Fines in spawning gravels < 6mm (49-point grid) expressed as the reach average	A reach average of < 19% for E channels and <14% for all other channel types
Pool frequency	5.5 frequency of pools to median bankfull width per reach
Supplemental Indicators	**Proposed Criterion**
Fish Population Dynamics	Documented healthy fish populations, with an emphasis on native species.
BEHI hazard rating, expressed as a reach average	Comparable with reference values based on Rosgen Stream type [a]
Percentage of eroding banks, based on the sum of both left and right bank lengths per reach	Non-eroding banks for at least 85% of reach for A, E, B, and C type streams. Future surveys should document stable or improving trends.
Percent of streambank with riparian shrubs based on greenline survey	≥ 48% Riparian shrubs
Proper Functioning Condition (PFC) riparian assessment	"Proper Functioning Condition" or "Functional-at Risk" with an upward trend and the intent of reaching "Proper Functioning Condition"
Macroinvertebrates	Mountain MMI > 63
	Valley MMI > 48
	RIVPACS > 0.80
Periphyton	Percent Probability of Impairment < 40%
Anthropogenic sediment sources.	No significant sources identified based on field and aerial surveys.

[a] Based on the BDNF channel morphology dataset and applies only to tributaries to the Big Hole River. A detailed discussion of the targets is provided in the following sections.

Several of the water quality targets for sediment in the Middle and Lower Big Hole TPA are based on regional reference data. It should be noted that the DEQ defines “reference” as the condition of a water body capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, reference condition reflects a water body’s greatest potential for water quality given historic and current land use activities. Water bodies used to determine reference conditions are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. In addition, this reference condition approach also does not reflect an effort to “turn back the clock” to conditions that may have existed before human settlement, but is intended to accommodate natural variations due to climate, bedrock, soils, hydrology and other natural physiochemical differences when establishing threshold values for sediment indicators. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry or hydrogeomorphology due to human activity.

5.4.1.1 Channel Morphology and Substrate Measurements

USFS data for approximately two hundred reference sites were used as a basis for determining departure from reference geomorphic condition and substrate size distribution (Bengeyfield, 1999). Approximately seventy of the reference sites were from the Greater Yellowstone Area, while the remaining sites were surveyed within the Beaverhead Deerlodge National Forest (BDNF), which includes portions of the Middle and Lower Big Hole TPA. Streams described as “reference” were not necessarily in pristine watersheds, though the streams had to be stable and in “proper functioning condition”. Streams which shifted a Level I Rosgen classification value (i.e. E to C) were reported as “non-functioning” and were not included in the reference dataset (Bengeyfield 2004). The entire reference dataset is available upon request from the BDNF and has been provided to the DEQ.

Water quality targets for the percent of fine sediment <6mm, channel width/depth ratio, entrenchment ratio, and the BEHI rating are based on the USFS channel morphology reference dataset from the Greater Yellowstone Area and BDNF. The 75th percentile was calculated from the reference dataset for each stream type and will be used as a basis for sediment water quality targets (**Table 5-3**). Since the water quality target depends on the stream type, the term “comparable to reference values” should be interpreted as “less than or equal to” the 75th percentile of similar type streams for the percent surface fines, width/depth ratio, and BEHI, while “comparable to reference values” should be interpreted as “greater than or equal to” the 75th percentile for similar type streams for the entrenchment ratio. In essence, lower values for surface fine sediment, width/depth ratio, and BEHI ratings are more desirable and suggest support of the cold water fishery and aquatic life beneficial uses. In general, higher values are desirable for the entrenchment ratio, though entrenchment ratio indicators will not be applied to streams that are naturally A channel types, since these stream types by definition are entrenched. In addition, no fine sediment indicators will be applied to streams that are naturally E5 or E6 stream types, since these stream types naturally have high amounts of fine sediment.

Table 5-3. Beaverhead Deerlodge National Forest Reference Dataset 75th Percentiles for Individual Rosgen Stream Types.

Parameter	A	B3	B4	B	C3	C4	C	E3	E4	E5	Ea	E
% surface fines < 6mm	24	12	25	20	14	29	29	20	38	99	40	44
Width/Depth Ratio	10	15	17	16	31	20	23	10	7	4	7	7
Entrenchment Ratio	N/A	1.8*	1.9	1.8*	5.1*	14.1	10.1	14.0	15.9	30.0	8.7	3.7*
Reach Average BEHI	24.2	27.1	31.7	29.7	26.9	26.5	26.5	26.3	24.2	22.0	22.7	23.6

*This value will be used as a target for all channels of this type (i.e. B,C, or E)

Surface Fine Sediment at the Reach Scale and in Riffles

The percent of surface fines less than 6 mm and 2 mm is a measurement of the fine sediment on the surface of a streambed and is directly linked to the support of the cold water fishery and aquatic life beneficial uses. Increasing concentrations of surficial fine sediment can negatively affect salmonid growth and survival (Suttle et al. 2004) and macroinvertebrate abundance and taxa richness (Mebane 2001; Zweig and Rabeni 2001). Some studies of salmonid and macroinvertebrate survival found an inverse relationship between fine sediment and survival (Suttle et al. 2004) whereas other studies have concluded the most harmful percentage falls within 10 and 40 percent fine sediment (Bjornn and Reiser 1991; Relyea et al. 2000).

During the 2005 and 2006 stream channel assessments, surface fines data were collected using a modified Wolman pebble count to collect a composite sediment sample proportionally by habitat type (e.g. riffles and pools) and also to sample riffle habitat only. The <6 mm fine sediment target is based on USFS Wolman pebble count reference data (**Table C-1**). The USFS dataset is based on the "zigzag" pebble count method, which is most comparable to the composite pebble count data from the Middle and Lower big Hole TPA as it also includes multiple habitat types. Particularly for B and C channel types, the reference dataset correlates with a study by Mebane (2001), which was based on Wolman riffle pebble counts and found the greatest number of salmonid and sculpin age classes when the 75th percentile of fine sediment <6 mm was less than 20-30 percent.

The USFS reference dataset does not include substrate size classes smaller than 6 mm. Although the Middle and Lower Big Hole TPA does not have adequate reference data to establish a target, as discussed in **Appendix B**. Because E channels tend to naturally be higher in fine sediment, data for E channels were grouped separately from all other channel types. For riffle fine sediment <2 mm in E channels, the 25th percentile of all data (n=76) is 15 percent and the median is 24 percent. Based on the reference values in **Table 5-3,** and that the distribution of E data is skewed to the right (i.e. high numbers), the 25th percentile is a more appropriate target than the median for E channels. For all other channel types, the median of all data (n=103) is 13 percent riffle fine sediment <2 mm. These percentages seem reasonable and are comparable to reference values from non E channels the Upper Big Hole (DEQ 2008). Based on reference values, literature values, and field observations, the water quality target for fine sediment <2 mm in riffles is 15 percent in E channels and 13 percent for all other channel types.

Surface Fine Sediment in Pool Tails

A particle size of 6 mm is commonly used to define fine sediment because of its potential to clog spawning redds and smother fish eggs by limiting oxygen availability (Irving and Bjornn 1984; Shepard et al. 1984). Survival of several salmonid species greatly declines as subsurface fine sediment <6 mm increases (Shepard et al. 1984; Reiser and White 1988; Weaver and Fraley 1991). Increasing surface fine sediment <6 mm also negatively affects both salmonids and sculpins (Mebane 2001), and sedimentation of pools reduces summer and overwintering habitat, causing a reduction in pool salmonid density (Bjornn et al. 1977).

A 49-point grid toss was used to estimate percent surface fines in pool tails (Kramer 1991); five grid tosses were performed in each pool tail, and the total percentage of fine sediment for each pool was averaged with all other pools in each sample reach. The Middle and Lower Big Hole TPA does not have adequate reference data to establish a target, but as discussed in Appendix B, the distribution of all data may be used to establish a target. Because E channels tend to naturally be higher in fine sediment, data for E channels were grouped separately from all other channel types. For all E channel data, the median percent of fines <6 mm in pool tail-outs was 19 percent and for all other channel types the median percent fines <6 mm in pool tail-outs was 14 percent. These percentages will be used as targets for a reach average of fine sediment <6 mm in pool tails.

It should be noted that watershed geology has a strong influence on substrate size distribution. For example, granitic watersheds often exhibit a natural bimodal size distribution. Several of the tributaries of the Middle and Lower Big Hole River listed as impaired due to sediment are located in watersheds with granitic geologies. These include Charcoal, Elkhorn, Fishtrap, Moose, and Willow Creeks. Therefore, watershed geology will be considered when evaluating the relationship between management actions and the percent of surface fine sediment.

Width/Depth Ratio and Entrenchment Ratio

The width/depth ratio and the entrenchment ratio are fundamental aspects of channel morphology and each provides a measure of channel stability, as well as an indication of the ability of a stream to transport and naturally sort sediment into a heterogeneous composition of fish habitat features (i.e. riffles, pools, and near bank zones). Changes in both the width/depth ratio and entrenchment ratio can be used as indicators of change in the relative balance between the sediment load and the transport capacity of the stream channel. As the width/depth ratio increases, streams become wider and shallower, suggesting an excess coarse sediment load (MacDonald et al. 1991). As sediment accumulates, the depth of the stream channel decreases, which is compensated for by an increase in channel width as the stream attempts to regain a balance between sediment load and transport capacity. Conversely, a decrease in the entrenchment ratio signifies a loss of access to the floodplain. Low entrenchment ratios signify that stream energy is concentrated in-channel during flood events versus having energy dissipation on the floodplain. Accelerated bank erosion and an increased sediment supply often accompany an increase in the width/depth ratio and/or a decrease in the entrenchment ratio (Knighton 1998, Rowe et al. 2003, Rosgen 1996).

Although, the 75th percentiles of entrenchment ratios for C and E channels in the Beaverhead Deerlodge reference dataset range from 3.7 to 15.9 (**Table 5-3**), they are not feasible targets as-is. If a C or E channel is meeting its potential and has an entrenchment ratio where it can adequately access its floodplain, additional channel stability is not gained by further increasing the entrenchment ratio. Therefore, it is not reasonable to set a target way above the threshold where the channel has adequate access to its floodplain. The target for each channel type will be set as the smallest entrenchment ratio from the Beaverhead Deerlodge reference data: B > 1.8, C > 5.1, and E > 3.7. A departure of the width/depth ratio and entrenchment ratio beyond the reference range for the appropriate stream type will be used as a water quality target for sediment impairments (**Table 5-3**).

Bank Erosion Hazard Index (BEHI)

Stream flow, sediment loads, riparian vegetation, and streambank material all influence bank stability, which, in turn, influences sediment contribution to the stream. The BEHI is a composite metric of streambank characteristics that affect overall bank integrity and is determined based on bank height, bankfull height, rooting depth, bank angle, surface protection, and bank materials/composition (Rosgen 1996). Measurements for each metric are combined to produce an overall score or “rating” of bank erosion potential. Low BEHI values indicate a low potential for bank erosion. A bank erosion hazard index beyond the reference range for the appropriate stream type will be used as a supplemental indicator for sediment impairments (**Table 5-3**).

The percent of eroding streambanks within a survey reach will be applied as a supplemental indicator for sediment impairments. Since streambank erosion is a natural process, this indicator will be used with caution. For example, just because eroding banks are present does not necessarily mean the erosion is human-induced or that there is an in-stream sediment problem. Additional information, such as observed bank trampling, removal of stabilizing vegetation, or increased water yield from timber harvest, will be considered. Departure from reference condition will apply when the percent of non-eroding banks within a survey reach is less than 85 percent for A, B, C and E type streams. These values are based on least impacted stream surveys in the Ruby Watershed, which, along with the Big Hole River and Beaverhead River, is one of the three forks of the Jefferson River.

5.4.1.2 Other Sediment Related Measures

Pool Frequency

Pool frequency is another indicator of sediment loading and dynamics that relates to changes in flow and channel geometry, but is an important component of a stream’s ability to support the fishery beneficial use. Sediment may limit pool habitat by filling in pools with fines. Alternatively, aggradation of larger particles may exceed the stream’s capacity to scour pools, thereby reducing the prevalence of this critical habitat feature.

Pool frequency in unaltered streams typically occurs on average at every 5-7 channel widths (Dunne and Leopold 1978, Rosgen 1996). Pool frequency can vary with channel type due to changes in gradient, topography, and bed material, however, and local or regional references reaches can help determine the most appropriate target value. Streams occupying higher gradient, confined reaches with boulder or bedrock substrate have less potential to scour pools than more meandering valley reaches with finer bed materials. The Middle and Lower Big Hole TPA does not have adequate reference data to establish a target, but as discussed in **Appendix B**, the distribution of all data may be used to establish a target. Data was not stratified for this target because the dominant substrate in reaches sampled on higher gradient streams (i.e. A and B channel types) in the dataset are similar to that in lower gradient streams, resulting in similar pool spacing. Despite the tendency to have higher fines and different pool spacing than other channel types, E channel data were not analyzed separately from other channel types because historic placer mining has disrupted pool spacing in many of the E channels. The median pool frequency for all channel types is 5.5 (n=43). This value is within the expected range of a pool every 5-7 channel widths. To control for variability in channel widths, these values are expressed as a function of the average number of median bankfull widths between pools. The bankfull width to pool frequency target will be equal to or less than 5.5.

Greenline Measurements

Interactions between the stream channel and the riparian vegetation along the streambanks are a vital component in the support of the beneficial uses of cold water fish and aquatic life. Riparian vegetation provides organic material used as food by aquatic organisms and supplies large woody debris that influences sediment storage and channel morphology. Vegetation helps stabilize streambanks and can provide shading, cover, and habitat for fish. During assessments conducted in 2005-2006, ground cover, understory vegetation, and overstory vegetation were cataloged at 10 foot intervals along the greenline at the bankfull channel margin along both sides of the stream channel for each survey reach. The percent of understory shrub cover is of particular interest in valley bottom streams historically dominated by willows and other riparian shrubs.

Although the Middle and Lower Big Hole TPA does not have adequate reference data to establish a supplemental indicator value, as discussed in Appendix B, the distribution of all data may be used. The median of all greenline data is 48 percent understory shrub cover and the 75th percentile is 74 percent. Given that the median understory shrub cover of reference reaches in the Upper Big Hole TPA ranges from 41-58 percent (DEQ 2008), a supplemental indicator of ≥ 48 percent understory shrub cover is reasonable for the Middle and Lower Big Hole TPA. The understory shrub cover will be applied in situations where riparian shrubs are a significant component of the streamside vegetation, such as in meadow areas. In some instances, understory shrub cover may be below the supplemental indicator value but herbaceous and wetland vegetation (i.e. groundcover) is dense with a tight root mass that stabilizes banks and filters out sediment from upland sources. Because some groundcover is more effective than others at providing soil stability (e.g. wetland or native vegetation vs. noxious weeds), there is no set value for groundcover but it may be used in conjunction with understory shrub cover to evaluate the riparian habitat. This supplemental indicator will not be applied in areas where dense conifer canopies and large substrate naturally limit the development of riparian shrubs.

Proper Functioning Conditions Assessments

The Proper Functioning Condition (PFC) method is a qualitative method for “assessing the physical functioning of riparian-wetland areas” (Prichard 1998). The hydrologic processes, riparian vegetation characteristics, and erosion/deposition capacities of streams were evaluated using the PFC method for each stream reach assessed in 2005-2006. Each reach was rated as being in “proper functioning condition” (PFC), “functional - at risk” (FAR), or “non-functioning” (NF). Based on these assessments, a supplemental indicator of either “proper functioning condition" or "functional – at risk" with an upward trend with the intent of attaining "proper functioning condition" is established for the Middle and Lower Big Hole TPA.

Macroinvertebrates

Siltation exerts a direct influence on benthic macroinvertebrates assemblages by limiting preferred habitat for some taxa by filling in spaces between gravel and by limiting attachment sites for other taxa that affix to substrate particles. Macroinvertebrate assemblages respond predictably to siltation with a shift in natural or expected taxa to a prevalence of sediment tolerant taxa over those that require clean gravel substrates. Macroinvertebrate bioassessments scores are an assessment of the macroinvertebrate assemblage at a site, and the DEQ uses two bioassessment methodologies to evaluate impairment condition and aquatic life beneficial use support.

The two macroinvertebrate assessment tools are the Multi-Metric Index (MMI) and the River Invertebrate Prediction and Classification System (RIVPACS). The rationale and methodology for both indices are presented in, "Biological Indicators of Stream Condition in Montana Using Benthic Macroinvertebrates," (Jessup et al., 2006). Unless noted otherwise, macroinvertebrate samples discussed within this document were collected according to DEQ protocols (Bukantis 1998; DEQ 2006c).

The MMI is organized based on different bioregions within Montana (e.g. Mountain, Low Valley, and Plains), and the Big Hole watershed falls within both Mountain and Low Valley MMI regions. The impairment thresholds are 63 and 48 for the mountain and low valley indices, respectively. These values are established as supplemental indicators for sediment impairments in the Middle and Lower Big Hole TPA. The RIVPACS model compares the taxa that are expected at a site under a variety of environmental conditions with the actual taxa that were found when the site was sampled and is expressed as a ratio of the Observed/Expected taxa (O/E value). The RIVPACS impairment threshold for all Montana streams is any O/E value <0.8. A RIVPAC score greater than 1.2 may indicate nutrient enrichment but is not indicative of impairment from other stressors. Therefore, a supplemental indicator value RIVPACS score of >0.80 is established for sediment impairments in the Middle and Lower Big Hole TPA.

Fish Population Dynamics

Information pertaining to fish species presence, general population trend data, and habitat quality will be used as supplemental sediment indicators for the Middle and Lower Big Hole River TPA. However, the fisheries information and quality ratings that are available will not be used as specific supplemental indicator variables.

Periphyton

Similarly to macroinvertebrates, increased sediment has a direct effect on composition and structure of periphyton communities. As a result of the predicted change in periphyton communities due to excess sediment, a metric has been developed for mountain/foothill streams and is applicable to the Middle and Lower Big Hole TPA (Tepley and Bahls 2007). The metric is based on percent abundance of diatoms, known as "increasers", which have a measurable increase in sediment rich environments and correspond to a probability of impairment. Unless noted otherwise, all periphyton samples discussed within this document were collected according to DEQ protocols (DEQ 1999). DEQ is currently working to develop a threshold value for this metric. The periphyton supplemental indicator will likely be modified in the future to reflect the threshold value, but at this time, the supplemental indicator will be a percent probability of impairment <40 percent.

Anthropogenic Sediment Sources

The presence of anthropogenic sediment sources does not always result in sediment impairment of a beneficial use. When there are no significant identified anthropogenic sources of sediment within the watershed of a 303(d)-listed steam, no TMDL will be prepared since Montana's narrative criteria for sediment cannot be exceeded in the absence of human causes. Human induced and natural sediment sources will be evaluated using recently collected data in comparison with the BDNF reference dataset, along with field observations and watershed scale source assessment information obtained using aerial imagery and GIS data layers. Source assessment analysis will be provided by 303(d)-listed water body in **Section 5.6**, with additional information in Appendices C, D, and E.

5.4.2 Existing Condition and Comparison to Water Quality Targets

This section includes existing data, a comparison of existing data to water quality targets and supplemental indicators, and a TMDL development determination for each 303(d) listed water body. All water bodies do not have data for all targets and supplemental indicators; all available relevant data are included in this section.

5.4.2.1 Big Hole River (middle segment)

The middle segment of the Big Hole River (MT41D001_020) was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, and low flow alterations on the 2006 303(d) List, which are forms of pollution commonly linked to sediment impairment. The Middle Big Hole River extends 43.8 miles from the confluence of Pintlar Creek downstream to the confluence with Divide Creek (**Figure A-2**).

Physical Condition and Sediment Sources

In addition to sediment and habitat monitoring conducted by DEQ in 2006, FWP and BLM have performed habitat assessments along the middle segment of the Big Hole River. FWP reported a wide degree of variability in habitat parameters in the Big Hole River from Pintlar Creek downstream to Deep Creek. Based on a 1994 survey, riffle habitat was least between Pintlar Creek and Toomey Creek, while pool habitat was least from Pintlar Creek downstream to York Gulch. No lateral scour pools were found from Pintlar Creek downstream to York Gulch or from Toomey Creek downstream to Fishtrap Creek. However, deep pools, runs and stable channel morphology along the Big Hole River between LaMarche Creek and Seymour Creek provide habitat for mature grayling (Magee and Lamothe 2003). Overall, pools in the Middle Big Hole TPA were generally described as low quality (Lamothe and Magee 2004). Overhanging vegetation has been found to be an indicator of Arctic grayling abundance, and the amount of overhanging vegetation in the 1994 survey was low throughout the study area; however, reaches with relatively high amounts of overhanging vegetation also had relatively high quality pools and lesser amounts of streambank erosion (Lamothe and Magee 2004).

The BLM conducted riparian assessments at twenty sites within grazing allotments over 3.5 miles along the middle Big Hole River between 1990 and 2002. 34 Percent of the surveyed stream length was "functional – at risk" or "nonfunctional". Impacts included heavy browsing of willows, poor willow regeneration and streambank failure associated with trampling.

The upper site monitored in 2006 (Middle Big Hole 1) was located upstream of the Mudd Creek Bridge in part of an Arctic grayling migration corridor (discussed below). This section had a low amount of woody vegetation, though riparian wetland vegetation and grasses covered 85 percent of the reach and provided bank stability. The streambanks appeared to have been trampled historically, and channel widening may have accompanied the loss of riparian vegetation. However, the wetland vegetation was trapping sediment and is likely building banks and narrowing the channel. The lower monitoring section (Middle Big Hole 2) was located downstream of the confluence with Deep Creek. This site was selected to represent the Big Hole River in areas where there was an extensive floodplain historically, much of which is now used for agriculture. This site is representative of the middle Big Hole River upstream of the confluence with the Wise River. There were several islands in this reach and it appeared that it would naturally be a multi-channel system. The main channel appeared over-widened and lacked habitat complexity, while the side channel along river right had a well-defined riffle-pool sequence. Riparian vegetation in the form of willows was denser in this monitoring section than the upper monitoring section, though only in a narrow band along the channel margin. Wetland vegetation and grasses comprised 83 percent of groundcover along the bankfull margin and limited streambank erosion, though road encroachment and an irrigation ditch along river left appeared to cause a shift in stream energy, causing some limited erosion.

Biological Data

Seven macroinvertebrate samples have been collected since 2002 and one periphyton sample was collected in 2003. These include samples by the Mudd Creek Bridge, Dickie Bridge and Jerry Creek Bridge from 2002 that were part of a larger study by the Big Hole River Foundation. The bioassessment scores are presented in **Table 5-5**. The Fishtrap sample was collected following USFS protocols, (Heitke et al. 2006) but all other samples were collected according to DEQ protocol. Habitat at the Dickie Bridge and Jerry Creek Bridge sites was rated as optimal, but the Mudd Creek Bridge site had the lowest habitat quality of all sites within that study due to limited riparian vegetation, bank erosion, excess fine sediment deposition, and extensive growths of macrophytes and filamentous algae. Overall, it was noted that habitat was optimal in the middle reach of the Big Hole River (McGuire 2003).

The entire length of the main stem of the Big Hole River is rated as having an outstanding fisheries resource value (MFISH 2004) and supports the last remaining strictly fluvial population of Arctic grayling in the continental United States. Although they are more common in the upper Big Hole River, Arctic grayling are rare year-round residents within the middle segment of the Big Hole River (MFISH 2004). An important Arctic grayling migration corridor extends from Pintlar Creek to Christiansens and is wide and shallow with few pools and a degraded riparian corridor (Magee and Lamothe 2003; J. Magee, pers. com. 2004). FWP has been monitoring the status of the Arctic grayling since 1991. In 1993, the Montana Fluvial Arctic Grayling Workgroup reported that grayling had been reduced to eight percent of their historical range and that populations had been reduced from 111 fish per mile in 1983 to 22-34 fish per mile in 1989-1991. Since that time, the age 1+ grayling population in several sections of the segment has ranged from 31-47 fish per mile between 1993 and 1996 to 73 in 1997, 46 (±33) in 1999, and 52 in 2002 (Magee and Byorth1996; Magee and Lamothe 2003). In 2003, the highest densities of Arctic grayling were found between Warm Springs Creek near the town of Jackson and Dickie Bridge, upstream of Wise River. Densities of Arctic grayling decreased downstream of Dickie Bridge, while brown trout and rainbow trout densities increased (Lamothe and Magee 2004). Forty-three age 1+ Arctic grayling were captured during spring spawning surveys conducted in seven reaches in 2003, with 74 percent of the fish age 3+ and 26 percent age 1 and age 2. Population monitoring conducted in the fall of 2003 found 502 Arctic grayling, of which 72 percent were young-of-the-year. Young-of-the-year grayling numbers have improved in recent years, though adult grayling numbers have remained at low levels (Magee and Lamothe 2003).

Westslope cutthroat trout do not typically inhabit the river but will move into the main stem of the Big Hole during good water years (R. Oswald, pers. comm. 2004). In 1989, the section of river between Jerry Creek and Dewey supported the largest population of rainbow trout within the entire main stem of the Big Hole River. The Jerry Creek section supported approximately 1,600 rainbow trout per mile in 2003, while the population was estimated at over 2,000 fish per mile in 2001. Peaks in rainbow trout population were associated with strong recruitment of cohorts of age 1 fish, which appears to be associated with moderate runoff peaks. The Big Hole River Drought Plan adopted in 1997 (and discussed in Section 2.2.3) has been identified as having a positive effect on the population of large rainbow trout.

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for the middle segment of the Big Hole are summarized in **Table 5-4** and **5-5**. All gray cells are above target or supplemental indicator thresholds.

Table 5-4. Middle Segment of the Big Hole River Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Middle Big Hole 1	24*	17*	97.1*	2.2	ND	ND	C4	C4	24.0	97.0	10	FAR
Middle Big Hole 2	16*	11*	86.1*	4.7	20.0*	1.2	C4	C4	19.9	95.0	39	FAR

ND = no data; *This value is included for informational purposes but will not be compared to a target because the applicable target was not derived using sufficient data for large rivers. Pebble count <6mm for this segment were based on a riffle pebble count.

Table 5-5. Biological Metrics for Middle Segment of the Big Hole River.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley MMI ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
EPA01-445	Near Fishtrap	unknown	Mountains	**48.7**	**0.48**
M03BGHLR01	Near Wise River	7/30/2003	Mountains	**61.1**	**0.46**
M03BGHLR01	Near Wise River	7/28/2004	Mountains	**53.5**	**0.57**
M03BGHLR01	Near Wise River	8/3/2005	Mountains	**55.4**	0.80
M03BGHLR19	Mudd Creek Bridge	8/29/2002	Mountains	**41.5**	**0.69**
M03BGHLR18	Dickie Bridge	8/29/2002	Mountains	**59.5**	1.03
M03BGHLR17	Jerry Creek Bridge	8/27/2002	Low Valley	65.1	0.95
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03BGHLR01	Near Wise River	7/30/2003	Mountains	<5%	

Summary and TMDL Development Determination
Median entrenchment ratios of 2.2 in the upper monitoring reach and 4.7 in the lower monitoring reach failed to meet the target of >5, suggesting slight channel entrenchment and a loss of access to the historic floodplain. Although no sediment targets were set for width/depth ratio in the main stem Big Hole River, the 2006 assessment notes indicated the upper reach was over widened. The upper reach was almost five times the target value for tributaries and the lower reach was slightly more than four times the target value for tributaries. Additionally, although there were no fine sediment targets for the main stem, as a larger system, it has the potential to transport larger bedload and would be expected to have fine sediment values less than the target for tributaries in the watershed. The upper reach is not far below the 6 mm target of 29 percent for tributary C4 channels and is above the 13 percent tributary target for sediment less than 2 mm. There were no pools in the upper reach, which is likely a function of the over-widened channel and flow alterations causing aggradation and also limiting the ability of the river to move large bedload and re-establish pools. Although the lower reach met the pool spacing target, the absence of pools in the upper reach supports the observations by FWP of low overall habitat quality and a lack of pools within upper portions of this segment.

Both monitoring reaches failed to meet the supplemental indicator for greenline shrubs, supporting the FWP, BLM, and DEQ observations of limited overhanging vegetation and willow recruitment that improves in a downstream direction. Despite limited riparian shrubs, the dense herbaceous and wetland groundcover seems to be limiting bank erosion; bank erosion and the percent of non-eroding banks were minimal and met the supplemental indicator value in both reaches. Both of these monitoring reaches were meeting their potential Rosgen channel type of C4 and were rated as “functional-at risk” based on the PFC methodology.

All but one macroinvertebrate sample failed to meet the MMI supplemental indicator value and four of the samples failed to meet the O/E supplemental indicator of 0.8. The biocriteria values disagree at the Dickie Bridge site, but because the O/E score is much greater than the threshold and the MMI score is close to the threshold, the O/E score should be weighted more heavily and indicates the macroinvertebrates are likely not impaired at that site (Feldman 2006). The low scores for both metrics at the Mudd Creek site support the observation of low habitat quality. Although young-of-the-year Arctic grayling numbers have increased in recent years, adult Arctic grayling numbers remain low.

Although there are no fine sediment and width/depth ratio targets for the main stem Big Hole River, the percentage of fine sediment and width/depth ratios are both greater than expected. The biggest limitation, however, is the lack of pool habitat. Although the middle segment was historically contained braided sections, it is now generally an over widened single channel. Additionally, sediment transport has likely been limited by becoming over widened and by flow alterations in the upper watershed (DEQ 2008), causing aggradation of large substrate and limiting the system's ability to scour pools. Although the periphyton samples and several of the macroinvertebrate samples do not indicate sediment impairment, samples near Fishtrap and the Mudd Creek Bridge suggest sediment-related effects to macroinvertebrates. The middle segment of the Big Hole River is an important corridor for Arctic grayling but its habitat value is limited by the lack of pools, which can be important areas for rearing and refugia. Although anthropogenic sources of grazing, roads, and irrigation along the main stem are limited by dense herbaceous riparian vegetation, this segment is receiving excess sediment from the Upper Big Hole watershed and contains 15 tributaries with sediment listings. Based on the anthropogenic sources in the watershed, changes in channel morphology, and sediment aggradation reducing pool frequency and limiting the river's ability to fully support fisheries and aquatic life, there is a link between sediment and the pollution listings from low flow and habitat alterations. A TMDL will be prepared for the middle segment of the Big Hole River.

5.4.2.2 Big Hole River (lower segment)

The lower segment of the Big Hole River was listed for physical substrate habitat alterations and low flow alterations on the 2006 303(d) List, which are forms of pollution commonly linked to sediment impairment. The lower Big Hole River extends 51.4 miles from Divide Creek to its mouth at the Jefferson River (**Figure A-2**).

Physical Condition and Sediment Sources

The lower Big Hole River is a dynamic river system in which the channel migrates across the floodplain eroding streambanks at the outside of meander bends and depositing point bars at the inside of meander bends. In many areas the river is naturally multi channeled. Only two major channel manipulations have reportedly occurred in the lower river. The first, near Melrose, involves a restoration project that was instituted to prevent the west channel from capturing the entire river and diverting it from the east channel. The restoration project resulted in 50 percent of the flow in each channel. The second project was conducted below Glen after the channel changed course during high water in 1995 and was left stranded behind a network of dikes. This three mile long restoration project re-established the flow in the main channel (R. Oswald, pers. com. 2004). In addition, smaller scale historic stabilization structures and irrigation diversions have been cited as causing a loss of fish habitat in the lower Big Hole River (FWP 1981).

In addition to DEQ monitoring in 2006, the BLM conducted riparian assessments at five sites within grazing allotments between 1995 and 2002. Three sites were rated as “proper functioning condition”, while two sites were rated as “functional – at risk”. The upper site sampled by DEQ in 2006 (Lower Big Hole 1) was located in a wide valley bottom upstream of Glen and downstream of the geologic constriction near Brown’s bridge and the I-15 crossing. The lower site sampled in 2006 (Lower Big Hole 2) was located downstream of the Notch Bottom fishing access site (FAS). Both sites had cottonwood regeneration on point bars, pole stage cottonwoods on the floodplain, and compound pools associated primarily with fallen cottonwoods. Also, at both sites streambank erosion at channel bends appeared mostly natural, but may have been influenced by historic grazing and the conversion of understory vegetation from shrubs to a thick herbaceous community dominated by reed canary grass. At the upper site, portions of the reach had mature willows and cottonwoods with some saplings but a limited shrub understory, indicating intensive historic grazing; however, that section was fenced off during the assessment, suggesting the riparian vegetation is recovering. Within the lower site, the riparian area extends across the valley floor, though grazing within the riparian zone beyond the fence is likely limiting the overall extent of the riparian vegetation. Overall, it appeared that the reaches were functioning naturally, with a loss of some middle aged riparian vegetation and floodplain connectively in some areas.

Biological Data

Seven macroinvertebrate samples have been collected since 2002 and one periphyton sample was collected in 2003. The bioassessment scores are presented in **Table 5-7**. The entire length of the main stem of the Big Hole River is rated as having an outstanding fisheries resource value (MFISH 2004), though dewatering during irrigation season is a serious threat to the fishery (MFWP 1989). Arctic grayling are rare year-round residents within the lower segment of the Big Hole River (MFISH 2004). Westslope cutthroat trout are not listed in the MFISH database, though they were described as extremely rare in 1989 (MFWP 1989). Arctic grayling and westslope cutthroat trout use large pools near Melrose as seasonal refuges during good streamflow years. In addition, whirling disease has been identified near Melrose, though no population level impacts to rainbow trout have been identified (R. Oswald, pers. com., 2004).

There are substantial populations of brown trout and rainbow trout in the lower segment of the Big Hole River. The estimated density of brown trout in 2003 was approximately 1,000 fish per mile in the Maiden Rock section, approximately 900 fish per mile in the Melrose section, and approximately 800 fish per mile in the Hog Back section. Rainbow trout density was estimated at over 500 fish per mile in the Melrose section in 2003. In contrast to rainbow trout, high spring runoffs do not appear to limit brown trout recruitment, though low flows and high water temperatures lead to declines in the brown trout population. Benefits of the Big Hole River Drought Management Plan adopted in 1997 (and discussed in **Section 2.2.3**) have been identified for the brown trout population in both the Maiden Rock and Melrose sections between 1999 and 2001. However, benefits were not observed in the Hog Back section, which was more severely impacted by elevated thermal regimes and lower streamflows than the upstream sections in 2001.

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for the lower segment of the Big Hole are summarized in **Tables 5-6** and **5-7**.

Table 5-6. Lower Segment of the Big Hole River Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Lower Big Hole 1	5*	3*	84.3 *	**1.7**	ND	2.5	C4	C4	19.7	85	50**	PFC
Lower Big Hole 2	6*	5*	65.3 *	**3.4**	ND	1.7	C4	C4	**34.3**	84	**41****	PFC

ND = no data; *This value is included for informational purposes but will not be compared to a target because the applicable target was not derived using sufficient data for large rivers. **The Lower Big Hole is dominated by cottonwood galleries but riparian shrubs are an expected component. Pebble count <6mm for this segment were based on a riffle pebble count.

Table 5-7. Macroinvertebrate Metrics for Lower Segment of the Big Hole River.
Bold text failed to meet the target (Low Valley ≥ 48, RIVPAC ≥ 0.80; Mtn Sediment Score≤ 0.260).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03BGHLR16	Maiden Rock	8/28/2002	Low Valley	72.4	0.95
M03BGHLR15	Kalsta Bridge	8/27/2002	Low Valley	56.7	1.26
M03BGHLR14	Notch Bottom	8/27/2002	Low Valley	49.5	0.88
M03BGHLR13	High Rd FAS	8/27/2002	Low Valley	69.1	0.88
M03BGHLR02	Near mouth	7/31/2003	Low Valley	84.8	1.01
M03BGHLR02	Near mouth	7/29/2004	Low Valley	75.1	1.26
M03BGHLR02	Near mouth	8/4/2005	Low Valley	77.2	1.01
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03BGHLR02	Near mouth	7/31/2003	Mountains/Foothill	<5%	

Summary and TMDL Development Determination
As with the middle segment of the Big Hole River, entrenchment ratios in the lower segment failed to meet the target, suggesting that access to the floodplain has been reduced. Although no sediment targets were set for width/depth ratio in the main stem Big Hole River, the median width/depth ratio for both reaches was three to four times the target value for tributaries.

However, higher W/D ratios are expected for a larger river. Both W/D measurements were less than in the middle segment (discussed in **5.4.2.2**) and the field notes did not mention the channel over widening in either reach. Although there were no fine sediment targets for the main stem, as a larger system, it has the potential to transport larger bedload and would be expected to have fine sediment values less than the target for tributaries in the watershed. The percent fine sediment <6mm and <2mm in both reaches are well below the target for tributaries, indicating fine sediment is not aggrading within this segment. Pool frequency was high at both monitoring locations. Pool habitat, fine sediment and stream channel geometry appear to be supportive of the fishery.

Streambank erosion in the upper reach met the supplemental indicator value for bank erosion while the lower reach exceeded the supplemental indicator value. The percent of reach with non-eroding banks was meeting the supplemental indicator value of ≥ 85 percent in the upper monitoring section, though it was slightly below the criteria in the lower monitoring section with a value of 84 percent. Field notes attributed streambank erosion to mostly natural sources. In the upper monitoring section, the percentage of deciduous shrubs in the understory met the supplemental indicator value, while the percent of shrubs was slightly below the supplemental indicator value in the lower reach. In addition, 32 percent of the upper monitoring section was lined with cottonwoods in the overstory, while 7 percent of the lower monitoring section was lined with cottonwoods in the overstory. However, groundcover of herbaceous and wetland vegetation covered 64 percent in upper reach and 84 percent in lower reach. Both of these monitoring sections were rated as “proper functioning condition” based on the PFC methodology.

All macroinvertebrate samples and the periphyton sample met the supplemental indicator values. Periphyton metrics were meeting supplemental indicator criteria. The BEHI score and the percent of eroding streambank failed to meet supplemental indicator criteria in the lower monitoring section, suggesting an increased sediment load from streambank sources. Re-establishment of cottonwoods on point bars indicates the system is healthy and natural processes have been maintained. The primary anthropogenic source of sediment within the lower Big Hole River watershed is rangeland grazing, though roads, silviculture, and irrigated agriculture are additional sources.

Overall, these results support that the lower segment of the Big Hole River is not fully supporting its beneficial uses due to habitat alterations or flow conditions, but the impairment from habitat and low flow does not appear to be linked to sediment impairment. Biological samples did not indicate impairment and good pool habitat was noted by both FWP and DEQ. There are no significant sediment sources along the main stem, and although the upper and middle segment of the Big Hole and 9 listed tributaries to the lower Big Hole are sources of excess sediment, they do not appear to be exceeding the supply or transport capacity of the lower Big Hole River. A TMDL will not be written for sediment for the lower segment of the Big Hole River. However, habitat BMPs recommended in the Restoration Strategy **Section 10.0** should be implemented to address the habitat impairment. Localized influences of aggradation near irrigation diversion structures and unnecessary rip rap should be addressed.

5.4.2.3 Birch Creek (upper segment)

The upper segment of Birch Creek (MT41D002_090) flows 12.8 miles from its headwaters to the National Forest boundary and was listed as impaired due to sedimentation/siltation on the 2006 303(d) List (**Figure A-2**).

Physical Condition and Sediment Sources
Land use activities within the Birch Creek watershed on National Forest lands include historic mining, timber harvest, livestock grazing, roads, and recreation. A large flood event resulting from a dam failure at Boot Lake prior to 1910 led to accelerated channel widening, bedload movement and deposition. The existing channel, which reformed within the deposited sediments, was described as stable with well-vegetated banks based on BDNF channel morphology surveys conducted in 1991 and 1994 (Bengeyfield 2004). However, sediment sources were cited including tributary streams, the Birch Creek Road, and bridge crossings constructed in the mid to late 1990s near Bridge Gulch and Armstrong Gulch. Additional morphological and habitat assessments were conducted at two reaches in 2005 by DEQ. The DEQ assessments also concluded that the channel had recovered from the historic dam failure; however, large “eroding banks” were observed where the stream had cut into the adjacent hillslopes. This condition suggests possible channel downcutting following the dam failure, potentially in combination with floodplain aggradation. The lower site was below a recently installed culvert; road fill within the floodplain was identified as lacking a floodplain drain and potentially being prone to failure. Additionally, road encroachment was observed along 14 percent of the lower monitoring reach as well as downstream of the section.

Biological Data
One macroinvertebrate and one periphyton sample was collected by DEQ in 2000. The bioassessment scores from those samples are presented in **Table 5-9**. Birch Creek has a moderate fisheries resource value (MFISH 2004). Fluctuating stream flows and inadequate in-stream cover have been identified as factors limiting trout populations (MFWP 1989). The abundance of westslope cutthroat trout is unknown within this segment.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for the upper segment of Birch Creek are summarized in **Tables 5-8** and **5-9**.

Table 5-8. Upper Segment of the Birch Creek Sediment Data Compared to Targets and Supplemental Indicators.
Shaded cells fail to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Birch 1 (USFS)	10	8	**28.1**	1.1	ND	ND	**B2c/B3c**	B3	ND	ND	ND	PFC
Birch 2 (USFS)	5	5	13.8	**1.5**	ND	ND	B3	B3	19.1	ND	ND	PFC
Birch 1 (DEQ)	3	4	15.3	1.8	**16**	2.8	B3a	B3a/ B3	**31.1**	92	70	FAR
Birch 2 (DEQ)	6	4	11.4	3.4	10	**9.2**	**C3b/B3**	B3	**33.5**	93	78	PFC

ND = no data

Table 5-9. Biological Metrics for the upper segment of Birch Creek.
Bold text failed fail to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03BRCHC06	USGS gage	7/19/2000	Mountains	70.7	1.01
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03BRCHC06	USGS gage	7/19/2000	Mountains/Foothill	5-10%	

Summary and TMDL Development Determination

During all assessments, the composite pebble count surface fines <6mm and riffle pebble count <2 mm remained below the target. The grid toss percent fines in pool tail-outs exceeded the target of ≤ 14 percent in upper DEQ reach (Birch 1) but met the target in the lower DEQ reach (Birch 2). The width/depth ratio exceeded the target in the upper USFS reach but was meeting the target at all other reaches. The pool spacing in the upper reach (Birch 1) met the target of 5.5 bankfull widths between pools but the lower reach (Birch 2) was almost double the target value, indicating a low number of pools in the lower reach. Field notes indicate the lower reach lacked well-defined pools and was a continuous riffle.

Streambank erosion in both DEQ reaches exceeded the supplemental indicator BEHI value but bank erosion at the lower USFS site (Birch 2) met the supplemental indicator value. This suggests an increased sediment load from streambank sources. Both DEQ reaches met the supplemental indicator value for percent non-eroding bank and percent greenline shrubs. The habitat at all but one site was rated as being in "proper functioning condition" and that site was rated as "functional-at risk". Both the macroinvertebrate and periphyton samples met the supplemental indicator value, suggesting aquatic life is not impaired.

The geology is naturally erosive and therefore the natural erosion rate can easily be accelerated by disturbance. The channel has mostly recovered from the 1910 dam failure, but channel widening and fine sediment accumulation has occurred in certain areas of the stream. Birch Creek is not attaining its potential stream type, both recently assessed reaches had an elevated risk of bank erosion, and recreational trails and roads are also contributing excess sediment. Additionally, although the biological data are not indicating impairment, failure to meet the pool tail fine sediment target, and pool spacing target indicates excess sediment is affecting pool habitat and could be limiting the cold water fishery and aquatic life beneficial use. This supports the 303(d) Listing and a sediment TMDL will be prepared for the upper segment of Birch Creek.

5.4.2.4 Birch Creek, Lower Segment

The lower segment of Birch Creek (MT41D002_100) extends 10.4 miles from the BDNF boundary to its confluence with the Big Hole River (**Figure A-2**). This segment was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, low flow alterations, other anthropogenic substrate alterations on the 2006 303(d) List, which are forms of pollution commonly linked to sediment impairment.

Physical Condition and Sediment Sources
DEQ performed a sediment and habitat assessment in 2005 along one reach within this segment. The reach was located just downstream of the I-15 crossing and had a remnant beaver dam perched above the floodplain, suggesting the channel incised after historic removal of beavers. There was dense algal growth on the substrate that precluded the assessment of fine sediment in pool tails. Descriptions of habitat conditions by FWP, the USFS, and DEQ indicate localized habitat degradation that increases in a downstream direction.

Biological Data
Macroinvertebrate samples were collected in 1994 and 2000, and a periphyton sample was collected in 2000. The bioassessment scores from those samples are presented in **Table 5-11**.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for the lower segment of Birch Creek are summarized in **Tables 5-10** and **5-11**.

Table 5-10. Lower Segment of Birch Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	**Riffle % <2mm**	**W/D Ratio**	**Entrenchment Ratio**	**Pool Tail % <6mm**	**Pool Spacing**	**Existing**	**Potential**	**BEHI**	**% Non-Eroding Bank**	**Greenline % Shrubs**	**Riparian Condition**
Birch 3	**15**	9	16.6	**2.2**	ND	**7.9**	**B3c/C3**	C3	**32.9**	89	62	FAR

ND = no data

Table 5-11. Biological Metrics for the lower segment of Birch Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
BKK027	Rd 801 crossing	8/15/1994	Mountains	67.4	1.04
M03BRCHC10	Upstream of Rd 311 crossing	7/19/2000	Low Valley	**44.0**	0.89
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03BRCHC10	Upstream of Rd 311 crossing	7/19/2000	Mountains/Foothill	<5%	

Summary and TMDL Development Determination
The composite pebble count surface fines <6mm slightly exceeded the target of ≤ 14 percent, but the riffle pebble count surface fines <2mm met the target. The width/depth ratio was within the target, but the entrenchment ratio of 2.2 failed to meet the target and is likely due to channel incisement after historic removal of beavers. The pool spacing was outside of the target range and pool grid toss was not performed because of dense algal cover on the streambed.

The channel type ranged from B3c to C3 and was not fully meeting its potential as a C3 channel. Streambank erosion failed to meet the supplemental indicator BEHI value, but the percent of reach with non-eroding banks met the supplemental indicator value. The reach also met the supplemental indicator value for percent understory shrubs. One macroinvertebrate sample failed to meet the MMI supplemental indicator value, but the O/E score for that sample was above the supplemental indicator value, suggesting non-impairment. The periphyton sample met the supplemental indicator value. This monitoring section was considered to be "functioning-at risk" based on the PFC methodology. The primary anthropogenic sources of sediment within the lower watershed are rangeland grazing and irrigated cropland, though roads are an additional source.

The channel has mostly recovered from the 1910 dam failure in the upper part of the watershed, and channel widening and fine sediment accumulation is localized to certain areas of the stream. Similar to the upper segment, the biological data are not indicating impairment, but Birch Creek is not attaining its potential stream type and it is not attaining fine sediment, and pool spacing targets. The geology is naturally erosive and therefore the background erosion rate can easily be accelerated by disturbance. The impairment from habitat alterations has accelerated the natural rate of erosion and is contributing excess sediment that is likely limiting fish and aquatic habitat. A sediment TMDL will be prepared for the lower segment of Birch Creek.

5.4.2.5 California Creek

California Creek was listed as impaired due to sedimentation/siltation and turbidity on the 2006 303(d) List. California Creek flows approximately 10.9 miles from its headwaters to its mouth at French Creek (tributary to the middle segment of the Big Hole) (**Figure A-2**). The majority of the California Creek drainage is within the Mt. Haggin Wildlife Management Area and the primary land use within this watershed is rangeland grazing.

Physical Condition and Sediment Sources

FWP reported toxic precipitates from the Anaconda Smelter, along with sheep grazing and fires, resulted in slow revegetation around Sugarloaf Mountain, while extensive timber harvest also occurred in this area in the late 1800's (MFWP 1989). An assessment conducted by DEQ in 1991 cited a loss of vegetation due to the Anaconda Smelter, natural erosiveness of Sugarloaf Mountain, timber harvest, grazing, and a poorly drained Forest Service road as sources of sediment.

The turbidity listing is based on total suspended solids (TSS) data from the early 1980s that was two times greater than in French Creek and five times greater than other streams in the Mt. Haggin area. The sources of turbidity identified in the DEQ assessment file are attributed to the natural and anthropogenic sediment sources in the watershed.

DEQ performed sediment and habitat assessments within two reaches along California Creek in 2006. The upper monitoring section (California 1) was located in a mountainous area that appeared to have been historically placer mined, while the lower monitoring section (California 2) was located in a valley bottom area that is currently used for rangeland grazing. The upper monitoring section was thought to be representative of much of the upper watershed, though placer mining impacts may be sporadically located along the stream. The stream type changed from E4 to B4c to F4 to G4c along the monitoring section, due to historic channel disturbance, with a potential stream type of E4. The lower monitoring section also had the potential of an E4 stream type, and it was at the potential at three out of five cross-sections, while two cross-sections were rated a C4 stream type. The lower monitoring section was representative of California Creek between the confluence with Sixmile Creek and the mouth, where California

Creek joins French Creek. The lower monitoring section was in a transitional zone where California Creek was changing from an E stream type to a C stream type.

Biological Data

Three macroinvertebrate and periphyton samples were collected in 2005. The bioassessment scores are presented in **Table 5-13**. The fisheries resource value of California Creek is moderate (MFISH 2004). FWP hypothesized that the relatively low numbers of trout may be related to sediment loading, high levels of arsenic and lead, or bank instability due to livestock grazing (MFWP 1989).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for California Creek are summarized in **Tables 5-12** and **5-13**.

Table 5-12. California Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
California 1	35	**16**	**8.8**	**2.1**	**21**	**9.0**	**E4/G4c/F4/B4c**	E4	**30.9**	95	52	FAR
California 2	15	11	**11.5**	15.6	9	3.5	E4/C4	E4	**29.4**	87	48	FAR

ND = no data

Table 5-13. Biological Metrics for California Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03CALC01	Hwy 274 Crossing	7/8/2005	Mountains	**56.9**	.81
M03CALC02	Near headwaters	7/7/2005	Mountains	**37.1**	**.41**
M03CALC03	Near mouth	7/12/2005	Mountains	**51.9**	**.72**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03CALC01	Hwy 274 Crossing	7/8/2005	Mountains	**80-90%**	
M03CALC02	Near headwaters	7/7/2005	Mountains	**40-50%**	
M03CALC03	Near mouth	7/12/2005	Mountains	**80-90%**	

Summary and TMDL Development Determination

During the 2006 assessment, the percent fine sediment targets for riffles and pool tails were exceeded in the upper reach (California 1), but all fine sediment targets were met in the lower reach (California 2). Field notes indicated that a loss of hillslope vegetation, which is likely due to arsenic deposition from the Anaconda Smelter, might lead to increased sediment loads from the California Creek watershed. In the upper monitoring section (California 1), a median width/depth ratio of 8.8 exceeded the target of 7 for E4 stream types, while a median entrenchment ratio of 2.1 failed to meet the target of >5. Over-widened and entrenched channel conditions in this reach were the result of historic placer mining, though the channel appeared to be in a state of recovery. The pool spacing target was exceeded in the upper reach (California 1), which is likely a combination of increased fine sediment loading and altered bed morphology from placer mining. A median width/depth ratio of 11.5 was exceeding the target of 7.0 for E4 stream types in the lower monitoring section (California 2), while a median entrenchment ratio of 15.6 was meeting the target criteria. Livestock grazing, which has lead to a decrease in riparian vegetation density, appeared to be the source of channel over-widening in the lower monitoring section (California 2).

Streambank erosion in both monitoring sections exceeded the supplemental indicator BEHI value. The percent of reach with non-eroding banks was meeting the supplemental indicator value of ≥ 85 percent, though there was a greater amount of streambank erosion in the lower monitoring section (California 2). Both monitoring reaches met the supplemental indicator value for riparian shrubs. Riparian conditions appeared to be improving in the upper monitoring section as woody vegetation re-colonizes historic placer tailings. In the lower monitoring section, field notes indicated that streambank erosion was closely correlated with areas lacking woody riparian vegetation. Both of these monitoring sections were rated as “functional-at risk” based on the PFC methodology.

All MMI scores were below the threshold of 63, and all the RIVPAC scores, but the site near the Highway 274 crossing (M03CALC01), were below the threshold of 0.80. These results indicate impairment of the macroinvertebrate community. The probability of impairment for periphyton indicated impairment from sediment at all three sites.

These results indicate that historical placer mining, upland vegetation impacts due to smelter fallout, and rangeland grazing in the riparian area have contributed to high width/depth ratios, slightly elevated levels of fine sediment, increased bank erosion, and an impaired aquatic community. These conditions limit fish habitat and likely affect spawning and rearing success. Although the low percentage of eroding banks and improving riparian vegetation in the upper reach suggest California Creek is recovering, these findings support the 303(d) sediment listing. A sediment TMDL will be prepared for California Creek.

5.4.2.6 Camp Creek

Camp Creek flows 14.3 miles from its headwaters to its confluence with the Big Hole River and was listed as impaired due to sedimentation/siltation on the 2006 303(d) List (**Figure A-2**). A small irrigation reservoir is located at stream mile 3.8 from the mouth.

Physical Condition and Sediment Sources
Several agencies have performed assessments of Camp Creek, including the BDNF, BLM, and DEQ. DEQ monitoring was performed in 2003 as part of the 303(d) assessment process and in 2005/2006 to facilitate the development of this TMDL. Data from that monitoring are presented in Table 5-14. The BDNF described the Camp Creek watershed as highly sensitive to erosion, especially on the southwest slope of Red Mountain (Bengeyfield 2004). Road encroachment of the channel was noted as well as a resulting straightening and steepening of the lower main stem of Camp Creek and some of the tributaries. Livestock trampling and grazing was identified as contributing to streambank instability and sediment load. Overall, Camp Creek on National Forest lands was described as an unstable riffle dominated G4 stream type entrenched in alluvium (Bengeyfield 2004).

The BLM assessed two sites in 1995 and three sites in 2003 within the Camp Creek grazing allotment along Camp Creek. Three of the sites were determined to be in “proper functioning condition” and the other two sites were rated as “functional – at risk”. Riparian vegetation impacts were related to the amount of decadent woody vegetation, utilization of trees and shrubs, shrub and tree regeneration, and the presence of undesirable herbaceous species. Impacts to streambanks due to both grazing and placer mining were noted. Beaver dams were noted at one site. DEQ assessment summaries from 2003 indicated pools were mostly shallow and filled with fine sediments, which also covered potential spawning gravels. Increasing lateral bank erosion was noted and attributed to removal of riparian vegetation, streambank trampling, and the presence of noxious weeds. A two-track road paralleling the stream was also noted as a sediment source. A lack of younger age classes was observed in the riparian woody vegetation communities.

Two monitoring section assessments were performed along Camp Creek in 2005 and 2006. The upper monitoring section (Camp 2) was located approximately 4 miles upstream of a reservoir created by an earthen dam. This monitoring section is representative of Camp Creek between Wickiup Creek and the reservoir. Dense riparian vegetation lined much of the stream between the reservoir and the monitoring section, but road encroachment was observed along a significant portion of the stream. Livestock grazing was causing channel over-widening in areas where the vegetation was less dense. The lower monitoring section (Camp 1) was located downstream of the reservoir and represents Camp Creek between the reservoir and the I-15 crossing; assessment notes mentioned that water in this reach is mostly irrigation return flow from the Big Hole River. Directly upstream and downstream of the I-15 crossing, Camp Creek flows through an irrigated area and is intercepted by a ditch that then flows into the Big Hole River. It appeared that the channel in the lower reach had historically been over widened but was transitioning towards its potential and becoming re-established within an entrenched flood-prone area. During sampling in 2005, the naturally erosive nature of the drainage was observed when a substantial amount of sediment was transported from ephemeral tributaries downstream of the reservoir during an episodic event and deposited in riparian vegetation and the channel.

Biological Data

Three macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-15**. The fisheries resource value is rated as substantial in Camp Creek downstream of Wickiup Creek and moderate further upstream (MFISH 2004). While Camp Creek is not currently considered to be supporting a population of westslope cutthroat trout, they were historically in the creek (MFWP 1989).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Camp Creek are summarized in **Tables 5-14** and **5-15**.

Table 5-14. Camp Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	**Targets**						**Supplemental Indicators**					
	Pebble Count		**Cross Section**		**Grid Toss**		**Rosgen Level II**		**BEHI**			
	Reach % <6mm	**Riffle % <2mm**	**W/D Ratio**	**Entrenchment Ratio**	**Pool Tail % <6mm**	**Pool Spacing**	**Existing**	**Potential**	**BEHI**	**% Non-Eroding Bank**	**Greenline % Shrubs**	**Riparian Condition**
M03CA MPC01	**72**	**58**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M03CA MPC02	**68**	**58**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M03CA MPC03	**40**	**35**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Camp 1	**41**	**18**	18.8	**2.0**	**66**	**5.8**	**B4c/F4/C4**	C4	**36.5**	89	76	FAR
Camp 2	**39**	**20**	17.0	**1.5**	**37**	**6.2**	**B4c/F4/C4**	B4c	31.5	89	51	FAR

ND = no data

Table 5-15. Biological Metrics for Camp Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03CAMPC01	Near mouth	9/14/2003	Low Valley	**38.4**	0.96
M03CAMPC02	2 miles east of I-15	9/15/2003	Low Valley	**46.7**	1.00
M03CAMPC03	1.4 miles upstream of Wickiup Creek	9/15/2003	Mountains	71.2	0.81
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03CAMPC01	Near mouth	9/14/2003	Mountains	20-30%	
M03CAMPC02	2 miles east of I-15	9/15/2003	Mountains	**40-50%**	
M03CAMPC03	1.4 miles upstream of Wickiup Creek	9/15/2003	Mountains	**>95%**	

Summary and TMDL Development Determination
Percent fine targets for riffles, the reach, and the pool tails were exceeded in all reaches. Both width/depth ratios were meeting the target; however, reaches recently assessed were not meeting

the entrenchment target and are moderately entrenched. Streambank erosion in Camp 1 was exceeding the supplemental indicator BEHI value, while the BEHI supplemental indicator was met in Camp 2. The percent of reach with non-eroding banks and the percent greenline shrubs were meeting the supplemental indicator values in both reaches. Both of these monitoring sections were rated as "functional-at risk" based on the PFC methodology.

Two of the macroinvertebrate samples did not meet the MMI supplemental indicator value, but in both instances, the RIVPAC score was well above the threshold. Therefore, the macroinvertebrate samples indicate sediment is not impairing the macroinvertebrate community. However, two of the three periphyton scores indicate that sediment is most likely impairing periphyton in Camp Creek.

Increases in the percent surface fines suggest an increased sediment supply. The elevated BEHI score in the lower monitoring reach (Camp 1) suggests an increased sediment load from streambank sources. The macroinvertebrate and periphyton scores indicate Camp Creek is not fully supporting aquatic life. In addition to limiting aquatic life, the excess sediment in riffles and pools and lack of pool habitat is likely limiting the fishery use and affecting spawning and rearing success. Camp Creek appears to have a large natural sediment load but rangeland grazing, roads, and irrigated agriculture are also sources of sediment. These results support the 303(d) sediment listing and a sediment TMDL will be developed for Camp Creek.

5.4.2.7 Canyon Creek

Canyon Creek was listed for low flow alterations and was not assessed for cold water fishery and aquatic life beneficial use support on the 2006 303(d) List. Canyon Creek flows 17.8 miles from its headwaters to its confluence with the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
The Beaverhead-Deerlodge National Forest performed channel morphology surveys at three sites on Canyon Creek in 1994. The stream was described as a well-functioning B3c with vigorous riparian vegetation for about 5 miles upstream the National Forest boundary (Canyon Up), while the channel was an entrenched "non-functional" G3c in the vicinity of the charcoal kilns (Canyon Down), which was likely a remnant of historic mining.

DEQ performed a sediment and habitat assessment along one reach in 2005. The site, Canyon 1, was located just downstream of the abandoned charcoal kilns and near the USFS Canyon Down site. The G3c conditions observed in 1994 were not observed during the assessment. Instead, the existing stream type ranged from C4 to E4, with a C4 potential stream type. In the current state, the monitoring section may represent reference conditions for streams flowing through mountain meadows in which the new potential following the removal of beavers is a C4 stream type. Limited road encroachment was observed at the lower end of the site as well as minor grazing impacts. A forest road that parallels Canyon Creek in the lower portion of the watershed includes several stream fords is likely a sediment source.

Biological Data

Macroinvertebrate samples were collected by DEQ at two sites on Canyon Creek in 2005. The bioassessment scores are presented in **Table 5-17**. The fisheries resource value is rated as substantial in Canyon Creek downstream of Vipond Creek and moderate further upstream (MFISH 2004).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Canyon Creek Creek are summarized in **Tables 5-16** and **5-17**.

Table 5-16. Canyon Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding	Greenline % Shrubs	Riparian Condition
Canyon Dn (USFS)	6	3	8.8	**1.1**	ND	ND	**G3c**	B3c	ND	ND	ND	**NF**
Canyon Mid (USFS)	13	13	**25.9**	**3.1**	ND	ND	C4	C4	ND	ND	ND	FAR
494BCanyon Up (USFS)	13	8	9.1	**1.6**	ND	ND	B3c	B3c	ND	ND	ND	PFC
Canyon 1	11	9	12.9	8.2	13	**5.3**	C4/E4	C4	25.0	86	76	PFC

ND = no data

Table 5-17. Biological Metrics for Canyon Creek.

Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley MMI ≥ 48, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03CNYNC01	USFS land near Trusty Gulch	Mountains	7/20/2005	70.2	1.02
M03CNYNC02	Near mouth	Low Valley	7/20/2005	70.2	0.86

Summary and TMDL Development Determination

All sites met the reach and riffle fine sediment target and the DEQ reach met the fine sediment target for pool tails. One of the USFS sites (Canyon Mid) exceeded the target for width/depth ratio and three of the four sites failed to meet the entrenchment ratio target. The DEQ reach (Canyon 1) was just below the pool spacing target but field notes indicated a well developed riffle-pool sequence.

The USFS site near the charcoal kilns (Canyon Down) failed to meet its potential Rosgen channel type, but was located near the DEQ assessment reach, which is transitioning toward its potential. The DEQ reach (Canyon 1) met the supplemental indicator value for BEHI, percent non-eroding bank, and percent understory shrubs. As this site was near the Canyon Down site, which was the only site rated as "non-functioning" for riparian condition, this indicates the riparian vegetation in that portion of Canyon Creek has recovered. Both macroinvertebrate samples met the supplemental indicator value for both indices, indicating support of aquatic life. The primary anthropogenic sources of sediment are rangeland grazing, roads, and timber harvest.

The assessment data indicate Canyon Creek does not have an excess sediment supply and is not transport limited. Although the channel is more entrenched than reference, the stream is meeting and/or transitioning to its potential channel type. The system is recovering from localized impacts associated with the charcoal kilns. Anthropogenic sediment sources are not significant and do not appear to be limiting aquatic life. Additional monitoring and a formal 303(d) assessment of all beneficial uses should be conducted in the future, but existing data indicate there is not a sediment impairment and a sediment TMDL will not be developed for Canyon Creek.

5.4.2.8 Charcoal Creek

Charcoal Creek flows 3.8 miles from its headwaters to its confluence with the Big Hole River (**Figure A-2**) and was listed as impaired due to sedimentation/siltation on the 2006 303(d) List.

Physical Condition and Sediment Sources
Recent sampling has occurred on Charcoal Creek by DEQ during 303(d) assessments and by the USFS. The BDNF described Charcoal Creek as a "functioning" E5b channel with 62 percent of the substrate finer than 6mm at one survey site located about 0.25 miles upstream of the National Forest boundary along the south face of the Fleecer Mountains. The survey reach was characterized by highly stable banks lined with sedge and willow. Infilling of old beaver ponds by sedge communities has lead to an E-type stream in an otherwise steep valley bottom (Salo 2004, Bengeyfield 2004). In general, the DEQ assessments noted Charcoal Creek has large sand deposits, both above and below the mouth of Charcoal Gulch. At both DEQ sites, there was considerable deposition of fine sediment in pools. An unpaved road parallels Charcoal Creek and encroaches on the creek in several places, particularly in the lower part of the watershed. There were frequent areas of clean gravels but also a fair amount of embeddedness, particularly in the lower reach. Streambank stability was noted to be high with little to no bank erosion, and the riparian vegetation was dense and near its potential. Overall, trout habitat was noted to be good in both reaches with an abundance of pool types and habitat created by woody debris, overhanging vegetation, and undercut banks. Minor pugging and old mines were observed in the upper reach and no evidence of recent grazing was seen on the lower reach. The assessment also noted that there is probably a high natural sediment load to Charcoal Creek because of the granitic geology.

Biological Data

One macroinvertebrate and periphyton sample was collected in 2003 and two macroinvertebrate samples were collected in 2004. The bioassessment scores are presented in **Table 5-19**.

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Charcoal Creek are summarized in **Tables 5-18** and **5-19**. Several parameters do not have quantitative data because no reaches were assessed in 2005/2006 and these results are from DEQ assessments in 2003.

Table 5-18. Charcoal Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
M03CHARC 02	**34**	**21**	ND	ND	ND	ND	B4	B4	ND	ND	ND	ND
M03CHARC 01	**63**	**36**	3.0	10.7	ND	ND	E4	E4	ND	ND	ND	ND

ND = no data

Table 5-19. Biological Metrics for Charcoal Creek.

Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03CHARC02	1 mile below headwaters	Mountains	6/15/2004	**60.3**	0.93
M03CHARC01	1/3 mile above the mouth	Mountains	6/15/2004	65.1	**0.78**
M03CHRGC01	Charcoal Gulch Creek	Mountains	7/23/2003	**52.5**	**0.66**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03CHRGC01	Charcoal Gulch Creek	7/23/2003	Mountains	**>95%**	

Summary and TMDL Development Determination
Both reaches assessed in 2003 exceeded the percent fines targets. However, the background fine sediment load to Charcoal Creek may be higher than the median of reference sites in the BDNF because of the granitic geology and historic beaver activity in the watershed. The only site with a measured width/depth ratio and entrenchment ratio was meeting the targets. Both sites were meeting their potential for Rosgen channel type. The MMI and RIVPAC scores exceeded the supplemental indicator values at two of the three sites. Because the value furthest from the threshold receives more weight when MMI and RIVPAC scores disagree (Feldman 2006), the results indicate the macroinvertebrates are not impaired at the headwater site but are impaired at the other two sites. The single periphyton sample indicates impairment.

On both reaches assessed in 2003, bank erosion was limited, riparian vegetation was near its potential, fish habitat was in good condition, and anthropogenic sources appeared minor. Although the biological supplemental indicators were not met, site assessment notes indicate elevated fine sediment is likely naturally occurring. No sediment TMDL will be prepared for Charcoal Creek at this time and additional monitoring is recommended to evaluate the extent of naturally occurring fine sediment, the significance of anthropogenic sources, and impacts to beneficial uses.

5.4.2.9 Corral Creek

Corral Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Corral Creek flows 5.1 miles from its headwaters to its confluence with Deep Creek, a tributary to the middle segment of the Big Hole River (**Figure A-2**). The primary land use within this watershed is rangeland grazing and silviculture, with the lower portion of the Corral Creek watershed situated within the Mt. Haggin Wildlife Management Area.

Physical Condition and Sediment Sources
Timber harvest along the upper reaches of Corral Creek and streambank erosion due to livestock grazing along the lower reaches were cited as a potential source of sediment by FWP (MFWP 1989). DEQ visited two sites as part of 303(d) assessments in 2001. One site was in the BDNF upstream of Road 2483 (M03CORLC01) and the other site was below the road (M03CORLC04). The upper section had good riparian vegetation with diversity of age classes and very little bank erosion or fine sediment in the channel. Large woody debris was abundant in the channel and the riparian condition at the site was rated as being in "proper functioning condition." In the lower monitoring section, streambank failure was common, as well as lots of fine sediment in pools, and the channel had historically been over-widened. Riparian vegetation in the lower section had poor vigor, and mature willows were dead or dying. Effects from timber harvest were noted, including upland erosion. The riparian condition at the lower site was rated as "not functioning."

DEQ performed two assessments along Corral Creek in 2006. The upper monitoring section (Corral 1) was located in a forested area where a clear-cut in 1980 and additional thinning throughout the 1990's took place on the hillslope along river left. This monitoring section appeared to be representative of the forested portion of Corral Creek upstream of the Dry Creek Road crossing. Within the upper monitoring section, hillslope erosion led to a small plume of sediment entering the channel, which appeared to be the result of either an old road paralleling the stream and/or timber harvest. This is a steep mountain channel with varying amounts of confinement that appeared to be the result of natural conditions. The lower monitoring section (Corral 2) was located in a willow-dominated valley bottom area that is currently used for rangeland grazing. Evidence of grazing was most apparent in areas with easy access (e.g. less dense willows, former road crossings, and no beaver activity). This monitoring section is representative of Corral Creek downstream of the Dry Creek road crossing. Corral Creek has become over-widened and entrenched. Extensive beaver complexes within this area also influence stream channel characteristics. During the site visit in 2006, it appeared that land use activities surrounding the lower monitoring section were more intensive historically.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2001. The bioassessment scores are presented in **Table 5-21**. The fisheries resource value of Corral Creek is moderate (MFISH 2004) and supports a good fishery for a stream of its size (MFWP 1989). While Corral Creek supports a population of westslope cutthroat trout, overall abundance is unknown (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Corral Creek are summarized in **Tables 5-20** and **5-21**.

Table 5-20. Corral Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Corral 1	**32**	14	5.6	2.0*	14	**5.6**	**E4a/B4a/A4**	A4	**39.3**	98	6**	FAR
Corral 2	29	**27**	**9.5**	**2.2**	16	**9.1**	**B4c/F4/C4/G4**	E4	**29.0**	89	**32**	FAR

ND = no data; *No entrenchment target for A stream types. **No supplemental indicator applied in areas with predominately coniferous vegetation

Table 5-21. Biological Metrics for Corral Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03CORLC01	Upstream of Rd 2483	7/10/2001	Mountains	74.5	0.93
M03CORLC04	Downstream of Rd 2483	7/10/2001	Mountains	63.2	**0.62**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03CORLC01	Upstream of Rd 2483	7/10/2001	Mountains	**60-70%**	
M03CORLC04	Downstream of Rd 2483	7/10/2001	Mountains	**70-80%**	

Summary and TMDL Development Determination
During the 2006 assessment, the reach percent fines exceeded the <6mm target criteria in the upper monitoring section (Corral 1), while the riffle percent fines exceeded the target in the lower monitoring section (Corral 2). The exceedance in Corral 1 is likely related to the upland sediment erosion noted during the field assessment. The target for fine sediment in pool tails was met in both reaches. The target for width/depth ratio was met at Corral 1, but was exceeded at Corral 2. Entrenchment was below the target for Corral 2, indicating a reduction in access to the floodplain and an increase in energy within the channel during high flow events. At Corral 2, channel over-widening and entrenchment appeared to be the result of stream crossings and a loss of riparian vegetation. The pool spacing target was exceeded in both reaches, although the Corral 1 was just over the target. This indicates pool habitat becomes much more limited in the lower segment of Corral Creek.

Streambank erosion in both monitoring sections exceeded the supplemental indicator BEHI value. Both reaches met the supplemental indicator value for non-eroding banks, though there was a greater amount of streambank erosion in the lower monitoring section. Due to the coniferous canopy in the upper reach, it was not compared to the supplemental indicator value. However, the lower reach did not have a coniferous overstory, yet failed to meet the supplemental indicator value for shrub cover. This reduction in riparian vegetation appeared to be the result of livestock grazing. Both of these monitoring sections did not meet their potential Rosgen channel type and the riparian habitat was rated as "functional-at risk". The RIVPAC score at the lower site (M03CORLC04) failed to meet the supplemental indicator value and indicates an impaired macroinvertebrate community at that site. Both periphyton samples indicate sediment impairment.

These results indicate an increased sediment supply and a decreased capacity to transport sediment, particularly in the lower part of Corral Creek. In addition to an impaired macroinvertebrate and periphyton community, excess fine sediment, a widened channel, and decreased pools and riparian understory is likely limiting the fisheries habitat and spawning and rearing success. The primary anthropogenic sources of sediment within the watershed include rangeland grazing, roads, and timber harvest. This information supports the 303(d) listing and a sediment TMDL will be completed for Corral Creek.

5.4.2.10 Deep Creek

Deep Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Deep Creek begins at the confluence of Sevenmile Creek and Tenmile Creek and flows 7.9 miles before its confluence with the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
There is a long history of timber harvest within the Deep Creek watershed, including the following tributaries that have appeared on the 303(d) List as impaired due to sediment: California Creek, Corral Creek, Sixmile Creek, Sevenmile Creek and Twelvemile Creek. Lands in this area were once owned by the USFS, but were transferred to the Anaconda Copper Company when smelter emissions led to tree mortality. The land was then transferred to the State and is now largely within the Mt. Haggin Wildlife Management Area. However, Louisiana-Pacific maintained a logging contract and performed extensive timber harvest into the 1990's. In addition, the Mt. Haggin Livestock Company holds a grazing lease within the Mt. Haggin Wildlife Management Area (MFWP 1989).

Stream restoration projects have been conducted along Deep Creek to enhance spawning and improve riparian vegetation. A post-restoration report indicated that medium to coarse gravels continued to dominate the reach, and pebble count data indicated a slight increase in gravel size since the completion of the project. Streambank erosion was occurring on 23 percent of the sites, which was 59 percent less than pre-project levels. Stream channel cross-section surveys indicated minor channel incision and minor widening, with a Rosgen C type channel remaining at all but one cross-section (Hydrotech 2001). More recently, stream habitat improvement projects conducted in the summer of 2003 included revegetation of riparian areas and fencing of streambanks along Deep Creek (Magee and Lamothe 2003). A portion of this project was observed at the downstream end of the lower monitoring section during the site visit in 2005.

In 2005, two monitoring sections were assessed by DEQ along Deep Creek. Both monitoring sections were located in a willow-dominated meadow through which the entire main stem of Deep Creek flows. The upper monitoring section (Deep 1) was located within the Mt. Haggin Wildlife Management Area. This monitoring section was located downstream of a former roadbed, which confines the channel to a single thread. Upstream of the roadbed, the channel contained three distinct threads due to the presence of beaver dams, with a small E channel, a small C channel and a larger C channel. Recently installed riparian fencing along the reach may preclude grazing from this site, though grazing upstream of the old road crossing was observed. This monitoring section is representative of Deep Creek upstream of the French Creek confluence. The lower monitoring section (Deep 2) was located in the lower mile of Deep Creek, approximately mid-way between Conner Gulch and the confluence with the Big Hole River and downstream of the French Creek confluence. This monitoring section is representative of Deep Creek downstream of the French Creek confluence.

Biological Data

One macroinvertebrate and periphyton sample was collected in 2001. The bioassessment scores are presented in **Table 5-23**. Arctic grayling are common in Deep Creek, which provides crucial winter habitat. The fisheries resource value of Deep Creek is outstanding downstream of the French Creek confluence and substantial further upstream (MFISH 2004). The lower two miles of Deep Creek provide spawning habitat for rainbow trout (MFWP 1989). Hatchery cutthroat trout were reportedly planted in Deep Creek between 1928 and 1954, while rainbow trout were stocked annually between 1958 and 1966. According to the Montana Rivers Information System, there were 50 grayling, 392 cutthroat trout, 392 brook trout, and 397 rainbow trout captured in Deep Creek in 1987. While Deep Creek contains a large population of brook trout, Magee and Byorth (1998) found the preferred microhabitat of Arctic grayling and brook trout differed sufficiently to minimize competitive interactions. In general, Arctic grayling were found higher in the water column and in areas of faster velocities, higher focal point elevations, and greater distance from cover than brook trout. It also was observed that Arctic grayling primarily relied upon depth and turbulence for cover (Magee and Byorth1998). In 2002, twelve Arctic grayling were captured in Deep Creek and the population was estimated at 7 Arctic grayling per mile (Magee and Lamothe 2003).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Deep Creek are summarized in **Tables 5-22** and **5-23**.

Table 5-22. Deep Creek Sediment Data Compared to Targets and Supplemental Indicators
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Deep 1	20	4	**15.7**	12.2	15	3.9	**C4/E4**	E4	**29.0**	**81**	65	FAR
Deep 2	18	10	**24.4**	**2.9**	**17**	4.4	**C4/B4c**	C4	**36.2**	**77**	**42**	FAR

ND = no data

Table 5-23. Biological Metrics for Deep Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03DEEPC02	Rd crossing on State land	7/11/2001	Mountains	67.8	**0.56**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03DEEPC02	Rd crossing on State land	7/11/2001	Mountains	>**95%**	

Summary and TMDL Development Determination
During the 2005 assessment, the reach and riffle fine sediment at both reaches met the target. The upper segment (Deep 1) met the pool tail target, but the lower segment (Deep 2) exceeded the target. Both reaches exceeded the target for width/depth ratio and Deep 2 did not meet the entrenchment target, indicating slight incision and a loss of access to the floodplain. Road encroachment in the vicinity of Conner Gulch may be partially responsible for the loss in floodplain access along the lower monitoring section. In both monitoring sections, transverse gravel bars oriented at an approximately 45º angle to the flow accompanied channel over-widening and suggested a loss of sinuosity. The gravel bars direct the thalweg into the eroding banks. Loss of sinuosity could be related to road encroachment upstream and an increase in stream power within the monitoring reaches. Both reaches met the pool spacing target and some very deep pools were seen in the lower reach.

Streambank erosion in both reaches did not meet both the BEHI and percent non-eroding the supplemental indicator value. Extensive streambank erosion along the lower monitoring section (Deep 2) appeared to be the result of livestock grazing, though a riparian fencing project was underway downstream of this reach during the site visit in 2005. The upper reach (Deep 1) met the percent shrubs supplemental indicator value of 48 percent, but the downstream reach was slightly below it. Additionally, the lower reach had 41 percent bare ground compared with 10 percent in the upper reach. Although the MMI score was above the supplemental indicator value, the RIVPAC score was well below the threshold, indicating macroinvertebrate impairment. The periphyton sample indicated close to 100 percent probability of impairment to the periphyton community. Channel types Deep 1 ranged from C4 to E4 because of increased width to depth ratios but the entire reach had the potential to be E4. Portions of Deep 2 have become slightly entrenched, causing the reach to be partially a B4c stream type when its potential is C4. Both of the monitoring sections were rated as "functional-at risk" based on the PFC methodology.

The high width/depth ratios, elevated percent surface fines in pool tail-outs in the lower reach, and high rates of erosion suggest a decrease in sediment transport capacity and an increased sediment supply. The data also indicate excess sediment is impairing aquatic life. Excess sediment in pools could decrease available spawning habitat and could also reduce pool depth, which is an important type of cover for Arctic grayling. The primary anthropogenic sources of sediment within the watershed are rangeland grazing, historic timber harvest, and the road network associated with logging. The assessments support the 303(d) listing and a sediment TMDL will be prepared for Deep Creek.

5.4.2.11 Delano Creek

Delano Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Delano Creek flows 2.3 miles from its headwaters to its mouth at Jerry Creek, a tributary to the middle segment of the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
Sediment assessments along Delano Creek include two channel morphology surveys conducted by the BDNF in 1999, which were located above and below a timber harvest (Delano Up and Delano Down). In addition, DEQ collected channel morphology data in 2003, while two monitoring section assessments were performed in 2006 to facilitate TMDL development. The drainage was heavily logged in the past, though a wide buffer protected the stream's physical habitat (MFWP 1989). The BDNF described geologies in the Jerry Creek watershed as moderate to high sediment producers with slopes that are moderate to steep.

During the assessment in 2003, DEQ described channel conditions as pristine until the lower 0.5 miles of the stream. There was no streambank erosion in the upper 1-mile long reach, while erosion due to hoof shear and a loss of riparian vegetation was noted in the lower reaches. Fine sediment concentrations were elevated in the lower reaches, though spawning gravels remained mostly clean. In 2006, the upper monitoring section (Delano 1) was located just downstream of a forest road crossing in the upper watershed. The upper monitoring section contained a naturally functioning channel flowing through a mountainous landscape and a coniferous forest. Clear-cut logging on the hillslope to the right of the channel did not encroach on the narrow valley bottom that contains the channel. However, it appeared that hillslope logging might have exposed some of the trees to more wind, with evidence of blow-downs in the valley bottom. The lower monitoring section in 2006 (Delano 2) was located in a transition zone where the stream flowed out of the forested mountain zone and into a willow-dominated meadow zone that contained most of the reach. Livestock access points have over-widened the channel in places and appear to have caused the channel to shift course as it enters the meadow. One of the lower sites from 2003, M03DLNOC02, was located within the lower reach from 2006.

Biological Data
Two macroinvertebrate samples and three periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-25**. The fisheries resource value is rated as outstanding in Delano Creek. Westslope cutthroat trout are abundant in Delano Creek, and in 1989, the only trout in Delano Creek was a genetically pure strand of westslope cutthroat trout (MFWP 1989). The population at that time was estimated at 134 cutthroat trout between 3.0 and 5.9 inches and 17 trout 6.0 inches and larger per 1,000 feet of stream (MFWP 1989). During the 2003 assessment, both cutthroat trout and brook trout were observed and DEQ noted that a large culvert on Forest Service Road 83 was a fish barrier.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Delano Creek are summarized in **Tables 5-24** and **5-25**.

Table 5-24. Delano Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Delano Down (USFS)	14	13	7.3	1.3*	ND	ND	**A3**	A2	**26.2**	ND	ND	PFC
Delano Up (USFS)	15	13	9.1	1.9*	ND	ND	A3	A3	**25.6**	ND	ND	PFC
M03DLNOC 01	9	8	ND	ND	ND	ND	B3	ND	ND	ND	ND	ND
M03DLNOC 02	27	**24**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Delano 1	7	6	9.1	1.5*	5	**7.1**	**A4/B4a**	A3	15.6	100	7**	PFC
Delano 2	**28**	14	6.3	13.7	2	**9.7**	**E4b**	E3b	22.8	91	**12**	FAR

ND = no data; *No target applied to A stream types. ** No supplemental indicator applied in areas with predominately coniferous vegetation.

Table 5-25. Biological Metrics for Delano Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03DLNOC01	Upstream of FS Rd 83 crossing	7/17/2003	Mountains	82.5	1.29
M03DLNOC02	Near mouth	7/17/2003	Mountains	63.2	**0.78**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03DLNOC01	Upstream of FS Rd 83 crossing	7/17/2003	Mountains	**60-70%**	
M03DLNOC02	Near mouth	7/17/2003	Mountains	20-30%	
M03DLNOC03	Near mouth	7/17/2003	Mountains	20-30%	

Summary and TMDL Development Determination
Only the lower DEQ site from 2006 (Delano 2) and from 2003 (M03DLNOC02) failed to meet one of the fine sediment targets. Although no existing or potential channel type was indicated during the 2003 sampling, the site was within the reach from 2006 and is likely the same. The reach composite percent fine sediment <6 mm at M03DLNOC02 was only 1 percent less than the same measurement in 2006 and corresponds to the site visit notes that fine sediment levels were elevated in the lower part of Delano Creek. Both reaches from 2006 were well below the sediment target for pool tails, which also supports the site notes from 2003 that spawning gravels were clean. The USFS and DEQ sites all met the target for width/depth ratio. Delano 2 was the only site where entrenchment could be compared to a target, but it met the target. Both reaches assessed in 2006 failed to meet the pool spacing target, indicating limited pool habitat.

Although the USFS sites slightly exceeded the BEHI supplemental indicator value, both 2006 DEQ reaches met the supplemental indicator value for bank erosion and the percent of reach with non-eroding banks. However, there was a greater amount of streambank erosion in the lower monitoring section (Delano 2). Large substrate “armored” the streambanks along the forested portion of Delano Creek. Delano 2 was well below the supplemental indicator value for shrub understory, but this was not unexpected because it was in a transition zone between a conifer forest and a shrub dominated meadow. However, evidence of livestock grazing was observed within the reach. The alternation between an A and B channel at the Delano 1 is typical of a step-pool system but the potential stream type was an A3, which would have larger substrate, suggesting additional sediment loads at one time. Also, both the lower DEQ and USFS sites (Delano 2 and Delano Down) did not meet their potential stream types because the existing stream types were one substrate size class smaller than their potential. It may be that silvicultural activities and the associated road network have led to an overall shift in streambed composition, since much of the watershed was harvested historically. Macroinvertebrates were meeting the supplemental indicator value at the upper site (M03DLNOC01) and just meeting it at the lower site (M03DLNOC02). However, the periphyton community at M03DLNOC01 indicated impairment while M03DLNOC02/3 met the supplemental indicator value. Delano 1 was considered in "proper functioning condition", while Delano 2 was rated as "functional-at risk" based on the PFC methodology. Both USFS sites contained A3 stream types in "proper functioning condition."

The elevated level of fine sediment in the composite and riffle pebble counts at the lower monitoring sections, along with shifts to stream types with finer substrate in both DEQ reaches and the lower USFS reach suggested increased sediment loads. Historic timber harvest may have led to an increase in sediment loads at one time, though a buffer was retained along the stream channel. In addition, ongoing grazing near the mouth is impacting a short reach of Delano Creek just upstream of the confluence with Jerry Creek. The biological indices indicate Delano Creek is not fully supporting aquatic life. Also, the lack of pool habitat is likely affecting fish communities. The primary anthropogenic source of sediment within the watershed is grazing, though roads and silviculture are additional sources. These results support the 303(d) listing and a sediment TMDL will be written for Delano Creek.

5.4.2.12 Divide Creek

Divide Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Divide Creek flows 12.2 miles from its headwaters to its mouth (**Figure A-2**).

Physical Condition and Sediment Sources

Several agencies have performed assessments in the Divide Creek watershed, including the BDNF and DEQ. In addition, two monitoring section assessments were performed on Divide Creek in 2006 to facilitate the development of this TMDL. It should be noted that the city of Butte utilizes water from the South Fork Divide Creek, which is a major tributary of Divide Creek. Thus, bankfull flows are very likely reduced along Divide Creek, resulting in altered channel morphology and decreased sediment transport capacity.

Surveys conducted by the BDNF found functioning streams in the Divide Creek drainage tended to have E4 and E5 channel types, while non-functioning streams were shifted toward B4c and B5c types (Bengeyfield 2004). Most of the stream survey sites were established within broad, low-gradient valley bottoms, which are typically sensitive to livestock grazing. The percent of fine sediment smaller than 6mm ranged from 44 to 92 percent for all sites. The dominance of granite parent material and low stream gradients both play a large role in the high level of fine sediment. A revised allotment management plan was signed in 1998, with riparian use criteria established for bank alteration, utilization, stubble height, and browse of woody species (Salo 2004).

DEQ collected sediment and channel morphology data at two sites on Divide Creek in 2003. The potential stream type was not indicated for either site, though field notes described a downcut channel that has stabilized to a C5 at the upper site (M03DIVDC01), while the lower site (M03DIVDC02) was described as an entrenched E5 that has stabilized from a G channel. Wetlands were numerous at the upper site and there were substantial irrigation withdrawals in the lower two miles of the stream. High fines were noted in the channel at both sites but riparian health and bank stability were high. Riparian fencing was observed and no cattle were grazing at either site. The lower reach was noted to be irrigation water from the Big Hole River.

Two monitoring section assessments were performed along Divide Creek in 2006. The upper monitoring section (Divide 1) was located in a channelized reach confined between a road and a fenced field. There was a narrow band of dense woody vegetation along the channel margin and fine sediment accumulations were noted in over-widened areas. The stream type ranged from B4c to F4, with a potential stream type of E4. A portion of the monitoring section appeared to be transitioning from an F to an E stream type through fine sediment deposition facilitated by wetland vegetation along the channel margin. The lower monitoring section (Divide 2) was located in an irrigated field. A center pivot irrigation system crossed the creek at several points upstream of the monitoring section and the crossings were hardened with angular cobbles. There was a relatively narrow riparian corridor of reed canary grass, with some willows along the channel margin. Cross-sectional area was much smaller than watershed area would suggest, indicating decreased streamflows and sediment transport capacity. Wetland vegetation along the channel margin was capturing sediment and appeared to be converting the channel from an F to an E stream type. There was very little streambank erosion due to wetland vegetation encroaching into the channel and reed canary grass on the streambanks. While this reach had a gravel/cobble substrate, local knowledge indicated that much of Divide Creek contains a sand-bed channel.

Biological Data

Two macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-27**. According to the FWP MFISH database, westslope cutthroat trout are common in the North and South Forks of Divide Creek. The fisheries resource value of Divide Creek is rated as substantial (MFISH 2004). Brook trout and rainbow trout predominate in the main stem of Divide Creek (MFWP 1989). Divide Creek is an area of periodic dewatering concern (MFISH 2004).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Divide Creek are summarized in **Tables 5-26** and **5-27**.

Table 5-26. Divide Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
M03DIVDC01	**66**	**65**	4.8	3.9	ND	ND	E5	ND	ND	ND	ND	PFC
M03DIVDC02	**54**	**45**	**9.1**	4.1	ND	ND	E4	ND	ND	ND	ND	PFC
Divide 1	**51**	**50**	**18.1**	**1.2**	**83**	3.5	**B4c/F4**	E4	**28.7**	**84**	73	FAR
648BDivide 2	**46**	**24**	**21.3**	**1.3**	**18**	3.5	**F4/C4/B4c**	C4	25.6	95	**26**	FAR

ND = no data

Table 5-27. Biological Metrics for Divide Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03DIVDC01	Downstream of Exit 111 at Feely	7/30/2003	Mountains	**27.2**	**0.42**
M03DIVDC02	Upstream of Hwy 43	7/30/2003	Low Valley	61.3	**0.60**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03DIVDC01	Downstream of Exit 111 at Feely	7/30/2003	Mountains	20-30%	
M03DIVDC02	Upstream of Hwy 43	7/30/2003	Mountains	**40-50%**	

Summary and TMDL Development Determination
The reach composite, riffle, and pool tail percent fine sediment targets were exceeded at all sites. In general, the upper sites had a higher percentage of fine sediment. The target for width/depth ratio was exceeded at all sites but the upper site from 2003 (M03DIVDC01). Both sites assessed in 2006 (Divide 1 and 2) did not meet the entrenchment target. Over-widened and entrenched channel conditions at Divide 1 monitoring section appeared to be the result of channelization by the road as well as livestock grazing.

Streambank erosion at Divide 1 exceeded the supplemental indicator BEHI value and was just barely under the supplemental indicator value for non-eroding banks. However, Divide 2 met both the BEHI and non-eroding bank supplemental indicator values. Divide 1 met the supplemental indicator value for understory shrub cover, but Divide 2 was well below it. Herbaceous and wetland groundcover in Divide 2 was 86 percent, however, and likely contributed to the lower level of bank erosion. Based on the PFC methodology, both sites assessed in 2003 were considered in "proper functioning condition", while both sites assessed in 2006 were rated as "functional-at risk". Macroinvertebrate samples from both sites indicated impairment and the periphyton sample from the lower site (M03DIVDC02) indicated impairment.

None of the fine sediment targets were met in either monitoring section, indicating dramatic changes in stream bed composition and channel morphology that are likely due to increased sediment loads and decreased sediment transport capacity. The biological data indicate Divide Creek is not fully supporting aquatic life, and excess fine sediment in riffles and pools is likely limiting fish spawning and rearing success. Although the geology could be contributing high loads of fine sediment, there are also human-related sources of sediment that have affected the riparian vegetation, channel morphology, and sediment loads. The primary anthropogenic sources of sediment within the watershed are rangeland grazing and irrigated agriculture, though roads and timber harvest are additional sources. The results support the 303(d) listing and a sediment TMDL will be prepared for Divide Creek.

5.4.2.13 Elkhorn Creek

Elkhorn Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Elkorn Creek flows 7.2 miles from its headwaters to its mouth at Jacobson Creek, which is a tributary to the Wise River (**Figure A-2**).

Physical Condition and Sediment Sources
In the late 1990s, a section of Elkhorn Creek impacted by the Elkhorn Mine was restored as part of the Elkhorn Stream Restoration Project. The project was conducted downstream of the Coolidge town site and included the removal of tailings from the streambed and the reconstruction of a functioning stream channel. A plume of fine sediment was released in Elkhorn Creek in 1999 during an attempt to drain a marshy area when silt fences holding the water failed. Tailings were reportedly removed from alongside the creek prior to the accident (Backus 1999).

At the upper site in 2003 (M03ELKHC01), DEQ noted that the cobble-dominated substrate in the reconstructed reach was embedded with sand-sized particles. The reach had good riparian vegetation with some bank erosion. Downstream of the mine site, the channel type changes from a B3 to a C4 when the stream enters a meadow dominated by willows and sedges. The lower reach (M03ELKHC02), which is near the mouth, had excellent pool habitat with deep undercut banks and a high density of large woody debris; however, some sand was deposited in pools. The source of the sand was unknown; granitic geology and historic mining were cited as potential sources. Upstream of the Coolidge town site and the restored reach, a DEQ assessment in 1998 found boulder substrate was embedded with sand, and naturally erosive granitic geology and historic mining were cited as potential sources.

One monitoring section assessment was performed in the restored reach in 2006 because the 2003 monitoring data suggested this site had high levels of fine sediment. This restoration project appears to only allow a certain streamflow through the restored reach, with additional water being routed down an overflow channel during the site visit. The restored reach of stream was considered a B4c stream type, since the “designed” flood-prone elevation limits any water from washing out onto the floodplain. Upstream of the monitoring section, beyond the restored reach, the stream was a B channel with large cobble and boulders and fine-medium gravels in the slow water areas, which appeared to be the result of granitic watershed geology. Downstream of the monitoring section, the restoration project continued into a meadow, where the stream is more of an E/C stream type. Both the assessment reach and the channel downstream in the meadow lacked pool habitat. Several site visits, along with the aerial assessment, suggest that the rest of Elkhorn Creek is relatively un-impacted by anthropogenic disturbances, though there are remnant impacts along the Coolidge town site, such as an abandoned structure that has fallen into the stream.

Biological Data

Five macroinvertebrate samples have been collected since 1992 and three periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-29**. The fisheries resource value of Elkhorn Creek is moderate. Elkhorn Creek has a westslope cutthroat trout population with an unknown abundance (MFISH 2004). Westslope cutthroat trout were only found upstream of the mining area (MFWP 1989).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Elkhorn Creek are summarized in **Tables 5-28** and **5-29**.

Table 5-28. Elkhorn Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Elkhorn 1	16	10	12.8	1.5*	6	**10**	B4c	B4c/ G4c	**42.0**	86	**21**	FAR
M03ELKH C01	**30**	**23**	14.3	6.7	ND	ND	**B4**	B3	ND	ND	ND	PFC
M03ELKH C02	19	10	14.9	16.2	ND	ND	C4	ND	ND	ND	ND	PFC

ND = no data; *No entrenchment target for G stream types.

Table 5-29. Biological Metrics for Elkhorn Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03EKHNC01	Above Coolidge Mine and Mill	7/20/2000	Mountains	**56.1**	0.96
M03ELKHC01	0.5 mile below town of Coolidge	7/23/2003	Mountains	66.1	**0.48**
M03ELKHC02	0.25 mile above mouth at Jacobson Creek	7/23/2003	Mountains	79.0	**0.48**
M03EKHNC09	Near mouth	7/20/2000	Mountains	64.9	**0.72**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03ELKHC01	0.5 mile below town of Coolidge	7/23/2003	Mountains	<5%	
M03EKHNC01	Above Coolidge Mine and Mill	7/20/2000	Mountains	5-10%	
M03ELKHC02	0.25 mile above mouth at Jacobson Creek	7/23/2003	Mountains	20-30%	
M03EKHNC09	Near mouth	7/20/2000	Mountains	**50-60%**	

Summary and TMDL Development Determination

The upper site from 2003 (M03ELKHC01) was the only site that exceeded the reach composite and riffle fine sediment targets. M03ELKHC01, however, was contained within the reach from 2006 (Elkhorn 1), indicating that excess fine sediment was flushed from the riffles between 2003 and 2006. The excess fines in 2003 could have been related to the silt fence failure during restoration in 1999. Elkhorn 1 also met the fine sediment target for pool tails. Although the fine sediment targets were met at Elkhorn 1 in 2006, observers noted that the gravel felt "glued in" during the pebble count, indicating an embedded substrate. All reaches met the width/depth ratio and entrenchment targets. Although field notes indicated excellent pool habitat at the lower reach from 2003 (M03ELKHC02), the pool spacing target was not met at Elkhorn 1 in 2006.

Streambank erosion exceeded the supplemental indicator BEHI value at Elkhorn 1, while the percent of reach with non-eroding banks was just meeting the supplemental indicator value of ≥ 85 percent. However, streambanks along this monitoring section were engineered during channel reconstruction through the incorporation of large boulders and the greenline data indicates 18 percent of the monitoring section was lined with riprap. The new channel cuts through what appear to be mine tailings, which remain unvegetated. Areas lacking protective boulders are highly erosive, especially along the left side of the river channel. A total of 21 percent of Elkhorn 1 was occupied by deciduous shrubs, which fails to meet the supplemental indicator of ≥ 49 percent. While this monitoring section was in a transitional area between a conifer forest and a willow-dominated meadow, the low percent of greenline shrubs is reflective of the unvegetated tailings through which this monitoring section flows. In addition, the greenline assessment indicated that 16 percent of Elkhorn 1 was "bare ground". Based on the PFC methodology, Elkhorn 1 was rated as "functional-at risk", and M03ELKHC01 and M03ELKHC2 were in "proper functioning condition." For macroinvertebrates, the uppermost site (M03EKHNC01) did not meet the MMI threshold and the rest of the sites did not meet the O/E threshold. Using the guidance that the score farthest from the threshold should carry more weight (Feldman 2006), this indicates impairment of macroinvertebrates at all sites except for the M03EKHNC01. However, for periphyton, only the site near the mouth (M03EKHNC09) indicates impairment of the periphyton community.

The site assessment and field data indicate the human-related sources of sediment are primarily concentrated near Coolidge and the abandoned Elkhorn mine site. The primary anthropogenic source of sediment within the watershed is historic mining and roads. Although field data also indicates a large background sediment load associated with the granitic geology, the mine tailings and associated bare ground along the streambanks is increasing bank erosion and contributing excess sediment to the stream. Although excess fines have been flushed through the assessment reach, they are likely contributing to the fine sediment accumulation observed in the lower part of the creek, which has a lower gradient, and could be limiting both aquatic life and fish communities in lower portions of Elkhorn Creek. The assessment information supports the 303(d) listing and a sediment TMDL will be written for Elkhorn Creek.

5.4.2.14 Fishtrap Creek

Fishtrap Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. The Fishtrap Creek watershed is on the east face of the Pintler Mountains, with the upper portion in the Anaconda Pintler Wilderness. The listed segment is 5.2 miles long and goes from the confluence of the West and Middle Forks of Fishtrap Creek to its mouth (**Figure A-2**). The watershed is characterized by granitic geologies with high sediment potential, though they occur on relatively low angled slopes.

Physical Condition and Sediment Sources

Assessments have been conducted along Fishtrap Creek by the BDNF, FWP, and DEQ as part of 303(d) and TMDL-related monitoring. The BDNF reported tributary streams are impacted by heavy livestock trampling of streambanks and the East Fork Fishtrap Creek was classified as a "functioning" E3b/E4b stream type with a downward trend (Bengeyfield 2004). In addition, DEQ noted heavy grazing throughout the riparian zone at the upper sample site (01) in 2003, though the floodplain remained vegetated with extensive willows. The DEQ assessments in 2003 noted bank erosion associated with hoof shear in the upper reach and a steep bank abutting the road on one side. No evidence of grazing was seen at the lower reach, but channel over widening was noted. FWP also identified a loss of riparian vegetation and streambank erosion as sediment sources to Fishtrap Creek (MFWP 1989).

Two monitoring sections along Fishtrap Creek were assessed in 2006. The upper monitoring section (Fishtrap 1) was located just downstream of the confluence on the West and Middle Forks of Fishtrap Creek. The upper monitoring section is likely representative of much of Fishtrap Creek from the assessment site upstream to the wilderness boundary. The channel was over-widened and some grazing was evident along the upper monitoring section, with livestock trails along the channel that were noted to be the main sediment source. Despite good riparian vegetation including dense willow growth, there was bank instability and erosion due to grazing. Streambanks were noted to be a minimal source of fine sediment. A large water diversion was observed upstream of the sample site. In addition, a ditch parallels the stream from a headgate on river right. The lower monitoring section (Fishtrap 2) was located near the confluence with the Big Hole River. FWP recently deepened pools within this reach to benefit Arctic grayling, which were found to use these pools for thermal refugia during the summer. The lower reach is unique, since the majority of Fishtrap Creek downstream of the National Forest boundary is comprised of a series of beaver complexes.

Biological Data

Two macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-31**. The fisheries resource value is high downstream of East Fork Fishtrap Creek and substantial further upstream (MFISH 2004). Arctic grayling reportedly use Fishtrap Creek for spawning (Byorth 1994). In 2002, a beaver dam that was acting as a fish passage barrier was removed from Fishtrap Creek. Surveys prior to removal of the beaver dam found 25 Arctic grayling in the lower 0.25 miles of Fishtrap Creek and no Arctic grayling upstream of the beaver dam (Magee and Lamothe 2003). As part of a stream habitat improvement project in 2003, eight pools were created in a section of lower Fishtrap Creek (Magee and Lamothe 2003).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Fishtrap Creek are summarized in **Tables 5-30** and **5-31**.

Table 5-30. Fishtrap Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Fishtrap 1	**15**	10	**21.0**	**1.7**	14	1.9	**B4**	B3	27.3	94	75	FAR
Fishtrap 2	**17**	8	19.0	**2.6**	9	4.8	**C4**	C3	20.9	95	55	FAR
M03FSHTC 01	**16**	**15**	**25.5**	ND	ND	ND	B3	ND	ND	ND	ND	PFC
M03FSHTC 02	**17**	**15**	**27.0**	**1.5**	ND	ND	B4	ND	ND	ND	ND	PFC

ND = no data

Table 5-31. Biological Metrics for Fishtrap Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%)

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03FSHTC01	Below forks of Fishtrap and Swamp Cr	7/16/2003	Mountains	68.6	0.97
M03FSHTC02	Downstream of Hwy 43	7/16/2003	Mountains	66.9	**0.66**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03FSHTC01	Below forks of Fishtrap and Swamp Cr	7/16/2003	Mountains	**40-50%**	
M03FSHTC02	Downstream of Hwy 43	7/16/2003	Mountains	**50-60%**	

Summary and TMDL Development Determination
All reaches exceeded the reach composite fine sediment target. The two DEQ sites from 2003 exceeded the riffle fine sediment target, but the reaches assessed in 2006 met both the riffle and pool tail fine sediment targets. All reaches but the lower one from 2006 (Fishtrap 2) exceeded the width/depth ratio target, and all available entrenchment ratios failed to meet the target. This indicates that the channel has become over-widened and lost access to its floodplain. Both reaches from 2006 met the pool spacing target.

Both reaches from 2006 met the BEHI, percent non-eroding banks, and percent understory shrub cover supplemental indicator values. The BEHI value in the upper reach (Fishtrap 1) was close to the supplemental indicator value, and this is partially due to the diversion structure upstream of the reach. No potential channel type was indicated during the 2003 assessments, but both reaches in 2006 were meeting their potential channel type, but had sediment one size class smaller than their potential (i.e. sand vs. gravel). This indicates an increased sediment supply and potentially a decrease in sediment transport. For macroinvertebrates, the lower site (M03FSHTC02) failed to meet the O/E threshold and indicates macroinvertebrate impairment. Both periphyton sites indicate impairment, but the lower site (M03FSHTC02) has a slightly higher probability of impairment. Based on the PFC methodology, both Fishtrap 1 and 2 were rated as “functional-at risk” and M03FSHTC01 and _02 were rated as “proper functioning condition.”

The elevated reach composite percent of fine sediment suggests increased sediment supply. Irrigation diversions in combination with grazing that has contributed to channel widening have also likely decreased the sediment transport capacity. Granitic geology within the watershed may be partially responsible for the fine sediment accumulations but numerous anthropogenic sources are also present. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though timber harvest and the associated road network are additional sources in the upper watershed, while irrigation diversions and cropland are additional sources in the lower watershed. The biological data indicate fine sediment is impairing the ability of Fishtrap Creek to fully support aquatic life. Excess fine sediment is also likely affecting fish communities. This information supports the 303(d) listing and a sediment TMDL will be developed for Fishtrap Creek.

5.4.2.15 French Creek

French Creek is not listed as impaired due to sediment, but DEQ performed a sediment and habitat assessment on one reach in 2005 because all beneficial uses were not assessed during the previous 303(d) listing cycle and it is a tributary to Deep Creek, which is listed for sediment/siltation on the 2006 303(d) List. The majority of the French Creek watershed is within the Mt. Haggin Wildlife Management Area. It flows 9.4 miles from its headwaters on the eastern slope of the Anaconda-Pintler Range to its mouth at Deep Creek (**Figure A-2**).

Physical Condition and Sediment Sources
Deforestation and erosion in this area lead to the creation of the Big Hole Forest Reserve in 1906, which later became the Deerlodge National Forest (Munday 2001). An 18-mile flume along from the upper French Creek watershed, which includes California Creek, Oregon Creek, and Sixmile Creek, was constructed to transport logs to Anaconda between 1906 and 1911. FWP

reported a loss of riparian vegetation due to emissions from the Anaconda Smelter and the chemical removal of riparian willows along much of the creek in 1965 (MFWP 1989).

Previous assessments along French Creek include a channel morphology survey by the BDNF at one site on French Creek in August of 1999 and a BLM riparian assessment within a grazing allotment in 1988. During the BDNF assessment, French Creek was considered a "functioning" C3 channel at the survey site (Bengeyfield 2004). The 1988 BLM assessment site was found "non-functional" based on the PFC methodology.

In 2005, one monitoring section (French 1) was assessed along French Creek since support of some beneficial uses had not yet been evaluated. The monitoring section was located just downstream of the second Highway 257 crossing. This monitoring section was representative of French Creek between the confluence with California Creek and the mouth, where French Creek joins Deep Creek. The reach had a well-developed riffle-pool sequence. This monitoring section is not representative of reaches observed to be impacted by placer mining upstream of the uppermost Highway 257 crossing.

Biological Data

Four macroinvertebrate and periphyton samples were collected in 2005. The bioassessment scores are presented in **Table 5-33**. The fisheries resource value of French Creek is moderate (MFISH 2004). FWP found trout populations in French Creek were below average for streams in the Big Hole watershed. There is a westslope cutthroat trout population described as rare in Moose Creek, which is a tributary to French Creek (MFISH 2004).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for French Creek are summarized in **Tables 5-32** and **5-33**.

Table 5-32. French Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
French 1	19	6	**23**	6.0	**20**	4.8	C4	C4	**35.6**	**76**	**34**	FAR
French (USFS)	11	11	22.7	**1.1**	ND	ND	C3	C3	**27.3**	ND	ND	PFC

ND = no data

Table 5-33. Biological Metrics for French Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03FNCHC01	0.5 mile below Julius Gulch	7/6/2005	Mountains	70.1	1.18
M03FNCHC02	1.25 miles d/s of Hwy 274 bridge	7/6/2005	Mountains	**49.9**	**0.63**
M03FNCHC03	100 ft upstream from Hwy 274	7/7/2005	Mountains	**57.2**	**0.62**
M03FNCHC04	150 feet upstream of Hwy 274	7/8/2005	Mountains	**36.2**	**0.63**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03FNCHC01	0.5 mile below Julius Gulch	7/6/2005	Mountains	**80-90%**	
M03FNCHC02	1.25 miles d/s of Hwy 274 bridge	7/6/2005	Mountains	**40-50%**	
M03FNCHC03	100 ft upstream from Hwy 274	7/7/2005	Mountains	**90-95%**	
M03FNCHC04	150 feet upstream of Hwy 274	7/8/2005	Mountains	**70-80%**	

Summary and TMDL Development Determination
Both the DEQ and USFS assessments met the targets for fine sediment in the reach composite and in riffles. However, the grid toss percent fines in pool tail-outs at French 1 exceeded the target, indicating an accumulation of fine sediment in spawning habitat. The DEQ reach (French 1) exceeded the target for width/depth ratio but the USFS site (French) met the target. However, French 1 did meet the entrenchment and pool spacing targets.

Both reaches are meeting their potential Rosgen channel type, but both failed to meet the supplemental indicator BEHI value. Additionally, French 1 did not meet the supplemental indicator values for percent of non-eroding banks and percent greenline shrubs. Livestock grazing appeared to be the cause of decreased riparian shrub density, which, in turn, resulted in increased streambank erosion. Both metrices indicate macroinvertebrate impairment at all sites except the uppermost site (M03FNCHC01). All periphyton samples indicate sediment impairment to the periphyton community. French 1 was rated as “functional-at risk” and French was rated as “proper functioning condition” based on the PFC methodology.

The primary anthropogenic source of sediment within the watershed is rangeland grazing, though historic mining, transportation, and timber harvest are additional sources. While not listed as impaired due to sediment, recently collected data suggest increased sediment loads associated with bank erosion and a decreased sediment transport capacity related to channel widening. The macroinvertebrate and periphyton data are indicating sediment impairment of aquatic life. Excess sediment and limited riparian vegetation are diminishing the quality of fish habitat and likely affecting the fishery beneficial use. A sediment TMDL will be prepared for French Creek.

5.4.2.16 Gold Creek

Gold Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Gold Creek flows 4.8 miles from its headwaters to its confluence with the Wise River (**Figure A-2**).

Physical Condition and Sediment Sources
Both the BDNF and DEQ have performed stream assessments on Gold Creek. The BDNF assessment in August of 1994 indicated Gold Creek was in "proper functioning condition". Overall, the upper DEQ site (M03GOLDC01) was described as a high-gradient, cobble dominated channel with healthy riparian vegetation and stable banks. Some grazing was noted at the lower end of the reach. At the lower site (M03GOLDC02), there was channel widening and streambank trampling as a result of livestock grazing. Channel widening was accompanied by a loss of riparian vegetation and fish habitat, though the gravels were described as clean. In addition, Gold Creek was cited as the source of a plume of sediment entering the Wise River.

During 2005, one monitoring section (Gold 1) was assessed on Gold Creek. This monitoring section was located in the valley bottom between the confluence with the Wise River and the road crossing and is unique along the stream segment. The stream type ranged from C4 to F4, with the F4 stream type occurring at the upper end of the reach just downstream of the road crossing. Just upstream of the Wise River, Gold Creek is an E4 stream type, which appears to be the potential stream type. There is extensive wetland vegetation along the lower half of the monitoring section. In addition, an abandoned road bed traversing the floodplain at the lower end of the monitoring section has also impacted the channel historically, limiting access to the floodplain.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-35**. The fisheries value of Gold Creek is moderate downstream of the South Fork and limited further upstream. Gold Creek has a westslope cutthroat trout population described as rare (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Gold Creek are summarized in **Tables 5-34** and **5-35**.

Table 5-34. Gold Creek Sediment Data Compared to Targets and Supplemental Indicators
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Gold 1	26	13	**20.4**	5.7	16	**8.3**	**C4/F4**	E4	**32.8**	91	**40**	FAR
M03GOLD C01	**37**	**30**	ND	ND	ND	ND	A3	ND	ND	ND	ND	PFC
M03GOLD C02	ND	ND	ND	ND	ND	ND	**C4**	E4	ND	ND	ND	FAR
Gold (USFS)	13	13	9.1	1.4	ND	ND	B4a	B4a	23.6	ND	ND	PFC

ND = no data

Table 5-35. Biological Metrics for Gold Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03GOLDC01	250 ft. above FS road 484	7/10/2003	Mountains	63.3	0.97
M03GOLDC02	100 ft. above mouth at Wise River	7/10/2003	Mountains	72.2	0.97
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03GOLDC01	250 ft. above FS road 484	7/10/2003	Mountains	**70-80%**	
M03GOLDC02	100 ft. above mouth at Wise River	7/10/2003	Mountains	**>95%**	

Summary and TMDL Development Determination
During the 2005 DEQ assessment (Gold 1) and USFS assessment (Gold), all fine sediment targets were met. However, both the reach and riffle fine sediment targets were exceeded at the site in 2003 (M03GOLDC01). Despite the abandoned roadbed in the floodplain at the lower end of the Gold 1 reach, the entrenchment target was met. However, Gold 1 failed to meet the

width/depth ratio and pool spacing targets, and the USFS site (Gold) did not meet the entrenchment target.

The USFS site was meeting its potential channel type, but the Gold 1 and M03GOLDC02 were not meeting their potential channel type. Also, the BEHI supplemental indicator value was met at the USFS site, but exceeded Gold 1. In 2005, Gold 1 the reach met the percent of reach with non-eroding banks supplemental indicator value, but failed to meet the supplemental indicator value for percent greenline shrubs. Gold 1 and M03GOLDC02 were rated as "functional-at risk" based on the PFC methodology. M03GOLDC01 and the Gold were rated as "proper functioning condition." Both macroinvertebrate samples met the MMI and O/E threshold, but both periphyton samples indicated impairment from sediment.

The percent surface fines target exceedances and high width/depth ratio suggest a decrease in sediment transport capacity and possibly an increased sediment supply. The high BEHI score and low percent of greenline shrubs suggest an increased sediment load from streambank sources. Although sediment does not appear to be harming the macroinvertebrates, the periphyton samples indicate sediment impairment. Excess sediment, limited riparian vegetation, and an overwidened channel are also likely affecting fish communities. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though historic timber harvest may be an additional source. These results support the 303(d) listing and a sediment TMDL will be completed for Gold Creek.

5.4.2.17 Grose Creek

Grose Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Grose Creek flows 3.4 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
One monitoring section assessment (Grose 1) was performed along Grose Creek in 2006. Grose Creek flowed through a meadow area upstream of the monitoring section, before entering an entrenched gulch lined by a band of aspens where the assessment was performed. Downstream of the site, the entrenched channel widened due to the placement of periodic rock check dams that form a series of wetlands. Downstream of the rock check dams, the wetland area widens, dispersing the flow before it becomes an entirely dry gulch. Grose Creek was dry at the road crossing upstream of the area of irrigated agriculture during all site visits over two years that included spring runoff in 2005 and 2006. It is likely that streamflow in Grose Creek is strongly influenced by localized and extreme rain events. It should be noted that the gulch has been used as a trash dump.

Biological Data
One macroinvertebrate and periphyton sample was collected in 2003. The bioassessment scores are presented in **Table 5-37**.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Grose Creek are summarized in **Tables 5-36** and **5-37**.

Table 5-36. Grose Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Grose 1	**78**	**63**	4.1	**1.5**	ND	ND	**B5a/A5/E5b**	E3a	**37.7**	85	**26**	**NF**

ND = no data

Table 5-37. Biological Metrics for Grose Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03GROSC01	1 mile above County Road	9/12/2003	Low Valley	**38.8**	**0.52**
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03GROSC01	1 mile above County Road	9/12/2003	Low Valley	**40-50%**	

Summary and TMDL Development Determination

During the 2006 assessment, the reach and riffle pebble counts failed to meet the target. Although the reach met the target for width/depth ratio, it failed to meet the entrenchment target. It is unclear why Grose Creek is entrenched within the monitoring section, though the rock check dams located downstream may be responsible. There were no pools within the monitoring section.

The reach was not meeting its potential Rosgen channel type, both from over-widening and excess fine sediment. The reach exceeded the supplemental indicator BEHI value and just barely met the supplemental indicator value for percent of reach with non-eroding banks. In addition, the bare “gulch” walls likely contribute sediment to the stream channel during precipitation events. The percent of greenline shrubs failed to meet the supplemental indicator value, being almost of desired value. Both the macroinvertebrate sample and periphyton sample indicate sediment impairment. This monitoring section was rated as "non-functioning" based on the PFC methodology.

The percent of fine sediment in both the composite and the riffle pebble counts exceeded the target criteria, suggesting increased sediment loads. Streambank erosion and a lack of riparian shrubs led to sediment inputs along this entrenched monitoring section. In addition, the biological data indicate impairment to aquatic life, and excess sediment and limited riparian vegetation are likely affecting fish communities. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though roads may be an additional source. This information supports the 303(d) listing and a sediment TMDL will be completed for Grose Creek.

5.4.2.18 Jerry Creek

Jerry Creek was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, and low flow alterations on the 2006 303(d) List, which are forms of pollution commonly linked to sediment impairment. The Jerry Creek watershed lies on the south face of the Fleecer Mountains, which are characterized by geologies that are moderate to high sediment producers and have moderate to steep slopes. Jerry Creek flows 12.3 miles from its headwaters to the Big Hole River (**Figure A-2**) and its watershed is entirely within grazing allotments.

Physical Condition and Sediment Sources
Livestock grazing has lead to "functioning - at risk" conditions along Jerry Creek as documented by channel morphology surveys conducted in 1999 by the BDNF within the upper watershed. Upstream of the confluence with Flume Creek (Jerry Up), Jerry Creek was an E3a stream type meeting its potential. Just above the confluence with Delano Creek (Jerry Mid), Jerry Creek was a C3b stream type, though reference conditions suggest it should be an E4. Stability decreased downstream of the confluence with Delano Creek, though no surveys were conducted in that section. Downstream of the confluence with Long Tom Creek (Jerry Down), Jerry Creek was an F3b stream type, while reference conditions suggested it should be a B3 stream type (Bengeyfield 2004).

Two monitoring section assessments were performed along Jerry Creek in 2005. The upper monitoring section (Jerry 1) was located downstream of the Indian Creek confluence on National Forest lands. The existing stream type ranged from a B4 to a C4b, with a potential of B3. Two irrigation diversions extended from the right side of the channel along this monitoring section. The lower monitoring section (Jerry 2) was located along the lower mile of Jerry Creek, where the stream flows through an alluvial fan before joining the Big Hole River. Channel measurements within this monitoring section found conditions ranged from a C4 to a B4c and the narrow floodplain was confined within an entrenched valley bottom. It appeared that this monitoring section had been channelized and possibly relocated at one time. There was one diversion leading off from the right side of the channel. The sinuosity was quite low (1.04), lending further evidence that this reach was historically channelized. The potential of this monitoring section considering the channelized condition is a B3c, though it may have been a meadow stream type (E) prior to channelization. Grazing was observed at both the upper and lower sites during monitoring in 2005, which extended from June until September.

Biological Data

Four macroinvertebrate samples were collected between 1994 and 2005, and two periphyton samples were collected in 2003 and 2005. The bioassessment scores are presented in **Table 5-39**. The fisheries resource value is rated as moderate in the lower reaches, substantial in the middle reaches, and outstanding in the upper reaches of Jerry Creek. The westslope cutthroat trout population of Jerry Creek is described as rare downstream of Libby Creek and common further upstream. Several tributaries of Jerry Creek also contain populations of westslope cutthroat trout. Delano Creek has an abundant westslope cutthroat trout population. Westslope cutthroat trout population abundance is common in Flume Creek, rare in Libby Creek, and unknown in Long Tom Creek and Indian Creek (MFISH 2004).

Rainbow trout use the lower portion of Jerry Creek for spawning. In 1976, redds were concentrated within the first 0.25 miles upstream from the mouth. In May of 1987, redds were found as far as 3 miles upstream from the mouth. FWP noted that dewatering in the lower reaches during the summer irrigation season negatively impacts nursery habitat for rainbow trout, reducing potential contributions to the Big Hole River (MFWP 1989).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Jerry Creek are summarized in **Tables 5-38** and **5-39**.

Table 5-38. Jerry Creek Sediment Data Compared to Targets and Supplemental Indicators
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Jerry 1	9	9	**20.7**	**1.6**	14	4.9	**B4c/C4b**	B3	20.8	86	40*	FAR
Jerry 2	**13**	11	**15.9**	2.1	**20**	**8.4**	**C4/B4c**	B3c	23.9	93	61	FAR
Jerry Up (USFS)	7	5	10.2	3.6	ND	ND	E3a	E3a	24.2	ND	ND	PFC
Jerry Mid (USFS)	9	5	11.8	3.0	ND	ND	C3b/E3b	C3b/ E3b	**27.4**	ND	ND	PFC
Jerry Down (USFS)	3	2	**23.3**	1.2	ND	ND	**F3b**	B3	**28.1**	ND	ND	FAR

* No supplemental indicator applied in areas with predominately coniferous vegetation

Table 5-39. Biological Metrics for Jerry Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03JERRC02	1.9 miles above the mouth	7/9/2005	Mountains	**42.4**	**0.66**
M03JERRC01	0.5 miles d/s of Delano Creek	7/10/2003	Mountains	**60.3**	0.86
WMTP99-0723	Near Moore Creek	7/7/2002	Mountains	**62.4**	1.32
BKK065	Near mouth	9/7/1994	Mountains	**46.1**	1.03
Periphyton					
Station ID	Location Description	Collected	Site Class	Probability of Impairment	
M03JERRC02	1.9 miles above the mouth	7/9/2005	Mountains	**60-70%**	
M03JERRC01	0.5 miles d/s of Delano Creek	7/10/2003	Mountains	**>95%**	

Summary and TMDL Development Determination
All fine sediment targets were met except for <6 mm in the reach and pool tail at the lower reach (Jerry 2) in 2006. The target for width/depth ratio was exceeded in both sections in 2006 and at the lowest USFS site (Jerry Down). Over-widening at the upstream DEQ section (Jerry 1) appeared to primarily be the result of livestock grazing, though development of the irrigation network may have had an influence. The width/depth ratio was only slightly exceeded at Jerry 2, which appeared to be channelized to facilitate irrigation diversion. Jerry 1 failed to meet the entrenchment target and Jerry 2 failed to meet the pool tail fine sediment and pool spacing targets.

Both 2006 monitoring sections and the upper USFS site (Jerry Up) met the supplemental indicator BEHI value but the two lower USFS sites (Jerry Mid and Jerry Down) exceeded the value. Both reaches from 2006 met the supplemental indicator value for percent of reach with non-eroding banks. Because of a coniferous overstory, the upper reach (Jerry 1) was not expected to meet the supplemental indicator value for greenline shrubs. However, the lower reach (Jerry 2) met the supplemental indicator value for understory shrub cover. Three out of the five reaches did not meet their potential Rosgen channel type. All four MMI scores did not meet the supplemental indicator value, but based on the O/E scores, macroinvertebrates are impaired at two of the sites. Both periphyton samples indicate a high probability of impairment and are from the same macroinvertebrate sites that indicated impairment. Three of the monitoring sections were rated as “functional-at risk” and two were rated as “proper functioning” based on the PFC methodology.

Although some assessment reaches are meeting sediment and morphological targets, the high width/depth ratios, percentage of fine sediment, and altered channel morphology at other reaches suggest a decrease in sediment transport capacity and possibly an increased sediment supply. Channelization related to the development of the irrigation network in the lower watershed may also influence the overall sediment transport capacity. In addition to impairing the macroinvertebrate and periphyton communities, these changes in sediment supply and channel form are likely reducing the quality of fish habitat and limiting fish spawning and rearing success. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though roads and timber harvest are additional sources. This information indicates there is a link between habitat impairment and excess sediment in Jerry Creek and a sediment TMDL will be completed for Jerry Creek.

5.4.2.19 Lost Creek

Lost Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Lost Creek flows 7.8 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**). Approximately the lower 0.5 mile of Lost Creek is ephemeral.

Physical Condition and Sediment Sources
Both the BDNF and DEQ have performed assessments on Lost Creek. In addition, two assessments were performed on Lost Creek in 2006 to facilitate the development of this TMDL. The BDNF performed channel morphology surveys at two sites on Lost Creek in 1994. These surveys found Lost Creek had excess fine sediment relative to its potential. Both sites surveyed by the BDNF were considered "non-functioning". Sources of sediment to Lost Creek included a road paralleling the creek along its entire length and heavy livestock use throughout the drainage (Bengeyfield 2004).

DEQ assessed Lost Creek at two sites in 2003 (Lost 1 and Lost 2). Excess fine sediment was noted in riffles and pools in both reaches. Channel incisement and bank erosion was noted at Lost 2, the lower reach. Streambank erosion due to hoof shear and a four-wheel drive road that crosses the creek in several locations as a fjord were noted as sources of sediment. Grazing was cited as an impact to riparian areas leading to reduced age class and species diversity.

Two monitoring section assessments were performed along Lost Creek in 2006. The upper monitoring section (Lost 1) flowed through an aspen stand and then into an area with a large amount of dead trees over the channel. Riparian vegetation was primarily rose, which is common in disturbed areas. Grazing was present but minimal and likely at a higher intensity historically. Larger aspens along this reach gave way to smaller aspens downstream as the channel goes dry. The lower monitoring section (Lost 2) was conducted upstream of the I-15 crossing and was intermittent during the survey in August of 2006, with no flow upstream of the monitoring section and diminishing flows within the monitoring section. It appeared the reach was altered historically and had a berm paralleling the channel and a dry channel to the left of the existing channel. Riparian vegetatation along entrenched portions of the channel was primarily weeds and roses, but some portions of the channel had a single band of cottonwoods and willows.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-41**.

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Lost Creek are summarized in **Tables 5-40** and **5-41**.

Table 5-40. Lost Creek Sediment Data Compared to Targets and Supplemental Indicators. Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	**Targets**						**Supplemental Indicators**					
	Pebble Count		**Cross Section**		**Grid Toss**		**Rosgen Level II**		**BEHI**			
	Reach % <6mm	**Riffle % <2mm**	**W/D Ratio**	**Entrenchment Ratio**	**Pool Tail % <6mm**	**Pool Spacing**	**Existing**	**Potential**	**BEHI**	**% Non-Eroding Bank**	**Greenline % Shrubs**	**Riparian Condition**
Lost 1	**31**	**16**	**11.2**	**2.0**	**23**	**9.0**	**E4b/B4**	E3b	**29.0**	97	48	FAR
Lost 2	**87**	**39**	6.1	**2.0**	ND	**13.6**	**E5b/B5/G5**	E3b	**30.2**	96	**39**	**NF**
Lost Dn (USFS)	**76**	**64**	2.5	6.1	ND	ND	**E5a**	E3a	ND	ND	ND	**NF**
Lost Up (USFS)	**41**	**34**	**18.6**	1.6	ND	ND	**B4a**	A3	**38.1**	ND	ND	**NF**
M03LOSTC01	**59**	**53**	ND	ND	ND	ND	ND	ND	ND	ND	ND	FAR
M03LOSTC02	**54**	**47**	ND	ND	ND	ND	ND	ND	ND	ND	ND	PFC

ND = no data

Table 5-41. Biological Metrics for Lost Creek. Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03LOSTC01	1 mile west of Interstate 15	9/13/2003	Low Valley	64.0	**0.77**
M03LOSTC02	4 miles from County Road	9/14/2003	Mountains	63.7	0.98
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03LOSTC01	1 mile west of Interstate 15	9/13/2003	Mountains	10-20%	
M03LOSTC02	4 miles from County Road	9/14/2003	Mountains	**40-50%**	

Summary and TMDL Development Determination
All available pebble count and grid toss data exceeded the fine sediment targets. Of the four reaches with width/depth ratio data, half of them exceeded the target. Both reaches assessed in 2006 failed to meet the entrenchment target and the pool spacing target.

All four reaches assessed for channel type failed to meet their potential, largely as a result of over widening and a predominance of fine sediment. All three reaches with BEHI data failed to meet the supplemental indicator value; however, the reaches from 2006 met the eroding bank supplemental indicator value with very high percentages of non-eroding banks. The upper section from 2006 (Lost 1) just met the supplemental indicator value for greenline shrubs and the lower reach (Lost 2) failed to meet the supplemental indicator value. This was likely because of historical disturbance and the current dominance of weeds and rose in much of the reach. The macroinvertebrate sample from the upper site (M03LOSTC01) indicates slight impairment and the other macroinvertebrate sample met both the MMI and O/E supplemental indicator values. The periphyton sample from the lower site (M03LOSTC02) is just over the supplemental indicator value. Three of the sites were rated as “non-functioning”, two were rated as “functional-at risk”, and one site was rated as “proper functioning condition” based on the PFC methodology.

The primary anthropogenic sources of sediment within the watershed are rangeland grazing and roads, while irrigated agriculture is an additional source. These sources have diminished the quality of the riparian habitat, altered channel morphology, and contributed to a decrease in sediment transport capacity and an increased sediment supply. Biological data suggest slight impairment of aquatic life. Excess sediment, lack of pools, an overwidened channel, and limited riparian vegetation all reduce the quality of fish habitat and are likely affecting fish communities. This information supports the 303(d) listing and a sediment TMDL will be completed for Lost Creek.

5.4.2.20 Moose Creek

Moose Creek was listed for low flow alterations on the 2006 303(d) List, which is a form of pollution commonly linked to sediment impairment. DEQ performed a sediment and habitat assessment on one reach in 2006 to determine if there is a link between sediment and the impairment from low flow alteration and because support for all beneficial uses had not been assessed during the previous 303(d) listing cycle. It flows 12.3 miles from its headwaters to its confluence with the Big Hole River at Maiden Rock (**Figure A-2**).

Physical Condition and Sediment Sources
Several agencies have performed assessments of Moose Creek including the BDNF, BLM, and DEQ. The BDNF conducted channel morphology surveys at several sites within the Moose Creek watershed, including one site on the main stem of Moose Creek. The main stem of Moose Creek was considered “non-functioning” at the assessment site, with entrenched conditions resulting from high levels of historic livestock use and the cumulative watershed effects of upstream land uses. However, willow regeneration and the colonization of point bars by sedges indicated the initial stages of recovery (Bengeyfield 2004). Loss of stream function along Moose

Creek was attributed primarily to livestock management, though the effects of past and recent timber management within the upper elevation zone of the watershed have not been documented. Sediment delivery from roads was limited to unmitigated segments near streams and unmitigated stream crossings. The lower reach of Moose Creek, which flows through the Humbug Spires Wilderness Study Area on lands under the jurisdiction of the BLM, is relatively undisturbed except for browse on willows (Bengeyfield 2004). The BLM performed assessments at six sites within grazing allotments between 1988 and 1995. Eighty two percent of the stream surveyed was rated "proper functioning condition" and the remaining 18 percent was rated as "functional – at risk".

The Moose Creek monitoring section (Moose 1) assessed in 2006 was located where the stream leaves the mountains and enters the valley upstream of the I-15 crossing. A forest road paralleled the stream at the upstream end of the monitoring section. Riparian vegetation along the monitoring section was dense and diverse, with alders and willows, while streambanks were naturally "armored" with large substrate along this B3 stream. Granitic geologies in the watershed lead to a naturally high amount of fine sediment in slow water areas and behind boulders. Potential impacts due to irrigated crop production were not assessed since this site was upstream of the area of irrigated agriculture.

Biological Data
Two macroinvertebrate samples were collected in 2005. The bioassessment scores are presented in **Table 5-43**. The fisheries resource value is rated as substantial for Moose Creek (MFISH 2004). While Moose Creek is not currently considered to be supporting a population of westslope cutthroat trout, a 1989 FWP report indicated that they were present in Moose Creek (MFWP 1989). North Fork Moose Creek has a population of westslope cutthroat trout with an unknown abundance (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Moose Creek are summarized in **Tables 5-42** and **5-43**.

Table 5-42. Moose Creek Sediment Data Compared to Targets and Supplemental Indicators
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	**Targets**							**Supplemental Indicators**					
	Pebble Count		**Cross Section**		**Grid Toss**			**Rosgen Level II**		**BEHI**			
	Reach %	**Riffle % <2mm**	**W/D Ratio**	**Entrenchment Ratio**	**Pool Tail % <6mm**		**Pool Spacing**	**Existing**	**Potential**	**BEHI**	**% Non-Eroding Bank**	**Greenline % Shrubs**	**Riparian Condition**
Moose 1	**29**	**17**	**15.9**	**1.7**	**36**		4.1	**B4**	B3	18.6	93	83	PFC

ND = no data

Table 5-43. Biological Metrics for Moose Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03MOOSC01	Near Maclean Creek	7/19/2005	Mountains	**53.9**	**0.75**
M03MOOSC03	Near mouth	7/19/2005	Low Valley	50.8	1.24

Summary and TMDL Development Determination
During the 2006 assessment, all fine sediment targets were exceeded. The width/depth ratio target of 15 was slightly exceeded and the entrenchment target of 1.8 was just below the target. The pool spacing target was met.

The reach failed to meet its potential Rosgen channel type because of a dominant amount of gravel instead of cobble (i.e. B4 vs B3). However, the reach met all supplemental indicator values for bank erosion, percent greenline shrubs, and riparian condition. This monitoring section was considered to be in "proper functioning condition" based on the PFC methodology. One of the two macroinvertebrate samples failed to meet both the MMI and O/E supplemental indicator values and indicated impairment.

All targets, except for pool spacing, were not met. Although the upper watershed appears to be recovering, historical land management within the upper watershed has caused the channel to become over widened and entrenched. Due to the 2006 assessment reach being upstream of the irrigation portion of the watershed, the link between low flow alterations and sediment could not be evaluated. However, despite the granitic geology, numerous human sources have contributed to a loss of sediment transport capacity and are also likely increasing the sediment supply. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though roads, timber harvest and irrigated agriculture are additional sources. The macroinvertebrate data indicate impairment of macroinvertebrates in the upper part of the watershed, and excess sediment and an overwidened channel are likely affecting the fishery beneficial use. As part of adaptive management, additional data should be collected in the future in the lower part of the watershed to determine if there is a relationship between sediment and the flow alteration impairment. However, based on sediment target exceedances and anthropogenic sources identified in the upper watershed, a sediment TMDL will be completed for Moose Creek.

5.4.2.21 Oregon Creek

Oregon Creek is a tributary of California Creek that is 1.8 miles long (**Figure A-2**) and was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. The entire Oregon Creek watershed is within the Mt. Haggin Wildlife Management Area.

Physical Condition and Sediment Sources
Hillslope erosion, due to a lack of vegetation associated with arsenic deposition from the Anaconda Smelter, is a continuing source of sediment in the upper part of the watershed. A

monitoring section assessment was performed at one site (Oregon 1) downstream of the Highway 257 crossing. Upstream of the road crossing, Oregon Creek is confined by the road and the existing channel is a series of beaver ponds containing fine sediments. The road is built upon a substantial amount of fill, which likely dramatically changed the nature of the valley through which the stream flows. Downstream of the road crossing, the monitoring section assessment was performed in a reach that was historically placer mined and a E3b stream type was becoming re-established. It appeared that the entire channel had been relocated during mining. The monitoring section was downcut and had a valley wall on the right bank and cobble sized tailings on the left bank. Very little bank erosion was observed and it was mostly associated with the stream cutting into the hillslope.

Biological Data

One macroinvertebrate and periphyton sample was collected in 2005. The bioassessment scores are presented in **Table 5-45**. The fisheries resource value of Oregon Creek is moderate (MFISH 2004). FWP reported a good fishery for a stream the size of Oregon Creek, though the lower reaches may be negatively affected by habitat destruction due to past placer mining and sediment inputs from eroding hillslopes and a road crossing (MFWP 1989).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Oregon Creek are summarized in **Tables 5-44** and **5-45**.

Table 5-44. Oregon Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Oregon 1	20	15	7.5	**3.3**	7	**9.6**	**E4b/B4**	E3b	22.6	98	89	FAR

ND = no data

Table 5-45. Biological Metrics for Oregon Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03ORGNC01	0.25 mile downstream of Hwy 274	7/7/2005	Mountains	**51.6**	**0.79**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03ORGNC01	0.25 mile downstream of Hwy 274	7/7/2005	Mountains	**60-70%**	

Summary and TMDL Development Determination
During the 2006 assessment, the composite and riffle pebble count surface fines were just meeting the targets of ≤ 20 percent and ≤ 15 percent. The grid toss target for fine sediment in the pool tail was met. The width/depth ratio target was also met, however, the reach failed to meet the entrenchment target. Channel entrenchment within this reach was the result of historic placer mining, though the channel appeared to be in a state of recovery. The pool spacing target was not met and was also likely a result of placer mining.

The assessment reach was transitioning to its potential Rosgen channel type of E3b. Very little streambank erosion was observed along this monitoring section, with both the BEHI rating and the percent of reach with non-eroding banks meeting the supplemental indicator values. Deciduous shrubs were found along 89 percent of the monitoring section, which meets the supplemental indicator of ≥ 49 percent. Field notes indicate that the narrow riparian corridor is densely vegetated with healthy willows that extend to the edge of the tailings. Both the macroinvertebrate sample and periphyton sample did not meet their supplemental indicator values and indicate impairment. This monitoring section was rated as "functional-at risk" based on the PFC methodology.

Entrenchment ratio and pool spacing were the only parameters that failed to meet target criteria, though much of Oregon Creek was comprised of beaver dams that precluded assessment. Although beaver activity is altering the sediment transport capacity of Oregon Creek, the legacy of historical activities within the watershed continues to contribute excess sediment to Oregon Creek that is limiting its ability to fully support aquatic life. The lack of pool habitat is likely affecting fish communities. The primary anthropogenic sources of sediment within the watershed are rangeland grazing, roads and mining. Landscape scale alterations due to valley fill for road construction, along with on-going hillslope erosion due to the loss of vegetation as a result of arsenic deposition from the Anaconda Smelter appear to be the major factors influencing sediment transport and accumulation in Oregon Creek. This information supports the 303(d) listing and a sediment TMDL will be prepared for Oregon Creek.

5.4.2.22 Pattengail Creek

Pattengail Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. It flows 18.8 miles from its headwaters to its mouth at the Wise River (**Figure A-2**).

Physical Condition and Sediment Sources

The Montana Power Company constructed a dam on Pattengail Creek in 1901, creating a reservoir that inundated approximately 2.5 miles of stream habitat. This dam failed in 1927, causing considerable scouring of the channel in lower Pattengail Creek and the Wise River (MFWP 1989). A streamflow of 23,000 cfs on the Big Hole River at the Melrose gaging station on June 14, 1927 resulted from the dam failure and was the highest flow ever recorded on the Big Hole River.

One monitoring section was assessed on Pattengail Creek (Pattengail 1) in 2006. This monitoring section was located between the site of the dam and the mouth, where Pattengail Creek flows into the Wise River. The upper part of the reach was over-widened with deep, slow moving water and then it progressed into a riffle-pool section. This reach is representative of Pattengail Creek from the assessment site downstream to the mouth. Extensive cobble deposits from the 1927 flood flows were observed on the forest floor several feet above the current channel elevation. Large substrate armored the banks and streambed and along with wetland vegetation, limited bank erosion. The substrate was considerably fine in the deep upper part of the reach. The existing channel appears to be narrowing, with cobble bars encroaching into the riffles in an apparent attempt to increase sinuosity. Alders were establishing at the bankfull level, with conifers at the flood-prone margin.

Biological Data

One macroinvertebrate and periphyton sample was collected in 2001. The bioassessment scores are presented in **Table 5-47**. The fisheries resource value of Pattengail Creek is substantial. Westslope cutthroat trout are common in the tributary of Reservoir Creek and abundant in the tributary of Lambrecht Creek. There are also Yellowstone cutthroat trout in the drainage (MFISH 2004).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Pattengail Creek are summarized in **Tables 5-46** and **5-47**.

Table 5-46. Pattengail Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Pattengail 1	12	2	**33**	**1.4**	11	3.2	B3c/ F3	B3c	19.2	99	44*	FAR

ND = no data; * No supplemental indicator applied in areas with predominately coniferous vegetation

Table 5-47. Biological Metrics for Pattengail Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03PATGC02	at mouth	7/11/2001	Mountains	**59.6**	**0.79**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03PATGC02	at mouth	7/11/2001	Mountains	**>95%**	

Summary and TMDL Development Determination
During the 2006 assessment, the composite pebble count surface fines <6mm was just meeting the target criteria of ≤ 12 percent for B3 streams, but both the fine sediment in riffles and in pool tails easily met the target. The reach failed to meet both the target for width/depth ratio and for entrenchment. The over-widened and entrenched channel conditions are likely the result of the dam failure. The pool spacing target was met.

Pattengail Creek was a B3c stream type in this monitoring section, which is the potential stream type. Very little streambank erosion was observed along this monitoring section, with both the BEHI rating and the percent of reach with non-eroding banks meeting the supplemental indicator values. Larger cutslopes observed at the downstream end of the monitoring section were not included in the bank erosion assessment since they appeared to be the result of the 1927 dam failure and subsequent flood event. The percent shrub understory was close to the supplemental indicator value although it was expected to be because of a coniferous overstory. Both the macroinvertebrate and periphyton samples failed to meet the supplemental indicator value and indicated impairment. This monitoring section was rated as “functional-at risk” based on the PFC methodology.

The altered channel morphology is likely related to the 1927 dam failure. Although the fine sediment targets were met and the assessment indicates the channel is still recovering from the dam failure, the biological data indicate Pattengail Creek is not fully supporting aquatic life due to excess sediment. The over-widening of the channel has likely reduced the sediment transport capacity of the channel, and the channel over-widening combined with effects to aquatic life are likely affecting fish communities. The primary anthropogenic source of sediment within the watershed is rangeland grazing. This information supports the listing and a sediment TMDL will be written for Pattengail Creek.

5.4.2.23 Rochester Creek

Rochester Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Its channel is 15.7 miles long (**Figure A-2**), however, Rochester Creek is an intermittent stream and flow typically does not reach the Big Hole River (USACE/BLM 2002).

Physical Condition and Sediment Sources
The BLM conducted riparian assessments at several sites. Overall, 1.1 miles of Rochester Creek were rated as “proper functioning condition”, 2.2 miles were rated as “functional-at risk” and 1.4 miles were rated as “non-functional”. In addition, 0.6 miles were rated as “non-functional” in 2001. Problems with riparian vegetation stemmed from the amount of decadent woody vegetation, utilization of trees and shrubs, and the presence of noxious weeds and undesirable herbaceous species. Trees were absent at some sites, while tree regeneration was reduced at other sites. Grazing, mining, and roads were noted as impacts to streambanks.

Two monitoring section assessments were performed along Rochester Creek in 2006. In the upper monitoring section (Rochester 1), the creek flowed through a “wetland” area with poorly defined streambanks and vegetation growing into the channel. Portions of this monitoring section resembled an entrenched gully (G type), with stream types ranging from C5b to B5 to G5 to F5b, with a potential of an E4b stream type. The stream was actively headcutting at one point within the monitoring section and again just downstream of the monitoring section. It is unclear how much historic mining has lead to a fining of the substrate within this “foothill” watershed, though it appeared that tailings deposits within the channel might have lead to aggradation. The stream was dry along the Thistle Mine tailings upstream of the monitoring section. This monitoring section appeared to be controlled by groundwater recharge. At the lower monitoring section (Rochester 2), Rochester Creek appears to have been converted to a ditch. The lower portion of the monitoring section was straightened and there was one large plunge pool associated with a headcut. The existing stream type shifted from an E4 to B4c to G4c in the downstream direction, with a potential stream type of E4.

Biological Data
One macroinvertebrate and one periphyton sample was collected in 2000. The bioassessment scores are presented in **Table 5-49**.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for the X are summarized in **Tables 5-48** and **5-49**.

Table 5-48. Rochester Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets							Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss			Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing		Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Rochester 1	**61**	**49**	**14.1**	**1.5**	ND	ND		**C5b/G5/ B5/F5b**	E4 b	**31.8**	96	**40**	**NF**
Rochester 2	**44**	**36**	6.1	**1.8**	ND	**291.4**		**E4/B4c/ G4c**	E4	**38.1**	95	**10**	**NF**

ND = no data

Table 5-49. Biological Metrics for Rochester Creek.
Bold text failed to meet the target (Low Valley ≥ 48, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03ROCHC09	1 mile above BLM boundary	7/18/2000	Low Valley	**42.0**	1.05
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03ROCHC09	1 mile above BLM boundary	7/18/2000	Mountains	20-30%	

Summary and TMDL Development Determination
During the 2006 assessment, the targets for reach and riffle pebble count surface fines were not met in both sections. In the upper monitoring section (Rochester 1), the width/depth ratio and entrenchment targets were not met. In the lower monitoring section (Rochester 2), the width/depth ratio target was met, but the channel was entrenched and not meeting the target. There were no pools in the upper reach and only one pool in the lower reach associated with a headcut, so neither reach met the pool spacing target and no grid tosses were performed.

Streambank erosion in both monitoring sections exceeded the supplemental indicator BEHI value. Both sections did not meet the supplemental indicator value for percent greenline shrubs. Despite lacking understory shrubs, the herbaceous and wetland groundcover in both reaches (74 percent in upper and 82 percent in lower) resulted in them both meeting the supplemental indicator value for percent of non-eroding banks.

For macroinvertebrates, the MMI score was below the threshold, but the O/E score was well above the threshold, indicating the macroinvertebrates are not impaired. Additionally, the periphyton sample indicated a low probability of impairment. Both of these monitoring sections were rated as “non-functioning” based on the PFC methodology.

Increases in the width/depth ratio and the percent surface fines suggest a decrease in sediment transport capacity and possibly an increased sediment supply. Although the biological samples did not indicate impairment, the high percentage of fine sediment, an over-widened channel, and lack of pool habitat are most likely limiting Rochester Creek from fully supporting fish and aquatic life. The primary anthropogenic sources of sediment within the watershed are rangeland grazing and mining, though roads and irrigated crop production are additional sources. This information supports the 303(d) listing and a sediment TMDL will be completed for Rochester Creek.

5.4.2.24 Sawlog Creek

Sawlog Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. It flows 5 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
The BDNF, DEQ and BLM have conducted assessments on Sawlog Creek. The BDNF conducted a channel morphology survey at one site on Sawlog Creek in 1994 and found a “nonfunctional” B5c stream type, when reference conditions suggested it should be an E4 stream type (Bengeyfield 2004). DEQ collected channel morphology and substrate data at one site in 2003. Riffle gravels were covered in silt and the stream was described as severely degraded from mile 1 to 3 on USFS land with active bank erosion. The assessment summary indicated that BLM land was well vegetated with willows and lodgepole pine but USFS land had poor riparian vegetation as a result of overgrazing. The BLM conducted a riparian assessment in 2002 at a site that had been rated as “functional – at risk” in 1995. The newer assessment determined that the site had improved to “proper functioning condition”.

Two monitoring section assessments were performed along Sawlog Creek in 2005 and 2006. The upper monitoring section (Sawlog 1) was located approximately 1 mile upstream of the confluence with the Big Hole River and was on USFS lands just upstream of the forest boundary. The lower monitoring section (Sawlog 2) was located on BLM land near the mouth. At the upper monitoring section, livestock grazing had impacted the stream channel and extensive pugging and hummocking was observed, while the lower monitoring section appeared to be in a state of recovery. The lower reach had dense riparian vegetation, although the stream was slightly incised. Since this site was close to the mouth of the Big Hole, it may be that the slight incisement is related to this confluence.

Biological Data

One macroinvertebrate sample and two periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-51**. The fisheries resource value of Sawlog Creek is moderate (MFISH 2004). While the MFISH database does not consider Sawlog Creek to contain Arctic grayling, an assessment by FWP revealed two Arctic grayling in a Sawlog Creek pool in 2002 (Magee and Lamothe 2003).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for the X are summarized in **Tables 5-50** and **5-51**.

Table 5-50. Sawlog Creek Sediment Data Compared to Targets and Supplemental Indicators.

Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Sawlog 1	**57**	**40**	**11.4**	**2.5**	**99**	**8.5**	**C4/B4c/E4**	E4	**30.7**	92	**22**	**NF**
Sawlog 2	**92**	**78**	3.3	**2.0**	ND	11.1	**E5/G5c/B5c**	E4	**29.2**	99	75	FAR
Sawlog D2 (USFS)	**100**	**82**	7.0	**1.6**	ND	ND	**B5c**	E4	**27.8**	ND	ND	**NF**
M03SWLGC01	**83**	**72**	ND	ND	ND	ND	ND	ND	ND	ND	ND	FAR

ND = no data

Table 5-51. Biological Metrics for Sawlog Creek.

Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03SWLGC01	0.1 mile above mouth	9/13/2003	Mountains	**24.0**	**0.16**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03SWLGC01	0.1 mile above mouth	9/13/2003	Mountains	**90-95%**	
M03SWLGC02	end of 4WD Road	9/13/2003	Mountains	30-40%	

Summary and TMDL Development Determination

All fine sediment data exceeded the targets by a large margin. The grid toss was not performed in the lower monitoring section (Sawlog 2) since the pool tail-outs were comprised entirely of sands and fine gravels. The upper site from the recent DEQ assessment (Sawlog 1) did not meet the target for width/depth ratio, but Sawlog 2 met the width/depth ratio target and the USFS site (Sawlog D2) was just meeting the target. However, all three sites with an entrenchment ratio had lost access to the floodplain and did not meet the entrenchment target. Over-widened and entrenched channel conditions along Sawlog Creek were the result of livestock grazing. Both recently assessed DEQ sites did not meet the pool spacing target.

All reaches assessed for Rosgen channel type have the potential of being an E4 channel type, and with the exception of a few segments, none of the reaches were meeting their potential. Streambank erosion in all monitoring sections exceeded the supplemental indicator BEHI value of 24.2 for E4 stream types. The percent of each monitoring section with non-eroding banks was meeting the supplemental indicator value of ≥ 85 percent, though there was a greater amount of streambank erosion in the upper monitoring section, along with extensive pugging and hummocking. Sawlog 1 failed to meet the supplemental indicator value for greenline shrubs. Along Sawlog 1, the stream channel retained extensive wetland vegetation, which has the potential to reduce width/depth ratios if allowed to grow. However, the wetland vegetation was heavily browsed along the entire monitoring section. There also appeared to be posts for electric fence, suggesting grazing management, though no wire was present. Sawlog 2 met the supplemental indicator value for greenline shrub. The macroinvertebrate sample was well under the threshold for both the MMI and O/E metrics, indicating severe impairment. The periphyton sample from the same site indicated a very high probability of impairment, but the other periphyton sample was just meeting the supplemental indicator value. Sawlog 1 was rated “non-functioning”, while Sawlog 2 was rated as “functional-at risk” based on the PFC methodology.

The high percentage of fine sediment, over-widening in the upper reach, and channel entrenchment at all reaches indicates an increase in sediment supply, decrease in sediment transport capacity, and a loss of floodplain access. Although the lower part of the watershed appears to be in recovery, the upper part of the watershed continues to be a source of excess sediment. The altered channel morphology and excess sediment is likely limiting the quantity and quality of fisheries habitat and affecting rearing and spawning success. Additionally, the biological data indicate impairment to aquatic life. The primary anthropogenic source of sediment within the watershed is rangeland grazing. This information supports the 303(d) listing and a sediment TMDL will be prepared for Sawlog Creek.

5.4.2.25 Sevenmile Creek

Sevenmile Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. The majority of the Sevenmile Creek watershed is within the Mt. Haggin Wildlife Management Area (**Figure A-2**).

Physical Condition and Sediment Sources

FWP noted streambank instability and soil erosion along the lower reaches due to vehicular travel and livestock grazing as environmental concerns (MFWP 1989).

Two monitoring section assessments were performed along Sevenmile Creek in 2006. The upper monitoring section (Sevenmile 1) was located in a mountainous area upstream of the Dry Creek Road crossing. It was a functioning E4b channel in a narrow valley bottom with willows and wetland vegetation. This monitoring section was representative of Sevenmile Creek upstream of the Dry Creek Road crossing. The lower monitoring section (Sevenmile 2) on Sevenmile Creek was located in a meadow area near the mouth and the confluence with Tenmile Creek. Streambank trampling and channel over-widening were noted and attributed to livestock grazing. This monitoring section was representative of Sevenmile Creek downstream of the Dry Creek Road crossing, though beaver dams also influence channel form in this valley bottom section.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2001. The bioassessment scores are presented in **Table 5-53**. Trout populations in Sevenmile Creek were described as slightly below average for Mt. Haggin area streams and other streams in the upper Big Hole River watershed (MFWP 1989). The fisheries resource value of Sevenmile Creek is moderate (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Sevenmile Creek are summarized in **Tables 5-52** and **5-53**.

Table 5-52. Sevenmile Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Sevenmile 1	26	13	**8.2**	**1.8**	**28**	4.7	**E4b/B 4/G4**	E4b	**32.4**	92	75	FAR
Sevenmile 2	37	**37**	**11.6**	**1.5**	**66**	4.9	**E4/G4 c/B4c/ F4/C4**	E4	**27.7**	93	**36**	FAR

ND = no data

Table 5-53. Biological Metrics for Sevenmile Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03SVNMC01	above road 2483	7/9/2001	Mountains	**52.8**	0.85
M03SVNMC03	below road 2483	7/9/2001	Mountains	66.6	**0.70**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03SVNMC01	above road 2483	7/9/2001	Mountains	**60-70%**	
M03SVNMC03	below road 2483	7/9/2001	Mountains	**90-95%**	

Summary and TMDL Development Determination

During the 2006 assessment, both sites met the target for reach fine sediment, but the lower site (Sevenmile 2) failed to meet the target for riffle fine sediment. The target for grid toss percent fines in pool tail-outs was exceeded in both monitoring sections. In the upper monitoring section (Sevenmile 1), there were numerous small pools and spawning brook trout were observed. Both reaches met the target for pool spacing. Both reaches failed to meet the target for width/depth ratio and entrenchment. However, at Sevenmile 1, two out of the five cross-section measurements had entrenchment ratios >5, indicating that entrenchment is localized based on the topography of this relatively narrow floodplain area. Livestock grazing and road crossings appeared to be the source of channel over-widening at Sevenmile 2. Field notes indicated that over-widened riffles at former road crossings accumulated fine sediments.

Portions of both reaches met their potential for Rosgen channel type, but overall, both reaches were failing to meet their potential. Streambank erosion in both monitoring sections exceeded the supplemental indicator BEHI value of 24.2 for E4 stream types. The percent of reach with non-eroding banks met the supplemental indicator value in both monitoring sections. Sevenmile 1 met the supplemental indicator value for greenline shrubs of ≥ 49 percent, but Sevenmile 2 failed to meet the supplemental indicator value. Both macroinvertebrate samples failed to meet the supplemental indicator value for one of the metrics and indicated impairment. Both periphyton samples were above the supplemental indicator value and indicated impairment. Both of the monitoring sections were rated as “functional-at risk” based on the PFC methodology.

Land use in the watershed is contributing excess sediment and has over widened the channel, which has decreased the sediment transport capacity. The fine sediment is showing some accumulation in the riffle habitat but has predominantly accumulated in the pools. The excess fine sediment is impairing the aquatic life and likely affecting fish communities by decreasing the quality of fisheries habitat. The primary anthropogenic sources of sediment within the watershed are rangeland grazing and roads. This information supports the 303(d) listing and a sediment TMDL will be prepared for Sevenmile Creek.

5.4.2.26 Sixmile Creek

Sixmile Creek is a tributary of California Creek that was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. The entire Sixmile Creek watershed is within the Mt. Haggin Wildlife Management Area (**Figure A-2**).

Physical Condition and Sediment Sources
An assessment by FWP noted eroding streambanks and channel instability in the lower reaches (MFWP 1989).

Two monitoring section assessments were performed along Sixmile Creek in 2006. The upper monitoring section (Sixmile 1) was located upstream of the Dry Creek Road Crossing, while the lower monitoring section (Sixmile 2) was located near the mouth and the confluence with California Creek. The upper monitoring section is representative of Sixmile Creek upstream of the Dry Creek Road crossing. The lower portion of Sixmile Creek downstream of the historic Mule Ranch is heavily impacted by grazing. The lower monitoring section contained an over-widened and entrenched F stream type in the upper portion, and then progressed into a G3 entrenched "gully" stream type associated with extensive slumping of the vertical streambanks. Progressing downstream, the channel became a more functional E stream type in places, while other areas were over-widening to a C stream type. In a fenced area upstream of this monitoring section, the stream appeared to be in better shape, suggesting that the monitoring section may be unique. Beaver dams likely also influence channel morphology and sediment transport in Sixmile Creek downstream of the Dry Creek Road crossing.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2001. The bioassessment scores are presented in **Table 5-55**. The fisheries resource value of Sixmile Creek is moderate (MFISH 2004). Fisheries data indicate Sixmile Creek is an important spawning and rearing area for the California-French Creek drainage. DEQ noted that abundant boulders and overhanging vegetation provided good fish habitat. Small numbers of westslope cutthroat trout were present in 1989, suggesting the possibility of larger populations in the upper drainage (MFWP 1989). However, westslope cutthroat trout are not listed in the 2004 MFISH database.

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Sixmile Creek are summarized in **Tables 5-54** and **5-55**.

Table 5-54. Sixmile Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Sixmile 1	**26**	**14**	10.8	**1.6**	**18**	**6.7**	**B4/G4c/ C4b**	B4	28.1	96	90	PFC
Sixmile 2	**37**	**16**	10.0	**1.5**	15	**6.1**	**G4/F4b/ E4b/B4**	E3b	**35.9**	**70**	**26**	**NF**

ND = no data

Table 5-55. Biological Metrics for Sixmile Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03SIXMC01	above road 2483	7/9/2001	Mountains	**45.5**	**0.77**
M03SIXMC02	below road 2483	7/9/2001	Mountains	**47.4**	**0.46**
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03SIXMC01	above road 2483	7/9/2001	Mountains	**80-90%**	
M03SIXMC02	below road 2483	7/9/2001	Mountains	**80-90%**	

Summary and TMDL Development Determination
During the 2006 assessment, the reach and riffle pebble count fine sediment targets were exceeded in both reaches. The fine sediment in pool tails target was exceeded at the upper reach (Sixmile 1) and met in the lower reach (Sixmile 2). Both reaches met the target for width/depth ratio but failed to meet the entrenchment target. Both reaches failed to meet the pool spacing target.

Neither reach was meeting its potential Rosgen channel type. Streambank erosion at Sixmile 1 was meeting the supplemental indicator for BEHI and non-eroding banks. Dense woody vegetation along channel margin in the upper monitoring section provided excellent bank stability. However, streambank erosion along Sixmile 2 exceeded the supplemental indicator BEHI value and failed to meet the supplemental indicator value for percent non-eroding banks.

Also, Sixmile 1 met the supplemental indicator value for percent greenline shrubs but Sixmile 2 failed to meet the supplemental indicator value with less than a third of the shrub understory as the upper reach. At Sixmile 2, streambank erosion was closely correlated with areas lacking woody riparian vegetation. Both of the macroinvertebrate samples and both of the periphyton samples failed to meet their supplemental indicator values and strongly indicate impairment. Sixmile 1 was considered to be in “proper functioning condition”, while Sixmile 2 was rated as “non-functioning” based on the PFC methodology.

Although field notes indicated the amount of degradation in the lower reach might be unique, fine sediment is also accumulating in riffle and pool habitat in the upper part of the watershed. The high percentage of fine sediment suggests an increased sediment supply, and the bank erosion values from the lower reach indicate bank erosion is likely a source. Additional sources are rangeland grazing and roads. The biological data indicate sediment is impairing aquatic life in Sixmile Creek. The high percentage of fines and low frequency of pools is also likely limiting the fishery beneficial use. This information supports the 303(d) listing and a sediment TMDL will be completed for Sixmile Creek.

5.4.2.27 Soap Creek

Soap Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. It flows 8.3 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
Both the BLM and DEQ have performed assessments on Soap Creek. DEQ conducted assessments at two sites on Soap Creek in 2003. The field notes indicated that livestock grazing has altered riparian communities. The conversion of sedge dominated systems to grasses and forbs, heavy utilization of willows, a lack of willow regeneration, and the presence of noxious weeds were noted. Road encroachment and culverts were frequent at the upper site (M03SOAPC01). There was a heavy fine sediment load at the upper site and sediment was trapped in the macrophytes but gravels were clean. The lower site, M03SOAPC02, flowed through a hay field and the channel became indiscernible about 0.75 miles from the mouth. Hoof shear and pugging were seen throughout the lower site as well as sediment pathways from the road. Overall, roads, grazing, and mining waste rock/tailings were cited as sediment sources. Assessments by the BLM at three grazing allotments in the mid to late 1990s found “functional – at risk” conditions.

Two TMDL-related assessments were performed along Soap Creek in 2006. Soap Creek arises from springs shortly upstream of the upper monitoring section (Soap 1) with additional springs observed along the site and water flowing out of the hillslope and across the road downstream of the site. This site was heavily grazed and lacked a deciduous understory. Downstream of the site, Soap Creek flows through an aspen dominated narrow riparian corridor. A road parallels and encroaches upon Soap Creek both along and downstream of the upper monitoring section. At the lower monitoring section (Soap 2), the channel was only scarcely defined, with water flowing in a narrow band and spilling out into a wider area of wetland vegetation. The valley was incised along this monitoring section, with the stream cutting a new channel in the valley bottom. Direct sediment contribution from the road was observed upstream of this assessment site. During a site visit in 2005, the channel went dry between the upper and lower monitoring sections, indicating that additional groundwater inputs may be occurring. Soap Creek appears to be intercepted by a ditch after it flows under I-15 and into the valley bottom, which is used for irrigated agriculture.

Biological Data
Two macroinvertebrate and periphyton samples were collected in 2003. The bioassessment scores are presented in **Table 5-57**. The fisheries resource value is rated as limited for Soap Creek (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Soap Creek are summarized in **Tables 5-56** and **5-57**.

Table 5-56. Soap Creek Sediment Data Compared to Targets and Supplemental Indicators. Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Soap 1	**33**	**42**	**11.1**	3.7	ND	ND	**E4a/ B4a**	E3a	**27.6**	**48**	**18**	**NF**
Soap 2	**66**	**32**	**11.0**	4.6	ND	ND	**E5b/ C5b**	E4b	**37.4**	99	**40**	**NF**
M03SOAP C01	36	**26**	6.4	4.7	ND	ND	E4	E4	ND	ND	ND	FAR
M03SOAP C02	**40**	**34**	5.8	5.2	ND	ND	E4	E4	ND	ND	ND	FAR

ND = no data

Table 5-57. Biological Metrics for Soap Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03SOAPC01	0.5 mile above Left Fork Soap Creek	7/30/2003	Mountains	**36.2**	**0.77**
M03SOAPC02	2.5 miles above Highway 15	7/30/2003	Mountains	**41.7**	0.97
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03SOAPC01	0.5 mile above Left Fork Soap Creek	7/30/2003	Mountains	**70-80%**	
M03SOAPC02	2.5 miles above Highway 15	7/30/2003	Mountains	**80-90%**	

Summary and TMDL Development Determination
All but the upper site from the 2003 assessment (M03SOAPC01) failed to meet the target for reach fine sediment and all sites failed to meet the riffle target. Both sections from 2006 failed to meet the target for width depth ratio, but the sites from 2003 met the target. All sites met the target for entrenchment ratio. There were no pools in either section assessed in 2006, so there was no grid toss or pool spacing data to compare to targets.

The sites assessed in 2003 were meeting their potential Rosgen channel type, but those assessed in 2006 failed to meet their potential. Streambank erosion in the upper monitoring section from 2006 (Soap 1) met the supplemental indicator BEHI value, though only 48 percent of the reach had non-eroding banks, which fails to meet the supplemental indicator value of ≥ 85 percent. Streambanks along this monitoring section were trampled by livestock, with "pugging and hummocking" observed along the entire length of the reach. In the lower monitoring section (Soap 2), a mean BEHI value of 37.4 failed to meet the supplemental indicator value, though this was due to the stream eroding into a cutslope at one location. Soap 2 met the supplemental indicator value for percent non-eroding banks. Both reaches from 2006 failed to meet the supplemental indicator value for greenline shrubs and were rated as "non-functioning" based on the PFC methodology. Although the O/E score for one macroinvertebrate sample met the supplemental indicator value, the results overall indicate impairment of the macroinvertebrate community. Both periphyton samples did not meet the supplemental indicator value and indicate impairment.

Increases in the width/depth ratio and the percent surface fines suggest a decrease in sediment transport capacity and possibly an increased sediment supply. Although the sites from 2003 and 2006 were in slightly different locations, the high/width depth ratio, failure to meet its potential channel type, and a non-functioning riparian zone in 2006 indicates that Soap Creek has become more degraded since 2003. The excess sediment is impairing both macroinvertebrates and periphyton, and the excess sediment, limited riparian vegetation, and lack of pools is likely affecting fish communities. The primary anthropogenic sources of sediment within the watershed are rangeland grazing and roads, though irrigated agriculture may be an additional source. This information supports the 303(d) listing and a sediment TMDL will be written for Soap Creek.

5.4.2.28 Trapper Creek

Trapper Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. It flows 17.4 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources
The BDNF performed channel morphology surveys at two sites along Trapper Creek in 1994. The upper Trapper Creek watershed was heavily mined in the 1800's and there was likely an increase in sediment loads during that time. Livestock grazing has reportedly led the stream channel to become entrenched along the middle portion of Trapper Creek. The upper reach, Trapper Up, was classified as a "non-functioning" F4 channel with the potential of being an E4 channel. Farther downstream, Trapper Creek turns to the east and the stream type changes to A3. This section, Trapper Down, was considered a reference reach during the assessment.

Two TMDL-related assessments were performed by DEQ along Trapper Creek in 2005 and 2006. The upper monitoring section (Trapper 1) was located at the downstream extent of National Forest Lands. This monitoring section was in a transition zone from a steep mountain channel to a lower gradient willow dominated valley bottom channel. Stream types varied from E4 to B4c to G4c suggesting impacts to channel morphology, while the potential stream type was E4. Upstream of the monitoring section, Trapper Creek was a naturally functioning A3 stream type.

Grazing impacts were observed along the monitoring section, while a road closely parallels the channel for approximately 0.4 miles downstream of the monitoring section, leading to channelized conditions and sediment input. Where the valley opens up, extensive fine sediment deposition was observed in an area formerly occupied by beaver dams. The lower monitoring section (Trapper 2) was lined with dense riparian vegetation, consisting primarily of willows, but also some alders. It appeared that the channel was over-widened historically and was in a state of recovery, with a potential of an E4 stream type.

Biological Data
Three macroinvertebrate and periphyton samples were collected in 2005. The bioassessment scores are presented in **Table 5-59**. Mining in the upper watershed has altered in-stream habitat locally where the stream flows through old tailing piles (MFWP 1989). FWP (1989) reported that depressed trout populations in Trapper Creek were mostly due to mine pollution. A 1980 sampling event found westslope cutthroat trout in Trapper Creek (MFWP 1989). In 2004, the distribution of westslope cutthroat trout was listed as unknown in Trapper Creek, as well as Sappington Creek, which is a tributary to Trapper Creek (MFISH 2004).

Comparison to Water Quality Targets
The existing data in comparison to the targets and supplemental indicators for Trapper Creek are summarized in **Tables 5-58** and **5-59**.

Table 5-58. Trapper Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Trapper 1	24	12	**7.9**	**2.3**	17	5.5	**E4/B4c/G4c**	E4	**33.3**	87	82	FAR
Trapper 2	37	**26**	**16.1**	9.0	**29**	**9.0**	**C4/B4c/E4**	E4	24.4	95	74	FAR
Trapper Dn (USFS)	15	**14**	7.7	1.4	ND	ND	A3	A3	16.5	ND	ND	PFC
Trapper Up (USFS)	29	**26**	**16.7**	1.2	ND	ND	**F4**	E4	**37.4**	ND	ND	**NF**

ND = no data

Table 5-59. Biological Metrics for Trapper Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03TRAPC01	near headwaters	7/14/2005	Mountains	74.6	1.04
M03TRAPC02	2 miles above mouth on BLM land	7/15/2005	Mountains	70.6	0.93
M03TRAPC03	above the USFS lower boundary	7/15/2005	Low Valley	49.3	1.05
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03TRAPC01	near headwaters	7/14/2005	Mountains	**50-60%**	
M03TRAPC02	2 miles above mouth on BLM land	7/15/2005	Mountains	**80-90%**	
M03TRAPC03	above the USFS lower boundary	7/15/2005	Mountains	10-20%	

Summary and TMDL Development Determination
All sites met the fine sediment target for the reach composite pebble count, but three of the sites exceeded the riffle fine sediment target. The Trapper Down site, which had been considered a reference, was only over the target by one percent. However, the other sites that exceeded the target both had 26 percent fine sediment <2mm in the riffle. Both of the DEQ sites and the upper USFS site (Trapper Up) exceeded the width/depth ratio target. At the DEQ upper monitoring section (Trapper 1), the entrenchment target was not met, indicating a lack of floodplain access, but the pool spacing and fine sediment pool tail targets were met. The lower DEQ reach (Trapper 2) met the entrenchment target but failed to meet the target for pool tail fine sediment and pool spacing.

All sites, but the USFS reference reach (Trapper Down), were not meeting their potential Rosgen channel type. Both Trapper 1 and Trapper Up site exceeded the supplemental indicator BEHI value. Trapper 2 was just barely exceeding the BEHI supplemental indicator value of 24.2 for E4 stream types. Both DEQ reaches met the supplemental indicator value for percent non-eroding bank, although there was a greater amount of streambank erosion at Trapper 1. Both DEQ reaches met the supplemental indicator value for percent greenline shrubs. Both of the DEQ monitoring sections were rated as "functional-at risk", Trapper Up was "non-functioning", and Trapper Down was in "proper functioning condition" based on the PFC methodology. All three macroinvertebrate samples met the supplemental indicator value for both the MMI and O/E metrics. Two of the three periphyton samples did not meet the supplemental indicator value and indicate impairment.

Increases in the width/depth ratio and the percent surface fines suggested a decrease in sediment transport capacity and possibly an increased sediment supply. The BEHI score failed to meet supplemental indicator criteria in both monitoring sections, suggesting an increased sediment load from streambank sources. Although some of the excess fine sediment may be related to historical beaver activity and the lower portion of Trapper Creek appeared to be recovering from historical disturbance, the system is over-widened, entrenched in some areas, and receiving sediment from several human-related sources. Although the macroinvertebrate community is not indicating impairment, the periphyton community is indicating a high probability of impairment from sediment. Additionally, channel overwidening, excess sediment in riffles and pools, and lack of pools are all likely affecting fish communities. The primary anthropogenic sources of sediment within the watershed are rangeland grazing and roads, while timber harvest and cropland are additional sources. This information supports the 303(d) listing and a sediment TMDL will be written for Trapper Creek.

5.4.2.29 Willow Creek

Willow Creek was listed for low flow alterations on the 2006 303(d) List, which is a form of pollution commonly linked to sediment impairment. Additionally, fisheries and aquatic life uses were not assessed during the 2006 303(d) Listing cycle and those uses are typically the most sensitive to excess sediment. Willow Creek flows 21 miles from its headwaters to its confluence with the Big Hole River (**Figure A-2**).

Physical Condition and Sediment Sources

The BDNF has collected stream morphology data at several sites on Willow Creek in 1991 (Willow), 1994 (Willow BLM) and 1998 (Willow Down, Mid, and Up). The survey reach on BLM lands was considered a reference reach. Impacts to Willow Creek reportedly include timber harvest, road building, grazing and recreation.

DEQ performed assessments at two sites in 2004 and 2005 (M03WILOC01 and M03WILOC02). The upper site (C01) was located on USFS land and the lower site (C02) was located on BLM land (**Figure A-8**). Minimal effects of grazing were observed at both sites, but anthropogenic sources were noted as minimal. The upper site was noted to have a high sediment load and part of the lower site was a beaver complex. Streambank stability, fish habitat, and riparian health were all rated high at both sites. A TMDL-related assessment was performed by DEQ at one site (Willow 1) on National Forest land in 2006 and was located approximately 0.5 mile upstream of the USFS Willow site. No data was collected in the lower watershed where Willow Creek flows though an area with agriculture-related land uses due to a lack of access. Willow 1 was located in a relatively low gradient reach of an otherwise steep mountain stream and runs along a semi-developed campground with recreational access. Willow 1 has well-developed pools associated with both large woody debris aggregates and overhanging banks with woody components.

Biological Data

Six macroinvertebrate samples and eight periphyton samples have been collected since 2004. The bioassessment scores are presented in **Table 5-61**. The westslope cutthroat trout population in the upper reaches of Willow Creek is described as rare. The fisheries resource value is rated as substantial downstream of North Creek and moderate further upstream (MFISH 2004). Numerous brook trout were observed during the DEQ site visit in 2006.

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for Willow Creek are summarized in **Tables 5-60** and **5-61**.

Table 5-60. Willow Creek Sediment Data Compared to Targets and Supplemental Indicators.
Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	**Targets**						**Supplemental Indicators**					
	Pebble Count		**Cross Section**		**Grid Toss**		**Rosgen Level II**		**BEHI**			
	Reach % <6mm	**Riffle % <2mm**	**W/D Ratio**	**Entrenchment Ratio**	**Pool Tail % <6mm**	**Pool Spacing**	**Existing**	**Potential**	**BEHI**	**% Non-Eroding Bank**	**Greenline % Shrubs**	**Riparian Condition**
Willow (USFS)	19	**16**	12.9	**1.4**	ND	ND	**B3/B4**	B4	ND	ND	ND	PFC
Willow BLM (USFS)	22	**20**	13.4	ND	ND	ND	B4	B4	24.9	ND	ND	PFC
Willow Down (USFS)	**27**	**27**	9.7	2.0	ND	ND	B3	B3	25.6	ND	ND	PFC
Willow Mid (USFS)	**25**	**23**	6	2.2	ND	ND	B3	B3	23.8	ND	ND	PFC
Willow Up (USFS)	78*	78*	**7.6**	2.4	ND	ND	E5	E5	**26.2**	ND	ND	FAR
Willow 1	30	**16**	**16.7**	**1.3**	**29**	2.0	**C4/B4c /E4/F4**	E4	**35.4**	92	82	PFC
M03WIL OC01	**17**	**15**	14.2	**4.6**	ND	ND	C3b	ND	ND	ND	ND	PFC
M03WIL OC02	49*	49*	16.5	**4.2**	ND	ND	C4/C5	ND	ND	ND	ND	PFC

ND = no data; *Not compared to fine sediment targets because potential substrate size is fine sediment.

Table 5-61. Biological Metrics for Willow Creek.
Bold text failed to meet the target (Mountain MMI ≥ 63, Low Valley ≥ 48, and RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	Location Description	Collected	Site Class	MMI	RIVPACS O/E
Macroinvertebrates					
M03WILOC01	Base of Thunderhead Mtn	7/16/2004	Mountains	72.1	0.99
M03WILOC01	Base of Thunderhead Mtn	7/26/2005	Mountains	**61.9**	1.15
M03WILOC01	Base of Thunderhead Mtn	9/15/2005	Mountains	65.6	1.15
M03WILOC02	Upstream of I-15	7/17/2004	Low Valley	65.9	**0.75**
M03WILOC02	Upstream of I-15	7/15/2005	Low Valley	53.8	0.90
M03WILOC02	Upstream of I-15	9/15/2005	Low Valley	**46.7**	1.05
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03WILOC01	Base of Thunderhead Mtn	7/16/2004	Mountains	20-30%	
M03WILOC01	Base of Thunderhead Mtn	8/15/2004	Mountains	30-40%	
M03WILOC01	Base of Thunderhead Mtn	9/14/2004	Mountains	20-30%	
M03WILOC01	Base of Thunderhead Mtn	8/21/2005	Mountains	10-20%	
M03WILOC02	Upstream of I-15	7/17/2004	Mountains	20-30%	
M03WILOC02	Upstream of I-15	9/11/2004	Mountains	**50-60%**	
M03WILOC02	Upstream of I-15	7/15/2005	Mountains	30-40%	
M03WILOC02	Upstream of I-15	8/16/2005	Mountains	**40-50%**	

Summary and TMDL Development Determination
The fine sediment target for the reach composite pebble count was exceeded at three of the six sites and the riffle target was exceeded at all sites. The Willow 1 site was the only site with pool data. It exceeded the fine sediment target for pool tails but met the pool spacing target. Two of the six sites, which were both near the recreational area, exceeded the width/depth ratio target. Four sites failed to meet the entrenchment target. However, because much of the channel is naturally confined, the channel is expected to be slightly more entrenched than reference.

Two of the six sites failed to meet their potential Rosgen channel type. Willow 1 and the upper USFS site (Willow Up) failed to meet the supplemental indicator BEHI value, suggesting a potential for increased sediment load from streambank sources. However, Willow 1 met the supplemental indicator value for non-eroding banks and greenline shrubs. Seven of the monitoring sections were considered to be in “proper functioning condition” based on the PFC methodology, and Willow Up was rated as “functional at risk”. Three of the six macroinvertebrate samples failed to meet the supplemental indicator value for one of the metrics but the other values were well above the supplemental indicator value, suggesting the macroinvertebrate community is not impaired. Two of the eight periphyton samples did not meet the supplemental indicator value. However, one value is just over the indicator value and the other value indicates a 50 percent probability. Given the low probability of the other samples, this suggests the periphyton community is not impaired.

The recreational site was the only anthropogenic source noted in the upper watershed near the DEQ assessment reach. Because minimal anthropogenic sources were observed in the upper watershed, high sediment levels in the assessed reaches may be related to the granitic geology. Overall, the biological samples do not indicate impairment. However, because all of the recent physical and biological data are from the upper watershed, where anthropogenic sources were noted as minimal, and because anthropogenic sources and channel conditions in the lower watershed cannot be evaluated at this time, there is insufficient information to make a TMDL development determination. No TMDL will be developed at this time for Willow Creek and additional source assessment is recommended for the entire watershed and monitoring is recommended in the lower part of the watershed.

5.4.2.30 Wise River

The Wise River flows 25.7 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**). It was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, and low flow alterations on the 2006 303(d) List, which are forms of pollution commonly linked to sediment impairment.

Physical Condition and Sediment Sources

A dam failure on Pattengail Creek in 1927 led to channel scouring and channel relocations on the Wise River that are still visible today (MFWP 1989). In 1994, DEQ noted eroding streambanks and a loss of riparian vegetation in heavily grazed areas. Fine sediment embedded in the substrate was thought to result from the granitic geology of the watershed. The BDNF conducted a channel morphology survey at one site (Wise River) in 1994. The Wise River was a "non-functioning" F4 at the survey site, when reference conditions indicated it should be a C3 (Bengeyfield 2004).

Three assessments were performed along the Wise River in 2005 and 2006 to facilitate TMDL development. Between the headwaters and the mouth, the Wise River alternates between open and confined reaches. The upper monitoring section (Wise 1) was located in a willow-dominated valley downstream of the Lacy Creek confluence near the USFS "Wise River" site. The Wise 2 monitoring section was located downstream of the Pattengail Creek confluence. A dam failure on Pattengail Creek in 1927 resulted in the highest flow ever recorded (23,000 cfs) on the Big Hole River. Large cobbles were observed strewn about the floodplain as a result of this dam failure. Large erosive "cutslopes" along this monitoring section appeared to be the result of the dam failure-induced flood. The existing hydrologic regime does not appear to be exacerbating erosion from these cutslopes, though they may be a source of fine sediment during heavy precipitation events. The lowermost monitoring section on the Wise River (Wise 3) was located downstream of the town of Wise River. A ditch along river left, riprap at the road crossing upstream, and development in the community of Wise River have likely reduced overall floodplain access within this section of river.

Biological Data

Five macroinvertebrate samples have been collected since 1994 and four periphyton samples were collected in 2005. The bioassessment scores are presented in **Table 5-63**. The fisheries resource value of the Wise River is rated as moderate downstream of Wyman Creek and high upstream of Wyman Creek. Westslope cutthroat trout are present throughout the Wise River watershed and were found in the Wise River as recently as 1980 (MFWP 1989). Several tributaries to the Wise River have westslope cutthroat trout populations described as common in the MFISH database including Adson Creek and Mono Creek. However, the Gold Creek, Sheep Creek, Swamp Creek, Wyman Creek, Lacy Creek and Jacobson Creek populations are described as rare. In addition, the distribution of Arctic grayling is described as incidental in Wise River, incidental and unknown in Wyman Creek, and unknown in Odell Creek (MFISH 2004).

Comparison to Water Quality Targets

The existing data in comparison to the targets and supplemental indicators for the Wise River are summarized in **Tables 5-62** and **5-63**.

Table 5-62. Wise River Sediment Data Compared to Targets and Supplemental Indicators. Bold text failed to meet their respective targets based on Rosgen Level II potential.

Reach ID	Targets						Supplemental Indicators					
	Pebble Count		Cross Section		Grid Toss		Rosgen Level II		BEHI			
	Reach % <6mm	Riffle % <2mm	W/D Ratio	Entrenchment Ratio	Pool Tail % <6mm	Pool Spacing	Existing	Potential	BEHI	% Non-Eroding Bank	Greenline % Shrubs	Riparian Condition
Wise 1	**20**	8	**35.1**	**2.2**	13	2.9	**C4/B4c**	C4	**34.7**	**74**	**25**	FAR
Wise 2	11	4	24.7	**2.0**	11	2.0	**C3/F3/ B3c**	C3	15.8	92	78	PFC
Wise 3	10	10	**35.1**	6.3	4	2.5	C3	C3	13.5	96	82	FAR
Wise River (USFS)	5	5	31.2	**1.3**	ND	ND	**F4**	C3	**36.5**	ND	ND	**NF**

ND = no data

Table 5-63. Biological Metrics for Wise River.
Bold text failed to meet the target (Mountain MMI ≥ 63, RIVPAC ≥ 0.80; Probability of Impairment < 40%).

Station ID	**Location Description**	**Collected**	**Site Class**	**MMI**	**RIVPACS O/E**
Macroinvertebrates					
M03WISER01	Upstream of Happy Creek	7/12/2005	Mountains	76.4	0.76
M03WISER02	Near Gold Creek	7/13/2005	Mountains	66.1	0.84
M03WISER03	Upstream of Stine Creek	7/13/2005	Mountains	**56.6**	0.82
M03WISER04	Downstream of Hwy 43	7/13/2005	Mountains	**58.7**	0.85
BKK164	Downstream of Hwy 43	9/7/1994	Mountains	**55.4**	0.99
Periphyton					
Station ID	**Location Description**	**Collected**	**Site Class**	**Probability of Impairment**	
M03WISER01	Upstream of Happy Creek	7/13/2005	Mountains	**30-40%**	
M03WISER02	Near Gold Creek	7/13/2005	Mountains	**40-50%**	
M03WISER03	Upstream of Stine Creek	7/13/2005	Mountains	**40-50%**	
M03WISER04	Downstream of Hwy 43	7/12/2005	Mountains	10-20%	

Summary and TMDL Development Determination
All sites met the reach composite fine sediment target, except for the upper DEQ site (Wise 1), which exceeded the target by one percent. All sites met the fine sediment target for riffles and pool tails. The width/depth ratio target was exceeded at Wise 1 and 3, and Wise 1 and 2 failed to meet the entrenchment target. At Wise 1, livestock grazing appears to be the primary reason for over-widened channel conditions, while the dam failure on Pattengail Creek in 1927 seems to be the primary factor controlling channel morphology in the Wise 2 and Wise 3 monitoring sections. The pool spacing target was met at all sites.

