# Low pH Total Maximum Daily Loads for the Youghiogheny River Basin in Garrett County, Maryland

**FINAL**

MARYLAND
DEPARTMENT OF THE ENVIRONMENT

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## ABBREVIATIONS

| | |
|---|---|
| AMD | acid mine drainage or acidic mine discharge |
| BASINS | Better Assessment Science Integrating Point and Nonpoint Sources |
| $CaCO_3$ | calcium carbonate |
| CAIR | Clean Air Interstate Rule |
| CFR | *Code of Federal Regulations* |
| cfs | cubic feet per second |
| $CO_2$ | carbon dioxide |
| COMAR | Code of Maryland Regulations |
| COOP | Cooperative Observer Network |
| DEM | Digital Elevation Model |
| DMR | discharge monitoring report |
| DOC | dissolved organic carbon |
| EPA | U.S. Environmental Protection Agency |
| FA | future allocation |
| $Fe(OH)_3$ | ferric hydroxide |
| $Fe^{+2}$ | ferrous iron |
| $Fe^{+3}$ | ferric iron |
| $FeS_2$ | iron sulfide |
| gpm | gallons per minute |
| $H^+$ | hydrogen ion |
| HSPF | Hydrologic Simulation Program FORTRAN |
| LA | load allocation |
| lb/d | pound per day |
| lb/yr | pound per year |
| MDAS | Mining Data Analysis System |
| MDE | Maryland Department of the Environment |
| MDP | Maryland Department of Planning |
| mg/L | milligrams per liter |
| mgd | million gallons per day |
| MOS | margin of safety |
| MSTLAY | Moisture Storage and Transport in Soil Layers |
| N | nitrogen |
| NCDC | NOAA's National Climatic Data Center |
| NHD | National Hydrography Data |
| NOAA | National Oceanic and Atmospheric Administration |
| $NO_x$ | nitrogen oxides |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| PCS | Permit Compliance System |
| SIC | standard industrial classification |
| SMCRA | Surface Mining Control and Reclamation Act |
| $SO_2$ | sulfur dioxide |
| STATSGO | State Soil Geographic Database |
| STORET | EPA's STOrage and RETrieval water quality database |

| | |
|---|---|
| TMDL | Total Maximum Daily Load |
| USGS | U.S. Geological Survey |
| WBAN | Weather Bureau Army-Navy |
| WLA | wasteload allocation |
| WQLS | water quality limited segment |
| WVDEP | West Virginia Department of Environmental Protection |
| WWTP | wastewater treatment plant |
| µeq/L | microequivalents per liter |
| µg/L | micrograms per liter |
| µS/cm | micro Siemen per centimeter |

## EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for impaired waterbodies. A TMDL establishes the amount of a pollutant that a waterbody can assimilate without exceeding its water quality standard for that pollutant. TMDLs provide the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991).

The Youghiogheny River watershed (Maryland basin number - 05020201) is in western Maryland. The Youghiogheny River flows through portions of West Virginia, Maryland, and Pennsylvania. The headwaters originate on Backbone Mountain in northern West Virginia (Preston County) and western Maryland (Garrett County). The river flows north through part of Maryland and through a small part of northern West Virginia before it enters Pennsylvania at the Youghiogheny River Lake. The river continues to flow north to its confluence with the Monongahela River in Pennsylvania. The Youghiogheny River watershed is dominated by forest (60 percent) and agriculture (27 percent). Urban land use accounts for less than 10 percent of the total watershed area and is mostly concentrated around rivers and other waterbodies.

The Youghiogheny River was identified on the state's list of water quality limited segments (WQLSs) as impaired by low pH (1996 listing), sediments (1996/2002 listing), and impacts to biological communities (2002/2004 listing). Previously, the Youghiogheny River was listed for nutrients on the 1996 303(d) list. Nutrients were de-listed on the 2002 303(d) list after an intensive survey by MDE showed that showed no nutrient impairment.

The Maryland Department of the Environment (MDE) recently conducted a water quality assessment of all historical data within the Youghiogheny River watershed to determine where violation of the pH water quality standard might exist. MDE conducted a survey in 2005 to monitor stream segments with the potential to be impaired and identified 25 as being impaired (Table ES-1) due to atmospheric deposition, acid mine drainage, or as having episodic or chronic acidification if a source was not determined through the assessment process. This document establishes a TMDL of low pH in the 25 impaired stream segments that will allow for the attainment of the associated designated uses.

According to Maryland's water quality standards, the Youghiogheny River's water quality must support its designated uses. The majority of the Youghiogheny watershed is designated as Use III-P - Nontidal Cold Waters with Public Water Supply [Code of Maryland Regulations (COMAR) 26.08.02.08S(4)]. Only Broad Ford Run and its tributaries, upstream of the dam on Broad Ford Run, have another designation: Use I-P for Water Contact Recreation and Protection of Nontidal Warm Water Aquatic Life with Public Water Supply (COMAR 26.09.02.08S(1)). For both categories, the pH numeric criteria requires that pH values may not be less than 6.5 or greater than 8.5 (COMAR 26.08.02.03-3(B)(1) & (F)(4)).

**Table ES-1. Impaired stream segments in the Youghiogheny River watershed**

| Station | Station code | Stream segment | pH source assessment |
|---|---|---|---|
| WM-1 | MYC0002 | Muddy Creek | Acid mine drainage & acidic deposition |
| WM-2 | SNO0000 | Snowy Creek | Acid mine drainage & acidic deposition |
| WM-3 | CHB0005 | Cherry Bottom Run | Episodic acidification |
| WM-4 | HER0028 | Herrington Creek | Episodic acidification |
| WM-6 | MUL0001 | Murley Run | Episodic acidification |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | Chronic acidification |
| WM-8 | HER0014 | Herrington Creek | Episodic acidification |
| WM-10 | BUG0013 | Bull Glade Run | Chronic acidification |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | Chronic acidification |
| WM-12 | MLR0001 | Millers Run | Episodic acidification |
| WM-14 | TOL0001 | Toliver Run | Episodic acidification |
| WM-15 | LAU0013 | Laurel Run | Acid mine drainage & acidic deposition |
| WM-16 | NED0005 | Ned Run | Episodic acidification |
| WM-17 | MYC0018 | Muddy Creek | Episodic acidification |
| WM-18 | HYR0001 | Hoyes Run | Not impaired |
| WM-19 | HYR0005 | Hoyes Run | Not impaired |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | Chronic acidification |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | Chronic acidification |
| WM-24 | UYM0000 | Unnamed tributary to Yough. Lake | Not impaired |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | Acid mine drainage |
| WM-27 | MXL0010 | Mill Run | Not impaired |
| WM-28 | BRC0003 | Bear Creek | Not impaired |
| WM-29 | DCP0001 | Deep Creek Lake Power Plant discharge | Not impaired |
| BM909 | BUF0082 | Buffalo Run | Chronic acidification |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | Acid mine drainage |
| BM915 | NXB0003 | North Branch Laurel Run | Acid mine drainage & acidic deposition |
| BM928 | LRL0018 | Laurel Run | Acid mine drainage & acidic deposition |
| BM929 | LRL0034 | Laurel Run | Chronic acidification |
| BM930 | TRR0007 | Trap Run | Acid mine drainage |
| BM931 | WRR0008 | White Rock Run | Chronic acidification |
| BM933 | WRG0003 | White Rock Glade | Chronic acidification |

A TMDL for a given pollutant and waterbody is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL must include an implicit or explicit margin of safety

(MOS) to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody and may include a future allocation (FA) component. The TMDL components are illustrated using the following equation:

$$TMDL = S\ WLAs + S\ LAs + MOS + FA$$

For this TMDL, the Mining Data Analysis System (MDAS) was used to represent the source-response linkage for pH. MDAS is a comprehensive data management and modeling system capable of representing loads from nonpoint and point sources in the watershed and simulating in-stream processes.

MDAS model simulation for a multiyear period inherently accounts for seasonal variation, a required component of TMDLs. Continuous simulation represents both hydrologic and source loading variability seasonally. In addition, the model takes critical conditions into account through dynamic model simulation (i.e., using the model to predict conditions over a long period of time that represents wet, dry, and average flow periods).

In TMDL development, allowable loadings from pollutant sources are determined, the sum of which amounts to a cumulative TMDL threshold, thus providing a quantitative basis for establishing water quality-based controls. To address pH impairments, chemical species that affect pH (such as sulfate, iron, aluminum, nitrate, and ammonium) were reduced in the model simulation to raise the pH above 6.5. The state reserves the rights to revise these allocations provided that the allocations are consistent with the achievement of water quality standards.

A total allowable TMDL loading was determined from these reductions. WLAs were assigned to six of the seven permitted facilities that discharge to waters above impaired monitoring stations. If a parameter limit was not in the permit, the present discharge levels were not adversely affecting the stream and a WLA was not given for these parameters or permits. An explicit MOS of 5 percent of the total TMDL was subtracted from the total TMDL to obtain the LAs. The LAs include nonpoint sources such as atmospheric deposition and abandoned mine drainage. A summary of annual LAs for the subwatersheds addressed in this report is presented in Table ES-2. Daily maximum loads are presented in full in Section 5 (Table 5-2) of this report. Table ES-3 compares the TMDL allocations to the baseline loads.

**Table ES-2. TMDL LAs for iron, aluminum, sulfate, nitrate, and ammonium yearly loads**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | LA | 79,663 | 53,593 | 1,642,486 | 42,074 | 9,679 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 4,686 | 3,153 | 96,617 | 2,475 | 569 |
| | | | FA | 9,372 | 6,305 | 193,234 | 4,950 | 1,139 |
| | | | Total | 93,721 | 63,050 | 1,932,337 | 49,498 | 11,387 |
| WM-2[b] | SNO0000 | Snowy Creek | LA | 198,637 | 145,025 | 5,054,641 | 115,512 | 27,127 |
| | | | WLA | 18 | 11 | 0 | 0 | 1,523 |
| | | | MOS | 11,686 | 8,532 | 297,332 | 6,795 | 1,685 |
| | | | FA | 23,371 | 17,063 | 594,664 | 13,590 | 3,371 |
| | | | Total | 233,712 | 170,631 | 5,946,637 | 135,896 | 33,705 |
| WM-3 | CHB0005 | Cherry Bottom Run | LA | 3,261 | 2,098 | 67,721 | 1,126 | 245 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 192 | 123 | 3,984 | 66 | 14 |
| | | | FA | 384 | 247 | 7,967 | 133 | 29 |
| | | | Total | 3,837 | 2,468 | 79,672 | 1,325 | 288 |
| WM-4 | HER0028 | Herrington Creek | LA | 27,255 | 20,193 | 717,023 | 16,869 | 4,021 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 1,603 | 1,188 | 42,178 | 992 | 237 |
| | | | FA | 3,206 | 2,376 | 84,356 | 1,985 | 473 |
| | | | Total | 32,065 | 23,756 | 843,557 | 19,846 | 4,731 |
| WM-6[c] | MUL0001 | Murley Run | LA | 2,249 | 2,811 | 490,988 | 8,045 | 1,827 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 132 | 165 | 28,882 | 473 | 107 |
| | | | FA | 265 | 331 | 57,763 | 946 | 215 |
| | | | Total | 2,645 | 3,306 | 577,633 | 9,464 | 2,150 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | LA | 104 | 159 | 39,768 | 532 | 124 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 6 | 9 | 2,339 | 31 | 7 |
| | | | FA | 12 | 19 | 4,679 | 63 | 15 |
| | | | Total | 123 | 187 | 46,786 | 626 | 145 |
| WM-8[d] | HER0014 | Herrington Creek | LA | 33,327 | 24,437 | 963,612 | 21,112 | 4,968 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 1,960 | 1,437 | 56,683 | 1,242 | 292 |
| | | | FA | 3,921 | 2,875 | 113,366 | 2,484 | 584 |
| | | | Total | 39,209 | 28,749 | 1,133,662 | 24,838 | 5,844 |
| WM-10 | BUG0013 | Bull Glade Run | LA | 294 | 449 | 112,925 | 1,514 | 352 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 17 | 26 | 6,643 | 89 | 21 |
| | | | FA | 35 | 53 | 13,285 | 178 | 41 |
| | | | Total | 346 | 528 | 132,853 | 1,781 | 414 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | LA | 140 | 213 | 53,550 | 718 | 167 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 8 | 13 | 3,150 | 42 | 10 |
| | | | FA | 16 | 25 | 6,300 | 84 | 20 |
| | | | Total | 164 | 250 | 63,000 | 845 | 197 |
| WM-12 | MLR0001 | Millers Run | LA | 7,931 | 5,702 | 273,935 | 5,924 | 1,202 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 467 | 335 | 16,114 | 348 | 71 |

**Table ES-2. (continued)**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| | | | FA | 933 | 671 | 32,228 | 697 | 141 |
| | | | Total | 9,331 | 6,708 | 322,276 | 6,970 | 1,415 |
| WM-14 | TOL0001 | Toliver Run | LA | 14,172 | 9,423 | 397,953 | 6,812 | 1,422 |
| | | | WLA | 0 | 0 | 0 | 0 | 330 |
| | | | MOS | 834 | 554 | 23,409 | 401 | 103 |
| | | | FA | 1,667 | 1,109 | 46,818 | 801 | 206 |
| | | | Total | 16,673 | 11,086 | 468,180 | 8,014 | 2,061 |
| WM-15 | LAU0013 | Laurel Run | LA | 6,021 | 8,743 | 1,252,566 | 29,377 | 6,581 |
| | | | WLA | 8 | 0 | 0 | 0 | 0 |
| | | | MOS | 355 | 514 | 73,680 | 1,728 | 387 |
| | | | FA | 709 | 1,029 | 147,361 | 3,456 | 774 |
| | | | Total | 7,093 | 10,285 | 1,473,607 | 34,561 | 7,743 |
| WM-16 | NED0005 | Ned Run | LA | 3,183 | 2,274 | 72,552 | 1,539 | 369 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 187 | 134 | 4,268 | 91 | 22 |
| | | | FA | 374 | 268 | 8,536 | 181 | 43 |
| | | | Total | 3,745 | 2,675 | 85,356 | 1,810 | 434 |
| WM-17[e] | MYC0018 | Muddy Creek | LA | 57,719 | 42,081 | 1,329,769 | 31,324 | 7,139 |
| | | | WLA | 752 | 101 | 0 | 0 | 0 |
| | | | MOS | 3,439 | 2,481 | 78,222 | 1,843 | 420 |
| | | | FA | 6,879 | 4,963 | 156,443 | 3,685 | 840 |
| | | | Total | 68,789 | 49,626 | 1,564,435 | 36,851 | 8,398 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | LA | 1,573 | 1,063 | 54,834 | 820 | 186 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 93 | 63 | 3,226 | 48 | 11 |
| | | | FA | 185 | 125 | 6,451 | 97 | 22 |
| | | | Total | 1,850 | 1,250 | 64,511 | 965 | 219 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | LA | 49 | 65 | 13,424 | 198 | 39 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 3 | 4 | 790 | 12 | 2 |
| | | | FA | 6 | 8 | 1,579 | 23 | 5 |
| | | | Total | 57 | 77 | 15,793 | 233 | 46 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | LA | 3,285 | 1,667 | 147,856 | 1,185 | 232 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 193 | 98 | 8,697 | 70 | 14 |
| | | | FA | 386 | 196 | 17,395 | 139 | 27 |
| | | | Total | 3,865 | 1,962 | 173,948 | 1,394 | 273 |
| BM909 | BUF0082 | Buffalo Run | LA | 1,906 | 2,123 | 238,483 | 4,602 | 898 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 112 | 125 | 14,028 | 271 | 53 |
| | | | FA | 224 | 250 | 28,057 | 541 | 106 |
| | | | Total | 2,242 | 2,498 | 280,568 | 5,414 | 1,056 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | LA | 504 | 420 | 45,811 | 816 | 173 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 30 | 25 | 2,695 | 48 | 10 |
| | | | FA | 59 | 49 | 5,390 | 96 | 20 |
| | | | Total | 593 | 495 | 53,895 | 960 | 204 |
| BM915 | NXB0003 | North Branch | LA | 2,807 | 1,921 | 90,465 | 1,748 | 361 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |

**Table ES-2. (continued)**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| | | Laurel Run | MOS | 165 | 113 | 5,321 | 103 | 21 |
| | | | FA | 330 | 226 | 10,643 | 206 | 42 |
| | | | Total | 3,302 | 2,260 | 106,430 | 2,056 | 425 |
| BM928[f] | LRL0018 | Laurel Run | LA | 13,478 | 8,838 | 315,092 | 5,573 | 1,152 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 793 | 520 | 18,535 | 328 | 68 |
| | | | FA | 1,586 | 1,040 | 37,070 | 656 | 136 |
| | | | Total | 15,857 | 10,398 | 370,696 | 6,556 | 1,355 |
| BM929 | LRL0034 | Laurel Run | LA | 205 | 347 | 89,098 | 1,366 | 265 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 12 | 20 | 5,241 | 80 | 16 |
| | | | FA | 24 | 41 | 10,482 | 161 | 31 |
| | | | Total | 241 | 409 | 104,822 | 1,607 | 312 |
| BM930 | TRR0007 | Trap Run | LA | 2,251 | 1,597 | 100,301 | 1,743 | 372 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 132 | 94 | 5,900 | 103 | 22 |
| | | | FA | 265 | 188 | 11,800 | 205 | 44 |
| | | | Total | 2,648 | 1,879 | 118,001 | 2,051 | 438 |
| BM931 | WRR0008 | White Rock Run | LA | 1,602 | 1,751 | 259,344 | 5,754 | 1,359 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 94 | 103 | 15,256 | 338 | 80 |
| | | | FA | 188 | 206 | 30,511 | 677 | 160 |
| | | | Total | 1,885 | 2,060 | 305,111 | 6,770 | 1,598 |
| BM933 | WRG0003 | White Rock Glade | LA | 1,291 | 2,227 | 380,867 | 9,839 | 2,215 |
| | | | WLA | 0 | 0 | 0 | 0 | 411 |
| | | | MOS | 76 | 131 | 22,404 | 579 | 154 |
| | | | FA | 152 | 262 | 44,808 | 1,158 | 309 |
| | | | Total | 1,519 | 2,620 | 448,079 | 11,576 | 3,090 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table ES-3. Comparison between baseline loads and TMDLs (lb/d)**

| Station | Station code | Station name | Load | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr)[a] |
|---|---|---|---|---|---|---|---|---|
| WM-1[b] | MYC0002 | Muddy Creek | Baseline | 100,058 | 67,295 | 2,299,943 | 91,368 | 11,409 |
| | | | TMDL | 93,721 | 63,050 | 1,932,337 | 49,498 | 11,387 |
| | | | % reduction | 6.3 | 6.3 | 16.0 | 45.8 | 0.2 |
| WM-2[c] | SNO0000 | Snowy Creek | Baseline | 339,230 | 245,788 | 6,779,850 | 251,595 | 33,520 |
| | | | TMDL | 233,712 | 170,631 | 5,946,637 | 135,896 | 33,705 |
| | | | % reduction | 31.1 | 30.6 | 12.3 | 46.0 | -0.6 |
| WM-3 | CHB0005 | Cherry Bottom Run | Baseline | 5,185 | 3,274 | 89,034 | 2,359 | 280 |
| | | | TMDL | 3,837 | 2,468 | 79,672 | 1,325 | 288 |
| | | | % reduction | 26.0 | 24.6 | 10.5 | 43.8 | -2.8 |
| WM-4 | HER0028 | Herrington Creek | Baseline | 49,330 | 34,982 | 961,242 | 36,783 | 4,706 |
| | | | TMDL | 32,065 | 23,756 | 843,557 | 19,846 | 4,731 |
| | | | % reduction | 35.0 | 32.1 | 12.2 | 46.0 | -0.5 |
| WM-6[d] | MUL0001 | Murley Run | Baseline | 28,147 | 24,131 | 632,158 | 17,542 | 2,153 |
| | | | TMDL | 2,645 | 3,306 | 577,633 | 9,464 | 2,150 |
| | | | % reduction | 90.6 | 86.3 | 8.6 | 46.0 | 0.2 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | Baseline | 2,457 | 2,129 | 50,350 | 1,166 | 146 |
| | | | TMDL | 123 | 187 | 46,786 | 626 | 145 |
| | | | % reduction | 95.0 | 91.2 | 7.1 | 46.3 | 0.1 |
| WM-8[e] | HER0014 | Herrington Creek | Baseline | 68,130 | 47,066 | 1,287,936 | 45,734 | 5,790 |
| | | | TMDL | 39,209 | 28,749 | 1,133,662 | 24,838 | 5,844 |
| | | | % reduction | 42.5 | 38.9 | 12.0 | 45.7 | -0.9 |
| WM-10 | BUG0013 | Bull Glade Run | Baseline | 6,929 | 5,987 | 143,118 | 3,314 | 415 |
| | | | TMDL | 346 | 528 | 132,853 | 1,781 | 414 |
| | | | % reduction | 95.0 | 91.2 | 7.2 | 46.3 | 0.1 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | Baseline | 3,284 | 2,838 | 67,853 | 1,572 | 197 |
| | | | TMDL | 164 | 250 | 63,000 | 845 | 197 |
| | | | % reduction | 95.0 | 91.2 | 7.2 | 46.3 | 0.1 |
| WM-12 | MLR0001 | Millers Run | Baseline | 17,943 | 11,868 | 365,751 | 12,366 | 1,405 |
| | | | TMDL | 9,331 | 6,708 | 322,276 | 6,970 | 1,415 |
| | | | % reduction | 48.0 | 43.5 | 11.9 | 43.6 | -0.7 |
| WM-14 | TOL0001 | Toliver Run | Baseline | 29,251 | 18,626 | 525,967 | 14,259 | 2,023 |
| | | | TMDL | 16,673 | 11,086 | 468,180 | 8,014 | 2,061 |
| | | | % reduction | 43.0 | 40.5 | 11.0 | 43.8 | -1.9 |
| WM-15 | LAU0013 | Laurel Run | Baseline | 70,855 | 58,324 | 1,664,904 | 63,843 | 7,768 |
| | | | TMDL | 7,093 | 10,285 | 1,473,607 | 34,561 | 7,743 |
| | | | % reduction | 90.0 | 82.4 | 11.5 | 45.9 | 0.3 |
| WM-16 | NED0005 | Ned Run | Baseline | 4,801 | 3,369 | 96,293 | 3,350 | 433 |
| | | | TMDL | 3,745 | 2,675 | 85,356 | 1,810 | 434 |
| | | | % reduction | 22.0 | 20.6 | 11.4 | 46.0 | -0.4 |
| WM-17[f] | MYC0018 | Muddy Creek | Baseline | 75,127 | 53,858 | 1,855,281 | 68,200 | 8,456 |
| | | | TMDL | 68,789 | 49,626 | 1,564,435 | 36,851 | 8,398 |
| | | | % reduction | 8.4 | 7.9 | 15.7 | 46.0 | 0.7 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | Baseline | 4,206 | 2,661 | 71,962 | 1,728 | 212 |
| | | | TMDL | 1,850 | 1,250 | 64,511 | 965 | 219 |
| | | | % reduction | 56.0 | 53.0 | 10.4 | 44.2 | -3.1 |

**Table ES-3. (continued)**

| Station | Station code | Station name | Load | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr)[a] |
|---|---|---|---|---|---|---|---|---|
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | Baseline | 719 | 559 | 17,242 | 414 | 46 |
| | | | TMDL | 57 | 77 | 15,793 | 233 | 46 |
| | | | % reduction | 92.0 | 86.3 | 8.4 | 43.7 | -0.1 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | Baseline | 7,578 | 3,097 | 197,556 | 2,506 | 284 |
| | | | TMDL | 3,865 | 1,962 | 173,948 | 1,394 | 273 |
| | | | % reduction | 49.0 | 36.7 | 12.0 | 44.3 | 3.8 |
| BM909 | BUF0082 | Buffalo Run | Baseline | 13,190 | 9,903 | 313,262 | 9,603 | 1,057 |
| | | | TMDL | 2,242 | 2,498 | 280,568 | 5,414 | 1,056 |
| | | | % reduction | 83.0 | 74.8 | 10.4 | 43.6 | 0.1 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | Baseline | 3,294 | 2,146 | 60,634 | 1,720 | 201 |
| | | | TMDL | 593 | 495 | 53,895 | 960 | 204 |
| | | | % reduction | 82.0 | 77.0 | 11.1 | 44.2 | -1.6 |
| BM915 | NXB0003 | North Branch Laurel Run | Baseline | 6,004 | 3,881 | 119,541 | 3,639 | 421 |
| | | | TMDL | 3,302 | 2,260 | 106,430 | 2,056 | 425 |
| | | | % reduction | 45.0 | 41.7 | 11.0 | 43.5 | -0.9 |
| BM928[g] | LRL0018 | Laurel Run | Baseline | 20,439 | 13,732 | 413,817 | 11,637 | 1,341 |
| | | | TMDL | 15,857 | 10,398 | 370,696 | 6,556 | 1,355 |
| | | | % reduction | 22.4 | 24.3 | 10.4 | 43.7 | -1.1 |
| BM929 | LRL0034 | Laurel Run | Baseline | 4,824 | 3,737 | 114,594 | 2,862 | 312 |
| | | | TMDL | 241 | 409 | 104,822 | 1,607 | 312 |
| | | | % reduction | 95.0 | 89.1 | 8.5 | 43.9 | 0.1 |
| BM930 | TRR0007 | Trap Run | Baseline | 7,157 | 4,583 | 132,060 | 3,655 | 431 |
| | | | TMDL | 2,648 | 1,879 | 118,001 | 2,051 | 438 |
| | | | % reduction | 63.0 | 59.0 | 10.6 | 43.9 | -1.7 |
| BM931 | WRR0008 | White Rock Run | Baseline | 17,134 | 12,255 | 344,375 | 12,551 | 1,596 |
| | | | TMDL | 1,885 | 2,060 | 305,111 | 6,770 | 1,598 |
| | | | % reduction | 89.0 | 83.2 | 11.4 | 46.1 | -0.2 |
| BM933 | WRG0003 | White Rock Glade | Baseline | 25,315 | 18,671 | 511,679 | 21,540 | 3,088 |
| | | | TMDL | 1,519 | 2,620 | 448,079 | 11,576 | 3,090 |
| | | | % reduction | 94.0 | 86.0 | 12.4 | 46.3 | 0.0 |

[a] The CAIR model predicts that ammonium in atmospheric deposition will increase in some areas.
[b] WM-1 includes upstream loads from WM-17.
[c] WM-2 includes upstream loads from WM-15.
[d] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[e] WM-8 includes upstream loads from WM-4.
[f] WM-17 includes upstream loads from WM-16.
[g] BM928 includes upstream loads from BM929.

## 1 INTRODUCTION AND BACKGROUND

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (at Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not supporting their designated uses even after pollutant sources have implemented technology-based controls. A TMDL establishes the maximum allowable load (mass per unit of time) of a pollutant that a waterbody is able to assimilate and still support its designated use(s). The maximum allowable load is determined using the relationship between pollutant sources and in-stream water quality. TMDLs provide a scientific basis for establishing water quality-based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of the state's water resources (USEPA 1991). TMDL development requires an assessment of a waterbody's assimilative capacity, critical conditions, and other considerations.

The Youghiogheny River was identified on Maryland's list of water quality limited segments (WQLSs) as impaired by low pH (1996 listing), sediments (1996/2002 listing), and impacts on biological communities (2002/2004 listing). Previously, the Youghiogheny River was listed for nutrients on the 1996 303(d) list. Nutrients were de-listed on the 2002 303(d) list after an intensive survey by MDE showed that showed no nutrient impairment.

The Maryland Department of the Environment (MDE) recently conducted a water quality assessment of all historical data within the Maryland portion of the Youghiogheny River watershed to determine where violation of the pH water quality standard may exist. From this analysis it was determined that 31 stream segments throughout the watershed have the potential for low pH impairment. Water quality monitoring data collected in 2005 by MDE indicate that observed pH levels frequently violate water quality standards for 25 segments in the Youghiogheny River watershed (Maryland basin number – 05020201) (Table 1-1 and Figure 1-1). The pollutant loadings were classified by source, including acid mine drainage (AMD) and atmospheric deposition. In addition, a segment could be classified as having chronic or episodic acidification with no identified source. Previously, a pH TMDL was developed for Cherry Creek, which is a tributary of Deep Creek Lake in the Youghiogheny River watershed and was approved by EPA on November 11, 2003. This document proposes to establish a TMDL of low pH in the 25 impaired stream segments that will allow for the attainment of the associated designated uses.

Only the portion of the Youghiogheny River watershed that flows into the Youghiogheny River Lake in Maryland is included in this TMDL. There are tributaries to the Youghiogheny River in Maryland that enter the Youghiogheny River in Pennsylvania. These tributaries are not part of this TMDL or report.

This TMDL report addresses the low pH impairment in the Youghiogheny River watershed. Low pH in a waterbody leads to acidic conditions. A pH of less than 5 is considered to be harmful to most stream biota (USEPA 1999). Healthy freshwater ecosystems have a diverse number of species (e.g., zooplankton, fish, and waterfowl) that depend on the freshwater environment for life. As pH becomes more acidic, the number of aquatic species and their populations tend to decline, with some species being more tolerant of low pH than others (USEPA 2007). Low pH in

**Table 1-1. Impaired stream segments in the Youghiogheny River watershed**

| Station | Station code | Stream segment | pH source assessment |
|---|---|---|---|
| WM-1 | MYC0002 | Muddy Creek | Acid mine drainage & acidic deposition |
| WM-2 | SNO0000 | Snowy Creek | Acid mine drainage & acidic deposition |
| WM-3 | CHB0005 | Cherry Bottom Run | Episodic acidification |
| WM-4 | HER0028 | Herrington Creek | Episodic acidification |
| WM-6 | MUL0001 | Murley Run | Episodic acidification |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | Chronic acidification |
| WM-8 | HER0014 | Herrington Creek | Episodic acidification |
| WM-10 | BUG0013 | Bull Glade Run | Chronic acidification |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | Chronic acidification |
| WM-12 | MLR0001 | Millers Run | Episodic acidification |
| WM-14 | TOL0001 | Toliver Run | Episodic acidification |
| WM-15 | LAU0013 | Laurel Run | Acid mine drainage & acidic deposition |
| WM-16 | NED0005 | Ned Run | Episodic acidification |
| WM-17 | MYC0018 | Muddy Creek | Episodic acidification |
| WM-18 | HYR0001 | Hoyes Run | Not impaired |
| WM-19 | HYR0005 | Hoyes Run | Not impaired |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | Chronic acidification |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | Chronic acidification |
| WM-24 | UYM0000 | Unnamed tributary to Yough. Lake | Not impaired |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | Acid mine drainage |
| WM-27 | MXL0010 | Mill Run | Not impaired |
| WM-28 | BRC0003 | Bear Creek | Not impaired |
| WM-29 | DCP0001 | Deep Creek Lake Power Plant discharge | Not impaired |
| BM909 | BUF0082 | Buffalo Run | Chronic acidification |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | Acid mine drainage |
| BM915 | NXB0003 | North Branch Laurel Run | Acid mine drainage & acidic deposition |
| BM928 | LRL0018 | Laurel Run | Acid mine drainage & acidic deposition |
| BM929 | LRL0034 | Laurel Run | Chronic acidification |
| BM930 | TRR0007 | Trap Run | Acid mine drainage |
| BM931 | WRR0008 | White Rock Run | Chronic acidification |
| BM933 | WRG0003 | White Rock Glade | Chronic acidification |

a waterbody affects gill function, egg development, and larval survival (USEPA 1999). Species that do not tolerate acidic environments will begin to lose the ability to reproduce, and even if a species is able to spawn, the offspring often do not survive the harsh acidic environment and might be more susceptible to disease or deformity (Environment Canada 2005).

When pH falls below 5, most fish cannot survive, and terrestrial animals, such as waterfowl, that are dependent on the aquatic species for survival are affected as their aquatic food sources are diminished (Environment Canada 2005). Metals concentrations in streams (e.g., aluminum) can also become toxic to fish when stream water and runoff entering the stream is acidic (USEPA 1999).

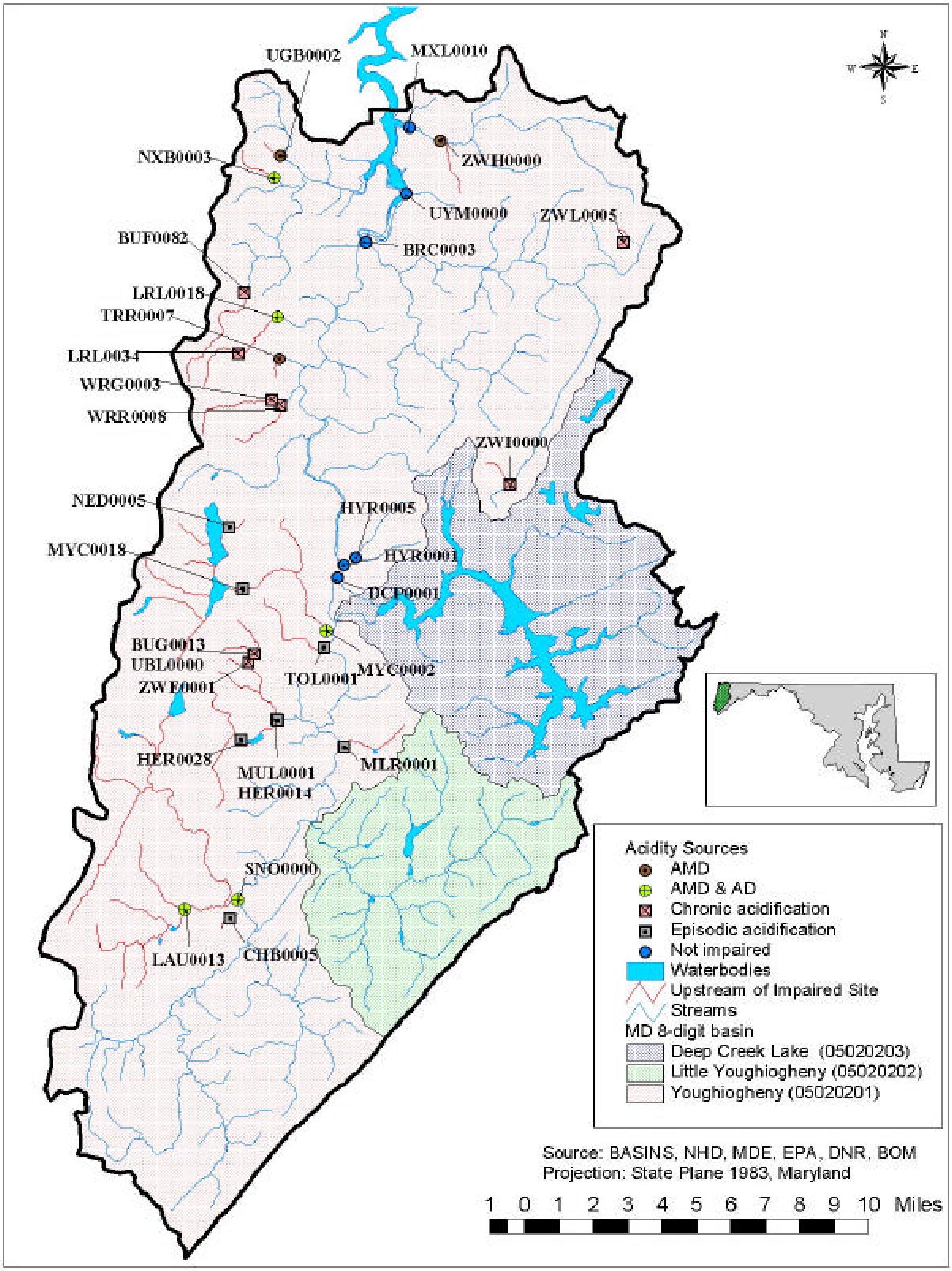


**Figure 1-1. Impaired monitoring locations in the Youghiogheny River watershed.**

### 1.1 Watershed Description

The Youghiogheny River flows through portions of West Virginia, Maryland, and Pennsylvania (Figure 1-2). The headwaters of the Youghiogheny River originate on Backbone Mountain in northern West Virginia (Preston County) and western Maryland (Garrett County). The river flows north through western Maryland and enters Pennsylvania through the Youghiogheny River Lake. The river continues to flow north to its confluence with the Monongahela River in Pennsylvania. The watershed's U.S. Geological Survey (USGS) hydrologic unit code is 05020006. The Maryland basin number is 05020201.

The entire Youghiogheny River watershed includes portions of Garrett County in Maryland; Preston County in West Virginia; and Allegheny, Fayette, Somerset, and Westmoreland Counties in Pennsylvania. However, the area of the Youghiogheny River watershed in this report restricted to the watershed portions in Maryland, West Virginia, and the southern regions of Fayette and Somerset Counties in Pennsylvania that flow to the Youghiogheny River Lake in Maryland.

### 1.2 Water Quality Problem Statement

There are several potential sources effecting pH in the Youghiogheny River watershed: atmospheric deposition (acid rain), AMD, agriculture, and naturally occurring conditions.

Acid rain is produced when atmospheric moisture reacts with gases to form sulfuric acid and nitric acids. These gases are primarily formed from nitrogen dioxides and sulfur dioxide, which enter the atmosphere through exhaust and smoke from burning fossil fuels such as gas, oil, and coal. Acid rain crosses political and watershed boundaries and can originate out of state.

Acid mine drainage occurs when surface and subsurface water percolates through coal-bearing minerals containing large amounts of pyrite and marcasite, which are crystalline forms of iron sulfide ($FeS_2$). The chemical reactions of the pyrite generate acidity in water. A synopsis of these reactions is as follows (Stumm and Morgan 1996):

- Exposure of pyrite to air and water causes the oxidation of pyrite.
- The sulfur component of pyrite is oxidized, releasing dissolved ferrous ($Fe^{+2}$) and hydrogen ($H^{+}$) ions. These hydrogen ions cause the acidity.
- The intermediate reaction with the dissolved $Fe^{+2}$ ions generates a precipitate, ferric hydroxide [$Fe(OH)_3$], and releases hydrogen ions, thereby causing more acidity.
- A third reaction occurs between the pyrite and the generated ferric ($Fe^{+3}$) ions contained in the ferric hydroxide precipitate, where more hydrogen ions (increasing acidity) are released as well as $Fe^{+2}$ ions, which enter the reaction cycle.

Agriculture can play a small role in acidifying streams. Fertilizers used on agricultural land, and sometimes lawns and parks, can contain large amounts of nitrogen. Through chemical reactions in surface and subsurface waters, which will be described later in this report, nitrogen can lower a waterbody's pH level.

pH levels can further be lowered by natural conditions such as wetlands, more specifically bogs, and the lack of stream buffering capacity. Bogs were identified as a source of acid impairment in

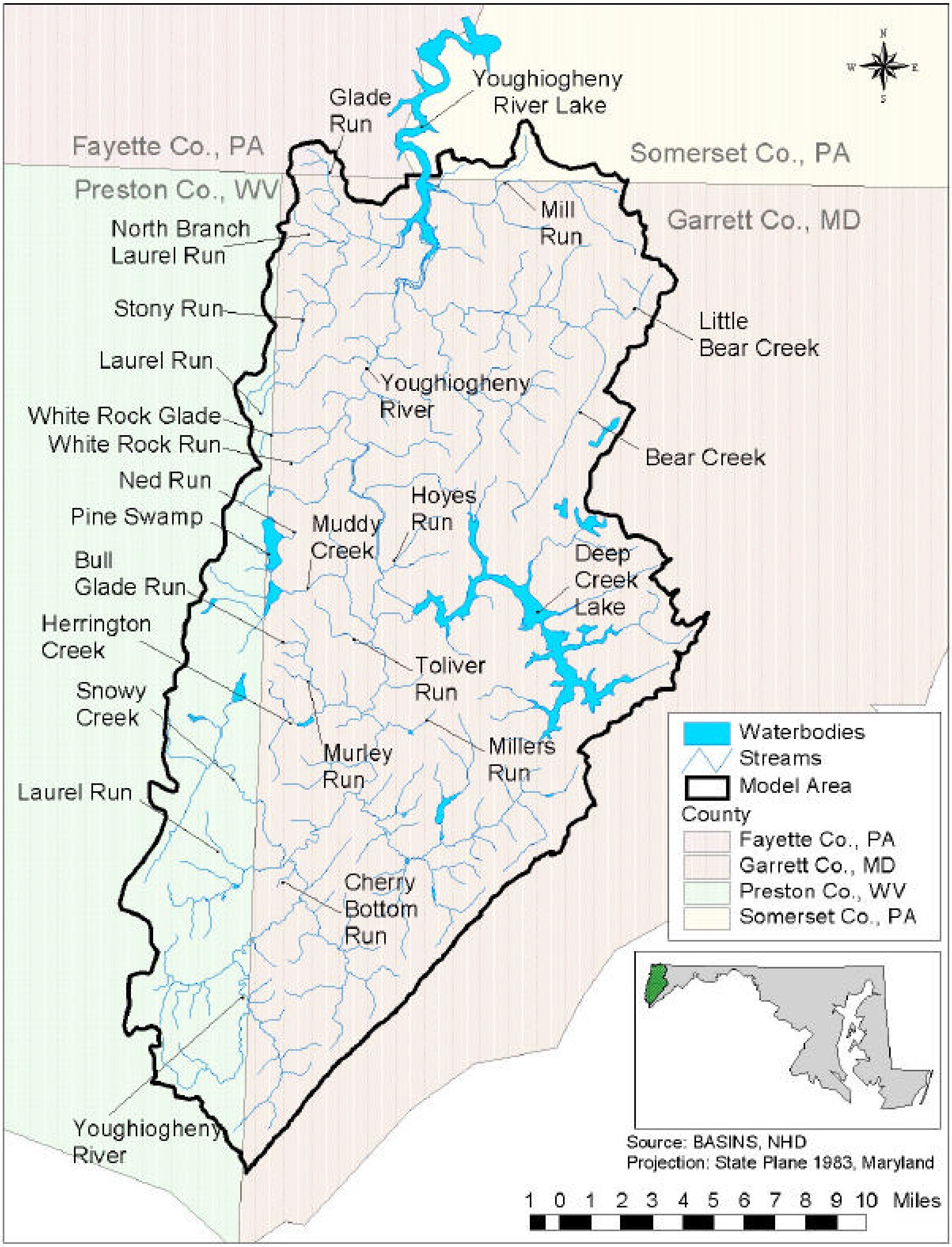


**Figure 1-2. Location of the Youghiogheny River watershed.**

the Cherry Creek watershed, which flows to Deep Creek Lake and then the Youghiogheny River (MDE 2003). Bogs receive most of their water from precipitation, which is naturally slightly acidic but could also be affected by acid rain, and pH might be decreased from the natural decomposition of organic materials (MDE 2003). Bogs have been identified only in the Cherry Creek watershed, which does not flow into any of the listed segments in this study. The other natural condition that could result in lowered pH levels is the lack of buffering-capacity in streams. The bedrock in the Youghiogheny River watershed is mainly sandstone, shale, and siltstone, which contain little calcium carbonate. There are only small areas containing limestone and calcareous shale that include calcium carbonate, which buffers excess hydrogen ions to raise pH levels in streams.

### 1.3 Water Quality Standards

Maryland water quality standards consist of two components: (1) designated and existing uses and (2) narrative or numeric water quality criteria necessary to support those uses. Furthermore, water quality standards serve the purpose of protecting public health, enhancing the quality of water, and protecting aquatic resources.

Maryland's water quality standards require the Youghiogheny River's water quality to support its designated uses. The majority of the Youghiogheny watershed is designated as Use III-P - Nontidal Cold Waters with Public Water Supply [Code of Maryland Regulations (COMAR) 26.08.02.08S(4)]. Only Broad Ford Run and its tributaries, upstream of the dam on Broad Ford Run, have another designation: Use I-P for Water Contact Recreation and Protection of Nontidal Warm Water Aquatic Life with Public Water Supply (COMAR 26.09.02.08S(1)). For both categories, the pH numeric criteria requires that pH values may not be less than 6.5 or greater than 8.5 (COMAR 26.08.02.03-3(B)(1) & (F)(4)).

The Youghiogheny River enters into Pennsylvania via the Youghiogheny River Lake. Pennsylvania's water quality standards are presented in Table 1-2 (PADEP 2006). Water quality standards for West Virginia (WVSOS 2006) and the national recommended water quality criteria by EPA (USEPA 2004) are also listed in Table 1-2.

### 1.4 Impaired Waterbodies

MDE monitored 31 stream segments in 2005 to identify pH-impaired streams. Of these, MDE identified 25 as being impaired. For a full description of the assessment process, see Section 2.2.1. These streams were identified as impaired due to atmospheric deposition, AMD, and organic sources or as having episodic or chronic acidification if a source was not determined through the assessment process. The mainstem of the Youghiogheny River is not among those stream segments identified as impaired.

The Youghiogheny River enters Pennsylvania through the Youghiogheny River Lake. Pennsylvania does not list the Youghiogheny River for pH impairments at this point. The Youghiogheny River is listed for mercury further downstream in Pennsylvania. USGS maintains a water quality station (USGS 03077500) at the Youghiogheny River Lake dam, which is 10 miles downstream from where the Youghiogheny River enters Pennsylvania. Data from this site showed pH, sulfate, iron, and aluminium meeting Pennsylvania standards.

**Table 1-2. Water quality standards**

| Parameter | Maryland | | Pennsylvania | | West Virginia | | EPA | |
|---|---|---|---|---|---|---|---|---|
| | Value | Comment | Value | Comment | Value | Comment | Value | Comment |
| Acidity | -- | | -- | | -- | | -- | |
| Alkalinity | -- | | 20 mg/L as $CaCO_3$ | | -- | | 20 mg/L | |
| Aluminum | -- | | 750 µg/L | | 750 µg/L<br><br>87 µg/L | Dissolved acute[a] aquatic life<br><br>Dissolved chronic[b] troutwaters aquatic life | 750 µg/L<br><br>87 µg/L | Freshwater max.concentration at pH 6.5–9.0<br><br>Freshwater continuous concentration at pH 6.5–9.0 |
| Ammonia Nitrogen | -- | | -- | Varies based on pH | -- | Varies | -- | Varies based on pH and temperature |
| Iron | -- | | 1.5 mg/L<br><br>0.3 mg/L | 30-day average total recoverable<br><br>Dissolved | 1.5 mg/L<br><br>0.5 mg/L | Total chronic[b] warmwater aquatic life & Human health contact recreation/ public water supply<br><br>Total chronic[b] troutwaters aquatic life | 1.0 mg/L<br><br>0.3 mg/L | Freshwater continuous concentration<br><br>Human health for consumption of water and organism |
| Nitrate | -- | | 10 mg/L as N | Nitrate + Nitrite | 10 mg/L as N | Human health for drinking water & consumption of organism | 10 mg/L | Human health for consumption of water and organism |
| pH | 6.5–8.5 | | 6.0–9.0 | | 6.0–9.0 | | 6.5–9.0<br><br>5.0–9.0 | Freshwater continuous range<br><br>Human health for consumption of water and organism |
| Sulfate | -- | | 250 mg/L | | -- | | -- | |

[a] One-hour average concentration not to be exceeded more than once every 3 years on the average.
[b] Four-day average concentration not to be exceeded more than once every 3 years on the average.

West Virginia lists the entire length of five stream segments within the Youghiogheny River watershed on its 2006 303(d) list. The segments are the Youghiogheny River (biological), Snowy Creek (aluminium, biological, and iron), Laurel Run (iron and pH), Wardwell Run (biological), and Maple Run (biological). The sources of the impairments are not known, except for Laurel Run, where the suspected source is AMD.