All sites, except Wise 3, were not meeting their potential Rosgen channel type. Accelerated rates of streambank erosion that exceeded the supplemental indicator value were only documented in Wise 1 and at the nearby USFS site. Wise 1 was also the only DEQ reach that failed to meet the supplemental indicator value for non-eroding banks and greenline shrubs. Although that information was not collected at the USFS site, its riparian condition was rated as “non-functioning”, suggesting bank erosion and riparian shrub cover was similar at that site. Riparian conditions appeared to improve in the downstream direction, with 78 percent deciduous shrubs in Wise 2 and 82 percent deciduous shrubs in Wise 3. Overall, it appeared that open and meandering reaches of the Wise River have been heavily grazed and extensive streambank erosion was noted in these areas (i.e Wise 1). Confined areas (i.e. Wise 2) do not appear to have been impacted by livestock grazing, partially due to the topographic confinement of the channel and naturally “armored” cobble streambanks in these sections. Wise 1 and Wise 3 were rated as “functional-at risk” based on the PFC methodology, while Wise 2 was rated in “proper functioning condition”. Three of the macroinvertebrate samples failed to meet the supplemental indicator value for one of the metrics, and for 2 of them, the other metric was close to the supplemental indicator value, indicating macroinvertebrate impairment. Three of the four periphyton samples exceeded the supplemental indicator value, suggesting impairment.

Wise 1 was just barely exceeding the reach fine sediment target and other fine sediment targets were met, but high bank erosion values in the upper watershed and increases in the width/depth ratio suggest a decrease in sediment transport capacity and an increased sediment supply. Irrigation withdrawals in the lower watershed also likely influence sediment transport capacity. Granitic geologies in the watershed likely provide a naturally elevated fine sediment load. Although sediment targets were generally met, the biological data indicate the Wise River is not fully supporting aquatic life because of excess sediment. Additionally, an overwidened channel, limited riparian vegetation, and excess bank erosion are all likely affecting fish communities. The primary anthropogenic source of sediment within the watershed is rangeland grazing, though historic mining, roads/transportation, timber harvest, and cropland are additional sources. This information suggests the habitat impairment is resulting in excess sediment loading to the Wise River that is limiting its ability to fully support fish and aquatic life. A sediment TMDL will be developed for the Wise River.

5.4.3 TMDL Development Summary

Based on the comparison of existing conditions to water quality targets, 26 sediment TMDLs will be developed in the Middle and Lower Big Hole TPA. **Table 5-64** summarizes the sediment TMDL development determinations and corresponds to **Table 1-1**, which contains the TMDL development status for all listed water body segments on the 2006 303(d) List. Water body segments with a TMDL development determination of "No" are recommended for additional review and/or monitoring and may require TMDL development in the future.

Table 5-64. Summary of TMDL development determinations.

Stream Segment	Water Body #	TMDL Development Determination (Y/N)
Big Hole River between Divide Cr and Pintlar Cr (Middle segment)	MT41D001_020	Y
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment)	MT41D001_010	N
Birch Creek headwaters to the National Forest Boundary	MT41D002_090	Y
Birch Creek from National Forest Boundary to mouth (Big Hole R)	MT41D002_100	Y
California Creek from headwaters to mouth (French Cr-Deep Cr)	MT41D003_070	Y
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	Y
Canyon Creek from headwaters to mouth (Big Hole R)	MT41D002_030	N
Charcoal Creek tributary of the Big Hole R	MT41D003_010	N
Corral Creek from headwaters to mouth (Deep Cr)	MT41D003_130	Y
Deep Creek from headwaters to mouth (Big Hole R)	MT41D003_040	Y

Table 5-64. Summary of TMDL development determinations.

Stream Segment	**Water Body #**	**TMDL Development Determination (Y/N)**
Delano Creek from headwaters to mouth (Jerry Cr)	MT41D003_030	Y
Divide Creek from headwaters to mouth (Big Hole R)	MT41D002_040	Y
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	MT41D003_220	Y
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	MT41D003_160	Y
French Creek from headwaters to mouth (Deep Cr)	MT41D003_050	Y
Gold Creek from headwaters to mouth (Wise R)	MT41D003_230	Y
Grose Creek from headwaters to mouth (Big Hole R)	MT41D002_060	Y
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	Y
Lost Creek from headwaters to mouth (Big Hole R)	MT41D002_180	Y
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock)	MT41D002_050	Y
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	MT41D003_080	Y
Pattengail Creek from headwaters to mouth (Wise R)	MT41D003_210	Y
Rochester Creek from headwaters to mouth (Big Hole R)	MT41D002_160	Y
Sawlog Creek tributary to Big Hole R	MT41D004_230	Y
Sevenmile Creek from headwaters to mouth (Deep Cr)	MT41D003_110	Y
Sixmile Creek from headwaters to mouth (California Cr)	MT41D003_090	Y
Soap Creek from headwaters to mouth (Big Hole R)	MT41D002_140	Y
Trapper Creek from headwaters to mouth (Big Hole R)	MT41D002_010	Y
Twelvemile Creek from headwaters to mouth (Deep Cr)	MT41D003_120	N
Wickiup Creek Tributary to Camp Cr (Big Hole R)	MT41D002_120	N
Willow Creek from headwaters to mouth (Big Hole R)	MT41D002_110	N
Wise River from headwaters to mouth (Big Hole R)	MT41D003_200	Y

5.5 Source Quantification

This section summarizes the current sediment load estimates from three broad source categories: unpaved road erosion, streambank erosion, and hillslope erosion. EPA sediment TMDL development guidance for source assessments state that the basic source assessment procedure includes compiling an inventory of all sources of sediment to the water body and using one or more methods to determine the relative magnitude of source loading, focusing on the primary and controllable sources of loading (EPA 1999). Additionally, regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(G)). The source assessment conducted for this TMDL evaluated loading from the primary sediment sources using standard DEQ methods, but the sediment loads presented herein represent relative loading estimates within each source category and, as no calibration has been conducted, should not be considered as actual loading values. Rather, relative estimates provide the basis for percent reductions in loads for each source category. Until better information is available and the linkage between loading and in-stream conditions becomes clearer, the loading estimates presented here should be considered as an evaluation of the relative contribution from sources and source areas that will be further refined in the future through adaptive management

5.5.1 Upland Erosion

Based on source assessment, hillslope erosion contributes approximately 65,260 tons/year to streams in the Middle and Lower Big Hole TPA. This assessment indicates that rangeland grazing on the "grasslands/herbaceous" and "shrubland" cover types is the most significant contributor to accelerated hillslope erosion in the Middle and Lower Big Hole TPA. Sediment loads due to hillslope erosion range from 118 tons/year in the Delano Creek watershed to 7,467 tons/year in the Wise River watershed. Since this assessment was conducted at the watershed scale, it is expected that larger watersheds will have greater sediment loads. Sediment loads normalized to watershed area are included in **Appendix C**. Note that a significant portion of the sediment load due to hillslope erosion is contributed by natural sources. Figure 5-1 contains annual sediment loads from upland erosion in 303(d) listed watersheds that have sediment TMDLs in **Section 5.6**. **Appendix C** contains additional information about sediment loads from upland erosion in the Middle and Lower Big Hole TPA by subwatershed, including all 6th code HUCs in the TPA.

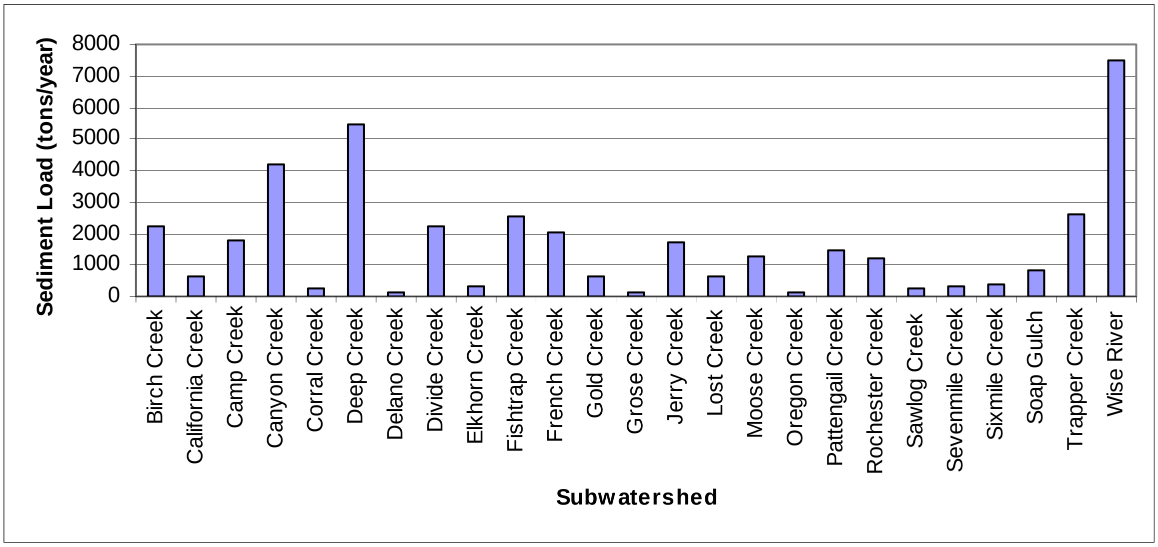


Figure 5-1. Existing Annual Sediment Load (tons/year) from Upland Erosion by 303(d) listed subwatersheds within the Middle and Lower Big Hole TPA.

5.5.2 Unpaved Roads

Based on the source assessment, unpaved roads are estimated to contribute 915 tons of sediment per year to streams in the Middle and Lower Big Hole TPA. Sediment loads due to unpaved roads range from 0 tons/year in the Gold Creek watershed to 139 tons/year in the Divide Creek watershed. Factors influencing sediment loads from unpaved roads at the watershed scale include the overall road density within the watershed and the configuration of the road network, along with factors related to road construction and maintenance. **Figure 5-2** contains annual sediment loads from unpaved roads in 303(d) listed watersheds that have sediment TMDLs in **Section 5.6**. **Appendix D** contains additional information about sediment loads from unpaved roads in the Middle and Lower Big Hole TPA by sub-watershed, including all that were assessed.

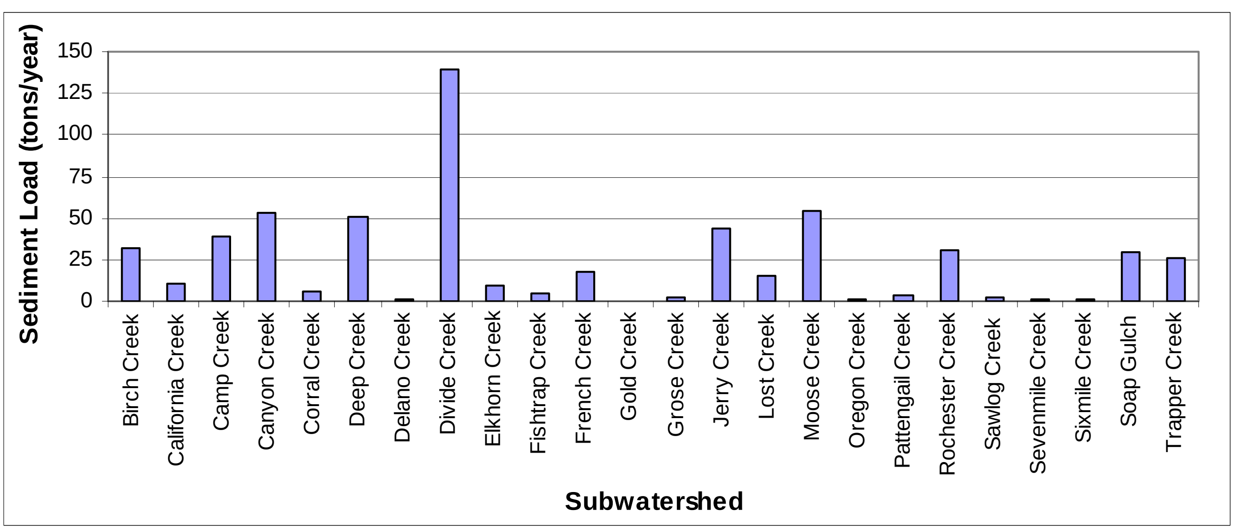


Figure 5-2. Existing Annual Sediment Load (tons/year) from Unpaved Roads in 303(d) listed Sub-watersheds within the Middle and Lower Big Hole TPA.

5.5.3 Streambank Erosion

Based on the source assessment, streambank erosion contributes an estimated 40,845 tons of sediment per year to the Middle and Lower Big Hole TPA. Sediment loads due to streambank erosion range from 9 tons/year in the Delano Creek watershed to 4,538 tons per year in the Wise River watershed. In the Middle and Lower Big Hole TPA, 54 percent of the sediment load due to streambank erosion is due to natural sources, while 46 percent is attributable to anthropogenic sources. Significant sources of streambank erosion include "riparian grazing" (20 percent), "transportation" (14 percent), and "cropland" (11 percent). **Figure 5-3** contains annual sediment loads from eroding streambanks within 303(d) listed watersheds that have sediment TMDLs in **Section 5.6**. **Appendix E** contains additional information about sediment loads from eroding streambanks in the Middle and Lower Big Hole TPA by sub-watershed, including all that were assessed.

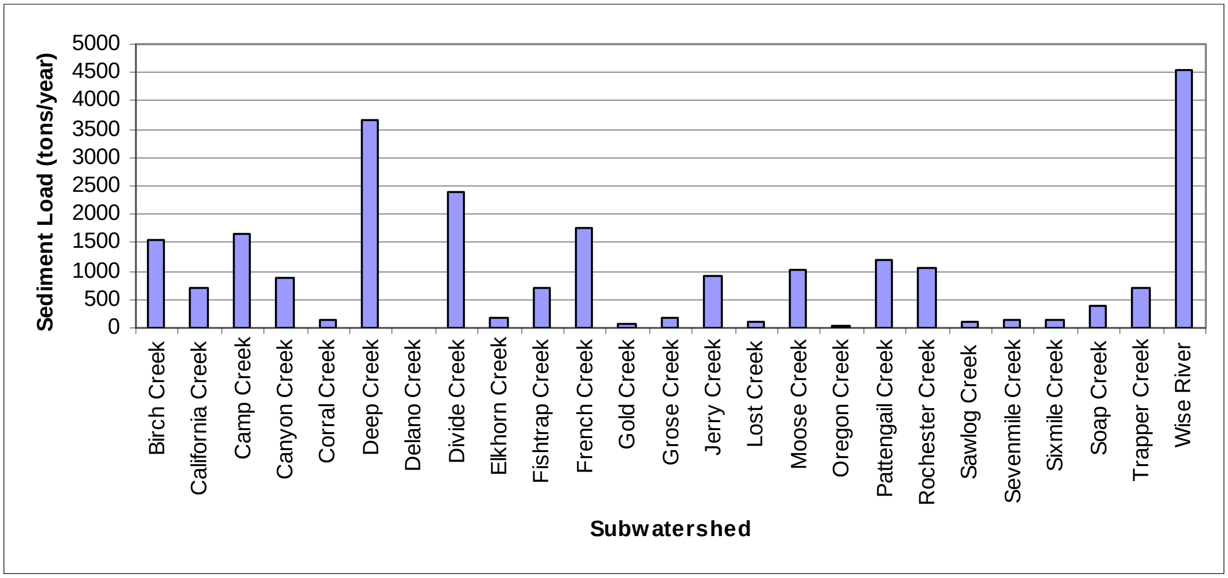


Figure 5-3. Existing Annual Sediment Load (tons/year) from Streambank Erosion by 303(d) listed Sub-watersheds within the Middle and Lower Big Hole TPA.

5.5.4 Source Assessment Summary

The estimated annual sediment load from all identified sources within the Middle and Lower Big Hole TPA is 107,020 tons. Each source type has different seasonal loading rates and the relative percentage from each source category does not necessarily indicate its importance as a loading source. Additionally, the different source assessment methodologies introduce differing levels of uncertainty, as discussed in **Section 5.7.3**. However, the modeling results for each source category, and the ability to proportionally reduce loading with the application of improved management practices (**Appendices C, D,** and **E**), provide an adequate tool to evaluate the relative importance of loading sources (i.e. sub watersheds and/or source types) and to focus water quality restoration activities for this TMDL analysis.

5.6 TMDL and Allocations

The sediment TMDL process for the Middle and Lower Big Hole TPA will adhere to the TMDL loading function discussed in **Section 4.0,** but use a percent reduction in loading allocated among sources and an inherent margin of safety. A percent reduction approach is used because there is uncertainty associated with the loads derived from the source assessment and using the estimated sediment loads creates a rigid perception that the loads are absolutely conclusive. The percent reduction TMDL approach constructs a plan that can be more easily understood for restoration planning. The total maximum daily loads for sediment are stated as an overall percentage of the average annual sediment load that can be achieved by the sum of each individual allocation to a source. The sediment TMDLs use a percent reduction allocation strategy based on estimates of BMP performances in the watershed.

Because there are no point sources (WLAs = 0) and sediment generally has a cumulative effect on beneficial uses, an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation. EPA encourages TMDLs to be expressed in the most applicable timescale, but also requires TMDLs to be presented as daily loads (Grumbles 2006); daily loads are provided in **Appendix F**.

The percent reduction allocations are based on the modeled BMP scenarios for each major source type (i.e. unpaved roads, upland erosion, and streambank erosion) and reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments. Sediment loading reductions are expected to be achieved through a combination of BMPs, and the most appropriate BMPs will vary by site. The allocation for roads was determined by assuming a reduction in the contributing length to 100 feet from each side of road crossings and 100 feet for near-stream roads. This is not a formal goal but an example of how reductions can be achieved. Because reference streams in the Middle and Lower Big Hole watershed (Bengeyfield 2004) generally have a moderate BEHI score (i.e. risk of bank erosion), the potential reduction associated with streambank erosion was derived by reducing the BEHI score for all assessed streambanks that exceeded the moderate category to a moderate BEHI score. For streambanks that were assessed, and had a moderate or lower BEHI score, no adjustment was made and the resulting allocation is a 0% reduction. Often, bank erosion sources are the result of historical land management activities that are not easily mitigated through changes in current management, can be very costly to restore, and are sometimes irreversible. Therefore, although the sediment load associated with bank erosion is presented in separate source categories (e.g. transportation, grazing, cropland, etc.), the allocation is presented as a percent reduction expected collectively from the anthropogenic sources. Streambank stability and erosion rates are largely a factor of the health of vegetation near the stream, and the reduction in bank erosion risk and sediment loading is expected to be achieved by applying BMPs within the riparian zone. Sediment load reductions at the watershed scale are based on the assumption that the same sources that affect a listed stream segment affect other streams within the watershed and that a similar percent sediment load reduction can be achieved through the application of BMPs throughout the watershed. Allocations for agricultural upland sources were derived by modeling the reduction in sediment loads that will occur by increasing ground cover through the implementation of BMPs. Examples include providing off-site watering sources, limiting livestock access to streams, conservation tillage, precision farming, and establishing riparian buffers. The allocation to agricultural sources includes both present and past influences, and is not meant to represent only current management practices. Many of the restoration practices that address current land use will reduce pollutant loads that are influenced from historic land uses. Note, a significant portion of the remaining upland sediment loads after BMPs is also a component of the "natural upland load". However, the assessment methodology did not differentiate between sediment loads with all reasonable BMPs and "natural" loads. Additional information regarding BMPs for all source categories is contained in **Section 9.0** (**Water Quality Restoration Strategy**) and **Appendices C, D,** and **E**.

Atmospheric deposition from the Anaconda Smelter has affected vegetation and accelerated upland erosion in the upper portions of Mt. Haggin. Affected watersheds include California, French, Oregon, and Deep Creeks. No specific allocations are made to atmospheric deposition but BMPs to re-establish and promote growth of vegetation are recommended in affected areas.

5.6.1 Big Hole River, Middle Segment

Sediment sources assessed within the middle segment of the Big Hole River watershed include roads, eroding streambanks, and upland erosion. Within those sources, anthropogenic source categories of sediment to the Big Hole River identified during this assessment include roads/transportation, grazing, silviculture, cropland and irrigation. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load within the middle segment of the Big Hole River is 49,675 tons/year; however, sediment loading from the upper segment of the Big Hole River is also contributing sediment and must be considered. Sediment loading in the upper Big Hole watershed is estimated at 141,976 ton/year (DEQ 2008). Therefore, the existing annual load for the middle segment of the Big Hole River is 191,651 tons. The total load is comprised of 58 percent from bank erosion, 40 percent from upland erosion, and 2 percent from roads (**Table 5-65**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 137,984 tons/year. To achieve this reduction in sediment loads, a 30 percent sediment load reduction is allocated to roads, while a 36 percent reduction is allocated to the following streambank erosion sources: transportation, riparian grazing, cropland, and irrigation. Streambank erosion sources in the upper Big Hole were not identified in that source assessment (DEQ 2008), but the sources are the same except for cropland. Sediment load allocations to upland sources include a 23 percent reduction for grazing and a 56 percent reduction for cropland. Logging is currently a very small source of upland sediment (<0.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for middle segment of the Big Hole River is expressed as a 28 percent reduction in total average annual sediment load.

Table 5-65. Middle Segment of the Big Hole River Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		2,629	30% reduction
Streambank Erosion	Upper Big Hole[1]	96,218	36% reduction
	Transportation	4,618	
	Riparian Grazing	2,931	
	Cropland	2,617	
	Irrigation	192	
	Natural Sources	5,190	N/A
Upland Sediment Sources[2]	Grazing	59,609	23% reduction
	Silviculture	546	No modeled increase
	Cropland	285	56% reduction
	Natural Sources	16,816	N/A
Total Sediment Load/TMDL		191,651	28% reduction

[1] Bank erosion sources in the Upper Big Hole were not identified in that source assessment but with the exception of cropland, are the same sources as the Middle Big Hole. A significant portion of this load also includes natural bank erosion.
[2] Grazing lands and cropland loads have a "natural load" component incorporated into them.

5.6.2 Birch Creek, Upper Segment

The upper segment of Birch Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the upper Birch Creek watershed include roads, eroding streambanks, and upland erosion. Based on the source assessment, the primary anthropogenic sources are upland erosion associated with agriculture and streambank erosion related to the historic dam failure in the upper watershed. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 2,015 tons/year and is comprised of 37 percent from bank erosion, 62 percent from upland erosion, and 1 percent from roads (**Table 5-66**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 1,749 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads. Because the only anthropogenic source of streambank erosion is the historic dam failure in 1910, no sediment allocation is applied to eroding streambanks. Sediment load allocations to upland sources include a 26 percent reduction for grazing. The total maximum daily sediment load for the upper segment of Birch Creek is expressed as a 13 percent reduction in total average annual sediment load.

Table 5-66. Upper Segment of Birch Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		24	40% reduction
Streambank Erosion	Natural Sources	606	N/A
	Other [1]	130	0% reduction
Upland Sediment Sources[2]	Grazing	981	26% reduction
	Natural Sources	274	N/A
Total Sediment Load/TMDL		2,015	13% reduction

[1] The "other" source of bank erosion is the historic dam failure.

[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.3 Birch Creek, Lower Segment

The lower segment of Birch Creek was listed as impaired due to physical substrate habitat alterations on the 2006 303(d) List and a sediment TMDL is being developed because a review of recent data indicated this impairment is associated with excess sediment. Sediment sources assessed within the lower Birch Creek watershed include roads, eroding streambanks, and upland erosion. Because sediment loading to the lower segment of Birch Creek also includes sediment from the upper segment, the TMDL and allocations are for the entire Birch Creek watershed. Of the sources assessed, the anthropogenic source categories identified during this assessment include roads, "other", grazing, and cropland. The "other" category is associated with the historic dam failure in the upper watershed. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes an increase in fine sediment. The current estimated annual sediment load is 3,827 tons/year and is comprised of 40 percent from bank erosion, 59 percent from upland erosion, and 1 percent from roads (**Table 5-67**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 3,010 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads, while a 54 percent reduction is allocated to the following streambank sediment sources: grazing and cropland. Similar to the upper watershed, the lower part of Birch Creek is still recovering from the dam failure and no allocation is made to streambank erosion associated with the dam failure. Sediment load allocations to upland sources include a 24 percent reduction for grazing and a 73 percent reduction for cropland. The total maximum daily sediment load for the lower segment of Birch Creek is expressed as a 21 percent reduction in total average annual sediment load.

Table 5-67. Lower Segment of Birch Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		32	40% reduction
Streambank Erosion	Riparian Grazing	540	54% reduction
	Cropland	40	
	Other[1]	130	0% reduction
	Natural Sources	835	N/A
Upland Sediment Sources[2]	Grazing	1,944	24% reduction
	Cropland	26	73% reduction
	Natural Sources	280	N/A
Total Sediment Load/TMDL		3,827	21% reduction

[1] The "other" source of bank erosion is the historic dam failure.
[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.4 California Creek

California Creek was listed as impaired due to sedimentation/siltation and turbidity on the 2006 303(d) List. Sediment sources assessed in the California Creek watershed include roads, eroding streambanks, and upland erosion. The primary anthropogenic source categories identified during this assessment include unpaved roads, grazing, mining and silviculture. Because the turbidity impairment is related to sediment sources in the watershed, the sediment TMDL will address both the sedimentation/siltation and turbidity listings. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form, an increase in fine sediment and an increase in streambank erosion. The current estimated annual sediment load is 1328 tons/year and is comprised of 53 percent from bank erosion, 46 percent from upland erosion, and 1 percent from roads (**Table 5-68**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 907 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads and a 21 percent reduction is allocated to upland grazing. Atmospheric deposition from the Anaconda Smelter has also accelerated upland erosion in the California Creek watershed. Although no specific allocation is made to atmospheric deposition, BMPs to re-establish and promote growth of vegetation are recommended in affected areas to help meet the TMDL. A 47 percent reduction is allocated to streambank erosion for the following sources: grazing, mining, and silviculture. Bank erosion attributed to mining and logging is primarily the result of historical practices. The total maximum daily sediment load for California Creek is expressed as a 32 percent reduction in total average annual sediment load.

Table 5-68. California Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		10	40% reduction
Streambank Erosion	Riparian Grazing	535	47% reduction
	Mining	78	
	Silviculture	10	
	Natural Sources	79	N/A
Upland Sediment Sources[1]	Grazing/Smelter Fallout vegetation toxicity	578	21% reduction
	Natural Sources	38	N/A
Total Sediment Load/TMDL		1,328	32% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads. Also upland loading from reduced vegetation due to Anaconda smelter fallout was difficult to break out on it’s own upland sediment category and is lumped with upland grazing soruces.

5.6.5 Camp Creek

Camp Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List (and solids suspended/bedload). Sediment sources assessed within the Camp Creek watershed include roads, eroding streambanks and upland erosion. Anthropogenic source categories identified during this assessment include roads/transportation, grazing, cropland and irrigation. As discussed in **Section 5.4.2**, increased sediment loads have lead to an increase in fine sediment. The current estimated annual sediment load is 3,450 tons/year and is comprised of 48 percent from bank erosion, 51 percent from upland erosion, and 1 percent from roads (**Table 5-69**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 2,464 tons/year. To achieve this reduction in sediment loads, a 36 percent sediment load reduction is allocated to roads, while a 43 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing, cropland, and irrigation. Sediment load allocations to upland sources include a 21 percent reduction for grazing and a 61 percent reduction for cropland. The total maximum daily sediment load for Camp Creek is expressed as a 29 percent reduction in total average annual sediment load.

Table 5-69. Camp Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		39	36% reduction
Streambank Erosion	Transportation	32	43% reduction
	Riparian Grazing	1154	
	Cropland	108	
	Irrigation	80	
	Other[1]	54	
	Natural Sources	213	N/A
Upland Sediment Sources[2]	Grazing	1660	21% reduction
	Cropland	6.7	61% reduction
	Natural Sources	103	N/A
Total Sediment Load/TMDL		3,450	29% reduction

[1] The "other" source of streambank erosion is from an upstream dam.
[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.6 Corral Creek

Corral Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed in the Corral Creek watershed include roads, eroding streambanks and upland erosion. The anthropogenic source categories of sediment identified during this assessment include roads, grazing and silviculture. As discussed in **Section 5.4.2**, increased sediment loads have lead to increased surface fines, while increases in the width/depth ratio along the lower reach suggest a decrease in sediment transport capacity. The current estimated annual sediment load is 446 tons/year and is comprised of 35 percent from bank erosion, 64 percent from upland erosion, and 1 percent from roads (**Table 5-70**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 341 tons/year. To achieve this reduction in sediment loads, a 32 percent sediment load reduction is allocated to roads, while a 40 percent reduction is allocated to the streambank erosion sources of grazing and logging, and a 22 percent reduction is allocated to upland grazing. Bank erosion attributed to logging is primarily the result of historical logging practices. Logging is currently a very small source of upland sediment (~1 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Corral Creek is expressed as a 24 percent reduction in total average annual sediment load.

Table 5-70. Corral Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		6.3	32% reduction
Streambank Erosion	Riparian Grazing	92	40% reduction
	Silviculture	21	
	Natural Sources	41	N/A
Upland Sediment Sources[1]	Grazing	259	22% reduction
	Silviculture	4.2	No modeled increase
	Natural Sources	22	N/A
Total Sediment Load/TMDL		446	24% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.7 Deep Creek

Deep Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Several tributaries of Deep Creek including California Creek, Corral Creek, French Creek, Oregon Creek, Sevenmile Creek, and Sixmile Creek are on the 2006 303(d) List for sediment or sediment-related impairments and have TMDLs within this document. Sediment loading from the entire Deep Creek watershed, including the listed tributaries, is incorporated into the Deep Creek TMDL. Sediment sources assessed within the Deep Creek watershed include roads, eroding streambanks and upland erosion. Approximately 63 percent of the existing load is from streambank erosion, but 38 percent of that load is attributed to natural streambank erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, silviculture, and cropland. The historic timber harvest likely increased sediment loads, water yields, and peak flows (D. Havig, pers. com., 2004). However, the TMDL is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006) and is currently estimated to be a very small source of sediment (<.5 percent of the total load).

As discussed in **Section 5.4.2**, increased sediment loads have lead to increased surface fines, while increases in the width/depth ratio along the lower reach suggest a decrease in sediment transport capacity. The current estimated annual sediment load is 9,180 tons/year and is comprised of 40 percent from bank erosion, 59 percent from upland erosion, and 1 percent from roads (**Table 5-71)**.

Through the application of BMPs, it is estimated that the sediment load can be reduced to 7,647 tons/year. To achieve this reduction in sediment loads, a 35 percent sediment load reduction is allocated to roads, while a 20 percent reduction is allocated to streambank erosion. Upland sediment sources are allocated a 21 percent reduction from grazing. The contribution from cropland is an insignificant source of upland sediment and there is no allocation to cropland.

Implementation of BMPs should maintain the contribution at or below the current level. Because upland logging is such a minimal source of sediment and logging activity is anticipated to remain at the current intensity, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. Logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). Atmospheric deposition from the Anaconda Smelter has also accelerated upland erosion in the Deep Creek watershed. Although no specific allocation is made to atmospheric deposition, BMPs to re-establish and promote growth of vegetation are recommended in affected areas to help meet the TMDL. The total maximum daily sediment load for Deep Creek is expressed as a 17 percent reduction in total average annual sediment load.

Table 5-71. Deep Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		51	35% reduction
Streambank Erosion	Transportation	322	20% reduction
	Riparian Grazing	1,955	
	Natural Sources	1,402	N/A
Upland Sediment Sources[1]	Grazing	5,000	21% reduction
	Silviculture	15	No modeled increase
	Cropland	1.7	0% reduction
	Natural Sources	433	N/A
Total Sediment Load/TMDL		9,180	17% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.6.8 Delano Creek

Delano Creek, which is a tributary to Jerry Creek, was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Delano Creek watershed include roads, eroding streambanks, and upland erosion, though most streambanks are naturally “armored” by large substrate along the majority of Delano Creek. Anthropogenic source categories of sediment identified during this assessment include roads and grazing. As discussed in **Section 5.4.2**, increased sediment loads have lead to increased surface fines in the lower reach and an overall “fining” of the streambed. The current estimated annual sediment load is 129 tons/year and is comprised of 8 percent from bank erosion, 91 percent from upland erosion, and 1 percent from roads (**Table 5-72**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 107 tons/year. To achieve this reduction in sediment loads, a 28 percent sediment load reduction is allocated to roads and a 19 percent sediment load reduction is allocated to upland grazing. There is no allocation to streambank erosion due to riparian grazing because the existing BEHI score was moderate. Although there is no formal allocation to streambank erosion, riparian grazing

BMPs should be used. The total maximum daily sediment load for Delano Creek is expressed as a 17 percent reduction in total average annual sediment load.

Table 5-72. Delano Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		1.5	28% reduction
Streambank Erosion	Riparian Grazing	8.8	0% reduction
	Natural Sources	<1	N/A
Upland Sediment Sources[1]	Grazing	108	19% reduction
	Natural Sources	10	N/A
Total Sediment Load/TMDL		129	17% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.9 Divide Creek

Divide Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Divide Creek watershed include roads, eroding streambanks and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, silviculture, cropland, and irrigation. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 4,783 tons/year and is comprised of 50 percent from bank erosion, 47 percent from upland erosion, and 3 percent from roads (**Table 5-73**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 4,210 tons/year. To achieve this reduction in sediment loads, a 36 percent sediment load reduction is allocated to roads, while a 7 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing, cropland and irrigation. Sediment load allocations to upland sources include a 20 percent reduction for grazing. The contribution from cropland is an insignificant source of upland sediment and there is no allocation to cropland. Implementation of BMPs should maintain the contribution at or below the current level. Logging is currently a very small source of sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. Logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Divide Creek is expressed as a 12 percent reduction in total average annual sediment load.

Table 5-73. Divide Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		139	36% reduction
Streambank Erosion	Transportation	604	7% reduction
	Riparian Grazing	665	
	Cropland	198	
	Irrigation	296	
	Natural Sources	639	N/A
Upland Sediment Sources[1]	Grazing	1,950	20% reduction
	Silviculture	9.0	No modeled increase
	Cropland	3.6	0% reduction
	Natural Sources	279	N/A
Total Sediment Load/TMDL		4,783	12% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.10 Elkhorn Creek

Elkhorn Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed in the Elkhorn watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment to Elkhorn Creek identified during this assessment include roads/transportation, mining, grazing, silviculture, and "other", which refers to a stream restoration project within an area of abandoned mine tailings. As discussed in **Section 5.4.2**, streambank erosion and a loss of riparian vegetation within the restored reach may lead to increased sediment loads. At this time, land use activities within the watershed, besides recreational visits to the Coolidge town site, appear relatively minor. Granitic geologies within the watershed likely provide a significant natural sediment load as well. The current estimated annual sediment load is 491 tons/year and is comprised of 33 percent from bank erosion, 65 percent from upland erosion, and 1 percent from roads (**Table 5-74**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 383 tons/year. To achieve this reduction in sediment loads, an 11 percent sediment load reduction is allocated to roads. Streambank erosion allocations include a 43 percent reduction each for transportation, mining, silviculture, and "other". Bank erosion attributed to logging is primarily the result of historical logging practices. From upland sources, a 25 percent reduction is allocated to grazing. Logging is currently a very small source of upland sediment (~1 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management

Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Elkhorn Creek is expressed as a 22 percent reduction in total average annual sediment load.

Table 5-74. Elkhorn Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		10	11% reduction
Streambank Erosion	Transportation	23	43% reduction
	Mining	43	
	Silviculture	16	
	Other[1]	32	
	Natural Sources	48	N/A
Upland Sediment Sources[2]	Grazing	230	25% reduction
	Silviculture	0.9	No modeled increase
	Natural Sources	88	N/A
Total Sediment Load/TMDL		491	22% reduction

[1] The “other” source of streambank erosion is a restoration project within an area of abandoned mine tailings.
[2] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.6.11 Fishtrap Creek

Fishtrap Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Fishtrap watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, silviculture, grazing, irrigation and cropland. As discussed in **Section 5.4.2**, increased sediment loads have lead to increased surface fines, while increases in the width/depth ratio suggest a decrease in sediment transport capacity. Granitic geologies within the watershed likely provide a significant natural sediment load as well. The current estimated annual sediment load is 3,234 tons/year and is comprised of 21 percent from bank erosion, 78 percent from upland erosion, and 1 percent from roads (**Table 5-75**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 2,649 tons/year. To achieve this reduction in sediment loads, a 31 percent sediment load reduction is allocated to roads. The allocation to streambank erosion is a 21 percent reduction collectively from transportation, riparian grazing and irrigation. From upland sediment sources, a 22 percent reduction is allocated to grazing and a 46 percent reduction is allocated to cropland. Logging is currently a very small source of sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. Logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Fishtrap Creek is expressed as an 18 percent reduction in total average annual sediment load.

Table 5-75. Fishtrap Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		4.2	31% reduction
Streambank Erosion	Transportation	13	21% reduction
	Riparian Grazing	419	
	Irrigation	109	
	Natural Sources	153	N/A
Upland Sediment Sources[1]	Grazing	2,110	22% reduction
	Silviculture	5.0	No modeled increase
	Cropland	35	46% reduction
	Natural Sources	386	N/A
Total Sediment Load/TMDL		3,234	18% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.12 French Creek

French Creek was not listed for a sediment-related impairment on the 2006 303(d) List, but DEQ performed a sediment and habitat assessment on one reach in 2005 because all beneficial uses were not assessed during the previous 303(d) listing cycle and it is a tributary to Deep Creek, which is listed for sediment/siltation on the 2006 303(d) List. Several tributaries of French Creek including California Creek, Oregon Creek, and Sixmile Creek are on the 2006 303(d) List for sediment or sediment-related impairments and have TMDLs within this document. Sediment loading from the entire French Creek watershed, including the listed tributaries, is incorporated into the French Creek TMDL.

Recently collected data discussed in **Section 5.4.2** suggest increased sediment loads associated with bank erosion and a decreased sediment transport capacity related to channel widening. Sediment sources assessed within the French Creek watershed include eroding streambanks, unpaved roads, and upland erosion. Anthropogenic source categories of sediment identified during the assessment include roads/transportation, grazing, mining, logging, and "other" (related to recreation). The current estimated annual sediment load is 3,772 tons/year and is comprised of 46 percent from bank erosion, 53 percent from upland erosion, and 1 percent from roads (**Table 5-76**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 2,928 tons/year. To achieve this reduction, a 38 percent reduction is allocated to roads and a 21 percent reduction is allocated to upland grazing. A 36 percent sediment load reduction is allocated to streambank erosion due to each of the following sources: transportation, riparian grazing, mining, silviculture, and recreation. Bank erosion attributed to logging is primarily the result of historical logging practices. Logging is currently a very small source of upland sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). Atmospheric deposition from the Anaconda Smelter has also accelerated upland erosion in the French Creek watershed. Although no specific allocation is made to atmospheric deposition, BMPs to re-establish and promote growth of vegetation are recommended in affected areas to help meet the TMDL. The total maximum daily sediment load for French Creek is expressed as a 22 percent reduction in total average annual sediment load.

Table 5-76. French Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		18	38% reduction
Streambank Erosion	Transportation	62	36% reduction
	Riparian Grazing	1,071	
	Mining	17	
	Silviculture	85	
	Other[1]	40	
	Natural Sources	477	N/A
Upland Sediment Sources[2]	Grazing	1781	21% reduction
	Silviculture	1.7	No modeled increase
	Natural Sources	220	N/A
Total Sediment Load/TMDL		3,773	22% reduction

[1] The "other" source of streambank erosion is related to recreation.
[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.13 Gold Creek

Gold Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Gold Creek watershed include eroding streambanks, roads, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include transportation, grazing, and "other", which refers to a historic road/railroad bed that crosses the floodplain. As discussed in **Section 5.4.2**, increased sediment loads have lead to increased surface fines, while increases in the width/depth ratio suggest a decrease in sediment transport capacity. The current estimated annual sediment load is 729 tons/year and is comprised of 10 percent from bank erosion and 90 percent from upland erosion (**Table 5-77**).

Through the application of BMPs, it is estimated that the sediment load can be reduced to 592 tons/year. To achieve this reduction in sediment loads, a 49 percent sediment load reduction is allocated to streambank erosion due to each of the following sources: transportation and riparian grazing. From upland sediment sources, a 22 percent reduction is allocated to grazing. The total maximum daily sediment load for Gold Creek is expressed as a 19 percent reduction in total average annual sediment load.

Table 5-77. Gold Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Streambank Erosion	Transportation	30	49% reduction
	Riparian Grazing	7.4	
	Other[1]	0.3	
	Natural Sources	37	N/A
Upland Sediment Sources[2]	Grazing	550	22% reduction
	Natural Sources	104	N/A
Total Sediment Load/TMDL		729	19% reduction

[1] The "other" source of bank erosion is related to a historic railroad/road bed that crosses the floodplain.
[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.14 Grose Creek

Grose Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Grose Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads, grazing, and cropland. As discussed in **Section 5.4.2**, increased sediment loads have lead to an increase in fine sediment. The current estimated annual sediment load is 294 tons/year and is comprised of 37 percent from bank erosion, 62 percent from upland erosion, and 1 percent from roads (**Table 5-78**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 174 tons/year. To achieve this reduction in sediment loads, a 34 percent sediment load reduction is allocated to roads, while a 62 percent reduction is allocated to streambank erosion associated with grazing. Sediment load allocations to upland sources include an 18 percent reduction for grazing and a 94 percent reduction for cropland. Although the load from natural upland erosion is not indicated in **Table 5-78**, a significant portion of the remaining load after BMP implementation is a component of the natural upland load. The total maximum daily sediment load for Grose Creek is expressed as a 40 percent reduction in total average annual sediment load.

Table 5-78. Grose Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		2.0	34% reduction
Bank Erosion Sources	Riparian Grazing	70	62% reduction
	Natural Sources	98	N/A
Upland Sediment Sources[1]	Grazing	12	18% reduction
	Cropland	1.2	94% reduction
Total Sediment Load/TMDL		294	40% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.15 Jerry Creek

Jerry Creek was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, and low flow alterations on the 2006 303(d) List, and a data review discussed in **Section 5.4.2** concluded that habitat alterations are linked to excess sediment. Increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. Sediment sources assessed within the Jerry Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads, grazing, cropland, and silviculture. The current estimated annual sediment load is 2,640 tons/year and is comprised of 34 percent from bank erosion, 64 percent from upland erosion, and 2 percent from roads (**Table 5-79**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 2,159 tons/year. To achieve this reduction in sediment loads, a 34 percent sediment load reduction is allocated to roads, while a 26 percent reduction is allocated to the following streambank erosion sources: riparian grazing, cropland, and silviculture. Bank erosion attributed to logging is primarily the result of historical logging practices. Sediment load allocations to upland sources include a 23 percent reduction for grazing. The contribution from cropland is an insignificant source of upland sediment and there is no allocation to cropland. Implementation of BMPs should maintain the contribution at or below the current level. Logging is currently a very small source of sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Jerry Creek is expressed as an 18 percent reduction in total average annual sediment load.

Table 5-79. Jerry Creek Sediment Source Load Allocations.

<table>
<tr><th colspan="2">Sediment Sources</th><th>Current Estimated Load (Tons/Year)</th><th>Sediment Load Allocations</th></tr>
<tr><td colspan="2">Roads</td><td>44</td><td>34% reduction</td></tr>
<tr><td rowspan="4">Streambank Sources</td><td>Riparian Grazing</td><td>543</td><td rowspan="3">26% reduction</td></tr>
<tr><td>Cropland</td><td>88</td></tr>
<tr><td>Silviculture</td><td>91</td></tr>
<tr><td>Natural Sources</td><td>183</td><td>N/A</td></tr>
<tr><td rowspan="4">Upland Sediment Sources[1]</td><td>Grazing</td><td>1,230</td><td>23% reduction</td></tr>
<tr><td>Silviculture</td><td>1.4</td><td>No modeled increase</td></tr>
<tr><td>Cropland</td><td>1.4</td><td>0% reduction</td></tr>
<tr><td>Natural Sources</td><td>459</td><td>N/A</td></tr>
<tr><td colspan="2">Total Sediment Load/TMDL</td><td>2,640</td><td>18% reduction</td></tr>
</table>

[1] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.6.16 Lost Creek

Lost Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Lost Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing and cropland. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 742 tons/year and is comprised of 15 percent from bank erosion, 83 percent from upland erosion, and 2 percent from roads (**Table 5-80**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 584 tons/year. To achieve this reduction in sediment loads, a 46 percent sediment load reduction is allocated to roads, while a 32 percent reduction is allocated to the following streambank erosion sediment sources: transportation and grazing. Sediment load allocations to upland sources include a 21 percent reduction for grazing. The contribution from cropland is an insignificant source of upland sediment and there is no allocation to cropland. Implementation of BMPs should maintain the contribution at or below the current level. The total maximum daily sediment load for Lost Creek is expressed as a 21 percent reduction in total average annual sediment load.

Table 5-80. Lost Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		15	46% reduction
Streambank Erosion	Transportation	7.6	32% reduction
	Riparian Grazing	90	
	Natural Sources	14	N/A
Upland Sediment Sources[1]	Grazing	568	21% reduction
	Cropland	1.1	0% reduction
	Natural Sources	46	N/A
Total Sediment Load/TMDL		742	21% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.17 Moose Creek

Moose Creek was on the 2006 303(d) List for low flow alterations and data collected during TMDL development and discussed in **Section 5.4.2** indicates the low flow alterations are likely linked to sediment impairment. Flow alterations and anthropogenic sediment sources have decreased the sediment transport capacity and increased the sediment supply to Moose Creek. Sediment sources assessed within the Moose Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, silviculture, and cropland. The current estimated annual sediment load is 2,334 tons/year and is comprised of 44 percent from bank erosion, 54 percent from upland erosion, and 2 percent from roads (**Table 5-81**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 1,778 tons/year. To achieve this reduction in sediment loads, a 33 percent sediment load reduction is allocated to roads, while a 49 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing, cropland and silviculture. Bank erosion attributed to logging is primarily the result of historical logging practices. Sediment load allocations to upland sources include a 24 percent reduction for grazing and a 38 percent reduction for cropland. Logging is currently a very small upland source of sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. To address logging associated streambank erosion and maintain low upland erosion rates, logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for Moose Creek is expressed as a 24 percent reduction in total average annual sediment load.

Table 5-81. Moose Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		54	33% reduction
Streambank Erosion	Transportation	184	49% reduction
	Riparian Grazing	254	
	Cropland	14	
	Silviculture	115	
	Natural Sources	467	N/A
Upland Sediment Sources[1]	Grazing	1,105	24% reduction
	Silviculture	5.8	No modeled increase
	Cropland	1.3	38% reduction
	Natural Sources	134	N/A
Total Sediment Load/TMDL		2,334	24% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.18 Oregon Creek

Oregon Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Oregon Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing and mining. The current estimated annual sediment load is 162 tons/year and is comprised of 20 percent from bank erosion, 79 percent from upland erosion, and 1 percent from roads (**Table 5-82**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 131 tons/year. To achieve this reduction in sediment loads, a 39 percent sediment load reduction is allocated to roads, while a 27 percent reduction is allocated to the following streambank erosion sources: transportation and mining. Sediment load allocations to upland sources include a 20 percent reduction for grazing. Atmospheric deposition from the Anaconda Smelter has also accelerated upland erosion in the Oregon Creek watershed. Although no specific allocation is made to atmospheric deposition, BMPs to re-establish and promote growth of vegetation are recommended in affected areas to help meet the TMDL. The total maximum daily sediment load for Oregon Creek is expressed as a 19 percent reduction in total average annual sediment load.

Table 5-82. Oregon Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		1.0	39% reduction
Streambank Erosion	Transportation	8.1	27% reduction
	Mining	13	
	Natural Sources	12	N/A
Upland Sediment Sources[1]	Grazing	128	20% reduction
Total Sediment Load/TMDL		162	19% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.19 Pattengail Creek

Pattengail Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Pattengail Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads, grazing, and "other", which refers to streambank erosion that resulted from the dam induced flood event in 1927. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 2,626 tons/year and is comprised of 45 percent from bank erosion, 54 percent from upland erosion, and less than 1 percent from roads (**Table 5-83**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 2,412 tons/year. To achieve this reduction in sediment loads, a 29 percent sediment load reduction is allocated to roads and a 27 percent sediment load reduction is allocated to upland grazing. Sediment inputs from streambank erosion due to dam failure were identified as a minor source of sediment and no potential for reduction was calculated. The total maximum daily sediment load for Pattengail Creek is expressed as an 8 percent reduction in total average annual sediment load.

Table 5-83. Pattengail Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		3.1	29% reduction
Streambank Erosion	Natural Sources	1167	N/A
	Other[1]	26	0% reduction
Upland Sediment Sources[2]	Grazing	791	27% reduction
	Natural Sources	639	N/A
Total Sediment Load/TMDL		2,626	8% reduction

[1] The "other" source of bank erosion is related to the dam-induced flood event in 1927.
[2] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.20 Rochester Creek

Rochester Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Rochester Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, mining, cropland, and irrigation. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 2,288 tons/year and is comprised of 46 percent from bank erosion, 53 percent from upland erosion, and 1 percent from roads (**Table 5-84**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 1,555 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads, while a 58 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing, mining, cropland, and irrigation. Sediment load allocations to upland sources include a 21 percent reduction for grazing. The total maximum daily sediment load for Rochester Creek is expressed as a 32 percent reduction in total average annual sediment load.

Table 5-84. Rochester Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		31	40% reduction
Streambank Erosion	Transportation	85	58% reduction
	Riparian Grazing	473	
	Cropland	63	
	Mining	60	
	Irrigation	121	
	Natural Sources	246	N/A
Upland Sediment Sources[1]	Grazing	1,205	21% reduction
	Natural Sources	4.3	N/A
Total Sediment Load/TMDL		2,288	32% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.21 Sawlog Creek

Sawlog Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Sawlog Creek watershed include roads, eroding streambanks and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads and grazing. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 373 tons/year and is comprised of 29 percent from bank erosion, 70 percent from upland erosion, and 1 percent from roads (**Table 5-85**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 307 tons/year. To achieve this reduction in sediment loads, a 42 percent sediment load reduction is allocated to roads, a 57 percent sediment reduction is allocated to riparian grazing induced streambank erosion, and a 20 percent sediment load reduction is allocated to upland grazing. The total maximum daily sediment load for Sawlog Creek is expressed as an 18 percent reduction in total average annual sediment load.

Table 5-85. Sawlog Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		1.9	42% reduction
Streambank Erosion	Riparian Grazing	48	57% reduction
	Natural Sources	61	N/A
Upland Sediment Sources[1]	Grazing	189	20% reduction
	Natural Sources	73	N/A
Total Sediment Load/TMDL		373	18% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.22 Sevenmile Creek

Sevenmile Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Sevenmile Creek watershed include roads, eroding streambanks and upland erosion. Anthropogenic source categories of sediment to Sevenmile Creek identified during this assessment include roads and grazing. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 468 tons/year and is comprised of 28 percent from bank erosion, 72 percent from upland erosion, and less than 1 percent from roads (**Table 5-86**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 384 tons/year. To achieve this reduction in sediment loads, a 39 percent sediment load reduction is allocated to roads, a 39 percent sediment reduction is allocated to riparian grazing induced streambank erosion, and a 21 percent sediment load reduction is allocated to upland grazing. The total maximum daily sediment load for Sevenmile Creek is expressed as an 18 percent reduction in total average annual sediment load.

Table 5-86. Sevenmile Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		1.0	39% reduction
Streambank Erosion	Riparian Grazing	46	39% reduction
	Natural Sources	86	N/A
Upland Sediment Sources[1]	Grazing	321	21% reduction
	Natural Sources	14	N/A
Total Sediment Load/TMDL		468	18% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.23 Sixmile Creek

Sixmile Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Sixmile Creek watershed include roads, eroding streambanks and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads and grazing. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 528 tons/year and is comprised of 28 percent from bank erosion, 72 percent from upland erosion, and less than 1 percent from roads (**Table 5-87**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 401 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads, a 48 percent sediment reduction is allocated to riparian grazing induced streambank erosion, and a 20 percent sediment load reduction is allocated to upland grazing. The total maximum daily sediment load for Sixmile Creek is expressed as a 24 percent reduction in total average annual sediment load.

Table 5-87. Sixmile Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		1.1	40% reduction
Streambank Erosion	Riparian Grazing	109	48% reduction
	Natural Sources	37	N/A
Upland Sediment Sources[1]	Grazing	378	20% reduction
	Natural Sources	2.7	N/A
Total Sediment Load/TMDL		528	24% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.6.24 Soap Creek

Soap Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Soap Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, and cropland. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 1,233 tons/year and is comprised of 31 percent from bank erosion, 67 percent from upland erosion, and 2 percent from roads (**Table 5-88**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 1,011 tons/year. To achieve this reduction in sediment loads, a 40 percent sediment load reduction is allocated to roads, while an 11 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing and cropland. Sediment load allocations to upland sources include a 21 percent reduction for grazing. The total maximum daily sediment load for Soap Creek is expressed as an 18 percent reduction in total average annual sediment load.

Table 5-88. Soap Creek Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		29	40% reduction
Streambank Erosion	Transportation	7.2	11% reduction
	Riparian Grazing	325	11% reduction
	Cropland	23	11% reduction
	Natural Sources	28	N/A
Upland Sediment Sources[1]	Grazing	809	21% reduction
	Natural Sources	12	N/A
Total Sediment Load/TMDL		1,233	18% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.6.25 Trapper Creek

Trapper Creek was listed as impaired due to sedimentation/siltation on the 2006 303(d) List. Sediment sources assessed within the Trapper Creek watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, silviculture and cropland. As discussed in **Section 5.4.2**, increased sediment loads have lead to changes in stream channel form and an increase in fine sediment. The current estimated annual sediment load is 3,326 tons/year and is comprised of 21 percent from bank erosion, 78 percent from upland erosion, and 1 percent from roads (**Table 5-89**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 2,589 tons/year. To achieve this reduction in sediment loads, a 42 percent sediment load reduction is allocated to roads, while a 37 percent reduction is allocated to the following streambank erosion sediment sources: transportation, grazing, and cropland. Sediment load allocations to upland sources include a 23 percent reduction for grazing and an 83 percent reduction for cropland. The total maximum daily sediment load for Trapper Creek is expressed as a 22 percent reduction in total average annual sediment load.

Although roads appear to be a smaller source of sediments they are likely impacting fisheries in specific areas of this watershed and should be considered a significant localized source in important fish spawning and rearing areas of the watershed.

Table 5-89. Trapper Creek Sediment Source Load Allocations.

Sediment Sources		Current Estimated Load (Tons/Year)	Sediment Load Allocations
Roads		26	42% reduction
Streambank Erosion	Transportation	9.4	37% reduction
	Riparian Grazing	425	
	Cropland	9.4	
	Natural Sources	253	N/A
Upland Sediment Sources[1]	Grazing	2,370	23% reduction
	Cropland	14	83% reduction
	Natural Sources	219	N/A
Total Sediment Load/TMDL		3,326	22% reduction

[1] A significant portion of the remaining loads after BMPs is also a component of the "natural upland load", though the assessment methodology didn't differentiate between sediment loads with all reasonable BMPs and "natural" loads.

5.6.26 Wise River

The Wise River was listed for physical substrate habitat alterations, alteration in streamside or littoral vegetative covers, and low flow alterations on the 2006 303(d) List, and a review of recent data as discussed in **Section 5.4.2** indicated these forms of pollution are linked to excess sediment. Several tributaries of the Wise River including Pattengail Creek, Elkhorn Creek, and Gold Creek are on the 2006 303(d) List for sediment or sediment-related impairments and have TMDLs within this document. Sediment loading from the entire Wise River watershed, including the listed tributaries, is incorporated into the Wise River TMDL.

Increased sediment loads have lead to changes in stream channel form and an increase in fine sediment, particularly in lower gradient and unconfined reaches. Sediment sources assessed within the Wise River watershed include roads, eroding streambanks, and upland erosion. Anthropogenic source categories of sediment identified during this assessment include roads/transportation, grazing, silviculture, cropland, irrigation, and "other", which describes streambank erosion resulting from the Pattengail Creek dam failure induced flood, recreation, and the stream restoration project on Elkhorn Creek. The current estimated annual sediment load is 12,037 tons/year and is comprised of 38 percent from bank erosion, 62 percent from upland erosion, and less than 1 percent from roads (**Table 5-90**).

Through the application of BMPs, it is estimated that the sediment load could be reduced to 9,358 tons/year. To achieve this reduction in sediment loads, a 36 percent sediment load reduction is allocated to roads, while a 61 percent reduction is allocated to the following streambank erosion sources: transportation, riparian grazing, cropland, and irrigation. Because at least 26 tons of the sediment in the "other" bank erosion category is related to the Pattengail Creek dam failure and no reduction is expected (see Pattengail Creek TMDL), the 61 percent reduction can only be applied to 55 tons. Therefore, the allocation to the "other" streambank erosion category is 42 percent. Sediment load allocations to upland sources include a 25 percent reduction for grazing. The contribution from cropland is an insignificant source of upland sediment and there is no allocation to cropland. Implementation of BMPs should maintain the contribution at or below the current level. Logging is currently a very small source of upland sediment (<.5 percent of the total load), and logging activity is anticipated to remain at the current intensity. Therefore, there is no formal reduction in sediment from upland logging activities and the allocation is for no modeled increase as a result of timber harvest. Logging practices should be conducted according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana Streamside Management Zone (SMZ) law (77-5-301 through 307 MCA). The total maximum daily sediment load for the Wise River is expressed as a 34 percent reduction in total average annual sediment load.

Table 5-90. Wise River Sediment Source Load Allocations.

Sediment Sources		**Current Estimated Load (Tons/Year)**	**Sediment Load Allocations**
Roads		32.0	36% reduction
Streambank Erosion	Transportation	48.0	61% reduction
	Riparian Grazing	2,065	
	Cropland	49.5	
	Irrigation	26.3	
	Natural Sources	2,268	N/A
	Other[1]	81.1	42% reduction
Upland Sediment Sources[2]	Grazing	5,096	25% reduction
	Silviculture	5.6	No modeled increase
	Cropland	4.2	0% reduction
	Natural Sources	2,361	N/A
Total Sediment Load/TMDL		12,037	34% reduction

[1] The “other” source of bank erosion is associated with the Pattengail Creek dam failure induced flood, recreation and the bank restoration project on Elkhorn Creek.
[2] A significant portion of the remaining loads after BMPs is also a component of the “natural upland load”, though the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

5.7 Seasonality and Margin of Safety

All TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and load allocations. TMDL development must also incorporate a margin of safety into the load allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes the considerations of seasonality and a margin of safety in the Lower and Middle Big Hole TPA sediment TMDL development process.

5.7.1 Seasonality

Seasonality of sediments impact to aquatic life is taken into consideration in the analysis within this document. Sediment loading varies considerably with season. For example, sediment delivery increases during spring months when snowmelt delivers sediment from upland sources and resulting higher flows scour streambanks. However, these higher flows also scour fines from streambeds and sort sediment sizes, resulting in a temporary decrease in the proportions of deposited fines in critical areas for fish spawning and insect growth. While fish are most susceptible to fine sediment deposition seasonally during spawning, fine sediment may affect aquatic insects throughout the year. Because both fall and spring spawning salmonids reside in the Middle and Lower Big Hole TPA, streambed conditions need to support spawning through all seasons. Additionally, reduction in pool habitat by either fine or course sediment alters the quantity and quality of adult fish habitat, and can therefore affect the adult fish population throughout the year. Therefore, sediment targets are not set for a particular season and source characterization is geared toward identifying average annual loads. Annual loads are appropriate because the impacts of delivered sediment are a long term impact once sediment enters the stream network, it may take years for sediment loads to move through a watershed. Although an annual expression of the TMDLs was determined as the most appropriate timescale to facilitate TMDL implementation, daily loads are provided in **Appendix F** to meet EPA requirements.

5.7.2 Margin of Safety

Incorporating a margin of safety (MOS) is a required component of TMDL development. The MOS accounts for the uncertainty between pollutant loading and water quality and is intended to ensure that load reductions and allocations are sufficient to sustain conditions that will support beneficial uses. The MOS may be applied implicitly by using conservative assumptions in the TMDL development process or explicitly by setting aside a portion of the allowable loading (EPA, 1999). This plan incorporates an implicit MOS in a variety of ways:

- The use of multiple targets to help verify beneficial use support determinations and assess standards attainment after TMDL implementation. Conservative assumptions were used during target development (see **Section 5.4.1**).
- The use of supplemental indicators, including biological indicators, to help verify beneficial use support determinations and assess standards attainment after TMDL implementation. Conservative assumptions were used during supplemental indicator development (see **Section 5.4.1**).
- Standards, targets and TMDLs that address both course and fine sediment delivery.
- The supplemental indicators may also provide an early warning method to identify pollutant-loading threats, which may not otherwise be identified, if targets are not met.
- Conservative assumptions were used for the source assessment process, including erosion rates, sediment delivery ratio, and BMP effectiveness (see **Appendices C, D,** and **E**).
- Consideration of seasonality (discussed above).
- The adaptive management approach evaluates target attainment and allows for refinement of load allocation, targets, modeling assumptions, and restoration strategies to further reduce uncertainties associated with TMDL development (discussed below and in **Section 10.2**).
- The use of "naturally occurring" sediment loads as described in ARM 17.30.602(17) (see **Appendix B**) to establish the TMDLs and allocations. This includes an allocation process that addresses all known human sediment causing activities, not just the significant sources.

5.7.3 Uncertainty and Adaptive Management

A degree of uncertainty is inherent in any study of watershed processes related to sediment. The assessment methods and targets used in this study to characterize impairment and measure future restoration are each associated with a degree of uncertainty. This TMDL document will include a monitoring and adaptive management plan to account for uncertainties in the field methods, targets, and supplemental indicators. Adaptive management addresses important considerations such as feasibility and uncertainty in establishment of targets. For the purpose of this document, adaptive management relies on continued monitoring of water quality and stream habitat conditions, continued assessment of impacts that human activities and natural conditions have on water quality and stream habitat conditions, and continued assessment of how aquatic life and cold water fish, particularly Arctic grayling and cutthroat trout, respond to changes in water quality and stream habitat conditions.

Under some natural conditions, such as large wildfires or extreme flow events, it may not be possible to satisfy all targets, loads, and allocations, because of natural short term background sediment load pulses. The loads and allocations established in this document are meant to apply to recent conditions of natural background and natural disturbance. The goal is to ensure that management activities are undertaken to achieve loading approximate to the TMDLs within a reasonable time frame and to prevent significant longer term excess loading during recovery from significant natural events. Also, it is possible that the natural potential of some streams will preclude achievement of some targets. For instance, natural geologic and other conditions may contribute sediment at levels that cause a deviation from numeric targets associated with sediment. Conversely, some targets may be underestimates of the potential of a given stream and it may be appropriate to apply more protective targets upon further evaluations. Supplemental indicators are used to help with these determinations. In these circumstances, it is important to recognize that the adaptive management approach provides the flexibility to refine targets and supplemental indicators as necessary to ensure protection of the resource and to adapt to new information concerning target achievability.

Sediment limitations in many streams in the Middle and Lower Big Hole TPA relate to a fine sediment fraction found on the stream bottom, while sediment modeling employed in the Middle and Lower Big Hole TPA examined all sediment sizes. In general, roads and upland sources produce mostly fine sediment loads, while streambank erosion can produce all sizes of sediment. Although upland erosion is known to be accelerated in watersheds that are lacking vegetation due to atmospheric deposition associated with the Anaconda Smelter, the rate of increase is unknown and this factor was not incorporated into the upland erosion model. This applies to the watersheds of California, Deep, French, and Oregon Creek. Additionally, excess sediment was noted on Trapper Creek as a result of the Glendale Smelter but this also could not be quantified. Since sediment source modeling may under-estimate or over-estimate natural inputs due to selection of sediment monitoring sections and the extrapolation methods used, model results should not be taken as an absolutely accurate account of sediment production within each watershed. Instead, source assessment model results should be considered as a tool to estimate sediment loads and make general comparisons of sediment loads from various sources.

Cumulatively, the source assessment methodologies address average sediment source conditions over long timeframes. Sediment production from both natural and human caused sources is driven by storm events. Pulses of sediment are produced periodically, not uniformly through time. Separately, each source assessments methodology introduces differing levels of uncertainty. For example, the road erosion method focuses on sediment production and sediment delivery locations from yearly precipitation events. The analysis did not include an evaluation of road culvert failures, which tend to add additional sediment loading during large flood events and would therefore increase the average yearly sediment loading if calculated over a longer time frame. Road loading also tends to focus in upper areas of watersheds where there is often limited hillslope or bank erosion loading. The bank erosion method focuses on both sediment production and sediment delivery and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading. The hillslope erosion model focuses primarily on sediment production across the landscape during typical rainfall years. Sediment delivery is partially incorporated based on distance to stream (**Appendix C**). The significant filtering role of riparian vegetation is not fully incorporated into the hillslope analysis, resulting in proportionally high modeled sediment loads from hillslope erosion relative to the amount of sediment actually delivered to streams.

Because the sediment standards relate to a water body's greatest potential for water quality given current and historic land use activities where all reasonable land, soil, and water conservation practices have been applied and resulting conditions are not harmful, detrimental, or injurious to beneficial uses, the percent reduction allocations are based on the modeled BMP scenarios for each major source type. The allocations reflect reasonable reductions as determined from literature, agency and industry documentation of BMP effectiveness, and field assessments, but if new information becomes available regarding the feasibility or effectiveness of BMPs, adaptive management allows for the refinement of TMDLs and allocations.

Additionally, as part of this adaptive management approach, shifts in the amount or intensity of land use activities should be tracked and incorporated into the source assessment to determine if allocations need to be revised. Cumulative impacts from multiple projects must also be a consideration. This approach will help track the recovery of the system and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity.

Undersized culverts are also a potential sediment source, but were not assessed within the scope of this project. The risk of culvert failure is related to the frequency and size of storm events. Total failure can result in a large sediment pulse, but for undersized culverts, even smaller events can flush excess instream sediment downstream and cause culverts to become fish passage barriers. Due to the uncertainty associated with sediment source assessment modeling, **Section 10.0** includes a monitoring and adaptive management plan to account for uncertainties in the source assessment results.

SECTION 6.0
NUTRIENTS

6.1 Introduction

Nutrients are needed for primary production to occur and produce food for aquatic insects and eventually the fishery. However, excessive concentrations of nutrients can affect a water body's ability to support its aquatic life, coldwater fisheries, drinking water, and recreation beneficial uses. At levels higher than most surface water bodies in Montana, excess nitrogen in the form of nitrate and nitrite can be toxic in drinking water and lead to illness or death, particularly in infants. Excess nutrients typically impair other beneficial uses by leading to a proliferation of algae growth, or algal blooms. Certain types of algal blooms can be toxic to fish, livestock (or other animals), and humans, making the water unsafe to drink or recreate in. Aside from the potential for toxicity, algae blooms are aesthetically unpleasing and this alone could deter recreation in the water body. Also, when the algae begin to die off, or at night when only respiration occurs, they decrease the amount of dissolved oxygen (DO) in the water. Levels of DO can become so low that aquatic organisms and fish become extremely stressed or die. Algal blooms can also affect the composition and density of macroinvertebrate communities, which are a primary food source for fish. Toxic algae, low DO, and a shift in the macroinvertebrate community, can all directly impact fish populations and may also result in a decrease in recreation. Recreation, which is largely based on fishing and other water-based activities, is the second highest source of revenue within the State of Montana.

6.2 Background Information

A total of ten water body segments in the Middle and Lower Big Hole TPA appeared on the 2006 Montana 303(d) List due to nutrient impairment (**Table 6-1**). One water body segment, Jerry Creek, was listed for impairment due to excess algal growth, which is a form of pollution typically linked to excess nutrients and increased solar input. TMDLs are prepared for total nitrogen and total phosphorus for Camp, Divide, Grose, Lost and Soap Creeks, which address the probable nutrient listings provided in **Table 6-1**. Charcoal, Fishtrap, Gold and Sawlog Creeks were listed for nutrients as probable causes of impairment after this TMDL project was initiated and are not completed at this time. These nutrient listings will be addressed in the future according to Montana's TMDL completion schedule.

Table 6-1. Impaired streams with identified nutrient related causes in the Middle and Lower Big Hole TMDL Planning Areas.

Stream Segment	Water Body #	Probable Nutrient Related Causes of Impairment	TMDLs prepared
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	Phosphorus (Total)	Total Nitrogen Total Phosphorus
Charcoal Creek tributary of the Big Hole R	MT41D003_010	Nitrogen (Total), Phosphorus (Total)	Will be completed at a later date.
Divide Creek from headwaters to mouth (Big Hole R)	MT41D002_040	Phosphorus (Total), Total Kjeldahl Nitrogen (TKN)	Total Nitrogen Total Phosphorus
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	MT41D003_160	Phosphorus (Total)	Will be completed at a later date.
Gold Creek from headwaters to mouth (Wise R)	MT41D003_230	Phosphorus (Total)	Will be completed at a later date.
Grose Creek from headwaters to mouth (Big Hole R)	MT41D002_060	Phosphorus (Total)	Total Nitrogen Total Phosphorus
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	Excess algal growth*	Will be completed at a later date.
Lost Creek in the Lower Big Hole Watershed	MT41D002_180	Nitrogen (Total), Phosphorus (Total)	Total Nitrogen Total Phosphorus
Sawlog Creek tributary to Big Hole R	MT41D004_230	Phosphorus (Total)	Will be completed at a later date.
Soap Creek from headwaters to mouth (Big Hole R)	MT41D002_140	Phosphorus (Total)	Total Nitrogen Total Phosphorus
Wickiup Creek Tributary to Camp Cr (Big Hole R)	MT41D002_120	Phosphorus (Total)	Will be completed at a later date.

*Algal growth is typically linked to increased nutrient production in a watershed.

It is acknowledged that existing nutrient data for the Middle and Lower Big Hole TPAs is limited and targets are based on a numeric translation of Montana's narrative nutrient standards. As a result, the magnitude and spatial analysis of the nutrient problems are not defined as well as may be desired, although controllable sources of nutrients in the watershed are fairly straightforward to understand since human influences are not diverse. The following nutrient TMDLs and allocations are presented as a framework starting point from which watershed stakeholders can voluntarily begin to address water quality problems in each watershed. The nutrient targets are considered interim values that may need to be revised in the future, and compliance with the targets is considered voluntary, because all human caused sources are considered nonpoint sources. An adaptive management strategy to facilitate revision of the nutrient targets, TMDLs, and allocations is presented in **Section 6.9**.

6.3 Information Sources and Assessment Methods

The TMDL effort included an existing data compilation, subsequent data collection (**Appendix H**) and finally applying a watershed nutrient model to each watershed (**Appendix G**). Aerial assessments using GIS, existing nutrient water quality data and stream field reconnaissance information were used to selected nutrient monitoring sites assessed in 2005 and 2006, which are depicted in **Appendix A – Map 8**. Existing conditions assessment involved a review of chemical, physical, and biological data to identify existing conditions. Source assessment involved applying a calibrated and validated nutrient model to each of the Big Hole tributaries where nutrient TMDLs were developed (**Table 6-1**). Each of these assessments are discussed in more detail in the following sections and in respective appendices.

6.4 Nutrient Water Quality Targets

Targets and supplemental indicators for nutrients are based upon interpretation of Montana's narrative water quality standards. These narrative criteria require, "*State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create conditions which produce undesirable aquatic life*" [ARM 17.30.637 (1)(e)]. Nutrient targets and supplemental indicators for the Middle and Lower Big Hole TPA include direct measures of nutrient concentrations in surface waters, measures of benthic algae chlorophyll *a* concentrations directly related to beneficial use impairment, and the role of riparian vegetation in mitigating nutrient loading through uptake and filtering. In addition, biological assemblages, which can provide an indication of nutrient enrichment based on the proportion of nutrient tolerant taxa, are considered.

6.4.1 Nutrient Concentrations and Chlorophyll *a*

The Big Hole River and its tributaries are mostly located in the Middle Rockies ecoregion. The most sensitive uses are those associated with fisheries and aquatic life uses. If these uses are protected, drinking water and agriculture uses will also be protected. The standard relative to fisheries and aquatic life prohibit "conditions which produce undesirable aquatic life" (ARM 17.30.637). The narrative standard does not define what undesirable aquatic life is, nor does it provide nutrient concentrations appropriate to control it. In response to EPA's directive to states to develop numeric nutrient criteria, Montana submitted a nutrient plan to EPA in 2002 detailing how they will determine which beneficial uses are impacted, how undesirable aquatic life will be defined, and how numeric nutrient criteria will be developed. Since 2002, Montana has conducted a number of technical studies and is pursuing development of numeric criteria for nutrients.

In the interim, to facilitate a measurable comparison of ambient water quality data with the narrative standards and to establish end-point nutrient goals for the TMDLs, indicators of nutrient impairment and threshold values have been selected based on the results of the work that

Montana has completed to date in an effort to ultimately develop numeric nutrient criteria (Suplee *et. al*., 2007; Suplee, 2005). The interim targets and associated indicator values provided in this document are not water quality standards. Rather, they are considered interim values subject to modification in the future following the adaptive management strategy presented in **Section 6.9**.

The selected interim targets for Middle and Lower Big Hole TPAs include total phosphorus (TP), total nitrogen (TN), and benthic chlorophyll-*a*. Interim threshold values for the nutrient parameters are presented in **Table 6-2**. These are growing season, or summer, values applied from July 1st through September 30th.

When evaluating compliance with these goals it is important to consider that high levels of phosphorous or nitrogen loading to a stream might not show up as elevated concentrations in the water column, particularly during growing season. This is because nutrient uptake by growing algae could occur to the extent that nutrient concentrations in the water column are significantly reduced within a given length of stream. Therefore, it is important to measure algae concentrations, represented by benthic chlorophyll *a*, at the same time that nutrient concentrations are being measured to provide an adequate characterization of water quality conditions. When subsequently evaluating compliance with the above endpoint goals, it is important to first evaluate compliance with the chlorophyll *a* values before drawing conclusions regarding compliance with either the total phosphorous or total nitrogen concentration values. Furthermore, the interim total phosphorous and total nitrogen targets are not to be applied as an absolute no exceedance rule since occasional minor exceedances of these values do not equate to conditions necessary to cause nuisance algae growth. All targets should be evaluated in conjunction with each other.

Table 6-2. Targets for Nutrients in the Middle and Lower Big Hole River TPAs.

Parameter	**Value**	**Rationale**
Targets		
Total Nitrogen	< 0.320 mg/L	Nutrient contributing to eutrophication.
NO_3 + NO_2 as N	< 0.100mg/L	Nutrient contributing to eutrophication and readily available to algae for growth.
Total Phosphorus	< 0.048 mg/L	Nutrient contributing to eutrophication.
Chlorophyll a	< 150 mg/m² for Foothill/Valley	Measures primary productivity of benthic algae and allows inference on nutrient loading. Direct measure of undesirable aquatic life.
Indicators		
Human Caused Sources	Significant human caused nutrient production or transport impacts are present.	If no significant human caused nutrient yield or transport changes are present in a watershed, restoration practices can not reduce loads. A TMDL is not necessary for naturally occurring sources.
Percent Shrubs along Greenline*	≥ 49%	Vegetation functions in the filtering and uptake of nutrients
Percent Bare Ground along Greenline	≤ 5%	Increased amount of bare ground suggests that near channel sources of sediment are elevated and filtering functions of riparian vegetation are limited

Applicable dissolved oxygen standards (**Appendix B**).

*Not applicable in areas with dense coniferous overstory or where natural soil or shade conditions limit shrub growth.

6.4.2 Riparian Vegetation

Field assessments conducted during 2005 and 2006 included an evaluation of understory shrub cover along the greenline, and corresponding measures of the percent of bare ground. These measures relate to nutrient conditions and are provided as supplemental indicators to address nutrient enrichment. The role of streamside vegetation in mitigating nutrient inputs occurs through several mechanisms. First, riparian vegetation filters runoff from upland areas. In addition, woody species, such as willows, which use groundwater, have the potential to mitigate nutrients contributed to streams from this source. Another assumption in applying these measures as indicators is that an intact, functioning riparian area suggests that livestock management practices limit accumulations of animal waste adjacent to the stream channel and reduce stream bank erosion which also contributes nutrient containing soils to the stream.

Based on the median understory shrub cover of 49 percent in reference reaches in the Upper Big Hole TPA, an indicator of ≥ 49 percent understory shrub cover is established. The same threshold value will also be applied for sediment impairments. The understory shrub cover will be applied in situations were riparian shrubs are a significant component of the streamside vegetation, such as in meadow areas. This indicator will not be applied in areas where dense conifer canopies or other natural conditions limit the development of riparian shrubs.

Bare and disturbed ground is typically an undesirable feature in riparian areas and often an indicator of anthropogenic disturbance. Livestock grazing practices have the potential to increase the amount of bare ground through vegetation removal and trampling. This has implications for nutrients as increased bare and disturbed ground suggests that near channel sources of sediment and nutrients are elevated due to a lack of bank protection afforded by vegetation. Moreover, high proportions of bare and disturbed ground limit the filtering capacity of riparian areas that limit introduction of fine sediment and associated nutrients through surface runoff. Reference reach summary statistics from the Upper Big Hole TPA identified a median value of 4 percent bare ground along valley tributaries and 6 percent bare ground along mountain tributaries. Based on the median value of the reference dataset from the Upper Big Hole, a supplemental indicator value of ≤ 5 percent bare and disturbed ground is established for all streams in the Middle and Lower Big Hole TPA.

6.4.3 Biological Indicators

Aquatic invertebrates and diatom assemblages are frequently used as a component of bioassessments since they are important indicators of stream ecosystem health. Both macroinvertebrate and diatom associations may provide supplemental indications of nutrient conditions. Biological community metrics may be presented in the impairment status section as supporting information for streams that have borderline nutrient and Chlorophyll *a* concentrations.

6.4.4 Summary of Targets and Supplemental Indicators for Nutrients

Targets and indicators for nutrient enrichment involve the use of multiple lines of evidence. These include water chemistry, chlorophyll *a* concentrations, vegetative cover, the amount of bare ground, and in some cases biological indicators. Combined, these parameters will provide a more holistic understanding of the trophic status of streams in the Middle and Lower Big Hole River TPA.

6.5 Existing Condition and Comparison to Water Quality Targets

6.5.1 Camp Creek

Camp Creek appeared on the 2006 303(d) List as impaired due to total phosphorus. Camp Creek flows from the Highland Mountains and eventually through the town of Melrose prior to entering the Big Hole River. The majority of the Camp Creek watershed is in the Camp Creek grazing allotment administered by the U.S. Bureau of Land Management. One of the recommendations of the recently published Southwest Highlands Watershed Assessment is to revise the Allotment Management Plan for the Camp Creek grazing allotment, including changes in the timing, duration, frequency and/or intensity of grazing, analysis of dormant season use, and examination of salting location and range improvement projects. Lower reaches flow through private land and where irrigated hay and pasture use occur.

Montana DEQ collected water quality samples at three sites along Camp Creek in September of 2003, which were numbered progressing upstream. Nitrogen concentrations increased in a downstream direction, with a total nitrogen concentration of 0.54 mg/L exceeding the water quality target of 0.32 mg/L at the lowermost site (M03CAMPC01) (**Table 6-3**). Nitrate+nitrite nitrogen exceeded the water quality target of 0.10 mg/L at two out of three sites, with values of 0.29 mg/L at the lowermost site and 0.17 mg/L at the middle site (M03CAMPC02). Total phosphorus exceeded the water quality target of 0.02 mg/L at all three sites, with a maximum value of 0.055 mg/L at the lowermost site. In addition, the average chlorophyll *a* concentration exceeded the target of 150 mg/m^2 at two out of three sites (**Table 6-3)**. An average chlorophyll *a* concentration of 183 mg/m^2 was found at the middle site during 2003.

In 2005 and 2006, nutrient data was collected at three sites along Camp Creek. Sample sites in 2005 include: site ML05CAMP02 downstream of the reservoir; site ML05CAMP04 downstream of the reservoir and upstream of a large irritation withdrawal; and site ML05CAMP05 near the mouth of Camp Creek. Samples sites in 2006 include: site ML05CAMP07 upstream of the reservoir; site ML05CAMP04 downstream of the reservoir and upstream of the major irritation withdrawal; and site ML05CAMP03 near the mouth of Camp Creek. Site ML05CAMP03 was substituted for site ML05CAMP05 in 2006 since site ML05CAMP05 was inundated by a series of beaver dams during the 2006 site visit. Both of these sites are near the mouth and appear to contain water mixed with irrigation return flows from the Big Hole River. This is supported by streamflow measurements from the two years that found streamflows of 2.7 cfs and 0.6 cfs at site ML05CAMP04 in 2005 and 2006, respectively, while a flow of 10.5 cfs was measured at site ML05CAMP05 in 2005 and a flow of 9.7 cfs was measured at site ML05CAMP03 in 2006. In 2006, site ML05CAMP07 was added in 2006 to document nutrient concentrations upstream of the reservoir where much of the rangeland grazing occurs. This site replaced site ML05CAMP02 which was located downstream of the reservoir and upstream of site ML05CAMP04. Sample sites in **Tables 6-3** from 2005 and 2006 are presented progressing downstream.

In 2005, total phosphorus and nitrate+nitrite nitrogen exceeded water quality targets at the uppermost site (ML05CAMP02), while total nitrogen, nitrate+nitrite nitrogen and total phosphorus exceeded water quality targets at the two lower sites (**Table 6-3**). In 2006, total phosphorus exceeded water quality targets at the uppermost site (ML05CAMP07), while total nitrogen, nitrate+nitrite nitrogen and total phosphorus exceeded water quality targets at the two lower sites. Overall, nutrient concentrations tended to greatly exceed water quality targets in Camp Creek in 2005, with the highest total nitrogen concentration (0.804 mg/L) in Camp Creek found was above Big Hole River water dilution via irrigation ditches. Also, the highest total phosphorus concentration (0.157 mg/L) in Camp Creek was also found above the influence of the Big Hole River derived irrigation network.

Table 6-3. Nutrient Concentrations in Camp Creek.

Sample Site	**Date**	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**NO2+NO3 (mg/L)**
M03CAMPC01	9/14/2003	**0.54**	**0.055**	**0.29**
M03CAMPC02	9/15/2003	0.17	0.029	**0.17**
M03CAMPC03	9/15/2003	ND	0.035	<0.01
ML05CAMP02	8/9/2005	0.290	0.033	**0.110**
ML05CAMP04	8/9/2005	**0.804**	**0.157**	**0.164**
ML05CAMP05	8/9/2005	**0.884**	**0.078**	**0.394**
ML05CAMP07	8/30/2006	0.214	0.025	0.024
ML05CAMP04	8/30/2006	**0.439**	0.038	**0.229**
ML05CAMP03	8/28/2006	1.338	**0.051**	**0.868**

*Bold text indicates target is exceeded.

Chlorophyll *a* data was collected at three sites along Camp Creek in 2005 and 2006. During 2005, the mean chlorophyll *a* concentration at the upper site (ML05CAMP02) was 69.5 mg/m² (**Table 6-4**). At the upper site, a large input of sediment a week prior to the sampling event had dramatically shifted the streambed, limiting the ability to collect chlorophyll *a* samples that documented a complete season's growth. At the middle site (ML05CAMP04), the average chlorophyll *a* concentration met the target of 150 mg/m². At the lower site (ML05CAMP05), chlorophyll *a* concentrations ranged from 28.3 mg/m² to 441.4 mg/m², with the site average exceeding target value.

In 2006, the mean chlorophyll *a* concentration at the upper site (ML05CAMP07) was 17.3 mg/m², below target value of 150 mg/m². At the middle site (ML05CAMP04), the site average meets the target value. At the lower site (ML05CAMP03), chlorophyll *a* values were 160 mg/m² which exceeds the target. During both years, chlorophyll *a* concentrations were higher at the upper site than at the lower site.

Table 6-4. Chlorophyll a Concentrations in Camp Creek.
Bold text failed to meet water quality target.

Sample Site	**Date**	**Mean Chlorophyll *a* (mg/m²)**
M03CAMPC01	9/14/2003	99.2
M03CAMPC02	9/15/2003	**183**
M03CAMPC03	9/15/2003	62.4
ML05CAMP02	8/9/2005	69.5
ML05CAMP04	8/9/2005	38.2
ML05CAMP05	8/9/2005	**160**
ML05CAMP07	8/30/2006	17
ML05CAMP04	8/30/2006	130
ML05CAMP03	8/28/2006	**221**

Two riparian vegetation monitoring section assessments were performed along Camp Creek in 2005 and 2006. The upper monitoring section was located approximately 4 miles upstream of the reservoir. This monitoring section is representative of Camp Creek between Wickiup Creek and the reservoir. The lower monitoring section was located downstream of the reservoir and represents Camp Creek between the reservoir and the I-15 crossing. In the upper monitoring section, 76 percent of the length was occupied by deciduous shrubs, which meets the supplemental indicator of ≥ 49 percent. Bare ground occupied 33 percent of the upper monitoring section, which fails to meet supplemental indicator criteria of ≤ 5 percent. In the lower monitoring section, 51 percent was lined with deciduous shrubs, which meets the supplemental indicator criteria. Bare ground occupied 24 percent of the lower monitoring section, which fails to meet supplemental indicator criteria. Filtering of nutrients produced from overland flow in upland areas may be impacted because of low groundcover.

6.5.1.1 Camp Creek Nutrient Conditions Summary

Total nitrogen, nitrate+nitrite nitrogen, total phosphorus, and chlorophyll *a* exceeded water quality targets in Camp Creek in 2003, 2005 and 2006. In addition, supplemental indicators suggest an increase in the amount of bare ground, which may lead to increased nutrient inputs. Camp Creek joins a ditch prior to the confluence with the Big Hole River. Nutrient concentrations are also elevated in this ditch, which flows into the Big Hole River just downstream of Melrose. The primary source of increased human influenced nutrient loads is rangeland grazing, though irrigated agriculture and the town of Melrose may also be sources. Nutrient TMDLs for total nitrogen and total phosphorus will be pursued because chlorophyll *a* is above targets, and is a direct link to an impairment condition and nutrients are above targets.

6.5.2 Divide Creek

Divide Creek appeared on the 2006 303(d) List as impaired due to total phosphorus and total Kjeldahl nitrogen (TKN). Lands surrounding the mainstem of Divide Creek are almost entirely privately owned. Landcover images indicate grazing and haying practices occur along the majority of the stream. Livestock grazing also occurs in the tributaries of Divide Creek on National Forest lands. A revised allotment management plan on National Forest lands was signed in 1998, with riparian use criteria established for bank alteration, utilization, stubble height and browse of woody species (Salo 2004). There is limited rural residential development within the watershed and the town of Divide is located near the mouth of Divide Creek.

Montana DEQ collected water quality samples at two sites on Divide Creek in July of 2003, while additional data was collected at two sites on Divide Creek in 2005 and 2006 to aid in the development of this water quality restoration plan. In 2005 and 2006, the upper site (ML05DIVD01) was located downstream of the confluence of the East and North forks of Divide Creek and the lower site was located at the Highway 43 crossing near Divide. These sites coincided with the sites assessed in 2003, which were also numbered progressing downstream. Since monitoring conducted in 2003 indicated nutrient concentrations were elevated at the upper site on Divide Creek, both the North Fork Divide Creek (ML05NFDV01) and East Fork Divide Creek (ML05EFDV01) were sampled in 2005 and 2006 in an attempt to identify potential nutrient sources to Divide Creek.

In 2003, total nitrogen values exceeded water quality targets at both sites, with a value of 0.65 mg/L at the upper site (M03DIVDC01) and a value of 0.57 mg/L at the lower site (M03DIVDC02) (**Table 6-5**). The nitrate+nitrite nitrogen concentration also exceeded water quality targets at the upper site. While water quality targets have not been established specifically for Total Kjeldahl nitrogen, concentrations of 0.56 mg/L and 0.57 mg/L were recorded in 2003. These values led to an exceedance of the water quality target for total nitrogen, which is made up of total Kjeldahl nitrogen, nitrate+nitrite nitrogen and ammonia nitrogen. Total phosphorus values of 0.181 mg/L at the upper site and 0.211 mg/L at the lower site exceeded the water quality target of 0.048 mg/L. The total phosphorus values from Divide Creek were the highest recorded values in the Middle and Lower Big Hole River TPA in 2003. Chlorophyll *a* concentrations met the water quality target.

In 2005, a total nitrogen concentration of 0.471 mg/L at the upper site (ML05DIVD01) and 0.600 mg/L at the lower site (ML05DIVD02) exceeded the water quality target of 0.32 mg/L (**Table 6-5**). A nitrate+nitrite nitrogen concentration of 0.071 mg/L at the upper site met the water quality target of 0.10 mg/L, while nitrate+nitrite nitrogen was below the detection limit at the lower site. The total Kjeldahl nitrogen concentration was 0.40 mg/L at the upper site and 0.60 mg/L at the lower site. These values led to an exceedance of the water quality target for total nitrogen, which is made up of total Kjeldahl nitrogen, nitrate+nitrite nitrogen and ammonia nitrogen. A total phosphorus concentration of 0.105 mg/L at the upper site and 0.057 mg/L at the lower site exceeded the water quality target of 0.048 mg/L.

In 2006, total nitrogen concentrations met the water quality target at both sites. While there is no water quality target developed for total Kjeldahl nitrogen, concentrations of 0.24 mg/L at the upper site and 0.2 mg/L at the lower site did not lead to an exceedance of the water quality target for total nitrogen. Total phosphorus concentrations exceeded water quality targets at both sites. Total nitrogen and total phosphorous were also found at levels higher than targets in both the East and North Forks of Divide Creek (**Table 6-6**).

Table 6-5. Nutrient Concentrations in Divide Creek.
Bold text failed to meet water quality target.

Sample Site	Date	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	NO2+NO3 (mg/L)	Total Phosphorus (mg/L)
MO3DIVDC01	7/30/2003	**0.65**	0.56	0.09	**0.181**
MO3DIVDC02	7/30/2003	**0.57**	0.57	<0.01	**0.211**
ML05DIVD01	8/9/2005	**0.471**	0.40	0.071	**0.105**
ML05DIVD02	8/10/2005	**0.600**	0.60	<0.005	**0.057**
ML05DIVD01	8/30/2006	0.282	0.24	0.042	**0.127**
ML05DIVD02	8/30/2006	0.200	0.2	<0.005	0.031

Table 6-6. Nutrient Concentrations in East Fork Divide Creek and North Fork Divide Creek.

Sample Site	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Kjeldahl Nitrogen (mg/L)	NO2+NO3 (mg/L)
ML05EFDV01	8/9/2005	0.510	0.118	0.51	<0.005
ML05EFDV01	8/30/2006	0.312	0.222	0.30	0.012
ML05NFDV01	8/10/2005	0.450	0.084	0.45	<0.005
ML05NFDV01	8/30/2006	0.186	0.062	0.16	0.026

Chlorophyll *a* data was collected at two sites along Divide Creek in 2005 and 2006. In 2005, the average chlorophyll *a* concentration was 126.3 mg/m² at the upper site were approaching but met the "foothill" target value of 150 mg/m² (ML05DIVD01). All other chlorophyll a samples were well below targets (**Table 6-7**).

Table 6-7. Chlorophyll a Concentrations in Divide Creek.

Sample Site	**Date**	**Mean Chlorophyll *a* (mg/m²)**
MO3DIVDC01	7/30/2003	16
MO3DIVDC02	7/30/2003	57
ML05DIVD01	8/9/2005	126
ML05DIVD02	8/10/2005	22
ML05DIVD01	8/30/2006	67
ML05DIVD02	8/30/2006	64

Two stream bank vegetation monitoring section assessments were performed along Divide Creek in 2006. The upper monitoring section was located in a channelized reach confined between a road and a fenced field. The lower monitoring section was located in an irrigated field. In the upper monitoring section, 73 percent of the length was occupied by deciduous shrubs, which meets the supplemental indicator of ≥ 49 percent. Bare ground occupied 2 percent of the upper monitoring section, which meets the supplement indicator criteria of ≤ 5 percent. In the lower monitoring section, 26 percent was lined with deciduous shrubs, which is below the supplemental indicator criteria. Bare ground occupied 4 percent of the lower monitoring section, which meets supplemental indicator criteria. Aerial and GIS assessments used for temperature modeling indicate that two specific reaches are in need of significant increases in shrub cover (**Section 8**). Shrub species prevent nutrients from entering streams because of nutrient uptake and producing denitrification zones near streams.

6.5.2.1 Divide Creek Water Quality Status Summary

In 2003 and 2005, total Kjeldahl nitrogen values led to an exceedance (i.e. were >0.32 mg/L) of the water quality target for total nitrogen, which is made up of Total Kjeldahl nitrogen, nitrate+nitrite nitrogen and ammonia nitrogen. Total nitrogen, nitrate+nitrite nitrogen and total phosphorus exceeded the water quality targets in 2005, while nitrate+nitrite nitrogen and total phosphorus exceeded the water quality targets in 2006. Chlorophyll *a* concentrations met the target value of 150 mg/m². In addition, supplemental indicators suggest a reduction in understory shrub cover along the lower monitoring section, which may lead to increased nutrient inputs. The primary sources of increased nutrient loads from human influenced activities are rangeland grazing and irrigated hay production. Rural residential development and the town of Melrose may also be minor sources. Data collected on the North and East forks of Divide Creek suggest nutrients production in the upper watershed also. Nitrogen and phosphorus TMDLs will be completed because of high nutrient concentrations.

6.5.3 Grose Creek

Grose Creek appeared on the 2006 303(d) List as impaired due to total phosphorus. Grose Creek flows through private lands and lands under the jurisdiction of the U.S. Bureau of Land Management. The majority of the stream flows through grass and sage brush rangelands, though the lower portion flows through the crop/pasture areas. The Sampling and Analysis Plan (DEQ 2005) called for assessing Grose Creek at the mouth. However, this creek appeared to be naturally dewatered upstream of the I-15 crossing and the area of irrigated agriculture during all monitoring events in 2005 and 2006.

Montana DEQ collected water quality samples at one site on Grose Creek in September of 2003. A total phosphorus concentration of 0.091 mg/L exceeded the water quality target of 0.048 mg/L at the sample site (**Table 6-8**). In 2005 and 2006, monitoring was conducted at two sites on Grose Creek, with both sites located upstream of the I-15 crossings and the area of irrigated agriculture. Total nitrogen and total phosphorus exceeded water quality targets at both sites during both monitoring events, while nitrate+nitrite nitrogen remained below the water quality target. Total nitrogen concentrations ranged from 0.470 mg/L to 0.709 mg/L, while total phosphorus concentrations ranged from 0.074 mg/L to 0.209 mg/L (**Table 6-8**). A lack of rocky substrate may limit chlorophyll *a* production in Grose Creek. Chlorophyll *a* sample concentrations met the target of 150 mg/m².

Table 6-8. Nutrient Concentrations in Grose Creek.

Sample Site	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	NO2+NO3 (mg/L)	Chlorophyll a (mg/m²)
M03GROSC01	9/12/2003	0.29	0.091	0.02	26.4
ML05GROS01	8/8/2005	0.576	0.105	0.016	112.6
ML05GROS02	8/8/2005	0.470	0.076	<0.005	42.0
ML05GROS01	8/29/2006	0.481	0.164	0.031	6.4
ML05GROS02	8/29/2006	0.709	0.209	0.039	11.8

One monitoring section assessment was performed along Grose Creek in 2006. The assessment reach was highly entrenched and lined by a band of aspens where the assessment was performed. In the monitoring section, 26 percent of the length was occupied by deciduous shrubs, which is below the supplemental indicator of ≥ 49 percent. Bare ground occupied 64 percent of the monitoring section, which fails to meet the supplemental indicator criteria of ≤ 5 percent.

6.5.3.1 Grose Creek Water Quality Status Summary

Total nitrogen and total phosphorus exceeded water quality targets at both sites during both monitoring events in 2005 and 2006. Total phosphorus exceeded the water quality target in 2003. Both sites met the chlorophyll *a* target in 2005/2006. However, due to a lack of rocky substrate and the small size of this stream, chlorophyll *a* production may be limited. Supplemental indicators suggest a reduction in understory shrub cover and an increase in the amount of bare ground, which may lead to increased nutrient inputs. The primary source of human caused nutrient loads is rangeland grazing, though irrigated agriculture may also be a source during those seemingly rare occasions when the stream is still flowing when it reaches the Big Hole River valley. Nitrogen and phosphorus TMDLs will be provided.

6.5.4 Jerry Creek

Jerry Creek was listed as impaired due to “excess algal growth” on the 2006 303(d) List, which is considered a nutrient related impairment since Montana’s narrative water quality standards states that surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will create conditions which produce undesirable aquatic life [ARM 17.30.637 (1)(e)]. The upper Jerry Creek watershed flows primarily through National Forest lands, while the lower four miles flow primarily through private land, with small sections of land under the jurisdiction of the U.S. Bureau of Land Management and one section of state land. There is limited rural residential development within the lower watershed. The U.S. Forest Service reported the entire Jerry Creek watershed is in grazing allotments. Grazing was observed at both the upper and lower sites during monitoring in 2005.

Montana DEQ sampled Jerry Creek at one site in the upper watershed in 2003 (M03JERRC01). All water quality targets were being met (**Table 6-9**). In addition, nutrient data collected as part of the EMAP (EPA’s Environmental Monitoring and Assessment Program) at one site (WMTP99-0273) on Jerry Creek in 2002 and 2003 indicated total nitrogen and total phosphorus concentrations were also meeting water quality targets.

Nutrient samples were collected at two additional monitoring sites within the lower four miles of Jerry Creek in August of 2005 and 2006. The upper site (ML05JERR01) is on National Forest lands, while the lower site (ML05JERR03) is on State land near the mouth. These two sites bracket the rural residential development. Total nitrogen, total phosphorus and nitrate+nitrite nitrogen met water quality targets at both sites during both monitoring events (**Table 6-9**).

Table 6-9. Nutrient Concentrations in Jerry Creek.

Sample Site	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	NO2+NO3 (mg/L)
WMTP99-0723	7/7/2002	0.099	0.007	
WMTP99-0723	7/13/2003	0.099	0.009	
WMTP99-0723	8/13/2003	0.083	0.004	
M03JERRC01	7/10/2003	<0.1	0.02	0.02
ML05JERR01	8/10/2005	0.18	0.004	<0.005
ML05JERR03	8/10/2005	0.20	0.014	<0.005
ML05JERR01	8/28/2006	0.031	0.011	0.031
ML05JERR03	8/28/2006	<0.10	0.011	<0.005

Chlorophyll *a* data was collected at two sites along Jerry Creek in 2005 and 2006. In 2005, the mean chlorophyll *a* concentration at the upper site (ML05JERR01) was 123.7 mg/m² (**Table 6-10**). At the lower site (ML05JERR03), the mean chlorophyll *a* concentration was 56.9 mg/m² in 2005. In 2006, the mean chlorophyll *a* concentration was 164.2 mg/m² at the upper site, exceeding the target of 150 mg/m². At the lower site, the mean chlorophyll *a* concentration was 93.7 mg/m², meeting the target. During both years, chlorophyll *a* concentrations were higher at the upper site than at the lower site.

Table 6-10. Chlorophyll a Concentrations in Jerry Creek.
Bold text failed to meet water quality target.

Sample Site	Date	Mean Chlorophyll *a* (mg/m²)
ML05JERR01	8/10/2005	123.7
ML05JERR03	8/10/2005	56.9
ML05JERR01	8/28/2006	**164.2**
ML05JERR03	8/28/2006	93.7

Two riparian vegetation monitoring section assessments were performed along Jerry Creek in 2005. The upper monitoring section (Jerry 1) was located downstream of the Indian Creek confluence on National Forest lands. The lower monitoring section (Jerry 2) was located on State land along the lower mile of Jerry Creek, where the stream flows through an alluvial fan before joining the Big Hole River. In the upper monitoring section, 40 percent of the length was occupied by deciduous shrubs, which is below the supplemental indicator of ≥ 49 percent. Bare ground occupied 36 percent of the upper monitoring section, which fails to meet the supplemental indicator of ≤ 5 percent. In the lower monitoring section, 61 percent was lined with deciduous shrubs, which meets the supplemental indicator criteria. Bare ground occupied 7 percent of the lower monitoring section, which fails to meet the supplemental indicator of ≤ 5 percent.

6.5.4.1 Jerry Creek Water Quality Status Summary

Nutrient concentrations met water quality targets, while chlorophyll *a* concentrations were exceeding the target at the upper site in 2005 and at both sites in 2006. In addition, supplemental indicators suggest a reduction in understory shrub cover and an increase in the amount of bare ground, which may lead to increased nutrient inputs. The primary human caused source of increased nutrient loads is rangeland grazing, though rural residential development may also be a source. Upper Jerry Creek was one of the most heavily used livestock grazing areas observed in this TPA. It is likely that nutrient conditions and/or solar radiation are influencing algae production in Jerry Creek. Although no nutrient samples were above targets, the water chemistry data set is not temporally robust and nutrient loads may occur during timeframes that were not sampled. More sampling is needed before a Nutrient TMDL is formed. Nutrient sampling in Jerry Creek will be identified in the follow up monitoring plan (**Section 10**). A sediment TMDL will be completed in the mean time and will provide goals for riparian vegetation regeneration which would intercept solar radiation and provide nutrient filtering capacity before algae can utilize the energy and nutrients.

6.5.5 Lost Creek

Lost Creek appeared on the 2006 303(d) List as impaired due to total nitrogen and total phosphorus. Lost Creek originates on National Forest land and then flows through a mix of private and state lands, along with lands under the jurisdiction of the U.S. Bureau of Land Management. Heavy livestock use throughout the drainage has been documented by the U.S Forest Service (Bengeyfield 2004). Lost Creek flows through evergreen forest and mixed forest cover types in the headwaters, then through grass rangeland and crop/pasture areas near the mouth.

The Sampling and Analysis Plan (DEQ 2005) called for assessing Lost Creek at the mouth. However, this creek was barely flowing downstream of the I-15 crossing and the area of irrigated agriculture during some of the monitoring events in 2005 and 2006 (including several visits to monitor potential metals and sediment impairments), and there was no water upstream of the lowermost site (ML05LOST03) during nutrient monitoring in 2006. In addition, Lost Creek was intermittent between sites ML05LOST01 and ML05LOST02 during nutrient monitoring in 2006. All sites assessed in 2005 and 2006 were located upstream of the I-15 crossing.

Montana DEQ collected nutrient samples at two sites on Lost Creek in September of 2003. A total nitrogen concentration of 0.48 mg/L was exceeding the water quality target of 0.32 mg/L at the upper site (M03LOSTC02) due to a nitrate+nitrite nitrogen concentration of 0.48 mg/L, which exceeded the water quality target of 0.10 mg/L (**Table 6-11**). Total phosphorus concentrations of 0.026 mg/L at the upper site and 0.033 mg/L at the lower site are below the water quality target of 0.048 mg/L. Chlorophyll *a* concentrations remained below the target of 150 mg/m² (**Table 6-12**).

In 2005, a total nitrogen concentration of 0.417 mg/L exceeded the water quality target of 0.32 mg/L at the upper site (ML05LOST01), while the nitrate+nitrite concentration of 0.247 mg/L exceeded the water quality target of 0.10 mg/L. Total nitrogen and nitrate+nitrite nitrogen met water quality targets at the lower two sites in 2005. Total phosphorus concentrations exceeded the water quality target of 0.048 mg/L at the lowermost site.

In 2006, nutrient concentrations followed a similar trend as in 2005. Total nitrogen and nitrate+nitrite nitrogen exceeded water quality targets at the upper site, but not the lower site. Total phosphorus exceeded water quality targets at both sites. Total phosphorus concentrations increased in the downstream direction. Since Lost Creek was observed to be intermittent between sites ML05LOST01 and ML05LOST02 in 2006, and dry at site ML05LOST03, it may be that ground water losses and gains influence nutrient concentrations in this stream.

Table 6-11. Nutrient Concentrations in Lost Creek.
Bold text failed to meet water quality target.

Sample Site	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	NO2+NO3 (mg/L)
M03LOSTC01	9/13/2003	0.14	**0.033**	0.03
M03LOSTC02	9/14/2003	**0.48**	0.026	**0.48**
ML05LOST01	8/8/2005	**0.417**	0.025	**0.247**
ML05LOST02	8/8/2005	0.100	0.032	<0.005
ML05LOST03	8/8/2005	0.286	**0.064**	0.006
ML05LOST01	8/29/2006	**0.321**	0.032	**0.161**
ML05LOST02	8/29/2006	0.228	**0.056**	0.008

A lack of rocky substrate apparently limits chlorophyll *a* growth in Lost Creek. In 2005 and 2006, ML05LOST01 and ML05LOST02 were sampled, though no chlorophyll *a* samples were collected at the lowermost site. The average concentrations at both sites in 2005 and 2006 met the target of 150 mg/m^2 (**Table 6-12**).

Table 6-12. Chlorophyll a Concentrations in Lost Creek.

Sample Site	Date	Mean Chlorophyll *a* (mg/m^2)
M03LOSTC01	9/13/2003	32
M03LOSTC02	9/14/2003	68
ML05LOST01	8/8/2005	15
ML05LOST02	8/8/2005	73
ML05LOST01	8/29/2006	5.4
ML05LOST02	8/29/2006	3.2

Two monitoring section assessments were performed along Lost Creek in 2006. The upper monitoring section flowed through an aspen stand. The lower monitoring section was conducted on State land upstream of the I-15 crossing. In the upper monitoring section, 48 percent of the length was occupied by deciduous shrubs, which approaches the supplemental indicator of ≥ 49 percent. Bare ground occupied 9 percent of the upper monitoring section, which exceeds the supplemental indicator criteria of ≤ 5 percent. In the lower monitoring section, 39 percent was lined with deciduous shrubs, which is also below the supplemental indicator criteria. Bare ground occupied 7 percent of the lower monitoring section, which fails to meet supplemental indicator criteria.

6.5.5.1 Lost Creek Water Quality Status Summary

In 2003, total nitrogen, nitrate+nitrite nitrogen, and total phosphorus exceeded water quality targets. In 2005 and 2006, total nitrogen, nitrate+nitrite nitrogen, and total phosphorus exceeded water quality targets. The average concentration of chlorophyll *a* at both sites in 2005 and 2006 met the target of 150 mg/m². Indicators suggest a reduction in understory shrub cover and an increase in the amount of bare ground, which may lead to increased nutrient inputs. The primary source of human caused nutrient loads is rangeland grazing, though irrigated agriculture may also be a source during those seemingly rare occasions when the stream is still flowing when it reaches the valley bottom. Nitrogen and phosphorous TMDLs will be pursued for Lost Creek because of elevated nutrient conditions.

6.5.6 Soap Creek

Soap Creek appeared on the 2006 303(d) List as impaired due to total phosphorus. Soap Creek originates on National Forest land and flows through lands under the jurisdiction of the U.S. Bureau of Land Management interspersed with smaller portions of private land. A portion of the Soap Creek watershed lies within the Camp Creek grazing allotment administered by the U.S. Bureau of Land Management. Soap Creek is intercepted by a ditch when it reaches the valley floor after is passes under I-15. Groundwater seeps were observed at the lower site (ML05SOAP02) in both 2005 and 2006.

Montana DEQ collected nutrient samples at two sites along Soap Creek in July of 2003. Total nitrogen and nitrate+nitrite nitrogen met water quality targets at both sites (**Table 6-13**). Total phosphorus was exceeding the water quality target of 0.048 mg/L with a concentration at 0.085 mg/L at the lower site (M03SOAP02). Chlorophyll *a* concentrations met the target of 150 mg/m² in all samples from 2003, 2004 and 2005 (**Table 6-14**).

In 2005, a total nitrogen concentration of 0.659 mg/L exceeded the water quality target of 0.32 mg/L at the upper site (ML05SOAP01), while a nitrate+nitrite nitrogen concentration of 0.099 mg/L exceeded the water quality target of 0.04 mg/L (**Table 6-13**). Total nitrogen and nitrate+nitrite nitrogen met water quality targets at the lower site (Ml05SOAP02). Total phosphorus concentrations of 0.058 mg/L at the upper site and 0.038 mg/L at the lower exceeded the water quality target of 0.02 mg/L.

In 2006, nutrient concentrations exhibited similar trends between the upper and lower sample sites, though concentrations were higher overall in 2006. A total nitrogen concentration of 0.713 mg/L exceeded the water quality target of 0.32 mg/L at the upper site, while a nitrate+nitrite nitrogen concentration of 0.163 mg/L exceeded the water quality target of 0.10 mg/L. At the lower site, total nitrogen and nitrate+nitrite nitrogen met the water quality target. Total phosphorus concentrations of 0.141 mg/L at the upper site and 0.047 mg/L at the lower site exceeded and approached the target of 0.048 mg/L respectively.

Table 6-13. Nutrient Concentrations in Soap Creek.
Bold text failed to meet water quality target.

Sample Site	Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	NO2+NO3 (mg/L)
M03SOAPC01	7/30/2003	<0.1	0.022	<0.01
M03SOAPC02	7/30/2003	0.3	**0.085**	0.03
ML05SOAP01	8/9/2005	**0.659**	**0.058**	0.099
ML05SOAP02	8/9/2005	0.194	0.038	0.024
ML05SOAP01	8/28/2006	**0.713**	**0.141**	**0.163**
ML05SOAP02	8/28/2006	0.276	0.047	0.046

Table 6-14. Chlorophyll a Concentrations in Soap Creek.

Sample Site	Date	Mean Chlorophyll *a* (mg/m^2)
M03SOAPC01	7/30/2003	14
M03SOAPC02	7/30/2003	23
ML05SOAP01	8/9/2005	38
ML05SOAP02	8/9/2005	7.0
ML05SOAP01	8/28/2006	2.1
ML05SOAP02	8/28/2006	25

Two monitoring section assessments were performed along Soap Creek in 2006. Soap Creek arises from springs shortly upstream of the upper monitoring section, with additional springs observed along the site, and water flowing out of the hillslope and across the road and into the creek downstream of the site. At the lower monitoring section, the channel was only scarcely defined, with water flowing in a narrow band and spilling out into a wider area of wetland vegetation. In the upper monitoring section, 18 percent of the length was occupied by deciduous shrubs, which is below the supplemental indicator of ≥ 49 percent. Bare ground occupied 52 percent of the upper monitoring section, which exceeds the supplemental indicator criteria of ≤ 5 percent. In the lower monitoring section, 40 percent was lined with deciduous shrubs, which is also below the supplemental indicator criteria. Bare ground occupied 9 percent of the lower monitoring section, which fails to meet the supplemental indicator criteria.

6.5.6.1 Soap Creek Water Quality Status Summary

In 2003, total phosphorus exceeded water quality targets. In 2005 and 2006, total nitrogen, nitrate+nitrite nitrogen, and total phosphorus exceeded water quality targets. Chlorophyll *a* concentrations remained below the target of 150 mg/m^2 in all samples from 2003, 2004 and 2005. In addition, supplemental indicators suggest a reduction in understory shrub cover and an increase in the amount of bare ground, which may lead to increased nutrient inputs. The primary human caused source of increased nutrient loads is rangeland grazing, though irrigated agriculture may also be a source.

6.5.7 Other Streams

Fishtrap Creek, Gold, Charcoal, Sawlog, and Wickiup Creeks have been listed recently on the 2006 integrated report for impairment likely from nutrients. These watersheds were not sampled because of the timeframe of the listings and this project. The middle and lower segments of the Big Hole River were sampled during this project and very limited data indicate nutrient conditions are above the targets presented in this document. No TMDLs will be pursued for these streams at this time but they will be addressed by future efforts.

6.6 Nutrient Source Assessment Techniques

Methods to develop an inventory of nutrient sources included field investigations and aerial surveys completed during the first portion of TMDL planning. Specific activities consisted of field reconnaissance, nutrient sampling, evaluations of riparian community structure and composition (**Appendix J**), bank erosion assessments (**Appendix E**), interviews with agency personnel regarding farming and grazing practices, and utilization of the Generalized Watershed Loading Functions nutrient modeling (GWLF) (**Appendix G**).

6.6.1 Initial Nutrient Assessment Planning

Initial efforts in the Middle/Lower Big Hole River TMDL planning area allowed determination of broad categories of sources attributable to nutrient enrichment with natural and agricultural sources emerging as the largest identifiable factors. No point sources are present. Residential development, municipalities, and forestry practices are limited and unlikely to contribute large amounts of nutrients to streams, although the modeling used does assess these sources. Because of its low population density of humans, especially adjacent to nutrient-listed streams, nutrient enrichment from residential development is a negligible component of the human-caused load. Septic systems and fertilized lawns are a limited source of nutrients in the watershed. Logging can result in short-lived spikes in nutrient loading (Likens et al. 1967); however, timber harvest activities in the basin are relatively old or currently at small scale, making this an unlikely source. Therefore, agricultural sources are the sole attributable significant human caused category of anthropogenic nutrient loading to nutrient listed streams that was further investigated. Sources of nutrients from agricultural activities include accelerated bank erosion from livestock, reduced riparian filtering form livestock grazing and browsing, fertilizer applications, and limited areas of upland vegetation reduction from livestock grazing.

When identifying sources of nutrient loading in the upper Big Hole, a number of categories of nutrient sources were obvious. Livestock are a significant potential source with accumulations of animal wastes across the landscape. Manure is a source of both nitrogen and phosphorus (Gilbertson et al. 1979) and contributes to eutrophication in streams. Also, fertilizer is used on hay fields and agricultural activities reduce the vegetation filtering capacity along streams. Grazing impacts also can reduce ground cover and stimulate higher overland and streambank erosion, and thus nutrients associated with soil loss. Significant natural landscape sources are also present; these include natural forest, grass and shrub land erosion and groundwater pathways. A land use and land cover based modeling approach was used to assess these human caused sources of nutrients along with other natural sources at a watershed scale.

6.6.2 Watershed Source Assessment Modeling and Supporting Information

The Generalized Watershed Loading Functions Model (GWLF) uses weather, soils, instream nutrient, stream discharge, land cover types, agricultural statistics, riparian condition information, fertilizer use, and streambank erosion information for model setup and calibration (**Appendix G**). The model was calibrated using data from the USGS site near Melrose on the Big Hole River and validated using data from a USGS gage in Willow Creek. After calibration, and existing condition model runs, the model was used for restoration scenario nutrient load assessments. The following paragraphs provided are about key data relative to human influenced sources used within the model, although **Appendix G** provides more detailed modeling information.

Riparian buffers serve as a nutrient filtering zone through a number of processes. Nutrient listed streams varied in terms of the potential for riparian buffers to filter and retain or convert nutrients and the general conditions of riparian vegetation conditions are assessed in the sediment TMDLs (**Section 5**). Riparian vegetation information was used to determine riparian filtration function inputs into the GWLF model. Both existing and restored riparian filtration function were considered within the model. Bank erosion was also considered within the model and riparian function, aerial photo and bank erosion assessments were used to estimate existing and restored bank erosion conditions within the GWLF model in a similar manner that the riparian filtering function was assessed.

Fertilizer application rates were estimated in coordination with NRCS, the Big Hole Watershed Committee, and local ranchers. Recent increases in costs, along with efforts to restore fluvial arctic grayling, have brought about a recent fertilizer application reduction. Pre winter 2007 application fertilizer rates were used for calibration since calibration data were from this timeframe and post 2007 rates are used for fertilizer reduction scenarios. Domestic animal numbers on the landscape were derived using 2000 census data and also verified in a few watersheds using USFS information and coordination with the local USFS range manager.

Upland erosion rates were assessed in the model via use of cover factors which represent existing conditions and those that represent conditions of healthy grass and shrubland range conditions. Domestic animal stocking rates were determined using data from U.S. Agricultural Statistics Service. Nutrient loads from animal waste are incorporated into each landscape domestic livestock inhabit. In general, the larger land based sources of nutrients were also larger nutrient sources.

6.7 Nutrient Source Assessments, TMDLs and Allocations

6.7.1 Nutrient TMDLs

Both total nitrogen and total phosphorus TMDLs will be provided for each watershed because restoration approaches within each watershed will address both nitrogen and phosphorus reductions. This approach also assures that TMDLs will provide goals for the watersheds in which nutrient conditions will control algal growth. The total nitrogen TMDL is provided in

Equation 6-1 and the total phosphorus TMDL applicable to all streams in need of a TMDL is provided in **Equation 6-2**. Future conditions will be considered meeting the TMDL if there is less than a 20 percent exceedance rate as long as exceedances are spatially and temporally random during the summer months. This exceedance rate allows for natural variability yet should protect against nutrient conditions that impact any use of the water. The TMDLs are applied only to the summer growing season during July, August and September.

Equation 6-1.

Total Nitrogen TMDL = CFS*1.72

Where: CFS = Average daily discharge in cubic feet per second

1.72 = Conversion factors combined with total nitrogen target from **Section 4.0**

Equation 6-2.

Total Phosphorus TMDL = CFS*0.264

Where: CFS = Average daily discharge in cubic feet per second

1.72 = Conversion factors combined with total phosphorus target from **Section 4.0**

6.7.2 Nutrient Source Assessment and Allocations

Modeling results from a calibrated GWLF model are used for assessing loads from existing sources (**Appendix G**). After calibration, a model scenario was completed where reasonable land, soil and water conservation practices are in place and results of this model run were used to determine the nutrient loads after restoration approaches were implemented. These include riparian vegetation restoration via grazing management, applying natural vegetation zones in hay production areas if they are lacking, reducing fertilizer applications on hay, and reducing bank erosion. The GWLF modeling results indicate that if these practices are implemented, the TMDLs are likely to be met (**Appendix G**). The existing source loads and load allocations provided in the tables of following sections are derived from the calibrated GWLF model. Many source categories are a combination of both natural and human influenced sources within land use categories.

Allocations are provided for a yearly timeframe because all sources fall within a nonpoint source category. Landscape scale, restoration approaches for these diffuse will reduce nutrient conditions during the applicable TMDL timeframes but also will provide year round reductions. The yearly allocations will provide monthly BMP implementation loads during the summer time which are provided in **Appendix G.** The estimated summer monthly loads after restoration implementation are usually much lower than the TMDL and this indicates a margin of safety has been built into the allocation approach. Also, a yearly allocation approach will address sources of nutrients if they are introduced to streams during runoff but stored in channel and become available during the summer growing season. All human caused significant sources are considered in the allocation approach and therefore the remaining load after implementation of reasonable land, soil and water conservation practices is considered naturally occurring according to state law. In practical terms, the allocation approach is to implement all reasonable land, soil and water conservation practices within each watershed unless the TMDL is being achieved with lesser application.

There are two major processes in which nutrient allocations are based upon. The primary processes are:

- Reducing nutrient mobilization from source areas
- Increasing interception of nutrients during their movement to the stream network within each watershed.
    - Groundwater
    - Surface water

An example of the allocation approach for reducing hay and pasture nitrogen loading is provided in **Figure 6-1**. The existing nitrogen load from Hay/Pasture areas in a watershed is 219 pounds. With efforts to reduce fertilizer use and flush less nitrogen from fields using improved irrigation practices in this source area, while still producing the same yield of hay, the existing load could be reduced by 17 lbs to 202 lbs. Of this 202 lbs, adjacent healthy stream side filter strips have the potential to reduce this load by an additional 50 percent down to 101 lbs, which is then the source area allocation to Hay/Pasture. For this source area, the nitrogen reduction can be greater than 50 percent with most of the reduction coming from improved riparian vegetation conditions. In other circumstances, practical reductions in fertilizer use may be a larger reduction than riparian management depending upon the characteristics of the watershed.

Figure 6-1. Riparian Zone Runoff and Groundwater treatment pathways

Upland & Riparian BMP Allocation Scenario Example				
Source	Existing Condition	Fertilizer Reduction and Grazing Management	Increased Riparian Buffer Filtration	Delivered Nitrogen Load
Hay/Pasture	219 lbs/yr →	202 lbs/yr →	50% reduction →	101 tons/yr

6.7.2.1 Camp Creek

See **Section 6.5.1** for Camp Creek's existing nutrient conditions assessment and applicable nutrient targets.

6.7.2.1.1 Camp Creek Nutrient Load Analysis

The applicable total nitrogen and total phosphorus TMDLs for Camp Creek are provided in **Equations 6-1 and 6-2**. Nutrient loads were measured at three locations on Camp Creek: 1) above the reservoir, 2) below the reservoir but above the irrigation ditch and 3) near the mouth of Camp Creek. Load assessment and comparison to TMDLs for total nitrogen and phosphorus sampling is presented in **Table 6-15** and **Figure 6-16**. Data represent field measurements collected during August 2005 and August 2006. Nitrogen concentrations and loading increase in a downstream direction. Phosphorous loading increased in a downstream direction but concentrations were highest below Camp Creek Reservoir.

Table 6-15. Camp Creek Total Nitrogen Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required to Meet TMDL
Upstream of reservoir	2.00	0.32	2.31	3.46	NA
Upstream of irrigation ditch	3.40	0.32	5.32	5.88	NA
	0.64	0.32	1.52	1.11	27
	2.70	0.32	11.72	4.67	60
Near mouth	9.70	0.32	70.08	16.76	76
	10.50	0.32	50.12	18.14	64

Table 6-16. Camp Creek Total Phosphorus Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required to Meet TMDL
Upstream of reservoir	2.00	0.048	0.27	0.53	NA
Upstream of irrigation ditch	3.40	0.048	0.61	0.90	NA
	0.64	0.048	0.13	0.17	NA
	2.70	0.048	2.29	0.71	69
Near mouth	9.70	0.048	2.67	2.56	4
	10.50	0.048	4.42	2.77	37

6.7.2.1.2 Nutrient Source Assessment Results

Nitrogen source assessment results indicate that grassland and shrubland combined make the largest source area and include natural background nitrogen loads, but also the human influence of slightly reduced vegetation from grazing. Another human influenced contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Forest land is the second largest contributor of nitrogen, yet this source is mostly natural except for limited grazing (**Figure 6-2**). Bank erosion, both natural and unnatural, is another smaller, but significant source of nitrogen to the stream. Hay/pasture nitrogen sources are also a smaller, but significant source and will also be considered in TMDL allocations and restoration approaches. Suburban lands are a small source.

Camp Creek's phosphorus source assessment results reveal grassland and shrubland combined as the most major contributor and include both natural background and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Forested areas make the next largest phosphorus source, yet this source is mostly natural except for limited grazing. Bank erosion is the next largest source of phosphorus to the stream, although it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing. Hay/pasture areas are a small contributor of phosphorus and will also be considered in TMDL allocations and restoration approaches due to their larger link with sediment production. Suburban areas are a very small source of phosphorus in this watershed.

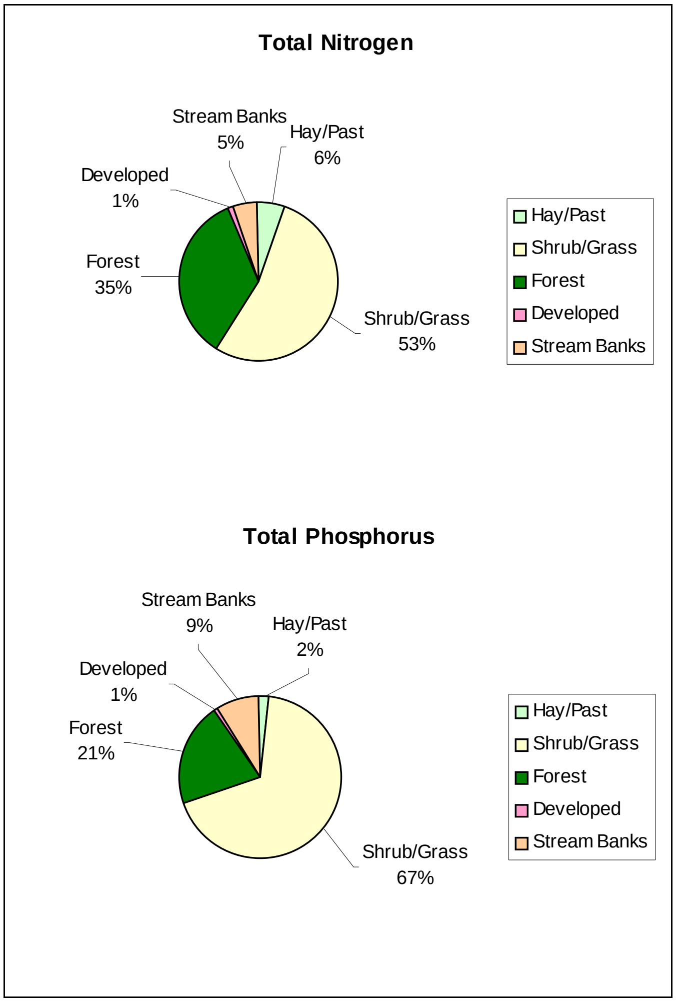


Figure 6-2. Camp Creek Nutrient Source Assessment Results

6.7.2.1.3 Camp Creek Nutrient Allocations

Camp Creek's nitrogen and phosphorus load allocations are provided in **Table 6-17** and **6-18** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that a significant amount of both nitrogen and phosphorus loads can be reduced by promoting natural riparian vegetation regrowth by managing grazing and moving hay production from these areas. Specific restoration approaches depend upon how specific riparian areas have been managed historically. Bank erosion reduction and grazing techniques along with fertilizer and irrigation management practices will also contribute to reduced nitrogen and phosphorus loads.

Because modeling uncertainty described in Appendix G and the fact that the model does not address spatial considerations within the watershed, load reductions based upon modeling results and used within **Tables 6-21 and 6-22** and those indicated in **Section 6.7.2.1.1** may contrast. Because of this contrast, the allocation approach is to implement all reasonable land, soil and water conservation practices within each allocation category unless the nutrient TMDLs are being achieved with lesser implementation.

Table 6-17. Camp Creek Total Nitrogen Allocations

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	413	Fertilizer/Grazing Management	373	25%	32%
	Hay Production Fertilizer		40		93	
Shrub and Grassland	Grazing	3805	Upland grazing management	3256	15%	27%
			549		488	
Forest	Grazing	2552	NA	2552	15%	15%
	Timber Harvest				382	
Developed	Urban	69	NA	69	0	No Change
Stream Banks	Grazing	362	Riparian vegetation restoration and grazing management	206	NA	43%
	Hay encroachment		156			
Point Sources	Waste load allocation	0.0	NA	0.0	0	No Change
Future Sources*	All	0.0	NA	0.0	0	No Change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

Table 6-18. Camp Creek Total Phosphorus Allocations

Source Area	Associated Human Activities	Existing Tot. P	Source Area Restoration Approach	Source Area Allocated Tot. P	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	39	Fertilizer/grazing management	16	25%	40%
	Hay Production Fertilizer		23		4	
Shrub and Grassland	Grazing	1412	Upland grazing management	915	15%	45%
			227		137	
Forest	Grazing	360	NA	360	15%	15%
	Timber Harvest				54.0	
Developed	Urban	12	NA	12	0	No Change
Stream Banks	Grazing	150	Riparian vegetation restoration and grazing management	86	NA	43%
	Hay encroachment		64			
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	No Change
Future Sources*	All	0.0	NA	0.0	0	No Change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

6.7.2.2 Divide Creek

See **Section 6.5.2** for Divide Creek's existing nutrient conditions assessment and applicable nutrient targets.

6.7.2.2.1 Divide Creek Nutrient Load Analysis

The applicable total nitrogen and total phosphorus TMDLs for Divide Creek are provided in **Equations 6-1 and 6-2**. Nutrient loads were compared to the TMDL at two locations on Divide Creek: 1) downstream of the North Fork and East Fork Confluence and 2) near the mouth. Load assessment and comparison to TMDLs for total nitrogen and phosphorus sampling is presented in **Table 6-19** and **Table 6-20**. Data represent field measurements collected during August 2005 and August 2006. Total nitrogen and phosphorus concentrations were consistently high at both sites. Loading of both nitrogen and phosphorus was consistent except for one sample at the lower sight during 2006 when streamflow was high and likely composed of mostly water diverted from the Big Hole River via irrigation ditches.

Table 6-19. Divide Creek Total Nitrogen Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required to Meet TMDL
Downstream of North & East Forks	0.11	0.32	0.17	0.03	82
	0.15	0.32	0.38	0.04	89
Near Mouth	0.11	0.32	0.12	0.03	75
	7.1	0.32	23.00	1.87	92

Table 6-20. Divide Creek Total Phosphorus Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required to Meet TMDL
Downstream of North & East Forks	0.11	0.048	0.08	0.01	88
	0.15	0.048	0.09	0.02	78
Near Mouth	0.11	0.048	0.02	0.01	50
	7.1	0.048	2.19	0.77	65

6.7.2.2.2 Divide Creek Nutrient Source Assessment Results

Nitrogen source assessment results indicate that grassland and shrubland combined make the largest source area and include natural background nitrogen loads, but also the human influence of slightly reduced vegetation from grazing. Another human influenced contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Forest land is the second largest contributor of nitrogen, yet this source is mostly natural except for limited grazing (**Figure 6-3**). Bank erosion, both natural and unnatural, is another smaller, but significant source of nitrogen to the stream. Hay/pasture nitrogen sources are also a smaller, but significant source and will also be considered in TMDL allocations and restoration approaches. Suburban lands are a small source.

Divide Creek's phosphorus source assessment results reveal grassland and shrubland combined as the most major contributor and include both natural background and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Forested areas make the next largest phosphorus source, yet this source is mostly natural except for limited grazing. Bank erosion is the next largest source of phosphorus to the stream, although it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing. Hay/pasture areas are a small contributor of phosphorus but will be considered in TMDL allocations and restoration approaches. Suburban areas are a very small source of phosphorus in this watershed.

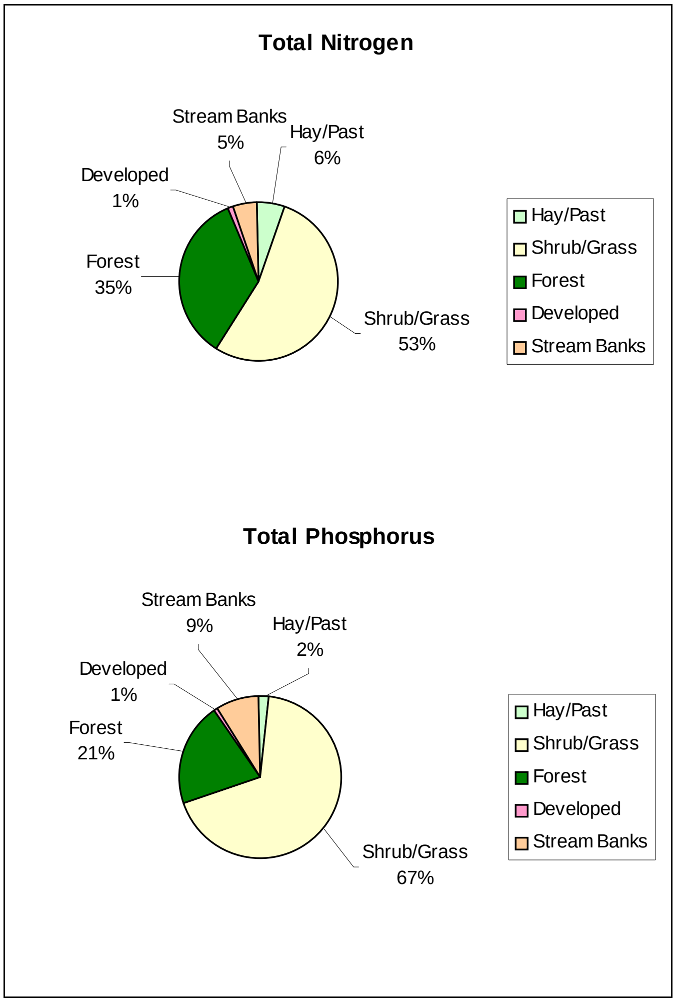


Figure 6-3. Divide Creek Nutrient Source Assessment Results

6.7.2.2.3 Divide Creek Nutrient Allocations

Divide Creek's nitrogen and phosphorus load allocations are provided in **Table 6-21** and **6-22** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that a significant amount of both nitrogen and phosphorus loads can be reduced by promoting natural riparian vegetation regrowth by managing grazing and moving hay production from these areas. Specific restoration approaches depend upon how specific riparian areas have been managed historically. Bank erosion reduction and grazing techniques along with fertilizer and irrigation management practices will also contribute to reduced nitrogen and phosphorus loads.

Because modeling uncertainty described in **Appendix G**, and the fact that the model does not address spatial considerations within the watershed, load reductions based upon modeling results and used within **Tables 6-21 and 6-22** and those indicated in **Section 6.7.2.2.1** may contrast. Because of this contrast, the allocation approach is to implement all reasonable land, soil and water conservation practices within each allocation category unless the nutrient TMDLs are being achieved with lesser implementation. There may be limited phosphorus deposits in Divide

Creek Watershed which may need consideration during adaptive management approaches within future TMDL reviews.

Table 6-21. Divide Creek Total Nitrogen Allocations

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	714	Fertilizer/Grazing Management	673	15%	20%
	Hay Production Fertilizer		41		101	
Shrub and Grassland*	Grazing	4229	Upland grazing management	3866	15%	22%
			363		580	
Forest	Grazing	7240	NA	7240	0%	No change
	Timber Harvest				0.0	
Developed	Urban	288	NA	288	0	No change
Stream Banks	Grazing	1434	Riparian Vegetation restoration and grazing management	1334	NA	7%
	Hay encroachment		100			
Point Sources	Waste Load Allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

Table 6-22. Divide Creek Total Phosphorus Allocations

Source Area	Associated Human Activities	Existing Tot. P	Source Area Restoration Approach	Source Area Allocated Tot. P	Pollutant Filtering via Riparian Vegetation Improvement (%)	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	44	Fertilizer/Grazing Management	18	15%	65%
	Hay Production Fertilizer		26		3	
Shrub and Grassland	Grazing	933	Upland grazing management	783	15%	39%
			150		117	
Forest	Grazing	950	NA	950	0%	No change
	Timber Harvest				0.0	
Developed	Urban	40	NA	40	0	No change
Stream Banks	Grazing	593	Riparian Vegetation restoration and grazing management	552	NA	7%
	Hay encroachment		41			
Point Sources	Waste Load Allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

6.7.2.3 Grose Creek

See **Section 6.5.3** for Grose Creek's existing nutrient conditions assessment and applicable nutrient targets.

6.7.2.3.1 Grose Creek Nutrient Load Analysis

The applicable total nitrogen and total phosphorus TMDLs for Grose Creek are provided in **Equations 6-1 and 6-2**. Nutrient loads were compared to the TMDL at two locations on Grose Creek. Load assessment and comparison to TMDLs for total nitrogen and phosphorus sampling is presented in **Table 6-23** and **Table 6-24**. Data represent field measurements collected during August 2005 and August 2006. Grose Creek is a very small stream and was at baseflow during all nutrient monitoring timeframes. Nitrogen and phosphorus concentrations and loading were similar at both sites but 2005 loads were slightly higher due to slightly higher stream flows.

Table 6-23. Grose Creek Nitrogen Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.15	0.32	0.47	0.26	45
	0.05	0.32	0.13	0.09	31
Lower site	0.13	0.32	0.33	0.22	33
	0.04	0.32	0.15	0.07	53

Table 6-24. Grose Creek Phosphorus Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.15	0.048	0.085	0.04	53
	0.05	0.048	0.044	0.01	77
Lower site	0.13	0.048	0.053	0.03	43
	0.04	0.048	0.045	0.01	78

6.7.2.3.2 Grose Creek Nutrient Source Assessment Results

Nitrogen source assessment results indicate that grassland and shrubland combined contribute over half the load and include natural sources and also the human influence of slightly reduced vegetation from grazing. Another human influenced contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Bank erosion is the second largest contributor of nitrogen, and this source is high influenced by livestock grazing (**Figure 6-4**). Hay/pasture areas are also a moderate, but significant source, and will also be considered in TMDL allocations and restoration approaches. Forested areas are a moderate source, yet this source is mostly natural except for limited grazing. There are almost no suburban lands.

Grose Creek's phosphorus source assessment results reveal grassland and shrubland combined as the most major contributor. This land type produces both natural background loading and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Bank erosion is the next largest source of phosphorus to the stream and it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing. Hay/pasture areas are a small contributor of phosphorus but will be considered in TMDL allocations and restoration approaches. Forested and developed areas do not contribute significant amounts of phosphorous to the watershed.

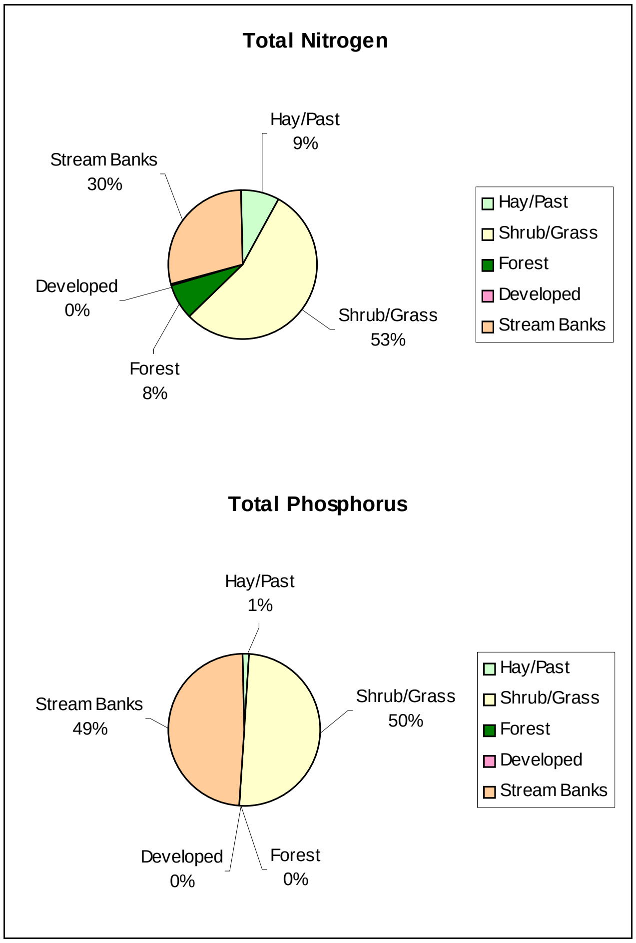


Figure 6-4. Grose Creek Nutrient Source Assessment Results

6.7.2.3.3 Grose Creek Nutrient Allocations

Grose Creek's nitrogen and phosphorus load allocations are provided in **Table 6-25** and **6-26** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that a significant amount of both nitrogen and phosphorus loads can be reduced by promoting natural riparian vegetation regrowth by managing grazing and moving hay production from these areas. Specific restoration approaches depend upon how specific riparian areas have been managed historically. Bank erosion reduction and grazing techniques along with fertilizer and irrigation management practices will also contribute to reduced nitrogen and phosphorus loads.

Because modeling uncertainty described in **Appendix G** and the fact that the model does not address spatial considerations within the watershed, load reductions based upon modeling results, and used within **Tables 6-25 and 6-26**, and those indicated in **Section 6.7.2.3.1** may contrast. Because of this contrast, the allocation approach is to implement all reasonable land, soil and water conservation practices within each allocation category unless the nutrient TMDLs are being achieved with lesser implementation.

Table 6-25. Grose Creek Total Nitrogen Allocations

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	**(reduction in lbs)**	**(lbs)**	**(reduction in lbs)**	**(% reduction)**
Hay/Past	Grazing	13	Fertilizer/Grazing Management	12.5	25%	27%
	Hay Production Fertilizer		0.5		3	
Shrub and Grassland	Grazing	80	Upland grazing management	66	15%	30%
			14		10	
Forest	Grazing	12	NA	12	15%	17%
	Timber Harvest				2	
Developed	Urban	0.5	NA	0.5	0	No change
Stream Banks	Grazing	44	Riparian Vegetation restoration and grazing management	16	NA	64%
	Hay encroachment		28			
Point Sources	Waste Load Allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

Table 6-26. Grose Creek Total Phosphorus Allocations

Source Area	Associated Human Activities	Existing Tot. P	Source Area Restoration Approach	Source Area Allocated Tot. P	Pollutant Filtering via Riparian Vegetation Improvement	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(lbs)
Hay/Past	Grazing	0.5	Fertilizer/Grazing Management	0.2	25%	60%
	Hay Production Fertilizer		0.3		0.1	
Shrub and Grassland	Grazing	18	Upland grazing management	12	15%	33%
			6		2	
Forest	Grazing	0.0	NA	0.0	15%	NA
	Timber Harvest				0.0	
Developed	Urban	0.1	NA	0.1	0	No change
Stream Banks	Grazing	18	Riparian Vegetation restoration and grazing management	7	NA	61%
	Hay encroachment		11			
Point Sources	Waste Load Allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources considered.

6.7.2.4 Lost Creek

See **Section 6.5.5** for Lost Creek's existing nutrient conditions assessment and applicable nutrient targets.

6.7.2.4.1 Lost Creek Nutrient Load Analysis

The applicable total nitrogen and total phosphorus TMDLs for Lost Creek are provided in **Equations 6-1 and 6-2**. Nutrient loads are compared to the TMDL at three locations on Lost Creek and descriptions of the sites are provided in **Section 6.5.5**. The stream is dry between each of these sites. Data represent field measurements collected during August 2005 and August 2006. Load assessment and comparison to TMDLs for total nitrogen and phosphorus sampling is presented in **Table 6-27** and **Table 6-28**. The highest nitrogen concentrations and stream discharge were found at the upper site. Monitoring at the middle and lower sites indicates no total nitrogen TMDL exceedances, yet this data set is small. Phosphorous concentrations were high and the loads were above the TMDL at all locations.

Table 6-27. Lost Creek Nitrogen Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.14	0.320	0.315	0.242	23
	0.04	0.320	0.069	0.069	NA
Middle site	0.03	0.320	0.016	0.052	NA
	0.01	0.320	0.012	0.017	NA
Lower site	0.02	0.320	0.031	0.035	NA

Table 6-28. Lost Creek Phosphorus Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.14	0.048	0.037	0.015	59
	0.04	0.048	0.011	0.004	64
Middle site	0.03	0.048	0.008	0.003	63
	0.01	0.048	0.003	0.001	67
Lower site	0.02	0.048	0.005	0.002	60

6.7.2.4.2 Lost Creek Nutrient Source Assessment Results

Nitrogen source assessment results indicate that grassland and shrub land combined contribute about half the load and include natural sources, and also the human influence of slightly reduced vegetation from grazing. Another human influenced contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Forested areas are a moderate source, yet this source is mostly natural except for limited grazing. Bank erosion and hay/pasture lands are also a modest contributor of nitrogen and will be considered in the allocations and restoration approaches (**Figure 6-5**). There are almost no suburban lands.

Lost Creek's phosphorus source assessment results reveal grassland, and shrubland combined as the most major contributor. This land type produces both natural background loading, and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Bank erosion is the next largest source of phosphorus to the stream and it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing, and natural erosion process. Hay/pasture areas are a moderate contributor of phosphorus and will be considered in TMDL allocations and restoration approaches. Forested areas are a moderate source, yet this source is mostly natural except for limited grazing.

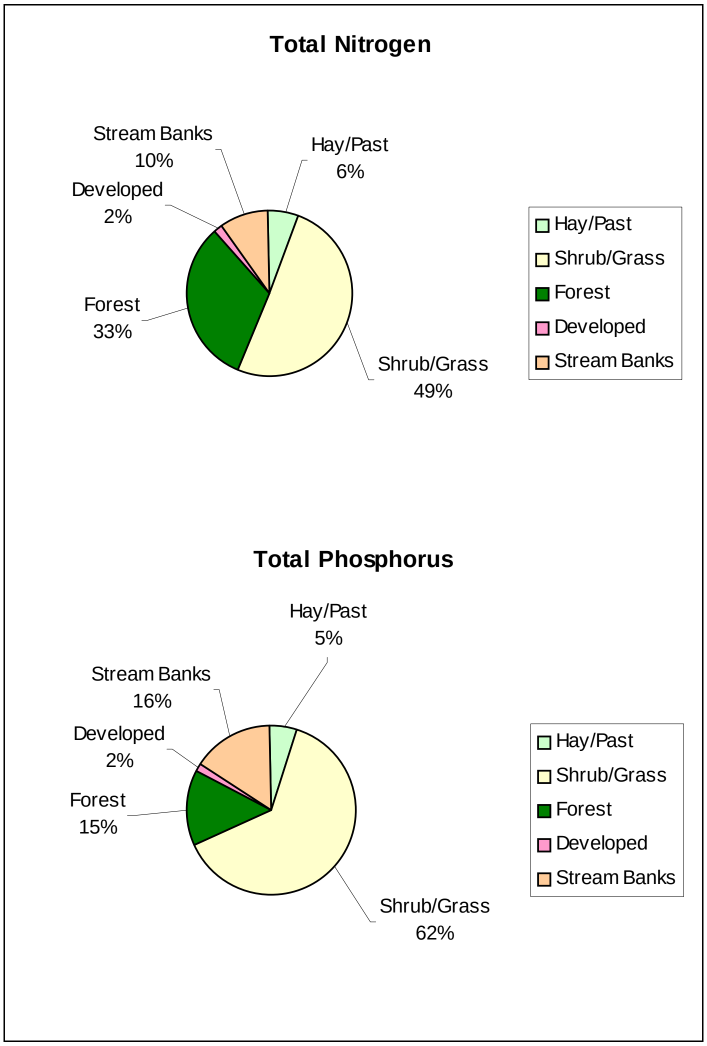


Figure 6-5. Lost Creek Nutrient Source Assessment Results

6.7.2.4.3 Lost Creek Nutrient Allocations

Lost Creek's nitrogen and phosphorus load allocations are provided in **Table 6-25** and **6-26** respectively. Allocations are presented by source area and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that significant amounts of both nitrogen and phosphorus loading can be reduced by promoting natural riparian vegetation regrowth. Riparian area filtering capacity improvements, and reduction in bank erosion rates can be achieved by managing grazing, and moving hay production from these areas. Specific restoration approaches depend upon how specific riparian areas have been managed historically. Bank erosion reduction and improved upland grazing techniques along with fertilizer and irrigation management practices will also contribute to reduced nitrogen and phosphorus loads.

Because modeling uncertainty described in **Appendix G** and the fact that the model does not address spatial considerations within the watershed, load reductions based upon modeling results and used within **Tables 6-29 and 6-30**, and those indicated in **Section 6.7.2.4.1** may contrast.

Because of this contrast, the allocation approach is to implement all reasonable land, soil and water conservation practices within each allocation category unless the nutrient TMDLs are being achieved with lesser implementation.

Table 6-29. Lost Creek Total Nitrogen Allocations

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement (%)	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	129	Fertilizer/grazing management	124	25%	28%
	Hay Production Fertilizer		5		31	
Shrub and Grassland	Grazing	1026	Upland grazing management	829	15%	31%
			197		124	
Forest	Grazing	681	NA	681	15%	15%
	Timber harvest				102	
Developed	Urban	34	NA	34	0	No change
Stream Banks	Grazing	200	Riparian vegetation restoration and grazing management	136	NA	32%
	Hay encroachment		64			
Point Sources	Waste load allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources.

Table 6-30. Lost Creek Total Phosphorus Allocations

Source Area	Associated Human Activities	Existing Tot. P	Source Area Restoration Approach	Source Area Allocated Tot. P	Pollutant Filtering via Riparian Vegetation Improvement (%)	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	28	Fertilizer/grazing management	25	25%	32%
	Hay production Fertilizer		3		6	
Shrub and Grassland	Grazing	329	Upland grazing management	247	15%	36%
			82		37	
Forest	Grazing	77	NA	77	15%	15%
	Timber harvest				12	
Developed	Urban	9	NA	9	0	No change
Stream Banks	Grazing	83	Riparian vegetation restoration and grazing management	56	NA	33%
	Hay encroachment		27			
Point Sources	Waste load allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources.

6.7.2.5 Soap Creek

See **Section 6.5.6** for Soap Creek's existing nutrient conditions assessment and applicable nutrient targets.

6.7.2.5.1 Lost Creek Nutrient Load Analysis

The applicable total nitrogen and total phosphorus TMDLs for Soap Creek are provided in **Equations 6-1 and 6-2**. Nutrient loads are compared to the TMDL at two locations on Lost Creek and descriptions of the sites are provided in **Section 6.5.6**. Data represent field measurements collected during August 2005 and August 2006. Load assessment and comparison to TMDLs for total nitrogen and phosphorus sampling is presented in **Table 6-31** and **Table 6-**

32. Nutrient consecrations were high at the upper site and also exceed the TMDL at this site. Nutrient conditions monitored at the lower site meet the total phosphorus and nitrogen TMDLs and Targets. Water at the lower site may come from local groundwater or irrigation ditches from the Big Hole River. Water from the upper site is intercepted by a large irrigation canal which carries water from the Big Hole River and likely water from the upper watershed does not influence low flow conditions at the lower site.

Table 6-31. Soap Creek Nitrogen Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.25	0.32	0.89	0.43	52
	0.01	0.32	0.04	0.02	50
Lower site	0.11	0.32	0.12	0.19	NA
	0.18	0.32	0.27	0.31	NA

Table 6-32. Soap Creek Phosphorus Load Assessment.

Site	Flow (cfs)	Target (mg/L)	Sampled Load (lbs/day)	TMDL (lbs/day)	% Reduction Required
Upper site	0.25	0.048	0.078	0.066	15
	0.01	0.048	0.008	0.003	63
Lower site	0.11	0.048	0.023	0.029	NA
	0.18	0.048	0.046	0.048	NA

6.7.2.5.2 Soap Creek Nutrient Source Assessment Results

Nitrogen source assessment results indicate that grassland and shrubland combined contribute about three fourths the load, and include natural sources, and also the human influence of slightly reduced vegetation from grazing. Another human influenced contribution of nitrogen from grass and shrub lands comes from domestic animal waste. Forested areas are a moderate source, yet this source is mostly natural except for limited grazing. Bank erosion and hay/pasture lands are also a modest contributor of nitrogen and will be considered in the allocations and restoration approaches (**Figure 6-6**). There are almost no suburban lands.

Soap Creek's phosphorus source assessment results reveal grassland and shrubland combined as the most major contributor. This land type produces both natural background loading, and the human influence of reduced upland vegetation from grazing systems which slightly elevates erosion. Bank erosion is the next largest source of phosphorus to the stream, and it is likely one of the more controllable human influenced sources. Bank erosion is highly influenced by domesticated livestock riparian grazing, and natural erosion process. Hay/pasture areas are a moderate contributor of phosphorus and will be considered in TMDL allocations and restoration approaches. Forested areas are a moderate source, yet this source is mostly natural except for limited grazing.

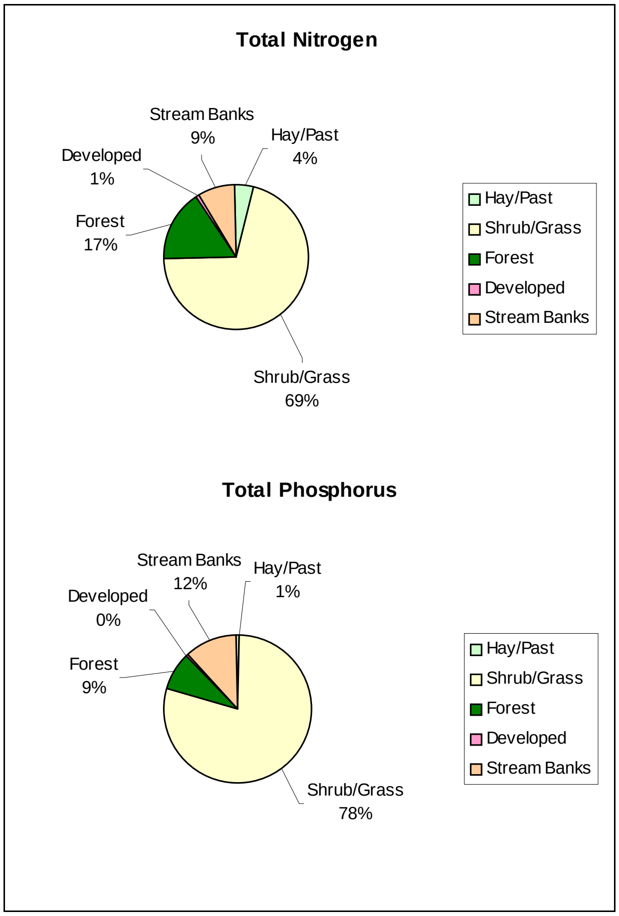


Figure 6-6. Soap Creek Nutrient Source Assessment Results

6.7.2.5.3 Soap Creek Nutrient Allocations

Soap Creek's nitrogen, and phosphorus load allocations are provided in **Table 6-33** and **6-34** respectively. Allocations are presented by source area, and also by the ability of riparian areas to filter nutrients as they move toward streams. Model results of the restoration scenarios indicate that significant amounts of both nitrogen, and phosphorus loading can be reduced by promoting natural riparian vegetation regrowth. Riparian area filtering capacity improvements and reduction in bank erosion rates can be achieved by managing grazing and moving hay production from these areas. Specific restoration approaches depend upon how specific riparian areas have been managed historically. Bank erosion reduction and improved upland grazing techniques along with fertilizer and irrigation management practices will also contribute to reduced nitrogen and phosphorus loads.

Because modeling uncertainty described in **Appendix G** and the fact that the model does not address spatial considerations within the watershed, load reductions based upon modeling results and used within **Tables 6-33 and 6-34** and those indicated in **Section 6.7.2.5.1** may contrast. Because of this contrast, the allocation approach is to implement all reasonable land, soil and water conservation practices within each allocation category unless the nutrient TMDLs are being achieved with lesser implementation.

Table 6-33. Soap Creek Total Nitrogen Allocations

Source Area	Associated Human Activities	Existing Tot. N	Source Area Restoration Approach	Source Area Allocated Tot. N	Pollutant Filtering via Riparian Vegetation Improvement (%)	Total Allocated Load From Source
		(lbs)	(reduction in lbs)	(lbs)	(reduction in lbs)	(% reduction)
Hay/Past	Grazing	102	Fertilizer/grazing management	97	25%	28%
	Hay production Fertilizer		5		24	
Shrub and Grassland	Grazing	1599	Upland grazing management	1277	15%	32%
			322		192	
Forest	Grazing	377	NA	377	15%	15%
	Timber harvest				56.6	
Developed	Urban	13	NA	13	0	No change
Stream Banks	Grazing	195	Riparian vegetation restoration and grazing management	174	NA	11%
	Hay encroachment		21			
Point Sources	Waste load allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources.

Table 6-34. Soap Creek Total Phosphorus Allocations

Source Area	Associated Human Activities	Existing Tot. P (lbs)	Source Area Restoration Approach (reduction in lbs)	Source Area Allocated Tot. P (lbs)	Pollutant Filtering via Riparian Vegetation Improvement (%) (reduction in lbs)	Total Allocated Load From Source (% reduction)
Hay/Past	Grazing Hay production Fertilizer	5.5	Fertilizer/grazing management 3.3	2.3	25% 0.6	71%
Shrub and Grassland	Grazing	531	Upland grazing management 133	398	15% 60	36%
Forest	Grazing Timber harvest	58	NA	58	15% 9	15%
Developed	Urban	2.2	NA	2.2	0	No change
Stream Banks	Grazing Hay encroachment	81	Riparian vegetation restoration and grazing management 9	72	NA	11%
Point Sources	Waste load allocation	0	NA	0	0	No change
Future Sources*	All	0	NA	0	0	No change

*If significant future nutrient sources occur, the allocation approach should be updated with new sources.

6.8 Uncertainty and Adaptive Management for Nutrient TMDLs

An adaptive management strategy is proposed to facilitate revision of the nutrient targets, TMDLs, and allocations for the Middle and Lower Big Hole TPAs. Although there is uncertainty in the loading values and relative contributions, there is a relatively high level of certainty that the land use practices which can be addressed via the identified BMPs will provide a large reduction. This is supported by the modeling, review of literature, overall source assessment results, and field observations.

Future nutrient and stream flow monitoring should occur in these streams to better characterize nutrient, discharge, and water use conditions. The allocation approach is supported by GWLF modeling that was calibrated at the Big Hole Watershed scale. As new monitoring results applicable to each TMDL are attained they should be compared to the water quality targets, TMDLs and modeling results. If monitoring results do not fall in line with the allocation approach, new allocation approaches which match specific data from the watershed should be considered.

There are two primary regulatory mechanisms through which water quality targets and TMDLs may be modified in the future, as follows: (1) Montana Code Annotated 75-5-703(9)(c) provides a provision for revising the TMDL based on an evaluation conducted by DEQ five years after the TMDL is completed and approved, and (2) DEQ has begun the initial steps of numeric standards development for nutrients. DEQ expects to start the formal rule making process for adoption of numeric standards within the next two years. Prior to the start of formal rulemaking, DEQ will provide opportunity for informal public comment, as well as for the formal public comment prescribed under statute. If Montana initiates the use of numeric nutrient criteria, these criteria may be used to revise the nutrient TMDLs provided in this document during future TMDL review. It is envisioned that the additional data collection and regulatory elements together will provide the needed data and information to revise the proposed interim nutrient targets, TMDLs and allocations.

There may be limited phosphorus deposits in Divide Creek Watershed which may need consideration during adaptive management approaches within future TMDL reviews.

6.9 Margin of Safety and Seasonal Considerations for Nutrient TMDLs

The nutrient margin of safety is inherently provided by conservative assumptions during the source assessment, and BMP implementation modeling scenarios. The allocation approach is built upon the modeled BMP scenarios where all reasonable land, soil, and water conservation practices are in place. Additionally, nutrient filtering efficiency by riparian areas was estimated on the low end of ranges that were investigated, and existing conditions of riparian zones were also accounted for during the filtering capacity improvement portion of the nutrient reduction assessment. The allocations are built upon restoration scenarios that are reasonably achievable. The adaptive management approach provided in **Section 6.8** also provides a feedback loop to address uncertainties between the allocations, targets, and TMDLs. The allocation approach calls for implementation of all reasonable land, soil and water conservation practices be implemented unless all targets are being met along the entire stream segment the TMDLs were written for.

The nutrient targets and TMDLs are provided to protect against nuisance algae growth during the summer, and apply only during this timeframe. Allocations are provided for year round conditions to ensure summer timeframe targets are met. Nonpoint source restoration approaches provided in **Section 9.0** should reduce nutrient concentrations, and loads during all seasons. The allocation approach, which applies to all seasons, is also consistent in protecting downstream uses in nutrient impacted reservoirs downstream of this TPA.

6.10 Nutrient Monitoring Strategies

Fishtrap, Gold, Charcoal, Sawlog, and Wickiup Creeks have been identified as potentially impaired by nutrient conditions in Montana’s 2006 Integrated Water Quality Report. These watersheds were not sampled because of the timeframe of the listings, and this project. The middle and lower segments of the Big Hole River were sampled during this project as an additional component not related to TMDL development but to provide recent data. This limited data indicates nutrient conditions in the Big Hole River are above the targets presented in this document. This data should be considered in upcoming monitoring and assessment plans for future Integrated Water Quality Reporting. No TMDLs will be pursued for these streams at this time but they will be addressed by future monitoring efforts.

Further nutrient and stream flow monitoring should occur periodically as restoration practices are implemented in watersheds were TMDLs were developed. Effectiveness monitoring should occur for a subset of restoration projects. Many other monitoring strategies pertinent to all pollutant types are provided in **Section 10.0** of this document.

SECTION 7.0
METAL TMDL COMPONENTS

7.1 Mechanism of Effects of Excess Metals to Beneficial Uses

Water bodies with metals concentrations exceeding aquatic life and/or human health criteria impair support of the beneficial uses of aquatic life, cold water fisheries, and drinking water. High metals concentrations may also affect agricultural uses. Elevated concentrations of heavy metals in streams and lakes can have a toxic, carcinogenic, or bioconcentrating effect on biota living in these environments. Consumption of drinking water or fish with elevated metals concentrations can result in chronic and acute effects in animals and humans.

7.2 Stream Segments of Concern

A total of 14 water body segments in the Middle and Lower Big Hole TPA were listed as impaired due to metals-related causes on the 2006 Montana 303(d) List (**Table 7-1**). All 2006 303(d) Listings are included in **Table 1-1** and the beneficial use support status of listed segments is presented in **Table 3-1**. Metals listings include arsenic, cadmium, copper, lead, mercury, and zinc. Although the Wise River was not listed for metals on the 2006 303(d) List, data was collected during TMDL development to aid in source assessment and will be discussed within this section.

Table 7-1. Water body segments in the Middle and Lower Big Hole TPA with metals listings on the 2006 303(d) List.

Stream Segment	Water Body #	Probable Causes of Impairment
Big Hole River between Divide Cr and Pintlar Cr (Middle segment)	MT41D001_020	Copper, Lead
Big Hole River from Divide Cr to the mouth at Jefferson River (Lower segment)	MT41D001_010	Cadmium, Copper, Lead, Zinc
California Creek from headwaters to mouth (French Cr-Deep Cr)	MT41D003_070	Arsenic, Metals
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	Arsenic
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	MT41D003_220	Arsenic, Cadmium, Copper, Lead, Zinc
French Creek from headwaters to mouth (Deep Cr)	MT41D003_050	Arsenic
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	Copper, Lead
Lost Creek from headwaters to mouth (Big Hole R)	MT41D002_180	Arsenic
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	MT41D003_080	Arsenic, Copper, Lead,

Table 7-1. Water body segments in the Middle and Lower Big Hole TPA with metals listings on the 2006 303(d) List.

Stream Segment	Water Body #	Probable Causes of Impairment
Rochester Creek from headwaters to mouth (Big Hole R)	MT41D002_160	Arsenic, Copper, Lead, Mercury
Sassman Gulch from headwaters to mouth (Big Hole R)	MT41D002_070	Arsenic
Sawlog Creek tributary to Big Hole R	MT41D004_230	Arsenic
Trapper Creek from headwaters to mouth (Big Hole R)	MT41D002_010	Copper, Lead, Zinc
Wickiup Creek Tributary to Camp Cr (Big Hole R)	MT41D002_120	Copper, Lead, Mercury

7.3 Information Sources and Assessment Methods

The total metals load entering a water body is equal to the sum of all contributing source areas. In general, this means that headwater areas will have fewer potential source areas, whereas locations lower in the watershed will have numerous potential source areas. Potential sources of metals loading in the Middle and Lower Big Hole TPA include:

- Natural background loading from mineralized geology
- Abandoned mines, including adit discharge/drainage from abandoned mines and runoff/drainage from abandoned mine tailings
- Atmospheric deposition from Anaconda Smelter and Glendale Smelter
- Instream and floodplain metals deposits from historical mining operations

Initially, GIS layers, historical water quality data, and aerial photos were used to determine the location and magnitude of general sources. GIS data included the DEQ High Priority Abandoned Hardrock Mine Sites, Montana Bureau of Mines and Geology (MBMG), Abandoned and Inactive Mines Database, and the U.S. Bureau of Mines Minerals Location Database prepared by the Montana State Library (**Appendix A, Figure A-6**). Geologic data from the USGS General Surficial Geology of Montana 1:500,000 scale map and soils data from the State Soil Geographic (STATSGO) database was also examined. Available sediment data were also analyzed because sediment can be a source of metals at mine sites and is also deposited in stream channels. A review of NPDES permits indicated there are no permitted metals point sources in the Middle and Lower Big Hole TPA.

Many of the 303(d) Listings are based on water column and sediment metals data from the 1960s, 1970s, and 1980s. Data collected prior to 1990 were used to aid in the initial coarse level source assessment and to help determine sampling locations for additional data collection, but are not used within this document in the existing data review due to potential data quality and reliability issues (reporting limits, collection, analysis and recording methods), and because conditions may have changed substantially since data collection. More recent data include DEQ's assessment data collected since 1990 (**Figure A-8**), and a Montana Tech of the University of Montana (MTech) study along the mainstem Big Hole River in 2001/2002 that included diurnal samples. To add to the limited historical dataset and document seasonal variability, DEQ conducted metals water quality and sediment monitoring in 2005 and 2006 in the listed watersheds during spring runoff and base flow conditions (**Figure A-9**). Sediment metals data was collected in an attempt to document "background" metals concentrations regardless of hydrologic conditions. Field and analytical protocols for the samples collected in 2005/2006 are described in *Water Quality Impairment Status Report and Sampling and Analysis Plan* (DEQ 2005), and raw data is contained in **Appendix H**.

The effect of runoff on metals concentrations can vary, as spring runoff may dilute metals sources that enter the stream though ground water or may increase erosion and erode soils/tailings containing metals. Mining areas may contribute metals through ground water discharge, which occurs year-round, but tend to be more apparent during low flow when surface water inputs are minimal. Examining water quality data under various hydrologic conditions is necessary to characterize water chemistry metal conditions.

7.3.1 Natural Background Loading

Natural background loading of metals occurs as a result of geologic conditions. Therefore, the degree of loading can vary considerably among sub-watersheds in the planning area, as geologic conditions vary throughout (**Figure A-4**). In areas that have been historically mined, or have received atmospheric deposition from the Anaconda Smelter, it is difficult to tease apart the background or natural levels of a metal contaminant from these other sources because no data exists prior to the start of mining in the area in the late 1800's. When possible, background loading will be accounted for separately from anthropogenic sources. However, because mining and/or smelting has affected all of the streams that are listed for metals impairment, the natural background loading may not be expressed separately from other loading, and even if it is expressed separately, a small component of the anthropogenic loading is assumed to be natural. The underlying assumption is that natural background sources alone would not result in the exceedance of TMDL target concentrations of metals in the water column, or in sediments. If future monitoring proves this to be incorrect, then this TMDL will be revised in accordance with the Adaptive Management strategy provided in **Section 7.8**.

7.3.2 Atmospheric Deposition

Watersheds that have been documented as receiving aerial deposition from the Anaconda Smelter are within the Deep Creek watershed and are noted in **Table 7-2**. Arsenic is a major component of smelter stack particulates, but emissions from the Anaconda Smelter also contained cadmium, copper, lead, and zinc (EPA and DEQ 1998). The Glendale Smelter, located in the lower portion of the Trapper Creek watershed, was a major smelter for the Bryant Mining District in the late 1880s and may have contributed to elevated metals in the Trapper Creek watershed and other surrounding areas.

7.3.3 Abandoned Mines

As discussed in **Section 2.2.4**, there are several high priority abandoned mines in the Middle and Lower Big Hole TPA and many other abandoned mines that have not been assessed as "high priority" (**Figures A-6 and A-9**). While monitoring has occurred at the majority of the high priority abandoned mine sites, there is typically not enough data upstream and downstream to designate a specific percentage of a total load from these sites relative to other abandoned mine sources. In general, there is also typically limited data for tailings and waste rock piles. In instances where there is adequate data, loading from abandoned mines, adits, and tailings will be evaluated separately as unpermitted point sources and provided a waste load allocation (WLA) where appropriate. Otherwise, the contribution from all abandoned mine sources (e.g. adits, waste rock, tailings) in a contributing area or entire watershed are grouped into a load from abandoned mines. This approach is premised on the assumption that reductions in metals loading can be achieved through the remediation of these abandoned mines and associated waste rock/tailings. **Table 7-2** summarizes the potentially contributing source areas for the streams of concern (see **Table 7-1**) in the Middle and Lower Big Hole TPA. The potentially contributing source areas were identified based on historical data and a review of the distribution of abandoned mines and will be discussed in more detail in **Section 7.6**, **Loading Summary and Allocations**.

Table 7-2. Summary of Potentially Contributing Source Areas for Metals to 303(d) Listed Streams

Stream Segment	**Potentially Contributing Source Areas**		
	Listed Tributaries or Those With Abandoned Mines	**Priority Abandoned Mines**	**Other**
Big Hole River (middle)	French Creek via Deep Creek, Wise River, Jerry Creek	Old Elkhorn	abandoned mines, placer mining, atmospheric deposition from Anaconda smelter via watersheds in the French Creek drainage
Big Hole River (lower)	Moose, Trapper, Soap, Wickiup, Birch and Rochester Creek	Maiden Rock	abandoned mines, placer mining
California Creek	Oregon Creek	None	placer mining, atmospheric deposition from Anaconda smelter
Camp Creek	Wickiup Creek	Clipper Mine	abandoned mines
Elkhorn Creek	None	Old Elkhorn	abandoned mines
French Creek	California Creek, Oregon Creek	None	abandoned mines, placer mining, atmospheric deposition from Anaconda smelter
Jerry Creek	Moores Creek	None	abandoned mines
Lost Creek	None	None	abandoned mines
Oregon Creek	None	None	placer mining, atmospheric deposition from Anaconda smelter

Table 7-2. Summary of Potentially Contributing Source Areas for Metals to 303(d) Listed Streams

Stream Segment	Potentially Contributing Source Areas		
	Listed Tributaries or Those With Abandoned Mines	**Priority Abandoned Mines**	**Other**
Rochester Creek	None	Watseca Mine, Thistle Mine Tailings	abandoned mines
Sassman Gulch	None	Tungsten Mill	Abandoned mines
Sawlog Creek	None	None	Unknown
Trapper Creek	headwater tributaries	Trapper Mine, Silver King Mine, Lower and Upper Cleve Mine, True Blue Mine	abandoned mines
Wickiup Creek	None	Clipper Mine	abandoned mines
Wise River	Elkhorn Creek	Old Elkhorn	abandoned mines

7.4 Water Quality Targets

7.4.1 Targets

For pollutants, such as metals, with numeric standards, the established state numeric water quality criteria, as defined in DEQ Circular DEQ-7 (DEQ 2008), is typically adopted as the water quality target. The acute and chronic numeric water quality criteria, as defined in Circular DEQ-7, are adopted as water quality targets for the metals of concern in the Middle and Lower Big Hole River TPA, which include arsenic, cadmium, copper, lead, iron, mercury, and zinc. Narrative standards found in Montana's general water quality prohibitions (ARM 17.30.637) apply to metals concentrations that are found associated with stream bottom sediments. **Appendix B** contains additional details on applicable numeric and narrative standards for metals.

7.4.1.1 Water Column Metals Concentrations

DEQ Circular DEQ-7 (DEQ 2008) contains numeric water quality criteria for Montana's surface and ground waters that are set at concentrations necessary to protect the beneficial uses of the waters. Acute and chronic toxicity aquatic life standards are designed to protect aquatic life uses, while the human health standard is designed to protect drinking water uses. Compliance with chronic water quality criteria are based on an average water quality metals concentration over a 96 hour period. Acute water quality criteria are applied as a 'not-to-exceed' value.

Water quality criteria (acute[1] and chronic aquatic[2] life, human health) for each parameter of concern in the Middle and Lower Big Hole TPA at a water hardness of 25 mg/L are shown in **Appendix B**, **Table B-4**. The numeric aquatic life criteria for most metals are dependent upon water hardness values, and as the hardness increases, the water quality criteria for a specific metal also increases. Consequently, where the aquatic life numeric criteria are used as the target, the water quality target values for specific metals will vary with water hardness. The acute and chronic aquatic life standards for cadmium, copper, lead, and zinc are hardness-dependent.

Water quality targets for metals are the State of Montana human health and acute and chronic aquatic life criteria as defined in DEQ Circular DEQ-7. A TMDL will be written when either the aquatic life or human health standard is exceeded. As discussed in **Appendix B**, the aquatic life numeric criteria will be used as a target for iron, because the human health criteria is a secondary maximum contaminant level based on aesthetic properties and would likely be removed via conventional treatment.

7.4.2 Supplemental Indicators

7.4.2.1 Sediment Metals Concentrations

As discussed in **Appendix B**, narrative standards found in Montana's general water quality prohibitions apply to metals concentrations that are found in stream bottom sediments. Stream sediment data may also be indicative of beneficial use impairment caused by elevated metals and are used as supplementary indicators of impairment. In addition to directly impairing aquatic life that interacts with the elevated metals in the sediment, the elevated sediment values can also be an indicator of elevated concentrations of metals during runoff conditions. This can be a particularly important supplemental indicator when high flow data is lacking.

The National Oceanic and Atmospheric Administration (NOAA) has developed Screening Quick Reference Tables for stream sediment quality that contain metals concentration guidelines for freshwater sediments (Buchman 2004). Screening criteria concentrations come from a variety of studies and investigations, and are expressed in Threshold Effects Levels (TEL) and Probable Effects Levels (PEL). TELs represent the sediment concentration below which toxic effects to aquatic life rarely occur, and are calculated as the geometric mean of the 15th percentile concentration of the toxic effects data set and the median of the no-effect data set. PELs represent the sediment concentration above which toxic effects frequently occur, and are calculated as the geometric mean of the 50th percentile concentration of the toxic effects data set and the 85th percentile of the no-effect data set. Although the State of Montana does not currently have criteria that define impairment condition based on sediment quality data, TELs and PELs provide a screening tool to evaluate the potential for impacts to aquatic life and can be

[1] No surface or ground water sample concentration shall exceed these values (DEQ-7)
[2] No surface or ground water average concentration shall exceed these values based upon a 4-day (96 hr) or longer period (DEQ-7)

used to assist in impairment determinations where water chemistry data are limited (**Table 7-3**). Because PELs represent the level at which toxic effects frequently occur, PEL exceedances will be given more weight than TEL exceedances. However, sediment metals information will be used as a supplemental indicator to water column data.

Table 7-3. Screening level criteria for sediment metals concentrations that will be used as supplemental indicators in the Middle and Lower Big Hole TPA.

Metal of Concern	**TEL (µg/g dry weight)**	**PEL (µg/g dry weight)**
Arsenic	5.9	17
Cadmium	0.596	3.53
Copper	35.7	197
Lead	35	91.3
Mercury	0.174	0.486
Zinc	123.1	315

7.4.2.2 Biological Toxicity Metrics

Biological metrics will be used, when available, as supplemental indicators for metals impairment for streams in which the sediment metals concentrations exceed guidance values. The biological metric supplemental indicator for metals is based on the percent of abnormal diatom cells in periphyton samples. Based on work by McFarland et al. (1997), toxic conditions are assumed when greater than 3 percent of the diatoms are deformed. Since other factors can lead to cell deformation, the percent of abnormal diatom cells will only be considered when sediment metals concentrations exceed supplemental indicator values.

7.4.2.3 Anthropogenic Metals Sources

The presence of anthropogenic metals sources does not always result in impairment of a beneficial use. When there are no significant identified anthropogenic sources of metals within the watershed of a 303(d) Listed stream, no TMDL will be prepared. Montana's narrative criteria for metals relate to anthropogenic causes, and natural levels of metals are assumed to be below the chronic water quality criteria for aquatic life under all flow conditions. Anthropogenic and natural sources will be evaluated using recently collected data, field observations and watershed scale source assessment information obtained using aerial imagery, GIS data layers, and other relevant information sources.

7.4.3 Summary of Targets and Supplemental Indicators for Metals

The metals targets and supplemental indicators are summarized in **Table 7-4**. TMDL determination is based on the following assumptions:

- Natural levels of metals are below the chronic water quality criteria for aquatic life under all flow conditions.
- Single water quality samples represent a 96-hour average water quality condition.

Whether or not a TMDL is developed depends on several factors:

- If there is any exceedance of the water quality target, and accompanying known anthropogenic sources, a TMDL will be developed.
- If there are no recent water quality target exceedances, but there is insufficient data to fully evaluate all seasonal flow conditions, then additional monitoring may be recommended instead of TMDL development.
- If water column samples meet water quality targets, sediment metals data and biological toxicity metrics will be reviewed and compared to supplemental indicator values. TMDL development determinations in situations without exceedances in water column data depend on the presence of anthropogenic sources and the number and magnitude of exceedances in sediment samples. If water column measurements meet the water quality targets, but both biological metrics and the sediment metals concentrations exceed the supplemental indicator criteria described within this document, a TMDL will be prepared or follow-up monitoring will be conducted.

Table 7-4. Targets and Supplemental Indicators for Metals in the Middle and Lower Big Hole TPA.

Water Quality Targets	**Proposed Criterion**
Montana's numeric water quality standards	As described in Circular DEQ-7
Supplemental Indicators	Proposed Criterion
% of abnormal diatom cells (periphyton)	<3
Sediment metal concentrations (µg/g dry weight)	Not impeding aquatic life use support: Comparable to NOAA guidance values (provided in Section 7.4.2.1)
Anthropogenic metals sources	No significant anthropogenic sources

7.4.4 Existing Condition and Comparison to Water Quality Targets

7.4.4.1 Big Hole River, Middle Segment (MT41D001_020)

The middle segment of the Big Hole River (**Figure A-2**) was listed for copper and lead on the 2006 303(d) List. The Middle Big Hole River extends 43.8 miles from the confluence of Pintlar Creek downstream to the confluence with Divide Creek.

Sources and Available Data
There is one high priority abandoned mine site on Elkhorn Creek in the upper Wise River watershed, which is a tributary that flows into the middle segment of the Big Hole River. There are additional high priority abandoned mine sites in the Upper Big Hole TPA as well, along with other abandoned mine sites throughout the Middle Big Hole TPA. Metals 303(d) Listings in the Middle Big Hole River are the result of data collected between the 1960's and 1980's. More recently, water samples were collected during low flow in August 2002 at Dickie Bridge as part of a diurnal study for a Master's thesis at MTech, and also at low flow and high flow in 2005/2006 as part of TMDL development (**Table 7-5**). The samples in 2005/2006 were collected at the Mudd Creek bridge near the upper part of the segment, at Dickie Bridge (between Deep

Creek and the Wise River), and at the Jerry Creek Fishing Access Site (FAS) downstream of Wise Creek (sites ML05MDBH01, _02, _03; **Figure A-9**).

Comparison to Water Quality Targets and TMDL Development Determination
Out of seven samples, one sample collected during high flow at the Jerry Creek FAS (ML05MDBH03) exceeded the chronic aquatic life standard for copper (**Table 7-5**). One of the two sediment samples slightly exceeded the supplemental indicator TEL value for copper. Based on the target and supplemental indicator exceedances, a copper TMDL will be developed for the middle segment of the Big Hole River.

The same high flow water sample that failed to meet the copper target slightly exceeded the chronic aquatic standard for lead. All other samples were below the detection limit; however, the high flow samples from 2005 were analyzed with a detection limit of 1µg/L, and at hardness values below 40 mg/L, the chronic standard is less than 1 µg/L. The other samples had an adequate detection limit to evaluate exceedances at low hardness values. Neither sediment sample exceeded the supplemental indicator values for lead. However, based on the single water column exceedance for lead, a lead TMDL will be developed for the middle segment of the Big Hole River.

Table 7-5. Copper and Lead Concentrations in the Middle Segment of the Big Hole River. Bold text denotes a target exceedance.

Sample Site	Location	Date	Total Recoverable Metal in Water Column (µg/L)			Sediment Metals Concentrations (µg/g dry wt.)	
			Copper	**Lead**	**Hardness (mg/L as CaCO3)**	**Copper**	**Lead**
Dickie Bridge[1]	Dickie Bridge	8/2002	0.61	<0.15	37.0	--	--
ML05MDBH01	Mudd Creek Bridge	6/6/2005*	1	<1	35.6	--	--
ML05MDBH02	Dickie Bridge	6/6/2005*	2	<1	37.1	--	--
ML05MDBH01	Mudd Creek Bridge	8/1/2005	<1	<0.5	41.2	**35.9**	8.17
ML05MDBH03	Jerry Creek FAS	8/1/2005	<1	<0.5	58.4	16.2	7.22
ML05MDBH01	Mudd Creek Bridge	5/18/2006*	2	<0.5	21.2	--	--
ML05MDBH03	Jerry Creek FAS	5/17/2006*	**3**	**0.6**	21.9	--	--

*High flow sampling event; [1]Highest measured value during diurnal sampling event

7.4.4.2 Big Hole River, Lower Segment (MT41D001_010)

The lower Big Hole River is listed for copper, cadmium, lead and zinc on the 2006 303(d) List and extends 51.4 miles from Divide Creek to its mouth at the Jefferson River (**Figure A-2**).

Sources and Available Data
Abandoned mine sites are scattered throughout the Lower Big Hole River TPA, with priority abandoned mine sites in the Moose, Trapper, Soap, Wickiup, Birch and Rochester Creek watersheds, as well as Sassman Gulch (**Figure A-6**). In addition, the Maiden Rock priority mine site is located along the Big Hole River just downstream from the Moose Creek confluence (**Figure A-6**). Metals 303(d) Listings in the lower segment of the Big Hole River are the result of data collected between the 1960’s and 1980’s. More recently, water samples were collected during low flow in September 2002 at Notch Bottom as part of a diurnal study for a Master’s thesis at MTech, and also at low flow and high flow in 2005/2006 as part of TMDL development (**Table 7-6**). The recent samples were collected at the Salmon Fly FAS near Melrose (ML05LWBH01), and near the mouth at the High Road FAS (ML05LWBH02).

Comparison to Water Quality Targets and TMDL Development Determination
All water samples were below the target for copper, cadmium, lead, and zinc. All cadmium samples were below the detection limit and all but one lead sample were below the detection limit. The lead concentration during high flow in 2006 at ML05LWBH01 was the same as the exceedance in the middle segment, but did not exceed the target because the water hardness was slightly higher in the lower segment. Because of arsenic listings in the watershed, arsenic was also measured, and there were no exceedances in the water column. Both sediment samples exceeded the TEL supplemental indicator value for arsenic and cadmium, but were below the PEL value. There were no deformed diatom cells in a 2001 periphyton sample collected at Maiden Rock, and there was 0.2 percent abnormal cells at Notch Bottom (Bahls 2001). Based on all water column samples meeting the target, periphyton samples meeting the supplemental indicator value, and sediment sample exceedances for arsenic and cadmium being lower than the PEL, no metals TMDLs will be developed for the lower segment of the Big Hole River. However, additional high flow monitoring should be conducted for lead and to determine the effects of arsenic and cadmium associated with the stream bottom sediments on beneficial uses.

Table 7-6. Metals Concentrations in the Lower Big Hole River.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)						Sediment Metals Concentrations (µg/g dry wt.)				
			As	Cu	Cd	Pb	Zn	Hardness (mg/L as CaCO3)	As	Cu	Cd	Pb	Zn
Notch Bottom[1]	Notch Bottom	9/2002	2.0	0.46	<0.084	<0.15	17.4	101.4	--	--	--	--	--
ML05L WBH01	Salmon Fly FAS	6/5/2005*	3	2	<0.1	<1	1.4	42.6	--	--	--	--	--
ML05L WBH02	High Rd FAS	6/4/2005*	4	3	<0.1	<1	3.8	51.2	--	--	--	--	--
ML05L WBH01	Salmon Fly FAS	8/2/2005	4	<1	<0.08	<0.5	1	83.7	**7.32**	28.7	**0.66**	21.0	101
ML05L WBH02	High Rd FAS	8/4/2005	5	<1	<0.08	<0.5	1	115	**11.4**	17.3	**0.63**	20.9	95.7
ML05L WBH01	Salmon Fly FAS	5/17/2006 *	3	2	<0.08	0.6	5.0	28.1	--	--	--	--	--
ML05L WBH02	High Rd FAS	5/16/2006 *	3	2	<0.08	<0.5	2.8	39.4	--	--	--	--	--

*High flow sampling event; [1]Highest measured values during diurnal sampling event

7.4.4.3 California Creek (MT41D003_070)

California Creek is listed for arsenic and iron on the 2006 303 (d) List. California Creek flows approximately 10.9 miles from its headwaters along the Continental Divide to its mouth at French Creek, a tributary to the middle segment of the Big Hole (**Figure A-2**). The majority of the California Creek drainage is within the Mt. Haggin Wildlife Management Area.