### 1.5 History of Mining in Western Maryland

Coal mining has occurred in western Maryland since the early 1700s. Deep mine production peaked in the early 1900s. Coal mining in Maryland peaked at 5.5 million tons in 1907 but usually averaged 4 to 5 million tons annually (USDOI 2006). Because of the design of the mines, water with high acid and iron concentrations ran into the streams. Underground mining declined in Maryland after 1945, with 91 percent of the mines being surface mines in 1977 (USDOI 2006). In the 1980s production fluctuated between 3 and 4.5 million tons annually (USDOI

2006). Currently in the Youghiogheny River watershed, mining is confined to the Lower Youghiogheny coal field, which is in the north-central portion of the watershed.

# 2 DATA INVENTORY AND ANALYSIS

## 2.1 Data Inventory

Table 2-1 outlines key data sets compiled for this project. The data sets include geographical and political information, such as county boundaries and land use, and in-stream monitoring data, such as water quality and flow. Descriptions of the data sets that were used in model development are given in Sections 2.1.1 through 2.1.8.

**Table 2-1. Data sets compiled for the Youghiogheny River watershed**

| Data type | Information sources |
|---|---|
| Reservoir boundaries and stream network | BASINS, USGS 7.5 minute Quads, MDE |
| Land use | Maryland Department of the Environment; West Virginia Gap Analysis from Natural Resource Analysis Center at West Virginia University; Pennsylvania Spatial Data Access |
| Soils | STATSGO |
| Watershed boundaries | USGS Hydrologic Unit Boundaries (8-digit), MDE |
| Topographic relief and elevation data | USGS 7.5 minute Quads, Digital Elevation Models from BASINS |
| Surface geology | Maryland Geological Survey |
| Active and abandoned mine locations | MDE |
| Flow data and locations | USGS |
| Meteorological data and locations [a] | National Oceanic and Atmospheric Administration – National Climatic Data Center (NOAA-NCDC) |
| Water quality data and locations | STORET, USGS, MDE |
| NPDES permitted facilities and locations [b] | Permit Compliance System (PCS), MDE |

[a] Precipitation, dry-bulb [air] temperature, dew point temperature, wind speed, cloud cover.

[b] NPDES permit limits, design flow, DMR data

### *2.1.1 Hydrology and Topography*

There are limited flow data available within the Youghiogheny River watershed. The USGS online database (NWISWeb) contains only three stations that have daily flow data for the past 15 years in the Youghiogheny River watershed (USGS 2005). These stations are shown in Figure 2-1 and listed in Table 2-2 with the period of record and measure of completeness for each gage. Seven other USGS stations are in the watershed; however, they do not contain daily flow data. The three stations with daily flow data are:

- Station 03075500 on the Youghiogheny River near Oakland, Maryland, which is in the southern part of the watershed and has a drainage area of 134 square miles.

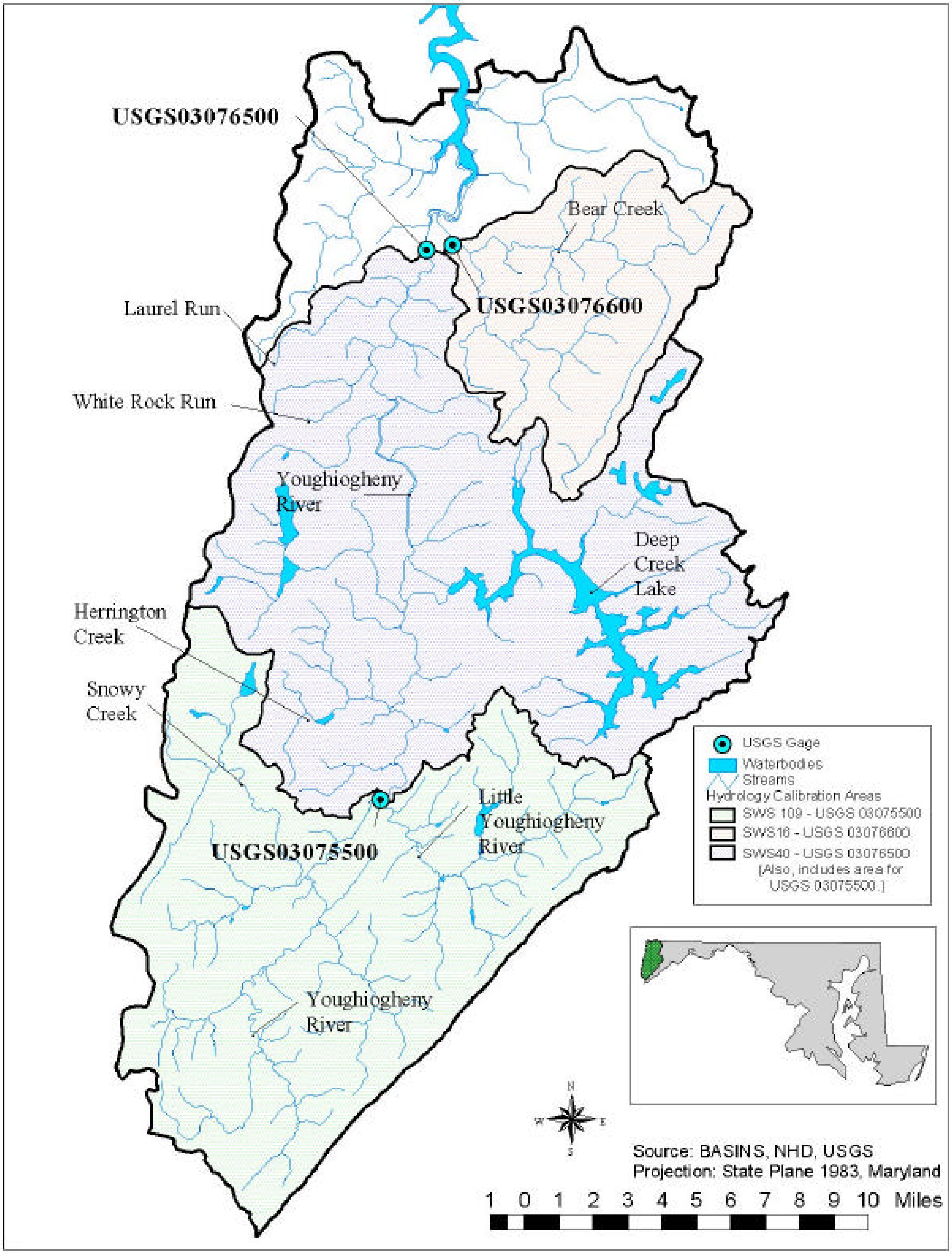


**Figure 2-1. USGS gages in the Youghiogheny River watershed.**

- Station 03076500 on the Youghiogheny River near Friendsville, Maryland, which is in the northern part of the watershed, has a drainage area of 295 square miles, and includes the area from station 03075500.
- Station 03076600 on Bear Creek near Friendsville, Maryland, which is in the northern part of the watershed and has a drainage area of 49 square miles.

**Table 2-2. USGS flow gaging stations in the Youghiogheny River watershed**

| Station | Station name | Start date | End date | Percent complete |
|---|---|---|---|---|
| 03075500 | Youghiogheny River near Oakland, MD | 08/26/1941 | 09/30/2005[b] | 100 |
| 03076500 | Youghiogheny River at Friendsville, MD | 12/01/1940[a] | 09/30/2005[b] | 100 |
| 03076600 | Bear Creek at Friendsville, MD | 10/01/1964 | 09/30/2005[b] | 100 |

[a] This station also has data from 8/17/1898 though 12/31/1904.
[b] Provisional data were used to expand the end date to 11/30/2005.

The elevation of the Youghiogheny River watershed ranges from approximately 1,300 feet to over 3,300 feet. The lowest area is along the river and its tributaries in the north-central part of the watershed. The highest areas and the steepest slopes are in the mountains in the western and eastern edges of the watershed. Topographic information was obtained from Digital Elevation Models (DEMs) from EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) (USEPA 2004) and USGS topographic maps.

#### *2.1.2 Climate*

The National Oceanic and Atmospheric Administration (NOAA) collects weather data from numerous regional climate stations. NOAA's National Climatic Data Center (NCDC) stores and distributes weather data gathered by the Cooperative Observer Network (COOP) throughout the United States and from Weather Bureau Army-Navy (WBAN) airways stations or surface airway stations. The COOP stations record hourly or daily rainfall data, while the surface airway stations record hourly rainfall plus additional hourly data.

The identification of the best weather data for this modeling effort was based on several factors including geographic coverage, data record, and data completeness. There were two stations used for this TMDL study, based mainly on geographic location. There are other nearby weather stations with more complete data sets; however, they are not considered representative of the watershed because they are on opposite sides of the surrounding mountains and most likely have different rainfall patterns. Information on the selected hourly and daily COOP and WBAN stations is presented in Figure 2-2 and Table 2-3. Table 2-3 also provides statistics regarding the period of record and the completeness of records expressed as percentages of reported data corresponding to the respective station's period of record.

Additional data for dry-bulb air temperature, wind speed, solar radiation, cloud cover, and dew point temperature data were required in addition to hourly precipitation and evapotranspiration. Precipitation, wind speed, temperature, and cloud cover data were taken directly from the NOAA stations. Solar radiation was calculated using the Hamon equation (Hamon 1961) using latitude (to determine the hours of sunshine) and cloud cover. Potential

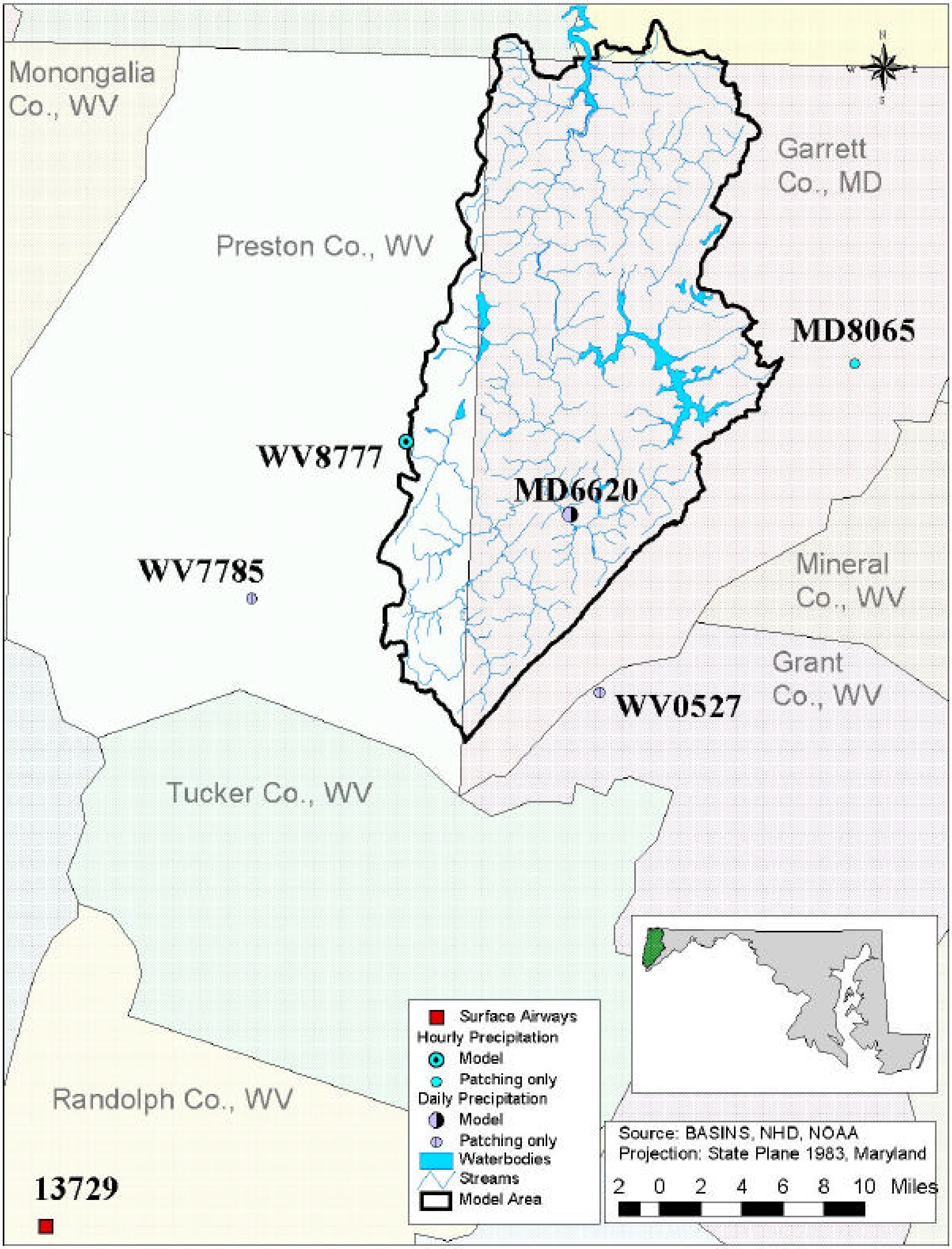


**Figure 2-2. Climate stations used in the Youghiogheny River watershed model.**

**Table 2-3. Available meteorological data**

| Station ID | Station name | Start date | End date[a] | Percent complete | Data type |
|---|---|---|---|---|---|
| 13729 | Elkins - Randolph Co Airport | 01/01/1980 | 12/31/2002 | 96 | Dew point temperature |
| | | | | 100 | Dry-bulb temperature |
| | | | | 96 | Windspeed and direction |
| | | | 04/30/1996 | 95 | Cloud cover |
| 186620 | Oakland 1 SE | 01/01/1948 | 12/31/2004 | 98 | Precipitation |
| 467785[b] | Rowlesburg 1 | 01/01/1948 | 12/31/2004 | 99 | Precipitation |
| MD8065[b] | Savage River Dam | 05/01/1949 | 12/31/2004 | 85 | Precipitation |
| WV8777 | Terra Alta No 1 | 01/01/1978 | 12/20/2004 | 90 | Precipitation |

[a] Unedited data were used to expand the end date to 11/30/2005.
[b] Data from this station were used to patch other stations for the model.

evapotranspiration was calculated using the Penman method (Penman 1948). The Penman equation uses air temperature, wind speed, solar radiation, and dew point temperature to compute pan evaporation. An additional conversion factor of 0.8 for winter and 1.0 for summer was applied to estimate potential evapotranspiration. This conversion factor is used to represent the influence of vegetative cover on the land surface.

### *2.1.3 Water Chemistry Data*

There are eight different sources of information on water quality for the Youghiogheny River watershed. Most information was provided by MDE. Additional data were obtained from EPA's STORET database (USEPA 2005a) and the West Virginia WAPbase database. Figure 2-3 and Table 2-4 present the available water quality data sets and the availability of the corresponding location data, flow data, data range, and parameters. The data sets contain many parameters including pH, nitrate, sulfate, total iron, dissolved iron, and total aluminum. Some data sets do not contain location information, such as latitude and longitude, or list specific dates of data collection. Therefore, these data sets could not be used for this study. Water quality data is summarized in Appendix A.

### *2.1.4 Land Use Data*

Because the portion of the watershed included in this study encompasses parts of three states, land use data were obtained from three different sources. Land use data for Maryland was obtained from Maryland Department of Planning (MDP). The land use data for Pennsylvania were obtained from the Pennsylvania Spatial Data Access Web site, which is housed at Pennsylvania State University (PSU 2003). The West Virginia land use data were obtained from the Natural Resource Analysis Center and West Virginia Cooperative Fish and Wildlife Research Unit from West Virginia University (WVU 2000).

Each land use data set has its own classification system; therefore, it was necessary to reclassify the land uses to be consistent between data sets. The MDP classifications were used as the basis for the reclassification. The detailed MDP classifications were grouped into seven categories (Table 2-5). The land use classifications from Pennsylvania and West Virginia were compared to the MDP categories and reclassified into the appropriate land use categories (Tables 2-6 and 2-7).

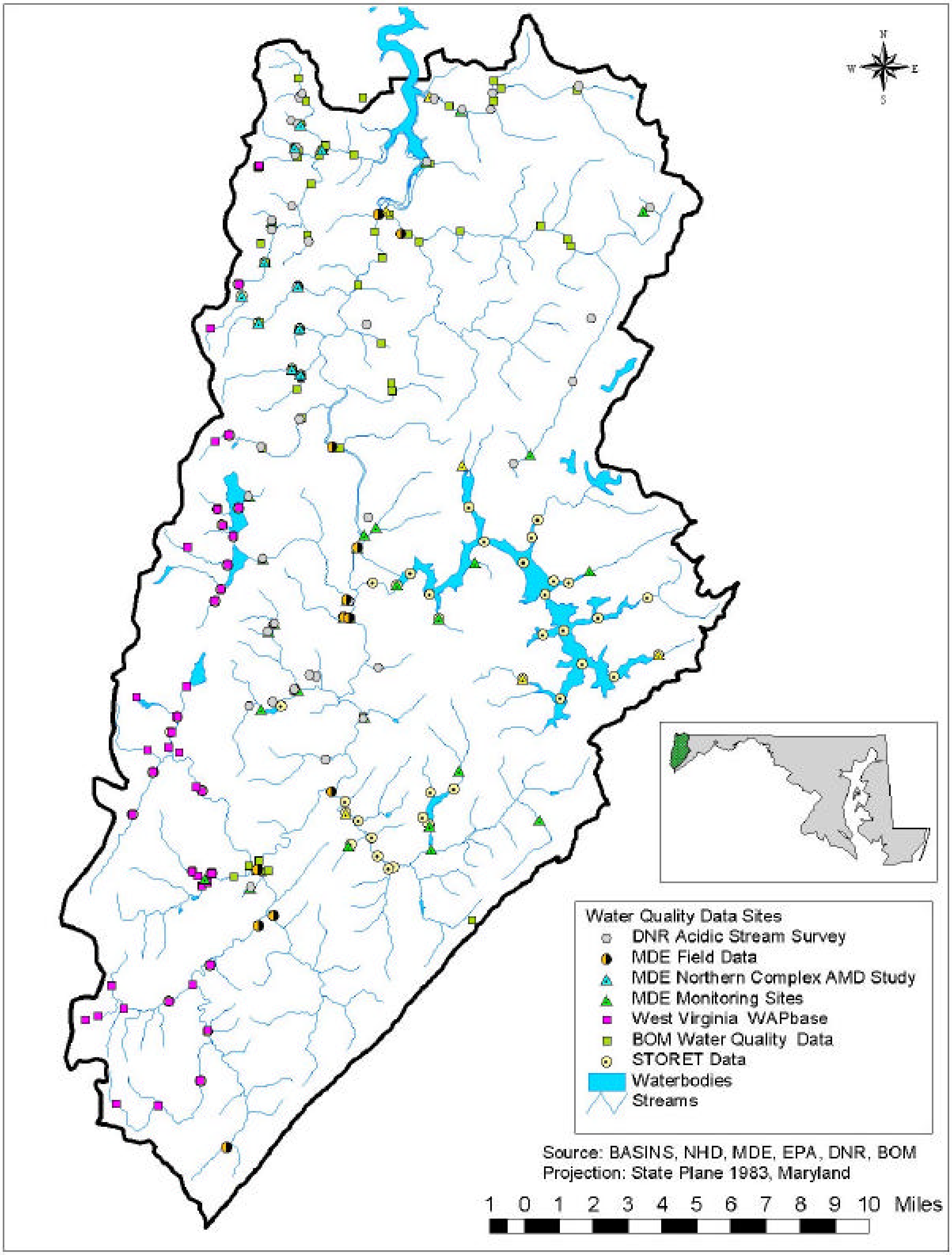


**Figure 2-3. Water quality stations in the Youghiogheny River watershed.**

**Table 2-4. Water quality monitoring data sets**

| Source file | No. of stations | % of stations with flow | Period of record | Location information | Parameter |
|---|---|---|---|---|---|
| Bureau of Mines (BOM) Data | 57 | 77.2 | 10/5/2000–7/30/2002 | Easting/ Westing | Aluminum, Alkalinity, Iron, Manganese, pH (Field & Lab), Flow |
| Maryland Department of Natural Resources (DNR) Acidic Stream Survey | 47 | 0.0 | 1999[a] | Latitude/ Longitude | Field pH |
| Maryland Biological Stream Survey (MBSS) Data | 66 | 0.0 | 1995–2002 [a] | None | pH (Field & Lab) |
| MDE Field Data | 13 | 92.3 | 5/5/1997–11/8/2000 | Latitude/ Longitude | Total Alkalinity, Field pH, Flow |
| | 45 | 0.0 | 3/28/2005–11/3/2005 | | Acid Neutralizing Capacity, pH, Chloride, Nitrate, Sulfate, Dissolved Organic Carbon, Alkalinity, Acidity, Hardness, Total Suspended Solids, Iron (Dissolved & Total), Total Aluminum |
| MDE Northern Complex AMD Study | 10 | 0.0 | 4/14/2003–12/4/2003 | Latitude/ Longitude | Aluminum (Inorganic, Organic, & Total), Alkalinity, Net Alkalinity, pH (Field & Closed), Iron |
| Northern Yough. Assessment | 10 | 0.0 | 4/14/2003–12/4/2003 | None | Field pH |
| EPA's STORET Database | 99 | 32.3 | 8/21/1977–12/4/2003 | Latitude/ Longitude | Aluminum (Inorganic, Organic, & Total), Alkalinity (Bicarbonate, Carbonate, & Total), Iron, Manganese, pH (Field & Lab), Flow |
| West Virginia WAPbase Database | 44 | 20 | 7/8/1996–8/31/2005 | Latitude/ Longitude | Acidity, Alkalinity, pH, Sulfate, Flow, Total Suspended Solids, Aluminum (Dissolved & Total), Iron (Dissolved & Total), Selenium (Dissolved & Total) |

[a] Specific date information is not available. Only sample year was provided.

**Table 2-5. Land use reclassifications from MDP data set**

| Detailed land use description | Model land use group | Detailed land use description | Model land use group |
|---|---|---|---|
| Agricultural breeding building | Agriculture | High-density residential | Urban built-up |
| Agriculture | Agriculture | Industrial | Urban built-up |
| Bare exposed rock | Barren land | Institutional | Urban built-up |
| Bare ground | Barren land | Low-density residential | Urban built-up |
| Barren land | Barren land | Medium-density residential | Urban built-up |
| Beaches | Barren land | Mixed forest | Forest |
| Brush | Forest | Open urban land | Urban built-up |
| Commercial - retail and wholesale services | Urban built-up | Orchards/vineyards/ horticulture | Agriculture |
| Cropland | Agriculture | Pasture | Agriculture |
| Deciduous forest | Forest | Row and garden crops | Agriculture |
| Evergreen forest | Forest | Transportation | Urban built-up |
| Extractive- surface mines/quarries/pits | Mining | Urban built-up | Urban built-up |
| Feeding operations | Agriculture | Water | Water |
| Forest | Forest | Wetlands | Wetlands |

**Table 2-6. Land use classification conversion between Pennsylvania and Maryland data sets**

| Pennsylvania detailed land use description | Maryland Detailed land use description | Model land use group |
|---|---|---|
| Coal mines | Extractive-surface mines/quarries/pits | Mining |
| Coniferous forest | Evergreen forest | Forest |
| Deciduous forest | Deciduous forest | Forest |
| Emergent wetland | Wetlands | Wetlands |
| Hay Pasture | Pasture | Agriculture |
| High-density urban | High-density residential | Urban built-up |
| Low-density urban | Low-density residential | Urban built-up |
| Mixed forest | Mixed forest | Forest |
| Probably row crops | Agriculture | Agriculture |
| Quarries | Extractive- surface mines/quarries/pits | Mining |
| Row crops | Row and garden crops | Agriculture |
| Transitional | Barren land | Barren land |
| Water | Water | Water |
| Woody wetland | Wetlands | Wetlands |

**Table 2-7. Land use classification conversion between West Virginia and Maryland data sets**

| West Virginia detailed land use description | Maryland Detailed land use description | Model land use group |
|---|---|---|
| Barren land - mining | Extractive-surface mines/quarries/pits | Mining |
| Conifer plantation | Evergreen forest | Forest |
| Cove hardwood forest | Deciduous forest | Forest |
| Diverse/mesophytic hardwood forest | Mixed forest | Forest |
| Forested wetland | Wetlands | Wetlands |
| Hardwood/conifer forest | Mixed forest | Forest |
| Herbaceous wetland | Wetlands | Wetlands |
| Intensive urban | High-density residential | Urban built-up |
| Light intensity urban | Low-density residential | Urban built-up |
| Major power lines | Urban built-up | Urban built-up |
| Major roads | Transportation | Urban built-up |
| Moderate intensity urban | Medium-density residential | Urban built-up |
| Mountain hardwood forest | Mixed forest | Forest |
| Oak dominant forest | Deciduous forest | Forest |
| Pasture/grassland | Pasture | Agriculture |
| Populated areas | Urban built-up | Urban built-up |
| Row crop agriculture | Row and garden crops | Agriculture |
| Shrub wetland | Wetlands | Wetlands |
| Shrubland | Brush | Forest |
| Surface water | Water | Water |
| Surface water | Water | Water |
| Woodland | Mixed forest | Forest |

Table 2-8 presents the final land use classifications and the area of each land use in the watershed. The dominant land use in the watershed is forest (60 percent) followed by agriculture

(27 percent). Urban land uses account for less than 10 percent of the total watershed area and are mostly concentrated around rivers and other waterbodies. Figure 2-4 presents the land use coverage for the Youghiogheny River watershed.

**Table 2-8. Land use areas used for the Youghiogheny River watershed**

| Detailed land use description | Model land use group | Area (acres) | Area (miles$^2$) | Percent land use |
|---|---|---|---|---|
| Cropland | Agriculture | 40,320 | 63.0 | 16.01 |
| Pasture | Agriculture | 26,568 | 41.5 | 10.55 |
| Orchards/vineyards/horticulture | Agriculture | 74 | 0.1 | 0.03 |
| Row and garden crops | Agriculture | 1,232 | 1.9 | 0.49 |
| Agricultural breeding building | Agriculture | 253 | 0.4 | 0.10 |
| | **Agriculture subtotal** | **68,447** | **106.9** | **27.18** |
| Barren land | Barren land | 206 | 0.3 | 0.08 |
| Bare ground | Barren land | 434 | 0.7 | 0.17 |
| | **Barren land subtotal** | **640** | **1.0** | **0.25** |
| Deciduous forest | Forest | 115,241 | 180.1 | 45.77 |
| Evergreen forest | Forest | 3,369 | 5.3 | 1.34 |
| Mixed forest | Forest | 30,061 | 47.0 | 11.94 |
| Brush | Forest | 3,212 | 5.0 | 1.28 |
| | **Forest subtotal** | **151,884** | **237.3** | **60.32** |
| Extractive-surface mines/quarries/pits | Mining | 873 | 1.4 | 0.35 |
| | **Mining subtotal** | **873** | **1.4** | **0.35** |
| Urban built-up | Urban built-up | 475 | 0.7 | 0.19 |
| Low-density residential | Urban built-up | 14,679 | 22.9 | 5.83 |
| Medium-density residential | Urban built-up | 2,779 | 4.3 | 1.10 |
| High-density residential | Urban built-up | 214 | 0.3 | 0.09 |
| Commercial | Urban built-up | 1,329 | 2.1 | 0.53 |
| Industrial | Urban built-up | 50 | 0.1 | 0.02 |
| Institutional | Urban built-up | 761 | 1.2 | 0.30 |
| Transportation | Urban built-up | 11 | 0.02 | 0.004 |
| Open urban land | Urban built-up | 1,273 | 2.0 | 0.51 |
| | **Urban built-up subtotal** | **21,572** | **33.7** | **8.57** |
| Water | Water | 5,125 | 8.0 | 2.04 |
| | **Water subtotal** | **5,125** | **8.0** | **2.04** |
| Wetlands | Wetlands | 3,241 | 5.1 | 1.29 |
| | **Wetlands subtotal** | **3241** | **5.1** | **1.29** |
| **Total** | | **251,782** | **393.4** | **100.00** |

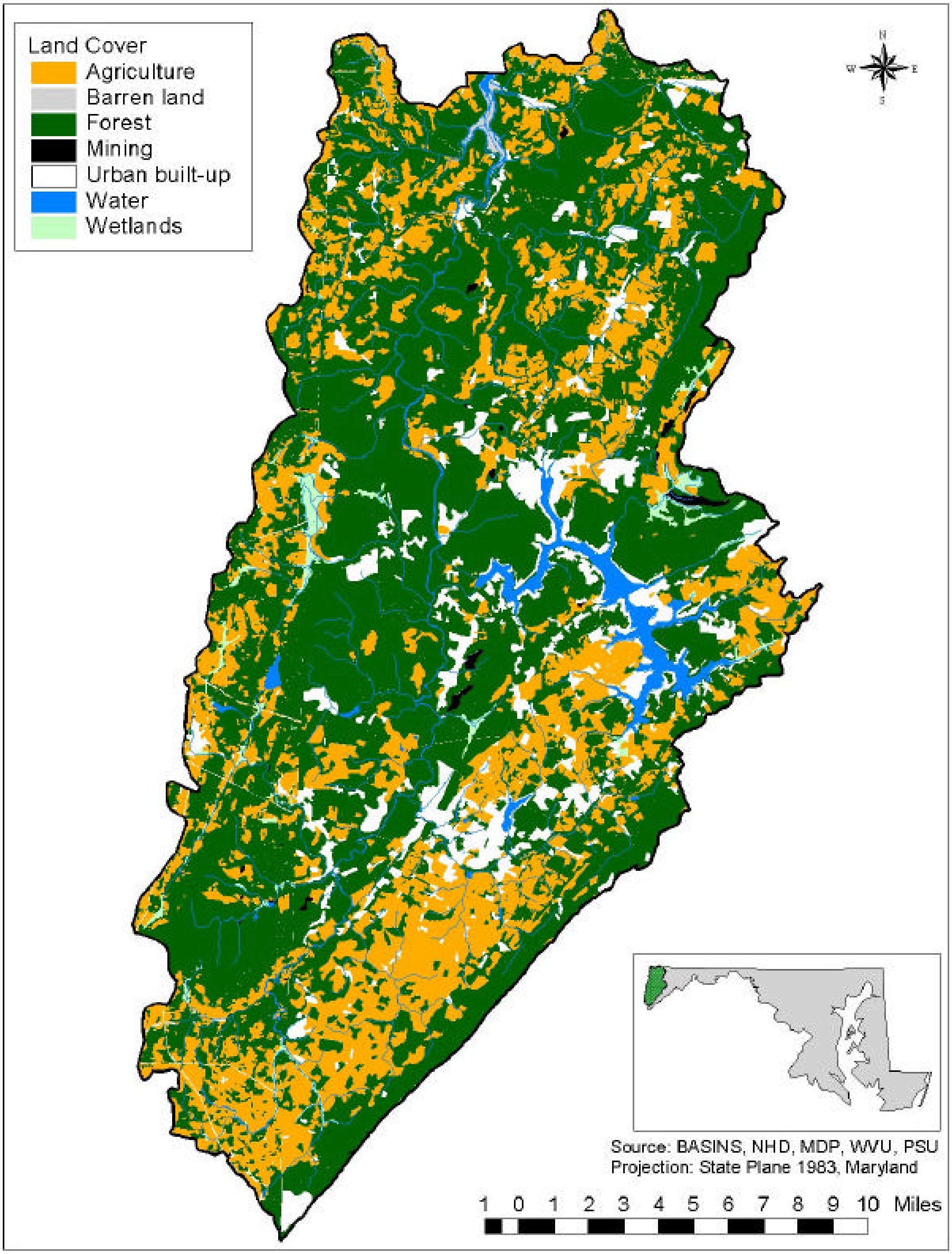


**Figure 2-4. Land use in the Youghiogheny River watershed.**

#### 2.1.5 Soils and Geology

The Natural Resources Conservation Service (NRCS) has defined four hydrologic soil groups providing a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils (Group D) that are poorly drained have the lowest infiltration rates with the highest amount of runoff, while sandy soils (Group A) that are well drained have high infiltration rates with little runoff. Data for the watershed were obtained from BASINS, which contains information from the State Soil Geographic Database (STATSGO) and are presented in Figure 2-5. The majority of the watershed contains soil group C. There are areas of soil group B northwest of Deep Creek Lake, west of Pine Swamp, along the southeastern portion of the watershed, and in the northern portion, east of Youghiogheny River Lake. There are only two small portions of soil group D southwest of Pine Swamp.

The Youghiogheny River watershed is in the Appalachian Plateaus Physiologic Province. This province is characterized by gentle folded sedimentary rocks, such as sandstone, shale, and siltstone. The rocks range in age from Devonian to Pennsylvanian and contain several coal beds.

Surface geology of the area consists of the Chemung Formation, Hampshire Formation, Pocono Group, Greenbrier Formation, Mauch Chunk Formation, Pottsville Formation, Allegheny Formation, and the Conemaugh Formation. Three of these formations contain coal-bearing layers: the Conemaugh Formation (Upper Freeport and Barton coals) and the Pottsville and Allegheny Formations (Upper Freeport and Brookville coals). The Greenbrier Formation is the only formation that contains limestone and calcareous shale. These rock types act as a natural acidity buffer; however, they are found only in small areas of the watershed and are usually upstream of mining activity.

#### 2.1.6 Historical Mining Data

Historical mining activities are an important consideration in the development of pH TMDLs. The study area contains numerous mining activities, but information on past activities is difficult to obtain because many operations did not keep thorough records. MDE provided information on mine drainage sources such as portals, sediment ponds, and pits (Figure 2-6). This information was plotted, and each location was assigned to its corresponding subwatershed in the model area. In all, 45 mine sources were included as model inputs. Few of the locations had concentration or flow data associated with them. In addition, Figure 2-6 shows areas of historical mining activities.

#### 2.1.7 Point Source Data

A point source, according to 40 CFR 122.3, is any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, and vessel or other floating craft from which pollutants are or could be discharged. The National Pollutant Discharge Elimination System (NPDES) program, established under Clean Water Act sections 318, 402, and 405, requires permits for the discharge of pollutants from point sources.

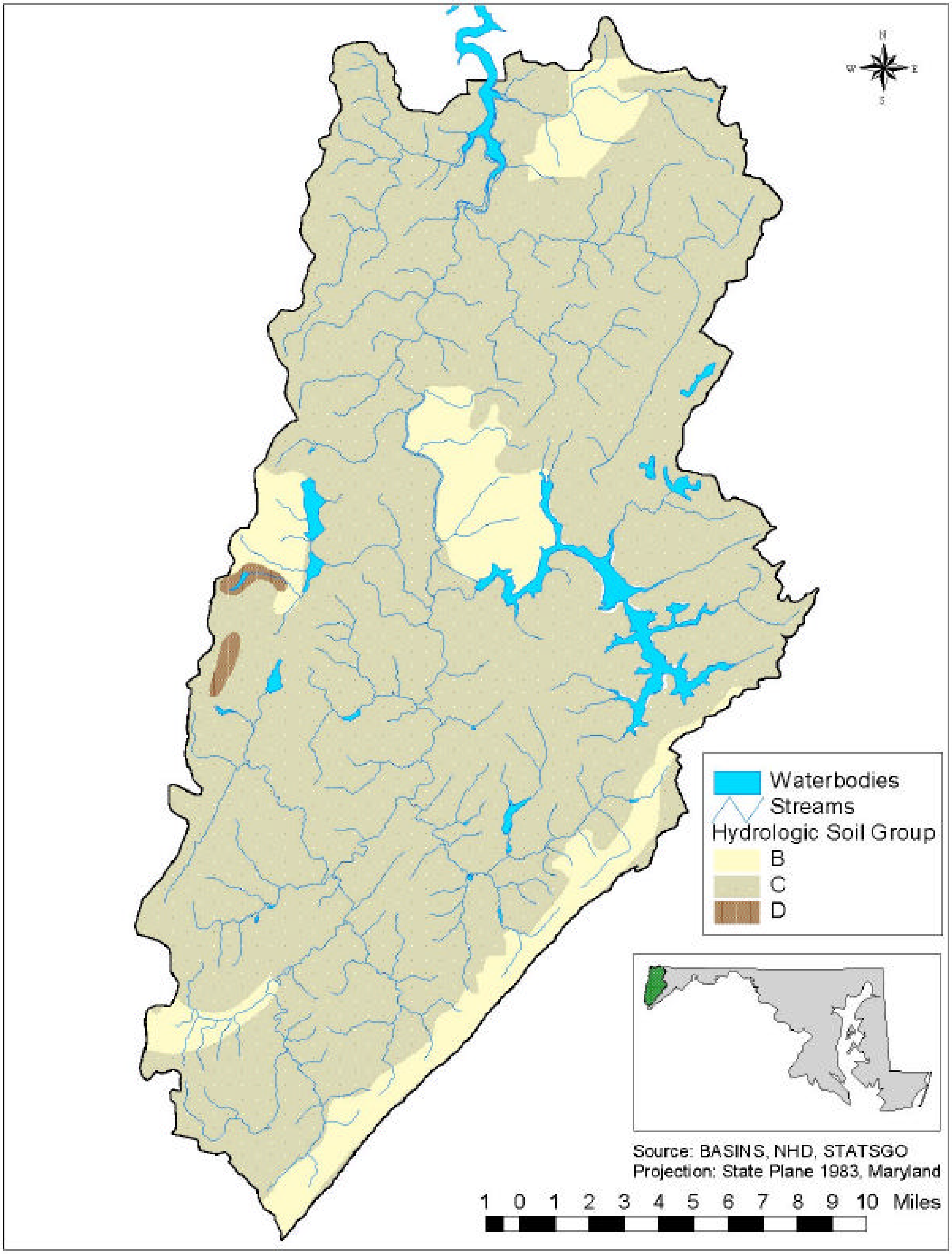


**Figure 2-5. Hydrologic soil groups in the Youghiogheny River watershed.**

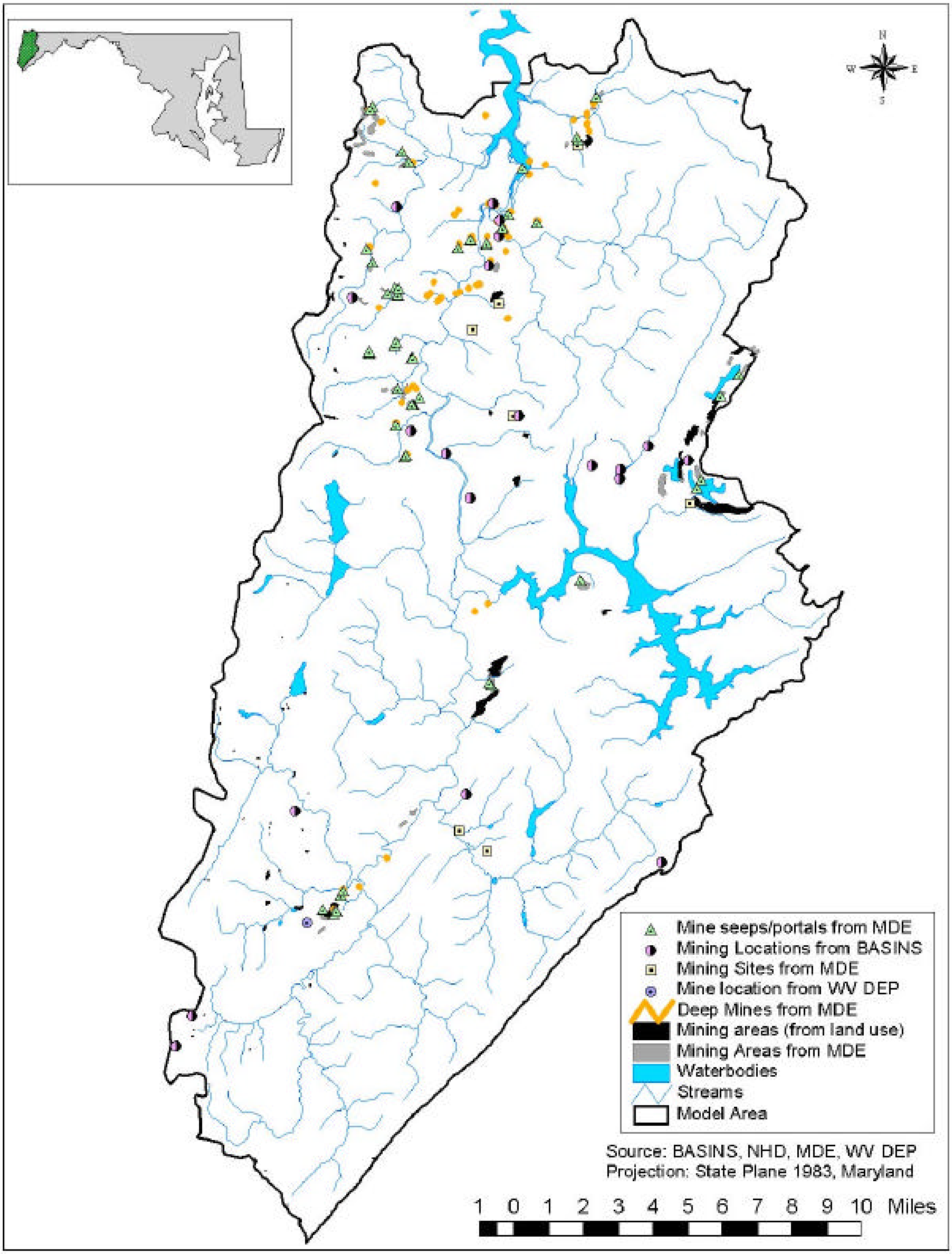


**Figure 2-6. Mining activities in the Youghiogheny River watershed.**

NPDES permit information was obtained from EPA's Permit Compliance System (PCS) (USEPA 2005b) and MDE. Table 2-9 identifies these permits, their permitted flow, and their permit limits for ammonia, total iron, and total aluminum. Figure 2-7 shows the locations of the seven NPDES permitted facilities in the TMDL area.

**Table 2-9. Permitted facilities included in the Youghiogheny River watershed model**

| NPDES permit number | Outlet | Facility | Permit flow (mgd) | Ammonia[a] (mg/L) | | Total iron (mg/L) | | Total aluminum (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Mon. avg | Daily avg | Mon. avg | Daily avg | Mon. avg | Daily avg |
| MD0052850 | 001A | Swallow Falls State Park WWTP | 0.062 | 3.5 (S) | 12 (S) | -- | -- | -- | -- |
| WV0033804 | 001 | Terra Alta STP | 0.25 | 2 | 4 | -- | -- | -- | -- |
| WV0086665 | 001 | Alpine Lake STP | 0.06 | -- | -- | -- | -- | -- | -- |
| WV0119113 | 002 | Cranesville Stone (quarry) | variable | -- | -- | 3.2 | 6 | 0.43 | 0.75 |
| WVG551149 | 001 | Alyeska, Inc. (Big Bear Lake Campground WWTP) | 0.03 | 3 (S)<br>6 (W) | 6 (S)<br>12 (W) | -- | -- | -- | -- |
| WVG610139 | 001 | Grimm Lumber, Inc. (sawmill) | 0.0026 | -- | -- | -- | 1 | -- | -- |
| WVG640110 | 001 | Terra Alta WTP | 0.005 | -- | -- | 1.2 | 2.5 | 0.75 | 1.5 |

[a] Ammonia limits contain summer and winter limits. Summer limits (S) are valid from May 1 through October 31. Winter limits (W) are valid November 1 through April 30.

The Surface Mining Control and Reclamation Act of 1977 (SMCRA, Public Law 95-87) and its subsequent revisions were enacted to establish a nationwide program to protect the beneficial uses of land or water resources, protect public health and safety from the adverse effects of current surface coal mining operations, and promote the reclamation of mined areas left without adequate reclamation before August 3, 1977. The SMCRA requires a permit for development of new, previously mined, or abandoned sites for the purpose of surface mining. Permittees are required to post a performance bond that will be sufficient to ensure the completion of reclamation requirements by a regulatory authority if the applicant forfeits its permit. Mines that ceased operations before the effective date of SMCRA (often called *pre-law* mines) are not subject to the requirements of SMCRA.

SMCRA Title IV is designed to provide assistance for the reclamation and restoration of abandoned mines, while Title V states that any surface coal mining operations are required to meet all applicable performance standards. Some general performance standards include the following:

- Restoring the land affected to a condition capable of supporting the uses that it was capable of supporting before any mining
- Backfilling and compacting (to ensure stability or to prevent leaching of toxic materials) to restore the approximate original contour of the land, including all highwalls

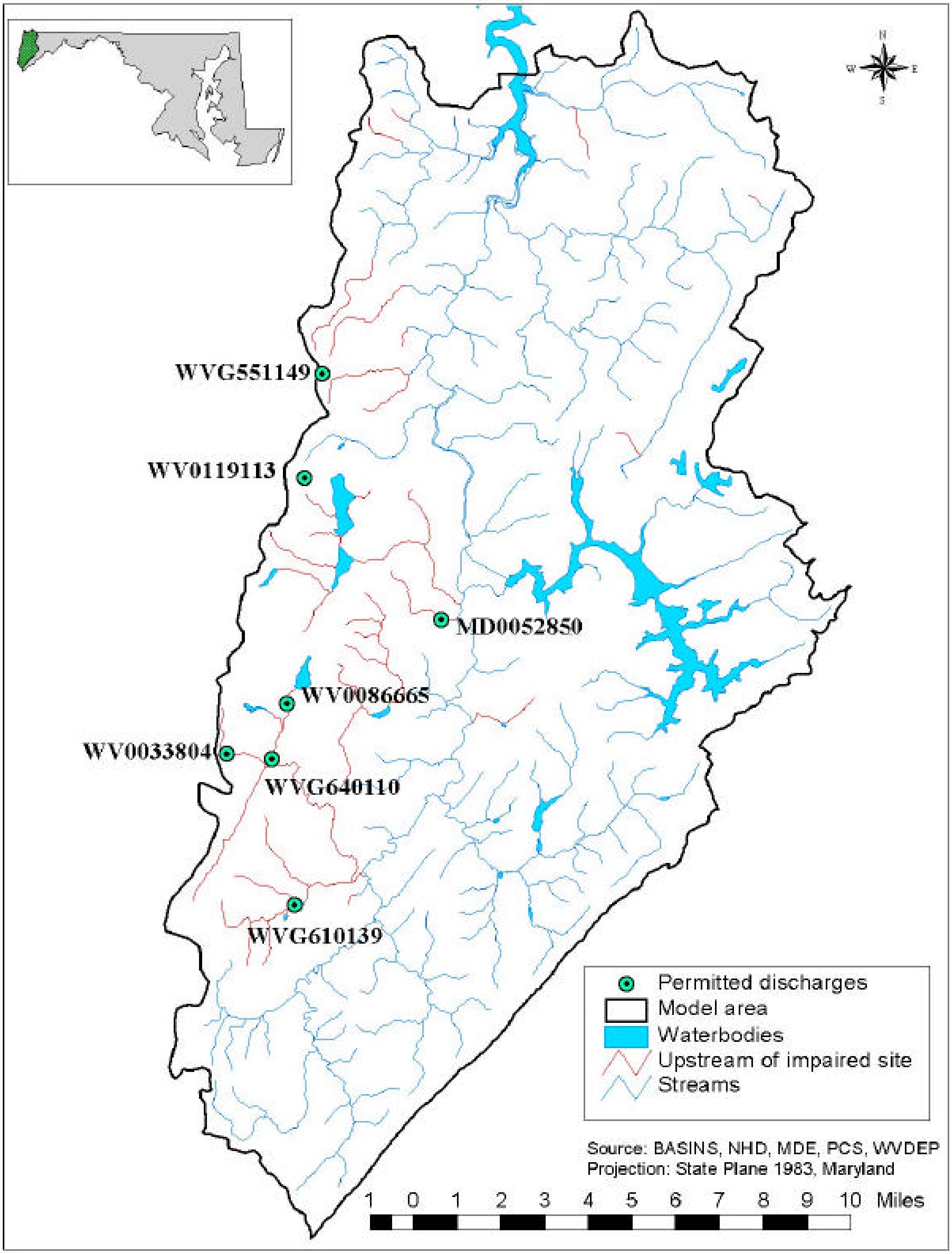


**Figure 2-7. NPDES permitted facilities discharging to waters upstream of impaired monitoring sites in the Youghiogheny River watershed.**

- Minimizing disturbances to the hydrologic balance and to the quality and quantity of water in surface water and groundwater systems both during and after surface coal mining operations and during reclamation by avoiding acid or other toxic mine drainage

Untreated coal mining-related point source discharges from deep, surface, and other mines typically have low pH values (that is, they are acidic) and contain high concentrations of metals (e.g., iron, aluminum, and manganese). Coal mining-related activities are commonly issued NPDES discharge permits that contain effluent limits for total iron, total manganese, nonfilterable residue, and pH. Many permits also include effluent monitoring requirements for total aluminum.