Sources and Available Data

Arsenic in California Creek is thought to be the result of atmospheric deposition from the Anaconda Smelter (FWP 1981). There are no priority abandoned mines in the California Creek watershed, although it was placer mined for gold and there are several abandoned mine sites in the upper reaches of the American Creek watershed (**Figure A-11**), which flows into California Creek downstream of the Highway 274 crossing. The iron listing is based on data from the early 1980s, and no additional data is available. The FWP study concluded iron was associated with eroding sediment (FWP 1981). Iron was not on the 2004 303(d) List and was not included in the 2005/2006 TMDL-related sampling effort. Therefore, no iron TMDL will be completed at this time for California Creek. Additional monitoring is recommended to help further characterize and evaluate iron concentrations in California Creek and assess the contribution from anthropogenic sources.

The arsenic listing is based on a July 1991 sample with a total recoverable arsenic concentration of 72µg/L. The sample was collected near the State Highway 274 crossing downstream of Oregon Creek, which is listed as impaired for arsenic, copper and lead on the 2006 303(d) List. Additional data were collected at low and high flow in 2005/2006 as part of 303(d) assessment work and TMDL development (**Table 7-7**). Samples were collected in the upper reaches of

California Creek (ML05CALI01 and M03CALC02), just downstream of the confluence with Oregon Creek and upstream of the Highway 274 crossing (ML05CALI02), and near the mouth of California Creek(ML03CALC03). Because of the copper listing on Oregon Creek, samples were also analyzed for copper.

Comparison to Water Quality Targets and TMDL Development Determination

In 2005 in upper California Creek, a high flow sample at ML05CALI01 was at the human health standard for arsenic (10µg/L), and a low flow sample was just below the human health standard at M03CALC02. All other samples exceeded the human health standard. A FWP study assessed dissolved arsenic concentrations in streams on Mt. Haggin in proximity to the Anaconda Smelter and found concentrations increased as the stream origin moved from the southwest to the northeast, and with the proximity of the stream headwaters to the Anaconda Smelter (**Figure A-10**). Slaughterhouse Creek originates in the southwest part of Mt. Haggin and is considered to be outside of the Anaconda Smelter aerial deposition zone; it is a low elevation stream with similar geology to California Creek and was not placer-mined (FWP 1989). The dissolved arsenic concentration in Slaughterhouse Creek was near 5µg/L at high and low flow, indicating that background arsenic concentrations in California Creek are likely close to 5µg/L and supports the assumption that background levels do not exceed the water quality standard. Concentrations in California Creek were similar at high flow and low flow and tended to increase between the upper sites and lower sites. In July 2005, the only sample event with samples from the headwaters to the mouth, the concentration increased from M03CALC02 to ML03CALC01, but then stayed the same (18µg/L) to the mouth (ML03CALC03). Arsenic concentrations in all sediment samples exceeded the TEL and all but one sample also exceeded the PEL supplemental indicator value. The arsenic concentration in sediment at the site below Oregon Creek was more than double the PEL in both samples from 2005. Based on the target and supplemental indicator exceedances, an arsenic TMDL will be developed for California Creek.

Copper was analyzed at three sites during low flow in 2005, and two sites during spring runoff in 2006. Copper at the lower site below the confluence with Oregon Creek (ML05CALI02) exceeded both the chronic and acute aquatic life criteria being more than double the acute standard during high flow sampling in 2006. The sediment samples from below the confluence of Oregon Creek and near the mouth of California Creek both exceeded the TEL supplemental indicator value for copper. Based on the target exceedance in the water column and supplemental indicator exceedances in the sediment, a copper TMDL will be developed for California Creek.

Table 7-7. Arsenic and Copper Concentrations in California Creek.
Bold text denotes a target exceedance.

Sample Site	Location	Date	Total Recoverable Metal in Water Column (µg/L)			Sediment Metals Concentrations (µg/g dry wt.)	
			Arsenic	Copper	Hardness (mg/L as CaCO3)	Arsenic	Copper
3124CA 01	d/s of Oregon Creek	7/31/1991	**72**	2	84	--	--
ML05C ALI01	Upper California Cr	6/6/2005*	10	--	65.2	--	--
ML05C ALI02	d/s of Oregon Creek	6/6/2005*	**18**	--	41.6	--	--
M03CA LC02	Near headwaters	7/7/2005	9	1	77	**17.5**	19.8
ML03C ALC01	d/s of Oregon Creek	7/8/2005	**18**	3	53	**77.2**	**49**
ML03C ALC03	Near mouth	7/12/2005	**18**	2	59	**10.4**	**66.6**
ML05C ALI01	Upper California Cr	8/1/2005	**11**	--	90.5	**23.4**	--
ML05C ALI02	d/s of Oregon Creek	8/1/2005	**21**	--	77.3	**45.7**	--
ML05C ALI01	Upper California Cr	5/18/2006*	**11**	5	64.4	--	--
ML05C ALI02	d/s of Oregon Creek	5/18/2006*	**23**	**11**	38.5	--	--

*High flow sampling event

7.4.4.4 Camp Creek (MT41D002_020)

Camp Creek is a tributary of the Big Hole River listed for arsenic on the 2006 303(d) List. Camp Creek flows 14.3 miles from its headwaters to its confluence with the Big Hole River (**Figure A-2**) and a small irrigation reservoir is located at stream mile 3.8 from the mouth.

Sources and Available Data
The Clipper Mine located in Wickiup Creek watershed, which is a tributary of Camp Creek, is a high priority abandoned mine site. There are also several other abandoned mines within the Camp Creek watershed. Samples collected in 1993 and 2004 on Wickiup Creek did not show elevated arsenic concentrations in the water column, but were slightly elevated in the sediment downstream of Clipper Mine, suggesting Wickiup Creek may be a source of arsenic to Camp Creek (see **Section 7.4.4.14**). Low flow samples were collected in 2003 and high flow samples were collected in 2005 and 2006 (**Table 7-8**). In 2003, Montana DEQ collected metals samples at three sites numbered progressing upstream (M03CAMPC01, _C02, _C03). In 2005, samples

were collected upstream of the Wickiup Creek confluence (ML05CAMP01), downstream of the reservoir on Camp Creek (ML05CAMP02), and near the mouth (ML05CAMP03). The lower site appeared to contain irrigation return flows and was replaced in 2006 by a site downstream of the confluence with Wickiup Creek (ML05CAMP06).

Comparison to Water Quality Targets and TMDL Development Determination

Arsenic exceeded human health standards at all three sites during base flow monitoring in 2003, with concentrations increasing in a downstream direction. All high flow water samples in 2005 and 2006 were below the arsenic target. This indicates that the arsenic is likely associated with the groundwater. Sediment samples collected in 2003 both exceeded the TEL and PEL supplemental indicator values for arsenic, and the concentration at the uppermost site was more than three times the PEL value. There are no recorded abandoned mine sites upstream of the uppermost sample site (M03CAMPC03) and aerial deposition is unlikely to be a factor in this portion of the watershed, indicating that arsenic concentrations may be naturally elevated above the target. The increasing concentrations downstream could be from naturally arsenic-rich sediment from the upper watershed being transported downstream or it could be associated with historic mining activities such as arsenic-rich mine tailings and waste rock. Due to the high level of uncertainty regarding background arsenic and the contribution from anthropogenic sources, no arsenic TMDL will be developed for Camp Creek and additional monitoring and/or assessment is recommended. If additional monitoring indicates the background concentration is greater than the target, a site-specific target may be necessary. Additional monitoring should focus on low flow conditions and assessing the background concentration and contribution from historical mining activities in Wickiup Creek and Camp Creek.

Table 7-8. Arsenic Concentrations in Camp Creek.
Bold text denotes a target exceedance.

Sample Site	**Water Quality Sample Date**	**Total Recoverable Metal in Water Column (µg/L)**	**Sediment Metals Concentrations (µg/g dry wt.)**
		As	**As**
M03CAMPC01	9/14/2003	**26**	--
M03CAMPC02	9/15/2003	**17**	**27.4**
M03CAMPC03	9/15/2003	**11**	**56.1**
ML05CAMP01	6/5/2005*	3	--
ML05CAMP02	6/5/2005*	3	--
ML05CAMP03	6/5/2005*	4	--
ML05CAMP01	5/17/2006*	4	--
ML05CAMP02	5/17/2006*	3	--
ML05CAMP06	5/17/2006*	3	--

*High flow sampling event

7.4.4.5 Elkhorn Creek (MT41D003_220)

Elkhorn Creek is listed for arsenic, cadmium, copper, lead and zinc on the 2006 303(d) List. Elkhorn Creek flows 7.2 miles from its headwaters to its mouth at Jacobson Creek, which is a tributary to the Wise River (**Figure A-2**).

Sources and Available Data
The Old Elkhorn Mine is a priority abandoned mine site in the Elkhorn Creek watershed, and there are several other abandoned mine sites within the watershed. DEQ conducted water quality monitoring in September of 1993 and noted an open adit was discharging at the Old Elkhorn Mine site, though a portion of the flow was captured in a settling pond before discharging into Elkhorn Creek. The USFS completed some reclamation work at the site in 2003, that included removing tailings associated with an impoundment and revegetating waste rock, but the adit discharge was left untreated. Adit discharge was again noted during stream assessment work related to TMDL development in July of 2006. Stream samples were collected in 2000 and 2003 at low flow and in 2005 and 2006 at high flow (**Table 7-9**). Samples were collected upstream and downstream of the Old Elkhorn Mine/town of Coolidge and also near the mouth.

Comparison to Water Quality Targets and TMDL Development Determination
The chronic and acute aquatic life standards for copper were exceeded in all but one sample, which was collected during the low flow upstream of Coolidge in 2003. One sediment sample exceeded the TEL supplemental indicator value for copper and three of the other samples exceeded both the TEL and PEL supplemental indicator values for copper. Based on these exceedances, a copper TMDL will be developed for Elkhorn Creek.

The chronic and acute aquatic life standards for zinc were exceeded in all but one sample, which was collected during low flow upstream of Coolidge in 2003. One sediment sample exceeded the TEL supplemental indicator value for zinc and the other two samples exceeded both the TEL and PEL supplemental indicator values for zinc. Based on these exceedances, a zinc TMDL will be developed for Elkhorn Creek.

Both low flow samples in 2000 met the target for cadmium, but all low flow and high flow samples in 2003, 2005, and 2006 exceeded water quality targets. Both low flow samples from 2003 and one high flow sample from 2005 near the mouth exceeded the chronic aquatic life standard and all other samples exceeded the chronic aquatic life standard and met or exceeded the acute aquatic life standard. The detection limit for one of the sediment samples was too high to compare to the supplemental indicator values, but the other three samples exceeded both the TEL and PEL supplemental indicator values for cadmium. Based on these exceedances, a cadmium TMDL will be developed for Elkhorn Creek.

None of the water samples exceeded the arsenic target. However, all samples were collected at low flow. All sediment samples except the 1993 sample above the mine exceeded the TEL supplemental indicator value for arsenic, and three of the sediment samples were more than double the PEL supplemental indicator value for arsenic. In addition, periphyton samples from 2003 revealed 11.2 percent abnormal cells at site 01 and 19.9 percent abnormal cells at site 02 (Bahls 2004). Additional high flow monitoring should be conducted for arsenic, but based on the severity of supplemental indicator value exceedances, there are likely exceedances of the arsenic target under high flow conditions. Additionally, the large increase in arsenic levels in the sediment between upstream and downstream of the Elkhorn mine/town of Coolidge indicate that area is a source of arsenic. An arsenic TMDL will be developed for Elkhorn Creek.

The 1993 water sample below the mine exceeded the chronic aquatic life standard for lead. No samples were analyzed for lead in 2005 or 2006 and samples from 2000 and 2003 had too high of a detection limit to evaluate target exceedances. Three of the five sediment samples exceeded both the TEL and PEL supplemental indicator values for lead and were more than double the PEL. Exceedances for other metals were greater at high flow than low flow, and given the elevated concentration of lead in the sediment at sites downstream of the mine and water column exceedances in the headwaters of the Wise River during high flow in 2005 and 2006, Elkhorn Creek likely exceeded water quality standards for lead. In addition, periphyton samples from 2003 revealed 11.2 percent abnormal cells at site M03ELKHC01 and 19.9 percent abnormal cells at site M03ELKHC02 (**Figure A-8**; Bahls 2004). Additional samples should be collected for lead at low flow and high flow and analyzed using a detection limit lower than the standard. However, based on the target exceedances in 1993, exceedances downstream in the Wise River, severity of supplemental indicator value exceedances, and that the source of lead is likely the same as for copper, cadmium, and zinc, a lead TMDL will be developed for Elkhorn Creek.

Table 7-9. Metals Concentrations in Elkhorn Creek.
Bold text denotes a target exceedance.

Sample Site	Location	Date	Total Recoverable Metal in Water Column (µg/L)						Sediment Metals Concentrations (µg/g dry wt.)				
			As	Cu	Cd	Pb	Zn	Hardness (mg/L as CaCO3)	As	Cu	Cd	Pb	Zn
01-169-SW-1/SE-1	d/s of Elkhorn mine	9/15/93	1.12[1]	**24**	4.59[1]	**1.88**	**159**	22.8	**7.1**	**52.9**	0.9[1]	7	**134**
01-169-SW-4/SE-2	u/s of Elkhorn mine	9/15/93	1.12[1]	2.33[1]	4.59[1]	0.94[1]	8.71[1]	17.3	4.0[1]	1.83	0.8[1]	5.5[1]	19
E-1	u/s of Coolidge	7/20/00	<3	1	<0.1	<3	<10	13	7	29	<5	12	107
E-9	d/s of Coolidge	7/20/00	<3	**8**	<0.1	<3	**50**	19	**42**	**565**	**12**	**192**	**1430**
M03ELKHC01	d/s of Coolidge	7/23/03	2	**15**	**0.3**	<1	**92**	18.9	**71.6**	**940**	**6.98**	**300**	**1020**
M03ELKHC02	Near mouth	7/23/03	2	**10**	**0.2**	<1	**52**	19.3	**38.9**	**764**	**13.2**	**234**	**1220**
ML05EKHR01	d/s of Coolidge	6/6/05*	--	**43**	**0.6**	--	**117.4**	15.4	--	--	--	--	--
ML05EKHR02	Near mouth	6/6/05*	--	**39**	**0.5**	--	**110.7**	15.4	--	--	--	--	--
ML05EKHR01	d/s of Coolidge	5/17/06*	--	**54**	**0.52**	--	**82.6**	14.2	--	--	--	--	--
ML05EKHR02	Near mouth	5/17/06*	--	**54**	**0.69**	--	**99.9**	15.1	--	--	--	--	--

*High flow sampling event; [1]Concentration below detection limit (detection limit indicated)

7.4.4.6 French Creek (MT41D003_050)

French Creek is listed for arsenic on the 2006 303(d) List. It flows 9.4 miles from its headwaters on the eastern slope of the Anaconda-Pintler Range to its mouth at Deep Creek (**Figure A-2**). The majority of the French Creek watershed is within the Mt. Haggin Wildlife Management Area.

Sources and Available Data

The listing is based on data from the early 1980s. There are several abandoned placer mine sites in an area known as French Gulch, which is a headwater tributary of French Creek. An industrial-scale placer mining camp on French Gulch began when gold was discovered in 1864, with production peaking in 1867. In 1898, French Gulch was dredged and “hydraulicked” along with neighboring tributaries. Mining impacts along French Gulch are still visible today (Munday 2001). Historic placer mining within the drainage, along with precipitate emitted by the Anaconda Smelter, is believed to be the source of arsenic in French Creek.

DEQ collected water samples at two sites during spring runoff in 2005 and 2006, while both water chemistry and sediment chemistry data were collected at the same sites during base flow conditions in 2005 (**Table 7-10**). The upper site (ML05FREN01) is just upstream of the confluence with California Creek and the Highway 274 crossing, while the lower site (ML05FREN02) is just upstream of the confluence with Deep Creek. Additional low flow water and sediment chemistry data were collected during 2005 at four sites spread out from near the headwaters to the mouth (**Table 7-10**).

Comparison to Water Quality Targets and TMDL Development Determination

Six of the ten samples exceeded the arsenic target and all exceedances occurred at sites downstream of the confluence with California Creek, which also contained several target exceedances for arsenic. All six sediment samples exceeded the TEL and PEL supplemental indicator values. The sediment sample with the greatest exceedance was collected downstream of the confluences with California Creek and Moose Creek. Based on these exceedances, an arsenic TMDL will be developed for French Creek.

Two of the water samples exceeded the chronic aquatic life standard for copper. Both exceedances occurred during high flow, were the same concentration, and occurred at the lower site downstream of the confluence with California Creek. Although California Creek is not listed for copper, as discussed in **Section 7.4.4.3**, the lower site on California Creek also exceeded the water quality target during high flow sampling. One of the six sediment samples exceeded the TEL supplemental indicator value for copper in sediment; the sample was collected downstream of the confluences with California Creek and Moose Creek. Based on the target exceedances in the water column and the supplemental indicator exceedance in the sediment, a copper TMDL will be developed for French Creek.

Table 7-10. Arsenic and Copper Concentrations in French Creek.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)			Sediment Metals Concentrations (µg/g dry wt.)	
			As	Cu	Hardness (mg/L as CaCO3)	As	Cu
ML05FREN01	u/s of California Creek	6/6/2005*	6	3	28.7	--	--
ML05FREN02	Near mouth	6/6/2005*	**14**	**5**	43.9	--	--
M03FNCHC01	Hdwaters nr Julius G.	7/5/2005	5	1	30	**40.9**	32.2
M03FNCHC04	d/s of Moose Creek	7/8/2005	**16**	2	55	**108**	**39.5**
M03FNCHC02	150 ft u/s Hwy 274	7/6/2005	**16**	2	50	**32**	30.8
M03FNCHC03	Near mouth	7/7/2005	**19**	2	52	**28.5**	27.4
ML05FREN01	u/s of California Creek	8/1/2005	9	<1	45.7	**32.2**	33.8
ML05FREN02	Near mouth	8/2/2005	**26**	1	68.9	**56.0**	27.1
ML05FREN01	u/s of California Creek	5/18/2006*	7	3	27.7	--	--
ML05FREN02	Near mouth	5/18/2006*	**14**	**5**	40.4	--	--

*High flow sampling event

7.4.4.7 Jerry Creek (MT41D003_020)

Jerry Creek is a tributary of the Big Hole River that is listed for copper and lead on the 2006 303(d) List. The Jerry Creek watershed lies on the south face of the Fleecer Mountains and flows 12.3 miles from its headwaters to the Big Hole River (**Figure A-2**).

Sources and Available Data

There are no priority abandoned mine sites in the Jerry Creek watershed, although there are several abandoned mines sites in the upper part of the watershed along Jerry Creek and Long Tom Creek and in the lower watershed along Parker and Indian Creeks. A low flow sample was collected by DEQ in 2003 upstream of these tributaries (**Table 7-11**). Water chemistry data was collected by DEQ at two sites during spring runoff in 2005 and 2006, and both water chemistry and sediment chemistry data were collected at three sites during base flow conditions in 2005. Samples were collected lower in the watershed, since monitoring data from 2003 indicated that metals impairments did not exist in the upper watershed. The uppermost sample site (ML05JERR01) is upstream of the Moores Creek confluence, while the lower sample sites (ML05JERR02 and M03JERRC02) are below the Moores Creek confluence and near the mouth.

Comparison to Water Quality Targets and TMDL Development Determination
Metals concentrations were meeting standards during all monitoring events, except for copper, which exceeded the acute aquatic life standard near the mouth during base flow monitoring in 2005. There were slightly over 1 percent abnormal cells in a 2003 periphyton sample at the upper site, which meets the supplemental indicator value for periphyton. Sediment samples for both sites met the supplemental indicator values for copper and lead. A replicate sediment sample collected at the lower site (JERR02) during low flow in 2005 was within 15 percent for all metals except copper; the replicate copper value was 44.8µg/g and slightly exceeding the TEL supplemental indicator value. This indicates elevated levels of copper in sediment may be localized. Based on all lead values meeting the targets and supplemental indicator values, no lead TMDL will be developed for Jerry Creek. Based on the exceedance of the acute aquatic life standard for copper and sources in Moores Creek, a copper TMDL will be developed for Jerry Creek. However, due to the single exceedance, additional samples should be collected to confirm the impairment.

Table 7-11. Metals Concentrations in Jerry Creek.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)			Sediment Metals Concentrations (µg/g dry wt.)	
			Cu	Pb	Hardness (mg/L as CaCO3)	Cu	Pb
2924JE01	Near mouth	9/7/1994	<1	<1	7.9	--	--
M03JERRC 01	Upper Jerry Creek	7/10/2003	<1	<1	44.1	--	--
ML05JERR 01	u/s of Moores Cr	6/5/2005*	1	<1	57.2	--	--
ML05JERR 02	Near mouth	6/5/2005*	1	<1	68.0	--	--
M03JERRC 02	1.9mi u/s of mouth	7/9/2005	<1	<0.5	88	23.5	15.6
ML05JERR 01	u/s of Moores Cr	8/3/2005	<1	<0.5	112	23.6	19.3
ML05JERR 02	Near mouth	8/3/2005	**26**	1	118	26.9	15.8
ML05JERR 01	u/s of Moores Cr	5/17/2006*	1	<0.5	53.0	--	--
ML05JERR 02	Near mouth	5/17/2006*	1	<0.5	63.9	--	--

*High flow sample

7.4.4.8 Lost Creek (MT41D002_180)

Lost Creek is listed for arsenic on the 2006 303(d) List. Lost Creek flows 7.8 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**). Approximately the lower 0.5 mile of Lost Creek is ephemeral.

Sources and Available Data

There are no priority abandoned mine sites in the Lost Creek watershed, although there are several abandoned mines in the upper part of the watershed. DEQ collected low flow samples in 2003 and high flow samples in 2005 and 2006 at two sites (**Table 7-12**). During spring runoff monitoring in 2006, the upper site (ML05LOST01) was inaccessible, so the second sample was collected at site ML05LOST03, which was established during nutrient monitoring and is the lowermost site on Lost Creek located just upstream of the I-15 crossing.

Comparison to Water Quality Targets and TMDL Development Determination

Arsenic concentrations exceeded the human health standard at both sites during low flow in 2003, but did not exceed the standard during high flow sampling in 2005 or 2006. A sediment sample collected in 2003 exceeded both the TEL and PEL supplemental indicator values for arsenic. In 2003 there were 3.9 percent abnormal diatom cells at the upper site (02) and only 0.3 percent abnormal cells at the lower site (01) (Bahls 2004). Based on the target and supplemental indicator exceedances, an arsenic TMDL will be developed for Lost Creek.

Table 7-12. Arsenic Concentrations in Lost Creek.
Bold text denotes a target exceedance.

Sample Site	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)		Sediment Metals Concentrations (µg/g dry wt.)
		As	Hardness (mg/L as CaCO3)	As
M03LOSTC01	9/13/2003	**27**	142	--
M03LOSTC02	9/14/2003	**28**	134	**22.8**
ML05LOST01	6/4/2005*	5	102	--
ML05LOST02	6/4/2005*	5	73.7	--
ML05LOST02	5/16/2006*	6	115	--
ML05LOST03	5/16/2006*	6	125	--

*High flow sample

7.4.4.9 Oregon Creek (MT41D003_080)

Oregon Creek is listed for arsenic, copper and lead on the 2006 303(d) List. Oregon Creek flows 1.8 miles from its headwaters along the Continental Divide to its confluence with California Creek (**Figure A-2**). The entire Oregon Creek watershed is within the Mt. Haggin Wildlife Management Area.

Sources and Available Data

The source of metals is likely historic placer gold mining and atmospheric deposition from the Anaconda Smelter. The DEQ and Montana Bureau of Mines and Geology (MBMG) databases do not list any abandoned mine sites within the watershed. Natural sources of arsenic may also be present. Oregon Creek was originally listed based on data from the early 1980s. Water chemistry data was collected by DEQ during low flow in 1991, low flow in 2005, and during spring runoff in 2005 and 2006 (**Table 7-13**). Two sediment samples were also collected during base flow conditions in 2005. The 1991 sample site was at the Highway 274 crossing and the recent sample site, (M03ORGN01/ML05ORGN01), was located near the mouth and the confluence with California Creek.

Comparison to Water Quality Targets and TMDL Development Determination

The arsenic human health standard was exceeded in all samples. The arsenic concentration in the sediment samples exceeded the TEL and PEL supplemental indicator values, and ranged from four to more than seven times the PEL. The low flow sample from 1991 and a low flow sample from 2005 exceeded the chronic aquatic life standard for copper and both high flow samples exceeded the chronic and acute aquatic life standard for copper. The copper concentration in both sediment samples exceeded the TEL supplemental indicator value. Based on recently collected data, copper impairments appear to be more pronounced during spring runoff, while arsenic concentrations were higher during base flow. In the data from the early 1980s, arsenic was slightly higher at high flow and the study concluded that atmospheric deposition from the Anaconda smelter is the probable source. Although the elevated concentration is likely partially related to natural sources, aerial deposition, and possibly historical placer mining, have also contributed to elevated arsenic. Arsenic and copper TMDLs will be developed for Oregon Creek.

All water samples met the target for lead, but both sediment samples exceeded the TEL supplemental indicator value. There are some data quality issues because the reported value in 1991 was less than the method detection limit and the detection limit in the high flow sample in 2005 was too high to detect all exceedances of the standard. In the FWP study from the 1980s, the Oregon Creek watershed was the only drainage in the Mt. Haggin area with elevated lead, and it was unknown whether it was related to atmospheric deposition from the Anaconda smelter, historical mining, or natural sources. Because there is a high level of uncertainty regarding sources, the sediment samples only exceeded the TEL, all water samples were below the targets, and there were data quality issues, no lead TMDL will be developed for Oregon Creek. Additional lead monitoring should be done to confirm the water column is meeting the standard, determine the biological effects of elevated concentrations in the sediment, and identify potential sources.

Table 7-13. Metals Concentrations in Oregon Creek.
Bold text denotes a target exceedance.

Sample Site	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)				Sediment Metals Concentrations (µg/g dry wt.)		
		As	Cu	Pb	Hardness (mg/L as CaCO3)	As	Cu	Pb
3124OR01	7/29/1991	**44**[1]	**5**[1]	1.0[2]	41.5	--	--	--
ML05ORGN01	6/6/2005*	**20**	**11**	<1	24.9	--	--	--
M03ORGNC01	7/7/2005	**29**	**5**	0.5	31	**121**	**89.3**	**44.4**
ML05ORGN01	8/2/2005	**35**	3	0.6	42.7	**77.7**	**106**	**62.5**
ML05ORGN01	5/18/2006*	**20**	**11**	<0.5	26.6	--	--	--

*High flow sample; [1]Reported value is off-scale high and actual concentration known to be greater; [2]Reported value is less than the method detection limit

7.4.4.10 Rochester Creek (MT41D002_160)

Rochester Creek is a 15.7 mile long tributary of the Big Hole River (**Figure A-2**). Rochester Creek is listed for arsenic, copper, lead and mercury on the 2006 303(d) List. Rochester Creek is an intermittent stream and flow typically does not reach the Big Hole River. According to a BLM assessment in 2001, Rochester Creek originates from springs north and west of the Watseca Mine, infiltrates into the ground upstream of the Rochester Mill tailings, and then resurfaces from springs at the southeastern end of the tailings impoundment (Tetra Tech 2002).

Sources and Available Data

Mining began in the Rochester Creek watershed in the 1860's and reached a peak between 1898 and 1905. The Watseca and Thistle Mines and tailings have both been identified by Montana DEQ as high priority abandoned hard rock mine sites, but reclamation responsibility has been transferred from the State to the BLM. Both historic and recent milling activities have occurred at the Watseca Mine. Rocky Mountain Minerals Inc. operated a cyanide vat leach operation that reprocessed Rochester Mill tailings and other mine waste to recover gold in the late 1980's and early 1990's and disposed of the tailings in a lined impoundment next to the Thistle Mine and within the floodplain of Rochester Creek (Tetra Tech 2002).

In addition to the priority abandoned mines, a reclamation investigation performed by the BLM in 2001 found thirty three other named and unnamed abandoned mines in the Rochester Creek watershed (Tetra Tech 2002). The reclamation investigation found waste rock associated with all abandoned mines and the largest quantities were associated with the Watseca Mine and Rochester Mill tailings. Waste rock and tailings were in the stream channel near the Watseca Mine, which had a breached tailings impoundment. The Rochester Mill tailings were noted to have off-road vehicle tracks that were partially within the stream channel during a 1993 DEQ assessment and were noted to be migrating via wind erosion and livestock tracking during a BLM assessment in 2001. The Rochester Mill tailings are currently being removed as part of a mining claim, and removal will likely be complete by the end of 2008. After the tailings are removed, the BLM plans to reclaim the site.

DEQ collected stream sediment samples in 1993 as part of an abandoned mines inventory upstream and downstream of the Rochester Mill tailings. Results indicated the release of arsenic, cadmium, mercury, and lead from tailings to stream sediment. No water was present in the channel during sampling in 1993. Subsequently, DEQ assessed metals in the water column at three sites in Rochester Creek in July of 2000 (**Table 7-14**). Sediment samples were collected at two of the sites. The sites sampled in 2000 start near the headwaters (R-1) and are numbered progressing downstream. DEQ assessed arsenic, copper, lead and mercury concentrations in the water column at two sites during spring runoff in 2005 and 2006 and during base flow conditions in 2005 (**Table 7-14**). The upper sample site (ML05ROCH01) was located downstream of the Watseca Mine, while the lower sample site (ML05ROCH02) was located downstream of the Rochester Mill tailings and Thistle Mine and tailings. Rochester Creek was intermittent between the upper and lower sites and was dry along the Rochester Mill tailings/Thistle Mine and tailings during all three monitoring events. The BLM collected water samples during low flow in 2001 at eleven sites near the Watseca Mine site and the Rochester Tailings (**Table 7-15**; and **Appendix A, Figure A-19**).

Comparison to Water Quality Targets and TMDL Development Determination
All but one DEQ sample exceeded the human health standard for arsenic and the 2005 low flow sample at the upper site also exceeded the chronic aquatic life standard of 150µg/L. Eight of the BLM samples exceeded the human health standard for arsenic and three of them exceeded the chronic aquatic life standard. DEQ sediment samples at all sites, but a sample collected in 2000 above the Watseca and Thistle mines, exceeded both the TEL and PEL supplemental indicator values for arsenic, with values ranging from more than 90 times to almost 300 times the PEL. Based on the target and supplemental indicator exceedances and the mining sources, an arsenic TMDL will be developed for Rochester Creek.

During BLM sampling in 2001, copper exceeded the chronic and acute aquatic life standard at three sites. Copper exceeded the chronic aquatic life standard at the upper DEQ site during a high flow sampling event in 2005. No other water samples exceeded the targets, but sediment samples exceeded both the TEL and PEL supplemental indicator values for copper, with values ranging from more than three times to almost fifteen times the PEL. Based on the target and supplemental indicator exceedances and the mining sources, a copper TMDL will be developed for Rochester Creek.

During BLM sampling in 2001, three samples exceeded the chronic aquatic life standard for lead. All DEQ water samples were below the standard for lead, and all but two samples were below the detection limit. DEQ sediment samples exceeded both the TEL and PEL supplemental indicator values for lead, with values ranging from more than 9 times to 21 times the PEL. Based on the target and supplemental indicator exceedances and the mining sources, a lead TMDL will be developed for Rochester Creek.

Mercury in the water column remained below the detection limit at both sites during all monitoring events in 2005 and 2006, though the type of analysis performed may not have been sensitive enough to accurately capture the true mercury concentration. During BLM sampling in 2001, the detection limit (0.08µg/L) and required quantitation limit (0.20µg/L) were both greater than the 0.05µg /L human health standard and the reported value for most samples was between the detection limit and the method quantitation limit. Therefore, all samples exceeded the standard (by at least a factor of two). However, two of the samples were greater than the quantitation limit and were between four and seven times the human health standard. The sediment sample from the upper site between the Watseca mine and Thistle mine exceeded both the TEL and PEL supplemental indicator value for mercury and the sediment sample from the lower site exceeded the TEL supplemental indicator value for mercury. Because of the exceedances in the water column in 2001, and the sediment samples exceeding the supplemental indicator values, a mercury TMDL will be developed for Rochester Creek. Due to the high detection limit during a 2001 sampling, additional water quality monitoring should be conducted with a lower detection limit to aid in the source assessment and determine the background concentration.

Table 7-14. Metals Concentrations in Rochester Creek from DEQ sites.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)					Sediment Metals Concentrations (µg/g dry wt.)			
			As	Cu	Pb	Hg	Hardness (mg/L as CaCO3)	As	Cu	Pb	Hg
R-1	Near headwaters on S Fork Roch.	7/18/2000	<3	2	<3	--	203	<5	24	7	--
R-3	d/s Watseca mine	7/18/2000	**129**	10	<3	--	218	**5,050**	**1,610**	**1,630**	--
R-9	d/s Thistle/ Rochester tailings	7/18/2000	**37**	3	<3	--	303	--	--	--	--
ML05ROCH01	d/s Watseca mine	6/4/2005*	**66**	7	<1	<0.1	205	--	--	--	--
ML05ROCH02	d/s Thistle/ Rochester tailings	6/4/2005*	**16**	2	<1	<0.1	251	--	--	--	--
ML05ROCH01	d/s Watseca mine	8/4/2005	**238**	10	5.0	<0.05	226	**3,770**	**2,940**	**1,960**	**0.55**
ML05ROCH02	d/s Thistle/ Rochester tailings	8/4/2005	**23**	1	<0.5	<0.05	259	**1,540**	**619**	**849**	**0.47**
ML05ROCH01	d/s Watseca mine	5/16/2006 *	**92**	**20**	6.2	<0.05	227	--	--	--	--
ML05ROCH02	d/s Thistle/ Rochester tailings	5/16/2006 *	**15**	2	<0.5	<0.05	269	--	--	--	--

*High flow sample

Table 7-15. Metals Concentrations in Rochester Creek during BLM reclamation investigation.
Bold text denotes a target exceedance.

Sample Site/Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)				
		As	Cu	Pb	Hg	Hardness (mg/L as CaCO3)
RWS1- near lower placer	7/12/2001	**68.4**	1.4[1]	1.8[1]	**0.38**	268
RSW2-400ft d/s of Rochester tailings	7/12/2001	**43.1**	13.6[1]	4.1	0.16[1]	252
RSW3-d/s end of Rochester tailings pond	7/12/2001	**25.5**	8.47[1]	3.3	0.17[1]	244
RSW4- adjacent to Rochester tailings where flow surfaces	7/12/2001	**51.1**	14.0[1]	3.3	0.13[1]	249
RSW5-u/s of Rochester tailings before water goes subsurface	7/12/2001	**273**	**50.3**	**23.0**	0.17[1]	208
RSW6- u/s of historic mill; d/s of confluence of Rochester Cr and unnamed trib (near ML05ROCH01)	7/12/2001	**374**	**65.1**	**16.6**	0.19[1]	196
RSW7-d/s of Watseca Mine and u/s of confluence with unnamed trib	7/12/2001	**375**	**52.6**	**13.6**	0.13[1]	230
RSW8-Unnamed trib just u/s of confluence with Rochester	7/12/2001	**15.8**	4.9[1]	3.7	0.14[1]	175
RSW9-u/s of Watseca Mine on Rochester Creek	7/12/2001	2.9[1]	1.3[2]	1.9[1]	0.14[1]	172
RSW10-Unnamed trib to Rochester d/s of Picard mine	7/12/2001	8.7[1]	4.3[1]	8.8	**0.22**	179
RSW11-Unnamed trib to Rochester u/s of known mines	7/12/2001	2.5[1]	1.3[2]	2.5[1]	0.16[1]	161

[1]Detected at a concentration between the detection limit and required quantitation limit; Not detected (detection limit is indicated)

7.4.4.11 Sassman Gulch (MT41D002_070)

Sassman Gulch is listed for arsenic on the 2006 303(d) List. It flows 6.5 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Sources and Available Data
There is one priority abandoned mine in the watershed, the Tungsten Mill Site, and it was reclaimed by the BLM in 1990. The site contains ten tailings ponds that had 18” of topsoil applied during the reclamation, and it is approximately 1000 feet from the gulch. The DEQ and MBMG databases did not identify any other abandoned mines in the watershed. Sassman Gulch was originally listed based on surface sediment samples near the mill and is currently listed based on elevated stream sediment data from 2005. Private groundwater wells, upgradient and

downgradient of the mill, were sampled in 1993 and both had less than 3 µg/L of arsenic, indicating that elevated arsenic in the stream sediment may not necessarily be related to the mill. DEQ site visits in 2003 and 2005 concluded that most of Sassman Creek is ephemeral and there are two perennial springs that surface in the lower part of the creek. Water and sediment chemistry data were collected in July 2005 in the spring-fed areas of the gulch, which are not connected via surface flow (**Table 7-16**).

Comparison to Water Quality Targets and TMDL Development Determination
Although samples were only collected in July, the surface flow and arsenic concentration is likely fairly consistent year-round since all water observed in the channel was from springs. Both samples met the water quality target for arsenic. The sediment sample from the upper site exceeded the TEL and PEL supplemental indicator values, with a concentration slightly more than double the PEL. Wind erosion of the tailings was common prior to reclamation and elevated arsenic in the sediment may be associated with the tailings. However, since both water samples met the target, there is limited sample data, and the source of elevated arsenic is unknown, no arsenic TMDL will be developed at this time. Additional monitoring should be conducted in the water column and the sediment, and possibly upland soil near the channel, to help further characterize and evaluate arsenic concentrations in Sassman Gulch and assess the contribution from anthropogenic sources, particularly the Tungsten Mill Site.

Table 7-16. Arsenic Concentrations in Sassman Gulch.
Bold text denotes a target exceedance.

Sample Site	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)	Sediment Metals Concentrations (µg/g dry wt.)
		As	**As**
M03SASMG01	7/15/2005	< 3[1]	**39.8**
M03SASMG02	7/15/2005	4	4.8

[1]Not detected (detection limit indicated)

7.4.4.12 Sawlog Creek (MT41D004_230)

Sawlog Creek is listed for arsenic on the 2006 303(d) List. It flows 5 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Sources and Available Data
No mines were identified within the watershed using literature and GIS mining layers as data sources. A low flow sample was collected in 2003 and two sites were sampled in 2006 during spring runoff (**Table 7-17**). One site was located at the mouth (ML05SWLG02) and the other site was approximately 1 mile upstream from the mouth (ML05SWLG01).

Comparison to Water Quality Targets and TMDL Development Determination
Arsenic exceeded the human health standard in the low flow sample from 2003, but met the target during spring runoff in 2006 at both sites. The source of arsenic within this watershed is unknown since there are no documented abandoned mine sites and it is not in an area of documented aerial deposition. Because no anthropogenic sources have been identified, no

arsenic TMDL will be completed for Sawlog Creek. Additional monitoring is recommended to help further characterize and evaluate arsenic concentrations in Sawlog Creek and determine if anthropogenic sources are present.

Table 7-17. Arsenic Concentrations in Sawlog Creek.
Bold text denotes a target exceedance.

Sample Site	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)
		As
M03SWLGC01	9/13/2003	**19**
ML05SWLG01	5/18/2006*	2
ML05SWLG02	5/18/2006*	2

*High flow sample

7.4.4.13 Trapper Creek (MT41D002_010)

Trapper Creek is a tributary of the Big Hole River that is listed for copper, lead and zinc on the 2006 303(d) List. It flows 17.4 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Sources and Available Data
There are several abandoned mine sites in the Trapper Creek watershed, including five priority abandoned mines. Collectively, the mines produced gold, silver, lead, copper, and zinc. All but one priority abandoned mine, the Silver King Mine, are located on tributaries to Trapper Creek. During a 1993 statewide inventory of abandoned mines, there was steeply graded waste rock but no mill tailings at the Silver King Mine site (DEQ 1993). The Trapper Mine site and the Lower and Upper Cleve Mine sites are priority abandoned mine sites along Sappington Creek, which is a tributary to Trapper Creek, while the True Blue Mine is a priority abandoned mine located on the tributary of Spring Creek. Waste rock and tailings were observed at Trapper Mine and in the floodplain of Sappington Creek, and severe erosion of waste rock into Sappington Creek was noted. The Lower/Upper Cleve Mine site had waste rock in the floodplain that extended into the channel and severe erosion of the waste rock into the creek was observed. The True Blue Mine site also had tailings and waste rock, which were documented for contributing sediment to the creek, and a spring with elevated copper, lead, and zinc concentrations surfaced near the foot of a mill at the site. Surface water and sediment samples collected near the priority abandoned mines were elevated for a combination of metals including arsenic, copper, cadmium, lead, and zinc. Historically, a smelter was located at the town of Glendale, which was on the lower part of Trapper Creek, and produced silver, lead, and copper.

Water chemistry data was collected at two sites during spring runoff in 2005 and 2006, while water chemistry and sediment chemistry data was collected during base flow at five sites in 2005 (**Table 7-18**). All sites were downstream of the five priority abandoned mines in the watershed. Two sites were in the upper part of the watershed (M03TRAPC01 and ML05TRAP01), two were downstream of Lockridge Canyon near the USFS boundary (M03TRAPC02 and ML05TRAP01), one was downstream of the historic Glendale smelter (ML05TRAP02), and one was near the mouth (M03TRAPC03).

Comparison to Water Quality Targets and TMDL Development Determination

The sites near the USFS boundary had a high flow exceedance of the acute and chronic aquatic life criteria for copper and a low flow exceedance of the chronic aquatic life criterion for copper. All five sediment samples exceeded the TEL supplemental indicator value for copper, and three of the sites exceeded the PEL supplemental indicator value. The sediment exceedances were close to 4 times the PEL at sites near the USFS boundary and almost twice the PEL at the site near the Glendale smelter. Based on the known anthropogenic sources and target and supplemental indicator exceedances, a copper TMDL will be developed for Trapper Creek.

All samples except a low flow sample near the USFS boundary exceeded the chronic aquatic life standard for lead and one sample exceeded the acute aquatic life standard for lead. All five sediment samples exceeded the TEL and PEL supplemental indicator values for lead, with values ranging from 4 to 95 times the PEL. Based on the known anthropogenic sources and target and supplemental indicator exceedances, a lead TMDL will be developed for Trapper Creek.

The sites near the USFS boundary had a high flow and low flow exceedance of the chronic and acute aquatic life standards for zinc. All five sediment samples exceeded the TEL and PEL supplemental indicator values for zinc, with values ranging from almost 3 to over 45 times the PEL. Based on the known anthropogenic sources and target and supplemental indicator exceedances, a zinc TMDL will be developed for Trapper Creek.

Although Trapper Creek is not listed for cadmium, three high flow samples and one low flow sample exceeded the chronic aquatic life standard for cadmium. All five sediment samples exceeded the TEL and PEL supplemental indicator values for cadmium, with values ranging from 1 to 15 times the PEL. Based on the known anthropogenic sources and target and supplemental indicator exceedances, a cadmium TMDL will be developed for Trapper Creek.

Trapper Creek is not listed for arsenic, and although none of the samples exceeded the arsenic targets, all sediment samples had high levels of arsenic. All five sediment samples exceeded the TEL and PEL supplemental indicator values for arsenic, with exceedances ranging from 3 to almost 16 times the PEL. Based on the known anthropogenic sources and the magnitude of supplemental indicator exceedances, an arsenic TMDL will be developed for Trapper Creek.

Table 7-18. Metals Concentrations in Trapper Creek in 2005 and 2006.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)						Sediment Metals Concentrations (µg/g dry wt.)				
			As	Cu	Cd	Pb	Zn	Hardness (mg/L as $CaCO_3$)	As	Cu	Cd	Pb	Zn
ML05TRAP01	u/s of USFS boundary	6/5/2005*	3	5	0.2	**14**	73.6	90.9	--	--	--	--	--
ML05TRAP02	d/s Glendale smelter	6/5/2005*	4	8	**0.4**	**22**	103.4	108	--	--	--	--	--
M03TRAPC01	Upper Creek d/s of mining	7/14/2005	<3	3	<0.1	**9**	20	167	**52.7**	**129**	**5.88**	**1080**	**1230**
M03TRAPC02	u/s of USFS boundary	7/15/2005	3	**9**	**0.4**	**51.3**	**130**	88	**269**	**712**	**39.3**	**6400**	**9570**
M03TRAPC03	2 mi u/s of mouth on BLM land	7/15/2005	4	3	0.1	**6.4**	30	71	**13.9**	**85.3**	**4**	**370**	**849**
ML05TRAP01	u/s of USFS boundary	8/4/2005	3	3	0.15	<0.5	65	111	**312**	**836**	**54.4**	**8,700**	**14,200**
ML05TRAP02	d/s Glendale smelter	8/4/2005	6	4	0.33	**8.0**	95	156	**76.4**	**352**	**20.3**	**1,680**	**4,140**
ML05TRAP01	u/s of USFS boundary	5/16/2006*	8	**27**	**0.8**	**128.0**	**232.6**	97.3	--	--	--	--	--
ML05TRAP02	d/s Glendale smelter	5/16/2006*	4	9	**0.41**	**20.9**	100.2	121	--	--	--	--	--

*High flow sample

7.4.4.14 Wickiup Creek (MT41D002_120)

Wickiup Creek is listed for copper, lead and mercury on the 2006 303(d) List. It flows 4.1 miles from its headwaters to its mouth at Camp Creek, a tributary to the Big Hole River (**Figure A-2**).

Sources and Available Data
The Clipper Mine is a priority abandoned mine site within the watershed and there are other abandoned mine sites as well. The DEQ collected water and sediment samples during low flow in 1993 upstream (SW2) and downstream (SW1) of the Clipper Mine site and in 2004 near the confluence with Camp Creek (M03WICK01) (**Table 7-19**). Additionally, water samples were collected and analyzed for copper at two sites during spring runoff in 2005 and 2006 (**Table 7-19**). The upper sample site (ML05WICK01) was located downstream of the Clipper Mine site,

while the lower sample site (ML05WICK02) was located just upstream of the confluence with Camp Creek.

Comparison to Water Quality Targets and TMDL Development Determination
During sampling in 1993, a seep was noted flowing out of a waste rock pile and a collapsed adit was seen and estimated have a discharge flowing at 20 gallons per minute. Although the seep discharge was not analyzed for metals, it had a specific conductance of 940µS/cm compared to 220µS/cm in the adit discharge, and based on elevated metals concentrations in the waste rock, it was assumed to have elevated metals concentrations. The adit discharge had a copper concentration of 3,050µg/L. Water and sediment samples collected upstream of the mine in 1993 (SW2/SE2) met the water quality targets and sediment supplemental indicator values. Copper exceeded the chronic and acute aquatic life criteria and the human health standard downstream of the mine site (SW-1) in 1993, and although concentrations were lower in subsequent samples, all other samples exceeded the human health standard. Both sediment samples exceeded the TEL and PEL supplemental indicator values for copper, with an exceedance more than 8 times the PEL at the upper site from 1993 and 2 times the PEL at the lower site sampled in 2004. Based on the known anthropogenic sources and target and supplemental indicator exceedances, a copper TMDL will be developed for Wickiup Creek.

Lead exceeded the chronic aquatic life standard in the 1993 sample, which did not meet quality control objectives for lead (see data flag in **Table 7-19**), and was below detection in the 2004 sample. The 1993 sediment sample exceeded the TEL supplemental indicator value for lead but the 2004 sample was well below the sediment supplemental indicator values for lead. Because the size of the dataset is limited and the 2004 sample meets water quality targets and supplemental indicators, no lead TMDL will be developed for Wickiup Creek at this time. Additional monitoring of the water column and sediment should be conducted under multiple hydrologic conditions to help further characterize and evaluate lead concentrations in Wickiup Creek and determine if TMDL development is necessary.

Although Wickiup Creek is not listed for arsenic and neither site with data exceeded the water quality target, the sediment samples had elevated arsenic. The sediment sample downstream of the Clipper Mine from 1993 exceeded the TEL and PEL supplemental indicator values for arsenic and was almost 3 times the PEL. The sediment sample upstream of the Clipper Mine from 1993, which likely represents the background level of arsenic, exceeded the TEL supplemental indicator value, indicating the sediment is likely naturally higher than the TEL. The sediment sample from 2004 exceeded the TEL supplemental indicator value for arsenic but was similar to the sediment concentration above the mine in 1993. Since there are no arsenic target exceedances in the water column and the sediment exceedance of the TEL supplemental indicator is likely close to the background level, no arsenic TMDL will be developed for Wickiup Creek. Additional water column and stream sediment monitoring is recommended to determine if an arsenic TMDL is necessary.

Mercury exceeded the human health standard of 0.05µg/L downstream of the mine site in 1993, although the mercury data did not meet quality control objectives (see data flags in **Table 7-19**). All sediment samples were below the detection limit for mercury and meet the supplemental indicator values. Due to the limited amount of recent data, data quality issues with the water column exceedances, and extremely low concentrations in the sediment, no mercury TMDL will be developed at this time for Wickiup Creek. Additional water column and stream sediment monitoring is recommended to determine if a mercury TMDL is necessary.

Table 7-19. Metals Concentrations in Wickiup Creek.
Bold text denotes a target exceedance.

Sample Site	**Water Quality Sample Date**	**Total Recoverable Metal in Water Column (µg/L)**					**Sediment Metals Concentrations (µg/g dry wt.)**			
		As	**Cu**	**Pb**	**Hg**	**Hardness (mg/L as CaCO3)**	**As**	**Cu**	**Pb**	**Hg**
47-029-SW1/SE1	8/24/1993	2.18	**206**	**2.72**[2]	**0.45**[2,3]	57.2	**44.4**	**1650**	**41.8**	0.031[1]
47-029-SW2/SE2	8/24/1993	2.67	1.55[1]	**3.52**[2]	**0.16**[2,3]	52.9	**10.4**	12.7	5.43[1]	0.034[1]
M03WICKC01	6/15/2004*	<3	**10**	<0.5	--	74.0	**15**	**450**	10.8	0.50[1]
ML05WICK01	6/5/2005*	--	**33**	--	--	45.6	--	--	--	--
ML05WICK02	6/5/2005*	--	**12**	--	--	65.6	--	--	--	--
ML05WICK01	5/17/2006*	--	**46**	--	--	42.9	--	--	--	--
ML05WICK02	5/17/2006*	--	**15**	--	--	63.2	--	--	--	--

*High flow sample; [1]Not detected at the reporting limit; [2]Estimated quantity; [3]Outlier for accuracy or precision

7.4.4.15 Wise River

The Wise River is not listed for metals impairments on the 2006 303(d) List. Elkhorn Creek, which is a headwater tributary of the Wise River, is the only tributary to the Wise River on the 2006 303(d) List for metals and is a potential source of metals loading to the Wise River. The Wise River flows 25.7 miles from its headwaters to its mouth at the Big Hole River (**Figure A-2**).

Sources and Available Data
The Old Elkhorn Mine located on Elkhorn Creek is a high priority abandoned mine site in the Wise River watershed. Additional tributary watersheds containing abandoned mines include Wyman, Lacy, Gold, Sheep, Adson, and Swamp Creeks.

At two sites, water chemistry data was collected during spring runoff in 2005 and 2006, and water chemistry and sediment chemistry data were collected twice during base flow in 2005 (**Table 7-20**). The upper sample site was located near the headwaters just downstream of the confluences of Jacobson and Mono creeks and the lower site was located near the mouth. Additional low flow water and sediment samples were collected in 2005 downstream of Gold Creek and in the lower part of Wise River just upstream of Butler Creek. Wise River samples will be reviewed for all metals that Elkhorn Creek is listed for including: arsenic, copper, cadmium, lead, and zinc. There were no exceedances of other metals water quality targets in the dataset.

Comparison to Water Quality Targets and TMDL Development Determination
All arsenic samples were below water quality targets and concentrations were fairly consistent from the headwaters to the mouth, suggesting mining-related arsenic sources are not present within the watershed. Four of the six sediment samples exceeded the TEL supplemental indicator

value for arsenic. Because there were no water quality target or PEL supplemental indicator value exceedances, no arsenic TMDL will be developed for the Wise River. Additional monitoring should be conducted to help further characterize and evaluate arsenic concentrations in the Wise River and to determine the effects of arsenic associated with streambed sediments on beneficial uses.

All high flow and two low flow samples exceeded the chronic aquatic life standard for copper and all but one of the exceedances also exceeded the acute aquatic life standard for copper. Four of the six sediment samples exceeded the TEL supplemental indicator value for copper. Based on sources identified and the target and supplemental indicator exceedances, a copper TMDL will be developed for the Wise River.

The chronic aquatic life standard for cadmium was exceeded at the upper site during high flow in 2005 and at both sites during high flow in 2006. All other samples were below the detection limit. Four of the six sediment samples exceeded the TEL supplemental indicator value for cadmium and one sample near the headwaters also exceeded the PEL supplemental indicator value. Based on sources identified and the target and supplemental indicator exceedances, a cadmium TMDL will be developed for the Wise River.

Both high flow samples in 2006 exceeded the chronic aquatic life standard for lead. All other samples were below the detection limit, but the detection limit during the high flow sampling event in 2005 was greater than the standard and may not have captured exceedances. Lead concentrations increased downstream, indicating there are additional lead sources than Elkhorn Creek. Both sediment samples from the headwaters site exceeded the TEL supplemental indicator value for lead. Based on the identified sources and target and supplemental indicator exceedances, a lead TMDL will be developed for the Wise River.

All water samples were below the zinc water quality targets. Four of the six sediment samples exceeded the TEL supplemental indicator value for zinc and one of the samples from the headwaters site also exceeded the PEL supplemental indicator value for zinc. No periphyton data are available. Based on the water quality data meeting targets during all flow conditions and sediment data not being multiple times greater than the supplemental indicator values, no zinc TMDL will be developed for the Wise River at this time. As determined in **Section 7.4.4.5**, a zinc TMDL will be developed for Elkhorn Creek, which is the probable source to the Wise River; in the absence of other sources, addressing zinc sources in Elkhorn Creek should ensure Wise River continues to maintain water quality standards for zinc and reduce sediment concentrations in the Wise River. Additional monitoring should be conducted to help further characterize and evaluate zinc concentrations in the Wise River and to determine the effects of zinc associated with streambed sediments on beneficial uses.

Table 7-20. Metals Concentrations in the Wise River.
Bold text denotes a target exceedance.

Sample Site	Location	Water Quality Sample Date	Total Recoverable Metal in Water Column (µg/L)						Sediment Metals Concentrations (µg/g dry wt.)				
			As	Cu	Cd	Pb	Zn	Hardness (mg/L as CaCO3)	As	Cu	Cd	Pb	Zn
ML05WISE01	Headwaters	6/6/2005*	<1	**10**	**0.1**	<1	28.5	15.1	--	--	--	--	--
ML05WISE02	Nr mouth	6/6/2005*	<1	**4**	<0.1	<1	6.6	17.2	--	--	--	--	--
M03WISER01	Headwaters	7/12/2005	<3	**4**	<0.1	<0.5	20	14	**11.4**	**55.7**	**0.74**	**37**	**189**
M03WISER02	d/s of Gold Cr	7/13/2005	<3	2	<0.1	<0.5	<10	28	<3	15.6	<0.5	8.7	76
M03WISER03	Lwr river u/s of Butler Cr	7/13/2005	<3	2	<0.1	<0.5	<10	24	**5.7**	**37.9**	**0.68**	16	**220**
M03WISER04	Nr mouth	7/13/2005	<3	1	<0.1	<0.5	<10	35	<3	12.6	<0.5	7.9	65
ML05WISE01	Headwaters	8/2/2005	1	**3**	<0.08	<0.5	22	21.4	**11.7**	**107**	**3.86**	**46.9**	**337**
ML05WISE02	Nr mouth	8/2/2005	1	<1	<0.08	<0.5	1	52.7	**10.4**	**78.6**	**1.56**	30.1	**252**
ML05WISE01	Headwaters	5/17/2006*	1	**10**	**0.15**	**1.1**	25.1	14.7	--	--	--	--	--
ML05WISE02	Nr mouth	5/17/2006*	2	**5**	**0.12**	**4.7**	21.2	15.1	--	--	--	--	--

*High flow sample

7.4.5 TMDL Development Determination Summary

Eleven stream segments in the Middle and Lower Big Hole TPA require the development of TMDLs for metals (**Table 7-21**). The metals of concern include arsenic, copper, cadmium, lead, mercury, and zinc. As discussed in **Section 4.4.4** by individual water body segment, some 303(d) Listings either do not have adequate data for TMDL development at this time or a data review indicated TMDL development is not necessary.

Table 7-21. Streams Requiring a TMDL for Metal Pollutants.

Water Body Segment	2006 303(d) Listing (metals)	Verified Target Exceedances and TMDL Developed
Big Hole River (middle)	Cu, Pb	Cu, Pb
Big Hole River (lower)	Cu, Cd, Pb, Zn	----
California Creek	As, Fe	As, Cu
Camp Creek	As	----
Elkhorn Creek	As, Cu, Cd, Pb, Zn	As, Cu, Cd, Pb, Zn
French Creek	As	As, Cu
Jerry Creek	Cu, Pb	Cu
Lost Creek	As	As
Oregon Creek	As, Cu, Pb	As, Cu
Rochester Creek	As, Cu, Pb, Hg	As, Cu, Pb, Hg
Sassman Gulch	As	----
Sawlog Creek	As	----
Trapper Creek	Cu, Pb, Zn	As, Cu, Cd, Pb, Zn
Wickiup Creek	Cu, Pb, Hg	Cu
Wise River	Not listed	Cu, Cd, Pb

----- No metals TMDLs developed

7.4.6 Additional Exceedances of Water Quality Targets or Supplemental Indicators

Several water body segments had water quality target or supplemental indicator exceedances but the dataset and/or source assessment was inadequate to make a TMDL development determination. Those exceedances are described below and monitoring recommendations for standards attainment are discussed within the **Monitoring Strategy** (**Section 10.0**).

7.4.6.1 Arsenic

Although Grose Creek, a tributary of the Big Hole River, was not listed for any metals on the 2006 303(d) List, a low flow water sample in 2003 exceeded the human health standard with a concentration of 47µg/L. Additional samples collected during spring runoff at one site in 2005 and 2006 were both below the human health standard for arsenic. The abandoned mines databases do not list any mines in the Grose Creek watershed. Because there was only a single exceedance and no anthropogenic sources are known, additional monitoring should be conducted.

Sediment samples in Jerry Creek exceeded the TEL supplemental indicator value for arsenic at all sites sampled in 2005 but there were no target exceedances in the water column. As discussed in **Section 7.4.4.7**, there are several abandoned mines within the watershed that could be sources of metals loading. Additional monitoring should be conducted at differing flows to assess the biological effect of elevated concentrations in the sediment and to characterize the sources.

7.4.6.2 Cadmium

Sediment samples in Jerry Creek exceeded the TEL supplemental indicator value for cadmium at two of the three sites sampled in 2005 but there were no target exceedances in the water column. A single sediment sample collected from Lost Creek in 2003 exceeded the TEL supplemental indicator value for cadmium but there were no target exceedances in the water column. Additional monitoring should be conducted on Jerry Creek and Lost Creek, including assessing the biological effect of elevated concentrations in the sediment.

All four water samples collected in Oregon Creek in 2005 and 2006 were below the targets, but the cadmium concentration was elevated in both sediment samples from 2005. The samples were collected at the same location (M03ORGNC01/ML05ORGN01) and one exceeded the TEL and the other sample exceeded both the TEL and PEL supplemental indicator values. Because both sediment samples did not exceed the PEL and all recent water samples were below the targets, no cadmium TMDL will be developed for Oregon Creek. Placer mining wastes and atmospheric deposition from the Anaconda Smelter are likely sources. Additional monitoring should be done to assess standards attainment in the water column, to determine the biological effects of elevated concentrations in the sediment, and to characterize sources.

7.4.6.3 Iron

California Creek is the only water body segment on the 2006 303(d) List for iron and there was no recent data to review, but Sassman Gulch and the Wise River had water samples with iron concentrations above the chronic aquatic life standard (1000µg/L). The iron exceedance in the Wise River occurred in a single sample collected near the mouth at high flow in 2006, and may largely be naturally occurring and associated with sediment. Both samples from Sassman Gulch exceeded the standard. The only source identified in the abandoned mines databases in Sassman Gulch is the Tungsten Mill Site, which was reclaimed in 1990. The water samples were collected in spring-fed sections of Sassman Gulch and may naturally have elevated iron concentrations. Because iron concentrations in both the Wise River and Sassman Gulch are likely naturally occurring, no iron TMDLs were developed for these water bodies. However, additional monitoring and source characterization is recommended.

7.4.6.4 Silver

Although there is no silver listing for the middle segment of the Big Hole River, there was an exceedance of the acute aquatic life standard during a 2005 high flow sampling event. The reported value was 1µg/L, which was the detection limit. All other values were below the detection limit. Unless hardness values are greater than 44mg/L, which only occurred in one sample, the standard is <1µg/L and exceedances cannot be determined with a detection limit of 1µg/L. The only other sample upstream of Dickie Bridge greater than the detection limit was 2µg/L and occurred on French Creek, a tributary to Deep Creek. All other water and sediment samples on French Creek remained below the detection limit. Additionally, a sample near the mouth of the Wise River exceeded the silver standard during high flow sampling in 2005. All other samples on the Wise River were below the detection limit (1µg/L) and no samples on Elkhorn Creek were analyzed for silver. Due to the high detection limit and limited amount of data available to aid in source assessment, no silver TMDLs will be done at this time and additional monitoring is recommended within the watershed of the middle segment of the Big Hole, particularly in the French Creek and Wise River watersheds.

7.5 TMDLs

TMDLs for metals represent the maximum amount of each metal that a stream can assimilate without exceeding water quality targets. A stream's ability to assimilate metal pollutants is based on its ability to dilute metal concentrations (i.e., stream discharge), and for many metals, the water hardness (which can effect toxicity and determines the numeric water quality criteria). Because both of these variables (stream flow and hardness) vary seasonally, the TMDL for a metal must be established so that it maintains protection of beneficial uses for the anticipated range of flow and hardness conditions.

Metals TMDLs are calculated using Equation 1 (below). Note that the chronic aquatic life criteria are used to calculate the TMDL. Using the chronic criteria to calculate an allowable daily load, rather than a 96-hour load limit (see **Section 7.4.1.1**), affords an implicit margin of safety in calculating the TMDL and also establishes a daily load limit expression. For arsenic and mercury, the human health criteria are used in calculating the TMDL as it is more stringent than the chronic aquatic life criteria.

Equation 1: TMDL = (X)*(Y)*(0.0054)

TMDL = Total Maximum Daily Load in lbs/day for metal of concern
X = the chronic aquatic life use criteria (target) with hardness adjustments where applicable in ug/l for metal of concern
Y = streamflow in cubic feet per second (cfs)
0.0054 = conversion factor

In addition to chronic aquatic life criteria, acute aquatic life criteria are also established as water quality targets, and are applied as an instantaneous in-stream pollutant concentration that shall not be exceeded (see **Section 7.4.1.1**). Metals sources contributing to chronic criteria exceedences are typically the same metals sources that contribute to acute criteria exceedances. In order to satisfy the TMDLs for chronic criteria, all sources of metals loading that contribute to an exceedence of the chronic criteria will require remediation to meet the allocations defined in **Section 7.6**. It is assumed that source reduction and remediation activity necessary to eliminate pollutant loading that exceeds the chronic criteria would also mitigate any shorter duration pulses that could contribute to an acute criteria exceedence. Meeting the allocations and TMDL for the chronic criteria will therefore satisfy both the chronic and acute targets for each metal.

As part of adaptive management to ensure that this assumption is correct, restoration and implementation strategies designed to reduce pollutant loads (Section 9.0) to meet the TMDLs must ensure that short term pulse loads that could result in either a chronic or acute in-stream exceedance are adequately mitigated.

Figure 7-1 shows the TMDL for arsenic under various flow conditions using the above equation. The TMDL curve is applicable to all arsenic TMDLs within this document. **Figure 7-2** shows the mercury TMDL for Rochester Creek under various flow conditions. Example high and low flow TMDLs, which were calculated using the equation above, are shown in **Table 7-22** for the 12 streams in the Middle and Lower Big Hole TPA requiring one or more metals TMDLs. The calculated TMDLs represent the maximum load (lbs/day) of each metal that each water body can receive without exceeding applicable water quality standards for the specified streamflow conditions and water hardness.

In most cases, the TMDLs were calculated based on high and low flow sampling events conducted in 2003, 2005, and 2006. No low flow samples were collected recently on Wickiup Creek; the low flow TMDL for Wickiup Creek is based on sample data from 1993. Sample data for the metals of concern, including those used to calculate TMDLs, are included in **Appendix H**. In general, there were two high flow sampling events and one low flow sampling event for each site, and almost all 303(d) Listed water body segments have two or more sites. High flow samples were collected in May or June and low flow samples were collected July through September. Note, for Lost Creek, the discharge during low flow sampling was estimated and was greater than during high flow sampling in May/June. The TMDL examples in **Table 7-22** were generated using sample data from sites with the greatest exceedance of the applicable water quality target. It is assumed that meeting the TMDL the location with the greatest exceedance will result in attainment of water quality standards throughout the water body. As shown in the far right column of **Table 7-22**, sample data were also used to calculate an existing load and determine the required percent load reduction to achieve the TMDL for each metal. Some TMDLs require a reduction at both high and low flow, whereas others only require a reduction during high or low flow. For TMDLs with no reductions indicated, it is assumed based on elevated sediment metals concentrations that there are water column impairments not captured in the sample data set. Restoration activities to address metals sources and meet the TMDLs are expected to also address sediment-related toxicity and metals-related impairment to beneficial uses.

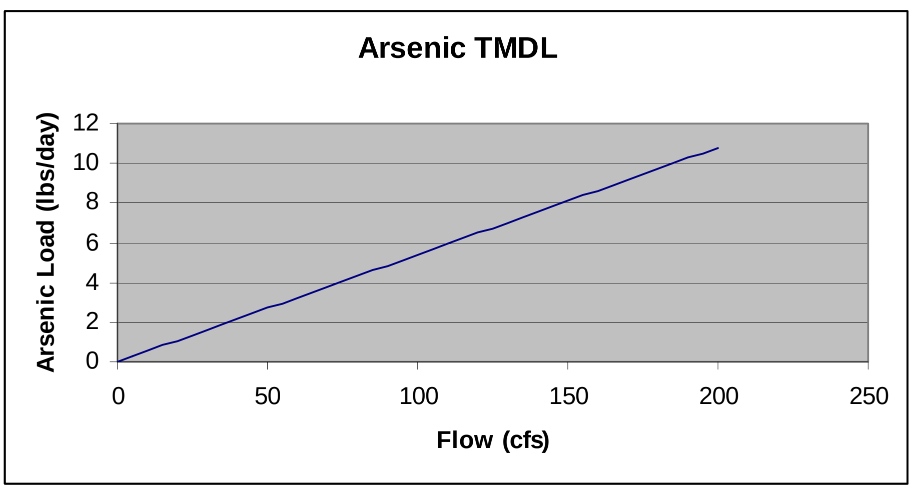


Figure 7-1. Arsenic TMDL curve that illustrates how the TMDL changes with flow.

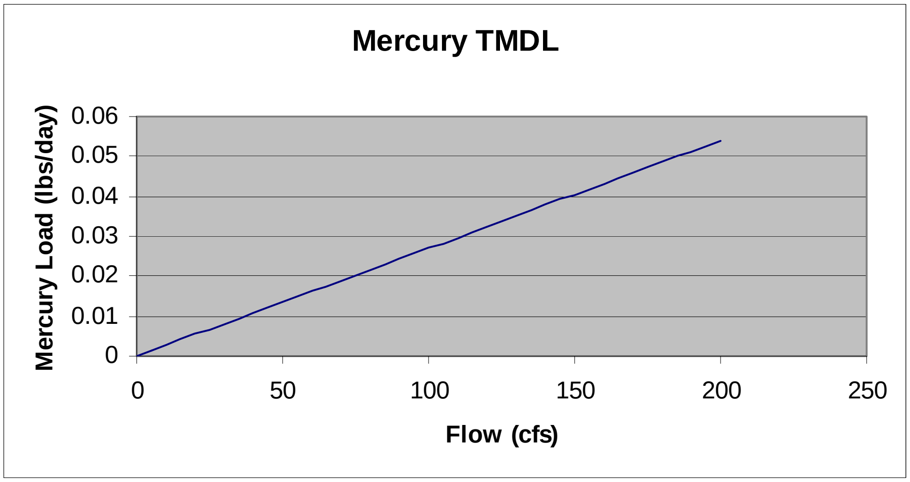


Figure 7-2. Mercury TMDL curve that illustrates how the TMDL changes with flow.

Table 7-22. Example Metal TMDLs for the Middle and Lower Big Hole TPA.

Stream Segment	Station	Discharge (cfs)		Hardness (mg/L CaCO3)		Metal	Target Conc. (µg/L)		Actual Conc. (µg/L)		TMDL (lbs/day)		Estimated Actual Load (lbs/day)		Percent Load Reduction Required Based on Sampled Target Exceedance*	
		High Flow	Low Flow	High Flow	Low Flow		High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow
Middle Big Hole	MDBH03	3,820	275	25	58.4	Copper	2.85	5.89	3	0.5	58.790	8.747	61.884	0.743	5%	0%
						Lead	0.54	1.60	0.6	0.25	11.139	2.376	12.377	0.371	10%	0%
California Creek	CALI02	51.1	4.8	N/A		Arsenic	10		23	21	2.759	0.259	6.347	0.544	57%	52%
				38.5	77.3	Copper	4.13	7.49	11	2	1.140	0.194	3.035	0.052	62%	0%
Elkhorn Creek	EKHR02 (high flow) ELKHC01 (low flow)	82.2	8.1	N/A		Arsenic	10		---	2	4.439	0.437	---	0.087	---	0%
				25 (all flows)		Copper	2.85		54	15	1.265	0.125	23.970	0.656	95%	81%
						Cadmium	0.01		0.69	0.3	0.004	0.0004	0.306	0.013	99%	97%
						Lead	0.54		---	0.5	0.240	0.024	---	0.022	---	0%
						Zinc	37.02		99.9	92	16.432	1.619	44.344	4.024	63%	60%
French Creek	FREN02	123.2	11.3	N/A		Arsenic	10		26	14	6.653	0.610	17.297	0.854	62%	29%
				40.4	68.9	Copper	4.30	6.79	5	1	2.861	0.414	14%	0.061	14%	0%
Jerry Creek	JERR02	95	8.8	63.9	118	Copper	6.36	10.75	1	26	3.263	0.511	0%	1.236	0%	59%
Lost Creek	LOST02	0.83	~2	N/A		Arsenic	10		6	28	0.045	0.108	0.027	0.302	0%	64%
Oregon Creek	ORGN01	9.1	0.4	N/A		Arsenic	10		20	35	0.491	0.022	0.983	0.076	50%	71%
				25	42.7	Copper	2.85	4.51	11	3	0.140	0.010	0.541	0.006	74%	0%
Rochester Creek	ROCH01 / RSW6 RSW1 (Hg low flow)	0.04	~0.01	N/A		Arsenic	10		92	374	0.002	0.0010	0.020	0.020	89%	95%
						Mercury	0.05		0.025	0.38	0.00001	0.000003	0.00001	0.00021	0%	660%
				205	226	Copper	17.23	18.72	20	65.1	0.004	0.0009	0.004	0.004	6%	75%
						Lead	7.93	8.98	6.2	16.6	0.002	0.001	0.001	0.0009	0%	55%
Trapper Creek	TRAP01 / TRAPC02	17.5	8.97	N/A		Arsenic	10		8	3	0.945	0.484	0.756	0.145	0%	0%
				97.3	88	Copper	27	9	27	9	0.861	0.405	2.552	0.436	66%	7%
						Cadmium	0.8	0.4	0.8	0.4	0.026	0.012	0.076	0.019	66%	38%
						Lead	128	51.3	128	51.3	0.290	0.131	12.096	2.485	98%	95%
						Zinc	232.6	130	232.6	130	11.063	5.208	21.981	6.297	50%	17%
Wickiup Creek	WICK02 (high flow)	1.8	0.5	42.9	57.2	Copper	4.53	5.79	46	206	0.044	0.016	0.447	0.556	90%	97%

Table 7-22. Example Metal TMDLs for the Middle and Lower Big Hole TPA.

Stream Segment	Station	Discharge (cfs)		Hardness (mg/L CaCO3)		Metal	Target Conc. (µg/L)		Actual Conc. (µg/L)		TMDL (lbs/day)		Estimated Actual Load (lbs/day)		Percent Load Reduction Required Based on Sampled Target Exceedance*	
		High Flow	Low Flow	High Flow	Low Flow		High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow	Low Flow
	SW-1 (low flow)															
Wise River	WISE02 (high flow) WISE01 (low flow)	600	25.2	25 (all flows)		Copper	2.85		5	3	9.234	0.388	16.200	0.408	43%	5%
						Cadmium	0.01		0.12	0.04	0.032	0.001	0.389	0.005	92%	0%
						Lead	0.54		4.7	0.25	1.750	0.073	15.228	0.034	89%	0%

*Percent load reductions do not include the explicit margin of safety described in Section 7.6. As shown in Section 7.6, percentages will increase slightly when the MOS is included

7.6 Loading Summary and Allocations

As discussed in **Section 4.0**, a TMDL is the sum of all of the load allocations (LAs), waste load allocations (WLAs), and a margin of safety (MOS). LAs are allowable pollutant loads assigned to non-point sources and may include the cumulative pollutant load from naturally occurring and human caused sources. The most common human caused non-point sources in the Middle and Lower Big Hole TPA are atmospheric deposition and sediment and soils contaminated by historic mining activity. WLAs are allowable pollutant loads that are assigned to point sources (permitted and non-permitted). Although there are no permitted point sources in the Middle and Lower Big Hole TPA, waste sources associated with historic mining such as adit discharges, tailings, and waste rock piles may be considered non-permitted point sources (and subject to a WLA) if data show that these sources are associated with discrete localized pollutant loading. Where adequate data are available, these non-permitted point sources may be given separate WLAs. If there are no data regarding the condition of abandoned mines or the presence of associated point sources, and abandoned mines cannot be isolated as a source of loading, they will be included in the LA. These abandoned mine sources may be given a WLA in the future if data indicates a discrete localized pollutant loading.

As discussed in **Section 4.0**, all TMDLs incorporate a MOS. Metals TMDLs in this document apply an implicit MOS through the adoption of a variety of conservative assumptions in calculating TMDLs and estimating pollutant loads. These assumptions are described in more detail in **Section 7.7.2.** Where uncertainties are high regarding estimates of pollutant loads from non-permitted point sources and the effectiveness of restoration activities, an explicit MOS of 10 percent will be applied (in addition to implicit MOS considerations).

The metals loading summaries and allocations are organized from upstream to downstream within the Middle and Lower Big Hole TPA. Loading summaries are based on the sample data provided in Section 7.4.4 and contained in Appendix H. Streams with common source areas are discussed together in the following sub-sections: Oregon Creek/California Creek/French Creek, Elkhorn Creek/Wise River, and Wickiup Creek/Camp Creek. All other streams are discussed individually. Because the TMDLs for the middle segment of the Big Hole River must account for loading from the entire watershed, its loading summary and allocations are discussed after all contributing source areas.

7.6.2 Oregon Creek/California Creek/French Creek

There are no priority abandoned mines within the French Creek watershed, which includes Oregon Creek and California Creek; atmospheric deposition from the Anaconda Smelter and historic placer mining are the likely sources of metals (FWP 1981). A study conducted by FWP in 1981 of dissolved arsenic concentrations in streams on Mt. Haggin (**Figure A-2**) found concentrations increased as the stream origin moved from the southwest to the northeast, and with the proximity of the stream headwaters to the Anaconda Smelter (**Figure A-10**). High elevation streams located in the southwestern portion of Mt. Haggin had an average dissolved arsenic concentration between 1.1 and 4µg/L that increased slightly between high and low flow (**Figure A-10**). California, Oregon, and French Creeks are the only streams that were noted as being historically placer mined, and they also originate at low elevations, where streams tend to have a higher natural level of dissolved chemical constituents. Oregon Creek, California Creek, and French Creek had the highest dissolved arsenic concentrations of all sampled Mt. Haggin streams within the Middle and Lower Big Hole TPA (averaging 24.9, 18.8, and 16.4µg/L, respectively). Other low elevation streams had average dissolved arsenic concentrations ranging from 5.3 to 9.2µg/L (**Figure A-10**). Only one low elevation stream, Slaughterhouse Creek, originates in the southwest part of Mt. Haggin and was considered to be outside of the Anaconda Smelter aerial deposition zone. It had a dissolved arsenic concentration of 5.2µg/L at high flow and a concentration of 5.4µg/L at low flow. Total and dissolved arsenic concentrations in the middle segment of the Big Hole River were measured in August 2002 and plotted on a 1:1 line, indicating almost 100 percent of the total arsenic was dissolved. This indicates that background total arsenic concentrations in Oregon Creek, California Creek, and French Creek are likely close to 5µg/L and supports the assumption that background levels do not exceed the water quality standard.

7.6.2.1 Oregon Creek (MT41D003_080)

Loading Summary
In Oregon Creek, both high flow samples had the same arsenic concentration (20µg/L), and both low flow samples had a greater concentration of arsenic (29 and 36µg/L, Table 7-13). This indicates groundwater may be the primary pathway for arsenic, which is not uncommon, as arsenic is highly soluble and mobile. Other watersheds affected by aerial deposition from the Anaconda Smelter have been documented as having elevated arsenic in the groundwater (EPA and DEQ 1998).

Copper concentrations, however, were greater at high flow than low flow, indicating copper is typically transported in surface runoff and is likely associated with mobilized sediment from upland areas due to aerial deposition or near-channel sources related to historic placer mining or other mining activity.

TMDLs and Allocations
As there are no point sources identified in Oregon Creek, no WLA is given and the TMDL consists solely of the non-point source LA. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. Therefore, the entire TMDL for arsenic and copper is allocated to the combined load from naturally occurring and historic mining-related sources (i.e. aerial deposition, placer mining waste, and other legacy mining deposits and wastes). The TMDL components are summarized below and **Table 7-23** shows TMDLs and allocations for measured high and low flow conditions in the Oregon Creek watershed. This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

$\mathbf{LA}_{\text{Oregon Creek}} = \mathbf{TMDL}_{\text{Oregon Creek}}$
$\mathbf{WLA}_{\text{Oregon Creek}} = \mathbf{NA}$
$\mathbf{MOS}_{\text{Oregon Creek}} = \mathbf{Implicit}$

Table 7-23. Metals TMDLs and load allocation example for Oregon Creek.

Metals TMDLs and Load Allocations for Oregon Creek at ORGN01			
Metal	**Flow Conditions**	**TMDL/Load Allocation (lbs/day)**	**Percent Reduction Needed**
Arsenic	High flow	0.491	50%
	Low flow	0.022	71%
Copper	High flow	0.140	74%
	Low flow	0.010	0%

High flow = 9.1 cfs @ hardness 27 mg/L, Low flow = 0.4 cfs @ hardness 43 mg/L

7.6.2.2 California Creek (MT41D003_070)

Loading Summary
In California Creek, arsenic concentrations were very similar between high and low flow and increased in a downstream direction. Arsenic concentrations in the upper part of California Creek (CALI01 & CALC02) were close to the standard (10µg/L) and then ranged from 18 and 23µg/L at the site downstream of Oregon Creek (CALC01/CALI02) (**Table 7-7**; **Figure A-11**). Because the concentration in upper California Creek is close to the standard, this does not provide much assimilative capacity downstream. For instance, although Oregon Creek did not meet the arsenic water quality target in high or low flow samples, even if the TMDL in Oregon Creek is met, the incoming load from tributaries between upper California Creek (CALI01 & CALC02) and CALC01/CALI02 will result in an average target exceedance of 79 percent. The only arsenic samples collected downstream of CALC01/CALI02 were collected in July 2005 at the mouth (CALC03) and in the tributaries of Sixmile Creek and American Creek (**Figure A-11**). The arsenic concentration was below the detection limit (1µg/L) in Sixmile Creek, which contributes less than 1 percent of the flow, and was 11µg/L in American Creek, which contributes almost half of the flow. Additional monitoring is recommended, particularly at CALC01/CALI02 and CALC03, but the data suggest loading from throughout the watershed is contributing to exceedances of the water quality target for arsenic.

Because California Creek is not on the 303(d) List for copper and analysis was added to California Creek because of the listing in Oregon Creek, copper data are limited to a low flow event in 2005 and high flow sampling in 2006. During high and low flow, the hardness value decreased between (CALI01 & CALC02) and CALC01/CALI02 by roughly 20mg/L as $CaCO_3$, which translates to a stricter water quality target downstream. The only water quality target exceedance occurred at high flow just downstream of the confluence with Oregon Creek (CALC01/CALI02). Although the dataset is limited, this suggests that target exceedances are associated with copper that is transported in surface runoff and is likely associated with mobilized sediment from upland areas due to aerial deposition or near-channel sources related to historic placer mining or other mining activity. During both the high and low flow sampling events, the copper concentration was greater at the site below Oregon Creek (CALC01/CALI02). However, much like arsenic, meeting the copper TMDL during high flow in Oregon Creek will not result in target attainment in California Creek because of loading from tributaries upstream of Oregon Creek. A low flow sample collected at the mouth of California Creek (CALC03) indicates loading from Sixmile and American Creeks is not likely to cause target exceedances in

California Creek, but because loading dynamics can change under different hydrologic conditions, additional sampling (particularly at high flow) is recommended on California Creek to refine the source assessment.

TMDLs and Allocations
As there are no point sources identified in California Creek, no WLA is given and the TMDL consists solely of the non-point source LA. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. Therefore, the entire TMDL for arsenic and copper is allocated by contributing source area to the combined load from naturally occurring and historic mining-related sources (i.e. aerial deposition, placer mining waste, and other legacy mining deposits and wastes). The contributing source areas are shown in Figure A-11 and are as follows:

- Oregon Creek watershed
- Remainder of the California Creek watershed (which includes areas upstream and downstream of Oregon Creek)

The source area allocations for California Creek are based on the example high and low flow TMDLs in **Table 7-22** (for sites CALI02 and ORGN01) and are provided in **Table 7-24**. The allocation to the remainder of the California Creek watershed (Source Area 2) is the difference between the TMDL and the allocation to Oregon Creek (Source Area 1). This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards. The TMDL components are summarized below.

$\mathbf{LA}_{\text{California Creek}} = \mathbf{LA}_{\text{Oregon Creek}} + \mathbf{LA}_{\text{Remainder of California Creek}} = \mathbf{TMDL}_{\text{California Creek}}$
$\mathbf{WLA}_{\text{California Creek}} = \mathbf{NA}$
$\mathbf{MOS}_{\text{California Creek}} = \mathbf{Implicit}$

Table 7-24. Metals TMDLs and load allocation example for California Creek.

Metals TMDLs for California Creek at CALI02				**Allocations (lbs/day)**	
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Percent Reduction Needed**	**Source Area 1: Oregon Creek**	**Source Area 2: Remainder of California Creek Watershed (TMDL – Source Area 1)**
Arsenic	High flow	2.759	57%	0.491	2.268
	Low flow	0.259	52%	0.022	0.237
Copper	High flow	1.140	62%	0.140	1.0
	Low flow	0.194	0%	0.010	0.184

For CALIO2: High flow = 51.1 cfs @ hardness 38.5 mg/L, Low flow = 4.8 cfs @ hardness 77.3 mg/L

7.6.2.3 French Creek (MT41D003_050)

Loading Summary

In French Creek, all samples upstream of California Creek (FREN01 & FNCHC01) were less than the arsenic human health standard (10µg/L), and all samples downstream of California Creek exceeded the standard (**Figure A-12**, **Table 7-10**). Arsenic concentrations were greater at low flow, indicating groundwater is the primary pathway for arsenic. Significant flows and elevated arsenic concentrations from California Creek contribute to elevated arsenic concentrations in French Creek; the arsenic load coming from California Creek accounts for roughly 50 percent to 65 percent of the arsenic load at the mouth of French Creek. However, the loading contribution from California Creek does not fully account for target exceedances in French Creek. Meeting the high and low flow TMDLs for California Creek will decrease the concentration in French Creek but not enough to meet water quality targets. Given that sediment samples from the entire watershed exceeded the PEL supplemental indicator value (**Section 7.4.4.6**), a low flow sample from the upper watershed (9µg/L at FREN01) is close to the human health standard, and concentrations increase downstream of California Creek between FNCHC02 and FNCHC03, it appears that additional loading in excess of natural background contributions occur throughout the French Creek watershed.

The only copper exceedances occurred during high flow in 2005 and 2006 near the mouth (FREN02) and the concentration was 5µg/L both years. Similar to California Creek, this suggests that target exceedances are associated with copper that is transported in surface runoff and is likely associated with mobilized sediment from upland areas due to aerial deposition or near-channel sources related to historic placer mining or other mining activity. Both high flow samples from upper French Creek (FREN01) were 3µg/L, just below the standard. California Creek only has high flow copper data for 2006, but the timing of the 2006 target exceedance at FREN02 corresponds to the target exceedance in California Creek. If the copper TMDL is met in California Creek during high flow, the load reduction will be sufficient to meet the TMDL in French Creek. However, because the copper exceedances only occurred during high flow, low flow data are limited to a single year, and aerial deposition and placer mining occurred in other areas of the French Creek watershed besides California Creek (e.g. placer mining waste was observed upstream of FREN01), additional samples should be taken to refine the copper source assessment.

TMDLs and Allocations

As there are no point-source pollutants identified in French Creek, no WLA is given and the TMDL consists solely of the non-point source LA. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. Therefore, the entire TMDL for arsenic and copper is allocated by contributing source area to the combined load from naturally occurring and historic mining-related sources (i.e. aerial deposition, placer mining waste, and other legacy mining deposits and wastes). The contributing source areas are shown in **Figure A-12** and are as follows:

- California Creek watershed (which includes inputs from Oregon Creek)
- Upper French Creek watershed (upstream of California Creek)

- Lower French Creek watershed (downstream of California Creek).

The source areas and sampling locations are shown in **Figure A-12**. The source area allocations for French Creek are based on the example high and low flow TMDLs in **Table 7-22** (for FREN01 and CALI02) and are provided in **Table 7-25**. The allocation to the California Creek watershed is based on the TMDL for CALI02 (**Section 7.6.2.2**), the upper French Creek watershed is based on sample data (**Appendix H**) from site FREN01 upstream of California Creek, and the allocation to the lower French Creek watershed is the difference between the TMDL and the sum of the allocations to the other source areas (i.e. Source Area 3 = TMDL – (Source Area 1 + Source Area 2). This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards. The TMDL components are summarized below.

LA $_{\text{French Creek}}$ = **LA** $_{\text{California Creek}}$ + **LA** $_{\text{Upper French}}$ + **LA** $_{\text{Lower French}}$ = **TMDL** $_{\text{French Creek}}$
WLA $_{\text{French Creek}}$ = **NA**
MOS $_{\text{French Creek}}$ = **Implicit**

Table 7-25. Metals TMDLs and load allocation example for French Creek.

Metals TMDLs for French Creek at FREN02			**Allocations (lbs/day)**		
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Source Area 1: California Creek Watershed (CALIO2)**	**Source Area 2: Upper French Creek Watershed (FREN01)**	**Source Area 3: Lower French Creek Watershed**
Arsenic	High flow	6.653	2.759	0.999	2.895
	Low flow	0.610	0.259	0.065	0.286
Copper	High flow	2.861	1.140	0.311	1.410
	Low flow	0.414	0.194	0.031	0.189

For FREN02: High flow = 123.2 cfs @ hardness 40.4 mg/L, Low flow = 11.3 cfs @ hardness 68.9 mg/L

7.6.3 Elkhorn Creek/Wise River

The Old Elkhorn Mine in the headwaters of Elkhorn Creek, which is a headwaters tributary to the Wise River, is the only priority abandoned mine site in the Wise River watershed, but there are numerous other abandoned mines. Although tailings were removed and waste rock was revegetated during reclamation work completed by the USFS in 2003, the adit continues to discharge into the creek and contaminated tailings and sediment from Elkhorn Creek are contributing to water quality exceedances in the Wise River.

7.6.3.1 Elkhorn Creek (MT41D003_220)

Loading Summary
Both low flow samples collected upstream of the Elkhorn Mine site were below the detection limit for all metals of concern and are assumed to represent the background concentration. No

high flow samples were collected upstream of the Elkhorn Mine but the metals concentrations are assumed to be below the detection limit. High and low flow exceedances occurred for copper, cadmium, and zinc, which suggest sources associated with groundwater and surface runoff.

Between the sampling site 0.5 miles downstream of the mine/Coolidge town site (ELKHC01/EKHR01) and at the mouth (ELKHC02/EKHR02) (**Figure A-13**), discharge was similar during low flow sampling but increased three to fourfold during high flow sampling. With the exception of high flow in 2006, the concentration of copper, cadmium, and zinc all decreased between these sites, suggesting dilution. In 2006, the discharge at the mouth was almost double that during high flow sampling in 2005; the copper concentration stayed the same and cadmium and zinc increased between 22 and 33 percent. This indicates that loading in the vicinity of the Elkhorn Mine (likely from the adit) is a consistent source, and during certain high flow events, additional loading in the lower part of Elkhorn Creek is contributing to target exceedances at the mouth (**Figure A-13**). High flow loading in the lower part of Elkhorn Creek could be associated with remnant tailings or contaminated sediment from the Elkhorn Mine or could be associated with an abandoned mine near the mouth. The limited amount of data indicate loading in the lower part of Elkhorn Creek is minor compared to loading from the Elkhorn Mine and would likely not result in target exceedances at the mouth if targets are met downstream of the mine, but loading from this area should be further characterized as part of future monitoring,

TMDLs and Allocations

The Elkhorn Mine has been identified as a discrete 'point-source area', and therefore a WLA is provided for Elkhorn Creek. Because of the uncertainty associated with the source of metals loading in the lower part of the watershed, the waste load allocation ($WLA_{Elkhorn\ Creek}$) incorporates the cumulative pollutant load from all abandoned mine sources in the watershed (Elkhorn Mine + other abandoned mine sources). Also, due to data limitations and uncertainties in estimating loads from abandoned mine lands, an explicit MOS of 10 percent of the TMDL is provided. The load allocation is to naturally occurring sources (LABackground) and is calculated using the laboratory analytical detection limits (**Table 7-26**) because:

- Actual natural occurring concentrations are unknown
- Metals concentrations above the Elkhorn Mine are below analytical detection limits
- Analytical detection limits are below the water quality target[3]
- Using a concentration at the detection limit to estimate naturally occurring metals loads incorporates an implicit MOS into the load allocation

The $\mathbf{WLA}_{Elkhorn\ Creek}$ is computed by subtracting the $\mathbf{LA}_{Background}$ and the $\mathbf{MOS}_{Elkhorn\ Creek}$ from the TMDL as shown in **Table 7-25**. The TMDL components are summarized below.

$$\mathbf{TMDL}_{Elkhorn\ Creek} = \mathbf{LA}_{Background} + \mathbf{WLA}_{Elkhorn\ Creek} + \mathbf{MOS}_{Elkhorn\ Creek}$$

[3] The detection limit for lead is 0.5µg/L and the target is 0.54µg/L at hardness = 25mg/L; Because the detection limit is very close to the target value, 0.4µg/L was used to calculate the background lead concentration

TMDLs and allocations will vary with streamflow. Example high and low flow TMDLs and allocations for Elkhorn Creek (**Table 7-27)** are based on recent high and low flow conditions (**Table 7-22**). Because no water column exceedances occurred for arsenic or lead in samples, those TMDL examples require no reductions. However, it is assumed based on elevated sediment metals concentrations that there are water column exceedances not captured in the sample data set. Restoration activities to reduce metals loads are expected to also address sediment-related toxicity and metals-related impairment to beneficial uses. This allocation scheme assumes applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

Table 7-26. Equation for computing the WLA for each metal.

Metal	$WLA_{Elkhorn}$ = TMDL – ($LA_{Background}$ + MOS)
Arsenic	(10 µg/L * Flow) – (1 µg/L * Flow)
Cadmium	(chronic conc[1] * Flow) – (0.08 µg/L * Flow)
Copper	(chronic conc[1] * Flow) – (1 µg/L * Flow)
Lead	(chronic conc[1] * Flow) – (0.4 µg/L * Flow)
Zinc	(chronic conc[1] * Flow) – (10 µg/L * Flow)

[1]The chronic aquatic life standard used to calculate the TMDL is hardness-dependent

Table 7-27. Metals TMDLs and load allocation example for Elkhorn Creek.

Metals TMDLs for Elkhorn Creek at EKHR02 (high flow) & ELKHC01 (low flow)				**MOS**	**Allocations (lbs/day)**	
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Percent Reduction Needed**	**10% MOS**	**LABackground (lbs/day)**	**WLAElkhorn (lbs/day)**
Arsenic	High flow	4.439	0%	0.444	0.444	3.551
	Low flow	0.437	0%	0.044	0.044	0.350
Cadmium	High flow	0.044	99%	0.004	0.036	0.004
	Low flow	0.004	97%	0.0004	0.003	0.0004
Copper	High flow	1.265	95%	0.127	0.444	0.695
	Low flow	0.125	83%	0.012	0.044	0.068
Lead	High flow	0.240	0%	0.024	0.178	0.038
	Low flow	0.024	0%	0.002	0.017	0.004
Zinc	High flow	16.432	67%	1.643	4.439	10.350
	Low flow	1.619	64%	0.162	0.437	1.020

High flow at EKHR02 = 82.2 cfs, Low flow at ELKHC01 = 8.1 cfs, Hardness = 25 mg/L

7.6.3.1 Wise River (MT41D003_200)

Loading Summary

The headwaters site in the Wise River (WISE01/WISER01) had high and low flow exceedances for copper and high flow exceedances of cadmium and lead (**Figure A-14**). Although there is no corresponding low flow data for Elkhorn Creek, the concentration and load of copper, cadmium, and lead all decreased during high flow in 2005 and 2006 between the mouth of Elkhorn Creek and the headwaters of the Wise River approximately 1.6 miles downstream. This indicates Elkhorn Creek is the major source of metals loading to the Wise River, and the incoming flow from other headwater tributaries, which have no known abandoned mines, dilutes the metals loads from Elkhorn Creek. If the Elkhorn Creek metals TMDLs are met, it is expected that water quality targets will be met in the upper part of the Wise River.

Low flow samples were collected at two sites between the headwaters and mouth (WISER02 and WISER03, **Figure A-14**); Cadmium and lead were below detection limits in all low flow samples, and copper exceeded the water quality target at the headwaters (WISE01/WISER01) but attenuated downstream because of additional flow from tributaries. Water quality exceedances at the mouth of the Wise River (WISE02/WISER04) occurred for cadmium, copper, and lead, and all exceedances were during high flow. Despite exceedances at the mouth of the Wise River, the concentration of copper and cadmium both decreased between the headwaters (WISE01/WISER01) and the mouth (WISE02/WISER04), indicating dilution by tributaries and minimal additional loading. Lead generally showed the same trend in a downstream direction, but the concentration increased almost fivefold between the headwater and mouth during high flow in 2006. Potential sources in the lower watershed are abandoned mines along Sheep or Adson Creek (**Figure A-14**) and in-stream and near channel sediment associated with historical mining activity. Site M03WISER03, near Stine Creek, had higher sediment concentrations of copper, cadmium, and lead than the site above it (M03WISER02) or at the mouth. The increase in loading from lead was so substantial that even if the entire load from the headwaters (WISE01/WISER01) is subtracted from the load at the mouth (WISE02/WISER04) and a concentration is back-calculated (i.e. 15.23 lbs/day – 1.19 lbs/day = 14.04 lbs/day; 14.04/600cfs * .0054 = 4.3 µg/L), in-stream lead concentrations would still exceed the chronic aquatic life criteria of 0.54 µg/L. Contrary to this, mass balance equations indicate that if TMDLs are met at the upper Wise River site, loading of cadmium and copper in the lower watershed during high flow is not substantial enough to exceed water quality targets. Additional monitoring is recommended to determine the source of lead in the lower watershed.

TMDLs and Allocations

As there are no point-source pollutants identified in the Wise River aside from the WLA provided for Elkhorn Creek (see **Section 7.6.3.1**), no additional wasteload allocations are given and the TMDL consists solely of the sum of the Wise River non-point source load allocation and the Elkhorn Creek TMDL allocations (LA +WLA+MOS). The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. The total load allocation for the Wise River is therefore equal to the TMDL and is allocated to the combined load from naturally occurring and historic mining-related sources (abandoned mines, placer mining waste, & other legacy mining deposits and wastes).

TMDL Wise River =TMDL Elkhorn Creek + LA Wise River (not including Elkhorn Creek)
WLA Wise River = NA
MOS Wise River = Implicit

Example TMDLs and allocations are provided in **Table 7-28** for sampled high and low flow conditions. The low flow example is for the uppermost site on the Wise River (WISE01) because low flow exceedances are the result of loading from Elkhorn Creek. During low flow, meeting the TMDLs in Elkhorn Creek, and subsequently at the upper Wise River site, should ensure the TMDLs are met elsewhere in the Wise River.

Because exceedances during high flow are the result of loading from Elkhorn Creek and other legacy mining sources throughout the watershed, the high flow example is from the mouth of the Wise River (WISE02). The available data suggest lead will exceed water quality targets at the mouth of the Wise River if TMDLs are met in Elkhorn Creek, but because the dataset is limited, high flow TMDL examples are also presented for cadmium and copper. As part of adaptive management, additional monitoring should be conducted to determine the contribution from abandoned mines and determine if point sources are present; if unpermitted mining point sources are found, a WLA will be developed.

Table 7-28. Metals TMDLs and load allocation example for the Wise River.

Metals TMDLs for Wise River at WISE02 (high flow) & WISE01 (low flow)				**Allocations (lbs/day)**	
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Percent Reduction Needed**	**LA_{Wise} (lbs/day)**	**$TMDL_{Elkhorn}$ (lbs/day)**
Cadmium	High flow	0.324	17%	0.280	0.044
	Low flow	0.014	0%	0.010	0.004
Copper	High flow	9.234	43%	7.969	1.265
	Low flow	0.388	5%	0.263	0.125
Lead	High flow	1.750	89%	1.510	0.240
	Low flow	0.073	0%	0.049	0.024

At WISE02: High flow = 600 cfs, At WISE01: Low flow = 25.2 cfs, Hardness = 25 mg/L

7.6.4 Jerry Creek (MT41D003_020)

Loading Summary

The only copper water quality exceedance in Jerry Creek exceeded the acute and chronic standard; it was collected downstream of Moores Creek during low flow in 2005 (JERR02) (**Figure A-15**). Water and sediment samples collected farther upstream in the watershed, including a sample collected at low flow in 2005 near Moores Creek (JERR01), indicate a low naturally occurring concentration of copper. There are no abandoned mines in the vicinity of the target exceedance; there are a few in the Indian/Parker Creek drainage and then farther upstream near the headwaters and along the major tributary of Long Tom Creek. The JERR02 site is also downstream of a geologic pinch point, which could be an area of groundwater upwelling. However, based on the available data, no source can be attributed to the target exceedance.

The 303(d) Listing for copper is based on data from the mid-1970s and because recent data only includes a single exceedance, additional monitoring should be conducted, particularly during low flow, to further characterize and evaluate copper concentrations and assess potential sources, both near the vicinity of the exceedance and also at abandoned mines.

TMDLs and Allocations

As there are no point-source pollutants identified in Jerry Creek, no WLA is given and the TMDL consists solely of the non-point source load allocation: The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. The total load allocation for Jerry Creek is therefore equal to the TMDL is allocated to the combined load from naturally occurring and historic mining-related sources. The TMDL components are summarized below and **Table 7-29** shows TMDLs and allocations for measured high and low flow conditions in the Jerry Creek watershed. This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

LA Jerry Creek =TMDL Jerry Creek
WLA Jerry Creek = NA
MOS Jerry Creek = Implicit

Table 7-29. Metals TMDLs and load allocation example for Jerry Creek.

Metals TMDLs and Load Allocations for Jerry Creek at JERR02			
Metal	**Flow Conditions**	**TMDL/Load Allocation (lbs/day)**	**Percent Reduction Needed**
Copper	High flow	3.263	0%
	Low flow	0.511	59%

High flow = 95 cfs @ hardness 63.9 mg/L, Low flow = 8.8 cfs @ hardness 118 mg/L

7.6.5 Big Hole River, Middle Segment (MT41D001_020)

Loading Summary

The only exceedances of copper and lead water quality targets on the middle segment of the Big Hole River occurred during high flow at the lowest sampling site (ML05MDBH03), which is located downstream of the confluence with the Wise River (**Figure A-16**). A sediment sample from a site in the upper part of the middle segment (ML05MDBH01) was slightly elevated above the copper TEL and was more than double the copper concentration in sediment at the lowest sampling site, indicating instream sediment from upstream may contribute to slightly elevated concentrations downstream during high flow. Abandoned mines have been identified by DEQ and MBMG along the mainstem of the Big Hole River (**Figure A-16**) but the condition of the mines and presence of point sources such as adits is unknown. Point sources typically result in exceedances during low flow, however, and there are no low flow exceedances of lead or copper in the Big Hole River.

The only tributary watershed with lead exceedances (and correspondingly, lead TMDLs) is the Wise River; a sample with a concentration 8.7 times greater than the water quality target was collected in 2006 one day before the lead exceedance in the Big Hole River, indicating the Wise River is likely the cause of the lead exceedances in the Big Hole River. Because the Wise River is likely causing the lead exceedance, if the lead TMDL is met in the Wise River, lead water quality targets are expected to be met in the Big Hole River. Although there are no lead TMDLs in tributaries to the middle segment of the Big Hole other than for the Wise River watershed, restoration activities to meet TMDLs for other metals will also likely reduce lead loading from tributaries and ensure the lead TMDL is met in the Big Hole River.

The Wise River and Deep Creek watersheds both had high flow exceedances for copper (**Figure A-16**). One high flow sample was collected between Deep Creek and the Wise River in 2005 and one high flow sample was collected downstream of the Wise River in 2006, making it difficult to make conclusions regarding relative copper loading contributions from the Deep Creek and Wise River watersheds. However, meeting the copper TMDLs in the Deep Creek and Wise River watersheds (i.e. California Creek, Oregon Creek, French Creek, Elkhorn Creek, and Wise River), is expected to result in attainment of water quality targets in the Big Hole River. For example, even if the contribution from the Deep Creek watershed is not accounted for and the current high flow load exceedance of the TMDL for copper at the mouth of the Wise River is subtracted from the load in the Big Hole downstream of the Wise River confluence, as shown in **Table 7-30**, the copper TMDL is expected to be met in the Big Hole River. Therefore, meeting the TMDLs in the Wise River and Deep Creek watersheds should result in the attainment of the TMDLs and water quality targets for copper and lead in the Big Hole River.

Table 7-30. Loading example illustrating that meeting the Wise River TMDLs will result in attainment of TMDLs in the middle segment of the Big Hole River

Metal	Wise River Current Load (lbs/day)	Wise River TMDL (lbs/day)	Wise River TMDL exceedance (lbs/day)	Big Hole Current Load (lbs/day)	Big Hole TMDL (lbs/day)	Big Hole Current Load – Wise River TMDL Exceedance (lbs/day)
Copper	16.2	9.234	6.966	61.884	58.79	54.918

TMDLs and Allocations

As there are no point-source pollutants identified in the middle segment of the Big Hole River aside from the WLA provided for Elkhorn Creek (see **Section 7.6.3.1**), no additional wasteload allocations are given and the TMDL consists solely of the sum of the middle Big Hole River non-point source load allocation and the TMDL allocations to the Wise River, French Creek and Jerry Creek source areas (**Table 7-31**). Although sample data indicate Jerry Creek is meeting the copper TMDL at high flow, it is included as a source area because it has an established TMDL. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. The total load allocation for the middle segment of the Big Hole River is therefore equal to the TMDL minus the sum of the established TMDLs for French Creek, Jerry Creek and Wise River, and is allocated to the combined load from naturally occurring and historic mining-related sources (aerial deposition, placer mining waste, & other legacy mining deposits and wastes). This allocation assumes the natural load does not exceed the standard and that remediation of abandoned mining sites will reduce loading to levels that meet the water quality standards and the TMDL. Additional monitoring should be conducted, particularly during high flow, to refine the source assessment.

$\mathbf{TMDL}_{\text{midBig Hole River}} = (\mathbf{TMDL}_{\text{Wise River}} + \mathbf{TMDL}_{\text{French Creek}} + \mathbf{TMDL}_{\text{Jerry Creek}}) +$
$\mathbf{LA}_{\text{midBig Hole River}}$ (not including French Creek, Wise River, Jerry Creek)
$\mathbf{WLA}_{\text{midBig Hole River}} = \mathbf{NA}$
$\mathbf{MOS}_{\text{midBig Hole River}} = \mathbf{Implicit}$

Table 7-31. Metals TMDLs and load allocation example for the middle segment of the Big Hole River.

Metals TMDLs for the Big Hole River at MDBH03				Allocations (lbs/day)			
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Percent Reduction Needed**	**LAmidBH (lbs/day)**	**TMDLWise (lbs/day)**	**TMDLFrench (lbs/day)**	**TMDLJerry (lbs/day)**
Copper	High flow	58.790	5%	43.432	9.234	2.861	3.263
	Low flow	8.747	0%	7.434	0.388	0.414	0.511
Lead	High flow	11.139	10%	9.389	1.750	N/A	N/A
	Low flow	2.376	0%	2.303	0.073	N/A	N/A

At MDBH03: High flow = 3820 cfs @ hardness 25 mg/L, Low flow = 275 cfs @ hardness 58.4 mg/L

7.6.6 Wickiup Creek (MT41D002_120)

Loading Summary

A low flow sample upstream of the Clipper Mine, a priority abandoned mine, met water quality targets and sediment supplemental indicator values, but all high and low flow samples downstream of the mine exceeded water quality targets (**Figure A-17**). The copper concentration and load at high flow in 2005 and 2006 decreased between a site downstream of the mine (WICK01) and at the mouth (WICK02), indicating loading is associated with the mine and is attenuated in a downstream direction. A DEQ inventory of the mine in 1993 noted six waste rock piles, a seep flowing out from one waste rock pile, and a discharging adit. All of these sources associated with the Clipper Mine are contributing to low and high flow exceedances of the chronic and acute water quality standards for copper.

TMDLs and Allocations

The Clipper Mine has been identified as a discrete 'point-source area', and therefore a waste load allocation is provided for Wickiup Creek. Because of the uncertainty associated with the source of metals loading in the lower part of the watershed, the waste load allocation (WLA Wickiup Creek) incorporates the cumulative pollutant load from the Clipper Mine and other abandoned mine sources in the watershed. Also, due to data limitations and uncertainties in estimating loads from abandoned mine lands, an explicit MOS of 10 percent of the TMDL is included. The load allocation (LA Background) is applied to naturally occurring sources within the watershed.

$\mathbf{TMDL}_{\text{Wickiup Creek}} = \mathbf{LA}_{\text{Wickiup Creek}} + \mathbf{WLA}_{\text{Wickiup Creek}} + \mathbf{MOS}_{\text{Wickiup Creek}}$

Example high and low flow TMDLs and allocations are included in **Table 7-32**. The LABackground is calculated using instream concentrations upstream of the mine (SW-2). No samples were collected upstream of the mine at high flow; the background concentration is assumed to be the same at all flows. Additional monitoring should be conducted during high flow to validate this assumption, and the LABackground may need to be modified in the future via adaptive management if data indicate a different background concentration at high flow. The

WLAWickiup is calculated by subtracting the LABackground and the MOSWickiup from the TMDL.

Table 7-32. Copper TMDL and load allocation example for Wickiup Creek.

Copper TMDL for Wickiup Creek at WICK02 (high flow) & SW-1 (low flow)				MOS	Allocations (lbs/day)	
Metal	Flow Conditions	TMDL (lbs/day)	Percent Reduction Needed	10% MOS	LABackground (lbs/day)	WLAWickiup (lbs/day)
Copper	High flow	0.044	91%	0.004	0.010	0.030
	Low flow	0.016	97%	0.002	0.003	0.012

At WICK02: High flow = 1.8cfs @ hardness 42.9mg/L, At SW-1: Low flow = 0.5cfs @ hardness 57.2mg/L

7.6.7 Lost Creek (MT41D002_180)

Loading Summary

Both arsenic exceedances occurred during low flow in 2003 and were downstream of abandoned mines (**Figure A-18**). The concentration was similar at both sites and almost 3 times the target (10µg/L). The general location of the abandoned mine on a tributary to Lost Creek (**Figure A-18**) was visited by MBMG and was noted to be marked in the incorrect location, but the mapped location is in the vicinity of several mineral prospects. The other abandoned mine shown in Figure A-18 is associated with an adit from the Lost Creek Mine and molytung exploration. According to the MBMG abandoned mine database, the adit was visited in 1995 and was caved in but the pits had high walls. The exceedances at low flow could indicate loading from groundwater or a discrete source associated with the mines such as an adit or waste rock pile. However, there is not enough sample data or enough known about the status of the mines to determine the source of elevated arsenic concentrations. No samples were collected upstream of the abandoned mines, but samples collected in the adjacent Willow Creek watershed, which has similar geology, had arsenic concentrations of <1 µg/L and 1 µg/L at two sample locations (inset in **Figure A-18**), indicating the naturally occurring arsenic concentration in the Lost Creek watershed is likely similar and well below the target.

TMDLs and Allocations

As there are no point sources identified in Lost Creek, no WLA is given and the TMDL consists solely of the non-point source LA. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Although data from Willow Creek suggest the background concentration is likely close to 1µg/L, no natural background load will be established for Lost Creek because of the limited dataset and uncertainty regarding contributions from legacy mining sources and their uncertain distribution throughout the watershed. Therefore, the entire TMDL for arsenic is allocated to the combined load from naturally occurring and historic mining-related sources. The TMDL components are summarized below and **Table 7-33** shows TMDLs and allocations for measured high and low flow conditions in the Lost Creek watershed.

LA $_{\text{Lost Creek}}$ **= TMDL** $_{\text{Lost Creek}}$
WLA $_{\text{Lost Creek}}$ **= NA**
MOS $_{\text{Lost Creek}}$ **= Implicit**

Table 7-33. Arsenic TMDL and load allocation example for Lost Creek.

Metals TMDLs and Load Allocations for Lost Creek at LOST01 (high flow) and LOSTC01 (low flow)			
Metal	**Flow Conditions**	**TMDL/Load Allocation (lbs/day)**	**Percent Reduction Needed**
Arsenic	High flow	0.0648	0%
	Low flow	0.0540	64%

At LOST01: High flow = 1.2 cfs, At LOSTC01: Low flow = visually estimated at 1 cfs

7.6.8 Rochester Creek (MT41D002_160)

Loading Summary
Data collected for the BLM as part of the *Final Rochester and Nez Perce Creek Drainage Basins Reclamation Project Reclamation Investigation Report* (USDI. 2003) are helpful in identifying metals source areas but associated loading cannot be evaluated because no flow data were collected. Flow data are limited to DEQ samples collected in 2005 and 2006. Rochester Creek is intermittent and primarily groundwater-fed; much of the upper watershed is typically dry, and seasonal runoff flows are generally less than 1 cfs.

Arsenic exceedances occurred at all flows but were greatest at low flow, and exceedances for copper, lead, and mercury only occurred at low flow. All metals were less than the detection limit in upper Rochester Creek (R-1) and upstream of abandoned mines on the major unnamed tributary that flows into Rochester Creek from the eastern part of the watershed (RSW11; **Figure A-19**). These concentrations are assumed to represent the background concentration.

Concentrations of all metals of concern increased downstream of the Picard Mine on the unnamed tributary (site RSW10; **Figure A-19**), indicating some loading from the Picard Mine (and potentially from other abandoned mines) on the unnamed tributary. The greatest target exceedances for arsenic, copper, and lead occurred consistently at sites immediately downstream of the Watseca Mine (**Figure A-19**). Downstream of the Watseca Mine, the flow goes subsurface and then resurfaces near the Rochester tailings. In samples collected downstream of Watseca Mine (R-3, ROCH01, RSW5) and farther downstream after flow resurfaces near the Rochester tailings (R-9, ROCH02, RSW4), concentrations of arsenic, copper, and lead were between 71 and 90 percent less near the Rochester tailings. In samples collected for the BLM, the concentration of arsenic, copper, and lead increased slightly downstream of the Rochester tailings and arsenic increased again at the lowest site near a historic placer mine (RSW1). The magnitude of exceedances downstream of Watseca Mine indicate the mine is the largest source of loading to Rochester Creek; however, because the stream's hydrology, and thus, metals target exceedances, are groundwater-driven and flow goes subsurface between Watseca Mine and Rochester tailings, it is difficult to identify a small source area or eliminate the Rochester tailings as a source.

The detection limit for mercury during BLM sampling was greater than the standard (0.05µg/L) and much of the reported data were at values between 0.14 and 0.19 µg/L, which was between the detection limit and quantitation limit. The reported values do not increase downstream of the Watseca Mine, and the only values above the detection limit were downstream of the Picard mine (RSW10) and near a historic placer mining site in the lower watershed (RWS1). The only sediment data from the channel was greater than the PEL supplemental indicator value downstream of the Watseca Mine (ROCH01) and between the TEL and PEL downstream of the Rochester tailings (ROCH02), indicating sources may also exist in these areas. The background mercury concentration in sediment collected by DEQ during a 1993 inventory of the Thistle Mine (**Figure A-19**) was 20µg/kg, almost 30 times less than the TEL, indicating elevated mercury in the water column and sediment is associated with historic mining.

TMDLs and Allocations

The Watseca Mine and associated nearby mining sources have been identified as a discrete 'point-source area' for arsenic, copper and lead, and therefore a waste load allocation is provided for Rochester Creek for those metals. As the potential sources of mercury are more diffuse than for the other metals, the mercury TMDL does not contain a WLA and is discussed separately.

Because of the uncertainty associated with the sources of metals loading, the waste load allocation ($WLA_{Rochester}$) includes the cumulative pollutant load from the Watseca Mine and other nearby abandoned mine sources (e.g. Rochester Tailings and Picard Mine) as identified in **Figure A-19**. Also, due to data limitations and uncertainties in estimating loads from abandoned mine lands, an explicit MOS of 10 percent of the TMDL is included. The load allocation ($LA_{Background}$) is applied to all naturally occurring sources and is calculated using the reported instream concentration for BLM sites RSW9 and RSW11. The sites RSW9 and RSW11 are located above mining activity and are assumed to represent naturally occurring background concentrations of metals. The reported BLM values at sites RSW9 and RSW11 are between the method detection limit and required quantitation limit and are slightly less than the detection limit indicated for DEQ samples at the background site (R-1). The TMDL components are summarized below and example high and low flow TMDLs and allocations for metals arsenic, copper and lead are included in **Table 7-34**.

For arsenic, copper, & lead: $\mathbf{TMDL}_{\text{Rochester Creek}} =$

$$\mathbf{LA}_{\text{Background}} + \mathbf{WLA}_{\text{Rochester}} + \mathbf{MOS}_{\text{Rochester Creek}}$$

Table 7-34. Arsenic, copper, and lead TMDLs and load allocation example for Rochester Creek.

Metals TMDLs for Rochester Creek at ROCH01				MOS	Allocations (lbs/day)	
Metal	**Flow Conditions**	**TMDL (lbs/day)**	**Percent Reduction Needed**	**10% MOS**	**LA (lbs/day)**	**$WLA_{Rochester}$ (lbs/day)**
Arsenic	High flow	0.0022	90%	0.0002	0.0006	0.0014
	Low flow	0.0010	96%	0.0001	0.0002	0.0007
Copper	High flow	0.0041	15%	0.0004	0.0003	0.0034
	Low flow	0.0009	77%	0.0001	0.0001	0.0007
Lead	High flow	0.0020	0%	0.0002	0.0004	0.0014
	Low flow	0.0004	59%	0.00004	0.0001	0.0003

At ROCH01: High flow = 0.04 cfs @ hardness = 205 mg/L, Low flow = 0.01 cfs @ hardness = 226 mg/L

For mercury, no WLA is given and the TMDL consists solely of the non-point source LA. The MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. Therefore, the entire TMDL for mercury is allocated to the combined load from naturally occurring and historic mining-related sources (i.e. placer mining waste and other legacy mining deposits and wastes). The mercury TMDL components are summarized below and **Table 7-35** shows mercury TMDLs and allocations for measured high and low flow conditions in the Rochester Creek watershed. This allocation assumes the natural load does not exceed the standard and that remediation of abandoned mining sites will reduce loading to levels that meet the water quality standards and the TMDL. Additional monitoring in Rochester Creek should include assessing metals loading from the unnamed tributary, conducting low-level mercury analysis on water samples, and continuing to monitor near the Watseca Mine and Rochester tailings to determine any effects of removal of the Rochester tailings.

For mercury: LA Rochester Creek = TMDL Rochester Creek
WLA Rochester Creek = NA
MOS Rochester Creek = Implicit

Table 7-35. Mercury TMDL and load allocation example for Rochester Creek.

TMDLs and Load Allocations for Rochester Creek at ROCH01			
Metal	**Flow Conditions**	**TMDL/Load Allocation (lbs/day)**	**Percent Reduction Needed**
Mercury	High flow	0.00001	0%
	Low flow	0.000003	660%

At ROCH01: High flow = 0.04 cfs @ hardness = 205 mg/L, Low flow = 0.01 cfs @ hardness = 226 mg/L

7.6.9 Trapper Creek (MT41D002_010)

Loading Summary

Water quality exceedances occurred at high and low flow for copper, cadmium, lead, and zinc in Trapper Creek. During high flow sampling in June 2005, metals concentrations increased from site TRAP01 to TRAP02, however, during high flow sampling in May 2006, metals concentrations decreased from site TRAP01 to TRAP02. Flows were higher in 2005 than in 2006: examination of data from the USGS gage on the Big Hole River near Melrose indicates the sample date in 2005 was on the falling limb of the hydrograph while the sample data in 2006 was on the rising limb of the hydrograph, which may explain the variation in concentrations from upstream to downstream sites. As discussed in the review of existing data in **Section 7.4.4.13**, tailings and waste rock are eroding into tributaries to upper Trapper Creek and several piles are even located in the floodplain. The high flow sampling in 2005 may not have a similar pattern of exceedances because it missed the sediment pulse associated with abandoned mines in the upper watershed.

In a July 2005 low flow sample collected approximately 1.5 miles downstream of the priority abandoned mines (TRAPC01), lead was the only metal that did not meet water quality targets. At the next downstream site by the BDNF boundary (TRAPC02/TRAP01), however, copper, cadmium, lead, and zinc all exceeded water quality targets during the same low flow sampling event in July 2005. However, during low flow sampling in August 2005, all metals met water quality targets at the site by the BDNF boundary (TRAPC02/TRAP01), and lead was the only exceedance at the next downstream site near the Glendale Smelter (TRAP02). The greatest sediment concentrations occurred at the upper site near the BDNF boundary, which is more than 5 miles downstream of the priority abandoned mines; for all metals, sediment concentrations at that site were greater than 5 times the concentration of metals at the uppermost site (M03TRAPC01), which is about 1.5 miles downstream of the priority abandoned mines.

The abandoned mines and diffuse sources in the upper watershed appear to be contributing to water quality exceedances at high and low flow. Data indicate several sources areas during both high and low flow, but differing patterns in the limited dataset preclude allocating the TMDL to different source areas. Loading is likely from a combination of abandoned mines, localized aerial deposition from the Glendale Smelter, and sources such as sediment contaminated from historical mining dispersed in upland areas, the floodplain, and in the streambed. The inventory of priority abandoned mines conducted in 1993 did not locate any discharging adits. The "non-priority" abandoned mines have been identified by DEQ and MBMG but the condition of the mines and presence of point sources such as adits is unknown.

TMDLs and Allocations

As there are no point-source pollutants identified in Trapper Creek, no WLA is given and the TMDL consists solely of the non-point source load allocation: MOS is addressed through implicit considerations (see **Section 7.7.2**). Due to the uncertainty regarding contributions from a variety of legacy mining sources and their uncertain distribution throughout the watershed, a natural background load cannot be established. Therefore, the entire TMDL for copper, cadmium, lead, and zinc is allocated to the combined load from naturally occurring and historic mining-related sources (i.e. placer mining waste and other legacy mining deposits and wastes). The TMDL components are summarized below.

LA $_{\text{Trapper Creek}}$ = **TMDL** $_{\text{Trapper Creek}}$
WLA $_{\text{Trapper Creek}}$ = **NA**
MOS $_{\text{Trapper Creek}}$ = **Implicit**

As part of adaptive management, additional monitoring should be conducted at high and low flow to determine the background concentration (upstream of mining influences) and refine the source assessment, including determining the contribution from abandoned mines and if point sources are present. If unpermitted mining point sources are found, a WLA will be developed. TMDLs and allocations for measured high and low flow conditions in the Trapper Creek watershed are shown in **Table 7-36**. Although no reductions are indicated for arsenic, it is assumed based on elevated sediment metals concentrations that there are water column exceedances not captured in the sample data set. Restoration activities to address metals sources are expected to also address sediment-related toxicity and metals-related impairment to beneficial uses. This allocation scheme assumes that natural loading rates do not cause water quality standards to be exceeded and applying BMPs to the human-caused metals sources will result in the loading reductions necessary to meet the TMDLs and water quality standards.

Table 7-36. Metals TMDLs and load allocation example for Trapper Creek.

Metals TMDLs and Load Allocations for Trapper Creek at TRAP01/TRAPC02			
Metal	**Flow Conditions**	**TMDL/Load Allocation (lbs/day)**	**Percent Reduction Needed**
Arsenic	High flow	0.945	0%
	Low flow	0.484	0%
Copper	High flow	0.861	66%
	Low flow	0.405	7%
Cadmium	High flow	0.026	66%
	Low flow	0.012	38%
Lead	High flow	0.290	98%
	Low flow	0.131	95%
Zinc	High flow	11.063	50%
	Low flow	5.208	17%

At TRAP01: High flow = 17.5 cfs @ hardness 97.3 mg/L, Low flow = 8.97cfs @ hardness 88 mg/L

7.7 Seasonality and Margin of Safety

All TMDL documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream (TMDLs), and load allocations. TMDL development must also incorporate a margin of safety into the load allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes the considerations of seasonality and a margin of safety in the Lower and Middle Big Hole TPA metal TMDL development process.

7.7.1 Seasonality

Seasonality addresses the need to ensure year round beneficial use support. Seasonality was considered for assessing loading conditions and for developing water quality targets, TMDLs, and allocation schemes. For metals TMDLs, seasonality is critical due to varying metals loading pathways and varying water hardness during high and low flow conditions. Loading pathways associated with overland flow and erosion of metals-contaminated soils and wastes tend to be the major cause of elevated metals concentrations during high flows, with the highest concentrations and metals loading typically occurring during the rising limb of the hydrograph. Loading pathways associated with ground water transport and/or adit discharges tend to be the major cause of elevated metals concentrations during low or base flow conditions. Hardness tends to be lower during higher flow conditions, thus leading to lower water quality standards for some metals during the runoff season. Seasonality is addressed in this document as follows:

- Metals concentrations and loading conditions are evaluated for both high flow and low flow conditions.
- Metals TMDLs incorporate stream flow as part of the TMDL equation.
- Metals targets apply year round, with monitoring criteria for target attainment developed to address seasonal water quality extremes associated with loading and hardness variations.
- Example targets, TMDLs and load reduction needs are developed for high and low flow conditions.

7.7.2 Margin of Safety

The margin of safety is to ensure that TMDLs and allocations are sufficient to sustain conditions that will support beneficial uses. As listed below, all TMDLs incorporate an implicit MOS in several ways. TMDLs with a WLA to non-permitted point sources also have an explicit MOS of 10 percent because of the uncertainty associated with loading from abandoned mines and the effectiveness of restoration activities. If additional monitoring indicates 10 percent is an inadequate margin of safety to ensure attainment of water quality standards or is an excessive margin of safety, it may be adjusted via the adaptive management process. The implicit margin of safety is applied by using conservative assumptions throughout the TMDL development process (U.S. EPA, 1999) and is addressed by the following:

Target attainment, refinement of load allocations, and, in some cases, impairment validations and TMDL-development decisions are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.
Chronic criteria was used to calculate a daily load limit rather than a 96-hour load limit
Sediment metals concentration criteria were used as secondary indicators.
Where background concentrations upstream of mining sources were available and below the detection limit for a metal, a conservative approach to calculating the LA to background sources was taken by using a concentration at the detection limit.

7.8 Adaptive Management

Uncertainties in the accuracy of field data, applicable target values, source assessments, loading calculations, modeling assumptions, and other considerations are inherent when assessing and evaluating environmental variables for TMDL development. While uncertainties are an undeniable fact of TMDL development, mitigation and reduction of uncertainties through **adaptive management** approaches is a key component of ongoing TMDL implementation and evaluation. Uncertainties, assumptions, and considerations are addressed throughout this document and point to the need to refine analysis, conduct further monitoring, and address unknowns in order to develop better understanding of impairment conditions and the processes that affect impairment. This process of adaptive management is predicated on the premise that targets, TMDLs, allocations, and the analyses supporting them are not static, but are processes subject to modification and adjustment as new information and relationships are understood.

The adaptive management process allows for continual feedback on the progress of restoration activities and status of beneficial uses. It provides the flexibility to refine targets as necessary to ensure protection of the resource or to adapt to new information concerning target achievability. For instance, as a result of additional monitoring and source refinement discussed in the **Section 10.0**, additional WLAs may be necessary and the allocations and margin of safety may be modified. Components may be changed to improve ways of achieving and measuring success. A monitoring and restoration plan is closely linked to the adaptive management process and is described in detail in **Sections 9.0 and 10.0**.

The water quality restoration targets and associated metals TMDLs developed for the Middle and Lower Big Hole TPA are based on future attainment of the B-1 classification water quality standards. In order to achieve attainment, all significant sources of metal loading must be addressed via all reasonable land, soil, and water conservation practices. It is recognized however, that in spite of all reasonable efforts, attainment of restoration targets may not be possible due to the potential presence of unalterable human-caused sources and/or natural background sources of metals loading. For this reason, an adaptive management approach is adopted for all metals targets described within this document. Under this adaptive management approach, all metals identified in this plan as requiring TMDLs will ultimately fall into one of the three categories identified below:

- Implementation of restoration activities resulting in full attainment of restoration targets for all parameters;
- Implementation of restoration activities fails to result in target attainment due to underperformance or ineffectiveness of restoration actions. Under this scenario the water body remains impaired and will require further restoration efforts associated with the pollutants of concern. The target may or may not be modified based on additional information, but conditions still exist that require additional pollutant load reductions to support beneficial uses and meet applicable water quality standards. This scenario would require some form of additional, refocused restoration work.
- Implementation of restoration activities fails to result in target attainment, but target attainment is deemed unachievable even though all applicable monitoring and restoration activities have been completed. Under this scenario, site-specific

water quality standards and/or the reclassification of the water body may be necessary. This would then lead to a new target (and TMDL) for the pollutant(s) of concern, and the new target could either reflect the existing conditions at the time or the anticipated future conditions associated with the restoration work that has been performed.

The DEQ Remediation Division and/or DEQ Standards Program personnel will lead this effort within DEQ to make determinations concerning the appropriateness of specific mine cleanup activities relative to expectations for mining cleanup efforts for any impairment condition associated with mining impacts. This includes consideration of appropriate evaluation of cleanup options, actual cleanup planning and design, as well as the appropriate performance and maintenance of the cleanup activities. Where NPDES permitted point sources are involved, the DEQ Permitting Program will also be involved. Determinations on the performance of all aspects of restoration activities, or lack thereof, will then be used along with available in-stream data to evaluate the appropriateness of any given target and beneficial use support. Reclamation activities and monitoring conducted by other parties, including but not limited to the USFS and BLM, should be incorporated into the process as well. The information will also help determine any further cleanup/load reduction needs for any applicable water body and will ultimately help determine the success of water quality restoration.

It is acknowledged that construction or maintenance activities related to restoration, construction/maintenance, and future development may result in short term increase in surface water metals concentrations. For any activities that occur within the stream or floodplain, all appropriate permits should be obtained before commencement of the activity. Federal and State permits necessary to conduct work within a stream or stream corridor are intended to protect the resource and reduce, if not completely eliminate, pollutant loading or degradation from the permitted activity. The permit requirements typically have mechanisms that allow for some short term impacts to the resource, as long as all appropriate measures are taken to reduce impact to the least amount possible.

SECTION 8.0
TEMPERATURE

This portion of the document focuses on temperature as an identified cause of water quality impairments in the Middle and Lower Big Hole TPA. It describes: 1) the mechanisms by which temperature impairs beneficial uses of streams, 2) the specific stream segments of concern, 3) the presently available data pertaining to temperature impairments in the watershed, 4) the various contributing sources of heat based on recent studies, and 5) the temperature TMDLs, allocations and margin of safety.

8.1 Thermal Impacts upon Sensitive Uses

Human influences which reduce stream shade, increase stream channel width and decrease the ability of the stream to assimilate solar heating all increase stream temperatures. Heated conditions have negative impacts upon aquatic life and fish which depend upon cool water for survival. Heated conditions exert more stress on fish by impacting metabolism. Cold water fish species reduce feeding rates and exert energy to survive in thermal conditions above their tolerance ranges which they have adapted to.

8.2. Stream Segments of Concern

A total of four water body segments in the Middle and Lower Big Hole TPA appeared on the 2006 Montana 303(d) List due to temperature related impairments. Streams identified in need of temperature TMDLs are Pintlar Creek, Divide Creek and two segments of the Big Hole River. Thermal loading TMDLs will be completed for all these water bodies except Pintlar Creek.

8.3 Temperature Targets

Montana's water quality standard for temperature specifies a maximum allowable increase above the "naturally occurring" temperature in order to protect the existing thermal regime for fish and aquatic life (see **Section 3.3.2.4**). For waters classified as A-1 or B-1, the maximum allowable increase over the naturally occurring temperature is 1°F, if the naturally occurring temperature is less than 66º Fahrenheit. Within the naturally occurring temperature range of 66-66.5 ºF, the allowable increase cannot exceed 67ºF. If the naturally occurring temperature is greater than 66.5ºF, the maximum allowable increase is 0.5º F [ARM 17.30.622(e) and ARM 17.30.623(e)]. In-stream temperature monitoring and predictive modeling both indicate that naturally occurring stream temperatures in the middle and lower segments of the Big Hole River, as well as in Divide Creek, are likely greater than 66.5°F during portions of the summer months. If this is true, the maximum allowable increase due to unmitigated human causes would be 0.5°F (0.23°C).

Extensive monitoring and an associated Heatsource v7.0 model (**Appendicies I** and **J**) was used to assess existing water temperatures in the middle and lower segments of the Big Hole River and in Divide Creek. The modeling is also used to determine if human caused disturbances within the watershed increase the water temperature above the "naturally occurring" level and, if so, to what degree. Stream temperature and riparian shading data collected in the summer of 2006, along with streamflow and ditch flow data, were used to calibrate the model for existing conditions. The potential to reduce stream temperatures through management measures was modeled based on seven scenarios.

Model results from an existing condition scenario and a scenario simulating reasonable land, soil and water conservation practices were used to assess existing and potential water temperature conditions in the middle and lower segments of the Big Hole River and Divide Creek relative to Montana's water quality standards. The relationship between anthropogenic disturbances and water temperature impairments as described in ARM 17.30.623(e) was evaluated as described below:

> If simulated stream temperatures derived from the Heatsource v7.0 model using the "existing conditions" data deviated by less than 0.5ºF from stream temperatures derived using the "potential conditions" data when all reasonable land, soil and water conservation practices were applied, then anthropogenic sources were concluded to not be causing or contributing to violations of the relevant to A-1 and B-1 water temperature standards and the stream was not considered to be impaired due to anthropogenic (or anthropogenically induced) thermal modifications.
>
> If simulated stream temperatures derived from the Heatsource v7.0 model using the "existing conditions" data deviated by greater than 0.5ºF from stream temperatures derived using the " potential conditions" data when all reasonable land, soil and water conservation practices were applied, then anthropogenic sources were concluded to be causing or contributing to violations of the relevant A-1 and B-1 water temperature standards and the stream was considered to be impaired due to anthropogenic thermal modifications.

Modeling estimated temperature conditions with varying influencing factors to simulate the difference between existing conditions and reasonable land, soil, and water conservation practices. The difference in temperatures is used to indicate if Montana's water quality temperature standard is likely being met or exceeded.

Also, the targets will incorporate an "or" statement where Montana's temperature standards should be met or all the physical condition targets should be met. In this approach, if all reasonable land, soil, and water conservation practices are installed, state standards are met. Yet, if the temperature standards are met, the use is supported, and not all areas need to have full installation of restoration practices to meet the standards.

8.3.1 Surrogate Targets

8.3.1.1 Riparian Canopy Density

Shade provided by riparian vegetation decreases the amount of solar radiation reaching the channel and buffers stream temperature fluctuations. Based on the Big Hole watershed temperature modeling effort, the reference condition for riparian vegetation along the Big Hole

River between Pintlar Creek and Wise River, as well as along Divide Creek, consists of 80 percent willows and 20 percent grass cover. Note that "willows" refers generally to shrubs found along the channel margin while grass cover denotes herbaceous and grass growth forms which provide much less shading to the stream channel. Reference riparian vegetation along the Big Hole River downstream of Wise River consists of 30 percent cottonwood gallery and 70 percent grass cover. In areas with only grass cover, these riparian types were replaced within the temperature model.

The influence of riparian canopy density on stream temperatures in the Middle and Lower Big Hole TMDL planning area was assessed within the Heatsource v7.0 temperature model on the basis of several input variables including land cover type, and vegetation height, density and overhang along the stream channel. These parameters were assessed at 100-meter intervals along the middle and lower segments of the Big Hole River and Divide Creek using GIS and aerial photo assessments. For the purpose of TMDL targets and allocations, riparian canopy density was considered to be the functional equivalent of the average percent of effective shade when all impacted riparian areas were replaced with reference vegetation along the stream banks.

Table 8-1. Targets for Temperature in the Middle and Lower Big Hole River TPA.

Water Quality Targets	Criteria
Maximum allowable increase over naturally occurring temperature	For waters classified as A-1 or B-1, a 1ºF maximum increase above naturally occurring water temperature is allowed within the range of 32ºF to 66ºF; within the naturally occurring range of 66ºF to 66.5ºF, no discharge is allowed which will cause the water temperature to exceed 67ºF; and where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF.
OR meet ALL of the indirect, temperature influencing targets below	
Riparian Shade	Big Hole River between Pintlar Creek and Wise River: 80% willows, 20% grass cover. Equivalent to an average of 3.5% effective shade.
	Big Hole River from Butte Diversion to the mouth: 30% cottonwood gallery, 70% grass cover. Equivalent to an average of 7.4% effective shade.
	Divide Creek: 80% willows and 20% grass cover. Equivalent to an average of 27% effective shade.
Channel width/depth ratio	Big Hole River from Pintlar Creek to Deep Creek: ≤ 60:1
	Divide Creek: comparable with reference values[a]
Irrigation water management	15% improvement in irrigation efficiency during the warmest months (mid-June through August).
Inflows to stream	No human caused surface water inflow, in single or in combination, will increase temperatures more than ½ ºF.

[a] Based on the Beaverhead-Deerlodge National Forest channel morphology dataset and applies only to Big Hole River tributary streams. A detailed discussion of the targets is provided in Section 5.

8.3.1.2 Width/Depth Ratio

Lower channel width-to-depth ratios are associated with the presence of deep pools and runs that resist daily fluctuations in stream temperature and provide better thermal protection for cold water fish (Riggers et al.1998). A decrease in depth tends to reduce the number of pools (Beschta and Platts 1986), while an increase in width allows greater inputs of solar radiation, which can lead to higher stream temperatures. Also, a narrower channel receives increased shade from a constant sized riparian canopy when compared to a wider channel. Thermal refuges provided by deep pools and overhead cover of riparian vegetation are essential for the long-term viability of the Arctic grayling, which use pools for thermal refugia in the summer (Lamothe and Magee 2003), as well as for over-wintering habitat (West et al. 1992). In the Middle and Lower Big Hole River, a width-to-depth ratio of ≤ 60 is a target for the reach extending from Pintlar Creek downstream past the confluence with Deep Creek (reaches 1-4 in the Heatsource v7.0 model). No width-to-depth ratio target is established for reaches extending farther downstream since this assessment indicates that the channel is not over-widened except for very localized areas in this reach of the River (**Table 8-1**). Divide Creek's width-to-depth ratio targets depend upon the type of stream channel found at a location. More detailed justification for tributary width-to-depth ratio targets are provided in **Section 5**.

8.3.1.3 Irrigation Water Management

Irrigation water withdrawals throughout the Big Hole River watershed are substantial since agriculture remains the primary land use within the watershed. Streamflow depletion due to irrigation withdrawals can lead to increased water temperatures since a lesser volume of generally shallower water will heat up more quickly from incoming solar radiation. Greater daily fluctuations in temperature can also be expected when flows are low. In addition to increased stream temperatures that can result from dewatering, irrigation return flows may be warmer than natural streams and may further contribute to increased water temperatures. Due to the importance of instream flows, a 15 percent improvement in irrigation efficiency during the warmest months of the year (July-Mid September) is recommended as an indirect water quality target for water temperature impairments. In addition, human induced surface water return flows, in single or in combination, should not increase temperatures above Montana standards.

8.3.2 Impact to Fish

Special temperature considerations are warranted for the Arctic grayling and the westslope cutthroat trout, which are listed by the State of Montana as species of concern (Carlson 2001). The upper incipient lethal temperature (UILT) for Arctic grayling is 77ºF (25ºC) (Lohr et al. 1996). The UILT is the temperature that is considered to be survivable indefinitely by 50 percent of the Arctic grayling population (Lohr et. al.1996). Recently conducted research by Bear (2005) found that the upper incipient lethal temperature (UILT), which is the temperature considered to be survivable indefinitely by 50 percent of the westslope cutthroat trout population, was 67ºF (19.7ºC), while the UILT for rainbow trout was 76ºF (24.2ºC).
Although these temperature thresholds are used as a reference that likely causes impacts to fish, they are not targeted temperatures and are not directly related to Montana's water quality standards.

8.4 Existing Conditions Summary

8.4.1 Big Hole River - Middle Segment (between Pintlar Creek and Divide Creek)

The middle segment of the Big Hole River was listed as impaired due to temperature on the 2006 303(d) List. Elevated summer water temperatures within the Big Hole River have been well documented over the past several decades. The U.S. Geological Survey began measuring temperature year-round at the Melrose gaging station in 1977 (Lower Big Hole River TPA), while seasonal temperature monitoring has been conducted at the Wisdom gaging station since 1988 (Upper Big Hole River TPA). In addition, intensive temperature monitoring at several sites was implemented by Montana Fish, Wildlife & Parks in the early 1990's as part of the Arctic grayling monitoring program. Most recently, Montana DEQ assessed temperature at several sites along the middle segment of the Big Hole River in the summer of 2006 for use in calibrating the Heatsource v7.0 stream temperature model.

Thermographs were placed at two stations within the Middle Big Hole River TPA during the summers of 1992 and 1994. The sample site located downstream of Pintlar Creek documented maximum temperatures of 81.5ºF (27.5ºC) in 1992 and 79.7ºF (26.5ºC) in 1994, while the sample site between LaMarche Creek and Deep Creek showed maximum temperatures of 79.7ºF (26.5ºC) in 1992 and 76.1ºF (24.5ºC) in 1994. Research conducted by Lohr et al. (1996) indicates that the upper incipient lethal temperature (UILT) for Arctic grayling, which is the temperature considered to be survivable indefinitely by 50 percent of the population, was 77ºF (25ºC). Thus, the maximum daily river temperatures in the warmest reaches of the middle Big Hole River were warm enough in both 1992 and 1994 to be lethal to Arctic grayling. High water temperatures in July of 1994 contributed to a fish kill that included Arctic grayling and seven other species (Lohr et al. 1996).

In 2002, maximum instream temperatures recorded by Montana Fish, Wildlife & Parks (MFWP) in the middle Big Hole River occurred during the period from July 11th through July 15th and the UILT for Arctic grayling was exceeded at 7 out of 10 stations (some stations were in the Upper Big Hole River TPA). The Big Hole River is wide and shallow with little riparian cover in the stretch of river between the mouth of the North Fork Big Hole River and the Mudd Creek Bridge. A monitoring location located between Pintlar Creek and Mudd Creek had the highest maximum temperature (80.8ºF) and the highest mean daily maximum (74.1ºF). Temperatures at the Christiansen's station exceeded 70ºF on 31 days in 2002 (Magee and Lamothe 2003). Maximum and mean temperatures were slightly lower at the Sportsman's station and there were fewer days exceeding 70ºF.

Montana Fish, Wildlife & Parks reported that the summer of 2003 was the fifth consecutive year of drought conditions. Maximum instream temperatures for most thermograph stations occurred between July 8th and July 21st. Water temperatures rose above 70°F at all mainstem monitoring stations during the summer of 2003. Several stations, including Christiansen's and Sportsman's in the Middle Big Hole TPA, exceeded upper incipient lethal temperatures (77°F) for Arctic grayling. The highest maximum temperature (80.1ºF) was recorded at the Pintlar station, which is at the upper end of the Middle Big Hole River TPA. Thus, it is likely that some of the temperature issues within the Middle Big Hole TPA originate higher in the watershed. The number of days with temperatures >70ºF in 2003 was more than double the amount in 2002 at both the Christiansen's and Sportsman's stations (Magee and Lamothe 2003).

In 2004, MFWP placed thermographs at several sites, including Christiansen's and Sportsman's, in the middle segment of the Big Hole River. Maximum temperatures occurred on July 16th and July 17th in 2004 for all sites, with water temperatures exceeding 70°F at all mainstem monitoring stations during the summer. It was noted that LaMarche Creek and Fishtrap Creek were both cooler than Steel Creek and Deep Creek, thereby providing thermal refugia for Arctic grayling. 2004 was noted to be the sixth consecutive year of drought conditions, despite above average summer precipitation (Magee et. al. 2005).

In 2005, MFWP placed thermographs at several sites, including Christiansen's and Sportsman's, in the middle segment of the Big Hole River. An additional site at Dickie Bridge was also established in 2005. Maximum temperatures occurred on July 13th and July 23rd at most sites in 2005. Temperatures increased from the headwaters downstream to Christiansen's and then decreased at the Sportsman's and Dickie Bridge sites. Water temperatures at the Christiansen's, and Sportsman's sites, which reportedly have high width/depth ratios and little woody riparian vegetation, exceeded the upper incipient lethal temperature of 77°F for Arctic grayling (Magee et. al. 2006).

In 2006, MFWP placed thermographs at several sites, including Sportsman's, Christiansen's and Dickie Bridge in the middle segment of the Big Hole River. Maximum temperatures were documented as occurring on July 21st and July 22nd at most thermograph sites during 2006. Similar to 2005, instream temperatures increased from the headwaters downstream to the Wisdom Bridge, then decreased at the Sportsman's and Dickie Bridge sites. In 2006, the Sportsman's site exceeded the UILT (77°F) for Arctic grayling. Fishtrap Creek, LaMarche Creek and Deep Creek had fewer hours above 70°F than the mainstem sites in 2006, with temperatures remaining below 77°F in these tributaries (Rens and Magee 2007). Thus, decreased temperatures at Dickie Bridge may have been at least partly due to cooler water inputs from Fishtrap, LaMarche, Seymour, and Deep creeks.

Montana DEQ conducted a detailed temperature study on the Big Hole River in 2006 and used the results of that study to model spatial changes in stream temperature. The results of that assessment are described in *Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006* , which is reproduced in **Appendix I**. The study included the measurement of streamflow and water temperature at twenty sites on the mainstem Big Hole River between Wisdom and the confluence with the Jefferson River, as well as measurements of streamside shading. In addition, streamflow was measured on forty-four tributaries and return flows and thirty three irrigation withdrawals. The results of that modeling effort indicated that most of the planning area was meeting the standard during 2006 (e.g. within the 0.23°C allowable increase), although standard violations assessed based on the 7-day average of the daily maximum temperature (7-DADmax) were found to occur at one location within the middle segment of the Big Hole River. The only portion of the middle segment of the Big Hole River that was not meeting Montana's water quality standards for temperature was between Pintlar Creek (and upstream in the upper Big Hole TPA) and Fishtrap Creek. Monitoring and modeling results indicated aquifer inputs in the vicinity of Fishtrap, LaMarche and Deep creeks leading to decreased temperatures. In addition, the modeling effort indicated that water temperatures largely "reset" in the vicinity of the Wise River primarily due to aquifer inputs, and the cool water from Wise River.

Results of the 2006 Big Hole River Heatsource v7.0 modeling effort demonstrate how upstream and localized conditions from a wide stream channel, low shading, and water use without reasonable irrigation water management practices heat the upper portion of this segment of the Big Hole River (**Table 8-2**). The results of the modeling effort suggest that 7-day average water temperatures (7Davg) currently exceed the naturally occurring temperature by 2.78°F. Furthermore, the 7-day average of the daily maximum temperature (7DADMax) likely exceeds the naturally occurring temperature by 4.05°F. When comparing the average weekly temperature or the 7DADMax, both are in excess of the maximum allowable increase of 0.5°F in the upper portion of this river segment.

At the lower end of this segment, the model indicates there is little thermal change from naturally occurring temperatures due to a natural resetting of the temperature because of natural cold groundwater and tributary inputs near Wise River and Dewy (**Table 8-2**). Also, the canyon below Dewy provides a naturally controlled, more narrow channel along with topographical shade.

Table 8-2. Estimated Temperature Reductions Achievable via Restoration Approach in the Middle Segment of the Big Hole River for Selected Locations Identified Using the Heatsource v7.0 Model.

Location	7-Day Average Temperature (7Davg)	7-Day Average of the Daily Maximum Temperatures (7-DADMax)
Big Hole River near Pintlar Creek	**- 2.78 °F**	**- 4.05 °F**
Big Hole River near Divide Creek	No change	- 0.09

* Bold values likely exceed the standard.

In 2006, DEQ gathered thermograph data in the middle segment of the Big Hole River between Pintlar Creek and Divide Creek (**Table 8-3**). The thermographs were deployed in mid-July and retrieved in early-August. Seasonal maximum values were observed to generally decrease in this segment, with a value of 80.5°F downstream of Pintlar Creek and a value of 72.2°F upstream of Divide Creek. Seasonal maximum values exceeded 80°F at the Pintlar Creek, Mudd Creek and Fishtrap FAS sites, while the 7-day average of the daily maximum temperature (7-DADMax) for these three sites all exceeded 78°F.

Table 8-3. Temperature Data Summary for the Middle Segment of the Big Hole River, Summer 2006.

Big Hole River Monitoring Site	Seasonal Maximum		7-Day Average of the Daily Maximum Temperature		Days >	Days >	Days >
	Date	Value	Date	Value (7-DADMax)	66 F	75 F	78 F
downstream of Pintlar Creek	07/22/06	80.5	07/21/06	78.4	24	15	4
downstream of Mudd Creek	07/22/06	80.8	07/24/06	78.7	24	15	3
downstream of Fishtrap FAS	07/22/06	81.0	07/21/06	79.0	43	15	8
at Dickie Bridge	07/22/06	78.4	07/20/06	76.8	24	14	1
upstream of Johnson Creek	07/22/06	77.7	07/20/06	76.2	24	9	0
upstream of Wise River	07/22/06	78.2	07/24/06	75.8	20	8	1
upstream of Jerry Creek	07/22/06	74.4	07/20/06	72.8	21	0	0
upstream of Divide Creek	07/23/06	73.4	07/25/06	72.2	18	0	0

.

Riparian canopy density was assessed using average percent effective shade data derived from the Heatsource v7.0 modeling effort which was calibrated from vegetation transect monitoring. For analysis purposes, the middle segment of the Big Hole River was divided into four reaches (**Table 8-4**). Average percent effective shade ranged from 1.4 to 7.9 within these four reaches. The target will not be applied in the canyon reach because the canyon itself provides topographical shade and limits riparian vegetation growth.

Table 8-4. Land Cover Densities along the Middle Segment of the Big Hole River.

Land Cover Density Assessment Reach	Upstream End of Reach	Downstream End of Reach	Existing % Effective Shade	Target % Effective Shade
1	Pintlar Creek	Mudd Creek Bridge	**1.4**	**1.7**
2	Mudd Creek Bridge	Deep Creek	**4.8**	**5.1**
3	Deep Creek	Wise River	**3.5**	**3.8**
4	Wise River	Butte Diversion	7.9	NA

*Bold text indicates exceedance of targets.

Width-to-depth ratios were measured at two sites along the middle segment of the Big Hole River during a 2006 sediment and habitat assessment. A width-to-depth ratio of 97.1 was measured upstream of the Mudd Creek bridge, while a width-to-depth ratio of 86.1 was measured just downstream of the Deep Creek confluence. Both of these measurements failed to meet the indirect width/depth ratio target of ≤ 60. Width-to-depth ratios are higher than these measures upstream of the monitoring locations.

The Big Hole River from the confluence with the Jefferson River to upstream of Willow Creek has been described as an area of chronic dewatering concern, while the entire Middle Big Hole River TPA is considered to be an area of periodic dewatering concern (MFISH 2004). Dewatering during the irrigation season was cited as the greatest threat to the fishery by Montana

Fish, Wildlife & Parks (1989). MFWP has requested a year-round flow of at least 800 cfs for the Big Hole River between Pintlar Creek and the old Divide Dam. This request was based on measurements made approximately seven miles upstream from the old Divide Dam, which is at the lower end of the Middle Big Hole River TPA (MFWP 1989). It is likely that this flow is not maintained naturally during some timeframes. The Big Hole River Drought Management Plan sets a streamflow trigger value of 100 cfs measured at the USGS Mudd Creek gage for the Big Hole River between the mouth of the North Fork Big Hole River and Dickie Bridge (BHWC 2007). Instream flow targets are not set; but the model used a reduction of irrigation diversions of 15 percent, which regional irrigation network studies indicate this level of irrigation efficiency improvement is usually reasonably achieved.

8.4.1.1 Middle Big Hole River Thermal Water Quality Status Summary

The Heatsource v7.0 modeling effort in the Big Hole River indicated that the 7-day average of the daily maximum temperature (7-DADmax) exceeds the naturally occurring temperature by 4.05 °F in the upper portion of the middle segment of the Big Hole River, which exceeds the maximum allowable increase of 0.5 °F. Also, width-to-depth ratios and shade from streamside vegetation fell below targets in most areas of this segment. Stream flow could be increased by reasonable irrigation water management activities and loss of buffering capacity from reduced flows contributes to temperature increases. A temperature TMDL will be provided for the middle segment of the Big Hole River.

8.4.2 Big Hole River, Lower Segment (from Divide Creek to mouth)

8.4.2.1 Stream Flow

The lower segment of the Big Hole River was listed as impaired due to temperature on the 2006 303(d) List. Elevated summer water temperatures within the Big Hole River have been well documented. The U.S. Geological Survey began measuring temperature year-round at the Melrose gaging station in 1977. At the Melrose gaging station, maximum daily temperatures have exceeded 70ºF every year since temperature monitoring began in 1977. In 2006, Montana DEQ assessed temperature at several sites along the Big Hole River for purposes of calibrating and running the Heatsource v7.0 model.

Dewatering issues in the lower segment of the Big Hole River have reportedly led to increased summer temperatures and associated decreases in dissolved oxygen concentrations. The Big Hole River from the confluence with the Jefferson River to upstream of Willow Creek has been described as an area of chronic dewatering concern. The entire Lower Big Hole River TPA has been characterized as an area of periodic dewatering concern (MFISH 2004). Montana Fish, Wildlife & Parks has requested a year-round flow of at least 650 cfs for the Big Hole River between the old Divide Dam and the mouth. This recommendation is based on flow measurements made near the mouth of the river (MFWP 1989).

Irrigation practices within the Big Hole watershed have been determined to influence interactions between surface water and groundwater. A study conducted by the Montana Bureau of Mines and Geology found that most gains in aquifer storage occurred in May and June when 30,000 acre-feet were added to the aquifer in the lower basin, which the study defined as extending from Maiden Rock to Notch Bottom (Marvin and Voeller 2000). The study found that groundwater elevations were near their peak by July and remained relatively stable due to a dynamic equilibrium between irrigation induced aquifer recharge (i.e.leaking ditches) and groundwater discharge to surface waters. Groundwater elevations were found to decline during August and September due mostly to evapotranspiration losses (the sum of evaporation and plant transpiration) rather than discharges to surface water. Once irrigation ceased in October and November, an average gain of 90 cfs in streamflow was noted in the river reach between Maiden Rock Canyon and Notch Bottom as a direct result of irrigation return flows along with cessation of irrigation diversions (Marvin and Voeller 2000).

Water from the lower segment of the Big Hole River is used to irrigate the valley bottoms between the mouth of Maiden Rock Canyon and the confluence with the Jefferson River, including the areas around Melrose, Glen and Twin Bridges. Irrigation withdrawals between Melrose and Twin Bridges in the early 1980's ranged from 80-210 cfs, with up to 328 cfs being removed from the river in the summer of 1980 (Wells and Decker-Hess 1981). There were an estimated total of 44 diversions between Divide Creek and the mouth by 1973 (Bahls 1978). The 2006 temperature modeling effort identified average irrigation withdrawals of 469 cfs between Pintlar Creek and the mouth during July 25-31, 2006, with much of this occurring in the lower segment of the Big Hole River (**Appendix I**). In addition, a recently completed assessment of streamflow data in the lower watershed for the period from July 1 to September 30 in 2001 through 2007 conducted by PBS&J for the Big Hole Watershed Committee indicated that streamflows decreased by an average of approximately 148 cfs between Notch Bottom and the High Road Bridge during the irrigation season. This recent study identified 34 mainstem diversions between Maiden Rock Canyon and the confluence with the Jefferson River.

8.4.2.2 Temperature

Montana DEQ conducted a detailed temperature study on the Big Hole River in 2006 and used the results of that study to model spatial changes in stream temperature. The results of that assessment are presented in *Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006* (**Appendix I**). This study included the measurement of streamflow and water temperature at 20 sites on the mainstem of the Big Hole River between Wisdom and the confluence of the Jefferson River, as well as measurements of streamside shading. In addition, streamflow was also measured on 44 tributaries and return flows and 33 irrigation withdrawals. The results of the modeling effort projected that most of the planning area was meeting the state water quality standard (e.g. within the 0.23°C allowable increase), although standard violations as assessed based on the 7-day average of the daily maximum temperature (7-DADmax) were identified at two locations along the lower segment of the Big Hole River:

1. between Melrose and Glen due to heavy irrigation and domestic water withdrawals; and
2. from approximately river mile 6.5 downstream (approximately Pennington Bridge to the confluence with the Jefferson River) due to the cumulative effects of dewatering.

Table 8-5 below summarizes the results of the 2006 Big Hole River Heatsource v7.0 modeling effort for selected scenarios at the watershed outlet. The results of the modeling effort suggest that 7-day average water temperatures (7Davg) currently exceed the "naturally occurring" temperature by 0.23°F. Furthermore, the 7-day average of the daily maximum temperature (7-DADmax) likely exceeds the "naturally occurring" temperature by 1.06°F, which is in excess of the maximum allowable increase of 0.5°F. The Heatsource v7.0 modeling effort identified water inefficient consumptive use as the major cause of increased stream temperatures and reduced riparian shading as the second largest cause of heating.

Table 8-5. Estimated Temperature Reductions Achievable via Restoration Approach in the Lower Segment of the Big Hole River for Selected Locations Identified Using the Heatsource v7.0 Model

Location	7-Day Average Temperature (7Davg)	7-Day Average of the Daily Maximum Temperatures (7-DADMax)
Near Confluence with Jefferson River	-0.23 °F	**-1.06 °F***

* Bold values likely exceed the standard.

In 2006, DEQ deployed 10 thermographs in the lower segment of the Big Hole River between Divide Creek and the confluence with the Jefferson River (**Table 8-6**). The thermographs were deployed in mid-July and retrieved in mid-August. Seasonal maximum temperatures were observed to increase in a downstream direction from a value of 74.0°F at the entrance to Maiden Rock Canyon to a value of 81.2°F near the High Road FAS. Seasonal maximum values exceeded 75°F at the USGS near Melrose gage site and all sites downstream, while the 7-day average of the daily maximum temperature (7-DADmax) exceeded 74°F at the USGS near Melrose gage site and all sites downstream. Note that the USGS near Melrose gage is located approximately 7 miles downstream of Melrose.

Table 8-6. Temperature Data Summary for the Middle Segment of the Big Hole River, Summer 2006.

Big Hole River Monitoring Site	Seasonal Maximum		7-Day Average of the Daily Maximum Temperature		Days >	Days >	Days >
	Date	Value	Date	Value (7-DADMax)	66 F	75 F	78 F
at Canyon Entrance	07/22/06	74.0	07/24/06	72.6	19	0	0
near Maiden Rock FAS	07/22/06	74.3	07/20/06	72.7	21	0	0
near Salmon Fly FAS	07/22/06	74.9	07/20/06	73.4	23	0	0
USGS near Melrose	07/22/06	75.3	07/20/06	74.2	34	1	0
near Glen FAS	07/22/06	76.5	07/24/06	74.5	23	4	0
USGS near Glen/Notch Bottom FAS	07/23/06	78.2	07/21/06	76.1	23	10	1
upstream of Pageville Canal	07/23/06	78.7	07/25/06	76.6	24	10	1
near Pennington Bridge FAS	07/22/06	78.0	07/25/06	76.6	24	12	1
upstream of Third Slough	07/22/06	78.3	07/25/06	77.3	55	12	1
near High Road FAS	07/28/06	81.2	07/26/06	79.9	24	23	15

Average percent effective shade along reaches of this river segment was assessed using GIS and aerial photos and riparian transect monitoring. For analysis purposes, the lower segment of the

Big Hole River was divided into six reaches (**Table 8-7**). Average percent effective shade ranged from 2.1 percent to 14.2 percent within these six reaches.

Table 8-7. Land Cover Densities along the Middle Segment of the Big Hole River.

Land Cover Density Assessment Reach	Upstream End of Reach	Downstream End of Reach	Existing % Effective Shade	Target % Effective Shade
5	Butte Diversion	mouth Maiden Rock Canyon	**14.2**	**14.7**
6	mouth Maiden Rock Canyon	Browns' Bridge FAS	**7.5**	**9.6**
7	Browns' Bridge FAS	Glen FAS	**6.3**	**7.5**
8	Glen FAS	Notch Bottom FAS	**2.1**	**3.2**
9	Notch Bottom FAS	Pennington FAS	**3.1**	**4.1**
10	Pennington FAS	confluence with Jefferson River	**3.8**	**5.4**

*Bold text indicates exceedance of targets.

8.4.2.3 Lower Big Hole River Water Quality Status Temperature Summary

The Heatsource v7.0 modeling effort in the Big Hole River indicated that 7-day average water temperatures (7Davg) are currently likely to exceed the "naturally occurring" temperature by 0.23°F in the most thermally impacted area, which does not exceed the state standard. Although, the 7-day average of the daily maximum temperature (7-DADmax) likely exceeds the "naturally occurring" temperature by 1.06°F, which also represents an exceedance of the maximum allowable increase of 0.5°F. Thus, the temperatures likely exceed standards in the lower segment of the Big Hole River, especially between Melrose and Glen and in the lowermost 6.5 miles of the Big Hole River upstream of the confluence with the Jefferson River. The heating can be attributed to stream flow and to a lesser extent, riparian shade conditions.

8.4.3 Divide Creek

8.4.3.1 Temperature, Stream Flow and Shade

Montana DEQ conducted a detailed temperature study on Divide Creek in 2006 and used the results of the study to model spatial changes in stream temperature in relation to different management scenarios. The results of the assessment are described in *Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006 Addendum-1* (**Appendix J**). The study included the measurement of streamflow and water temperature at several sites on Divide Creek as well as several measurements of streamside shading. The results of the modeling indicated that Divide Creek was not likely to be meeting the temperature standard (e.g. within the 0.5°F allowable increase) along a portion of its length. The 7-day average of the daily maximum temperature (7-DADmax) was estimated as exceeding the standard along two reaches of Divide Creek:

1. stream mile 13.5-7.5 (downstream of the confluence with Curley Creek); and
2. stream mile 4.5-2.5 (upstream of the where the Divide Canal enters Divide Creek).

Thus, Divide Creek temperature conditions likely do not meet state temperature standards along much of the mainstem upstream of where the Divide Canal enters. This assessment indicated that inter-basin water transfers from the Big Hole River through the Divide Canal lead to increased streamflows and decreased water temperatures in the lower 4.0 kilometers of Divide Creek. Due to the additional water inputs through the Divide Canal, the natural condition scenario, which excludes these inputs, resulted in warmer water temperatures than are currently observed in Divide Creek. Based on this result, it is the opinion of Montana DEQ that return flow is a benefit to Divide Creek, but diverts flow from the Big Hole River which is also impacted by temperature conditions. **Table 8-8** summarizes the results of the Heatsource v7.0 modeling effort in Divide Creek for selected scenarios.

Table 8-8. Estimated Temperature Reductions Achievable via Restoration Approach in Divide Creek for Selected Locations Identified Using the Heatsource v7.0 Model

Location	**7-Day Average of the Daily Maximum Temperatures (7-DADMax)**
Stream mile 12.9	**-1.76***
Stream mile 2.7 (Just upstream of Divide Diversion input)	**-0.81**
Near Confluence with Big Hole River	-0.16

* Bold values likely exceed the standard.

The results of the modeling effort indicated that the 7-day average of the daily maximum temperature (7DADMax) is currently likely to exceed the “naturally occurring” temperature by 0.16°F at the watershed outlet. While this value does not exceed the maximum allowable increase of (0.5°F), temperature conditions upstream at stream miles 13.5-7.5 and 4.5-2.5 do likely exceed the standard (**Table 8-8**). Decreased stream temperatures in the lower 2.5 miles of Divide Creek were the result of inflows from the Divide Canal. The Heatsource v7.0 modeling effort indicated that an increase in shade in the reaches identified above would be the most effective management measure for reducing in-stream water temperatures in Divide Creek.

In 2006, DEQ deployed 6 thermographs in Divide Creek (**Table 8-9**), as well as on the East Fork Divide Creek, North Fork Divide Creek, and the Divide Canal. The thermographs were deployed in mid-July and retrieved in early-August. A maximum value of 78.5°F was observed at mile 10.5. Temperatures decreased downstream of mile 2.5 due to inputs from the Divide Canal, in which a maximum temperature of 71.5°F was observed. Temperatures again increased downstream of the Divide Canal, with a maximum value of 76.2°F recorded at the mouth of Divide Creek.

Table 8-9. Temperature Data Summary for Divide Creek, Summer 2006.

Divide Creek Monitoring Site	Seasonal Maximum		7-Day Average of the Daily Maximum Temperature		Days >	Days >	Days >
	Date	Value	Date	Value (7-DADMax)	66 F	75 F	78 F
East Fork Divide Creek	07/22/06	75.3	07/24/06	73.1	15	1	0
North Fork Divide Creek	07/26/06	69.5	07/28/06	66.0	4	0	0
Divide Creek Mainstem (23.38 km)	07/22/06	67.5	07/25/06	66.1	5	0	0
Divide Creek Mainstem (17.07 km)	07/22/06	78.5	07/24/06	76.6	22	12	2
Divide Creek Mainstem (13.30 km)	07/22/06	74.0	07/24/06	72.4	17	0	0
Divide Creek Mainstem (4.30 km)	07/24/06	77.2	07/24/06	76.3	18	9	0
Divide Canal Inflow	07/23/06	71.5	07/23/06	70.2	13	0	0
Divide Creek Mainstem (3.65 km)	07/23/06	71.5	07/24/06	70.3	12	0	0
Divide Creek Mainstem (0.0 km)	07/21/06	76.2	07/20/06	74.4	18	2	0

Along Divide Creek, the average percent effective shade is 22 percent and the target is 27 percent. Although in two more heavily impacted reaches the effective shade was approximately 5 percent and the target in these areas is 14 percent. These two areas, which were identified at the beginning of this section, should be prioritized for riparian restoration. These were the only two reaches where temperature standards were exceeded.

8.4.3.2 Temperature Summary for Divide Creek

The Heatsource v7.0 modeling effort for Divide Creek suggested that the 7-day average of the daily maximum temperature (7-DADmax) currently exceeds the “naturally occurring” level at two locations: stream miles 13.5-7.5 and 4.5-2.5. Inflows from the Divide Canal increased the streamflow and decreased instream water temperatures in the lower 2.5 miles of Divide Creek. A temperature TMDL will be completed for Divide Creek because standards are exceeded. The TMDL will call for heat reductions influenced by increasing shade from improved riparian vegetation in the reaches identified above. Stream flow does not appear to have significant impact to temperature other than reducing temperatures in the lower portion of the stream.

8.5 Temperature TMDLs

Total maximum daily loads are based on the loading of a pollutant to a water body. In the case of temperature, thermal heating or loading is assessed. Federal Code indicates that for each thermally listed water body the total maximum daily thermal load cannot be exceeded in order to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife. Such estimates shall take into account the water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters. Under the current regulatory framework for development of TMDLs, flexibility has been allowed for specifying allocations since *"TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure."* The main document of this TMDL uses other measures to fulfill requirements of Section 303(d) of the Clean Water Act. Development of surrogate allocations and an implicit margin of safety following U.S. EPA guidance (EPA, 1999) is appropriate for the main document in this case because a loading based approach would not provide additional utility and the intent of the TMDL process is achieved by using other appropriate measures in the main document. Additionally, there are no point sources that affect heat in the watershed. However, U.S. EPA recently has requested numeric daily time steps for all TMDLs; therefore, these are presented in **Appendix F**. Also, Instantaneous (by the second) Maximum Loads (IMLs) are also provided in **Appendix F** because averaged daily loading timeframes do not address the critical periods when temperature conditions affect uses in the Big Hole Watershed. Afternoon temperatures during the heat of the summer are the most critical timeframe for fishery impacts.

There are no known point sources contributing to thermal loading in the watershed. Nonpoint source (NPS) thermal loading presents a scenario that differs from most pollutants because the "sources" are not heat sources in the true sense. Rather, they are alterations to riparian vegetation, channel geometry, and flow volumes which lead to increased insulation of the water and decreased thermal inertia. These factors ultimately promote warmer or cooler water temperatures by influencing thermal transfer from the surrounding environment to the stream. As detailed in the existing conditions, these alterations are apparent along some reaches of the Big Hole River and Divide Creek. Because of their role in influencing temperature regime and thermal loading, these "sources" will be referred to as influential factors.

Modeling results provided much of the technical framework for developing a surrogate-based temperature TMDL and allocation approach (**Appendices I and J**). Influences to instream temperatures are not always intuitive at a watershed scale and the modeling effort helped estimate the relative effects that stream shading, channel geometry, and stream flow have on temperature during the hottest time of year. Field assessment data and best professional judgment from a team of professionals are also incorporated into the temperature allocation process because there are inherent uncertainties and assumptions associated with modeling results.

The temperature TMDLs based upon influential factors, will result in the thermal loading reduction necessary to obtain compliance with Montana's temperature water quality standards. The applicable standard for the temperature limited streams in the Middle and Lower Big Hole TPA are a 0.5ºF increase above "naturally occurring" temperatures during timeframes that are naturally above 66.5ºF. The allocation for thermal load reduction will be expressed as surrogate measurements in this section of the main document because restoration approaches tie into this strategy. Load based TMDLs are provided in **Appendix F**. The surrogates for thermal loading include four approaches to reduce thermal loading:

- The percent change in riparian canopy cover over the river that will achieve reference potential, applied to the sources that are currently limiting shade.
    - *Human Influences:* Almost all of the impact to riparian canopy cover is due to present or historic agricultural activities.

   - *Link to thermal conditions*:
     More shading reduces sunlight, and thus heat, entering the stream.
     Riparian vegetation creates a microclimate that is cooler than the surrounding landscape.
- Percent reduction in bankfull width to depth ratio of the Upper and Middle Big Hole River channel geometry.
   - *Human Influences*: Almost all of the impact to width to depth ratios in the Upper Big Hole River is due to present or historic agricultural activities. The impacts in the Middle Big Hole River segment are likely a combination of many historic impacts and potentially some natural considerations.
   - *Link to thermal conditions*:
     Lower width to depth ratio equates to a deeper, narrower channel that has small contact area with warm afternoon air.
     Lower width to depth ratio will increase the effectiveness of shading produced by the riparian canopy.
- Increase instream flow volume due to voluntary reasonable irrigation water management practices and water leasing system that fit into existing water right framework.
   - *Human Influences*: All of the impact to reduced stream flow is due to agricultural activities.
   - *Link to thermal conditions*:
     Increased water volume can attenuate a given thermal load to a lower temperature than a lesser volume of water.
     More water in the stream channel decreases the surface area to water volume ratio. A decreased surface to volume ratio decreases the attenuation capacity of the stream.
- Reduction in warm water irrigation return flows via adaptive management approach.
   - *Human Influences*: Return flows may result from the agricultural irrigation system.
   - *Link to thermal conditions*:
     Increased thermal load

Thermal conditions within the Big Hole River are largely the result of complex interactions among the factors outlined above, which prevents an easy interpretation of the influence of each one separate from the others. Modeling results indicate that all of these factors are affecting temperature in the Upper Big Hole River. The following section will provide surrogate load allocation approaches. The allocations indicate the relative change needed for each temperature influencing factor. If allocations are met in combination, they will achieve Montana’s temperature standards. All thermal load reductions from the surrogate TMDL approach are allocated to agricultural activities and can be achieved by applying reasonable land, soil, and water conservation practices. The allocation approach was built upon reference conditions within the watershed where conservation practices are in use, but the land is supporting agricultural activities.

8.5.1 Big Hole River, Middle Segment (Pintlar Creek to Divide Creek)

8.5.1.1 Source Assessment

Upstream impacts within the upper and North Fork Big Hole TMDL planning areas are a significant source of thermal load to this segment of the Big Hole River. See the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach document to identify sources upstream of Pintlar Creek. Sources upstream include reduced stream bank canopy, inefficient irrigation during hot summer timeframes, and wide stream channels. Most of the impacts to these influencing factors come from agricultural practices.

Aerial photo evaluations indicated reduced shrub cover and a very wide, shallow channel was evident along the Big Hole River from Pintlar Creek (upstream extent of this river segment) to Wise River. Below Wise River there are very localized impacts to riparian communities and a naturally armored channel in a confined canyon controls the channel dimension. A key factor in assessing riparian vegetation was a natural shift from climax riparian types above and below Wise River. Shrubs, mainly willow, are a significant component of climax riparian vegetation above Wise River, while cottonwood galleries begin to appear downstream of Wise River. The aerial photo and streamside vegetation monitoring results indicate lack of shading and a wide channel are significant factors influencing thermal loading on the upper portion of this segment above Wise River.

Stream flow and temperature monitoring indicate large groundwater inputs near Wise River reduce temperatures naturally. This includes a large spring creek that should be considered as a cold source of water that could further mitigate heated water. Also, cooler water from the Wise River mixes with the heated water from the Big Hole River. Therefore, much of the natural and human influenced heating from the upper Big Hole Valley is dissipated in this area. Modeling results indicate that these influences, along with stream bed inflow from groundwater, almost 'reset' the thermal conditions and negate the human influences from upstream (**Appendix I**).

8.5.1.2 TMDL and Allocations

The Heatsource v7.0 model indicated that increasing riparian shade, decreasing channel width/depth ratios and improving summer-season streamflows through increased irrigation efficiency, will result in significant temperature reductions in the middle segment of the Big Hole River above Wise River (**Appendix I**). A decrease in width/depth ratios, increasing riparian vegetation produced shade, and increasing irrigation efficiencies during the heat of the summer in the upper segment of the Big Hole River (above Pintlar Creek) is also a vital factor in reducing stream temperatures within the middle segment of the Big Hole River. See the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach document for allocations within the upper Big Hole Watershed (above Pintlar Creek).

The TMDL is the sum of the allocations and the allocations are the heat reduction associated with each of the allocated changes to influencing factors identified in **Table 8-10**. Allocations for shade in the middle segment of the Big Hole River involve increasing stream bank canopy density on many banks to 80 percent willows and 20 percent grass cover upstream of Wise River. This would achieve an average percent effective shade anywhere from 1.7 to 7.9 percent depending upon the reach (**Table 8-10**). Allocations for width/depth ratios involve decreasing the width/depth ratio to ≤ 60 in the middle segment of the Big Hole River from Pintlar Creek to just downstream of the Deep Creek confluence (see **Table 2** in **Appendix I** for reach specifics).

Increased stream flow through improvements in irrigation efficiency during hot summer months require a watershed wide restoration approach and should be applied throughout the Big Hole River Watershed. A 15 percent increase in irrigation efficiency applied to instream flows during the summer months was used in the model to demonstrate how summer time irrigation efficiencies could affect stream temperatures in the middle segment of the Big Hole River. All reasonable irrigation water management practices with water savings applied to instream flow via a local, voluntary approach is needed for increasing dissipative capacity of the River. Regional irrigation infrastructure and management studies indicate this increase is likely feasible.

Table 8-10. Temperature TMDL and allocations for the Middle Segment of the Big Hole River.

Temperature Surrogates	Stream		Targets and Existing Conditions	Load Allocations - The thermal load reduction associated with:
Thermal Load Surrogates				
Percent Effective Shade	Middle Big Hole River	Pintlar Creek to Mudd Creek Bridge	From 1.4% to 1.7%	15% increase in shade
		Mudd Creek Bridge to Deep Creek	From 4.8% to 5.1%	5% increase
		Deep Creek to Wise River	From 3.5% to 3.8%	9% increase
		Wise River to Butte Diversion	7.9%	No decrease
	See the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach document for allocations within the upper Big Hole Watershed (above Pintlar Creek).			
	See riparian vegetation targets of the sediment TMDLs for tributary streams to the Middle Big Hole River segment (**Section 5**).			
Width-to-depth ratio	Big Hole River		Decrease the median W/D ratio from 92 to $\leq$ 60 above Wise River	34% decrease
	See the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach document for allocations within the upper Big Hole Watershed (above Pintlar Creek).			
	See Sediment TMDLs for tributary streams to the Middle Big Hole River segment (**Section 5**).			
Irrigation Return Flows	Big Hole River and Tributaries		Unknown but likely a minor source. Address in adaptive management	If present, reduce warm water irrigation return flows by 50%
AND Assimilative Capacity Surrogates follow (not an allocation):				
In-stream Flow	Big Hole River and Tributaries		Stream flows are often below flows recommended for most sensitive uses.	All reasonable irrigation and urban (Butte) water management practices with water savings applied to in-stream flow on mainstem and tributaries via a local, voluntary approach.

8.5.2 Big Hole River, Lower Segment

8.5.2.1 Source Assessment

The Heatsource v7.0 model indicated that increasing riparian shade and improving summer-season streamflows through increased irrigation efficiency will result in temperature reductions in the lower segment of the Big Hole River. Improving summer time irrigation efficiency and preserving that water for instream flow will likely have the largest cooling effect for the river; although shade provided by riparian vegetation is reduced in very limited areas. According to monitoring and subsequent modeling efforts these areas heat the river only slightly (**Appendix I**). Increasing instream flow from improved irrigation efficiency is the most significant factor in reducing temperatures. Streamflow is a key factor for reducing instream temperatures. Increased flows dissipate heat and result in lower temperatures.

8.5.2.2 TMDL and Allocations

The TMDL is the sum of the allocations and the allocations are the heat reduction associated with each of the allocated changes to influencing factors identified in **Table 8-10**. Allocations for shade involve increasing riparian shade in all reaches of the river from the Butte Diversion to the confluence with the Jefferson River. This would be achieved by increasing percent effective shade near the stream channel to 14.7-3.2 percent depending upon the reach (**Table 8-11**). Depending upon the reach, the allocations to activities which affect riparian shade will be the heat reductions associated with increasing effective shade by 3.5 to 52 percent depending upon the reach of this river. Also, heat associated with warm tributaries will be addressed by sediment TMDL targets.

Increased stream flow through improvements in irrigation efficiency during hot summer months require a watershed wide restoration approach and should be applied throughout the Big Hole River Watershed. A 15 percent increase in irrigation efficiency applied to instream flows during the summer months was used in the model to demonstrate how summer time irrigation efficiencies could affect stream temperatures in the middle segment of the Big Hole River. All reasonable irrigation water management practices with water savings applied to instream flow via a local, voluntary approach is needed for increasing dissipative capacity of the River. Regional irrigation infrastructure and management studies indicate this increase is likely feasible.

Table 8-11. Temperature TMDL and allocations for the Lower Segment of the Big Hole River.

Temperature Surrogates	Stream		Targets and Existing Conditions	Load Allocations - The thermal load reduction associated with:
Thermal Load Surrogates				
Percent Effective Shade	Lower Big Hole River	Butte Diversion to lower end of Maiden Rock Canyon	From 14.2% to 14.7%	3.5% Increase
		Maiden Rock Canyon to Browns Bridge FAS	From 7.5% to 9.6%	28% Increase
		Browns Bridge FAS to Glen FAS	From 6.3% to 7.5%	19% Increase
		Glen FAS to Notch Bottom FAS	From 2.1% to 3.2%	52% Increase
		Notch Bottom FAS to Pennington FAS	From 3.1% to 4.1%	32% Increase
		Pennington FAS to Jefferson River	From 3.8% to 5.4%	42% Increase
	See riparian vegetation targets applying to sediment TMDLs for tributary streams to the Middle and Lower Big Hole River segments (**Section 5**).			
Width-to-depth ratio	Big Hole River		Decrease the median W/D ratio from 92 to ≤ 60 above Wise River	34% decrease
	See the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach document for allocations within the upper Big Hole Watershed (above Pintlar Creek).			
	See Sediment TMDLs for tributary streams to the Middle Big Hole River segment (**Section 5**).			
Irrigation Return Flows	Big Hole River and Tributaries		Unknown but likely a minor source. Address in adaptive management	If present, reduce warm water irrigation return flows by 50%
AND Assimilative Capacity Surrogates follow (not an allocation):				
In-stream Flow	Big Hole River and Tributaries		Stream flows are often below flows recommended for most sensitive uses.	All reasonable irrigation urban (Butte) water management practices with water savings applied to in-stream flow on mainstem and tributaries via a local, voluntary approach.

8.5.3 Divide Creek

The Heatsource v7.0 model indicated that increasing riparian shade will result in temperature reductions in Divide Creek. Percent effective shade should increase from 22 percent to 27 percent on average along the stream. Thus, an allocation will be the reduction in heat associated with a 23 percent increase in effective shade is applied for Divide Creek. Monitoring and modeling indicated that water use does not significantly heat this stream, and in fact cools the lower reaches of this stream via a diversion and irrigation returns from the Big Hole River (**Appendix I**). Also, all reasonable urban water management practices that save water and apply it to instream use should occur. Butte withdraws water in the Divide Creek headwaters for urban drinking water, irrigation and industrial uses.

8.6 Margin of Safety and Seasonal Considerations

All TMDL/Water Quality Restoration Planning documents must consider the seasonal variability, or seasonality, on water quality impairment conditions, maximum allowable pollutant loads in a stream, and load allocations. TMDL development must also incorporate a margin of safety into the load allocation process to account for uncertainties in pollutant sources and other watershed conditions, and ensure (to the degree practicable) that the TMDL components and requirements are sufficiently protective of water quality and beneficial uses. This section describes, in detail, considerations of seasonality and a margin of safety in the temperature TMDL development process.

The margin of safety is addressed in several ways as part of this document:

- Montana's water quality standards are applicable to any timeframe and any season. The temperature modeling analysis investigated temperature conditions during the heat of the summer when the temperature standards are most likely exceeded.
- Targets provide guidance on both temperature conditions in relation to Montana's temperature standards and to surrogate measures that will influence temperatures.
- Surrogate based TMDL allocation approaches are provided in the main document.
- Montana has also built an inherent margin of safety into Montana's temperature standards. In effect, Montana's standard for B1 streams incorporates a combined load allocation and wasteload allocation equal to 0.5-1°F depending on naturally occurring temperature conditions at any time of the year. This small shift in allowed temperature increase will protect all beneficial uses in the Middle and Lower Big Hole TPA and should equate to cooler water in the Big Hole River watershed if the three load reduction approaches provided in this document are followed.
- The margin of safety considerations for the thermal surrogate TMDL apply an implicit safety factor, because if they are fully achieved, would reduce temperatures to naturally occurring levels without the standards consideration of 0.5°F or 1°F heating above naturally occurring temperatures.
- The assessment addressed instream flows that affect the streams dissipative capacity to absorb heat.
- Compliance with targets and refinement of load allocations are all based on an adaptive management approach that relies on future monitoring and assessment for updating planning and implementation efforts.

Seasonal considerations are significant for temperature. Obviously, with high temperatures being a primary limiting factor for Arctic grayling and other coldwater fish in the Big Hole River, summer temperatures are a paramount concern. Therefore, focusing on summer thermal regime is an appropriate approach. Seasonality addresses the need to ensure year round beneficial use support. Seasonality is addressed in this TMDL document as follows:

- Temperature monitoring occurred during the summer season, which is the warmest time of the year. Modeling simulated heat of the summer conditions when instream temperatures are most stressful to the fishery. The fishery is the most sensitive use in regard to thermal conditions.
- Temperature targets apply year round, but are most applicable to summer conditions.
- Restoration approaches will help to stabilize stream temperatures year round and may prevent anchor ice, which would limit fish habitat and food sources during the winter.

8.7 Adaptive Management

An adaptive management process in Montana TMDL law allows for feedback on the progress of restoration activities and status of beneficial uses. If restoration activities occur in the watershed which significantly address the allocations or TMDL, future monitoring should be implemented to determine the progress toward meeting the TMDL. At that point, TMDL components may be changed to improve ways of achieving and measuring success based upon new information. USGS gage data, with associated temperature data, should continue to be collected to track long term flow and temperature conditions. Restoration projects should be tracked at a watershed scale and monitored for efficiency.

Tributary thermal, stream discharge and irrigation management assessments would be useful for further defining the potential for thermal restoration within each tributary and for assessing the cooling effects each tributary would provide to the Big Hole River.

8.8 Monitoring Plan

Monitoring temperature should be conducted long term at the existing USGS gaging stations, including:

- below Mudd Creek (06024540)
- at Maiden Rock (06025250)
- near Melrose (06025500)
- near Glen (06026210)
- below Hamilton Ditch near Twin Bridges (06026420)

Temperature monitoring in Divide Creek could also involve the establishment of a temperature monitoring network. Increased canopy density and decreased width/depth ratios should be monitored using similar methods employed in the 2006 temperature study (**Appendices I and J**) to assure that results are comparable. An assessment of flows in irrigation ditches should also be undertaken throughout the irrigation season. In addition, riparian canopy density monitoring for further apportioning of shade impacts to specific sources may be needed to refine restoration actions in specific areas. Long term tracking of stream bank shade and summer time stream flow producing restoration projects should be initiated.