#### *2.1.8 Nonpoint Source Data*

Nonpoint sources of pollutants are diffuse, non-permitted sources. They most often result from precipitation-driven runoff. The two main sources of nonpoint source pollution that contribute to low pH levels in the Youghiogheny River watershed are mining and atmospheric deposition. Mining was previously described, and atmospheric deposition is described below.

The majority of acid deposition occurs in the eastern United States. In March 2005 EPA issued the Clean Air Interstate Rule (CAIR), which places caps on emissions for sulfur dioxide and nitrogen dioxides for the eastern United States. It is expected that CAIR will reduce sulfur dioxide emissions by more than 70 percent and nitrogen oxides emissions by more than 60 percent from 2003 emission levels (USEPA 2005c). Because the pollution is highly mobile in the atmosphere, reductions based on CAIR in West Virginia, Ohio, and Pennsylvania will likely improve the quality of precipitation in the Youghiogheny River watershed.

Atmospheric deposition occurs by two main methods: wet and dry. Wet deposition occurs through rain, fog, and snow. Dry deposition occurs from gases and particles. Dry deposition accounts for approximately half of the atmospheric deposition of acidity (USEPA 2005d). Particles and gases from dry deposition can be washed from trees, roofs, and other surfaces by precipitation after it is deposited and washed into streams. Winds blow the particles and gases contributing to acid deposition over large distances, including political boundaries such as state lines. The primary pollutants from atmospheric deposition are sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_x$). The majority of sulfur dioxides (two-thirds) and one-fourth of nitrogen oxides are from fossil fuel burning electric power generating plants (USEPA 2005d).

Atmospheric deposition data were obtained from the EPA Office of Air Quality Planning and Standards at Research Triangle Park, North Carolina. The data are a result of air quality modeling in support of the CAIR. The data include concentrations of sulfate and nitrogen oxides in wet and dry deposition. For the technical information on these data, see the *Technical Support Document for the Final Clean Air Interstate Rule—Air Quality Modeling* (USEPA 2005e).

## 2.2 Data Analysis

### *2.2.1 Source Assessment*

Streams in the Youghiogheny River watershed were monitored in the spring and fall of 2005. MDE analyzed the monitoring results following the method summarized below and in Table 2-10 for identifying the source(s) of acid impairments in streams.

- Assuming baseflow conditions, there is most likely no major source of acidification if the acid neutralizing capacity (ANC) of the stream is greater than 200 µeq/L.
- If agriculture represents greater than 50 percent of the drainage area for the monitoring location and the nitrogen nitrate ($NO_3$-N) level is greater than 100 µeq/L (˜ 14 mg/L), there is a strong probability that agriculture is the major influence in stream acidification.
- If sulfate levels are greater than 500 µeq/L (˜ 24 mg/L), the primary acidification source is most likely acid mine drainage (AMD).
- If sulfate is greater than 300 µeq/L (˜ 14 mg/L), there is the potential that the stream could be affected by both AMD and atmospheric deposition.
- If conductivity is greater than 80–100 µS/cm, the stream is considered AMD-influenced.
- If the levels of organic ions are greater than the levels of nitrate and sulfate, there is the potential that the stream is acidified by organic acids.
- If the concentration of dissolved organic carbon (DOC) is greater than 8 mg/L, the stream could be influenced by organic sources and atmospheric deposition.
- Finally, stream water quality can be broken into three levels of acidification depending on the levels of ANC:
    - Low (ANC > 50 and = 200 µeq/L): This level has episodic acidification, especially during high-intensity storm events, and occasionally long-duration storms.
    - Very Low (ANC > 0 and = 50 µeq/L): This level has chronic acidification where small acid inputs would drive the stream below 0 µeq/L.
    - Acidic (ANC = 0 µeq/L): These streams have a baseflow ANC that remains below 0 µeq/L.

Results of the data assessment are presented in Table 1-1 and Figure 1-1. Of the 31 segments that MDE monitored, 6 segments were found not to be pH impaired. Five stations were assessed as having impairments due to AMD and atmospheric deposition, three due to just AMD only, nine due to chronic acidification, and eight due to episodic acidification.

### *2.2.2 Data Trends*

Data trends were not able to be determined because of the limited amount of available data.

**Table 2-10. Methodology for assessment of stream acidification in Maryland**

| Water chemistry measurement | | Source of acidification |
|---|---|---|
| Baseflow ANC < 200 µeq/L | No **?** | None |
| Yes **?** | | |
| Agriculture > 50% of drainage area and $NO_3$-N > 100 µeq/L (˜ 1.4 mg/L) | Yes **?** | Possible agricultural influence |
| No **?** | | |
| $SO_4$ = 500 µeq/L (˜ 24 mg/L) | Yes **?** | Primarily acid mine drainage |
| No **?** | | |
| $SO_4$ = 300 µeq/L (˜ 14 mg/L) | Yes **?** | Possibly affected by both acid mine drainage and atmospheric deposition—look at conductivity (> 80–100 µS/cm consider AMD influenced) |
| No **?** | | |
| Organic Ions > $NO_3$ + $SO_4$ | Yes **?** | Primarily organic sources |
| No **?** | | |
| DOC > 8 mg/L | Yes **?** | Affected by both organic sources and atmospheric deposition |
| No **?** | | |
| Baseflow ANC 50–200 µeq/L | Yes **?** | Stream vulnerable to episodic acidification |
| No **?** | | |
| Baseflow ANC < 50 µeq/L | Yes **?** | Chronic acidification (Baseflow ANC may be less than 0 µeq/L.) |

## 3 TECHNICAL APPROACH

Establishing the relationship between in-stream water quality targets and source loadings is a critical component of TMDL development. It allows for evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. This section presents the approach taken to develop the linkage between sources and in-stream response for TMDL development in the Youghiogheny River watershed.

A watershed model is a useful tool for providing a quantitative linkage between sources and in-stream response. It is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring, land-based processes over an extended period, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes using the land-based and subsurface calculations as input. Once a model has been adequately set up and calibrated for a watershed, it can be used to quantify the existing loading of pollutants from subwatersheds or from land use categories and also can be used to assess the impacts of a variety of hypothetical scenarios.

The following technical factors were critical to selecting an appropriate watershed model:

- The model should be able to address the pollutants of concern (e.g., pH).
- The model should be able to simulate processes and constituents that influence pH levels, such as sulfate, iron and aluminum.
- The model should be able to simulate chemical processes and interactions in the surface and subsurface environments because the cumulative effect of these two environments and chemical/biological reactions will affect in-stream pH levels.
- The model should be able to address a watershed with primarily rural land uses.
- The model should provide adequate time-step estimation of flow and not over-simplify storm events to provide accurate representation of rainfall events/snowmelt and resulting peak runoff.
- The model should be capable of simulating various pollutant transport mechanisms (e.g., groundwater contributions, sheet flow).
- The model should be able to simulate wet and dry atmospheric deposition.
- The model should include an acceptable snowmelt routine.

Using the above considerations, the Mining Data Analysis System (MDAS) was selected for modeling the Youghiogheny River watershed. MDAS is a re-coded C++ version of the Hydrologic Simulation Program Fortran (HSPF) model. MDAS integrates comprehensive data storage and management capabilities and the original HSPF algorithms. MDAS's algorithms are identical to a subset of those in the HSPF model. A brief overview of the HSPF model is provided below, and a detailed discussion of HSPF-simulated processes and model parameters is available in the HSPF User's Manual (Bicknell et al. 1996).

HSPF is a comprehensive watershed and receiving water quality modeling framework that was originally developed in the mid-1970s. During the past several years, it has been used to develop hundreds of EPA-approved TMDLs, and it is generally considered the most advanced hydrologic and watershed loading model available. The hydrologic portion of HSPF is based on the Stanford

Watershed Model (Crawford and Linsley 1966), which was one of the pioneering watershed models developed in the 1960s. The HSPF framework is developed in a modular fashion with many different components that can be assembled in different ways, depending on the objectives of the individual project. The model includes three major modules:

- PERLND for simulating watershed processes on pervious land areas
- IMPLND for simulating processes on impervious land areas
- RCHRES for simulating processes in streams and vertically mixed lakes

All three of these modules include many subroutines that calculate the various hydrologic and water quality processes in the watershed. Many options are available for both simplified and complex process formulations. Spatially, the watershed is divided into a series of subwatersheds representing the drainage areas that contribute to each of the stream reaches. These subwatersheds are then further subdivided into segments representing different land uses. For the developed areas, the land use segments are further divided into the pervious (PERLND) and impervious (IMPLND) fractions. The stream network (RCHRES) links the surface runoff and groundwater flow contributions from each of the land segments and subwatersheds and routes them through the waterbodies using storage routing techniques. The stream model includes precipitation and evaporation from the water surfaces, as well as flow contributions from the watershed, tributaries, and upstream stream reaches. Flow withdrawals can also be accommodated. The stream network is constructed to represent all the major tributary streams, as well as different portions of stream reaches where significant changes in water quality occur.

Like the watershed components, several options are available for simulating water quality in the receiving waters. The simpler options consider transport through the waterways and represent all transformations and removal processes using simple, first-order decay approaches. The framework is flexible and allows different combinations of constituents to be modeled depending on data availability and the objectives of the study.

The current version of MDAS includes algorithms for simulation of pollutant accumulation and washoff from land surfaces. MDAS integrates comprehensive data storage and management capabilities, a dynamic watershed model, and a data analysis/post-processing system into a convenient PC-based Windows interface that dictates no software requirements. For the Youghiogheny River pH TMDL, MDAS was updated to include additional modules from HSPF plus new modules designed specifically for this TMDL. Each of the additional modules is briefly described below and is more thoroughly explained in Appendix B.

The first module that was added to MDAS from HSPF was atmospheric deposition. With this addition, the model is able to model dry and wet deposition. Users have the option to enter fluxes (mass per area per time) for dry deposition and concentrations for wet deposition, which the program automatically combines with the input rainfall time series to compute the resulting flux. Either type of deposition data can be input as a constant value or alternatively, as a set of monthly values that is used for each year of the simulation.

The Moisture Storage and Transport in Soil Layers (MSTLAY) module, which was copied from HSPF, uses the fluxes that are computed from surface water, converts them into soil moisture and interlayer fluxes, and makes them usable for adsorption/desorption in solute transport calculations. MSTLAY estimates moisture storages in the four soil layers, in addition to the fluxes of moisture between the storages.

Six modules were created to better simulate pH in the subsurface and in stream reaches by modeling sulfate and nitrogen species. These modules, which are further described in Appendix B, include routines to calculate the transfer and transformation of the different constituents in surface water and subsurface soils.

All these modules were added to MDAS to better predict pH levels in the streams because of the following factors:

- Sulfate and nitrate from atmospheric deposition carry hydrogen, which is the source of acidity, and play a role in water quality in the eastern United States.
- Acidity from atmospheric deposition might intensify or buffer pH levels in the subsurface environment.
- Minerals in the subsurface buffer pH.
- Seasonal biological activity generates carbon dioxide, which can influence pH. Carbon dioxide saturated interflow/groundwater can increase pH when the transport water is subjected to air and the carbon dioxide is released from the water.
- Biological nitrogen transformation, which changes concentrations of nitrate and ammonium, influences pH.
- Increased pH levels could again decrease pH because of dissolved aluminum entering surface water from interflow/groundwater flow.

All these processes are important to consider in the pH modeling process and were added to the MDAS model to better predict pH in the Youghiogheny River watershed. A generalized diagram of how the model flows is shown in Figure 3-1.

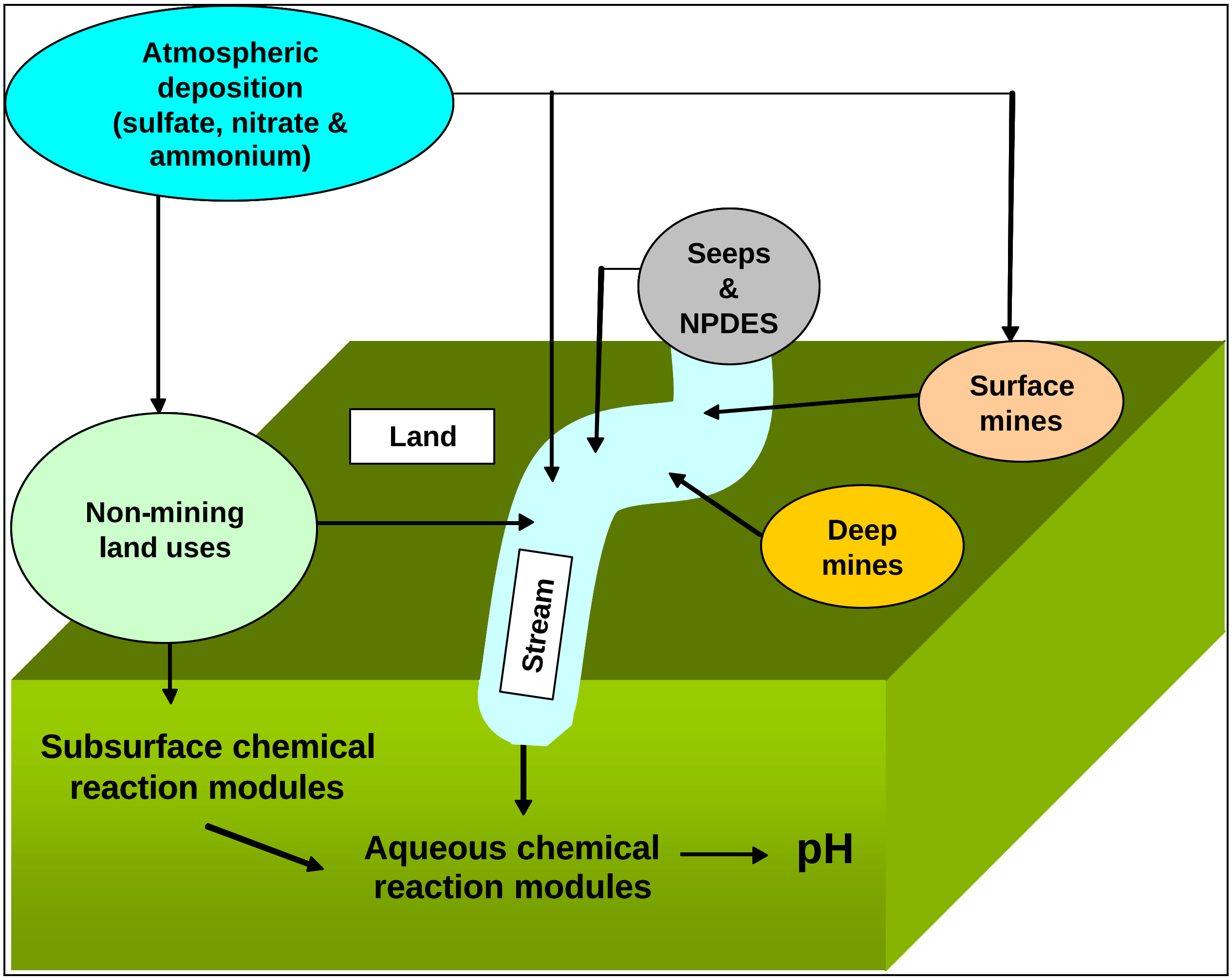


**Figure 3-1. Generalized diagram of pollutant flow in the modeling process.**

# 4 MDAS Model Development

## 4.1 Model Configuration

Configuration of the model involved consideration the following five major components, all of which provide the basis for the model's ability to estimate flow and pollutant loadings:

- Watershed subdivision, which provides the basis for how the model is set up (e.g. land uses are input into the model by watershed subdivisions)
- Stream representation, which represents the actual stream channels in the model
- Land use representation, which provides the basis for distributing runoff and pollutant loading characteristics throughout the basin
- Meteorological data, which drive the watershed model
- Hydrologic and pollutant representation, which refers to the MDAS modules or algorithms used to simulate hydrologic processes (e.g., surface runoff, infiltration) and flow and pollutant transport through streams and rivers

### *4.1.1 Watershed Subdivision*

Watershed subdivision refers to the subdivision of the entire watershed into smaller, discrete subwatersheds for modeling and analysis. MDAS calculates watershed processes using user-defined, hydrologically connected subwatersheds. These subdivisions were based on stream networks and topographic variability and secondarily on the locations of flow and water quality monitoring stations to facilitate model calibration. Using this method, 183 subwatersheds were defined for the Youghiogheny River watershed (Figure 4-1).

### *4.1.2 Stream Representation*

Each delineated subwatershed in the MDAS model was conceptually represented with a single stream assumed to be a completely mixed, one-dimensional segment with a constant cross-section. The National Hydrography Data set (NHD) stream reach network was used to determine the representative stream length for each subwatershed. The stream lengths were used along with the 30-meter National Elevation Data set to calculate reach slope.

Channel dimensions for a number of segments were available from field surveys. Assuming representative trapezoidal geometry for all streams, mean stream depth and channel width were estimated using regression curves that relate upstream drainage area to stream dimensions (Rosgen 1996). Rating curves consisted of a representative depth-outflow-volume-surface area relationship. Estimated Manning's roughness coefficients of 0.035 were applied to each representative stream reach using typical literature values for natural streams (Chapra 1997).

### *4.1.3 Land Use Representation*

MDAS requires a basis for distributing hydrologic and pollutant loading parameters. This is necessary to appropriately represent hydrologic variability throughout the watershed, which is influenced by land surface and subsurface characteristics. It is also necessary to represent

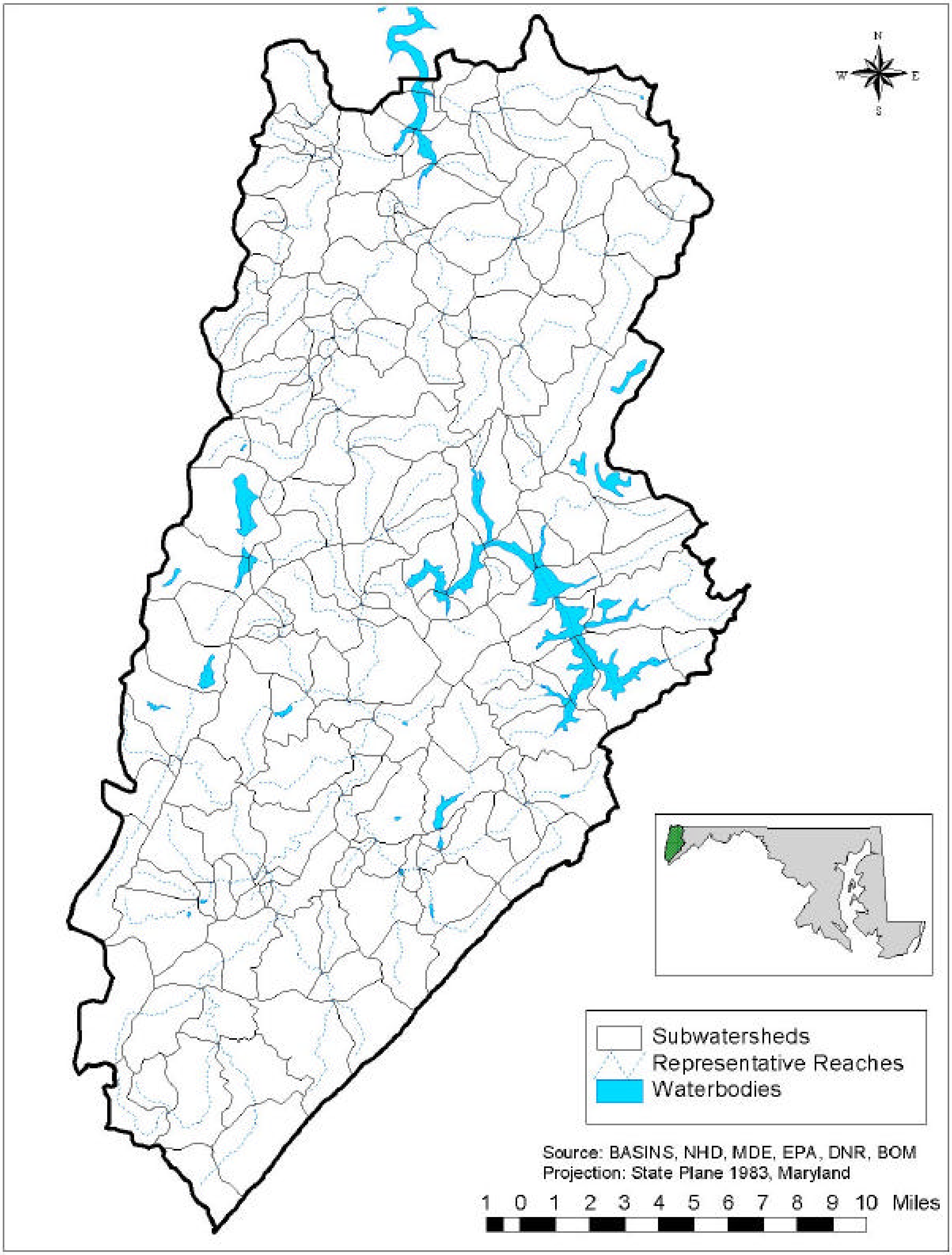


**Figure 4-1. Watershed delineation for the Youghiogheny River watershed MDAS model.**

variability in pollutant loading, which is highly related to land practices. Land use typically represents the primary unit for computing both water quantity and quality. In addition to the need for land use data in computing water quantity and quality, nonpoint source management decisions are also frequently based on land use related activity at the subwatershed level. Therefore, it is important to have a detailed land use representation with classifications that are meaningful for load allocation and load reduction. The following sections describe the source and rationale for the land use data used in the modeling effort.

Existing land use and land cover in the watershed were determined from information provided by MDE. The land use data for the portion of the watershed in Pennsylvania were obtained from the Pennsylvania Spatial Data Access Web site, which is housed at Pennsylvania State University (PSU 2003). The West Virginia land use data were obtained from the Natural Resource Analysis Center and West Virginia Cooperative Fish and Wildlife Research Unit from West Virginia University (WVU 2000). Each land use data set has its own classification system; therefore, it was necessary to reclassify the land uses to be consistent between data sets. The MDE classifications were used as the basis for the reclassification. The detailed MDE classifications were grouped into seven general categories (Table 2-5). Forest areas include deciduous forest, evergreen forest, and brush. Agriculture includes row crops, orchards, pasture, and non-specific cropland. Urban built-up areas include residential, commercial, industrial, institutional (e.g. schools, hospitals), and major highways.

#### 4.1.4 Meteorological Representation

Hydrologic processes are time varying and depend on changes in environmental conditions such as precipitation, temperature, and wind speed. As a result, meteorological data are a critical component of watershed models.

Meteorological conditions are the driving force for nonpoint source transport processes in watershed modeling. Generally, the finer the spatial and temporal resolution available for meteorology, the more representative the simulation of associated watershed processes will be. At a minimum, precipitation and potential evapotranspiration are required as large factors for most watershed models. For the Youghiogheny River watershed, where the snowfall and snowmelt processes are a significant factor in watershed-wide hydrology, additional data were required for snow simulation. These data were temperature, dew point temperature, wind speed, and solar radiation.

The available precipitation data for a given station are not always 100 percent complete. An effort was made to select weather stations with a high level of completeness, above 90 percent. However, precipitation stations might contain various intervals of accumulated, missing, or deleted data.[1] In these circumstances, rainfall patching must be performed. Patching involves using the *normal-ratio method*, which estimates a missing rainfall record with a weighted average from surrounding stations with similar rainfall patterns. Accumulated, missing, and deleted data records were repaired using hourly rainfall patterns at nearby stations with unimpaired data.

[1] Accumulated data represent cumulative precipitation over several hours, but the exact hourly distribution of the data is unknown.

Upon reviewing the available weather data, it was concluded that there were only two adequate precipitation gages for the Youghiogheny River watershed: Oakland 1 SE (COOP# 186620) and Terra Alta No 1 (COOP# WV8777). The additional weather data were obtained from Elkins–Randolph Co Airport (WBAN# 13729).

Data from these gages were used to develop an input file with hourly time-series of data from January 1987 through November 2005. An hourly time step for weather data was required to properly reflect diurnal temperature changes (and the resulting influence on whether precipitation was modeled as rainfall or snow) and provide adequate resolution for rainfall/runoff intensity to drive erosion and water quality processes during storms or snowmelt events.

#### *4.1.5 Hydrologic and Pollutant Representation*

*Soils*

To account for the variability of hydrology characteristics throughout the watershed associated with different soil types or topography, three groups of hydrology parameters were configured in the model. The hydrologic soil group classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have the worst infiltration rates (D soils), while sandy soils that are well-drained have the best infiltration rates (A soils).

Hydrologic group data for the watershed were obtained from the STATSGO database. The data were summarized using the major hydrologic group in the surface layers of the map unit. Soils in the Youghiogheny River watershed are primarily classified as C, having moderate to slow infiltration rates when saturated. These hydrologic groups served as a starting point for the designation of infiltration and groundwater flow parameters during the MDAS setup.

*Point Sources*

Point source contributions of flow, ammonium, total iron, and total aluminum were incorporated into the model. Data were obtained from EPA's PCS database (Section 2.1.7), directly from permits provided by MDE, and information proved from the West Virginia Department of Environmental Protection. For model calibration, monthly flows and concentrations, obtained from discharge monitoring reports (DMRs), were used when they were available, and permitted flows were used when DMR information was not available. Table 4-1 lists the permit, flow statistics, concentration statistics, and the data source for the information. Because WV0119113 is for stormwater, its discharge is automatically calculated by the model and thus not included.

**Table 4-1. Modeled permitted flow and ammonium concentrations**

| Permit | Outfall | Min flow (cfs) | Avg flow (cfs) | Max flow (cfs) | Parameter | Min conc. (mg/L) | Avg conc. (mg/L) | Max conc. (mg/L) | Data source |
|---|---|---|---|---|---|---|---|---|---|
| MD0052850 | 001A | 0.0000 | 0.0392 | 0.0897 | Ammonia | 0.00 | 1.44 | 3.50 | DMR/permit |
| WV0033804 | 001 | 0.1702 | 0.3932 | 0.6607 | Ammonia | 0.00 | 0.79 | 10.40 | DMR |
| WV0086665 | 001 | 0.0082 | 0.1126 | 0.4232 | -- | -- | -- | -- | DMR |
| WVG551149 | 001 | 0.0464 | 0.0464 | 0.0464 | Ammonia | 3.00 | 4.50 | 6.00 | permit |
| WVG610139 | 001 | 0.0040 | 0.0040 | 0.0040 | Total iron | 1.00 | 1.00 | 1.00 | permit |
| WVG640110 | 001 | 0.0077 | 0.0077 | 0.0077 | Total aluminum | 0.75 | 0.75 | 0.75 | permit |
| | | | | | Total iron | 1.20 | 1.20 | 1.20 | permit |

*Nonpoint Source Representation*

Nonpoint source contributions of nitrate, ammonium, sulfate, iron, and aluminum were represented in the model through a number of mechanisms. Contributions were land use dependent and represented through surface, interflow, and groundwater outflows. Concentrations were initially based on literature values and then calibrated to correspond to observed concentrations (Section 4.2.2). In addition to the land use-based contributions, specific contributions were also included in the model for atmospheric deposition and mine seepage.

Atmospheric deposition was represented by two different pathways in the model: dry deposition and wet deposition. Both pathways were represented similarly for land uses and included contributions for nitrate, ammonium, and sulfate. Dry-weather deposition was represented using a constant load over time (weight/area/time). Wet deposition was represented by associating a specified concentration with precipitation data in the model. Data for both types of deposition were obtained from the EPA Office of Air Quality Planning and Standards at Research Triangle Park, North Carolina. The data are a result of air quality modeling in support of the CAIR. The data include concentrations of sulfate and nitrogen oxides in wet and dry deposition. For additional information on these data, please see the *Technical Support Document for the Final Clean Air Interstate Rule—Air Quality Modeling* (USEPA 2005e).

Dry and wet deposition were represented for two different time periods in the model. The year 2001 was used to represent current conditions for calibration. Predicted levels for 2020 were used in the model to represent TMDL conditions. These levels are reflective of the CAIR reducing emissions to the 2020 estimated levels. Table 4-2 presents both 2001 levels and predicted 2020 levels.

**Table 4-2. Modeled atmospheric deposition concentrations and fluxes**

| 2001 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan.** | **Feb.** | **Mar.** | **Apr.** | **May** | **Jun.** | **Jul.** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| **Dry deposition (gram/acre-day)** | | | | | | | | | | | | |
| $NH_4$ | 0.29 | 0.28 | 0.51 | 0.80 | 0.88 | 1.00 | 0.86 | 0.56 | 0.69 | 0.64 | 0.47 | 0.45 |
| $NO_3$ | 0.18 | 0.18 | 0.27 | 0.17 | 0.05 | 0.03 | 0.02 | 0.04 | 0.02 | 0.06 | 0.12 | 0.11 |
| $SO_4$ | 30.40 | 26.39 | 29.08 | 20.63 | 35.82 | 43.54 | 34.36 | 43.11 | 38.91 | 35.30 | 27.59 | 39.89 |
| **Wet deposition (mg/L)** | | | | | | | | | | | | |
| $NH_4$ | 0.15 | 0.10 | 0.21 | 0.28 | 0.35 | 0.28 | 0.11 | 0.11 | 0.09 | 0.08 | 0.12 | 0.17 |
| $NO_3$ | 1.11 | 0.96 | 1.32 | 1.16 | 1.34 | 1.22 | 0.69 | 0.54 | 0.47 | 0.43 | 0.95 | 1.85 |
| $SO_4$ | 1.14 | 1.44 | 1.58 | 2.47 | 4.18 | 4.17 | 2.16 | 1.93 | 1.31 | 0.85 | 1.39 | 2.43 |
| | | | | | | | | | | | | |
| **2020** | | | | | | | | | | | | |
| | **Jan.** | **Feb.** | **Mar.** | **Apr.** | **May** | **Jun.** | **Jul.** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
| **Dry deposition (gram/acre-day)** | | | | | | | | | | | | |
| $NH_4$ | 0.40 | 0.42 | 0.62 | 1.08 | 1.22 | 1.55 | 1.22 | 0.63 | 1.05 | 0.96 | 0.71 | 0.59 |
| $NO_3$ | 0.17 | 0.18 | 0.23 | 0.17 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.05 | 0.10 | 0.10 |
| $SO_4$ | 10.51 | 8.83 | 9.38 | 5.82 | 9.13 | 8.92 | 7.96 | 7.27 | 9.41 | 9.74 | 8.25 | 12.43 |
| **Wet deposition (mg/L)** | | | | | | | | | | | | |
| $NH_4$ | 0.16 | 0.10 | 0.22 | 0.28 | 0.35 | 0.27 | 0.11 | 0.11 | 0.08 | 0.08 | 0.12 | 0.17 |
| $NO_3$ | 0.72 | 0.57 | 0.79 | 0.61 | 0.57 | 0.49 | 0.26 | 0.21 | 0.21 | 0.19 | 0.44 | 1.85 |
| $SO_4$ | 0.63 | 0.73 | 0.97 | 1.34 | 1.90 | 1.58 | 0.86 | 0.81 | 0.59 | 0.47 | 0.79 | 1.26 |

Mine seepage was modeled as a constant input (flow and concentration) at specific, known, abandoned mine locations. Pollutants in the mine seepage included iron, aluminum, and sulfate. Mine seepage locations were available through MDE and are shown in Figure 2-6, labeled as "Mine seeps/portals from MDE." Flow and chemical data were not provided for most sites, so median values of the available data were used. Table 4-3 presents the flow and chemical data that were used for these seeps and portals.

### 4.2 Calibration and Validation

After initially configuring the watershed model, model calibration and validation for hydrology and water quality were performed. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Validation is performed for different monitoring stations without further parameter adjustments to ensure that the model represents other periods as well as it does at the original calibration periods. If the model exhibited a poor validation, the calibration process was revisited. Upon completion of the calibration and validation at selected locations, a calibrated data set containing parameter values for each modeled land use and soil type was obtained.

#### *4.2.1 Hydrology Calibration*

Hydrologic calibration was performed after the initial model setup. For MDAS, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, physical, and chemical characteristics of the watershed and compounds of interest. Calibration is based on several years of simulation to evaluate parameters under a variety of climatic conditions. The calibration procedure results in parameter values that produce the best overall agreement between simulated and observed flows throughout the calibration period.

Three USGS flow-gaging stations were used for MDAS hydrology calibration and validation (Figure 2-1). These stations are listed in Table 2-2 with periods of records and measures of completeness. The calibration years were selected after examining annual precipitation variability and the availability of observation data. The periods were determined to represent a range of hydrologic conditions including low-, mean-, and high-flow conditions. Calibration for these conditions is necessary to ensure that the model accurately predicts a range of conditions over the entire simulation period.

During calibration, parameters influencing the simulation of runoff, infiltration, and evapotranspiration were adjusted using land use and soil type. Modeling parameters were varied to keep with observed temporal trends and soil and land cover characteristics. An attempt was made to keep the modeling parameters within the guidelines included in the BASINS Technical Note 6 (USEPA 2000).

Key considerations in the hydrology calibration included the overall water balance, the high-flow and low-flow distribution, storm-flow volumes and timing, and seasonal variation. At least three criteria for goodness of fit were used for calibration: volumetric comparison, graphical comparison, and the relative error method. The calculation of runoff volumes at various time

**Table 4-3. Flow and chemical data for mine seeps and portals used in the model**

| Site ID | Type | Date | Field pH | Iron (mg/L) | Aluminum (mg/L) | Sulfate (mg/L) | Flow (cfs) |
|---|---|---|---|---|---|---|---|
| MY-00037[a] | Seep | | 2.88[a] | 50.6[a] | 24.6[a] | 916[a] | 0.0045[b] |
| C-57-S1 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| C-62-S1 | Seep | | 4 | 10[b] | 1[c] | 201[b] | 0.0668 |
| C-62-S2 | Seep | | 6 | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| C-65-S1 | Seep | | 6 | 10[b] | 1[c] | 201[b] | 0.0111 |
| FR-03-P2 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-03-S1 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-07-P4 | Portal | | 4.5 | 10[b] | 1[c] | 201[b] | 0.0223 |
| FR-08-P1 | Portal | | 5.5 | 10[b] | 1[c] | 201[b] | 0.0022 |
| FR-09-P10 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P15 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P18 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P2 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P22 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P24 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P25 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P26 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P29 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| FR-09-P31 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| OK-01-P1 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| OK-01-P2 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| SR-02-P1 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| SR-02-P2 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| SR-02-P3 | Portal | 07/17/02 | 5.5 | 45 | 0 | 201 | 0.0111 |
| SR-02-S1 | Seep | 07/17/02 | 6 | 10 | 0 | 7 | 0.0045 |
| SR-02-S2 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| SR-03-P3 | Portal | | 4.5 | 10[b] | 1[c] | 201[b] | 0.0022 |
| SR-03-P7 | Portal | | 4.75 | 10[b] | 1[c] | 201[b] | 0.0022 |
| SR-03-P8 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0022 |
| Y-01-P1 | Portal | 07/08/02 | 6[b] | 1 | 0 | 250 | 0.0045[b] |
| Y-06-P2 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-06-Site1 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-07-P7 | Portal | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-10-O1 | Open Pit | | 7.5 | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-10-O2 | Open Pit | | 7.5 | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-10-S1 | Seep | | 6.5 | 10[b] | 1[c] | 201[b] | 0.0223 |
| Y-11-S1 | Seep | | 6 | 10[b] | 1[c] | 201[b] | 0.0067 |
| Y-13-S1 | Seep | 06/25/02 | 6 | 3 | 0 | 110 | 0.0557 |
| Y-18-S1 | Seep | | 4.5 | 10[b] | 1[c] | 201[b] | 0.0022 |
| Y-19-S1 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-20-S1 | Seep | | 4.5 | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-22-O1 | Open Pit | | 7 | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-22-O2 | Open Pit | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |
| Y-24-S1 | Seep | 07/31/02 | 6 | 19 | 0 | 216 | 0.0045 |
| Y-24-S2 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0022 |
| Y-9-S1 | Seep | | 6[b] | 10[b] | 1[c] | 201[b] | 0.0045[b] |

[a] Data from West Virginia Department of Environmental Protection.
[b] Median of data available at other seeps
[c] All reported concentrations were reported as less than 1. Value assumed to be 1.

scales (e.g., daily, monthly) provides an assessment of the model's ability to accurately simulate the water budget.

For this model, two stations (USGS 03075500 and USGS 03076600) were used in the hydrology calibration, and one station (USGS 03076500) was used for validation. Each station used the period from January 1, 1994, through November 30, 2005, as the model period. Result plots and tables are included in Appendix C. Stations USGS 03076600 and USGS 03076500 showed the best correlation between predictions and monitoring data. Discrepancies, most notably at USGS 03075500, can largely be explained by differences in measured precipitation data (used in the model) and the actual precipitation that fell within the watershed. The weather stations that were used in the model often contained localized storm events that did not occur over the entire watershed, thus creating peaks in the modeled results that were not present in the observed data. Likewise, the model did not predict storms at other times because the precipitation data did not include events that might have occurred in the watershed. These types of discrepancies are common and acceptable in watershed modeling applications.

Overall, the calibration and validation results demonstrated that the model predicts hydrology soundly. The calibration results for USGS 03075500 (Youghiogheny River near Oakland) followed seasonal trends of the observed data, slightly under-predicting observed data. There were two periods—one in 1999 and the other in 2000—when localized storm events were not captured in the weather station data used, and thus, modeled flow was well below the observed peaks during those storm events. Calibration results at USGS 03076600 (Bear Creek at Friendsville) followed seasonal trends similar to the observed data, slightly over-predicting observed low flow data during the summer months. Validation results at USGS 03076500 (Youghiogheny River at Friendsville) showed the best comparison between the observed and modeled flows, slightly under-predicting flow in the late spring months.

#### *4.2.2 Water Quality Calibration*

After hydrology was sufficiently calibrated, water quality calibration was performed. The water quality calibration consisted of running the watershed model, comparing water quality output to available water quality observation data, and adjusting pollutant loading and in-stream water quality parameters within a reasonable range. Recent data (2003–2005) were used for the calibration process to ensure that current conditions were simulated.

The 25 monitoring stations classified as impaired by MDE were used for MDAS water quality calibration and validation (Table 1-1 and Figure 1-1). Half the stations were used for calibration and the other half for validation. The periods used depended on the data and were either 2005 or 2003–2005. Ammonium was the only exception to the calibration period. No samples were analyzed for ammonium during 2003 or 2005, so data from 1998 were used. In addition, only three of the 25 stations had ammonium data.

During calibration, parameters influencing the simulation of water quality were adjusted using land use and soil type. Modeling parameters were adjusted so that model concentrations corresponded with observed concentrations. Calibration and validation were conducted for nitrate, ammonium, sulfate, iron, aluminum, and pH.

For nitrate and ammonium calibration, calibration parameters included the nitrogen transformation rates in the different model layers (surface layer, upper subsurface layer, lower subsurface layer, and streams) and precipitation of organic nitrogen in streams. In addition, a temperature correction for nitrogen transformation rates was calibrated.

The calibration of sulfate was conducted by adjusting stream and subsurface variables. Calibration parameters included desorption ratio (DESORP), sulfate transformation rate ($kk_1$), and background concentrations, which were land use specific.

After nitrogen and sulfate calibrations were completed, metals and pH calibrations were conducted, mainly with the subsurface chemical reaction parameters and background concentrations. Specific parameters included precipitation rates, metal dissolution constants, base saturation percentage, aluminum solubility constant, carbon dioxide ($CO_2$) pressure, and the aluminum selectivity constant.

During water quality calibration, it became clear that some calibration and validation locations contain unknown sources of metals, sulfate, or pH. These locations often exhibited higher concentrations than locations where mine seeps were known to exist. To account for these sources, which were assumed to be unidentified abandoned mines, mining land use was adjusted by removing acres from the forest land use and adding them to the mining land use. The additional acreage was retained during the allocation process. This shift in land use did not adversely affect the hydrology calibration.

Examples of pH calibration and validation are presented in Figures 4-2 and 4-3. Model calibration and validation results, for all parameters, are presented in Appendices D through I. Most of the modeled pH levels were within the pH observed range.

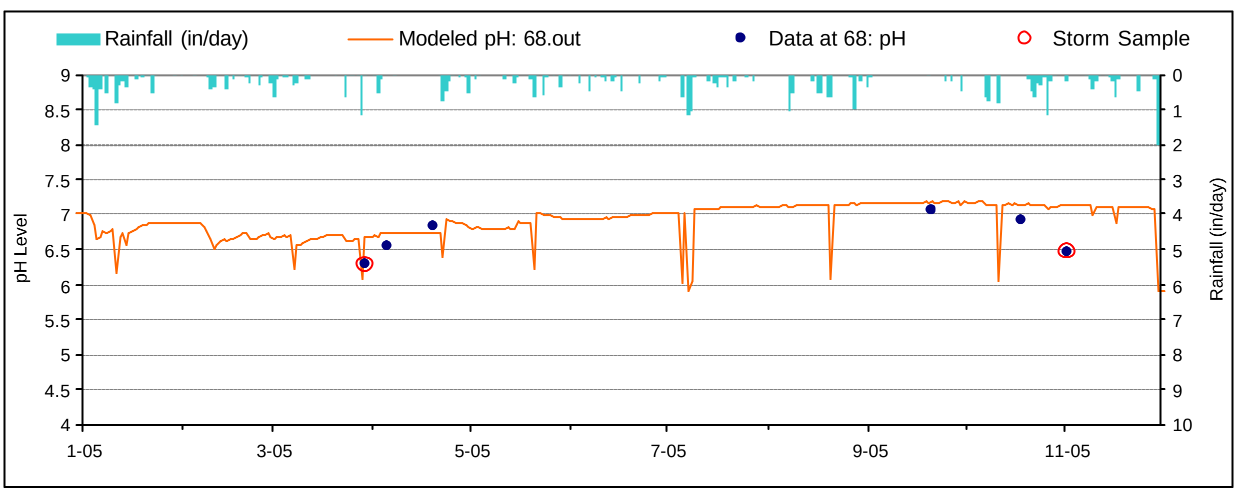


**Figure 4-2. pH Calibration plot for Muddy Creek (MYC0018/WM-17).**

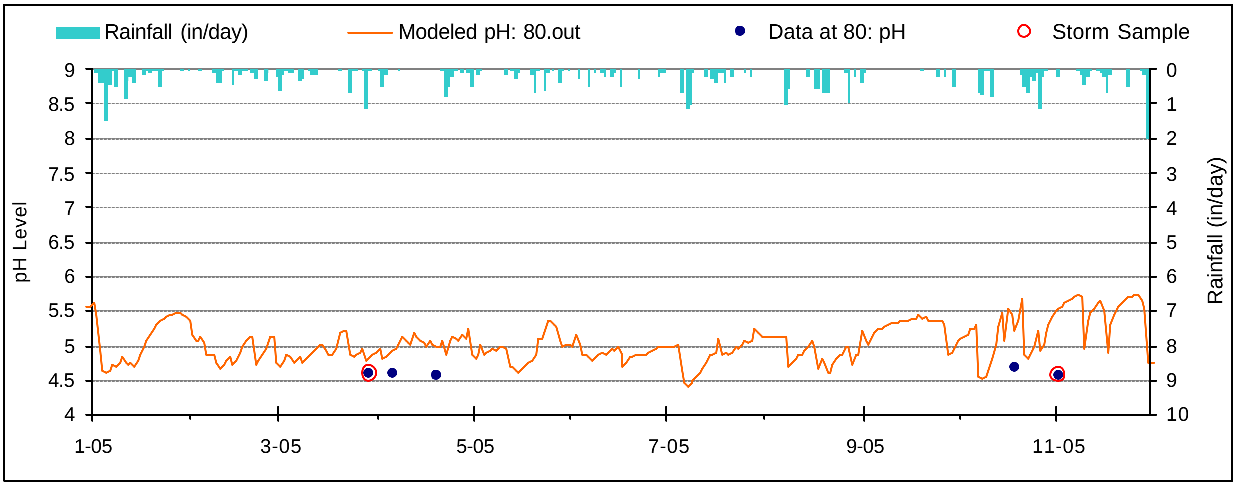


**Figure 4-3. pH Validation plot for UT to Bull Glade Run (ZWE0001/WM-7).**

There were several watersheds where the iron, aluminum, or sulfate concentrations were either lower than observed data or higher than observed data, although the pH simulation was reasonable. Further investigation is needed in these watersheds. For instance, if the modeled iron concentrations were too low but the pH and the other parameters were fairly well represented, it could mean there is a local source of iron that had not been identified (and thus generally not represented in the model). Similarly, if modeled iron, aluminum, and sulfate (the hallmarks of AMD) are below observed levels and modeled pH is reasonable, the watershed might have a greater acid-neutralizing capability than calibrated for, or there could be an acid-neutralizing source (e.g., Hoyes Run [WM-18/HYR0001 and WM-19/HYR0005] where a carbonate mine [MDG499801A] is located). Additionally, in watersheds where pH predictions reasonably match observations and iron, aluminum, and sulfate are modeled below observed levels, there might be an additional source of acidity not represented in the model.

### 4.3 Assumptions and Limitations

The goal of the modeling calibration was to determine a set of parameters that best describe hydrologic and water quality processes in the Youghiogheny River watershed. Using the best available data, model output was evaluated at representative calibration gages. The MDAS model is considered calibrated to the currently available data. Imprecision in the model output is present and expected and are primarily governed by uncertainty with the model inputs. Some uncertainties with the inputs is corrected during the calibration process (i.e., infiltration rates, interception capacity). Others simply appear as unexplained variance between the modeled and observed data. Model uncertainty is difficult to quantify because it changes as temporal and spatial conditions vary. The remainder of this section outlines the model inputs and limitations most likely to cause errors or uncertainty with the model output.

Weather gages are most likely the largest source of model uncertainty. Only two precipitation gages were available for the modeling analysis, and they were responsible for generating precipitation data for 393 square miles. In addition, the climate station used for climate data (e.g., temperature, cloud cover) was outside the watershed. The lack of weather gages significantly increases model uncertainty in terms of amount and timing of water flowing through the system.

Lack of weather gages particularly increases model uncertainty during storm events (timing and volume of water).

Because of the large watershed size and model limitations, large areas of land were lumped together as modeling subwatersheds. This process inherently simplifies watershed representation and reduces some level of detail. However, this process most likely introduces little modeling uncertainty when compared to the other potential sources of uncertainty.