SECTION 9.0
FRAMEWORK WATER QUALITY RESTORATION STRATEGY

9.1 Summary of Restoration Strategy

This section provides a framework strategy for water quality restoration in the Middle and Lower Big Hole watershed, focusing on how to meet conditions that will likely achieve the TMDLs presented in this document. This section identifies which activities will contribute the most reduction in pollutants for each TMDL. Limited information about spatial application of each restoration activity will be provided.

This section should assist stakeholders in developing a more detailed adaptive Watershed Restoration Plan (WRP) in the future. The locally-developed WRP will likely provide more detailed information about restoration goals and spatial considerations within the watershed. The WRP may also encompass broader goals than the focused water quality restoration strategy outlined in this document. The intent of the WRP is to serve as a locally organized "road map" for watershed activities, sequences of projects, prioritizing types of projects, and funding sources towards achieving local watershed goals, including water quality improvements. Within this plan, the local stakeholders would identify and prioritize streams, tasks, resources, and schedules for applying Best Management Practices (BMPs). As restoration experiences and results are assessed through watershed monitoring, this strategy could be adapted and revised by stakeholders based on new information and ongoing improvements.

Sediment, nutrient, and temperature TMDLs were recently completed for the Upper and North Fork Big Hole TPA (DEQ 2009). That TPA is within the watershed of the Middle and Lower Big Hole River, and the restoration strategy within the Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach (DEQ 2009) is very similar to the strategy within this document. The WRP for the Middle and Lower Big Hole TPA should either be developed in conjunction with or should coordinate with the WRP for the Upper and North Fork Big Hole TPA.

9.2 Role of DEQ, Other Agencies, and Stakeholders

The DEQ does not implement TMDL pollutant reduction projects for nonpoint source activities, but can provide technical and financial assistance for stakeholders interested in improving their water quality. The DEQ will work with participants to use the TMDLs as a basis for developing locally-driven WRPs, administer funding specifically to help fund water quality improvement and pollution prevention projects, and can help identify other sources of funding.

Because most nonpoint source reductions rely on voluntary measures, it is important that local landowners, watershed organizations, and resource managers continue to work collaboratively with local and state agencies to achieve water quality restoration which will progress toward meeting water TMDL targets and load reductions. Specific stakeholders and agencies that have been, and will likely continue to be, vital to restoration efforts include the Big Hole Watershed Committee (BHWC), Big Hole River Foundation, USFS, NRCS, DNRC, FWP, and DEQ. Other organizations and non-profits that may provide assistance through technical expertise, funding, educational outreach, or other means include Montana Water Trust, Montana Water Center, University of Montana Watershed Health Clinic, and MSU Extension Water Quality Program.

9.2.1 Coordinated Effort between Fishery and Water Quality Restoration

Many of the restoration strategies in this section fall in line with another important watershed conservation effort, the Candidate Conservation Agreement with Assurances (CCAA) (USFWS and MFWP, 2006). The CCAA agreement between MFWP and the US Fish and Wildlife Service affords private landowners who implement specified conservation practices on their lands protection from additional regulations in the event that the Arctic grayling would receive protection under the Endangered Species Act (ESA). The CCAA agreement includes the entire Upper and North Fork Big Hole TPA and the upper portion of the Middle and Lower Big Hole TPA. Its lower boundary extends to just upstream of the Dickie Bridge (**Figure A-11**). In the Middle and Lower Big Hole, the majority of the Arctic grayling priority habitat areas are located on private lands. Final goals of TMDL and CCAA efforts may differ, but the two processes are linked. Water quality laws in Montana are set to protect all beneficial uses of a stream, with fish and aquatic life being some of the most sensitive. TMDLs are provided to protect all uses, including grayling, against adverse conditions that increased pollutant loads may cause.

The CCAA specifies a series of key restoration actions for stream areas supporting Arctic grayling, including maintenance of clean water flows and riparian/stream restoration. In addition, the CCAA assigns agency and landowner responsibilities for implementation of conservation activities and provides extensive landowner participation. These CCAA elements facilitate implementation of restoration activities conserving Arctic grayling populations, as well as supporting beneficial water uses. Many of the CCAA fishery restoration activities will overlap with restoration activities outlined in this document, especially riparian habitat improvement, bank erosion restoration, stream channel stability, and stream flow improvements. Although the specific goals of restoration differ between the CCAA and TMDL, areas targeted for implementation of CCAA fishery projects and TMDL water quality improvement projects may overlap at times, and restoration funding and activities should be coordinated.

9.3 Watershed Restoration Goals

The following are general water quality goals provided in this TMDL document:

- Provide technical guidance for full recovery of aquatic life beneficial uses to all impaired streams within the Middle and Lower TPA by improving sediment, nutrient, metal, and temperature water quality conditions. This technical guidance is provided by the TMDL components in the document which include:
    - water quality targets,
    - pollutant source assessments, and
    - general restoration guidance which should meet the TMDL allocations.
- Assess watershed restoration activities to address significant pollutant sources. Costs and benefits are both generally considered, although this analysis does not use a detailed cost/benefit analysis. General spatial guidance will be provided for restoration activities.

A WRP is a locally-derived plan that can be more dynamic than the TMDL document. It can be refined as activities progress and address more broad goals than those included in this TMDL document. The following elements may be included in a stakeholder-derived WRP in the near future:

- Support for implementing restoration projects to protect water conditions so that all streams in the watershed maintain good water quality with an emphasis on waters with TMDLs completed.
- More detailed cost/benefit analysis and spatial considerations for water quality improvement projects.
- Develop an approach for future BMP installment and efficiency results tracking.
- Provide information and education components to assist with stakeholder outreach about restoration approaches, benefits and funding assistance.
- Other various watershed health goals.
- Weed control initiatives
- Other local watershed based issues.

Specific water quality goals (i.e. targets) for each pollutant are detailed in the section pertaining to each pollutant (**Sections 5-8**). These targets serve as the basis for long-term effectiveness monitoring for achieving the above water quality goals. These targets specify satisfactory conditions to ensure protection and/or recovery of beneficial uses of water bodies in the Middle and Lower Big Hole TPA. **Section 10** identifies a general monitoring strategy and recommendations designed to track implementation water quality conditions and restoration successes.

9.4 Overview of Management Recommendations

Sediment TMDLs were completed for 26 water body segments, including the middle segment of the Big Hole River. Temperature TMDLs were completed for the middle and lower segments of the Big Hole River and Divide Creek, and nutrient TMDLs were completed for five tributaries to the Big Hole River. TMDLs were completed for a variety of metals on 11 water body segments, including the middle segment of the Big Hole River. Other streams in the watershed may be in need of TMDLs, but insufficient information about them precludes TMDL formation at this time. In general, sediment, thermal, and nutrient loading can all be greatly reduced by focusing restoration efforts on streamside riparian restoration and long term riparian zone management. Stream channel restoration may be necessary in areas that have lost channel integrity due to long term riparian vegetation impacts. Other sediment restoration actions include unpaved road erosion control near streams. The most notable nutrient specific restoration approach, besides streamside riparian vegetation restoration, includes fertilizer and irrigation management. Temperature TMDL attainment will depend upon improving stream shade using increased riparian vegetation, stream channel narrowing/deepening, and irrigation and stockwater conservation management on both the Big Hole River and significant tributaries. Activities that reduce sediment loading will also decrease metals loading, but abandoned mines are the most important source to target for metals restoration.

9.4.1 Sediment Restoration Approach

Streamside riparian vegetation restoration and long term riparian area management are vital restoration practices that must be implemented across the watershed to achieve the sediment TMDLs. Vigorous native streamside riparian vegetation provides root mass which hold streambanks together. Suitable root mass density ultimately slows bank erosion. Riparian vegetation filters sediment from upland runoff. Therefore, improving riparian vegetation will decrease bank erosion by improving streambank stability and will also reduce sediment delivery from upland sources. Sediment is also deposited more heavily in healthy riparian zones during flooding because water velocities slow in these areas enough for excess sediment to settle out.

The predominant cause of riparian and stream channel degradation in the Middle and Lower Big Hole TPA comes from grazing of domesticated livestock in and near streams. Restoration recommendations involve improved grazing management, including the timing and duration of grazing, the development of multi-pasture systems that include riparian pastures, and the development of off-site watering areas. Additionally, grazing management, combined with some additional fencing costs in many riparian areas, would promote natural recovery. Active vegetation planting along with bank sloping may increase costs, but still remains within a reasonable and relatively cost effective restoration approach. When stream channel restoration work is needed because of altered stream channels, costs increase and projects should be assessed on a case by case basis. In general, these are sustainable agricultural practices that promote attainment of conservation objectives while meeting agricultural production goals. The BMPs aim to prevent availability, transport, and delivery of sediment by a combination of minimizing sediment delivery, reducing the rate of runoff, and intercepting sediment transport. The appropriate BMPs will differ by landowner and are recommended to be part of a comprehensive farm/ranch plan.

Although roads may be a small source of sediment at the watershed scale, sediment derived from roads may cause significant localized impact in some stream reaches. Restoration approaches for unpaved roads near streams should be to divert water off of roads and ditches before it enters the stream. The diverted water should be routed through natural healthy vegetation, which will act as filter zones for the sediment laden runoff before it enters streams. Sediment loads from culvert failure and culvert caused scour were not assessed by the TMDL source assessment, but should be considered in road sediment restoration approaches.

Areas that have increased erosion as a result of mining-related atmospheric deposition should be evaluated within the WRP. As the result of a 2008 Consent Decree between the State of Montana, the EPA, and the Atlantic Richfield Company (ARCO), reclamation of soils affected by the Anaconda Smelter is currently planned for 2010 on the Clark Fork side of Mt. Haggin, but affected soils in the Big Hole watershed are not currently eligible for funding from the settlement (Greg Mullen, pers. comm., 2008). However, activities such as revegetation and limited shrub plantings, which will be used during the reclamation, are also applicable to affected soils in the Big Hole watershed. Historic placer mining activities may have very localized impacts that affect sediment production within the watershed. If found, mining caused sediment sources that can be restored at reasonable costs could be prioritized into the watershed restoration plan. Any other unknown sediment sources could also be incorporated into the watershed restoration plan while considering cost and sediment reduction benefits.

All of these best management practices are considered reasonable restoration approaches due to their benefit and generally low costs. Riparian restoration and road erosion control are standard best management practices identified by NRCS, and are not overly expensive to our society. Although the appropriate BMP will vary by water body and site, controllable sources and BMP types can be prioritized by watershed to reduce sediment loads in individual streams between 8 and 40 percent (**Table 9-1**).

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
Big Hole River, middle segment	191,651	28%	1	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Includes bank erosion in Upper Big Hole. Bank erosion minimal along mainstem, though several tributaries are major contributors of sediment. Increase riparian shrub density, reduce channel width/depth ratios, increase floodplain access, and facilitate multi-channel system processes along mainstem.
			2	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Most applicable to tributary streams.
Birch Creek, upper segment	2,015	13%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Unpaved roads	Road maintenance and runoff BMPs	Road paralleling portion of stream. Large culvert with fill in floodplain.
Birch Creek, lower segment	3,827	21%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Interbasin water transfer reduces streamflow. Active grazing management occurring.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
California Creek	1,328	32%	1	Upland sediment from smelter fallout and grazing	Riparian grazing management and upland vegetation restoration in smelter fallout areas.	Atmospheric deposition of toxic precipitates from Anaconda Smelter may reduce revegetation success.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily in meadow sections downstream of the confluence with Sixmile Creek.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Camp Creek	3,450	29%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed. Reservoir likely acts as a sediment trap.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Improve irrigation infrastructure to reduce geomorphic impacts.
			3	Unpaved roads	Road maintenance and runoff BMPs	Road paralleling portion of stream. Road crosses several highly erosive ephemeral tributary channels downstream of the reservoir.
Corral Creek	446	24%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Particularly in the lower meadow reaches, where Corral Creek, Sevenmile Creek and Tenmile Creek come together.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Deep Creek	9,180	15%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Extensive erosion on several tributaries, including California, French, Sixmile and Corral creeks. Also erosion on mainstem of Deep Creek above/below the confluence with French Creek. Riparian fencing has recently been added to portion of Deep Creek.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed, particularly on tributaries.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
Delano Creek	129	17%	1	Upland sediment from grazing	Riparian grazing management	Primarily in lower watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily in lower watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in upper watershed.
Divide Creek	4,783	12%	1	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Limited due to decreased streamflows from water withdrawls.
			2	Upland sediment from grazing	Riparian grazing management, Move haying from riparian greenline	Mainstem flows through irrigated agriculture.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily along tributary streams.
Elkhorn Creek	491	22%	1	Upland sediment from grazing	Riparian grazing management	Limited in watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration	Limited to area flowing through abandoned mine site.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in lower watershed.
Fishtrap Creek	3,234	18%	1	Upland sediment from grazing	Riparian grazing management	Primarily in lower watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Extensive beaver dams in lower watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in lower watershed. Upper Watershed is Wilderness Area.
French Creek	3,773	22%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative	Riparian vegetation restoration, riparian grazing management	On French Creek, as well as tributary streams. Primarily in meadow sections. Also placer mined reaches.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
				condition		
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Gold Creek	729	19%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily in meadow sections in lower watershed.
Grose Creek	294	40%	1	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Portion of channel severely entrenched with exposed eroding banks.
			2	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Jerry Creek	2,640	19%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Throughout watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Lost Creek	742	21%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Small stream with relatively low banks.
			3	Unpaved roads	Road maintenance and runoff BMPs	Road paralleling much of stream.
Moose Creek	2,334	24%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed, particularly in upper watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Upper watershed and downstream of I-15 crossing.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
			3	Unpaved roads	Road maintenance and runoff BMPs	Portion of creek flows through a Wilderness Study Area.
Oregon Creek		19%	1	Upland sediment from grazing	Riparian grazing management	Atmospheric deposition of toxic precipitates from Anaconda Smelter may reduce revegetation success.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration	At Highway 257 crossing.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Pattengail Creek	2,626	8%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily related to historic dam failure.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in lower watershed.
Rochester Creek	2,288	32%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Mining impacts and channelization for irrigation use. Headcutting observed at several sites.
			3	Unpaved roads	Road maintenance and runoff BMPs	Road paralleling much of stream.
Sawlog Creek	373	18%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed. Electric fence may currently be used.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Throughout watershed, particularly from mile 1 to mile 3 upstream from the confluence with the Big Hole River.
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in lower watershed.
Sawlog Creek	373	18%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed. Electric fence may currently be used.
			2	Eroding banks needing sustainable riparian zone	Riparian vegetation restoration, riparian grazing management	Throughout watershed, particularly from mile 1 to mile 3 upstream from the confluence with the Big Hole River.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
				vegetative condition		
			3	Unpaved roads	Road maintenance and runoff BMPs	Primarily in lower watershed.
Sevenmile Creek	468	18%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily in meadow sections of lower watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Sixmile Creek	528	24%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Primarily in meadow sections of lower watershed near Mule Ranch.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.
Soap Creek	1,233	18%	1	Upland sediment from grazing	Riparian grazing management	Upper watershed has a confined valley that directs cattle into the valley bottom.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Small stream with relatively low banks.
			3	Unpaved roads	Road maintenance and runoff BMPs	Road paralleling much of stream.
Trapper Creek	3,326	22%	1	Upland sediment from grazing	Riparian grazing management	Throughout watershed.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Throughout watershed.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed. Road parallels portion of stream. Headwaters areas are likely impacted by road sediment entering streams. Road BMPs are an important restoration strategy in this watershed.

Table 9-1. Summary of Sediment Load Reductions and Ranked Restoration Strategy by watershed

Name of Water body	Current Sediment Loads (tons per year)	TMDL Sediment Load Reduction (% of total load)	Source and Restoration Rank	Ranked Controllable Sources	Ranked BMP Type	Spatial Concerns
Wise River	12,037	34%	1	Upland sediment from grazing	Riparian grazing management	Particularly in meadow reaches and tributaries.
			2	Eroding banks needing sustainable riparian zone vegetative condition	Riparian vegetation restoration, riparian grazing management	Partially related to historic dam failure downstream of Pattengail Creek.
			3	Unpaved roads	Road maintenance and runoff BMPs	Throughout watershed.

9.4.2 Nutrient Restoration Approach

Restoration recommendations for nutrient impaired streams in the Middle and Lower Big Hole TPA primarily involve improved grazing management and improved management of irrigation water, along with fertilizer application and runoff from croplands. The goal of the nutrient restoration recommendations is to reduce nutrient input to stream channels by increasing the filtering and uptake capacity of riparian vegetation areas, decreasing the amount of bare ground, and limiting the transport of nutrients off of irrigated croplands. The following restorations recommendations apply to one or more of the nutrient impaired stream segments, with segment specific recommendations presented in **Table 9-2**:

- Improve streamside grazing management,
- Develop off-stream watering for livestock,
- Improve management of irrigation systems and fertilizer applications, and
- Incorporate streamside vegetation buffer to irrigated croplands and confined feeding areas

In addition to the agricultural related BMPs, a reduction of sediment delivery from roads and eroding streambanks is another component of the nutrient reduction restoration plan. Additional sediment related BMPs are presented in **Section 9.4.1**. Note that Grose Creek and Lost Creek generally go dry upstream of the area of irrigated agriculture, while Camp Creek and Soap Creek are intercepted by irrigation ditches prior to their confluences with the Big Hole River.

Table 9-2. Restoration Recommendations for Nutrient Impaired Streams.

Stream Segment	Restoration Recommendations	Restoration Priority Rating	Potential Parties Involved
Jerry Creek	improve riparian grazing management	High	BDNF, BLM, State of MT, BHWC
	develop off-stream watering	Moderate	BDNF, BLM, State of MT, BHWC
Camp Creek	improve riparian grazing management	High	BDNF, BLM, BHWC
	develop off-stream watering	Low	BDNF, BLM, BHWC
	incorporate riparian buffer to irrigated croplands and confined feeding areas	High	BHWC, private, NRCS
	improve management of irrigation return flows and fertilizer management	Moderate	BHWC, DNRC
	reduce sediment inputs from unpaved road paralleling stream	Moderate	BDNF, BLM
Divide Creek	improve grazing management	High	BDNF, BHWC
	develop off-stream watering	Moderate	BDNF, BHWC
	examine fertilizer use in the watershed	High	BHWC, DNRC
	incorporate riparian buffer to irrigated croplands and confined feeding areas	Moderate	BHWC
Grose Creek	improve riparian grazing management	High	BLM
	develop off-stream watering	Moderate	BLM
Lost Creek	improve riparian grazing management	Moderate	BDNF, BLM, State of MT
	reduce sediment inputs from unpaved road paralleling stream	Moderate	BDNF, BLM
Soap Creek	improve riparian grazing management	High	BDNF, BLM
	examine impact of irrigation and fertilizer use in the lower watershed	High	BHWC, DNRC
	reduce sediment inputs from unpaved road paralleling stream	Moderate	BDNF, BLM

9.4.3 Metals Restoration Approach

This section outlines strategies for addressing metals loading sources in need of restoration activities within Middle and Lower Big Hole TPA. The restoration strategies focus on regulatory mechanisms and/or programs applicable to the controllable source types present within the watershed; which, for the most part, are associated with historic mining and mining legacy issues. Potential metals loading sources associated with abandoned mines include discharging mine adits and mine waste materials on-site and in-channel. The goal of the metals restoration plan is to limit the input of metals to stream channels from priority abandoned mine sites and other identified sources of metals impairments. Additional analysis is likely required for most of the priority abandoned mine sites to identify site specific metals delivery pathways and to develop mitigation plans.

In addition to high priority abandoned mine sites, atmospheric deposition from the Anaconda Smelter and Glendale Smelter, and also potentially historic placer mining, have led to increased metals loads to several streams in the planning area and should be incorporated into the WRP. Streams affected by aerial deposition from the Anaconda Smelter are concentrated within the Deep Creek watershed and include California Creek, French Creek, and Oregon Creek. The lower portion of the Trapper Creek watershed may also be affected by aerial deposition from the Glendale Smelter. Placer mining occurred sporadically throughout the watershed, but most notably in the California Creek, French Creek and Oregon Creek watersheds. The source assessment indicated that these sources are contributing excess metals via eroding sediment and groundwater. Although restoration of these sources will reduce metals and sediment loading, reductions in groundwater metals concentrations associated with nonpoint sources may be much more difficult to address and may not occur for a long time.

Goals and objectives for future restoration work include the following:

- Prevent soluble metal contaminants or metals contaminated solid materials in the waste rock and tailings materials/sediments from migrating into adjacent surface waters to the extent practicable.

- Reduce or eliminate concentrated runoff and discharges that generate sediment and/or heavy metals contamination to adjacent surface waters and groundwater to the extent practicable.

- Identify, prioritize, and select response and restoration actions based on a comprehensive source assessment and streamlined risk analysis of mine sites.

9.4.4 Temperature Restoration Approach

A temperature TMDL was developed for the Middle and Lower Big Hole River and Divide Creek by means of a temperature model which utilized water temperature, stream flow and streamside vegetation data. This effort collected detailed streamflow and irrigation system flow measurements, but was only a snapshot of irrigation use during the end of July. The approach for attainment of temperature targets is based upon reaching stream channel and streamside vegetation conditions equaling reference areas. Areas in need of increased riparian shade are mostly above Wise River and into the Upper Big Hole Valley and tributaries. Limited areas of decreased shading from Wise River to the confluence with the Beaverhead River also exist, but are less prevalent. Also, the Big Hole River stream channel above Wise River is wide and shallow, which contributes to heating. There is not a simple fix for stream channel restoration on a river this size. Channel restoration between Wise River and Wisdom would be very costly and could have unforeseen impacts, so it should be studied prior to initiation and should be considered a lower priority than restoring stream bank vegetation.

Another very important restoration factor for meeting temperature conditions that support instream uses depends upon irrigation and stock water management with water savings being applied to instream flow during warm summer months. Irrigaiton water management should not only include areas along the Big Hole River but also work on tributaries were cooler streams enters the Big Hole River. These include, but are not limited to, Deep Creek, Fishtrap Creek, Wise River, Mudd Creek, Moose Creek, Willow Creek, Birch Creek and others. Increased stream flows would provide thermal buffering capacity. Irrigation also has a large influence on ground water in the Big Hole valley, which in turn, influences surface water conditions. Irrigation efficiency projects should consider how they could affect cool groundwater return flows during the summer months prior to initiation. Irrigation efficiencies in the upper Big Hole Valley and below Notch Bottom should be the highest priority for temperature restoration. Activities in the watershed are already addressing streamflow, such as CCAA agreements and a Drought Management Plan. However, local coordination and planning are especially important for future flow management activities, because State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705). More detailed irrigation system restoration approaches are presented in **Section 9.5.4**.

9.4.5 Pollution Restoration Approach

Although TMDL development is not required for pollution listings, they are frequently linked to pollutants, and addressing pollution sources is an important component of TMDL implementation. Pollution listings within the Middle and Lower Big Hole TPA include alteration in stream-side or littoral vegetative covers, physical substrate habitat alterations, other anthropogenic substrate alterations, low flow alterations, and other flow regime alterations. Typically, habitat impairments are addressed during implementation of sediment, nutrient, and temperature TMDLs. Although flow alterations have the most direct link with temperature, and temperature TMDLs are the only TMDLs that explicity address flow, adequate flow is also critical for transporting sediment and diluting metals and nutrient inputs. Therefore, if restoration goals within the Middle and Big Hole TPA are not also addressing pollution impairments, additional pollution-related BMP implementation should be considered. Habitat and flow BMPs are discussed below in **Section 9.5**.

The anthropogenic management of the forested uplands within the Big Hole River watershed has affected the structure of the forest community and its interrelations with riparian function and water yield. There exists considerable debate about both the extent and nature of human-caused changes in the forest landscape, and the need and means to address those changes. Though not explicitly addressed within the TMDL and allocations section of this document, this discussion is included as an additional tool for the prioritization of riparian restoration strategies. In focusing on issues relating to forest alteration and restoration in central western Montana, this section is a modest attempt to identify how long term management of fire suppression in forested uplands has the potential to affect water yields and sediment production. In addition this section introduces some basic restoration strategies that could be implemented to offset such affects.

Many upland portions of the Big Hole Watershed are experiencing a substantial increase in the density of conifer species. A combination of historic rangeland grazing, fire suppression and low timber harvest rates in many areas of the watershed has contributed to the increase in conifer woodlands and a reduction in open grasslands. The density of trees, and the aerial extent of these communities, is evidenced by historic photos and the age structure of these woodlands. These trees may effectively out-compete other shrub and herbaceous species resulting in decreased and/or inconsistent water yields. In addition, in many areas conifers represent the natural occurring dominant riparian vegetation. In these areas conifers are critical to shade and stream geomorphology, and are protected via the Montana's Stream Side Zone law. Therefore, any pointed conifer reduction efforts should: use all applicable erosion BMPs, mitigate associated road network, and only reduce confer shade along streams if historic evidence clearly define if conifer encroachment in riparian areas has occurred. This section in no way advocates riparian harvest in areas where mature conifers are the natural stream side vegetation (although prescribed burning in such areas may be appropriate in a case by case basis).

Restoratin approaches which relate to habitat and flow are further discussed below in **Section 9.5**.

9.5 Restoration Approaches by Source

General management recommendations are outlined below for the major sources of human caused pollutant loads in the Middle and Lower Big Hole TPA: grazing, cropland, riparian vegetation removal, irrigation, unpaved roads, and mining-related sources. Applying ongoing BMPs are the core of the sediment reduction strategy, but are only part of the restoration strategy. Restoration activities may also address other current pollution-causing uses and management practices. In some cases, efforts beyond implementing new BMPs may be required to address key sediment sources. In these cases, BMPs are usually identified as a first effort and an adaptive management approach will be used to determine if further restoration approaches are necessary to achieve water quality standards. Monitoring is also an important part of the restoration process. Monitoring recommendations are outlined in **Section 11.0**.

A wide variety of grazing management, riparian restoration, fencing, nutrient management, stockwater efficiency, irrigation efficiency and other watershed restoration improvements have been implemented in recent years in many parts of the Middle and Lower Big Hole TPA. Recent improvements include CCAA restoration efforts, which are limited to upstream of the Dickie Bridge and focus on improving fishery habitat (water quantity and riparian habitat), water quality (thermal and nutrient management), and fish habitat fragmentation (dewatering, barriers to migration, entrainment, and habitat simplification).

9.5.1 Grazing

Development of riparian grazing management plans is a goal for landowners in the watershed who do not currently have such plans. Private land owners may be assisted by state, county federal, and local conservation groups to establish and implement appropriate grazing management plans. Note that riparian grazing management does not necessary eliminate all grazing in these areas. Nevertheless, in some areas, a more restrictive management strategy may be necessary for a period in order to accelerate re-establishment of a riparian community with the most desirable species composition and structure.

Grazing management includes the timing and duration of grazing, the development of multi-pasture systems, including riparian pastures, and the development of off-site watering areas. The key strategy of the recommended grazing BMPs is to develop and maintain healthy riparian vegetation and minimize disturbance of the stream bank and channel. The primary recommended BMPs for the Middle and Lower Big Hole River Watershed are providing off-site watering sources, limiting livestock access to streams and hardening the stream at access points, planting woody vegetation along stream banks, and establishing riparian buffers. Although bank revegetation is a preferred BMP, in some instances bank stabilization may be necessary prior to planting vegetation. Other general grazing management recommendations and BMPs to address grazing sources of pollutants and pollution are listed below (**Table 9-3**). Further information on grazing BMPs can be obtained in **Appendix A** of Montana's NPS Management Plan (DEQ, 2007).

Table 9-3. General grazing/wildlife BMPs and management techniques (from NRCS 2001; DNRC 1999).

BMP and Management Techniques	Pollutants Addressed
Design a grazing management plan and determine the intensity, frequency, duration, and season of grazing to promote desirable plant communities and productivity of key forage species. In this case, native riparian	Sediment, temperature, nutrients
Encourage the growth of woody species (willow, alder, etc.) along the streambank, which will limit animal access to the stream and provide root support to the bank.	Sediment, nutrients, temperature
Establish riparian buffer strips of sufficient width and plant composition to filter and take up nutrients and sediment from concentrated animal feeding operations.	Sediment, nutrients,
Create riparian buffer area protection grazing exclosures through fencing.	Sediment, temperature, nutrients
Maintain adequate vegetative cover to prevent accelerated soil erosion, protect streambanks, and filter sediments. Set target grazing use levels to maintain both herbaceous and woody plants.	Sediment
Ensure adequate residual vegetative cover and regrowth and rest periods. Periodically rest or defer riparian pastures during the critical growth period of plant species.	Sediment, nutrients
Distribute livestock to promote dispersion and decomposition of manure and to prevent the delivery of manure to water sources.	Nutrients
Alternate a location's season of use from year to year. Early spring use can cause trampling and compaction damage when soils and streambanks are wet. If possible, develop riparian pastures to be managed as a separate unit through fencing.	Nutrients, sediment
Provide off-site, high quality water sources.	Nutrients, sediment
Periodically rotate feed and mineral sites and generally keep them in uplands.	Nutrients, sediment
Place salt and minerals in uplands, away from water sources (ideally ¼ mile from water to encourage upland grazing).	Sediment, nutrients, temperature

Table 9-3. General grazing/wildlife BMPs and management techniques (from NRCS 2001; DNRC 1999).

BMP and Management Techniques	Pollutants Addressed
Monitor livestock forage use and adjust strategy accordingly.	Sediment, nutrients, temperature
Monitor and manage beaver populations to trap sediment and slow runoff in some areas of tributaries. If appropriate, manage beaver populations on Big Hole River to reduce riparian tree mortality.	Sediment, temperature
Create hardened stream crossings.	Sediment

9.5.2 Animal Feeding Operations

Animal feeding operations (AFOs) can pose a number of risks to water quality and public health due to the amount of animal manure and wastewater they generate. To minimize water quality and public health impacts from AFOs and land applications of animal waste, the USDA and EPA released the Unified National Strategy for AFOs in 1999 (NRCS 2005). This strategy encourages owners of AFOs of any size or number of animals to voluntarily develop and implement site-specific Comprehensive Nutrient Management Plans (CNMPs) by 2009. This plan is a written document detailing manure storage and handling systems, surface runoff control measures, mortality management, chemical handling, manure application rates, schedules to meet crop nutrient needs, land management practices, and other options for manure disposal. An AFO that meets certain specified criteria is referred to as a Concentrated Animal Feeding Operation (CAFO), and in addition may be required to obtain a Montana Pollution Discharge Elimination System (MPDES) permit as a point source. Montana's AFO compliance strategy is based on federal law and has voluntary, as well as, regulatory components. If voluntary efforts can eliminate discharges to state waters, in some cases no direct regulation is necessary through a permit. Operators of AFOs may take advantage of effective, low cost practices to reduce potential runoff to state waters, which additionally increase property values and operation productivity. Properly installed vegetative filter strips, in conjunction with other practices to reduce waste loads and runoff volume, are very effective at trapping and detaining sediment and reducing transport of nutrients and pathogens to surface waters, with removal rates approaching 90 percent (NRCS 2005). Other options may include clean water diversions, roof gutters, berms, sediment traps, fencing, structures for temporary manure storage, shaping, and grading. Animal health and productivity also benefit when clean, alternative water sources are installed to prevent contamination of surface water. Studies have shown benefits in red meat and milk production of 10 to 20 percent by livestock and dairy animals when good quality drinking water is substituted for contaminated surface water.

Opportunities for financial and technical assistance (including CNMP development) in achieving voluntary AFO and CAFO compliance are available from conservation districts and NRCS field offices. Voluntary participation may aide in preventing a more rigid regulatory program from being implemented for Montana livestock operators in the future.

Further information may be obtained from the DEQ website at: http://www.deq.mt.gov/wqinfo/mpdes/cafo.asp. Montana's NPS pollution control strategies for addressing AFOs are summarized in the bullets below:

- Work with producers to prevent NPS pollution from AFOs.
- Promote use of State Revolving Fund for implementing AFO BMPs.
- Collaborate with MSU Extension Service, NRCS, and agriculture organizations in providing resources and training in whole farm planning to farmers, ranchers, conservation districts, watershed groups and other resource agencies.
- Encourage inspectors to refer farmers and ranchers with potential nonpoint source discharges to DEQ watershed protection staff for assistance with locating funding sources and grant opportunities for BMPs that meet their needs. (This is in addition to funds available through NRCS and the Farm Bill).
- Develop early intervention of education & outreach programs for small farms and ranches that have potential to discharge nonpoint source pollutants from animal management activities. This includes assistance from the DEQ internal (Permitting Division), as well as external entities (DNRC, local watershed groups, conservation districts, MSU Extension, etc.).

9.5.3 Cropland

The primary strategy of the recommended cropland BMPs is to reduce sediment and nutrient inputs. The major factors involved in decreasing sediment loads are reducing the amount of erodible soil, reducing the rate of runoff, and intercepting eroding soil before it enters water bodies. The main BMP recommendations for the Middle and Lower Big Hole Watershed are vegetated filter strips (VFS) and riparian buffers. Both of these methods reduce the rate of runoff, promote infiltration of the soil (instead of delivering runoff directly to the stream), and intercept sediment. Effectiveness is typically about 70 percent for filter strips and 50 percent for buffers (DEQ 2007). Filter strips and buffers are most effective when used in conjunction with agricultural BMPs that reduce the availability of erodible soil such as conservation tillage, crop rotation, stripcropping, and precision farming. Additional BMPs and details on the suggested BMPs can be obtained from NRCS and in **Appendix A** of Montana's NPS Management Plan (DEQ 2007).

Reducing sediment loading will decrease loading of sediment-bound nutrients, but nutrient management is also needed to reduce nutrient loading. Nutrient management is managing the amount, source, placement, form, and timing of plant nutrients and soil amendments. Nutrient management components of the conservation plan should include the following information (NRCS MT 590-1):

- Field maps and soil maps,
- Planned crop rotation or sequence,
- Results of soil, water, plant, and organic materials sample analysis,
- Realistic expected yields,
- Sources of all nutrients to be applied,
- Nutrient budget, including credits of nutrients available,
- Nutrient rates, form, timing, and application method to meet crop demands and soil quality concerns,
- Location of designated sensitive areas, and
- Guidelines for operation and maintenance.

More information about nutrient management techniques can be found at your local NRCS office or in the NRCS publication MT 590-1.

9.5.4 Irrigation

Flow alteration and dewatering are commonly considered water quantity rather than water quality issues. However, changes to stream flow can have a profound effect on the ability of a stream to attenuate pollutants, especially nutrients, metals and heat. Flow reduction may increase water temperature, allow sediment to accumulate in stream channels, reduce available habitat for fish and other aquatic life, and may cause the channel to respond by changing in size, morphology, meander pattern, rate of migration, bed elevation, bed material composition, floodplain morphology, and streamside vegetation if flood flows are reduced (Andrews and Nankervis 1995, Schmidt and Potyondy 2004). Restoration targets and implementation strategies recognize the need for specific flow regimes, and may recommend flow-related recommendations and enhancements as a means to achieve full support of beneficial uses. However, local coordination and planning are especially important for flow management because State law indicates that legally obtained water rights cannot be divested, impaired, or diminished by Montana's water quality law (MCA 75-5-705).

Irrigation management is a critical component of attaining both Arctic grayling conservation and TMDL goals. Irrigation efficiency management practices in the Big Hole Watershed should involve investigating how to reduce the amount of stream water diverted during July and August, while still growing crops on traditional cropland. It may be desirable to promote inefficient irrigation practices earlier in the year to promote groundwater return during July and August. Understanding irrigation water, groundwater and surface water interactions is an important part of understanding how irrigation practices will affect stream flow during specific seasons. Irrigation management is particularly important during periods of drought. As discussed in **Section 2.2.3**, there is a Big Hole Drought Management Plan that was adopted by the Big Hole Water Shed Committee (BHWC) in partnership with FWP, DNRC, and the NRCS. As part of the plan, the BHWC will issue weekly updates to irrigators during drought periods and regular updates as needed during non-drought periods. The plan, which relies on voluntary actions to conserve water, has flow targets for different reaches of the river and an education and outreach component. The CCAA (MFWP and USFWS 2005) also provides a plan to meet stream flow targets. The stream flows in both plans will help meet temperature goals. The CCAA partner agencies, NRCS and DNRC, will be responsible for developing water management plans for participating landowners and ensuring implementation of conservation measures. These landowner agreements include provisions for an implementation schedule requiring that implementation activities begin no later than the date upon which the site-specific landowner plan is finalized.

9.5.4.1 Irrigation Flow Restoration Recommendations

Achieve minimum flow targets
It is unknown if the recommended flows in the CCAA agreement and Big Hole Drought Management Plan can be maintained by installing and using all reasonable irrigation efficiency

management practices. All reasonable irrigation efficiency management practices should be pursued on a voluntary basis. Maintaining these minimum flows in the Big Hole River will require that minimum flows also be maintained in at least some of the tributary streams.

Improving Irrigation Efficiency During Low Streamflow Timeframes
Many of the irrigation practices in the Big Hole Watershed are based in flood irrigation methods. Many head gates and ditches leak, which can decrease the amount of water in-channel flows. The following recommended activities would result in notable water savings.

- Install upgraded head gates for more exact control of water diversions and to minimize leakage when not in operation.
- Develop more efficient means to supply water to livestock.
- Determine necessary amounts of water to divert that would reduce over watering and improve forage quality and production.
- Redesign irrigation systems.
- Upgrade ditches (including possible lining) to increase ditch conveyance efficiency.

The CCAA (MFWP and USFWS 2005) program includes a provision for the NRCS to conduct a comprehensive investigation of existing attributes of water rights on the enrolled lands and determine the suitable irrigation diversion amount needed for production of crops. This investigation will occur within 30 months of participant enrollment. Following determination of the CCAA diversion amount, enrolled landowners will have flexibility to upgrade their irrigation systems using one or several of the listed recommended options above.

Although the CCAA is limited to the upper watershed and applies only to enrolled landowners, the BHWC, in conjunction with the NRCS and DNRC, will work with interested landowners to upgrade their systems and alter cropping and irrigation practices. Additionally, as part of the Big Hole Drought Management Plan, FWP will offer assistance to irrigators who are willing to reduce water diversions. These potential water savings will add to in channel flows during critical timeframes, reduce summer water temperatures, and benefit instream uses.

Irrigation system improvements should not be overlooked in the lower portion of the Big Hole Watershed. Application of irrigation water savings practices to save water for instream uses during the heat of the summer is a high priority for restoration.

Future studies could investigate irrigation water return flow timeframes from specific areas along the Big Hole River and in tributaries. A portion of spring and early summer flood irrigation water likely returns as cool groundwater to the River during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas were year round irrigation efficiencies could be more beneficial to preserving flow in the River during hot summer timeframes. Winter baseflow should also be considered during these investigations.

9.5.5 Riparian Vegetation Removal

Reduction of riparian vegetative cover by various land management activities is a principal cause of water quality and habitat degradation in the Middle and Lower Big Hole TPA. Although implementation of passive BMPs that allow riparian vegetation to recover at natural rates is typically the most cost-effective approach, active restoration (i.e. plantings) may be necessary in some instances. The primary advantage of riparian plantings is that installation can be accomplished with minimum impact to the stream channel, existing vegetation, and private property. In addition to providing shade (and possible reduced water temperature) and cover for aquatic species, riparian plantings can develop root masses that penetrate deep into the soils, increasing bank resilience to erosion. All areas that are actively restored with vegetation must have a reasonable approach to protecting the invested effort from further degradation from livestock or hay production.

Factors influencing the appropriate riparian restoration would include severity of degradation, site-potential for various species, and availability of local sources for transplant materials. In general, riparian plantings would promote establishment of functioning stands of native species (grasses and willows). The following recommended restoration measures would allow for stabilization of the soil, decreasing sediment delivery to the stream, and increasing absorption of nutrients from overland runoff.

- Harvest and transplant locally available sod mats with an existing dense root mass which provide immediate promotion of bank stability and filtering nutrients and sediments.
- Transplanting mature shrubs, particularly willows (*Salix* sp.), provides rapid restoration of instream habitat and water quality through overhead cover and stream shading as well as uptake of nutrients.
- Seeding with native graminoids (grasses and sedges) and forbs is a low cost activity where lower bank shear stresses would be unlikely to cause erosion.
- Willow sprigging would expedite vegetative recovery, involving harvest of dormant willow stakes from local sources.

9.5.6 Unpaved Roads

The road sediment reduction represents the estimated sediment load that would remain once all contributing road treads, cut slopes, and fill slopes were reduced to 100 feet (from each side of a crossing). This distance was selected as an example to illustrate the potential for sediment reduction through BMP application and is not a formal goal at every crossing. For example, many roads may easily have a smaller contributing length, while others may not be able to meet a 100ft milestone. Achieving this reduction in sediment loading from roads may occur through a variety of methods at the discretion of local land managers and restoration specialists. Road BMPs can be found on the Montana DEQ or DNRC websites and within Montana’s NPS Management Plan (DEQ, 2007). Examples include:

- Providing adequate ditch relief up-grade of stream crossings.
- Constructing waterbars, where appropriate, and up-grade of stream crossings.
- Instead of cross pipes, using rolling dips on downhill grades with an embankment on one side to direct flow to the ditch. When installing rolling dips, ensure proper fillslope stability and sediment filtration between the road and nearby streams.

- Insloping roads along steep banks with the use of cross slopes and cross culverts.
- Outsloping low traffic roads on gently sloping terrain with the use of a cross slope.
- Using ditch turnouts and vegetative filter strips to decrease water velocity and sediment carrying capacity in ditches.
- For maintenance, grading materials to the center of the road and avoiding removing the toe of the cutslope.
- Preventing disturbance to vulnerable slopes.
- Using topography to filter sediments; flat, vegetated areas are more effective sediment filters.
- Where possible, limit road access during wet periods when drainage features could be damaged.

9.5.6.1 Road Crossings

Although culverts were not part of the source assessment, they can be large sources of sediment, and should be included in the restoration strategy. A field survey should be conducted and combined with local knowledge to prioritize culverts for restoration. As culverts fail, they should be replaced by culverts that pass a 100 year flood on fish bearing streams and at least 25 year events on non fish bearing streams. Culverts should be at grade with the streambed, and inlets and outlets should be vegetated and armored. Some road crossings may not pose a feasible situation for upgrades to these sizes because of road bed configuration; in those circumstances, the largest size culvert feasible should be used.

Another consideration for culvert upgrades will be providing fish passage. During the assessment and prioritization of culverts, additional crossings should be assessed for streams where fish passage is a concern. Each fish barrier should be assessed individually to determine if it functions as an invasive species and/or native species barrier. These two functions should be weighed against each other to determine if each culvert acting as a fish passage barrier should be mitigated. Montana FWP can aid in determining if a fish passage barrier should be mitigated, and, if so, it should be involved in culvert design. If funding is available, culverts should be prioritized and replaced prior to failure.

9.5.7 Bank hardening/riprap/revetment/floodplain development

The use of riprap or other "hard" approaches is not recommended and is not consistent with water quality protection or implementation of this plan. Although it is necessary in some instances, it generally redirects channel energy and exacerbates erosion in other places. Bank armoring should be limited to areas with a demonstrated infrastructure threat. Where deemed necessary, apply bioengineered bank treatments to induce vegetative reinforcement of the upper bank, reduce stream scouring energy, and provide shading and cover habitat. Limit infrastructure threats by reducing floodplain development through land use planning initiatives (e.g. the Subdivision Regulations and the Big Hole River Conservation Development Standards in Madison County).

Bank stabilization using natural channel design techniques can provide both bank stability and habitat potential. The primary recommended structures are large woody debris jams. These natural arrays can be constructed to emulate historical debris assemblages that were introduced to the channel by the adjacent cottonwood dominated riparian community types. When used in together, woody debris jams and straight log vanes can benefit the stream and fishery by improving bank stability, reducing bank erosion rates, adding protection to fill slopes and/or embankments, reducing near-bank shear stress, and enhancing aquatic habitat and lateral channel margin complexity.

9.5.8 Forestry and Timber Harvest

Currently, timber harvest is not significantly affecting sediment production in the Middle and Lower Big Hole TPA, but harvesting will likely continue in the future within the Beaverhead Deerlodge National Forest (BDNF) and on private land. Future harvest activities should be conducted by all landowners according to Forestry BMPs for Montana (MSU Extension Service 2001) and the Montana SMZ Law (77-5-301 through 307 MCA). The Montana Forestry BMPs cover timber harvesting and site preparation, harvest design, other harvesting activities, slash treatment and site preparation, winter logging, and hazardous substances. While the SMZ Law is intended to guide commercial timber harvesting activities in streamside areas (i.e. within 50 feet of a water body), the riparian protection principles behind the law can be applied to numerous land management activities (i.e. timber harvest for personal use, agriculture, development). Prior to harvesting on private land, landowners or operators are required to notify the Montana DNRC. DNRC is responsible for assisting landowners with BMPs and monitoring their effectiveness. The Montana Logging Association and DNRC offer regular Forestry BMP training sessions for private landowners.

Timber harvest should not increase the peak water yield by more than 10 percent of historic conditions. If a natural disturbance, such as a forest fire, increases peak water yield, the increase should be accounted for as part of timber harvest management.

9.5.9 Mining/Smelter Fallout -Related

Because restoration of metals sources that are not also associated with sediment are typically implemented under state and federal programs, this section will discuss general restoration programs and funding mechanisms that may be applicable to the metals sources instead of specific BMPs. The need for further characterization of impairment conditions and loading sources is addressed through the framework monitoring plan in **Section 11.0**. A number of state and federal regulatory programs have been developed over the years to address water quality problems stemming from historic mines, associated disturbances, and metal refining impacts. Some regulatory programs and approaches considered most applicable to Middle and Lower Big Hole watershed include:

- The State of Montana Mine Waste Cleanup Bureau's Abandoned Mine Lands (AML) Reclamation Program,
- The Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA), which incorporates additional cleanup options under the Controlled Allocation of Liability Act (CALA) and the Voluntary Cleanup and Redevelopment Act (VCRA).

Montana Mine Waste Cleanup Bureau Abandoned Mine Reclamation Program
The Montana Department of Environmental Quality's Mine Waste Cleanup Bureau (MWCB), part of the DEQ Remediation Division, is responsible for reclamation of historical mining disturbances associated with abandoned mines in Montana.

The MWCB abandoned mine reclamation program is funded through the Surface Mining Control and Reclamation Act of 1977 (SMCRA) with SMCRA funds distributed to states by the federal government. In order to be eligible for SMCRA funding, a site must have been mined or affected by mining processes, and abandoned or inadequately reclaimed, prior to August 3, 1977 for private lands, August 28, 1974 for Forest Service administered lands, and prior to 1980 for lands administered by the U.S. Bureau of Reclamation. Furthermore, there must be no party (owner, operator, other) who may be responsible for reclamation requirements, and the site must not be located within an area designated for remedial action under the federal Superfund program or certain other programs. The DEQ reclamation priority number or responsible agency for the priority abandoned mines in watersheds with TMDLs in this document are listed in **Table 9-4.**

Table 9-4. Priority Abandoned Mine Sites Identified as Potential Sources of Metals Impairments.

Priority Abandoned Mine	Watershed	DEQ Priority # or Responsible Agency
Old Elkhorn	Elkhorn Creek/Wise River	Referred to USFS
Clipper Mine	Wickiup/Camp Creek	97
Watseca Mine, Thistle Mine/Tailings	Rochester Creek	Referred to BLM
Trapper Mine	Trapper Creek	66
Silver King Mine		42
Lower and Upper Cleve Mine		36
True Blue Mine		45

Montana Comprehensive Environmental Cleanup and Responsibility Act (CECRA)
Reclamation of historic mining-related disturbances administered by the State of Montana and not addressed under SMCRA, are typically addressed through the DEQ State Superfund or CECRA program. The CECRA program maintains a list of facilities potentially requiring response actions based on the confirmed release or substantial threat of a release of a hazardous or deleterious substance that may pose an imminent and substantial threat to public health, safety or welfare or the environment (ARM 17.55.108). Listed facilities are prioritized as maximum, high, medium, or low priority or in operation and maintenance status based on the potential threat posed. Currently there are four facilities on the CECRA priority list in the Middle and Lower Big Hole River watershed (**Table 9-5**), but only two of the facilities have hazards associated with the metals of concern (i.e. 303(d) metals listings).

Table 9-5. Facilities on the CECRA priority list within the Middle and Lower Big Hole TPA.

Site	Location	Priority
Elkhorn Mine and Mill[1]	Elkhorn Creek	Transferred to USFS
Hirschy Corrals[2]	Not near a water body	Medium
Rhodia Maiden Rock Mine[2]	Big Hole River, lower segment	High
Tungsten Mill Tailings[1]	Sassman Gulch	High

[1]Federal facility; [2]Hazards not associated with any metals listings in the Middle and Lower Big Hole TPA

CECRA also encourages the implementation of voluntary cleanup activities under the Voluntary Cleanup and Redevelopment Act (VCRA), and the Controlled Allocation and Redevelopment Act (CALA). It is possible that any historic mining-related metals loading sources identified in the watershed in the future could be added to the CECRA list and addressed through CECRA, with or without the VCRA and/or CALA process. A site can be added to the CECRA list at DEQ's initiative, or in response to a written request made by any person to the department containing the required information.

Other Programs

In addition to the programs discussed above, other funding may be available for water quality restoration activities. These sources may include the yearly Resource Indemnity Trust/Reclamation and Development Grants Program (RIT/RDGP) or the EPA Section 319 Nonpoint Source yearly grant program. The RIT/RDG program can provide up to $300,000 to address environmental related issues. This money can be applied to sites included on the Mine Waste Cleanup Bureau's Abandoned Mine Lands (AML) priority list, but of low enough priority where cleanup under AML is uncertain. RIT/RDG program funds can also be used for conducting site assessment/ characterization activities such as identifying specific sources of water quality impairment.

Section 319 grant funds are typically used to help identify, prioritize, and implement water quality protection projects with focus on TMDL development and implementation of nonpoint source projects. Individual contracts under the yearly grant typically range from $20,000 to $150,000, with a 25 percent or more match requirement. RIT/RDG and 319 projects typically need to be administered through a non-profit or local government such as a conservation district, a watershed planning group, or a county.

SECTION 10.0
MONITORING STRATEGY

10.1 Introduction

The monitoring strategy discussed in this section and is an important component of watershed restoration, a requirement of TMDL development under Montana's TMDL law, and the foundation of the adaptive management approach. While targets and allocations are calculated using the best available data, the data are only an estimate of a complex ecological system. The MOS is put in place to reflect some of this uncertainty, but other issues only become apparent when restoration strategies are underway. Having a monitoring strategy in place allows for feedback on the effectiveness of restoration activities (whether TMDL targets are being met), if all significant sources have been identified, and whether attainment of TMDL targets is feasible. Data from long term monitoring programs also provide technical justifications to modify restoration strategies, targets, or allocations where appropriate. Some field procedures have been revised since data collection for TMDL development. All future monitoring should adhere to standard DEQ protocols. Where applicable, analytical detection limits must be below the numeric standard.

The monitoring strategy presented in this section is meant to provide a starting point for the development of more detailed, and specific planning efforts regarding monitoring needs. It does not assign monitoring responsibility. It is expected that monitoring recommendations provided will assist local land managers, stakeholder groups, and federal and state agencies in developing appropriate monitoring plans to meet aforementioned goals. Funding for future monitoring is uncertain and variable due to economic and political change. Prioritization of monitoring activities depends on stakeholder priorities for restoration activities and funding opportunities.

10.2 Adaptive Management Approach

An adaptive management approach is recommended to manage costs as well as achieve success in meeting the water quality standards and supporting all beneficial uses. This approach works in cooperation with the monitoring strategy and as new information is collected, it allows for adjustments to the restoration goals or pollutant targets, TMDLs, and/or allocations, as necessary.

10.3 Follow-up Monitoring

The primary focus of follow-up monitoring is to

1. Identify weak links in the existing conditions assessments if needed.
2. Strengthen the spatial understanding of sources for future restoration work, which will also strengthen source assessment analysis.
3. Track restoration projects as they are implemented and assess their effectiveness.

Hydrology is initially addressed because it can influence all pollutants, and then each pollutant category with TMDLs in this document is addressed.

10.3.1 Hydrology

A water balance and irrigation efficiency study should be conducted for the Middle and Lower Big Hole watershed. Additionally, the study should determine if the irrigation infrastructure or management can be modified to reduce/retain more instream flow during environmentally sensitive timeframes. Once feasible irrigation improvements are identified and planned, additional monitoring should be conducted to quantify irrigation effects to groundwater, and ultimately to surface water as improvements are implemented. As irrigation efficiency projects are implemented, effectiveness monitoring should occur to see how much water is saved by each project. An economic analysis of each irrigation efficiency project should also occur to determine the cost of the saved water. The recently completed report for the Upper Jefferson River can be used as an example approach to determining the most cost effective saving water alternatives. This effort would need local initiation. Funding would likely come from both local match, and also federal and state sources.

10.3.2 Sediment

Sediment TMDLs have been developed for twenty six water body segments in the Middle and Lower Big Hole TPA. Since data collection for the sediment source assessment, DEQ has modified several aspects of the procedure, including standardizing a stratification procedure for selecting representative sediment/habitat sampling sites, and incorporating riparian buffer health into the hillslope model. These modifications, as well as others identified by DEQ when follow-up monitoring commences, should be considered during follow-up monitoring. Strengthening source assessments should also include assessment of future sources as they arise. The extent of monitoring should be consistent with the extent of potential impacts, and can vary from basic BMP compliance inspections to establishing baseline conditions and measuring target parameters below the project area before the project, and after completion of the project. Cumulative impacts from multiple projects must also be considered. This approach will help track the recovery of the system, and the impacts, or lack of impacts, from ongoing management activities in the watershed. Under these circumstances, additional targets and other types of water quality goals may need to be developed to address new stressors to the system, depending on the nature of the activity. If these new sources occur, new data should be used to update TMDL allocations.

The geology in several areas of the watershed is naturally erosive, and although anthropogenic sources exacerbate the rate of erosion, additional monitoring is recommended to gain a better understanding of natural sediment loading from streambank retreat rates. These watersheds include the Wise River and Birch, Camp, Delano, Divide, Elkhorn, Fishtrap, Jerry, and Moose Creeks. Streambank retreat rates are part of the equation for calculating sediment loading from near-stream sediment sources for sediment TMDLs and allocation. The current sediment TMDLs are calculated using literature values for streambank retreat rates. Measuring streambank retreat rates on water bodies within the Middle and Lower Big Hole TPA would be useful to verify or revise the current TMDLs and would also be useful for completing, or revising sediment TMDLs in other watersheds throughout Montana in similar settings. Bank retreat rates can be determined by installing a series of bank pins at different positions on the streambank at several transects in sites placed in a range of landscape settings and stability ratings. Bank erosion is documented after high flows and throughout the year for several years to capture retreat rates under a range of flow conditions.

As primary water quality targets (percent surface fines, macroinvertebrates, and width-to-depth ratio) are based primarily on reference conditions thought to be appropriate for streams in the Middle and Lower Big Hole TPA, further monitoring of the target/indicator parameters in reference streams is needed to help increase confidence that the TMDL targets and supplemental indicator values best represent a translation of the narrative water quality standards for sediment (**Appendix B**). The methods for determining reference conditions are described in **Appendix B**. Reference data was determined to be insufficient for development of target values for fine sediment and width/depth ratios in the mainstem Big Hole River. Determining these target values should be a goal for future monitoring of reference conditions.

In addition to further reference data collection for validation of established water quality targets, collection of water quality target parameter data will assist in evaluation of target attainment, and impairment status. Collection of primary target parameters (percent surface fines, macroinvertebrates, and width-to-depth ratio) at various locations throughout the 303(d) Listed water bodies will allow a larger data set to be developed, and may clarify the relationship between targets and impairment of beneficial uses. DEQ recommends that primary target parameters be collected annually at several established monitoring sites in order to evaluate attainment of water quality targets over time. The reduction of all preventable and significant anthropogenic sediment sources is a primary goal of this document. Accordingly, the TMDL implementation team will conduct 5-year inventories of these sources and will track progress towards meeting this goal.

Other parameters that may be measured for TMDL-related monitoring, or impairment status monitoring include the frequency of pools and LWD, sinuosity, proper function condition assessments (PFC), algal bioassessments, and fish population dynamics. The siltation index is currently being revised by DEQ, but may be a good parameter to measure in the future as it is directly related to aquatic life support. Subsurface sediment may also be collected as most literature values regarding fisheries survival and fine sediment are for subsurface sediment collected with a McNeil core sampler, and existing sediment data within the Middle and Lower Big Hole TPA are for surface sediment. Although there is a relationship between the percentage of subsurface sediment and surface sediment (Platts et al. 1989), the relationship varies and DEQ is currently conducting method comparisons to determine how variable the relationship is within Montana.

Several water body segments with sediment TMDLs in this document were either not assessed for the coldwater fishery beneficial use, or were listed for pollution causes commonly linked to sediment impairment on the 2006 303(d) List. In situations where available data suggest a link between habitat impairment and sediment, a TMDL was developed and a 303(d) assessment is recommended. In other cases, insufficient data were available to make a TMDL development determination, and additional monitoring in combination with a 303(d) assessment is recommended. Twelvemile Creek and Wickiup Creek are on the 2006 303(d) List for sediment, but because they were not on the 2004 303(d) List for sediment, no source assessment data were collected during TMDL development. They will be addressed during future TMDL development. Guidance for future monitoring and assessment work is provided in **Table 10-1**.

Table 10-1. Water bodies segments recommended for 303(d) reassessment and/or additional monitoring prior to reassessment

Water Body Segment	Reason for Reassessment	TMDL	Additional Monitoring Recommended Prior to Reassessment
Big Hole River (middle)	Not currently listed for sediment; Comparison of data to targets indicate a link between habitat impairment and sediment	Yes	No
Birch Creek (lower)	Not currently listed for sediment; Comparison of data to targets indicate a link between habitat impairment and sediment	Yes	No
Canyon Creek	Not assessed for CWF; TMDL development data indicate no significant anthropogenic sources	No	Yes
Charcoal Creek	Currently listed for sediment; TMDL development data suggest substantial natural sediment load and minimal anthropogenic sources	No	Yes
French Creek	Not assessed for CWF; TMDL development data indicate sediment is limiting beneficial use support	Yes	No
Jerry Creek	Not currently listed for sediment; Comparison of data to targets indicate a link between habitat impairment and sediment	Yes	No
Moose Creek	Not assessed for CWF; TMDL development data indicate sediment is limiting beneficial use support	Yes	Yes
Twelvemile Creek	N/A	No	Yes
Wickiup Creek	N/A	No	Yes
Willow Creek	Not assessed for CWF; Insufficient data to make a TMDL development determination	No	Yes
Wise River	Not currently listed for sediment; Comparison of data to targets indicate a link between habitat impairment and sediment	Yes	No

CWF = cold water fishery beneficial use

10.3.3 Nutrients

Fishtrap, Gold, Charcoal, Sawlog, and Wickiup Creeks have been identified as potentially impaired by nutrient conditions in Montana’s 2006 Integrated Water Quality Report. These watersheds were not not included in this TMDL project because of the timeframe of the listings were after the beginning of this project. The middle and lower segments of the Big Hole River were sampled during this project as an additional component not related to TMDL development but to provide recent data. This limited data indicates nutrient conditions in the Big Hole River are above the targets presented in this document, and should be considered in upcoming monitoring and assessment plans for future Integrated Water Quality Reporting. No TMDLs will be pursued for these streams at this time but they will be addressed by future monitoring efforts.

Restoration project tracking for nutrient TMDLs should consider any of the restoration activities which address sources identified in each of the TMDL allocation approaches. As restoration activities are implemented, a subset should be monitored to determine associated nutrient reductions. Future nutrient monitoring should assess total phosphorus, total nitrogen and nitrate + nitrite constituents at the least. Some of the effectiveness monitoring will likely involve monitoring, and simple extrapolation approaches.

10.3.4 Metals

Metals TMDLs have been developed for eleven water body segments in the Middle and Lower Big Hole TPA. Each water body with metals TMDLs will need additional sampling prior to reclamation. In general, allocations to non-priority abandoned mines are clumped, and the locations of abandoned mines are identified in a DEQ and/or MBMG database. Although many of the mines in the database have been visited to determine the location, and condition of abandoned mines, additional reconnaissance is needed assess the potential contribution from those mines, and to identify abandoned mine sources that are contributing to exceedances of metals targets, but are not identified in either of the State databases. For instance, follow up monitoring in the Wise River watershed should include characterizing loading, particularly for lead, from abandoned mines or other mining-related sources (e.g. mining wastes/deposits) in the lower watershed. The reconnaissance effort of historic mining sources should also include watersheds with no abandoned mines identified in the State databases. This includes Sawlog Creek, California Creek, and Oregon Creek. Priority abandoned mines were assessed during a 1993 inventory by the DEQ, but conditions and source areas at those mines may have changed since then, and additional monitoring is recommended to determine the nature of reclamation work required to meet TMDLs. Even in areas where reclamation work has been conducted, such as at the Elkhorn Mine on Elkhorn Creek, additional reclamation work may need to occur in order to meet water quality standards.

Because the contribution from placer-mined areas is unknown, additional source assessment and monitoring within the Deep Creek and Rochester watersheds should include areas that were historically placer-mined. Follow-up monitoring for mercury in Rochester Creek (and other watersheds) should include low-level analysis (i.e. detection limit = 0.01µg/L). Follow-up monitoring should also include monitoring of background concentrations at high and low flow, because much of the existing background data were collected at low flow. In areas of known atmospheric deposition, such as in the Deep Creek, Sassman Gulch, and Trapper Creek watersheds, soil samples may be needed to help refine the source assessment. Within the California Creek watershed, additional sampling is particularly needed between the confluence of Oregon Creek and the mouth to refine the arsenic source assessment. In watersheds with unpermitted point sources, such as Elkhorn Creek, Rochester Creek, and Wickiup Creek, follow up monitoring should target the point sources to help refine the WLA source areas. Future metals monitoring should include total suspended solids (TSS) and possibly some dissolved metals to help determine the role of sediment in metals target exceedances.

It is important to note that monitoring recommendations are based on TMDL related efforts to protect beneficial uses in a manner consistent with Montana's water quality standards. Other regulatory programs with water quality protection responsibilities may impose additional requirements to ensure full compliance with all appropriate local, State and Federal laws. For example, reclamation of a mining related source of metals under Comprehensive Environmental Cleanup and Responsibility Act (CECRA) will likely require source-specific sampling requirements, which cannot be defined at this time, to determine the extent of and the risk posed by contamination, and to evaluate the success of specific remedial actions.

Standards attainment monitoring should include analysis of a suite of total recoverable metals (e.g. As, Cu, Cd, Pb, Zn), sediment samples, hardness, pH, and TSS for all pollutant-water body combinations. As a result of water and sediment data collected during TMDL development, TMDLs were developed for several metals that were not on the 2006 303(d) List, and TMDLs were not developed for some listed metals because recent data did not exceed water quality targets and/or anthropogenic sources were not identified. Based on the data evaluations within this document (**Section 7.4.4**), several metals have been identified as priorities for future metals monitoring (**Table 10-2)**.

Table 10-2. Metals Monitoring Recommendations

Water Body Segment	Recommended Monitoring	Recommended 303(d) Assessment (& Rationale)
Big Hole River (middle)	Ag	Ag (potential new listing)
Big Hole River (lower)	Pb (during HF); biological effects of As and Cd in sediment	Cu, Cd, Pb, Zn (potential delistings)
California Creek	Cu, Fe	Cu (potential new listing), Fe (potential delisting)
Camp Creek	As (during LF)	---
Deep Creek	As, Cu, Ag	As, Cu, Ag (potential new listings)
Elkhorn Creek	As (during HF), Ag	Ag (potential new listing)
French Creek	Cu, Ag	Cu, Ag (potential new listings)
Grose Creek	As	---
Jerry Creek	Cu, Pb (particularly at LF); biological effects of As and Cd in sediment	Pb (potential delisting)
Lost Creek	biological effect of Cd in sediment	---
Moose Creek (upper)	General metals monitoring in upper raches of Moose Creek to determine if toxic effects are excerted on fishery	Potential metal listing
Oregon Creek	Cd, Pb; biological effect of Pb in sediment	Pb (potential delisting)
Sassman Gulch	As, Fe; upland soils near the channel	---
Sawlog Creek	As	---
Trapper Creek	As, Cd	As, Cd (potential new listings)
Wickiup Creek	As (during LF), Pb, Hg	Pb, Hg (potential delistings)
Wise River	Cu, Cd, Fe, Pb, Ag, Zn; biological effects of As and Zn in sediment	Cu, Cd, Pb (potential new listings)

HF = high flow; LF = low flow

10.3.5 Temperature

Temperature monitoring of the Big Hole River is currently monitored at various locations by Montana Fish Wildlife and Parks and United States Geological Survey (USGS). These locations are adequate to monitor trends. If shade conditions are improved, or summer time irrigation efficiencies are realized along specific reaches of the Big Hole River or Divide Creek, restoration effectiveness monitoring should include in-stream temperature, effective shade, stream bank vegetation measures (offset, height, density), streamflow, and irrigation water use monitoring. A large scale monitoring effort would not be needed until allocations have been addressed by significant restoration activities.

10.4 Implementation and Restoration Effectiveness Monitoring

As defined by Montana State Law (75-5-703(9)), DEQ is required to evaluate progress towards meeting TMDL goals, and water quality standards after implementation of reasonable land, soil, and water conservation practices. If this evaluation demonstrates that water quality standards, and beneficial use support have not been achieved within five years, DEQ is required to conduct a formal evaluation of progress in restoring water quality, and the status of reasonable land, soil, and water conservations practice implementation to determine if:

- The implementation of a new or improved phase of voluntary reasonable land, soil, and water conservation practices is necessary.
- Water quality is improving, but more time is needed for compliance with water quality standards.
- Revisions to the TMDL are necessary to achieve applicable water quality standards and full support of beneficial uses.

Although DEQ is responsible for TMDL-related monitoring, it is envisioned that much of it could occur under coordination with land managers and local interests. Implementation and restoration monitoring may include summaries of such items as the length of road upgraded to BMP standards, length of decommissioned roads, fish passage barriers corrected, or tracking riparian shade disturbances, as well as the estimated impact of these actions in terms of decreased pollutant loading or improved habitat. Restoration projects should be tracked by the coordinating agency and/or stakeholders. Monitoring recommendations for varying road and agricultural BMPs, and abandoned mine reclamation are provided below (**Tables 10-3 to 10-5)**. The recommendations provided are not an exhaustive list, and specific details of the implementation and restoration monitoring will be coordinated with local stakeholders and DEQ before future restoration activities occur. To ensure that TMDL implementation is effective in achieving full support of beneficial uses, this monitoring should be closely tied to standards attainment monitoring.

10.4.1 Road BMPs

Monitoring road sediment delivery is necessary to determine if BMPs are effective, to determine which are most effective, and to determine which practices or sites require modification to achieve water quality goals. Effectiveness monitoring should be initiated prior to implementing BMPs at treatment sites.

Monitoring actual sediment routing is difficult or prohibitively expensive. It is likely that budget constraints will influence the number of monitored sites. A detailed monitoring study design should be developed once specific restoration projects are identified. Monitoring at specific locations should continue for a period of 2-3 years after BMPs are initiated to overcome environmental variances. Specific types of monitoring for separate issues and improvements are listed in **Table 10-3**.

Table 10-3. Monitoring Recommendations for Road BMPs

General Restoration Technique	Monitoring Recommendation	Recommended Methodology
Ditch Relief Culverts or Ditch Relief at Stream Crossings	• Place silt trap directly upslope of tributary crossing to determine mass of sediment routed to that point • Rapid inventory to document improvements and condition	• Sediment yield monitoring based on existing literature/USFS methods • Revised Washington Forest Practices Board methodology
Culvert upgrades	• Repeat road crossing inventory after implementation • Fish passage and culvert condition inventory	• Revised Washington Forest Practices Board methodology • Montana State (DNRC) culvert inventory methods
Improved Road Maintenance	• Repeat road inventory after implementation • Monitor streambed fine sediment (grid or McNeil core) and sediment routing to stream (silt traps) below specific problem areas	• Revised Washington Forest Practices Board methodology • Standard sediment monitoring methods in literature

10.4.2 Agricultural BMPs

Management improvements related to grazing, irrigation, and crop production have been implemented in many areas throughout the Middle and Lower Big Hole River TPA. These projects have been implemented through NRCS, State, other federal, or private funds, and often include monitoring specific to those projects. Additional monitoring is recommended below for future improvements and projects. Effectiveness monitoring is closely linked to monitoring for standards attainment, and in areas where BMPs are aimed at reducing nutrient loading, monitoring should also include nutrient water quality samples.

Grazing BMPs function to reduce grazing pressure along streambanks and riparian areas. Recovery resulting from implementing BMPs may be reflected in improved water quality, channel narrowing, cleaner substrates, and recovery of vegetation along streambanks and riparian areas. Effectiveness monitoring for grazing BMPs should be conducted over several years, making sure to start monitoring prior to BMP implementation. If possible, monitoring reaches should be established in pastures keeping the same management as well as in those that have changed. Where grazing management includes moving livestock according to riparian use level guidelines, it is important to monitor changes within the growing season as well as over several years. Monitoring recommendations to determine seasonal and longer-term changes resulting from implementing grazing BMPs are outlined below in **Table 10-4**.

Table 10-4. Effectiveness Monitoring Recommendations for Grazing BMPs by Restoration Concern.

Recovery Concern	Monitoring Recommendations	Methodology or Source
Seasonal impacts on riparian area and streambanks	Seasonal monitoring during grazing season using riparian grazing use indicators • Streambank alteration • Riparian browse • Riparian stubble height at bank and "key area"	BDNF/BLM riparian guidelines (Bengeyfield and Svoboda, 1998)
Long-term riparian area recovery	• Photo points • PFC/NRCS Riparian Assessment (every 5-10 yrs) • Vegetation Survey (transects perpendicular to stream and spanning immediate floodplain) every 5-10 years o Strip transects- Daubenmire 20cm x 50cm grid or point line transects	Harrelson et al., 1994; Bauer and Burton, 1993; NRCS, 2001 Stream Assessment Protocols
Streambank stability	Greenline (i.e. near bank vegetation) including bare ground, bank stability, woody species regeneration (every 3-5 years)	Modified from Winward, 2000
Channel stability	Cross-sectional area, with % fines/ embeddedness • Channel cross-section survey • Wolman pebble count • Grid or McNeil core sample	Rosgen, 1996; Harrelson et al., 1994
Aquatic habitat condition	• Aquatic macroinvertebrate sampling • Pool quality • R1/R4 aquatic habitat survey	DEQ biomonitoring protocols; Hankin and Reeves, 1988; USFS 1997 R1R4 protocols
General stream corridor condition	EMAP/Riparian Assessment (every 5-10 yrs)	NRCS 2001 Stream Assessment Protocols; U.S. EPA 2003.

10.4.3 Abandoned Mine Reclamation

Each reclamation site will have site-specific needs but general recommendations for mine site remediation effectiveness monitoring are outlined in **Table 10-5**.

Table 10-5. Effectiveness monitoring recommendations for abandoned mine reclamation sites.

Parameter	Monitoring Recommendations
Water quality	Sample for heavy metals, pH, and TSS in water column at high and low flow above and below mine site. Collect sediment samples at low flow. Monitoring should be initiated prior to remediation efforts and continue for at least 10 years after site restoration. Monitoring should include biomonitoring (i.e. periphyton and macroinvertebrates) at low flow every 3 years.
Vegetation re-establishment	Greenline survey every 3 years, including bank stability, shrub regeneration, and bare ground. Vegetation transects across floodplain for vegetation community structure and regeneration.

10.5 Watershed-Scale Monitoring

Monitoring should be conducted at a watershed scale over several years to determine if restoration activities are improving water quality, instream flow, and aquatic habitat and communities. It is important to remember that degradation of aquatic resources happens over many decades, and that restoration is also a long-term process. Long-term monitoring should be an understood component of any restoration effort.

Trends in water quality are difficult to define, and even more difficult to relate directly to restoration or other changes in management, due to the natural high variability in water quality conditions. Improvements in water quality, or aquatic habitat resulting from restoration activities on listed streams are most likely to be evident by target attainment, and may include increases in instream flow, changes in communities and distribution of fish and other bioindicators, improvements in bank stability and riparian habitat, changes in channel cumulative width/depths, fine sediment deposition and channel substrate embeddedness. Specific monitoring methods, priorities, and locations, particularly on tributaries, will depend heavily on the type of restoration projects implemented, landscape or other natural setting, the land use influences relative to potential monitoring sites, and budgetary and time constraints. On the mainstem Big Hole River, long term water quality assessment should occur at the USGS gage stations at Melrose (6025500) and near Glen (6026210) to document long term trends in temperature, nutrients and potentially TSS.

SECTION 11.0
STAKEHOLDER AND PUBLIC COMMENTS

Stakeholder and public involvement is a component of TMDL planning efforts supported by EPA guidelines and Montana State Law. Public comment on the Middle and Lower Big Hole River TMDLs involved two components. First, stakeholders and a technical advisory group (including private landowners, conservation groups, and agency representatives) were kept abreast of the TMDL process through periodic meetings, and were provided opportunities to review and comment on interim technical documents which ultimately became appendices to the final TMDL document. The stakeholders and a technical advisory group also were allowed a stakeholder draft comment timeframe during which the draft document was posted on the Big Hole Watershed Committee's website until the public comment draft was posted for the public comment period on DEQ's website. In addition, presentations about the draft TMDL document were provided to the following groups:

- Technical Advisory Group – Butte, MT, January 29th, 2009
- Stakeholder Feedback – South of Divide, MT, February 4th , 2009

The second component of public involvement was a public comment period. This public review period began on February 16th, 2009 and extended through March 20th, 2009. A public meeting on February 18th, 2009 in Divide, Montana provided an overview of the Upper and North Fork Big Hole River TMDLs and Watershed Water Quality Planning Framework document. The meeting provided an opportunity to solicit public input and comments on the plan. This meeting and the opportunity to provide public comment on the draft document were advertised via a press release by DEQ and was included in a number of local newspapers. Copies of the main document were available at the Divide Post Office, Beaverhead Conservation District in Dillon, Mile High Conservation District in Butte, and at the State Library in Helena, and via the internet on DEQ's web page or via direct communication with the DEQ project manager.

Appendix K includes a summary of the public comments received and the DEQ response to these comments. The original comment letters are located in the project files at DEQ and may be reviewed upon request.

DEQ also provides an opportunity for public comment during the biennial review of the Montana's Integrated Water Quality Report that includes the 303(d) List. This includes public meetings and opportunities to submit comments either electronically or through traditional mail. DEQ announces the public comment opportunities through several media including press releases and the Internet.

SECTION 12
REFERENCES

Andrews, E. D.; and J. M. Nankervis. 1995. Effective Discharge and the Design of Channel Maintenance Flows for Gravel-Bed Rivers: Natural and Anthropogenic Influences in Fluvial Geomorphology. Geophysical Monograph 89, p. 151-164.

Backus, Perry. 1999. Sediment flushed into Wise River: Workers at Coolidge ghost town accidentally release plume into creek. The Montana Standard, October 15, 1999.

Bahls, L.L. 1978. Streamflow and water quality in the lower Big Hole River; Summer 1977

Bear, E. A. 2005. Effects of temperature on survival and growth of westslope cutthroat trout and rainbow trout: implications for conservation and restoration. Master's thesis. Montana State University, Bozeman.

Bengeyfield, P. 1999. Analysis of Reference Reach Data and the Prediction of Stream Types. Proceedings of American Water Resources Association Special Symposium of Wildland Hydrology. Bozeman, MT.

Bengeyfield, P. 2004. Presentation at the Grazing Riparian Ecosystems course, Helena, MT, September 2004.

Beschta, R. L., and W. S. Platts. 1986. Morphological Features of Small Streams: Significance and Function. American Water Resources Association, Water Resources Bulletin 22(3):369-379.

BHWC. 2007. Big Hole River Drought Management Plan. Big Hole Watershed Committee.

Bjornn, T. C., and six coauthors. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho, Forest, Wildlife and Range Experiment Station, Bulletin 17. Moscow.

Bjorn, T. C. and D. W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138.

Brown, M. 2004. United States Bureau of Land Management Abandoned Mine Lands Program. Personal communication, September 2004

Bukantis, Robert. 1998. Rapid Bioassessment Macroinvertebrate Protocols: Sampling and Sample Analysis SOPs. Montana Department of Environmental Quality. Water Quality Division, Helena, Montana. Working Draft.

Byorth, P.A and J.P. Magee. 1996. Big Hole River Arctic grayling recovery project: Annual monitoring report 1995. Submitted to Fluvial Arctic Grayling Workgroup. Montana Fish, Wildlife, & Parks, Bozeman, MT

Byorth, P.A. 1994. Big Hole River Arctic grayling recovery project: Annual monitoring report 1993. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Fish, Wildlife, and Parks, Bozeman.

Buchman, M. F. 2004. NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1. Coastal Protection and Restoration Division. National Oceanic and Atmospheric Administration. Seattle Washington.

Carlson, J. 2001. Coordinator, Montana Animal Species of Concern Committee. Montana Animal Species of Special Concern. Montana Natural Heritage Program and Montana Fish, Wildlife, and Parks, Helena MT

Downing, D. 2004. United States Forest Service Fisheries Biologist, Wisdom Ranger District. Personal communication, August 2004.

Dunne and Leopold. 1978. Water in Environmental Planning. W.H. Freeman Company, New York.

Elliot, William J. 2006. "The Roles of Natural and Human Disturbances in Forest Soil Erosion," in *Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management*, ed. P. N. Owens and A. J. Collins, (Wallingford, United Kingdom: CABI Publishing), 177-199.

Elliot, William J. and Robichaud, Peter R. 2001. Comparing Erosion Risks from Forest Operations to Wildfire. The International Mountain Logging and 11th Pacific Northwest Skyline Symposium. Seattle, WA.

Feldman, David. 2006. A Report to the DEQ Water Quality Planning Bureau on the Proper Interpretation of Two Recently Developed Macroinvertebrate Bioassessment Models. Helena, MT, Montana Department of Environmental Quality.

Gilbertson, C.B., F.A. Norstadt, A.C. Mathers, R.F. Holt, A.P. Barnett. T.M. McCalla, C.A. Onstad, and R.A. Young. 1979. Animal waste utilization on cropland and pastureland. US Environmental Protection Agency, EPA-600/2-70-59.

Gunderson, Robert. 2009. US Bureau of Land Management (BLM). Dillon Field Office, Montana. Personal communication, January 2009.

Grumbles, 2006 Environmental Protection Agency TMDL communication memo.

Havig, D. 2004. United States Forest Service District Ranger, Wisdom Ranger District. Personal communication, August 2004.

Heitke, J. D., E. J. Archer, D. D. Dugaw, B. A. Bouwes, E. A. Archer, R. C. Henderson, J. L. Kershner. 2006. Effectiveness monitoring for streams and riparian areas: sampling protocol for stream channel attributes. Unpublished. Online. http://www.fs.fed.us/biology/fishecology/emp.

Hydrotech Water Resource Consultants. 2001. Deep Creek Watershed and Spawning Enhancement Projects: 2000 project monitoring report.

Irving, J. S. and T. C Bjornn. 1984. Effects of Substrate Size Composition on Survival of Kokanee Salmon and Cutthroat Trout and Rainbow Trout Embryos. University of Idaho. Cooperative Fishery Research Unit. Technical Report 84-6. Moscow, Idaho.

Jessup, Benjamin, Hawkins, Chuck, and Stribling, James. 2006. Biological Indicators of Stream Condition in Montana Using Macroinvertebrates. Owings Mills, MD, Tetra Tech, Inc.

Lamothe, P.J. and J.P. Magee. 2003. Movement and habitat selection of Arctic grayling, brook trout, and mountain whitefish during drought conditions on in the Big Hole River, MT. Submitted to: Fluvial Arctic Grayling Workgroup. Montana, Fish, Wildlife and Parks, Bozeman, MT

Lamothe, P., and J. Magee. 2004. Linking Arctic grayling abundance to physical habitat parameters in the upper Big Hole River, Montana. Montana Fish, Wildlife, and Parks, Dillon. 29 pp.

Likens, G.E., F.H. Bormann, N.M. Johnson and R.S. Pierce. 1967. The effect of forest management on the nutrient budget of a northern hardwood ecosystem. Bull. Ecol. Soc. Amer. 48(2):53.

Lohr, S.C., P.A., Byorth, C.M. Kay, and W.P. Dwyer. 1996. High-temperature tolerances of Fluvial Arctic Grayling and comparison with summer river temperatures of the Big Hole River, MT. *Transactions of the American Fisheries Society* 12:933-939

Knighton, D. 1998, Fluvial Forms and Processes. John Wiley and Sons Inc., New York, New York.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry on streams in the Pacific Northwest and Alaska. EPA 910/9-91-001.

McFarland, B.H., B.H. Hill, and W.T. Willingham. 1997. Abnormal Fragilaria spp. (Bacillariophyceae) in streams impacted by mine drainage. Journal of Freshwater Ecology 12(1):141-149

Magee, J.P. and P. Lamothe. 2003. Big Hole River fluvial Arctic grayling monitoring report 2002. Unpublished report submitted to fluvial Arctic grayling workgroup. Montana Fish, Wildlife and Parks. Dillon, MT. 70 pp.

Magee, J.P., and E.N. Rens, and P.J. Lamothe. 2005. Big Hole River Arctic Grayling Recovery Project: Annual monitoring report 2004. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Department of Fish, Wildlife and Parks, Bozeman.

Magee, J.P., and E.N. Rens, and P.J. Lamothe. 2006. Big Hole River Arctic Grayling Recovery Project: Annual monitoring report 2005. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Department of Fish, Wildlife and Parks, Bozeman.

Magee, J.P., and P.A. Byorth. 1998b. Competitive interactions of Arctic grayling and sympatric species in the Big Hole River drainage, Montana. *Transactions of the American Fisheries Society* 127:921-931.

Marvin, R.K., and T.L. Voeller. 2000. Hyrdology of the Big Hole Basin and an assessment of the affects of the hydrologic budget. Montana Bureau of Mines & Geology Open File Report 417. Montana Bureau of Mines & Geology, Butte, MT

McGuire, D. L. 2003. Macroinvertebrate based assessment of the Big Hole River, MT, August 2002. Unpublished. 26pp.

Mebane, C. A. 2001. Testing Bioassessment Metrics: Macroinvertebrate, Sculpin, and Salmonid Responses to Stream Habitat, Sediment, and Metals. Environmental Monitoring and Assessment 67:293-322.

Montana Fish, Wildlife and Parks and the United States Fish and Wildlife Service. 2005. Candidate conservation agreement with assurances for fluvial Arctic grayling in the Upper Big Hole River. FWS Tracking #: TE 1044150-0. 42 pp.

Montana Fish, Wildlife and Parks. 1981. Annual fisheries report.

Montana Department of Environmental Quality (MDEQ). 2005. Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (QAPP). Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Montana Department of Environmental Quality (MDEQ). 2006. 2006 Integrated 305(b)/303(d) Water Quality Impairment List and Reports. Helena, MT, Montana Department of Environmental Quality.

Montana Department of Environmental Quality (MDEQ). 2005b. 2005 TMDL Monitoring Summary: Middle and Lower Big Hole River Water Quality Restoration Planning Areas. Prepared by Land and Water Consulting, Inc., Helena, Montana. December 2005.

Montana Department of Environmental Quality (MDEQ). 2006b. 2006 Stream Monitoring Summary: Middle and Lower Big Hole River Water Quality Restoration Planning Areas. Prepared by PBS&J, Helena, Montana. December 2006.

Montana Department of Environmental Quality (MDEQ). 2006c. Standard Operating Procedure, Water Quality Assessment Process and Methods (APPENDIX A to 303(d) 2000 - 2004).

WQPBWQM-001, Rev#: 02. Helena, MT, Montana Department of Environmental Quality.

Montana Department of Environmental Quality (MDEQ). 2007. Unpaved Road Runoff Sediment Assessment: Middle and Lower Big Hole River Water Quality Restoration Planning Areas. Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Montana Department of Environmental Quality (MDEQ). 2007b. Streambank Erosion Source Assessment: Middle and Lower Big Hole River Water Quality Restoration Planning Areas. Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Montana Department of Environmental Quality (MDEQ). 2009. Upper and North Fork Big Hole River Planning Area TMDLs and Framework Water Quality Restoration Approach.

Montana Department of Environmental Quality (MDEQ). 2008. Circular WQB-7: Montana numeric water quality standards. Montana Department of Environmental Quality, Planning, Prevention, and Assistance Division – Water Quality Standards Section. Helena, Montana. February 2008. Available at: http://www.deq.state.mt.us/wqinfo/Circulars/WQB-7.PDF.

Montana Department of Fish, Wildlife, and Parks (MFWP). 1989. Application for Reservations of Water in the Missouri River Basin Above Fort Peck Dam.

Montana Department of Fish, Wildlife and Parks (MFWP). 2004. MFISH. Montana Fisheries Information System Database Query. Available at http://nris.state.mt.us/scripts/esrimap/dll?name=MFISH&Cmd=INST.

Montana State University (MSU) Extension Service. 2001. Water Quality BMPs for Montana Forests. MT DNRC Forestry Division

Mullen, Greg. 2008. Montana Department of Justice, Natural Resource Damage Program. Personal communication, November 2008.

Munday, Patrick. 2001. Montana's Last Best River: The Big Hole and Its People. Lyons Press.

Oswald, R.A. 1981. Aquatic Resource Inventory of the Mt. Haggin Area. Montana FWP, Region 3, Bozeman, Montana. Project Number 3323.

Oswald, R. 2004. Montana Fish, Wildlife & Parks Fisheries Biologist. Personal communication, September 2004.

Platts, W. S.; and R. L. Nelson. 1989. Stream Canopy and Its Relationship to Salmonid Biomass in the Intermountain West. North American Journal of Fisheries Management 9:446-457.

Prichard, D. J.; and Eight Others. 1998. Riparian Area Management TR-1737-15. A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. USDI Bureau of Land Management, National Applied Resource Sciences Center, Denver, Colorado.

Relyea, C. B., Minshall, G. W., and Danehy, R. J. 2000. Stream Insects as Bioindicatores of Fine Sediment. Water Environment Federation Specialty Conference. Watershed 2000 . Boise, ID, Idaho State University.

Rens, E.N., and J.P. Magee. 2007. Montana Arctic Grayling Annual Monitoring Report, 2006. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Fish, Wildlife & Parks, Bozeman.

Rice, R. M., Rothacher, J. S., and Megahan, W. F. 1972. Erosional Consequences of Timber Harvesting: An Appraisal. National Symposium on Watersheds in Transition. 321-329. Urbana, IL, American Water Resources Association.

Riggers, Brian W.; Arne Rosquist; Richard Kramer; and Mike Bills. 1998. An Analysis of Fish Habitat and Population Conditions in Developed and Undeveloped Watersheds on the Lolo National Forest. U.S. Forest Service, Lolo National Forest. Missoula, MT.

Reiser, D. W., and R. G. White. 1988. Effects of two sediment size-classes on survival of steelhead and chinook salmon eggs. North American Journal of Fisheries Management 8(4): 432-437.

Rosgen, Dave L. 1996. Applied River Morphology. Wildland Hydrology. Lakewood, CO.

Rosgen, David 2001. Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II - 9-15, March 25-29, 2001, Reno, NV.

Rowe Mike; Don Essig; and Ben Jessup. 2003. Guide to Selection of Sediment Targets for Use in Idaho TMDLs. Idaho Department of Environmental Quality, Boise, ID.

Salo, D.W. 2004. North Zone Forest Hydrologist, Beaverhead-Deerlodge National Forest, August 20, 2004.

Schmidt, LJ, and JP Potyondy P. 2004. Quantifying channel maintenance instream flows: an approach for gravel-bed streams in the Western United States. Gen. Tech. Rep. RMRSGTR-128. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station, 33 p.

Shepard, B. B.; S. A. Leathe; T. M. Weaver; and M. D. Enk. 1984. Monitoring Levels of Fine Sediment Within Tributaries to Flathead Lake, and Impacts of Fine Sediment on Bull Trout Recruitment. Pages 146-156. In: R. Richardson and F.H. Hamre (eds.). Wild Trout III, Trout Unlimited, Vienna, Virginia.

Suplee, Michael W., Arun Varghese, and Joshua Cleland. 2007. Developing Nutrient Criteria for Streams: An Evaluation of the Frequency Distribution Method. *Journal of the American Water Resources Association.* 43(2): 456-472

Suplee, Michael W. 2005. Best Use of the June 2005 Nutrient Data Statistical Summaries. Helena, Mt, Montana Department of Environmental Quality.

Suttle, Kenwyn, Mary Power, Jonathan Levine, Camille McNeely. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmon. Ecological Applications, 14(4):969-974.

Tepley, M and L. Bahls. 2005. Updated Statistical Analyses of Water Quality Data, Compliance Tools, and Changepoint Assessment for Montana Rivers and Streams. Montana Department of Environmental Quality. 28pp.

USDI. 2003b. DRAFT Chapters 1 and 2. Reclamation Investigation and Engineering Evaluation and Cost Analysis for the Rochester and Nez Piece Creek Drainage Basins Reclamation Project Rochester Mining District, Madison County, Montana. Prepared by Tetra Tech EM Inc., Helena, Montana. Prepared for U.S. Army Corps of Engineers and U.S. Bureau of Land Management.

Weaver, T.; and J. Fraley. 1991. Fisheries Habitat and Fish Populations. p. 53 – 68. In Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program. June 1991. Flathead Basin Commission, Kalispell, Montana.

Wells, J.D. and J. Decker-Hess. 1981. Inventory and survey of the waters of the Big Hole and Beaverhead drainages, July 1, 1980 through June 1, 1981. Southwest Montana fisheries study.

West, R.L., M.W. Smith, W.E. Barber, J.B. Reynolds and H. Hop. 1992. Autumn migration and overwintering of Arctic grayling in coastal streams of the Arctic National Wildlife Refuge, Alaska. Transactions of the American Fisheries Society 121(6):709-715.

Zweig, L. D., and C. F. Rabeni. 2001. Biomonitoring for Deposited Sediment Using Benthic Invertebrates: A Test on Four Missouri Streams. Journal of the North American Benthological Society 20:643-657

APPENDIX A
MAPS

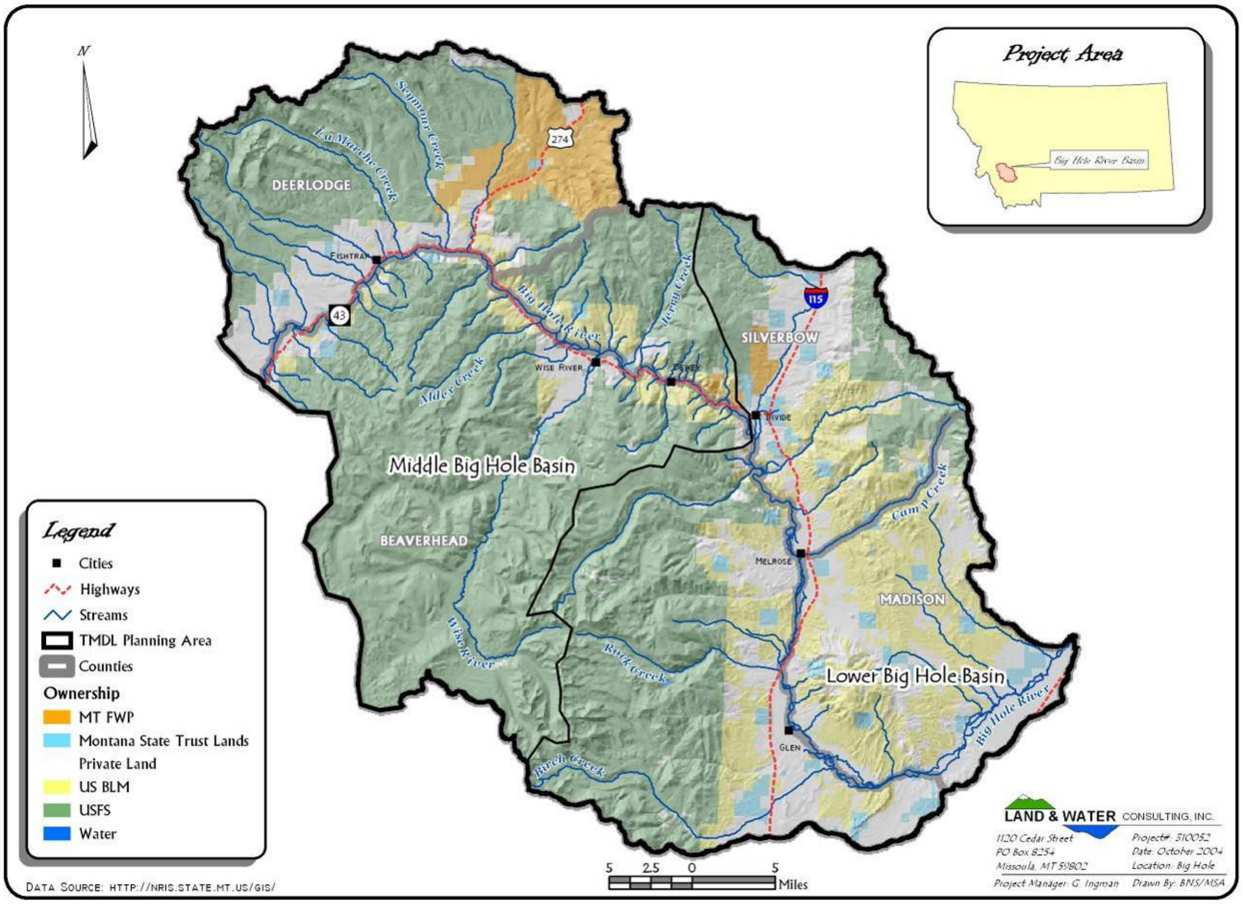


Figure A-1. Middle and Lower Big Hole River TDML Planning Area.

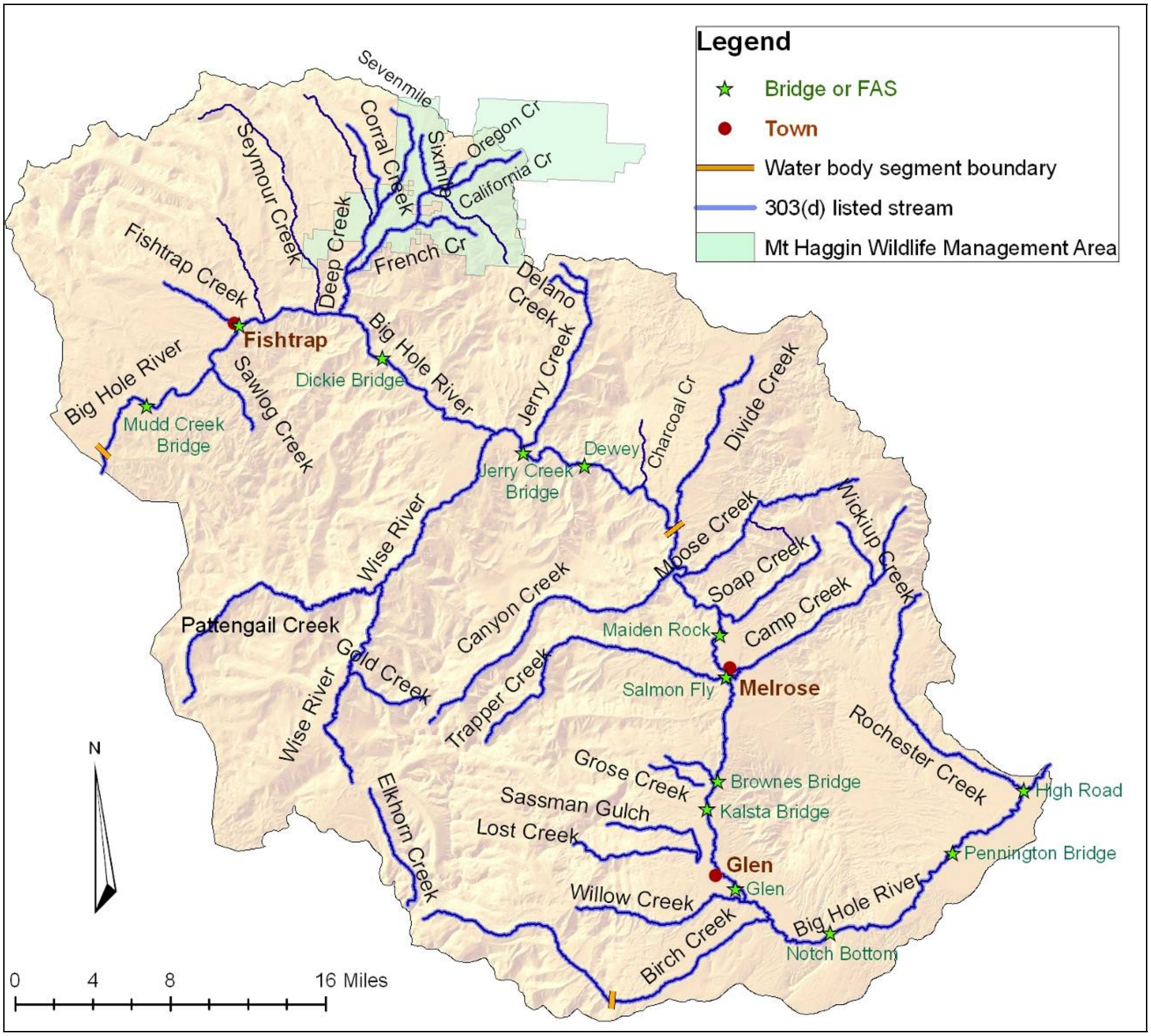


Figure A-2. 303(d) Listed water bodies in the Middle and Lower Big Hole TPA.

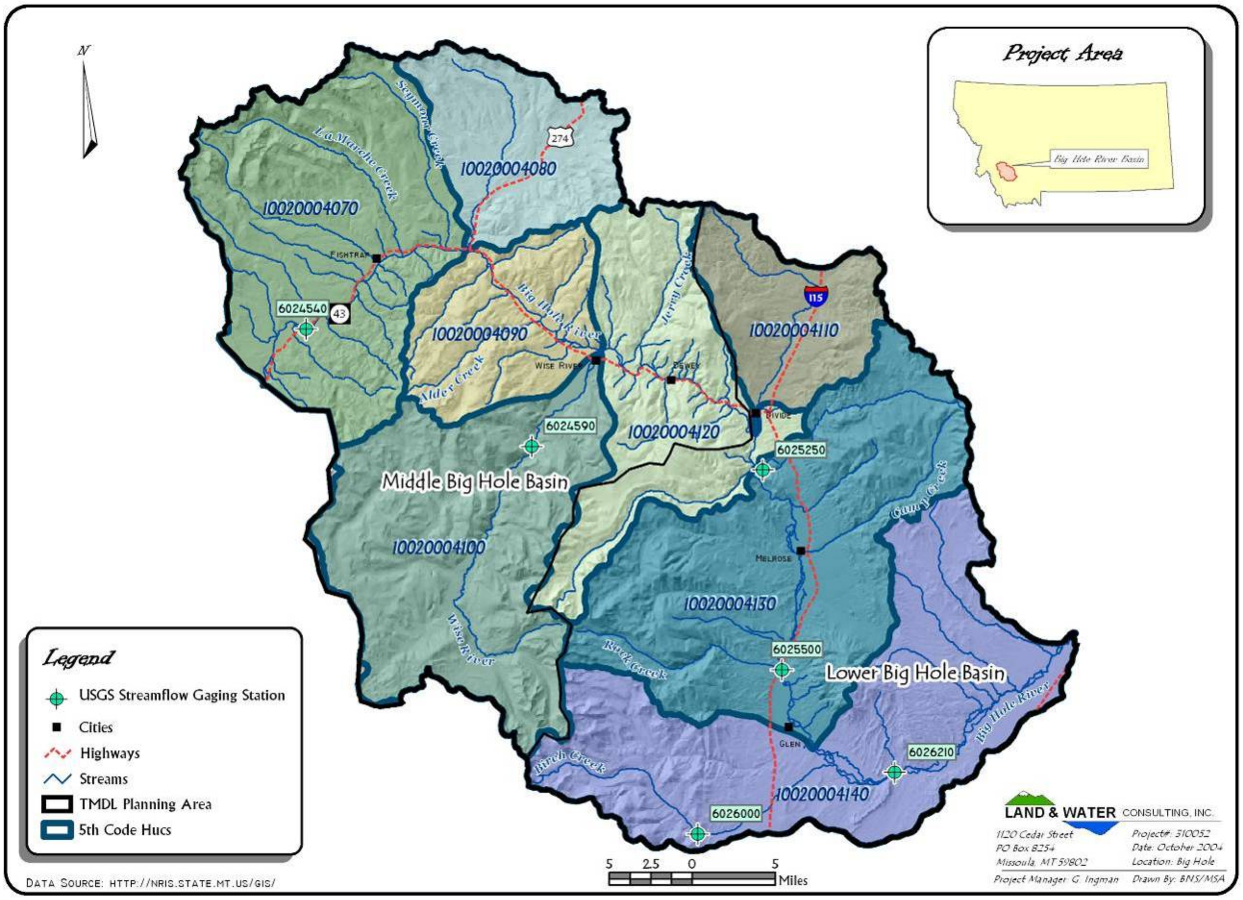


Figure A-3. USGS gauging stations in the Middle and Lower Big Hole TPA.

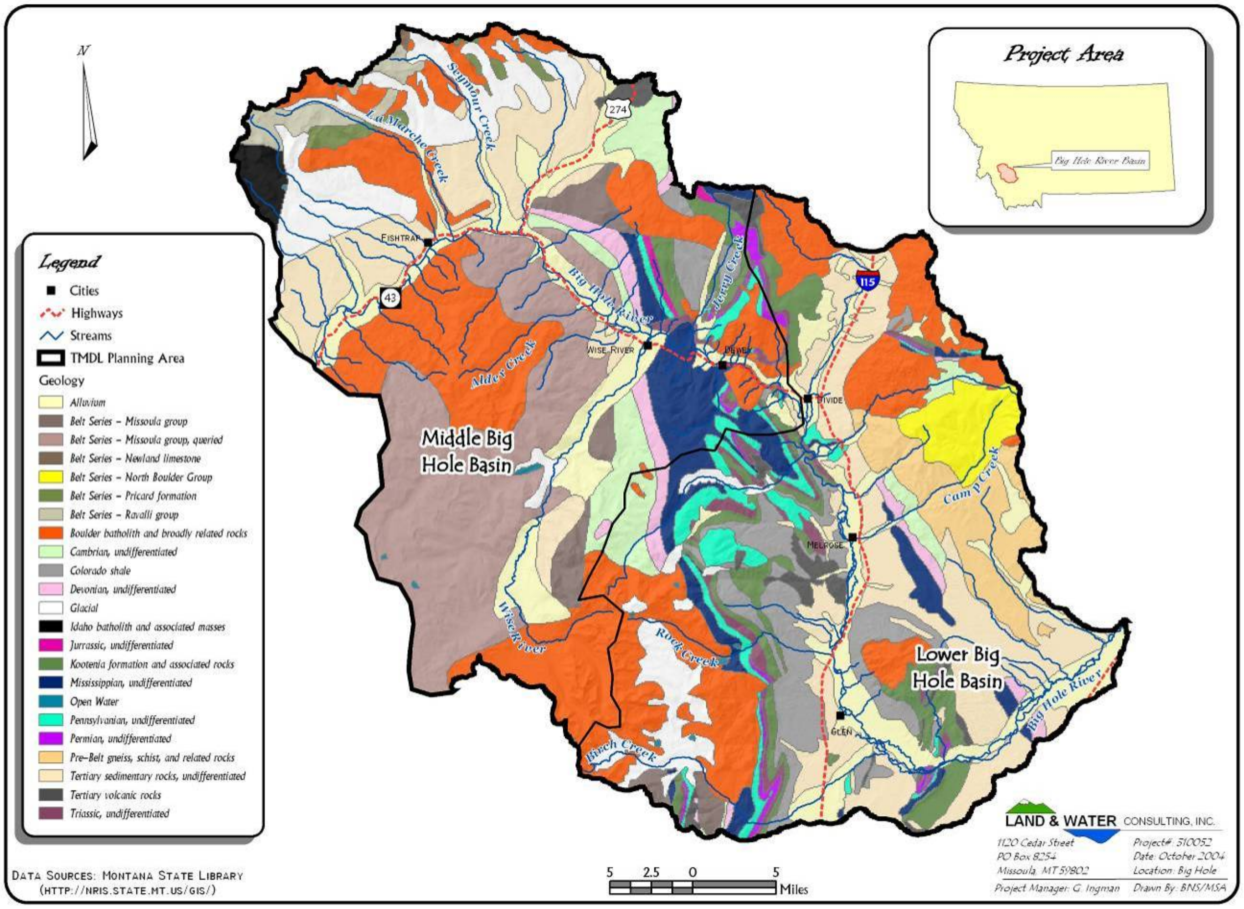


Figure A-4. Geology in the Middle and Lower Big Hole TPA.

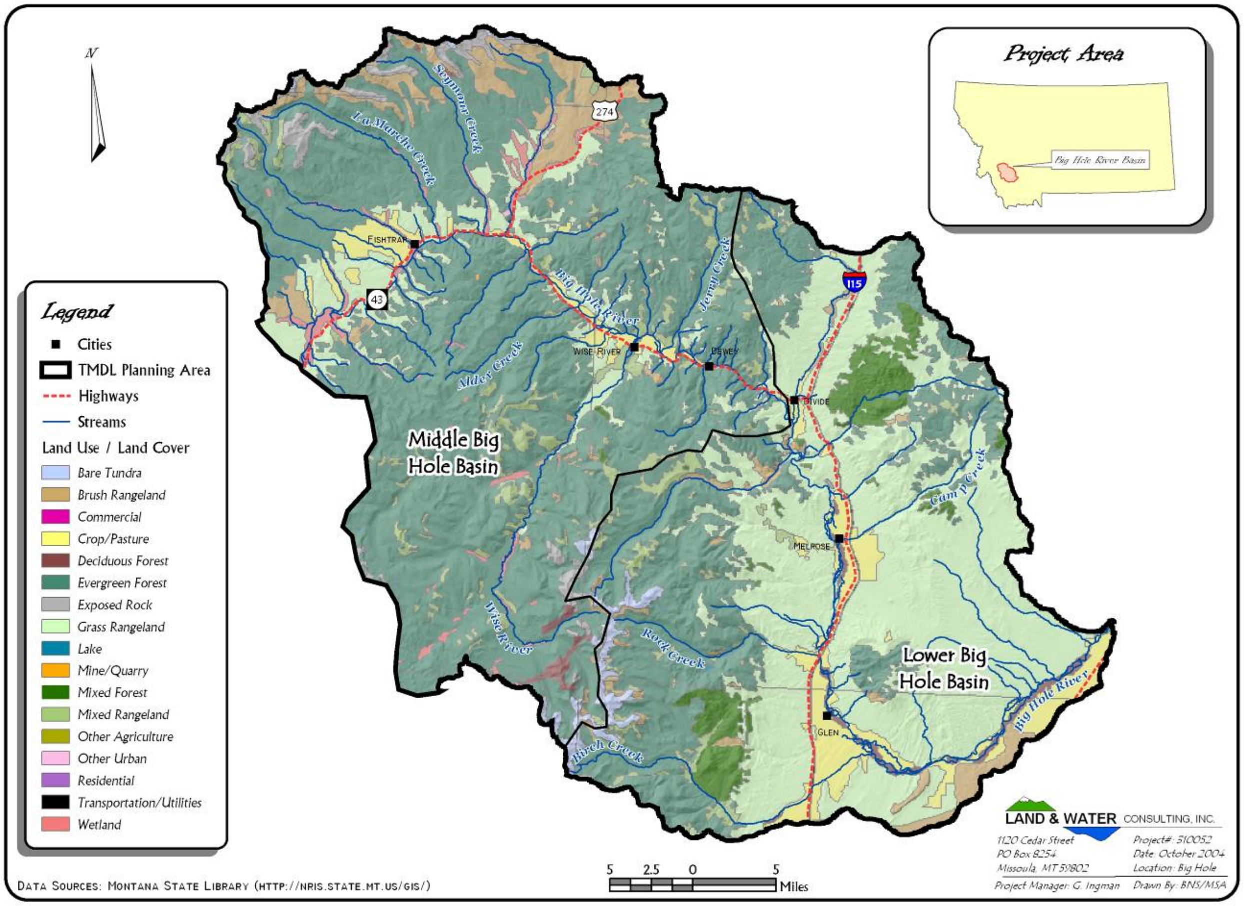


Figure A-5. Land use and land cover in the Middle and Lower Big Hole TPA.

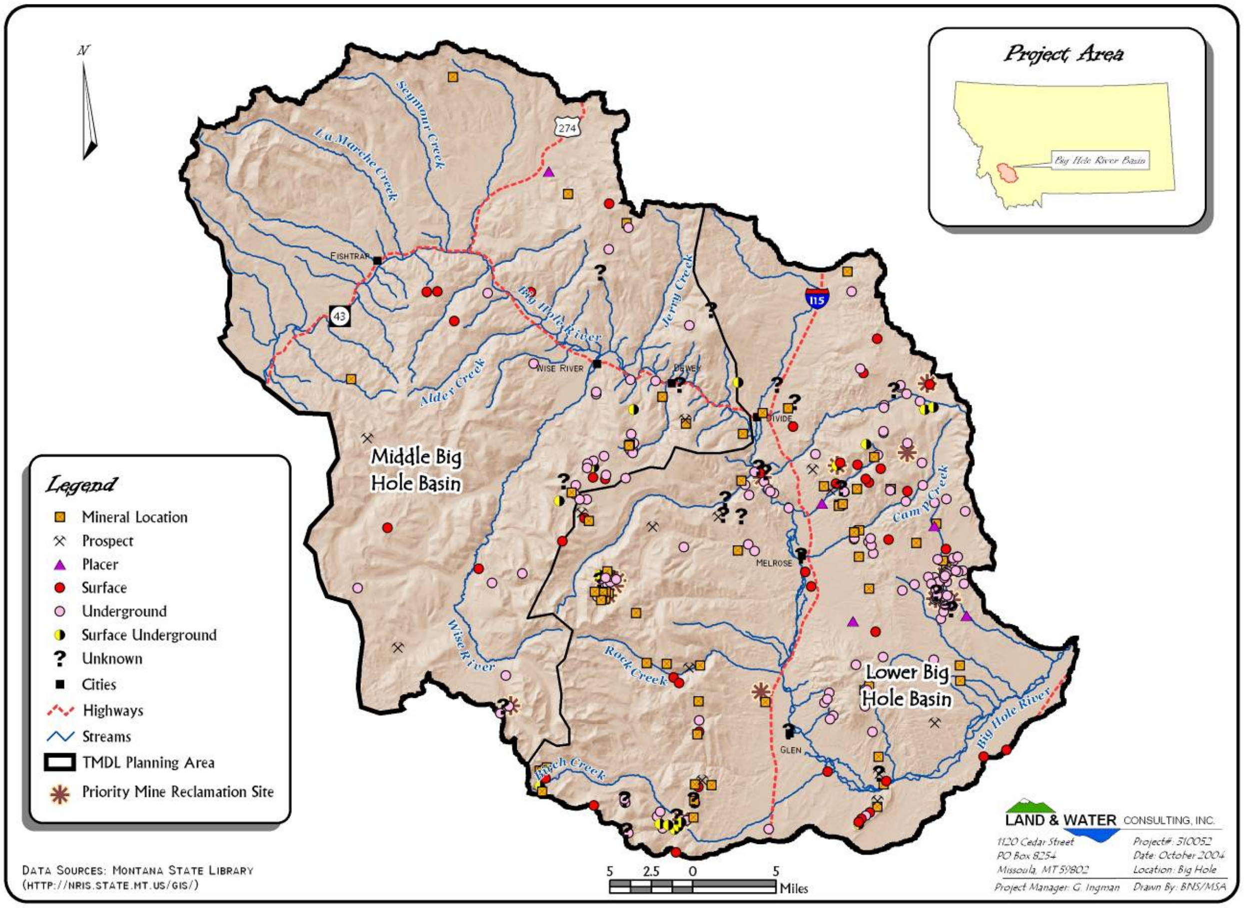


Figure A-6. Abandoned mines, including priority abandoned mines, within the Middle and Lower Big Hole River TPA.

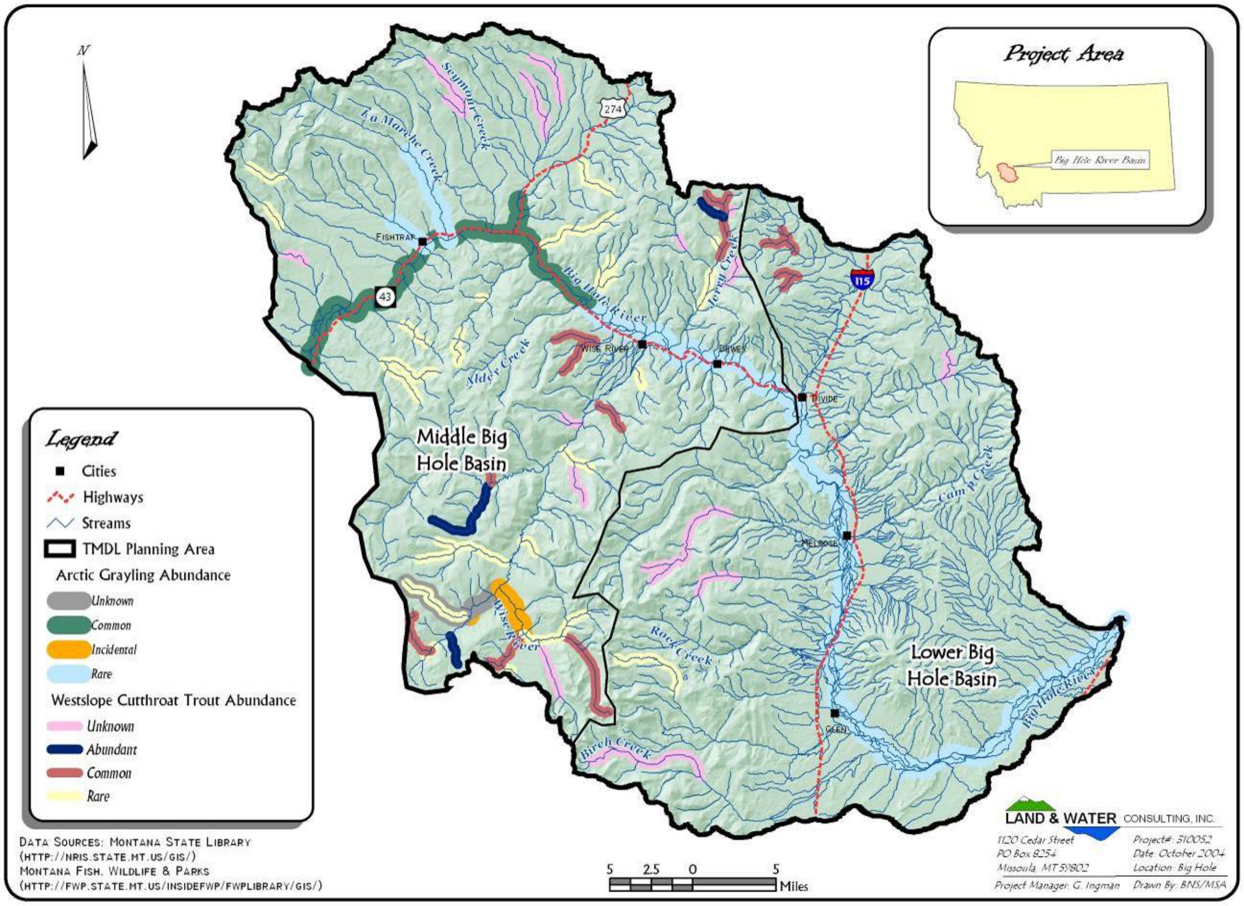


Figure A-7. Westslope Cutthroat Trout and Arctic Grayling Distribution in the Middle and Lower Big Hole River TPA.

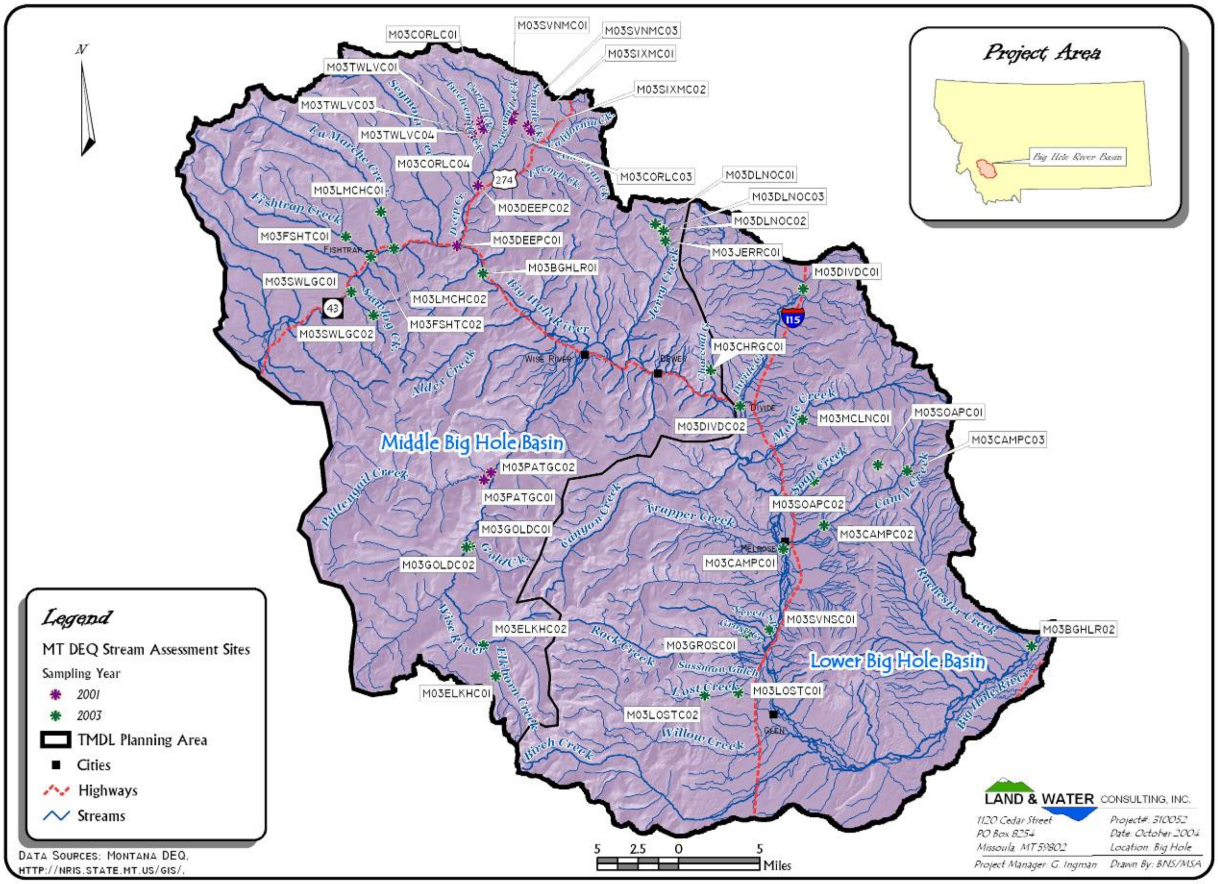


Figure A-8. DEQ monitoring sites in the Middle and Big Hole TPA.

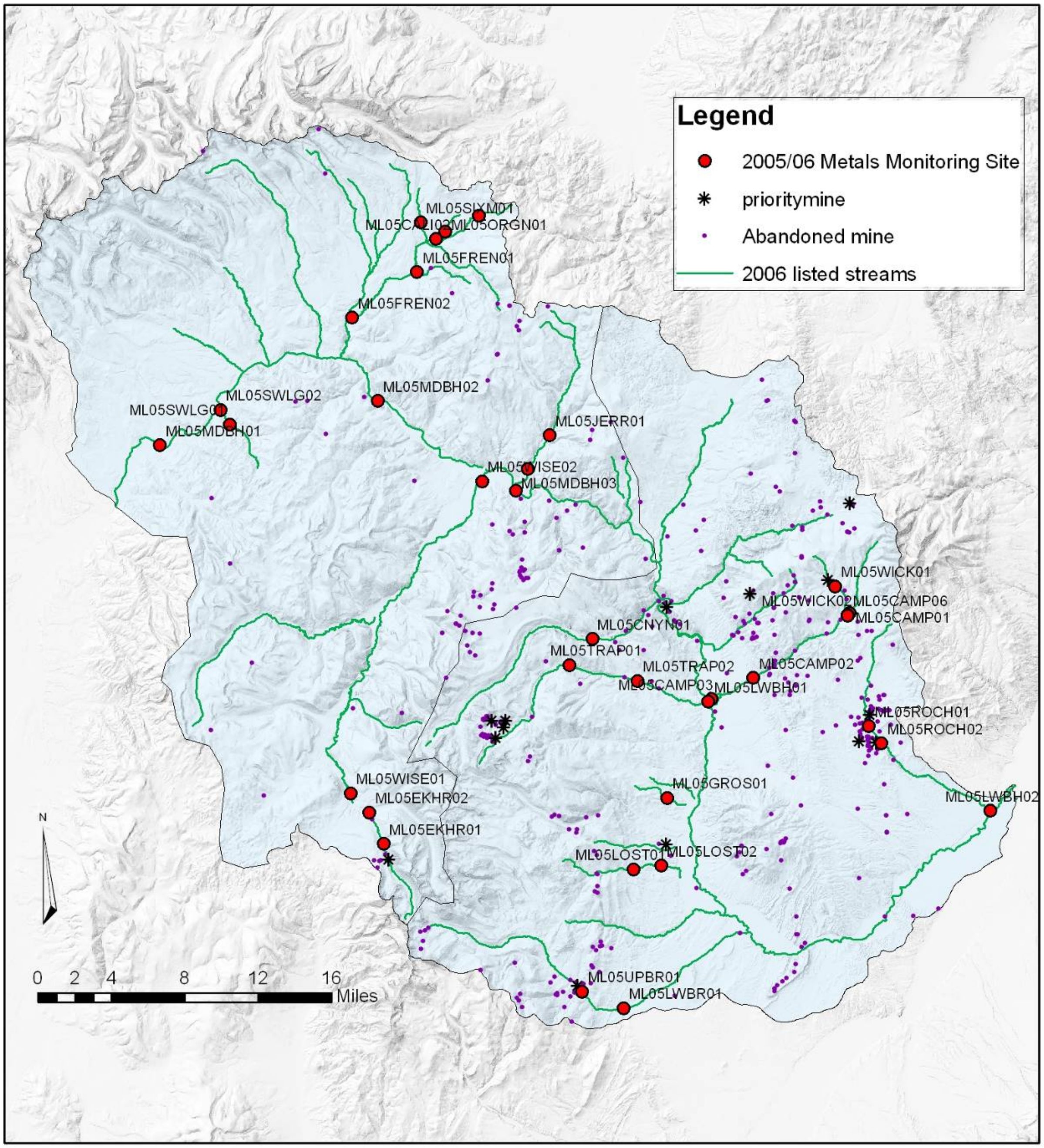


Figure A-9. 2005-2006 DEQ metals monitoring sites.

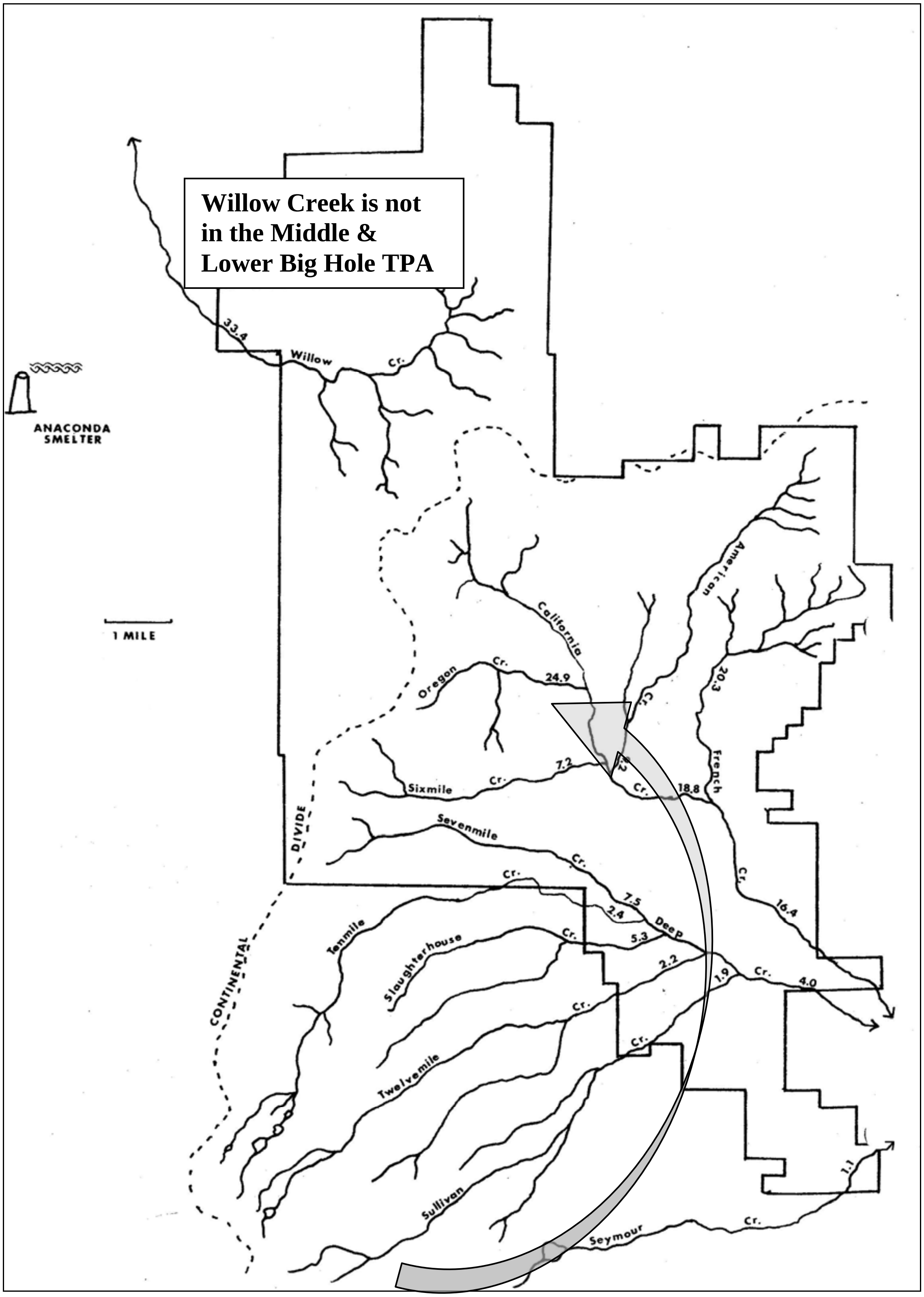


Figure A-10. Average concentration of dissolved arsenic (ug/L) in Mt. Haggin streams relative to the location of the Anaconda Smelter (adapted from Oswald, 1981). Arrow indicates direction of increase in concentration.

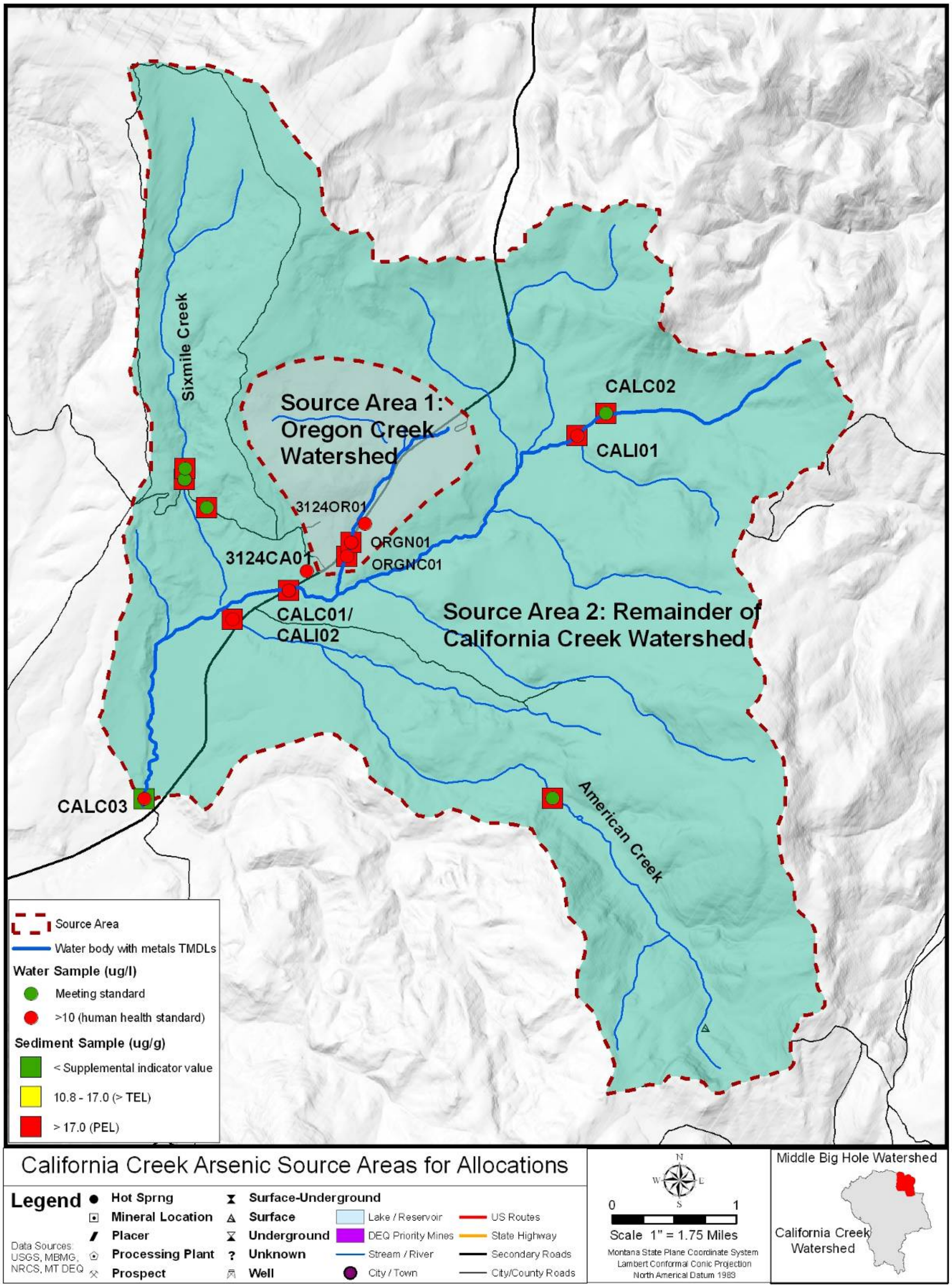


Figure A-11. Metals sampling locations and loading source area for California Creek.

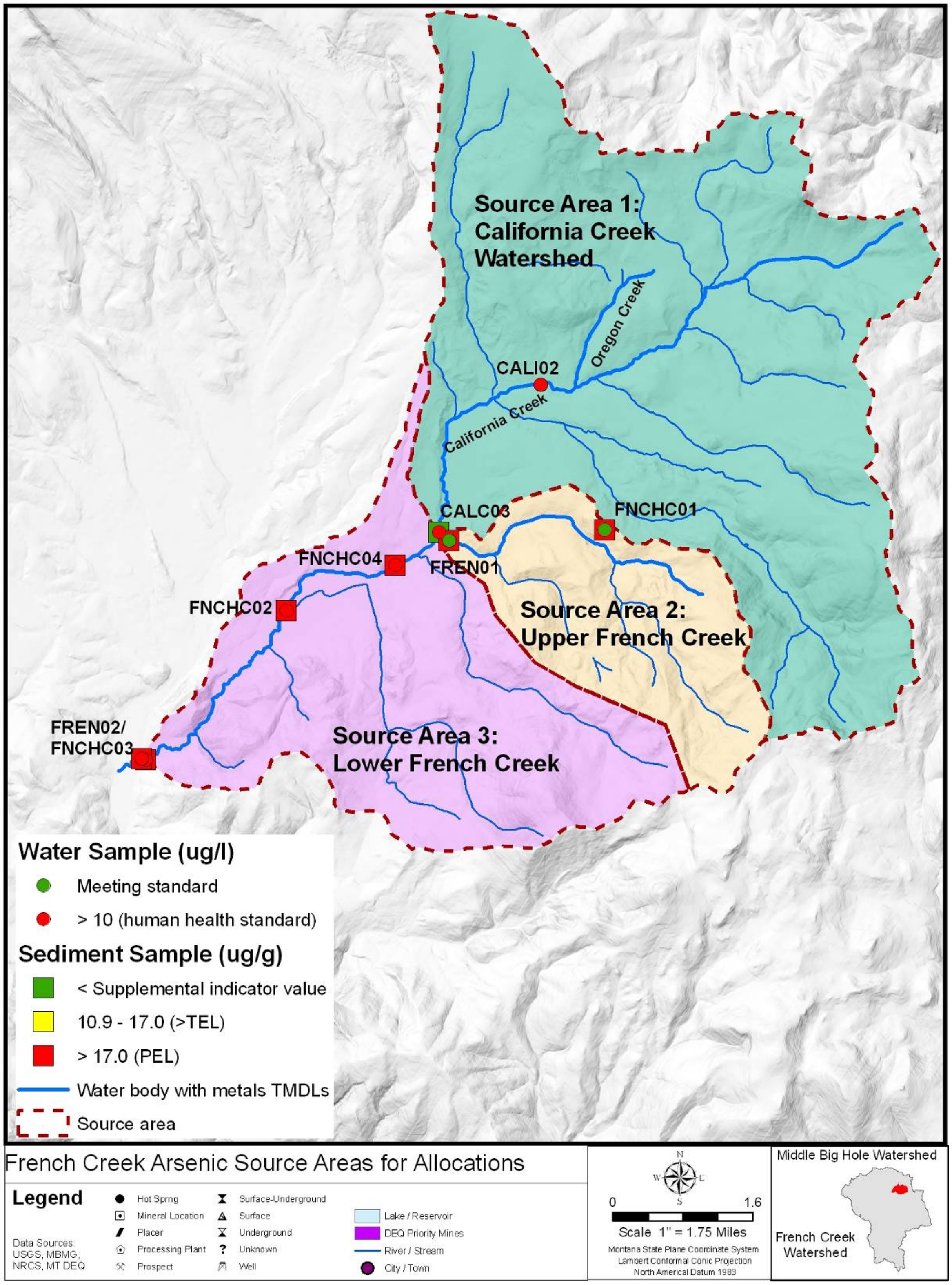


Figure A-12. Metals sampling locations and loading source area for French Creek.

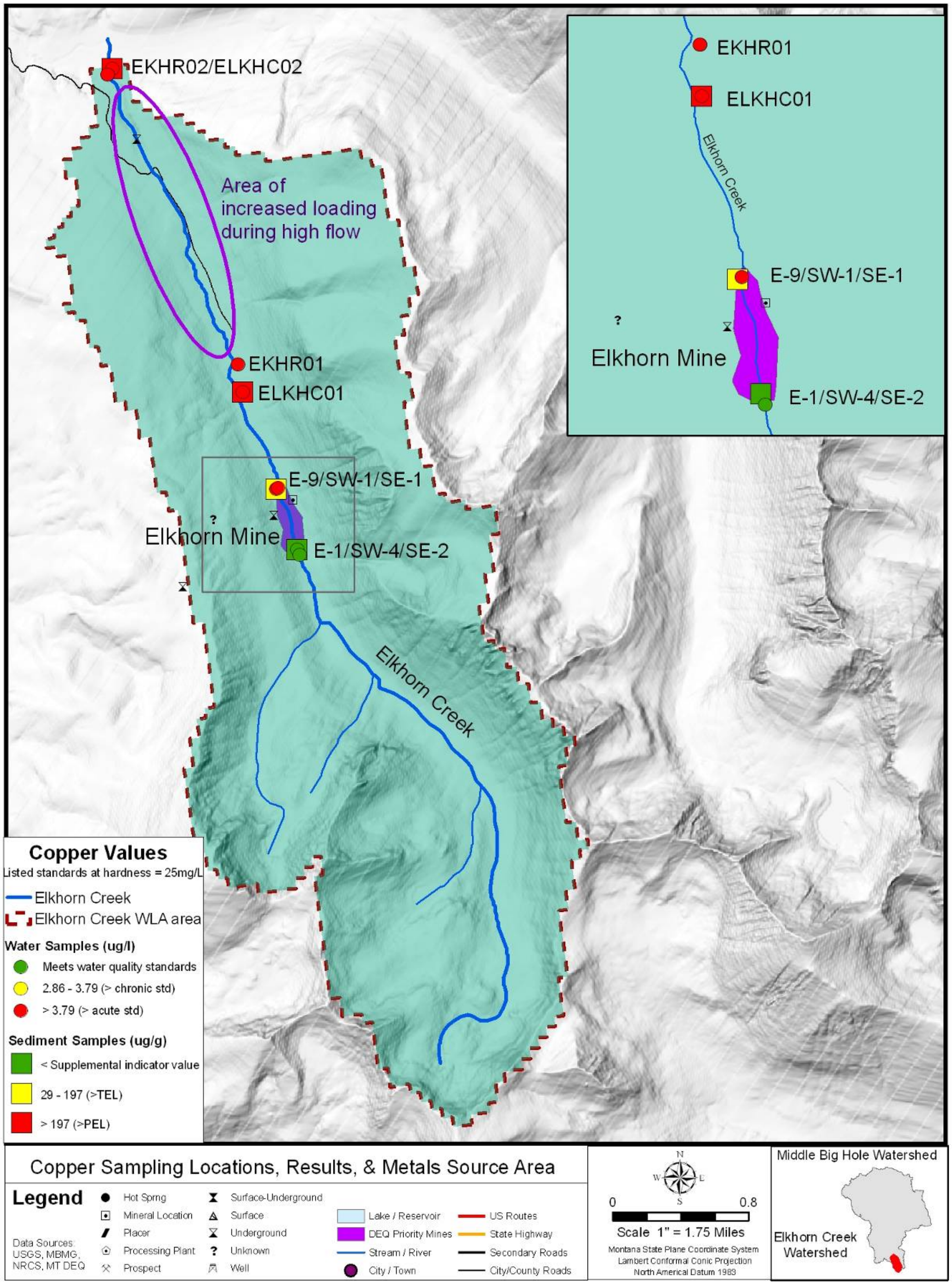


Figure A-13. Metals sampling locations and loading source area for Elkhorn Creek.

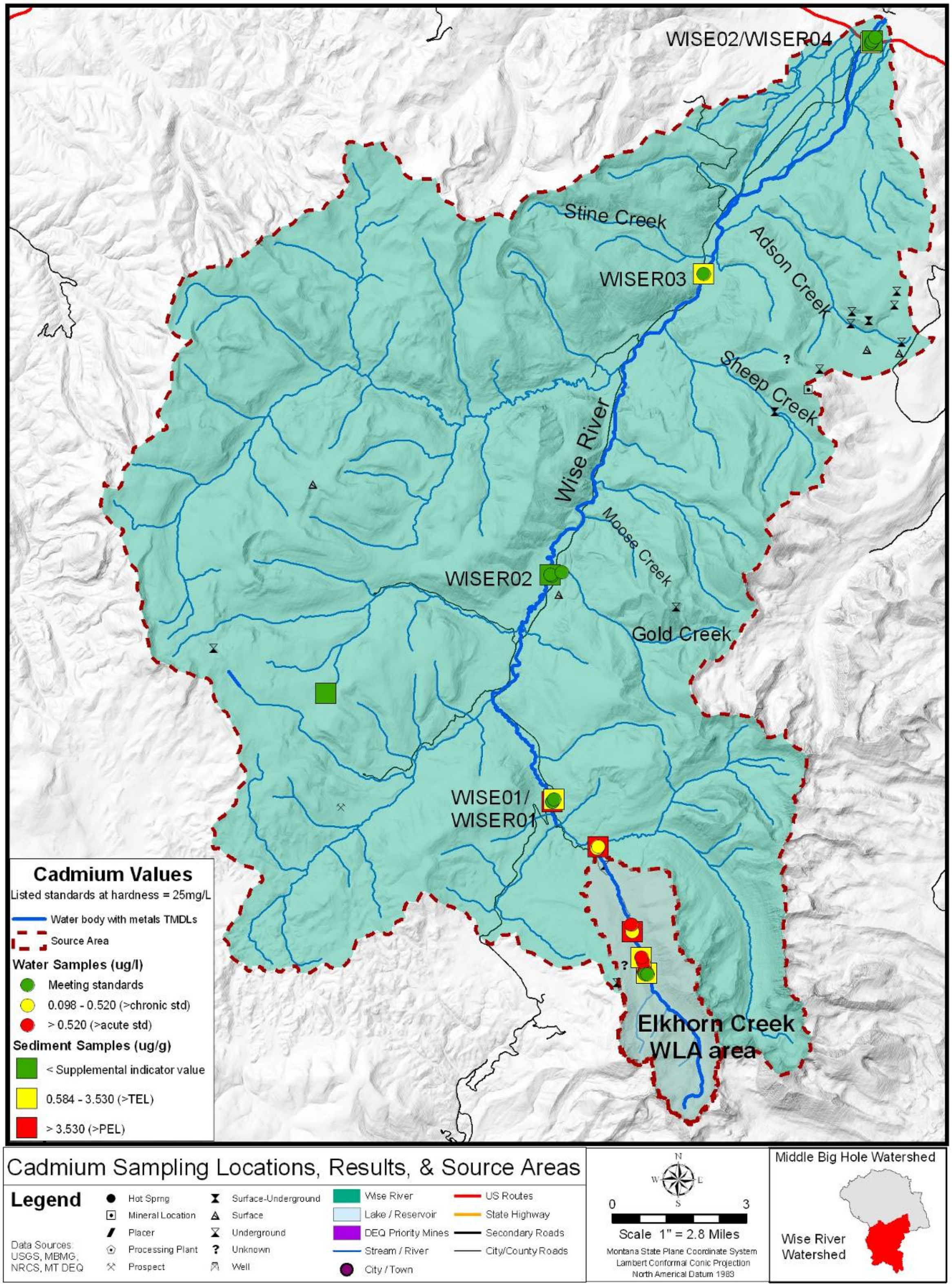


Figure A-14. Metals sampling locations and loading source area for the Wise River.

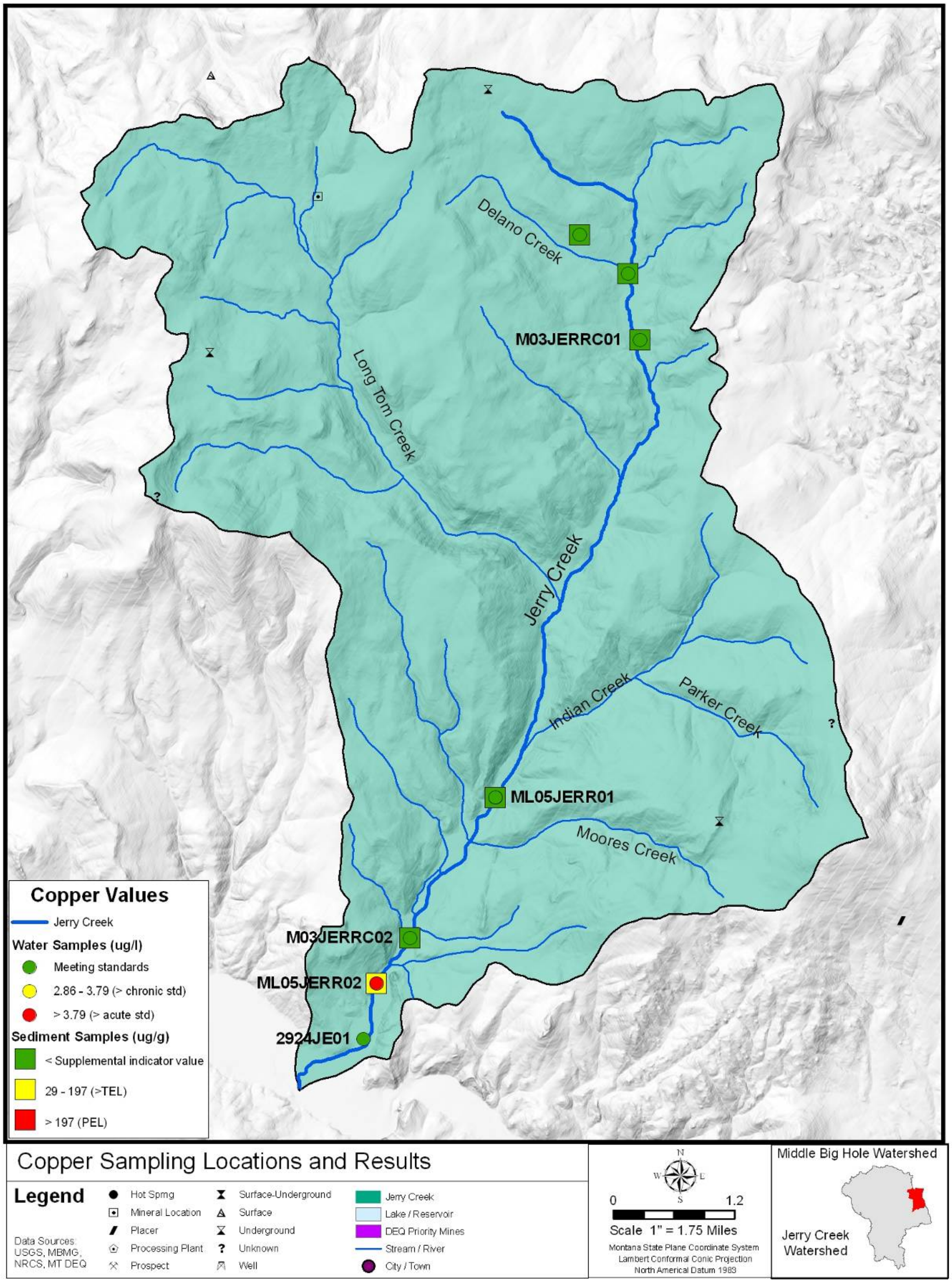


Figure A-15. Metals sampling locations and loading source area for Jerry Creek.

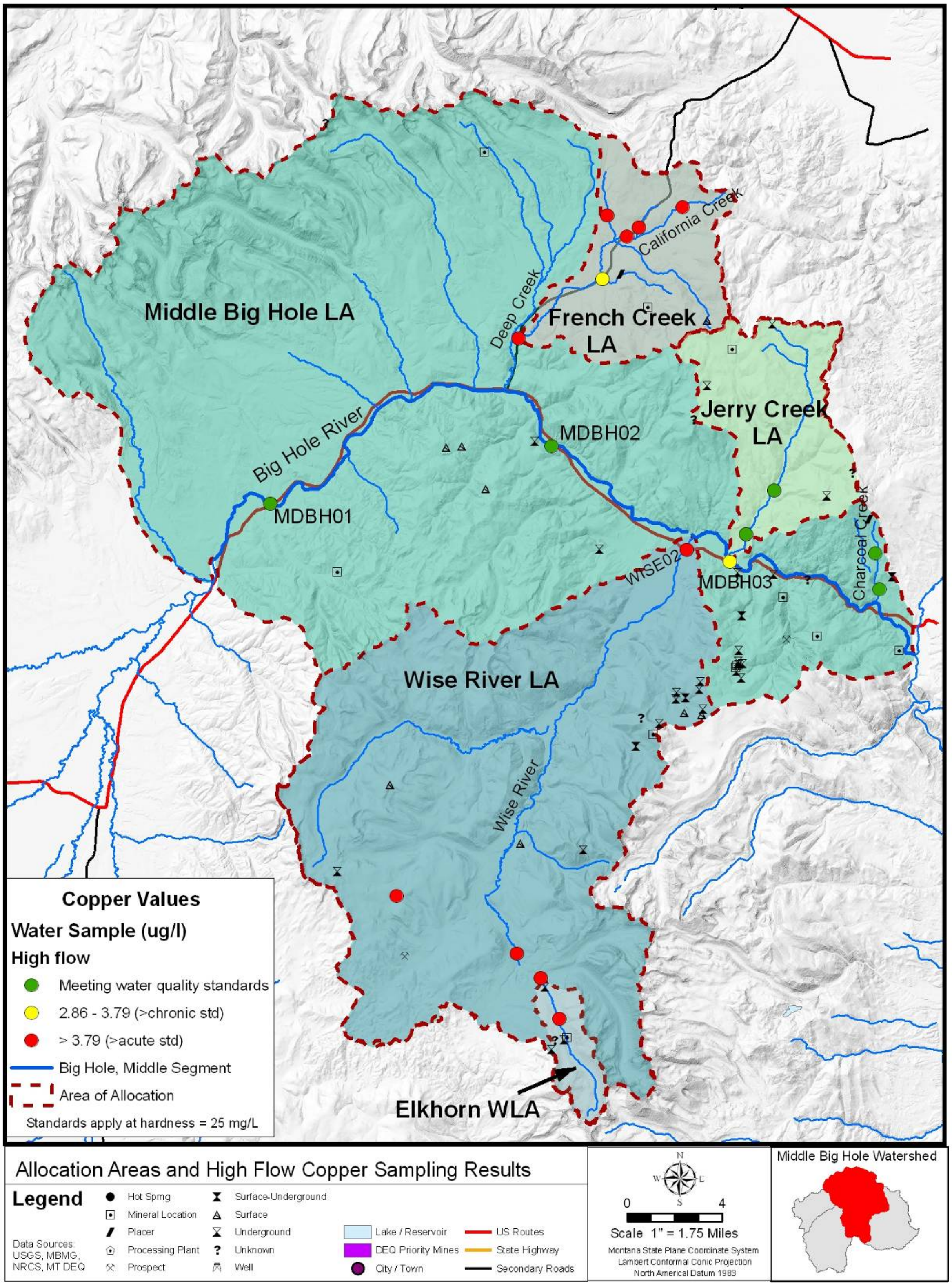


Figure A-16. Metals sampling locations and loading source area for the middle segment of the Big Hole River.

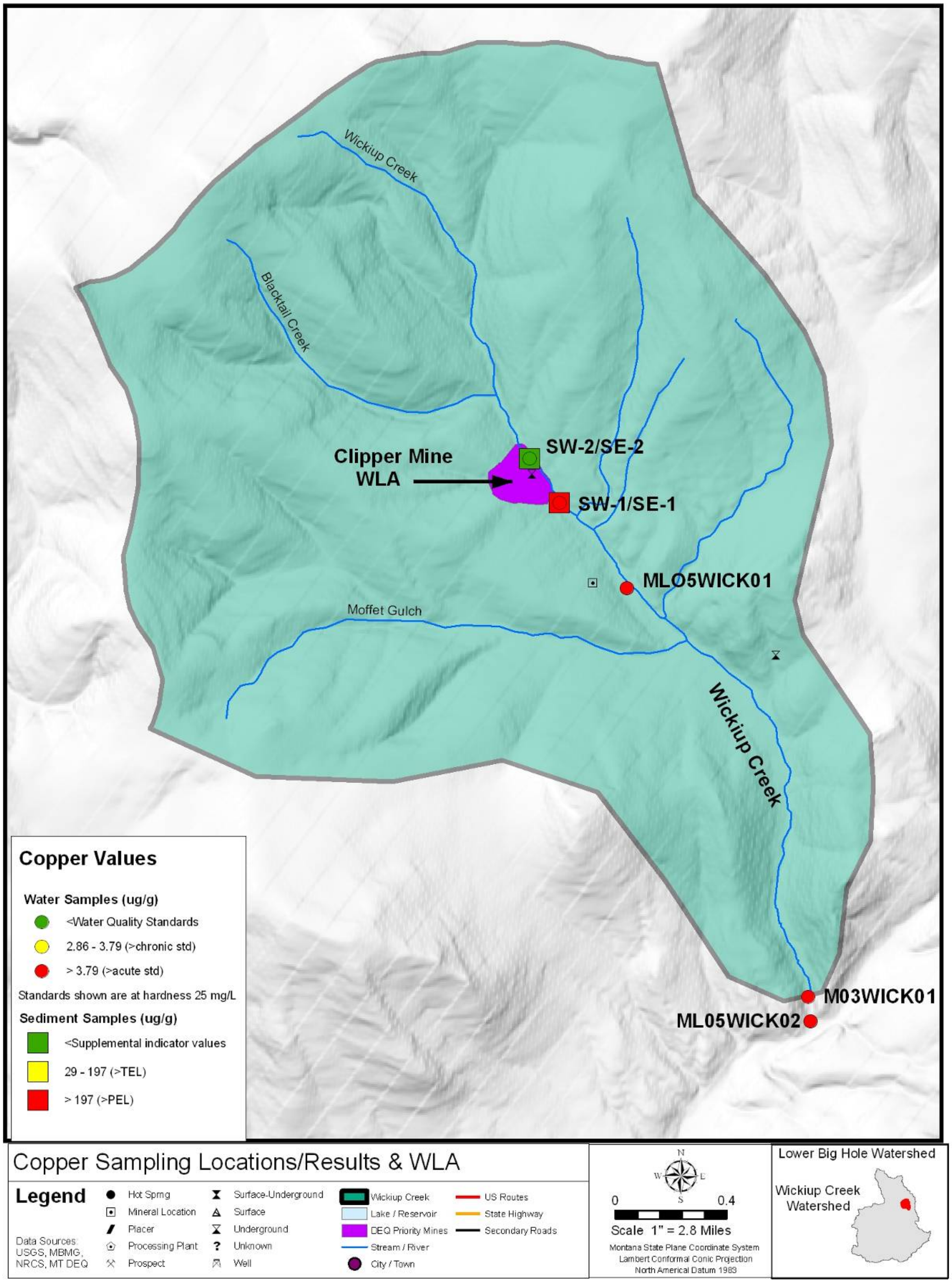


Figure A-17. Metals sampling locations and loading source area for Wickiup Creek.

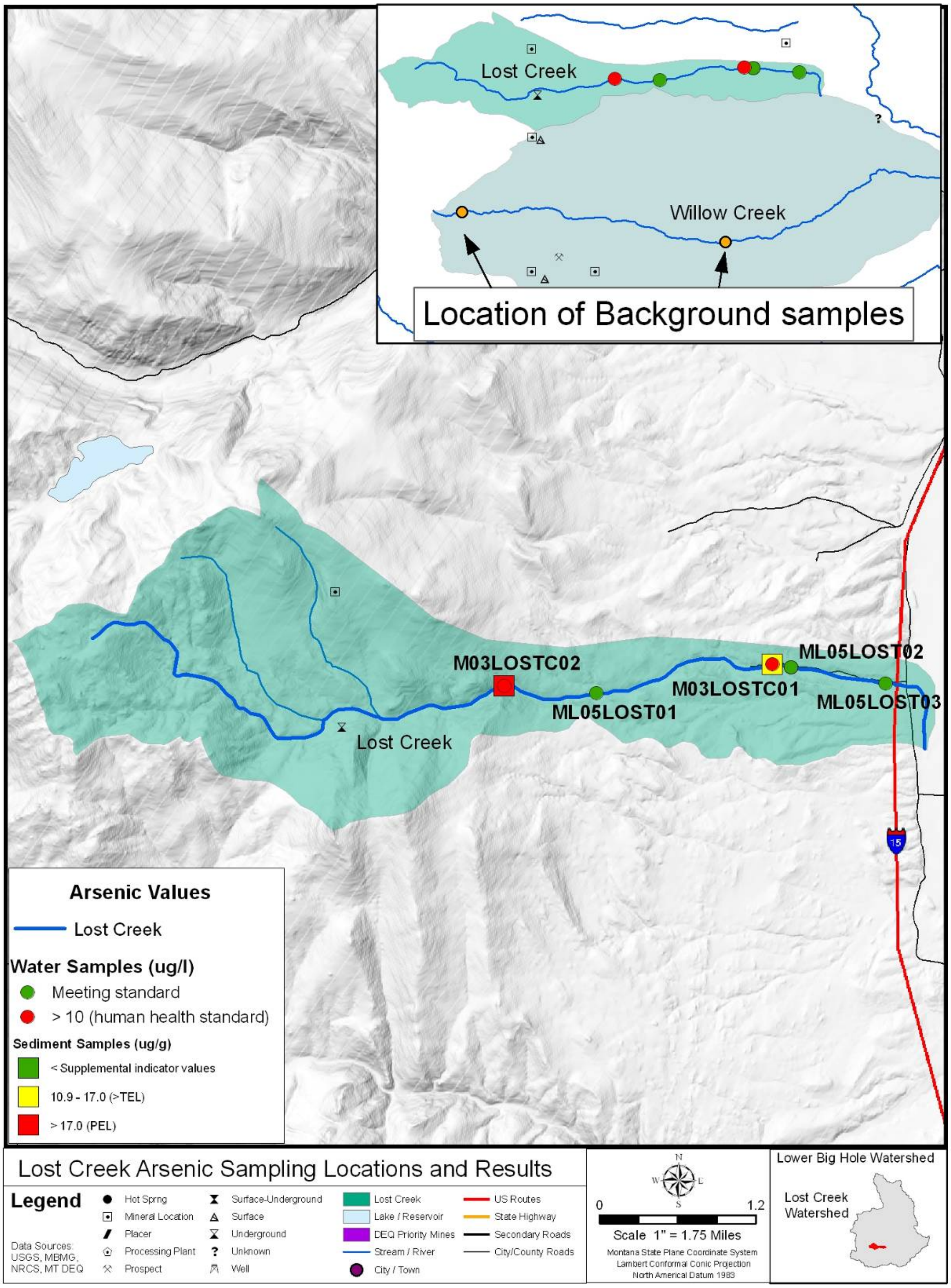


Figure A-18. Metals sampling locations and loading source area for Lost Creek.

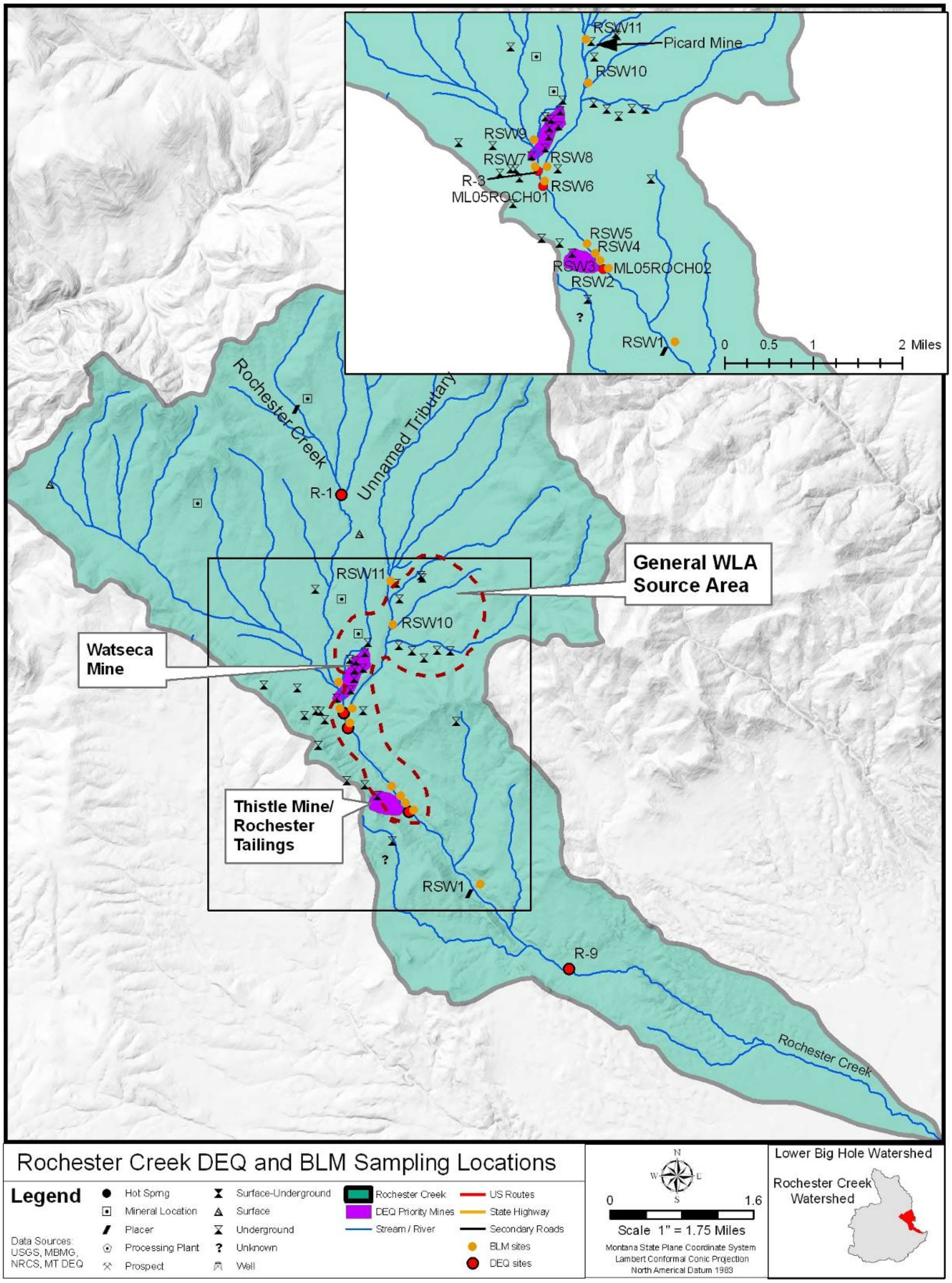


Figure A-19. Metals sampling locations and loading source area for Rochester Creek.

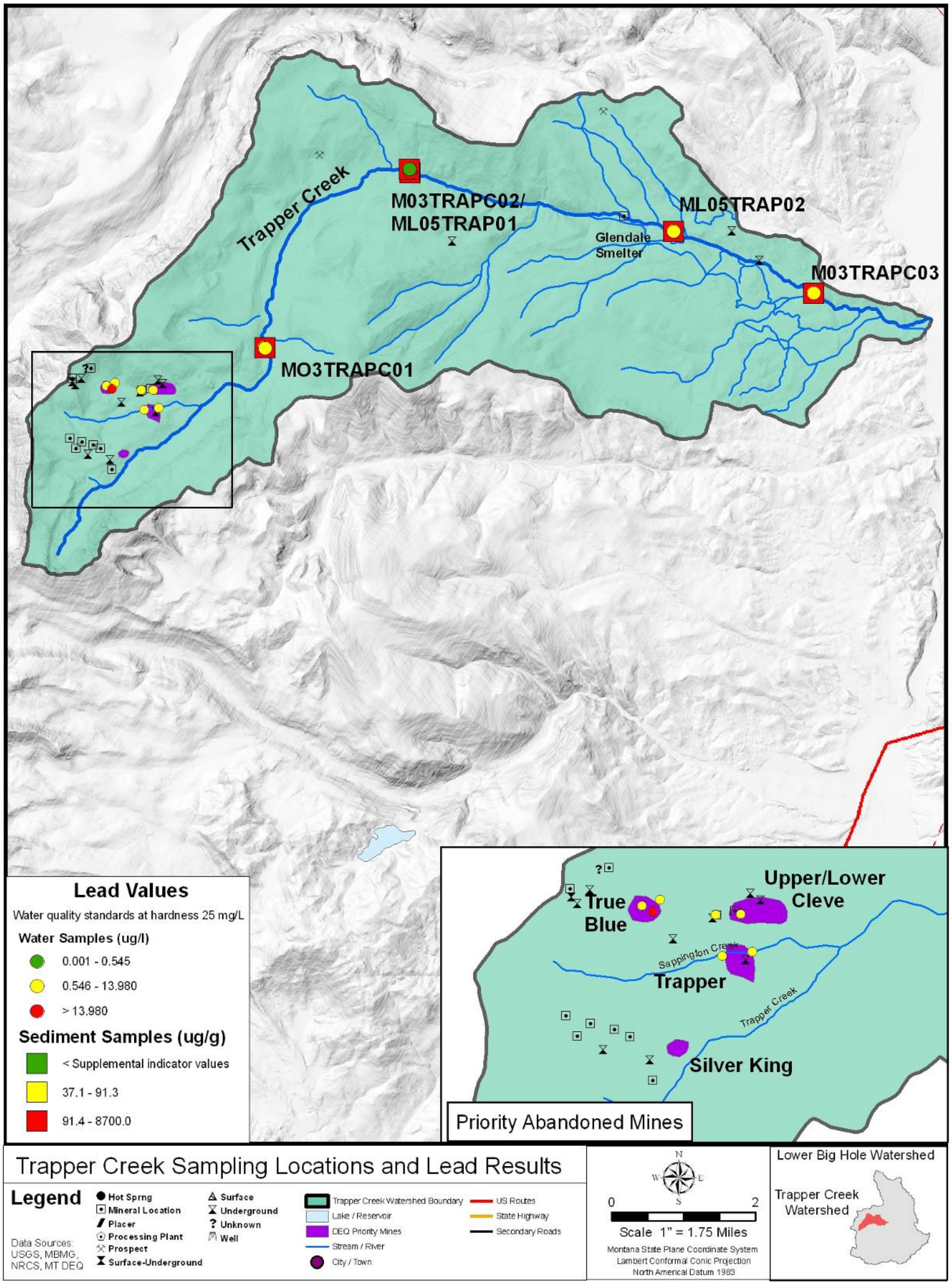


Figure A-20. Metals sampling locations and loading source area for Trapper Creek.

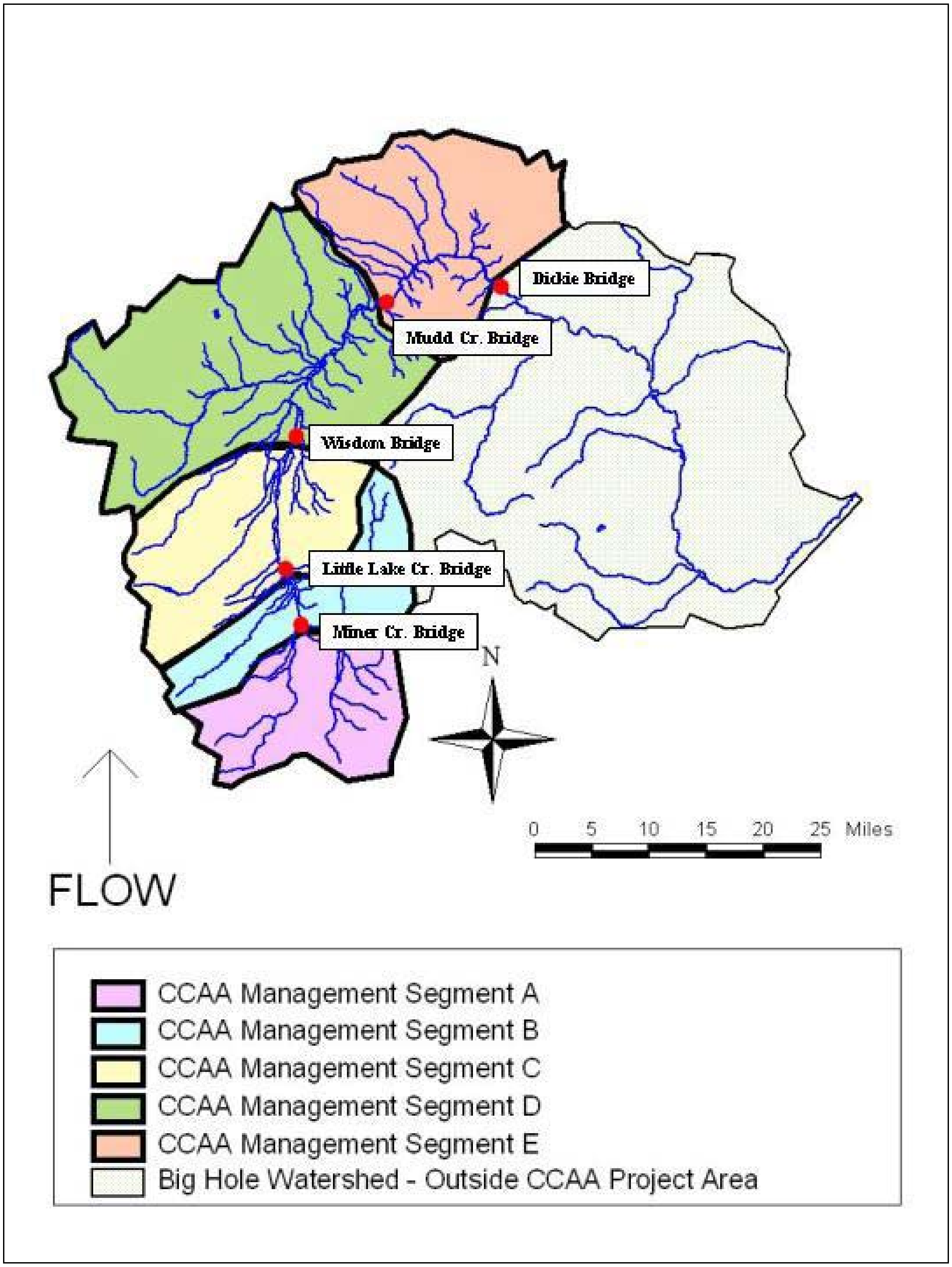


Figure A-21. Boundaries of CCAA Agreement showing separate management areas (FWP et al 2006)

APPENDIX B
REGULATORY FRAMEWORK AND REFERENCE CONDITION APPROACH

This appendix presents details about applicable Montana Water Quality Standards (WQS) and the general and statistical methods used for development of reference conditions.

B.1 TMDL Development Requirements

Section 303 of the Federal Clean Water Act (CWA) and the Montana WQA (Section 75-5-703) requires development of TMDLs for impaired water bodies that do not meet Montana WQS. Although water bodies can become impaired from pollution (e.g. flow alterations and habitat degradation) and pollutants (e.g. nutrients, sediment, and metals), the CWA and Montana State Law (75-5-703) both require TMDL development for waters impaired only by pollutants. Section 303 also requires states to submit a list of impaired water bodies to EPA every two years. Prior to 2004, EPA and DEQ referred to this list as the 303(d) List.

Since 2004, EPA has requested that states combine the 303(d) List with the 305(b) report containing an assessment of Montana's water quality and its water quality programs. EPA refers to this new combined 303(d)/305(b) report as the Integrated Water Quality Report. The 303(d) List also includes identification of the probable cause(s) of the water quality impairment problems (e.g. pollutants such as metals, nutrients, sediment or temperature), and the suspected source(s) of the pollutants of concern (e.g. various land use activities). State law (MCA 75-5-702) identifies that a sufficient credible data methodology for determining the impairment status of each water body is used for consistency; the actual methodology is identified in DEQ's Water Quality Assessment Process and Methods (DEQ 2006b). This methodology was developed via a public process and was incorporated into the EPA-approved 2000 version of the 305(b) report (now also referred to as the Integrated Report).

Under Montana State Law, an "impaired water body" is defined as a water body or stream segment for which sufficient credible data shows that the water body or stream segment is failing to achieve compliance with applicable WQS (Montana Water Quality Act; Section 75-5-103(11)). A "threatened water body" is defined as a water body or stream segment for which sufficient credible data and calculated increases in loads show that the water body or stream segment is fully supporting its designated uses but threatened for a particular designated use because of either (a) proposed sources that are not subject to pollution prevention or control actions required by a discharge permit, the nondegradation provisions, or reasonable land, soil, and water conservation practices or (b) documented adverse pollution trends (Montana WQA; Section 75-5-103(31)). State Law and Section 303 of the CWA require states to develop all necessary TMDLs for impaired or threatened water bodies, as of now there are no threatened water bodies within the Middle and Lower Big Hole TPA.

A TMDL is a pollutant budget for a water body identifying the maximum amount of the pollutant that a water body can assimilate without causing applicable WQS to be exceeded. TMDLs are often expressed in terms of an amount, or load, of a particular pollutant (expressed in units of mass per time, such as pounds per day). TMDLs must account for loads/impacts from point and nonpoint sources in addition to natural background sources and must incorporate a margin of safety and consider influences of seasonality on analysis and compliance with Water Quality Standards (WQS).

To satisfy the Federal CWA and Montana State Law, TMDLs will be developed for each water body-pollutant combination identified on Montana's 2006 303(d) List of impaired waters in the Middle and Lower Big Hole TPA. State Law (Administrative Rules of Montana 75-5-703(8)) also directs Montana DEQ to "...support a voluntary program of reasonable land, soil, and water conservation practices to achieve compliance with water quality standards for nonpoint source activities for water bodies that are subject to a TMDL…". This is an important directive that is reflected in the overall TMDL development and implementation strategy within this plan. It is important to note that water quality protection measures are not considered voluntary where such measures are already a requirement under existing Federal, State, or local regulations.

B.2 Applicable Water Quality Standards

WQS include the uses designated for a waterbody, the legally enforceable standards that ensure that the uses are supported, and a non-degradation policy that protects the high quality of a waterbody. The ultimate goal of this TMDL document, once implemented, is to ensure that all designated beneficial uses are fully supported and all standards are met. Water quality standards form the basis for the targets described within each pollutant section of the document. Pollutants addressed in this Water Quality Planning Framework include: sediment, nutrients, metals, and temperature. This section provides a summary of the applicable water quality standards for each of these pollutants.

B.2.1 Classification and Beneficial Uses

Classification is the assignment (designation) of a single or group of uses to a waterbody based on the potential of the waterbody to support those uses. Designated Uses or Beneficial Uses are simple narrative descriptions of water quality expectations or water quality goals. There are a variety of "uses" of state waters including growth and propagation of fish and associated aquatic life; drinking water; agriculture; industrial supply; and recreation and wildlife. The Montana WQA directs the Board of Environmental Review (BER) (i.e., the state) to establish a classification system for all waters of the state that includes their present (when the Act was originally written) and future most beneficial uses (ARM 17.30.607-616) and to adopt standards to protect those uses (ARM 17.30.620-670).

Montana, unlike many other states, uses a watershed based classification system with some specific exceptions. As a result, *all* waters of the state are classified and have designated uses and supporting standards. All classifications have multiple uses and in only one case (A-Closed) is a specific use (drinking water) given preference over the other designated uses. Some waters may not actually be used for a specific designated use, for example, as a public drinking water supply; however, the quality of that waterbody must be maintained suitable for that designated use. When natural conditions limit or preclude a designated use, permitted point source discharges or non-point source activities or pollutant discharges may not make the natural conditions worse.

Modification of classifications or standards that would lower a water's classification or a standard (i.e., B-1 to a B-3), or removal of a designated use because of natural conditions can only occur if the water was originally misclassified. All such modifications must be approved by the BER, and are undertaken via a Use Attainability Analysis (UAA) that must meet EPA requirements (40 CFR 131.10(g), (h) and (j)). The UAA and findings presented to the BER during rulemaking must prove that the modification is correct and all existing uses are supported. An existing use cannot be removed or made less stringent.

Descriptions of Montana's surface water classifications and designated beneficial uses are presented in **Table B-1**. All water bodies within the Middle and Lower Big Hole TPA are classified as either A-1 or B-1 (see **Section 3.1, Table 3-1** for individual stream classifications).

Table B-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
A-CLOSED CLASSIFICATION:	Waters classified A-Closed are to be maintained suitable for drinking, culinary and food processing purposes after simple disinfection.
A-1 CLASSIFICATION:	Waters classified A-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment for removal of naturally present impurities.
B-1 CLASSIFICATION:	Waters classified B-1 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-2 CLASSIFICATION:	Waters classified B-2 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
B-3 CLASSIFICATION:	Waters classified B-3 are to be maintained suitable for drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-1 CLASSIFICATION:	Waters classified C-1 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.
C-2 CLASSIFICATION:	Waters classified C-2 are to be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

Table B-1. Montana Surface Water Classifications and Designated Beneficial Uses

Classification	Designated Uses
C-3 CLASSIFICATION:	Waters classified C-3 are to be maintained suitable for bathing, swimming and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl and furbearers. The quality of these waters is naturally marginal for drinking, culinary and food processing purposes, agriculture and industrial water supply.
I CLASSIFICATION:	The goal of the State of Montana is to have these waters fully support the following uses: drinking, culinary and food processing purposes after conventional treatment; bathing, swimming and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

B.2.2 Standards

In addition to the Use Classifications described above, Montana's WQS include numeric and narrative criteria as well as a nondegradation policy.

Numeric surface WQS have been developed for many parameters to protect human health and aquatic life. These standards are in the Department Circular WQB-7 (DEQ 2006a). The numeric human health standards have been developed for parameters determined to be toxic, carcinogenic, or harmful and have been established at levels to be protective of long-term (i.e., life long) exposures as well as through direct contact such as swimming.

The numeric aquatic life standards include chronic and acute values that are based on extensive laboratory studies including a wide variety of potentially affected species, a variety of life stages and durations of exposure. Chronic aquatic life standards are protective of long-term exposure to a parameter. The protection afforded by the chronic standards includes detrimental effects to reproduction, early life stage survival, and growth rates. In most cases the chronic standard is more stringent than the corresponding acute standard. Acute aquatic life standards are protective of short-term exposures to a parameter and are not to be exceeded.

High quality waters are afforded an additional level of protection by the nondegradation rules (ARM 17.30.701 et. seq.,) and in statute (75-5-303 MCA). Changes in water quality must be "non-significant" or an authorization to degrade must be granted by the Department. However, under no circumstance may standards be exceeded. It is important to note that waters that meet or are of better quality than a standard are high quality for that parameter, and nondegradation policies apply to new or increased discharges to that the waterbody.

Narrative standards have been developed for substances or conditions for which sufficient information does not exist to develop specific numeric standards. The term "Narrative Standards" commonly refers to the General Prohibitions in ARM 17.30.637 and other descriptive portions of the surface WQS. The General Prohibitions are also called the "free from" standards; that is, the surface waters of the state must be free from substances attributable to discharges, including thermal pollution, that impair the beneficial uses of a waterbody. Uses may be impaired by toxic or harmful conditions (from one or a combination of parameters) or conditions that produce undesirable aquatic life. Undesirable aquatic life includes bacteria, fungi, and algae.

The standards applicable to the list of pollutants addressed in the Middle and Lower Big Hole TPA are summarized, one-by-one, below. In addition to the standards below, the beneficial use support standard for a A-1 and B-1 streams, as defined above, can apply to other conditions, often linked to pollution, limiting aquatic life. These other conditions can include impacts from dewatering/flow alterations, impacts from habitat modifications, or impacts from excess algae.

Sediment

Sediment (i.e., coarse and fine bed sediment) and suspended sediment are addressed via the narrative criteria identified in **Table 3-2**. The relevant narrative criteria do not allow for harmful or other undesirable conditions related to increases above naturally occurring levels or from discharges to state surface waters. This is interpreted to mean that water quality goals should strive toward a condition in which any increases in sediment above naturally occurring levels are not harmful, detrimental or injurious to beneficial uses (see definitions in **Table B-2**).

Table B-2. Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.623(2)	No person may violate the following specific water quality standards for waters classified B-1.
17.30.623(2)(f)	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except a permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife.
17.30.637(1)	State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will.
17.30.637(1)(a)	Settle to form objectionable sludge deposits or emulsions beneath the surface of the water or upon adjoining shorelines.
17.30.637(1)(d)	Create concentrations or combinations of materials that are toxic or harmful to human, animal, plant, or aquatic life.
	The maximum allowable increase above naturally occurring turbidity is: 0 NTU for A-closed; 5 NTU for A-1, B-1, and C-1; 10 NTU for B-2, C-2, and C-3)
17.30.602(17)	"Naturally occurring" means conditions or material present from runoff or percolation over which man has no control or from developed land where all reasonable land, soil, and water conservation practices have been applied.

Table B-2. Applicable Rules for Sediment Related Pollutants.

Rule(s)	Standard
17.30.602(21)	"Reasonable land, soil, and water conservation practices" means methods, measures, or practices that protect present and reasonably anticipated beneficial uses. These practices include but are not limited to structural and nonstructural controls and operation and maintenance procedures. Appropriate practices may be applied before, during, or after pollution-producing activities.

Turbidity

The allowable changes in turbidity (above natural) is a rather small 5 or 10 nephelometric turbidity units (NTU), see table above. The likely direct effects of increased turbidity are on recreation, aesthetics and drinking water supplies. Indirectly increased turbidity can be linked to an increased pathogen potential, total recoverable metals concentration, and increased total suspended sediment. Turbidity cannot be equated with other parameters. Turbidity is a measure of light scatter in water. Suspended or colloidal solids like phytoplankton, metal precipitates or clay may cause the light scatter. In some cases it may be a useful and easily measured surrogate for total suspended solids (TSS) but only after paired flow and seasonal (full hydrograph) turbidity and TSS data have been collected and a statistically significant correlation exists.

Nutrients

The narrative standards applicable to nutrients elsewhere in Montana are contained in the General Prohibitions of the surface water quality standards (ARM 17.30.637 et. Seq.,). The prohibition against the creation of "*conditions which produce undesirable aquatic life*" is generally the most relevant to nutrients. Undesirable aquatic life includes bacteria, fungi, and algae.

Most waters of Montana are protected from excessive nutrient concentrations by narrative standards. The exception is the Clark Fork River above the confluence with the Flathead River, where numeric water quality standards for total nitrogen (300 ug/l) and total phosphorus (20 ug/l upstream of the confluence with the Blackfoot River and 39 ug/l downstream of the confluence) as well as algal biomass measured as chlorophyll *a* (summer mean and maximum of 100 and 150 mg/m^2, respectively) have been established. Additionally, numeric human health standards exist for nitrogen (**Table B-3**), but the narrative standard is most applicable to nutrients as the concentration in most water bodies in Montana is well below the human health standard and the nutrients contribute to undesirable aquatic life at much lower concentrations than the human health standard.

Table B-3. Human Health Standards for Nitrogen for the State of Montana.

Parameter	Human Health Standard (µL)1
Nitrate as Nitrogen (NO3-N)	10,000
Nitrite as Nitrogen (NO2-N)	1,000
Nitrate plus Nitrite as N	10,000

1Maximum Allowable Concentration.