Point source discharges have the potential to affect flow and water quality in a stream. The MDAS model can account for these sources by using time-series inputs of flow and concentrations. However, most point sources report data only on a monthly basis (or less frequently), and data was extrapolated to provide daily model input. In other cases, very little information was available about the point sources, and best professional judgment was used to estimate flow, timing, or outfall location. Point source uncertainties have the greatest potential to affect model output during low-flow events, when point sources make up a larger percentage of the load.

Mining information for the model is limited. Few mine seep data were available. The flow information for these seeps were labeled as estimated. The values used for the model are considered assumptions. If more data are obtained and contributions are found to be more significant than current estimates, mine seeps may have an effect on modeled pH. In addition, as mentioned in Section 4.2.2, land area was subtracted from forest land use and added to the mining land use based on observed concentrations. This assumed that based on monitoring data, additional mine lands/seeps were present in the watersheds, though they have not yet been identified.

Each MDAS/HSPF model is driven by the basic physiographic characteristics that make up a watershed—land use, soils, slopes, and geology (Section 2.1). Therefore, physiographic data must be accurate and complete for each subwatershed. Potential errors were introduced into the model because several of these physiographic characteristics were simplified to facilitate modeling. In addition, physiographic characteristics change over time and are not necessarily represented by the available data and the chosen calibration period. However, this process most likely does not introduce much modeling error when compared to the other potential sources or error.

The model was built to simulate only iron, aluminum, sulfate, nitrate, and ammonium. These constituents were assumed to have the greatest impact on pH levels in the watershed, based on a review of available data. There are other metals and ions that could affect pH, but these were not included in the model.

Atmospheric deposition was based on a regional model and predicted values. It was assumed to contribute at a constant rate (in terms of dry deposition) and a constant concentration (for wet deposition) over multiple years and the entire watershed.

For LAs, the $CO_2$ pressure was adjusted at a number of locations because $CO_2$ is created by respiration and the decay of organic matter. For acidic streams with pH levels as low as 4.4, these processes do not occur. With improved pH levels, these processes are likely to occur, thus changing the $CO_2$ pressure to values reflective of less impaired watersheds.

The following is a list of the major limitations and assumptions in the MDAS model for predicting pH:

- No explicit AMD chemical reactions are incorporated
- Chemical reactions are based on an equilibrium concept, with no kinetic considerations.
- Nitrogen transformations are assumed to be a first-order reaction.
- Sulfate adsorption to soil particles is assumed to be linear.
- Generated soil $CO_2$ follows a seasonal sine curve.

### 4.4 Baseline Model Results

The calibrated and validated model was run for a "baseline" condition. This condition was essentially the starting point for TMDL analysis. For the baseline condition, permit flows and permit limits were included in the model instead of observed DMR flows and concentrations. (Permit information is provided in Table 2-9.) By using these permit values, the total loading from a point source is included in the model.

To give a sense of the extent of impairment at each location, the baseline pH minimum, mean, and maximum are shown in Table 4-4. Streams that exhibited lower pH minimum values generally required the greatest load reductions to achieve pH criteria. The model was run for the period of December 1, 2004, through November 30, 2005. This produced daily loads, which were then summed over the year to create the yearly loads, which are presented in Table 4-5 and subsequent tables.

Tables 4-5 through 4-8 present baseline loadings (before TMDL reductions) of the total daily loads per watershed, yearly loads per watershed, loads from atmospheric deposition, and loads from mine seeps. Table 4-5 presents the total baseline modeled loads for the model year for iron, aluminum, sulfate, nitrate, and ammonium at each station. Table 4-6 presents the baseline yearly atmospheric loads for sulfate, nitrate, and ammonium, based on Table 4-2 over each impaired watershed. Table 4-7 presents the baseline yearly loads of iron, aluminum, and sulfate from mine seeps and portals in the impaired watersheds based on Table 4-3. Table 4-8 presents that portion of loads in Table 4-5 that originate in West Virginia.

**Table 4-4. Modeled baseline pH minimum, mean, and maximum**

| Station | Station code | Station name | pH minimum | pH mean | pH maximum |
|---|---|---|---|---|---|
| WM-1 | MYC0002 | Muddy Creek | 5.78 | 6.87 | 7.19 |
| WM-2 | SNO0000 | Snowy Creek | 4.86 | 6.76 | 7.34 |
| WM-3 | CHB0005 | Cherry Bottom Run | 4.75 | 6.65 | 7.32 |
| WM-4 | HER0028 | Herrington Creek | 4.83 | 6.73 | 7.39 |
| WM-6 | MUL0001 | Murley Run | 4.27 | 5.63 | 7.19 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 4.22 | 5.16 | 7.10 |
| WM-8 | HER0014 | Herrington Creek | 4.65 | 6.54 | 7.36 |
| WM-10 | BUG0013 | Bull Glade Run | 4.23 | 5.25 | 7.12 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 4.22 | 5.26 | 7.12 |
| WM-12 | MLR0001 | Millers Run | 4.99 | 6.94 | 7.42 |
| WM-14 | TOL0001 | Toliver Run | 4.65 | 6.50 | 7.26 |
| WM-15 | LAU0013 | Laurel Run | 4.37 | 6.01 | 7.24 |
| WM-16 | NED0005 | Ned Run | 4.87 | 6.88 | 7.37 |
| WM-17 | MYC0018 | Muddy Creek | 5.40 | 6.83 | 7.15 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 4.42 | 6.14 | 7.28 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 4.47 | 5.99 | 7.35 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 4.79 | 6.37 | 6.72 |
| BM909 | BUF0082 | Buffalo Run | 4.62 | 6.51 | 7.33 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 4.35 | 5.52 | 7.16 |
| BM915 | NXB0003 | North Branch Laurel Run | 4.86 | 6.86 | 7.37 |
| BM928 | LRL0018 | Laurel Run | 4.73 | 6.53 | 7.32 |
| BM929 | LRL0034 | Laurel Run | 4.35 | 5.90 | 7.26 |
| BM930 | TRR0007 | Trap Run | 4.57 | 6.32 | 7.29 |
| BM931 | WRR0008 | White Rock Run | 4.43 | 5.75 | 7.26 |
| BM933 | WRG0003 | White Rock Glade | 4.26 | 5.21 | 7.09 |

**Table 4-5. Modeled baseline iron, aluminum, sulfate, nitrate, and ammonium yearly loads**

| Station | Station code | Station name | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 100,058 | 67,295 | 2,299,943 | 91,368 | 11,409 |
| WM-2[b] | SNO0000 | Snowy Creek | 339,230 | 245,788 | 6,779,850 | 251,595 | 33,520 |
| WM-3 | CHB0005 | Cherry Bottom Run | 5,185 | 3,274 | 89,034 | 2,359 | 280 |
| WM-4 | HER0028 | Herrington Creek | 49,330 | 34,982 | 961,242 | 36,783 | 4,706 |
| WM-6[c] | MUL0001 | Murley Run | 28,147 | 24,131 | 632,158 | 17,542 | 2,153 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 2,457 | 2,129 | 50,350 | 1,166 | 146 |
| WM-8[d] | HER0014 | Herrington Creek | 68,130 | 47,066 | 1,287,936 | 45,734 | 5,790 |
| WM-10 | BUG0013 | Bull Glade Run | 6,929 | 5,987 | 143,118 | 3,314 | 415 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 3,284 | 2,838 | 67,853 | 1,572 | 197 |
| WM-12 | MLR0001 | Millers Run | 17,943 | 11,868 | 365,751 | 12,366 | 1,405 |
| WM-14 | TOL0001 | Toliver Run | 29,251 | 18,626 | 525,967 | 14,259 | 2,023 |
| WM-15 | LAU0013 | Laurel Run | 70,855 | 58,324 | 1,664,904 | 63,843 | 7,768 |
| WM-16 | NED0005 | Ned Run | 4,801 | 3,369 | 96,293 | 3,350 | 433 |
| WM-17[e] | MYC0018 | Muddy Creek | 75,127 | 53,858 | 1,855,281 | 68,200 | 8,456 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 4,206 | 2,661 | 71,962 | 1,728 | 212 |

**Table 4-5. (continued)**

| Station | Station code | Station name | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 719 | 559 | 17,242 | 414 | 46 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 7,578 | 3,097 | 197,556 | 2,506 | 284 |
| BM909 | BUF0082 | Buffalo Run | 13,190 | 9,903 | 313,262 | 9,603 | 1,057 |
| BM913 | UGB0002 | Unnamed tributary | 3,294 | 2,146 | 60,634 | 1,720 | 201 |
| BM915 | NXB0003 | North Branch Laurel Run | 6,004 | 3,881 | 119,541 | 3,639 | 421 |
| BM928[f] | LRL0018 | Laurel Run | 20,439 | 13,732 | 413,817 | 11,637 | 1,341 |
| BM929 | LRL0034 | Laurel Run | 4,824 | 3,737 | 114,594 | 2,862 | 312 |
| BM930 | TRR0007 | Trap Run | 7,157 | 4,583 | 132,060 | 3,655 | 431 |
| BM931 | WRR0008 | White Rock Run | 17,134 | 12,255 | 344,375 | 12,551 | 1,596 |
| BM933 | WRG0003 | White Rock Glade | 25,315 | 18,671 | 511,679 | 21,540 | 3,088 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 4-6. Baseline (2001) yearly loads from atmospheric deposition**

| Station | Station code | Station name | Dry (lb/yr) | | | Wet (lb/yr) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Sulfate | Nitrate | Ammonium | Sulfate | Nitrate | Ammonium |
| WM-1[a] | MYC0002 | Muddy Creek | 326,104 | 998 | 5,980 | 283,738 | 131,014 | 22,833 |
| WM-2[b] | SNO0000 | Snowy Creek | 583,525 | 1,786 | 10,700 | 507,716 | 234,434 | 40,856 |
| WM-3 | CHB0005 | Cherry Bottom Run | 9,394 | 29 | 172 | 8,173 | 3,774 | 658 |
| WM-4 | HER0028 | Herrington Creek | 81,042 | 248 | 1,486 | 70,513 | 32,559 | 5,674 |
| WM-6[c] | MUL0001 | Murley Run | 76,216 | 233 | 1,398 | 66,315 | 30,620 | 5,336 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 6,019 | 18 | 110 | 5,237 | 2,418 | 421 |
| WM-8[d] | HER0014 | Herrington Creek | 116,166 | 356 | 2,130 | 101,074 | 46,670 | 8,134 |
| WM-10 | BUG0013 | Bull Glade Run | 17,325 | 53 | 318 | 15,074 | 6,960 | 1,213 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 8,233 | 25 | 151 | 7,163 | 3,307 | 576 |
| WM-12 | MLR0001 | Millers Run | 46,572 | 143 | 854 | 40,521 | 18,710 | 3,261 |
| WM-14 | TOL0001 | Toliver Run | 60,040 | 184 | 1,101 | 52,240 | 24,121 | 4,204 |
| WM-15 | LAU0013 | Laurel Run | 175,455 | 537 | 3,217 | 152,661 | 70,490 | 12,285 |
| WM-16 | NED0005 | Ned Run | 9,214 | 28 | 169 | 8,017 | 3,702 | 645 |
| WM-17[e] | MYC0018 | Muddy Creek | 229,624 | 703 | 4,211 | 199,792 | 92,253 | 16,077 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 7,135 | 22 | 131 | 6,208 | 2,867 | 500 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 2,682 | 8 | 49 | 2,334 | 1,078 | 188 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 28,272 | 87 | 518 | 24,599 | 11,358 | 1,979 |
| BM909 | BUF0082 | Buffalo Run | 47,816 | 146 | 877 | 41,604 | 19,211 | 3,348 |
| BM913 | UGB0002 | Unnamed tributary | 6,917 | 21 | 127 | 6,018 | 2,779 | 484 |
| BM915 | NXB0003 | North Branch Laurel Run | 16,638 | 51 | 305 | 14,477 | 6,684 | 1,165 |
| BM928[f] | LRL0018 | Laurel Run | 56,761 | 174 | 1,041 | 49,387 | 22,804 | 3,974 |

**Table 4-6. (continued)**

| Station | Station code | Station name | Dry (lb/yr) | | | Wet (lb/yr) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Sulfate | Nitrate | Ammonium | Sulfate | Nitrate | Ammonium |
| BM929 | LRL0034 | Laurel Run | 18,082 | 55 | 332 | 15,733 | 7,265 | 1,266 |
| BM930 | TRR0007 | Trap Run | 16,118 | 49 | 296 | 14,024 | 6,476 | 1,129 |
| BM931 | WRR0008 | White Rock Run | 33,430 | 102 | 613 | 29,087 | 13,431 | 2,341 |
| BM933 | WRG0003 | White Rock Glade | 44,178 | 135 | 810 | 38,439 | 17,749 | 3,093 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 4-7. Baseline yearly loads from mine seeps and portals**

| Mine Seep | Associated station | Associated station code | Associated station name | Aluminum (lb/yr) | Iron (lb/yr) | Sulfate (lb/yr) |
|---|---|---|---|---|---|---|
| MY-00037 | WM-15 | LAU0013 | Laurel Run | 234.2 | 443.9 | 8,036 |
| OK-01-P1 | WM-2 | SNO0000 | Snowy Creek | 8.8 | 87.7 | 1,763 |
| OK-01-P2 | WM-2 | SNO0000 | Snowy Creek | 8.8 | 87.7 | 1,763 |
| SR-02-P3 | BM930 | TRR0007 | Trap Run | 21.9 | 986.9 | 4,408 |
| SR-02-S2 | BM930 | TRR0007 | Trap Run | 8.8 | 87.7 | 1,763 |
| Y-10-O1 | BM928 | LRL0018 | Laurel Run | 8.8 | 87.7 | 1,763 |
| Y-10-O2 | BM928 | LRL0018 | Laurel Run | 8.8 | 87.7 | 1,763 |
| Y-10-S1 | BM928 | LRL0018 | Laurel Run | 43.9 | 438.6 | 8,817 |
| Y-11-S1 | BM928 | LRL0018 | Laurel Run | 13.2 | 131.6 | 2,645 |
| Y-18-S1 | BM931 | WRR0008 | White Rock Run | 4.4 | 43.9 | 882 |
| Y-24-S1 | WM-3 | CHB0005 | Cherry Bottom Run | 8.8 | 166.7 | 1,895 |
| Y-24-S2 | WM-3 | CHB0005 | Cherry Bottom Run | 4.4 | 43.9 | 882 |

**Table 4-8. Baseline yearly loads from West Virginia**

| Station | Station code | Station name | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|
| WM-2[a] | SNO0000 | Snowy Creek | 300,697 | 217,871 | 6,010,047 | 223,029 | 28,364 |
| WM-4 | HER0028 | Herrington Creek | 16,697 | 11,840 | 325,352 | 12,450 | 1,593 |
| WM-15 | LAU0013 | Laurel Run | 69,614 | 57,309 | 1,635,928 | 62,732 | 7,632 |
| WM-17 | MYC0018 | Muddy Creek | 53,627 | 39,035 | 1,233,075 | 29,046 | 6,620 |
| BM909 | BUF0082 | Buffalo Run | 1,597 | 1,779 | 199,777 | 3,855 | 752 |
| BM929 | LRL0034 | Laurel Run | 201 | 341 | 87,524 | 1,341 | 260 |
| BM933 | WRG0003 | White Rock Glade | 11,448 | 8,443 | 231,386 | 9,741 | 1,211 |

[a] WM-2 includes upstream loads from WM-15.

# 5 ALLOCATION ANALYSIS

A TMDL is the total amount of pollutant that can be assimilated by the receiving waterbody while still achieving water quality standards or goals. It is composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody and may include a future allocation (FA) component. Conceptually, this definition is represented by the equation:

$$TMDL = S\ WLAs + S\ LAs + MOS + FA$$

In TMDL development, allowable loadings from each pollutant source are summed to a cumulative TMDL threshold, thus providing a quantitative basis for establishing water quality-based controls. TMDLs can be expressed as a mass loading (e.g., grams of pollutant per year) or as a concentration in accordance with 40 CFR 130.2(l). The state reserves the right to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

## 5.1 TMDL Endpoints

TMDL endpoints represent the water quality targets used to quantify TMDLs and their individual components. The water quality criteria for pH allow no values below 6.5 or above 8.5. For pH to meet criteria, chemical species that affect pH (such as sulfate, iron, aluminum, nitrate, and ammonium) were reduced to raise pH above 6.5. Appendix B (Model Development and Configuration) contains a detailed description of the pH modeling approach.

There are several possible causes for low pH in waterbodies. Atmospheric acid deposition (acid rain), abandoned mine drainage, natural conditions, and other human activities are being considered as sources in the Youghiogheny River watershed. On the basis of these source considerations, sulfate, nitrate, ammonium, aluminum, and iron were selected to predict pH and assigned allocations to reach the TMDL endpoint. Sulfate and nitrate are common species in acid deposition.

Acid rain can affect pH of streams over large areas. Sulfate and nitrate were selected as TMDL endpoints because hydrogen ions associate with atmospheric sulfate and nitrate, which, during and after precipitation events, have the potential to add acidity to soils and streams, thus reducing pH.

Ammonia in present in aqueous systems in two forms: ammonia ($NH_3$) and ionized ammonia ($NH_4^+$), also known as ammonium. When ammonia enters stream with low pH, the ammonia becomes ammonium which might increase pH. When ammonium enters a stream with high pH, it releases hydrogen ions which, in turn, lower stream pH. Ammonium was selected because it is also a result of atmospheric deposition and is a critical chemical species for bacterial-facilitated nitrogen transformation in soils. This nitrogen transformation changes nitrate and other nitrogen species in addition to changing chemical conditions within the soils. This process affects hydrogen concentrations, and thus, affects pH.

Increased acidity from mining activities is also a concern in western Maryland. Aluminum, iron, and sulfate were selected as inputs from the mining areas because these ions and their associated acid loadings can be large enough to influence in-stream pH, depending on local geology and condition of the mines. Decreasing these ions from abandoned mine areas will increase pH. In addition, hydrogen, which is generated from the previously mentioned nitrate and sulfate reactions, dissolves aluminosilicate to form free aluminum ions in soils. The newly generated free aluminum ions can further increase acidity.

These interconnected biogeochemical and physical reactions are simulated in the model to estimate daily stream pH conditions. Although the derived TMDLs are based on best professional judgment using current data in the calibrated model, meeting these TMDLs might not be necessary if alternative remediation and future monitoring prove that pH is being corrected without reducing these parameters.

### 5.2 Critical Conditions and Seasonal Variations

Federal regulations (40 CFR 130.7(c)(1)) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is vulnerable. Critical conditions are the set of environmental conditions, which, if met, will ensure the attainment of objectives for all other conditions. Nonpoint source loading is typically precipitation-driven. In-stream impacts tend to occur during wet-weather and storm events that cause surface runoff to carry pollutants to waterbodies. During dry periods, little or no land-based runoff occurs, and elevated in-stream pollutant levels could be due to point sources. Because of the presence of both point and nonpoint sources in the watershed, both high-flow and low-flow periods were taken into account during TMDL development. This was accomplished through dynamic model simulation (i.e., using the model to predict conditions over a long period of time that represents wet, dry, and average flow periods).

The TMDL must also consider seasonal variation. MDAS model simulation for a multiyear period inherently accounts for seasonal variation. Continuous simulation represents both hydrologic and source loading variability seasonally. The constituent concentrations simulated on a daily time step by the model were compared to the TMDL endpoints. Allocations that met these endpoints throughout the modeling period were developed and are presented in Section 5.3.

### 5.3 TMDLs and Allocations

For the load reduction simulation (TMDL simulation), the model was run similar to the baseline condition. For the baseline condition, permit flows and permit limits were included in the model instead of observed DMR flows and concentrations. (Permit information is provided in Table 2-9.) By using these permit values, the total loading from a point source is included in the model.

TMDLs and source allocations were developed on a subwatershed basis for each of the impaired watersheds in Table 1-1. TMDL allocations include the LAs for nonpoint sources and the WLAs for point sources. A top-down methodology was followed to develop these TMDLs and allocate loads to sources. Headwaters were analyzed first because their loading affects downstream water quality. Loading contributions (of aluminum, iron, sulfate, nitrate, and ammonium) were reduced from applicable sources in these waterbodies until pH criteria were met. The loading contributions of unimpaired headwaters and the reduced loadings for impaired headwaters were then routed through downstream waterbodies. Using this method, contributions from all sources were weighted equitably and pH criteria were achieved throughout the system. Reductions in sources affecting impaired headwaters ultimately led to improvements downstream and effectively decreased necessary loading reductions from downstream sources. Source allocations were developed for aluminum, iron, sulfate, nitrate, and ammonium.

Allocations were assigned so that pH did not fall below 6.5. Table 5-1 presents the pH ranges in the impaired watersheds after allocations were applied. Subsections 5.3.1, 5.3.2, and 5.3.3 describe WLAs, LAs, and the MOS and the FA components, respectively. Table 5-2 summarizes the yearly TMDL allocations and Table 5-3 compares the TMDL allocations to the baseline loads. The model was run to for the period of December 1, 2004, through November 30, 2005. This produced daily loads that were then summed over the year to create the yearly loads, which are presented in Table 5-2 and subsequent tables. Note that the atmospheric deposition contribution of ammonia is expected to increase in the model area based on the CAIR model, thus some TMDL conditions are greater than baseline conditions.

One way to express loads is through load duration curves. Figure 5-1 is an example of a curve for iron for Laurel Run (LRL0034/BM929). Points at the lower end of the curve plot (0 through 10 percent) represent high-flow conditions where only 0 through 10 percent of the flow exceeds the plotted point. Conversely, points on the high end of the plot (90 to 100 percent) represent low-flow conditions. The load duration curve shows the calculation of the TMDL at any flow rather than at a single, critical flow. The official TMDL number is reported as a single number, but the curve is provided to demonstrate the value of the acceptable load at any flow. Tables 5-4 through 5-8 present the maximum daily load by flow percentile range for iron, aluminum, sulfate, nitrate, and ammonium, respectively. Appendix J presents additional daily statistics and load duration curves by flow percentile range for each segment.