Metals

Numeric criteria for metals in Montana include specific standards for the protection of both aquatic life and human health. As described above, acute and chronic criteria have been established for the protection of aquatic life. The criteria for some metals vary according to the hardness of the water. The standards for cadmium, copper, chromium (III), lead, nickel, silver and zinc vary according to the hardness of the water. These standards have an inverse relationship to toxicity (decreasing hardness causes increased toxicity). The applicable numeric criteria for the metals of concern at a hardness of 25 mg/L in the Middle and Lower Big Hole River TPA are presented in **Table B-4**. Narrative standards within the General Prohibitions [ARM 17.30.637 (c)(d)] apply to metals associated with stream sediment. They state "State surface waters must be free from substances attributable to municipal, industrial, agricultural practices or other discharges that will: (c) produce odors, colors, or other conditions as to which create a nuisance or render undesirable tastes to fish flesh or make fish inedible; and (d) create concentrations or combinations of materials which are toxic or harmful to human, animal, plant, or aquatic life;

The human health standards for iron and manganese are secondary maximum contaminant levels that are based on aesthetic water properties such as taste, odor, and the tendency of these metals to cause staining. Neither iron nor manganese is classified as a toxin or a carcinogen. Therefore, narrative standards adopted for these metals state that concentrations "must not reach values that interfere with the uses specified in the surface and ground water standards" (Circular DEQ-7 DEQ 2008). The secondary Maximum Contaminant Levels (MCLs) for iron and manganese, 300 ug/L and 50 ug/L respectively, serve as use support "guidance" together with consideration of the number, degree, and timing of exceedences and the concentrations of these metals likely to occur after conventional treatment. If the data indicates that the human health guidance values for iron and manganese would be consistently exceeded after conventional treatment, use of the water body for drinking water is considered impaired for these constituents. If most of the iron and manganese are in the particulate phase, they can be removed by conventional treatment. Diurnal sampling of dissolved and total Fe and Mn in the Big Hole River has indicated a high percentage of both elements is associated with particulate matter (Wenz 2003). Therefore, for the purposes of this TMDL document, the secondary MCL guidance values for iron and manganese are not applied and are not considered in the evaluation of water quality data. The chronic aquatic life standard of 1,000 µg/L for iron is considered applicable and is used as the metals target for iron.

It should be noted that recent studies have indicated some metals concentrations vary through out the day because of diel pH and alkalinity changes. In some cases the variation can cross the standard threshold (both ways) for a metal. Montana water quality standards are not time of day dependent.

Table B-4. Montana Numeric Surface Water Quality Standards for Metals.

Parameter	**Aquatic Life Standards**		**Human Health Standards**
	Acute (µg/L) (1)	**Chronic (µg/L) (2)**	**Surface Water (µg/L) (1)**
Arsenic (TR)	340	150	10
Cadmium (TR)	0.52 @ 25 mg/l hardness **(3)**	0.097 @ 25 mg/l hardness **(3)**	5
Copper (TR)	3.79 @ 25 mg/l hardness **(3)**	2.85 @ 25 mg/l hardness **(3)**	1,300
Iron (TR)	---	1000	300**(4)**
Lead (TR)	13.98 @ 25 mg/l hardness **(3)**	0.545 @ 25 mg/l hardness **(3)**	15
Mercury (TR)	1.7	0.91	0.05
Zinc (TR)	37 @ 25 mg/l hardness **(3)**	37 @ 25 mg/l hardness **(3)**	2,000
(1) Maximum allowable concentration.			
(2) No four-day (96-hour) or longer period average concentration may exceed these values.			
(3) Standard is dependent on the hardness of the water, measured as the concentration of $CaCO_3$ (mg/L), and ranges			
(4) Secondary maximum contaminant level guidance for aesthetic water properties such as taste and odor.			
Note: TR = Total Recoverable			

Hardness-based standards for aquatic criteria are calculated using the following equation and are used for determining impairment:

Chronic = exp.{mc[ln(hardness)]+bc} where mc and bc are values from **Table B-4**.

Table B-4. Coefficients for Calculating Metals.

Parameter	**Ba (acute)**	**Bc (chronic)**
Cadmium	-3.924	-4.719
Copper	-1.700	-1.702
Lead	-1.46	-4.705
Zinc	0.884	0.884

Note: If hardness is <25 mg/L as CaCO3, the number 25 must be used in the calculation. If hardness is equal or greater than 400 mg/L as CaCO3, 400 mg/L must be used for the hardness value in the calculation.

<u>Temperature</u>

Montana's temperature standards were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the temperature standards address a maximum allowable increase above "naturally occurring" temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana's temperature standards address the maximum allowable decrease or rate at which cooling temperature changes (below naturally occurring) can occur to avoid fish and aquatic life temperature shock.

For waters classified as A-1 or B-1, the maximum allowable increase over naturally occurring temperature (if the naturally occurring temperature is less than 66º Fahrenheit) is 1°F. In the naturally occurring range of 66-66.5°F, an increase can not exceed 67°F. If the naturally occurring temperature is greater than 66.5ºF, the maximum allowable increase is 0.5º F [ARM 17.30.622(e) and ARM 17.30.623(e)]. A 2°F per hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55°F. A 2°F maximum decrease below naturally occurring water temperature is allowed within the range of 55°F to 32°F.

B.3 Reference Conditions

B.3.1 Reference Conditions as Defined in DEQ's Standard Operating Procedure for Water Quality Assessment (2006b)

DEQ uses the reference condition to evaluate compliance with many of the narrative WQS. The term "reference condition" is defined as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. In other words, the reference condition reflects a waterbody's greatest potential for water quality given historic land use activities.

DEQ applies the reference condition approach for making beneficial use-support determinations for certain pollutants (such as sediment) that have specific narrative standards. All classes of waters are subject to the provision that there can be no increase above naturally occurring concentrations of sediment and settleable solids, oils, or floating solids sufficient to create a nuisance or render the water harmful, detrimental, or injurious. These levels depend on site-specific factors, so the reference conditions approach is used.

Also, Montana's WQS do not contain specific provisions addressing nutrients (nitrogen and phosphorous), or detrimental modifications of habitat or flow. However, these factors are known to adversely affect beneficial uses under certain conditions or combination of conditions. The reference conditions approach is used to determine if beneficial uses are supported when nutrients, flow, or habitat modifications are present.

Waterbodies used to determine reference condition are not necessarily pristine or perfectly suited to giving the best possible support to all possible beneficial uses. Reference condition also does not reflect an effort to turn the clock back to conditions that may have existed before human settlement, but is intended to accommodate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant alterations of biology, chemistry, or hydrogeomorphology due to human activity. Therefore, reference conditions should reflect minimum impacts from human activities. A reference approach attempts to identify the potential condition that could be attained (given historical land use) by the application of reasonable land, soil, and water conservation practices. DEQ realizes that presettlement water quality conditions usually are not attainable.

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar seasons and/or hydrologic conditions for both waters. For example, the Total Suspended Solids (TSS) of a stream at base flow during the summer should not be compared to the TSS of reference condition that would occur during a runoff event in the spring. In addition, a comparison should not be made to the lowest or highest TSS values of a reference site, which represent the outer boundaries of reference conditions.

The following methods may be used to determine reference conditions:

Primary Approach

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar geology, hydrology, morphology, and/or riparian habitat.
- Evaluating historical data relating to condition of the waterbody in the past.
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired segment of the same stream.

Secondary Approach

- Reviewing literature (e.g. a review of studies of fish populations, etc., that were conducted on similar waterbodies that are least impaired.
- Seeking expert opinion (e.g. expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential).
- Applying quantitative modeling (e.g. applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.).

DEQ uses the primary approach for determining reference condition if adequate regional reference data are available and uses the secondary approach to estimate reference condition when there are no regional data. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

B.3.2 Use of Statistics for Developing Reference Values or Ranges

Reference value development must consider natural variability as well as variability that can occur as part of field measurement techniques. Statistical approaches are commonly used to help incorporate variability. One statistical approach is to compare stream conditions to the mean (average) value of a reference data set to see if the stream condition compares favorably to this value or falls within the range of one standard deviation around the reference mean. The use of these statistical values assumes a normal distribution, whereas water resources data tend to have a non-normal distribution (Hensel and Hirsch 1995). For this reason, another approach is to compare stream conditions to the median value of a reference data set to see if the stream condition compares favorably to this value or falls within the range defined by the 25th and 75th percentiles of the reference data. This is a more realistic approach than using one standard deviation since water quality data often include observations considerably higher or lower than most of the data. Very high and low observations can have a misleading impact on the statistical summaries if a normal distribution is incorrectly assumed, whereas statistics based on non-normal distributions are far less influenced by such observations.

Figure B-1 is an example boxplot type presentation of the median, 25th and 75th percentiles, and minimum and maximum values of a reference data set. In this example, the reference stream results are stratified by two different stream types. Typical stratifications for reference stream data may include Rosgen stream types, stream size ranges, or geology. If the parameter being measured is one where low values are undesirable and can cause harm to aquatic life, then measured values in the potentially impaired stream that fall below the 25th percentile of reference data are not desirable and can be used to indicate impairment. If the parameter being measured is one where high values are undesirable, then measured values above the 75th percentile can be used to indicate impairment.

The use of a non-parametric statistical distribution for interpreting narrative WQS or developing numeric criteria is consistent with EPA's guidance for determining nutrient criteria (EPA 2000). Furthermore, the selection of the applicable 25th or 75th percentile values from a reference data set is consistent with ongoing DEQ guidance development for interpreting narrative WQS where it is determined that there is "good" confidence in the quality of the reference sites and resulting information (DEQ 2004). If it is determined that there is only a "fair" confidence in the quality of the reference sites, then the 50th percentile or median value should be used, and if it is determined that there is "very high" confidence, then the 90th percentile of the reference data set should be used. Most reference data sets available for water quality restoration planning and related TMDL development, particularly those dealing with sediment and habitat alterations, would tend to be "fair" to "good" quality. This is primarily due to the limited number of available reference sites/data points available after applying all potentially applicable stratifications on the data, inherent variations in monitoring results among field crews, the potential for variations in field methodologies, and natural yearly variations in stream systems often not accounted for in the data set.

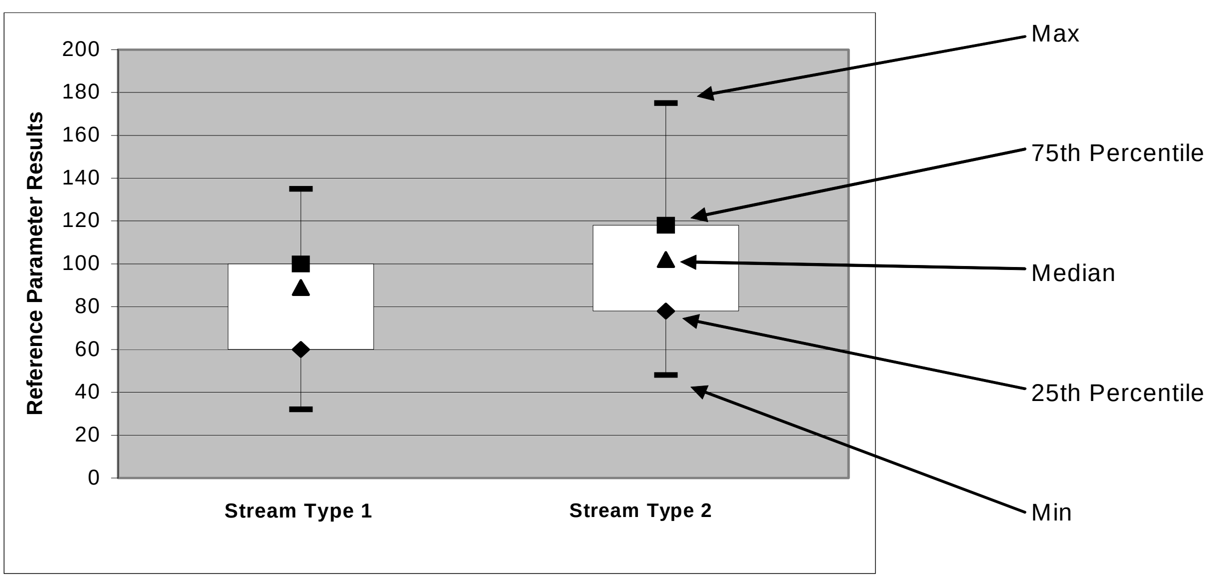


Figure B-1. Boxplot Example for Reference Data.

The above 25th – 75th percentile statistical approach has several considerations:

1. It is a simple approach that is easy to apply and understand.
2. About 25 percent of all streams would naturally fall into the impairment range. Thus, it should not be applied unless there is some linkage to human activities that could lead to the observed conditions. Where applied, it must be noted that the stream's potential may prevent it from achieving the reference range as part of an adaptive management plan.
3. About 25 percent of all streams would naturally have a greater water quality potential than the minimum water quality bar represented by the 25^{th} to 75^{th} percentile range. This may represent a condition where the stream's potential has been significantly underestimated. Adaptive management can also account for these considerations.
4. Obtaining reference data that represents a naturally occurring condition, as defined above in **Table B-4**, can be difficult, particularly for larger waterbodies with multiple land uses within the drainage. This is because all reasonable land, soil, and water conservation practices may not be in place in many larger water bodies across the region. Even if these practices are in place, the proposed reference stream may not have fully recovered from past activities, such as riparian harvest, where reasonable land, soil, and water conservation practices were not applied.
5. A stream should not be considered impaired unless there is a relationship between the parameter of concern and the beneficial use such that not meeting the reference range is likely to cause harm or other negative impacts to the beneficial use as described by the WQS in **Table B-2**. In other words, if not meeting the reference range is not expected to negatively impact aquatic life, cold water fish, or other beneficial uses, then an impairment determination should not be made based on the particular parameter being evaluated. Relationships that show an impact to the beneficial use can be used to justify impairment based on the above statistical approach.

As identified in (2) and (3) above, there are two types of errors that can occur due to this or similar statistical approaches where a reference range or reference value is developed: (1) A stream could be considered impaired even though the naturally occurring condition for that stream parameter does not meet the desired reference range or (2) a stream could be considered not impaired for the parameter(s) of concern because the results for a given parameter fall just within the reference range, whereas the naturally occurring condition for that stream parameter represents much higher water quality and beneficial uses could still be negatively impacted. The implications of making either of these errors can be used to modify the above approach, although the approach used will need to be protective of water quality to be consistent with DEQ guidance and WQS (DEQ 2004). Either way, adaptive management is applied to this water quality plan and associated TMDL development to help address the above considerations.

Where the data do suggest a normal distribution or reference data is presented in a way that precludes use of non-normal statistics, the above approach can be modified to include the mean plus or minus one standard deviation to provide a similar reference range with all of the same considerations defined above.

Options When Regional Reference Data is Limited or Does Not Exist

In some cases, there is very limited reference data and applying a statistical approach like above is not possible. Under these conditions the limited information can be used to develop a reference value or range, with the need to note the greater level of uncertainty and perhaps a greater level of future monitoring as part of the adaptive management approach. These conditions can also lead to more reliance on secondary type approaches for reference development as defined in **Section B.1.3.1**.

Another approach would be to develop statistics for a given parameter from all streams within a watershed or region of interest (EPA 2000). The boxplot distribution of all the data for a given parameter can still be used to help determine potential target values knowing that most or all of the streams being evaluated are either impaired or otherwise have a reasonable probability of having significant water quality impacts. Under these conditions you would still use the median and the 25th or 75th percentiles as potential target values, but you would use the 25th and 75th percentiles in a way that is opposite from how you use the results from a regional reference distribution. This is because you are assuming that, for the parameter being evaluated, as many as 50% to 75% of the results from the whole data distribution represent questionable water quality. **Figure B-2** is an example of statistical distribution where higher values represent better water quality. In **Figure B-2**, the median and 25th percentiles represent potential target values versus the median and 75th percentiles discussed above for regional reference distribution. Whether you use the median, the 25th percentile, or both should be based on an assessment of how impacted all the measured streams are in the watershed. Additional consideration of target achievability is important when using this approach. Also, there may be a need to also rely on secondary reference development methods to modify how you apply the target and/or to modify the final target value(s). Your certainty regarding indications of impairment or non-impairment may be lower using this approach, and you may need to rely more on adaptive management as part of TMDL implementation.

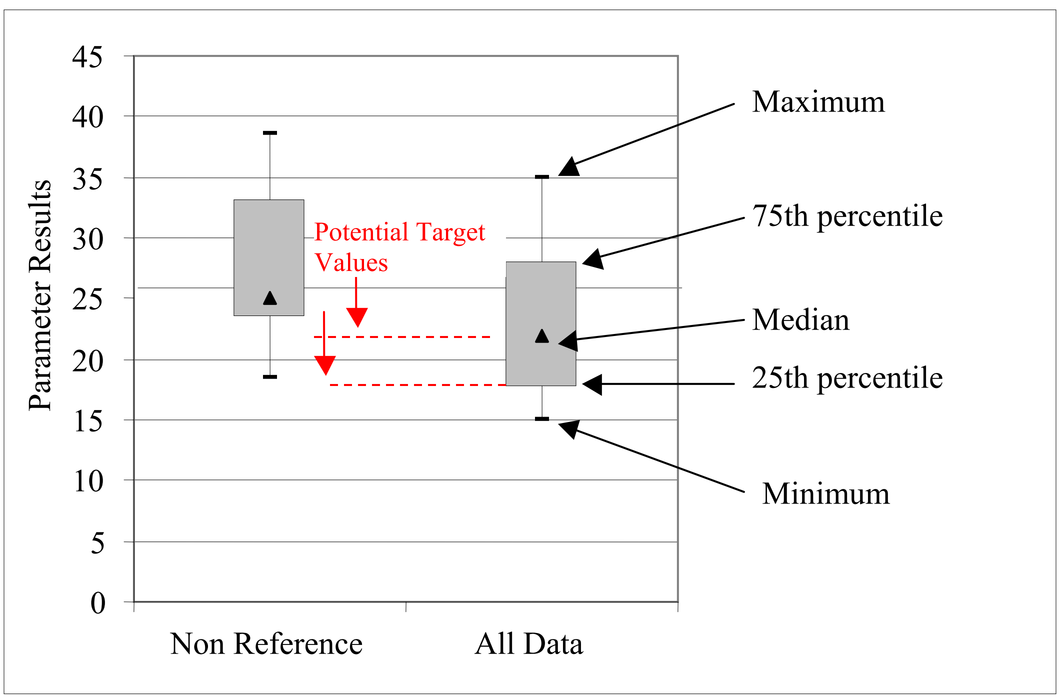


Figure B-2. Boxplot example for the use of all data to set targets.

REFERENCES

Hensel, D.R., and R.M. Hirsch. 1995. Statistical Methods in Water Resources. Studies in Environmental Science 49. Elsevier Science Publishers B.V., Amsterdam, The Netherlands.

Montana Department of Environmental Quality (DEQ). 1999. Requirements for Non-Point Sources of Pollution Impacting High-Quality and Impaired Waters. DEQ Internal Guidance. Helena, MT.

DEQ. 2004. Wadeable Streams of Montana's Hi-Line Region: An Analysis of Their Nature and Condition, with an Emphasis on Factors Affecting Aquatic Plant Communities and Recommendations to Prevent Nuisance Algae Conditions. Available at: http://www.deq.state.mt.us/wqinfo/Standards/Master_Doc_DII.pdf.

DEQ. 2006a. Circular WQB-7: Montana numeric water quality standards. Montana Department of Environmental Quality, Planning, Prevention, and Assistance Division – Water Quality Standards Section. Helena, Montana. February 2006. Available at: http://deq.mt.gov/wqinfo/Standards/CompiledDEQ-7.pdf.

DEQ. 2006b. Water Quality Assessment Process and Methods Standard Operating Procedure. Appendix A to 303(d) 2000 – 2004. WQPBWQM-001, Rev. 2, August 2006. Available at: http://www.deq.mt.gov/wqinfo/QAProgram/SOP%20WQPBWQM-001.pdf.

United States Environmental Protection Agency (USEPA). 2000. Nutrient Criteria Technical Guidance Manual, Rivers and Steams. Washington, D.C.: United States Environmental Protection Agency, EPA-822-B00-002. Available at: http://www.epa.gov/waterscience/criteria/nutrient/guidance/rivers/

Wenz, Adam C. 2003. Diurnal Variations in the Water Quality of the Big Hole River. Montana Tech of the University of Montana. Master's thesis. May 2003.

APPENDIX C
SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION IN THE MIDDLE AND LOWER BIG HOLE WATERSHED

Introduction

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE), and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of Best Management Practices (BMPs). For this evaluation, the primary BMP evaluated includes the modification in upland management practices. When reviewing the results of the upland sediment load model it is important to note that a significant portion of the remaining sediment loads after BMPs in areas with grazing and/or silvicultural land-uses is also a component of the “natural upland load”. However, the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

A list of land cover classifications used in the USLE model is presented in **Table C-1**, along with a description of which land-use was associated with each cover type for the purposes of sediment source assessment and load allocations.

Table C-1. Land Cover Classifications for the USLE Model.

Land Cover Classifications	Land-use / Sediment Source
Bare Rock/Sand/Clay	Natural Source
Deciduous Forest	Natural Source
Evergreen Forest	Natural Source
Mixed Forest	Natural Source
Woody Wetlands	Natural Source
Logging	Silviculture
Grasslands/Herbaceous	Grazing
Shrubland	Grazing
Pasture/Hay	Cropland
Small Grains	Cropland

Universal Soil Loss Equation (USLE)

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

$$A = RK(LS)CP \text{ (in tons acre}^{-1}\text{ year}^{-1}\text{)}$$

where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P) (Wischmeier and Smith 1978, Renard et al. 1991). The USLE estimates average soil loss from sheet and rill erosion but does not estimate soil loss from gully erosion. USLE was selected for the Middle and Lower Big Hole watershed due to its relative simplicity, ease in parameterization, and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) the Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe, 1999). A detailed description of the general USLE model parameters is presented below.

The **R-factor** is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons acre-1 year-1) and the maximum 30-minute rainfall intensity (inches hour-1). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The **K-factor,** or soil erodibility factor, indicates the susceptibility of soil to resist erosion. It is derived by the measurement of soil particle size (texture), percent organic matter, structure, and permeability. It is a measure of the average soil loss (tons acre-1 hundreds of ft-tons-1 per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard Soil Conservation Service (SCS) erosion plot that is 72.6 ft long with a uniform slope of 9 percent.

The **LS-factor** is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-value, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen, (1998), flow lengths are seldom greater than 400 or shorter than 20 feet.

The **C-factor** or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that effect erosion, including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks, 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) canopy cover effects, (2) effects of low-growing vegetal cover, mulch, and litter, and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the Middle and Lower Big Hole watershed, Brooks (1997) cautions that more work has been carried out in determining the agriculturally based C-factors rather than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The **P-factor** (conservation practice factor) is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing, and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally-based conservation practices.

Modeling Approach

Sediment delivery from hillslope erosion was estimated using a Universal Soil Loss Equation (USLE) based model to predict soil loss, along with a sediment delivery ratio (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale grid format, GIS model using ArcView v 9.0 GIS software.

Desired results from the modeling effort include the following: (1) annual sediment load from each of the water quality limited segments on the state's 303(d) List, and (2) the mean annual source distribution from each land category type. Based on these considerations, a GIS-modeling approach (USLE 3-D) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

Modeling Scenarios

Two upland management scenarios were proposed as part of the Middle and Lower Big Hole River modeling project. They include: (1) an existing condition scenario that considers the current land use cover and management practices in the watershed and (2) an improved grazing and cover management scenario.

Erosion was differentiated into two source categories for each scenario: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 - Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning.

Data Sources

The USLE-3D model was parameterized using a number of published data sources. These include information from: (1) USGS, (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land use management and cropping practices was acquired from the Montana Agricultural Extension Service and the Natural Resource Conservation Service (NRCS). Specific GIS coverages used in the modeling effort included the following:

<u>R – Rainfall factor</u>. Grid data of this factor was obtained from the NRCS, and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

<u>K – Soil erodibility factor</u>. Polygon data of this factor were obtained from the NRCS General Soil Map (STATSGO) database. The USLE K factor is a standard component of the STATSGO soil survey. STATSGO soils polygon data were summarized and interpolated to grid format for this analysis.

LS – Slope length and slope factors. These factors were derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel.

C – Cropping factor. This factor was estimated using the National Land Cover Dataset (NLCD), using C-factor interpretations provided by the NRCS and refined by Montana DEQ using SCS C-factor tables (Brooks et al. 1997). C-factors are intended to be conservatively representative of conditions in the Middle and Lower Big Hole valley.

P – Management practices factor. This factor was set to 1, as consultation with the NRCS State Agronomist suggests that this value is the most appropriate representation of current management practices in the Middle and Lower Big Hole valley (i.e. no use of contour plowing, terracing, etc).

Method

An appropriate grid for each factors' values was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors were performed as follows:

Middle and Lower Big Hole DEM

The digital elevation model (DEM) for the Middle and Lower Big Hole watershed was the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area (the Middle and Lower Big Hole watershed), and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the Middle and Lower Big Hole was used for these analyses. First the DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of Middle and Lower Big Hole watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

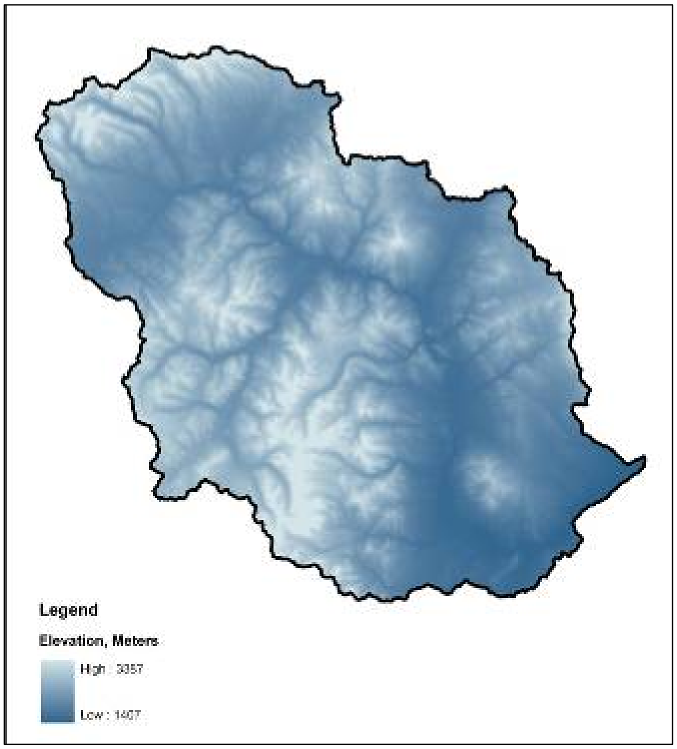


Figure C-1. Digital Elevation Model (DEM) of the Middle and Lower Big Hole watershed, prepared for hydrologic analysis.

R-Factor

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the Middle and Lower Big Hole watershed, to match the project's standard grid definition.

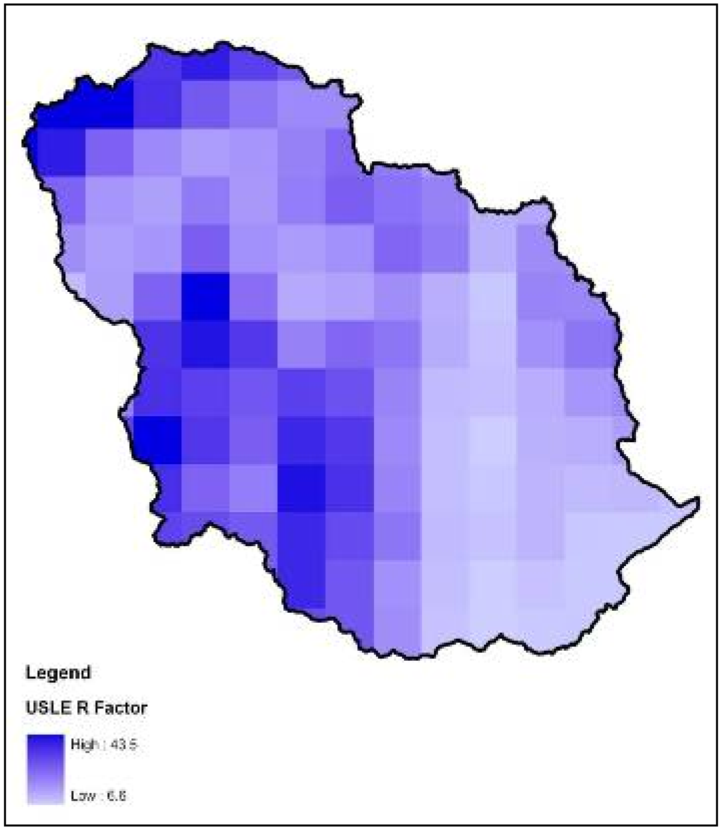


Figure C-2. ULSE R factor for the Middle and Lower Big Hole Watershed.

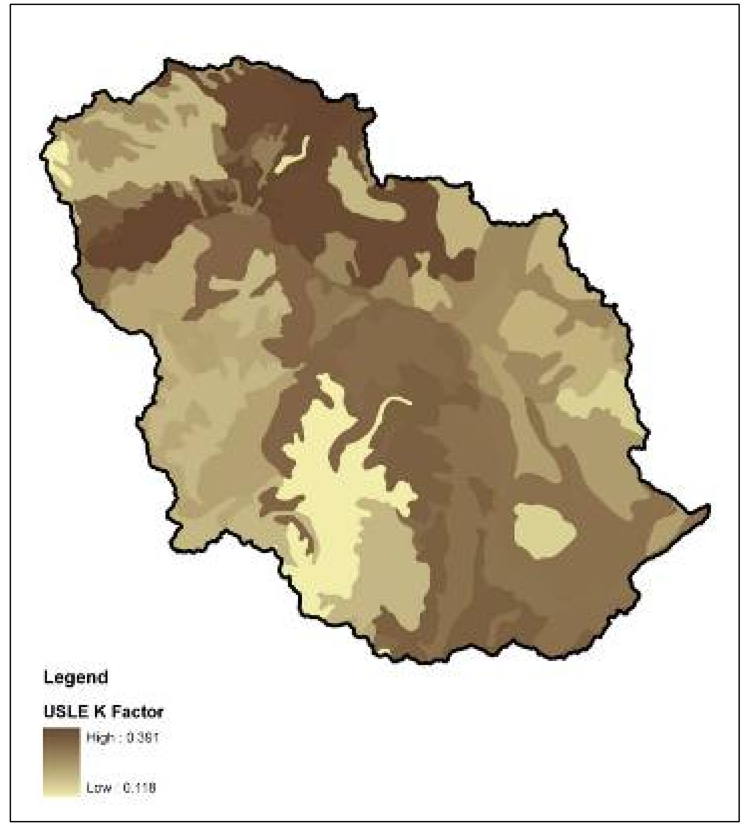


Figure C-3. ULSE K factor for the Middle and Lower Big Hole Watershed.

The soil erodibility factor grid was compiled from 1:250K STATSGO data, as published by the NRCS. STATSGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the STATSGO map units, and the polygon coverage was converted to a 10m analytic grid for use in this analysis.

LS- Factor

The equation used for calculating the slope length and slope factor was that given in the updated definition of USLE, as published in USDA handbook #537:

$$LS = (\lambda/72.6)^m\ (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

Where:

λ = slope length in feet. This value was determined by applying GIS based surface analysis procedures to the Middle and Lower Big Hole watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, λ was limited to that maximum value.

θ = cell slope as calculated by GIS based surface analysis procedures from the Middle and Lower Big Hole watershed DEM

m = 0.5 if percent slope of the cell >= 5
= 0.4 if percent slope of the cell >= 3.5 AND < 5
= 0.3 if percent slope of the cell >= 1 AND < 3.5
= 0.2 if percent slope of the cell < 1

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

C-Factor

The cover management factor of the USLE reflects the varying degree of erosion protection that results from different cover types. It integrates a number of factors including vegetative cover, plant litter, soil surface, and land management. For the purpose of this study, the C-factor is the only USLE parameter that can be altered by the influence of human activity. Based on this, C-factors were estimated for the existing condition and improved management scenarios (**Table C-2**). The C-factor change for agricultural cover types between management scenarios corresponds to increases in the percent of land cover that are achievable through the application of various best management practices (**Table C-3**). For natural sources (i.e. bare rock, deciduous forest, and evergreen forest), the C-factor is the same for both scenarios. A C-factor slightly higher than a deciduous/evergreen forest was used for logged areas because logging intensity within the watershed is generally low and because practices, such as riparian clear-cutting, that tend to produce high sediment yields have not been used since at least 1991, when the MT Streamside Management Zone (SMZ) law was enacted. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006). The logging C-factor is the same for both management scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities.

C-factors were defined spatially through use of a modified version of the Anderson land cover classification (1976) and the 1992 30m Landsat Thematic Mapper (TM) multi-spectral imaging National Land Cover Data (NLCD), 1992) (**Figure-4**). C-factor values were assigned globally to each land type and range from 0.001 to 1.0. These data were re-projected to Montana State plane projection/coordinate system, and resampled to the standard 10m grid. No field efforts were initiated as part of this study to refine C-factor estimation for the watershed.

Table C-2. Middle and Lower Big Hole River C-Factor; Existing and improved management conditions.

NLCD Code	Description	C-Factor	
		Existing Condition	Improved Management Condition
		0.001	0.001
41	Deciduous Forest	0.003	0.003
42	Evergreen Forest	0.003	0.003
43	Mixed Forest	0.003	0.003
91	Woody Wetlands	0.0001	0.0001
51	Shrubland	0.046	0.031
71	Grasslands Herbaceous	0.042	0.035
81	Pasture /Hay	0.020	0.013
83	Small Grains	0.240	0.015
N/A	Logging	0.006	0.006

Table C-3. Changes in percent ground cover for agricultural land cover types between existing and improved management conditions.

Land Cover	Existing % ground cover	Improved % ground cover
Shrubland	55	65
Grasslands Herbaceous	55	65
Pasture /Hay	65	75
Small Grains	20	40

NLCD – Land cover

In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes over the time since the NLCD image was taken. Given that we are looking for watershed and subwatershed scale effects, this was considered to be a reasonable assumption. Given the relative simplicity of the land use mix in the Big Hole valley, and the relative stability of that land use over the 14 years since the Landsat image that the NLCD is based on was shot. One adjustment was made to the NLCD, however. That adjustment was to quantify the amount of logging that has occurred since 1992, and to also identify areas that are reforesting over that same period. As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may effect sediment production.

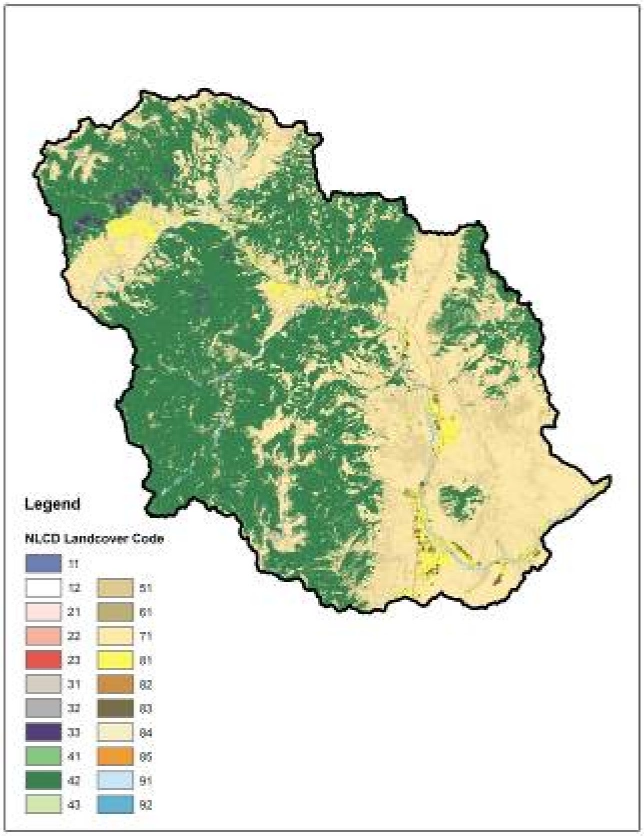


Figure C-4. NLCD Landcover for the Middle and Lower Big Hole Watershed.

Adjustment for logging and reforestation was accomplished by comparing the 1992 NLCD grid for the Middle and Lower Big Hole watershed with the 2005 National Agriculture Imagery Program (NAIP) aerial photography. Areas which were coded as a forest type (41 or 42) on the NLCD were recoded to 'logged' if:

- They appeared to be otherwise (typically bare ground, grassland, or shrubland) on the NAIP photos, and
- There were indications of indicated logging activity (proximity to forest or logging roads, appearance of stands, etc).

Sediment Delivery Ratio

A sediment delivery ratio (SDR) factor was created for each grid cell, based on the relationship between the distance from the delivery point to the stream established by Dube, Megahan & McCalmon in their development of the Washington Road Surface Erosion Model (WARSEM). This relationship was developed by integrating the results of several previous studies (principally those of Megehan and Ketchison) which examined sediment delivery to streams downslope of forest roads. They found that the proportion of sediment production that is ultimately delivered to streams declines with distance from the stream (**Table C-4**) with the balance of the sediment being deposited between the point of production and the stream. We believe the use of this relationship to develop a SDR for a USLE based model is a conservative (i.e. tending toward the high end of the range of reasonable values) estimate of sediment delivery from hillslope erosion, especially in light of the fact that the USLE methodology does not account for gully erosion. The SDR factor was applied to the results of the USLE model to estimate sediment delivered from hill slope sources, by calculating the distance from each cell to the nearest stream channel, and multiplying the sediment production of that cell by the corresponding distance based percentage of delivery.

Table C-4. The percent of sediment delivered by distance from a water body.

Distance from Culvert (ft)	Percent of Total Eroded Sediment Delivered
0	100
35	70
70	50
105	35
140	25
175	18
210	10
245	4
280	3
315	2
350	1

Although the SDR factor accounts for the distance of sediment production cells from the stream channel, it does not account for riparian condition and the ability of riparian vegetation to filter out sediment and prevent it from entering the stream. Depending on the vegetation type and buffer width, healthy riparian buffers can remove anywhere from 50-90 percent of sediment (Castelle and Johnson 2000; Hook 2003; DEQ 2007). Therefore, the USLE model used for source assessment may have overestimated existing loads and underestimated potential reductions due to hillslope erosion.

Results

Figures C-5 and **C-6** present the USLE based hillslope model's prediction of existing and potential conditions graphically for the Middle and Lower Big Hole watershed. **Table C-5** contains the estimated existing and potential sediment load from hillslope erosion for the Middle and Lower Big Hole watershed and broken out by the 6^{th} code HUC and existing land cover type. Note, because of the HUC-6 scale, the loads for French and Deep creeks are not cumulative for those watersheds and differ from the cumulative loads presented in the document.

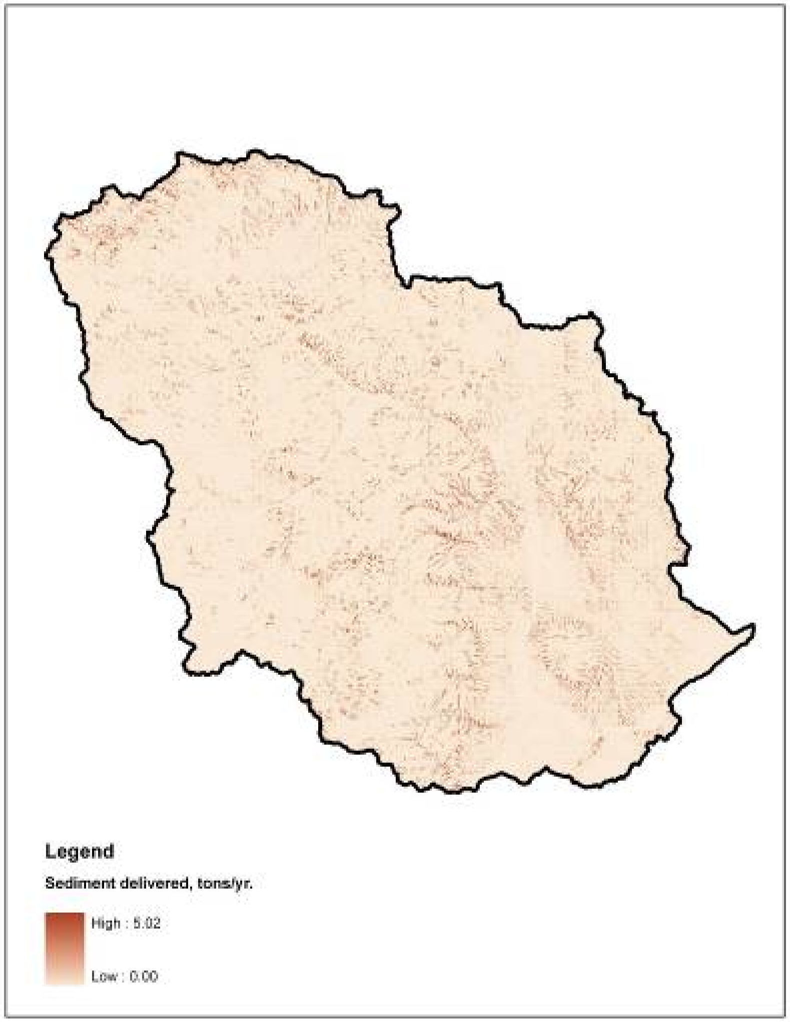


Figure C-5. Estimated sediment delivery from hill slopes, existing conditions.

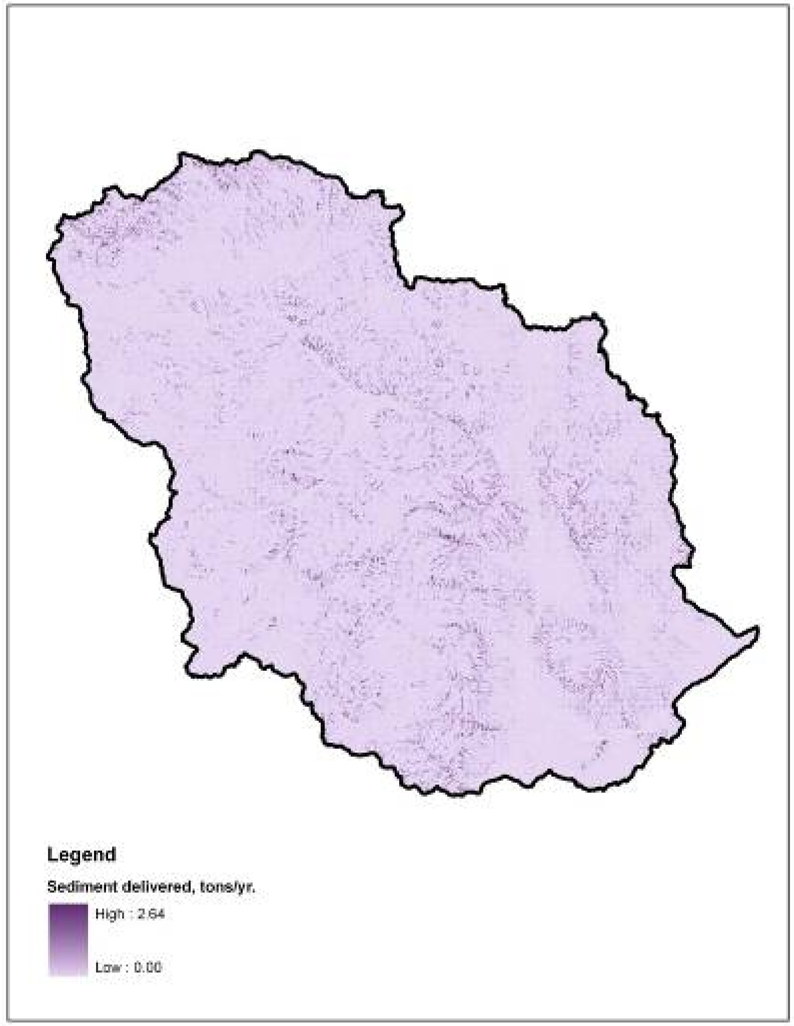


Figure C-6. Estimated sediment delivery from hill slopes, BMP conditions.

Table C-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). The Middle and Lower Big Hole watershed is bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Alder Creek	13256	351	314	0.026	0.024
American Creek	4252	261	212	0.061	0.050
Big Hole River-Biltmore Hot Springs	21813	1400	1087	0.064	0.050
Big Hole River-Brownes Gulch	17961	1037	799	0.058	0.044
Big Hole River-Dewey	20878	2200	1733	0.105	0.083
Big Hole River-Dickie Bridge	15620	1636	1271	0.105	0.081
Big Hole River-Fishtrap	29976	1361	1107	0.045	0.037
Big Hole River-Lost Creek	11874	769	599	0.065	0.050
Big Hole River-Meadow Creek	22893	1339	1077	0.059	0.047
Big Hole River-Melrose	14465	1133	863	0.078	0.060
Big Hole River-Quartz Hill Gulch	23492	1815	1469	0.077	0.063
Big Hole River-Squaw Creek	18764	514	416	0.027	0.022
Big Hole River-Stevens Slough	19568	1124	868	0.057	0.044
Big Hole River-Twin Bridges	22725	969	769	0.043	0.034
Birch Creek	32726	2250	1760	0.069	0.054
Bryant Creek	11787	536	465	0.045	0.039
California Creek	8889	616	492	0.069	0.055
Camp Creek	19700	1770	1413	0.090	0.072
Canyon Creek	31065	4193	3382	0.135	0.109
Charcoal Gulch	1596	134	109	0.084	0.068
Cherry Creek	11275	1232	995	0.109	0.088
Corral Creek	3377	285	227	0.084	0.067
Deep Creek	22337	2074	1659	0.093	0.074
Delano Creek	1284	118	97	0.092	0.075
Elkhorn Creek	7149	318	261	0.044	0.037
Fishtrap Creek	31604	2537	2066	0.080	0.065
French Creek	12532	616	509	0.049	0.041
Gold Creek	4813	654	535	0.136	0.111
Grose Creek	1899	124	101	0.065	0.053
Headwaters Wise River	23606	1126	909	0.048	0.039
Jerry Creek	27376	1692	1412	0.062	0.052
Lacy Creek	11183	297	255	0.027	0.023
LaMarche Creek	30732	3979	3256	0.129	0.106
Lost Creek	4967	615	495	0.124	0.100
Lower Divide Creek	15553	730	591	0.047	0.038

Table C-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). The Middle and Lower Big Hole watershed is bolded.

6th Code HUC Subwatershed	Acres	Existing Load (tons/yr)	Potential Load (tons/yr)	Normalized Existing Load (tons/acre/yr)	Normalized Potential Load (tons/acre/yr)
Lower Pattengail Creek	12669	672	543	0.053	0.043
Lower Willow Creek	19556	1549	1166	0.079	0.060
Lower Wise River	15849	729	611	0.046	0.039
McCartney Creek	12875	869	684	0.068	0.053
Mclean Creek	2095	134	105	0.064	0.050
Middle Pattengail Creek	15254	306	277	0.020	0.018
Middle Wise River	19615	1615	1314	0.082	0.067
Moose Creek	25871	1246	986	0.048	0.038
Mudd Creek	9822	194	164	0.020	0.017
Nez Perce Creek	14031	507	406	0.036	0.029
North Fork Divide Creek	18537	493	420	0.027	0.023
Oregon Creek	1314	128	103	0.098	0.078
Rochester Creek	21414	1209	953	0.056	0.045
Rock Creek	22414	1689	1333	0.075	0.059
Sassman Gulch	3487	266	207	0.076	0.059
Sawlog Creek	3926	262	224	0.067	0.057
Seven Springs Creek	3648	219	165	0.060	0.045
Sevenmile Creek	2863	335	269	0.117	0.094
Seymour Creek	20527	1902	1526	0.093	0.074
Sixmile Creek	2843	381	307	0.134	0.108
Soap Gulch	5768	822	650	0.142	0.113
Squaw Creek	12887	363	324	0.028	0.025
Trapper Creek	25610	2604	2058	0.102	0.080
Twelvemile Creek	5883	754	613	0.128	0.104
Upper Divide Creek	22932	1019	834	0.044	0.036
Upper Pattengail Creek	16803	452	398	0.027	0.024
Upper Willow Creek	22066	1161	936	0.053	0.042
Upper Wise River	16058	993	801	0.062	0.050
Wickiup Creek	3891	281	228	0.072	0.059
Wyman Creek	18298	303	266	0.017	0.015
Middle and Lower Big Hole Watershed	**971797**	**65260**	**52444**	**0.067**	**0.054**

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Alder Creek	Evergreen Forest	207	207
	Grasslands/Herbaceous	44	37
	Shrubland	93	63
	Logging	7	7
*Alder Creek Total		351	314
American Creek	Evergreen Forest	53	53
	Grasslands/Herbaceous	119	99
	Shrubland	89	60
*American Creek Total		261	212
Big Hole River-Biltmore Hot Springs	Grasslands/Herbaceous	1001	834
	Pasture/Hay	5	3
	Shrubland	369	249
	Small Grains	25	2
Big Hole River-Biltmore Hot Springs Total		1,400	1,087
Big Hole River-Brownes Gulch	Evergreen Forest	20	20
	Grasslands/Herbaceous	712	593
	Pasture/Hay	16	10
	Shrubland	257	173
	Small Grains	31	2
Big Hole River-Brownes Gulch Total		1,037	799
Big Hole River-Dewey	Evergreen Forest	184	184
	Grasslands/Herbaceous	1269	1058
	Pasture/Hay	4	3
	Shrubland	723	487
	Small Grains	19	1
*Big Hole River-Dewey Total		2,200	1,733
Big Hole River-Dickie Bridge	Evergreen Forest	201	201
	Grasslands/Herbaceous	821	684
	Logging	12	12
	Pasture/Hay	22	14
	Shrubland	529	356
	Small Grains	52	3
*Big Hole River-Dickie Bridge Total		1,636	1,270

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Big Hole River-Fishtrap	Evergreen Forest	230	230
	Grasslands/Herbaceous	757	631
	Logging	5	5
	Pasture/Hay	68	44
	Shrubland	293	197
	Small Grains	9	1
*Big Hole River-Fishtrap Total		1,361	1,107
Big Hole River-Lost Creek	Evergreen Forest	22	22
	Grasslands/Herbaceous	508	423
	Pasture/Hay	7	4
	Shrubland	222	149
	Small Grains	11	1
Big Hole River-Lost Creek Total		769	599
Big Hole River-Meadow Creek	Evergreen Forest	237	237
	Grasslands/Herbaceous	648	540
	Pasture/Hay	28	18
	Shrubland	418	282
	Small Grains	8	1
*Big Hole River-Meadow Creek Total		1,339	1,077
Big Hole River-Melrose	Evergreen Forest	5	5
	Grasslands/Herbaceous	661	551
	Pasture/Hay	4	3
	Shrubland	452	304
	Small Grains	12	1
Big Hole River-Melrose Total		1,133	863
*Big Hole River-Quartz Hill Gulch	Evergreen Forest	368	368
	Grasslands/Herbaceous	796	664
	Logging	3	3
	Pasture/Hay	13	8
	Shrubland	633	426
	Small Grains	2	0
Big Hole River-Quartz Hill Gulch Total		1,815	1,469

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Big Hole River-Squaw Creek	Evergreen Forest	38	38
	Grasslands/Herbaceous	341	284
	Logging	9	9
	Pasture/Hay	4	3
	Shrubland	122	82
*Big Hole River-Squaw Creek Total		514	416
Big Hole River-Stevens Slough	Evergreen Forest	3	3
	Grasslands/Herbaceous	769	641
	Pasture/Hay	7	5
	Shrubland	325	219
	Small Grains	21	1
Big Hole River-Stevens Slough Total		1,124	868
Big Hole River-Twin Bridges	Evergreen Forest	3	3
	Grasslands/Herbaceous	757	631
	Pasture/Hay	2	1
	Shrubland	198	134
	Small Grains	9	1
Big Hole River-Twin Bridges Total		969	769
Birch Creek	Bare Rock/Sand/Clay	2	2
	Evergreen Forest	278	278
	Grasslands/Herbaceous	1,022	851
	Pasture/Hay	9	6
	Shrubland	922	621
	Small Grains	17	1
Birch Creek Total (lower)		2,250	1,760
Bryant Creek	Evergreen Forest	227	227
	Grasslands/Herbaceous	157	131
	Logging	15	15
	Shrubland	137	92
*Bryant Creek Total		536	465
California Creek	Evergreen Forest	38	38
	Grasslands/Herbaceous	403	336
	Shrubland	175	118
*California Creek Total		616	492

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Camp Creek	Evergreen Forest	102	102
	Grasslands/Herbaceous	1,191	993
	Pasture/Hay	2	1
	Shrubland	469	316
	Small Grains	4	0
	Woody Wetlands	1	1
Camp Creek Total		1,770	1,413
Canyon Creek	Evergreen Forest	312	312
	Grasslands/Herbaceous	2,851	2,376
	Logging	1	1
	Shrubland	1,028	693
Canyon Creek Total		4,193	3,382
Charcoal Gulch	Evergreen Forest	19	19
	Grasslands/Herbaceous	77	65
	Shrubland	37	25
*Charcoal Gulch Total		134	109
Cherry Creek	Evergreen Forest	124	124
	Grasslands/Herbaceous	781	651
	Shrubland	327	221
Cherry Creek Total		1,232	995
Corral Creek	Evergreen Forest	22	22
	Grasslands/Herbaceous	163	136
	Logging	4	4
	Shrubland	96	65
*Corral Creek Total		285	227
Deep Creek	Bare Rock/Sand/Clay	2	2
	Evergreen Forest	122	122
	Grasslands/Herbaceous	1,363	1,136
	Logging	7	7
	Pasture/Hay	2	1
	Shrubland	578	390
	Woody Wetlands	1	1
*Deep Creek Total		2,074	1,659
Delano Creek	Evergreen Forest	10	10
	Grasslands/Herbaceous	88	73
	Shrubland	20	14
*Delano Creek Total		118	97
Elkhorn Creek	Evergreen Forest	88	88

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
	Grasslands/Herbaceous	113	94
	Logging	1	1
	Shrubland	117	79
*Elkhorn Creek Total		318	261
Fishtrap Creek	Bare Rock/Sand/Clay	1	1
	Deciduous Forest	1	1
	Evergreen Forest	383	383
	Grasslands/Herbaceous	1,466	1,222
	Logging	5	5
	Pasture/Hay	27	18
	Shrubland	644	434
	Small Grains	8	1
	Woody Wetlands	1	1
*Fishtrap Creek Total		2,537	2,065
French Creek	Evergreen Forest	126	126
	Grasslands/Herbaceous	329	274
	Logging	2	2
	Shrubland	160	108
*French Creek Total		616	509
Gold Creek	Evergreen Forest	104	104
	Grasslands/Herbaceous	378	315
	Shrubland	172	116
*Gold Creek Total		654	535
Grose Creek	Grasslands/Herbaceous	114	95
	Shrubland	9	6
	Small Grains	1	0
Grose Creek Total		124	101
Headwaters Wise River	Bare Rock/Sand/Clay	4	4
	Evergreen Forest	310	310
	Grasslands/Herbaceous	295	246
	Shrubland	516	348
*Headwaters Wise River Total		1,126	908

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	**Land Cover Classification**	**Existing Sediment (tons/yr)**	**Potential Sediment (tons/yr)**
Jerry Creek	Evergreen Forest	457	457
	Grasslands/Herbaceous	764	637
	Logging	1	1
	Pasture/Hay	1	1
	Shrubland	466	314
	Woody Wetlands	1	1
*Jerry Creek Total		1,692	1,412
Lacy Creek	Evergreen Forest	152	152
	Grasslands/Herbaceous	32	26
	Logging	1	1
	Shrubland	113	76
*Lacy Creek Total		297	255
LaMarche Creek	Bare Rock/Sand/Clay	5	5
	Evergreen Forest	685	685
	Grasslands/Herbaceous	2,196	1,830
	Logging	3	3
	Pasture/Hay	2	1
	Shrubland	1,085	731
	Small Grains	3	0
*LaMarche Creek Total		3,979	3,256
Lost Creek	Evergreen Forest	46	46
	Grasslands/Herbaceous	414	345
	Shrubland	154	104
	Small Grains	1	0
Lost Creek Total		615	495
Lower Divide Creek	Evergreen Forest	37	37
	Grasslands/Herbaceous	557	464
	Pasture/Hay	1	1
	Shrubland	133	89
	Small Grains	3	0
Lower Divide Creek Total		730	591
Lower Pattengail Creek	Bare Rock/Sand/Clay	1	1
	Evergreen Forest	214	214
	Grasslands/Herbaceous	130	108
	Shrubland	327	221
*Lower Pattengail Creek Total		672	543

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Lower Willow Creek	Evergreen Forest	33	33
	Grasslands/Herbaceous	823	686
	Pasture/Hay	10	7
	Shrubland	649	437
	Small Grains	33	2
	Woody Wetlands	1	1
Lower Willow Creek Total		1,549	1,166
Lower Wise River	Evergreen Forest	217	217
	Grasslands/Herbaceous	301	251
	Logging	3	3
	Pasture/Hay	4	3
	Shrubland	204	137
*Lower Wise River Total		729	611
McCartney Creek	Evergreen Forest	4	4
	Grasslands/Herbaceous	622	518
	Pasture/Hay	2	2
	Shrubland	237	160
	Small Grains	4	0
McCartney Creek Total		869	684
Mclean Creek	Evergreen Forest	7	7
	Grasslands/Herbaceous	79	65
	Shrubland	49	33
Mclean Creek Total		134	105
Middle Pattengail Creek	Evergreen Forest	182	182
	Grasslands/Herbaceous	66	55
	Shrubland	58	39
*Middle Pattengail Creek Total		306	277
Middle Wise River	Evergreen Forest	421	421
	Grasslands/Herbaceous	548	456
	Shrubland	645	435
	Woody Wetlands	2	2
*Middle Wise River Total		1,615	1,314

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Moose Creek	Evergreen Forest	127	127
	Grasslands/Herbaceous	631	526
	Logging	6	6
	Mixed Forest	5	5
	Pasture/Hay	1	1
	Shrubland	474	319
	Woody Wetlands	2	2
Moose Creek Total		1,246	986
Mudd Creek	Evergreen Forest	66	66
	Grasslands/Herbaceous	69	57
	Logging	6	6
	Pasture/Hay	8	5
	Shrubland	44	30
	Small Grains	1	0
*Mudd Creek Total		194	164
Nez Perce Creek	Grasslands/Herbaceous	407	339
	Shrubland	100	68
Nez Perce Creek Total		507	406
North Fork Divide Creek	Evergreen Forest	152	152
	Grasslands/Herbaceous	233	194
	Logging	4	4
	Shrubland	104	70
North Fork Divide Creek Total		493	420
Oregon Creek	Grasslands/Herbaceous	102	85
	Shrubland	26	18
*Oregon Creek Total		128	103
Rochester Creek	Evergreen Forest	4	4
	Grasslands/Herbaceous	859	716
	Shrubland	345	233
Rochester Creek Total		1,209	953
Rock Creek	Evergreen Forest	255	255
	Grasslands/Herbaceous	819	682
	Pasture/Hay	6	4
	Shrubland	578	390
	Small Grains	31	2
Rock Creek Total		1,688	1,333

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Sassman Gulch	Evergreen Forest	12	12
	Grasslands/Herbaceous	149	124
	Shrubland	105	71
Sassman Gulch Total		266	207
Sawlog Creek	Evergreen Forest	73	73
	Grasslands/Herbaceous	149	124
	Shrubland	40	27
*Sawlog Creek Total		262	224
Seven Springs Creek	Grasslands/Herbaceous	106	88
	Shrubland	113	76
Seven Springs Creek Total		219	165
Sevenmile Creek	Evergreen Forest	14	14
	Grasslands/Herbaceous	240	200
	Shrubland	81	55
*Sevenmile Creek Total		335	269
Seymour Creek	Bare Rock/Sand/Clay	2	2
	Evergreen Forest	186	186
	Grasslands/Herbaceous	1,133	944
	Logging	6	6
	Shrubland	574	387
	Woody Wetlands	1	1
*Seymour Creek Total		1,902	1,526
Sixmile Creek	Evergreen Forest	3	3
	Grasslands/Herbaceous	309	257
	Shrubland	69	47
*Sixmile Creek Total		381	307
Soap Gulch	Evergreen Forest	12	12
	Grasslands/Herbaceous	578	482
	Shrubland	231	156
Soap Gulch Total		822	650
Squaw Creek	Evergreen Forest	182	182
	Grasslands/Herbaceous	129	108
	Shrubland	52	35
*Squaw Creek Total		363	324

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Trapper Creek	Evergreen Forest	219	219
	Grasslands/Herbaceous	1,499	1,249
	Pasture/Hay	2	2
	Shrubland	871	587
	Small Grains	12	1
Trapper Creek Total		2,604	2,058
Twelvemile Creek	Evergreen Forest	54	54
	Grasslands/Herbaceous	543	452
	Logging	2	2
	Shrubland	155	104
*Twelvemile Creek Total		754	613
Upper Birch Creek[1]	Bare Rock/Sand/Clay	2	2
	Evergreen Forest	278	278
	Grasslands Herbaceous	409	340
	Shrubland	572	385
Upper Birch Creek Total[1]		1,261	1,005
Upper Divide Creek	Evergreen Forest	89	89
	Grasslands/Herbaceous	726	605
	Logging	6	6
	Shrubland	197	133
	Woody Wetlands	1	1
Upper Divide Creek Total		1,019	834
Upper Pattengail Creek	Evergreen Forest	242	242
	Grasslands/Herbaceous	91	75
	Shrubland	119	80
*Upper Pattengail Creek Total		452	398
Upper Willow Creek	Bare Rock/Sand/Clay	2	2
	Evergreen Forest	170	170
	Grasslands/Herbaceous	607	506
	Logging	2	2
	Shrubland	380	256
Upper Willow Creek Total		1,161	936
Upper Wise River	Evergreen Forest	259	259
	Grasslands/Herbaceous	295	245
	Logging	1	1
	Shrubland	439	296
*Upper Wise River Total		993	801

Table C-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the Middle and Lower Big Hole watershed (i.e. all HUCs). HUCS within the middle Big Hole watershed are denoted with an asterisk.

Subwatershed	Land Cover Classification	Existing Sediment (tons/yr)	Potential Sediment (tons/yr)
Wickiup Creek	Evergreen Forest	30	30
	Grasslands/Herbaceous	183	152
	Logging	1	1
	Shrubland	68	46
Wickiup Creek Total		281	228
Wyman Creek	Evergreen Forest	165	165
	Grasslands/Herbaceous	50	42
	Logging	1	1
	Shrubland	87	59
*Wyman Creek Total		303	266
Middle and Lower Big Hole Watershed	**Bare Rock**	**20**	**20**
	Deciduous Forest	**1**	**1**
	Evergreen Forest	**8,600**	**8,600**
	Mixed Forest	**5**	**5**
	Grasslands/Herbaceous	**36,430**	**30,359**
	Logging	**110**	**110**
	Pasture/Hay	**258**	**168**
	Shrubland	**19,505**	**13,144**
	Small Grains	**318**	**20**
	Woody Wetlands	**12**	**12**
Middle and Lower Big Hole Total		**65,260**	**52,439**

[1]The loads for the Upper Birch Creek watershed were derived outside of the model based on the land cover acreage in the upper watershed compared to the entire Birch Creek watershed.

References

Brooks, K.N., P.F. Ffolliott, H.M Gregersen, and L.F. DeBano. 1997. Hydrology and the Management of Watersheds – second edition. Iowa State University Press. Ames, Iowa.

Castelle, A.J. and A.W. Johnson, 2000. Riparian Vegetation Effectiveness. Technical Bulletin No. 799, National Council for Air and Stream Improvement (NCASI), Research Triangle Park, NC.

Doe, W.W. III, Jones D.S., Warren, S.D. 1999. The Soil Erosion Model Guide for Military Land Mangers: Analysis of Erosion Models for Natural and Cultural Resources Applications. Technical Report ITL 99-XX. U.S. Army Engineer Waterways Experiment Station.

Elliot, W.J. 2006. The Roles of Natural and Human Disturbances in Forest Soil Erosion. In Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management. Eds. Owens, P.N. and A.J. Collins. 177-199. CABI publishing. Wallingford, United Kingdom.

Elliot, W.J. and P.R. Robichaud. Comparing Erosion Risks from Forest Operations to Wildfire. 2001. The International Mountain Logging and 11th Pacific Northwest Skyline Symposium, 2001. 78-89.

Hook, Paul B. 2003. Sediment Retention in Rangeland Riparian Buffers. Journal of Environmental Quality. 32(3): 1130-1137.

Montana DEQ. 2007. Montana Nonpoint Source Management Plan. July 2007. Available at: http://deq.mt.gov/wqinfo/nonpoint/2007NONPOINTPLAN/Final/NPSPlan.pdf.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE). USDA Agriculture Handbook No. 703, 404 pp.

Rice, R.M., J.S. Rothacher, and W.F. Megahan. 1972. Erosional Consequences of Timber Harvesting: An Appraisal. In National Symposium on Watersheds in Transition. American Water Resources Association, Urbana, Illinois.

Wischmeier, W.H., and Smith, D.D., 1978, Predicting rainfall erosion losses, a guide to conservation planning. Agriculture Handbook No. 537, US Department of Agriculture, Washington D.C.

APPENDIX D
UNPAVED ROAD RUNOFF SEDIMENT ASSESSMENT

MIDDLE AND LOWER BIG HOLE RIVER WATER QUALITY RESTORATION PLANNING AREAS

Prepared for:

Montana Department of Environmental Quality
P.O. 200901
Helena, MT 59620-0901

Prepared by:

PBS&J
P.O. Box 239
Helena, MT 59624

January 2007

Project No. B15532.09

TABLE OF CONTENTS

1.0 INTRODUCTION.. D-1

2.0 DATA COLLECTION AND EXTRAPOLATION D-1
- 2.1 Field Data Collection D-1
- 2.2 Mean Sediment Loads.. D-8
- 2.3 Extrapolation of Sediment Loads to Watershed Scale.............................. …D-8

3.0 SEDIMENT LOAD ANALYSIS D-11
- 3.1 Road Ownership... D-11

4.0 APPLICATION of BEST MANAGEMENT PRACTICES............................ D-17

5.0 REFERENCES... D-22

ATTACHMENTS

Attachment A Field Data and FroSAM Modeled Sediment Loads
Attachment B GPS Points

LIST OF FIGURES

Figure 2-1 *Overview of Middle and Lower Big Hole Road Network*
Figure 2-2 *Middle and Lower Big Hole Road Network (northwest portion)*
Figure 2-3 *Middle and Lower Big Hole Road Network (northeast portion)*
Figure 2-4 *Middle and Lower Big Hole Road Network (southwest portion)*
Figure 2-5 *Middle and Lower Big Hole Road Network (southeast portion)*

LIST OF TABLES

Table 3-1 Estimated Sediment Loads from Unpaved Road Crossings and Near-stream Road Segments by Landscape Type
Table 3-2 *Number of Unpaved Road Crossings*
Table 3-3 *Number and Length of Near-stream Segments*
Table 3-4 *Sediment Loading from Unpaved Road Crossings*
Table 3-5 *Sediment Loading from Near-stream Segments*
Table 3-6 *Total Sediment Loading from Unpaved Roads*
Table 4-1 Estimated Average Reduction in Sediment Loading through the Application of Best Management Practices
Table 4-2 *Sediment Loading from Unpaved Road Crossings with the Application of BMPs*
Table 4-3 *Sediment Loading from Near-stream Segments with the Application of BMPs*
Table 4-4 *Total Sediment Loading from Unpaved Roads with the Application of BMPs*
Table 4-5 *Percent Reduction in Sediment Loading through the Application of BMPs*

1.0 INTRODUCTION

This report presents an assessment of sediment loading from unpaved roads within most of the watersheds on the 2006 303(d) List for sediment-related impairment in the Middle and Lower Big Hole TMDL planning area. This assessment employed GIS, field data collection, and sediment modeling to assess sediment inputs from the unpaved road network to the stream network. Methods employed in this assessment are outlined in the *Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan* (MDEQ 2005). Additional information regarding GIS techniques, and monitoring site selection can be found in the Sampling and Analysis Plan for this project: *Middle and Lower Big Hole TPA Unpaved Road Sediment Monitoring Plan* (MDEQ 2006). Sediment loading for unpaved roads in the French Creek watershed was not initially assessed as part of this effort but was performed later and the assessment results are included as an addendum in **Section 4.1** of this appendix.

2.0 DATA COLLECTION AND EXTRAPOLATION

Prior to field data collection, GIS layers of the stream network and road network were used to identify unpaved road crossings throughout the Middle and Lower Big Hole watershed. Areas where the road encroaches upon the stream channel, referred to as “near-stream” road segments, were also identified in GIS. Each identified unpaved road crossing and near-stream road segment was assigned attributes for road name, surface type, road ownership/management, stream name, subwatershed and landscape setting. A subset of unpaved road crossings representing the range of conditions identified in GIS was selected for field evaluation.

2.1 Field Data Collection

Unpaved road crossings and near-stream segments were assessed on each landscape type in proportion to their overall abundance, as described in the *Middle and Lower Big Hole TPA Unpaved Road Sediment Monitoring Plan* (MDEQ 2006), which outlined a strategy to sample approximately 5 percent of the unpaved road crossings on each landscape type. A total of 1,123 unpaved crossings were identified prior to field data collection. Eleven percent of the crossings (123) were within the valley landscape type, 24 percent (273 crossings) fell within the foothill landscape type, and 65 percent (727 crossings) fell within the mountain landscape type (MDEQ 2006).

A total of 53 unpaved road crossings and 34 near-stream segments were assessed in the field using the Forest Road Sedimentation Assessment Methodology (FroSAM) (**Figures 2-1** through **2-5**). Thirty-two crossings were assessed on the mountain landscape, while 13 crossings were assessed on the foothill landscape, and 7 crossings were assessed on the valley landscape. In the field, near stream segments were selected based on best professional judgment while traveling roads on which specific crossings were selected for evaluation. On the mountain landscape, 25 near-stream road segments were assessed, while 9 near-stream road segments on the foothill landscape were assessed. No near-stream segments were assessed on the valley landscape due to the small overall area of valley landscape and the observation that the majority of the roads were paved and/or did not parallel a stream channel.

Near-stream segments were initially defined as unpaved roads within 150 feet of the stream channel, though this was reduced to 100 feet after observing a lack of sediment contribution from roads farther away, which was primarily due to vegetative buffer, and valley topography. Sediment contribution from near-stream road segments will be described in this report based on “input-points” since it was observed in the field that sediment contribution tended to occur at certain points along a near-stream segment of road.

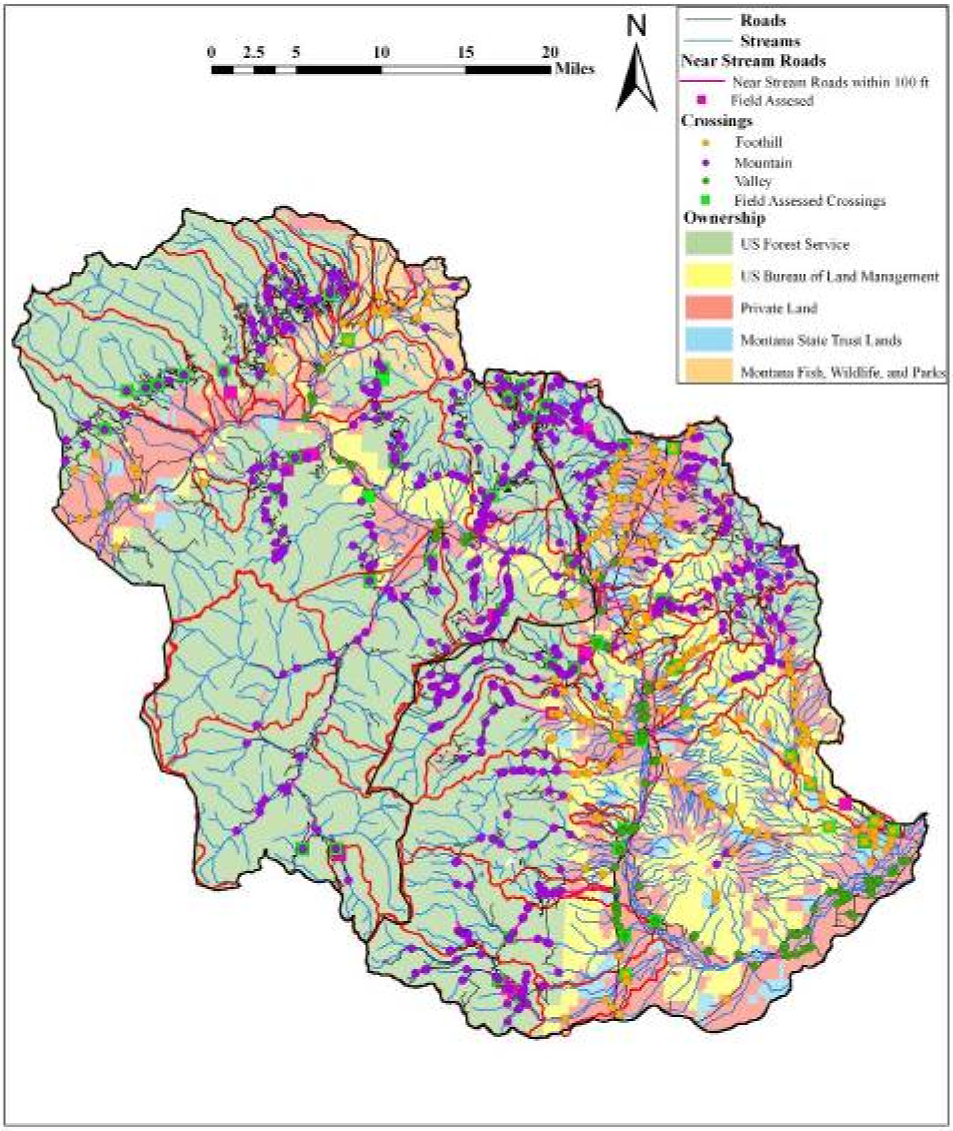


Figure 2-1. Overview of Middle and Lower Big Hole Road Network.

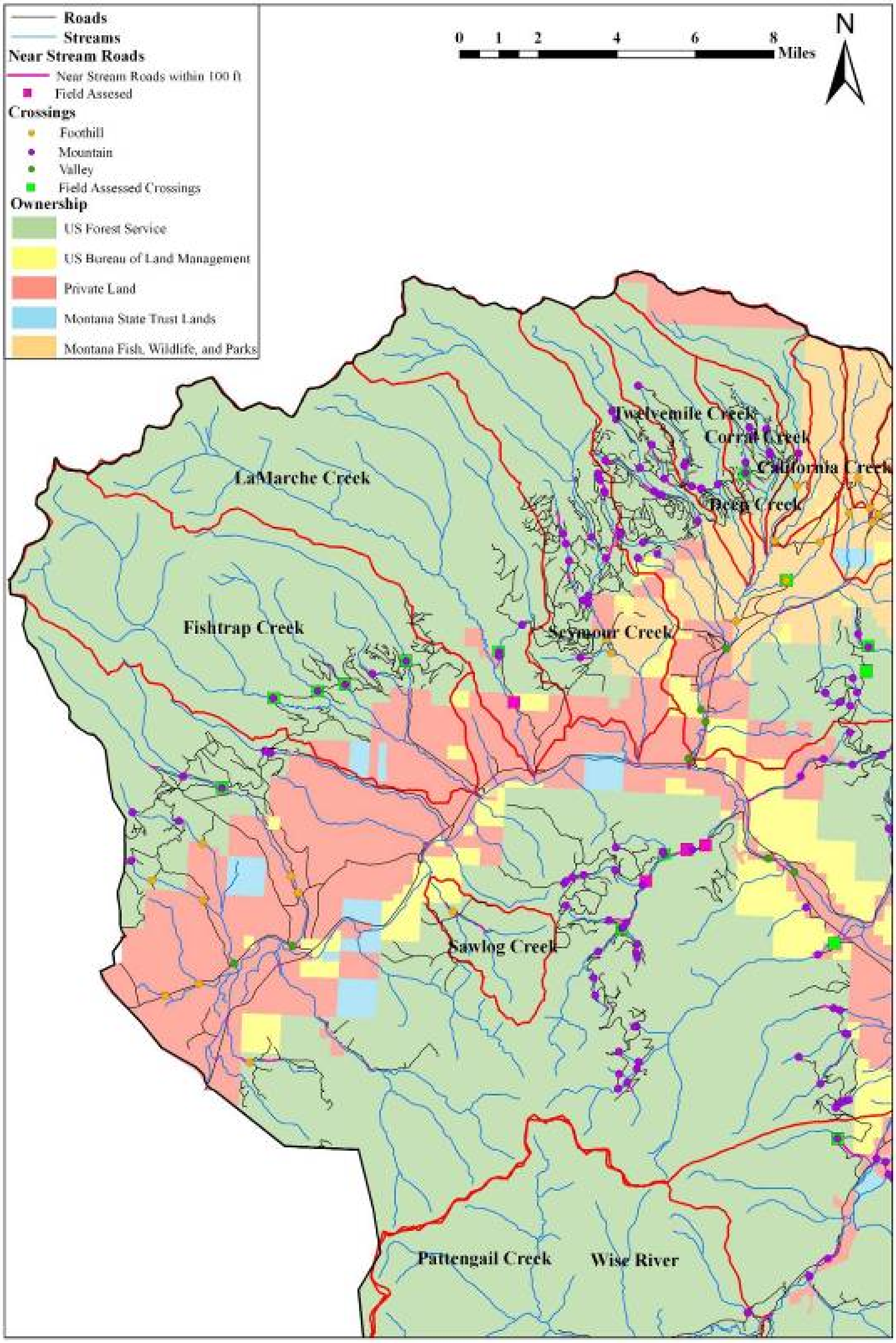


Figure 2-2. Middle and Lower Big Hole Road Network (northwest portion).

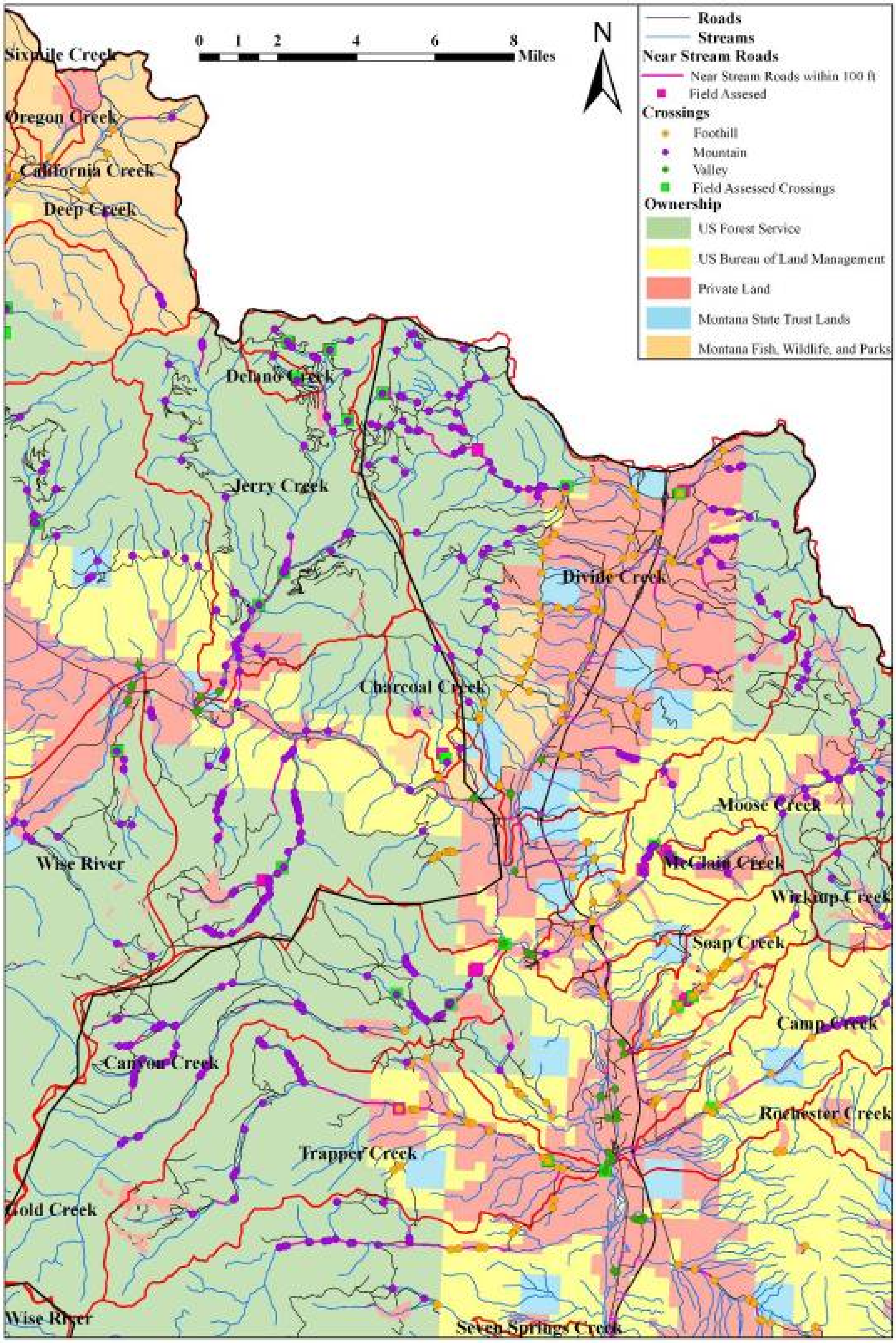


Figure 2-3. Middle and Lower Big Hole Road Network (northeast portion).

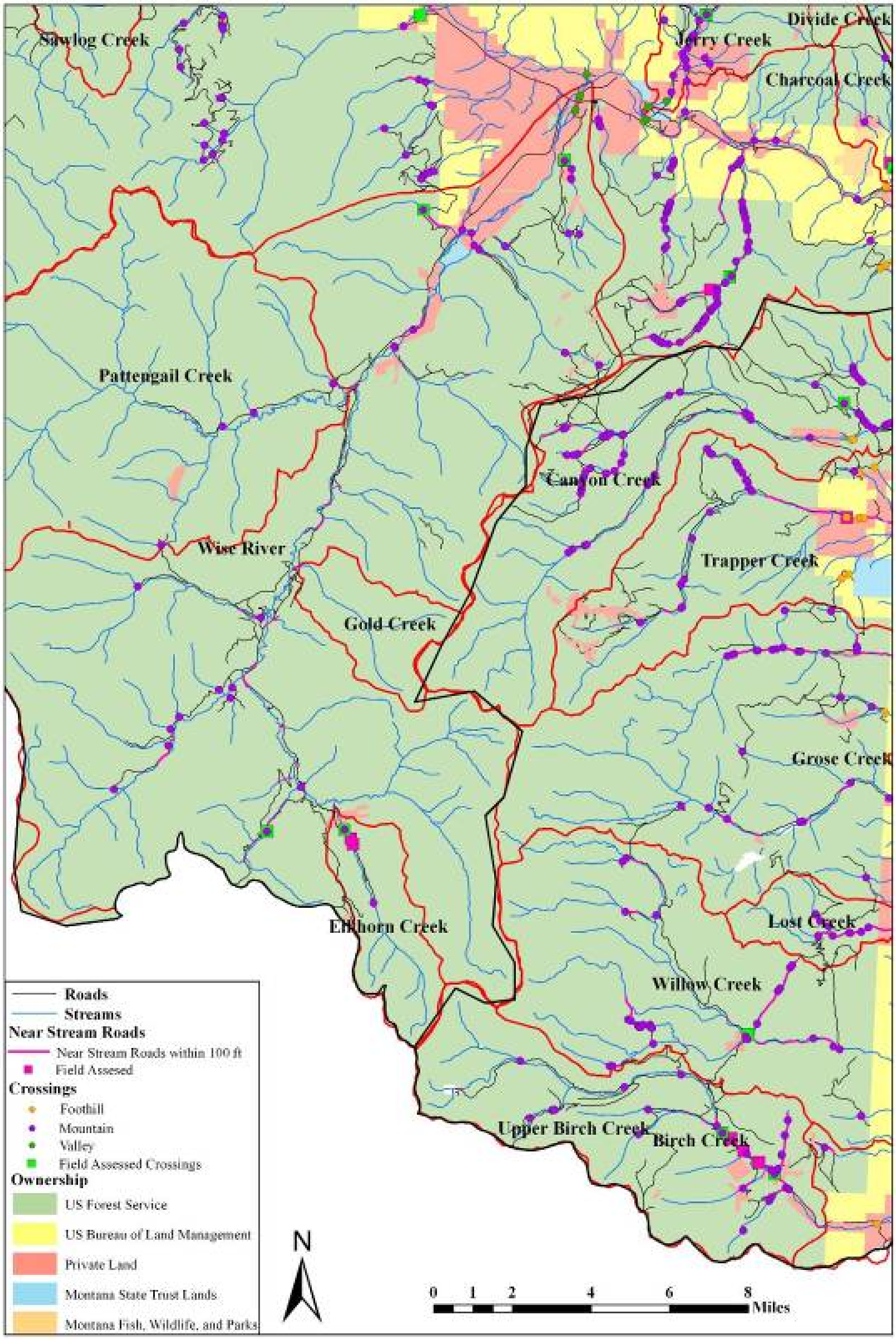


Figure 2-4. Middle and Lower Big Hole Road Network (southwest portion).

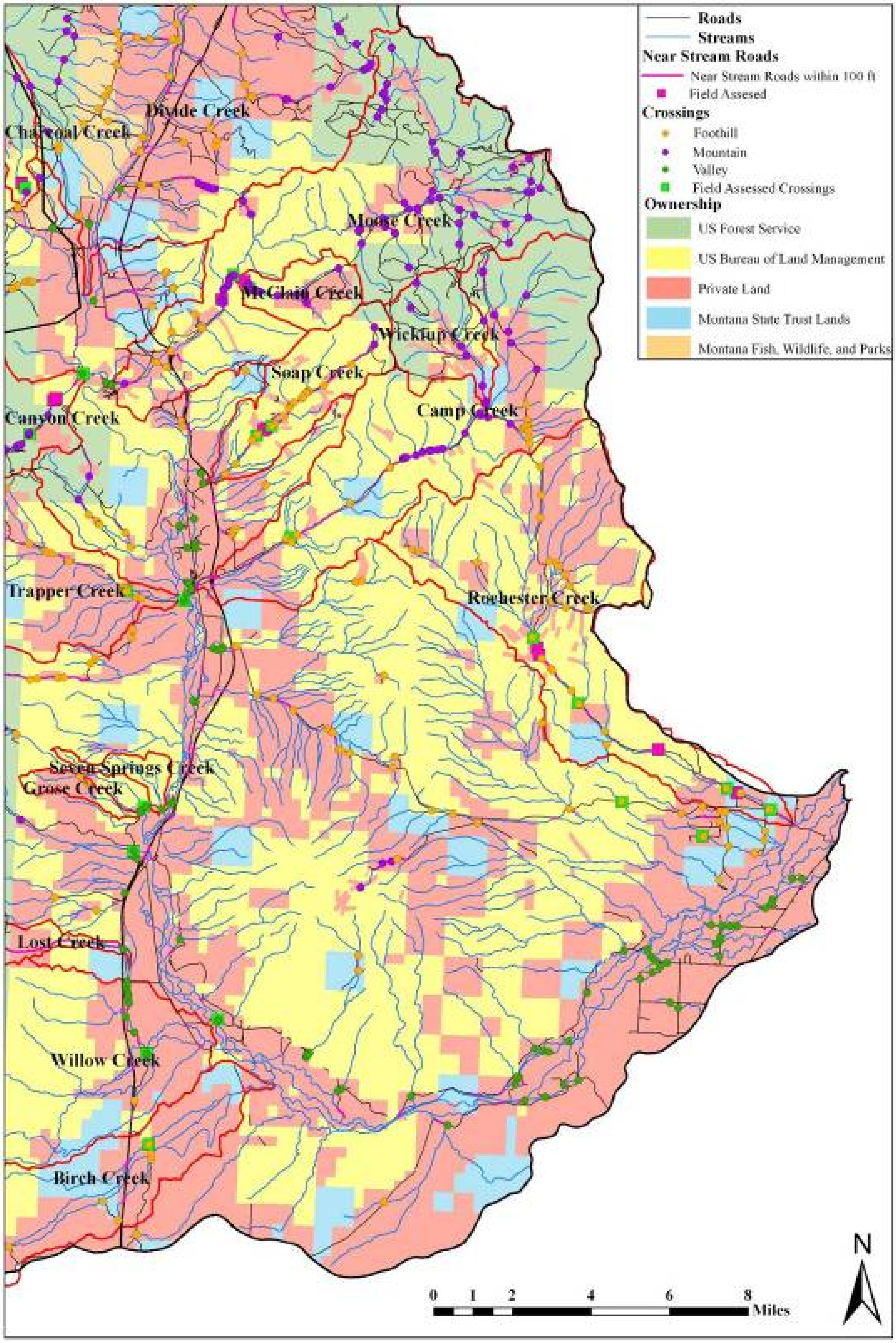


Figure 2-5. Middle and Lower Big Hole Road Network (southeast portion).

2.2 Mean Sediment Loads

Based on data collected in the field, the mean sediment contribution from both unpaved road crossings, and near-stream road segments was determined for each landscape type. Sediment loads from unpaved road crossings on the mountain landscape averaged an estimated 0.76 tons/year (**Table 2-1**). On the foothill landscape, sediment contributions from unpaved road crossings averaged an estimated 0.96 tons/year, while on the valley landscape sediment contributions from unpaved road crossings averaged an estimated 0.39 tons/year. Near-stream road segments contributed an average of an estimated 0.56 tons/year on the mountain landscape, and 0.58 tons/year on the foothill landscape. No near-stream road segments were assessed on the valley landscape, because of the small overall area of valley landscape, where the majority of the roads were paved and/or did not parallel the stream channels. The complete field dataset, along with the FroSAM modeled sediment loads, is presented in **Attachment A** and GPS points of the assessment sites are presented in **Attachment B**.

Table 2-1. Mean Sediment Loads from Field-assessed Road Crossings and Near-stream Road Segments.

Sediment Source	Landscape Type	Number of Sites Assessed	Mean Sediment Load (Tons/Year)
Crossing	Mountain	33	0.76
Crossing	Foothill	13	0.96
Crossing	Valley	7	0.39
	TOTAL	***53***	
Near-stream	Mountain	25	0.56
Near-stream	Foothill	9	0.58
Near-stream	Valley	0	no data
	TOTAL	***34***	

2.3 Extrapolation of Sediment Loads to the Watershed Scale

The sediment load (tons/year) from unpaved road crossing was calculated based on landscape type, the number of unpaved road crossings, and the length of unpaved road within 100 feet of a stream channel. The average sediment contribution from unpaved road crossings, and near-stream road segments was used to assign sediment loads to sites not assessed in the field. Sediment loads from unpaved road crossings were assigned based on landscape type. For near-stream road segments, an average of 0.57 tons/year was used on all landscape types.

2.3.1 Error Reduction

Following field data collection, GIS data was reviewed for accuracy. This review was conducted since field observations suggested that the GIS script used to generate stream crossings tended to over-estimate the number of crossings in situations where a stream was paralleled by a road in a relatively narrow or confined valley bottom. This over-estimation was due to inherent inaccuracies associated with the road, and stream layers used. The error percentage for the unpaved road crossings within the 19 2004 listed watersheds was evaluated through a detailed visual assessment of 2005 color aerial imagery, along with site-specific knowledge, and ground-truthing during field assessment. One-hundred percent of the GIS identified road crossings were reviewed within the watersheds of the 19 segments listed as impaired due to sediment in 2004, and the suspected incorrect crossings were removed from the tally for each watershed that appeared on the 2004 303(d) List as impaired due to sediment (crossings were not manually removed from the GIS file). An average percentage of error per landscape type was determined based on this review. The valley crossings were highly accurate and had 0 percent error. The foothill crossings had an average error of 4 percent, and the mountain crossings had an error of 28 percent. Error rates in the GIS assessment were closely tied to stream valley confinement. These percentages were then extrapolated to the 1996 303(d) Listed watersheds, and the Middle and Lower Big Hole watershed. This lead to a reduction in the number of crossings originally assigned through GIS for the site selection process. The total number of unpaved road crossings originally delineated in GIS was reduced from 1,123 to 908 **(Table 2-2)**. While there is no way of knowing the exact number of crossings with complete certainty given the imprecise GIS data layers, the adjusted number is thought to be more accurate than the original number.

Table 2-2. Refined Number of Unpaved Road Crossings.

Landscape	Unpaved Road Crossings According to GIS Analysis	Unpaved Road Crossings with Aerial Photo and Field Assessment Adjustment
Mountain	727	523
Foothill	273	262
Valley	123	123
Total	**1,123**	**908**

Near-stream road segments were initially defined as unpaved roads within 150 feet of the stream channel using GIS, though this was reduced to 100 feet after noting a lack of sediment contribution from roads farther away. Similar to the road crossings, inaccuracies in the GIS roads, and stream layers make it difficult to evaluate the actual length of road within 100 feet of the channel. Initially, a total of 232.2 miles of road were identified in the Middle and Lower Big Hole watershed as being within 150 feet of a stream, with 206.3 miles of unpaved road. When unpaved roads within 100 feet of the stream were examined, there were 80.9 miles. However, using this number to calculate sediment loads would lead to an over-estimate of sediment contributions from near-stream segments since this distance includes road lengths already accounted for at crossings. An average of 270 feet of contributing road length was determined for each crossing. Thus, the near-stream road length was recalculated by subtracting the average length of the field assessed road crossings (270 feet) for each crossing from the overall road length. This eliminated load duplication for near-stream road segments and crossings.

Sediment loads were assigned to near-stream roads segments based on the length of road contributing at an “input point”, since unpaved roads were observed to contribute sediment to stream channels at identifiable points during field data collection. The average contributing length for near-stream road segments assessed in the field was 265 feet. This contributing length was estimated to represent the length of road contributing appreciable sediment to an identified “input point” for every 1,100 feet of unpaved road within 100 feet of the stream. This means that each assessed near-stream segment "input point" accounted for 24 percent (i.e. 265/1,100) of the total near-stream road length measured in GIS. To adjust for this contribution per 1,100 feet of near-stream road, the total near stream road length for each subwatershed was divided by 265 feet to estimate the total number of near-stream road segments, and then 24 percent of that number was used to represent the total length of each segment that contributes sediment to the stream channel **(Table 2-3)**.

Table 2-3. Refined Near-stream Road Segment Lengths.

Landscape	Unpaved Road within 100 Feet (Miles)	Estimated Contributing Length of Parallel Roads within 100 Feet (Miles)	Estimated Number of Near -stream Road Segments with appreciable "Input Points"
Mountain	46.5	11.2	222
Foothill	23.3	5.6	112
Valley	11.1	2.7	53
Total	**80.9**	**19.4**	**387**

3.0 SEDIMENT LOAD ANALYSIS

The sediment loads were calculated by landscape type using the refined number of unpaved road crossings and near stream road segments **(Table 3-1).** The overall watershed scale sediment load from unpaved road crossings is estimated at 694.8 tons/year, while near-stream road segments contribute an estimated 220.6 tons of sediment per year.

Table 3-1. Estimated Sediment Loads from Unpaved Road Crossings and Near-stream Road Segments by Landscape Type.

Sediment Source	Landscape Type	Number of Sites	Mean Sediment Load (Tons/Year)	Total Sediment Load (Tons/Year)
Crossing	Mountain	523	0.76	398
Crossing	Foothill	262	0.96	249
Crossing	Valley	123	0.39	48
TOTAL		**908**		***695***
N-stream	Mountain	222	0.56	124
N-stream	Foothill	112	0.58	65
N-stream	Valley	53	0.57	30
TOTAL		**387**		***219***

3.1 Road Ownership

Unpaved road crossings and near-stream road segments were classified by watershed, landscape type, and land ownership. Several entities are responsible for land management in the Middle and Lower Big Hole TPA, including the State of Montana (both Montana Fish, Wildlife and Parks and Montana Trust managed lands), the U.S. Bureau of Land Management, U. S. Forest Service, and private landowners. Road ownership and maintenance responsibilities fall on the federal land management agencies, local counties, and private landowners. Data for the number of crossings, and near stream road segments are presented in **Table 3-2** and **Table 3-3** for each landowner. Estimated sediment loads resulting from the unpaved road network are presented for each landowner in **Tables 3-4**, **3-5** and **3-6**. Sediment loads were calculated using the average sediment load per landscape type from **Table 2-1**, and the number of crossings and near-stream segments presented in **Tables 3-4** and **3-5**.

Table 3-2. Number of Unpaved Road Crossings.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	# of Crossings			# of Crossings			# of Crossings			# of Crossings			# of Crossings			# of Crossings
	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	
Upper Birch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	**18**
California	0	5	2	0	0	0	0	1	0	0	0	0	0	0	0	**8**
Camp	0	0	0	0	1	1	0	7	10	0	4	8	0	0	4	**35**
Corral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	**7**
Deep	0	9	6	0	0	0	3	1	0	0	0	1	0	1	31	**52**
Delano	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**2**
Divide	0	7	0	0	5	0	3	39	22	0	0	0	0	3	55	**134**
Fishtrap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
Gold	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Grose	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Lost	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6	**7**
Oregon	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Pattengail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	**4**
Rochester	0	0	0	0	4	0	0	17	0	0	6	0	0	0	0	**27**
Sawlog	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Sevenmile	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Sixmile	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Soap Gulch	0	0	0	0	0	0	1	3	0	0	18	2	0	0	0	**24**
Trapper	0	0	0	0	0	0	0	7	0	0	5	0	0	1	3	**16**
Lower Birch	0	0	0	0	1	0	0	5	0	0	0	0	0	0	1	**6**
Canyon	0	0	0	0	0	0	1	0	0	0	0	0	0	2	50	**53**
Charcoal Gulch	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	**2**
Elkhorn	0	0	0	0	0	0	18	0	0	0	0	0	0	0	1	**19**
Jerry	0	0	0	1	0	0	1	0	13	0	0	1	0	0	29	**45**
LaMarche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**2**
McClain	0	0	0	0	0	0	0	0	1	0	0	8	0	0	0	**9**
Moose	0	0	0	0	0	0	1	6	12	1	0	20	0	0	17	**57**
Seven Springs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Seymour	0	0	0	0	0	0	0	0	0	0	0	0	0	2	10	**12**
Twelvemile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	**5**
Willow	0	0	0	0	0	0	12	1	1	0	0	0	0	0	22	**36**
Wise	0	0	0	0	0	0	4	0	3	0	0	0	0	0	22	**29**
Wickiup	0	0	0	0	0	1	0	0	3	0	0	1	0	0	1	**6**
Middle and Lower BigHole Combined	1	18	6	3	27	4	117	143	76	2	54	40	1	20	395	**909**
Middle Big Hole	1	12	6	1	0	3	17	8	22	2	0	9	1	13	191	**285**
Lower Big Hole	0	7	0	2	27	1	100	135	55	0	54	32	0	7	204	**624**

Table 3-3. Number and Length of Near-stream Segments.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total	Total
Watershed	# of near stream segments			# of near stream segments			# of near stream segments			# of near stream segments			# of near stream segments			# of near stream segments	Near stream length (ft)
	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn		
Upper Birch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	**17**	**4632**
California	0	4	1	0	0	0	0	1	0	0	0	0	0	0	0	**6**	**1496**
Camp	0	0	0	0	1	1	0	4	5	0	2	4	0	0	2	**19**	**4910**
Corral	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**2**	**446**
Deep	0	3	2	0	0	0	1	0	0	0	0	0	0	0	11	**18**	**4757**
Delano	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**11**
Divide	0	3	0	0	2	0	1	14	8	0	0	0	0	1	20	**49**	**12925**
Fishtrap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**	**198**
Gold	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Grose	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**1**	**299**
Lost	0	0	0	3	0	0	0	0	0	0	0	0	0	0	16	**18**	**4840**
Oregon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**18**
Pattengail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**49**
Rochester	0	0	0	0	1	0	0	5	0	0	2	0	0	0	0	**8**	**2249**
Sawlog	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**2**	**420**
Sevenmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**16**
Sixmile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**60**
Soap Gulch	0	0	0	0	0	0	1	2	0	0	10	1	0	0	0	**13**	**3494**
Trapper	0	0	0	0	0	0	0	9	0	0	6	0	0	1	4	**20**	**5355**
Lower Birch	0	0	0	0	1	0	0	4	0	0	0	0	0	0	1	**5**	**1303**
Canyon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	22	**24**	**6266**
Charcoal Gulch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**270**
Elkhorn	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	**3**	**668**
Jerry	0	0	0	0	0	0	0	0	5	0	0	1	0	0	11	**18**	**4770**
LaMarche	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**82**
McClain	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0	**6**	**1468**
Moose	0	0	0	0	0	0	0	2	4	0	0	6	0	0	5	**18**	**4642**
Seven Springs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**67**
Seymour	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	**9**	**2485**
Twelvemile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	**3**	**712**
Willow	0	0	0	0	0	0	8	1	1	0	0	0	0	0	14	**24**	**6305**
Wise	0	0	0	0	0	0	3	0	2	0	0	0	0	0	15	**20**	**5248**
Wickiup	0	0	0	0	0	1	0	0	2	0	0	0	0	0	1	**4**	**1071**
Middle and Lower BigHole Combined	0	8	3	1	11	2	50	61	32	1	23	17	1	9	168	**387**	**102539**
Middle Big Hole	0	5	3	0	0	1	7	3	9	1	0	4	1	6	82	**122**	**32419**
Lower Big Hole	0	3	0	1	11	1	43	58	23	0	23	13	0	3	87	**265**	**70296**

Table 3-4. Sediment Loading from Unpaved Road Crossings.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load
	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	(tons/year)
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	**13.7**
California	0.0	4.8	1.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**7.2**
Camp	0.0	0.0	0.0	0.0	1.0	0.8	0.0	6.7	7.6	0.0	3.8	6.1	0.0	0.0	3.0	**28.9**
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	**5.3**
Deep	0.0	8.6	4.6	0.0	0.0	0.0	1.2	1.0	0.0	0.0	0.0	0.8	0.0	1.0	23.6	**40.5**
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	**1.5**
Divide	0.0	6.7	0.0	0.0	4.8	0.0	1.2	37.1	16.7	0.0	0.0	0.0	0.0	2.9	41.8	**111.0**
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	**3.8**
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.3**
Lost	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	**5.0**
Oregon	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	**3.0**
Rochester	0.0	0.0	0.0	0.0	3.8	0.0	0.0	16.2	0.0	0.0	5.7	0.0	0.0	0.0	0.0	**25.7**
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	**1.0**
Sevenmile	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Sixmile	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.9	0.0	0.0	17.1	1.5	0.0	0.0	0.0	**21.9**
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	0.0	4.8	0.0	0.0	1.0	2.3	**14.6**
Lower Birch	0.0	0.0	0.0	0.0	0.9	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	**6.0**
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.8	37.8	**40.0**
Charcoal Gulch	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	**1.6**
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	**8.1**
Jerry	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	9.8	0.0	0.0	1.1	0.0	0.0	21.9	**33.6**
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	**1.6**
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	6.0	0.0	0.0	0.0	**7.1**
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.4	5.5	9.3	0.4	0.0	15.3	0.0	0.0	13.1	**44.0**
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	7.7	**9.5**
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	**3.8**
Willow	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.9	1.1	0.0	0.0	0.0	0.0	0.0	16.4	**23.1**
Wise	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	2.2	0.0	0.0	0.0	0.0	0.0	17.0	**20.7**
Wickiup	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	2.2	0.0	0.0	0.5	0.0	0.0	1.1	**4.9**
Middle and Lower Big Hole Combined	0.4	17.3	4.9	1.2	25.5	3.3	45.6	135.9	58.0	0.8	51.1	30.6	0.6	19.2	300.4	**694.8**
Middle Big Hole	0.4	10.9	4.9	0.4	0.0	2.2	6.6	7.3	16.4	0.8	0.0	6.6	0.6	12.8	145.0	**214.9**
Lower Big Hole	0.0	6.4	0.0	0.8	25.5	1.1	39.0	128.6	41.6	0.0	51.1	24.1	0.0	6.4	155.4	**479.9**

Table 3-5. Sediment Loading from Near-stream Segments.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)
	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	**10.0**
California	0.0	2.0	0.8	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**3.2**
Camp	0.0	0.0	0.0	0.0	0.3	0.3	0.0	2.1	3.0	0.0	1.2	2.4	0.0	0.0	1.2	**10.6**
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	**1.0**
Deep	0.0	1.8	1.2	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.2	0.0	0.2	6.1	**10.2**
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Divide	0.0	1.5	0.0	0.0	1.0	0.0	0.6	8.1	4.6	0.0	0.0	0.0	0.0	0.6	11.4	**27.8**
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	**0.4**
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**
Lost	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	**10.4**
Oregon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**0.1**
Rochester	0.0	0.0	0.0	0.0	0.7	0.0	0.0	3.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	**4.8**
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	**0.9**
Sevenmile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Sixmile	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.0	0.0	5.6	0.6	0.0	0.0	0.0	**7.5**
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	3.6	0.0	0.0	0.7	2.2	**11.5**
Lower Birch	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	**2.8**
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	12.7	**13.5**
Charcoal Gulch	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	**0.6**
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**1.4**
Jerry	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	2.9	0.0	0.0	0.3	0.0	0.0	6.5	**10.3**
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0.2**
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	2.7	0.0	0.0	0.0	**3.2**
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	2.1	0.2	0.0	3.5	0.0	0.0	3.0	**10.0**
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	4.5	**5.3**
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	**1.5**
Willow	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.4	0.5	0.0	0.0	0.0	0.0	0.0	8.1	**13.6**
Wise	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	1.1	0.0	0.0	0.0	0.0	0.0	8.6	**11.3**
Wickiup	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0	0.3	0.0	0.0	0.5	**2.3**
Middle and Lower Big Hole Combined	0.2	4.4	1.6	0.7	6.5	1.0	28.4	34.7	18.5	0.5	13.0	9.8	0.3	4.9	95.9	**220.6**
Middle Big Hole	0.2	2.8	1.6	0.2	0.0	0.7	4.2	1.9	5.3	0.5	0.0	2.1	0.4	3.3	46.6	**69.7**
Lower Big Hole	0.0	1.6	0.0	0.5	6.5	0.3	24.2	32.8	13.3	0.0	13.0	7.7	0.0	1.6	49.6	**151.2**

Table 3-6. Total Sediment Loading from Unpaved Roads.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)
	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6	23.6
California	0.0	6.8	2.3	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4
Camp	0.0	0.0	0.0	0.0	1.3	1.1	0.0	8.8	10.6	0.0	5.0	8.5	0.0	0.0	4.2	39.4
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	6.3
Deep	0.0	10.3	5.7	0.0	0.0	0.0	1.8	1.1	0.0	0.0	0.0	1.0	0.0	1.1	29.7	50.7
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
Divide	0.0	8.1	0.0	0.0	5.8	0.0	1.8	45.1	21.3	0.0	0.0	0.0	0.0	3.5	53.2	138.8
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Lost	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	15.4
Oregon	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
Rochester	0.0	0.0	0.0	0.0	4.5	0.0	0.0	19.2	0.0	0.0	6.8	0.0	0.0	0.0	0.0	30.5
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	1.9
Sevenmile	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Sixmile	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.7	3.8	0.0	0.0	22.7	2.1	0.0	0.0	0.0	29.4
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	0.0	0.0	8.3	0.0	0.0	1.7	4.4	26.1
Lower Birch	0.0	0.0	0.0	0.0	1.3	0.0	0.0	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.9	8.8
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	2.3	50.5	53.4
Charcoal Gulch	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.7	2.2
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	9.6
Jerry	0.0	0.0	0.0	0.6	0.0	0.0	0.6	0.0	12.8	0.0	0.0	1.4	0.0	0.0	28.4	43.9
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	8.7	0.0	0.0	0.0	10.3
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.6	6.5	11.4	0.6	0.0	18.8	0.0	0.0	16.1	54.0
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	12.1	14.8
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	5.4
Willow	0.0	0.0	0.0	0.0	0.0	0.0	9.2	1.3	1.6	0.0	0.0	0.0	0.0	0.0	24.6	36.7
Wise	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	3.3	0.0	0.0	0.0	0.0	0.0	25.6	32.0
Wickiup	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	3.2	0.0	0.0	0.8	0.0	0.0	1.6	7.2
Middle and Lower Big Hole Combined	0.6	21.8	6.5	1.9	32.1	4.3	74.0	170.6	76.5	1.3	64.1	40.4	0.9	24.0	396.3	915.3
Middle Big Hole	0.6	13.8	6.5	0.6	0.0	2.9	10.8	9.2	21.7	1.3	0.0	8.7	0.9	16.1	191.6	284.6
Lower Big Hole	0.0	8.0	0.0	1.3	32.1	1.4	63.2	161.4	54.9	0.0	64.1	31.8	0.0	8.0	205.0	631.1

4.0 APPLICATION OF BEST MANAGEMENT PRACTICES

The application of Best Management Practices (BMPs) at unpaved road crossings and near-stream road segments would reduce the sediment load from the unpaved road network. Sediment load reductions due to BMPs was evaluated by reducing the contributing road length to 100 feet from each side of a crossing (200 feet total) and to 100 feet for each near-stream road segment. These parameters were applied in the FroSAM model to the crossings and near-stream segments assessed in the field to evaluate the potential for sediment load reductions through the application of BMPs. Crossing lengths that exceeded 200 feet were reduced to 200 feet for the tread length, cutslope length and fillslope length. For unpaved road crossings with contributing lengths less than 200 feet, no adjustment was made. Similarly, near-stream road lengths that exceeded 100 feet were reduced to 100 feet for the tread length, cutslope length and fillslope lengths. No adjustment was made for near-stream road lengths less than 100 feet.

Sediment loads following the application of BMPs were calculated for unpaved road crossings and near-stream segments using the FroSAM model. On average, sediment loads from unpaved road crossings on the mountain landscape were reduced from 0.76 tons/year to 0.55 tons/year (**Table 4-1**). On the foothill landscape, sediment contributions from unpaved road crossings were reduced from 0.96 tons/year to 0.58 tons/year, while on the valley landscape the average sediment contributions from unpaved road crossings remained the same (0.39 tons/year). Through the application of BMPs, the average sediment load from near-stream road segments was reduced from 0.56 tons/year to 0.25 tons/year on the mountain landscape and from 0.58 tons/year to 0.31 tons/year on the foothill landscape. No near-stream road segments were assessed on the valley landscape.

Average sediment loads in each landscape type were extrapolated to the watershed scale based on the number of crossings and length of near-stream road segments. The reduced loads per watershed, landscape type and ownership are shown in **Table 4-2** (Unpaved Crossings) and **Table 4-3** (Near-stream Roads) for the watersheds with sediment-related impairments on the 2006 303(d) List, including the entire middle and lower Big Hole TMDL Planning Area. Potential sediment load reductions achieved via BMP implementation are summarized in **Table 4-4**. With the application of BMPs, the estimated annual sediment load from unpaved roads in the Middle and Lower Big Hole TMDL Planning areas was reduced from 695 tons to 488 tons for unpaved crossings and from 219 tons to 105 tons for near-stream road segments. The overall potential for sediment load reduction from unpaved roads is 35 percent in the Middle and Lower Big Hole TPA, from an existing load of 915 tons/year to a load of 593 tons/year through the application of BMPs (**Table 4-5**).

Table 4-1. Estimated Average Reduction in Sediment Loading through the Application of Best Management Practices.

Sediment Source	Landscape Type	Number of Sites	Mean Sediment Load (Tons/Year)	Total Sediment Load (Tons/Year)
Crossing	Mountain	523	0.55	288
Crossing	Foothill	262	0.58	152
Crossing	Valley	123	0.39	48
TOTAL		**908**		***488***
Near-stream	Mountain	222	0.25	55
Near-stream	Foothill	112	0.31	35
Near-stream	Valley	53	0.28	15
TOTAL		**387**		***105***

Table 4-2. Sediment Loading from Unpaved Road Crossings with the Application of BMPs.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)
	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	**9.9**
California	0.0	2.9	1.1	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.6**
Camp	0.0	0.0	0.0	0.0	0.6	0.6	0.0	4.1	5.5	0.0	2.3	4.4	0.0	0.0	2.2	**19.6**
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	**3.9**
Deep	0.0	5.2	3.3	0.0	0.0	0.0	1.2	0.6	0.0	0.0	0.0	0.6	0.0	0.6	17.1	**28.5**
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	**1.1**
Divide	0.0	4.1	0.0	0.0	2.9	0.0	1.2	22.6	12.1	0.0	0.0	0.0	0.0	1.7	30.3	**74.8**
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	**2.8**
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.0**
Lost	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	**3.7**
Oregon	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	**2.2**
Rochester	0.0	0.0	0.0	0.0	2.3	0.0	0.0	9.9	0.0	0.0	3.5	0.0	0.0	0.0	0.0	**15.7**
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	**0.6**
Sevenmile	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**
Sixmile	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.6**
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.7	0.0	0.0	10.4	1.1	0.0	0.0	0.0	**13.7**
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	2.9	0.0	0.0	0.6	1.7	**9.2**
Lower Birch	0.0	0.0	0.0	0.0	0.6	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	**3.7**
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.1	27.3	**28.8**
Charcoal Gulch	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	**1.2**
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	**7.8**
Jerry	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.0	7.1	0.0	0.0	0.8	0.0	0.0	15.8	**24.5**
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	**1.2**
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	4.4	0.0	0.0	0.0	**5.1**
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.3	6.7	0.4	0.0	11.1	0.0	0.0	9.5	**31.4**
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	5.5	**6.7**
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	**2.8**
Willow	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.6	0.8	0.0	0.0	0.0	0.0	0.0	11.9	**17.9**
Wise	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.0	0.0	12.3	**15.4**
Wickiup	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	1.6	0.0	0.0	0.4	0.0	0.0	0.8	**3.6**
Middle and Lower BigHole Combined	0.4	10.6	3.6	1.2	15.6	2.4	45.6	83.0	42.0	0.8	31.2	22.2	0.6	11.7	217.4	**488.0**
Middle Big Hole	0.4	6.7	3.6	0.4	0.0	1.6	6.6	4.5	11.9	0.8	0.0	4.8	0.6	7.8	104.9	**154.4**
Lower Big Hole	0.0	3.9	0.0	0.8	15.6	0.8	39.0	78.5	30.1	0.0	31.2	17.4	0.0	3.9	112.5	**333.6**

Table 4-3. Sediment Loading from Near-stream Segments with the Application of BMPs.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)
	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	Valley	Foothill	Mtn	
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	**4.4**
California	0.0	1.1	0.4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**1.7**
Camp	0.0	0.0	0.0	0.0	0.2	0.1	0.0	1.1	1.3	0.0	0.7	1.1	0.0	0.0	0.5	**5.0**
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	**0.4**
Deep	0.0	1.0	0.5	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.1	2.7	**4.7**
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Divide	0.0	0.8	0.0	0.0	0.6	0.0	0.3	4.4	2.0	0.0	0.0	0.0	0.0	0.3	5.0	**13.4**
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	**0.2**
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.3**
Lost	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	**4.6**
Oregon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Rochester	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.7	0.0	0.0	0.6	0.0	0.0	0.0	0.0	**2.6**
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	**0.5**
Sevenmile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Sixmile	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0	3.1	0.3	0.0	0.0	0.0	**4.0**
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	2.0	0.0	0.0	0.4	0.9	**6.0**
Lower Birch	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**1.5**
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.6	**6.0**
Charcoal Gulch	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	**0.3**
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.7**
Jerry	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	1.3	0.0	0.0	0.1	0.0	0.0	2.9	**4.5**
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**0.1**
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.2	0.0	0.0	0.0	**1.4**
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.9	0.1	0.0	1.5	0.0	0.0	1.3	**4.5**
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.0	**2.4**
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	**0.7**
Willow	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	3.6	**6.2**
Wise	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.5	0.0	0.0	0.0	0.0	0.0	3.8	**5.0**
Wickiup	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.2	**1.0**
Middle and Lower Big Hole Combined	0.1	2.4	0.7	0.4	3.5	0.5	13.9	18.9	8.1	0.2	7.1	4.3	0.2	2.7	42.1	**105.0**
Middle Big Hole	0.1	1.5	0.7	0.1	0.0	0.3	2.0	1.0	2.3	0.2	0.0	0.9	0.2	1.8	20.4	**31.7**
Lower Big Hole	0.0	0.9	0.0	0.2	3.5	0.2	11.9	17.8	5.8	0.0	7.1	3.4	0.0	0.9	21.7	**73.5**

Table 4-4. Total Sediment Loading from Unpaved Roads with the Application of BMPs.

Ownership	MT FWP			MT Trusts			Private			BLM			USFS			Total
Watershed	Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load (tons/year)			Load
	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	Valley	Foothill	Mountain	(tons/year)
Upper Birch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	14.3
California	0.0	4.0	1.5	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2
Camp	0.0	0.0	0.0	0.0	0.7	0.7	0.0	5.2	6.8	0.0	3.0	5.5	0.0	0.0	2.7	24.6
Corral	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	4.3
Deep	0.0	6.2	3.8	0.0	0.0	0.0	1.5	0.7	0.0	0.0	0.0	0.6	0.0	0.7	19.7	33.2
Delano	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1
Divide	0.0	4.8	0.0	0.0	3.5	0.0	1.5	27.0	14.1	0.0	0.0	0.0	0.0	2.1	35.3	88.2
Fishtrap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.9
Gold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grose	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Lost	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	8.3
Oregon	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Pattengail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2
Rochester	0.0	0.0	0.0	0.0	2.7	0.0	0.0	11.5	0.0	0.0	4.1	0.0	0.0	0.0	0.0	18.3
Sawlog	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1
Sevenmile	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Sixmile	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Soap Gulch	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.3	0.0	0.0	13.5	1.4	0.0	0.0	0.0	17.7
Trapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	4.9	0.0	0.0	1.0	2.6	15.2
Lower Birch	0.0	0.0	0.0	0.0	0.8	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.2
Canyon	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.4	32.9	34.8
Charcoal Gulch	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	1.4
Elkhorn	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	8.5
Jerry	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	8.4	0.0	0.0	0.9	0.0	0.0	18.7	29.1
LaMarche	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3
McClain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	5.5	0.0	0.0	0.0	6.5
Moose	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.9	7.7	0.5	0.0	12.6	0.0	0.0	10.8	35.9
Seven Springs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seymour	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	7.5	9.1
Twelvemile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	3.4
Willow	0.0	0.0	0.0	0.0	0.0	0.0	6.9	0.8	1.0	0.0	0.0	0.0	0.0	0.0	15.4	24.1
Wise	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	2.1	0.0	0.0	0.0	0.0	0.0	16.1	20.5
Wickiup	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	0.5	0.0	0.0	1.0	4.6
Middle and Lower BigHole Combined	0.5	13.0	4.3	1.5	19.1	2.8	59.6	101.8	50.1	1.0	38.3	26.5	0.7	14.4	259.5	593.0
Middle Big Hole	0.5	8.2	4.3	0.5	0.0	1.9	8.7	5.5	14.2	1.0	0.0	5.7	0.7	9.6	125.4	186.1
Lower Big Hole	0.0	4.8	0.0	1.0	19.1	0.9	50.9	96.4	35.9	0.0	38.3	20.8	0.0	4.8	134.2	407.1

Table 4-5. Percent Reduction in Sediment Loading through the Application of BMPs.

Watershed	Total Sediment Load from Unpaved Roads (tons/year)	Total Sediment Load from Unpaved Roads with the Application of BMPs (tons/year)	Potential Reduction in Sediment Load through the Application of BMPs (tons/year)	Percent Reduction in Sediment Load through the Application of BMPs
Upper Birch	23.6	14.3	9.4	40%
California	10.4	6.2	4.2	40%
Camp	39.4	24.6	14.8	38%
Corral	6.3	4.3	2.0	32%
Deep	50.7	33.2	17.5	35%
Delano	1.5	1.1	0.4	28%
Divide	138.8	88.2	50.5	36%
Fishtrap	4.2	2.9	1.3	31%
French	17.7	11.0	6.7	38%
Gold	0.0	0.0	0.0	0%
Grose	2.0	1.3	0.7	34%
Lost	15.4	8.3	7.0	46%
Oregon	1.0	0.6	0.4	39%
Pattengail	3.1	2.2	0.9	29%
Rochester	30.5	18.3	12.2	40%
Sawlog	1.9	1.1	0.8	42%
Sevenmile	1.0	0.6	0.4	39%
Sixmile	1.1	0.7	0.4	40%
Soap Gulch	29.4	17.7	11.7	40%
Trapper	26.1	15.2	10.9	42%
Lower Birch	8.8	5.2	3.6	41%
Canyon	53.4	34.8	18.6	35%
Charcoal Gulch	2.2	1.4	0.8	35%
Elkhorn	9.6	8.5	1.0	11%
Jerry	43.9	29.1	14.8	34%
LaMarche	1.8	1.3	0.6	30%
McClain	10.3	6.5	3.7	36%
Moose	54.0	35.9	18.0	33%
Seven Springs	0.0	0.0	0.0	0%
Seymour	14.8	9.1	5.7	39%
Twelvemile	5.4	3.4	1.9	36%
Willow	36.7	24.1	12.5	34%
Wise	32.0	20.5	11.5	36%
Wickiup	7.2	4.6	2.7	37%
Middle and Lower Big Hole Combined	915.3	593.0	322.3	35%
Middle Big Hole	284.6	186.1	98.5	35%
Lower Big Hole	631.1	407.1	224.0	35%

4.1 French Creek Addendum

The French Creek watershed was not assessed individually during the forest road assessment since it was not listed as impaired due to sediment, but was assessed later after a review of existing data, and comparison to targets indicated French Creek may not be fully supporting all beneficial uses due to excess sediment. However, during the initial assessment, sediment loads from unpaved roads for three sub-watersheds were assessed: California Creek, Sixmile Creek, and Oregon Creek. The sediment load for the Deep Creek watershed, to which French Creek is a significant tributary, was also assessed. During TMDL compilation, an additional assessment of sediment loads from the unpaved road network within the French Creek watershed outside of the California, Sixmile and Oregon Creek watersheds was performed. During this assessment, total of 8 additional unpaved road crossings were identified using GIS. All crossings were located on the mountain landscape on lands managed by the Beaverhead-Deerlodge National Forest. Following error reduction procedures outlined in **Section 2.3.1**, this number was reduced by 28 percent, for an estimate of 6 additional road crossings. This results in a total of 16 road crossings in the French Creek watershed. In addition to road crossings, an additional 1,735 feet of road within 100 feet of a stream channel was identified in GIS, which brings the total to 3,309 feet in the French Creek watershed. Based on this assessment, it was estimated that unpaved roads in the French Creek watershed contribute an annual sediment load of 17.7 tons. With the application of BMPs, it is estimated that this load could be reduce by 38 percent to 11.0 tons/year.

5.0 REFERENCES

Montana DEQ 2005. Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (QAPP). Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Montana DEQ 2006. Middle and Lower Big Hole TPA Unpaved Road Sediment Monitoring Plan. Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

ATTACHMENT A
FIELD DATA AND FROSAM MODELED SEDIMENT LOADS

MIDDLE AND LOWER BIG HOLE RIVER TMDL PLANNING AREAS

	TREAD											CUTSLOPE									FILLSLOPE									TOTAL	
Location Number	Tread Length (ft)	Tread Width (ft)	Acres of Tread	Base Erosion Rate (tons/ac/yr)	Gravel Factor	Traffic Factor	Percent Cover	Cover Factor	Percent Delivery	Delivery Factor	Tread Delivery (tons/yr)	Cutslope Length (ft)	Avg. Cutslope Width (ft)	Acres of Cutslope	Base Erosion Rate (tons/ac/yr)	Percent Cover	Cover Factor	Percent Delivery	Delivery Factor	Cutslope Delivery (tons/yr)	Fillslope Length (ft)	Avg. Fillslope Width (ft)	Acres of Fillslope	Base Erosion Rate (tons/ac/yr)	Percent Cover	Cover Factor	Percent Delivery	Delivery Factor	Fillslope Delivery (tons/yr)	***Location Total Sediment (tons/yr)***	Landscape
ATV	25	8	0.005	30	1	1	70	0.23	75	0.75	0.02376			0.000	30				0	0.00000			0.000	30				0	0.00000	0.024	Mountain
N-100	320	20	0.147	30	1	1	0	1	5	0.05	0.22039	280	8	0.051	30	50	0.37	5	0.05	0.02854	320	15	0.110	30	90	0.15	5	0.05	0.02479	0.274	Mountain
N-1001	320	17	0.125	30	1	1	0	1	5	0.05	0.18733			0.000	30				0	0.00000			0.000	30				0	0.00000	0.187	Mountain
N-1034	350	12	0.096	30	1	1	60	0.3	5	0.05	0.04339	70	8	0.013	30	70	0.23	5	0.05	0.00444			0.000	30				0	0.00000	0.048	Mountain
N-1056	375	18	0.155	30	1	1	0	1	50	0.5	2.32438	375	15	0.129	30	50	0.37	50	0.5	0.71668	375	12	0.103	30	50	0.37	50	0.5	0.57335	3.614	Mountain
N-1243	195	13	0.058	30	1	1	10	0.77	25	0.25	0.33608	195	2	0.009	30	30	0.53	25	0.25	0.03559			0.000	30				0	0.00000	0.372	Mountain
N-1254	220	13	0.066	30	0.5	1	20	0.63	50	0.5	0.31023	70	10	0.016	30	80	0.18	5	0.05	0.00434	220	5	0.025	30	90	0.15	75	0.75	0.08523	0.400	Mountain
N-134	580	12	0.160	30	1	1	20	0.63	25	0.25	0.75496			0.000	30				0	0.00000			0.000	30				0	0.00000	0.755	Foothill
N-1370	245	16	0.090	30	1	1	0	1	25	0.25	0.67493			0.000	30				0	0.00000	15	3	0.001	30	70	0.23	75	0.75	0.00535	0.680	Foothill
N-235	120	15	0.041	30	1	1	10	0.77	50	0.5	0.47727	120	12	0.033	30	70	0.23	75	0.75	0.17107	60	6	0.008	30	80	0.18	100	1	0.04463	0.693	Foothill
N-236	260	15	0.090	30	1	1	0	1	5	0.05	0.13430	110	8	0.020	30	60	0.3	5	0.05	0.00909			0.000	30				0	0.00000	0.143	Foothill
N-251	120	24	0.066	30	1	1	0	1	5	0.05	0.09917			0.000	30				0	0.00000			0.000	30				0	0.00000	0.099	Foothill
N-278	165	20	0.076	30	1	1	0	1	50	0.5	1.13636	165	9	0.034	30	20	0.63	50	0.5	0.32216	165	7	0.027	30	30	0.53	50	0.5	0.21080	1.669	Foothill
N-381	250	22	0.126	30	1	1	0	1	5	0.05	0.18939			0.000	30				0	0.00000			0.000	30				0	0.00000	0.189	Foothill
N-526	420	10	0.096	30	1	1	50	0.37	50	0.5	0.53512			0.000	30				0	0.00000			0.000	30				0	0.00000	0.535	Mountain
N-654	70	15	0.024	30	0.5	2	0	1	75	0.75	0.54236	65	15	0.022	30	60	0.3	25	0.25	0.05036	20	5	0.002	30	80	0.18	75	0.75	0.00930	0.602	Mountain
N-655	180	12	0.050	30	1	1	30	0.53	50	0.5	0.39421	180	12	0.050	30	70	0.23	50	0.5	0.17107			0.000	30				0	0.00000	0.565	Mountain
N-659	375	13	0.112	30	1	1	20	0.63	5	0.05	0.10576	375	15	0.129	30	90	0.15	25	0.25	0.14527	100	15	0.034	30	80	0.18	5	0.05	0.00930	0.260	Mountain
N-703	245	17	0.096	30	1	1	50	0.37	75	0.75	0.79600			0.000	30				0	0.00000			0.000	30				0	0.00000	0.796	Mountain
N-738	190	20	0.087	30	1	1	0	1	5	0.05	0.13085			0.000	30				0	0.00000	190	8	0.035	30	70	0.23	100	1	0.24077	0.372	Mountain
N-781	270	15	0.093	30	1	1	10	0.77	5	0.05	0.10739			0.000	30				0	0.00000	270	10	0.062	30	90	0.15	5	0.05	0.01395	0.121	Mountain
N-826	290	16	0.107	30	1	1	20	0.63	25	0.25	0.50331	220	5	0.025	30	90	0.15	25	0.25	0.02841			0.000	30				0	0.00000	0.532	Mountain
N-866	180	20	0.083	30	1	1	20	0.63	5	0.05	0.07810	180	15	0.062	30	80	0.18	5	0.05	0.01674	180	8	0.033	30	90	0.15	5	0.05	0.00744	0.102	Mountain
N-928	490	22	0.247	30	1	1	0	1	5	0.05	0.37121	490	7	0.079	30	70	0.23	5	0.05	0.02717	490	15	0.169	30	90	0.15	5	0.05	0.03796	0.436	Mountain
N-954	160	16	0.059	30	1	1	10	0.77	25	0.25	0.33939	160	5	0.018	30	40	0.45	25	0.25	0.06198	160	10	0.037	30	70	0.23	5	0.05	0.01267	0.414	Mountain
N-963	60	17	0.023	30	0.5	1	0	1	25	0.25	0.08781	85	8	0.016	30	70	0.23	25	0.25	0.02693			0.000	30				0	0.00000	0.115	Mountain
N-992	440	16	0.162	30	1	1	10	0.77	5	0.05	0.18667	85	10	0.020	30	50	0.37	5	0.05	0.01083			0.000	30				0	0.00000	0.197	Mountain
N-Bryant	220	20	0.101	30	1	1	20	0.63	5	0.05	0.09545			0.000	30				0	0.00000	220	10	0.051	30	80	0.18	5	0.05	0.01364	0.109	Mountain
N-Bryant-2	575	24	0.317	30	1	2	20	0.63	5	0.05	0.59876	400	20	0.184	30	60	0.3	5	0.05	0.08264	45	10	0.010	30	90	0.15	5	0.05	0.00232	0.684	Mountain
N-Camp	165	15	0.057	30	1	1	20	0.63	75	0.75	0.80540			0.000	30				0	0.00000	10	6	0.001	30	50	0.37	75	0.75	0.01147	0.817	Foothill
N-Divide	250	13	0.075	30	1	1	20	0.63	5	0.05	0.07051	200	6	0.028	30	80	0.18	5	0.05	0.00744	250	3	0.017	30	90	0.15	5	0.05	0.00387	0.082	Mountain
N-Divide-2	210	20	0.096	30	0.5	1	0	1	75	0.75	1.08471	100	15	0.034	30	60	0.3	75	0.75	0.23244	60	10	0.014	30	90	0.15	5	0.05	0.00310	1.320	Mountain
N-Elkhorn	50	15	0.017	30	0.5	2	0	1	75	0.75	0.38740			0.000	30				0	0.00000	50	10	0.011	30	60	0.3	75	0.75	0.07748	0.465	Mountain
N-Soap	470	18	0.194	30	1	1	10	0.77	5	0.05	0.22432			0.000	30				0	0.00000			0.000	30				0	0.00000	0.224	Foothill
N-Trapper	170	15	0.059	30	1	1	10	0.77	75	0.75	1.01420	170	15	0.059	30	70	0.23	75	0.75	0.30294	170	5	0.020	30	80	0.18	100	1	0.10537	1.423	Mountain
X-100	380	15	0.131	30	1	1	0	1	25	0.25	0.98140			0.000	30				0	0.00000			0.000	30				0	0.00000	0.981	Mountain
X-1001	60	15	0.021	30	1	1	0	1	25	0.25	0.15496			0.000	30				0	0.00000	50	3	0.003	30	40	0.45	75	0.75	0.03487	0.190	Mountain
X-1006	22	15	0.008	30	1	1	70	0.23	5	0.05	0.00261			0.000	30				0	0.00000			0.000	30				0	0.00000	0.003	Mountain
X-1034	225	15	0.077	30	1	1	10	0.77	50	0.5	0.89489			0.000	30				0	0.00000	60	4	0.006	30	70	0.23	50	0.5	0.01901	0.914	Mountain
X-104	135	21	0.065	30	1	1	10	0.77	25	0.25	0.37585			0.000	30				0	0.00000			0.000	30				0	0.00000	0.376	Valley
X-1056	450	15	0.155	30	1	1	10	0.77	25	0.25	0.89489			0.000	30				0	0.00000			0.000	30				0	0.00000	0.895	Mountain
X-117	50	26	0.030	30	1	1	20	0.63	5	0.05	0.02820			0.000	30				0	0.00000	20	10	0.005	30	60	0.3	25	0.25	0.01033	0.039	Foothill
X-124	520	15	0.179	30	1	1	10	0.77	25	0.25	1.03409	430	18	0.178	30	50	0.37	25	0.25	0.49308	45	3	0.003	30	80	0.18	50	0.5	0.00837	1.536	Mountain
X-1243	165	14	0.053	30	1	1	0	1	75	0.75	1.19318	190	5	0.022	30	20	0.63	75	0.75	0.30914	15	2	0.001	30	40	0.45	100	1	0.00930	1.512	Mountain
X-1254	110	14	0.035	30	0.5	1	0	1	25	0.25	0.13258			0.000	30				0	0.00000	40	10	0.009	30	90	0.15	50	0.5	0.02066	0.153	Mountain
X-126	150	24	0.083	30	0.5	2	0	1	25	0.25	0.61983			0.000	30				0	0.00000	85	10	0.020	30	70	0.23	50	0.5	0.06732	0.687	Valley
X-130	20	12	0.006	30	1	1	0	1	50	0.5	0.08264			0.000	30				0	0.00000	20	5	0.002	30	50	0.37	100	1	0.02548	0.108	Valley
X-134	190	12	0.052	30	1	1	20	0.63	75	0.75	0.74194			0.000	30				0	0.00000			0.000	30				0	0.00000	0.742	Foothill
X-1370	100	15	0.034	30	1	1	20	0.63	25	0.25	0.16271	40	7	0.006	30	60	0.3	25	0.25	0.01446	100	3	0.007	30	80	0.18	50	0.5	0.01860	0.196	Foothill
X-235	400	15	0.138	30	1	1	20	0.63	5	0.05	0.13017			0.000	30				0	0.00000	40	2	0.002	30	80	0.18	75	0.75	0.00744	0.138	Foothill
X-236	680	14	0.219	30	1	1	0	1	25	0.25	1.63912			0.000	30				0	0.00000	30	4	0.003	30	90	0.15	75	0.75	0.00930	1.648	Foothill
X-251	180	22	0.091	30	1	1	0	1	25	0.25	0.68182			0.000	30				0	0.00000	20	3	0.001	30	80	0.18	75	0.75	0.00558	0.687	Foothill
X-278	24	22	0.012	30	1	2	0	1	75	0.75	0.54545			0.000	30				0	0.00000	24	4	0.002	30	30	0.53	100	1	0.03504	0.580	Foothill
X-283	290	14	0.093	30	1	1	30	0.53	25	0.25	0.37049			0.000	30				0	0.00000			0.000	30				0	0.00000	0.370	Foothill
X-30	150	18	0.062	30	1	1	0	1	25	0.25	0.46488			0.000	30				0	0.00000			0.000	30				0	0.00000	0.465	Valley
X-335	100	20	0.046	30	0.5	2	0	1	50	0.5	0.68871			0.000	30				0	0.00000	100	20	0.046	30	80	0.18	50	0.5	0.12397	0.813	Valley
X-34	25	22	0.013	30	1	1	10	0.77	5	0.05	0.01458			0.000	30				0	0.00000	10	3	0.001	30	60	0.3	100	1	0.00620	0.021	Valley
X-374	540	28	0.347	30	0.5	1	10	0.77	5	0.05	0.20045	260	16	0.096	30	70	0.23	5	0.05	0.03295	500	20	0.230	30	90	0.15	5	0.05	0.05165	0.285	Mountain
X-381	230	24	0.127	30	1	1	0	1	25	0.25	0.95041			0.000	30				0	0.00000	20	4	0.002	30	50	0.37	75	0.75	0.01529	0.966	Foothill
X-443	20	17	0.008	30	1	1	0	1	50	0.5	0.11708			0.000	30				0	0.00000	20	2	0.001	30	70		50	0.5	0.00000	0.117	Mountain
X-526	850	10	0.195	30	1	1	50	0.37	75	0.75	1.62448	260	14	0.084	30	20	0.63	75	0.75	1.18450	10	4	0.001	30	90		5	0.05	0.00000	2.809	Mountain
X-654	240	18	0.099	30	0.5	2	0	1	5	0.05	0.14876			0.000	30				0	0.00000	280	12	0.077	30	60	0.3	25	0.25	0.17355	0.322	Mountain
X-655	470	12	0.129	30	1	1	30	0.53	50	0.5	1.02934	50	12	0.014	30	40	0.45	50	0.5	0.09298	40	5	0.005	30	90	0.15	75	0.75	0.01550	1.138	Mountain
X-659	80	16	0.029	30	0.5	1	10	0.77	25	0.25	0.08485			0.000	30				0	0.00000	80	6	0.011	30	80	0.18	25	0.25	0.01488	0.100	Mountain
X-703	65	18	0.027	30	1	1	50	0.37	25	0.25	0.07454			0.000	30				0	0.00000	40	10	0.009	30	70	0.23	50	0.5	0.03168	0.106	Mountain
X-731	1000	18	0.413	30	1	1	10	0.77	25	0.25	2.38636			0.000	30				0	0.00000	25	5	0.003	30	80	0.18	75	0.75	0.01162	2.398	Mountain
X-738	65	20	0.030	30	1	2	0	1	50	0.5	0.89532			0.000	30				0	0.00000	40	4	0.004	30	80	0.18	75	0.75	0.01488	0.910	Mountain
X-781	475	12	0.131	30	1	1	50	0.37	100	1	1.45248	98	5	0.011	30	90	0.15	25	0.25	0.01265	20	10	0.005	30	90	0.15	25	0.25	0.00517	1.470	Mountain
X-836	140	21	0.067	30	1	1	10	0.77	75	0.75	1.16932			0.000	30				0	0.00000	55	13	0.016	30	15	0.7	75	0.75	0.25852	1.428	Mountain
X-837	260	18	0.107	30	1	1	20	0.63	25	0.25	0.50764	90	10	0.021	30	20	0.63	50	0.5	0.19525	65	12	0.018	30	80	0.18	50	0.5	0.04835	0.751	Mountain
X-839	75	18	0.031	30	1	1	20	0.63	5	0.05	0.02929	30	5	0.003	30	50	0.37	25	0.25	0.00956	75	10	0.017	30	50	0.37	25	0.25	0.04778	0.087	Mountain
X-840	270	18	0.112	30	1	1	0	1	25	0.25	0.83678	270	10	0.062	30	50	0.37	5	0.05	0.03440	60	5	0.007	30	50	0.37	50	0.5	0.03822	0.909	Mountain
X-845	95	15	0.033	30	1	1	10	0.77	25	0.25	0.18892			0.000	30				0	0.00000	180	12	0.050	30	80	0.18	5	0.05	0.01339	0.202	Mountain
X-866	405	15	0.139	30	1	1	10	0.77	5	0.05	0.16108	220	20	0.101	30	40	0.45	25	0.25	0.34091	120	12	0.033	30	90	0.15	5	0.05	0.00744	0.509	Mountain
X-91	25	20	0.011	30	1	1	0	1	75	0.75	0.25826			0.000	30				0	0.00000	20	1	0.000	30	50	0.37	75	0.75	0.00382	0.262	Valley
X-928	320	15	0.110	30	1	1	0	1	25	0.25	0.82645	230	8	0.042	30	80	0.18	25	0.25	0.05702	10	5	0.001	30	90	0.15	75	0.75	0.00387	0.887	Mountain
X-946	120	20	0.055	30	1	1	10	0.77	25	0.25	0.31818			0.000	30				0	0.00000	120	15	0.041	30	60		50	0.5	0.00000	0.318	Mountain
X-952	85	17	0.033	30	1	1	10	0.77	50	0.5	0.38314			0.000	30				0	0.00000	40	15	0.014	30	90	0.15	5	0.05	0.00310	0.386	Mountain
X-954	220	16	0.081	30	1	1	10	0.77	25	0.25	0.46667	50	15	0.017	30	20	0.63	100	1	0.32541	135	18	0.056	30	90	0.15	25	0.25	0.06276	0.855	Mountain
X-962	420	15	0.145	30	0.5	1	0	1	5	0.05	0.10847	360	20	0.165	30	50	0.37	25	0.25	0.45868	100	30	0.069	30	90	0.15	5	0.05	0.01550	0.583	Mountain
X-963	160	17	0.062	30	0.5	1	0	1	25	0.25	0.23416	120	20	0.055	30	60	0.3	5	0.05	0.02479	60	6	0.008	30	90	0.15	50	0.5	0.01860	0.278	Mountain
X-992	340	15	0.117	30	1	1	40	0.45	25	0.25	0.39514	150	20	0.069	30	50	0.37	25	0.25	0.19112	50	5	0.006	30	80	0.18	50	0.5	0.01550	0.602	Mountain
X-Camp	390	15	0.134	30	1	1	20	0.63	100	1	2.53822			0.000	30				0	0.00000			0.000	30				0	0.00000	2.538	Foothill
X-Canyon	190	15	0.065	30	1	1	10	0.77	100	1	1.51136	110	8	0.020	30	30	0.53	100	1	0.32121			0.000	30				0	0.00000	1.833	Mountain
X-Divide	300	13	0.090	30	1	1	20	0.63	25	0.25	0.42304	170	10	0.039	30	50	0.37	5	0.05	0.02166	60	5	0.007	30	90	0.15	5	0.05	0.00155	0.446	Mountain
X-Melrose	1500	5	0.172	30	1	2	10	0.77	25	0.25	1.98864			0.000	30				0	0.00000			0.000	30				0	0.00000	1.989	Foothill
X-Soap	300	15	0.103	30	1	1	0	1	50	0.5	1.54959	110	8	0.020	30	40	0.45	50	0.5	0.13636	70	10	0.016	30	70	0.23	75	0.75	0.08316	1.769	Foothill
X-Trap-2	195	22	0.098	30	1	1	0	1	25	0.25	0.73864			0.000	30				0	0.00000	22	5	0.003	30	60	0.3	100	1	0.02273	0.761	Foothill

Location Number	Comments
ATV	ATV stream crossing in wet meadow
N-100	periodic culverts drain road, ~40' to channel
N-1001	road mostly away from stream
N-1034	between drain dips, ~90' to channel
N-1056	measured between 2 waterbars, sediment deposition evident in gulch, road parrallels channel in drainage, is within 15 feet in many places, dry gulch
N-1243	designed drain dip transport sediment 50'+ from road, ~70' to channel
N-1254	~5' to channel in places, direct delivery where berm fails
N-134	road puddles in depressional area before crossing, flows out toward channel, ~25' to channel
N-1370	fillslope leading to stream, ~10' to channel, inputs where road slopes toward channel
N-235	contribution from multiple rills on fillslope, ~5' to channel, which is more of a "wetland"
N-236	puddle spills over onto vegetative buffer, road drains both ways, ~80' to channel
N-251	flat, bladed road with berms and a sandy surface, ~60 to channel
N-278	obvious input point at rill, ~70' to channel
N-381	wetland buffer in flat valley bottom, ~70' to channel
N-526	long contributing road segment with defined rills, bermed road, ~30' to channel
N-654	short contributing section within ~5' of channel, small contributing fillslope
N-655	rolling dip discharges toward channel, ~40 to channel down steep bank
N-659	culvert drains ditch that intercepts springs, though much of road outsloped from ditch
N-703	input upstream of crossing, ~15' to channel
N-738	channel encroachment for ~190', with high delivery from fillslope, though road sloped toward hillslope
N-781	vegetative buffer on fillslope, cutslope erosion retained in ditch, ~80' to channel
N-826	road drains both directions, ~12' to channel, beaver dams in stream raise water elevation
N-866	shale field cutslope, vegetation on fillslope, ~60' to channel
N-928	~110' to channel with 100' sediment plume below culvert, plume captured by flat vegetated valley bottom
N-954	cutslope leads to culvert that has a minor BMP at outlet, ~50' to channel
N-963	sediment basin, springs, ~20' to channel
N-992	road drains both directions, ~30' to channel
N-Bryant	road primarily outsloped, vegetated buffer, cutslope interceptd by ditch, ~40' to channel
N-Bryant-2	vegetative buffer on fillslope, ~100' to channel
N-Camp	road outsloped toward stream, direct fillslope contribution
N-Divide	much of sediment appears to settle on road prior to crossing, ~50' to channel
N-Divide-2	road insloped toward ditch, relief culvert with sediment plume, ~20' to channel
N-Elkhorn	short contributing section within ~5' of channel, much of road outsloped or flat
N-Soap	rill down road outlets at break in berm, vegetative buffer intercepts plume, ~60' to channel
N-Trapper	road encroachment, ditch drains into culverts then to channel, fillslope mostly rocky
X-100	limited input due to flat road and vegetative buffer
X-1001	bridge raised, fill slopes deliver sediment, stream ford downstream of bridge is also a source
X-1006	input limited since road runoff delivered downslope of crossing
X-1034	road downslopes toward crossing, livestock trail provides input point
X-104	gravel carried onto bridge by traffic then transported to channel, fillslope barrier
X-1056	rills on road lead to crossing, small ditches on both sides, most delivery at upstream side, some vegetative buffer, dry gulch
X-117	bridge structure appears to prevent most sediment delivery
X-124	large cutslope leads around bend to crossing, some vegetative buffer
X-1243	measured from drainage dip, large rills and direct delivery at crossing, cutslopes on both sides of road
X-1254	berms reduce input, rocky/vegetated fillslopes
X-126	parking area drainging into culvert may provide additional contribution
X-130	sediment input from fillslope and road only at crossing
X-134	substantial road drainage, flow appears to go into ditch approximately 25 feet from crossing which has some vegetative filter
X-1370	limited input, dry gulch
X-235	some road erosion appears to be captured in a puddle that acts as a sediment trap
X-236	road contributing from both directions, rills in road and puddle at crossing berms at crossing may limit delivery
X-251	road draining from both sides, though is somewhat outsloped
X-278	bladed road with berms on both sides, blading contributes sediment at crossing
X-283	majority of road sediment discharged ~20 upslope of crossing, dry gulch
X-30	ditch transports some road sediment, fillslopes have barriers
X-335	gravel carried onto bridge by traffic then transported to channel
X-34	minimal delivery due to flat road and berm
X-374	large vegetated fillslope, stream through long culver
X-381	bladed road
X-443	minimal input from road due to outslope
X-526	long contributing road segment with defined rills and cutslope capture
X-654	measured from culvet, plume along vegetated ditch toward channel, delivery from fill
X-655	partial drain dip removes some of sediment, puddle near crossing appears to flow to channel
X-659	perched culvert, limited fillslope delivery
X-703	portion of eroding road surface captured by sediment basin
X-731	long contributing road length, somewhat naturally graveled, low delivery due to flattening of slope at crossing
X-738	fillslope contribution, as well as portion of road up Farlin gulch
X-781	obvious sediment plume on bridge with depths of 0.1-0.2 feet directly contributing from steep rutted road, sand bars observed in stream below crossing
X-836	road sloping to downstream side of bridge with obvious delivery paths, cutslope appeared to wash off of outsloped road
X-837	road contribution appeared limited, though ditch at the base of the cut/fill slope appeared to be a pathway
X-839	basically flat road grade, minimal input from rocky cut and fillslopes
X-840	sediment delivery pathway at base of cutslope, ditched side of road appeared to have low delivery
X-845	measured from waterbar, fillslopes well vegetated, delivery appeared low
X-866	fillslope vegetated, large cutslope partially buffered by vegetation
X-91	gravel carried onto bridge by traffic then transported to channel, fillslope barrier
X-928	measured from waterbar, ditch with high transport capacity, wooden barrier on fillslope, some BMPs
X-946	fillslope contribution
X-952	measured from drainage dip, fillslope and ditches well vegetated
X-954	minimal input from road, cutslope has direct delivery
X-962	large, rocky fillslope, some cutslope delivery
X-963	road outsloped toward culvert outlet
X-992	contributing road measured from observed discharge point down to crossing, dry gulch
X-Camp	road draining from both sides to stream ford, large gullies leading to channel
X-Canyon	2nd ford progressing downstream, with significant contributing road length
X-Divide	road outsloped, cutslope erosion mostly intercepted by vegetation
X-Melrose	long, contributing road segments from both sides, plus ditch, plume of sediment observed in the dry gulch
X-Soap	input above and below actual crossing
X-Trap-2	sediment plume within 5' of channel, direct fillslope contribution

ATTACHMENT B
GPS POINTS

MIDDLE AND LOWER BIG HOLE RIVER TMDL PLANNING AREAS

Site	Latitude	Longitude	Landscape	Remarks
X-117	45.42145	-112.69723	Foothill	
X-1370	45.68413	-112.65562	Foothill	
X-235	45.59029	-112.48137	Foothill	
X-278	45.55370	-112.37826	Foothill	
X-236	45.61366	-112.50634	Foothill	
X-283	45.54299	-112.41351	Foothill	
X-374	45.87400	-112.72560	Mountain	
X-134	45.95381	-113.06976	Foothill	
X-251	45.56096	-112.40148	Foothill	
X-Melrose	45.55454	-112.45637	Foothill	
X-Camp	45.64726	-112.63583	Foothill	
X-Soap	45.68806	-112.64799	Foothill	
X-Trap 2	45.62509	-112.72068	Foothill	
X-381	45.87302	-112.66528	Foothill	
X-1254	45.74316	-112.67142	Mountain	
X-1243	45.73854	-112.66254	Mountain	
X-781	45.82267	-113.14854	Mountain	
X-866	45.85083	-113.12771	Mountain	
X-526	45.77198	-112.78305	Mountain	
X-952	45.93089	-113.02503	Mountain	
X-954	45.92159	-113.02554	Mountain	
X-130	45.82078	-113.03591	Valley	
X-1006	45.74891	-113.02953	Mountain	
X-124	45.76954	-112.95626	Mountain	
X-992	45.68441	-112.80371	Mountain	
X-100	45.44974	-112.84022	Mountain	
X-703	45.51677	-113.09646	Mountain	
X-654	45.51869	-113.05617	Mountain	
X-738	45.39862	-112.82307	Mountain	
X-928	45.41299	-112.85146	Mountain	
X-1056	45.72925	-112.86663	Mountain	
X-1034	45.85191	-113.00432	Mountain	
X-443	45.82559	-112.88502	Mountain	
X-655	45.92307	-112.87583	Mountain	
X-659	45.90985	-112.86977	Mountain	
X-962	45.89509	-112.84217	Mountain	
X-946	45.83789	-112.87249	Mountain	
X-845	45.86746	-113.36263	Mountain	
X-836	45.91744	-113.26879	Mountain	
X-839	45.90479	-113.31467	Mountain	
X-840	45.90144	-113.33764	Mountain	
X-1001	45.92251	-113.22017	Mountain	
X-731	45.99235	-113.09446	Mountain	
X-837	45.90782	-113.30040	Mountain	
X-Canyon	45.68137	-112.77515	Mountain	
X-Divide	45.90545	-112.82440	Mountain	
X-963	45.92077	-112.85329	Mountain	
X-30	45.52925	-112.71150	Valley	
X-91	45.62226	-112.69035	Valley	
X-335	45.46853	-112.66366	Valley	
X-126	45.70448	-112.74823	Valley	

Site	Latitude	Longitude	Landscape	Remarks
X-34	45.54587	-112.70685	Valley	
X-104	45.45495	-112.70034	Valley	
N-1056	45.72415	-112.87672	Mountain	
N-1001	45.90418	-113.21088	Mountain	
N-134	45.95369	-113.07000	Foothill	
N-954	45.92172	-113.02550	Mountain	
N-781	45.84046	-113.13684	Mountain	
N-866	45.85290	-113.11608	Mountain	
N-Bryant	45.85474	-113.10627	Mountain	
N-Bryant 2	0.00000	0.00000	Mountain	No Satallites
N-1034	45.85324	-113.00493	Mountain	
N-Elkhorn	45.51351	-113.05122	Mountain	
N-654	45.51549	-113.05262	Mountain	
N-703	45.51670	-113.09660	Mountain	
N-526	45.77370	-112.78485	Mountain	
N-992	45.69421	-112.76342	Mountain	
N-826	45.69492	-112.76183	Mountain	
N-278	45.57438	-112.43829	Mountain	
N-236	45.61008	-112.50402	Foothill	
N-235	45.60748	-112.50289	Foothill	
N-251	45.55952	-112.39640	Foothill	
N-928	45.41100	-112.84666	Mountain	
N-100	45.40654	-112.83975	Mountain	
N-738	45.40254	-112.83154	Mountain	
N-Camp	45.64723	-112.63582	Foothill	
N-Soap	45.68700	-112.65074	Foothill	
N-1370	45.68629	-112.65208	Foothill	
N-Trapper	45.64209	-112.79984	Mountain	
N-1243	45.74112	-112.66547	Mountain	
N-1254	45.73391	-112.67698	Mountain	
N-Divide	45.90528	-112.82332	Mountain	
N-659	45.90910	-112.87001	Mountain	
N-655	45.92254	-112.87488	Mountain	
N-963	45.92081	-112.85361	Mountain	
N-Divide 2	45.88611	-112.77308	Mountain	
N-381	45.87411	-112.66346	Foothill	
ATV	45.76947	-112.95639	Mountain	

APPENDIX E
STREAMBANK EROSION ASSESSMENT

MIDDLE AND LOWER BIG HOLE RIVER WATER QUALITY RESTORATION PLANNING AREAS

Prepared for:

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
c/o Darrin Kron
P.O. Box 200901
Helena, MT 59620-0901

Prepared by:

PBS&J
P.O. Box 239
Helena, MT 59624

January 2007

Project No. B15532.09

TABLE OF CONTENTS

1.0 INTRODUCTION..E-7
1.1 Sediment Impairments E-7

2.0 DATA COLLECTION AND EXTRAPOLATION E-9
2.1 Field Data Collection E-9
2.2 Estimating Sediment Loads from Field Data...E-10
2.3 Streambank Composition...E-10
2.4 Data Extrapolation E-11

3.0 SEDIMENT LOADING DUE TO STREAMBANK EROSION......................E-13
3.1 Monitoring Section Sediment Loads E-13
3.2 Stream Reach Sediment Loads E-17
3.3 Stream Segment Sediment Loads E-17
3.4 Watershed Sediment Loads...E-21

4.0 POTENTIAL SEDIMENT LOAD REDUCTION..E-25

5.0 REFERENCES..E-29

ATTACHMENTS

Attachment A *Streambank Erosion Database*

FIGURES

Figure 2-1 *Monitoring Sections*

TABLES

Table 2-1 *Annual Streambank Retreat Rates (Feet/Year) (adapted from Rosgen 1996)*
Table 2-2 *Streambank Bulk Density (adapted from USDI 1998)*
Table 3-1 *Monitoring Section Sediment Loads due to Streambank Erosion*
Table 3-2 *Monitoring Section Sediment Loads from Individual Sources due to Streambank Erosion*
Table 3-3 *Stream Segment Sediment Loads from Individual Sources due to Streambank Erosion*
Table 3-4 *Summary of Sediment Loads due to Streambank Erosion at the Watershed Scale*
Table 3-5 *Watershed Sediment Loads from Individual Sources due to Streambank Erosion*
Table 4-1 *Expected BEHI Values for Various Stream Types based on the BDNF Reference Dataset*
Table 4-2 *Monitoring Section Sediment Loads with BEHI Reduced to "Moderate"*
Table 4-3 *Stream Segment Sediment Loads from Individual Sources with BEHI Reduced to "Moderate"*

1.0 INTRODUCTION

This report presents an assessment of sediment loading due to streambank erosion along stream segments listed as impaired due to sediment in the Middle and Lower Big Hole TMDL Planning Areas (TPA). Sediment loads due to streambank erosion were calculated based on field data collected in 2005 and 2006. Data collected in the field was extrapolated to the listed stream segments based on the Aerial Assessment Database compiled prior to field data collection. This data was also used to estimate sediment loading at the watershed scale and to assess the potential to decrease sediment inputs due to streambank erosion. The following reports provide further background information for this assessment:

Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (MDEQ 2005)

Aerial Assessment of Selected Stream Segments in the Middle and Lower Big Hole TMDL Planning Area (MDEQ 2006)

A*erial Assessment of the Middle and Lower Big Hole TMDL Planning Area: Pintlar Creek to the Beaverhead River* (Applied Geomorphology/DTM Consulting 2005)

Water Quality Status Report and Sampling and Analysis Plan: Middle and Lower Big Hole River Water Quality Restoration Planning Areas (MDEQ 2005)

1.1 Sediment Impairments

Sediment loading due to streambank erosion was assessed in the field on 20 of the 23 sediment listings on the 2006 303(d) List including upper Birch, California, Camp, Corral, Deep, Delano, Divide, Elkhorn, Fishtrap, Gold, Grose, Lost, Oregon, Pattengail, Rochester, Sawlog, Sevenmile, Sixmile, Soap, and Trapper creeks. Additional assessments were performed on 9 stream segments with 2006 303(d) pollution listings that were potentially related to sediment such as low flow or habitat alterations. Those assessments were performed on the middle and lower segments of the Big Hole River, Wise River, lower Birch, Canyon, French, Moose, Jerry, and Willow creeks. Based on the 303(d) listing status when sampling was conducted, no assessments were performed on Charcoal, Twelvemile, or Wickiup Creek.

2.0 DATA COLLECTION AND EXTRAPOLATION

Streambank erosion assessments were performed on 222 streambanks along 49 monitoring sections covering 29 stream segments within the Middle and Lower Big Hole TPA. In general, two monitoring sections were assessed in each stream segment. Eroding streambank assessments were typically performed along a 900-foot monitoring section, though lengths varied from 600 feet on the smallest streams to approximately 3,500 feet on the Big Hole River. A total of 10.1 miles (53,125 feet) of stream were assessed. Monitoring section locations are presented in **Figure 2-1**.

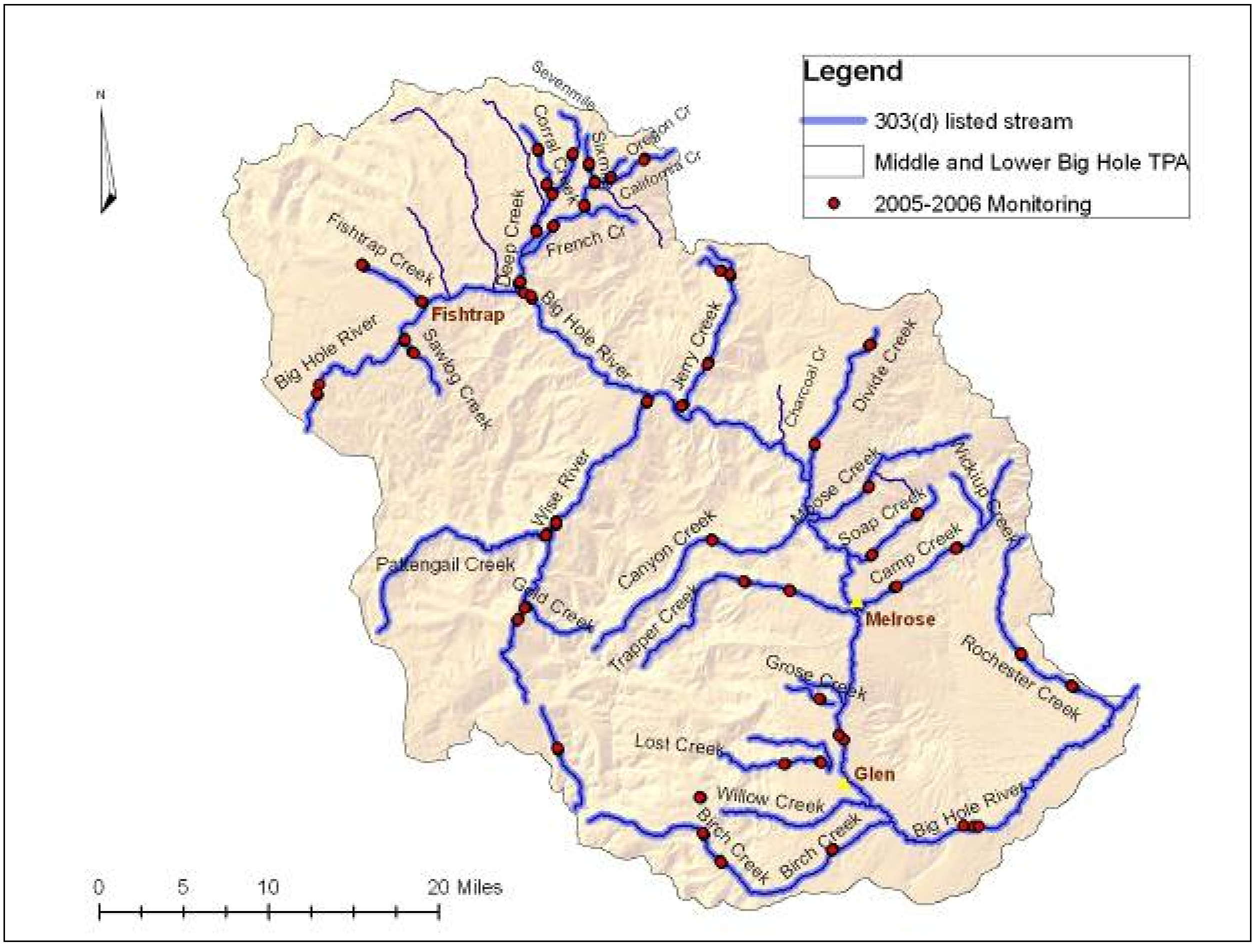


Figure 2-1. Monitoring Sections.

2.1 Field Data Collection

Streambank erosion was assessed by performing Bank Erosion Hazard Index (BEHI) measurements and evaluating the Near Bank Stress (NBS) (Rosgen 1996, 2004). The BEHI score was determined at each eroding streambank based on the following parameters: bank height, bankfull height, root depth, root density, bank angle and surface protection. BEHI categories range from “very low” to “extreme”. At each eroding streambank, the NBS was determined by performing a channel cross-section measurement. The NBS is the ratio of the near-bank maximum bankfull depth (measured as the deepest point in the 1/3 of the channel closest to the bank) to the bankfull mean depth (Rosgen 2004). NBS categories range from "very low" to "extreme". The length, height, and composition of each eroding streambank were noted and the source of streambank instability was identified based on the following near-stream source categories:

- Transportation
- Riparian Grazing
- Cropland
- Mining
- Silviculture
- Irrigation-shifts in stream energy
- Natural Sources
- Other

The source of streambank erosion was evaluated based on observed anthropogenic disturbances and the surrounding land-use practices. For example, an eroding streambank in a heavily grazed area in which all the willows had been removed was assigned a source of "100% riparian grazing", while an eroding streambank due to road encroachment upstream was assigned a source of "100% transportation". Naturally eroding streambanks were considered the result of "natural sources". The "other" category was chosen when streambank erosion resulted from a source not described in the list. If multiple sources were observed, then a percent was noted for each source.

2.2 Estimating Sediment Loads from Field Data

The length of eroding streambank, mean height, and the annual retreat rate were used to determine the annual sediment input from eroding streambanks (in cubic feet). The length and mean height were measured in the field, while the annual retreat rate was determined based on the relationship between BEHI and NBS scores. Streambank retreat rates measured in the Lamar River in Yellowstone National Park (Rosgen 1996) were applied to streambanks in the Middle and Lower Big Hole TPA (**Table 2-1**). The annual sediment input in cubic feet was then converted into cubic yards (divided by 27 cubic feet per yard) and finally converted into tons per year based on the bulk density of the streambank to provide an annual sediment load.

Table 2-1. Annual Streambank Retreat Rates (Feet/Year) (adapted from Rosgen 1996).

		Near Bank Stress				
		Very Low	**Low**	**Moderate**	**High**	**Very High**
BEHI	Low	0.019	0.042	0.089	0.19	
	Moderate	0.082	0.17	0.33	0.62	1.3
	High - Very High	0.29	0.44	0.7	1.1	1.7
	Extreme	0.6	0.83	1.3	1.7	2.3

2.3 Streambank Composition

Bulk density of streambanks in the Middle and Lower Big Hole TPA was determined based on streambank composition data collected in the field and standard soil weights compiled by the U.S Department of the Interior (USDI 1998). Soil weights in the "well-graded" category were selected to most accurately reflect streambank composition, since "well-graded" suggests a wide array of size classes, which is likely what is found in nature. Based on data collected in the 49 monitoring sections, the average streambank composition was 70% "silt/sand" and 30% "gravel/cobbles". This composition most closely resembles the soil group described as "well-graded sand". Based on the minimum value of the USDI dry unit weight for "well-graded sand", a value of 107 pounds/foot³ (1.44 tons/yard³) was estimated as the average bulk density of streambank material (USDI 1998) (**Table 2-2**). The minimum value was selected to account for plant roots within the streambank that would decrease the overall soil density.

Streambanks along the mainstem of the Big Hole River in the Lower Big Hole TPA were determined to have a composition differing from the entire watershed, where many of the assessed sections were on smaller tributary streams. Based on the 13 eroding streambanks assessed along the lower Big Hole River, an average composition of 43% "silt/sand" and 57% "gravel/cobbles" was observed. This composition most closely resembles the soil group described as "well-graded gravel with silt". Based on the minimum value of the USDI dry unit weight for "well-graded gravel with silt", a value of 89 pounds/foot³ (1.20 tons/yard³) was estimated as the average weight of the streambank material (USDI 1998).

Table 2-2. Streambank Bulk Density (adapted from USDI 1998).

Sample Area	Sample Size	Mean Composition		Soil Group	Minimum Dry Unit Weight (Pounds/Foot³)	Minimum Dry Unit Weight (Tons/Yard³)
		Sand / Silt (%)	Gravel / Cobbles (%)			
Entire Watershed	225	70	30	Well-graded sand	107	1.44
Lower Big Hole	13	43	57	Well-graded gravel with silt	89	1.20

2.4 Data Extrapolation

Streambank erosion, measured along 49 monitoring sections, was extrapolated to the stream reach and stream segment scales based on the Aerial Assessment Database. In the field, **monitoring sections** were selected in areas that were representative of the overall stream condition at the stream reach scale. Sediment loads, derived from the monitoring sections, were extrapolated to the stream reach scale. **Stream reaches** were defined in the Aerial Assessment Database prior to field work through the use of GIS data layers and aerial imagery (Applied Geomorphology/DTM Consulting 2005, MDEQ 2005). Sediment loads extrapolated to the stream reach scale were then summed to achieve an estimate of sediment input due to streambank erosion to each 303(d) listed **stream segment**. Sediment loading at the watershed scale and the potential to decrease streambank erosion were also estimated. The extrapolation process was outlined in the *Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan* (MDEQ 2005), which presented the following definitions:

Definitions: *Stream Segment – 303(d) listed segment*
Stream Reach – Aerial or field verified subdivision of the stream segment with like land cover and Rosgen level 1 stream type

Monitoring Section – A 900 foot or 20xbankfull width (whichever is longer) section of a reach where detailed monitoring occurs that represents conditions along a stream reach

3.0 SEDIMENT LOADING DUE TO STREAMBANK EROSION

3.1 Monitoring Section Sediment Loads

Eroding streambank assessments were performed along a total of 10.1 miles of stream in the Middle and Lower Big Hole TPA. A total sediment load of 551.8 tons/year was attributed to eroding streambanks within the monitoring sections. Sediment loads due to streambank erosion from these individual monitoring sections ranged from 0.0 tons/year in monitoring section "Delano 1" to 147.5 tons/year in monitoring section "Lower Big Hole 2". A summary of eroding streambank conditions and sediment loading is presented in **Table 3-1**. Sediment loads calculated for each monitoring section were normalized to a length of 1000 feet for the purpose of comparison and extrapolation. Mean BEHI scores, length of eroding bank, percent of eroding bank, stream type at the laser level cross-section, and the potential stream type are also presented for each monitoring section in **Table 3-1**.

At the monitoring section scale, 2.8% of the bank erosion was attributed to transportation, 51.1% was attributed to riparian grazing, 2.1% was attributed to mining, 0.2% was attributed to silviculture, 3.3% was attributed to irrigation, 33.6% was attributed to natural sources and 6.9 % was attributed to "other", which includes the impact of historic dam failures that affected three of the stream segments (upper Birch Creek, Pattengail Creek and the Wise River) in the Middle and Lower Big Hole TPA. Other sources of bank erosion identified within the monitoring sections include recreation and inadequate stream restoration projects. An overall sediment load from eroding streambanks of 366.6 tons/year (66.4%) was attributed to anthropogenic sources, while 185.2 tons/year (33.6%) was attributed to natural sources. Eighty percent (294.6 tons/year) of the anthropogenically induced sediment load is due to streambank erosion in 16 of the monitoring sections (33%), while the remaining 33 monitoring sections account for only 20% of the anthropogenically induced streambank sediment load. The 16 monitoring sections contributing 80% of the anthropogenically derived sediment load include: Birch 3, California 2, Camp 1, Camp 2, Deep 2, Elkhorn 1, French 1, Grose 1, Lower Big Hole 1, Lower Big Hole 2, Sawlog 1, Sixmile 2, Soap 1, Trapper 1, Willow 1, and Wise 1. Sediment loads, due to streambank erosion for each monitoring section, are provided for each source in **Table 3-2**.

Table 3-1. Monitoring Section Sediment Loads due to Streambank Erosion.

Monitoring Section	Mean BEHI Score	Length of Eroding Bank (Feet)	Reach Length (Feet)	Percent of Reach with Eroding Bank	Sediment Loading from Monitoring Section (Tons/Year)	Sediment Loading per 1000' of Stream (Tons/Year)	Stream Type at Laser Level Cross-section	Potential Stream Type
Birch 1	27.0	146	900	8.1	4.8	5.4	B3a	B3a/B3
Birch 2	28.5	122	900	6.8	8.3	9.2	C3b	B3
Birch 3	32.9	190	900	10.6	8.8	9.8	B3c	C3
California 1	30.9	95	900	5.3	3.3	3.7	E4	E4
California 2	29.4	236	900	13.1	12.0	13.3	E4	E4
Camp 1	32.5	207	900	11.5	18.0	20.0	B4c	C4
Camp 2	31.5	195	900	10.8	10.5	11.7	C4	B4c
Canyon 1	25.0	250	900	13.9	6.3	7.0	C4	C4
Corral 1	39.3	31	900	1.7	1.6	1.8	E4a	A4
Corral 2	29.0	205	900	11.4	5.0	5.6	E4	E4
Deep 1	27.0	346	900	19.2	13.2	14.7	C4	E4
Deep 2	36.2	460	1000	23.0	42.6	42.6	C4	C4
Delano 1	15.6	0	900	0.0	0.0	0.0	A4	A3
Delano 2	22.8	166	900	9.2	1.9	2.1	E4b	E3b
Divide 1	23.0	288	900	16.0	4.8	5.4	B4c	E4
Divide 2	25.6	91	900	5.1	2.0	2.2	F4	C4
Elkhorn 1	42.0	249	900	13.8	14.6	16.3	B4c	B4c
Fishtrap 1	27.3	109	900	6.1	2.8	3.1	B4	B3
Fishtrap 2	20.9	94	900	5.2	1.4	1.5	C4	C3
French 1	35.6	428	900	23.8	28.0	31.1	C4	C4
Gold 1	32.8	164	900	9.1	4.5	5.0	C4	E4
Grose 1	37.7	185	600	15.4	18.2	30.3	B5a	E3a
Jerry 1	20.8	245	900	13.6	6.2	6.9	B4c	B3
Jerry 2	23.9	127	900	7.1	1.8	2.0	C4	B3c
Lost 1	29.0	43	700	3.1	1.0	1.4	E4b	E3b
Lost 2	30.2	52	600	4.3	2.1	3.4	E5b	E3b
Lower Big Hole 1	19.7	1000	3245	15.4	42.1	13.0	C4	C4
Lower Big Hole 2	34.3	1139	3530	16.1	147.5	41.8	C4	C4
Middle Big Hole 1	24.0	233	3400	3.4	3.3	1.0	C4	C4
Middle Big Hole 2	20.0	323	3450	4.7	6.3	1.8	C4	C4
Moose 1	14.9	120	900	6.7	2.5	2.8	B4	B3
Oregon 1	22.6	29	600	2.4	1.1	1.8	E4b	E3b
Pattengail 1	19.2	17	900	0.9	1.4	1.5	B3c	B3c
Rochester 1	31.8	73	900	4.1	3.1	3.4	C5b	E4b
Rochester 2	38.1	85	900	4.7	5.1	5.6	E4	E4
Sawlog 1	30.7	145	900	8.1	7.6	8.5	C4	E4
Sawlog 2	29.2	10	600	0.6	0.2	0.4	E5	E4
Sevenmile 1	32.4	142	900	7.9	7.5	8.3	E4b	E4b
Sevenmile 2	27.7	118	900	6.6	2.8	3.1	E4	E4
Sixmile 1	28.1	79	900	4.4	3.2	3.6	B4	B4
Sixmile 2	35.9	538	900	29.9	23.9	26.6	G4	E3b
Soap 1	27.6	940	900	52.2	14.1	15.6	E4a	E3a
Soap 2	37.4	15	600	1.3	1.9	3.1	E5b	E4b
Trapper 1	33.3	237	900	13.2	8.3	9.2	E4	E4
Trapper 2	24.4	91	900	5.1	0.7	0.7	C4	E4
Willow 1	35.4	153	1000	7.7	14.3	14.3	C4	E4
Wise 1	34.7	462	900	25.7	28.9	32.1	B4c	C4
Wise 2	13.9	95	1200	4.0	0.7	0.5	C3	C3
Wise 3	13.5	90	1100	4.1	1.5	1.4	C3	C3

Table 3-2. Monitoring Section Sediment Loads from Individual Sources due to Streambank Erosion.

Stream Segment	Sediment Load	Sources								Total Load
		Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Birch 1	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	1.22	3.62	**4.8**
	Percent	0%	0%	0%	0%	0%	0%	25%	75%	
Birch 2	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	8.32	0.00	**8.3**
	Percent	0%	0%	0%	0%	0%	0%	100%	0%	
Birch 3	Tons/Year	0.00	8.79	0.00	0.00	0.00	0.00	0.00	0.00	**8.8**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
California 1	Tons/Year	0.00	0.00	0.00	3.29	0.00	0.00	0.00	0.00	**3.3**
	Percent	0%	0%	0%	100%	0%	0%	0%	0%	
California 2	Tons/Year	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	**12.0**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Camp 1	Tons/Year	0.00	5.19	0.00	0.00	0.00	3.97	4.24	4.56	**18.0**
	Percent	0%	29%	0%	0%	0%	22%	24%	25%	
Camp 2	Tons/Year	0.00	10.54	0.00	0.00	0.00	0.00	0.00	0.00	**10.5**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Canyon 1	Tons/Year	0.38	2.01	0.00	0.00	0.00	0.00	3.91	0.00	**6.3**
	Percent	6%	32%	0%	0%	0%	0%	62%	0%	
Corral 1	Tons/Year	0.00	0.00	0.00	0.00	0.81	0.00	0.81	0.00	**1.6**
	Percent	0%	0%	0%	0%	50%	0%	50%	0%	
Corral 2	Tons/Year	0.00	5.01	0.00	0.00	0.00	0.00	0.00	0.00	**5.0**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Deep 1	Tons/Year	0.00	1.62	0.00	0.00	0.00	0.00	11.63	0.00	**13.2**
	Percent	0%	12%	0%	0%	0%	0%	88%	0%	
Deep 2	Tons/Year	3.48	35.60	0.00	0.00	0.00	0.00	3.56	0.00	**42.6**
	Percent	8%	83%	0%	0%	0%	0%	8%	0%	
Delano 1	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**
	Percent	0%	0%	0%	0%	0%	0%	0%	0%	
Delano 2	Tons/Year	0.00	1.92	0.00	0.00	0.00	0.00	0.00	0.00	**1.9**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Divide 1	Tons/Year	2.94	0.53	0.00	0.00	0.00	1.37	0.00	0.00	**4.8**
	Percent	61%	11%	0%	0%	0%	28%	0%	0%	
Divide 2	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.99	0.99	0.00	**2.0**
	Percent	0%	0%	0%	0%	0%	50%	50%	0%	
Elkhorn 1	Tons/Year	0.00	0.00	0.00	7.32	0.00	0.00	0.00	7.32	**14.6**
	Percent	0%	0%	0%	50%	0%	0%	0%	50%	
Fishtrap 1	Tons/Year	0.00	1.75	0.00	0.00	0.00	1.01	0.00	0.00	**2.8**
	Percent	0%	63%	0%	0%	0%	37%	0%	0%	
Fishtrap 2	Tons/Year	0.09	0.69	0.00	0.00	0.00	0.00	0.60	0.00	**1.4**
	Percent	7%	50%	0%	0%	0%	0%	43%	0%	
French 1	Tons/Year	0.00	24.80	0.00	0.00	0.00	0.00	0.00	3.20	**28.0**
	Percent	0%	89%	0%	0%	0%	0%	0%	11%	
Gold 1	Tons/Year	3.59	0.88	0.00	0.00	0.00	0.00	0.00	0.04	**4.5**
	Percent	80%	20%	0%	0%	0%	0%	0%	1%	
Grose 1	Tons/Year	0.00	6.39	0.00	0.00	0.00	0.00	0.00	11.79	**18.2**
	Percent	0%	35%	0%	0%	0%	0%	0%	65%	
Jerry 1	Tons/Year	0.00	6.10	0.00	0.00	0.00	0.00	0.15	0.00	**6.2**
	Percent	0%	98%	0%	0%	0%	0%	2%	0%	
Jerry 2	Tons/Year	0.00	1.84	0.00	0.00	0.00	0.00	0.00	0.00	**1.8**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Lost 1	Tons/Year	0.48	0.52	0.00	0.00	0.00	0.00	0.00	0.00	**1.0**
	Percent	48%	52%	0%	0%	0%	0%	0%	0%	

Table 3-2. *Continued*

Stream Segment	Sediment Load	Sources								Total Load
		Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Lost 2	Tons/Year	0.00	2.05	0.00	0.00	0.00	0.00	0.00	0.00	**2.1**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Lower Big Hole 1	Tons/Year	0.00	11.57	0.00	0.00	0.00	0.00	30.55	0.00	**42.1**
	Percent	0%	27%	0%	0%	0%	0%	73%	0%	
Lower Big Hole 2	Tons/Year	0.00	49.88	0.00	0.00	0.00	6.43	91.16	0.00	**147.5**
	Percent	0%	34%	0%	0%	0%	4%	62%	0%	
Middle Big Hole 1	Tons/Year	0.00	2.46	0.00	0.00	0.00	0.00	0.87	0.00	**3.3**
	Percent	0%	74%	0%	0%	0%	0%	26%	0%	
Middle Big Hole 2	Tons/Year	3.02	0.00	0.00	0.00	0.00	1.43	1.90	0.00	**6.3**
	Percent	48%	0%	0%	0%	0%	22%	30%	0%	
Moose 1	Tons/Year	0.41	0.00	0.00	0.00	0.00	0.00	2.08	0.00	**2.5**
	Percent	16%	0%	0%	0%	0%	0%	84%	0%	
Oregon 1	Tons/Year	0.00	0.01	0.00	0.61	0.00	0.00	0.47	0.00	**1.1**
	Percent	0%	1%	0%	56%	0%	0%	43%	0%	
Pattengail 1	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38	**1.4**
	Percent	0%	0%	0%	0%	0%	0%	0%	100%	
Rochester 1	Tons/Year	0.00	3.07	0.00	0.00	0.00	0.00	0.00	0.00	**3.1**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Rochester 2	Tons/Year	0.00	2.74	0.00	0.00	0.00	2.33	0.00	0.00	**5.1**
	Percent	0%	54%	0%	0%	0%	46%	0%	0%	
Sawlog 1	Tons/Year	0.00	7.63	0.00	0.00	0.00	0.00	0.00	0.00	**7.6**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Sawlog 2	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	**0.2**
	Percent	0%	0%	0%	0%	0%	0%	100%	0%	
Sevenmile 1	Tons/Year	0.00	1.40	0.00	0.00	0.00	0.00	6.05	0.00	**7.5**
	Percent	0%	19%	0%	0%	0%	0%	81%	0%	
Sevenmile 2	Tons/Year	0.00	2.82	0.00	0.00	0.00	0.00	0.00	0.00	**2.8**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Sixmile 1	Tons/Year	0.00	2.28	0.00	0.00	0.00	0.00	0.95	0.00	**3.2**
	Percent	0%	71%	0%	0%	0%	0%	29%	0%	
Sixmile 2	Tons/Year	0.00	23.90	0.00	0.00	0.00	0.00	0.00	0.00	**23.9**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Soap 1	Tons/Year	0.00	14.06	0.00	0.00	0.00	0.00	0.00	0.00	**14.1**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Soap 2	Tons/Year	0.00	1.86	0.00	0.00	0.00	0.00	0.00	0.00	**1.9**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Trapper 1	Tons/Year	0.00	7.53	0.00	0.00	0.00	0.00	0.00	0.76	**8.3**
	Percent	0%	91%	0%	0%	0%	0%	0%	9%	
Trapper 2	Tons/Year	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	**0.7**
	Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Willow 1	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	6.91	7.36	**14.3**
	Percent	0%	0%	0%	0%	0%	0%	48%	52%	
Wise 1	Tons/Year	0.00	19.55	0.00	0.00	0.00	0.00	8.45	0.91	**28.9**
	Percent	0%	68%	0%	0%	0%	0%	29%	3%	
Wise 2	Tons/Year	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.54	**0.7**
	Percent	0%	0%	0%	0%	0%	0%	17%	83%	
Wise 3	Tons/Year	0.75	0.00	0.00	0.00	0.00	0.75	0.00	0.00	**1.5**
	Percent	50%	0%	0%	0%	0%	50%	0%	0%	

3.2 Stream Reach Sediment Loads

Sediment loads calculated at the monitoring section scale were extrapolated to the aerial assessment stream reach and stream segment scales. The monitoring section sediment load was extrapolated directly to the stream reach in which it was located. Stream reaches in which no monitoring section was located were assigned a sediment load due to streambank erosion based on the most similar monitoring section. This decision was based on several factors including the existing and potential stream type, valley type, the surrounding landscape, land-use practices, information in the Aerial Assessment Database, a review of 2005 color aerial imagery in GIS, and best professional judgment based on site-specific knowledge acquired during the monitoring section assessment process.

Sources of sediment due to streambank erosion at the stream reach and stream segment scales were determined based on monitoring section data and the Aerial Assessment Database. Sources of streambank erosion at the monitoring section scale were assigned directly to the aerial assessment reach in which they occurred. Sources of sediment to stream reaches in which no monitoring section was located were evaluated using the Aerial Assessment Database, which included information for “prominent land use”, “indictors of potential degradation”, and “potential sources of potential degradation”. Additional information regarding these parameters can be found in the *Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan* (MDEQ 2005). A review of color aerial imagery from 2005 and on-the-ground knowledge gained during the assessment process were used as supporting information when assigning sediment sources.

For aerial assessment stream reaches in which no monitoring section was located, 34% of the sediment load was considered to be the result of natural background erosion. This is based on the percent of natural sediment load attributed to streambank erosion in the monitoring sections (**see Section 2.1**). Anthropogenic sediment loads in these stream reaches was estimated to be 66% of the total sediment load. Sediment loading due to streambank erosion was assigned to the anthropogenic sources of sediment observed within each stream reach on an equal basis. For example, if “grazing” and “silviculture” were both observed within a stream reach, then both were assigned 33% of the total sediment load (50% of the anthropogenic sediment load). This process was performed individually for each reach, with sediment loads assigned to each observed source based on the overall estimated reach load. Thus, sources of sediment in reaches with low overall sediment loads accounted for less of the total sediment load at the reach scale than sources of sediment in reaches with high sediment loads. When no anthropogenic sources were indicated in the aerial assessment database, 100% of the estimated sediment load was considered natural. Data extrapolated to the stream reach scale is presented in the Streambank Erosion Database in **Attachment A**. This database is an extension of the Aerial Assessment Database prepared prior to field data collection.

3.3 Stream Segment Sediment Loads

Sediment loads were extrapolated to 386.3 miles of listed stream segments based on stream reaches defined in the Aerial Assessment Database. Sediment loads extrapolated from the monitoring sections scale to the stream reaches scale were summed to obtain a sediment load for each stream segment (**Attachment A**). A total estimated sediment load of 15,167.8 tons/year was attributed to eroding streambanks on the assessed stream segments. Estimated sediment loads for 303(d) listed stream segments ranged from 8.8 tons/year for Delano Creek to 6030.1 tons/year for the lower segment of the Big Hole River. At the stream segment scale, 5.4% of the bank erosion was attributed to transportation, 34.1% was attributed to riparian grazing, 5.2% was attributed to cropland, 0.6% was attributed to mining, 1.2% was attributed to silviculture, 0.9% was attributed to irrigation, 50.2% was attributed to natural sources and 2.3% was attributed to "other". An overall sediment load of 7,554.3 tons/year (49.8%) from eroding banks was attributed to anthropogenic sources, while 7,613.5 tons/year (50.2%) were attributed to natural sources. Sediment loads due to streambank erosion for each stream segment are provided for each source in **Table 3-3**.

Table 3-3. Stream Segment Sediment Loads from Individual Sources due to Streambank Erosion.

Stream Segment	Stream Segment Length (Miles)	Sediment Load	Sources								Total Load
			Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Big Hole River, middle	45.9	**Tons/Year**	106.68	67.71	60.45	0.00	0.00	4.44	119.90	0.00	359.2
		Percent	30%	19%	17%	0%	0%	1%	33%	0%	
Big Hole River, lower	48.6	**Tons/Year**	226.07	1216.37	491.93	0.00	0.00	27.99	4067.76	0.00	6030.1
		Percent	4%	20%	8%	0%	0%	0%	67%	0%	
Birch Creek, upper	13.8	**Tons/Year**	0.00	0.00	0.00	0.00	0.00	0.00	352.56	75.77	428.3
		Percent	0%	0%	0%	0%	0%	0%	82%	18%	
Birch Creek, lower	10.7	**Tons/Year**	0.00	369.77	27.10	0.00	0.00	0.00	156.82	0.00	553.7
		Percent	0%	67%	5%	0%	0%	0%	28%	0%	
California Creek	7.9	**Tons/Year**	0.00	215.75	0.00	31.32	4.12	0.00	31.95	0.00	283.1
		Percent	0%	76%	0%	11%	1%	0%	11%	0%	
Camp Creek	15.5	**Tons/Year**	14.10	502.81	46.91	0.00	0.00	34.72	92.76	23.71	715.0
		Percent	2%	70%	7%	0%	0%	5%	13%	3%	
Canyon Creek	18.4	**Tons/Year**	160.65	31.16	0.00	0.00	0.00	0.00	211.15	0.00	403.0
		Percent	40%	8%	0%	0%	0%	0%	52%	0%	
Corral Creek	5.1	**Tons/Year**	0.00	58.12	0.00	0.00	13.31	0.00	25.87	0.00	97.3
		Percent	0%	60%	0%	0%	14%	0%	27%	0%	
Deep Creek	9.2	**Tons/Year**	76.27	462.50	0.00	0.00	0.00	0.00	331.63	0.00	870.4
		Percent	9%	53%	0%	0%	0%	0%	38%	0%	
Delano Creek	2.3	**Tons/Year**	0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00	8.8
		Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Divide Creek	14.0	**Tons/Year**	51.21	56.45	16.82	0.00	0.00	25.14	54.25	0.00	203.9
		Percent	25%	28%	8%	0%	0%	12%	27%	0%	
Elkhorn Creek	7.2	**Tons/Year**	16.85	0.00	0.00	31.62	11.81	0.00	35.08	23.63	119.0
		Percent	14%	0%	0%	27%	10%	0%	29%	20%	
Fishtrap Creek	5.8	**Tons/Year**	1.13	36.52	0.00	0.00	0.00	9.51	13.33	0.00	60.5
		Percent	2%	60%	0%	0%	0%	16%	22%	0%	
French Creek	10.6	**Tons/Year**	26.39	455.75	0.00	7.17	36.25	0.00	202.93	17.01	745.5
		Percent	4%	61%	0%	1%	5%	0%	27%	2%	
Gold Creek	4.9	**Tons/Year**	19.42	4.78	0.00	0.00	0.00	0.00	24.00	0.22	48.4
		Percent	40%	10%	0%	0%	0%	0%	50%	0%	
Grose Creek	3.4	**Tons/Year**	0.00	69.73	0.00	0.00	0.00	0.00	11.98	86.29	168.0
		Percent	0%	42%	0%	0%	0%	0%	7%	51%	
Jerry Creek	12.7	**Tons/Year**	0.00	173.29	27.93	0.00	29.14	0.00	58.29	0.00	288.6
		Percent	0%	60%	10%	0%	10%	0%	20%	0%	
Lost Creek	7.8	**Tons/Year**	3.84	45.28	0.00	0.00	0.00	0.00	6.91	0.00	56.0
		Percent	7%	81%	0%	0%	0%	0%	12%	0%	
Moose Creek	17.0	**Tons/Year**	39.67	54.77	3.04	0.00	24.88	0.00	100.61	0.00	223.0
		Percent	18%	25%	1%	0%	11%	0%	45%	0%	

Table 3-3. ***Continued***

Stream Segment	Stream Segment Length (Miles)	Sediment Load	Sources								Total Load
			Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Oregon Creek	1.7	**Tons/Year**	4.04	0.03	0.00	6.51	0.00	0.00	6.06	0.00	16.6
		Percent	24%	0%	0%	39%	0%	0%	36%	0%	
Pattengail Creek	18.7	**Tons/Year**	0.00	0.00	0.00	0.00	0.00	0.00	458.62	10.19	468.8
		Percent	0%	0%	0%	0%	0%	0%	98%	2%	
Rochester Creek	15.7	**Tons/Year**	22.82	126.90	16.87	16.22	0.00	32.36	66.01	0.00	281.2
		Percent	8%	45%	6%	6%	0%	12%	23%	0%	
Sawlog Creek	4.6	**Tons/Year**	0.00	33.72	0.00	0.00	0.00	0.00	43.43	0.00	77.1
		Percent	0%	44%	0%	0%	0%	0%	56%	0%	
Sevenmile Creek	6.3	**Tons/Year**	0.00	45.90	0.00	0.00	0.00	0.00	86.11	0.00	132.0
		Percent	0%	35%	0%	0%	0%	0%	65%	0%	
Sixmile Creek	4.3	**Tons/Year**	0.00	99.38	0.00	0.00	0.00	0.00	33.88	0.00	133.3
		Percent	0%	75%	0%	0%	0%	0%	25%	0%	
Soap Creek	8.3	**Tons/Year**	4.90	220.64	15.40	0.00	0.00	0.00	18.64	0.00	259.6
		Percent	2%	85%	6%	0%	0%	0%	7%	0%	
Trapper Creek	17.4	**Tons/Year**	3.05	137.82	3.05	0.00	0.00	0.00	68.63	13.14	225.7
		Percent	1%	61%	1%	0%	0%	0%	30%	6%	
Willow Creek	21.6	**Tons/Year**	28.48	81.71	65.22	0.00	62.64	0.00	272.90	77.44	588.4
		Percent	5%	14%	11%	0%	11%	0%	46%	13%	
Wise River	27.1	**Tons/Year**	14.00	602.10	14.44	0.00	0.00	7.66	661.46	23.64	1323.3
		Percent	1%	45%	1%	0%	0%	1%	50%	2%	

3.4 Watershed Sediment Loads

Sediment loads due to streambank erosion at the watershed scale were estimated based on data collected throughout the Middle and Lower Big Hole TPA. A total of 10.1 miles of stream were assessed in 2005 and 2006. Results from monitoring sites along these 10.1 miles were extrapolated to the 386.3 miles of listed stream segments. Based on a modified version of the USGS National Hydrography Dataset (NHD), in which irrigation ditches were removed, there are a total 2,346.4 miles of stream in the Middle and Lower Big Hole TPA (**Table 3-4**). Thus, sediment loads from a total of 1,960.1 miles of stream remain unaccounted for at the watershed scale.

Sediment input along the 1,960.1 miles of un-assessed streams was evaluated using the 25th percentile of sediment loading from the entire dataset of assessed streams. Based on the 25th percentile of the entire dataset at the stream segment scale, which includes both assessed reaches and reaches to which data was extrapolated, an annual sediment load of 13.1 tons/mile was estimated to be the natural background rate of streambank erosion within the Middle and Lower Big Hole TPA. This value is equivalent to 2.5 tons/year of sediment input from every 1000 feet of stream. In an attempt to refine this value, the 25th percentile for streambank erosion at the monitoring section scale, which includes only assessed reaches, was also reviewed, resulting in a value of 2.04 tons/year. Thus, an annual background erosion rate of approximately 2-2.5 tons per 1000 feet of stream is thought to be appropriate for streams in the Middle and Lower Big Hole TPA.

Based on an estimated background sediment load of 13.1 tons/mile (2.5 tons/1000 feet) a total estimated sediment load of 40,845 tons/year was attributed to eroding streambanks within the Middle and Lower Big Hole TPA. Streambank erosion sediment loads and sources at the watershed scale for assessed stream segments are presented in **Table 3-5**.

Table 3-4. Summary of Sediment Loads due to Streambank Erosion at the Watershed Scale.

TMDL Planning Area	Stream Length (Miles)	Length of Stream Assessed using Aerial Imagery (Miles)	Length of Stream Unassessed (Miles)	Estimated Sediment Load for Assessed Streams	Estimated Sediment Load for Unassessed Streams based on Stream Segment Extrapolation (13.1 Tons/Mile/Year)	Total Sediment Load
Middle Big Hole	977.0	174.2	802.8	5032.0	10516.3	15548.3
Lower Big Hole	1369.4	212.1	1157.3	10135.8	15160.9	25296.7
Total	**2346.4**	**386.3**	**1960.1**	**15167.8**	**25677.2**	**40845.0**

Table 3-5. Watershed Sediment Loads from Individual Sources due to Streambank Erosion.

Stream Segment	Total Stream Length within Watershed based on NHD (Miles)	Sediment Load	Sources								Total Load
			Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Big Hole River, middle	977.0	**Tons/Year**	4617.99	2931.13	2616.68	0.00	0.00	192.29	5190.20	0.00	15548.3
		Percent	30%	19%	17%	0%	0%	1%	33%	0%	
Big Hole River, lower	1369.4	**Tons/Year**	948.40	5102.75	2063.66	0.00	0.00	117.40	17064.47	0.00	25296.7
		Percent	4%	20%	8%	0%	0%	0%	67%	0%	
Birch Creek, upper	37.3	**Tons/Year**	0.00	0.00	0.00	0.00	0.00	0.00	605.87	130.22	736.1
		Percent	0%	0%	0%	0%	0%	0%	82%	18%	
Birch Creek, lower	30.2	**Tons/Year**	0.00	540.16	39.59	0.00	0.00	0.00	229.09	0.00	808.8
		Percent	0%	67%	5%	0%	0%	0%	28%	0%	
California Creek	40.3	**Tons/Year**	0.00	535.08	0.00	77.67	10.21	0.00	79.23	0.00	702.2
		Percent	0%	76%	0%	11%	1%	0%	11%	0%	
Camp Creek	86.2	**Tons/Year**	32.34	1153.57	107.63	0.00	0.00	79.66	212.82	54.40	1640.4
		Percent	2%	70%	7%	0%	0%	5%	13%	3%	
Canyon Creek	54.6	**Tons/Year**	349.76	67.83	0.00	0.00	0.00	0.00	459.70	0.00	877.3
		Percent	40%	8%	0%	0%	0%	0%	52%	0%	
Corral Creek	9.5	**Tons/Year**	0.00	92.32	0.00	0.00	21.14	0.00	41.09	0.00	154.6
		Percent	0%	60%	0%	0%	14%	0%	27%	0%	
Deep Creek	151.9	**Tons/Year**	322.36	1954.86	0.00	0.00	0.00	0.00	1401.72	0.00	3678.9
		Percent	9%	53%	0%	0%	0%	0%	38%	0%	
Delano Creek	2.3	**Tons/Year**	0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00	8.8
		Percent	0%	100%	0%	0%	0%	0%	0%	0%	
Divide Creek	181.8	**Tons/Year**	603.60	665.29	198.19	0.00	0.00	296.25	639.36	0.00	2402.7
		Percent	25%	28%	8%	0%	0%	12%	27%	0%	
Elkhorn Creek	10.4	**Tons/Year**	22.82	0.00	0.00	42.82	16.00	0.00	47.51	32.01	161.2
		Percent	14%	0%	0%	27%	10%	0%	29%	20%	
Fishtrap Creek	54.2	**Tons/Year**	12.92	419.24	0.00	0.00	0.00	109.20	153.08	0.00	694.4
		Percent	2%	60%	0%	0%	0%	16%	22%	0%	
French Creek	68.1	**Tons/Year**	62.01	1070.82	0.00	16.85	85.18	0.00	476.81	39.96	1751.6
		Percent	4%	61%	0%	1%	5%	0%	27%	2%	
Gold Creek	7.0	**Tons/Year**	30.14	7.42	0.00	0.00	0.00	0.00	37.24	0.34	75.1
		Percent	40%	10%	0%	0%	0%	0%	50%	0%	
Grose Creek	3.4	**Tons/Year**	0.00	69.71	0.00	0.00	0.00	0.00	11.98	86.27	168.0
		Percent	0%	42%	0%	0%	0%	0%	7%	51%	
Jerry Creek	61.3	**Tons/Year**	0.00	542.92	87.49	0.00	91.29	0.00	182.62	0.00	904.3
		Percent	0%	60%	10%	0%	10%	0%	20%	0%	
Lost Creek	12.0	**Tons/Year**	7.62	89.80	0.00	0.00	0.00	0.00	13.70	0.00	111.1
		Percent	7%	81%	0%	0%	0%	0%	12%	0%	
Moose Creek	78.9	**Tons/Year**	183.91	253.93	14.10	0.00	115.38	0.00	466.49	0.00	1033.8
		Percent	18%	25%	1%	0%	11%	0%	45%	0%	

Table 3-5. *Continued*

Stream Segment	Total Stream Length within Watershed based on NHD (Miles)	Sediment Load	Sources								Total Load
			Transportation	Riparian Grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural Sources	Other	
Oregon Creek	3.0	**Tons/Year**	8.05	0.06	0.00	12.99	0.00	0.00	12.08	0.00	33.2
		Percent	24%	0%	0%	39%	0%	0%	36%	0%	
Pattengail Creek	74.0	**Tons/Year**	0.00	0.00	0.00	0.00	0.00	0.00	1166.90	25.94	1192.8
		Percent	0%	0%	0%	0%	0%	0%	98%	2%	
Rochester Creek	74.2	**Tons/Year**	85.09	473.24	62.92	60.49	0.00	120.69	246.18	0.00	1048.6
		Percent	8%	45%	6%	6%	0%	12%	23%	0%	
Sawlog Creek	7.0	**Tons/Year**	0.00	47.60	0.00	0.00	0.00	0.00	61.29	0.00	108.9
		Percent	0%	44%	0%	0%	0%	0%	56%	0%	
Sevenmile Creek	6.3	**Tons/Year**	0.00	45.90	0.00	0.00	0.00	0.00	86.11	0.00	132.0
		Percent	0%	35%	0%	0%	0%	0%	65%	0%	
Sixmile Creek	5.2	**Tons/Year**	0.00	108.71	0.00	0.00	0.00	0.00	37.06	0.00	145.8
		Percent	0%	75%	0%	0%	0%	0%	25%	0%	
Soap Creek	17.7	**Tons/Year**	7.22	325.19	22.70	0.00	0.00	0.00	27.47	0.00	382.6
		Percent	2%	85%	6%	0%	0%	0%	7%	0%	
Trapper Creek	53.3	**Tons/Year**	9.40	425.13	9.40	0.00	0.00	0.00	211.70	40.54	696.2
		Percent	1%	61%	1%	0%	0%	0%	30%	6%	
Willow Creek	84.1	**Tons/Year**	68.14	195.46	156.01	0.00	149.85	0.00	652.82	185.25	1407.5
		Percent	5%	14%	11%	0%	11%	0%	46%	13%	
Wise River	270.6	**Tons/Year**	48.01	2064.94	49.53	0.00	0.00	26.26	2268.53	81.09	4538.4
		Percent	1%	45%	1%	0%	0%	1%	50%	2%	

4.0 POTENTIAL SEDIMENT LOAD REDUCTION

This section is provided for technical guidance in determining sediment allocations to human influenced activities that cause streambank erosion. The results are only one of a number of components that will be considered during the TMDL sediment allocation process. The results are provided to determine a reasonable amount of sediment reduction to sources that influence streambank erosion. The allocation process will also consider economic feasibility of restoration from each significant source and regional BMP effectiveness studies. Determining a potential overall load reduction from streambank erosion also will help define how much sediment production from streambank erosion is likely derived from natural conditions.

4.1 Reference Condition and Best Management Practices

The Beaverhead-Deerlodge National Forest (BDNF) reference dataset indicates that a “moderate” BEHI score (20-29.5) can be expected on reference streams with the following stream types: A, C, (C3, C4) and E (E3, E4, E5, Ea) (**Table 4-1**) (Bengeyfield 2004). Streams classified as B stream types are on the border of the “moderate” and “high” (30.0-39.5) BEHI categories, with B3 streams falling in “moderate” category and B4 streams falling in the “high” category. A “moderate” BEHI score indicates that a streambank is eroding, but that the erosion is limited by such factors as vegetation along the top of the bank, a deep binding root mass, low bank height, and large substrate along the toe of the bank.

Based on the BDNF reference dataset, it was determined that functioning streams in the Middle and Lower Big Hole TPA would tend to have a “moderate” BEHI score. In situations where a loss of riparian vegetation along the channel margin has lead to BEHI scores greater than “moderate”, applying Best Management Practices (BMPs) that promote the growth of woody vegetation along the streambank is the primary way to decrease the BEHI score to “moderate”. More extreme cases of bank erosion may require manual re-vegetation and/or active channel restoration.

Table 4-1. Expected BEHI Values for Various Stream Types based on the BDNF Reference Dataset.

A	B3	B4	B	C3	C4	C	E3	E4	E5	Ea	E
24.2	27.1	31.7	29.7	26.9	26.5	26.5	26.3	24.2	22	22.7	23.6

4.2 Streambank Erosion Sediment Load Reductions

To estimate a potential decrease in sediment loading due to improved streambank stability, BEHI values in the existing dataset that exceeded the “moderate” category were reduced to “moderate” and loads were re-calculated. Applying a “moderate” BEHI score to eroding streambanks assessed along the individual monitoring sections generally leads to a reduction in sediment loads (**Table 4-2**). The exception is when the existing streambank condition was described as “moderate” and no further potential for reduction was identified. Reductions calculated at the monitoring section scale were extrapolated to the stream segment scale using the Aerial Assessment Database (**Table 4-3**). Note that the 0% reduction identified in **Table 4-3** for the middle segment of the Big Hole River, the upper segment of Birch Creek, Delano Creek, and

Pattengail Creek indicates that streambank erosion does not currently exceed a “moderate” BEHI score due to anthropogenic disturbances. The percent reduction identified at the stream segment scale was then extrapolated directly to the watershed scale. Thus, as contributing source areas, streambank erosion on tributaries to listed stream segments should also meet the “moderate” BEHI requirement. This reduction often resulted in a “moderate BEHI/low NBS” combination for an expected retreat rate of 0.17 tons/year. Because there was no streambank erosion within the monitoring sections on the middle segment of the Big Hole River, an estimated reduction at the watershed scale of 33% was used based on the average reduction estimated for the entire Middle and Lower Big Hole TPA. Through BMPs, the actual length and height of eroding banks could also be reduced, which would lead to further reductions in sediment loading.

Table 4-2. Monitoring Section Sediment Loads with BEHI Reduced to "Moderate".

Monitoring Section	Sediment Loading from Monitoring Section (Tons/Year)	Sediment Loading per 1000' of Stream (Tons/Year)	Sediment Loading from Monitoring Section with "Moderate" BEHI (Tons/Year)	Sediment Loading per 1000' of Stream with "Moderate" BEHI
Birch 1	4.84	5.38	4.84	5.38
Birch 2	8.32	9.25	6.74	7.49
Birch 3	8.79	9.77	4.02	4.46
California 1	3.29	3.66	2.57	2.86
California 2	12.00	13.34	5.44	6.04
Camp 1	17.97	19.96	15.31	17.01
Camp 2	10.54	11.72	5.63	6.26
Canyon 1	6.30	7.00	5.22	5.80
Corral 1	1.61	1.79	0.62	0.69
Corral 2	5.01	5.57	3.25	3.61
Deep 1	13.25	14.72	13.25	14.72
Deep 2	42.64	42.64	21.44	21.44
Delano 1	0.00	0.00	0	0.00
Delano 2	1.92	2.13	1.92	2.13
Divide 1	4.84	5.38	4.05	4.50
Divide 2	1.99	2.21	1.99	2.21
Elkhorn 1	14.65	16.28	5.49	6.10
Fishtrap 1	2.77	3.08	1.72	1.92
Fishtrap 2	1.39	1.54	1.39	1.54
French 1	28.00	31.11	12.72	14.13
Gold 1	4.52	5.02	2.31	2.57
Grose 1	18.18	30.29	6.4	10.66
Jerry 1	6.24	6.94	4.52	5.02
Jerry 2	1.84	2.04	1.71	1.90
Lost 1	1.00	1.42	1	1.42
Lost 2	2.05	3.42	0.89	1.48
Lower Big Hole 1	42.12	12.98	42.12	12.98
Lower Big Hole 2	147.47	41.78	68.65	19.45
Middle Big Hole 1	3.34	0.98	3.34	0.98
Middle Big Hole 2	6.35	1.84	6.35	1.84
Moose 1	2.49	2.76	2.49	2.76
Oregon 1	1.09	1.81	0.8	1.33
Pattengail 1	1.38	1.53	1.38	1.53
Rochester 1	3.07	3.41	1.3	1.44
Rochester 2	5.07	5.63	1.79	1.99
Sawlog 1	7.63	8.48	3.28	3.64
Sawlog 2	0.23	0.38	0.23	0.38
Sevenmile 1	7.46	8.29	2.95	3.28
Sevenmile 2	2.82	3.13	1.93	2.15
Sixmile 1	3.24	3.60	2.53	2.81
Sixmile 2	23.90	26.55	11.48	12.76
Soap 1	14.06	15.62	14.06	15.62
Soap 2	1.86	3.09	0.52	0.87
Trapper 1	8.29	9.21	4.96	5.51
Trapper 2	0.67	0.74	0.67	0.74
Willow 1	14.27	14.27	5.9	5.90
Wise 1	28.91	32.12	9.52	10.57
Wise 2	0.66	0.55	0.66	0.55
Wise 3	1.50	1.36	1.5	1.36

Table 4-3. Potential Sediment Load Reduction from Stream Segments with BEHI Reduced to "Moderate".

Stream Segment	Total Load (Tons/Year)	Total Load with "Moderate" BEHI (Tons/Year)	Total Load due to Anthropogenic Sources (Tons/Year)	Total Load with "Moderate" BEHI due to Anthropogenic Sources (Tons/Year)	Potential Reduction in Anthropogenic Sediment Load with "Moderate" BEHI (Tons/Year)	Percent Reduction in Anthropogenic Sediment Load with "Moderate" BEHI
Big Hole River, middle	359.2	359.2	239.3	239.3	0.0	0%
Big Hole River, lower	6030.1	3935.7	1962.4	1270.9	691.4	35%
Birch Creek, upper	428.3	377.9	75.8	75.8	0.0	0%
Birch Creek, lower	553.7	252.8	396.9	181.2	215.7	54%
California Creek	283.1	156.3	251.2	132.2	119.0	47%
Camp Creek	715.0	408.2	622.3	352.8	269.4	43%
Canyon Creek	403.0	341.6	191.8	156.0	35.8	19%
Corral Creek	97.3	56.6	71.4	42.8	28.6	40%
Deep Creek	870.4	752.5	538.8	430.7	108.0	20%
Delano Creek	8.8	8.8	8.8	8.8	0.0	0%
Divide Creek	203.9	192.6	149.6	139.2	10.4	7%
Elkhorn Creek	119.0	71.0	83.9	48.0	35.9	43%
Fishtrap Creek	60.5	50.7	47.2	37.4	9.8	21%
French Creek	745.5	489.8	542.6	346.2	196.3	36%
Gold Creek	48.4	36.5	24.4	12.5	11.9	49%
Grose Creek	168.0	66.4	156.0	59.7	96.3	62%
Jerry Creek	288.6	212.9	230.4	170.6	59.8	26%
Lost Creek	56.0	40.3	49.1	33.4	15.7	32%
Moose Creek	223.0	126.3	122.4	62.1	60.2	49%
Oregon Creek	16.6	12.2	10.6	7.8	2.8	27%
Pattengail Creek	468.8	436.7	10.2	10.2	0.0	0%
Rochester Creek	281.2	128.0	215.2	90.8	124.3	58%
Sawlog Creek	77.1	34.2	33.7	14.5	19.3	57%
Sevenmile Creek	132.0	66.1	45.9	27.9	18.0	39%
Sixmile Creek	133.3	69.1	99.4	51.5	47.9	48%
Soap Creek	259.6	224.3	240.9	213.6	27.4	11%
Trapper Creek	225.7	168.2	157.1	99.6	57.5	37%
Willow Creek	588.4	366.7	315.5	183.7	131.8	42%
Wise River	1323.3	733.5	661.8	257.7	404.2	61%

5.0 REFERENCES

Applied Geomorphology/DTM Consulting. 2005. Aerial Assessment of the Middle and Lower Big Hole TMDL Planning Area Pintlar Creek to the Beaverhead River (Draft). Prepared by Applied Geomorphology, Inc. and DTM Consulting, Bozeman, Montana. Prepared for Big Hole River Foundation, Butte, Montana.

Bengeyfield, P. 2004. Beaverhead-Deerlodge National Forest Stream Morphology Data.

MDEQ. 2005. Water Quality Status Report and Sampling and Analysis Plan: Middle and Lower Big Hole River Water Quality Restoration Planning Areas. Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

MDEQ 2005. Middle and Lower Big Hole TMDL Planning Area Sediment Monitoring Quality Assurance Project Plan (QAPP). Prepared by PBS&J, Helena, Montana. Prepared for Montana Department of Environmental Quality, Water Quality Planning Bureau, Helena, Montana.

Rosgen, D. 1996 Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Rosgen, D. 2004. River Assessment and Monitoring Field Guide, Lubrecht Forest, MT, August 2-12, 2004. Wildland Hydrology, Inc, Fort Collins, Colorado.

USDI 1998. Earth Manual Part 1 Third Edition. U.S. Department of the Interior, Bureau of Reclamation, Earth Sciences and Research Laboratory, Geotechnical Research, Technical Research Center, Denver, Colorado.

ATTACHMENT A

STREAMBANK EROSION DATABASE

MIDDLE AND LOWER BIG HOLE RIVER TMDL PLANNING AREAS

Stream	Reach	Sinuosity	Valley Slope	Channel Slope	Rosgen Classification	Relative Bank Stability	Most Similar Stream Section used for Modeling Sediment Loading (Monitoring Sections in Red)	Sediment Load due to Bank Erosion per 1000 Feet (Tons/Year)	Sediment Load due to Bank Erosion per Mile (Tons/Year)	Aerial Assessment Reach Length (Miles)	Sediment Load due to Bank Erosion for Entire Aerial Assessment Reach (Tons/Year)	Sediment Source (Percent)								Sediment Load by Sediment Source (Tons/Year)							
												Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other	Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other
Big Hole River	BH 35	1.09	0.13%	0.12%	C	High	Middle Big Hole 1	0.98	5.17	1.98	10.26		66%					34%		0.00	6.77	0.00	0.00	0.00	0.00	3.49	0.00
Big Hole River	BH 36	1.14	0.10%	0.09%	C/Da	Mod	**Middle Big Hole 1**	**0.98**	5.18	3.52	18.22		74%					26%		0.00	13.46	0.00	0.00	0.00	0.00	4.76	0.00
Big Hole River	BH 37	1.14	0.16%	0.14%	C	High	Middle Big Hole 1	0.98	5.17	3.15	16.32	22%	22%	22%				34%		3.59	3.59	3.59	0.00	0.00	0.00	5.55	0.00
Big Hole River	BH 38	1.01	0.06%	0.05%	F	High	Middle Big Hole 1	0.98	5.17	1.39	7.17	33%	33%					34%		2.37	2.37	0.00	0.00	0.00	0.00	2.44	0.00
Big Hole River	BH 39	1.09	0.16%	0.15%	C	Mod	Middle Big Hole 1	0.98	5.17	3.19	16.50	22%	22%	22%				34%		3.63	3.63	3.63	0.00	0.00	0.00	5.61	0.00
Big Hole River	BH 40	1.03	0.27%	0.26%	F	High	Middle Big Hole 1	0.98	5.17	2.77	14.35		33%	33%				34%		0.00	4.74	4.74	0.00	0.00	0.00	4.88	0.00
Big Hole River	BH 41	1.05	0.28%	0.27%	F	High	Middle Big Hole 1	0.98	5.17	3.14	16.22	66%						34%		10.71	0.00	0.00	0.00	0.00	0.00	5.52	0.00
Big Hole River	BH 42	1.10	0.23%	0.21%	C/Da	Mod	**Middle Big Hole 2**	**1.84**	9.71	2.04	19.77	48%					22%	30%		9.40	0.00	0.00	0.00	0.00	4.44	5.93	0.00
Big Hole River	BH 43	1.04	0.28%	0.27%	F	High	Middle Big Hole 2	1.84	9.72	1.89	18.33	33%	33%					34%		6.05	6.05	0.00	0.00	0.00	0.00	6.23	0.00
Big Hole River	BH 44	1.14	0.22%	0.19%	C	Mod	Middle Big Hole 2	1.84	9.72	8.06	78.28	22%	22%	22%				34%		17.22	17.22	17.22	0.00	0.00	0.00	26.62	0.00
Big Hole River	BH 45	1.15	0.45%	0.39%	C/F	High	Middle Big Hole 2	1.84	9.72	6.67	64.78	33%		33%				34%		21.38	0.00	21.38	0.00	0.00	0.00	22.03	0.00
Big Hole River	BH 46	1.05	0.37%	0.35%	F	High	Middle Big Hole 2	1.84	9.72	3.50	34.01	66%						34%		22.45	0.00	0.00	0.00	0.00	0.00	11.56	0.00
Big Hole River	BH 47	1.09	0.28%	0.26%	C/F	High	Middle Big Hole 2	1.84	9.72	4.63	44.96	22%	22%	22%				34%		9.89	9.89	9.89	0.00	0.00	0.00	15.29	0.00
Big Hole River	BH 48	1.10	0.41%	0.37%	F	High	Lower Big Hole 1	12.98	68.53	6.22	426.08	32%						68%		136.35	0.00	0.00	0.00	0.00	0.00	289.73	0.00
Big Hole River	BH 49	1.15	0.32%	0.28%	Da	Low	Lower Big Hole 1	12.98	68.53	6.80	465.84	10%	11%	11%				68%		46.58	51.24	51.24	0.00	0.00	0.00	316.77	0.00
Big Hole River	BH 50	1.44	0.64%	0.45%	C	Mod	Lower Big Hole 1	12.98	68.53	4.87	333.57		32%					68%		0.00	106.74	0.00	0.00	0.00	0.00	226.83	0.00
Big Hole River	BH 51	1.19	0.03%	0.02%	C	Low	**Lower Big Hole 1**	**12.98**	68.53	2.25	154.07		27%					73%		0.00	42.32	0.00	0.00	0.00	0.00	111.76	0.00
Big Hole River	BH 52	1.11	0.35%	0.32%	Da	Low	Lower Big Hole 1	12.98	68.53	4.82	330.29		16%	16%				68%		0.00	52.85	52.85	0.00	0.00	0.00	224.60	0.00
Big Hole River	BH 53	1.16	0.37%	0.32%	C	Low	Lower Big Hole 1	12.98	68.53	2.68	183.84		32%					68%		0.00	58.83	0.00	0.00	0.00	0.00	125.01	0.00
Big Hole River	BH 54	1.17	0.31%	0.26%	Da	Low	Lower Big Hole 1	12.98	68.53	3.18	217.64		16%	16%				68%		0.00	34.82	34.82	0.00	0.00	0.00	148.00	0.00
Big Hole River	BH 55	1.06	0.23%	0.22%	C	Mod	**Lower Big Hole 2**	**41.78**	220.58	2.91	641.85		34%				4%	62%		0.00	217.11	0.00	0.00	0.00	27.99	396.75	0.00
Big Hole River	BH 56	1.23	0.23%	0.18%	C	Low	Lower Big Hole 2	41.78	220.60	3.02	667.09		16%	16%				68%		0.00	106.73	106.73	0.00	0.00	0.00	453.62	0.00
Big Hole River	BH 57	1.27	0.35%	0.27%	C	Low	Lower Big Hole 2	41.78	220.60	1.21	266.59		16%	16%				68%		0.00	42.66	42.66	0.00	0.00	0.00	181.28	0.00
Big Hole River	BH 58	1.38	0.32%	0.23%	C	Low	Lower Big Hole 2	41.78	220.60	2.67	588.02		16%	16%				68%		0.00	94.08	94.08	0.00	0.00	0.00	399.85	0.00
Big Hole River	BH 59	1.37	0.18%	0.13%	Da	Low	Lower Big Hole 2	41.78	220.60	1.96	431.45	10%	11%	11%				68%		43.15	47.46	47.46	0.00	0.00	0.00	293.39	0.00
Big Hole River	BH 60	1.17	0.38%	0.32%	C/Da	Low	Lower Big Hole 2	41.78	220.60	4.24	935.75		32%					68%		0.00	299.44	0.00	0.00	0.00	0.00	636.31	0.00
Big Hole River	BH 61	1.13	0.45%	0.40%	D	Low	Lower Big Hole 2	41.78	220.60	1.76	388.02		16%	16%				68%		0.00	62.08	62.08	0.00	0.00	0.00	263.86	0.00
Birch Creek	Birch 01	1.08			A	Mod	Delano 1	0.00	0.00	2.67	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Birch Creek	Birch 02	1.07	6.5%	6.1%	B	Low	Birch 1	5.38	28.41	2.16	61.38							100%		0.00	0.00	0.00	0.00	0.00	0.00	61.38	0.00
Birch Creek	Birch 03	1.04	2.5%	2.4%	B	Mod	**Birch 1**	**5.38**	28.41	3.57	101.29							25%	75%	0.00	0.00	0.00	0.00	0.00	0.00	25.52	75.77
Birch Creek	Birch 04	1.09	3.7%	3.4%	B	High	**Birch 2**	**9.25**	48.82	5.44	265.66							100%		0.00	0.00	0.00	0.00	0.00	0.00	265.66	0.00
Birch Creek	Birch 05	1.19	2.4%	2.0%	E	Mod	Birch 3	9.77	51.59	1.62	83.49							100%		0.00	0.00	0.00	0.00	0.00	0.00	83.49	0.00
Birch Creek	Birch 06	1.11	2.0%	1.8%	E	Mod	**Birch 3**	**9.77**	51.58	4.93	254.52		100%							0.00	254.52	0.00	0.00	0.00	0.00	0.00	0.00
Birch Creek	Birch 07	1.16	1.5%	1.3%	E	Mod	Birch 3	9.77	51.59	2.59	133.56		66%					34%		0.00	88.15	0.00	0.00	0.00	0.00	45.41	0.00
Birch Creek	Birch 08	1.12	1.9%	1.7%	F	Mod	Birch 3	9.77	51.59	1.59	82.13		33%	33%				34%		0.00	27.10	27.10	0.00	0.00	0.00	27.93	0.00
California	California 01	1.03	19.0%	18.4%	Aa+	High	Corral 1	1.79	9.45	0.66	6.24					66%		34%		0.00	0.00	0.00	0.00	4.12	0.00	2.12	0.00
California	California 02	1.08	2.9%	2.7%	B	High	**California 1**	**3.66**	19.33	1.62	31.32				100%					0.00	0.00	0.00	31.32	0.00	0.00	0.00	0.00
California	California 03	1.17	1.5%	1.3%	E	Mod	California 1	3.66	19.32	0.86	16.62							100%		0.00	0.00	0.00	0.00	0.00	0.00	16.62	0.00
California	California 04	1.15	1.7%	1.5%	C/E	Mod	California 1	3.66	19.32	2.01	38.84		66%					34%		0.00	25.64	0.00	0.00	0.00	0.00	13.21	0.00
California	California 05	1.27	1.7%	1.3%	C/E	Mod	**California 2**	**13.34**	70.41	2.70	190.11		100%							0.00	190.11	0.00	0.00	0.00	0.00	0.00	0.00
Camp Creek	Camp 01	1.05	20.3%	19.4%	A	High	Delano 1	0.00	0.00	2.52	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Camp Creek	Camp 02	1.03	4.8%	4.6%	B	High	Corral 1	1.79	9.45	2.44	23.06		66%					34%		0.00	15.22	0.00	0.00	0.00	0.00	7.84	0.00
Camp Creek	Camp 03	0.90	2.4%	2.7%	B	High	**Camp 2**	**11.72**	61.86	6.69	413.68		100%							0.00	413.68	0.00	0.00	0.00	0.00	0.00	0.00
Camp Creek	Camp 04	1.05	2.5%	2.4%	B/E	High	**Camp 1**	**19.96**	105.41	0.89	93.39		29%				22%	24%	25%	0.00	26.99	0.00	0.00	0.00	20.62	22.06	23.71
Camp Creek	Camp 05	1.08	2.1%	2.0%	E	Mod	Camp 2	11.72	61.88	1.56	96.77		33%	33%				34%		0.00	31.94	31.94	0.00	0.00	0.00	32.90	0.00
Camp Creek	Camp 06	1.09	1.1%	1.0%	E	Mod	Camp 2	11.72	61.88	1.42	88.11	16%	17%	17%			16%	34%		14.10	14.98	14.98	0.00	0.00	14.10	29.96	0.00

Stream	Reach	Sinuosity	Valley Slope	Channel Slope	Rosgen Classification	Relative Bank Stability	Most Similar Stream Section used for Modeling Sediment Loading (Monitoring Sections in Red)	Sediment Load due to Bank Erosion per 1000 Feet (Tons/Year)	Sediment Load due to Bank Erosion per Mile (Tons/Year)	Aerial Assessment Reach Length (Miles)	Sediment Load due to Bank Erosion for Entire Aerial Assessment Reach (Tons/Year)	Sediment Source (Percent)								Sediment Load by Sediment Source (Tons/Year)							
												Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other	Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other
Canyon Creek	Canyon 01	1.09	6.4%	5.8%	A/B	high	Delano 1	0.00	0.00	2.20	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canyon Creek	Canyon 02	1.13	3.0%	2.6%	B/C	High	Pattengail 1	1.53	8.08	8.76	70.78							100%		0.00	0.00	0.00	0.00	0.00	0.00	70.78	0.00
Canyon Creek	Canyon 03	1.11	2.9%	2.6%	B/E	High	Canyon 1	7.00	36.97	2.64	97.72	6%	32%					62%		5.91	31.16	0.00	0.00	0.00	0.00	60.65	0.00
Canyon Creek	Canyon 04	1.02	3.2%	3.1%	B	High	Birch 2	9.25	48.84	4.80	234.47	66%						34%		154.75	0.00	0.00	0.00	0.00	0.00	79.72	0.00
Corral	Corral 01	1.02	15.8%	15.4%	Aa+	High	Corral 1	1.79	9.45	0.64	6.05					66%		34%		0.00	0.00	0.00	0.00	3.99	0.00	2.06	0.00
Corral	Corral 02	1.04	8.4%	8.1%	A	High	Corral 1	1.79	9.46	1.97	18.63					50%		50%		0.00	0.00	0.00	0.00	9.32	0.00	9.32	0.00
Corral	Corral 03	1.07	4.2%	4.0%	B	High	Corral 2	5.57	29.41	0.81	23.82		66%					34%		0.00	15.72	0.00	0.00	0.00	0.00	8.10	0.00
Corral	Corral 04	1.12	2.7%	2.4%	E	High	Corral 2	5.57	29.41	0.64	18.82		66%					34%		0.00	12.42	0.00	0.00	0.00	0.00	6.40	0.00
Corral	Corral 05	1.03	1.9%	1.9%	E	Mod	Corral 2	5.57	29.39	1.02	29.98		100%							0.00	29.98	0.00	0.00	0.00	0.00	0.00	0.00
Deep Creek	Deep 01	1.61	1.5%	1.0%	E	High	Deep 1	14.72	77.72	2.08	162.05		66%					34%		0.00	106.95	0.00	0.00	0.00	0.00	55.10	0.00
Deep Creek	Deep 02	1.42	1.2%	0.8%	E	Mod	Deep 1	14.72	77.72	2.31	179.35		12%					88%		0.00	21.88	0.00	0.00	0.00	0.00	157.47	0.00
Deep Creek	Deep 03	1.25	1.0%	0.8%	E	High	Deep 1	14.72	77.72	1.54	119.46		66%					34%		0.00	78.84	0.00	0.00	0.00	0.00	40.62	0.00
Deep Creek	Deep 04	1.46	0.7%	0.4%	C	Mod	Deep 1	14.72	77.72	2.22	172.46	33%	33%					34%		56.91	56.91	0.00	0.00	0.00	0.00	58.64	0.00
Deep Creek	Deep 05	1.45	0.8%	0.5%	C	Mod	Deep 2	42.64	225.15	1.05	237.08	8%	83%					8%		19.35	197.91	0.00	0.00	0.00	0.00	19.81	0.00
Delano	Delano 01	1.43	16.7%	11.7%	Aa+	High	Delano 1	0.00	0.00	0.94	0.00					66%		34%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delano	Delano 02	1.04	10.9%	10.5%	A	High	Delano 1	0.00	0.00	0.61	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delano	Delano 03	1.05	6.6%	6.3%	A	High	Delano 2	2.13	11.24	0.78	8.77		100%					0%		0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00
Divide Creek	Div 01	1.09	0.7%	0.6%	F/G	Mod	Divide 1	5.38	28.39	1.89	53.63	61%	11%				28%			32.54	5.85	0.00	0.00	0.00	15.24	0.00	0.00
Divide Creek	Div 02	1.52	0.5%	0.3%	E	Mod	Divide 2	2.21	11.67	3.26	38.05	22%	22%	22%				34%		8.37	8.37	8.37	0.00	0.00	0.00	12.94	0.00
Divide Creek	Div 03	1.09	0.5%	0.4%	F/G	Mod	Divide 1	5.38	28.41	0.55	15.61	66%						34%		10.30	0.00	0.00	0.00	0.00	0.00	5.31	0.00
Divide Creek	Div 04	2.59	1.5%	0.6%	E	Mod	Divide 2	2.21	11.67	4.39	51.18		66%					34%		0.00	33.78	0.00	0.00	0.00	0.00	17.40	0.00
Divide Creek	Div 05	1.63	0.6%	0.4%	E	Mod	Divide 2	2.21	11.65	1.70	19.80						50%	50%		0.00	0.00	0.00	0.00	0.00	9.90	9.90	0.00
Divide Creek	Div 06	1.48	0.5%	0.3%	F/G	Mod	Divide 2	2.21	11.67	0.97	11.27		33%	33%				34%		0.00	3.72	3.72	0.00	0.00	0.00	3.83	0.00
Divide Creek	Div 07	1.47	0.5%	0.4%	E		Divide 2	2.21	11.67	1.23	14.32		33%	33%				34%		0.00	4.73	4.73	0.00	0.00	0.00	4.87	0.00
Elkhorn	Elkhorn 01	1.26	11.3%	9.0%	A	High	Delano 1	0.00	0.00	3.38	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elkhorn	Elkhorn 02	1.02	4.0%	3.9%	B	Mod	Moose 1	2.76	14.57	0.83	12.10				66%			34%		0.00	0.00	0.00	7.98	0.00	0.00	4.11	0.00
Elkhorn	Elkhorn 03	1.08	2.1%	2.0%	B	High	Elkhorn 1	16.28	85.93	0.55	47.26				50%				50%	0.00	0.00	0.00	23.63	0.00	0.00	0.00	23.63
Elkhorn	Elkhorn 04	1.05	2.0%	1.9%	B/E	Mod	Fishtrap 1	3.08	16.26	1.57	25.53	66%						34%		16.85	0.00	0.00	0.00	0.00	0.00	8.68	0.00
Elkhorn	Elkhorn 05	1.02	5.2%	5.1%	A	High	Birch 1	5.38	28.41	0.63	17.90					66%		34%		0.00	0.00	0.00	0.00	11.81	0.00	6.08	0.00
Elkhorn	Elkhorn 06	1.80	1.9%	1.1%	E	Mod	California 2	13.34	70.44	0.23	16.20							100%		0.00	0.00	0.00	0.00	0.00	0.00	16.20	0.00
Fishtrap Creek	Fish 01	1.13	3.0%	2.7%	B/C	High	Fishtrap 1	3.08	16.24	1.60	25.95		63%				37%			0.00	16.44	0.00	0.00	0.00	9.51	0.00	0.00
Fishtrap Creek	Fish 02	1.47	1.5%	1.0%	C/E	Mod	Fishtrap 2	1.54	8.13	2.16	17.57		66%					34%		0.00	11.59	0.00	0.00	0.00	0.00	5.97	0.00
Fishtrap Creek	Fish 03	1.30	1.3%	1.0%	C	Mod	Fishtrap 2	1.54	8.13	2.09	16.97	7%	50%					43%		1.13	8.49	0.00	0.00	0.00	0.00	7.36	0.00
French Creek	French 01	1.04	12.7%	12.2%	A/B	High	Corral 1	1.79	9.45	1.30	12.24					66%		34%		0.00	0.00	0.00	0.00	8.08	0.00	4.16	0.00
French Creek	French 02	1.02	3.7%	3.7%	B	High	Sixmile 1	3.60	19.01	2.25	42.69					66%		34%		0.00	0.00	0.00	0.00	28.17	0.00	14.51	0.00
French Creek	French 03	0.95	1.9%	2.0%	E	Mod	California 1	3.66	19.32	0.56	10.87				66%			34%		0.00	0.00	0.00	7.17	0.00	0.00	3.70	0.00
French Creek	French 04	1.10	1.2%	1.1%	C/F	Mod	California 2	13.34	70.44	1.14	79.97	33%	33%					34%		26.39	26.39	0.00	0.00	0.00	0.00	27.19	0.00
French Creek	French 05	1.13	0.9%	0.8%	C		French 1	31.11	164.26	1.24	204.35		66%					34%		0.00	134.87	0.00	0.00	0.00	0.00	69.48	0.00
French Creek	French 06	1.52	1.1%	0.7%	C	Mod	French 1	31.11	164.26	0.90	148.64		89%						11%	0.00	131.64	0.00	0.00	0.00	0.00	0.00	17.01
French Creek	French 07	1.42	0.6%	0.4%	C	Mod	Deep 1	14.72	77.72	1.28	99.15		66%					34%		0.00	65.44	0.00	0.00	0.00	0.00	33.71	0.00
French Creek	French 08	1.46	1.1%	0.7%	C/E	Mod	Deep 1	14.72	77.72	1.90	147.60		66%					34%		0.00	97.41	0.00	0.00	0.00	0.00	50.18	0.00
Gold Creek	Gold 01	1.03			C	High	Delano 1	0.00	0.00	1.86	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gold Creek	Gold 02	1.12	4.3%	3.8%	E	High	Delano 2	2.13	11.25	2.13	24.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	24.00	0.00
Gold Creek	Gold 03	1.03	7.3%	7.0%	B		Gold 1	5.02	26.49	0.92	24.42	80%	20%						1%	19.42	4.78	0.00	0.00	0.00	0.00	0.00	0.22

Stream	Reach	Sinuosity	Valley Slope	Channel Slope	Rosgen Classification	Relative Bank Stability	Most Similar Stream Section used for Modeling Sediment Loading (Monitoring Sections in Red)	Sediment Load due to Bank Erosion per 1000 Feet (Tons/Year)	Sediment Load due to Bank Erosion per Mile (Tons/Year)	Aerial Assessment Reach Length (Miles)	Sediment Load due to Bank Erosion for Entire Aerial Assessment Reach (Tons/Year)	Sediment Source (Percent)								Sediment Load by Sediment Source (Tons/Year)							
												Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other	Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other
Grose	Grose 01	1.07	7.4%	6.9%	A	Mod	Lost 1	1.42	7.50	1.04	7.80		66%					34%		0.00	5.15	0.00	0.00	0.00	0.00	2.65	0.00
Grose	Grose 02	1.18	5.8%	4.9%	A	High	Lost 2	3.42	18.06	1.01	18.24		66%					34%		0.00	12.04	0.00	0.00	0.00	0.00	6.20	0.00
Grose	Grose 03	1.07	5.8%	5.4%	A	High	**Grose 1**	**30.29**	159.95	0.83	132.76		35%						65%	0.00	46.47	0.00	0.00	0.00	0.00	0.00	86.29
Grose	Grose 04	1.02	3.8%	3.7%	G	Mod	Lost 2	3.42	18.06	0.51	9.21		66%					34%		0.00	6.08	0.00	0.00	0.00	0.00	3.13	0.00
Jerry Creek	Jerry 01	1.06	7.8%	7.4%	A	High	Delano 1	0.00	0.00	1.86	0.00					66%		34%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jerry Creek	Jerry 02	1.12	4.8%	4.3%	B	High	Delano 2	2.13	11.25	0.80	9.02					66%		34%		0.00	0.00	0.00	0.00	5.96	0.00	3.07	0.00
Jerry Creek	Jerry 03	1.18	1.9%	1.6%	E	Mod	Sevenmile 2	3.13	16.53	1.74	28.79		33%			33%		34%		0.00	9.50	0.00	0.00	9.50	0.00	9.79	0.00
Jerry Creek	Jerry 04	1.09	4.0%	3.7%	B	High	Fishtrap 1	3.08	16.26	0.57	9.23		33%			33%		34%		0.00	3.05	0.00	0.00	3.05	0.00	3.14	0.00
Jerry Creek	Jerry 05	1.02	1.7%	1.6%	E	Mod	Jerry 1	6.94	36.64	0.88	32.23		33%			33%		34%		0.00	10.64	0.00	0.00	10.64	0.00	10.96	0.00
Jerry Creek	Jerry 06	1.05	4.6%	4.4%	B/C	High	**Jerry 1**	**6.94**	36.64	2.94	107.60		98%					2%		0.00	105.04	0.00	0.00	0.00	0.00	2.56	0.00
Jerry Creek	Jerry 07	1.09	2.3%	2.1%	C/E	Mod	Jerry 1	6.94	36.64	2.31	84.62		33%	33%				34%		0.00	27.93	27.93	0.00	0.00	0.00	28.77	0.00
Jerry Creek	Jerry 08	1.13	2.2%	1.9%	F/G	High	**Jerry 2**	**2.04**	10.77	1.59	17.15		100%							0.00	17.15	0.00	0.00	0.00	0.00	0.00	0.00
Lost	Lost 01	1.29	18.6%	14.4%	Aa+	High	Delano 1	0.00	0.00	2.46	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lost	Lost 02	1.08	7.0%	6.5%	A	High	Lost 1	1.42	7.50	1.65	12.37		66%					34%		0.00	8.16	0.00	0.00	0.00	0.00	4.21	0.00
Lost	Lost 03	1.03	9.5%	9.2%	A	High	**Lost 1**	**1.42**	7.52	1.07	8.05	48%	52%							3.84	4.21	0.00	0.00	0.00	0.00	0.00	0.00
Lost	Lost 04	1.07	6.1%	5.7%	Ea	High	Lost 1	1.42	7.50	1.06	7.95		66%					34%		0.00	5.25	0.00	0.00	0.00	0.00	2.70	0.00
Lost	Lost 05	1.62	5.0%	3.1%	Ea	High	**Lost 2**	**3.42**	18.08	1.53	27.66		100%							0.00	27.66	0.00	0.00	0.00	0.00	0.00	0.00
Moose Creek	Moose 01	1.01			A	High	Delano 1	0.00	0.00	1.62	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moose Creek	Moose 02	1.06	7.6%	7.2%	B	High	Corral 1	1.79	9.45	1.43	13.54					66%		34%		0.00	0.00	0.00	0.00	8.94	0.00	4.61	0.00
Moose Creek	Moose 03	1.07	3.9%	3.6%	E	Mod	Sevenmile 1	8.29	43.77	1.10	48.32		33%			33%		34%		0.00	15.95	0.00	0.00	15.95	0.00	16.43	0.00
Moose Creek	Moose 04	1.16	2.9%	2.5%	F/G	Mod	Rochester 2	5.63	29.73	0.42	12.49		66%					34%		0.00	8.25	0.00	0.00	0.00	0.00	4.25	0.00
Moose Creek	Moose 05	1.14	1.0%	0.9%	E	Mod	Sawlog 2	0.38	2.01	2.86	5.74							100%		0.00	0.00	0.00	0.00	0.00	0.00	5.74	0.00
Moose Creek	Moose 06	1.03	3.1%	3.0%	B/E	Mod	Sixmile 1	3.60	19.01	0.45	8.47							100%		0.00	0.00	0.00	0.00	0.00	0.00	8.47	0.00
Moose Creek	Moose 07	1.08	1.2%	1.1%	E	Mod	Sawlog 2	0.38	2.01	1.57	3.14							100%		0.00	0.00	0.00	0.00	0.00	0.00	3.14	0.00
Moose Creek	Moose 08	1.04	10.8%	10.4%	A	Mod	Corral 1	1.79	9.45	0.93	8.78							100%		0.00	0.00	0.00	0.00	0.00	0.00	8.78	0.00
Moose Creek	Moose 09	1.10	2.0%	1.8%	E	High	Sawlog 2	0.38	2.01	1.19	2.39							100%		0.00	0.00	0.00	0.00	0.00	0.00	2.39	0.00
Moose Creek	Moose 10	1.08	3.5%	3.2%	B/E	High	Moose 1	2.76	14.57	1.06	15.39	66%						34%		10.15	0.00	0.00	0.00	0.00	0.00	5.23	0.00
Moose Creek	Moose 11	1.11	3.1%	2.8%	C/E	Mod	**Moose 1**	**2.76**	14.60	0.83	12.05	16%						84%		1.98	0.00	0.00	0.00	0.00	0.00	10.08	0.00
Moose Creek	Moose 12	1.17	1.5%	1.3%	E	High	Trapper 2	0.74	3.91	2.36	9.21		33%	33%				34%		0.00	3.04	3.04	0.00	0.00	0.00	3.13	0.00
Moose Creek	Moose 13	1.24	1.0%	0.8%	C/E	Mod	California 2	13.34	70.44	1.18	83.44	33%	33%					34%		27.54	27.54	0.00	0.00	0.00	0.00	28.37	0.00
Oregon	Oregon 01	1.08	2.7%	2.5%	B	Mod	Oregon 1	1.81	9.56	1.28	12.23	33%			33%			34%		4.04	0.00	0.00	4.04	0.00	0.00	4.16	0.00
Oregon	Oregon 02	1.02	3.4%	3.3%	G	Mon	**Oregon 1**	**1.81**	9.58	0.46	4.41		1%		56%			43%		0.00	0.03	0.00	2.48	0.00	0.00	1.90	0.00
Pattengail	Pattengail 01	1.13	7.4%	6.5%	A	High	Delano 1	0.00	0.00	3.20	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pattengail	Pattengail 02	1.09	4.5%	4.1%	A	High	Delano 1	0.00	0.00	2.49	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pattengail	Pattengail 03	1.17	2.2%	1.9%	B	High	Fishtrap 1	3.08	16.26	2.53	41.14							100%		0.00	0.00	0.00	0.00	0.00	0.00	41.14	0.00
Pattengail	Pattengail 04	1.18	4.0%	3.4%	B	High	Fishtrap 1	3.08	16.26	2.03	33.01							100%		0.00	0.00	0.00	0.00	0.00	0.00	33.01	0.00
Pattengail	Pattengail 05	2.23	0.9%	0.4%	E	Mod	Deep 1	14.72	77.72	2.09	162.44							100%		0.00	0.00	0.00	0.00	0.00	0.00	162.44	0.00
Pattengail	Pattengail 06	1.43	1.8%	1.3%	Bc	High	Fishtrap 1	3.08	16.26	0.68	11.06							100%		0.00	0.00	0.00	0.00	0.00	0.00	11.06	0.00
Pattengail	Pattengail 07	1.87	0.3%	0.1%	E	Mod	Deep 1	14.72	77.72	2.68	208.29							100%		0.00	0.00	0.00	0.00	0.00	0.00	208.29	0.00
Pattengail	Pattengail 08	2.37	0.2%	0.1%	E	High	Sawlog 2	0.38	2.01	1.86	3.73							34%	66%	0.00	0.00	0.00	0.00	0.00	0.00	1.27	2.46
Pattengail	Pattengail 09	1.24	0.2%	0.2%	F	High	Pattengail 1	1.53	8.08	0.51	4.12							34%	66%	0.00	0.00	0.00	0.00	0.00	0.00	1.40	2.72
Pattengail	Pattengail 10	1.12	1.0%	0.9%	Bc	Mod	**Pattengail 1**	**1.53**	8.09	0.62	5.01								100%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.01

Stream	Reach	Sinuosity	Valley Slope	Channel Slope	Rosgen Classification	Relative Bank Stability	Most Similar Stream Section used for Modeling Sediment Loading (Monitoring Sections in Red)	Sediment Load due to Bank Erosion per 1000 Feet (Tons/Year)	Sediment Load due to Bank Erosion per Mile (Tons/Year)	Aerial Assessment Reach Length (Miles)	Sediment Load due to Bank Erosion for Entire Aerial Assessment Reach (Tons/Year)	Sediment Source (Percent)								Sediment Load by Sediment Source (Tons/Year)							
												Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other	Transportation	Riparian grazing	Cropland	Mining	Silviculture	Irrigation - shifts in stream energy	Natural sources	Other
Rochester	Rochester 01	1.07	18.6%	17.3%	Aa+	High	Lost 1	1.42	7.50	1.57	11.77							100%		0.00	0.00	0.00	0.00	0.00	0.00	11.77	0.00
Rochester	Rochester 02	1.06	5.9%	5.5%	A	High	Lost 1	1.42	7.50	2.09	15.67		66%					34%		0.00	10.34	0.00	0.00	0.00	0.00	5.33	0.00
Rochester	Rochester 03	1.14	3.2%	2.8%	G/F	High	Rochester 1	3.41	18.00	2.73	49.15		33%		33%			34%		0.00	16.22	0.00	16.22	0.00	0.00	16.71	0.00
Rochester	Rochester 04	1.07	2.7%	2.5%	G/F	High	**Rochester 1**	**3.41**	18.00	2.19	39.41		100%							0.00	39.41	0.00	0.00	0.00	0.00	0.00	0.00
Rochester	Rochester 05	1.12	2.6%	2.3%	B	High	Rochester 1	3.41	18.00	3.84	69.14	33%	33%					34%		22.82	22.82	0.00	0.00	0.00	0.00	23.51	0.00
Rochester	Rochester 06	1.18	2.1%	1.8%	C/F	Mod	**Rochester 2**	**5.63**	29.73	2.37	70.46		54%				46%			0.00	38.10	0.00	0.00	0.00	32.36	0.00	0.00
Rochester	Rochester 07	1.12	2.7%	2.4%	C/F	High	Rochester 2	5.63	29.73	0.86	25.56			66%				34%		0.00	0.00	16.87	0.00	0.00	0.00	8.69	0.00
Sawlog Creek	Saw 01	1.02	16.2%	15.9%	A	High	Delano 1	0.00	0.00	0.61	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sawlog Creek	Saw 02	1.07	4.5%	4.2%	B/E	High	Corral 1	1.79	9.45	0.40	3.81							100%		0.00	0.00	0.00	0.00	0.00	0.00	3.81	0.00
Sawlog Creek	Saw 03	1.03	9.0%	8.7%	A	High	Corral 1	1.79	9.45	0.81	7.63							100%		0.00	0.00	0.00	0.00	0.00	0.00	7.63	0.00
Sawlog Creek	Saw 04	1.02	2.8%	2.7%	E	High	Sawlog 1	8.48	44.77	0.65	29.24							100%		0.00	0.00	0.00	0.00	0.00	0.00	29.24	0.00
Sawlog Creek	Saw 05	1.02	2.7%	2.7%	B	High	**Sawlog 1**	**8.48**	44.79	0.75	33.72		100%							0.00	33.72	0.00	0.00	0.00	0.00	0.00	0.00
Sawlog Creek	Saw 06	1.05	1.8%	1.8%	E	Mod	**Sawlog 2**	**0.38**	1.99	1.38	2.74							100%		0.00	0.00	0.00	0.00	0.00	0.00	2.74	0.00
Sevenmile	Sevenmile 01	1.08	11.9%	11.1%	Aa+	High	Corral 1	1.79	9.45	1.16	10.96							100%		0.00	0.00	0.00	0.00	0.00	0.00	10.96	0.00
Sevenmile	Sevenmile 02	1.09	6.0%	5.5%	A	Mod	Corral 1	1.79	9.45	0.73	6.90							100%		0.00	0.00	0.00	0.00	0.00	0.00	6.90	0.00
Sevenmile	Sevenmile 03	1.13	5.5%	4.9%	A	High	**Sevenmile 1**	**8.29**	43.75	1.51	66.06		19%					81%		0.00	12.43	0.00	0.00	0.00	0.00	53.63	0.00
Sevenmile	Sevenmile 04	1.11	2.8%	2.6%	E	High	Sevenmile 2	3.13	16.53	2.60	42.97		66%					34%		0.00	28.36	0.00	0.00	0.00	0.00	14.61	0.00
Sevenmile	Sevenmile 05	1.04	1.9%	1.9%	E	Mod	**Sevenmile 2**	**3.13**	16.52	0.31	5.12		100%							0.00	5.12	0.00	0.00	0.00	0.00	0.00	0.00
Sixmile	Sixmile 01	1.05	8.3%	7.9%	A	High	Corral 1	1.79	9.45	1.15	10.87							100%		0.00	0.00	0.00	0.00	0.00	0.00	10.87	0.00
Sixmile	Sixmile 02	1.07	3.8%	3.6%	E	High	Corral 1	1.79	9.45	1.22	11.53							100%		0.00	0.00	0.00	0.00	0.00	0.00	11.53	0.00
Sixmile	Sixmile 03	1.10	9.3%	8.5%	A	High	Sixmile 1	3.60	19.01	0.33	6.27							100%		0.00	0.00	0.00	0.00	0.00	0.00	6.27	0.00
Sixmile	Sixmile 04	1.05	4.5%	4.3%	A	High	**Sixmile 1**	**3.60**	19.00	0.93	17.67		71%					29%		0.00	12.46	0.00	0.00	0.00	0.00	5.21	0.00
Sixmile	Sixmile 05	1.08	3.9%	3.6%	Bc	Mod	**Sixmile 2**	**26.55**	140.19	0.62	86.92		100%							0.00	86.92	0.00	0.00	0.00	0.00	0.00	0.00
Soap	Soap 01	1.13	14.3%	12.7%	Aa+	High	Lost 1	1.42	7.50	1.00	7.50		66%					34%		0.00	4.95	0.00	0.00	0.00	0.00	2.55	0.00
Soap	Soap 02	1.06	7.6%	7.1%	A	High	**Soap 1**	**15.62**	82.50	2.28	188.10		100%							0.00	188.10	0.00	0.00	0.00	0.00	0.00	0.00
Soap	Soap 03	1.06	5.6%	5.3%	A	High	Lost 1	1.42	7.50	1.98	14.85	33%	33%					34%		4.90	4.90	0.00	0.00	0.00	0.00	5.05	0.00
Soap	Soap 04	1.15	4.9%	4.3%	F/G	Low	**Soap 2**	**3.09**	16.33	1.02	16.66		100%							0.00	16.66	0.00	0.00	0.00	0.00	0.00	0.00
Soap	Soap 05	1.08	3.3%	3.1%	G	Low	Soap 2	3.09	16.32	0.56	9.14		66%					34%		0.00	6.03	0.00	0.00	0.00	0.00	3.11	0.00
Soap	Soap 06	1.45	1.0%	0.7%	E	High	Soap 2	3.09	16.32	1.43	23.33			66%				34%		0.00	0.00	15.40	0.00	0.00	0.00	7.93	0.00
Trapper Creek	Trap 01	1.06	10.1%	9.6%	A	High	Delano 1	0.00	0.00	3.31	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trapper Creek	Trap 02	1.06	5.8%	5.5%	B	High	Delano 1	0.00	0.00	1.96	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trapper Creek	Trap 03	3.01	7.8%	2.6%	B/E	High	Moose 1	2.76	14.57	1.83	26.63							100%		0.00	0.00	0.00	0.00	0.00	0.00	26.63	0.00
Trapper Creek	Trap 04	1.57	11.2%	7.2%	B	High	Moose 1	2.76	14.57	2.56	37.29							100%		0.00	0.00	0.00	0.00	0.00	0.00	37.29	0.00
Trapper Creek	Trap 05	1.06	3.0%	2.8%	B	Mod	**Trapper 1**	**9.21**	48.63	2.94	143.05		91%						9%	0.00	129.90	0.00	0.00	0.00	0.00	0.00	13.14
Trapper Creek	Trap 06	1.06	1.7%	1.6%	B/E	Mod	**Trapper 2**	**0.74**	3.93	1.24	4.87		100%							0.00	4.87	0.00	0.00	0.00	0.00	0.00	0.00
Trapper Creek	Trap 07	1.16	2.2%	1.9%	E	Mod	Trapper 2	0.74	3.91	3.55	13.86	22%	22%	22%				34%		3.05	3.05	3.05	0.00	0.00	0.00	4.71	0.00
Willow Creek	Willow 01	1.08	8.9%	8.3%	A	High	Delano 1	0.00	0.00	3.56	0.00							100%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Willow Creek	Willow 02	1.08	5.9%	5.4%	A/B	High	Birch 1	5.38	28.41	3.34	94.91					66%		34%		0.00	0.00	0.00	0.00	62.64	0.00	32.27	0.00
Willow Creek	Willow 03	1.06	3.2%	3.0%	B	High	**Willow 1**	**14.27**	75.36	1.99	150.13							48%	52%	0.00	0.00	0.00	0.00	0.00	0.00	72.69	77.44
Willow Creek	Willow 04	1.07	5.5%	5.2%	F/G	Mod	Moose 1	2.76	14.57	1.71	24.99		66%					34%		0.00	16.49	0.00	0.00	0.00	0.00	8.50	0.00
Willow Creek	Willow 05	1.08	2.5%	2.3%	B	High	Moose 1	2.76	14.57	2.56	37.25							100%		0.00	0.00	0.00	0.00	0.00	0.00	37.25	0.00
Willow Creek	Willow 06	1.09	3.6%	3.3%	B	High	Jerry 2	2.04	10.77	3.74	40.33							100%		0.00	0.00	0.00	0.00	0.00	0.00	40.33	0.00
Willow Creek	Willow 07	1.19	2.2%	1.8%	C	Mod	Birch 3	9.77	51.59	2.51	129.48	22%	22%	22%				34%		28.48	28.48	28.48	0.00	0.00	0.00	44.02	0.00
Willow Creek	Willow 08	1.24	0.6%	0.5%	F	Mod	Birch 3	9.77	51.59	2.16	111.31		33%	33%				34%		0.00	36.73	36.73	0.00	0.00	0.00	37.84	0.00

APPENDIX F
TOTAL MAXIMUM DAILY LOADS

F.1 SEDIMENT

F.1.1 Overview

A percent reduction approach was used for the sediment TMDLs within this document because there is uncertainty associated with the loads derived from the source assessment, and using the estimated sediment loads creates a rigid perception that the loads are absolutely conclusive. However, because daily loads are a required product of TMDL development and percent reductions are most relevant at an annual scale, loads within this appendix are expressed as daily loads. Daily loads should not be considered absolutely conclusive and may be refined in the future as part of the adaptive management process. The TMDLs may not be feasible at all in locations within the watershed, but if the allocations are followed, sediment loads are expected to be reduced to a degree that the sediment targets are met and beneficial uses are no longer impaired.

F.1.2 Approach

The average annual sediment loads determined from source assessments (**Section 5.0**) were used, along with historical flow and suspended sediment data from the Big Hole River, to determine average daily sediment loads for water bodies in the Middle and Lower Big Hole TPA. A sediment rating curve was developed using daily flow and suspended solids load data collected from 1960 through 1964 at the USGS gage on the Big Hole River near Melrose, MT (Station 6025500) (**Figure F-1**). The gage near Melrose was selected based on its period of record (1923-current) and amount of suspended solids data.

The daily mean discharge based on 84 years of record (1923-2007) at the USGS gage was then plugged into the equation for the sediment rating curve to get a daily suspended sediment load. The suspended sediment load is only a fraction of the total load from the source assessment, but provides an approximation of the relationship between sediment and flow in the Big Hole River. Based on the sum of the calculated daily sediment loads, a daily percentage relative to the annual suspended sediment load was calculated for each day. The daily percentages were then applied to the total average annual loads associated with the TMDL percent reductions from **Section 5.0** to determine the average daily load. To conserve resources, this appendix contains daily loads for the Wise River as an example. As discussed in **Section 5.6.26**, the TMDL for the Wise River is a 34 percent reduction in the total average annual sediment load, which is roughly equivalent to 9,358 tons/year. The daily percentages discussed above were then multiplied by the annual load of 9,358 tons to get a daily expression of the Wise River TMDL (**Figure F-2, Table F-1**). Although the relationship between sediment and flow is likely different within the 303(d) Listed tributaries in the Middle and Lower Big Hole Watershed than in the Big Hole River, it was used to determine average daily loads because it is the best available data and TMDL implementation activities will not be driven by the daily loads. The daily loads are a composite of the allocations, but as allocations are not feasible on a daily basis, they are not contained within this appendix. If desired, daily allocations may be obtained by applying allocations provided in **Section 5.6** to the daily load. Daily loads for all other TMDLs may be derived by using the daily percentages in **Table F-1** and the TMDLs expressed as an average annual load, which are discussed in **Section 5.6** and also provided in **Table F-2**.

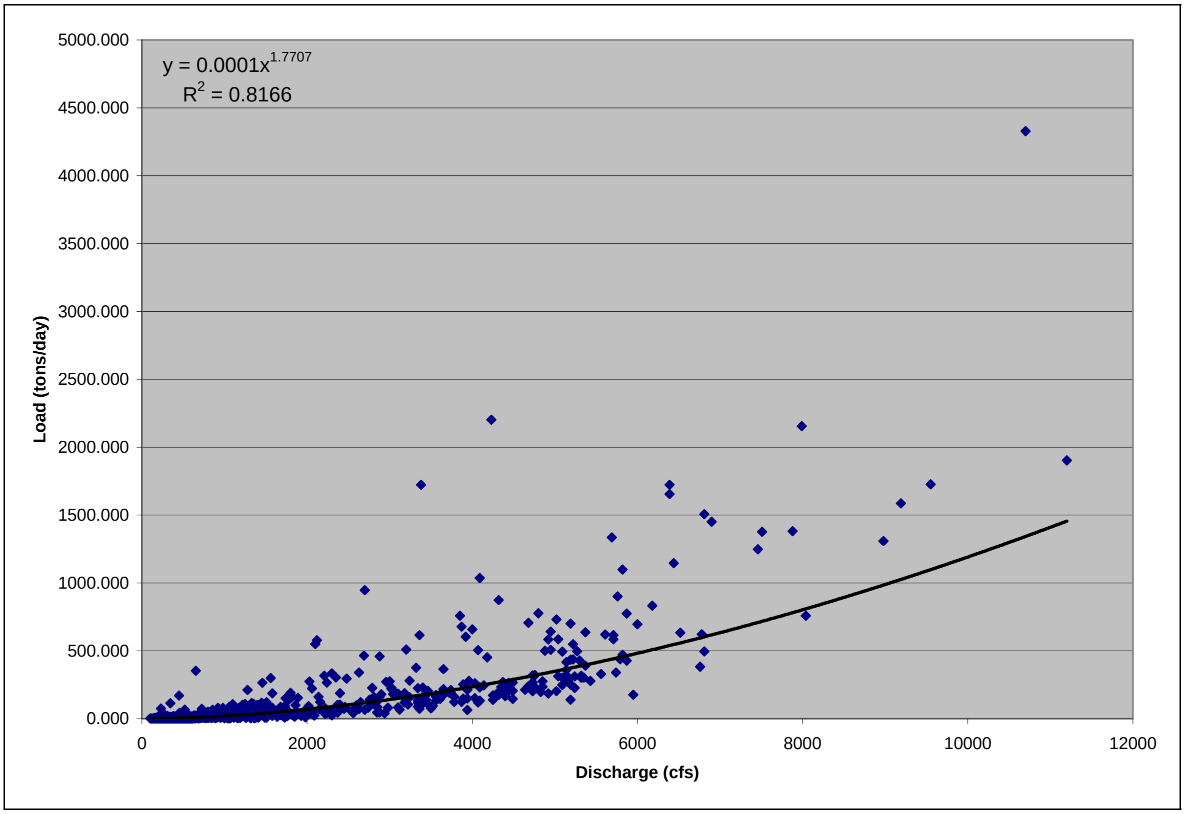


Figure F-1. Sediment Rating Curve for the Big Hole River

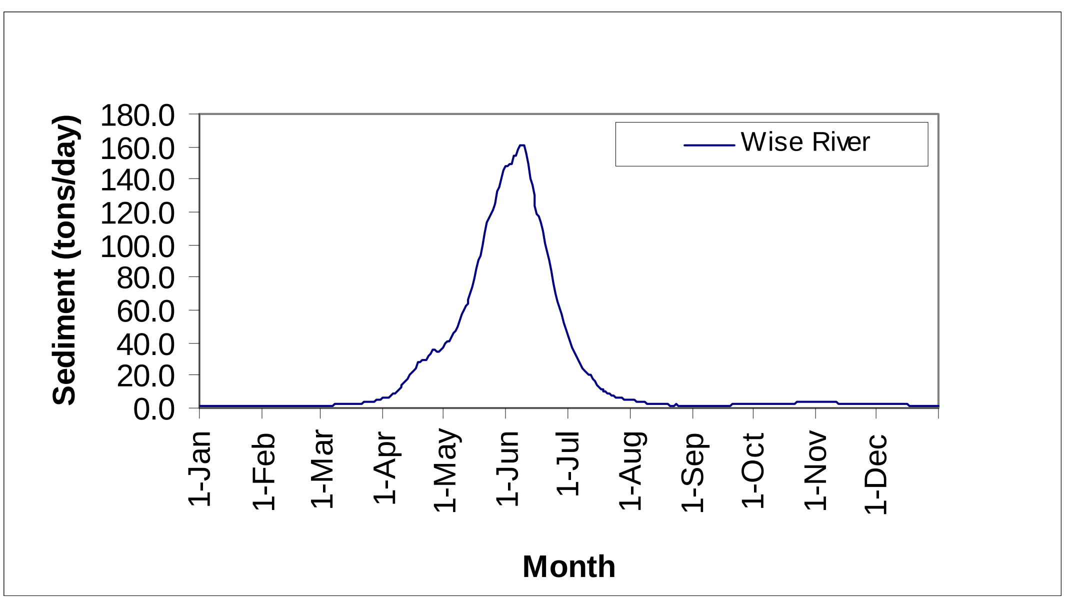


Figure F-2. Average Daily Sediment Load for the Wise River

Table F-1. Daily Sediment TMDL for the Wise River.

Month	Day	Daily % of annual load	Wise River TMDL (tons/day)	Month	Day	Daily % of annual load	Wise River TMDL (tons/day)
Jan	1	0.02%	2.0	Feb	17	0.02%	2.0
Jan	2	0.02%	2.0	Feb	18	0.02%	2.0
Jan	3	0.02%	2.0	Feb	19	0.02%	2.0
Jan	4	0.02%	1.9	Feb	20	0.02%	2.0
Jan	5	0.02%	1.9	Feb	21	0.02%	2.0
Jan	6	0.02%	1.9	Feb	22	0.02%	2.1
Jan	7	0.02%	1.9	Feb	23	0.02%	2.1
Jan	8	0.02%	1.9	Feb	24	0.02%	2.1
Jan	9	0.02%	1.9	Feb	25	0.02%	2.1
Jan	10	0.02%	1.9	Feb	26	0.02%	2.2
Jan	11	0.02%	1.9	Feb	27	0.02%	2.2
Jan	12	0.02%	1.9	Feb	28	0.02%	2.1
Jan	13	0.02%	1.9	Feb	29	0.02%	2.1
Jan	14	0.02%	1.9	Mar	1	0.02%	2.1
Jan	15	0.02%	1.9	Mar	2	0.02%	2.1
Jan	16	0.02%	1.9	Mar	3	0.02%	2.1
Jan	17	0.02%	1.9	Mar	4	0.02%	2.1
Jan	18	0.02%	1.8	Mar	5	0.02%	2.1
Jan	19	0.02%	1.8	Mar	6	0.02%	2.2
Jan	20	0.02%	1.8	Mar	7	0.02%	2.3
Jan	21	0.02%	1.8	Mar	8	0.02%	2.3
Jan	22	0.02%	1.8	Mar	9	0.03%	2.4
Jan	23	0.02%	1.8	Mar	10	0.03%	2.5
Jan	24	0.02%	1.8	Mar	11	0.03%	2.5
Jan	25	0.02%	1.8	Mar	12	0.03%	2.7
Jan	26	0.02%	1.8	Mar	13	0.03%	2.7
Jan	27	0.02%	1.8	Mar	14	0.03%	2.8
Jan	28	0.02%	1.8	Mar	15	0.03%	2.9
Jan	29	0.02%	1.8	Mar	16	0.03%	3.1
Jan	30	0.02%	1.8	Mar	17	0.04%	3.3
Jan	31	0.02%	1.9	Mar	18	0.04%	3.4
Feb	1	0.02%	1.9	Mar	19	0.04%	3.5
Feb	2	0.02%	2.0	Mar	20	0.04%	3.6
Feb	3	0.02%	1.9	Mar	21	0.04%	3.7
Feb	4	0.02%	1.9	Mar	22	0.04%	3.8
Feb	5	0.02%	1.9	Mar	23	0.04%	4.1
Feb	6	0.02%	2.0	Mar	24	0.04%	4.2
Feb	7	0.02%	2.0	Mar	25	0.05%	4.3
Feb	8	0.02%	2.0	Mar	26	0.05%	4.5
Feb	9	0.02%	2.1	Mar	27	0.05%	4.8
Feb	10	0.02%	2.0	Mar	28	0.06%	5.6
Feb	11	0.02%	2.0	Mar	29	0.07%	6.4
Feb	12	0.02%	2.0	Mar	30	0.07%	6.6
Feb	13	0.02%	1.9	Mar	31	0.07%	6.9
Feb	14	0.02%	1.9	Apr	1	0.08%	7.2
Feb	15	0.02%	1.9	Apr	2	0.08%	7.7
Feb	16	0.02%	1.9	Apr	3	0.08%	7.8

Table F-1. Daily Sediment TMDL for the Wise River.

Month	Day	Daily % of annual load	Wise River TMDL (tons/day)	Month	Day	Daily % of annual load	Wise River TMDL (tons/day)
Apr	4	0.09%	8.7	May	21	1.36%	127.1
Apr	5	0.10%	9.8	May	22	1.44%	134.4
Apr	6	0.12%	10.9	May	23	1.46%	136.9
Apr	7	0.13%	12.4	May	24	1.50%	140.0
Apr	8	0.15%	13.9	May	25	1.52%	142.6
Apr	9	0.17%	15.8	May	26	1.58%	148.3
Apr	10	0.18%	17.1	May	27	1.67%	156.1
Apr	11	0.20%	18.6	May	28	1.70%	159.5
Apr	12	0.22%	20.2	May	29	1.78%	166.2
Apr	13	0.23%	21.6	May	30	1.84%	172.3
Apr	14	0.25%	23.6	May	31	1.87%	175.1
Apr	15	0.28%	25.9	Jun	1	1.87%	175.1
Apr	16	0.30%	27.8	Jun	2	1.88%	175.8
Apr	17	0.31%	29.3	Jun	3	1.88%	175.8
Apr	18	0.35%	32.6	Jun	4	1.95%	182.8
Apr	19	0.35%	32.9	Jun	5	1.95%	182.8
Apr	20	0.36%	34.0	Jun	6	2.00%	187.1
Apr	21	0.38%	35.3	Jun	7	2.04%	190.6
Apr	22	0.38%	35.3	Jun	8	2.04%	190.6
Apr	23	0.40%	37.4	Jun	9	2.03%	189.9
Apr	24	0.43%	39.9	Jun	10	1.96%	183.5
Apr	25	0.45%	42.2	Jun	11	1.89%	176.5
Apr	26	0.45%	42.5	Jun	12	1.78%	166.2
Apr	27	0.44%	41.0	Jun	13	1.73%	161.5
Apr	28	0.43%	40.7	Jun	14	1.65%	154.2
Apr	29	0.45%	42.2	Jun	15	1.56%	145.7
Apr	30	0.47%	43.7	Jun	16	1.50%	140.7
May	1	0.50%	46.7	Jun	17	1.48%	138.2
May	2	0.51%	47.5	Jun	18	1.43%	133.8
May	3	0.52%	48.7	Jun	19	1.37%	128.3
May	4	0.55%	51.5	Jun	20	1.27%	118.8
May	5	0.58%	54.0	Jun	21	1.21%	113.5
May	6	0.60%	56.1	Jun	22	1.15%	107.3
May	7	0.62%	58.2	Jun	23	1.06%	99.0
May	8	0.67%	63.0	Jun	24	0.97%	90.5
May	9	0.73%	68.0	Jun	25	0.89%	82.9
May	10	0.76%	71.2	Jun	26	0.82%	76.5
May	11	0.79%	73.6	Jun	27	0.77%	71.7
May	12	0.80%	75.0	Jun	28	0.72%	67.5
May	13	0.83%	77.9	Jun	29	0.66%	61.7
May	14	0.89%	82.9	Jun	30	0.62%	57.8
May	15	0.93%	87.4	Jul	1	0.56%	52.3
May	16	1.01%	94.2	Jul	2	0.52%	48.3
May	17	1.08%	101.2	Jul	3	0.47%	44.0
May	18	1.15%	107.3	Jul	4	0.43%	40.7
May	19	1.18%	110.7	Jul	5	0.41%	38.1
May	20	1.26%	118.2	Jul	6	0.37%	34.3

Table F-1. Daily Sediment TMDL for the Wise River.

Month	Day	Daily % of annual load	Wise River TMDL (tons/day)	Month	Day	Daily % of annual load	Wise River TMDL (tons/day)
Jul	7	0.33%	31.0	Aug	22	0.02%	2.2
Jul	8	0.31%	29.0	Aug	23	0.02%	2.2
Jul	9	0.29%	27.5	Aug	24	0.02%	2.3
Jul	10	0.28%	25.9	Aug	25	0.02%	2.2
Jul	11	0.26%	24.4	Aug	26	0.02%	2.2
Jul	12	0.25%	23.6	Aug	27	0.02%	2.1
Jul	13	0.23%	21.3	Aug	28	0.02%	2.0
Jul	14	0.21%	19.4	Aug	29	0.02%	1.9
Jul	15	0.19%	17.3	Aug	30	0.02%	1.9
Jul	16	0.17%	15.6	Aug	31	0.02%	1.9
Jul	17	0.15%	14.2	Sep	1	0.02%	1.8
Jul	18	0.14%	13.2	Sep	2	0.02%	1.8
Jul	19	0.13%	12.4	Sep	3	0.02%	1.8
Jul	20	0.13%	12.0	Sep	4	0.02%	1.7
Jul	21	0.12%	11.2	Sep	5	0.02%	1.7
Jul	22	0.11%	10.6	Sep	6	0.02%	1.7
Jul	23	0.10%	9.8	Sep	7	0.02%	1.7
Jul	24	0.10%	8.9	Sep	8	0.02%	1.8
Jul	25	0.09%	8.2	Sep	9	0.02%	1.9
Jul	26	0.08%	7.7	Sep	10	0.02%	1.9
Jul	27	0.08%	7.4	Sep	11	0.02%	1.8
Jul	28	0.07%	6.9	Sep	12	0.02%	1.9
Jul	29	0.07%	6.6	Sep	13	0.02%	1.9
Jul	30	0.07%	6.3	Sep	14	0.02%	1.9
Jul	31	0.07%	6.3	Sep	15	0.02%	1.9
Aug	1	0.06%	6.1	Sep	16	0.02%	1.9
Aug	2	0.06%	5.7	Sep	17	0.02%	2.0
Aug	3	0.06%	5.4	Sep	18	0.02%	2.0
Aug	4	0.05%	5.1	Sep	19	0.02%	2.1
Aug	5	0.05%	4.8	Sep	20	0.02%	2.3
Aug	6	0.05%	4.5	Sep	21	0.03%	2.4
Aug	7	0.04%	4.1	Sep	22	0.03%	2.4
Aug	8	0.04%	3.8	Sep	23	0.03%	2.4
Aug	9	0.04%	3.5	Sep	24	0.03%	2.4
Aug	10	0.04%	3.3	Sep	25	0.03%	2.4
Aug	11	0.03%	3.2	Sep	26	0.03%	2.4
Aug	12	0.03%	3.1	Sep	27	0.03%	2.5
Aug	13	0.03%	2.9	Sep	28	0.03%	2.5
Aug	14	0.03%	2.8	Sep	29	0.03%	2.6
Aug	15	0.03%	2.7	Sep	30	0.03%	2.7
Aug	16	0.03%	2.6	Oct	1	0.03%	2.8
Aug	17	0.03%	2.5	Oct	2	0.03%	2.8
Aug	18	0.03%	2.4	Oct	3	0.03%	2.9
Aug	19	0.02%	2.3	Oct	4	0.03%	3.0
Aug	20	0.02%	2.2	Oct	5	0.03%	3.0
Aug	21	0.02%	2.2	Oct	6	0.03%	3.0

Table F-1. Daily Sediment TMDL for the Wise River.

Month	Day	Daily % of annual load	Wise River TMDL (tons/day)	Month	Day	Daily % of annual load	Wise River TMDL (tons/day)
Oct	7	0.03%	3.1	Nov	22	0.03%	3.0
Oct	8	0.03%	3.1	Nov	23	0.03%	2.9
Oct	9	0.03%	3.1	Nov	24	0.03%	2.9
Oct	10	0.03%	3.2	Nov	25	0.03%	3.1
Oct	11	0.03%	3.2	Nov	26	0.03%	3.1
Oct	12	0.04%	3.3	Nov	27	0.03%	2.9
Oct	13	0.04%	3.4	Nov	28	0.03%	2.8
Oct	14	0.04%	3.4	Nov	29	0.03%	2.8
Oct	15	0.04%	3.5	Nov	30	0.03%	2.7
Oct	16	0.04%	3.6	Dec	1	0.03%	2.8
Oct	17	0.04%	3.6	Dec	2	0.03%	2.9
Oct	18	0.04%	3.6	Dec	3	0.03%	2.9
Oct	19	0.04%	3.6	Dec	4	0.03%	2.8
Oct	20	0.04%	3.6	Dec	5	0.03%	2.6
Oct	21	0.04%	3.7	Dec	6	0.03%	2.5
Oct	22	0.04%	3.8	Dec	7	0.03%	2.4
Oct	23	0.04%	3.9	Dec	8	0.02%	2.3
Oct	24	0.04%	3.9	Dec	9	0.03%	2.4
Oct	25	0.04%	3.9	Dec	10	0.03%	2.4
Oct	26	0.04%	4.0	Dec	11	0.03%	2.5
Oct	27	0.04%	4.0	Dec	12	0.03%	2.4
Oct	28	0.04%	4.0	Dec	13	0.03%	2.4
Oct	29	0.04%	3.9	Dec	14	0.03%	2.3
Oct	30	0.04%	3.9	Dec	15	0.03%	2.3
Oct	31	0.04%	3.9	Dec	16	0.02%	2.3
Nov	1	0.04%	3.9	Dec	17	0.02%	2.2
Nov	2	0.04%	3.8	Dec	18	0.02%	2.1
Nov	3	0.04%	3.9	Dec	19	0.02%	2.1
Nov	4	0.04%	4.0	Dec	20	0.02%	2.1
Nov	5	0.04%	3.9	Dec	21	0.02%	2.1
Nov	6	0.04%	4.0	Dec	22	0.02%	2.1
Nov	7	0.04%	4.0	Dec	23	0.02%	2.2
Nov	8	0.04%	4.0	Dec	24	0.02%	2.2
Nov	9	0.04%	4.0	Dec	25	0.02%	2.1
Nov	10	0.04%	3.9	Dec	26	0.02%	2.1
Nov	11	0.04%	3.8	Dec	27	0.02%	2.2
Nov	12	0.04%	3.7	Dec	28	0.02%	2.1
Nov	13	0.04%	3.7	Dec	29	0.02%	2.0
Nov	14	0.04%	3.6	Dec	30	0.02%	2.0
Nov	15	0.04%	3.6	Dec	31	0.02%	2.0
Nov	16	0.04%	3.5				
Nov	17	0.04%	3.5				
Nov	18	0.04%	3.5				
Nov	19	0.04%	3.4				
Nov	20	0.03%	3.2				
Nov	21	0.03%	3.1				

Table F-2. Sediment TMDLs expressed as an average annual load (tons/year).

Stream Segment	Water Body #	TMDL expressed as average annual load (tons/year)
Big Hole River between Divide Cr and Pintlar Cr (Middle segment)	MT41D001_020	137,984
Birch Creek headwaters to the National Forest Boundary	MT41D002_090	1,749
Birch Creek from National Forest Boundary to mouth (Big Hole R)	MT41D002_100	3,010
California Creek from headwaters to mouth (French Cr-Deep Cr)	MT41D003_070	907
Camp Creek from headwaters to mouth (Big Hole R)	MT41D002_020	2,464
Corral Creek from headwaters to mouth (Deep Cr)	MT41D003_130	341
Deep Creek from headwaters to mouth (Big Hole R)	MT41D003_040	7,647
Delano Creek from headwaters to mouth (Jerry Cr)	MT41D003_030	107
Divide Creek from headwaters to mouth (Big Hole R)	MT41D002_040	4,210
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	MT41D003_220	383
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	MT41D003_160	2,649
French Creek headwaters to mouth (Deep Creek)	MT41D003_050	2,928
Gold Creek from headwaters to mouth (Wise R)	MT41D003_230	592
Grose Creek from headwaters to mouth (Big Hole R)	MT41D002_060	174
Jerry Creek from headwaters to mouth (Big Hole R)	MT41D003_020	2,159
Lost Creek in the Lower Big Hole Watershed	MT41D002_180	584
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock)	MT41D002_050	1,778
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	MT41D003_080	131
Pattengail Creek from headwaters to mouth (Wise R)	MT41D003_210	2,412
Rochester Creek from headwaters to mouth (Big Hole R)	MT41D002_160	1,555
Sawlog Creek tributary to Big Hole R	MT41D004_230	307
Sevenmile Creek from headwaters to mouth (Deep Cr)	MT41D003_110	384
Sixmile Creek from headwaters to mouth (California Cr)	MT41D003_090	401
Soap Creek from headwaters to mouth (Big Hole R)	MT41D002_140	1,011
Trapper Creek from headwaters to mouth (Big Hole R)	MT41D002_010	2,589
Wise River from headwaters to mouth (Big Hole R)	MT41D003_200	9,358

F.2 TEMPERATURE DAILY TMDLS AND INSTANTANEOUS TEMPERATURE LOADS

The temperature TMDLs are the sum of waste load allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources (**Equation F-1**). Although there are no point sources in this watershed and therefore are no WLAs. In addition, the TMDL includes a margin of safety (MOS) that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving stream.

Equation F-1.

$$TMDL = \Sigma WLA + \Sigma LA + MOS.$$

Where:

ΣWLA = Waste Load Allocation = Pollutants from NPDES Point Sources
ΣLA = Load Allocation = Pollutants from Nonpoint Sources + Natural Sources
MOS = Margin of Safety

Total maximum daily loads are based on the loading of a pollutant to a water body. Federal Codes indicate that for each thermally listed water body the total maximum daily thermal load cannot be exceeded in order to assure protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife. Such estimates shall take into account the water temperatures, flow rates, seasonal variations, existing sources of heat input, and the dissipative capacity of the identified waters. The following approach for setting numeric temperature TMDLs considers all of the factors listed above.

The numeric daily thermal loads (TMDLs) and instantaneous thermal load (ITLs) presented in this appendix apply to all portions of the temperature impaired waters in Middle and Lower Big Hole River TMDL Planning Areas. This appendix provides daily and instantaneous heat loading limits for the middle and lower segments of Big Hole River and Divide Creek. All waters in this planning area are classified as A-1 or B-1. Montana's temperature standard for A-1 or B-1 water body classifications are depicted in **Figure F-3**.

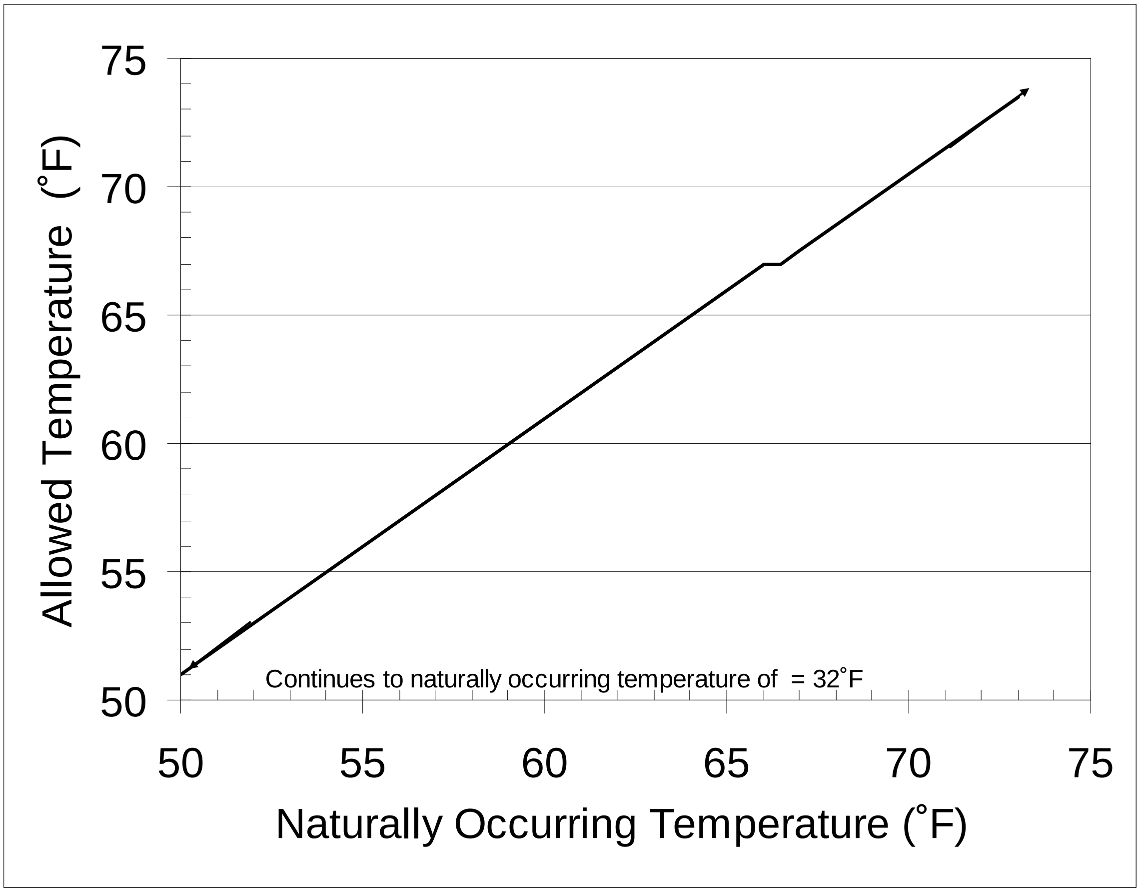


Figure F-3. In-stream Temperatures Allowed by Montana's A-1 and B-1 Classification Temperature Standard

F.2.1 Daily Thermal Load

The allowed temperature can be calculated using Montana's A-1 classification temperature standards (**Figure F-3**) and using a modeled or estimated naturally occurring daily average temperature. The daily average total maximum load at any location in the water body is provided **Equation F-2**. The daily allowable loading is expressed as the allowable loading to the liquid form of the water in the stream. This is defined as the kilocalorie increase associated with the warming of the water from 32°F to the temperature that represents compliance with Montana's temperature standard as determined from **Figure F-3**.

Equation F-2

$$(\Delta-32)*(Q)*(1.36*10^{6}) = TMDL$$

Where:

Δ = allowed temperatures from **Figure F-3** using daily temperature condition
Q = average daily discharge in cubic feet per second (CFS)
TMDL = daily TMDL in Calories (kilocalories) per day above water's melting point
Conversion factor = 1359209

There are no point sources that increase water temperatures, and therefore, no wasteload allocations for the watershed. The TMDL load allocation for each stream is a combination of the ½ °F allowable loading shared between the human caused sources without reasonable land, soil, and water conservation practices in addition to the naturally occurring loading as defined in state law. Because temperatures are estimated to be naturally above 66 °F at times, one-half degree allowable increase in temperature is used for the TMDL and allocations. See the main document for more information about surrogate allocations, which are more applicable to restoration approaches. The surrogate allocations should meet the daily thermal load. The daily numeric TMDL allocation is equal to the load allocation shared by all human-caused sources without reasonable land, soil, and water conservation practices plus the load allocated to naturally occurring temperatures as shown in **Equation F-3**.

Equation F-3

Load Allocation = Allowable Human Sources + Naturally Occurring Thermal Loads

Where:

Naturally Occurring Thermal Loads = (Naturally Occurring Temperature (°F) from Modeling Scenarios -32)*(Discharge (CFS))*($1.36*10^6$)

Allowable Human Sources above naturally occurring conditions = (1/2°F)*($1.36*10^6$)*(Discharge (CFS))

F.2.2 Instantaneous Thermal Load

Because of the dynamic temperature conditions during the course of a day, an instantaneous thermal load (ITL) is also provided for temperature. For temperature, the daily average thermal conditions are not always an effective indicator of impairment to fisheries. The heat of the day is usually the most stressful timeframe for salmonids and char. Also, in high altitudes, thermal impacts that heat during the day may produce advanced cooling conditions during the night so that the daily temperature fluctuations increase greatly, with potentially significant negative impacts to fish without much impact on daily average temperature conditions. Therefore, Montana provides an instantaneous thermal load to protect during the hottest timeframes in mid to late afternoon when temperatures are most stressful to the fishery, which is the most sensitive use in reference to thermal conditions.

The instantaneous load is computed by the second. The allowed temperature can be calculated using Montana’s A-1 or B-1 classification temperature standards (**Figure F-3**) and using a modeled or estimated naturally occurring instantaneous temperature. The instantaneous total maximum load (per second) at any location in the water body is provided by **Equation F-4**. The allowable loading over a second is expressed as the allowable loading to the liquid form of the water in the stream. This is defined as the kCal increase associated with the warming of the water from 32°F to the temperature that represents compliance with Montana's temperature standard as determined from **Figure F-3**.

Equation F-4

(Δ-32)*(Q)*(15.73) = Instantaneous Thermal Load (ITL)

Where:

Δ = allowed temperatures from **Figure F-3** using daily temperature condition
Q = instantaneous discharge in CFS
ITL = Allowed thermal load per second in kilocalories per day above water's melting point
Conversion factor = 15.73

There are no point sources that increase water temperatures, and therefore, no instantaneous wasteload allocations for the watershed. The ITL load allocation for each stream is a combination of the 1/2°F allowable loading shared between the human caused sources without reasonable land, soil, and water conservation practices in addition to the naturally occurring loading as defined in state law. Because temperatures are estimated to be naturally above 66 °F at times, one-half degree allowable increase in temperature is used for the TMDL and allocations. See the main document for more information about surrogate allocations, which are more applicable to restoration approaches. The surrogate allocations should meet the ITL. The ITL allocation is equal to the load allocation shared by all human caused sources without reasonable land, soil and water conservation practices plus the load allocated to naturally occurring temperatures as shown in **Equation F-5**.

Equation F-5

Load Allocation = Allowable Human Sources + Naturally Occurring Thermal Loads

Where:

Naturally Occurring Thermal Loads = (Naturally Occurring Temperature (°F) from Modeling Scenarios -32)*(Discharge (CFS))*(15.73)

Allowable Human Sources above naturally occurring conditions = (1/2°F)*(15.73)*(Discharge (CFS))

F.2.3 Margins of Safety, Seasonal Variations and Future Sources

See **Section 7** of the main document for this discussion.

F.2.4 Example Numeric TMDL Application for the Big Hole River above Pintlar Creek

Big Hole River Daily Thermal Load Example Application

Monitoring along with Heatsource and SNTEMP (Stream Network Temperature Model) models were completed on the Big Hole River and Divide Creek (**Appendices I and J**). Modeling scenarios used reference riparian shade conditions throughout the watershed along with an estimated increase of 15 percent irrigation efficiency increase during warm summer months to estimate naturally occurring temperatures where all reasonable land, soil, and water conservation practices are in place with existing land use. Naturally occurring average daily temperature at the Big Hole River's confluence with Pintlar Creek during a hot day of summer 2006 was estimated at 67.3°F using SNTEMP modeling. This temperature is then used to determine the allowable temperature according to **Figure F-3**, Montana's temperature standard. The allowable mean daily temperature is estimated at 67.8°F during the hottest days of the summer. **Equation F-2** from above is used to calculate the upper portion of the Middle segment Big Hole River TMDL during the hottest days of the summer. This location was one of the most heavily impacted thermal areas found along the Middle Segment of the Big Hole River during the source assessment.

Example:

$(\Delta\text{-}32)*(Q)*(1.36*10^6) = \text{TMDL}$

Where:

Δ = allowed temperatures from **Figure F-3** using daily temperature condition = **67.8°F**
Q = average daily discharge in cubic feet per second (CFS) = **101cfs**
TMDL = daily TMDL in Calories (kilocalories) per day above water's melting point = **$4.92*10^9$ kilocal/day**

The Upper Big Hole River load allocation to human caused heat sources not addressed by reasonable land, soil, and water conservation practices for the TMDL is $6.87*10^7$ kilocalories per day. The remainder of the TMDL is appropriated to naturally occurring thermal load. Since there are no NPDES permits that affect water temperature, there is zero waste load allocation. During warm summer days the mean daily temperature of this site exceeds the average daily TMDL. Similar exorcises could be completed for the middle reaches of Divide Creek and the lower reaches lower section of the Big Hole River, but these examples are not provided because they lack utility.

Big Hole River Instantaneous Thermal Load

The instantaneous thermal load (ITL) is described as the heat passing a monitoring location per second. The most sensitive timeframe for the fishery occurs during the heat of the day for the hottest period of the year. The same modeling described earlier in this appendix was used to model daily maximum temperatures. The naturally occurring daily maximum temperature in the Big Hole River near Pintlar Creek's confluence during one of the hottest days of summer 2006 was estimated at 73.5°F using a SNTEMP model. This temperature is then used to determine the allowable temperature according to **Figure F-3**, Montana's temperature standard. Therefore, the allowable maximum temperature during this timeframe is estimated at 74.0°F during a hot summer day. **Equation F-4** from above is used to calculate the upper portion of the Middle Big Hole River's ITL during one of the hottest days of the summer.

Example:

(Δ-32)*(Q)*(15.73) = Instantaneous Thermal Load (ITL)

Where:
Δ = allowed temperatures from **Figure F-3** using instantaneous temperature condition = **74.0°F**
Q = average daily discharge in cubic feet per second (CFS) = **101cfs**
ITL = Allowed thermal load per second in kilocalories per day above water's melting point = **66,700 kilocal/second**

The Middle Big Hole River's load allocation to human caused heat sources not addressed by reasonable land, soil, and water conservation practices for the ITL is 794 kilocalories per second. Since there are no NPDES permits that affect water temperature, there is zero waste load allocation. The remainder of the load allocation for the ITL is apportioned to naturally occurring thermal loading. During the hottest days of the summer the ITL is greatly surpassed in the Big Hole River near the confluence with Pintlar Creek (near the upstream limit of the middle Big Hole River Segment). This is the most heavily impacted reach of the Big Hole River regarding thermal impacts. This indicates that Montana's temperature standard at this site is not being met during an important timeframe for the most sensitive use. Similar exorcises could be completed for the middle reaches of Divide Creek and the lower reaches lower section of the Big Hole River and the ITL would be exceeded, but these examples are not provided because they lack utility. Any measured location on the temperature impaired streams could apply to the ITL.

APPENDIX G
BIG HOLE RIVER WATERSHED NUTRIENT TMDL GWLF MODELING DOCUMENTATION

K. Flynn and D. Kron
TMDL Technical Report DMS-2008-10

DOCUMENT PURPOSE

This document has been prepared to support nutrient source assessments and loading estimates for the Big Hole River Watershed Nutrient TMDL. It is intended to provide a brief synopsis of the project and substantiate numerical estimates of nitrogen and phosphorus delivery in the watershed. Work has been completed cooperatively by the Water Quality Modeling and Planning Sections of the Montana Department of Environmental Quality.

LIST OF ACRONYMS

ACRONYM	
AMC	Antecedent Moisture Condition
AU	Animal Units
AUM	Animal Units per Month
ARM	Administrative Rules of Montana
AWC	Available Water Capacity
BMPs	Best Management Practices
CN	Curve Number
CMPPCT	Composition Percentage
CN	Curve Number
COOP	Cooperative Observer
CWA	Clean Water Act
CWAIC	Clean Water Act Information Center
DEQ	Montana Department of Environmental Quality
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GRTS	Grants Reporting and Tracking System
GWLF	Generalized Watershed Loading Functions
HUC	Hydrologic Unit Code
K	Soil Erodibility Factor
LULC	Land Use/Land Cover
MOS	Margin of Safety
MUID	Map Unit ID
N	Nitrogen
NRCS	Natural Resource Conservation Service
NED	National Elevation Datum
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NO2+NO3	Nitrate plus Nitrite
NPS	Nonpoint Source
NURP	Nationwide Urban Runoff Program
NWIS	National Water Information System
P	Phosphorus
SCS	Soil Conservation Service
SDR	Sediment Delivery Ratio
SNOTEL	Snow Telemetry System
SRP	Soluble Reactive Phosphorus
SSC	Suspended Sediment Concentration
STATSGO	State Soil Geographic Database
STORET	Storage and Retrieval Water Quality Database
TN	Total Nitrogen
TP	Total Phosphorus

TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation

TABLE OF CONTENTS

TABLE **PAGE**

List of Figures ... G-9
List of Tables ... G-11
Section 1.0 Introduction ... G-15
1.1 Previous Studies ... G-16
1.2 Nutrient Criteria in Montana (ARM 17.30.637) ... G-16
Section 2.0 Study Area ... G-19
2.1 Climate ... G-19
2.2 Streamflow ... G-19
2.3 Land Use ... G-20
2.4 Soil ... G-20
Section 3.0 Data Compilation & Assessment ... G-23
3.1 Flow ... G-23
3.2 Chemistry ... G-24
3.3 Data Assessment ... G-24
Section 4.0 Modeling Approach ... G-29
Section 5.0 GWLF Model Development ... G-31
5.1 GWLF Model Description ... G-31
5.2 GIS Pre-processing ... G-31
5.3 Climate Input ... G-31
5.4 Water Balance/Hydrologic Input ... G-32
5.5 Sediment Input ... G-35
5.6 Nutrient Input ... G-35
5.7 Model Calibration-Validation ... G-37
5.8 Model Evaluation Criteria ... G-37
5.9 Model Sensitivity/Uncertainty ... G-38
Section 6.0 Results and Discussion ... G-39
6.1 Water Balance/Hydrology ... G-39
6.2 Sediment ... G-39
6.3 Nutrients ... G-40
6.4 Summary ... G-41
Section 7.0 TMDL Source Assessment ... G-45
7.1 Francis Creek ... G-46
7.2 Steel Creek ... G-47
7.3 Jerry Creek ... G-49
7.4 Camp Creek ... G-50
7.5 Divide Creek ... G-51
7.6 Grose Creek ... G-52
7.7 Lost Creek ... G-53
7.8 Soap Creek ... G-54
7.9 Wickiup Creek ... G-55
7.10 Summary of TMDL Source Assessment Results ... G-56
Section 8.0 Scenario Analysis ... G-57

8.1 Baseline Scenario G-57
8.2 Fertilizer Reduction Scenario G-57
8.2 Stream Bank Erosion Scenario G-58
8.3 Upland Erosion Scenario G-59
8.4 Riparian Filter Strip Scenario G-59
8.5 Animal Stocking Density Scenario G-61
Section 9.0 TMDL Scenario G-63
9.1 Francis Creek G-65
9.3 Jerry Creek G-71
9.4 Camp Creek G-75
9.5 Divide Creek G-77
9.6 Grose Creek G-80
9.7 Lost Creek G-83
9.8 Soap Creek G-86
9.9 Wickiup Creek G-89
9.10 TMDL Scenario Summary G-92
Section 10.0 Conclusion G-93
Section 11.0 References G-95
Appendix – A1 Irrigation Calculations G-99
Appendix – A2 Livestock Calculations G-101
Appendix – A3 Non-recoverable Animal Manure Calculations G-103
Appendix – A4 Model Input and Output G-105

LIST OF FIGURES

FIGURES **PAGE**

Figure 1. Study of map showing 303(d) listed stream segments, elevation and terrain (DEM), streamflow gaging stations, climate stations, and transportation network G-17
Figure 2. a) Climate at Wisdom COOP 249067 (valley) and Mule Creek SNOTEL (mountainous) sites (1971-2000); b) hydrology at the four operational USGS gages in the watershed (1997-2006). G-20
Figure 3. Biweekly nitrate concentrations (NO3--), daily suspended sediment concentration (SSC), and daily flow at USGS 06017000 Big Hole River near Melrose. G-26
Figure 4. Monthly nitrate (NO3-) and suspended sediment (SSC) concentration, and daily flow at USGS 6025800 Willow Creek near Glen. G-27
Figure 5. Box and whisker plots showing mean (e.g. green dot), median, quartiles, and ranges of total nitrogen (TN), dissolved nitrogen (NO2+NO3), total phosphorus (TP), and dissolved phosphorus (SRP) data collected in the Big Hole River watershed from 1970-current. G-28
Figure 6. Map showing calibration and validation watersheds and 303(d) listed subbasins.... G-30
Figure 7. Landcover of the Big Hole River watershed (Homer, et al., 2001)........ G-34
Figure 8. Calibration and validation plots for sediment and hydrology G-42
Figure 9. Calibration and validation plots for nutrients and hydrology........ G-43
Figure 10. Summary of estimated nitrogen sources in each TMDL watershed........ G-45
Figure 11. Summary of estimated phosphorus sources in each TMDL watershed. G-46
Figure 12. Graphical Nutrient Source Assessment for Francis Creek. G-47
Figure 13. Graphical Nutrient Source Assessment for Steel Creek. G-48
Figure 14. Graphical Nutrient Source Assessment for Jerry Creek. G-49
Figure 15. Graphical Nutrient Source Assessment for Camp Creek. G-50
Figure 16. Graphical Nutrient Source Assessment for Divide Creek. G-51
Figure 17. Graphical Nutrient Source Assessment for Grose Creek. G-52
Figure 18. Graphical Nutrient Source Assessment for Lost Creek. G-53
Figure 19. Graphical Nutrient Source Assessment for Soap Creek. G-54
Figure 20. Graphical Nutrient Source Assessment for Wickiup Creek. G-55
Figure 21. Summary of estimated nitrogen and phosphorus reductions in TMDL watersheds from implementation of all reasonable land, soil and water conservation practices (ARM 17.30.602). G-64
Figure 22. Estimated existing and proposed monthly loads of nitrogen and phosphorus in Francis Creek. G-65
Figure 23. Estimated monthly loads of nitrogen and phosphorus in Steel Creek; including existing conditions, interim criteria, and BMP implementation results........ G-68
Figure 24. Estimated monthly loads of nitrogen and phosphorus in Jerry Creek; including existing conditions, interim criteria, and BMP implementation results........ G-71
Figure 25. Estimated monthly loads of nitrogen and phosphorus in Camp Creek; including existing conditions, interim criteria, and BMP implementation results........ G-75
Figure 26. Estimated monthly loads of nitrogen and phosphorus in Divide Creek; including existing conditions, interim criteria, and BMP implementation results........ G-78
Figure 27. Estimated monthly loads of nitrogen and phosphorus in Grose Creek; including existing conditions, interim criteria, and BMP implementation results........ G-81

Figure 28. Estimated monthly loads of nitrogen and phosphorus in Lost Creek; including existing conditions, interim criteria, and BMP implementation results. G-84
Figure 29. Estimated monthly loads of nitrogen and phosphorus in Soap Creek; including existing conditions, interim criteria, and BMP implementation results.................. G-87
Figure 30. Estimated monthly loads of nitrogen and phosphorus in Wickiup Creek; including existing conditions, interim criteria, and BMP implementation results.................. G-90

LIST OF TABLES

Tables **PAGE**

Table 1. Water quality limited reaches in the Big Hole River watershed impaired from nutrients. G-15
Table 2. Interim numeric criteria for the Big Hole River Watershed (Suplee et al., 2007)...... G-16
Table 3. Representative climate stations for the Big Hole River Watershed (1971-2000)....... G-19
Table 4. USGS streamflow and water quality stations in the Big Hole River Watershed........ G-23
Table 5. Characteristics of calibration and validation sites for GWLF modeling effort. G-29
Table 6. Landcover and aggregated land classes used in the GWLF modeling (original source, NLCD 2001). G-32
Table 7. Curve numbers used in GWLF modeling. G-33
Table 8. USLE parameter assignment for GWLF modeling. G-35
Table 9. EMC parameters used in GWLF model. G-36
Table 10. Summary of calibration and validation statistics from Big Hole River GWLF model. G-39
Table 11. Summary of observed and simulated mean concentrations and dissolved nutrient ratios in the Big Hole River GWLF model. G-40
Table 12. Tabular Nutrient Source Assessment for Francis Creek. G-47
Table 13. Tabular Nutrient Source Assessment for Steel Creek. G-48
Table 14. Tabular Nutrient Source Assessment for Jerry Creek. G-49
Table 15. Tabular Nutrient Source Assessment for Camp Creek. G-50
Table 16. Tabular Nutrient Source Assessment for Divide Creek. G-51
Table 17. Tabular Nutrient Source Assessment for Grose Creek. G-52
Table 18. Tabular Nutrient Source Assessment for Lost Creek. G-53
Table 19. Tabular Nutrient Source Assessment for Soap Creek. G-54
Table 20. Tabular Nutrient Source Assessment for Wickiup Creek. G-55
Table 20. Nutrient reductions for fertilizer reduction scenario in the Big Hole River watershed. G-58
Table 21. Nutrient reductions for the bank erosion scenario. G-58
Table 22. Nutrient reductions for the upland erosion scenario. G-59
Table 23. Assumed filtering efficiency of fully-functioning 10-m (30-ft) riparian buffer strip G-59
Table 24. Nutrient reductions for the riparian filter strip scenario. G-60
Table 25. Stocking rate guidelines for dryland pastures and crop aftermath (MSU, 2003). G-61
Table 26. Nutrient reductions for the livestock density scenario. G-62
Table 27. Nitrogen reduction summary table. G-63
Table 28. Phosphorus reduction summary table G-63
Table 29. Monthly tabular data of estimated monthly streamflow and pollutant loads for Francis Creek. G-65
Table 30. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek. G-66
Table 31. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek. G-67

Table 32. Monthly tabular data of estimated monthly streamflow and pollutant loads for Steel Creek. G-68
Table 33. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek. G-69
Table 34. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek. G-70
Table 35. Monthly tabular data of estimated monthly streamflow and pollutant loads for Jerry Creek. G-72
Table 36. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek. G-73
Table 37. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek. G-74
Table 38. Monthly tabular data of estimated monthly streamflow and pollutant load for Camp Creek. G-75
Table 39. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek. G-76
Table 40. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek. G-77
Table 41. Monthly tabular data of estimated monthly streamflow and pollutant load for Divide Creek. G-78
Table 42. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek. G-79
Table 43. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek. G-80
Table 44. Monthly tabular data of estimated monthly streamflow and pollutant load for Grose Creek. G-81
Table 45. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek. G-82
Table 46. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek. G-83
Table 47. Monthly tabular data of estimated monthly streamflow and pollutant load for Lost Creek. G-84
Table 48. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek. G-85
Table 49. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek. G-86
Table 50. Monthly tabular data of estimated monthly streamflow and pollutant load for Soap Creek. G-87
Table 51. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek. G-88
Table 52. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek. G-89
Table 53. Monthly tabular data of estimated monthly streamflow and pollutant load for Wickiup Creek. G-90
Table 54. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek. G-91

Table 55. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek. G-92
Table A3-1: 1950 CENSUS OF AGRICULTURE (USDA, 1952) G-103
Table A3-2: 2002 CENSUS OF AGRICULTURE (USDA, 2004) G-104
Table A3-3: Estimated Livestock Distributions of TMDL Watersheds G-104

SECTION 1.0
INTRODUCTION

Nineteen tributaries are characterized as "water quality-limited" in the Big Hole River watershed due to nutrient impairment (Table 1; CWAIC, 2008). To satisfy Federal Clean Water Act requirements, Total Maximum Daily Loads (TMDLs) must be developed for these water bodies such that they support beneficial uses. As part of this effort, a low-detail modeling study was completed by Montana Department of Environmental Quality (DEQ) to estimate nutrient source contributions and seasonal loadings of nitrogen and phosphorus from various land uses. The Generalized Watershed Loading Functions (GWLF) model was selected for the analysis due to its relative simplicity in model application and usefulness in simulating hydrology and mass loadings of pollutants on a monthly time-scale. Due to current TMDL scheduling priorities, only a subset of the impaired water bodies in each TMDL Planning Area (TPA) were evaluated as part of the current TMDL effort. The remaining tributaries will be addressed according to the scheduling timeframes outlined in the consent decree. A map of the 303(d) listed reaches evaluated as part of this project are shown in **Figure 1.**

Table 1. Water quality limited reaches in the Big Hole River watershed impaired from nutrients.

Water body ID1,2	**Reach Segment**	**Probable Cause**
	Upper TPA[3]	
Francis Creek	MT41D004_200	Nitrogen/Phosphorus (total)
Steel Creek	MT41D004_190	Phosphorus (total)
McVey Creek	MT41D004_210	Nitrogen/Phosphorus (total)
Rock Creek	MT41D004_120	Nitrogen/Phosphorus (total)
Swamp Creek	MT41D004_110	Nitrogen/Phosphorus (total)
Fox Creek	MT41D004_170	Phosphorus (total)
Pine Creek	MT41D004_160	Phosphorus (total)
Warm Springs Creek	MT41D004_180	TKN/Phosphorus (total)
	Middle TPA[3]	
Jerry Creek	MT41D003_020	Excess algal growth
Charcoal Creek	MT41D002_150	Nitrogen/Phosphorus (total)
Fishtrap Creek	MT41D003_160	Phosphorus (Total)
Gold Creek	MT41D003_230	Phosphorus (Total)
Sawlog Creek	MT41D004_230	Phosphorus (Total)
	Lower TPA[3]	
Camp Creek	MT41D002_020	Phosphorus (Total)
Divide Creek	MT41D002_040	TKN/Phosphorus (Total)
Grose Creek	MT41D002_060	Phosphorus (Total)
Lost Creek	MT41D002_180	Nitrogen/Phosphorus (total)
Soap Creek	MT41D002_140	Phosphorus (Total)
Wickiup Creek	MT41D002_120	Phosphorus (Total)

[1] Source: 2006 303(d) List.
[2] Items shown in white are being addressed as part of the current TMDL effort. Greyed items will be addressed at a later date.
[3] TPA (TMDL Planning Area) segments are subsets of the overall Big Hole River Watershed used to divide the project area into manageable units for TMDL planning.

1.1 Previous Studies

A literature review was completed prior to the initiation of the project to identify if previous studies would be of use in modeling. Those of interest to DEQ are shown below:

1. **USGS bi-weekly monitoring** – USGS collected bi-weekly nitrate (NO3-) and daily sediment samples in the lower portion of the Big Hole River watershed from 1960-1964. Sediment is of interest due to its affinity for nutrient sorption.
2. **Statewide water quality monitoring network monitoring** – DEQ conducted nutrient sampling at multiple locations in the watershed from 2003-2005 as part of the statewide monitoring network. Sampling was limited to a frequency of once per year, in the growing season.
3. **TMDL source assessment monitoring** – DEQ monitored nutrients at multiple sites from 2003 and 2005 as part of TMDL source assessment activities. Data collection was limited to the growing season, with a frequency of one to two samples per summer.

The pertinence of these studies toward the modeling is detailed further in subsequent sections. Applicability toward nutrient criteria is described below.

1.2 Nutrient Criteria in Montana (ARM 17.30.637)

Montana is currently governed by narrative nutrient criteria, specifically, that surface waters must be free from municipal, industrial, and agricultural discharges that produce undesirable aquatic life [ARM 17.30.637 (1)(e)]. In instances where water bodies do not support beneficial uses, TMDLs and associated water quality restoration plans must be developed. Nineteen such tributaries were identified as impaired on the 2006 303(d) List. Nine are being addressed as part of the Big Hole River watershed TMDL (**Table 1**). Because narrative criteria are somewhat problematic for total maximum daily load analysis, interim numeric criteria were used as a surrogate instead. Those applicable for the Big Hole River TMDL (e.g. the Middle Rockies Ecoregion) are shown in **Table 2**. Modeling will be conducted to assess strategies that can be implemented such that these interim criteria are achieved.

Table 2. Interim numeric criteria for the Big Hole River Watershed (Suplee et al., 2007).

Constituent	Target Value
Total nitrogen (TN)	≤ 0.39 mg/L (winter) ≤ 0.52 mg/L (runoff) ≤ 0.32 mg/L (growing season)
Total phosphorus (TP)	≤ 0.03 mg/L (winter) ≤ 0.05 mg/L (runoff) ≤ 0.049 mg/L (growing season)
Chlorophyll a	≤ 150 mg/m² for Foothill/Valley

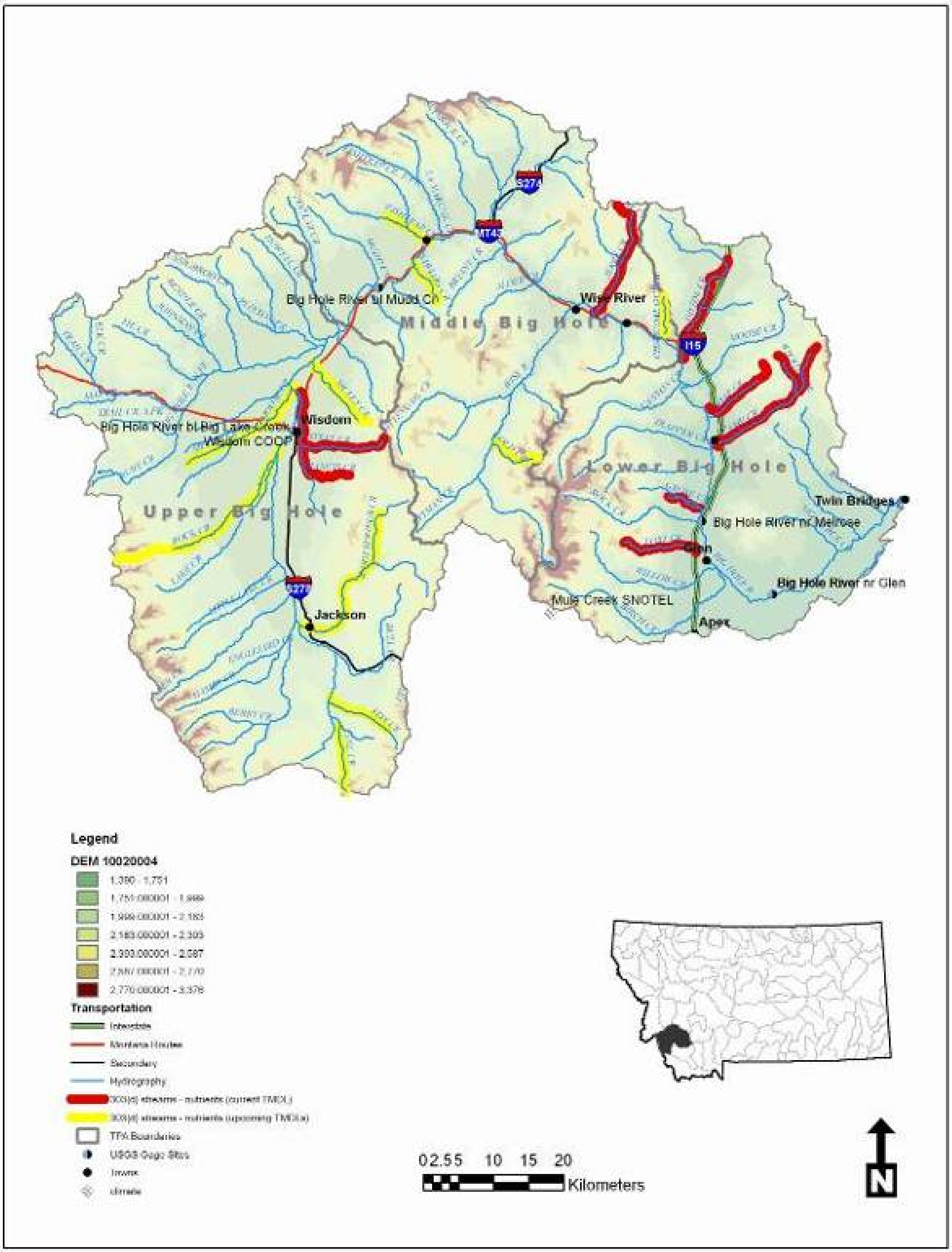


Figure 1. Study of map showing 303(d) listed stream segments, elevation and terrain (DEM), streamflow gaging stations, climate stations, and transportation network. Stream segments highlighted in red are being addressed in the current TMDL. The remaining listings will be completed at a later date.

SECTION 2.0 STUDY AREA

The Big Hole River drains approximately 7,250-km2 (2,800-mi2) of high- and mid-elevation mountainous topography in southwestern Montana. Originating from the continental divide, the river flows 247-km past the towns of Jackson, Wisdom, Wise River, Melrose, and Glen before reaching its endpoint near Twin Bridges (**Figure 1**). Elevations in the watershed range from 1,399 to 3,388 meters (4,590 to 11,115 feet), and mean basin elevation is 2,149 meters (7,050 feet). The entire watershed is part of United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 10020004. Three distinct planning segments are being addressed by DEQ as part of the TMDL. These include: (1) the upper TPA which extends from the headwaters to Pintlar Creek, (2) middle TPA which extends from Pintlar Creek to Divide Creek, and (3) lower TPA which extends from Divide Creek to the Beaverhead River.

2.1 Climate

Climate in the Big Hole River watershed is inter-montane continental, with marked seasonality. Wisdom cooperative observer (COOP) station 249067 and the Mule Creek SNOTEL station provide representative information regarding the basin (**Table 3**, **Figure 2a**). Valleys are predominantly arid, and the mountains wet, with a 30-year average annual precipitation at Wisdom of 30.2 centimeters (11.9 inches) (1971-2000). The Mule Creek SNOTEL receives nearly double this amount; 76.6 centimeters annually (30.2 inches). The observed variation in precipitation is typical of climates in mountainous regions and has been described previously by Farnes (1975) and Marvin and Voller (2000). Temperatures are also consistent with mountainous climates with warmer valleys and cooler uplands, the exception being during the winter months when inversions occur. Mean monthly temperature at Wisdom is 2.0ºC (35.6ºF) while the Mule Creek SNOTEL site is 0.8ºC (33.4ºF).

Table 3. Representative climate stations for the Big Hole River Watershed (1971-2000).

Station ID	Agency	Elevation	Mean Annual Precipitation	Mean Annual Temperature[1]
Wisdom COOP 249067 (valley)	NOAA	1847 m (6060 ft)	30.2 cm (11.9 inches)	2.0ºC (35.6ºF)
Mule Creek SNOTEL (mountain)	NRCS	2530 m (8300 ft)	76.6 cm (30.2 inches)	0.8ºC (33.4ºF)

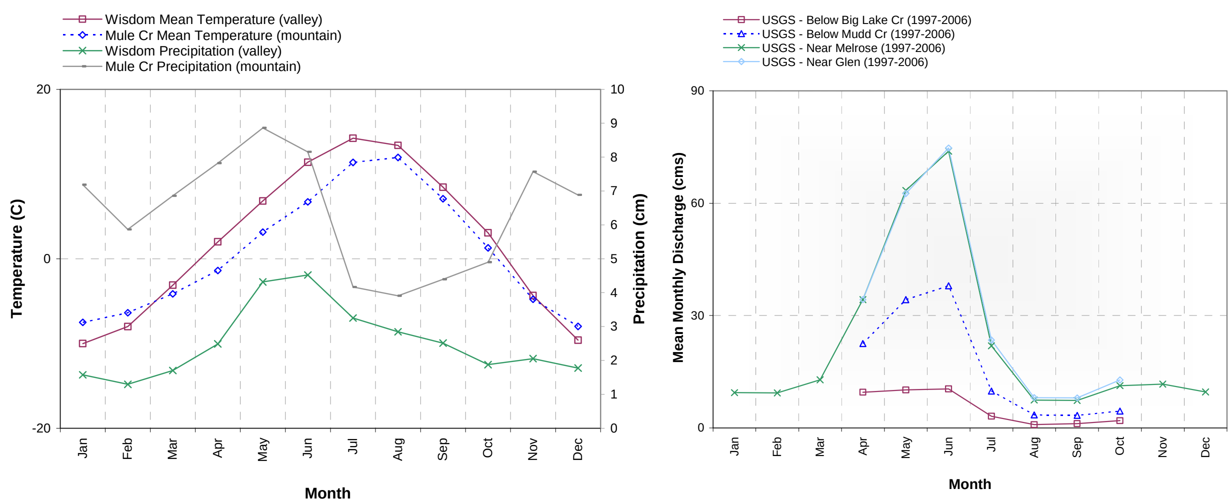
[1] Mean annual temperature statistics not compiled by NRCS for 1971-2000. Entire period of record used instead.

2.2 Streamflow

There are four operational USGS gaging stations in the Big Hole River watershed: (1) USGS 06024450 Big Hole River below Big Lake Creek at Wisdom, MT, (2) USGS 06016000 Big Hole River below Mudd Creek, (3) USGS 06017000 Big Hole River nr Melrose, and (4) USGS 06018500 Big Hole River nr Glen. Based on review of their hydrographs, surface water hydrology is predominately snowmelt driven, with spring snowmelt beginning in mid to late March, peaking in June, and then rapidly declining in July and August toward baseflow (**Figure b**). Baseflow and/or low flow conditions then persist to the following spring when winter snow accumulation once again begins to melt.

2.3 Land Use

Land use in the Big Hole River consists primarily of agriculture, with cow-calf operations being the dominant production practice. Many stock owners pasture their livestock on National Forest range during the summer months and grow irrigated grass or alfalfa hay for winter feed. In the headwaters, logging and associated activities, such as road construction, have been known to occur, but only to a minor extent. The same goes for urban encroachment and residential development. No point source discharges or wastewater discharges were identified in the watershed and the towns of Jackson, Wisdom, Wise River, Melrose, and Glen all have relatively low septic densities, all under 200 people (U.S. Census, 2000).



a) **b)**

Figure 2. a) Climate at Wisdom COOP 249067 (valley) and Mule Creek SNOTEL (mountainous) sites (1971-2000); b) hydrology at the four operational USGS gages in the watershed (1997-2006).

2.4 Soil

Soils in the Big Hole River watershed are highly variable and depend on location. In general they have moderate infiltration rates and consist mainly of deep well drained soils with fine to coarse textures. The Maurice-Phillipsburg-Thayne loam is the predominant soil series in the Upper Big Hole River TPA. It is found at the lower elevations between Jackson and Wisdom. The Ovando-Elkner-Shadow is a gravelly-silt-loam found at mid elevations of the Pintler and Pioneer Mountains, and dominates the Middle Big Hole River Planning Area. Finally, the Trimad-Kalsted-Crago is a silt-loam found throughout much of the Lower Big Hole River Planning Area

(DEQ, 2007). Soils information was acquired from the State Soil Geographic (STATSGO) database (NRCS, 1994).

SECTION 3.0 DATA COMPILATION & ASSESSMENT

A data compilation and assessment was initially completed to identify available information for modeling. Two types of data were assessed: (1) flow data and (2) water chemistry data. Both the USGS National Water Information System (NWIS, 2008) and the U.S. Environmental Protection Agency's (EPA) STORET databases (STORET, 2008) were queried. Results are briefly described below.

3.1 Flow

Observed streamflow is a required component for hydrologic calibration and was obtained directly from the USGS. Gaging stations that have historically operated in the Big Hole River watershed are shown in **Table 4**, and most contain suitable observational data for modeling (e.g. daily streamflow). Periods of record and associated water quality observations are also indicated.

Table 4. USGS streamflow and water quality stations in the Big Hole River Watershed.

USGS No.	Site Name	Begin Date	End Date	# of Nutrient Observ.	# of SSC Observ.
6025270	Moose Cr ab Maclean Cr nr Divide MT	10/1/1997	9/30/1999	0	0
6025480	Rock Cr bl Brownes Lake nr Glen MT	9/1/1997	10/31/1999	0	0
6025700	Willow Cr Diversions to Birch Cr nr Glen MT	4/21/1946	9/30/1966	0	0
6026206	Upper Raffety Ditch near Glen MT	4/24/1998	10/31/1999	0	0
6024510	West Fork Ruby Creek near Wisdom MT	4/1/1995	9/30/1996	0	0
6024000	Miner Creek near Jackson MT	5/24/1948	10/31/1953	0	0
6025800	Willow Creek near Glen MT	8/1/1962	10/31/1999	36	21
6026000	Birch Creek near Glen MT	5/1/1946	10/6/1976	21	15
6023500	Big Hole River near Jackson MT	4/29/1948	10/31/1953	0	0
6024470	Swamp Creek near Wisdom MT	3/28/1995	9/30/1996	0	0
6024500	Trail Creek near Wisdom MT	6/29/1948	7/20/1972	2	0
6024590	Wise River near Wise River MT	9/28/1972	9/30/1985	0	0

Table 4. USGS streamflow and water quality stations in the Big Hole River Watershed.

USGS No.	Site Name	Begin Date	End Date	# of Nutrient Observ.	# of SSC Observ.
6024450	Big Hole River bl Big Lake Cr at Wisdom MT	5/1/1988	5/11/2008	0	0
6024540	Big Hole River bl Mudd Cr nr Wisdom MT	10/1/1997	5/11/2008	0	0
6024580	Big Hole River near Wise River MT	6/1/1979	10/2/1981	0	0
6025000	Big Hole River near Dewey MT	9/1/1910	9/30/1913	0	0
6025250	Big Hole River at Maiden Rock nr Divide MT	10/1/1997	5/11/2008	0	0
6025500	Big Hole River near Melrose MT	10/1/1923	5/11/2008	102	1465
6026210	Big Hole River near Glen MT	9/11/1997	5/11/2008	0	0
6026400	Big Hole River near Twin Bridges MT	7/25/1979	10/1/1981	50	0
6026420	Big Hole R bl Hamilton Ditch nr Twin Bridges, MT	7/1/2007	9/30/2007	0	0

3.2 Chemistry

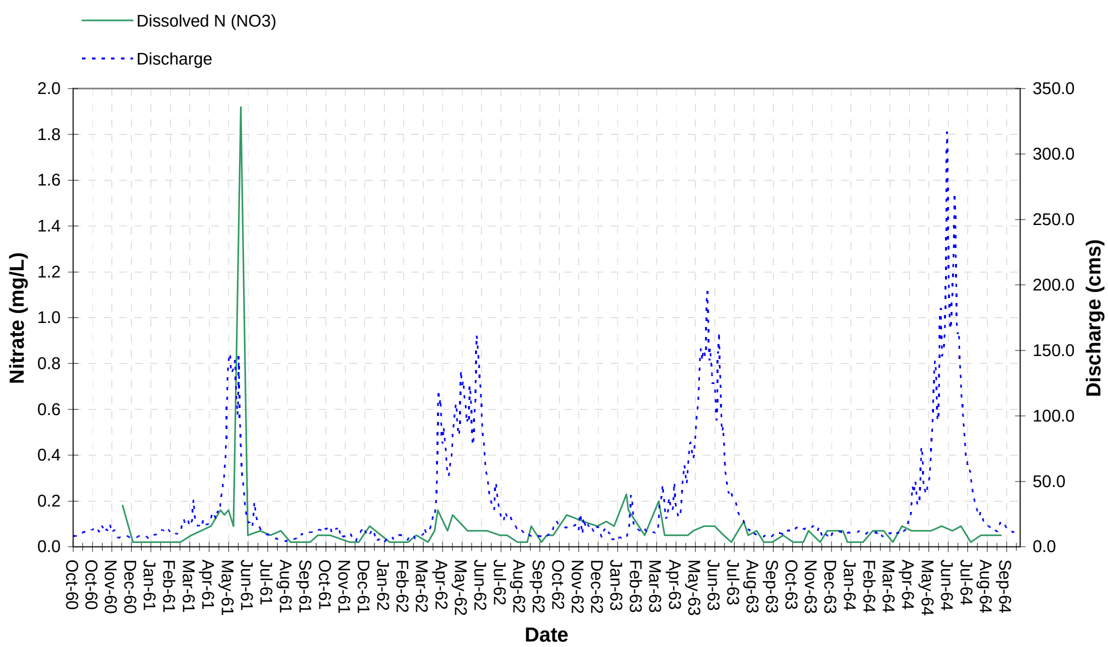
Water chemistry data are necessary for quality calibration. As such, the USGS and STORET records were evaluated to ensure suitability for modeling. Based on this reconnaissance, only a handful of sites have adequate sediment and nutrient observations for modeling. This includes USGS 6025800 Willow Creek near Glen and USGS 6025500 Big Hole River near Melrose, MT. No suitable data were found in STORET. Thus a calibration and validation approach was formulated around those stations. This is described in **Section 3.6**. An assessment of this data is provided in the following section.

3.3 Data Assessment

3.3.1 Time Series

Bi-weekly nutrient samples (NO3-) and daily suspended sediment samples were collected at USGS 06017000 Big Hole River near Melrose from 1960-1964. Monthly nutrient and SSC samples were collected at USGS 6025800 Willow Creek near Glen from 1962-1965. Based on the data, pollutant loading is consistently correlated with early season hydrograph response (**Figure 3** and **Figure 4**). Fluctuations in nitrate appear to be infrequent short duration events which presumably are associated with overland flow from agricultural landscapes. Sediment peaks are more prolonged and are believed to occur primarily from bank erosion during sustained snowmelt (rather than rainfall induced upland erosion).
3.3.2 Graphical and statistical analysis

STORET contains a wealth of standalone water chemistry data. A population based approach was used to estimate cursory statistical information from STORET, such as mean and median concentrations, upper and lower quartiles, and ranges for total nitrogen (TN), nitrate (NO3-), total phosphorus (TP), and soluble reactive phosphorus (SRP) (**Figure 5**). In general, nutrient concentrations appear to have remained relatively consistent over time, with dissolved nitrogen (e.g. NO3-) exhibiting the most variability. This largely is consistent with the hypothesis that overland flow infrequently contributes dissolved loadings during the runoff period.



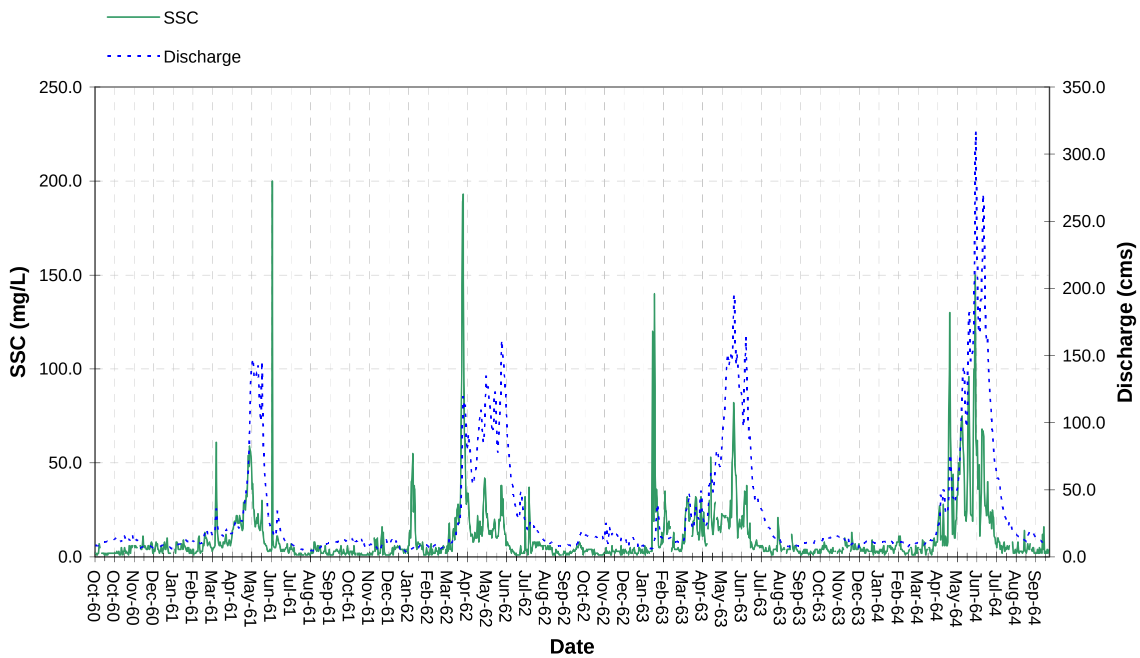
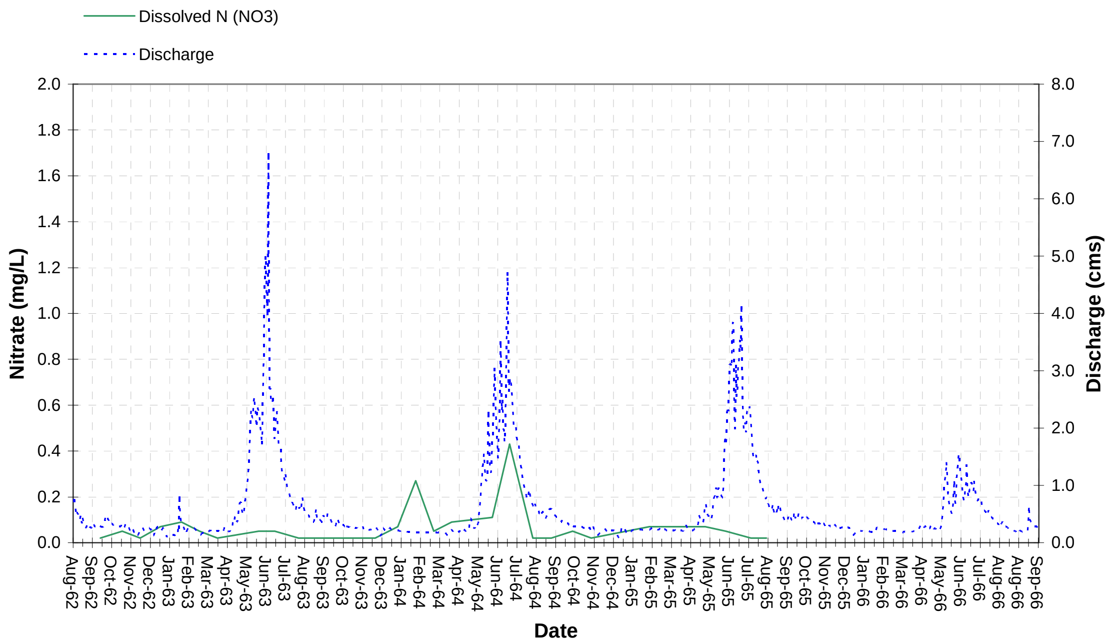


Figure 3. Biweekly nitrate concentrations (NO3--), daily suspended sediment concentration (SSC), and daily flow at USGS 06017000 Big Hole River near Melrose.



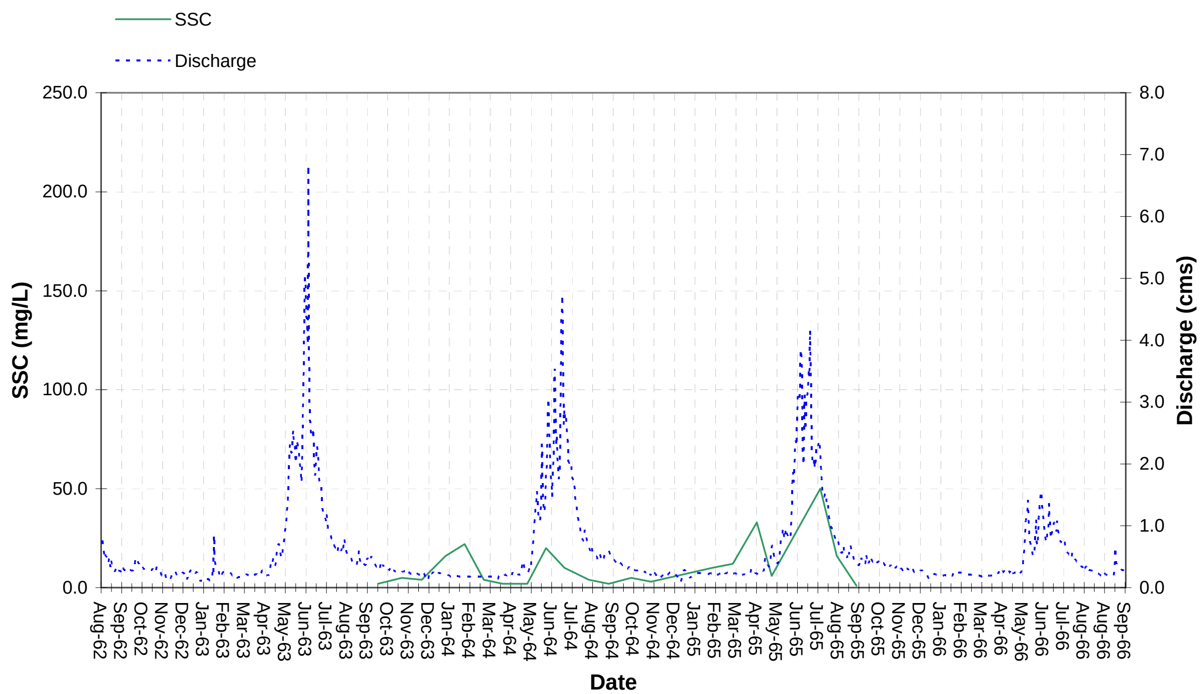


Figure 4. Monthly nitrate (NO3-) and suspended sediment (SSC) concentration, and daily flow at USGS 6025800 Willow Creek near Glen.

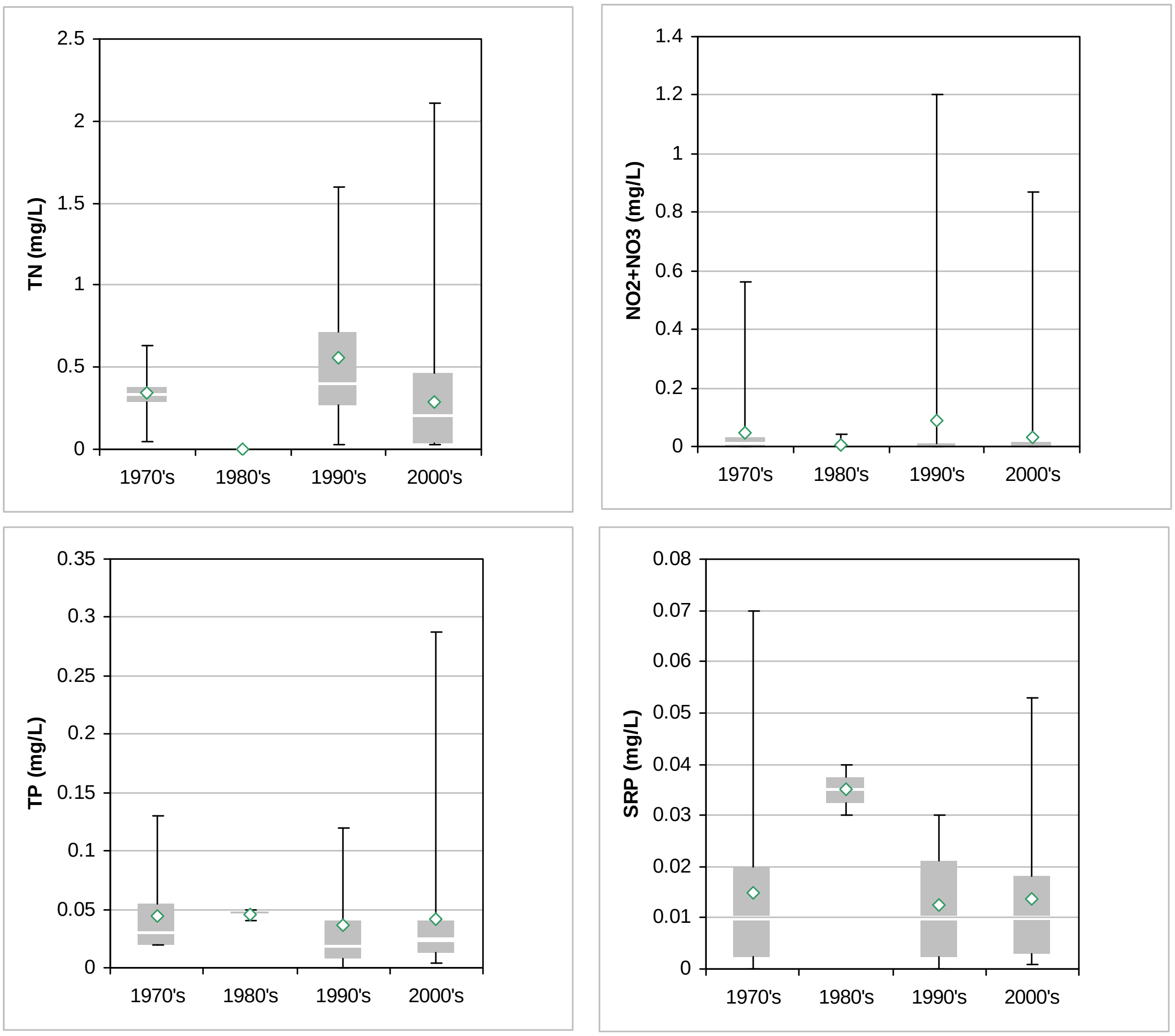


Figure 5. Box and whisker plots showing mean (e.g. green dot), median, quartiles, and ranges of total nitrogen (TN), dissolved nitrogen (NO2+NO3), total phosphorus (TP), and dissolved phosphorus (SRP) data collected in the Big Hole River watershed from 1970-current. Information originates from the STORET database.

Note: Number of observations during each decade shown below

Species	**1970's**	**1980's**	**1990's**	**2000's**
TN	10	0	11	219
NO2+NO3	18	62	15	189
TP	11	2	15	188
SRP	50	2	6	57

SECTION 4.0
MODELING APPROACH

From review of the data assessment, it was found that suitable data are available for development of a GWLF model of the Big Hole River watershed. The USGS database contains the necessary paired flow and chemistry data for calibration and validation, while observations from STORET can be used to fill data gaps (such as dissolved to total nutrient ratios and anticipated mean concentrations for TP, SRP, TN, and NO2+NO3). Thus the modeling project was initiated. A parameter transfer approach was used in the model development phase where calibration was completed on USGS 0601000 Big Hole River near Melrose, while a separate validation model was developed for a watershed similar in size to the TMDL watersheds, e.g. USGS 6025800 Willow Creek near Melrose. Attributes of each of the simulated watersheds are shown in **Table 5.**

Table 5. Characteristics of calibration and validation sites for GWLF modeling effort.

USGS No.	Site Name	Area (km2)	Forested Area (%)	Mean Elev. (m)	Mean Prcp (cm)
6025800	Willow Creek near Glen MT	92.8	74.7	2,224	71.3
6025500	Big Hole River near Melrose MT	6,384	57.3	2,149	63.1

The location of the proposed calibration and validation watersheds, along with the nine watersheds where TMDL analysis will be completed are shown in **Figure 6**. GWLF model input development activities are described in the following section.

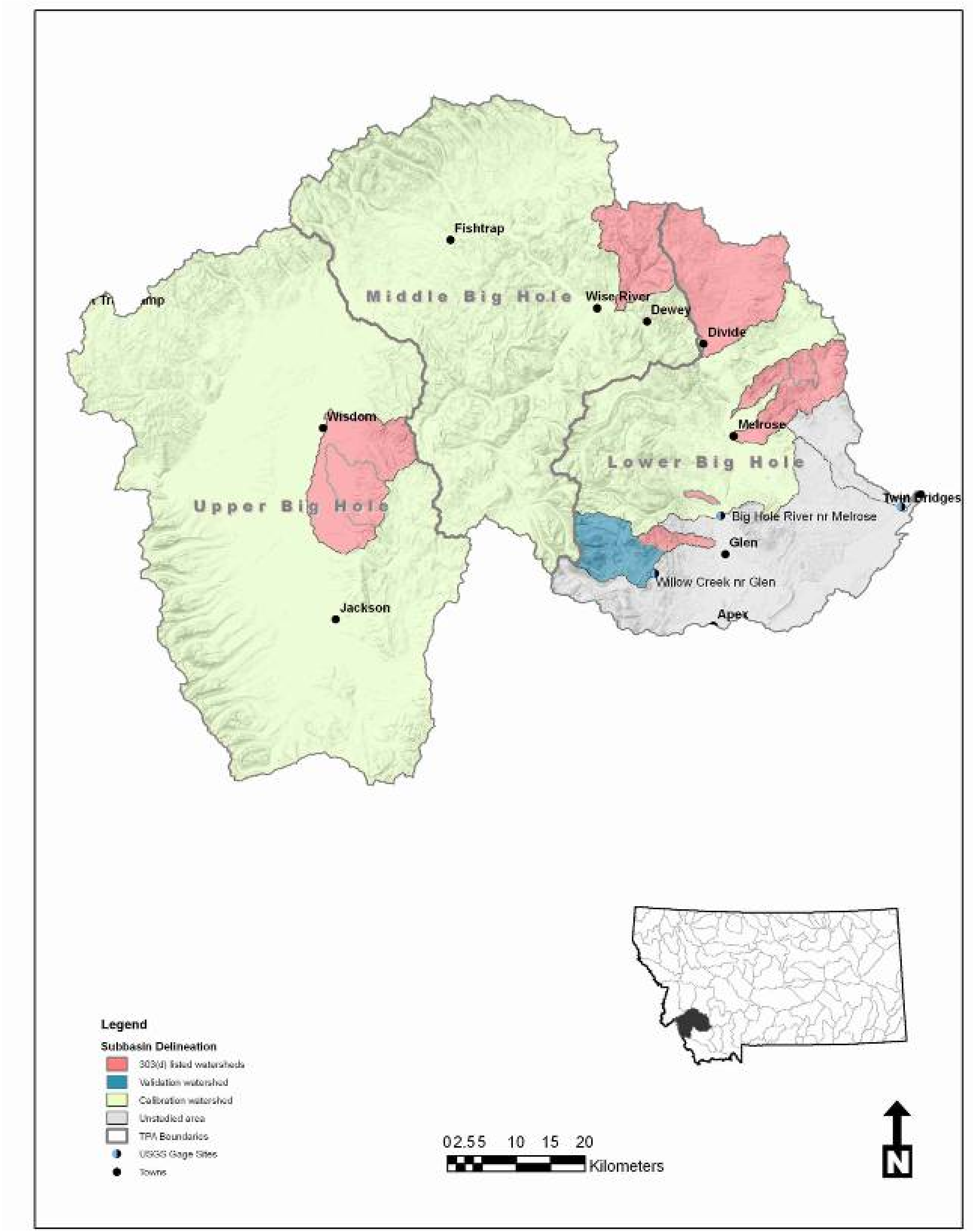


Figure 6. Map showing calibration and validation watersheds and 303(d) listed subbasins. The area in grey was not evaluated as part of the TMDL effort.

SECTION 5.0
GWLF MODEL DEVELOPMENT

5.1 GWLF Model Description

The Generalized Watershed Loading Functions model (GWLF) is a daily time-step model used in prediction of runoff, sediment, nitrogen, and phosphorus loads in variable sized watersheds. Rainfall, snowmelt, evapotranspiration, infiltration, dissolved and solid phase nutrient loading, and streambank erosion are all simulated as part of the model. It was written with the express purpose of requiring no calibration, and the model simply aggregates loads from each of the source areas in the watershed to form the overall pollutant load. The model is not spatially explicit and contains no routing component, therefore the complexity falls between that of detailed, process based simulation models and simple export coefficient models. GWLF has been endorsed by the U.S. EPA as a good "mid-level" model for simulating most of the key mechanisms controlling nutrient fluxes within a watershed (U.S. EPA, 1999).

5.2 GIS Pre-processing

The ArcView3.2 AVGWLF Geographic Information System (GIS) interface (Evans et al., 2002) was used to expedite the initial model setup and parameterization of GWLF. Fundamental input data for AVGWLF are topography (e.g. digital elevation model; DEM), land use/landcover (LULC), soils information, and climate. GIS data sources used in the Big Hole River GWLF model include:

- National Elevation Dataset (NED) – The USGS NED is a 1:24,000 scale DEM is used in calculation the slope length/steepness for the Universal Soil Loss Equation (USLE.) The BASINS version of the NED was used (USEPA, 2004).
- National Hydrography Dataset (NHD) – NHD is a 1:24,000 scale vector coverage of stream topology and was also taken from BASINS (USEPA, 2004). It was used as a definition of the channel network subject to bank erosion in the model.
- National Land Cover Dataset (NLDC) –NLCD (Homer et al., 2001) is a 29- category land cover classification (30-m grid) available over the conterminous U.S. It was used to develop gridded landcover inputs for runoff and erosion computations. (**Figure 7**)
- STATSGO Soils – The STATSGO soil map (NRCS, 1994) is a 1:250,000 scale generalization of detailed soil survey data that was used to develop soil erosion properties and associated information for runoff and erosion calculations.

5.3 Climate Input

Climate input for GWLF was based on Wisdom cooperative observer (COOP) station 249067, with adjustment for orographic precipitation and temperature variation using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) (Daily et al., 2000), and environmental lapse rate. The annual ratio between the site data, and that of the watershed being modeled, was used in this adjustment. PRISM data was taken directly from the Montana Natural

Resource Information System (NRIS, 2008), and the environmental lapse rate from the International Civil Aviation Organization (ICAO, 2008) was used.

5.4 Water Balance/Hydrologic Input

Hydrology in GWLF is partitioned into surface water and groundwater components using the SCS-curve number (CN) methodology. Curve number estimation procedures are described below.

5.4.1 Curve Number Estimation

Curve number was estimated using the combination of the National Land Cover Dataset (NLCD; Homer et al., 2001) and STATSO soil database (NRCS, 1994). Six aggregated source categories were used in facilitating the modeling including: water, developed, forest, grassland, shrub/scrub (e.g. sagebrush), and pasture/hay. They are shown in **Table 6**. Of these, forest, grassland, and shrubland comprise over 90 percent of the total watershed area (43.9 percent, 34.3 percent, and 14.0 percent respectively). The remaining portions include open water (0.3 percent), developed lands (1.5 percent), and pasture/hay (5.8 percent). Curve numbers derived for each of these land classes are shown in **Table 7**.

Table 6. Landcover and aggregated land classes used in the GWLF modeling (original source, NLCD 2001).

NLCD 2001 Landcover	Area (hectares)[2]	Percentage (%)	GWLF-E Re-classified Landcover
Open Water	1,141	0.2%	Open Water
Perennial Ice, Snow	49	0.0%	
Developed, Open Space	4,604	0.6%	Developed
Developed, Low Intensity	1,235	0.2%	
Developed, Medium Intensity	190	0.0%	
Developed, High Intensity	4	0.0%	
Barren Land, Rock	3,739	0.5%	Forest
Deciduous Forest	341	0.0%	
Evergreen Forest	378,881	52.1%	
Mixed Forest	98	0.0%	
Woody Wetlands	1,942	0.3%	
Emergent Herbaceous Wetlands	43	0.0%	
Shrub, Scrub	37,888	5.2%	Shrub, Scrub
Grassland, Herbaceous	273,009	37.5%	Grassland, Herbaceous
Pasture/Hay	21,157	2.9%	Pasture/Hay
Cultivated Crops (1)	2,963	0.4%	

[1] Review of aerial photographs and NLCD 2001 indicate that cultivated crops typically consist of alfalfa and/ or hay.
[2] Areas for entire watershed; not be confused with areas used in modeling.

Table 7. Curve numbers used in GWLF modeling.

GWLF-E Re-classified Land Class	Dominant Hydrologic Soil Group	Curve Number AMC II
Developed	B	70
Evergreen Forest	A	45
Shrub, Scrub	B	49
Grassland, Herbaceous	B	62
Pasture/Hay	B	58

5.4.2 Irrigation

Irrigation was accounted for in GWLF using crop evapotranspiration (ET) from the Dillon (DLNM) AGRIMET site and associated crop area. Losses of 25 percent were assumed to occur in the distribution system. Estimated withdrawls were then directly subtracted from the overall "streamflow" component of the water balance with the provision that the diverted value did not exceed simulated streamflow (e.g. no negative streamflow calculations). The calculation procedure for this methodology is shown in the **Appendix A1**.

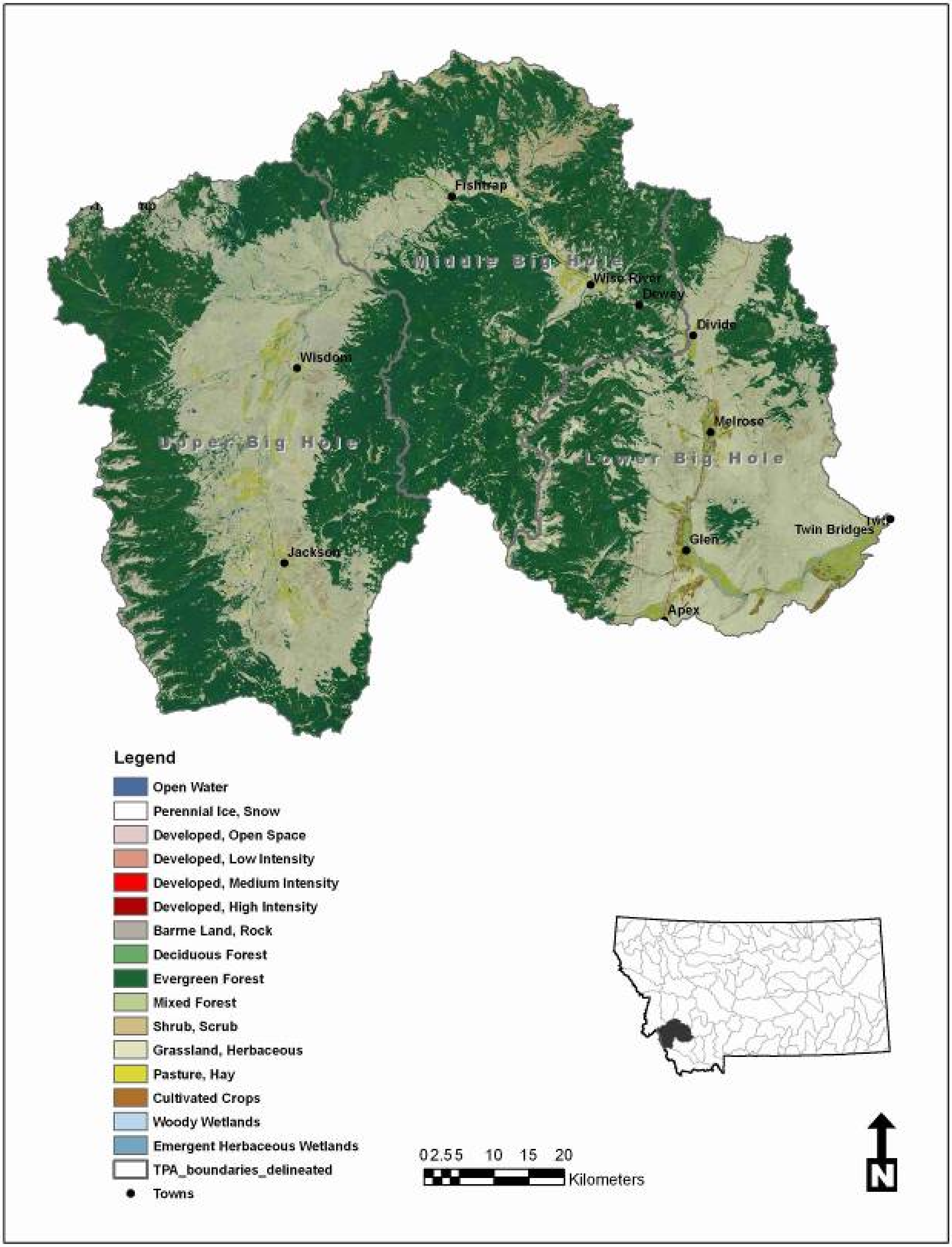


Figure 7. Landcover of the Big Hole River watershed (Homer, et al., 2001).

5.5 Sediment Input

5.5.1 Hillslope Erosion

Erosion and sedimentation are computed in GWLF using the Universal Soil Loss equation (USLE). Input parameters used in the GWLF modeling are shown in **Table 8** and are consistent with studies conducted elsewhere by DEQ.

Table 8. USLE parameter assignment for GWLF modeling.

USLE Assignment[1,2]						**Assignment Details**	
GWLF-E Re-classified Land Class	**[3]K-Factor**	**[4]LS-Factor**	**[5]C-factor**	**[6]P-factor**	**Ground or canopy Cover**	**Canopy Type**	**Cover Type**
Developed	WS	WS	0.09	1	---	none	G/W
Evergreen Forest	WS	WS	0.003	1	---	forest	60% duff
Shrub, Scrub	WS	WS	0.05	1	---	20" brush	G
Grassland, Herbaceous	WS	WS	0.07	1	---	none	G
Pasture/Hay	WS	WS	0.02	1	---	none	G

[1] WS = Watershed specific; computed from GIS layers
[2] Rainfall erosivity factor calculated from daily precipitation
[3] Soil erodibility factor from NRCS STATSGO grid
[4] Topographic factor calculated from Basins DEM
[5] Cover management factor from Brooks, 1999 and MCcuen, 1998
[6] P-factor of unity applied (e.g. no conservation practices)

5.5.1 Streambank Erosion

Streambank erosion is computed within GWLF using a rating curve approach. Parameterization of the lateral bank erosion "a" coefficient was completed solely through model calibration. In order to properly scale parameters for watersheds with differing streamflow conditions, "a" was adjusted to maintain a consistent lateral erosion rate for each watershed (e.g. to maintain the rate determined in the calibration). Coefficients used in the modeling are shown in the model input in the **Appendix A3**.

5.6 Nutrient Input

5.6.1 Dissolved Nutrients

Dissolved nutrients in GWLF are simulated using event mean concentrations (EMCs). Those coefficients used in the modeling were fine-tuned through model calibration (**Table 9**) and were in agreement with the literature (see Haith et al., 1992; USEPA, 1983; USEPA, 2001). Dissolved nutrient concentrations in groundwater were based on the land use with the most subsurface water yield, which for the most part, was from forested areas. Thus the EMC for forest surface runoff was applied to dissolved groundwater (e.g. 0.05 and 0.02 mg/L N and P) and appeared to yield the best results during model calibration.

Table 9. EMC parameters used in GWLF model.

Land Use	Dissolved Nitrogen (mg/L)	Dissolved Phosphorus (mg/L)
Developed (kg/ha/day)	0.012	0.002
Evergreen Forest	0.05	0.02
Shrub, Scrub	0.5	0.1
Grassland, Herbaceous	0.5	0.1
Pasture/Hay	3.5	0.25

5.6.2 Organic/Solid Phase Nutrients

Solid phase nutrients in GWLF originate from landscape and streambank based soil erosion. Since watershed specific information was not available regarding soil nutrient concentrations, values were taken from the national map provided in the GWLF user's manual. A value of 1500 mg/kg was used for nitrogen and 620 mg/kg for phosphorus. During calibration, it was found that GWLF was unable to account a large organic load from forested environments. Therefore, an organic load component was added to the model using the computed forest water yield and an associated concentration of organic nitrogen and phosphorus observed in forest surface runoff (0.24 and 0.017 mg/L of nitrogen and phosphorus respectively). This modification brought the balance of dissolved nutrient to total nutrient ratios into much closer alignment.

5.6.3 Non-Recoverable Animal Manure

Non-recoverable animal manure loads were estimated in GWLF using livestock density data from the U.S. Agricultural Statistics Service (NASS, 2008) and an associated delivery ratio to surface waters. Manure composition taken directly from the Animal Waste Management, National Engineering Handbook (NRCS, 1999) and an adjustment procedure was used to correct the number of reported animals to actual animal units (AU). Delivery ratio of nutrient loads from animal manure was based entirely on the literature (see Pieterse et al., 2003; Johnes, 1996; De Wite, 2000; Johnson et al., 1976; and Olness et al., 1980) and a value of 5 percent for nitrogen, and 0.01 percent for phosphorus were used in the modeling. More information on the farm animal manure calculations can be found in the Appendix.

5.6.4 Septic Systems

Septic system loads were crudely estimated using aerial imagery (2005 NAIP) and data from the STEPL Model Input Data Server which provides coarse, regional level information about per capita tank use and failure rates from the National Environmental Service Center (1992). Estimated septic densities for each of the watersheds are shown in the Appendix, and are considered approximations only.

5.7 Model Calibration-Validation

The general approach toward GWLF calibration and validation, was typical of that of any watershed modeling endeavor: (1) calibration of monthly streamflow, (2) sediment calibration, and then (3) nutrient calibration. Calibrated reach parameters are shown in Attachment-A, and are based on user experience, knowledge of the watershed, and recommendations from the GWLF user's manual. Those used in the calibration include SCS curve number, evapotranspiration coefficient, saturated and unsaturated aquifer parameters, groundwater recession constant, deep aquifer/seepage coefficient, monthly rainfall erosivity coefficient, streambank sediment coefficient, event mean concentrations (EMCs), and groundwater nutrient EMCs.

5.8 Model Evaluation Criteria

Performance statistics were selected prior to model development to assess monthly and seasonal streamflow, sediment, and nutrient predictions from GWLF. The first criterion used in the project was percent bias (PBIAS), which is a measure of the average tendency of the simulated temperatures to be larger or smaller than an observed value. Optimal PBIAS is 0.0 while a positive value indicates a model bias toward overestimation. A negative value indicates bias toward underestimation. PBIAS is calculated as follows:

$$PBIAS = \frac{\sum_{i=1}^{n}(O_{isim} - O_{iobs})}{\sum_{i=1}^{n}(O_{iobs})} \times 100$$

Equation 1

where

PBIAS = deviation in percent
Tiobs = observed value
Tisim = simulated value

DEQ defined acceptable model bias for the Big Hole River GWLF model as ±15 percent, similar to that reported in the literature by Van Liew et al. (2005) and Donigian et al. (1983). The second evaluation criterion was the Nash-Sutcliffe coefficient of efficiency (NSE; Nash and Sutcliffe, 1970). NSE expresses the fraction of the measured variance that is reproduced by the model. As error in the model is reduced, the NSE coefficient is inherently increased. Simulation results are considered to be good for NSE > 0.75, while values between 0.36 and 0.75 are considered satisfactory (Motovilov et al. 1999). NSE is calculated as:

$$NS_E = 1 - \frac{\sum_{i=1}^{n}(O_{iobs} - O_{isim})^2}{\sum_{i=1}^{n}(O_{iobs} - O_{avg})^2}$$

Equation 2

where

NSE = coefficient of efficiency
Tavg = average simulated value

Reported statistics for calibration and validation of each of the measures shown previously are shown in **Section 6.0**.

5.9 Model Sensitivity/Uncertainty

Given the "limited-detail" nature of this study, model sensitivity and uncertainty were not addressed as part of this project. To some extent, model uncertainty can be characterized by review of the results and discussion section. It is recommended that a margin of safety (MOS) be built into the TMDL to account for this inherent error.

SECTION 6.0
RESULTS AND DISCUSSION

6.1 Water Balance/Hydrology

6.1.1 Calibration

Monthly streamflow for the calibration is shown in **Figure 8**. Inspection of the observed and predicted values shows satisfactory agreement. In general, the model predicts growing season streamflow values very well (May-September), while predictions during the winter months are poor. This largely is due to the inability to lag groundwater from month to month. Snowmelt appears to be accurately represented based on the rising limb of the hydrograph, and the falling limb is also well simulated. PBIAS and NSE were +1.1 percent and 0.69 respectively (**Table 10**).

6.1.2 Validation

Results of the hydrologic validation on Willow Creek (a gaged tributary similar in size to the TMDL watersheds) are only slightly different from the calibration. PBIAS and NSE were +8.9 percent and 0.58 (**Figure 9**) which largely demonstrates that the parameter transfer approach is effective for hydrologic predictions for the remaining TMDL watersheds.

Table 10. Summary of calibration and validation statistics from Big Hole River GWLF model.

Watershed	Hydrology		Sediment[1]		Nutrients	
	NSE	PBIAS	NSE	PBIAS	NSE	PBIAS
Big Hole River near Melrose, MT (calibration)	0.69	+1.1%	0.54	+0.4%	0.56	+0.7%
Willow Creek near Glen, MT (validation)	0.58	+8.9%	-4.61	+145.6%	0.39	-8.7%

[1]Validation much better than reported if two outlier peaks removed; NSE = 0.54 and PBIAS = +21.2%.

6.2 Sediment

6.2.1 Calibration

PBIAS and NSE for the sediment calibration were +0.4 percent and 0.54 respectively (**Figure 8**). Sediment peaks generally follow hydrograph response, and a majority of the sediment load in the watershed occurs during the months of May, June, and July. Based on the modeling results, the source of this load is primarily streambank erosion. Several false peaks do occur, and are likely a result of spatial variability in precipitation. Overpredictions are consistent with oversimulated peaks in hydrology.

6.2.2 Validation

Analysis of the validation model show very poor results. PBIAS and NSE were +145.6 percent and 4.61 (**Figure 9**). This is largely as a result of two vastly over-simulated sediment peaks in the months of 10/1963 and 6/1964. Again, these are likely a function of precipitation variability in the watershed and predictions would be much better in the absence of these peaks (i.e. PBIAS of +21.2 percent and NSE of 0.54). Fortunately, errors in sediment simulation have only minor impacts on simulated organic nitrogen and phosphorus loads. Thus it is believed that the use of GWLF for TMDL planning is still valid.

6.3 Nutrients

6.3.1 Calibration

Calibration of the nutrients was inherently uncertain, as many of the nutrient species were not measured at the USGS gage sites. Because of this, the model was first calibrated to observed USGS dissolved nitrogen data (e.g. measured NO3-), and then a quasi-calibration was completed to fit the remaining species to mean concentration and dissolved to total nutrients ratios observed in STORET. PBIAS and NSE for the NO3- calibration was +0.7 percent and 0.56 (**Table 10**) while simulated and observed dissolved nitrogen and phosphorus concentrations and ratios are shown in **Table 11**.

6.3.2 Validation

The validation performed similar to the calibration, with PBIAS and NSE of -8.7 percent and 0.39. Validation concentrations and statistics are shown in **Table 11**. Clearly, nutrient simulations are adequate for low certainty TMDL planning.

Table 11. Summary of observed and simulated mean concentrations and dissolved nutrient ratios in the Big Hole River GWLF model.

Watershed	Nitrogen			Phosphorus		
	TN (mg/L)	NO2+ NO3 (mg/L)	Dissolved: Total ratio	TP (mg/L)	SRP (mg/L)	Dissolved : Total ratio
STORET – all observations	0.31	0.03	0.10	0.041	0.014	0.34
Big Hole River near Melrose, MT (calibration)	0.28	0.08	0.29	0.049	0.026	0.53
Willow Creek near Glen, MT (validation)	0.27	0.06	0.22	0.046	0.022	0.48
Reference Non-reference from Suplee et al. (2007)	0.22 0.40	0.02 0.10	0.09 0.25	0.01 0.04	0.005 0.020	0.50 0.50

6.4 Summary

Given that hydrology, sediment, and nutrients are adequately simulated in GWLF, TMDL development activities for impaired water bodies in the Big Hole River watershed were initiated and area detailed in subsequent sections.

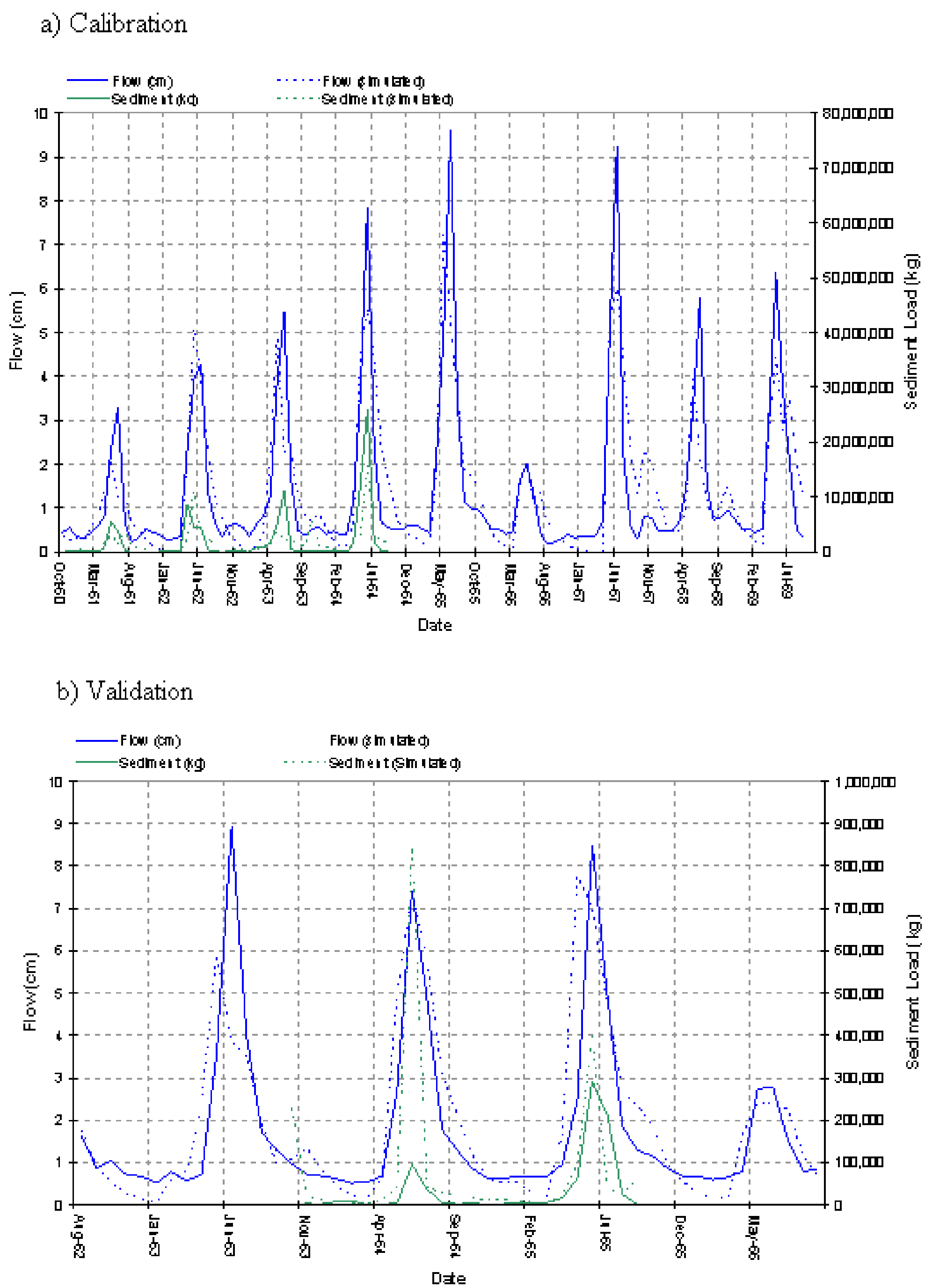
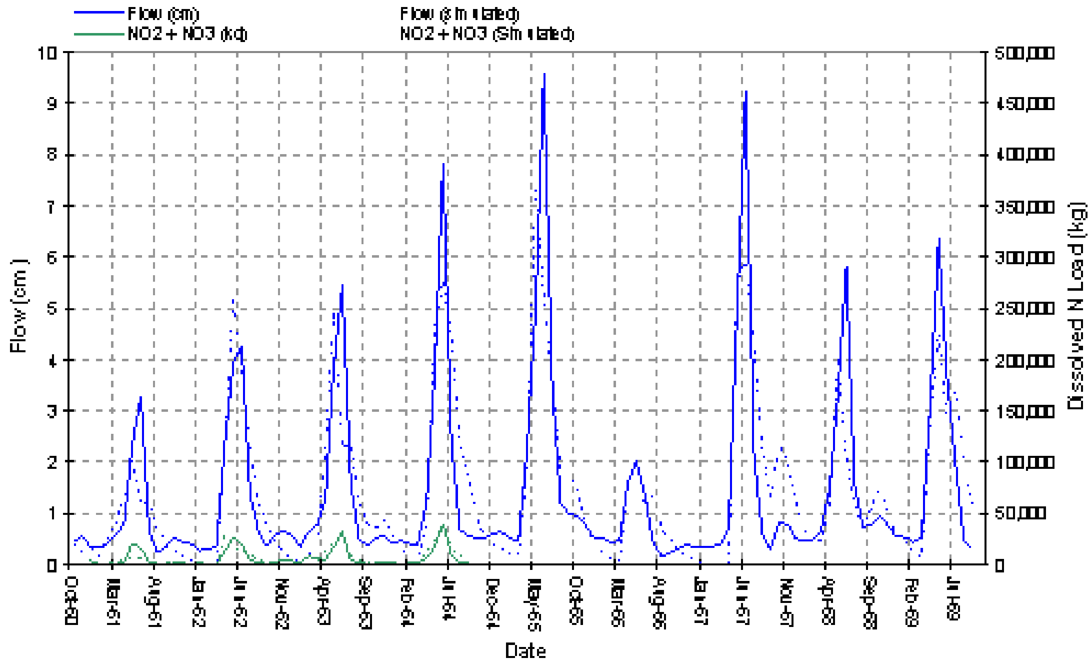


Figure 8. Calibration and validation plots for sediment and hydrology for a) USGS gage 6025500 Big Hole River near Melrose, MT and b) USGS gage 6025800 Willow Creek near Glen MT.

a) Calibration



b) Validation

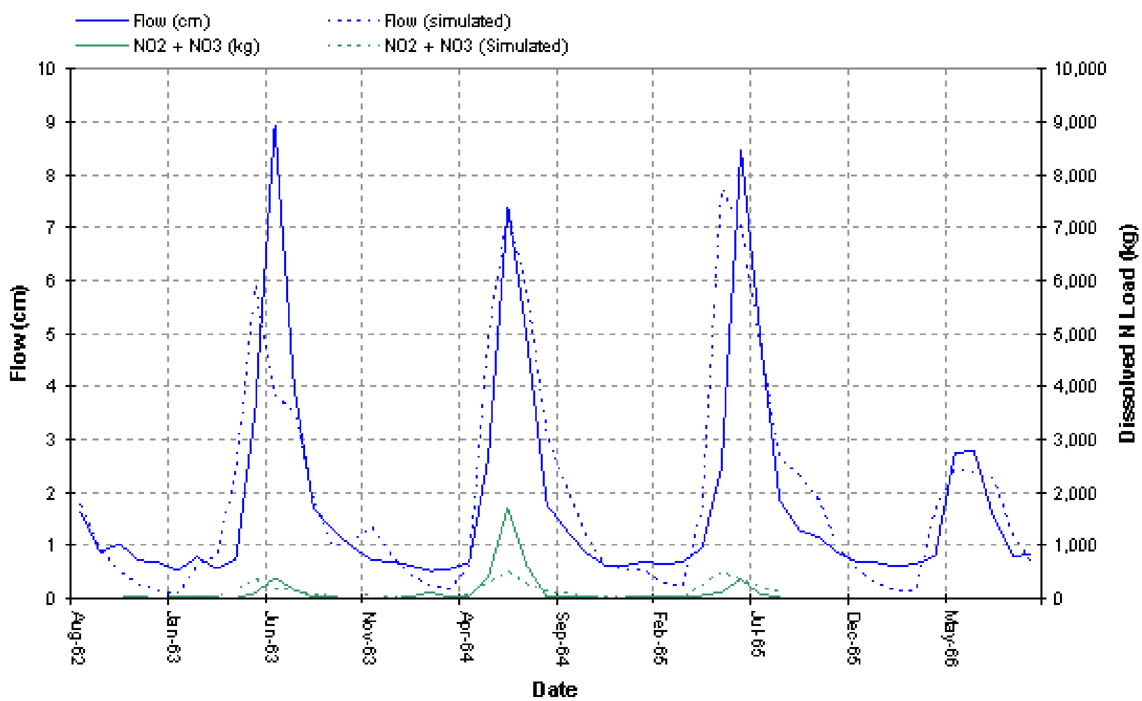


Figure 9. Calibration and validation plots for nutrients and hydrology for a) USGS gage 6025500 Big Hole River near Melrose, MT and b) USGS gage 6025800 Willow Creek near Glen MT.

SECTION 7.0
TMDL SOURCE ASSESSMENT

Following validation of the modeling approach, source estimates for the TMDL watersheds were completed over a representative period for which the data were compiled (24 years). A summary of the predicted annual nitrogen and phosphorus source contributions for each of the TMDL watersheds are shown in **Figure 10** and **Figure 11**. Simulated sources include: (1) hay/pasture (including fertilizer application and grazing), (2) shrub and grassland (with effects of grazing), (3) forested areas (including grazing), (4) developed areas (including both urban runoff and septic effluent), and (5) streambanks. Non-recoverable animal manure from each land use was lumped into its specific source category based on the estimated percentage cattle were on each land cover type (e.g. on hay/pasture 20 percent of the time, grassland/shrub 60 percent, and forest 20 percent). Individual source assessments for each of the TMDL watersheds are shown in **Figures 12-20** and **Tables 10-18**.

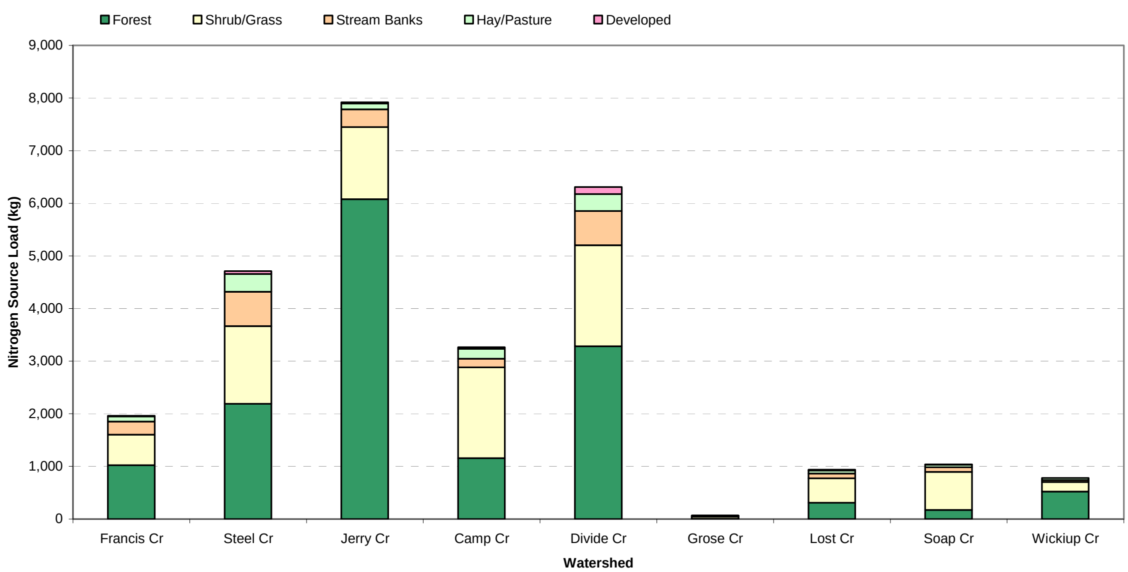


Figure 10. Summary of estimated nitrogen sources in each TMDL watershed.

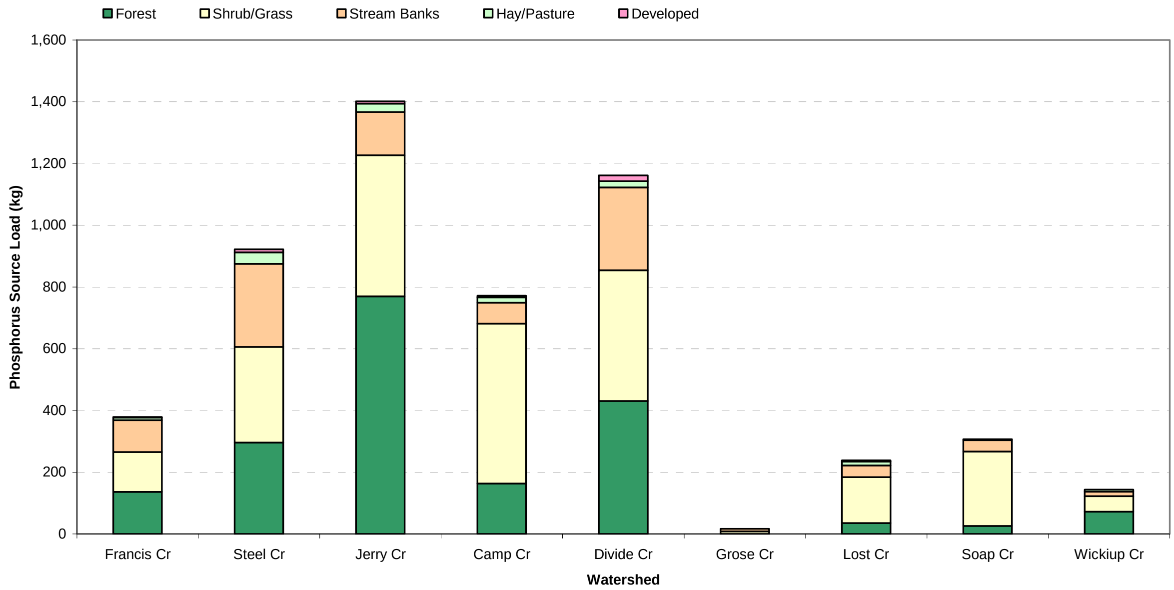
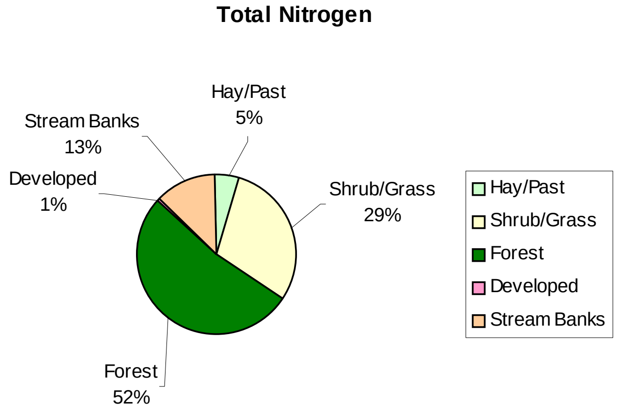


Figure 11. Summary of estimated phosphorus sources in each TMDL watershed.

7.1 Francis Creek

The existing condition source assessment for Francis Creek is shown below (**Figure 12**, **Table 12**).



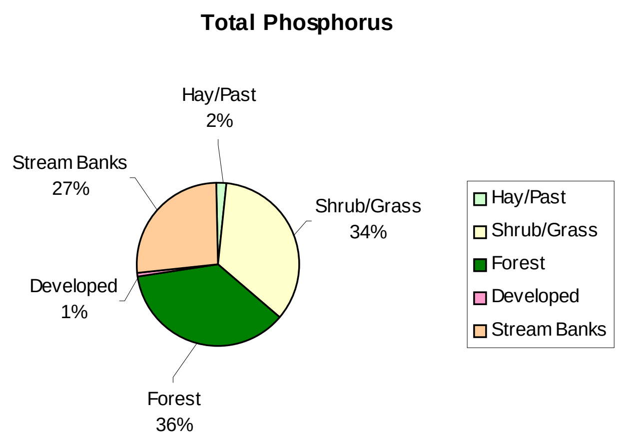


Figure 12. Graphical Nutrient Source Assessment for Francis Creek.

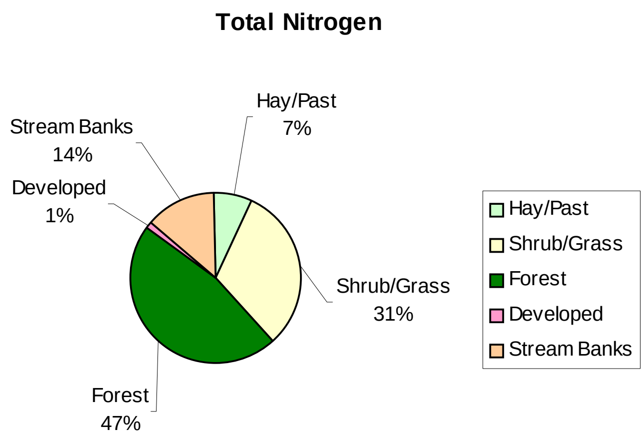
Table 12. Tabular Nutrient Source Assessment for Francis Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	130	0.39	0.40	13.7	99.3	1.8	8.4
Shrub/Grass	3311	0.76	86.36	104.6	578.2	69.2	129.1
Forest	3036	0.05	20.75	0.8	1024.5	13.2	136.5
Developed	35	1.59	0.56	0.0	11.1	0.0	2.3
Stream Banks			166.06	0.0	249.1	0.0	103.0
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.2 Steel Creek

The existing condition source assessment for Steel Creek is shown below (**Figure 13**, **Table 13**).



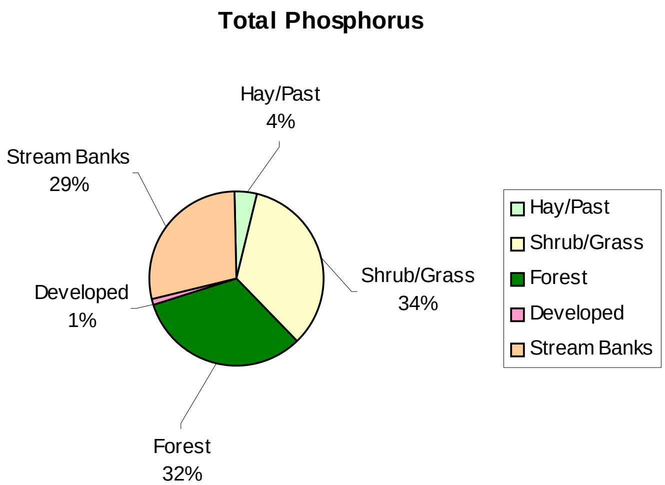


Figure 13. Graphical Nutrient Source Assessment for Steel Creek.

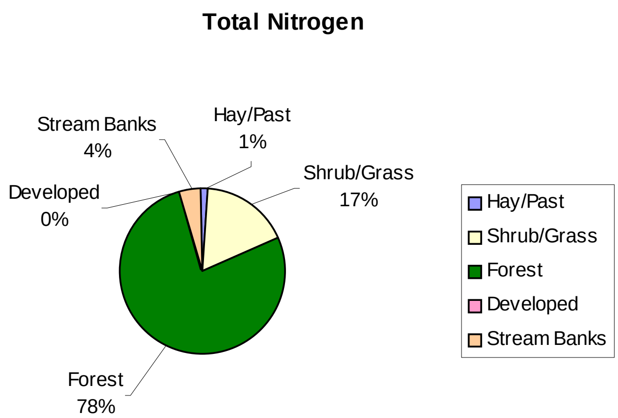
Table 13. Tabular Nutrient Source Assessment for Steel Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	828	0.52	1.75	108.6	338.7	15.7	37.2
Shrub/Grass	8610	0.97	152.76	352.1	1474.0	148.5	309.8
Forest	6008	0.06	34.87	1.7	2192.4	22.3	296.3
Developed	192	1.97	2.02	0.0	57.5	0.0	9.5
Stream Banks			434.22	0.0	651.3	0.0	269.2
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.3 Jerry Creek

The existing condition source assessment for Jerry Creek is shown below (**Figure 14**, **Table 14**).



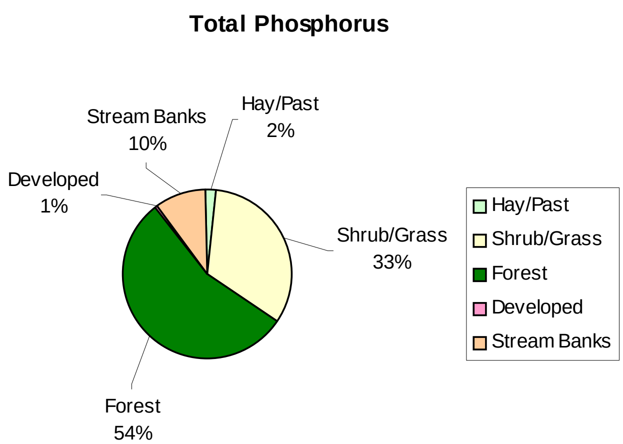


Figure 14. Graphical Nutrient Source Assessment for Jerry Creek.

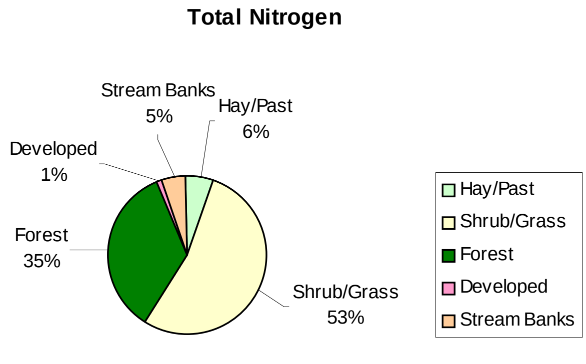
Table 14. Tabular Nutrient Source Assessment for Jerry Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	29	1.68	0.07	13.0	114.5	1.7	27.0
Shrub/Grass	2106	3.08	447.67	250.8	1370.6	130.7	457.0
Forest	9741	0.32	121.02	15.6	6076.3	81.3	770.2
Developed	1	5.09	0.01	0.0	21.2	0.0	8.2
Stream Banks			224.97	0.0	337.5	0.0	139.5
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.4 Camp Creek

The existing condition source assessment for Camp Creek is shown below (**Figure 15**, **Table 15**).



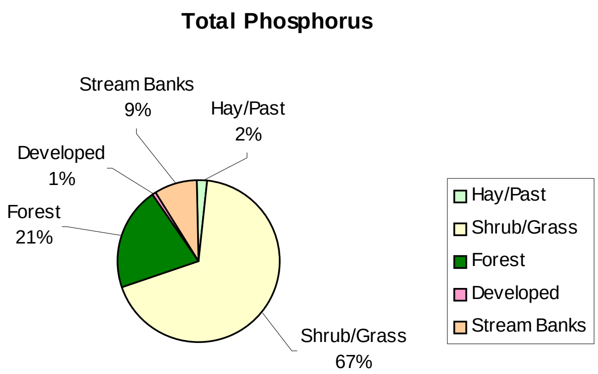


Figure 15. Graphical Nutrient Source Assessment for Camp Creek.

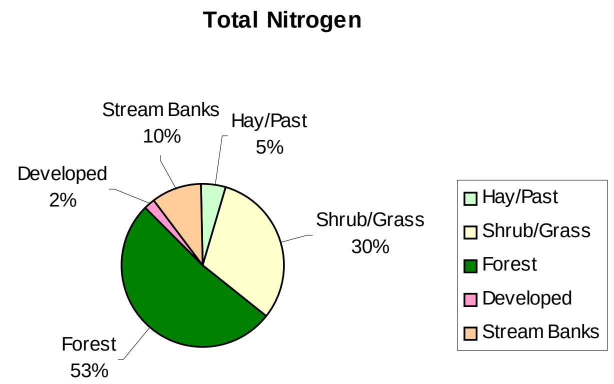
Table 15. Tabular Nutrient Source Assessment for Camp Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	315	0.53	0.52	43.4	186.9	6.0	17.7
Shrub/Grass	5684	0.99	601.92	230.8	1725.5	300.7	517.9
Forest	2784	0.07	28.46	0.9	1157.4	18.0	163.3
Developed	95	1.99	0.80	0.0	31.3	0.0	5.4
Stream Banks			109.54	0.0	164.3	0.0	67.9
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.5 Divide Creek

The existing condition source assessment for Divide Creek is shown below (**Figure 16**, **Table 16**).



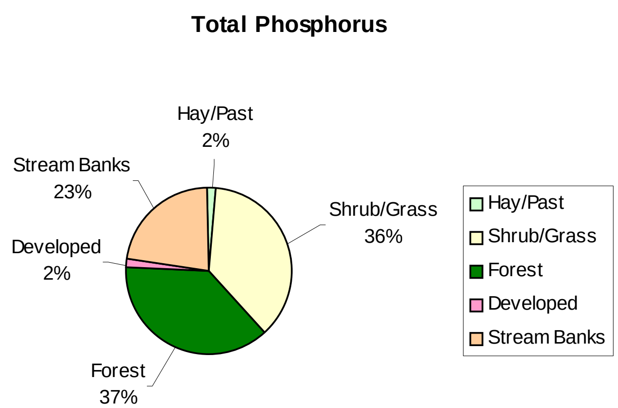


Figure 16. Graphical Nutrient Source Assessment for Divide Creek.

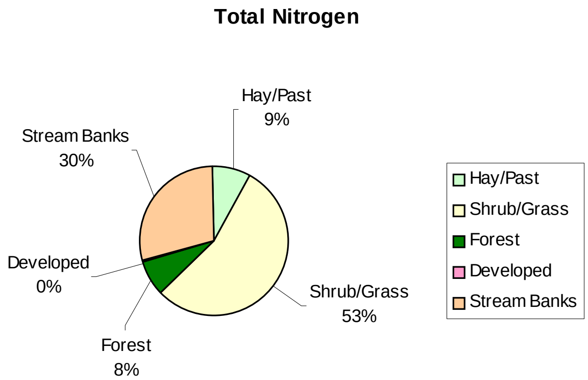
Table 16. Tabular Nutrient Source Assessment for Divide Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	496	0.24	0.58	33.6	324.0	4.1	20.0
Shrub/Grass	11845	0.48	341.79	250.0	1918.1	255.2	423.4
Forest	11622	0.02	44.09	1.3	3283.6	27.9	430.7
Developed	598	1.18	8.08	0.0	130.6	0.0	18.3
Stream Banks			433.73	0.0	650.6	0.0	268.9
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.6 Grose Creek

The existing condition source assessment for Grose Creek is shown below (**Figure 17**, **Table 17**).



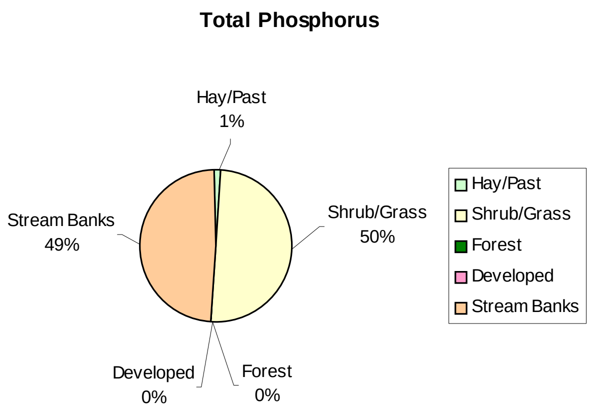


Figure 17. Graphical Nutrient Source Assessment for Grose Creek.

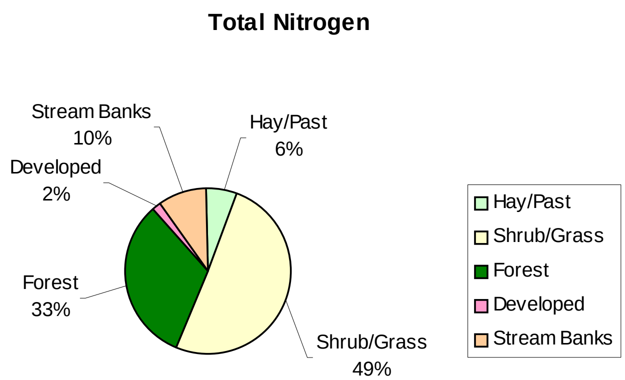
Table 17. Tabular Nutrient Source Assessment for Grose Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	21	0.02	0.04	0.1	5.9	0.0	0.2
Shrub/Grass	393	0.05	12.61	0.9	36.3	8.0	8.3
Forest	1	0.00	0.00	0.0	5.3	0.0	0.0
Developed	4	0.20	0.04	0.0	0.2	0.0	0.0
Stream Banks			13.43	0.0	20.1	0.0	8.3
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.7 Lost Creek

The existing condition source assessment for Lost Creek is shown below (**Figure 18**, **Table 18**).



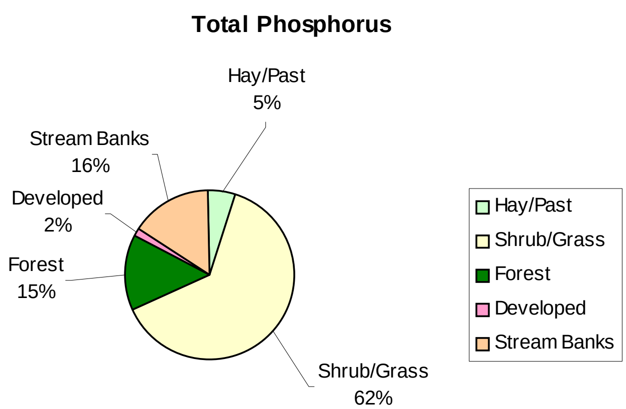


Figure 18. Graphical Nutrient Source Assessment for Lost Creek.

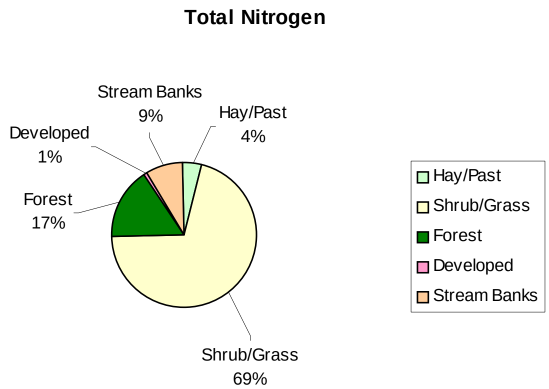
Table 18. Tabular Nutrient Source Assessment for Lost Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	10	0.47	0.04	1.2	58.7	0.2	12.6
Shrub/Grass	1243	0.89	192.82	45.7	465.3	115.8	149.1
Forest	949	0.06	13.27	0.3	309.0	8.3	35.1
Developed	29	1.77	1.48	0.0	15.6	0.0	4.2
Stream Banks			60.58	0.0	90.9	0.0	37.6
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater1			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.8 Soap Creek

The existing condition source assessment for Soap Creek is shown below (**Figure 19, Table 19**).



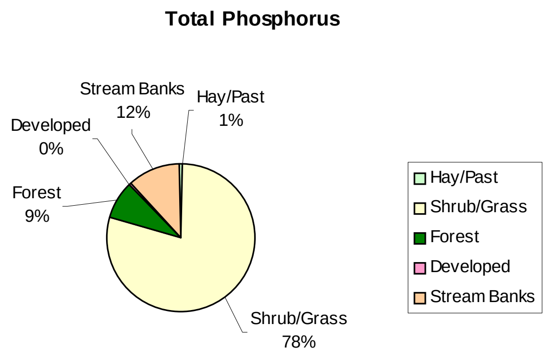


Figure 19. Graphical Nutrient Source Assessment for Soap Creek.

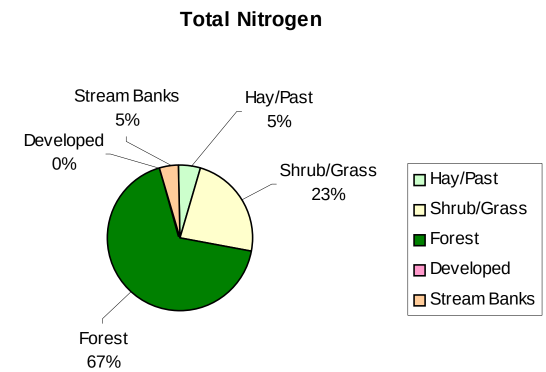
Table 19. Tabular Nutrient Source Assessment for Soap Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	42	0.35	0.02	3.9	46.3	0.5	2.5
Shrub/Grass	1981	0.67	329.82	54.0	725.3	175.6	240.8
Forest	365	0.04	5.33	0.1	171.2	3.3	26.4
Developed	22	1.46	0.28	0.0	5.8	0.0	1.0
Stream Banks			58.93	0.0	88.4	0.0	36.5
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.9 Wickiup Creek

The existing condition source assessment for Wickiup Creek is shown below (**Figure 20, Table 20**).



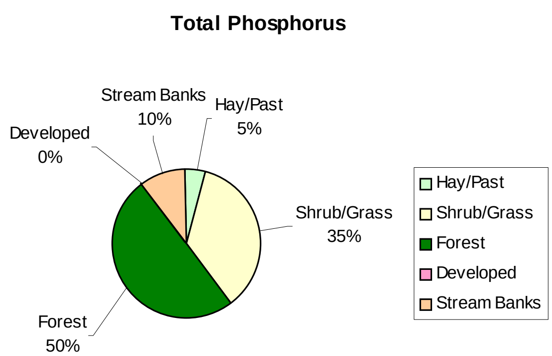


Figure 20. Graphical Nutrient Source Assessment for Wickiup Creek.

Table 20. Tabular Nutrient Source Assessment for Wickiup Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	56	0.95	2.08	13.9	38.2	1.9	6.6
Shrub/Grass	505	1.50	53.39	37.9	180.4	40.7	50.4
Forest	1034	0.11	8.16	0.6	523.0	5.3	72.0
Developed	0	0.00	0.00	0.0	0.0	0.0	0.0
Stream Banks			23.54	0.0	35.3	0.0	14.6
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.10 Summary of TMDL Source Assessment Results

In review of the existing condition source assessment, nitrogen and phosphorus loads are a function of land cover type, soils, topography, and associated land management practices. For the most part, forest and shrub/grassland provide the largest natural loads in the TMDL watersheds while anthropogenic sources are primarily of agricultural origin. Those loads consist of non-recoverable animal manure, grazing, and fertilization of hay/pasture, along with minor contributions from developed lands. Streambanks were also found to contribute a moderate amount of nitrogen and phosphorus to TMDL watersheds. In any case, existing loads for each of the impaired watersheds were estimated. **Section 8.0** details scenarios that evaluate mitigation measures for significant and controllable sources.

SECTION 8.0
SCENARIO ANALYSIS

Following the estimation of existing condition sources, a number of scenarios were evaluated so that watershed managers can provide reasonable recommendations for meeting water quality criteria in the river. Specifically, modeling scenarios were formulated to address the following: (1) baseline conditions, (2) a fertilizer reduction scenario, (3) streambank erosion reduction scenario, (4) upland erosion reduction scenario, (5) riparian buffer scenario, and (6) a livestock density reduction scenario.

8.1 Baseline Scenario

The baseline scenario describes existing conditions in the watershed and has been described previously (**Section 7.0**). Simulated values from this scenario form the basis for which all other scenarios will be compared.

8.2 Fertilizer Reduction Scenario

Agricultural fertilizer management was identified as a potential methodology for reducing nutrient loads in the Big Hole River. It is a common perception among watershed managers that fertilizer application rates could be decreased without affecting crop yield. This is most likely true, and for all intents and purposes, has already occurred due to prohibitive costs of fertilizer and through conservation strategies such as the Candidate Conservation Agreement with Assurances (CCAA) program. Reported cutbacks in the watershed are estimated at a change in application rate of 90.9 kg (200 lbs) of 29-6-6 mix application (nitrogen, phosphorus, potassium) to 45.5-68.2 kg/acre (100-150 lbs/acre) of 29-0-0 (personal communication, Erik Kalsta/Big Hole River Watershed Committee). Since DEQ considers this a reasonable BMP, the fertilizer reduction scenario was designed to estimate this nutrient reduction. Results are shown in **Table 20**. In general, very little change was observed in the watershed nutrient yield. This is due to the fact that hay/pasture is only a minor land use in most watersheds, as well as that some believe a greater amount of land is fertilized than characterized as hay/pasture in the NLCD (e.g. thus underestimating the actual influence fertilizer reduction). No investigations were completed to confirm this assertion.

Table 20. Nutrient reductions for fertilizer reduction scenario in the Big Hole River watershed.

Watershed	TN Reduction (kg)	Watershed Reduction (%)	TP Reduction (kg)	Watershed Reduction (%)
Francis	7.4	0.4%	4.9	1.3%
Steel	39.8	0.8%	21.6	2.3%
Jerry	19.0	0.4%	16.1	1.8%
Camp	17.9	0.5%	10.4	1.3%
Divide	18.1	0.3%	11.7	1.0%
Grose	0.1	0.2%	0.1	0.7%
Lost	2.2	0.2%	1.5	0.5%
Soap	2.2	0.2%	1.5	0.5%
Wickiup	5.6	0.7%	3.2	2.2%

The nitrogen EMC was reduced by 25 percent or 68.2/90.9 to reflect the change in application rate.

Phosphorus was adjusted to that of natural conditions (e.g. grassland), which totaled a 60 percent reduction.

8.2 Stream Bank Erosion Scenario

Stream bank erosion was identified as a nutrient source in many of the TMDL watersheds, therefore, a scenario was developed to address achievable pollutant reductions via stabilization of eroding or trampled stream banks. Relative reductions in bank erosion (in percent) were taken directly from the sediment TMDL, and then were applied to the computed streambank erosion load in GWLF to estimate the net change in nutrient load. Based on results of this scenario, watershed loads can be reduced by approximately 1-18 percent for nitrogen and 1-30 percent for phosphorus (**Table 21**).

Table 21. Nutrient reductions for the bank erosion scenario.

Watershed	GWLF Bank Load (kg x 1000)	Assumed Reduction (%)	TN Reduction (kg)	Watershed Reduction (%)	TP Reduction (kg)	Watershed Reduction (%)
Francis	166.06	26%	64.8	3.3%	26.8	7.1%
Steel	434.22	48%	312.6	6.6%	129.2	14.0%
Jerry	224.97	26%	87.7	1.1%	36.3	2.6%
Camp	109.54	43%	70.7	2.2%	29.2	3.8%
Divide	433.73	7%	45.5	0.7%	18.8	1.6%
Grose	13.43	62%	12.5	18.4%	5.2	30.5%
Lost	60.58	32%	29.1	3.1%	12.0	5.0%
Soap	58.93	11%	9.7	0.9%	4.0	1.3%
Wickiup	23.54	12%	4.2	0.5%	1.8	1.2%

8.3 Upland Erosion Scenario

Upland erosion was also considered for its underlying effect on nitrogen and phosphorus loads in TMDL watersheds. A similar procedure to the bank erosion scenario was completed, whereby results of the sediment TMDL were applied directly to computed values in GWLF (e.g. through changes in the cover management factor). Estimated reductions are shown in **Table 22**. Again, phosphorus was the nutrient most strongly associated with reductions in sedimentation.

Table 22. Nutrient reductions for the upland erosion scenario.

Watershed	**GWLF Upland Load (kg x 1000)**	**Assumed Reduction (%)**	**TN Reduction (kg)**	**Watershed Reduction (%)**	**TP Reduction (kg)**	**Watershed Reduction (%)**
Francis	108.07	14%	40.5	2.1%	16.7	4.4%
Steel	191.40	15%	69.5	1.5%	28.7	3.1%
Jerry	568.77	17%	144.7	1.8%	59.8	4.3%
Camp	631.70	20%	249.4	7.6%	103.1	13.3%
Divide	394.54	17%	164.9	2.6%	68.2	5.9%
Grose	12.69	19%	6.2	9.1%	2.6	15.1%
Lost	207.61	20%	89.4	9.5%	36.9	15.5%
Soap	335.45	21%	146.1	14.1%	60.4	19.7%
Wickiup	63.63	19%	27.2	3.5%	11.2	7.8%

8.4 Riparian Filter Strip Scenario

Riparian filter strips have been shown to be effective in removing phosphorus and nitrogen from surface water runoff and groundwater (Wegner, 1999; Peterjohn and Correll, 1985; Evans et al., 2001). In the case of the Big Hole River, it is believed riparian enhancement could have some utility in reducing nutrient loads in impaired watersheds. Filtering/uptake capacity is dependent on the condition of the riparian filter strip and associated width. Evans et al. (2001) provides filtering efficiencies for use in GWLF (**Table 23**).

Table 23. Assumed filtering efficiency of fully-functioning 10-m (30-ft) riparian buffer strip.

Phosphorus	Nitrogen	Sediment
54%	52%	58%

GWLF user's manual (Evans et al., 2001.)

Because certain locations in the watershed may already contain a functional buffer, DEQ derived four general conditions to provide an estimate of the current filtering capacity potential. These include non-functioning, partially-functioning, nearly-functioning, and functioning buffer strips as described below (determined from air photo assessment and greenline monitoring as):

1. Non-functioning – areas with severely degraded riparian zones having a very high proportion of bare banks, high lateral erosion rates, higher bare ground rates, and largely devoid of woody vegetation.

2. Partially-functioning – areas that have patchy riparian zones and could use more grazing management or setbacks from active hay production operations.
3. Nearly-functioning – areas that are in fair condition overall but have patchy areas that could use grazing BMPs.
4. Fully-functioning – well vegetated area with minimal impact and functioning as desired.

Using this information, the following assumptions regarding reduction attainability were made for each of the TMDL watersheds in the scenario:

- Francis Creek: 50 percent reduction potential for grassland, shrub, hay; 15 percent for forest
- Steel Creek: 50 percent reduction potential for grassland, shrub, hay
- Jerry Creek: 25 percent reduction potential in all areas
- Camp Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Divide Creek: 15 percent reduction potential for grassland, shrub, hay
- Grose Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Lost Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Soap Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Wickiup Creek: 15 percent reduction potential in all areas

The cumulative estimated effect of riparian filer strips is shown in **Table 24**.

Table 24. Nutrient reductions for the riparian filter strip scenario.

Watershed	TN Reduction	Watershed Reduction (%)	TP Reduction	Watershed Reduction (%)
Francis	468.4	23.9%	78.4	20.7%
Steel	851.7	18.1%	148.3	16.1%
Jerry	1849.4	23.4%	294.5	21.0%
Camp	437.3	13.4%	88.5	11.5%
Divide	308.9	4.9%	54.5	4.7%
Grose	6.7	9.9%	0.9	5.3%
Lost	116.8	12.4%	24.9	10.4%
Soap	123.6	11.9%	31.3	10.2%
Wickiup	106.3	13.7%	17.2	12.0%

Net filtering efficiency includes filtering of non-recoverable animal manure

8.5 Animal Stocking Density Scenario

Since animals are an anthropogenic source in many of the TMDL watersheds, a scenario was developed to assess relative stocking densities in the watershed (e.g. whether reductions in livestock should be recommended by DEQ). Forage biomass was used as the primary indicator of approximate maximum stocking rates, and recommended values from Dryland Pastures in Montana and Wyoming Species and Cultivars, Seeding Techniques and Grazing Management (MSU, 2003) were used as a general guideline for this estimate (**Table 25**). With conservative assumptions, such as a precipitation zone of 10-14 inches, and crested wheatgrass as the primary grassland forage, 0.61 hectares (1.5 acres) are required per animal unit per month (AUM). Assuming a six-month grazing period from May-October, 3.6 ha (9.0) acres would be required per animal unit (AU). Thus, the overall calculated carrying capacity of the study area upstream of Melrose is approximately 70,430 AU (using grassland as a surrogate for grazing area). When compared with the National Agricultural Statistics Service (NASS), current stocking density is 39,669 AU, which indicates that no reductions are necessary (**Table 26**). It should be noted, this is an estimate only (not considering available winter feed), and does not constitute a recommendation for increased livestock production in the watershed. Stocking density calculations are shown in **Appendix A4**.

Table 25. Stocking rate guidelines for dryland pastures and crop aftermath (MSU, 2003).

Pasture	Precipitation Zone (inches)	AUM Per Acre	Acre Per AUM
Crested wheatgrass	10–14	0.67	1.5
	15–18	1.00	1.0
Russian wildrye	10–14	0.50	2.0
	15–18	1.00	1.0
Pubescent wheatgrass	13–14	0.75	1.3
	15–18	1.25	0.8
Intermediate wheatgrass	14–18	1.50	0.7
Meadow bromegrass	16–18	1.50	0.7
Timothy	16–18	1.25	0.8
Orchardgrass	16–18	1.50	0.7
Grain aftermath	10-14 15-18	0.20 0.30	5.0 3.3
Hay aftermath	10-14 15-18	0.40 0.50	2.5 2.0

AUM = 1,000 lb cow/calf pair

Table 26. Nutrient reductions for the livestock density scenario.

Watershed	TN Reduction	Watershed Reduction (%)	TP Reduction	Watershed Reduction (%)
Francis	0.0	0.0%	0.0	0.0%
Steel	0.0	0.0%	0.0	0.0%
Jerry	0.0	0.0%	0.0	0.0%
Camp	0.0	0.0%	0.0	0.0%
Divide	0.0	0.0%	0.0	0.0%
Grose	0.0	0.0%	0.0	0.0%
Lost	0.0	0.0%	0.0	0.0%
Soap	0.0	0.0%	0.0	0.0%
Wickiup	0.0	0.0%	0.0	0.0%

SECTION 9.0
TMDL SCENARIO

A final scenario was formulated to assess the integrated effects of previous scenarios, e.g. effectively all reasonable soil and water conservation practices as outlined in ARM 17.30.602. Results were then compared to proposed interim nutrient criteria as outlined in **Section 1.2**. A summary of individual scenario results, combined nutrient reductions, and associated reduction percentages for each TMDL watershed is shown in **Table 27**, **Table 28**, and **Figure 21**. Individual results are detailed in **Figures 23-31** and **Tables 31-56**.

Table 27. Nitrogen reduction summary table.

Watershed	Fertilizer Scenario (kg)	Stream-bank Scenario (kg)	Upland Scenario (kg)	Filter Strip Scenario (kg)	Animal Scenario (kg)	Overall Reduction (kg)	Total Load (kg)	% Red.
Francis Cr	7.4	64.8	40.5	468.4	0.0	581.1	1,962.1	30%
Steel Cr	39.8	312.6	69.5	851.7	0.0	1,273.7	4,713.9	27%
Jerry Cr	19.0	87.7	144.7	1,849.4	0.0	2,100.9	7,920.0	27%
Camp Cr	17.9	70.7	249.4	437.3	0.0	775.2	3,265.5	24%
Divide Cr	18.1	45.5	164.9	308.9	0.0	537.4	6,306.9	9%
Grose Cr	0.1	12.5	6.2	6.7	0.0	25.6	67.9	38%
Lost Cr	2.2	29.1	89.4	116.8	0.0	237.5	939.4	25%
Soap Cr	2.2	9.7	146.1	123.6	0.0	281.6	1,037.0	27%
Wickiup Cr	5.6	4.2	27.2	106.3	0.0	143.3	776.9	18%

Table 28. Phosphorus reduction summary table

Watershed	Fertilizer Scenario (kg)	Stream-bank Scenario (kg)	Upland Scenario (kg)	Filter Strip Scenario (kg)	Animal Scenario (kg)	Overall Reduction (kg)	Total Load (kg)	% Red.
Francis Cr	4.9	26.8	16.7	78.4	0.0	126.8	379.3	33%
Steel Cr	21.6	129.2	28.7	148.3	0.0	327.9	922.1	36%
Jerry Cr	16.1	36.3	59.8	294.5	0.0	406.8	1,401.7	29%
Camp Cr	10.4	29.2	103.1	88.5	0.0	231.2	772.1	30%
Divide Cr	11.7	18.8	68.2	54.5	0.0	153.2	1,161.4	13%
Grose Cr	0.1	5.2	2.6	0.9	0.0	8.7	16.9	52%
Lost Cr	1.5	12.0	36.9	24.9	0.0	75.3	238.5	32%
Soap Cr	1.5	4.0	60.4	31.3	0.0	97.2	307.2	32%
Wickiup Cr	3.2	1.8	11.2	17.2	0.0	33.4	143.6	23%

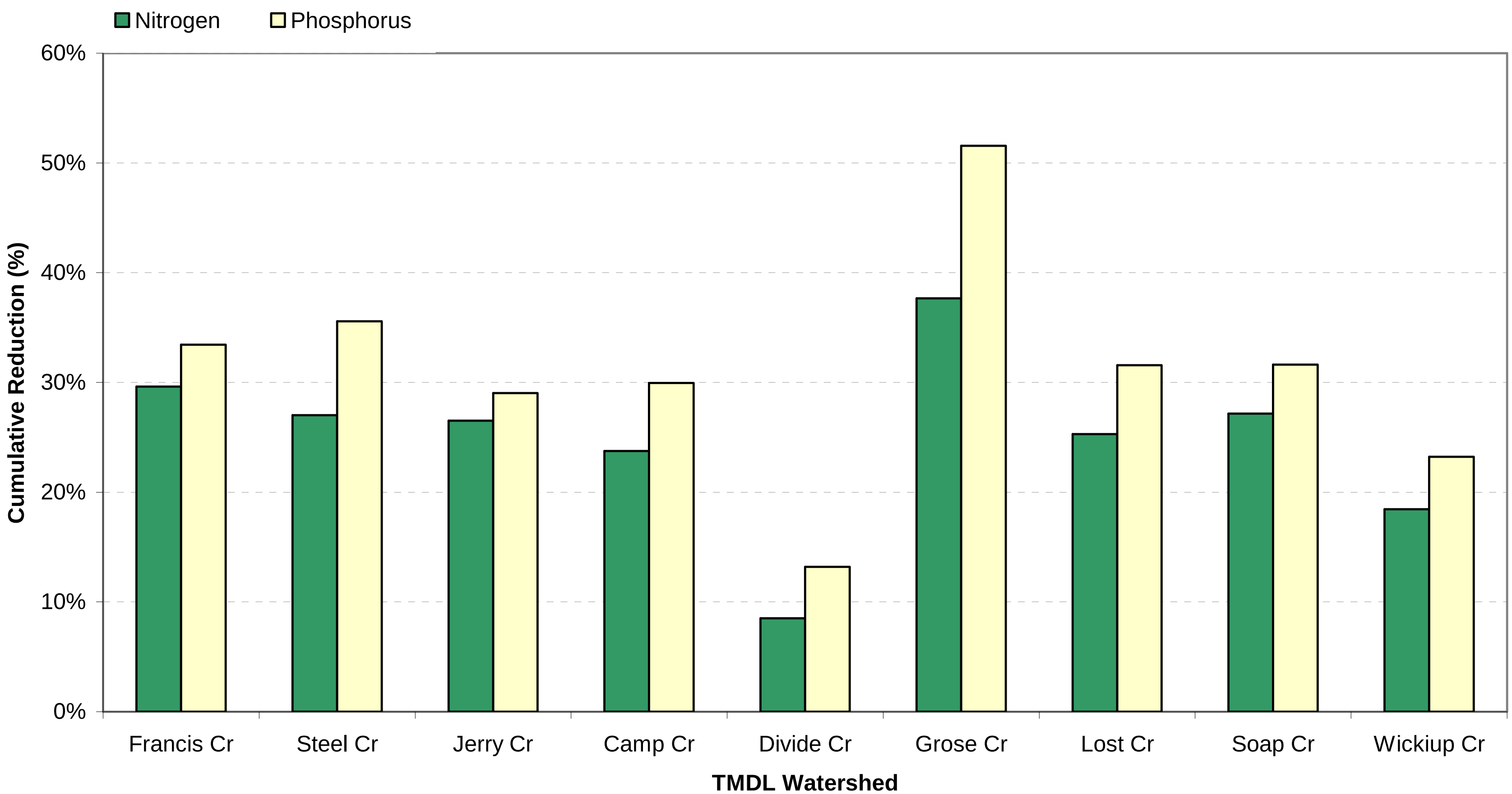
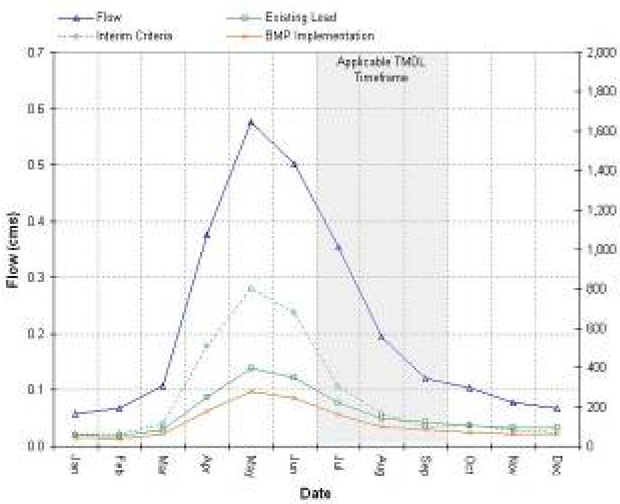


Figure 21. Summary of estimated nitrogen and phosphorus reductions in TMDL watersheds from implementation of all reasonable land, soil and water conservation practices (ARM 17.30.602).

9.1 Francis Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Francis Creek are shown in **Figure 22**, **Table 29**, **Table 30**, and **Table 31**.



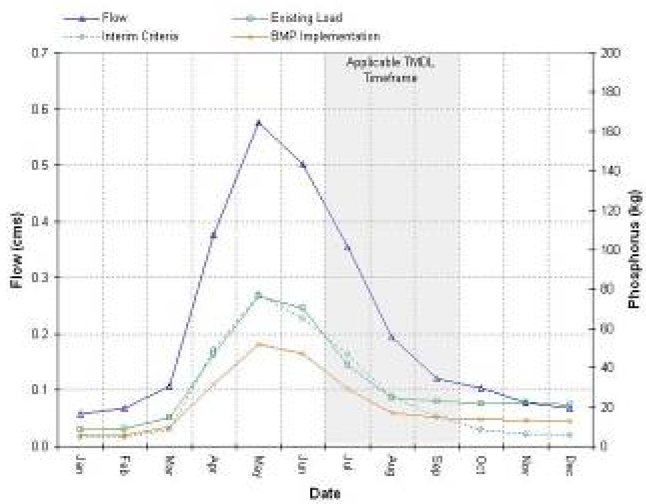


Figure 22. Estimated existing and proposed monthly loads of nitrogen and phosphorus in Francis Creek.

Table 29. Monthly tabular data of estimated monthly streamflow and pollutant loads for Francis Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.06	57.2	61.0	41.2	8.4	4.7	5.7
Feb	0.07	52.2	63.5	37.1	8.7	4.9	5.9
Mar	0.11	84.8	111.7	60.5	14.9	8.6	10.0
Apr	0.38	248.0	507.9	177.9	46.5	48.8	31.8
May	0.58	394.0	802.5	280.6	76.6	77.2	52.1
Jun	0.50	350.4	677.2	246.1	70.1	65.1	47.0
Jul	0.35	220.9	304.2	158.7	41.6	46.6	29.1
Aug	0.19	140.6	166.7	100.8	24.5	25.5	16.9
Sep	0.12	122.4	100.0	84.5	23.0	15.3	14.7
Oct	0.10	103.3	109.2	70.1	21.7	8.4	13.5
Nov	0.08	96.3	78.7	63.2	22.0	6.1	13.2
Dec	0.07	92.0	71.1	60.2	21.1	5.5	12.6

Table 30. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	99.3	Fertilizer/Grazing Management 7.6	91.7	50% 45.8	45.8
Shrub and Grassland	Grazing	578.2	Upland grazing management 40.3	537.9	50% 268.9	268.9
Forest	Grazing Timber Harvest	1024.5	NA	1024.5	15% 153.7	870.8
Developed	Urban	11.1	NA	11.1	0	11.1
Stream Banks	Grazing Hay encroachment	249.1	Riparian Vegetation restoration and grazing management 64.8	184.3	NA	184.3
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1962.1	112.7	1849.4	468.4	1381.0
Estimated overall % reduction			6%		25%	30%

Table 31. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	8.4	Fertilizer/Grazing Management 5.0	3.5	50% 1.7	1.7
Shrub and Grassland	Grazing	129.1	Upland grazing management 16.7	112.4	50% 56.2	56.2
Forest	Grazing Timber Harvest	136.5	NA	136.5	15% 20.5	116.0
Developed	Urban	2.3	NA	2.3	0	2.3
Stream Banks	Grazing Hay encroachment	103.0	Riparian Vegetation restoration and grazing management 26.8	76.2	NA	76.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		379.3	48.4	330.8	78.4	252.4
Estimated overall % reduction			13%		24%	33%

9.2 Steel Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Steel Creek are shown in **Figure 23**, **Table 32**, **Table 33**, and **Table 34**.

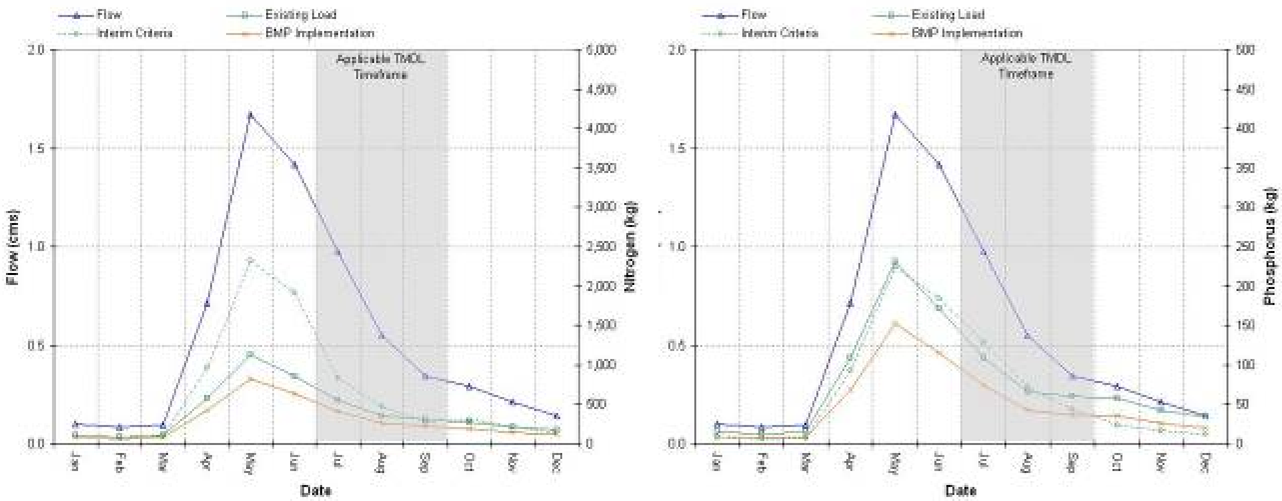


Figure 23. Estimated monthly loads of nitrogen and phosphorus in Steel Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 32. Monthly tabular data of estimated monthly streamflow and pollutant loads for Steel Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.10	111.1	103.7	82.0	14.9	8.0	8.8
Feb	0.08	84.7	79.3	61.4	12.2	6.1	7.0
Mar	0.09	104.5	97.6	76.7	14.7	7.5	8.6
Apr	0.71	574.7	959.5	419.8	109.1	92.3	68.1
May	1.67	1125.3	2325.7	827.2	231.5	223.6	152.7
Jun	1.42	854.2	1911.0	630.7	171.2	183.7	114.9
Jul	0.98	548.4	835.7	405.9	108.9	128.0	73.4
Aug	0.55	354.3	470.4	259.9	65.4	72.0	42.3
Sep	0.34	310.8	285.2	222.7	59.7	43.7	36.9
Oct	0.29	266.9	304.9	187.2	57.9	23.5	35.3
Nov	0.21	206.1	213.5	145.0	42.3	16.4	25.6
Dec	0.14	172.9	146.4	121.9	34.1	11.3	20.5

Table 33. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek.

Source Area	Associated Human Activities	Existing Tot. N (kg)	Source Area Restoration Approach (reduction in kg)	Source Area Allocated Tot. N (kg)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)	Total Allocated Load From Source (kg)
Hay/Past	Grazing Hay Production Fertilizer	338.7	Fertilizer/Grazing Management 40.8	297.9	50% 149.0	149.0
Shrub and Grassland	Grazing	1474.0	Upland grazing management 68.6	1405.4	50% 702.7	702.7
Forest	Grazing Timber Harvest	2192.4	NA	2192.4	0% 0.0	2192.4
Developed	Urban	57.5	NA	57.5	0	57.5
Stream Banks	Grazing Hay encroachment	651.3	Riparian Vegetation restoration and grazing management 312.6	338.7	NA	338.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		4713.9	422.0	4291.9	851.7	3440.3
Estimated overall % reduction			9%		20%	27%

Table 34. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	37.2	Fertilizer/Grazing Management 22.0	15.2	50% 7.6	7.6
Shrub and Grassland	Grazing	309.8	Upland grazing management 28.4	281.5	50% 140.7	140.7
Forest	Grazing Timber Harvest	296.3	NA	296.3	0% 0.0	296.3
Developed	Urban	9.5	NA	9.5	0	9.5
Stream Banks	Grazing Hay encroachment	269.2	Riparian Vegetation restoration and grazing management 129.2	140.0	NA	140.0
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		922.1	179.6	742.5	148.3	594.1
Estimated overall % reduction			19%		20%	36%

9.3 Jerry Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Jerry Creek are shown in **Figure 24**, **Table 35**, **Table 36**, and **Table 37**.

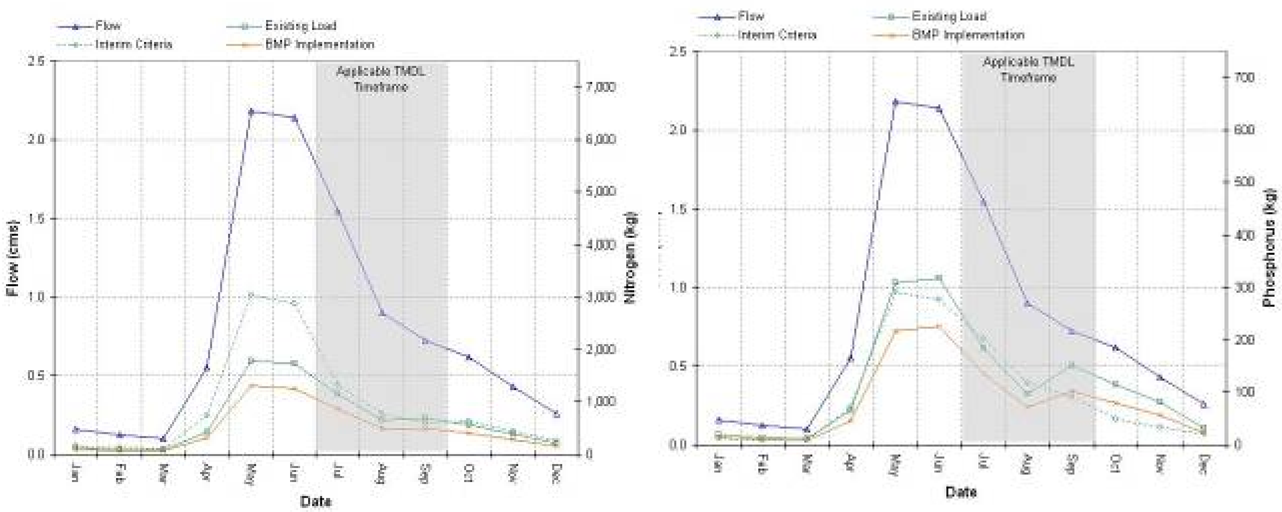


Figure 24. Estimated monthly loads of nitrogen and phosphorus in Jerry Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 35. Monthly tabular data of estimated monthly streamflow and pollutant loads for Jerry Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.16	129.3	166.8	96.2	19.0	12.8	13.9
Feb	0.12	91.8	115.8	67.9	13.9	8.9	10.0
Mar	0.10	87.2	106.5	64.6	12.9	8.2	9.3
Apr	0.55	426.2	747.3	317.1	66.1	71.9	46.8
May	2.18	1782.2	3038.6	1313.6	309.5	292.2	218.1
Jun	2.14	1726.6	2884.2	1264.5	318.5	277.3	226.6
Jul	1.54	1152.9	1322.6	861.7	184.2	202.5	136.3
Aug	0.90	658.8	775.3	496.1	97.3	118.7	73.2
Sep	0.72	697.1	600.5	494.4	151.3	92.0	102.1
Oct	0.62	562.6	643.9	404.2	114.6	49.5	78.9
Nov	0.43	397.3	435.4	284.3	82.1	33.5	56.3
Dec	0.26	208.0	273.3	154.7	32.3	21.0	23.5

Table 36. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	114.5	Fertilizer/Grazing Management 19.0	95.5	25% 23.9	71.6
Shrub and Grassland	Grazing	1370.6	Upland grazing management 144.7	1225.9	25% 306.5	919.4
Forest	Grazing Timber Harvest	6076.3	NA	6076.3	25% 1519.1	4557.3
Developed	Urban	21.2	NA	21.2	0	21.2
Stream Banks	Grazing Hay encroachment	337.5	Riparian Vegetation restoration and grazing management 87.7	249.7	NA	249.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		7920.0	251.4	7668.6	1849.4	5819.2
Estimated overall % reduction			3%		24%	27%

Table 37. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	27.0	Fertilizer/Grazing Management 16.2	10.8	25% 2.7	8.1
Shrub and Grassland	Grazing	457.0	Upland grazing management 59.8	397.1	25% 99.3	297.9
Forest	Grazing Timber Harvest	770.2	NA	770.2	25% 192.5	577.6
Developed	Urban	8.2	NA	8.2	0	8.2
Stream Banks	Grazing Hay encroachment	139.5	Riparian Vegetation restoration and grazing management 36.3	103.2	NA	103.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1401.7	112.2	1289.5	294.5	995.0
Estimated overall % reduction			8%		23%	29%

9.4 Camp Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Camp Creek are shown in **Figure 26**, **Table 38**, **Table 39, and Table 40**.

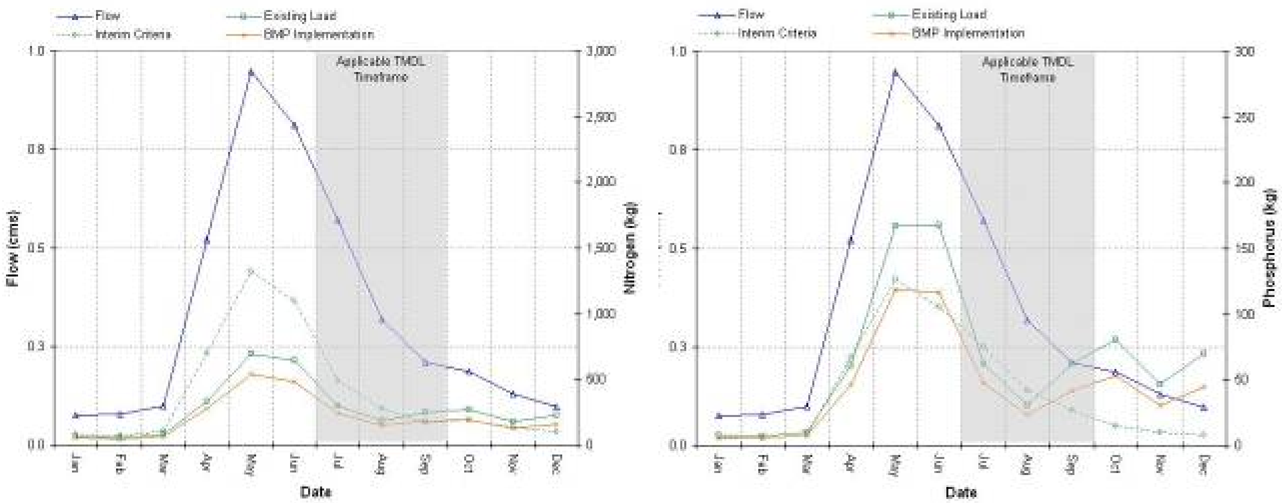


Figure 25. Estimated monthly loads of nitrogen and phosphorus in Camp Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 38. Monthly tabular data of estimated monthly streamflow and pollutant load for Camp Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.08	67.0	79.6	55.7	7.6	6.1	5.8
Feb	0.08	54.4	72.7	44.8	7.1	5.6	5.3
Mar	0.10	75.2	103.9	61.9	10.3	8.0	7.7
Apr	0.52	335.2	701.7	274.3	60.6	67.5	45.8
May	0.95	694.5	1320.3	535.3	166.8	127.0	119.2
Jun	0.81	640.6	1094.1	478.0	167.9	105.2	116.7
Jul	0.57	298.9	488.6	240.7	62.0	74.8	47.4
Aug	0.32	180.8	272.7	148.7	30.1	41.8	23.4
Sep	0.21	248.3	173.3	182.1	62.4	26.5	41.6
Oct	0.19	269.6	193.9	188.5	80.8	14.9	52.8
Nov	0.13	175.0	131.6	125.9	46.6	10.1	30.6
Dec	0.10	225.8	100.4	154.2	69.9	7.7	44.7

Table 39. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	186.9	Fertilizer/Grazing Management 18.2	168.8	25% 42.2	126.6
Shrub and Grassland	Grazing	1725.5	Upland grazing management 249.1	1476.4	15% 221.5	1254.9
Forest	Grazing Timber Harvest	1157.4	NA	1157.4	15% 173.6	983.8
Developed	Urban	31.3	NA	31.3	0	31.3
Stream Banks	Grazing Hay encroachment	164.3	Riparian Vegetation restoration and grazing management 70.7	93.7	NA	93.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		3265.5	337.9	2927.5	437.3	2490.3
Estimated overall % reduction			10%		15%	24%

Table 40. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	17.7	Fertilizer/Grazing Management 10.5	7.2	25% 1.8	5.4
Shrub and Grassland	Grazing	517.9	Upland grazing management 103.0	414.9	15% 62.2	352.7
Forest	Grazing Timber Harvest	163.3	NA	163.3	15% 24.5	138.8
Developed	Urban	5.4	NA	5.4	0	5.4
Stream Banks	Grazing Hay encroachment	67.9	Riparian Vegetation restoration and grazing management 29.2	38.7	NA	38.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		772.1	142.7	629.5	88.5	541.0
Estimated overall % reduction			18%		14%	30%

9.5 Divide Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Divide Creek are shown in **Figure 26**, **Table 41**, **Table 42** and **Table 43**.

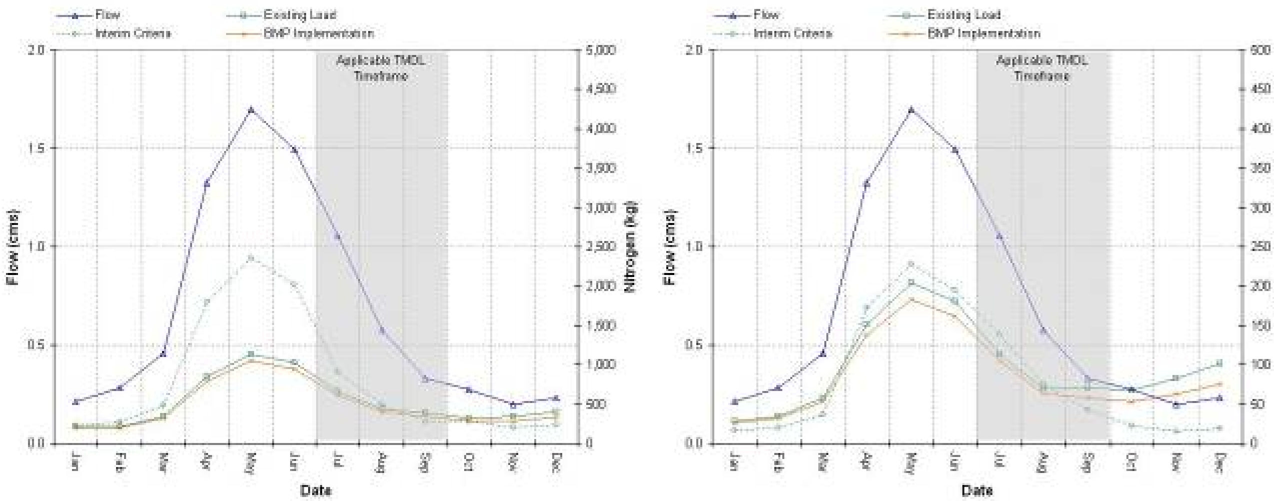


Figure 26. Estimated monthly loads of nitrogen and phosphorus in Divide Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 41. Monthly tabular data of estimated monthly streamflow and pollutant load for Divide Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.21	208.0	220.3	195.1	28.5	16.9	25.9
Feb	0.28	215.2	268.2	201.5	34.5	20.6	31.4
Mar	0.46	342.5	478.9	320.7	57.6	36.8	52.5
Apr	1.33	849.1	1788.0	794.5	151.3	171.9	137.5
May	1.70	1127.1	2362.8	1046.7	203.5	227.2	182.5
Jun	1.50	1020.8	2017.9	944.2	180.7	194.0	161.0
Jul	1.05	655.4	903.8	617.1	112.9	138.4	105.0
Aug	0.58	431.1	495.1	403.3	69.7	75.8	63.7
Sep	0.33	389.9	275.1	347.4	70.9	42.1	57.8
Oct	0.28	323.4	287.4	283.1	67.3	22.1	53.6
Nov	0.20	343.1	201.2	285.4	83.1	15.5	62.1
Dec	0.23	401.2	239.5	330.5	101.4	18.4	75.2

Table 42. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	324.0	Fertilizer/Grazing Management 18.4	305.6	15% 45.8	259.8
Shrub and Grassland	Grazing	1918.1	Upland grazing management 164.6	1753.5	15% 263.0	1490.5
Forest	Grazing Timber Harvest	3283.6	NA	3283.6	0% 0.0	3283.6
Developed	Urban	130.6	NA	130.6	0	130.6
Stream Banks	Grazing Hay encroachment	650.6	Riparian Vegetation restoration and grazing management 45.5	605.1	NA	605.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		6306.9	228.5	6078.4	308.9	5769.5
Estimated overall % reduction			4%		5%	9%

Table 43. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	20.0	Fertilizer/Grazing Management 11.8	8.2	15% 1.2	7.0
Shrub and Grassland	Grazing	423.4	Upland grazing management 68.0	355.4	15% 53.3	302.1
Forest	Grazing Timber Harvest	430.7	NA	430.7	0% 0.0	430.7
Developed	Urban	18.3	NA	18.3	0	18.3
Stream Banks	Grazing Hay encroachment	268.9	Riparian Vegetation restoration and grazing management 18.8	250.1	NA	250.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1161.4	98.7	1062.7	54.5	1008.2
Estimated overall % reduction			8%		5%	13%

9.6 Grose Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Grose Creek are shown in **Figure 27**, **Table 44**, **Table 45** and **Table 46**.

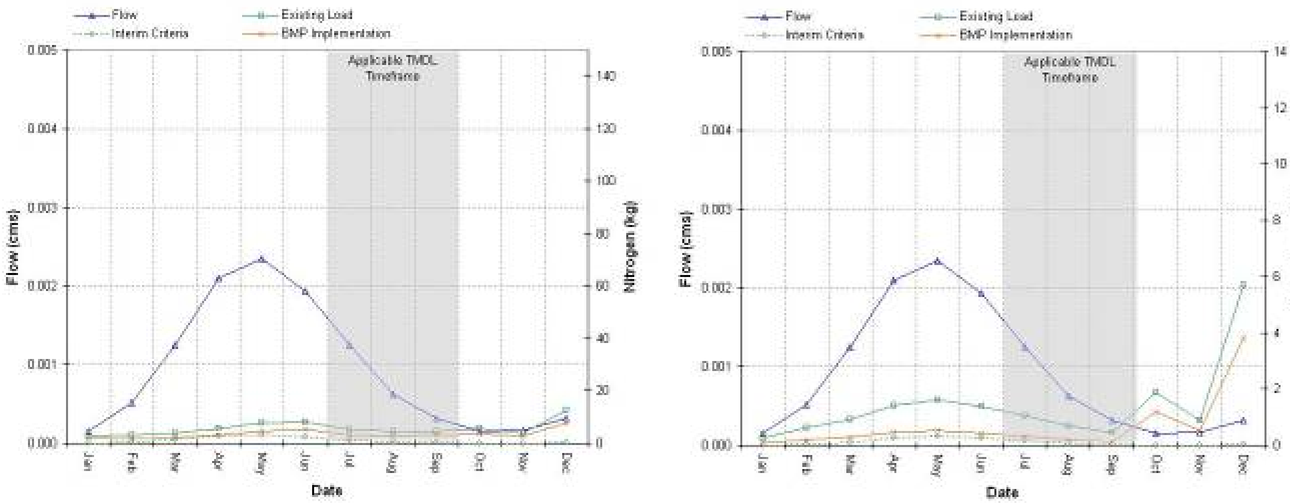


Figure 27. Estimated monthly loads of nitrogen and phosphorus in Grose Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 44. Monthly tabular data of estimated monthly streamflow and pollutant load for Grose Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.00	2.7	0.2	2.0	0.3	0.0	0.1
Feb	0.00	3.0	0.5	1.8	0.6	0.0	0.2
Mar	0.00	3.9	1.3	2.1	0.9	0.1	0.3
Apr	0.00	5.8	2.8	3.1	1.4	0.3	0.5
May	0.00	7.8	3.3	4.6	1.6	0.3	0.5
Jun	0.00	8.2	2.6	5.3	1.4	0.3	0.4
Jul	0.00	5.2	1.1	3.1	1.0	0.2	0.3
Aug	0.00	4.5	0.5	3.0	0.7	0.1	0.2
Sep	0.00	4.4	0.3	3.2	0.5	0.0	0.1
Oct	0.00	5.5	0.2	3.5	1.9	0.0	1.2
Nov	0.00	3.8	0.2	2.7	0.9	0.0	0.5
Dec	0.00	12.9	0.3	7.8	5.7	0.0	3.8

Table 45. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	5.9	Fertilizer/Grazing Management 0.2	5.7	25% 1.4	4.3
Shrub and Grassland	Grazing	36.3	Upland grazing management 6.2	30.2	15% 4.5	25.7
Forest	Grazing Timber Harvest	5.3	NA	5.3	15% 0.8	4.5
Developed	Urban	0.2	NA	0.2	0	0.2
Stream Banks	Grazing Hay encroachment	20.1	Riparian Vegetation restoration and grazing management 12.5	7.7	NA	7.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		67.9	18.8	49.1	6.7	42.3
Estimated overall % reduction			28%		14%	38%

Table 46. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek.

Source Area	Associated Human Activities	Existing Tot. P (lbs)	Source Area Restoration Approach (reduction in lbs)	Source Area Allocated Tot. P (lbs)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)	Total Allocated Load From Source (lbs)
Hay/Past	Grazing Hay Production Fertilizer	0.2	Fertilizer/Grazing Management 0.1	0.1	25% 0.0	0.1
Shrub and Grassland	Grazing	8.3	Upland grazing management 2.5	5.8	15% 0.9	4.9
Forest	Grazing Timber Harvest	0.0	NA	0.0	15% 0.0	0.0
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	8.3	Riparian Vegetation restoration and grazing management 5.2	3.2	NA	3.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		16.9	7.8	9.1	0.9	8.2
Estimated overall % reduction			46%		10%	52%

9.7 Lost Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Lost Creek are shown in **Figure 28**, **Table 47**, **Table 48**, and **Table 49**.

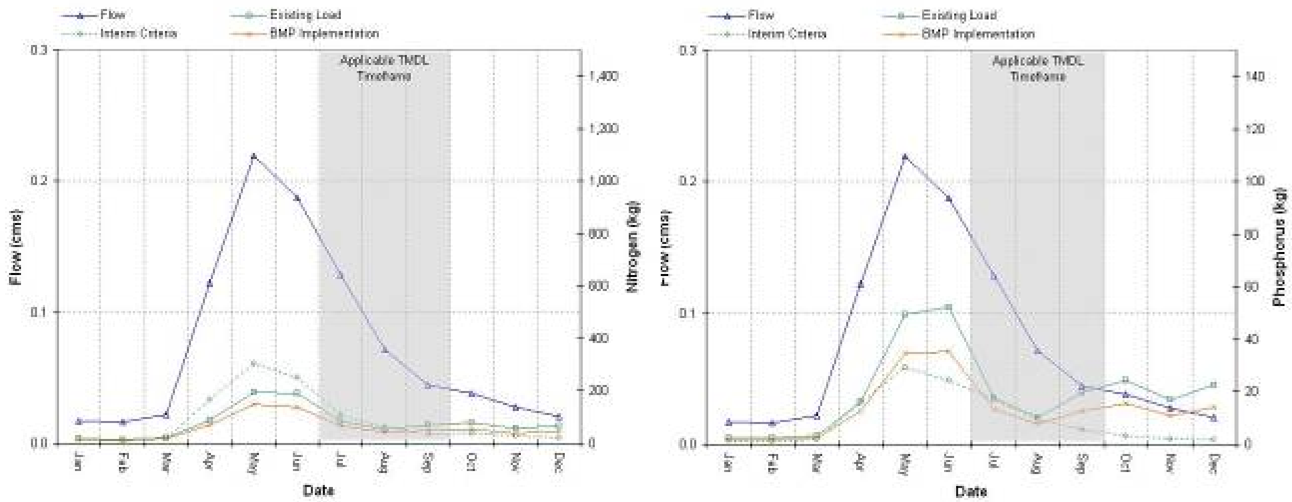


Figure 28. Estimated monthly loads of nitrogen and phosphorus in Lost Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 47. Monthly tabular data of estimated monthly streamflow and pollutant load for Lost Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	18.1	17.4	14.9	2.5	1.3	1.8
Feb	0.02	15.1	15.7	12.3	2.3	1.2	1.7
Mar	0.02	20.5	22.6	16.7	3.2	1.7	2.4
Apr	0.12	86.9	164.7	71.5	16.4	15.8	12.6
May	0.22	195.0	305.1	148.0	49.4	29.3	34.6
Jun	0.19	190.9	252.9	139.4	52.5	24.3	35.5
Jul	0.13	84.5	110.7	67.8	17.8	16.9	13.3
Aug	0.07	54.1	61.4	43.4	10.4	9.4	7.7
Sep	0.04	71.7	37.1	51.1	19.7	5.7	12.8
Oct	0.04	76.9	40.0	52.2	24.4	3.1	15.6
Nov	0.03	56.7	27.8	38.9	17.2	2.1	10.9
Dec	0.02	69.0	21.8	45.5	22.8	1.7	14.2

Table 48. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	58.7	Fertilizer/Grazing Management 2.2	56.4	25% 14.1	42.3
Shrub and Grassland	Grazing	465.3	Upland grazing management 89.4	375.9	15% 56.4	319.5
Forest	Grazing Timber Harvest	309.0	NA	309.0	15% 46.3	262.6
Developed	Urban	15.6	NA	15.6	0	15.6
Stream Banks	Grazing Hay encroachment	90.9	Riparian Vegetation restoration and grazing management 29.1	61.8	NA	61.8
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		939.4	120.7	818.7	116.8	701.9
Estimated overall % reduction			13%		14%	25%

Table 49. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	12.6	Fertilizer/Grazing Management 1.5	11.1	25% 2.8	8.3
Shrub and Grassland	Grazing	149.1	Upland grazing management 36.9	112.2	15% 16.8	95.3
Forest	Grazing Timber Harvest	35.1	NA	35.1	15% 5.3	29.8
Developed	Urban	4.2	NA	4.2	0	4.2
Stream Banks	Grazing Hay encroachment	37.6	Riparian Vegetation restoration and grazing management 12.0	25.5	NA	25.5
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		238.5	50.5	188.1	24.9	163.2
Estimated overall % reduction			21%		13%	32%

9.8 Soap Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Soap Creek are shown in **Figure 29**, **Table 50**, **Table 51**, and **Table 52**.

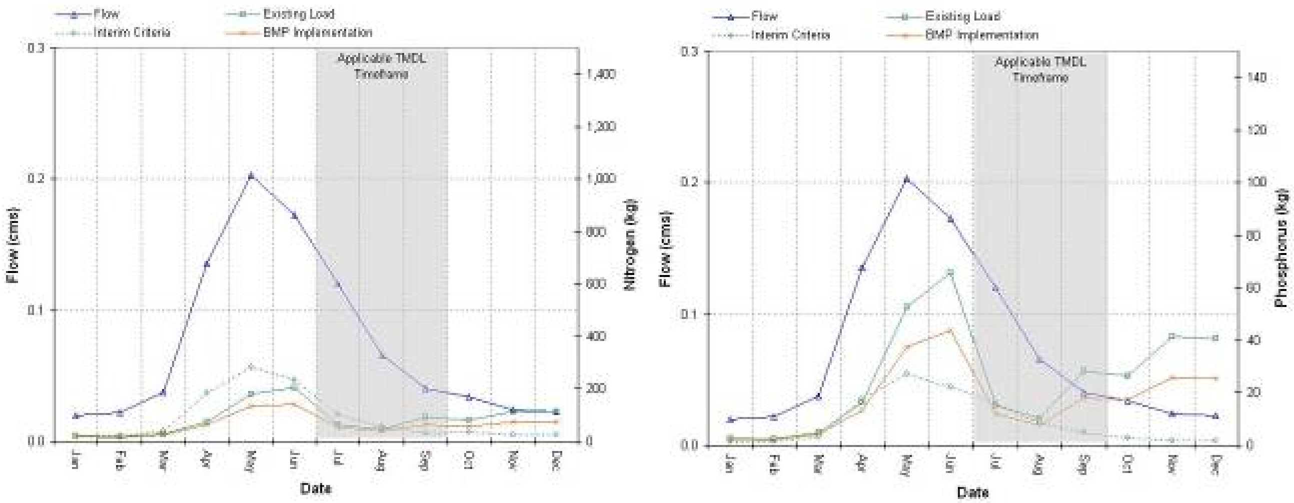


Figure 29. Estimated monthly loads of nitrogen and phosphorus in Soap Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 50. Monthly tabular data of estimated monthly streamflow and pollutant load for Soap Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	20.3	20.7	17.5	2.7	1.6	2.2
Feb	0.02	16.6	20.7	14.3	2.6	1.6	2.2
Mar	0.04	27.4	39.5	23.4	4.9	3.0	4.1
Apr	0.14	75.7	183.0	64.6	16.1	17.6	13.4
May	0.20	181.8	283.2	136.1	52.9	27.2	37.4
Jun	0.17	203.9	233.1	143.2	65.7	22.4	44.0
Jul	0.12	63.7	103.3	52.4	15.2	15.8	12.2
Aug	0.07	47.5	56.3	38.8	10.2	8.6	7.9
Sep	0.04	91.3	33.2	63.3	28.1	5.1	18.2
Oct	0.03	80.9	35.7	55.0	26.7	2.7	17.3
Nov	0.02	114.9	24.4	74.0	41.3	1.9	25.9
Dec	0.02	113.1	23.5	72.7	40.7	1.8	25.4

Table 51. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	46.3	Fertilizer/Grazing Management 2.2	44.1	25% 11.0	33.1
Shrub and Grassland	Grazing	725.3	Upland grazing management 146.1	579.2	15% 86.9	492.3
Forest	Grazing Timber Harvest	171.2	NA	171.2	15% 25.7	145.5
Developed	Urban	5.8	NA	5.8	0	5.8
Stream Banks	Grazing Hay encroachment	88.4	Riparian Vegetation restoration and grazing management 9.7	78.7	NA	78.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1037.0	158.0	878.9	123.6	755.4
Estimated overall % reduction			15%		14%	27%

Table 52. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	2.5	Fertilizer/Grazing Management 1.5	1.0	25% 0.3	0.8
Shrub and Grassland	Grazing	240.8	Upland grazing management 60.4	180.4	15% 27.1	153.3
Forest	Grazing Timber Harvest	26.4	NA	26.4	15% 3.9	22.4
Developed	Urban	1.0	NA	1.0	0	1.0
Stream Banks	Grazing Hay encroachment	36.5	Riparian Vegetation restoration and grazing management 4.0	32.5	NA	32.5
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		307.2	65.9	241.3	31.3	210.0
Estimated overall % reduction			21%		13%	32%

9.9 Wickiup Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek are shown in **Figure 30**, **Table 53**, **Table 54**, and **Table 55**.

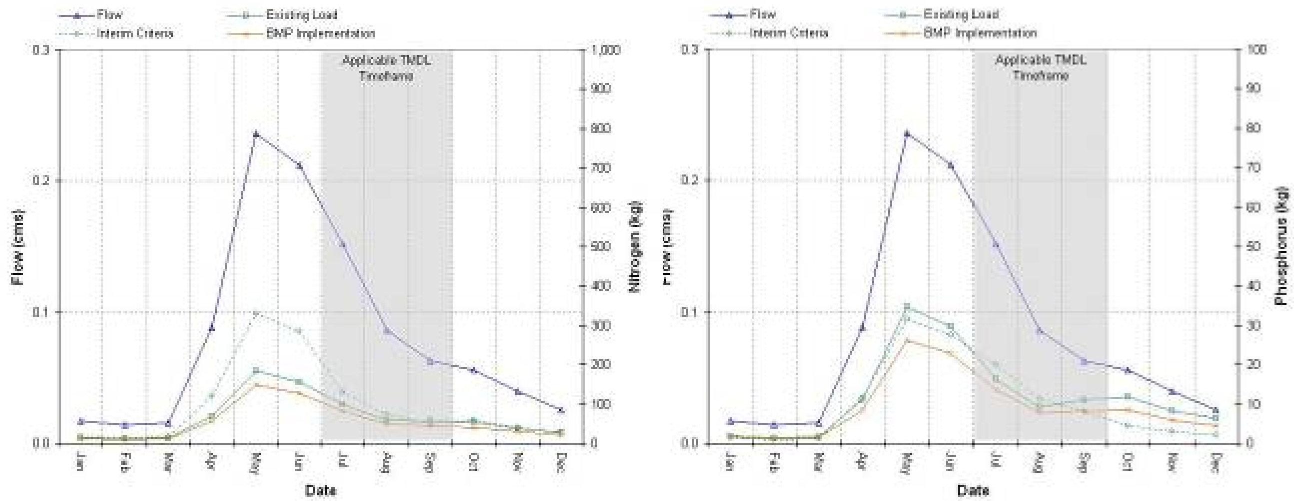


Figure 30. Estimated monthly loads of nitrogen and phosphorus in Wickiup Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 53. Monthly tabular data of estimated monthly streamflow and pollutant load for Wickiup Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	14.3	17.4	12.2	1.9	1.3	1.6
Feb	0.01	10.8	13.1	9.2	1.5	1.0	1.2
Mar	0.02	13.2	16.2	11.3	1.8	1.2	1.5
Apr	0.09	67.7	119.4	56.0	11.2	11.5	8.5
May	0.24	182.9	329.3	148.4	34.6	31.7	26.1
Jun	0.21	155.7	286.1	126.4	29.8	27.5	22.9
Jul	0.15	98.4	130.2	83.4	16.2	19.9	13.6
Aug	0.09	58.5	74.0	49.8	9.1	11.3	7.7
Sep	0.06	55.5	52.1	44.2	11.0	8.0	8.1
Oct	0.06	53.1	58.5	41.1	11.9	4.5	8.5
Nov	0.04	38.1	39.8	29.6	8.3	3.1	6.0
Dec	0.03	28.6	26.7	21.9	6.4	2.1	4.5

Table 54. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	38.2	Fertilizer/Grazing Management 6.7	31.5	15% 4.7	26.8
Shrub and Grassland	Grazing	180.4	Upland grazing management 26.1	154.3	15% 23.1	131.2
Forest	Grazing Timber Harvest	523.0	NA	523.0	15% 78.4	444.5
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	35.3	Riparian Vegetation restoration and grazing management 4.2	31.1	NA	31.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		776.9	37.0	739.9	106.3	633.6
Estimated overall % reduction			5%		14%	18%

Table 55. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	6.6	Fertilizer/Grazing Management 3.6	3.0	15% 0.4	2.5
Shrub and Grassland	Grazing	50.4	Upland grazing management 10.8	39.6	15% 5.9	33.7
Forest	Grazing Timber Harvest	72.0	NA	72.0	15% 10.8	61.2
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	14.6	Riparian Vegetation restoration and grazing management 1.8	12.8	NA	12.8
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		143.6	16.2	127.4	17.2	110.2
Estimated overall % reduction			11%		13%	23%

9.10 TMDL Scenario Summary

Clearly, the combined benefit of BMP implementation is a general reduction of nutrient loading in the watersheds which closely approximates interim numeric criteria (in most cases). Thus it is believed that upland and streambank erosion mitigation, riparian buffer enhancement, and reductions in fertilizer application are appropriate BMP recommendations for the upcoming TMDL. Ultimately, it will be up to the discretion of the watershed managers on which options are recommended for future action.

SECTION 10.0
CONCLUSION

GWLF was used to simulate monthly nitrogen and phosphorous loads for the upcoming Big Hole River nutrient TMDL. Through modeling, it was found that forest, grassland, and shrub/scrub provide a large natural background load in most watersheds, and that a majority of the anthropogenic load is of agricultural origin. Sources identified during the project include non-recoverable animal manure, grazing, fertilization, and urban lands. Streambanks were also found to contribute a substantial nitrogen and phosphorus load. Following the source assessment, scenarios were formulated to assess the relative effectiveness of BMP treatments in each of the impaired watersheds. Riparian buffer strip enhancement was shown to be the most effective treatment and anthropogenic pollutant removal ranged from approximately 5-25 percent. When combined with other implementation practices such as streambank and upland erosion mitigation and fertilizer application decreases, reductions ranged from approximately 10-50 percent in each watershed. In most cases, the computed load following BMP implementation load very much approximated interim numeric nutrient criteria. As a result, the primary recommendation is establishment of functioning riparian buffers, followed by streambank and upland erosion reductions. Finally, a reminder should be made that the modeling was relatively low-certainty, and for all intensive purposes, computed loads and associated reductions used in the TMDL development are estimates only.

SECTION 11.0
REFERENCES

AGRIMET. Accessed May 7, 2007 from Bureau of Reclamation. http://www.usbr.gov/gp/agrimet/index.cfm

ARM 17.30.623 (Administrative Rules of Montana). Section 17 – Water Quality, B-1 Classification Standards. Accessed October 9, 2007 from http://arm.sos.mt.gov/17/17-2715.htm.

ASTM (American Society for Testing and Materials). 1984. Standard Practice for Evaluating Environmental Fate Models of Chemicals. Designation E978-84. Philadelphia, PA. 8 p.

Alexander, R.B., Smith, R.A., Schwartz, G.E., Boyer, E.W., Nolan, J.V., and J.W. Brakebill. XXXX. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. 1 U.S. Geological Survey, National Water Quality Assessment Program. Contents: 29 pages; Figures S1-S6; Tables S1-S5.

Brooks, K.N., 1987. Hydrology and the Management of Watersheds – second edition. Iowa State University Press. Ames, Iowa 50014.

CWAIC (Clean Water Act Information Center). Accessed May 7, 2007 from Montana Department of Environmental Quality. http://www.deq.state.mt.us/ CWAIC/default.aspx.

Deer Lodge County Water Resources Survey (WRS). 1955. Part I: History of the Land and Water use on Irrigated Areas and Part II: Maps showing irrigated areas in color sesignating the sources of supply. State Engineer's Office. Helena, MT.

Diskin, M.H. and Simon, E. (1977). "A procedure for the selection of objective functions for hydrologic simulation models." Journal of Hydrology, 34, 129-149.

Daly, C., Taylor, G.H., Gibson, W.P., Parzybok, T.W., Johnson, G.L., and P.A. Pasteris. 2000. High-quality spatial climate data sets for the United States and Beyond. Transactions of the ASCE. Vol. 43(6) p 1957-1962. Daily, 2000 http://www.prism.oregonstate.edu/pub/prism/docs/asae00-spatial_climate_datasets-daly.pdf

De Wit, M., 1999. Nutrient fluxes in the Rhine and Elbe Basins. PhD Thesis, Utrecht University, Utrecht, 163 pp.

Dillaha, T.A., J.H. Sherrard, D. Lee, V.O. Shanholtz, S. Mostaghimi, and W.L. Magette, 1986. Use of Vegetative Filter Strips to Minimize Sediment and Phosphorus Losses from Feedlots. Virginia Water Resources Research Center, VA Tech. State University, Bulletin 151.

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, R.L. Day, 2002. A comprehensive GIS-based modeling approach for predicting nutrient loads in watersheds. J. Spatial Hydrology 2(2), (www.spatialhydrology.com).

Evans, B.M., S.A. Sheeder, D.W. Lehning, 2003. A spatial technique for estimating streambank erosion based on watershed characteristics. J. Spatial Hydrology 3(2), (www.spatialhydrology.com).

Evans, B.M., S.A. Sheeder, and K.J. Corradini, 2007. AVGWLF, Version 7.0: Users G

Evans, B.M. and K.J. Corradini, 2007. AVGWLF, Version 7.0: A Guide to Creating Software-Compatible Data Sets. Penn State Institutes of the Environment, 34 pp.

Evans, B.M., D.W. Lehning, and K.J. Corradini, 2007. PRedICT Version 2.0: Users Guide for the Pollutant Reduction Impact Comparison Tool. Penn State Institutes of Energy and the Environment, 44 pp.

Evans, B.M. and K.J. Corradini, 2007. AVGWLF, Version 7.0: A Guide to Creating Software-Compatible Data Sets. Penn State Institutes of the Environment, 34 pp.

Evans, B.M., D.W. Lehning, and K.J. Corradini, 2007. PRedICT Version 2.0: Users Guide for the Pollutant Reduction Impact Comparison Tool. Penn State Institutes of Energy and the Environment, 44 pp.

Farnes, P.E., and B.A. Shafter. 1975. Hydrology of the Jefferson River Drainage. USDA Soil Conservation Service. Bozeman, MT.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

Haith, D.R., R. Mandel, and R.S. Wu, 1992. GWLF: Generalized Watershed Loading Functions User's Manual, Vers. 2.0. Cornell University, Ithaca, NY. (Stewart, et al., 1975)

Holzworth, L., Mosley, J. Cash, D. Koch, D., and K. Crane. 2003. Dryland Pastures in Montana and Wyoming: Species and Cultivars, Seeding Techniques, and Grazing Management. Montana State University Extension Service.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 7, July 2004, pp. 829-840

International Civil Aviation Organization (ICAO). Accessed June 15, 2008 from http://www.icao.int/.

James, L.D. and S.J. Burges. 1982. Selection, Calibration, and Testing of Hydrologic Models. In: Hydrologic Modeling of Small Watersheds. ASAE Monograph No. 5. C.T. Haan, H.P. Johnson, D. L. Brakensiak (eds). American Society of Agricultural Engineers, St Joseph, MI. Chap 11. pp 437-474.

Johnes, P.J. 1996. Evaluation and management of the impact of land use change on the nitrogen and phosphorus load delivered to surface waters: the export coefficient modeling approach. Journal of Hydrology. 183, 323-349.

Johnson, A.H., Bouldin, D.R., Goyette, E.A., Hedges, A.M., 1976. Phosphorus loss by stream transport from a rural watershed: quantities, processes, and sources. Journal of Environmental Quality. 5 (2) 148-157

Marvin, R.K., and Voeller, T.L. 2000. Hydrology of the Big Hole Basin and an assessment of the affects of irrigation of the hydrologic budget. Montana Bureau of Mines and Geology Open File Report 417. Montana Bureau of Mines and Geology, Butte, Montana.

Montana Code Annotated. 2003. Montana Water Quality Act. Title 75. Environmental Protection Chapter 5. Water Quality.

McCuen, R.H., 1998. Hydrologic Analysis and Design" – second edition. Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458.

NASS (National Agricultural Statistics Service). USDA. Accessed May 10, 2008 from http://www.nass.usda.gov/index.asp.

DEQ (Montana Department of Environmental Quality). Draft TMDL document. Unpublished.

Nash, J.E., and V. Sutcliffe, 1970: River flow forecasting through conceptual models, I. A discussion of principles. Journal of Hydrology. 10: 282-290.

NRCS (Natural Resources Conservation Service), 1994. State Soil Geographic (STATSGO) database: Data Use Information. Miscellaneous Publication Number 1492

NRCS (Natural Resources Conservation Service). 1999. Animal Waste Management, National Engineering Handbook Part 651. Agricultural Waste Management Field Handbook.

Olness, A., Rhoades, E.D., Smith, S.J., and R.G. Menzel. 1980. Fertilizer nutrient losses from rangeland watersheds in central Oklahoma. Journal of Environmental Quality. 9(1), 81-87.

Pieterse, N.M, Bleutena W., and S. E. Jørgensen. 2003. Contribution of point sources and diffuse sources to nitrogen and phosphorus loads in lowland river tributaries. Journal of Hydrology. Volume 271, Issue 1-4, 10 February 2003, Pages 213-225.

Redfield, A.C., The biological control of chemical factors in the environment, American Scientist, 1958

Suplee, M.W., Varghese, A., and J. Cleland. 2007. Developing nutrient criteria for streams: an evaluation of the frequency distribution method. Journal of the American Water Resources Association. 43(2):453-472.

Thomann, R.V. 1982. Verification of Water Quality Models. Jour. Env. Engineering Div. (EED) Proc. ASCE, 108:EE5, October.

U.S. Census Bureau. Accessed June 15, 2008 from http://www.census.gov/.

U.S. Environmental Protection Agency, 1983. Results of the Nationwide Urban runoff program. Volume I – Final Report. Water Planning Division. Washington, DC.

U.S. Environmental Protection Agency, 1999. Protocols for developing nutrient TMDLs. EPA 841-B-99-007. Office of Water (4503 F), Washington, D.C.

U.S. Environmental Protection Agency, 2001. PLOAD version 3.0 – An ArcView GIS Tool to Calculate Nonpoint sources of pollution in watershed and storm water projects. User's Manual. CH2M Hill, Inc.

U.S. EPA. 2004. Better Science Integrating Point and Nonpoint Sources (BASINS) version 3.1.

U.S. Geological Survey National Water Information System (NWIS). Accessed May 10, 2008 from http://waterdata.usgs.gov/nwis.

Van Greisven, A., and W. Bauwens. 2003. Multiobjective autocalibration for semidistributed water quality models . Water Resources Research. 39(12):1348.

Wegner, S. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Office of Public Service and Outreach. Institute of Ecology University of Georgica.

WRCC (Western Regional Climate Center). Accessed May 10, 2008 from http://www.wrcc.dri.edu.

APPENDIX – A1 IRRIGATION CALCULATIONS

ET values for pasture/hay from Dillon AGRIMET site (1997-2006)

```
**************************************************************************
*     *   DAILY    *  *  *  *  *  *  *  *
*     * CROP WATER USE-(IN) * DAILY*   *   *   * 7 * 14 *
* CROP START* PENMAN ET - SEP * FORE *COVER* TERM* SUM * DAY* DAY *
*   DATE*---------------------* CAST * DATE* DATE* ET * USE* USE *
*     * 27  28  29  30 *   *   *   *   *  *   *
*-----------*---------------------*------*------------------*----------*-----
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 18.4 * 0.0* 0.2  1997
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 20.9 * 0.0* 0.2  1998
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 20.9 * 0.0* 0.2  1999
* PAST 420 * 0.08 0.07 0.07 0.00 * 0.00 * 530 * 930 * 24.1 * 0.4* 1.0  2000
* PAST 420 * 0.09 0.06 0.07 0.00 * 0.00 * 530 * 930 * 24.6 * 0.5* 1.2  2001
* PAST 420 * 0.04 0.05 0.06 0.00 * 0.00 * 530 * 930 * 23.0 * 0.3* 0.9  2002
* PAST 420 * 0.08 0.06 0.08 0.00 * 0.00 * 530 * 930 * 25.6 * 0.5* 1.2  2003
* PAST 420 * 0.06 0.06 0.05 0.00 * 0.00 * 530 * 930 * 23.0 * 0.4* 0.7  2004
* PAST 420 * 0.08 0.06 0.08 0.00 * 0.00 * 530 * 930 * 22.9 * 0.4* 1.0  2005
* PAST 420 * 0.07 0.08 0.06 0.00 * 0.00 * 530 * 930 * 24.3 * 0.4* 0.8  2006
* PAST 420 * 0.08 0.05 0.02 0.00 * 0.00 * 530 * 930 * 25.2 * 0.4* 0.8  2007
*-----------*---------------------*------*------------------*----------*-----
                    AVG  22.7
```

Example irrigation calculation used in GWLF model of USGS Big Hole River nr Melrose, MT:

Irrigated area (pasture/hay) = 14,750 ha
Total watershed area = 636,522 ha
AGRIMET crop water use = 57.8 cm/yr (pasture) (22.7 inches)

$$= \frac{14,750ha}{636,522ha} \times 57.8cm/yr$$

Crop water use requirement = 1.4 cm/yr
Distribution losses = 25%

Net diversion value = 1.7 cm/yr (distribute over summer months)

APPENDIX – A2 LIVESTOCK CALCULATIONS

Livestock calculations used in GWLF modeling are detailed below.

Available Data:

National Agricultural Statistics Service data from 1998-2007 (NASS, 2008)

106,900 cows and calves
12,600 ewes and lambs
750 horses (estimated)

Convert to AUM (NRCS, 2003)
Assume: cow/calf pair = 1 AUM
ewe/lamb = 0.3 AUM
horse = 1.25 AUM

Livestock estimate for grazing season (May-October; 6 months)

53,450 pair cattle x 1 AUM x 6	= 320,700 AUM
6,300 pair sheep x 0.3 AUM x 6	= 11,340 AUM
750 horses x 6	= 5,625 AUM
	= 337,665 AUM

Carrying capacity estimate

221,830 ha of grassland in watershed
0.61 ha (1.5 acres) per AUM

= 363,656 AUM

Stocking rate less than carrying capacity 

APPENDIX – A3 NON-RECOVERABLE ANIMAL MANURE CALCULATIONS

Table A3-1: 1950 CENSUS OF AGRICULTURE (USDA, 1952)						
MONTANA COUNTY DATA INVENTORY						
County	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**	
Beaverhead	95,819	2,813	101,047	6,745	15,384	
Deer Lodge	5,611	1,015	9,668	560	8,402	
Granite	22,032	892	3,713	881	5,832	
Madison	60,990	5,972	89,918	4,549	27,655	
Ravalli	35,912	6,804	14,637	3,200	59,808	
Silver Bow	7,405	614	4,117	772	6,008	
Correct for percentage of area in each county contained in Big Hole Watershed						
	County Area[1]					
County	**Correction**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Beaverhead	35.19%	33,719	990	35,558	2,374	5,414
Deer Lodge	43.70%	2,452	444	4,225	245	3,672
Granite	0.39%	86	3	14	3	23
Madison	5.65%	3,446	337	5,080	257	1,563
Ravalli	0.63%	226	43	92	20	377
Silver Bow	39.03%	2,890	240	1,607	301	2,345
	TOTAL	**42,819**	**2,057**	**46,577**	**3,200**	**13,392**
	Adjust for Watershed Area[2]	38,537	1,851	41,920	2,880	12,053
	Convert to GWLF Animal Units[3]	27,297	1,311	29,693	2,040	8,538
	Round	**27,300**	**1,310**	**29,690**	**2,040**	**8,540**

[1]County percentages taken from STEPL model data server
[2]Big Hole Watershed area = 2,762 mi^2; Melrose gage area = 2,476 mi^2 (e.g. 0.90 conversion)
[3]Assume 1/2 of animals are offspring
each count as 1/4 mature animal (0 at birth 1/2 at weaning)
on landscape 1/2 year (March-September)

Table A3-2: 2002 CENSUS OF AGRICULTURE (USDA, 2004)

MONTANA COUNTY DATA INVENTORY						
County	**Cattle**	**Hogs[1]**	**Sheep**	**Horses**	**Poultry**	
Beaverhead	135,926	15	15,823	2,679	295	
Deer Lodge	8,739	0	1,065	378	0	
Granite	21,737	100	457	881	396	
Madison	70,892	0	4,803	2,526	947	
Ravalli	33,846	854	4,473	4,927	2,319	
Silver Bow	5,937	40	291	758	68	
Correct for percentage of area in each county contained in Big Hole Watershed						
	County Area[2]					
County	**Correction**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Beaverhead	35.19%	47,832	5	5,568	943	104
Deer Lodge	43.70%	3,819	0	465	165	0
Granite	0.39%	85	0	2	3	2
Madison	5.65%	4,005	0	271	143	54
Ravalli	0.63%	213	5	28	31	15
Silver Bow	39.03%	2,317	16	114	296	27
	TOTAL	**58,272**	**27**	**6,448**	**1,581**	**200**
	Adjust for Watershed Area[3]	52,445	24	5,804	1,423	180
	Convert to GWLF Animal Units[4]	37,148	17	4,111	1,008	128
	Round	**37,150**	**20**	**4,110**	**1,010**	**130**

[1]Values in grey estimated; data withheld to avoid disclosing information for individual farms
[2]County percentages taken from STEPL model data server
[3]Big Hole Watershed area = 2,762 mi^2; Melrose gage area = 2,476 mi^2 (e.g. 0.90 conversion)
[4]Assume 1/2 of animals are offspring
each count as 1/4 mature animal (0 at birth 1/2 at weaning)
on landscape 1/2 year (March-September)

Table A3-3: Estimated Livestock Distributions of TMDL Watersheds

Use area of grassland in watershed to distribute farm animals							
Watershed		**Grassland area (ha)**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Melrose gage		221830	37150	20	4110	1010	130
Willow Cr		1187	200	0	20	10	0
Lost Cr		1132	190	0	20	10	0
Camp		4822	810	0	90	20	0
Wickuip		505	80	0	10	0	0
Soap		1650	280	0	30	10	0
Divide		11500	1930	0	210	50	10
Jerry		1210	200	0	20	10	0
Steel		7902	1320	0	150	40	0
Francis		3041	510	0	60	10	0
Grose		389	70	0	10	0	0

APPENDIX – A4 MODEL INPUT AND OUTPUT

A4-1 SEPTIC DENSITY ESTIMATES

Septic density estimates were completed using NAIP aerial imagery. Approximate numbers of buildings (and associated septic fields) are shown below.

Watershed	Area (ha)
Melrose	495
Willow	0
Wickiup	0
Francis	0
Steel	10
Jerry	5
Camp	10
Divide	30
Grose	0
Lost	5
Soap	2

A4-2 Stocking Density Calculations

Livestock calculations used in GWLF modeling are detailed below.

Available Data:

National Agricultural Statistics Service data from 1998-2007 (NASS, 2008)

106,900 cows and calves
12,600 ewes and lambs
750 horses (estimated)

Convert to AUM (NRCS, 2003)

Assume:		
	cow/calf pair	= 1 AUM
	ewe/lamb	= 0.3 AUM
	horse	= 1.25 AUM

Livestock estimate for grazing season (May-October; 6 months)

53,450 pair cattle x 1 AUM x 6	= 320,700 AUM
6,300 pair sheep x 0.3 AUM x 6	= 11,340 AUM
750 horses x 1.25 x 6 =	= 5,625 AUM
	= 337,665 AUM

Carrying capacity estimate

221,830 ha of grassland in watershed
0.61 ha (1.5 acres) per AUM
= 363,656 AUM

Stocking rate less than carrying capacity ☑

A4-3 – Modeling Input and Output Tables

Due to large content DEQ will provide model input and tables upon request.

APPENDIX H
RAW DATA: SEDIMENT AND METALS

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Big Hole River between Divide Cr and Pintlar Cr	behind Fishtrap School	1990	--	--	--	--	MFWP data, recent aerial photo data	--	--	34% FAR or NF
	upstream Hwy 43 Bridge	1990	--	--	--	--		--	--	
	Mudd Creek Bridge	2002	--	--	--	--		--	--	
	Dickie Bridge	2002	--	--	--	--		--	--	
	Jerry Creek Bridge	2002	--	--	--	--		--	--	
	BH-16,17,20,21,22,26, 33,34,37 & DL-1,6,8,18,29	1998-2002	--	--	--	--		--	--	
	Middle Big Hole 1	9/19/2006	26	19	97.1	27.9	C4	C4	10	FAR
			21	14	--	23.2	--	--		
			--	--	--	24.4	--	--		
			--	--	--	22.2	--	--		
			--	--	--	22.2	--	--		
	Middle Big Hole 2	9/20/2006	16	10	86.1	20.9	C4	C4	39	FAR
			16	13	--	26.5	--	--		
			--	--	--	22.8	--	--		
			--	--	--	12.9	--	--		
			--	--	--	16.6	--	--		
Big Hole River from Divide Cr to the mouth (Jefferson River)	Maiden Rock	2001, 2002	--	--	--	--	recent aerial photo data	--	--	38% FAR or NF
	Kalsta Bridge	2002	--	--	--	--		--	--	
	Notch Bottom	2001, 2002	--	--	--	--		--	--	
	High Road	2002	--	--	--	--		--	--	
	SB-26,27	1995-2001	--	--	--	--		--	--	
	Lower Big Hole 1	10/1/2006	7	4	84.3	25.1	C4/B4c	C4	50	PFC
			5	2	--	17.9	--	--		
			--	--	--	26.6	--	--		
			--	--	--	11.2	--	--		
			--	--	--	17.6	--	--		
	Lower Big Hole 2	10/15/2006	5	4	65.3	37.6	C4	C4	41	PFC
			6	5	--	30.3	--	--		
			--	--	--	33.9	--	--		
			--	--	--	39.9	--	--		
			--	--	--	29.6	--	--		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Birch Creek headwaters to the National Forest Boundary	Birch	9/9/1991	10	8	28.1	--	B2c/B3c	B3	--	PFC
	Birch 2	7/1/1994	5	5	13.8	19.1	B3	B3	--	PFC
	B-6	2000	--	--	--	--	--	--	--	--
	Birch 1	9/21/2005	3	2	16.8	37.9	B3a	B3a/B3	70	FAR
			7	3	10.9	26.1	B3a	B3a/B3		
			5	5	13.9	29.1	B3a	B3a/B3		
			--	--	19.4	27.3	B3a	B3a/B3		
			--	--	15.3	34.9	B3a	B3a/B3		
	Birch 2	9/20/2005	6	4	13.1	28.7	C3b	B3	78	PFC
			5	5	12.2	27.0	C3b	B3		
			3	3	9.1	32.8	C3b	B3		
			--	--	9.8	37.6	C3b	B3		
			--	--	11.4	41.2	B3	B3		
Birch Creek from National Forest Boundary to mouth (Big Hole R)	B-10	2000	--	--	--	--	--	--	--	--
	Birch 3	10/14/2005	15	9	18.9	42.6	B3c	C3	62	FAR
			12	6	16.6	26.7	B3c	C3		
			16	11	17.4	16.6	C3	C3		
			--	--	14.5	38.4	B3c	C3		
			--	--	10.0	40.0	C3	C3		
California Creek from headwaters to mouth (French Cr-Deep Cr)	CF-7	2000	--	--	--	--	--	--	--	--
	California 1	7/24/2006	35	28	9.4	22.7	E4	E4	52	FAR
			28	18	8.8	40.6	B4c	E4		
			16	13	8.0	29.5	E4	E4		
			--	--	17.3	--	F4/B4c	E4		
			--	--	6.4	--	G4c	E4		
	California 2	7/24/2006	15	11	15.6	22.8	E4	E4	48	FAR
			12	9	11.5	25.8	E4	E4		
			14	13	18.8	36.3	C4	E4		
			--	--	11.5	30.9	E4	E4		
			--	--	7.9	31.1	E4	E4		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Camp Creek from headwaters to mouth (Big Hole R)	M03CAMPC01	9/14/2003	72	58	--	--	--	--	--	44% FAR
	M03CAMPC02	9/15/2003	68	58	--	--	--	--	--	
	M03CAMPC03	9/15/2003	40	35	--	--	--	--	--	
	RO-2, 3,46 and SB-5,6	1995-2003	--	--	--	--	--	--	--	
	Camp 1	9/30/2005	41	27	18.8	42.5	B4c	C4	76	FAR
			17	12	31.8	32.9	F4	C4		
			33	23	10.3	32.2	C4	C4		
			--	--	15.0	42.0	B4c	C4		
			--	--	58.3	32.7	F4	C4		
	Camp 2	9/8/2006	39	35	12.4	26.4	C4	B4c	51	FAR
			27	19	17.0	37.9	B4c	B4c		
			32	21	31.8	15.0	B4c/F4	B4c		
			--	--	12.7	33.1	B4c	B4c		
			--	--	18.2	45.1	B4c	B4c		
Canyon Creek from headwaters to mouth (Big Hole R)	Canyon Dn	9/7/1994	6	3	8.8	29.4	G3c	B3c		NF
	Canyon Mid	5/25/1994	13	13	25.9	23.8	C4	C4		FAR
	Canyon Up	8/2/1994	13	8	9.1	19.2	B3c	B3c		PFC
	Canyon 1	9/23/2005	11	9	14.2	34.3	C4	C4	76	PFC
			17	14	7.6	27.4	E4	C4		
			6	4	12.9	15.9	C4	C4		
			--	--	10.2	23	E4	C4		
			--	--	15.2	24.5	C4	C4		
Charcoal Gulch tributary of the Big Hole River	M03CHRGC01	7/23/2003	60	59	--	--	A2	--	--	--
	SB-8	1999	--	--	--	--	--	--	--	FAR
Corral Creek from headwaters to mouth (Deep Cr)	M03CORLC01 (C-1)	7/10/2001	--	--	--	--	--	--	--	--
	M03CORLC04 (C-4)	7/10/2001	--	--	--	--	--	--	--	--
	Corral 1	9/5/2006	32	21	5.6	40.0	E4a	A4	6	FAR
			22	13	9.6	38.6	B4a	A4		
			20	14	5.0	--	E4a	A4		
			--	--	8.5	--	B4a/A4	A4		
			--	--	5.4	--	B4a/A4	A4		
	Corral 2	9/7/2006	29	23	8.1	28.8	E4	E4	32	FAR
			29	23	17.3	25.6	B4c/F4	E4		
			36	30	30.7	24.3	B4c/C4	E4		
			--	--	9.5	41.5	B4c/G4	E4		
			--	--	2.7	25.0	E4	E4		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Deep Creek from headwaters to mouth (Big Hole R)	M03DEEPC02 (D-2)	7/11/2001	--	--	--	--	--	--	--	--
	CF-11	2000	--	--	--	--	--	--	--	--
	CF-16	2000	--	--	--	--	--	--	--	--
	DL-04	2000	--	--	--	--	--	--	--	FAR
	Deep 1	10/11/2005	20	14	16.5	28.4	C4	E4	65	FAR
			7	3	19.7	29.5	C4	E4		
			7	5	3.0	31.0	E4	E4		
			--	--	14.3	25.6	C4	E4		
			--	--	15.7	30.6	C4	E4		
	Deep 2	10/12/2005	18	12	28.4	37.8	C4	C4	42	FAR
			15	7	33.4	34.7	C4	C4		
			20	12	19.2	37.7	C4	C4		
			--	--	17.5	43.3	C4	C4		
			--	--	24.4	27.7	B4c	C4		
Delano Creek from headwaters to mouth (Jerry Cr)	Delano Down	7/6/1999	13.8	12.9	7.3	26.2	A3	A2	--	PFC
	Delano Up	6/30/1999	15	13	9.1	25.6	A3	A3	--	PFC
	M03DLNOC01	7/16/2003	9	8	--	--	B3	--	--	
	M03DLNOC02	7/17/2003	27	24	--	--	--	--	--	--
	M03DLNOC03	7/17/2003	--	--	--	--	--	--	--	--
	Delano 1	7/27/2006	7	3	4.9	15.6	A4	A3	7	PFC
			13	7	13.1	--	B4a	A3		
			10	5	9.1	--	B4a	A3		
			--	--	9.9	--	A4	A3		
			--	--	7.1	--	A4	A3		
	Delano 2	7/27/2006	28	19	8.6	15.2	E4b	E3b	15	FAR
			14	10	9.6	27.9	E4b	E3b		
			29	17	6.3	23.7	E4b	E3b		
			--	--	4.1	18.5	E4b	E3b		
			--	--	2.7	28.6	E4b	E3b		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Divide Creek from headwaters to mouth (Big Hole R)	M03DIVDC01	7/30/2003	66	65	--	--	C5	--	--	--
	M03DIVDC02	7/30/2003	54	45	--	--	E5	--	--	--
	Divide 1	8/3/2006	51	39	18.2	27.7	B4c	E4	73	NF
			67	50	12.9	20.3	F4	E4		
			74	50	18.1	31.2	F4	E4		
			--	--	18.0	35.7	B4c	E4		
			--	--	20.7	--	F4	E4		
	Divide 2	8/2/2006	46	36	21.3	24.6	F4	C4	26	FAR
			31	26	22.9	28.9	F4	C4		
			26	21	22.5	25.8	F4	C4		
			--	--	15.5	24.0	C4	C4		
			--	--	14.1	24.7	B4c	C4		
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	E-1	7/20/2000	--	--	--	--	--	--	--	--
	E-9	7/20/2000	--	--	--	--	--	--	--	--
	M03ELKHC01	7/23/2003	30	23	14.3	--	B3	--	--	--
	M03ELKHC02	7/23/2003	19	10	14.9	--	C4	--	--	--
	Elkhorn 1	7/26/2006	16	12	14.5	39.4	B4c	B4c	21	FAR
			12	6	12.8	39.0	B4c	B4c		
			20	14	9.0	44.3	B4c/G4c	B4c		
			--	--	12.1	42.7	B4c	B4c		
			--	--	21.7	44.4	B4c	B4c		
Fishtrap Creek confluence of West & Middle Fks to mouth (Big Hole)	M03FSHTC01	7/16/2003	16	15	25.5	--	--	--	--	--
	M03FSHTC02	7/16/2003	17	15	27.0	--	--	--	--	--
	Fishtrap 1	8/31/2006	15	6	14.6	41.5	B4	B3	75	FAR
			12	8	27.9	27.6	B4	B3		
			17	12	21.0	34.5	B4	B3		
			--	--	16.4	13.4	B4	B3		
			--	--	23.2	19.3	B4	B3		
	Fishtrap 2	9/6/2006	17	9	20.1	13.4	C4	C3	55	FAR
			6	6	18.5	20.9	C4	C3		
			15	10	13.2	28.3	C4	C3		
			--	--	19.0	--	C4	C3		
			--	--	22.6	--	B4c	C3		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
French Creek from headwaters to mouth (Deep Cr)	French	8/9/1999	11	11	22.7	27.3	C3	C3		
	French 1	9/27/2005	19	17	23	44.7	C4	C4	34	FAR
			5	4	17.0	29.0	C4	C4		
			8	7	25.1	27.7	C4	C4		
			--	--	27.8	37.1	C4	C4		
			--	--	21.4	39.7	C4	C4		
Gold Creek from headwaters to mouth (Wise R)	Gold	8/24/1994	13	13	9.1	23.6	B4a	B4a	--	PFC
	M03GOLDC01	7/10/2003	37	30	--	--	A3	--	--	--
	M03GOLDC02	7/10/2003	--	--	--	--	C4	E4	--	--
	Gold 1	9/29/2005	26	19	17.4	45.1	C4	E4	40	FAR
			22	17	20.4	40.8	F4	E4		
			11	8	6.8	25.2	C4	E4		
			--	--	41.8	23.7	C4	E4		
			--	--	35.0	29.2	C4	E4		
Grose Creek from headwaters to mouth (Big Hole R)	M03GROSC01	9/12/2003	--	--	--	--	--	--	--	--
	Grose 1	8/3/2006	78	64	1.8	37.0	B5a/A5	E3a	13	NF
			71	49	12.3	38.3	A5	E3a		
			85	77	14.0	33.7	B5a	E3a		
			--	--	2.3	34.6	B5a/A5	E3a		
			--	--	4.1	44.7	B5a/E5b	E3a		
Jerry Creek from headwaters to mouth (Big Hole R)	Jerry Up	6/30/1999	7	5	10.2	24.2	E3a	E3a	--	PFC
	Jerry Mid	7/6/1999	9	5	11.8	27.4	C3b/E3b	C3b/E3b	--	PFC
	Jerry Down	8/2/1999	3	2	23.3	28.1	F3b	B3	--	FAR
	M03JERRC01	7/10/2003	--	--	--	--	--	--	--	--
	Jerry 1	9/28/2005	9	7	22.4	33.8	B4	B3	40	FAR
			11	9	20.0	11.3	B4	B3		
			10	9	43.5	25.5	B4	B3		
			--	--	20.7	13.5	B4	B3		
			--	--	19.9	20.1	C4b	B3		
	Jerry 2	9/28/2005	13	7	11.9	23.1	C4	B3c	61	FAR
			21	13	19.3	28.5	B4c	B3c		
			14	9	12.6	23.2	B4c	B3c		
			--	--	36.2	34.8	B4c	B3c		
			--	--	15.9	10.0	C4	B3c		
LaMarche Creek from headwaters to mouth (Big Hole River)	M03LMCHC01	7/16/2003	15	14	28.1	--	B3	--	--	--
	M03LMCHC02	7/16/2003	16	16	23.4	--	B3	--	--	--
	D-2-1	6/19/1905	--	--	--	--	--	--	--	FAR

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Lost Creek in the Lower Big Hole Watershed	Lost Dn (BLM)	5/27/1994	76	64	2.5		E5a	E3a	--	NF
	Lost Up	5/26/1994	41	34	18.6	38.1	B4a	A3	--	NF
	M03LOSTC01	9/13/2003	59	53	--	--	--	--	--	--
	M03LOSTC02	9/14/2003	54	47	--	--	--	B4	--	--
	Lost 1	8/29/2006	31	16	11.1	29.1	E4b	E3b	48	FAR
			31	17	11.3	28.9	E4b	E3b		
			28	15	23.3	--	B4	E3b		
			--	--	10.4	--	B4	E3b		
			--	--	11.2	--	B4	E3b		
	Lost 2		87	83	6.1	25.5	E5b	E3b	39	NF
			53	43	5.2	29.2	B5/G5	E3b		
			49	34	12.9	36.0	B5/G5	E3b		
			--	--	15.6	--	B5/G5	E3b		
			--	--	2.1	--	E5b	E3b		
McLain Creek tributary to Moose Cr (Big Hole River)	M03MCLNC01	7/31/2003	93	73	1.94	--	--	--	--	--
	SB-80-1 , SB-80-2, SB-1	1989, 1995	--	--	--	--	--	--	--	PFC
Moose Creek from headwaters to mouth (Big Hole R at Maiden Rock)	SB-2, SB-3, SB-4, SB-29, DL-24-1, DL-24-2	1988-1995	--	--	--	--	--	--	--	22% FAR
			--	--	--	--	--	--	--	
	Moose 1	9/21/2006	29	19	18.2	17.9	B4	B3	83	PFC
			25	14	24.8	24.8	B4	B3		
			27	19	13.2	18.9	B4	B3		
			--	--	15.9	12.9	B4	B3		
			--	--	15.4	--	B4	B3		
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	Oregon 1	7/31/2006	20	12	4.2	22.9	E4b	E3b	89	FAR
			30	25	10.7	12.6	B4	E3b		
			7	5	7.5	32.3	B4/E4b	E3b		
			--	--	7.5	--	E4b	E3b		
			--	--	2.8	--	E4b	E3b		
Pattengail Creek from headwaters to mouth (Wise R)	M03PATGC02 (P-2)	2001	--	--	--	--	--	--	--	--
	Pattengail 1		12	5	22.9	19.2	B3c	B3c	44	FAR
			7	2	70.7		B3c	B3c		
			1	1	31.7		F3	B3c		
			--	--	33.0		B3c	B3c		
			--	--	41.6		B3c	B3c		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Rochester Creek from headwaters to mouth (Big Hole R)	R-9		--	--	--	--	--	--	--	77% FAR or NF
	RO-32, 39, 43, 56, 57		--	--	--	--	--	--	--	
	Rochester 1	9/18/2006	61	55	14.1	35.7	C5b	E4b	40	NF
			73	52	9.1	27.0	G5/B5	E4b		
			64	46	14.9	28.9	B5	E4b		
			--	--	13.2	30.5	F5b	E4b		
			--	--	18.5	36.9	B5	E4b		
	Rochester 2	9/18/2006	44	30	7.8	34.8	E4	E4	10	NF
			37	23	5.2	39.4	E4	E4		
			63	48	4.6	47.7	B4c/G4c	E4		
			--	--	6.1	38.1	B4c/G4c	E4		
			--	--	10.2	30.4	G4c	E4		
Sawlog Creek tributary to Big Hole R	Sawlog D2	7/21/1994	--	--	7	27.8	B5c	E4	--	NF
	M03SWLGC01	9/13/2003	83	72	--	--	--	--	--	--
	M03SWLGC02	9/13/2003	--	--	--	--	--	--	--	--
	BH-38-2	2002	--	--	--	--	--	--	--	PFC
	Sawlog 1	10/13/2005	57	38	18.8	36.6	C4	E4	22	NF
			60	50	32.0	30.4	B4c	E4		
			39	29	11.4	27.8	C4	E4		
			--	--	2.5	29.5	E4	E4		
			--	--	3.2	29.2	E4	E4		
	Sawlog 2	7/25/2006 & 8/31/2006	92	64	3.3	29.2	E5	E4	75	FAR
			95	61	7.0	--	G5c	E4		
			100	95	6.6	--	B5c/E5	E4		
			--	--	3.1	--	G5c	E4		
			--	--	1.1	--	E5	E4		
Seven Springs Creek Headwaters to mouth (Browns Gulch-Big Hole R)	No Sediment Data Reported		--	--	--	--	--	--	--	--

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Sevenmile Creek from headwaters to mouth (Deep Cr)	M03SVNM01 (SV-1)	7/9/2001	--	--	--	--	--	--	--	
	M03SVNM02 (SV-2)	7/9/2001	--	--	--	--	--	--	--	
	DL-7	1995	--	--	--	--	--	--	--	PFC
	Sevenmile 1	9/28/2006	26	20	7.8	38.0	E4b	E4b	39	FAR
			15	12	3.6	33.0	B4/G4	E4b		
			25	14	10.0	34.2	G4	E4b		
			--	--	13.8	37.2	B4/G4	E4b		
			--	--	8.2	19.5	E4b	E4b		
	Sevenmile 2	9/7/2006	37	24	4.8	29.3	E4	E4	--	FAR
			40	34	11.4	24.6	G4c	E4		
			46	39	11.6	27.5	B4c	E4		
			--	--	85.9	30.6	F4	E4		
			--	--	21.4	26.4	C4	E4		
Seymour Creek from headwaters to mouth (Big Hole River)	No Sediment Data Reported		--	--	--	--	--	--	--	--
Sixmile Creek from headwaters to mouth (California Cr)	M03SIXMC01 (S-1)	7/9/2001	--	--	--	--	--	--	--	--
	M03SIXMC02 (S-2)	7/9/2001	--	--	--	--	--	--	--	--
	Sixmile 1	7/31/2006	24	18	12.5	41.4	B4	B4	90	PFC
			19	12	7.6	15.8	B4/G4	B4		
			21	15	10.8	27.9	B4	B4		
			--	--	9.6	28.5	B4	B4		
			--	--	22.3	27.0	C4b	B4		
	Sixmile 2	8/1/2006	26	22	8.9	42.7	G4	E3b	26	NF
			25	22	24.1	44.7	F4b	E3b		
			13	9	4.5	34.7	E4b	E3b		
			--	--	10.0	24.7	E4b	E3b		
			--	--	23.3	32.9	B4	E3b		

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Soap Creek from headwaters to mouth (Big Hole R)	M03SOAPC01	7/30/2003	36	26	--	--	E4	--	--	100% FAR
	M03SOAPC02	7/30/2003	40	34	--	--	E4	--	--	
	SB-22, 24, 81	--	--	--	--	--	--	--	--	
	Soap 1	7/28/2006	33	25	4.2	30.3	E4a	E3a	--	--
			46	38	10.0	26.9	E4a	E3a		
			53	46	15.6	23.9	B4a	E3a		
			--	--	11.1	29.2	E4a	E3a		
			--	--	12.4	--	E4a	E3a		
	Soap 2	7/25/2006	66	52	11.6	37.4	E5b	E4b	40	NF
			58	35	6.4	--	E5b	E4b		
			40	29	11.0	--	E5b	E4b		
			--	--	8.5	--	E5b	E4b		
			--	--	16.0	--	C5b	E4b		
Trapper Creek from headwaters to mouth (Big Hole R)	Trapper Dn	5/23/1994	15	14	7.7	16.5	A3	A3	--	PFC
	Trapper Up	5/24/1994	29	26	16.7	37.4	F4	E4	--	NF
	Trapper 1	9/22/2005	24	16	5.3	29.2	E4	E4	82	FAR
			19	13	12.3	38.5	B4c	E4		
			20	11	7.9	22.9	E4	E4		
			--	--	6.1	40.6	G4c	E4		
			--	--	8.2	35.2	E4	E4		
	Trapper 2	9/21/2006	37	21	13.8	19.5	C4	E4	74	FAR
			41	28	16.4	20.2	C4	E4		
			43	23	18.2	28.7	C4	E4		
			--	--	16.1	29.3	B4c	E4		
			--	--	2.8		E4	E4		
Twelvemile from headwaters to mouth (Deep Cr)	T-1	2001	--	--	--	--	--	--	--	--
	T-2	2001	--	--	--	--	--	--	--	--
	T-4	2001	--	--	--	--	--	--	--	--
Wickiup Creek Tributary to Camp Cr (Big Hole R)	Data forthcoming									

Table H-1. Sediment and habitat raw data for the Middle and Lower Big Hole TPA.

Stream Segment	Sample Site	Sample Date	% of Fine Sediment <6mm	% of Fine Sediment <2mm	Channel Width/Depth Ratio	Bank Erosion Hazard Index	Existing Stream Type	Potential Stream Type	Greenline Transect (% Shrubs)	PFC Rating
Willow Creek from headwaters to mouth (Big Hole R)	Willow	9/5/1991	19	16	12.9	NA	B3/B4	B4	--	PFC
	Willow BLM	9/20/1994	23	21	13.8	21	B3c	B3c	--	PFC
	Willow Down	8/12/1998	27	27	9.7	25.6	B3	B3	--	PFC
	Willow Mid	8/12/1998	25	23	6	23.8	B3	B3	--	PFC
	Willow Up	8/12/1998	78	78	7.6	26.2	E5	E4	--	FAR
	Willow 1		30	19	13.8	41.7	C4	E4	82	FAR
			12	11	17.0	37.3	B4c/F4	E4		
			24	20	33.1	39.4	B4c/F4	E4		
			--	--	16.7	23.1	B4c/F4	E4		
			--	--	9.0	--	E4	E4		
Wise River from headwaters to mouth (Big Hole R)	Wise River	8/30/1994	5	5	31.2	36.5	F4	C3	--	NF
	Wise 1	10/10/2005	20	10	22.5	34.0	B4c	C4	25	FAR
			22	12	35.1	30.7	B4c	C4		
			9	4	36.3	36.2	C4	C4		
			--	--	40.3	40.0	C4	C4		
			--	--	33.1	32.5	B4c	C4		
	Wise 2	10/11/2005	11	7	21.7	19.2	C3	C3	78	PFC
			6	5	15.5	17.9	B3	B3		
			5	3	24.7	24.0	F3	C3		
			--	--	27.9	6.2	B3c	C3		
			--	--	25.0	11.5	B3c	C3		
	Wise 3		10	8	34.7	13.5	C3	C3	82	FAR
			15	13	35.1	--	C3	C3		
			9	7	37.8	--	C3	C3		
			--	--	31.8	--	C3	C3		
			--	--	53.4	--	C3	C3		

Table H-2. Metals and percent abnormal diatom raw data for the Middle and Lower Big Hole TPA

Stream Segment	Sample Site	Sample Date	Flow (cfs)	Total Recoverable Metal in Water Column (µg/L)							Hardness (mg/L as CaCO3)	% Abn. Diatom Cells	Sediment Metals Concentrations (µg/g)						
				As	Cu	Cd	Pb	Zn	Hg	Ag			As	Cu	Cd	Pb	Zn	Hg	Ag
Big Hole River between Divide Cr and Pintlar Cr	Mudd Creek	8/3/2001	123	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-
	Dickie Bridge	8/6-7/2002	217	2.4	0.61	<0.084	<0.15	20.9	-	<0.14	37.0	-	-	-	-	-	-	-	-
	ML05MDBH01	6/6/2005	1000	2	1	<0.1	<1	<0.5	-	<1	35.6	-	-	-	-	-	-	-	-
	ML05MDBH02	6/6/2005	1500	3	2	<0.1	<1	0.8	-	1	37.1	-	-	-	-	-	-	-	-
	ML05MDBH01	8/1/2005	188	4	<1	<0.08	<0.5	<1	<0.05	<1	41.2	-	8.43	35.9	0.68	8.17	43.6	-	<1
	ML05MDBH03	8/1/2005	275	4	<1	<0.08	<0.5	<1	<0.05	<1	58.4	-	6.25	16.2	<0.5	7.22	48.0	-	<1
	ML05MDBH03	8/1/2005	275	-	-	-	-	-	-	-	-	-	8.99	15.4	<0.5	8.20	48.2	-	<1
	ML05MDBH01	5/18/2006	2450	2	2	<0.08	<0.5	1.8	-	<1	21.2	-	-	-	-	-	-	-	-
	ML05MDBH03	5/17/2006	3820	3	3	<0.08	0.6	8.1	-	<1	21.9	-	-	-	-	-	-	-	-
Big Hole River from Divide Cr to the mouth (Jefferson River)	Maiden Rock	8/4/2001	381	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-
	Notch Bottom	8/4/2001	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
	Notch Bottom	9/9-10/2002	-	2.0	0.46	<0.084	<0.15	17.4			101.4	-	-	-	-	-	-	-	-
	ML05LWBH01	6/5/2005	2370	3	2	<0.1	<1	1.4	-	<1	42.6	-	-	-	-	-	-	-	-
	ML05LWBH02	6/4/2005	2670	4	3	<0.1	<1	3.8	-	<1	51.2	-	-	-	-	-	-	-	-
	ML05LWBH01	8/2/2005	330	4	<1	<0.08	<0.5	1	<0.05	<1	83.7	-	7.32	28.7	0.66	21.0	101	-	<1
	ML05LWBH02	8/4/2005	327	5	<1	<0.08	<0.5	1	<0.05	<1	115	-	11.4	17.3	0.63	20.9	95.7	-	<1
	ML05LWBH01	5/17/2006	3750	3	2	<0.08	0.6	5	-	<1	28.1	-	-	-	-	-	-	-	-
	ML05LWBH02	5/16/2006	2860	3	2	<0.08	<0.5	2.8	-	<1	39.4	-	-	-	-	-	-	-	-
California Creek from headwaters to mouth (French Cr-Deep Cr)	3124CA01	7/31/1991	~10	72	>2	<0.2	>1	37	-	-	84	-	-	-	-	-	-	-	-
	CF-16	2000	-	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-
	ML05CALI01	6/6/2005	8.70	10	-	-	-	-	-	-	65.2	-	-	-	-	-	-	-	-
	ML05CALI02	6/6/2005	33.40	18	-	-	-	-	-	-	41.6	-	-	-	-	-	-	-	-
	ML05CALI02	6/6/2005	33.40	17	-	-	-	-	-	-	41.7	-	-	-	-	-	-	-	-
	M03CALC02	7/7/2005	2.16	9	1	<0.1	<0.5	<10	<0.1	<3	77.0	-	17.5	19.8	<0.5	14.4	53	<0.5	<1
	ML03CALC01	7/8/2005	12.22	18	3						53.0	-	77.2	49	1.81	29	112	-	<1
	ML03CALC03	7/12/2005	17.04	18	2	<0.1	<0.5	<10			59.0	-	10.4	66.6	0.86	38.4	203	<0.5	<1
	ML05CALI01	8/1/2005	1.10	11	-	-	-	-	-	-	90.5	-	23.4	-	-	-	-	-	-
	ML05CALI02	8/1/2005	4.80	21	-	-	-	-	-	-	77.3	-	45.7	-	-	-	-	-	-
	ML05CALI01	5/18/2006	10.60	11	5	-	-	-	-	-	64.4	-	-	-	-	-	-	-	-
	ML05CALI02	5/18/2006	51.10	23	11	-	-	-	-	-	38.5	-	-	-	-	-	-	-	-

Table H-2. Metals and percent abnormal diatom raw data for the Middle and Lower Big Hole TPA

Stream Segment	Sample Site	Sample Date	Flow (cfs)	Total Recoverable Metal in Water Column (µg/L)							Hardness (mg/L as CaCO3)	% Abn. Diatom Cells	Sediment Metals Concentrations (µg/g)						
				As	Cu	Cd	Pb	Zn	Hg	Ag			As	Cu	Cd	Pb	Zn	Hg	Ag
Camp Creek from headwaters to mouth (Big Hole R)	M03CAMPC01	9/14/2003	13.42	26	<1	<0.1	<1	4	-	<1	149	0.0	-	-	-	-	-	-	-
	M03CAMPC02	9/15/2003	1.52	17	<1	<0.1	<1	<1	-	<1	114	0.0	27.4	27.2	<0.5	37	82.8	-	<1
	M03CAMPC03	9/15/2003	E 4	11	<1	<0.1	<1	<1	-	<1	50.1	0.0	56.1	29.8	<0.5	17.3	124	-	<1
	ML05CAMP01	6/5/2005	7.40	3	-	-	-	-	-	-	118	-	-	-	-	-	-	-	-
	ML05CAMP02	6/5/2005	4.50	3	-	-	-	-	-	-	43.0	-	-	-	-	-	-	-	-
	ML05CAMP03	6/5/2005	19.80	4	-	-	-	-	-	-	117	-	-	-	-	-	-	-	-
	ML05CAMP01	5/17/2006	10.10	4	2	-	-	-	-	-	<45	-	-	-	-	-	-	-	-
	ML05CAMP02	5/17/2006	7.90	3	-	-	-	-	-	-	<109	-	-	-	-	-	-	-	-
	ML05CAMP06	5/17/2006	12.20	3	4	-	-	-	-	-	<50.4	-	-	-	-	-	-	-	-
Elkhorn Creek headwaters to mouth (Jacobson Cr-Wise R)	SW-1/SE-1	9/15/1993	7.00	<1.12	23.6	<4.59	1.88	159	<0.12	-	22.8	-	7.09	52.9	<0.9	6.68	134	<0.031	-
	SW-4/SE-2	9/15/1993	5.00	<1.12	<2.33	<4.59	<.94	<8.71	<0.12	-	17.3	-	<4	1.83	<0.8	<5.5	19	<0.030	-
	E-1	7/20/2000	6.96	<3	1	<0.1	<3	<10	-	<3	13	-	7	29	<5	12	107	-	<5
	E-9	7/20/2000	8.13	<3	8	<0.1	<3	50	-	<3	19	-	42	565	12	192	1430	-	<5
	M03ELKHC01	7/23/2003	8.10	2	15	0.3	<1	92	-	<1	18.9	11.2	71.6	940	6.98	300	1020	-	4.98
	M03ELKHC02	7/23/2003	7.12	2	10	0.2	<1	52	-	<1	19.3	19.9	38.9	764	13.2	234	1220	-	3.53
	ML05EKHR01	6/6/2005	11.70	-	43	0.6	-	117.4	-	-	15.4	-	-	-	-	-	-	-	-
	ML05EKHR02	6/6/2005	43.10	-	39	0.5	-	110.7	-	-	15.4	-	-	-	-	-	-	-	-
	ML05EKHR01	5/17/2006	29.50	-	54	0.52	-	82.6	-	-	14.2	-	-	-	-	-	-	-	-
	ML05EKHR02	5/17/2006	82.20	-	54	0.69	-	99.9	-	-	15.1	-	-	-	-	-	-	-	-
French Creek from headwaters to mouth (Deep Cr)	ML05FREN01	6/6/2005	10.20	6	3	<0.1	<1	<0.5	-	<1	28.7	-	-	-	-	-	-	-	-
	ML05FREN02	6/6/2005	88.00	14	5	<0.1	<1	2.6	-	<1	43.9	-	-	-	-	-	-	-	-
	M03FNCHC01	7/6/2005	3.16	5	1	<0.1	<0.5	<10	<0.1	<3	30.0	-	40.9	32.2	<0.5	36.7	84	<0.5	<1
	M03FNCHC04	7/8/2005	36.53	16	2	<0.1	<0.5	<10	<0.1	<3	55.0	-	108	39.5	<0.5	18.7	94	-	<1
	M03FNCHC02	7/6/2005	18.88	16	2	<0.1	<0.5	<10	<0.1	<3	50.00	-	32	30.8	<0.5	14.1	74	<0.5	<1
	M03FNCHC03	7/7/2005	24.84	19	2	<0.1	<0.5	<10	<0.1	<3	52.0	-	28.5	27.4	<0.5	12.1	62	<0.5	<1
	ML05FREN01	8/1/2005	1.20	9	<1	<0.08	<0.5	<1	<0.05	2	45.7	-	32.2	33.8	1.31	30.6	83.9	-	<1
	ML05FREN02	8/2/2005	11.30	26	1	<0.08	<0.5	1	<0.05	<1	68.9	-	56.0	27.1	0.61	12.5	55.1	-	<1
	ML05FREN01	5/18/2006	18.50	7	3	<0.08	<0.5	0.8	-	<1	27.7	-	-	-	-	-	-	-	-
	ML05FREN02	5/18/2006	123.20	14	5	<0.08	0.6	3.2	-	<1	40.4	-	-	-	-	-	-	-	-

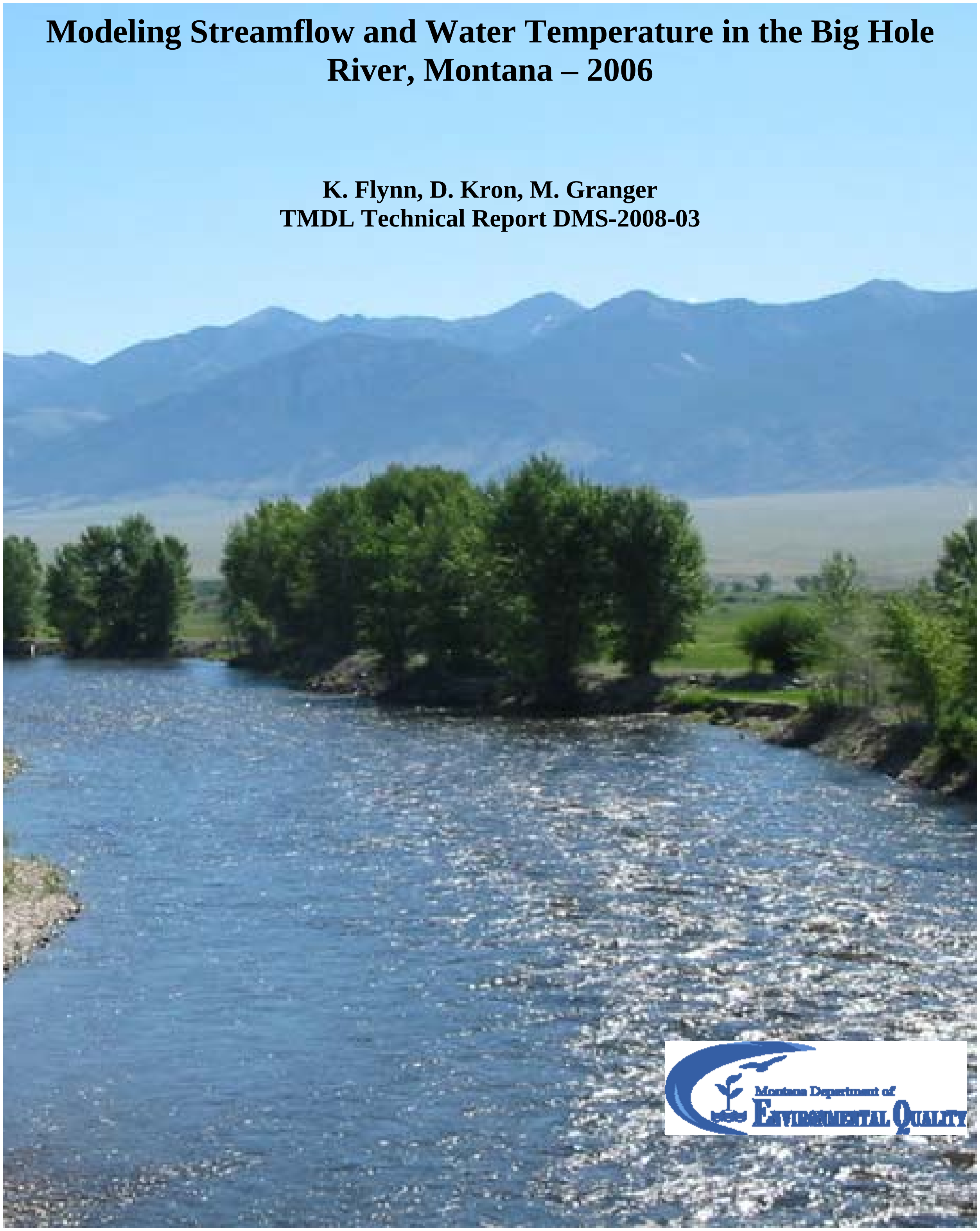
Table H-2. Metals and percent abnormal diatom raw data for the Middle and Lower Big Hole TPA

Stream Segment	Sample Site	Sample Date	Flow (cfs)	Total Recoverable Metal in Water Column (µg/L)							Hardness (mg/L as CaCO3)	% Abn. Diatom Cells	Sediment Metals Concentrations (µg/g)						
				As	Cu	Cd	Pb	Zn	Hg	Ag			As	Cu	Cd	Pb	Zn	Hg	Ag
Jerry Creek from headwaters to mouth (Big Hole R)	M03JERRC01	7/10/2003	7.00	3	<1	<0.1	<1	<1	-	<1	44.1	1.1	5.98	17.5	0.54	15.9	77.1	-	<0.2
	ML05JERR01	6/5/2005	78.70	3	1	<0.1	<1	0.8	-	<1	57.2	-	-	-	-	-	-	-	-
	ML05JERR02	6/5/2005	71.90	3	1	<0.1	<1	0.7	-	<1	68.0	-	-	-	-	-	-	-	-
	M03JERRC02	7/9/2005	21.32	<3	<1	<0.1	<0.5	<10	<0.1	<3	88.0	-	10.6	23.5	<0.5	15.6	87	-	<1
	ML05JERR01	8/3/2005	9.50	3	<1	<0.08	<0.5	<1	<0.05	<1	112	-	15.1	23.6	0.89	19.3	92.8	-	<1
	ML05JERR02	8/3/2005	8.80	3	26	<0.08	1	18	<0.05	<1	118	-	11.4	26.9	0.85	15.8	87.6	-	<1
	ML05JERR02	8/3/2005	8.80	-	-	-	-	-	-	-	-	-	9.67	44.8	0.91	16.8	100	-	<1
	ML05JERR01	5/17/2006	99.00	3	1	<0.08	<0.5	4	-	<1	53.0	-	-	-	-	-	-	-	-
	ML05JERR02	5/17/2006	95.00	2	1	<0.08	<0.5	1.5	-	<1	63.9	-	-	-	-	-	-	-	-
Lost Creek in the Lower Big Hole Watershed	M03LOSTC01	9/13/2003	~1	27	<1	<0.1	<1	<1	-	<1	142	0.3	16.8	14.9	0.8	18.8	79.8	-	<1
	M03LOSTC02	9/14/2003	~2	28	<1	<0.1	<1	<1	-	<1	134	3.9	22.8	15.2	0.7	17.9	80.9	-	<1
	ML05LOST01	6/4/2005	1.20	5	-	-	-	-	-	-	102	-	-	-	-	-	-	-	-
	ML05LOST02	6/4/2005	1.00	5	-	-	-	-	-	-	73.7	-	-	-	-	-	-	-	-
	ML05LOST02	5/16/2006	0.83	6	-	-	-	-	-	-	115	-	-	-	-	-	-	-	-
	ML05LOST03	5/16/2006	0.18	6	-	-	-	-	-	-	125	-	-	-	-	-	-	-	-
Oregon Creek headwaters to mouth (California Cr - French Cr - Deep)	3124OR01	7/29/1991	~2	>44	>5	<0.2	<1	>26	-	-	42	-	-	-	-	-	-	-	-
	ML05ORGN01	6/6/2005	6.60	20	11	<0.1	<1	-	-	-	24.9	-	-	-	-	-	-	-	-
	M03ORGNC01	7/7/2005	1.42	29	5	<0.1	0.5	<10	<0.1	<3	31.0	-	121	89.3	1.87	44.4	194	<0.5	<1
	ML05ORGN01	8/2/2005	0.40	35	3	<0.08	0.6	-	-	-	42.7	-	77.7	106	4.04	62.5	-	0.1	-
	ML05ORGN01	5/18/2006	9.10	20	11	<0.08	<0.5	-	-	-	26.6	-	-	-	-	-	-	-	-
Rochester Creek from headwaters to mouth (Big Hole R)	SE-3	6/15/1993	-	-	-	-	-	-	-	-	-	-	291	66.7	<0.6	204	43	<0.024	-
	R-1	7/18/2000	-	<3	2	<0.1	<3	<10	-	<3	203	-	<5	24	<5	7	48	-	-
	R-3	7/18/2000	-	129	10	0.2	<3	<10	-	<3	218	-	5050	1610	11	1630	155	-	-
	R-9	7/18/2000	-	37	3	<0.1	<3	<10	-	<3	303	-	-	-	-	-	-	-	-
	R-10	7/18/2000	-	38	3	<0.1	<3	<10	-	<3	304	0.0	-	-	-	-	-	-	-
	ML05ROCH01	6/4/2005	0.04	66	7	-	<1	-	<0.1	-	205	-	-	-	-	-	-	-	-
	ML05ROCH02	6/4/2005	0.10	16	2	-	<1	-	<0.1	-	251	-	-	-	-	-	-	-	-
	ML05ROCH01	8/4/2005	0.01E	238	10	-	5.0	-	<0.05	-	226	-	3770	2940	-	1960	-	0.6	-
	ML05ROCH01	8/4/2005	0.01E	245	10	-	5.3	-	<0.05	-	227	-	3040	2800	-	1860	-	0.6	-
	ML05ROCH02	8/4/2005	0.10	23	1	-	<0.5	-	<0.05	-	259	-	1540	619	-	849	-	0.5	-
	ML05ROCH01	5/16/2006	0.005 E	92	20	-	6.2	-	<0.05	-	227	-	-	-	-	-	-	-	-
	ML05ROCH02	5/16/2006	0.26	15	2	-	<0.5	-	<0.05	-	269	-	-	-	-	-	-	-	-

Table H-2. Metals and percent abnormal diatom raw data for the Middle and Lower Big Hole TPA

Stream Segment	Sample Site	Sample Date	Flow (cfs)	Total Recoverable Metal in Water Column (µg/L)							Hardness (mg/L as CaCO3)	% Abn. Diatom Cells	Sediment Metals Concentrations (µg/g)						
				As	Cu	Cd	Pb	Zn	Hg	Ag			As	Cu	Cd	Pb	Zn	Hg	Ag
Sassman Gulch from headwaters to mouth (Big Hole R)	M03SASMG01	7/15/2005	E 0.1	<3	2	<0.1	1.4	<10	<0.1	<3	<217	-	39.8	34.3	0.66	17	68	<0.5	<1
	M03SASMG02	7/15/2005	E 0.1	4	3	0.2	1.9	10	<0.1	<3	<244	-	4.8	21	<0.5	12.9	78	<0.5	<1
Sawlog Creek tributary to Big Hole R	M03SWLGC01	9/13/2003	1.50	19	<1	<0.1	<1	<1	-	<1	<109	0.0	-	-	-	-	-	-	-
	M03SWLGC02	9/13/2003	1.00	-	-	-	-	-	-	-	<116	0.0	-	-	-	-	-	-	-
	ML05SWLG01	5/18/2006	3.00	2	-	-	-	-	-	-	<82.2	-	-	-	-	-	-	-	-
	ML05SWLG02	5/18/2006	3.00	2	-	-	-	-	-	-	<84.7	-	-	-	-	-	-	-	-
Trapper Creek from headwaters to mouth (Big Hole R)	ML05TRAP01	6/5/2005	22.70	3	5	0.2	14	73.6	-	<1	90.9	-	-	-	-	-	-	-	-
	ML05TRAP02	6/5/2005	14.20	4	8	0.4	22	103	-	<1	108	-	-	-	-	-	-	-	-
	M03TRAPC01	7/14/2005	13.95	<3	3	<0.1	9	20	<0.1	<3	71	-	52.7	129	5.88	1080	1230	1.9	9.8
	M03TRAPC02	7/15/2005	8.97	3	9	0.4	51.3	130	<0.1	<3	88	-	269	712	39.3	6400	9570	9.4	53.8
	M03TRAPC03	7/15/2005	12.09	4	3	0.1	6.4	30	<0.1	<3	167	-	13.9	85.3	4	370	849	0.6	3.9
	ML05TRAP01	8/4/2005	6.00	3	3	0.15	<0.5	65	<0.05	<1	111	-	312	836	54.4	8700	14200	-	14.6
	ML05TRAP02	8/4/2005	2.70	6	4	0.33	8.0	95	<0.05	<1	156	-	76.4	352	20.3	1680	4140	-	10.3
	ML05TRAP01	5/16/2006	17.50	8	27	0.8	128.0	232.6	-	1	97.3	-	-	-	-	-	-	-	-
	ML05TRAP02	5/16/2006	5.50	4	9	0.41	20.9	100.2	-	<1	121	-	-	-	-	-	-	-	-
Wickiup Creek Tributary to Camp Cr (Big Hole R)	SW2/SE2	8/24/1993	0.43	2.67	1.55	2.57	3.5	13.1	0.2	-	53	-	10.4	12.7	0.8	5.43	27.3	<0.034	-
	SW-1/SE-1	8/24/1993	~0.5	2.18	206	2.57	2.72	7.9	0.45	-	57.2	-	44.4	1650	1.1	41.8	43.7	<0.031	-
	M03WICKC01	6/15/2004	0.49	<3	10	<0.1	<0.5	<1	-	<3	74.0	-	15	450	1.7	10.8	86.4	<0.5	<1
	ML05WICK01	6/5/2005	1.10	-	33	-	-	-	-	-	45.6	-	-	-	-	-	-	-	-
	ML05WICK02	6/5/2005	1.40	-	12	-	-	-	-	-	65.6	-	-	-	-	-	-	-	-
	ML05WICK01	5/17/2006	1.80	-	46	-	-	-	-	-	42.9	-	-	-	-	-	-	-	-
	ML05WICK02	5/17/2006	2.10	-	15	-	-	-	-	-	63.2	-	-	-	-	-	-	-	-
Wise River from headwaters to mouth (Big Hole R)	ML05WISE01	6/6/2005	150.00	<1	10	0.1	<1	28.5	-	<1	15.1	-	-	-	-	-	-	-	-
	ML05WISE02	6/6/2005	400.00	<1	4	<0.1	<1	6.6	-	2	17.2	-	-	-	-	-	-	-	-
	M03WISER01	7/12/2005	58.83	<3	4	<0.1	<0.5	20	<0.1	<3	14.0	-	11.4	55.7	0.74	37	189	<0.5	<1
	M03WISER02	7/13/2005	99.06	<3	2	<0.1	<0.5	<10	<0.1	<3	28.0	-	<3	15.6	<0.5	8.7	76	<0.5	<1
	M03WISER03	7/13/2005	200.00	<3	2	<0.1	<0.5	<10	<0.1	<3	24.0	-	5.7	37.9	0.68	16	220	0.7	<1
	M03WISER04	7/13/2005	90.29	<3	1	<0.1	<0.5	<10	<0.1	<3	35.0	-	<3	12.6	<0.5	7.9	65	<0.5	<1
	ML05WISE01	8/2/2005	25.20	1	3	<0.08	<0.5	22	<0.05	<1	21.4	-	11.7	107	3.86	46.9	337	-	<1
	ML05WISE02	8/2/2005	17.00	1	<1	<0.08	<0.5	1	<0.05	<1	52.7	-	10.4	78.6	1.56	30.1	252	-	<1
	ML05WISE01	5/17/2006	200.00	1	10	0.15	1.1	25.1	-	<1	14.7	-	-	-	-	-	-	-	-
	ML05WISE02	5/17/2006	600.00	2	5	0.12	4.7	21.2	-	<1	15.1	-	-	-	-	-	-	-	-

APPENDIX I
MODELING STREAMFLOW AND WATER TEMPERATURE IN THE BIG HOLE RIVER, MONTANA - 2006



Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006

K. Flynn, D. Kron, M. Granger
TMDL Technical Report DMS-2008-03

Front Cover: Big Hole River above the confluence with the Jefferson River

Image courtesy of: Big Sky Fishing.Com; http://www.bigskyfishing.com

Other Credits:

Outreach and landowner coordination: Big Hole River Watershed Committee
Field data collection: Watershed Consulting, Inc.

EXECUTIVE SUMMARY

The one-dimensional, dynamic water quality model Heatsource v7.0 was applied to the Big Hole River in southwestern Montana to evaluate stream temperature improvement scenarios for a 152.5 kilometer reach extending from approximately Wisdom to the confluence with the Beaverhead River near Twin Bridges. This reach has been identified as a primary concern due to elevated summer temperatures, low late-season flows, and the presence of Arctic grayling. An extensive field investigation was completed during summer 2006 to support the modeling. This included measurement of streamflow and water temperature at 20 Big Hole River main-stem locations, 44 tributaries and irrigation return flows, and 33 irrigation withdrawls.

Characterization of river hydraulics, measurement of stream shade, and continuous monitoring of climate were also completed. Results of predictive modeling suggest that the Big Hole River is impaired due to management activities, and that decreases of 0.13 and 0.59ºC (0.23 and 1.06ºF) in average and maximum temperatures could be achieved per implementation of "all reasonable soil and water conservation practices" (ARM 17.30.602). Temperatures would be 0.69 and 2.76ºC (1.24 and 4.97ºF) cooler under natural conditions. Through analysis of shade, geomorphology, and instream flow conditions, it was shown that flow alteration is the most significant contributor to warming of river, and subsequently, the most feasible alternative for returning the Big Hole to a more natural thermal regime. This of course, would require decreases in consumptive use either through irrigation efficiency improvements, or decreases in domestic water withdrawl. Finally, a unique condition was identified near the center of the watershed where significant groundwater influx and topographic shading result in thermal "resetting" of in-stream water temperatures. This functionally separates the upper and lower Big Hole River TMDL planning areas, and will allow for future management of the river as two distinct segments. This work has been initiated by the Montana Department of Environmental Quality as part of the Total Maximum Daily Load (TMDL) program.

TABLE OF CONTENTS

Background **I-13**
Prior Studies I-13
Montana Temperature Standard (ARM 17.30.623) I-14
Study Area **I-15**
Climate I-15
Surface Water I-15
Groundwater I-16
Groundwater-Surface water I-16
Irrigation & Domestic Use I-18
Methods and Materials **I-21**
Site Selection I-21
Temperature Data I-21
Discharge Data I-21
Climate Data I-22
Morphological and Shade Data I-22
Model Development **I-23**
Model Description I-23
GIS Pre-processing I-23
Simulation Period and Global Control Specifications I-24
Hydrology/Mass Transfer Input I-24
Hydraulic Input I-30
Climate Input I-32
Shade Input I-32
Model Evaluation Criteria I-36
Model Calibration Procedure I-38
Model Validation/Confirmation I-38
Results & Discussion **I-41**
Hydrology I-41
Hydraulics I-41
Shade I-42
Water Temperature I-42
Scenario Analysis **I-49**
Baseline Scenario I-49
Shade Scenario I-49
Channel Morphology Scenario I-50
Water Consumptive Use Scenario I-54
Natural Condition Scenario I-56
Naturally Occurring Scenario (ARM 17.30.602) I-56
Use Attainment Scenario I-57
Conclusion **I-59**
References **I-61**

Appendix-A – Model Documentation – Contact DEQ

FIGURES

Figure 1. Big Hole River watershed, hydrography, and stream-flow gaging stations. I-17
Figure 2. Big Hole River climate at Divide 2 NW (1971-2000); b) USGS hydrology. I-18
Figure 3. Example of TTools radial sampling algorithm. I-24
Figure 4. Summary of mean daily discharge, temperature, and associated statistics for the USGS gage near Melrose, MT (USGS 06025500). I-25
Figure 5. Locations of major inflow, outflow, and climate monitoring on the Big Hole River ……………………………………………………………………………………...I-27
Figure 6. Streamflow during the critical temperature limiting period I-28
Figure 7. Hourly plots of water temperature for selected I-29
Figure 8. Box and whisker plots of tributary temperature data collected on the Big Hole River from the July 25-31, 2007. ....I-30
Figure 9. Unique reaches defined for model parameterization of hydraulics. Elevation data taken from USGS National Elevation Dataset (NED) 30-m grid. I-31
Figure 10. Adjusted climatic conditions over the July 25-31, 2006 modeling period at the three localized climate stations. I-34
Figure 11. Example of digitized riparian landcover classification used in the Big Hole River Model near Melrose. I-35
Figure 12. Big Hole River simulated and observed hydrology for July 28th of the July 25-31, 2006 modeling period. Observed measurements were taken instantaneously over the 7-day study period and may not necessarily reflect conditions that day. I-42
Figure 13. Big Hole River simulated and observed hydraulics I-43
Figure 15. Longitudinal temperature profile of the Big Hole River displaying Tmin, Tmax, Tavg, and mean discharge for July 28th of the July 25-31, 2006 modeling period. I-46
Figure 16. Diurnal plots of observed and simulated temperature for the 19 monitoring stations on the Big Hole River during the July 25-31, 2006 modeling period. I-47
Figure 17. Longitudinal temperature effects of management scenarios on the Big Hole River I-51
Figure 18. Longitudinal profile of discharge in the watershed as part of the water use scenario. I-55

TABLE OF TABLES

.

Table 1. Instantaneous measured inflow, outflow, and associated water balance for the Big Hole River during the July 25-31, 2006 modeling period. I-26
Table 2. Hydraulic parameters used in the Big Hole River Heatsource v7.0 model. I-32
Table 3. Riparian landcover types and associated attributes used in Heatsource v7.0 shading calculations. I-33
Table 4. Summary of parameter sensitivity for the Big Hole River Heatsource v7.0 model. I-38
Table 5. Hourly water temperature calibration statistics for July 25-31, 2006 modeling period. I-45
Table 6. Temperature changes at end of simulation reach resulting from modification of shade on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments). I-50
Table 7. Temperature changes at end of simulation reach resulting from modification of river morphology of the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments). I-51
Table 8. Temperature changes at end of simulation reach resulting from modification of consumptive use on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments). I-55
Table 9. Temperature changes at end of simulation reach resulting from natural conditions on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments). I-56
Table 10. Temperature changes at end of simulation reach resulting from naturally occurring conditions on the Big (both SSTEMP and Heatsource v7.0 modeled segments). I-57

Conversion Factors and Datum

1 meter = 3.2808 feet
1 cubic meter per second (cms) = 35.313 cubic feet per second (cfs)
1 kilometer = 0.622 miles
1 square kilometer = 0.386 square miles

ACRONYMS

7Davg	7-day mean temperature
7Dmax	7-day maximum temperature
7Dmin	7-day minimum temperature
7Q5	7-day 5-year low flow
ARM	Administrative Rules of Montana
BHWC	Big Hole River Watershed Committee
BLM	Bureau of Land Management
BMPs	Best Management Practices
ºC	Degrees Celsius
COOP	Cooperative Observer
CWA	Clean Water Act
cfs	cubic feet per second
cms	cubic meters per second
CWAIC	Clean Water Act Information Center
DEM	Digital Elevation Model
DEQ	Montana Department of Environmental Quality
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ET	Evapotranspiration
ºF	Degrees Fahrenheit
FWP	Montana Fish, Wildlife, and Parks
FY	Fiscal Year
GIS	Geographic Information System
HUC	Hydrologic Unit Code
LULC	Land Use/Land Cover
LSWCP	Land, Soil, and Water Conservation Practices
NAD83	National Accumulation of Datum - 1983
NAIP	National Agricultural Imagery Program
NAVD88	National Accumulation of Vertical Datum - 1988
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NIST	National Institute of Standards and Technology
NLDC	National Land Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NSE	Nash-Sutcliffe Coefficient of Efficiency
PBIAS	Percent Bias
QA	Quality Assurance
RAWS	Remote Automated Weather Station
SSR	Sum of Squared Residuals
SSTEMP	Stream Segment Temperature Model
TMDL	Total Maximum Daily Load
Tavg	Mean daily water temperature

Tmax	Maximum daily water temperature
Tmin	Minimum daily water temperature
TPA	TMDL Planning Area
UILT	Upper incipient lethal limit
USFWS	U.S. Fish and Wildlife Service
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WRCC	Western Regional Climate Center
WRS	Water Resource Surveys

BACKGROUND

Conflicting demands between irrigated agriculture, anglers, and aquatic species have long been an issue in the arid west (Thomas and Anderson, 1976; Anderson, 1982; Pimentel et al, 1997; Pringle, 2000). The Big Hole River in southwestern Montana is no different, and mounting evidence suggests that low flow conditions and extensive dewatering have elevated summer water temperatures to such that beneficial uses of the water body are impaired (CWAIC, 2006). As a result, Montana Department of Environmental Quality (DEQ) has commissioned a water temperature study to such that the mechanistic relationship between instream water temperature, stream morphology, riparian conditions, and associated water management practices can be established for the summer critical low-flow period. Specifically, the one-dimensional, dynamic stream water quality model Heatsource v7.0 (Boyd and Kasper, 2004) was applied to a 152.5 kilometer reach extending from approximately Wisdom to the confluence with the Beaverhead River near Twin Bridges to evaluate irrigation improvement efficiencies and associated scenarios as part of the Total Maximum Daily Load (TMDL) program. This reach has been identified as a primary concern due to elevated summer temperatures, low late-season flows, and the presence of the last remaining native population of river-dwelling Arctic grayling in the lower 48 states (Magee et al., 2006; Rens and Magee, 2007). Subsequent analysis was also completed for a 94.5-km reach upstream of the project site using SSTEMP (Barthalow, 1989) to evaluate potential changes in headwater boundary conditions from upstream management activities.

Prior Studies

The Big Hole River has long been a concern in regard to elevated water temperatures and aquatic species. Lohr et al. (1996) documented fish kills in July of 1994 as water temperatures reached the upper incipient lethal limit (UILT) for Arctic grayling of 25ºC (77ºF). Again, in 2002 and 2003, Magee and Lamothe (2003, 2004) recorded instream temperatures well above the UILT. Maximum values those years exceeded 27ºC (80.8ºF) and 26ºC (80.1ºF) respectively. The temporal duration of these impairments has been well characterized. According to the Big Hole River Watershed Committee (2000), threshold daily water temperatures near the center of the watershed (e.g. the USGS gage near Melrose) has exceeded the indicator target of 21.1ºC (70ºF) at least once every year since 1977 while the 7-day average daily maximum temperature [7Dmax; e.g. 20ºC (68ºF)] has been exceeded 19 out of 22 years. Temperatures have been shown to be elevated in the lower reaches as well, with large longitudinal gradients extending as far downstream as Twin Bridges (Gammons et al., 2001). Significant surface water withdrawl has been cited as the greatest threat to the fishery (FWP 1989). As such, Montana Fish, Wildlife, and Parks (FWP) has characterized the river as chronically dewatered from approximately Glen to the confluence with the Jefferson River, and periodically throughout much of the rest of the watershed (MFISH 2007). Persistent drought has exacerbated effects of water use such that FWP has requested several year-round flow reservations to minimize the extent of withdrawl during the critical flow period (Rens and Magee, 2007). In addition to these preventative measures, the Big Hole River Drought Management Plan has been drafted to address voluntary water conservation and fishing closures in the basin. Currently, there are three triggers that result in fishing closures on the river (BHWC 2000): (1) when river temperatures exceed 21.1ºC (70ºF) for over 8 hours per day for three consecutive days, (2) when flows fall below 2.8 cms (100 cfs) at the USGS Mudd Creek gage, or (3) when flows are less than 7.1 cms (250 cfs) at the Melrose gage. In addition to these efforts, ongoing conservation projects have been implemented to improve streamflow, protect the function of streams and riparian habitats, and identify and eliminate threats to grayling (Rens and Magee, 2007). Thus, some action has already been taken to mitigate the symptoms of the temperature impairment in the basin. However, DEQ wishes to evaluate river corridor management scenarios to such that cumulative effects of these activities on instream temperatures can be identified. The goal of this study is to identify whether a suite of best management practices (BMPs) can be implemented in the river corridor to such that the Montana steam temperature standard is attained and maintained (ARM 17.30.623).

Montana Temperature Standard (ARM 17.30.623)

Montana's instream temperature standard was originally developed to address point source discharges, and therefore it is difficult to interpret for non-point sources without use of water quality models. This is especially true when attempting to characterize departure from "naturally occurring" conditions which effectively reflects the implementation of "all reasonable soil and water conservation practices" (ARM 17.30.602). As currently written, a maximum allowable increase of 0.55ºC (1ºF) over "naturally occurring" is acceptable for B-1 waters when natural temperatures are within the range of 0ºC to 18.9 ºC (32ºF to 66ºF). For temperatures 19.2 ºC (66.5ºF) or greater, a 0.23ºC (0.5ºF) increase is allowed (ARM 17.30.623 (2)(e)). Monitoring and modeling has been structured to such that the existing temperature regime can be adequately addressed along with the expected temperatures from implementation of BMP improvements.

STUDY AREA

The Big Hole River drains approximately 7,250-km2 (2,800-mi2) of high- and mid-elevation mountainous topography in southwestern Montana. Originating from the continental divide, the river flows 247-km past the towns of Jackson, Wisdom, Wise River, Melrose, and Glen before reaching its endpoint near Twin Bridges. The entire watershed is part of United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 10020004 and consists predominantly of wide alluvial valleys that are constrained at a number of locations by narrowing geological outcrops. Currently, 242.5 km (150.7 miles) of the mainstem are listed as impaired for thermal modification (CWAIC, 2006). Given the size of the watershed, the study area has been broken into three distinct planning segments: (1) the upper TMDL planning area (TPA) which extends from the headwaters to Pintlar Creek, (2) middle TPA which extends from Pintlar Creek to Divide Creek (near Wisdom and Melrose respectively), and (3) the lower TPA which extends from Divide Creek to the confluence with the Beaverhead River. The DEQ study is focused primarily on the lower two TPA's extending from Pintlar Creek to the confluence with the Beaverhead River. The project site is most easily accessed via I-15 between Butte and Dillon, Highway-141 between Melrose and Wisdom, and on Burma Road between Glen and Twin Bridges (**fig 1**).

Climate

Climate in the Big Hole River watershed is inter-montane continental, with marked seasonality (**fig. 2a**). Cooperative observation station Divide 2 NW (COOP ID 242421) indicates that average temperatures during 1971-2000 range from 25 to 30°C in the summer months to as low as -10°C in the winter (WRCC, 2007). July and August are the warmest months of the year, and are influenced by Pacific high pressure systems that cause long periods of warm and dry weather. Clear skies and warm days prevail during these months. Because of the high elevation of the watershed, the diurnal variation in temperature is often greater that other areas of Montana, which is characteristic of warm days and cool nights (Deer Lodge WRS, 1955). Average precipitation in the watershed ranges from 250-300 mm (10-12 inches) in the valleys to over 1,000 mm (50 inches) in the mountains (Marvin and Voller, 2000). Most of this precipitation occurs during the spring and winter months.

Surface Water

Watershed hydrology is predominately snowmelt driven and there are three operational USGS gaging stations in the study area. These include: (1) USGS 06016000 Big Hole River below Mudd Creek, (2) USGS 06017000 Big Hole River nr Melrose, and (3) USGS 06018500 Big Hole River nr Glen. Additionally, a fourth gage exists upstream of the project site, USGS 06024450 Big Hole River below Big Lake Creek at Wisdom, MT. Mean monthly streamflow for the period of record for the four sites (1997-2006) is shown in **fig. 2b**. Typically, spring snowmelt begins in mid to late March, peaks in June, and then rapidly declines in July and August toward baseflow. Minimum discharges usually occur during late summer months and often result in late-season shortages of irrigation water (Marvin and Voller, 2000). Tributary inflow to the Big Hole River is highly variable, and depends largely on drainage area and basin elevation. The largest tributary to the Big Hole River is Wise River, which contributes mean annual discharge of 3.9 cms (138 cfs). Other important tributaries in the study reach include Fishtrap Creek, LaMarche Creek, Deep Creek, Divide Creek, and Willow Creek.

Groundwater

According to Marvin and Voeller (2000), tertiary and quaternary sediment deposits are the most important hydrogeologic features of the Big Hole River. These stratigraphic layers form the extensive groundwater system that immediately underlies the Big Hole River. Both Marvin et al., (1997) and Marvin and Voeller (2000) provide detailed information on groundwater resources in the basin. From review of their work, seasonal groundwater head fluctuations occur in excess of 1.5-4.5 m (5-15 feet) during the irrigation season as a result of percolation losses from irrigated pastures and irrigation canals. Losses, combined with spring rain and snowmelt, contribute to substantial gains in aquifer storage during May and June. In late summer (e.g. July and August), infiltrating water is thought to be consumed by evapotranspiration (ET) rather than being returned to surface water. Finally, at the onset of plant dormancy, return flow again becomes a significant component of the water balance and streamflow gains of 2.5 cms (90 cfs) are reported. During the period of 1997-2006, a gain of 3.25 cms (115 cfs) was observed (fig. 2b).

Groundwater-Surface water

Several groundwater-surface water interaction studies have been completed in the Big Hole Watershed in recent years. Levings (1986) noted that flood irrigation in the upper watershed was a significant contributor of recharge to the near surface aquifer. Marvin (1997) quantified the extent of surface water losses and found that 0.027 cms per km (0.6 cfs per mile) was lost from irrigation ditches to groundwater. Further work completed by Marvin and Voller (2000) confirmed that irrigation losses in the basin were significant. They documented gains in groundwater storage and associated return flows during the spring and fall months. In the summer, much of this water is consumed by evapotranspiration (ET) rather than being discharged back to the river through return flow and/or shallow groundwater accretion.

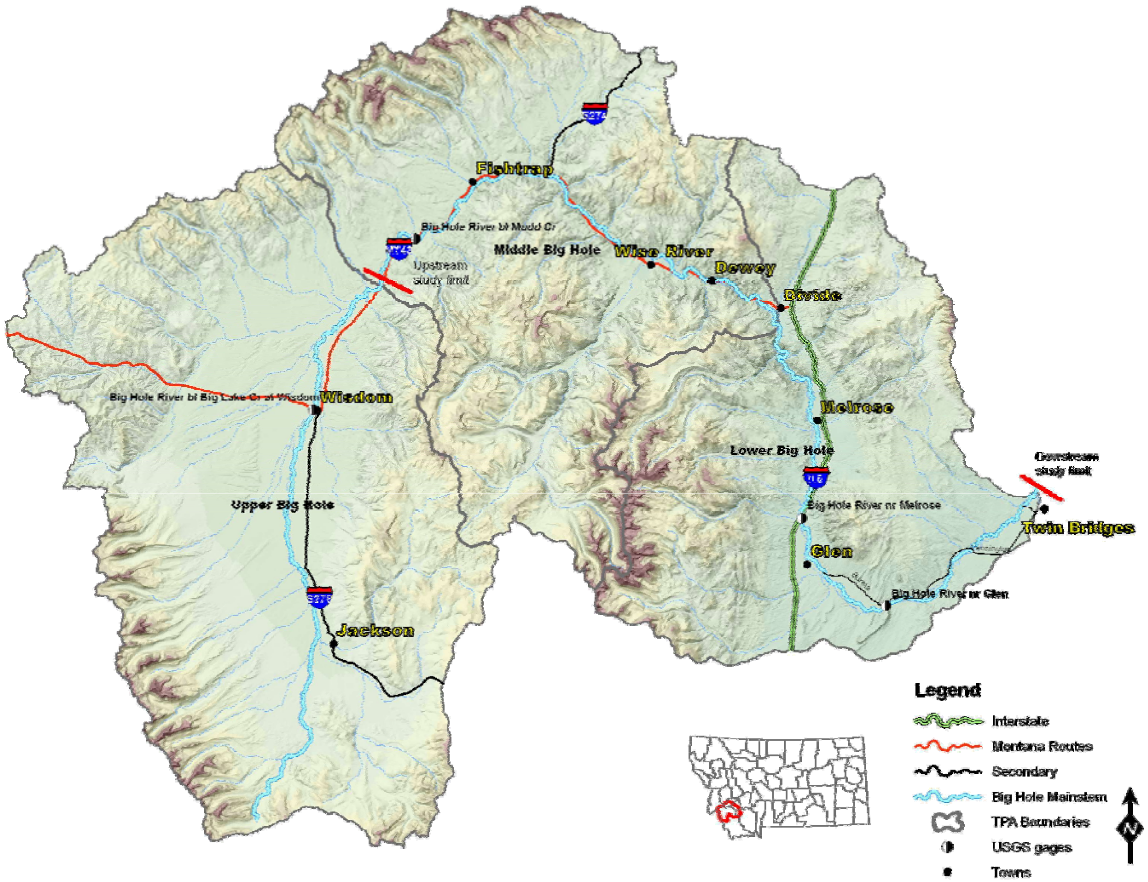


Figure 1. Big Hole River watershed, hydrography, and stream-flow gaging stations. The modeling reach extends from downstream of Wisdom to the watershed outlet near Twin Bridges, MT. The limits of the project reach are delineated in red.

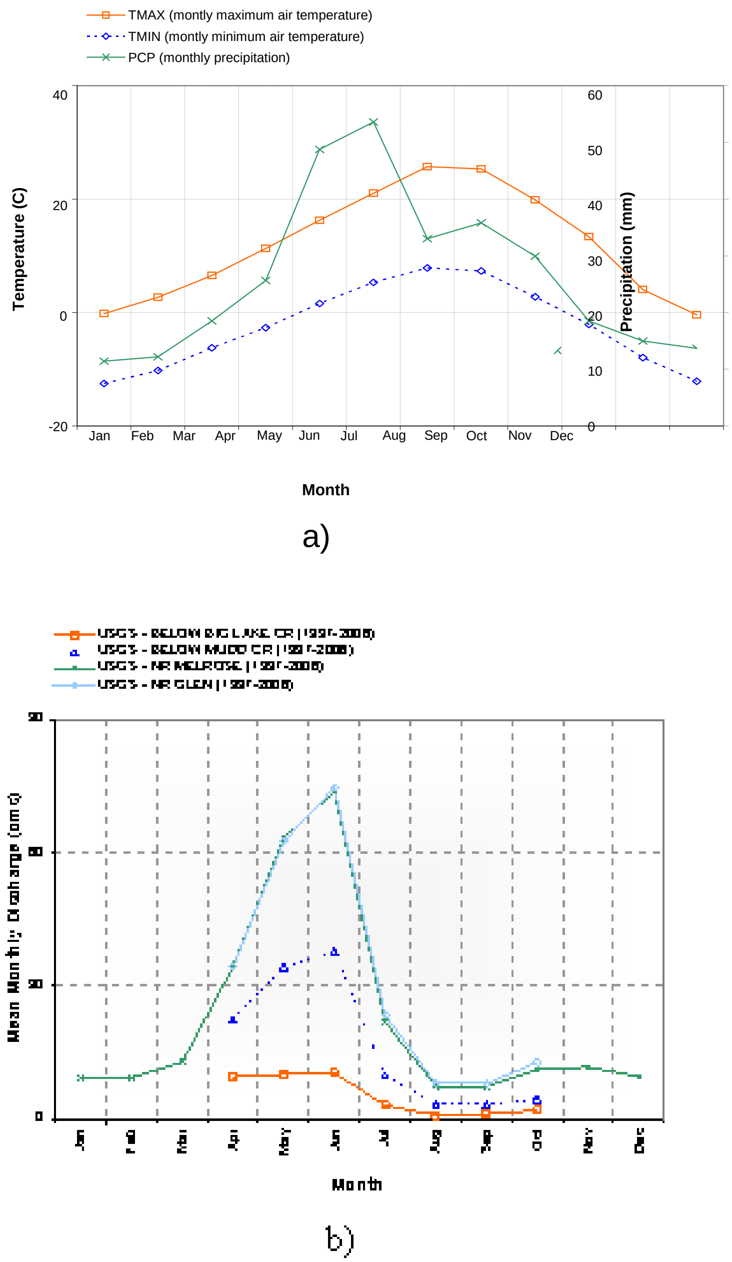


Figure 2. Big Hole River climate at Divide 2 NW (1971-2000); b) USGS hydrology.

Irrigation & Domestic Use

Alfalfa and grass hay production are the primary agricultural practices in the Big Hole River watershed that require irrigation. Two cuttings of hay occur in the lower basin while the upper basin is limited to one due to climate. Irrigation water is typically distributed through unlined ditches and canals, with field application by either flooding or sprinkler (Marvin and Voller, 2000). Irrigation is reported heaviest downstream of Melrose. According to Wells and Decker-Hess (1981), withdrawals in the lower Big Hole between Melrose and Twin Bridges have ranged from between 2.27 to 5.95 cms (80-210 cfs), with up to 9.29 cms (328 cfs) being removed from the river during the summer of 1980. Bahls (1978) qualitatively supports this assertion reporting 44 diversions between Divide Creek and the mouth. While irrigation in the upper Big Hole is less documented, it is still significant. In 2004 a total of 15 ranchers were paid to stop irrigating approximately 5,500 ha (13,685 acres) in the upper basin with financial assistance from the Natural Resources Conservation Service (NRCS). Prior to implementation, the river was dewatered to 0.85 cms (30 cfs). Days after shutoff streamflow rose significantly (MRA, 2007). **Note:** DEQ's review of this event indicates the response was likely biased from rains and associated runoff response.

Domestic water use in the Big Hole is somewhat limited. The primary user is the Butte-Silver Bow Water Utility. During July 2006, average pumping from the Feeley Plant near Divide was 0.38 cms (13.4 cfs).

METHODS AND MATERIALS

An intensive field data collection effort was completed during the summer of 2006 to characterize continuous water temperature, meteorological forcings (e.g. air temperature, relative humidity, wind speed, etc.), and the associated water balance in support of the modeling effort. The intensive one-week synoptic monitoring program was supplemented with information from the USGS National Water Information Program, National Oceanic and Atmospheric Administration (NOAA), Cooperative Observer program (COOP), Remote Automated Weather Station (RAWS) program, and Bureau of Reclamation AGRIMET network to provide comprehensive data regarding the project reach.

Site Selection

Sites for discharge and temperature monitoring were identified by DEQ as part of the original project scoping (DEQ/Watershed Consulting, 2006). In total, 20 main-stem locations, 44 tributaries and irrigation return flows, and 33 irrigation withdrawals were monitored in the field. Sites were accessed primarily by watercraft, as project teams floated through the study reach to characterize water exchanges and associated temperatures for modeling. Irrigation diversions were identified using Montana Water Resource Surveys (WRS) for Deer Lodge (1955), Madison (1965), and Silver Bow Counties (1955). Since no survey was published for Beaverhead County, these points were identified in the field by GPS, and then were later correlated with information from the Lower Big Hole River Irrigation Study currently in progress by PBS&J (J. Dunn, personal communication, February 2008).

Temperature Data

Continuous temperature data loggers were used to record diurnal variations in temperature as outlined in Barthalow (1989). Temperature dataloggers used in the Big Hole River modeling study were Optic StowAway® model number WTA32-05+37. The StowAway® is a completely sealed underwater temperature logger with the capability to record continuous readings from 0.5 seconds to 9 hours. Temperature measurements were made at 15-minute increments, and were read on the hour for model input/calibration purposes. Logger calibration checks were completed both pre- and post deployment, and were within the acceptable range specified by DEQ (2007). Loggers have a National Institute of Standards and Technology (NIST) traceable temperature accuracy of ±0.2°C, therefore the absolute accuracy is 0.4ºC. Loggers were in the field for approximately one month.

Discharge Data

All major inflows and outflows were monitored over a one-week period to describe hydrologic flux in the watershed. Flow measurements were made using the current meter procedures discussed by Rantz (1982), or were estimated via the floating object procedure described by DEQ (1995). A combination of portable meters including a Marsh-McBirney Model 2000 Flo-Mate solid state meter, Price AA traditional meter, pygmy meter, and a propeller-based Swoffer meter were used. Relative precision of the measurements were addressed through meter tests at multiple depths within a single cross-section. Velocity variation was ±7.5 percent which is consistent with that of Harmel et al. (2000). Quality assurance (QA) checks also were made at discharge cross-section transects within ±5 percent.

Climate Data

Climate was field monitored so that measurements in the river corridor could be correlated with that of surrounding COOP, RAWS, and AGRIMET stations. Air temperature and wet bulb depressions were measured with a U.S. Weather Bureau type sling phsychrometer having accuracy of ±0.5 °C. Wind speed was measured with a Dwyer hand-held wind meter (±0.2 m/s for low scales and ±1.3 m/s for high scales). Observations of cloud cover were also made to the nearest 10 percent. All measurements were completed four times daily.

Morphological and Shade Data

River morphology and riparian vegetation data were assessed in the field to characterize direct solar radiation losses from topography and vegetative shade. The following measurements were made to support the modeling: (1) bankfull and wetted channel width, (2) tree heights, (3) canopy density, (4) channel overhang, and (5) shade at specified transects. A fiberglass-tape, range-finder, clinometer, canopy densitometer, and solar pathfinder™ were used to acquire these attributes.

MODEL DEVELOPMENT

Model Description

Heatsource v7.0 is a dynamic continuous temperature model that operates on a sub hourly time-step (Boyd and Kasper, 2004). All components of the heat balance are simulated, including incoming shortwave radiation, terrestrial longwave radiation, thermal conduction and convection, evaporative flux, and ground flux. Forcing functions required to simulate the heat flux across the air-water interface include air temperature, wind speed, relative humidity, and cloud cover. These interact with shade, river morphology, and adjacent tributaries to provide a comprehensive description of mass/heat transfer and advection/dispersion throughout the simulated system. Springs, tributaries, and return flows are assumed to be mixed instantaneously over the finite difference step in the model, and trapezoidal channel geometry and Manning's equation are used to estimate flow velocity and associated hydraulics for a given discharge and reach configuration. Evaporation is simulated using either a simplified mass transfer function, or a version the Penman method (Dingman, 2002). Dynamic water routing is completed by a simultaneous solution of the St. Venant equations for continuity and momentum using either the Muskingum approximation or explicit finite difference method. Hyporheic flow is also simulated.

GIS Pre-processing

Heatsource v7.0 includes a spatially explicit ArcView3.2 GIS pre-processor called TTools for efficient calculation of morphologic and shading attributes at river scales (Boyd and Kaspar, 2004). Fundamental input data required for implementation of TTools includes: (1) site topography in the form of a digital elevation model (DEM), (2) digitized channel morphology (e.g. bankfull widths and centerline), (3) digitized riparian vegetation shapefile, and (4) user-defined vegetation characteristics. The 30-m USGS National Elevation Dataset (NED) was used for calculation of topographic characteristics. Channel centerline, bankfull geometry, and riparian vegetation classification were all digitized by DEQ using 2004 National Agricultural Imagery Program (NAIP) photography at a scale of 1:5,000. These were then converted to 1-m grid resolution for model pre-processing. Project coordinate system and datum were State-Plane NAD83 and NAVD88.

TTools includes a longitudinal and radial sampling algorithm that calculates site-specific morphologic and shading characteristics, such as channel width and slope, topographic shade, and vegetative shade at user defined nodes (i and i+1) along the channel centerline (**fig. 3**). A node distance of 100-m was used in the case of the Big Hole River and radial samples were completed at 15-m spacing to determine landcover attributes (e.g. tree height, density, channel overhang, etc.) for associated shading calculations. Additional information on TTools and Heatsource v7.0 setup are discussed in subsequent sections.

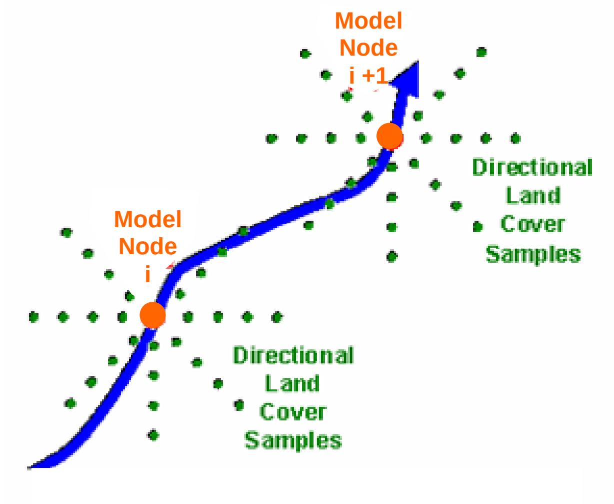


Figure 3. Example of TTools radial sampling algorithm.

Simulation Period and Global Control Specifications

Following the initial pre-processing, the model simulation period was chosen to be consistent with the critical limiting period, i.e. where standards are most likely to be exceeded. Based on a review of water temperature data at USGS 06025500 Big Hole River nr Melrose MT (2000-2006) (**fig. 4**), this period most frequently occurs in late July to early August, when air temperatures are the highest, and when photoperiod is sufficiently long. Thus, the field data-collection was pre-scheduled to be coincident with this time period. Ultimately, the week of July 25-31, 2005 was used in the modeling. Other information specified during initial project planning were control information, such as finite difference distances (dx) and time steps (dt)], evaporation approaches, and routing methodologies. Several combinations of dx/dt were evaluated as part of initial model testing including 500, 1,000, and 2,000-m distances and 5, 10, and 15 minute time increments. The combination of a 10-minute time-step and 1,000-m distance step was found to most readily balance model run time with computational rigor. The mass transfer evaporation approach (using Penman coefficients) and Muskingum channel routing, were used as available data did not support use of more complex methodologies.

Hydrology/Mass Transfer Input

Hydrology and mass transfer data from the 2006 field effort were used to define the overall water balance and associated boundary conditions for the modeling (**table 1**). Prior to the initiation of the project, flow conditions were evaluated in context with the historical gage record to determine their relative relationship with no low flow-frequency. As observed in **fig. 4**, mean daily discharge at the USGS gage near Melrose for July 25-31, 2006 was approximately 4.2 cms (150 cfs). The mean daily statistic is nearer 17 cms (~600 cfs). This indicates that flows during 2006 were roughly equivalent to the 7-day, 5-year low flow condition (7Q5) (McCarthy, 2004); a duration and frequency that DEQ feels is appropriate for temperature study. Thus, the model application was developed for the 7-day period of July 25-31, 2006; at, or near, the 7Q5. Locations of all hydrology/mass transfer monitoring sites are shown in **fig. 5.** A more detailed map is in **Appendix A**.

As seen in fig. **6a** and **b**, the hydrograph during the modeling period is clearly characteristic of unsteady flow conditions. Analysis of the 7-day period from July 25-31, 2006 indicates that a headwater change of nearly 50 percent occurred at the upstream end of the project reach (USGS gage near Wisdom). Subsequent downstream gages also exhibit similar effects. Given such large variation over a relative short time-period, it was decided that a dynamic upstream boundary condition was necessary to adequately reflect in-river flow conditions. Hourly data from the USGS Mudd Creek gage were used to distribute flow through time at this site. All other hydrology/mass transfer boundaries were considered steady-state, an assumption that was largely necessitated due to the fact that continuous flow monitoring of tributaries/irrigation exchanges was not feasible. Identified cross-correlation between USGS gages in the upper and lower reaches further supports the steady-flow assumption.

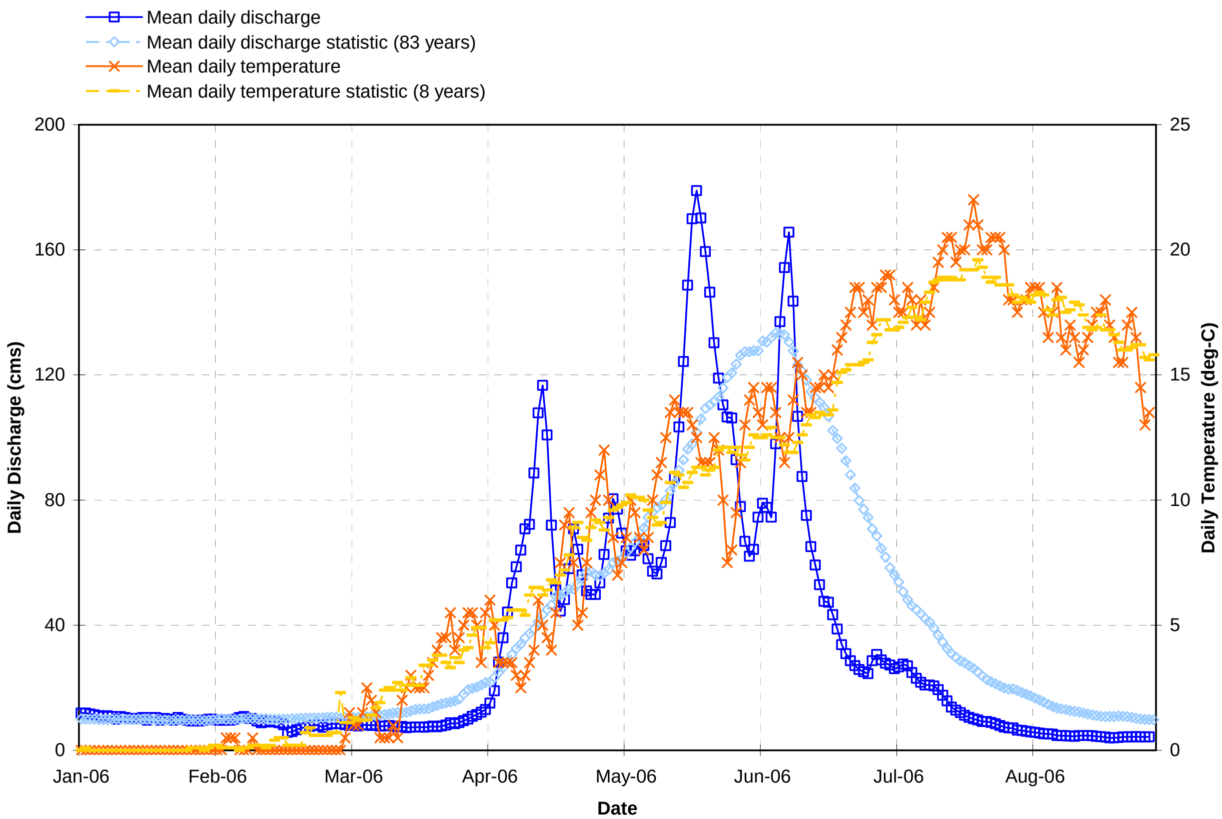


Figure 4. Summary of mean daily discharge, temperature, and associated statistics for the USGS gage near Melrose, MT (USGS 06025500). Data from USGS National Water Information System (NWIS).

Table 1. Instantaneous measured inflow, outflow, and associated water balance for the Big Hole River during the July 25-31, 2006 modeling period. All data are in cubic meters per second (m^3/s).

BIG HOLE RIVER WATER BALANCE 7/25-31/06	m^3/s	GWH_20 EST
Z01 - BIG HOLE RVR BELOW PINTLAR CR	**2.917**	
R02 - C-S WASTE RT	0.010	
R48 - BACON-NYHART RT	0.057	
R61 - SEEFIELD RT	0.028	0.064
R03 - MUDD CR	0.021	
R04 - SQAW CR	0.046	
TOTAL	**3.079**	**GAINING**
USGS 06016000 - BIG HOLE RVR @ MUDD CR	**3.143**	**3.143**
R52 - TOOMEY SPRING	0.012	
R54 - TOOMEY CR	0.014	0.824
TOTAL	**3.169**	**GAINING**
Z02 - BIG HOLE RVR 4.5 KM BELOW MUDD CR	**3.993**	**3.993**
T05 - SAWLOG CR	0.038	
R58 - STEWART CR	0.187	
R60 - PADDOCK/SOPER RT	0.020	0.080
R06 - FISHTRAP CR	0.779	
TOTAL	**5.017**	**GAINING**
Z03 - BIG HOLE RVR BELOW FISHTRAP FAS	**5.097**	**5.097**
R07 - LAMARCHE CR	0.575	0.077
TOTAL	**5.672**	**GAINING**
Z04 - BIG HOLE RVR BELOW SEYMOUR CR	**5.749**	**5.749**
R09 - BACON RTN	0.028	
R01 - SEYMOUR CR	0.116	
R05 - DEEP CR	0.767	-0.605
R08 - BRYANT CR	0.125	
A06 - BEAR CR	0.050	
TOTAL	**6.835**	**LOSING**
Z06 - BIG HOLE RVR ABOVE JOHNSON CR	**6.230**	**6.230**
R26 - JOHNSON CR	0.075	
A11 - ALDER CR	0.040	
R40 - UNNAMED DVT	-0.133	
R29 - MEADOW CR	0.170	-1.087
R31 - MEADOW CR RT	0.130	
TOTAL	**6.512**	**LOSING**
Z22 - BIG HOLE RVR ABOVE WISE RIVER	**5.425**	**5.425**
R71 - WISE RVR-1 (WEST)	1.463	
R32 - WISE RVR-2 (EAST)	0.595	0.076
TOTAL	**7.483**	**GAINING**
Z07 - BIG HOLE RVR ABOVE JERRY CR	**7.559**	**7.559**
R33 - JERRY CR	0.073	
I10 - SRING GULCH	0.087	2.897
TOTAL	**7.719**	**GAINING**
Z46 - BIG HOLE RVR NR POWERHOUSE FAS	**10.616**	**10.616**
O01 - BH PUMP ST. DVT	-0.439	
O08 - DIVIDE CANAL DVT	-0.700	
I11 - SHELTON-KAMBICH DVT	-0.255	
R39 - SHELTON-KAMBICH RT	0.023	-0.712
R10 - UNNAMED DVT	-0.084	
R38 - SHELTON-KAMBICH RT	0.028	
TOTAL	**9.189**	**LOSING**
Z21 - BIG HOLE RVR ABOVE DIVIDE CR	**8.477**	**8.477**
R16 - DIVIDE CR-1 (EAST)	0.102	
R20 - DIVIDE CR-2 (WEST)	0.085	1.052
I16 - UNNAMED TRIB (GOAT MTN)	0.079	
TOTAL	**8.743**	**GAINING**
Z08 - BIG HOLE RVR @ MAIDENROCK CANYON	**9.795**	**9.795**
R35 - CANYON CR	0.112	
I50 - MOOSE CR	0.238	
I17 - MCCAULY-1 DVT	-0.586	0.578
R12 - MERIWETHER DVT	-0.470	
TOTAL	**9.089**	**GAINING**
Z09 - BIG HOLE RVR NR MAIDENROCK FAS	**9.667**	**9.667**

Z09 - BIG HOLE RVR NR MAIDENROCK FAS	**9.667**	**9.667**
R34 - MCCAULY-2, MELROSE DVT	-0.484	
R15 - MERIWETHER RTN	0.189	
R36 - SOAP CR	0.064	
I20 - ROBBINS (MERIWETHER) DVT	-0.057	
O02 - BOWE (CARPENTER) DVT	-0.163	
R23 - CAMP CR	0.021	1.563
O03 - STREB (PENDERGAST) DVT	-0.156	
O07 - GALLAGHER DVT	-0.445	
I27 - TRAPPER CR	0.068	
TOTAL	**8.704**	**GAINING**
Z10+11 - BIG HOLE RVR NR SALMON FLY FAS	**10.267**	**10.267**
I24 - CHERRY CR	0.092	
R18 - GALLAGHER-STREB RT	0.295	
I40 - KALSTA DVT	-0.334	
O23 - HAGENBARTH-1 DVT	-0.585	-1.135
R37 - ROCK CREEK	0.041	
O22 - HAGENBARTH-2 DVT	-0.174	
TOTAL	**9.602**	**LOSING**
Z12 USGS 06017000 - BH RVR NR MELROSE	**8.467**	**8.467**
I31 - KALSTA RT	0.239	
O20 - GAINY DVT	-0.070	-1.667
EST - GARRISON-KILWIEN DVT	-0.500	
TOTAL	**8.136**	**LOSING**
Z13 - BIG HOLE RVR NR GLEN FAS	**6.469**	**6.469**
R27 - WILLOW CR	0.450	
O10 - STEVENS SLOUGH (GARRISON) DVT	-0.113	
R28 - BIRCH CR	0.025	
O11 - COCANOUGHAR-1 (RAFFERTY) DVT	-0.175	1.886
O12 - COCANOUGHAR-2 (RAFFERTY) DVT	-0.238	
O13 - BRYAN DVT	-0.120	
TOTAL	**6.298**	**GAINING**
Z14 - USGS 06018500 - BH RVR @ NOTCH FAS	**8.184**	**8.184**
O05 - LARSON-NARANICH (JS) DVT	-0.750	-0.864
TOTAL	**7.434**	**LOSING**
Z15 - BIG HOLE RVR ABOVE PAIGEVILLE DVT	**6.570**	**6.570**
R30 - LARSON-NARANCICH RT	0.207	
O14 - SANDY DITCH DVT	-0.133	
O15 - PAIGEVILLE CANAL	-1.642	0.693
I37 - NARANCICH DVT	-0.600	
I38 - SANDY DITCH RT	0.200	
TOTAL	**4.602**	**GAINING**
Z16 - BIG HOLE RVR @ PENNINGTON BR FAS	**5.295**	5.295
I90 - PENNINGTON BR DVT	-0.060	
O17 - OWSLEY SLOUGH (BH COOP)	-2.197	0.345
I41 - PENNINGTON BR RT	0.015	
TOTAL	**3.053**	**GAINING**
Z17 - BIG HOLE RVR ABOVE THIRD SLOUGH	**3.398**	3.398
O18 - THIRD SLOUGH (ORPHAN HOME)	-0.269	
O19 - LOGAN-SMITH DVT	-0.174	-0.059
O21 - LOTT-HARVEY DVT	-0.271	
TOTAL	**2.684**	**LOSING**
Z18+Z19 - BIG HOLE RVR NR HIGH ROAD FAS	**2.625**	2.625
O68 - SIEDENSTICKER (HAMILTON) DVT	-0.049	
O67 - UNNAMED DVT	-0.150	
TOTAL	**2.426**	**LOSING**
CONFLUENCE W/ BEAVERHEAD	NO MEASUREMENT	**END**
Z20 - BEAVERHEAD RVR		4.531
COMBINE - JEFFERSON RVR HEADWATERS		6.957

Notes:

(1) Z01, R02, R48, etc. – field measurement ID (not necessarily in alphanumeric order)

(2) Those field measurement ID's with "A" or "I" prefix estimated in field using floating object method

(3) Z05 (Dickie Bridge) – flow measurement did not meet QA/QC requirements

(4) DVT = diversion

(5) RT = return flow

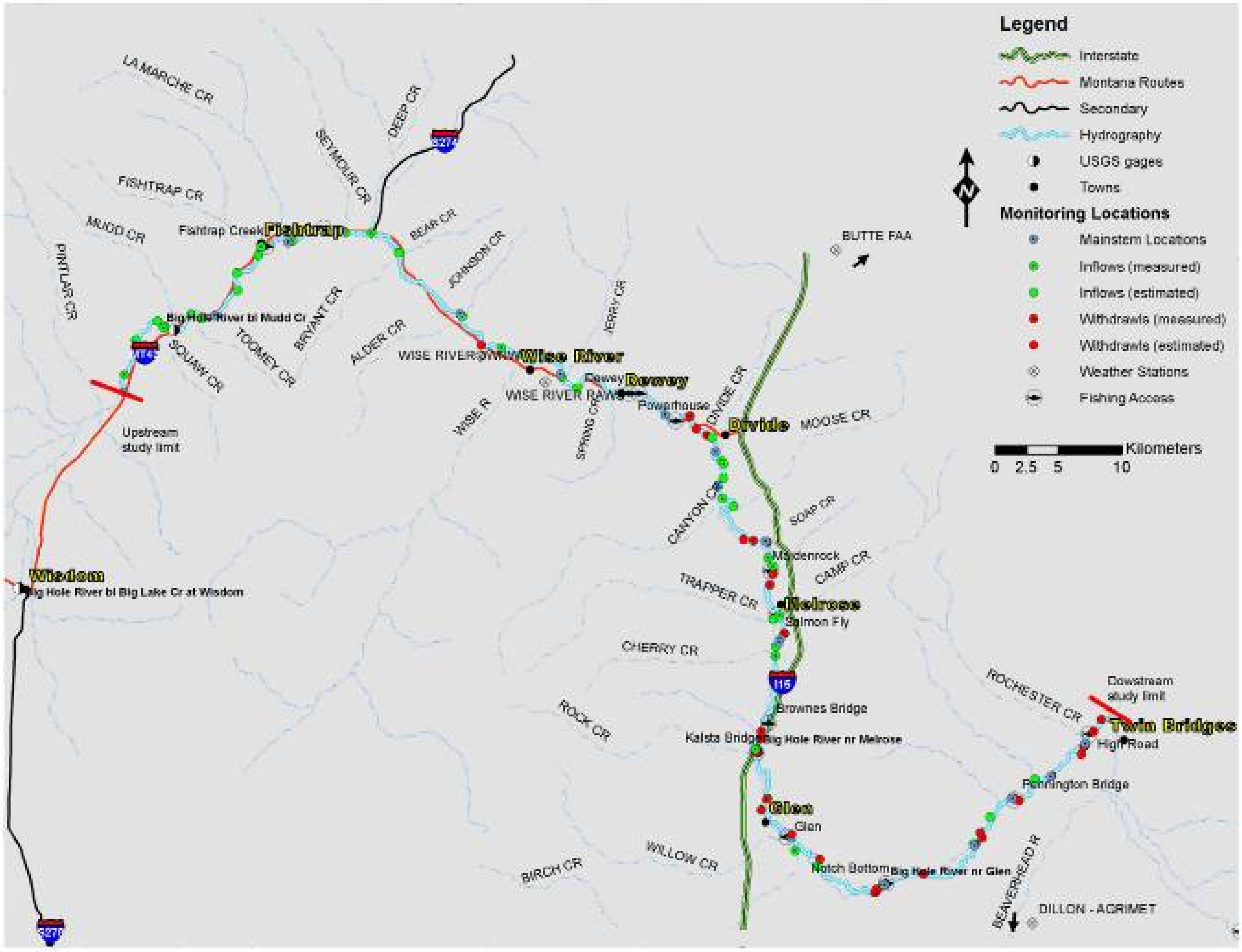


Figure 5. Locations of major inflow, outflow, and climate monitoring on the Big Hole River.

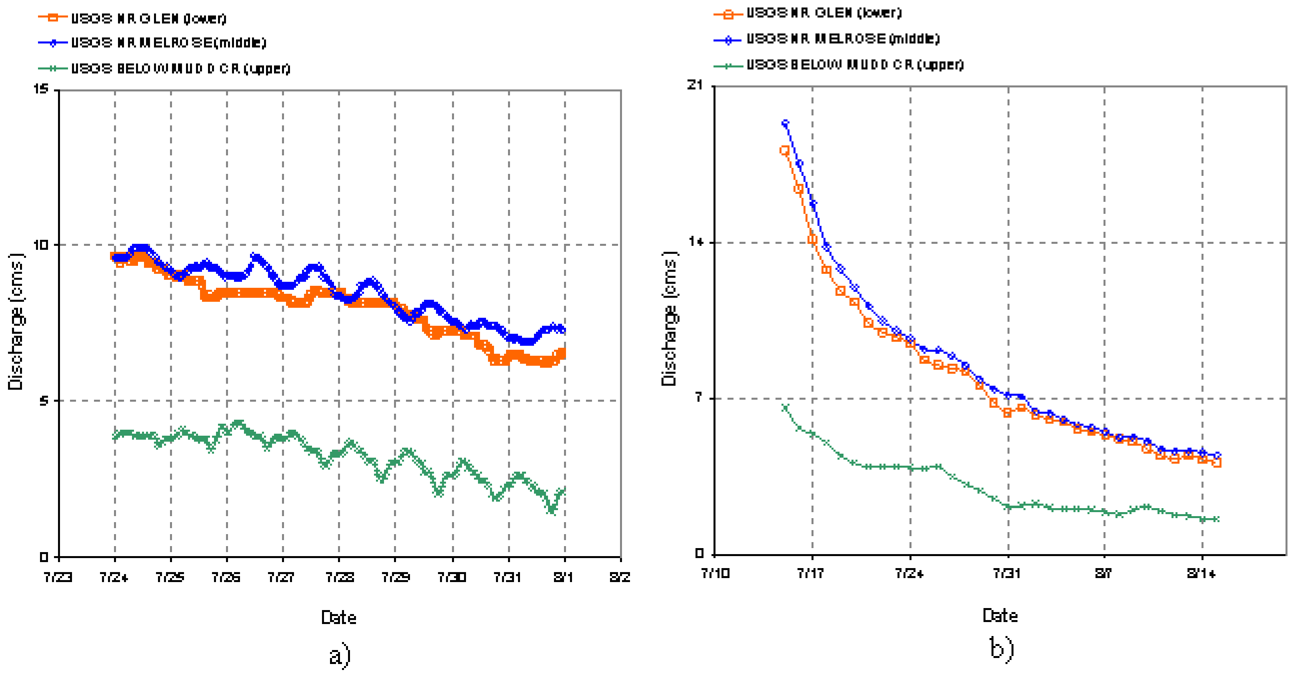
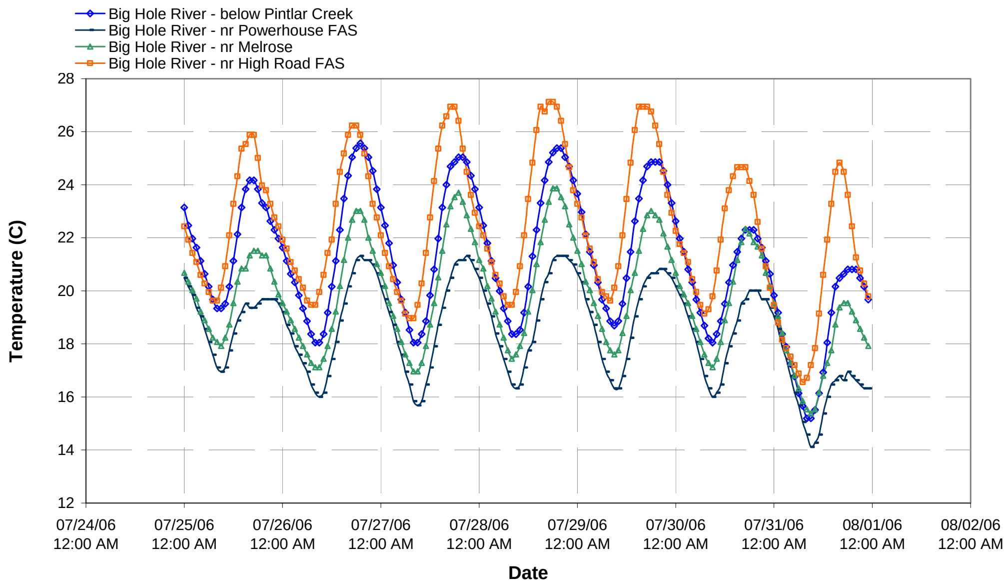


Figure 6. Streamflow during the critical temperature limiting period a) streamflow during the critical temperature limiting period - 2006; b) hourly plot Jul. 25-31; daily plot Jul. 15-Aug. 15.

While discharge measurements were input as steady-flow (with the exception of the headwater condition), temperature measurements were made as time-variable using data from Hobo temperature loggers. In locations where continuous temperature data were not collected, instantaneous field measurements were completed to such that an hourly distribution could be developed from the relationship between instrumented and un-instrumented sites. Aspect, proximity, and contributing watershed area were the primary attributes used in the paired watershed approach. Given the voluminous amount of data collected at these sites, much of it cannot be presented in the text of this report. However, a subset of hourly plots for both mainstem and tributary sites are shown in **fig 7a** and **7b**. In general, tributaries exhibit greater diel fluctuation than mainstem sites, an they are also much cooler. In both locations, temperatures reach maximums at approximately 6:00-7:00 p.m., while nighttime minimums occur in the morning at 9:00 to 10:00 a.m.

Box and whisker plots from incoming tributaries to the Big Hole River are shown in **fig. 8**. While minimums and maximums vary throughout the watershed, it is recognized that irrigation return flows often have a much larger range of maximum and minimum temperatures, and associated quartiles, compared to that of natural tributary flow. This is most likely a function of flow volume at these sites and forms a preliminary understanding of the cumulative influence of irrigation returns on water temperature.

a)



b)

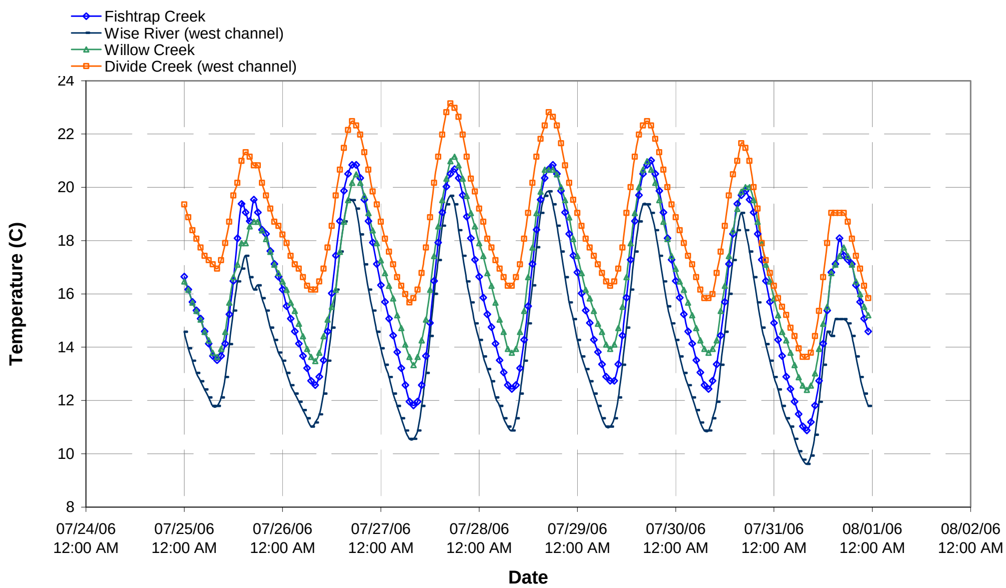


Figure 7. Hourly plots of water temperature for selected a) mainstem and b) tributary monitoring stations on the Big Hole River for the July 25-31, 2006 monitoring period.

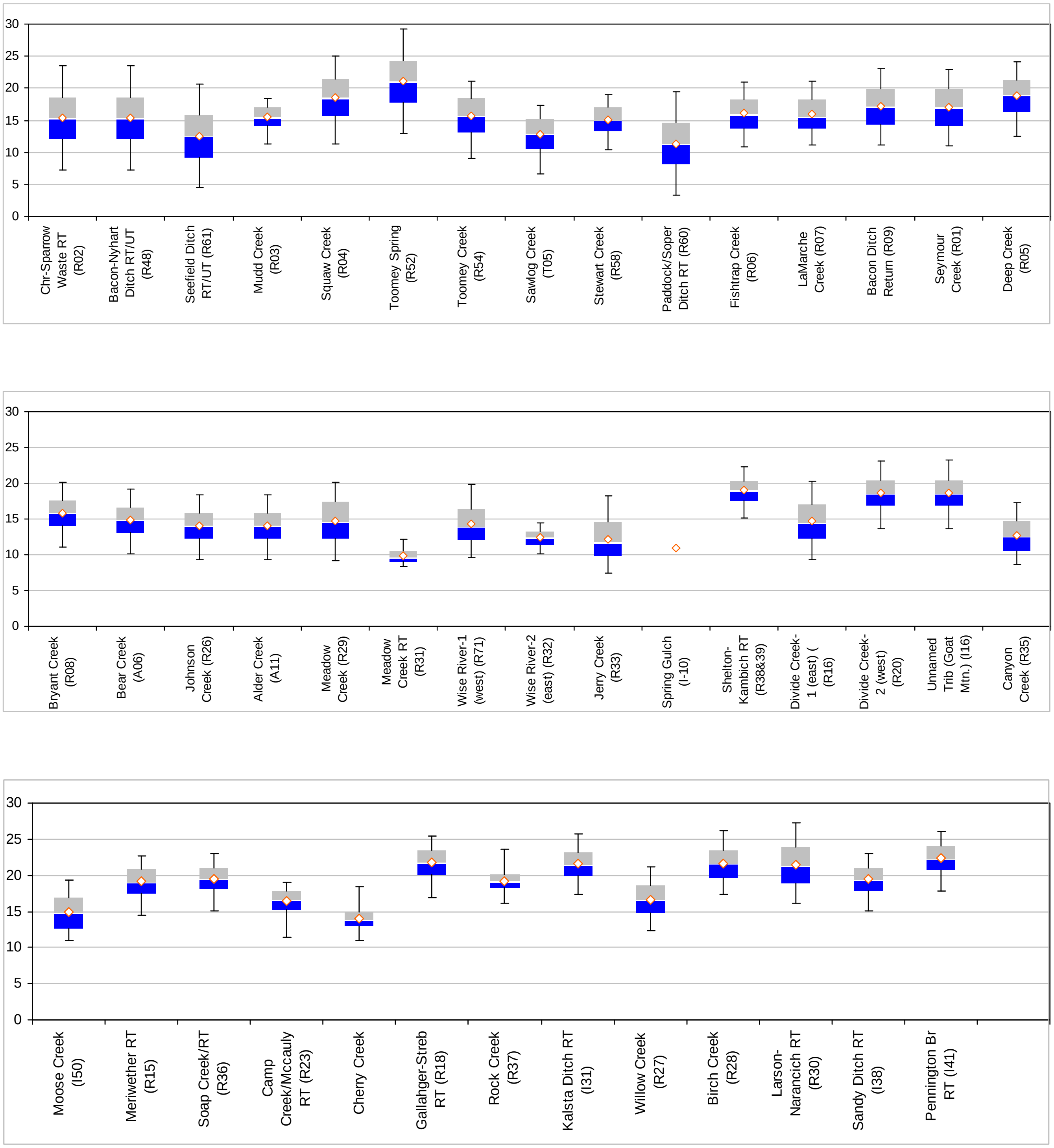


Figure 8. Box and whisker plots of tributary temperature data collected on the Big Hole River from the July 25-31, 2007. From top left to bottom right, plots are in sequential order going downstream.

Hydraulic Input

Bankfull width, width-depth ratio, channel side slope, gradient, Muskingum routing coefficients, and Manning's roughness coefficients are all required hydraulic inputs for Heatsource v7.0. Unknown variables such as velocity, depth, and wetted channel width are then computed for a given flow condition using Manning's equation and assumed trapezoidal channel geometry. Hydraulic input for the model was developed as follows: (1) bankfull width was measured in the GIS at 100-m intervals using digitized left and right bank polylines as part of the initial TTools processing, (2) width-depth ratio and channel side slope were regressed using measured field parameters, and (3) Manning's roughness coefficient was directly estimated from USGS gage sites using known channel geometry and a wide channel approximation. Roughness values were shown to much higher than those typically published in the literature (0.05-0.14; see Chow 1959; Sturm, 2001). This is reflective of the increasing effect of resistance with decreasing hydraulic depth, filamentous algae, pools and riffles, and other unknown obstructions USACE (1993). Values of 0.09-0.12 were used in the modeling (see **Appendix A**). Fourteen reaches were identified for unique parameterization of hydraulics based on channel gradient from the USGS NED (**fig. 9**). They were characterized as shown in **table 2**.

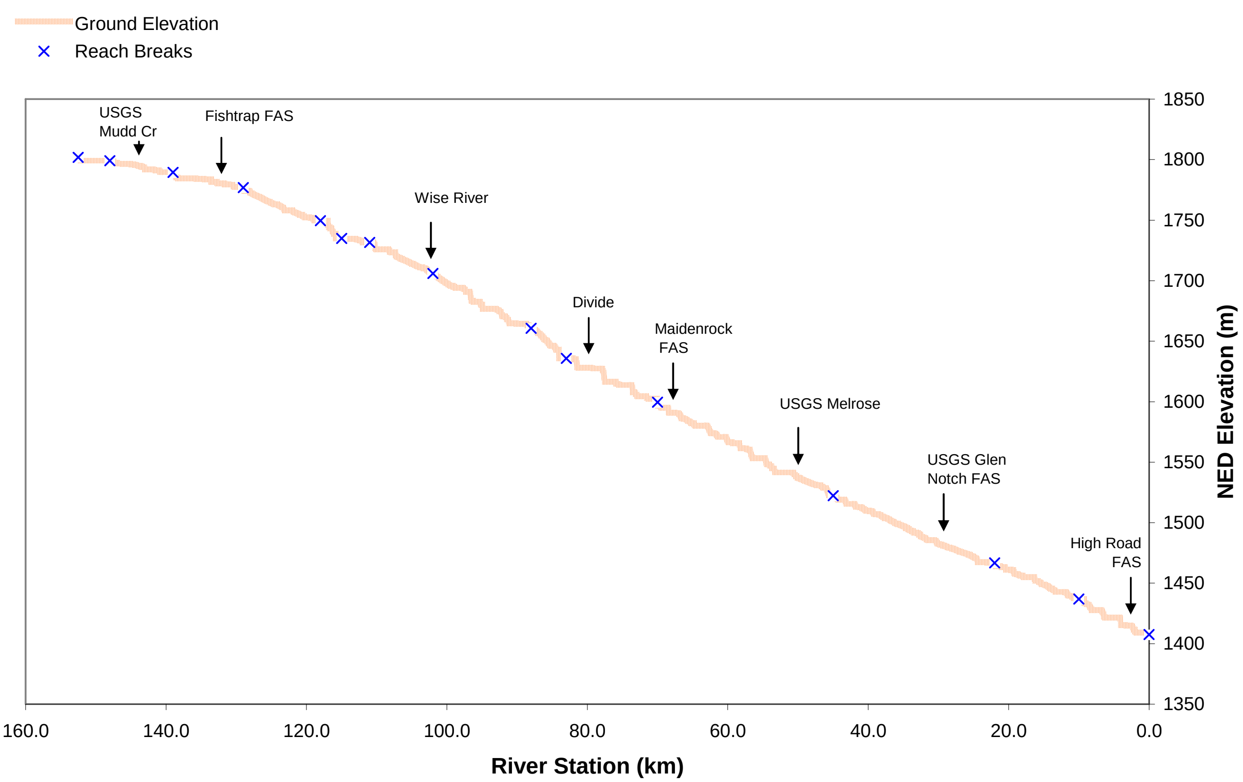


Figure 9. Unique reaches defined for model parameterization of hydraulics. Elevation data taken from USGS National Elevation Dataset (NED) 30-m grid.

Climate Input

Three climate stations were used to provide hourly temperature (°C), wind speed (m/s), and relative humidity (%) data for the modeling effort. The Wise River RAWS site, Bert-Mooney FAA (e.g. Butte), and Dillon Valley Agrimet station were apportioned to representative modeling reaches to account for localized climate. Because meteorological data collected outside of the river corridor is at times not representative of conditions encountered near the river (Troxler and Thackston, 1975; Bartholow 1989), field measurements taken from within the river corridor were used to perform a climate adjustment. Of all inputs adjusted (e.g. temperature, wind speed, and relative humidity), relative humidity was found to vary the most between locations. At times, it was 15-20 percent greater in the river corridor than at surrounding climate stations. Climate data used in the modeling are shown in **fig. 10**.

Shade Input

Fifteen riparian landcover types were identified through air photo interpretation and ground-truth to parameterize typical reach shading attributes in the model (**table 3**). Verified model parameters were then assigned to corresponding land classes to form the base input for radial shading calculations in Heatsource v7.0. An example of the digitized landcover used for this process is shown in **fig. 11** (near Melrose and the Salmon Fly FAS).

Table 2. Hydraulic parameters used in the Big Hole River Heatsource v7.0 model.

River Reaches	Gradient (%)	Width- Depth Ratio	Mannings "n"
Reach 1	0.062%	90	0.09
Reach 2	0.108%	80	0.09
Reach 3	0.126%	80	0.09
Reach 4	0.249%	80	0.10
Reach 5	0.490%	70	0.10
Reach 6	0.082%	70	0.10
Reach 7	0.284%	70	0.10
Reach 8	0.324%	70	0.10
Reach 9	0.496%	70	0.10
Reach 10	0.302%	70	0.10
Reach 11	0.297%	60	0.10
Reach 12	0.242%	60	0.10
Reach 13	0.248%	50	0.12
Reach 14	0.293%	50	0.12

Table 3. Riparian landcover types and associated attributes used in Heatsource v7.0 shading calculations.

Land Cover	Height (m)	Density (%)	Over-hang (m)
Bare	4.9	40%	0.00
Coniferous (sparse)	5.7	75%	0.10
Coniferous (dense)	17.2	40%	0.10
Deciduous (sparse)	18.9	85%	0.30
Deciduous (dense)	14.5	55%	0.00
Grass/sedge (sparse)	16.0	85%	0.00
Grass/sedge (dense)	0.4	50%	0.00
Grass 75%/deciduous 25%	0.5	90%	0.10
NSDZ/water	2.9	64%	0.05
Transportation	11.7	60%	0.13
Willow (sparse)	12.9	63%	0.08
Willow/ (dense)	0.0	0%	0.00
Willow/deciduous	0.0	0%	0.00
Willow/deciduous/conifer	4.9	68%	0.09
Willow 50%/grass 50%	0.0	0%	0.00

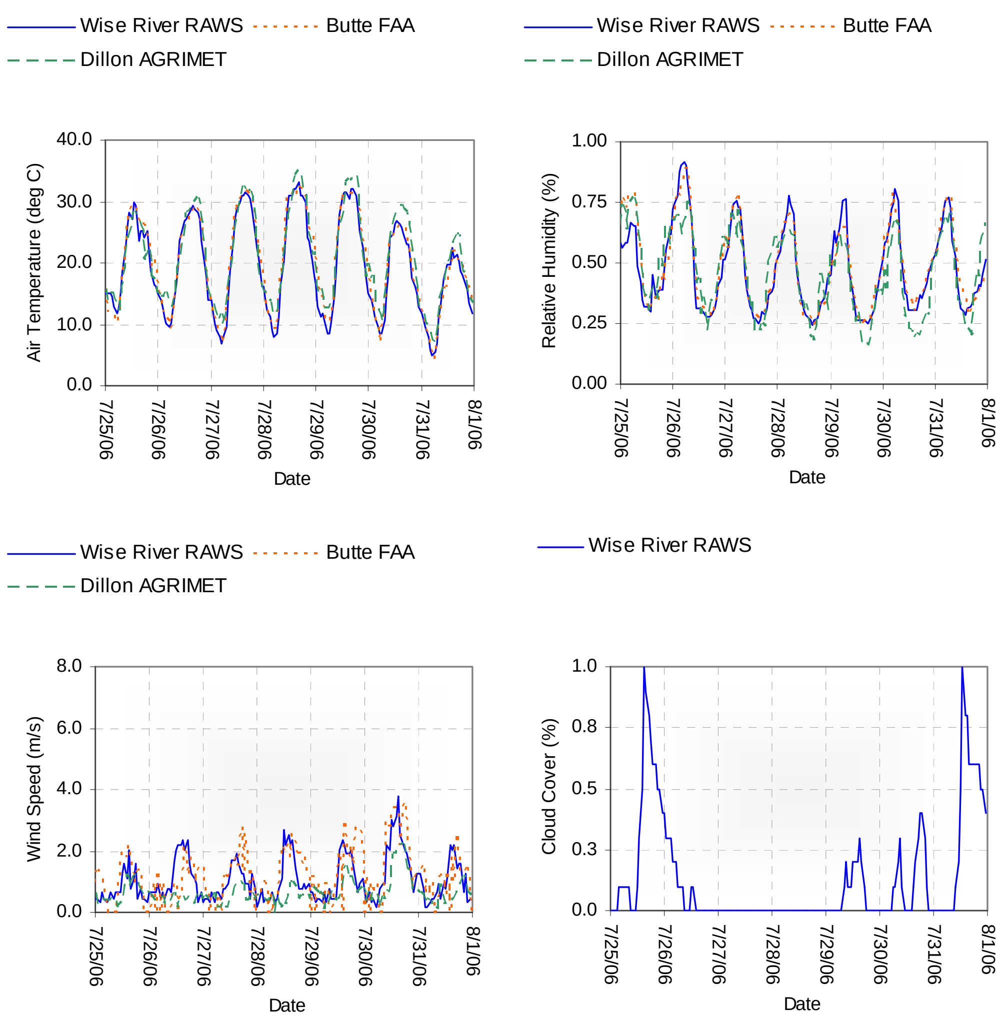


Figure 10. Adjusted climatic conditions over the July 25-31, 2006 modeling period at the three localized climate stations.

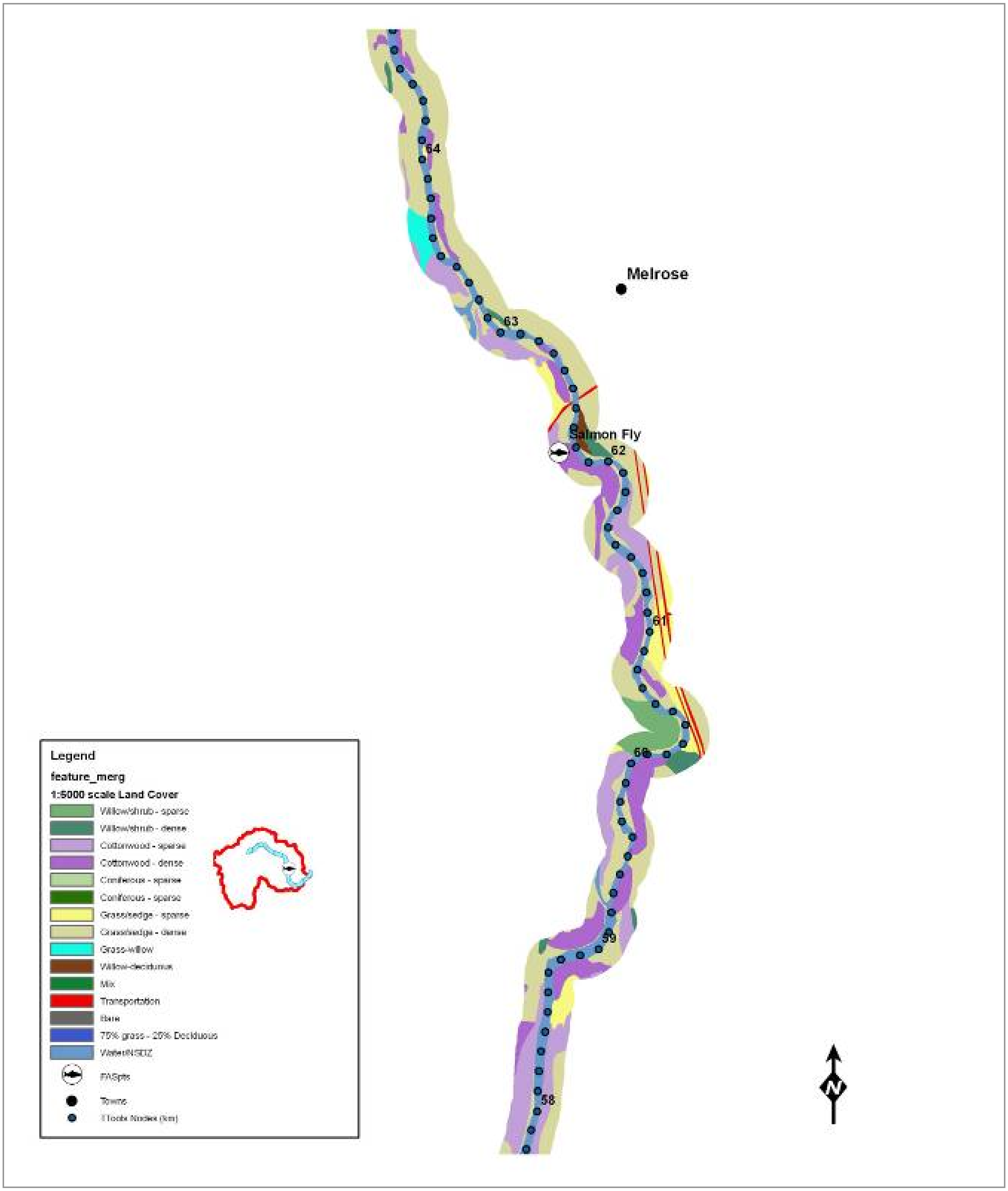


Figure 11. Example of digitized riparian landcover classification used in the Big Hole River Model near Melrose. The 2004 NAIP imagery was used at a 1:5,000 scale to produce a 1-m raster landcover dataset.

Model Evaluation Criteria

Following model input development, performance statistics were selected to assess hourly and 7-day average temperature predictions from Heatsource v7.0. The first criterion was percent bias (PBIAS), which is a measure of the average tendency of the simulated temperatures to be larger or smaller than an observed value. Optimal PBIAS is 0.0 while a positive value indicates a model bias toward overestimation. A negative value indicates bias toward underestimation. PBIAS is calculated as follows:

$$PBIAS = \frac{\sum_{i=1}^{n}(T_{isim} - T_{iobs})}{\sum_{i=1}^{n}(T_{iobs})} \times 100 \qquad (1)$$

where

PBIAS = deviation of temperature in percent
Tiobs = observed temperature (ºC)
Tisim = simulated temperature (ºC)

DEQ has defined acceptable model bias as less than or equal to ±5 percent, which is more stringent than typically reported in the literature [Van Liew et al. (2005) and Donigian et al. (1983)]. The second evaluation criterion used in evaluation of model efficiency, was the Nash-Sutcliffe coefficient of efficiency (NSE; Nash and Sutcliffe, 1970). NSE expresses the fraction of the measured temperature variance that is reproduced by the model. As error in the model is reduced, the NSE coefficient is inherently increased. Simulation results are considered to be good for NSE > 0.75, while values between 0.75 and 0.36 are considered satisfactory (Motovilov et al. 1999). NSE is calculated as:

$$NS_E = 1 - \frac{\sum_{i=1}^{n}(T_{iobs} - T_{isim})^2}{\sum_{i=1}^{n}(T_{iobs} - T_{avg})^2} \qquad (2)$$

where

NSE = coefficient of efficiency
Tavg = average simulated temperature (ºC)

A final criterion used in the Big Hole River modeling is the sum of squared residuals (SSR), which is a commonly used objective function for hydrologic model calibration. It compares the difference between the modeled and observed ordinates, and uses the squared differences as the measure of fit. Thus a difference of 2°C between the predicted and observed values is four times worse than a difference of 1°C. Squaring the differences also treats both overestimates and underestimates by the model as undesirable. The equation for calculation of SSR is shown below (Diskin and Simon, 1977).

$$SSR = \sum_{i=1}^{n}(T_{iobs} - T_{isim})^2 \qquad (3)$$

where

SSR = sum of squared residuals

Sensitivity Analysis & Model Uncertainty

Model uncertainty was assessed using a simple one-at-a-time (OAT) sensitivity analysis with parameter perturbations of ±10 percent and ±30 percent. The OAT methodology ensures that changes in output can unambiguously be attributed to the changes in model input. Parameter sensitivity is typically expressed as a normalized sensitivity coefficient (NSC) as shown below (Brown and Barnwell, 1987).

$$NSC = \left| \frac{\Delta Y_o / Y_o}{\Delta X_I / X_I} \right| \quad (4)$$

where

NSC = normalized sensitivity coefficient
ΔYo = change in the output variable Yo
ΔXi = change in the input variable Xi

NSCs for model parameters in Heatsource v7.0 are shown in **table 4** and are taken as the average results of the four sensitivity runs for the most downstream modeling node (±10 percent and ±30 percent perturbations). Results indicate that parameters directly related to heat flux or mass transfer (ground temperature, air temperature, relative humidity, groundwater flow, and tributary flow) are highly sensitive in the Big Hole River watershed. Those related to flow routing were not (roughness, Muskingum-x, width-depth ratio, etc.). Given knowledge of parameter sensitivity, model prediction error and associated uncertainty were qualified as moderate-to highly-certain for the project. This is largely due to the fact that the most influential model input parameters were fairly well known (either directly measured or estimated in the field), while those that were relatively in-sensitive, were not. No other efforts were made to assess uncertainty as part of this project.

Table 4. Summary of parameter sensitivity for the Big Hole River Heatsource v7.0 model.

Parameter	Rank	NSC
Ground temperature (ºC)	1	0.24
Air temperature (ºC)	2	0.21
Relative humidity (%)	3	0.12
Groundwater Q (cms)	4	0.07
Tributary Q (cms)	5	0.07
Groundwater temperature (ºC)	6	0.06
Wind speed (m/s)	7	0.04
Mass transfer “a” coefficient	8	0.03
Cloud cover (%)	9	0.03
Irrigation diversion (m/s)	10	0.03
Tributary temperature (ºC) Bankfull width (m) Headwater Q (cms) Manning’s “n” (dimensionless) Shade density (%) Width-depth ratio Channel z-angle (1:z) Headwater temperature (ºC) Particle size (mm) Muskingum “x” (dimensionless) Bed Ks (mm/s) Embeddedness (%)		<0.03

Model Calibration Procedure

The Big Hole River Heatsource v7.0 model was calibrated in an iterative fashion, from up-to downstream, based on the evaluation criteria identified previously. Generalized information related to model calibration can be found in Thomann (1982), James and Burges (1982), and ASTM (1984). Meteorological forcing data were first assessed as part of the calibration for artifacts of unrepresentative input data, e.g. where the model consistently has anomalous over-or under-prediction for only a portion of the simulation period. Cloud cover was the primary calibration parameter used in this instance. Additional calibration parameters included wind speed, groundwater accretion temperature, and Manning’s roughness coefficient. All were adjusted within a reasonable range such that agreement between observed and simulated values occurred. Final calibrated reach parameters are shown in **Attachment A**. Subsequent PBIAS, NSE, and SSR values for the temperature calibration are described in the Results and Discussion section.

Model Validation/Confirmation

After calibration, a model should be validated or confirmed against an independent dataset. This effectively demonstrates that the model performs adequately over a range of conditions beyond that which it was calibrated to (Barthalow, 1989; Chapra and Reckow, 1983; Chapra, 1997). Unfortunately, independent data outside of the 2006 field effort do not exist for validation purposes largely, due to the dynamic conditions encountered in the watershed. Therefore, several auxiliary lines of evidence were evaluated in a “low-level” confirmation exercise. This included: (1) an in-depth comparison of calculated physical subroutines in the model with that of field observations (e.g. hydrology, hydraulics, and shading discussed in subsequent sections) and (2) assessment of appropriate instream water temperature responses to varying climatic conditions.

RESULTS & DISCUSSION

Hydrology

Simulated streamflow for July 28th of the July 25-31, 2006 modeling period is shown in **fig. 12**. Inspection of the observed and predicted values shows very good agreement. Hydrology is within ±5 percent at all monitoring nodes, and mean prediction PBIAS and standard error were +0.4 percent and 0.2 cms respectively (comparing daily simulated flow values with instantaneous field-measurements). Clearly, surface water hydrology is a function of the combined influence of tributary inflow, irrigation withdrawal and return flow, split channel flow (e.g. braiding), and localized groundwater accretion. Major surface water inflows occur in the Fishtrap, LaMarche, and Deep Creek and Wise River areas, and geological valley controls such as the Greenwood Bottoms, Maidenrock Canyon, and Notch Bottom provide substantial groundwater accretion. A large portion of the dewatering occurs in the lower reaches between Notch Bottom FAS and the High Road FAS near Twin Bridges.

In review of the water balance, little, if any, groundwater discharge to surface water occurs during the modeling period. This is consistent with the findings of Marvin and Voller (2000) who suggest that during the summer months, a majority of the irrigation losses from leaky ditches and flood irrigation are consumed by ET rather than returning to surface water through groundwater flow. Groundwater influx in the Big Hole River watershed does occur in two instances: (1) where large groundwater flow systems converge and intersect with the Big Hole alluvial aquifer, and (2) where geological valley controls contract the effective subsurface flow area causing pinching and localized expression of surface water. This influx is followed by immediate losses in the downstream direction as the valley expands. Both mechanisms of groundwater accretion/hyporheic exchange have been previously documented in the literature (Stanford and Ward, 1993; Ward et al., 1999; Malard et al; 1999). The regional alluvial aquifer convergence mentioned previously occurs in the Big Hole River near Fishtrap, LaMarche, and Deep Creeks (river km 132-122), near Wise River (km-102), and by Glen (km 68-58). Geological controls occur at Greenwood Bottom, Maiden Rock Canyon, and Notch Bottom (river km-88.5, 72.5, and 7.5 respectively).

Hydraulics

Correct simulation of river hydraulics ensures that the air-water interface and associated water column are exposed to an accurate duration of meteorological forcings within the model. A comparison of model hydraulics against measured field data for confirmation purposes is shown in **fig 13**. In general, good agreement is seen between observed and simulated values. Mean PBIAS for computed channel velocities, wetted widths, and associated depths were -5.3 percent, 4.6 percent, and 19.9 percent respectively. Standard errors were and 0.08 m/s and 10 and 0.1 meters respectively. These are adequate given the gross simplification of channel geometry in Heatsource v.7.0 in contrast to more detailed hydraulic models.

Shade

Simulated stream shade includes shading from both topography and vegetation and integrates the effects of channel aspect, offset, and width at a particular model node. Stream shade predictions ranged from 1 to 36 percent at individual model nodes, and averaged 5.7 percent for the entire study reach. Overall, simulation PBIAS was 3.5 percent with a standard error (in percent shade) of 4 percent. While this is not great, when compared to site specific observations taken with a solar pathfinder, model simulation values are within reason (**fig. 14**). Modeled shade appears to track well with observed measurements and shows several distinct shading peaks occurring at river km-130, 80, and 50. These are a function of topography rather than vegetation, and correspond to topographic angles of greater than 10-degrees. Discrepancies between simulated and observed values exemplify the difference between measured point values and averages over the 1,000-m distance step.

Water Temperature

With concurrence between hydrology, hydraulics, and shade, it was expected that simulated water temperatures in Heatsource v7.0 would be in good agreement with observed values. Computed and observed minimum, mean, and maximum water temperatures for July 28th of the July 25-31, 2007 modeling period are shown in **fig. 15**. Hourly diurnal plots are in **fig. 16**. Overall, there is excellent agreement between both. In review of the calibration statistics, PBIAS was largely negligible (0.2 percent), hourly NSE was 0.88, SSQR = 51.49, and standard error = 0.6°C. Individual calibration statistics for modeling nodes are shown in **table 5**.

Examination of the longitudinal profile of the Big Hole River provides significant information regarding instream water temperatures, and associated system dynamics. Beginning at the upstream boundary, the temperature remains relatively constant until reaching Fishtrap, LaMarche and Deep Creeks. Significant cooling occurs, attenuates, and then occurs again near Wise River due to groundwater accretion and topographic shading. Much of the rest of the reach is characteristic of warming conditions. Temperatures reach 27°C (80.6°F) prior to reaching the confluence with the Beaverhead River.

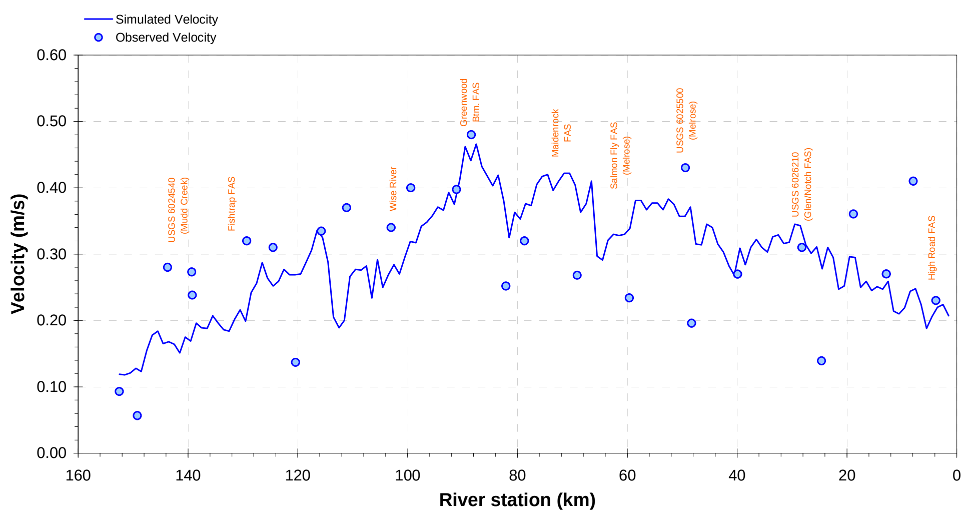
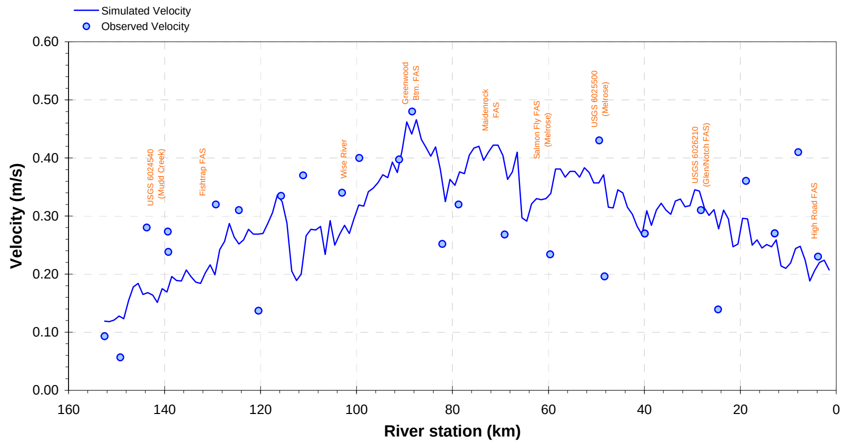
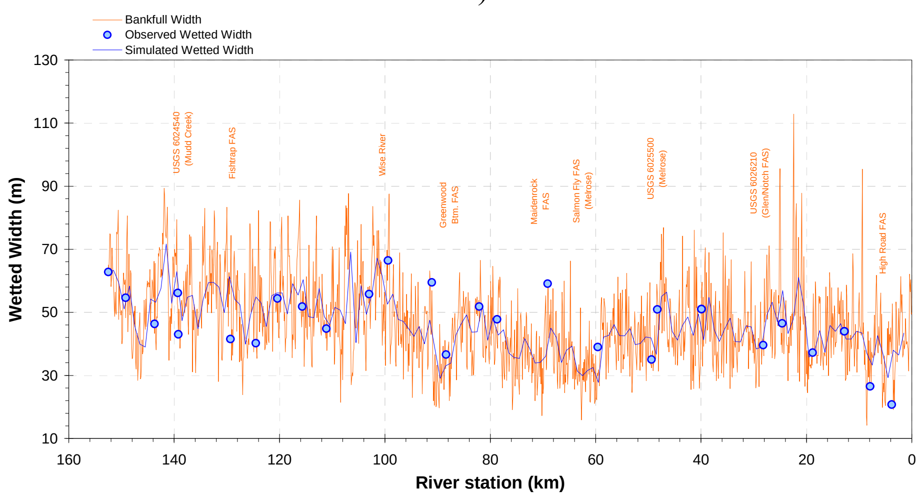


Figure 12. Big Hole River simulated and observed hydrology for July 28th of the July 25-31, 2006 modeling period. Observed measurements were taken instantaneously over the 7-day study period and may not necessarily reflect conditions that day.

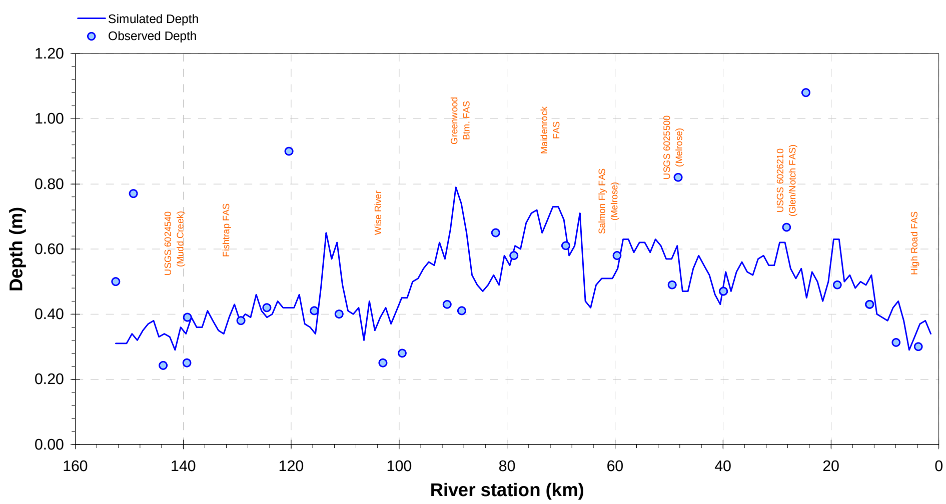
Figure 13. Big Hole River simulated and observed hydraulics: a) mean velocity, b) mean wetted channel width, and c) mean hydraulic depth for July 28th of the July 25-31, 2006 modeling period. Observed measurements were taken instantaneously over the 7-day study period and may not necessarily reflect conditions that day.



a)



b)



c)

From further review of **fig. 15**, the relationship between instream flow volume and associated water temperatures is apparent. As flows diminish, temperature increases. Rates of warming specifically increase in three instances: (1) in the upper reaches from low flow headwater conditions, (2) in several of the split flow locations due to a decrease in volume and increase in wetted surface area (e.g. river km 59.5 and 39.5), and (3) in the lower 40-km where much of the dewatering occurs. That said, the most heavily warmed sections are the upper and lower reaches. In both areas, temperatures exceed the UILT for Arctic Grayling (25ºC, 77ºF) and also are elevated above that which have been shown to cause the breakdown of physiological bodily processes for salmonid species (Boyd and Kasper, 2004). Fortunately, temperatures are moderated in center of the watershed by groundwater influx and shading, otherwise, extremes in the lower watershed would be much more severe.

In calibration of surface water temperature (both the longitudinal profile and diurnal plots), groundwater accretion temperature was found to vary depending on the method of accretion (see **figure 15** and **16**). In areas where large alluvial groundwater systems converged, a temperature of 11°C (51.8°F) was used. This is consistent with temperatures reported by Marvin and Voller (2000) for groundwater in the Big Hole basin as well as those found in a 2007 query of the Groundwater Information Center (GWIC) database. In instances where both regional groundwater flow and geological controls occur, a temperature of 16°C (60.8°F) was used. For areas with consistent hyporheic exchange due to oxbowing and valley morphological controls, a temperature of 19°C (66.2°F) was used. Results are consistent with Boyd and Kasper (2004), Malard et al., (2001), Constantz and Thomas (1997), and Siliman and Booth (1993) who all indicate that shallow groundwater/hyporheic water temperatures are warmer than deep cold subsurface flows, and tend to be influenced by infiltrating stream water, thereby closely patterning diel surface water temperature fluctuations.

Overall, a very good surface water temperature calibration was achieved based on model statistical efficiency. Scenarios for TMDL planning and analysis are described in the following sections.

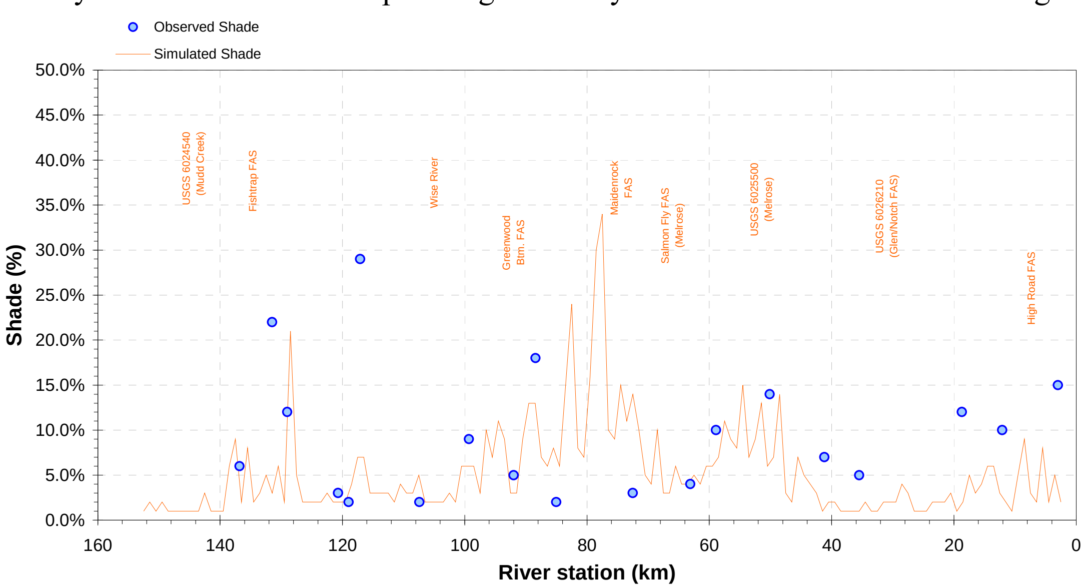


Figure 14. Big Hole River simulated and observed shade for July 28th of the July 25-31, 2006 modeling period.

Table 5. Hourly water temperature calibration statistics for July 25-31, 2006 modeling period.

Site ID	PBIAS	NSE	SSR	SE
RIVER KM – 139.2 (Z02)	-0.7%	0.91	45.73	0.7
RIVER KM – 129.3 (Z03)	-4.3%	0.82	116.83	0.6
RIVER KM – 124.5 (Z04)	-2.4%	0.87	75.06	0.7
RIVER KM – 115.7 (Z05)	-0.4%	0.91	47.97	0.7
RIVER KM – 111.1 (Z06)	2.3%	0.87	73.52	0.5
RIVER KM – 103.0 (Z22)	1.6%	0.84	92.38	1.0
RIVER KM – 99.4 (Z07)	1.8%	0.91	47.02	0.6
RIVER KM – 87.6 (Z46)	0.8%	0.79	57.85	0.8
RIVER KM – 82.1 (Z21)	0.6%	0.91	24.32	0.5
RIVER KM– 78.7 (Z08)	1.5%	0.90	27.91	0.5
RIVER KM – 69.1 (Z09)	1.7%	0.84	52.04	0.6
RIVER KM – 59.6 (Z10)	1.5%	0.86	52.48	0.7
RIVER KM – 49.4 (Z12)*	2.0%	0.86	46.80	0.6
RIVER KM – 39.9 (Z13)	1.4%	0.84	54.10	0.8
RIVER KM – 28.2 (Z14)*	-1.2%	0.93	22.11	0.4
RIVER KM – 18.8 (Z15)	-0.2%	0.93	22.37	0.5
RIVER KM – 12.8 (Z16)	-0.2%	0.91	28.05	0.6
RIVER KM – 07.9 (Z17)	-0.5%	0.88	40.69	0.6
RIVER KM – 03.7 (Z19)	-1.8%	0.91	51.01	0.7
AVG	0.2%	0.88	51.49	0.6

*Located at USGS gage sites

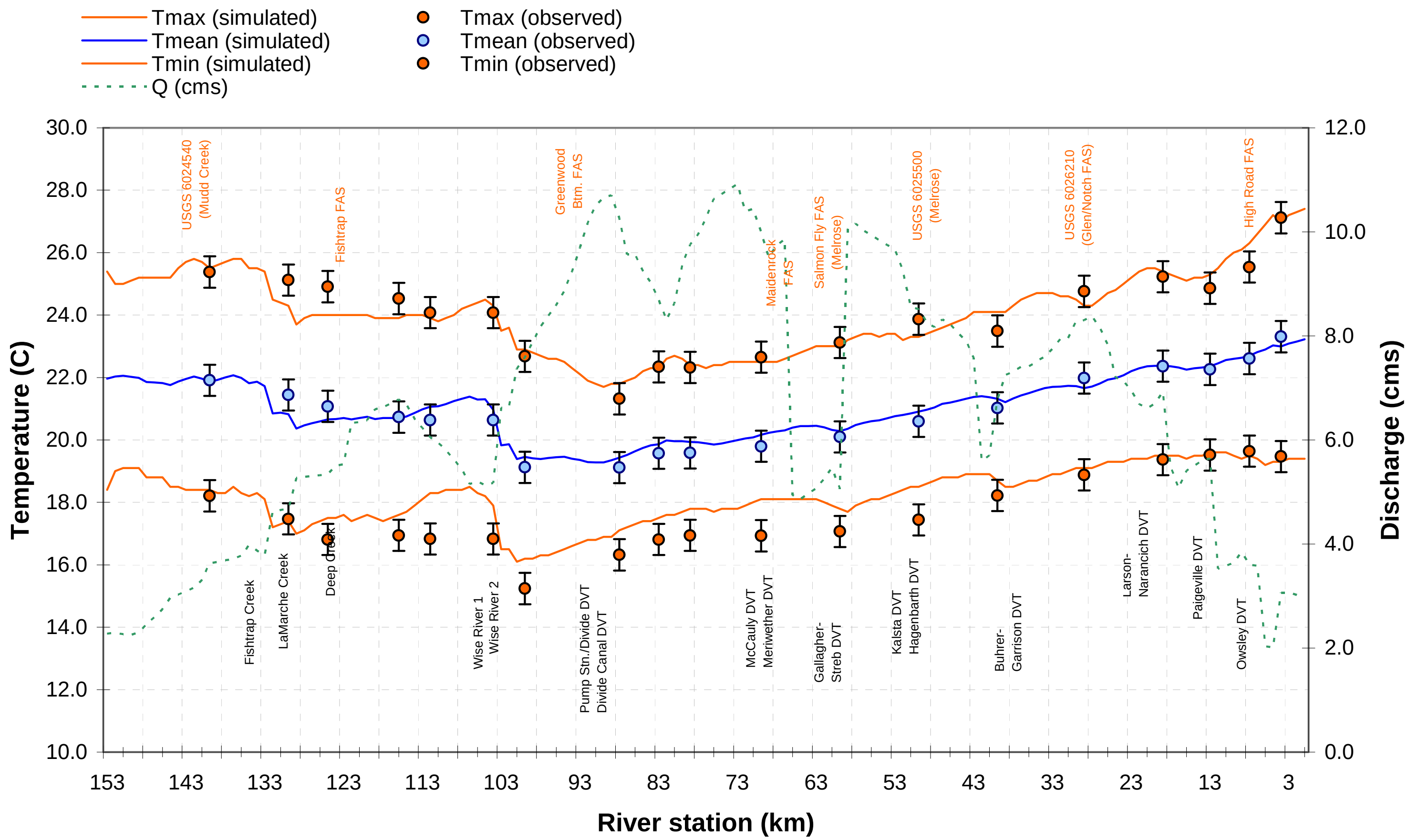
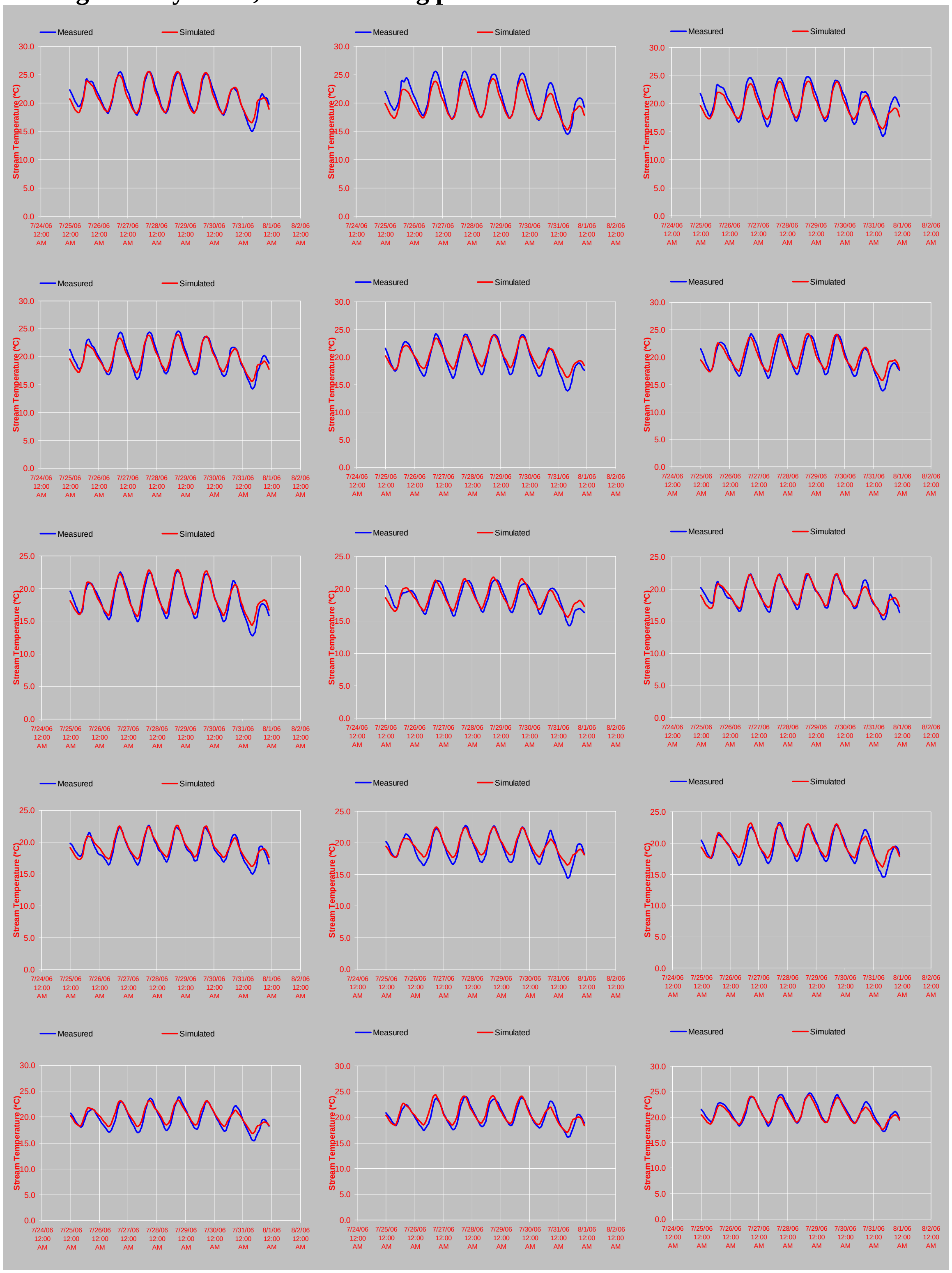
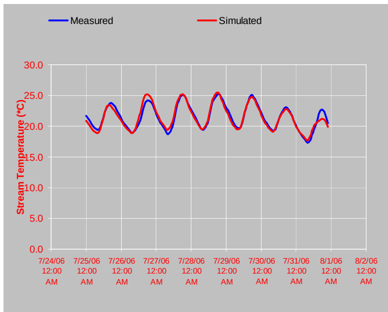
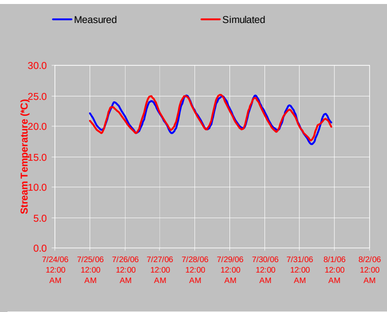


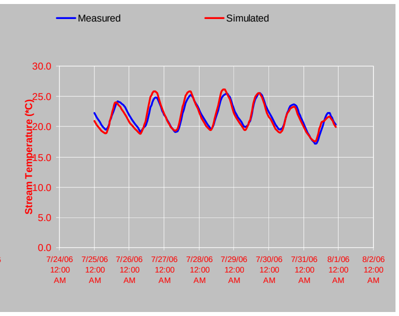
Figure 15. Longitudinal temperature profile of the Big Hole River displaying Tmin, Tmax, Tavg, and mean discharge for July 28th of the July 25-31, 2006 modeling period. Error bounds of measured data (±0.2 ºC datalogger accuracy) are shown along with major inflows and outflows.

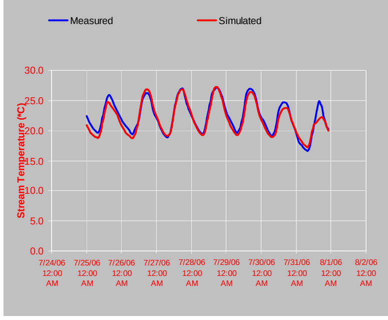
Figure 16. Diurnal plots of observed and simulated temperature for the 19 monitoring stations on the Big Hole River during the July 25-31, 2006 modeling period.




Measured
Simulated
Stream Temperature (°C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7/24/06 12:00 AM
7/25/06 12:00 AM
7/26/06 12:00 AM
7/27/06 12:00 AM
7/28/06 12:00 AM
7/29/06 12:00 AM
7/30/06 12:00 AM
7/31/06 12:00 AM
8/1/06 12:00 AM
8/2/06 12:00 AM


Measured
Simulated
Stream Temperature (°C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7/24/06 12:00 AM
7/25/06 12:00 AM
7/26/06 12:00 AM
7/27/06 12:00 AM
7/28/06 12:00 AM
7/29/06 12:00 AM
7/30/06 12:00 AM
7/31/06 12:00 AM
8/1/06 12:00 AM
8/2/06 12:00 AM


Measured
Simulated
Stream Temperature (°C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7/24/06 12:00 AM
7/25/06 12:00 AM
7/26/06 12:00 AM
7/27/06 12:00 AM
7/28/06 12:00 AM
7/29/06 12:00 AM
7/30/06 12:00 AM
7/31/06 12:00 AM
8/1/06 12:00 AM
8/2/06 12:00 AM


Measured
Simulated
Stream Temperature (°C)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
7/24/06 12:00 AM
7/25/06 12:00 AM
7/26/06 12:00 AM
7/27/06 12:00 AM
7/28/06 12:00 AM
7/29/06 12:00 AM
7/30/06 12:00 AM
7/31/06 12:00 AM
8/1/06 12:00 AM
8/2/06 12:00 AM

SCENARIO ANALYSIS

A number of scenarios were developed as part of this study so that watershed managers can provide reasonable recommendations for meeting water quality criteria in the river. Vegetation losses from the riparian corridor, natural channel mophometry, and irrigation withdrawals have all been cited as causes for elevated water temperature in the Big Hole River (DEQ, 2004). However, little has been done to associate management activities in the river corridor with instream temperatures. Specifically, modeling scenarios were formulated to address the following: (1) baseline conditions, (2) a shade scenario in which reference shade is applied across the project reach, (3) a morphology scenario where channel mophometry is assumed to be under reference conditions, (4) water consumptive use scenario where effects of irrigation and domestic withdrawls are assessed, (5) a natural condition scenario with no anthropogenic influence, (6) naturally occurring scenario in which all reasonable land, soil, and water conservation practices are applied (ARM 17.30.602), and (7) a use attainment scenario where the model is applied toward a specific BMP for illustrative purposes.

Baseline Scenario

The baseline scenario describes existing conditions in the watershed and is merely a reflection of the calibration. In review, baseline modeling was completed during drought and in low flow conditions approaching the 7Q5. The simulation results have been documented in prior sections and indicate a very good water temperature calibration based on performance statistics of NSE, PBIAS, and SSR. Water temperature was shown to decrease from the upstream study limit to approximately Wise River, and then increase thereafter. Simulated values from the baseline scenario form the basis for which all other scenarios will be compared. For the rest of the document, temperature comparisons are reported as the 7-day minimum (7Dmin), 7-day average (7Davg), and 7-day maximum (7Dmax) water temperature.

Shade Scenario

During the field reconnaissance, the riparian corridor was characterized as being in good condition, with little observed disturbance. In order to exclude shade as a viable control on water temperature in the Big Hole River, a hypothetical shading scenario was run to characterize the maximum possible influence of shade on in-stream temperature. The following assumptions were made in the shade scenario: (1) all open/grassed sites, barren areas, and any other area with diminished shading vegetation, was assumed to be converted to reference shade condition and (2) all other conditions were held constant. Reference shade was defined as the combination of 80 percent willow and 20 percent grass in the upper study reach (e.g. km 152.5-102.0) and a mix of 30 percent cottonwood gallery and 70 percent grass cover in the lower 102 km. The breakpoint for the vegetation change was Wise River, which is a clear demarcation in regard to hydrology, climate, and associated soils.

In addition to these changes, a secondary component was integrated into the modeling to assess the influence of upstream shading on the headwater boundary condition of Heatsource v7.0. A SSTEMP model from a previous study (DEQ, upper Big Hole River TMDL unpublished) was linked with Heatsource v7.0 so that the influence of upstream management activities could be propagated downstream. SSTEMP is a single segment model that operates on a daily time step and computes many of the same heat flux components as Heatsource v7.0. In total, 94.5 km of river outside of the detailed study reach were evaluated. The model originated at the watershed headwaters and extended as far downstream as Pintlar Creek (e.g. upper TPA boundary). A zero flow headwater condition, as described in Barthalow (1989), was used to calibrate SSTEMP water temperature to project hydrology and meteorology. Model assumptions for the SSTEMP shading scenario were as follows: (1) shade was assumed to be at reference condition in the upper TPA as identified by willow cover of height 4-m, crown of 1-m, density of 43%, and offset of 0.5-m (DEQ, upper Big Hole TMDL unpublished), and (2) all other conditions remained constant.

Baseline and simulated shade, along with associated in-stream water temperatures at the outlets of the upper and lower TPAs are shown in **table 6** and **fig. 17a**. Average shade in the upper TPA increased significantly, from 3.5 percent to 11.3 percent. Shade in the middle-lower TPA increased only 0.9 percent (5.7 percent to 6.6 percent). This translates into decreases of 0.38 and 0.82°C (0.68 and 1.48°F) in 7Dmin and 7Dmax at the upper TPA boundary while decreases of only 0.03 and 0.06°C (0.05 and 0.11°F) were observed at the watershed outlet near Twin Bridges (lower TPA). Clearly, shade is of great importance to localized conditions in the upper TPA (e.g. near the headwater boundary), but has little effect on the rest of the river. Standard violations were shown to extend 6-km into the detailed study reach, although these quickly attenuate as the river re-adjusts to meteorological and associated mass-transfers conditions in the Fishtrap Creek area. No other exceedances were observed in the middle or lower TPAs. Results strongly suggest that shade, while important to upper basin thermal dynamics, is not an integral component of the heat balance in the middle and lower Big Hole River TPAs. Thus shade improvement is not recommended as an alternative for temperature restoration strategies in the middle and lower basin. It should, however, be considered in the upper TPA to mitigate impairments near the upper detailed study reach boundary (e.g. first 6-km).

Table 6. Temperature changes at end of simulation reach resulting from modification of shade on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments).

Condition	% Shade	Tmin	Tavg	Tmax
Baseline (94.5-km)	3.5%	17.05	21.18	25.31
Shade Scenario	11.3%	16.67	20.58	24.49
Δ TEMP-Uppr TPA		-0.38	-0.60	-0.82
Baseline (152.5 km)	5.7%	18.93	22.17	25.59
Shade Scenario	6.6%	18.90	22.12	25.53
Δ TEMP-Lowr TPA		-0.03	-0.05	-0.06
Δ TEMP – all [(1)]		-0.04	-0.05	-0.05

[(1)]Average deviation of all model nodes, not just watershed outlet

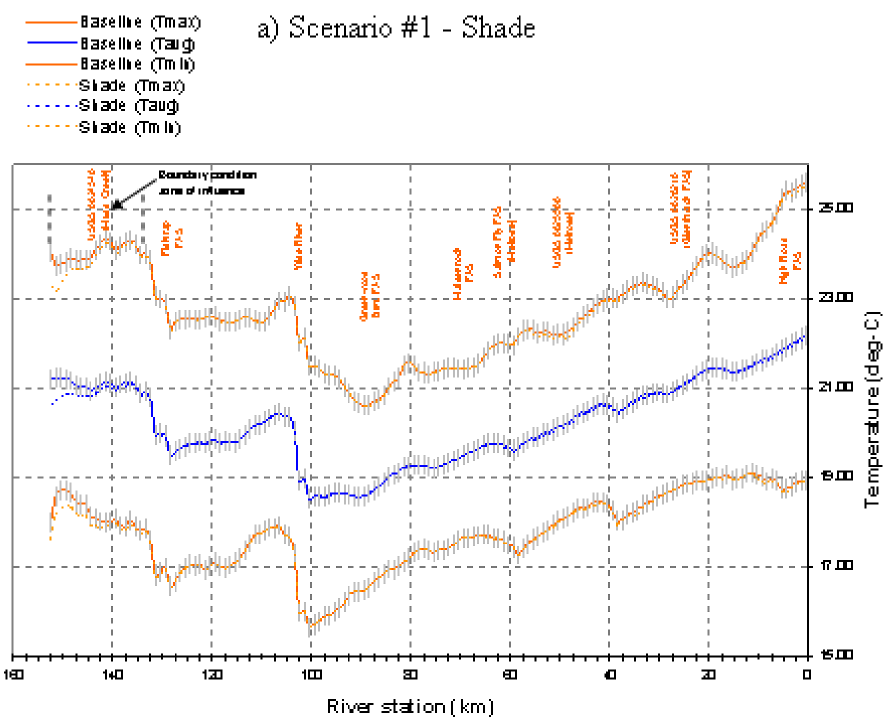
Channel Morphology Scenario

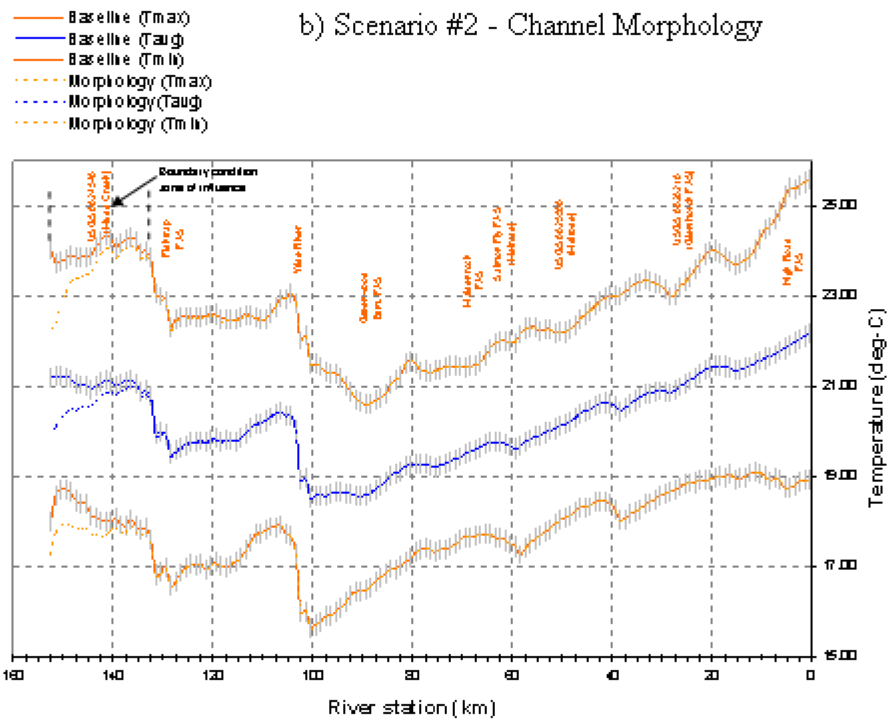
A channel morphology scenario was also completed to assess the influence of physical geometry on the overall heat balance of the reach. Similar to the shade scenario, both SSTEMP and Heatsource were used for this purpose. A coarse parameterization was completed to identify whether the wide reaches of the Big Hole River (width-depth ratios approaching 80 and 90) could potentially be altered to reduce the air-water interface, and subsequently, lower instream temperatures. Model parameterizations were formulated using targets from DEQ (upper Big Hole TMDL unpublished) and included the following assumptions: (1) width-depth ratios in the upper TPA were reduced by 30 percent, (2) width-depth ratios over 60 in the lower 152.5 km were set to 60, and (3) all other model parameters were held constant. Results of the SSTEMP model runs show that substantial reductions (up to 1.79°C; 3.22°F in 7Dmax) can be achieved at the upstream end of the project reach (**table 7**). This effect quickly reverts back toward baseline, though, as the water column is subjected to prolonged exposure of atmospheric conditions (**fig. 17b**). Because changes are short lived, and do not propagate into the heavily warmed lower sections of the river, morphology modification is not recommended as a suitable mechanism for controlling instream temperatures in the lower Big Hole River TPA. It does remain a viable option upstream of Pintlar Creek.

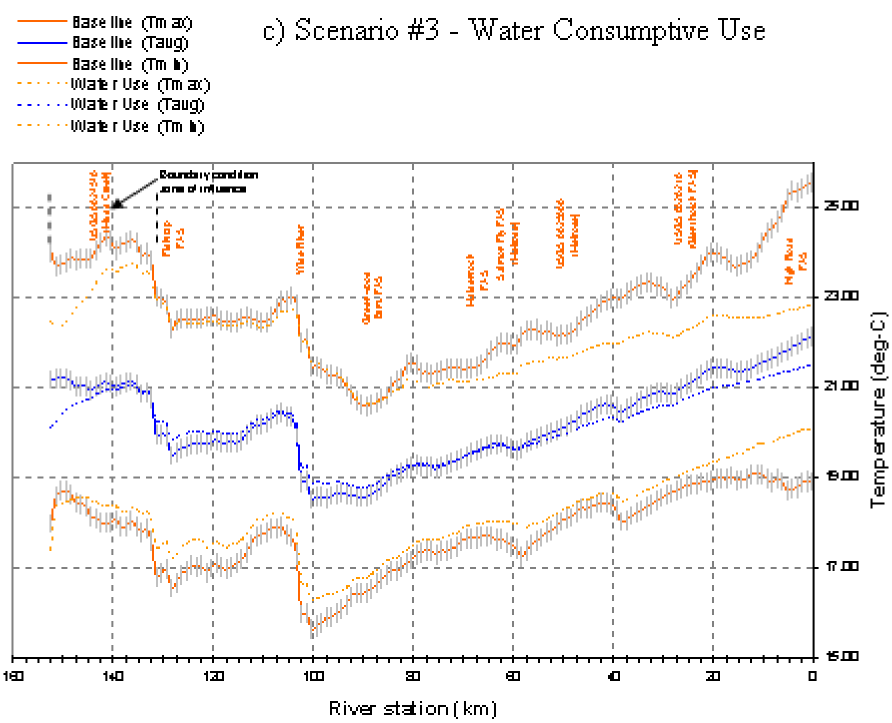
Table 7. Temperature changes at end of simulation reach resulting from modification of river morphology of the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments).

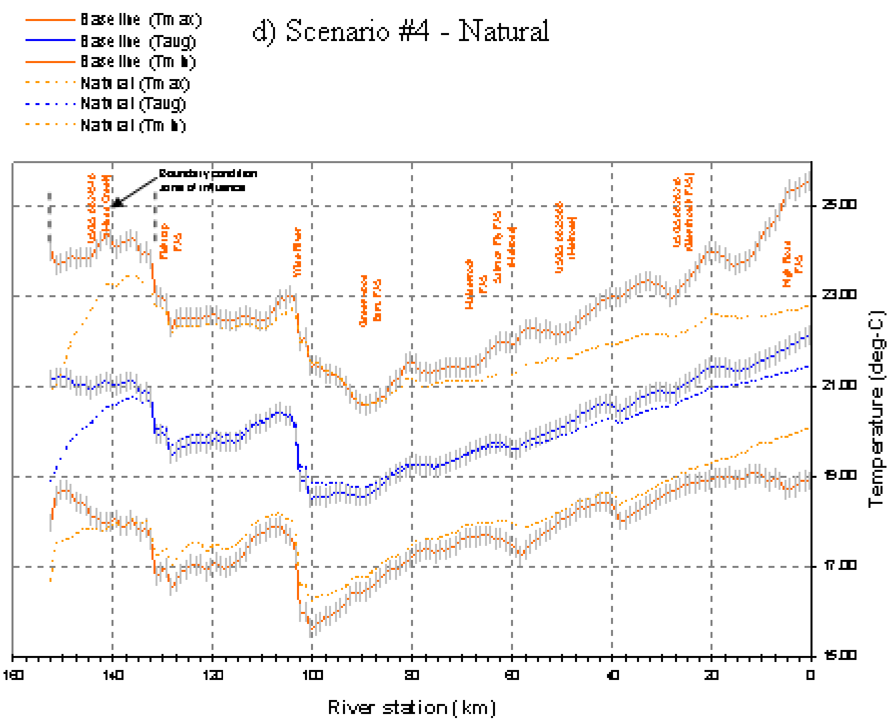
Condition	W-D Ratio	Tmin	Tavg	Tmax
Baseline (94.5-km)	35	17.05	21.18	25.31
Morph Scenario	25	16.34	19.86	23.38
Δ TEMP-Pintlar Cr		-0.71	-1.32	-1.93
Baseline (152.5 km)	>60	18.93	22.17	25.59
Morph Scenario	≤60	18.93	22.16	25.57
Δ TEMP-Twin Br		0.00	-0.01	-0.02
Δ TEMP – all		-0.06	-0.07	-0.07

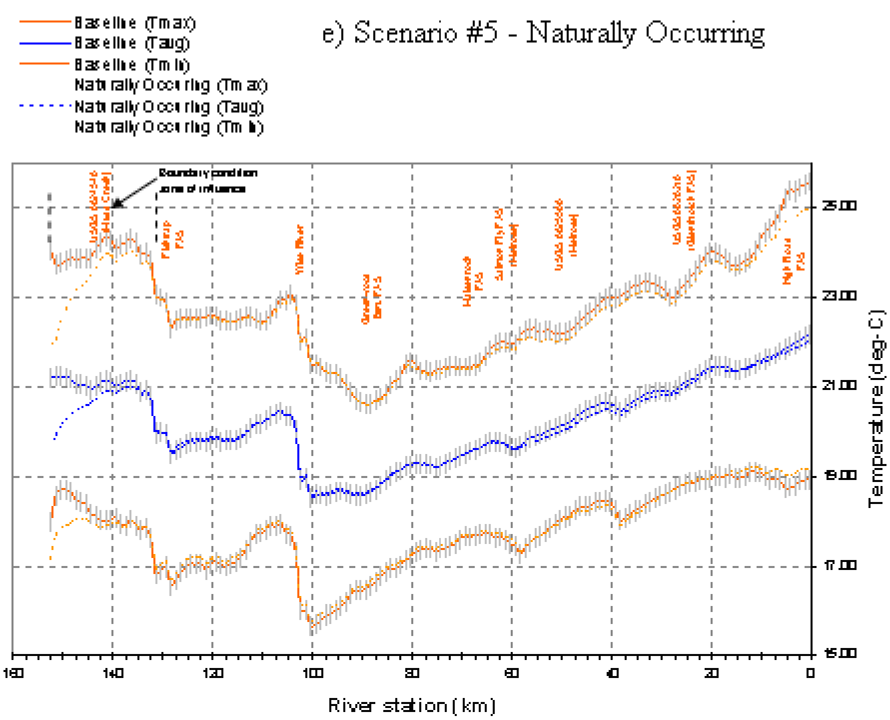
Figure 17. Longitudinal temperature effects of management scenarios on the Big Hole River. The grey shaded area represents ±0.23ºC degree variation from that of baseline conditions. Scenarios that deviate outside the 0.23ºC boundary indicate potential impairment.

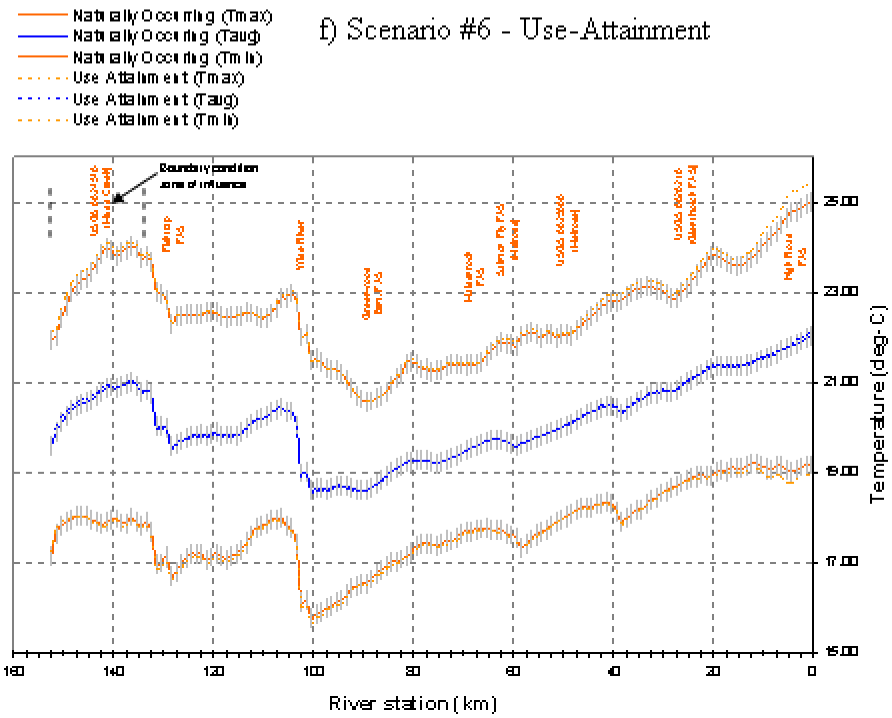



b) Scenario #2 - Channel Morphology
Baseline (Tmax)
Baseline (Taug)
Baseline (Tmin)
Morphology (Tmax)
Morphology (Taug)
Morphology (Tmin)
Boundary condition zone of influence
Temperature (deg-C)
River station (km)


c) Scenario #3 - Water Consumptive Use
Baseline (Tmax)
Baseline (Taug)
Baseline (Tmin)
Water Use (Tmax)
Water Use (Taug)
Water Use (Tmin)
Boundary condition zone of influence
Temperature (deg-C)
River station (km)


d) Scenario #4 - Natural
Baseline (Tmax)
Baseline (Taug)
Baseline (Tmin)
Natural (Tmax)
Natural (Taug)
Natural (Tmin)
Boundary condition zone of influence
25.00
23.00
21.00
19.00
17.00
15.00
Temperature (deg-C)
160
140
120
100
80
60
40
20
0
River station (km)


e) Scenario #5 - Naturally Occurring
Baseline (Tmax)
Baseline (Taug)
Baseline (Tmin)
Naturally Occurring (Tmax)
Naturally Occurring (Taug)
Naturally Occurring (Tmin)
Boundary condition zone of influence
25.00
23.00
21.00
19.00
17.00
15.00
Temperature (deg-C)
160
140
120
100
80
60
40
20
0
River station (km)

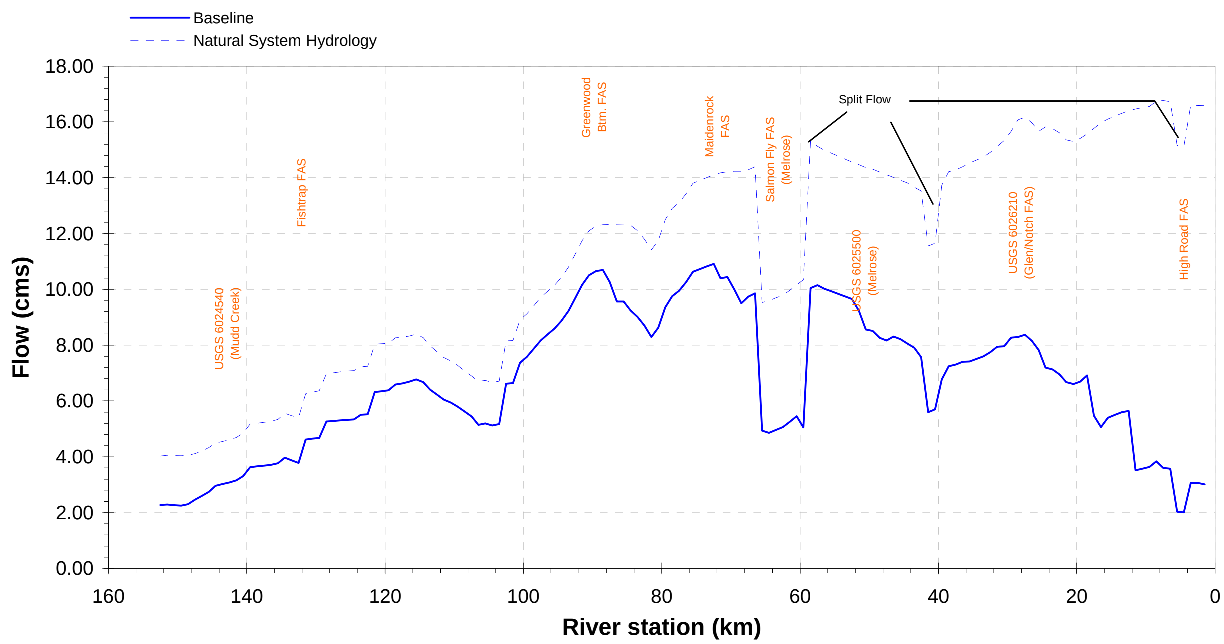


Water Consumptive Use Scenario

The water consumptive use scenario describes the thermal effect of irrigation and domestic water use on the Big Hole River. Although Montana standards do not necessarily apply to consumptive water use, it is important to assess the cumulative effect of these practices on the overall thermal regime of the river. The simple relationship presented by Brown (1969), suggests that large volume streams are less responsive to temperature changes, and conversely, low flow streams will exhibit greater diel fluctuations in stream temperature. The following assumptions were made in the water consumptive use scenario: (1) 1.75 cms (~60 cfs) of natural flow were returned upstream of the detailed study reach along with a corresponding change in temperature, (2) all diversions were removed from the detailed study along with any known return flows, and (3) no additional changes were made.

Overall, it was identified that 13.267 cms (~469 cfs) was diverted from the river during July 25-31 2006 to meet water use requirements in the middle and lower TPA's (**fig. 18**; see **Appendix A**). Withdrawal rates are slightly higher than those reported by Wells and Decker-Hess (1981) who indicate up to 9.29 cms (328 cfs) was removed from the river during the summer of 1980, as well as Marvin and Voller (2000), who estimate crop ET alone at 4.9 cms (171 cfs) in the lower basin. With unknown losses in the distribution system, and unaccounted ET in the middle basin, it is very reasonable to assume water withdrawls routinely approximate 9-13 cms in the late summer months. During 2006, all but 0.439 cms were used for agricultural purposes.

Figure 18. Longitudinal profile of discharge in the watershed as part of the water use scenario. The 1.75 m3/s headwater increase is included in this approximation along with removal of all diversions in the study area.



Model simulations of natural system hydrology indicate that significant changes in temperature occur at the upstream boundary and watershed outlet from irrigation and domestic water withdrawls **(table 9**, **fig. 17c**). 7Davg and 7Dmax are shown to decrease by 0.65 and 2.73°C (1.17 and 4.91°F), while 7Dmin actually increases as due to additional system volume, its associated thermal inertia, and the relative change in the ratio of contribution of groundwater to surface water. Interestingly, water temperatures largely "reset" in the area around Wise River. This phenomena was also observed in other scenarios and is suggestive that the basin could be broken into two independent management segments with independent remedial objectives. Clearly, flow augmentation in the Big Hole River is a crucial improvement necessary for modification of instream water temperature in the middle and lower TPA's.

Table 8. Temperature changes at end of simulation reach resulting from modification of consumptive use on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments).

Condition	Q (cms)	Tmin	Tavg	Tmax
Baseline (94.5 km)	3.135	17.05	21.18	25.31
Water Scenario	4.885	16.53	20.08	23.63
Δ TEMP-Pintlar Cr	1.75	-0.52	-1.10	-1.68
Baseline (152.5 km)	3.022	18.93	22.17	25.59
Water Scenario	16.579	20.09	21.52	22.86
Δ TEMP-Twin Br		+1.16	-0.65	-2.73
Δ TEMP – all		+0.41	-0.09	-0.66

Natural Condition Scenario

The natural condition scenario reflects the temperature regime that would be expected absent of the influence of man. While this type of scenario is clearly not realistic from a socio-economic implementation standpoint, it does allow for characterizing the extent of departure from natural conditions, and subsequently, the maximum potential improvement in the watershed. It may also be helpful in future resource conservation efforts. For the purpose of this study, natural conditions were defined as the removal of all human influences that affect heat or mass transfer. Natural condition scenario assumptions include the following: (1) reference shade conditions as described in the shade scenario, (2) modified morphology in the 94.5 km reach upstream and constant channel morphology downstream, (3) the same irrigation and consumptive use conditions as in the water consumptive use scenario, and (4) no other associated changes.

Results of the natural condition scenario parallel that of the previous scenario (e.g. water consumptive use) with 7Davg and 7Dmax decreasing by 0.69 to 2.76°C (1.24 and 4.97°F) and 7Dmin increasing (**table 9**). The marked concurrence between the natural condition and water use scenarios confirm that irrigation and domestic withdrawls are the predominant impairment affecting the Big Hole River; much more so than that of shade and morphology. The natural condition profile is shown in **fig. 17d**.

Table 9. Temperature changes at end of simulation reach resulting from natural conditions on the Big Hole River (both SSTEMP and Heatsource v7.0 modeled segments).

Condition		Tmin	Tavg	Tmax
Baseline (94.5 km)		17.05	21.18	25.31
Natural Scenario		15.83	18.90	21.97
Δ TEMP-Pintlar Cr		-1.22	-2.28	-3.34
Baseline (152.5 km)		18.93	22.17	25.59
Natural Scenario		20.07	21.48	22.83
Δ TEMP-Twin Br		+1.14	-0.69	-2.76
Δ TEMP – all		+0.30	-0.20	-0.77

Naturally Occurring Scenario (ARM 17.30.602)

The naturally occurring scenario defines water temperature conditions resulting from the implementation of all reasonable land, soil, and water conservation practices (LSWCP), e.g. where stringent best management practices are implemented as outlined in ARM 17.30.602. Essentially, "naturally occurring" establishes the bar for which the allowable 0.23°C (0.5°F) temperature increase is compared to, and effectively determines the impairments status of a water body. Assumptions used in the development of the naturally occurring scenario include the following: (1) identical shade conditions to those described in the shade scenario, (2) modified morphology in the 94.5 km reach upstream, (3) constant channel morphology downstream, (4) a 15 percent (0.5cms) irrigation efficiency improvement in the upper TPA (per DEQ and DNRC estimates), (5) a 15 percent irrigation/domestic water use efficient in the middle and lower TPAs (DEQ estimated), and (6) no other associated changes.

Results of the naturally occurring scenario suggest that 7Davg and 7Dmax would be reduced by 0.13 and 0.59°C (0.23 and 1.06ºF), respectively, while nighttime minimums would increase by 0.26°C (**table**

10 and **fig 17e**). As such, a majority of the river in its current form already meets the State of Montana temperature standard (e.g. within the 0.23°C allowable increase). Standard violations in 7Dmax do occur in three locations: (1) in the upper reaches as a result of upstream management conditions (river km-152.5-135.5), (2) at river km-55.5 between Melrose and Glen from heavy irrigation and domestic withdrawal, and (3) from river km-10.5 dowstream due to cumulative effects of dewatering. Management activities should be prioritized to address these most impacted sections first, while then worrying about other areas of the river later.

Table 10. Temperature changes at end of simulation reach resulting from naturally occurring conditions on the Big (both SSTEMP and Heatsource v7.0 modeled segments).

Condition		Tmin	Tavg	Tmax
Baseline (94.5 km)		17.05	21.18	25.31
Naturally Scenario		16.24	19.65	23.06
Δ TEMP-Pintlar Cr		-0.81	-1.53	-2.25
Baseline (152.5 km)		18.93	22.17	25.59
Naturally Scenario		19.19	22.04	25.00
Δ TEMP-Twin Br		+0.26	-0.13	-0.59
Δ TEMP – all		+0.01	-0.09	-0.19

Use Attainment Scenario

A final scenario was developed to illustrate the utility of the Heatsource v7.0 model for future application in the Big Hole River. In this hypothetical scenario, the hypothesis was formulated that 10 percent irrigation efficiency (as opposed to 15 percent, all other factors the same), would be sufficient to meet the State temperature standard. The hypothesis was tested using identical assumptions to that of the naturally occurring scenario, with the exception of the change in flow. Results indicate that, for the most part, 10 percent irrigation efficiency would meet allowable increases by State law. Exceedances did occur, however, in the lower watershed, largely disproving the hypothesis (**fig. 17d**). Therefore, the next step would be to develop a new set of assumptions (perhaps something like a 10 percent efficiency improvement in the upper reaches and 15 percent in the lower reaches) as a subsequent test to assess whether water quality standards can be met. Ultimately, the goal would be to identify a suite of BMPs that are agreeable between watershed stakeholders and managers to such that the Montana temperature standard is attained and maintained. This, of course, would require cooperative efforts between landowners, watershed groups, managers, modelers, and the general public. For the time being, a watershed-wide 15 percent improvement in flow, along with shading improvement in the upper, middle, and lower TPA's, and morphology improvements in the upper TPA, are recommended to meet the state temperature standard.

CONCLUSION

Water temperature modeling was completed on the Big Hole River using Heatsource v7.0 and SSTEMP to such that the mechanistic relationship between instream water temperature, stream morphology, riparian conditions, and water management practices could be established for the summer critical low-flow period. Through scenario analysis, it was shown that flow alteration was the most crucial management component influencing water temperature in the basin and that existing water temperatures are 0.59ºC (1.06ºF) warmer than that of naturally occurring conditions. They are 2.76ºC (4.97ºF) higher than natural. Thus, the key management recommendation originating from this study is to protect and reestablish instream flows to the extent possible.

It was found during the modeling, that much of the middle and lower Big Hole River TPAs already meet the State's temperature criteria. Three areas of concern do exist: (1) in the reaches upstream of Fishtrap Creek/FAS as a result of management conditions in the upper TPA, (2) at river km-55.5 between Melrose and Glen from heavy irrigation and domestic water withdrawal, and (3) from approximately river km-10.5 downstream to Twin Bridges due to cumulative effects of dewatering. It was found that voluntary water conservation of 15 percent would be necessary to meet the state temperature standard in those reaches. Further modeling is recommended such that specific BMPs can be established cooperatively between stakeholders and watershed managers to refine this 15 percent estimate.

Finally, a unique "resetting" condition was identified near the center of the watershed where significant groundwater influx and topographic shading result a thermal buffering of instream water temperatures. This functionally separates the upper and middle/lower Big Hole River TMDL planning areas and would allow for future management of the river in two distinct segments.

REFERENCES

ARM 17.30.623 (Administrative Rules of Montana). Section 17 – Water Quality, B-1 Classification Standards. Accessed October 9, 2007 from http://arm.sos.mt.gov/17/17-2715.htm.

Anderson, R.L. 1982. Conflict Between Establishment of Instream Flows and Other Water Uses on Western Streams. Journal of the American Water Resources Association 18 (1), 61–65.

ASTM (American Society for Testing and Materials). 1984. Standard Practice for Evaluating Environmental Fate Models of Chemicals. Designation E978-84. Philadelphia, PA. 8 p.

Bahls, L. 1978. Streamflow and Water Quality in the Lower Big Hole River Summer 1977. Agency Report. Montana Department of Health and Environmental Sciences.

Bartholow, J.M., 1989. Stream Temperature Investigations: Field and Analytic Methods. Instream Flow Information Paper No. 13. U.S. Fish Wildlife Service Biological Report. 89(17). 139 pp.

BHWC (Big Hole River Watershed Committee). 1999. Big Hole River Drought Management Plan.

Brown, G.W. 1969. Predicting temperatures of small streams. Water Resources Research. 5(1) p. 68-75.

Bundschuh, J. 1993. Modeling annual variations of spring and groundwater temperatures asscociated with shallow aquifer systems. J. Hydrol. 142: 427-444.

Chapra, S.C. 1997. Surface Water Quality Modeling. McGraw-Hill Companies, Inc., New York.

Chapra, S.C. and K.H. Reckow. 1983. Engineering Approaches For Lake Management. Vol. 2: Mechanistic Modeling. Butterworth Publishers, Boston.

Constantz, J., and C.L. Thomas. 1997. Stream bed temperature profiles as indicators of percolation characteristics beneath arroyos in the middle Rio Grande Basin, USA. Hydrol. Processes. 11: 1621-1634.

CWAIC (Clean Water Act Information Center). Accessed October 9, 2007 from Montana Department of Environmental Quality. http://www.deq.state.mt.us/ CWAIC/default.aspx.

Deer Lodge County Water Resources Survey (WRS). 1955. Part I: History of the Land and Water use on Irrigated Areas and Part II: Maps showing irrigated areas in color sesignating the sources of supply. State Engineer's Office. Helena, MT.

Diskin, M.H. and Simon, E. (1977). "A procedure for the selection of objective functions for hydrologic simulation models." Journal of Hydrology, 34, 129-149.

FWP (Montana Fish, Wildlife, and Parks), 1989. Application for reservations of water in the Missouri River basin above Fort Peck Dam, Volume 2. June 1989. Upper Missouri instream flow studies Contract No. MT950-CTO-36.

Gammons, C., Ridenour, R. and A. Wenz. 2001. Diurnal and Longitudinal Variations in Water Quality on the Big Hole River and Tributaries During the Drought of August, 2000. Montana Bureau of Mines and Geology Open File Report 424.

Harmel, R.D., Cooper, R.J., Slade, R.M., Haney, R.L., and J.G. Arnold. 2006. Cumulative uncertainty in measured streamflow and water quality data for small watersheds. Transactions of the ASABE. Vol. 49(3): 689-701.

James, L.D. and S.J. Burges. 1982. Selection, Calibration, and Testing of Hydrologic Models. In: Hydrologic Modeling of Small Watersheds. ASAE Monograph No. 5. C.T. Haan, H.P. Johnson, D. L. Brakensiak (eds). American Society of Agricultural Engineers, St Joseph, MI. Chap 11. pp 437-474.

Levings, J.F., 1986. Water resources of the Big Hole basin, southwestern Montana: Montana Bureau of Mines and Geology, Memoir 59, 72 p.

Lohr, S.C., P.A. Byorth, C.M. Kay, and W.P. Dwyer. 1996. High-temperature tolerances of Fluvial Arctic Grayling and comparison with summer river temperatures of the Big Hole River, Montana. Transactions of the American Fisheries Society 125:933-939.Magee and Lamothe (2003, 2004)

Magee, J.P. and P.J. Lamothe. 2003. Big Hole River Arctic grayling recovery project: Annual monitoring report 2002. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Fish, Wildlife, and Parks, Bozeman, Montana

Magee, J.P. and P.J. Lamothe. 2004. Fluvial Arctic grayling monitoring report 2003. Submitted to: Fluvial Arctic Grayling Workgroup. Montana Fish, Wildlife, and Parks, Bozeman, Montana.

Magee, J., Rens, E., and P. Lamothe. 2006. Arctic Grayling Recovery Program: Montana Arctic Grayling Monitoring Report 2005. Montana Department of Fish, Wildlife and Parks. Dillon, Montana.

Malard, F., Mangin, A., Uehlinger, U. and J.V. Ward. 2001. Thermal heterogeneity in the hyporheic zone of a glacial floodplain. Can. JU. Fish. Aquat. Scie. 58: 1319-1335.

Marvin, R. K. 1997. Ground-water/surface-water interactions in the upper Big Hole basin, Montana: Montana Bureau of Mines and Geology open-file report 349. 58 p.

Marvin, R.K., and Voeller, T.L. 2000. Hydrology of the Big Hole Basin and an assessment of the affects of irrigation of the hydrologic budget. Montana Bureau of Mines and Geology Open File Report 417. Montana Bureau of Mines and Geology, Butte, Montana.

McCarthy, P.M., 2005, Statistical summaries of streamflow in Montana and adjacent areas, water years 1900 through 2002: U.S. Geological Survey Scientific Investigations Report 2004-5266, 317 p.

DEQ (Montana Department of Environmental Quality)., 2007. QA/QC of datalogger recovery for Big Hole River. DEQ monitoring program.

DEQ/Watershed Consulting. 2006. Quality Assurance Project Plan and Sampling and Analysis Plan for Big Hole River.

DEQ. Monitoring Guidance. Accessed May 15, 2006 from http://www.deq.state.mt.us/wqinfo/monitoring/ SOP/pdf/11-04.pdf

DEQ (Montana Department of Environmental Quality). 2004. Watershed Characterization Report – Middle and Lower Big Hole Water Quality Restoration Planning Areas. Prepared by Land and Water Consulting.

MFISH (Montana Fisheries Information System). Accessed October 9, 2007 from http://maps2.nris.mt.gov/scripts/esrimap.dll?name=MFISH&Cmd=INST&WCmd=Stream.

Montana Code Annotated. 2003. Montana Water Quality Act. Title 75. Environmental Protection Chapter 5. Water Quality.

MRA (Montana River Action) website. Accessed May 9, 2007 from http://www.montanariveraction.org.html

Nash, J.E., and V. Sutcliffe, 1970: River flow forecasting through conceptual models, I. A discussion of principles. Journal of Hydrology. 10: 282-290.

Phillip, A. 1999. A chemical study of irrigation and return flow waters in the Big Hole River basin of southwest Montana: Montana Tech – University of Montana M.S. thesis, 104 p.

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., Barsky, T., Tariche, S., Schreck, J., and S. Alpert, 1997. Water Resources: Agriculture, Environment, and Society. BioScience, Vol. 47, No. 2. pp. 97-106.

Pringle, C. M. 2000. Threats to U.S. public lands from cumulative hydrologic alterations outside of their boundaries. Ecological Applications Vol. 10, No.4. pp. 971-989.

Rens, E.. and J. Magee. 2007. Arctic Grayling Recovery Program: Montana Arctic Grayling Monitoring Report 2006. Montana Department of Fish, Wildlife and Parks. Dillon, Montana.

Thomann, R.V. 1982. Verification of Water Quality Models. Jour. Env. Engineering Div. (EED) Proc. ASCE, 108:EE5, October.

Thomas, J.L. and R.L. Anderson. 1976. Water-energy conflicts in Montana's Yellowstone River Basin. Water Resources Bulletin. Vol. 12, No. 4.

Troxler, R.W., and E. L. Thackston, 1975. Effect of Meteorological Variables on Temperature Changes in Flowing Streams. Ecological Research Series EPA-660/3-75-002.
Siliman, S.E., Ramirez, J., and R.L. McCabe. 1995. Quantifying downflow through creek sediments using temperature series: one-dimensional solution incorporating measured surface temperature. J. Hydrol. 167: 99-119.
Van Liew, M.W., Arnold, J.G., and D.D. Bosch. 2005. Problems and Potential of Autocalibrating a Hydrologic Model. Transactions of the ASCE. Vol. 48(3): 1025-1040.
Ward, J.V., Malard, F., tockner, K. and U. Uehligner. 1999. Influence of groundwater on surface water conditions in a glacial flood plain of the Swiss Alps.Hydrol. Process. 13: 277-293.
Wells, J.D. and J. Decker-Hess. 1981. Inventory and survey of the waters of the Big Hole and Beaverhead drainages, July 1, 1980 through June 1, 1981. Southwest Montana fisheries study.
WRCC (Western Regional Climate Center). Accessed October 9, 2007 from http://www.wrcc.dri.edu.
USACE (United States Army Corps of Engineers). 1993. Engineering and Design - River Hydraulics. EM 1110-2-1416. 15 October 1993.

APPENDIX J
MODELING STREAMFLOW AND WATER TEMPERATURE IN THE BIG HOLE RIVER, MONTANA – 2006
ADDENDUM-1; DIVIDE CREEK

Kyle Flynn, Darrin Kron, Marcus Granger

TMDL Technical Report DMS-2008-03

Montana Department of Environmental Quality
Water Quality Planning Bureau
Watershed Modeling Program
1520 East Sixth Avenue, PO Box 200901
Helena, MT 59620-0901
March 2008

Suggested Citation:

Flynn, K., Kron, D., Granger, M. 2008. Modeling Streamflow and Water Temperature in the Big Hole River, Montana – 2006. Addendum-1; Divide Creek. TMDL Technical Report DMS-2008-03. Montana Department of Environmental Quality.

ADDENDUM SUMMARY

The purpose to this addendum is to document temperature modeling activities completed on Divide Creek, as part of the Big Hole River temperature TMDL. Previously, a comprehensive modeling assessment was completed on 152.5 kilometers of the mainstem Big Hole River using Heatsourcev7.0. A similar approach was applied to 27.75 km of Divide Creek, albeit greatly simplified in scope. Identical methods and material to that of the mainstem study were used, thus these are not detailed as part of this addendum. The addendum does include discussions specific to Divide Creek, including the study area, model inputs, results and discussion, and scenario analyses. Overall, it was found that shade was main contributor to observed temperature exceedances in the watershed, and that maximum predicted water temperatures would be reduced up to 0.25°C (0.45°F) with the improvement of riparian cover. Because of this, riparian improvement projects are the primary recommendation to mitigate temperature impairments in the Divide Creek watershed. In-stream flow was also found to be significant, albeit, in an unusual way. Return flow from the Big Hole River via the Divide Canal was shown to moderate temperatures by 2.80°C (5.04°F). Finally, irrigation within Divide Creek itself was also assessed, and is believed to a possible source of temperature impairment in the watershed. Uncertainty in field data made this conclusion largely speculative and further study is warranted to make concrete conclusions about the impact.

TABLE OF CONTENTS

Contents PAGE

Study Area **J-11**
Model Development **J-13**
GIS Pre-processing J-13
Simulation Period and Global Control Specifications J-13
Hydrology/Mass Transfer Input J-13
Hydraulic Input J-13
Climate Input J-13
Shade Input J-15
Results & Discussion **J-16**
Hydrology J-16
Hydraulics J-16
Shade J-16
Water Temperature J-17
Scenario Analysis **J-21**
Baseline Scenario J-21
Shade Scenario J-21
Water Consumptive Use Scenario (Flow-1) J-22
Irrigation Return Flow Scenario (Flow-2) J-22
Natural Condition Scenario J-23
Naturally Occurring Scenario (ARM 17.30.602) J-23
Conclusion **J-27**
References **J-27**

Appendix A1 – Model Documentation –Contact DEQ

TABLE OF FIGURES

Figures PAGE

Table J-1. Water balance for Divide Creek during the July 25-31, 2006 modeling period....... J-14
Table J-2. Hydraulic parameters used in the Divide Creek Heatsource v7.0 model. J-15
Table J-3. Riparian landcover types and associated attributes used in Heatsource v7.0 shading calculations. J-16
Table J-4. Hourly water temperature calibration statistics for July 25-31, 2006 modeling period. J-17
Table J-5. Temperature changes resulting from modification of shade on Divide Creek. J-21
Table J-6. Temperature changes resulting from water consumptive use in Divide Creek. J-22
Table J-7. Temperature changes from Divide Canal Irrigation return flow. J-23
Table J-8. Temperature changes resulting from natural conditions in Divide Creek. J-23
Table J-9. Temperature changes resulting from naturally occurring conditions in Divide Creek. J-24

TABLE OF TABLES

Tables PAGE

Figure J-1. Divide Creek study area showing terrain, hydrography, and monitoring locations. J-11
Figure J-2. Representative plots of water temperature in Divide Creek during the modeling period of July 25-31, 2006. .... J-14
Figure J-3. Unique reaches defined for model parameterization of hydraulics. Elevation data taken from USGS National Elevation Dataset (NED) 30-m grid. J-15
Figure J-4. Simulated and observed hydrology and hydraulics for Divide Creek J-18
Figure J-5. Simulated stream shade for the July 28th of the July 25-31, 2006 modeling period. . J-19
Figure J-6. Diurnal plots of observed and simulated temperature on Divide Creek during the July 25-31, 2006 modeling period J-19
Figure J-7. Longitudinal temperature profile of Divide Creek displaying Tmin, Tmax, Tavg, and discharge for July 28th of the July 25-31, 2006 modeling period. J-20

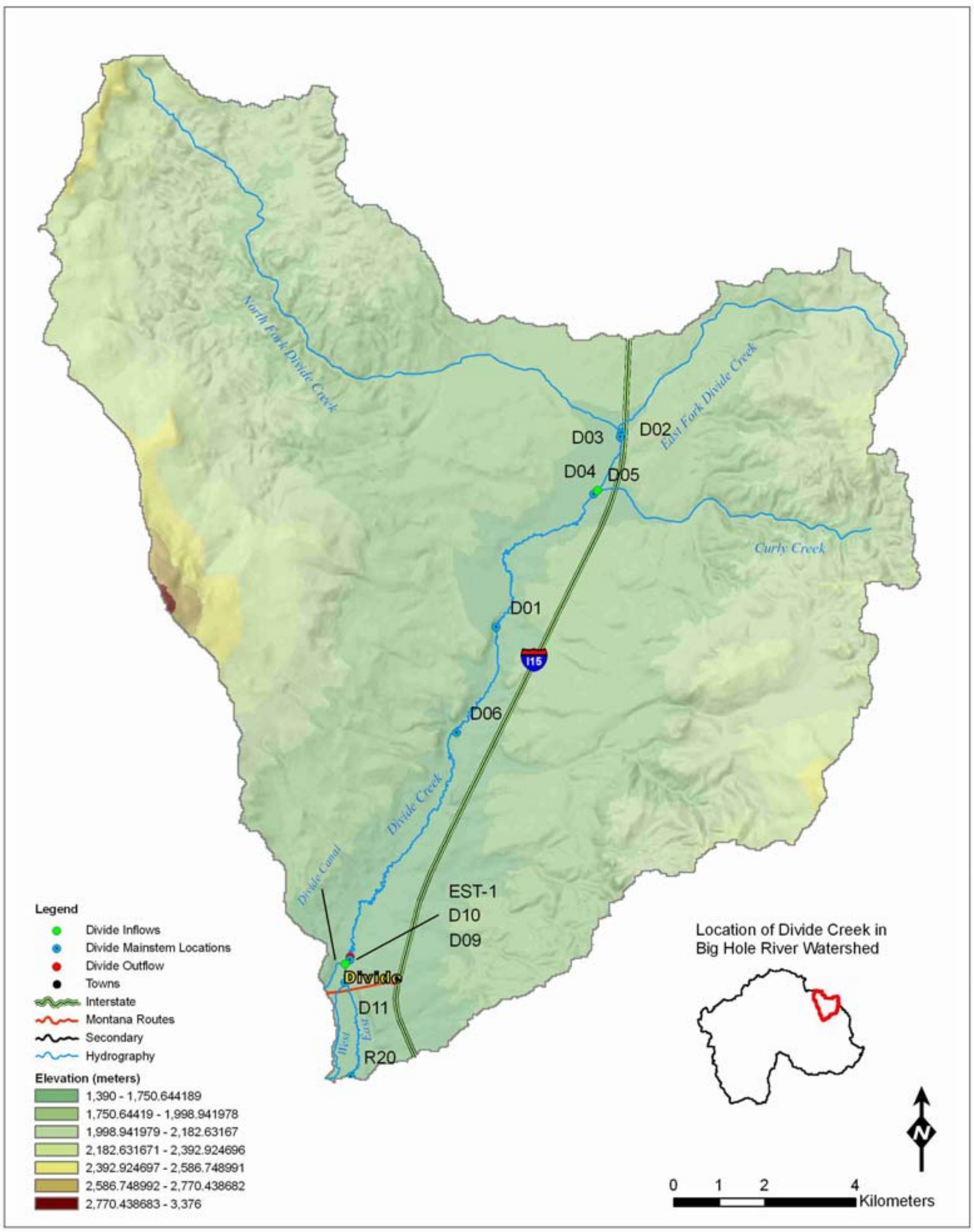
.

STUDY AREA

Divide Creek is a relatively small tributary to the Big Hole River that drains approximately 245-km2 (153-mi2) of low-elevation topography in the north-central portion of the watershed (**Figure J-1**). It is part of the Lower Big Hole River TMDL Planning Area (TPA), and extends south from the continental divide near Butte, MT to the town of Divide, MT. The North and East Forks form the headwaters, and flow approximately 24.9-km (15.5-mi) prior to reaching the Big Hole River. In the last 4-km of the project reach, the stream splits into two separate channels (east and west branches), appropriately near the town of Divide

.

Figure J-1. Divide Creek study area showing terrain, hydrography, and monitoring locations.



MODEL DEVELOPMENT

GIS Pre-processing

TTools was used for the initial setup of the Divide Creek model. The 30-m USGS National Elevation Dataset (NED) was used for calculation of topographic characteristics including elevation and gradient using digitized channel centerline and bankfull geometry. Riparian vegetation classification was completed by MDEQ using the 2004 National Agricultural Imagery Program (NAIP) photography at a scale of 1:5,000. Raster input files at a 1-m grid resolution were then developed for model pre-processing. Project coordinate system and datum were State-Plane NAD83 and NAVD88. A node distance of 50-m was for longitudinal sampling, and 1-m increments were used to determine landcover and shading attributes.

Simulation Period and Global Control Specifications

To maintain consistency with the mainstem modeling effort, the same simulation period of July 25 through 31, 2006 was used in the Divide Creek analysis. Additionally, a scaled down distance, and time-step of that of the mainstem model was used, 250-m and 5 minutes respectively.

Hydrology/Mass Transfer Input

Hydrology and mass transfer data from the 2006 field effort were used to define the overall water balance for the simulation reach (**Table J-1**). Due to the fact that the stream splits into two channels in the last 4-km, only the east channel was modeled as part of the analyses. This is because it appears to be the main natural conveyance for surface water, and that groundwater and unmeasured irrigation return flow appear to be the dominant influences on the western channel. Diurnal temperatures of dataloggers deployed in Divide Creek during the study are shown in **Figure J-2**.

Hydraulic Input

Hydraulic input for the Divide Creek model was developed using the Heatsourcev7.0 TTools extension. Manning's roughness coefficient was estimated from the mainstem modeling effort, and the three reaches were identified for unique parameterization of hydraulics based on channel gradient (**Table J-2** and **Figure J-3**).

Climate Input

The Bert-Mooney Federal Aviation Agency (FAA) station in Butte, MT was used for the Divide Creek modeling effort to be consistent with station assignments used in the mainstem modeling effort. Information regarding observations during the study period are included in the text of the mainstem modeling report.

Table J-1. Water balance for Divide Creek during the July 25-31, 2006 modeling period. All data are in cubic meters per second (m3/s).

DIVIDE CREEK WATER BALANCE 7/25-31/06		m^3/s	GWH_20 EST
D03 -NORTH FORK DIVIDE CREEK		**0.000**	↑
D02 - EAST FORK DIVIDE CREEK		0.010	-0.003
D04 - CURLY CREEK		0.002	↓
	TOTAL	**0.012**	**LOSING**
D05 - DIVIDE CREEK MAINSTEM (23.38 KM)		**0.009**	**0.009**
			↑
			-0.004
	TOTAL	**0.009**	**LOSING**
D01 - DIVIDE CREEK MAINSTEM (17.07 KM)		**0.005**	**0.005**
			↑
			0.012
	TOTAL	**0.005**	**GAINING**
D06 - DIVIDE CREEK MAINSTEM (13.30 KM)		**0.017**	**0.017**
EST1 - WEST BRANCH DIVIDE CR DVT		-0.016	0.000
	TOTAL	**0.001**	**BALANCED**
D10 - DIVIDE CREEK MAINSTEM (4.30 KM)		**0.001**	**0.001**
D09 - DIVIDE CANAL RTN		0.312	↑
			-0.048
	TOTAL	**0.313**	**LOSING**
D11 - DIVIDE CREEK MAINSTEM (3.65 KM)		**0.265**	**0.265**
			↑
			-0.180
	TOTAL	**0.265**	**LOSING**
R20 - DIVIDE CREEK OUTLET (0.00 KM)		**0.085**	**0.085**

Notes:
(1) D01, D02, R20, etc. – field ID (not necessarily in alphanumeric order)
(2) DVT = diversion
(3) RTN = return flow

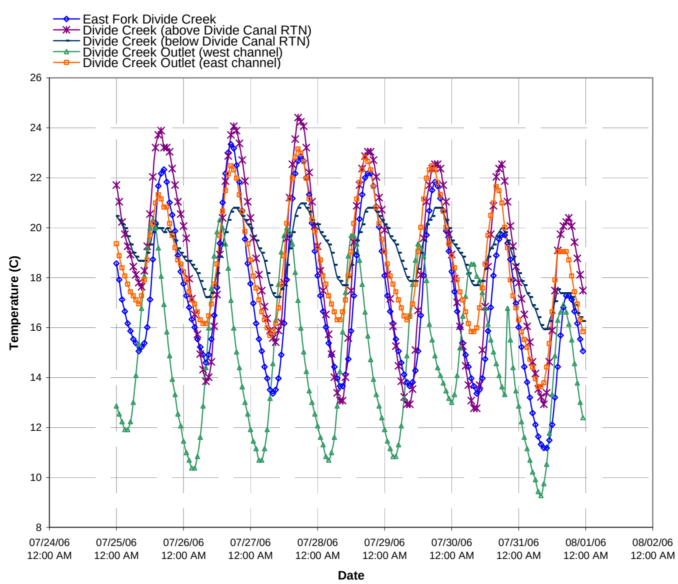


Figure J-2. Representative plots of water temperature in Divide Creek during the modeling period of July 25-31, 2006.

Shade Input

Eight riparian landcover types were identified through air photo interpretation, and ground-truth to parameterize typical reach shading attributes in the model (**Table J-3**). Verified model parameters were then assigned to corresponding land classes to complete the radial shading calculations in Heatsource v7.0.

Table J-2. Hydraulic parameters used in the Divide Creek Heatsource v7.0 model.

River Reaches	Gradient (%)	Width- Depth Ratio	Mannings "n"
Reach 1	2.4%	10	0.12
Reach 2	1.0%	10	0.12
Reach 3	0.1%	15	0.12

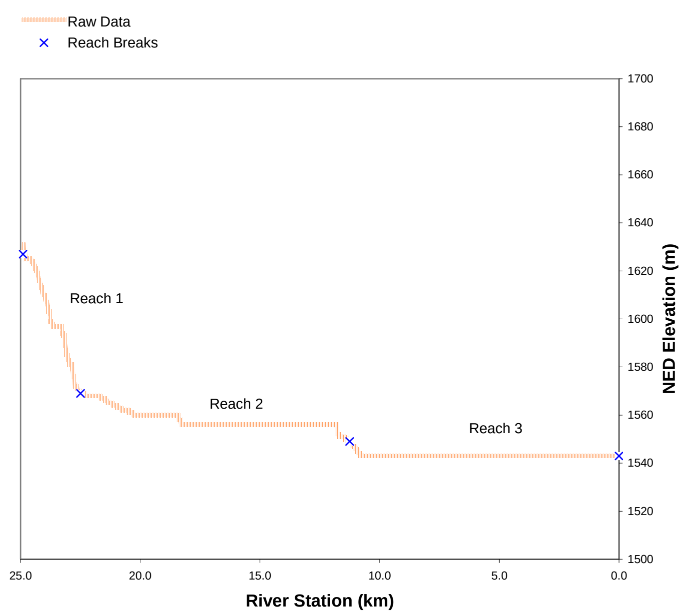


Figure J-3. Unique reaches defined for model parameterization of hydraulics. Elevation data taken from USGS National Elevation Dataset (NED) 30-m grid.

Table J-3. Riparian landcover types and associated attributes used in Heatsource v7.0 shading calculations.

Land Cover	Height (m)	Density (%)	Over-hang (m)
Bare	0.0	0%	0.0
Deciduous (sparse)	17.2	40%	3.0
Developed	0.0	0%	0.0
Grass/sedge	0.4	50%	0.0
NSDZ/water	0.0	0%	0.0
Pasture/field	0.5	90%	0.1
Transportation	0.0	0%	0.0
Willow (sparse)	4.9	40%	1.0
Willow (dense)	5.7	75%	1.5

RESULTS & DISCUSSION

Hydrology

Flow conditions in Divide Creek were difficult to reproduce in Heatsourcev7.0 due the extremely low flows (<0.01 cms), and the number of significant figures carried in the model calculations. As a result, hydrology had a poor statistical calibration as evidenced by an average PBIAS of 281.6 percent (e.g. comparing daily simulated flow values with instantaneous field-measurements). However, given that the standard error is quite low (e.g. 0.005 cms or 0.2 cfs), it is apparent that the model is performing satisfactorily. Observed and predicted results for July 28th of the July 25-31, 2006 modeling period confirm this observation, and are shown in **Figure J-4.**

Hydraulics

A comparison of model hydraulics against measured field data is also shown in **Figure J-4**. In general, acceptable agreement is seen between observed and simulated velocities, and wetted widths. Mean PBIAS for computed channel velocities, and wetted widths were 264.9 percent and -93.5 percent, respectively. Standard errors were 0.05 m/s and 0.1 meters. Again, this illustrates the propensity for relatively small simulation errors to manifest as large errors in PBIAS.

Shade

Simulated stream shade is shown in **Figure J-5**. Predictions ranged from approximately 10 to 90 percent, and averaged 22.2 percent for the study reach. A majority of the shade was observed in the upper 5-km due to extensive willow canopy, and a very narrow channel. Modeled shade appears to track adequately with observed measurements, and overall simulation PBIAS was 57.5 percent with a standard error (in percent shade) of 4.3 percent.

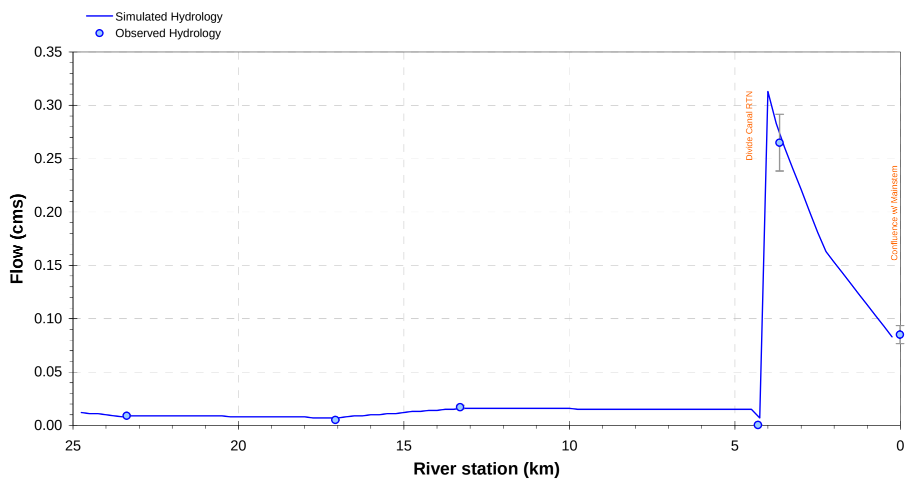
Water Temperature

Hourly diurnal temperature plots for the simulation period are shown in **Figure 6**. The longitudinal temperature profile is shown in **Figure 7**. Clearly the model performs best in the lower two reaches, which contain the highest flow volume. In review of the temperature calibration, average PBIAS was 2.0 percent, NSE was 0.33, SSQR = 493.2, and standard error = 1.7°C. Individual calibration statistics for model calibration nodes are shown in Table J-4. Overall, there appears to be acceptable agreement between observed and predicted water temperatures. This demonstrates the utility of the model for TMDL planning.

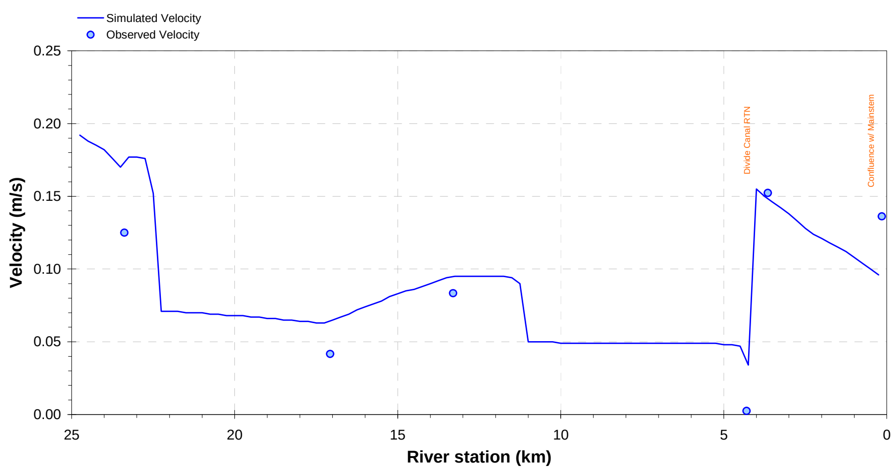
Table J-4. Hourly water temperature calibration statistics for July 25-31, 2006 modeling period.

Site ID	PBIAS	NSE	SSR	SE
River km – 23.38 (D05)	6.5%	0.49	162.9	0.6
River km – 17.07 (D01)	3.4%	<0	1,072.1	3.1
River km – 13.30 (D06)	-1.5%	<0	737.7	1.7
River km – 04.30 (D10)	1.6%	0.00	898.2	2.9
River km – 03.65 (D11)	-0.2%	0.92	11.0	0.3
River km – 00.01 (R20)	1.9%	0.59	77.0	1.4
AVG	2.0%	0.33	493.2	1.7

a)



b)



c)

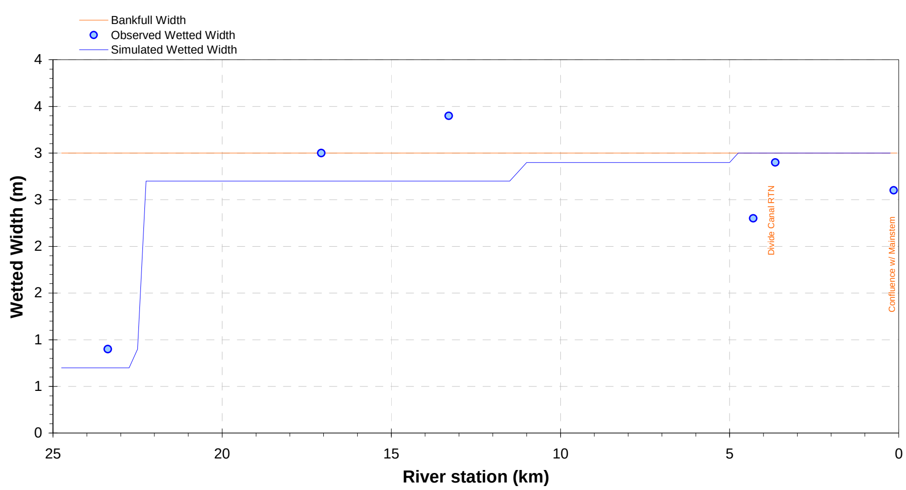


Figure J-4. Simulated and observed hydrology and hydraulics for Divide Creek: a) hydrology, b) mean channel velocity, and c) mean wetted width for July 28th of the July 25-31, 2006 modeling period. Observed measurements were taken instantaneously over the study period and may not necessarily reflect conditions that day.

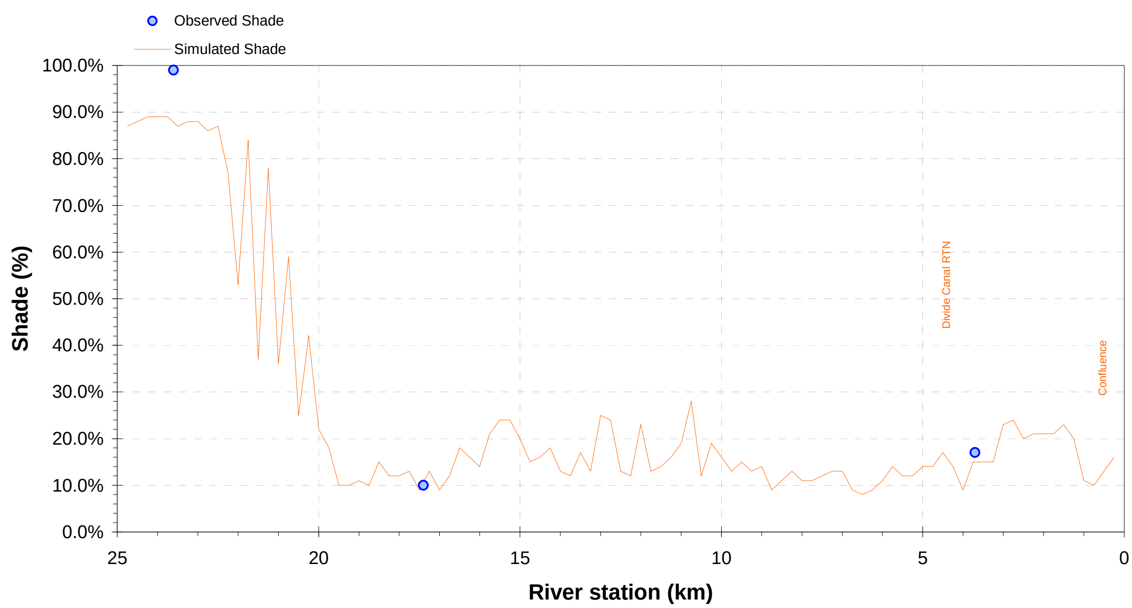


Figure J-5. Simulated stream shade for the July 28th of the July 25-31, 2006 modeling period.

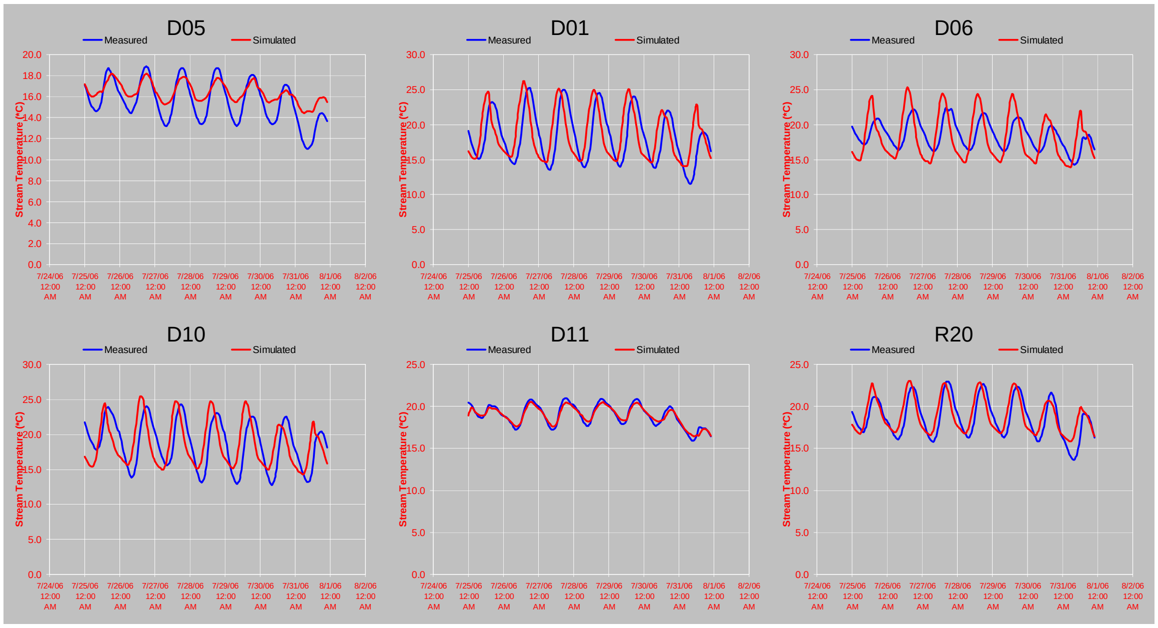


Figure J-6. Diurnal plots of observed and simulated temperature on Divide Creek during the July 25-31, 2006 modeling period. Nodes are order from up to downstream going from left to right and top to bottom.

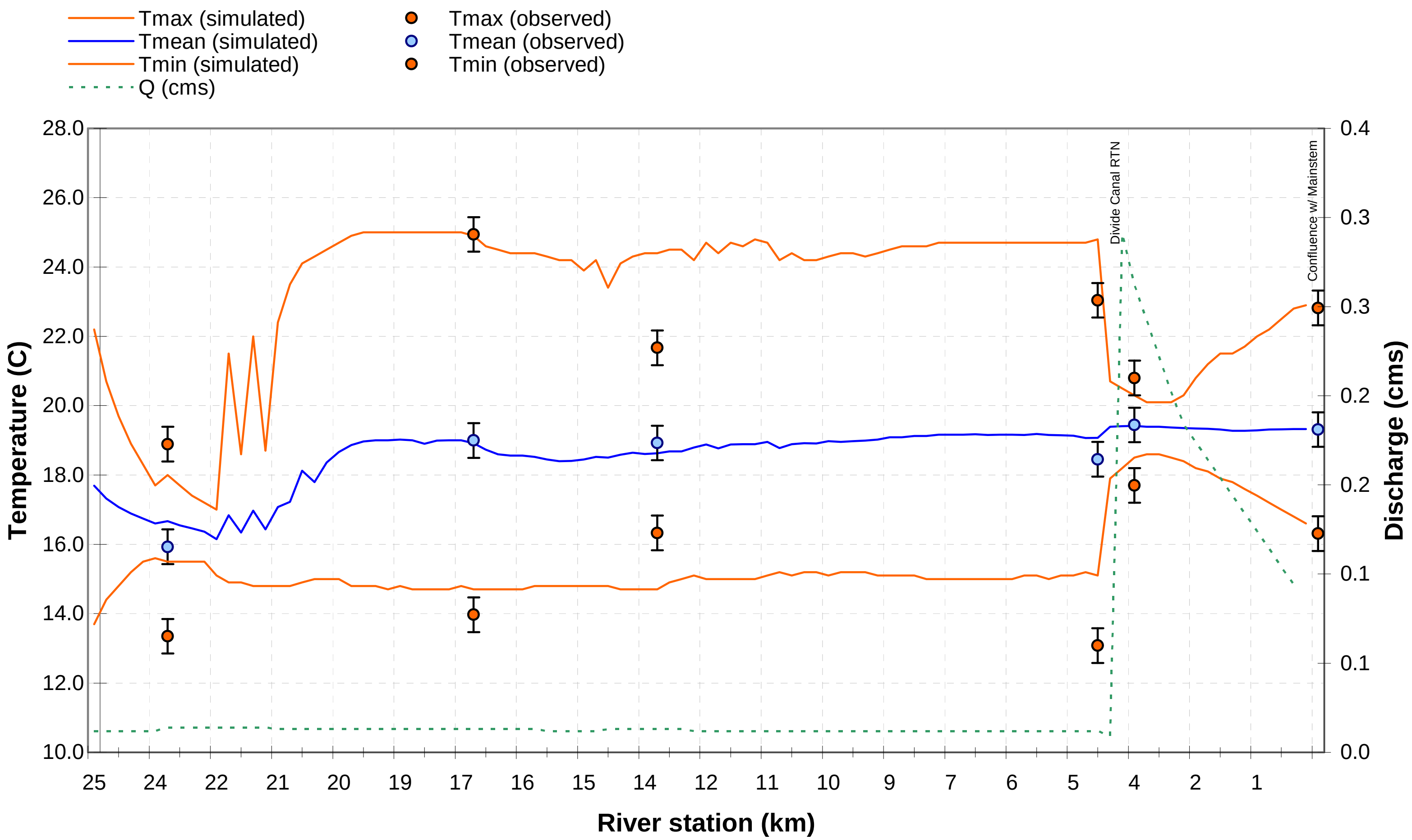


Figure J-7. Longitudinal temperature profile of Divide Creek displaying Tmin, Tmax, Tavg, and discharge for July 28th of the July 25-31, 2006 modeling period. Error bounds of measured data (±0.2 ºC datalogger accuracy) are shown along with major inflows and outflows.

SCENARIO ANALYSIS

Following model development, a number of scenarios were formulated so that watershed managers can provide reasonable recommendations for meeting water quality criteria in the river. Specifically, modeling scenarios addressed the following: (1) baseline conditions, (2) a shade scenario in which reference shade was applied across the project reach, (3) water consumptive use scenario where effects of irrigation, and domestic withdrawls were assessed, (4) a second flow scenario where the effects of irrigation return flow from the Big Hole River were addressed, (5) a natural condition scenario with no anthropogenic influence, and (6) naturally occurring scenario in which all reasonable land, soil, and water conservation practices were applied (ARM 17.30.602).

Baseline Scenario

The baseline scenario describes existing conditions, and is merely a reflection of the calibration. The simulation results have been documented in prior sections and indicate a marginal water temperature calibration based on performance statistics of NSE, PBIAS, and SSR. Simulated values from the baseline scenario form the basis for which all other scenarios will be compared. For the rest of the document, temperature comparisons are reported as the 7-day minimum (7Dmin), 7-day average (7Davg), and 7-day maximum (7Dmax) temperature.

Shade Scenario

Shade was assessed to identify its potential influence on water temperature in Divide Creek. A shading scenario was run to characterize the maximum possible influence of stream shade on in-stream temperature based on the following assumptions: (1) all open/grassed sites, barren areas, and any other area with diminished shading vegetation was assumed to be converted to reference shade condition and (2) all other conditions were held constant. Reference shade was defined as the combination of 80 percent willow and 20 percent grass, which is identical to the assumptions made in the mainstem study. Results indicate that average shade would be increased from 22.2 percent to 27.2 percent (e.g. 5 percent) which translates to an average 7Dmax decrease of 0.25°C (0.45°F) at the watershed outlet. The decrease in temperature averaged 0.19 (0.34°F) across all modeling nodes. From review of the shade scenario, minor standard violations were observed at a number of locations in the study reach (e.g. change of >0.23°C; mostly in 7Dmax). Because of this, riparian improvement activities are recommended from stream kilometer 22.0-12.0 and 7.5-4.0 km, to mitigate these impacts. Baseline and simulated shade, along with associated in-stream water temperatures are shown in **Table J-5** and **Figure J-8**.

Table J-5. Temperature changes resulting from modification of shade on Divide Creek.

Condition	% Shade	Tmin	Tavg	Tmax
Baseline	22.2%	16.44	18.88	22.19
Shade Scenario	27.2%	16.51	18.77	21.94
Δ TEMP-Outlet		+0.07	-0.11	-0.25
Δ TEMP – all (1)		+0.08	-0.07	-0.19

(1)Average deviation of all model nodes, not just watershed outlet

Water Consumptive Use Scenario (Flow-1)

The water consumptive use scenario describes the thermal effect of irrigation, and domestic water use directly from Divide Creek. For the purpose of this scenario, natural stream hydrology was simulated including the removal of irrigation withdrawals, or associated return flows from Divide Creek (including any known inter-basin transfer to or from the drainage). Because of this, the baseline model run was first reformatted to exclude the Divide Canal return flow which was significantly altering temperatures in the lower 4-km of the study reach. In completion of the scenario, it was apparent that very little water was actually available for diversion in Divide Creek. An estimated 0.008 cms (0.28 cfs) was transferred to the west fork of Divide Creek near stream km-4.35. This withdrawl was inferred to be for irrigation, however, since no direct field observations were made regarding the water use, the assumption was characterized as highly uncertain. If irrigation was the reason for removal, modeling results show that standard violations would occur downstream of the diversion, and 7Dmax and 7Dmin temperatures would be 0.57 and 2.47°C cooler (1.03 and 4.5°F) without it (**Table J-6** and **Figure J-8**). However, the uncertainty regarding assumptions in this scenario should strongly be considered by managers and used with caution in interpretation of results.

Table J-6. Temperature changes resulting from water consumptive use in Divide Creek.

Condition	Q (cms)	Tmin	Tavg	Tmax
Baseline(1)	0.011	17.50	20.55	24.51
Flow-1 Scenario	0.019	15.03	18.69	23.94
Δ TEMP-Outlet		-2.47	-1.86	-0.57
Δ TEMP – all (2)		-0.26	-0.19	-0.11

(1) Baseline taken at 0.50-km; channel dry at 0.25-km
(2) Average deviation of all model nodes, not just watershed outlet

Irrigation Return Flow Scenario (Flow-2)

The Divide Canal return flow from the Big Hole River was identified in the previous section as having a significant influence on water temperature in Divide Creek. Therefore a second irrigation return flow scenario was developed to ascertain how the removal of this water would affect in-stream temperature in Divide Creek. Assumptions of this scenario included those already made in the first irrigation scenario, with the focus specifically being the effect of the Divide Canal. In review of the results, return flow from the canal is actually a benefit to Divide Creek, buffering temperatures, and adding to instream flow. 7Dmax and 7Dmin would be 2.80 and 0.63°C warmer without it (5.04 and 1.13°F) (**Table J-7** and **Figure J-8**). When compared to the previous irrigation scenario, it is apparent that the effects of the canal far outweigh those occurring from irrigation within Divide Creek, thus it is the opinion of DEQ that the return flow is of benefit to Divide Creek

Table J-7. Temperature changes from Divide Canal Irrigation return flow.

Condition		**Tmin**	**Tavg**	**Tmax**
Baseline(1)		17.50	20.55	24.51
Flow-2 Scenario		16.87	18.88	21.71
Δ TEMP-Outlet		-0.63	-1.67	-2.80
Δ TEMP – all (2)		+0.13	-0.14	-0.58

(1) Baseline taken at 0.50-km; channel dry at 0.25-km
(2) Average deviation of all model nodes, not just watershed outlet

Natural Condition Scenario

The natural condition scenario reflects the temperature regime that would be expected absent of the influence of man. While this type of scenario is clearly not realistic from a socio-economic standpoint, it does afford the ability to characterize the extent of departure from natural conditions, and subsequently, the maximum potential improvement in the watershed. For the purpose of the study, natural conditions were defined as the removal of all human influences that affect heat or mass transfer. Natural condition scenario assumptions include the following: (1) reference shade conditions were applied as described in the shade scenario, (2) the same irrigation and consumptive use conditions as in the water consumptive use scenario were applied (e.g. natural system hydrology), and (3) no other associated changes. Results of the natural condition scenario parallel that of the flow scenarios, and indicate that maximum temperatures in Divide Creek would actually be warmer if returned to natural conditions (e.g. no return flows from the Big Hole River). 7Dmax would increase by 0.90 (1.62°F), while 7Dmean and 7Dmin would decrease (**Table J-8** and **Figure J-8**). It appears overall, that natural conditions are less desirable to aquatic life than that of existing condition.

Table J-8. Temperature changes resulting from natural conditions in Divide Creek.

Condition		**Tmin**	**Tavg**	**Tmax**
Baseline		16.44	18.88	22.19
Natural Scenario		15.19	18.50	23.09
Δ TEMP-Outlet		-1.25	-0.38	+0.90
Δ TEMP – all (1)		-0.14	-0.32	+0.28

(1)Average deviation of all model nodes, not just watershed outlet

Naturally Occurring Scenario (ARM 17.30.602)

The naturally occurring scenario defines water temperature conditions resulting from the implementation of all reasonable land, soil, and water conservation practices (LSWCP) as outlined in ARM 17.30.602. Essentially, "naturally occurring" establishes the bar for which the allowable 0.23°C (0.5°F) temperature increase is compared to. Assumptions used in the development of the naturally occurring scenario include the following: (1) identical shade conditions to those described in the shade scenario, (2) a 15 percent reduction in the assumed 0.008 cms irrigation withdrawl to the west fork channel, and (3) a reduction of 15 percent in the return flow from the Divide Canal and associated withdrawls (per the assumptions in the mainstem modeling effort). Results of the scenario very much parallel the shade scenario, suggesting that under naturally occurring conditions (as defined by state law) shade would be the primary TMDL necessity to decrease water temperatures in Divide Creek. Standard violations still occur at stream kilometer 22.0-12.0 and 7.5-4.0 km (**Table J-9** and **Figure J-8**), and 7Dmax and 7Dmin would be 0.09 and 0.11°C cooler than current (0.16 and 0.20ºF). Therefore, the primary management recommendation coming from this study is to prioritize and address reaches for shade improvement as part of the upcoming TMDL effort.

Table J-9. Temperature changes resulting from naturally occurring conditions in Divide Creek.

Condition		Tmin	Tavg	Tmax
Baseline		16.44	18.88	22.19
Naturally Scenario		16.33	18.75	22.10
Δ TEMP-Outlet		-0.11	-0.13	-0.09
Δ TEMP – all (1)		+0.05	-0.07	-0.17

(1)Average deviation of all model nodes, not just watershed outlet

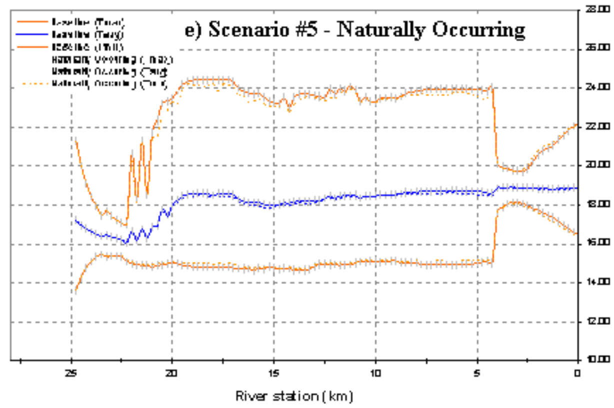
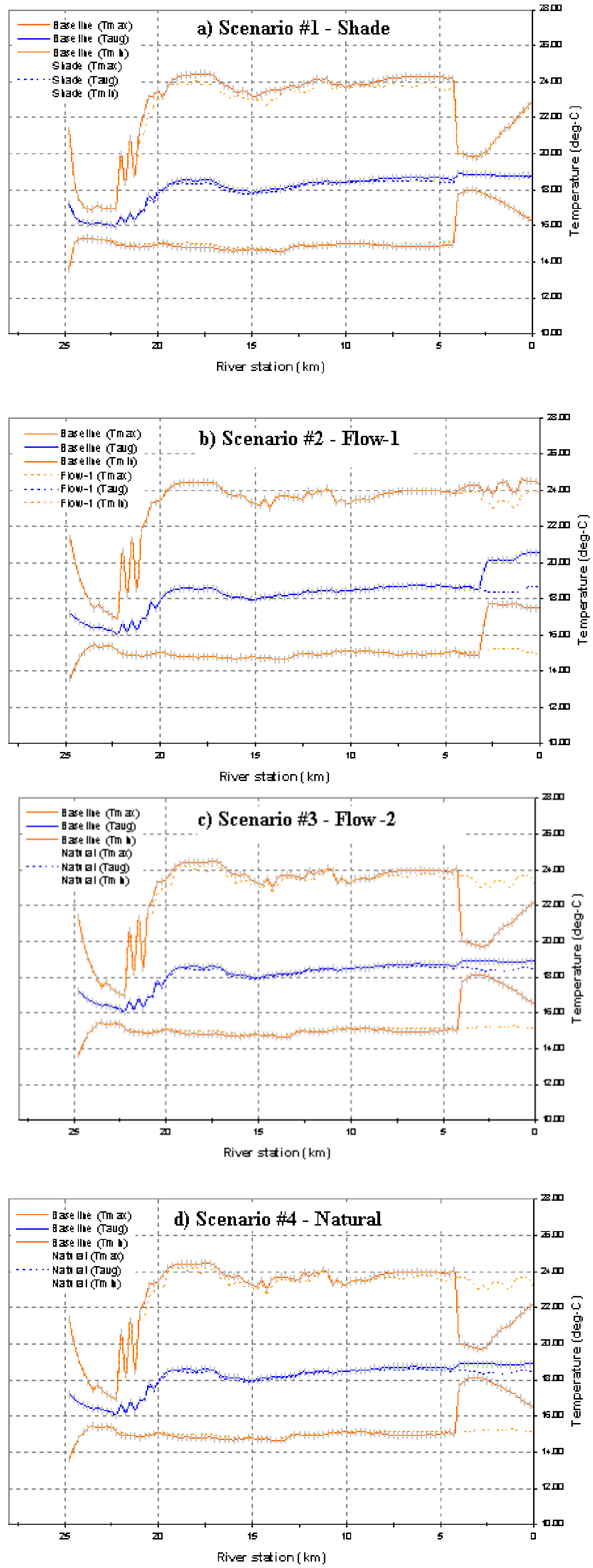


Figure J-8. Longitudinal temperature effects of management scenarios on Divide Creek. The grey shaded area represents ±0.23ºC degree variation from that of baseline conditions. Scenarios that deviate outside the 0.23ºC boundary indicate potential impairment.



CONCLUSION

Modeling was completed on Divide Creek using Heatsource v7.0 to better understand the relationship between instream water temperature, riparian conditions, and water management practices for the summer critical low-flow period. Through scenario analysis, it was shown that shade, and riparian corridor enhancement were the primary mechanisms for achieving “naturally occurring conditions” in the watershed. Thus the key management recommendation originating from this study is to protect and reestablish effective riparian areas to the extent possible. In-stream flow was also shown to be important to stream thermodynamics, and return flow from the Big Hole River (e.g. Divide Canal) was found to buffer maximum and minimum water temperatures in the lower reaches of Divide Creek. Finally, irrigation from within Divide Creek itself was also assessed, and was found to be a potential source of impairment in the watershed. This conclusion was constrained by uncertainty in field data and further study is warranted to make concrete determinations about associated impacts, if any.

REFERENCES

Please refer to main document

APPENDIX K
RESPONSE TO PUBLIC COMMENTS

As described in **Section 12.0**, the formal public comment period for the Upper and North Fork Big Hole River TMDLs extended from February 16th, 2009 and extended through March 20th, 2009. Three individuals/organizations submitted formal written comments during the public comment period. Excerpts of the comments have been organized by primary topics in this section. Responses prepared by DEQ follow each of the individual comments. The original comment letters are located in the project files at DEQ and may be reviewed upon request.

1. General TMDL Process and Considerations

Comment 1.1: A significant omission in the draft TMDL plan is that DEQ does not address nutrient impairment of several streams on both the 1996 *and* 2006 303 (d) lists. On page 22, DEQ states that certain pollutants were not addressed "due to project budget and time constraints." Also, on page 193 DEQ lists several nutrient impaired streams, including Fishtrap, Gold, Charcoal, Sawlog, and Wickiup creeks, and states that these watersheds were not sampled due to the "timeframe of the listings and this project." DEQ dismisses the development of these TMDLs by stating that they will be addressed by future efforts.

> **Response 1.1:** Section 1.2 was edited to reflect that the project budget did not impose limitations on pursuing impairment listings for this TPA. The Integrated Report listing process is ongoing, and not a stagnant process between reports. Because of this, a portion of the nutrient listings in the TPA which appear on the 2006 list did not become evident in time for inclusion into this project, while other 2006 nutrient listings were evident at project initiation. Fishtrap, Gold, Charcoal, Sawlog, and Wickiup creeks were listed after the nutrient portion of this TMDL project was initiated. After a certain timeframe during each TMDL project, DEQ can not easily incorporate TMDLs for new pollutant/water body listings.
>
> A TMDL was not completed for a 1996 nutrient listing for the Big Hole River because there was not sufficient information to indicate if a TMDL is needed, new numeric standards may apply in the near future, and it was not identified for potential nutrient impairment on the current impaired waters list at project initiation. Alternatively, this project did monitor nutrient conditions in the Big Hole River for use in future impairment listing assessment activities and possible nutrient TMDL development.

Comment 1.2: DEQ similarly postpones the development of TMDLs for sediment in Twelvemile and Wickiup creeks. Although an adaptive management approach such as in section 10 is to be commended, the indefinite postponement of TMDLs for pollutants addressed on the 303 (d) lists is not justified. We are concerned about open ended delays for TMDL development for pollutants because of a lack of resources. Certainly, a large portion of our membership works for state and federal agencies, and we understand limited budgets and time constraints. Still, the indefinite delays present a concern.

Response 1.2: Section 5.2 was edited to indicate that the impairment listing timeframe for these pollutant/water body combinations was later than the TMDL project initiation timeframe. After a certain timeframe during each TMDL project, DEQ can not easily incorporate TMDLs for new pollutant/water body listings. The sediment listings for Twelvemile and Wickiup Creek are not addressed within this document and will be addressed during future TMDL development.

2. Water Quantity and Temperature

Comment 2.1: First, I am pleased about the emphasis on river temperature and the effect of water withdrawal on water temperatures in the lower reaches of the river. I believe that the lower river from the Notch Bottom to the confluence has great potential for fisheries improvement, but for that to happen there will have to be improvements in water quantity and water quality. In 2009 Fish Wildlife, and Parks will begin monitoring the fish population in this area of the river to establish a baseline of fisheries information. With the cooperation of local water users, the Big Hole Watershed Group is involved in current projects aimed at improving water quality and quantity in the lower river. It is our hope that, through cooperative efforts between water users, the watershed group and government agencies, water quantity and quality can be improved in the lower river, resulting in improvements to aquatic habitat and recreational fisheries.

Response 2.1: DEQ hopes local interests pursue restoration of water quality issues in the Big Hole River Watershed. DEQ promotes coordinated efforts to address water quality restoration. As stated, temperature impacts are related to water quantity in the Big Hole River above Wisdom and downstream of Notch Bottom. The nonpoint source program at DEQ is designed to assist local objectives which will result in water quality restoration.

Comment 2.2: One aspect of flow improvement that I feel was omitted from the document is the importance of tributary stream inputs to the main river to moderate flows and temperature. Most of the tributaries that enter the Big Hole from Pintlar Creek downstream flow from high mountain peaks through heavily forested areas. Because of this, stream temperatures are often less than those that may be present in the mainstem Big Hole River. Several substantial tributary streams from the Pintlar Creek to the mouth are dewatered. If improvements to irrigation systems and infrastructure could be made to maintain flows in these streams, substantial improvements in flows and temperature are possible in the Big Hole River. Streams that may fit into this category could include Mudd Creek, Seymor Creek, Wise River, Divide Creek, Moose Creek, Camp Creek, Rock Creek, Willow Creek, and Birch Creek. This is not a comprehensive list and it is not clear what, if anything, could be done to improve stream flows; however, opportunities likely exist to improve water quality and quantity in the Big Hole River through tributary inputs. Improvements in flow in these tributary streams will also likely benefit fisheries by maintaining connectivity between spawning and rearing streams and the main river. Improvements could also benefit other native aquatic species like the pearlshell mussel.

Response 2.2: DEQ agrees that water management in the tributaries may affect stream flow and thermal conditions in the Big Hole River. **Tables 8-10 and 8-11** were amended to include tributary irrigation water management into the TMDL allocations for the Big Hole

River. Tributary irrigation water management was also added to the restoration and adaptive management sections (8.7 and 9.4.4) of the document.

Comment 2.3: Similar to the TMDL developed for the upper Big Hole River, this TMDL acknowledges the relationship between dewatering and temperature, and the MCAFS applauds DEQ for addressing dewatering as a cause of thermal loading. Nonetheless, by not addressing temperature in the many dewatered tributaries, this plan is limited in its ability to protect cold water fisheries. Dewatered tributaries act as point sources of thermal loading to the main stem, and the load allocation portion of the TMDL should have reflected these inputs. DEQ uses this approach in identifying watershed scale contributions of sediment, and the same principles apply. Moreover, in the Big Hole River, Arctic grayling, and presumably other fishes, seek thermal refuge in tributaries during summer months, and limiting the analysis of temperature to the main stem and a single tributary ignores seasonal habitat use. Identifying dewatered tributaries with potential to maintain greater flow through cooperative agreements with irrigators would have provided a pragmatic approach to improving water quality, and protecting sensitive species. This sort of analysis could have an important nexus to the restoration and conservation efforts currently underway in the watershed lead by Montana Fish Wildlife and Parks and the Big Hole Watershed Committee, among others.

Response 2.3: See response to comment 2.2. The comment is correct in that tributaries do act as thermal sources to the Big Hole River. Allocation tables were updated to reflect this source of potential heating. The adaptive management and monitoring sections of the document were also updated to include follow up monitoring of tributary irrigation water management practices and tributary influences on the Big Hole River.

Comment 2.4: The draft TMDL and water quality restoration plan for the middle and lower Big Hole River is an improvement over recent plans because it addresses the link between temperature and dewatering. Nonetheless, to address thermal loading effectively, DEQ should have taken a watershed scale approach, as occurs with basin-wide sediment load modeling.

Response 2.4: Montana DEQ addresses stream flow and irrigation water management for temperature TMDLs where it appears to be an influencing factor upon thermal conditions. In some of Montana's TMDL Planning areas where TMDLs have been completed, irrigation management did not appear to influence stream temperatures considerably, and therefore it was not necessary to address flow within the context of TMDL development and meeting Montana water quality standards. See responses to comment 2.2 and 2.3 for response to the watershed approach to thermal modeling.

3. Sediment

Comment 3.1: There are a few specific areas of concern that currently impact fisheries in the area covered by the lower Big Hole TMDL. First is the area near upper California Creek. This area has been severely impacted by the Anaconda smelter operations. Fallout from the smelter has destroyed the vegetation on the hill slopes resulting in chronic erosion and fine sediment inputs into California Creek and later into French and Deep creeks. Reclamation of similar areas on the Pacific side of the Continental Divide are underway using settlement funds; however, funding from this source is not currently available for areas on the Atlantic side of the Continental Divide. Chronic fine sediment loads from California Creek are likely resulting in significant impacts to fisheries and other aquatic organism. Pearlshell mussels are particularly sensitive to high amounts of fine sediment and there is a population of these mussels in Deep Creek, downstream of California and French creeks. It is unknown whether mussels are present in either California or French creeks, but it is likely that they were present historically. Reclamation of this area should be a high priority to improve water quality in the drainage.

> **Response 3.1**: The TMDL identifies sediment issues derived from vegetation suppression due to smelter fallout in Section 9.4.1 Table 9-1. Also, Table 5-68 was updated to reflect smelter fallout as a source addressed by the sediment TMDL allocation. DEQ contacted Montana NRDP during the TMDL project to express smelter fallout concerns in the Big Hole Watershed and the fact that NRDP boundaries are set to the west of the continental divide near this area of concern.

Comment 3.2: Another important area that is being impacted by fine sediment inputs is upper Trapper Creek. Trapper Creek is home to native westslope cutthroat trout. Fine sediment from existing roads and from past mining sites likely negatively affect fisheries habitat and fish populations in the drainage. Many sections of the main Trapper Creek road upstream of Sappington Creek to the top of the drainage suffer from chronic fine sediment erosion. Fine sediment originating from roads is entering stream networks and likely having substantial impacts on aquatic habitats. Brook trout are also present in Trapper Creek and compete with the native cutthroats. High fine sediment loads tend to favor the non-native brook trout, which have less stringent spawning requirements than westslope cutthroat trout. Addressing the issues of fine sediment loading from roads and mining areas should also be a priority of future restoration activities.

> **Response 3.2:** Unpaved roads are identified as a source of sediment in the Trapper Creek Watershed and provided a sediment allocation on a percent reduction basis. Section 5.6.25 and Table 9.1 were amended to provide a larger focus on sediment reductions from unpaved roads. Additional language was added which explains that roads may be a localized source and may affect uses in specific areas of the watershed even though loads appear to be small compared to other sources in the watershed.

4. Metals

Comment 4.1: One last area of concern that does not appear to have been monitored for water quality, particularly as it relates to potential mining impacts, is the upper reaches of Moose Creek. Fisheries surveys in the area indicate that there may be mining related water quality impacts in the North Fork Moose Creek. This may be a location to perform additional water quality measurements to determine if historic mining activities are having an impact on water quality.

> **Response 4.1**: Table 10.2 was updated to incorporate this comment into guidance for future monitoring activities.

5. Water Quality Restoration

Comment 5.1: In regard to water quantity, I believe this plan did not address the potential to increase flows through vegetative manipulation. I am generally concerned about timber harvest and the positive impacts it has on the water budget. Using BMP's and improved logging methods would mitigate many of the negative impacts associated with logging. Increasing instream flows has a positive impact on most of the water quality issues. It has been my experience in dealing with resource and wildlife issues in the last 20 years, that objective science is lacking on both sides. Many of these scientific studies are designed toward a predetermined outcome and are used west wide rather than on a site specific basis. The ability of a forested canopy to intercept and evapo-transpire precipitation is huge and needs to be considered in addressing water quantity. This needs to be considered in this exercise.

> **Response 5.1:** There exists considerable debate about both the extent and nature of human-caused changes in the forest landscape, and the need and means to address those changes. Though not explicitly addressed within the TMDL and allocations section of this document, Section 9.4.5 (restoration section) was amended to address this comment by including a discussion of forest management, conifer density and water yield.

Comment 5.2: Not much is known in the basin about underground storage capacities and the eventual return flows. There have been a few site specific studies that shed some light; we need to know more. Underground storage is most efficient, returns water to the stream at a later date and at a lower temperature in the summer and a higher temperature in the winter. An effort to identify areas in the basin that have the capacity to store water under ground during high flow with resulting delayed return flows is a way to address instream flows and water temperature. This needs to be addressed at least as a tool in this TMDL.

> **Response 5.2:** The irrigation system in the Big Hole River Watershed likely acts as a groundwater storage system from early season irrigation while at the same time providing stream dewatering at potentially critical low flows. Future studies should investigate irrigation water return flow timeframes from specific areas along the Big Hole River and tributaries. A portion of spring and early summer flood irrigation water likely returns as cool groundwater to the River during the heat of the summer. These critical areas could be identified so that they can be preserved as flood irrigation areas, with water use improvement practices for irrigation during periods of low flow and elevated temperatures. Other irrigated areas which do not contribute to summer groundwater returns to the river should be identified as areas were irrigation efficiencies are beneficial to preserving flow in the River during hot summer timeframes. The quantity of winter baseflow should also be considered during these investigations. Section 9.5.4.1, Irrigation and Stream Flow Restoration Recommendations, was amended to address this comment.

Comment 5.3: The health of the riparian area as it relates to shade and cooler water temperatures is important. In the lower Big Hole between Melrose and below the Notch Bottom, the beaver is doing significant damage to the cottonwood stands along the river. We have fenced the entire river along our land above Glen to enhance the riparian character of the bank to naturally armor the bank against erosion. This practice also increases brush, trees and results in more shade. The beaver caused riparian damage and their control certainly should be addressed in this document.

> **<u>Response 5.3:</u>** Though not explicitly addressed within the TMDL and allocations section of this document, Table 9.3 in the Restoration Section was amended to include beaver and wildlife management. The following language was added to the table:
>
> > "Monitor and manage beaver populations to trap sediment and slow runoff in some areas of tributaries. If appropriate, manage beaver populations on Big Hole River to reduce riparian tree mortality. "
>
> Thank you for your stewardship of the riparian area.