**Table 5-1. TMDL pH minimum, mean, and maximum**

| Station | Station code | Station name | pH minimum | pH average | pH maximum |
|---|---|---|---|---|---|
| WM-1 | MYC0002 | Muddy Creek | 6.50 | 6.97 | 7.23 |
| WM-2 | SNO0000 | Snowy Creek | 6.51 | 7.02 | 7.40 |
| WM-3 | CHB0005 | Cherry Bottom Run | 6.58 | 7.08 | 7.40 |
| WM-4 | HER0028 | Herrington Creek | 6.51 | 7.05 | 7.45 |
| WM-6 | MUL0001 | Murley Run | 6.60 | 7.05 | 7.37 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 6.60 | 7.06 | 7.37 |
| WM-8 | HER0014 | Herrington Creek | 6.53 | 7.03 | 7.44 |
| WM-10 | BUG0013 | Bull Glade Run | 6.62 | 7.06 | 7.37 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 6.62 | 7.06 | 7.37 |
| WM-12 | MLR0001 | Millers Run | 6.67 | 7.10 | 7.46 |
| WM-14 | TOL0001 | Toliver Run | 6.57 | 7.04 | 7.33 |
| WM-15 | LAU0013 | Laurel Run | 6.55 | 7.05 | 7.41 |
| WM-16 | NED0005 | Ned Run | 6.57 | 7.09 | 7.45 |
| WM-17 | MYC0018 | Muddy Creek | 6.50 | 6.95 | 7.20 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 6.63 | 7.07 | 7.38 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 6.60 | 7.10 | 7.42 |

**Table 5-1. (continued)**

| Station | Station code | Station name | pH minimum | pH average | pH maximum |
|---|---|---|---|---|---|
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 6.50 | 6.71 | 6.86 |
| BM909 | BUF0082 | Buffalo Run | 6.63 | 7.07 | 7.44 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 6.52 | 7.05 | 7.38 |
| BM915 | NXB0003 | North Branch Laurel Run | 6.54 | 7.05 | 7.41 |
| BM928 | LRL0018 | Laurel Run | 6.50 | 7.02 | 7.36 |
| BM929 | LRL0034 | Laurel Run | 6.72 | 7.08 | 7.39 |
| BM930 | TRR0007 | Trap Run | 6.55 | 7.06 | 7.40 |
| BM931 | WRR0008 | White Rock Run | 6.62 | 7.06 | 7.40 |
| BM933 | WRG0003 | White Rock Glade | 6.61 | 7.04 | 7.35 |

**Table 5-2. Summary of yearly LA, WLA, MOS, and total TMDLs**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | LA | 79,663 | 53,593 | 1,642,486 | 42,074 | 9,679 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 4,686 | 3,153 | 96,617 | 2,475 | 569 |
| | | | FA | 9,372 | 6,305 | 193,234 | 4,950 | 1,139 |
| | | | Total | 93,721 | 63,050 | 1,932,337 | 49,498 | 11,387 |
| WM-2[b] | SNO0000 | Snowy Creek | LA | 198,637 | 145,025 | 5,054,641 | 115,512 | 27,127 |
| | | | WLA | 18 | 11 | 0 | 0 | 1,523 |
| | | | MOS | 11,686 | 8,532 | 297,332 | 6,795 | 1,685 |
| | | | FA | 23,371 | 17,063 | 594,664 | 13,590 | 3,371 |
| | | | Total | 233,712 | 170,631 | 5,946,637 | 135,896 | 33,705 |
| WM-3 | CHB0005 | Cherry Bottom Run | LA | 3,261 | 2,098 | 67,721 | 1,126 | 245 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 192 | 123 | 3,984 | 66 | 14 |
| | | | FA | 384 | 247 | 7,967 | 133 | 29 |
| | | | Total | 3,837 | 2,468 | 79,672 | 1,325 | 288 |
| WM-4 | HER0028 | Herrington Creek | LA | 27,255 | 20,193 | 717,023 | 16,869 | 4,021 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 1,603 | 1,188 | 42,178 | 992 | 237 |
| | | | FA | 3,206 | 2,376 | 84,356 | 1,985 | 473 |
| | | | Total | 32,065 | 23,756 | 843,557 | 19,846 | 4,731 |
| WM-6[c] | MUL0001 | Murley Run | LA | 2,249 | 2,811 | 490,988 | 8,045 | 1,827 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 132 | 165 | 28,882 | 473 | 107 |
| | | | FA | 265 | 331 | 57,763 | 946 | 215 |
| | | | Total | 2,645 | 3,306 | 577,633 | 9,464 | 2,150 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | LA | 104 | 159 | 39,768 | 532 | 124 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 6 | 9 | 2,339 | 31 | 7 |
| | | | FA | 12 | 19 | 4,679 | 63 | 15 |
| | | | Total | 123 | 187 | 46,786 | 626 | 145 |
| WM-8[d] | HER0014 | Herrington Creek | LA | 33,327 | 24,437 | 963,612 | 21,112 | 4,968 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 1,960 | 1,437 | 56,683 | 1,242 | 292 |
| | | | FA | 3,921 | 2,875 | 113,366 | 2,484 | 584 |
| | | | Total | 39,209 | 28,749 | 1,133,662 | 24,838 | 5,844 |

**Table 5-2. (continued)**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| WM-10 | BUG0013 | Bull Glade Run | LA | 294 | 449 | 112,925 | 1,514 | 352 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 17 | 26 | 6,643 | 89 | 21 |
| | | | FA | 35 | 53 | 13,285 | 178 | 41 |
| | | | Total | 346 | 528 | 132,853 | 1,781 | 414 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | LA | 140 | 213 | 53,550 | 718 | 167 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 8 | 13 | 3,150 | 42 | 10 |
| | | | FA | 16 | 25 | 6,300 | 84 | 20 |
| | | | Total | 164 | 250 | 63,000 | 845 | 197 |
| WM-12 | MLR0001 | Millers Run | LA | 7,931 | 5,702 | 273,935 | 5,924 | 1,202 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 467 | 335 | 16,114 | 348 | 71 |
| | | | FA | 933 | 671 | 32,228 | 697 | 141 |
| | | | Total | 9,331 | 6,708 | 322,276 | 6,970 | 1,415 |
| WM-14 | TOL0001 | Toliver Run | LA | 14,172 | 9,423 | 397,953 | 6,812 | 1,422 |
| | | | WLA | 0 | 0 | 0 | 0 | 330 |
| | | | MOS | 834 | 554 | 23,409 | 401 | 103 |
| | | | FA | 1,667 | 1,109 | 46,818 | 801 | 206 |
| | | | Total | 16,673 | 11,086 | 468,180 | 8,014 | 2,061 |
| WM-15 | LAU0013 | Laurel Run | LA | 6,021 | 8,743 | 1,252,566 | 29,377 | 6,581 |
| | | | WLA | 8 | 0 | 0 | 0 | 0 |
| | | | MOS | 355 | 514 | 73,680 | 1,728 | 387 |
| | | | FA | 709 | 1,029 | 147,361 | 3,456 | 774 |
| | | | Total | 7,093 | 10,285 | 1,473,607 | 34,561 | 7,743 |
| WM-16 | NED0005 | Ned Run | LA | 3,183 | 2,274 | 72,552 | 1,539 | 369 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 187 | 134 | 4,268 | 91 | 22 |
| | | | FA | 374 | 268 | 8,536 | 181 | 43 |
| | | | Total | 3,745 | 2,675 | 85,356 | 1,810 | 434 |
| WM-17[e] | MYC0018 | Muddy Creek | LA | 57,719 | 42,081 | 1,329,769 | 31,324 | 7,139 |
| | | | WLA | 752 | 101 | 0 | 0 | 0 |
| | | | MOS | 3,439 | 2,481 | 78,222 | 1,843 | 420 |
| | | | FA | 6,879 | 4,963 | 156,443 | 3,685 | 840 |
| | | | Total | 68,789 | 49,626 | 1,564,435 | 36,851 | 8,398 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | LA | 1,573 | 1,063 | 54,834 | 820 | 186 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 93 | 63 | 3,226 | 48 | 11 |
| | | | FA | 185 | 125 | 6,451 | 97 | 22 |
| | | | Total | 1,850 | 1,250 | 64,511 | 965 | 219 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | LA | 49 | 65 | 13,424 | 198 | 39 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 3 | 4 | 790 | 12 | 2 |
| | | | FA | 6 | 8 | 1,579 | 23 | 5 |
| | | | Total | 57 | 77 | 15,793 | 233 | 46 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | LA | 3,285 | 1,667 | 147,856 | 1,185 | 232 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 193 | 98 | 8,697 | 70 | 14 |
| | | | FA | 386 | 196 | 17,395 | 139 | 27 |

**Table 5-2. (continued)**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| | | | Total | 3,865 | 1,962 | 173,948 | 1,394 | 273 |
| BM909 | BUF0082 | Buffalo Run | LA | 1,906 | 2,123 | 238,483 | 4,602 | 898 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 112 | 125 | 14,028 | 271 | 53 |
| | | | FA | 224 | 250 | 28,057 | 541 | 106 |
| | | | Total | 2,242 | 2,498 | 280,568 | 5,414 | 1,056 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | LA | 504 | 420 | 45,811 | 816 | 173 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 30 | 25 | 2,695 | 48 | 10 |
| | | | FA | 59 | 49 | 5,390 | 96 | 20 |
| | | | Total | 593 | 495 | 53,895 | 960 | 204 |
| BM915 | NXB0003 | North Branch Laurel Run | LA | 2,807 | 1,921 | 90,465 | 1,748 | 361 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 165 | 113 | 5,321 | 103 | 21 |
| | | | FA | 330 | 226 | 10,643 | 206 | 42 |
| | | | Total | 3,302 | 2,260 | 106,430 | 2,056 | 425 |
| BM928[f] | LRL0018 | Laurel Run | LA | 13,478 | 8,838 | 315,092 | 5,573 | 1,152 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 793 | 520 | 18,535 | 328 | 68 |
| | | | FA | 1,586 | 1,040 | 37,070 | 656 | 136 |
| | | | Total | 15,857 | 10,398 | 370,696 | 6,556 | 1,355 |
| BM929 | LRL0034 | Laurel Run | LA | 205 | 347 | 89,098 | 1,366 | 265 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 12 | 20 | 5,241 | 80 | 16 |
| | | | FA | 24 | 41 | 10,482 | 161 | 31 |
| | | | Total | 241 | 409 | 104,822 | 1,607 | 312 |
| BM930 | TRR0007 | Trap Run | LA | 2,251 | 1,597 | 100,301 | 1,743 | 372 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 132 | 94 | 5,900 | 103 | 22 |
| | | | FA | 265 | 188 | 11,800 | 205 | 44 |
| | | | Total | 2,648 | 1,879 | 118,001 | 2,051 | 438 |
| BM931 | WRR0008 | White Rock Run | LA | 1,602 | 1,751 | 259,344 | 5,754 | 1,359 |
| | | | WLA | 0 | 0 | 0 | 0 | 0 |
| | | | MOS | 94 | 103 | 15,256 | 338 | 80 |
| | | | FA | 188 | 206 | 30,511 | 677 | 160 |
| | | | Total | 1,885 | 2,060 | 305,111 | 6,770 | 1,598 |
| BM933 | WRG0003 | White Rock Glade | LA | 1,291 | 2,227 | 380,867 | 9,839 | 2,215 |
| | | | WLA | 0 | 0 | 0 | 0 | 411 |
| | | | MOS | 76 | 131 | 22,404 | 579 | 154 |
| | | | FA | 152 | 262 | 44,808 | 1,158 | 309 |
| | | | Total | 1,519 | 2,620 | 448,079 | 11,576 | 3,090 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-3. Comparison between baseline loads and TMDLs (lb/d)**

| Station | Station code | Station name | Load | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr)[a] |
|---|---|---|---|---|---|---|---|---|
| WM-1[b] | MYC0002 | Muddy Creek | Baseline | 100,058 | 67,295 | 2,299,943 | 91,368 | 11,409 |
| | | | TMDL | 93,721 | 63,050 | 1,932,337 | 49,498 | 11,387 |
| | | | % reduction | 6.3 | 6.3 | 16.0 | 45.8 | 0.2 |
| WM-2[c] | SNO0000 | Snowy Creek | Baseline | 339,230 | 245,788 | 6,779,850 | 251,595 | 33,520 |
| | | | TMDL | 233,712 | 170,631 | 5,946,637 | 135,896 | 33,705 |
| | | | % reduction | 31.1 | 30.6 | 12.3 | 46.0 | -0.6 |
| WM-3 | CHB0005 | Cherry Bottom Run | Baseline | 5,185 | 3,274 | 89,034 | 2,359 | 280 |
| | | | TMDL | 3,837 | 2,468 | 79,672 | 1,325 | 288 |
| | | | % reduction | 26.0 | 24.6 | 10.5 | 43.8 | -2.8 |
| WM-4 | HER0028 | Herrington Creek | Baseline | 49,330 | 34,982 | 961,242 | 36,783 | 4,706 |
| | | | TMDL | 32,065 | 23,756 | 843,557 | 19,846 | 4,731 |
| | | | % reduction | 35.0 | 32.1 | 12.2 | 46.0 | -0.5 |
| WM-6[d] | MUL0001 | Murley Run | Baseline | 28,147 | 24,131 | 632,158 | 17,542 | 2,153 |
| | | | TMDL | 2,645 | 3,306 | 577,633 | 9,464 | 2,150 |
| | | | % reduction | 90.6 | 86.3 | 8.6 | 46.0 | 0.2 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | Baseline | 2,457 | 2,129 | 50,350 | 1,166 | 146 |
| | | | TMDL | 123 | 187 | 46,786 | 626 | 145 |
| | | | % reduction | 95.0 | 91.2 | 7.1 | 46.3 | 0.1 |
| WM-8[e] | HER0014 | Herrington Creek | Baseline | 68,130 | 47,066 | 1,287,936 | 45,734 | 5,790 |
| | | | TMDL | 39,209 | 28,749 | 1,133,662 | 24,838 | 5,844 |
| | | | % reduction | 42.5 | 38.9 | 12.0 | 45.7 | -0.9 |
| WM-10 | BUG0013 | Bull Glade Run | Baseline | 6,929 | 5,987 | 143,118 | 3,314 | 415 |
| | | | TMDL | 346 | 528 | 132,853 | 1,781 | 414 |
| | | | % reduction | 95.0 | 91.2 | 7.2 | 46.3 | 0.1 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | Baseline | 3,284 | 2,838 | 67,853 | 1,572 | 197 |
| | | | TMDL | 164 | 250 | 63,000 | 845 | 197 |
| | | | % reduction | 95.0 | 91.2 | 7.2 | 46.3 | 0.1 |
| WM-12 | MLR0001 | Millers Run | Baseline | 17,943 | 11,868 | 365,751 | 12,366 | 1,405 |
| | | | TMDL | 9,331 | 6,708 | 322,276 | 6,970 | 1,415 |
| | | | % reduction | 48.0 | 43.5 | 11.9 | 43.6 | -0.7 |
| WM-14 | TOL0001 | Toliver Run | Baseline | 29,251 | 18,626 | 525,967 | 14,259 | 2,023 |
| | | | TMDL | 16,673 | 11,086 | 468,180 | 8,014 | 2,061 |
| | | | % reduction | 43.0 | 40.5 | 11.0 | 43.8 | -1.9 |
| WM-15 | LAU0013 | Laurel Run | Baseline | 70,855 | 58,324 | 1,664,904 | 63,843 | 7,768 |
| | | | TMDL | 7,093 | 10,285 | 1,473,607 | 34,561 | 7,743 |
| | | | % reduction | 90.0 | 82.4 | 11.5 | 45.9 | 0.3 |
| WM-16 | NED0005 | Ned Run | Baseline | 4,801 | 3,369 | 96,293 | 3,350 | 433 |
| | | | TMDL | 3,745 | 2,675 | 85,356 | 1,810 | 434 |
| | | | % reduction | 22.0 | 20.6 | 11.4 | 46.0 | -0.4 |
| WM-17[f] | MYC0018 | Muddy Creek | Baseline | 75,127 | 53,858 | 1,855,281 | 68,200 | 8,456 |
| | | | TMDL | 68,789 | 49,626 | 1,564,435 | 36,851 | 8,398 |
| | | | % reduction | 8.4 | 7.9 | 15.7 | 46.0 | 0.7 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | Baseline | 4,206 | 2,661 | 71,962 | 1,728 | 212 |
| | | | TMDL | 1,850 | 1,250 | 64,511 | 965 | 219 |
| | | | % reduction | 56.0 | 53.0 | 10.4 | 44.2 | -3.1 |

**Table 5-3. (continued)**

| Station | Station code | Station name | Load | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr)[a] |
|---|---|---|---|---|---|---|---|---|
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | Baseline | 719 | 559 | 17,242 | 414 | 46 |
| | | | TMDL | 57 | 77 | 15,793 | 233 | 46 |
| | | | % reduction | 92.0 | 86.3 | 8.4 | 43.7 | -0.1 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | Baseline | 7,578 | 3,097 | 197,556 | 2,506 | 284 |
| | | | TMDL | 3,865 | 1,962 | 173,948 | 1,394 | 273 |
| | | | % reduction | 49.0 | 36.7 | 12.0 | 44.3 | 3.8 |
| BM909 | BUF0082 | Buffalo Run | Baseline | 13,190 | 9,903 | 313,262 | 9,603 | 1,057 |
| | | | TMDL | 2,242 | 2,498 | 280,568 | 5,414 | 1,056 |
| | | | % reduction | 83.0 | 74.8 | 10.4 | 43.6 | 0.1 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | Baseline | 3,294 | 2,146 | 60,634 | 1,720 | 201 |
| | | | TMDL | 593 | 495 | 53,895 | 960 | 204 |
| | | | % reduction | 82.0 | 77.0 | 11.1 | 44.2 | -1.6 |
| BM915 | NXB0003 | North Branch Laurel Run | Baseline | 6,004 | 3,881 | 119,541 | 3,639 | 421 |
| | | | TMDL | 3,302 | 2,260 | 106,430 | 2,056 | 425 |
| | | | % reduction | 45.0 | 41.7 | 11.0 | 43.5 | -0.9 |
| BM928[g] | LRL0018 | Laurel Run | Baseline | 20,439 | 13,732 | 413,817 | 11,637 | 1,341 |
| | | | TMDL | 15,857 | 10,398 | 370,696 | 6,556 | 1,355 |
| | | | % reduction | 22.4 | 24.3 | 10.4 | 43.7 | -1.1 |
| BM929 | LRL0034 | Laurel Run | Baseline | 4,824 | 3,737 | 114,594 | 2,862 | 312 |
| | | | TMDL | 241 | 409 | 104,822 | 1,607 | 312 |
| | | | % reduction | 95.0 | 89.1 | 8.5 | 43.9 | 0.1 |
| BM930 | TRR0007 | Trap Run | Baseline | 7,157 | 4,583 | 132,060 | 3,655 | 431 |
| | | | TMDL | 2,648 | 1,879 | 118,001 | 2,051 | 438 |
| | | | % reduction | 63.0 | 59.0 | 10.6 | 43.9 | -1.7 |
| BM931 | WRR0008 | White Rock Run | Baseline | 17,134 | 12,255 | 344,375 | 12,551 | 1,596 |
| | | | TMDL | 1,885 | 2,060 | 305,111 | 6,770 | 1,598 |
| | | | % reduction | 89.0 | 83.2 | 11.4 | 46.1 | -0.2 |
| BM933 | WRG0003 | White Rock Glade | Baseline | 25,315 | 18,671 | 511,679 | 21,540 | 3,088 |
| | | | TMDL | 1,519 | 2,620 | 448,079 | 11,576 | 3,090 |
| | | | % reduction | 94.0 | 86.0 | 12.4 | 46.3 | 0.0 |

[a] The CAIR model predicts that ammonium in atmospheric deposition will increase in some areas.
[b] WM-1 includes upstream loads from WM-17.
[c] WM-2 includes upstream loads from WM-15.
[d] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[e] WM-8 includes upstream loads from WM-4.
[f] WM-17 includes upstream loads from WM-16.
[g] BM928 includes upstream loads from BM929.

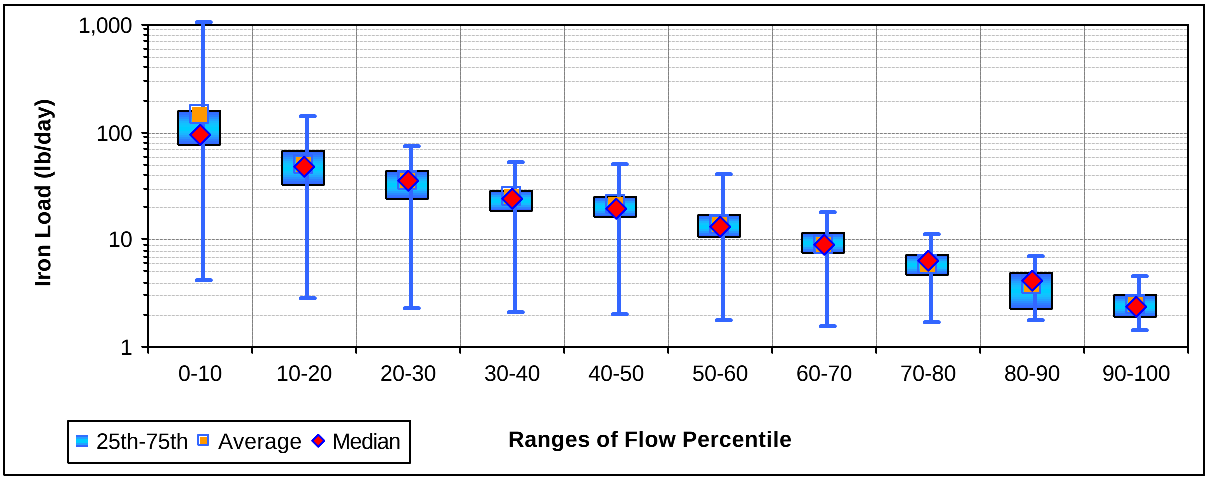


**Figure 5-1. Example of load duration curve for iron for Laurel Run (LRL0034/BM929)**

**Table 5-4. TMDL maximum daily iron loads by flow percentile range (lb/d)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 234,621 | 55,671 | 68,559 | 18,408 | 21,391 | 24,210 | 14,488 | 7,017 | 3,036 | 3,871 |
| WM-2[b] | SNO0000 | Snowy Creek | 667,850 | 192,394 | 213,176 | 55,183 | 110,294 | 123,775 | 92,946 | 35,033 | 12,950 | 18,826 |
| WM-3 | CHB0005 | Cherry Bottom Run | 14,817 | 3,651 | 1,872 | 2,166 | 2,306 | 2,573 | 1,194 | 680 | 280 | 826 |
| WM-4 | HER0028 | Herrington Creek | 90,118 | 25,870 | 30,155 | 7,547 | 11,660 | 13,524 | 9,834 | 3,763 | 1,410 | 1,958 |
| WM-6[c] | MUL0001 | Murley Run | 6,011 | 1,255 | 1,316 | 481 | 293 | 455 | 151 | 108 | 68 | 50 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 314 | 62 | 80 | 39 | 18 | 53 | 10 | 8 | 4 | 4 |
| WM-8[d] | HER0014 | Herrington Creek | 99,026 | 27,851 | 31,796 | 8,672 | 16,411 | 18,948 | 12,281 | 5,028 | 1,852 | 2,583 |
| WM-10 | BUG0013 | Bull Glade Run | 871 | 172 | 218 | 101 | 48 | 135 | 26 | 20 | 12 | 10 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 410 | 82 | 103 | 48 | 23 | 64 | 12 | 9 | 5 | 5 |
| WM-12 | MLR0001 | Millers Run | 39,624 | 7,834 | 3,115 | 2,046 | 3,261 | 1,994 | 855 | 568 | 242 | 614 |
| WM-14 | TOL0001 | Toliver Run | 63,741 | 14,888 | 7,338 | 8,006 | 8,408 | 9,498 | 4,290 | 2,483 | 1,022 | 2,976 |
| WM-15 | LAU0013 | Laurel Run | 16,161 | 3,313 | 3,443 | 1,178 | 806 | 1,148 | 480 | 258 | 166 | 118 |
| WM-16 | NED0005 | Ned Run | 10,354 | 2,244 | 2,768 | 669 | 706 | 729 | 548 | 238 | 90 | 116 |
| WM-17[e] | MYC0018 | Muddy Creek | 170,600 | 38,870 | 51,274 | 11,560 | 9,749 | 9,918 | 6,489 | 4,190 | 1,909 | 1,606 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 7,886 | 1,721 | 905 | 1,048 | 1,531 | 1,283 | 570 | 337 | 130 | 447 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 232 | 29 | 14 | 11 | 19 | 6 | 4 | 3 | 2 | 1 |

**Table 5-4. (continued)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 3,558 | 1,433 | 1,239 | 1,002 | 772 | 533 | 471 | 409 | 332 | 186 |
| BM909 | BUF0082 | Buffalo Run | 9,498 | 1,357 | 633 | 482 | 337 | 214 | 174 | 84 | 55 | 36 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 2,764 | 536 | 226 | 242 | 261 | 404 | 122 | 75 | 31 | 84 |
| BM915 | NXB0003 | North Branch Laurel Run | 13,734 | 2,615 | 1,076 | 888 | 850 | 881 | 403 | 257 | 107 | 286 |
| BM928[f] | LRL0018 | Laurel Run | 66,544 | 13,592 | 5,435 | 6,005 | 6,039 | 6,239 | 3,026 | 1,852 | 728 | 2,343 |
| BM929 | LRL0034 | Laurel Run | 1,000 | 134 | 70 | 51 | 47 | 38 | 17 | 11 | 6 | 4 |
| BM930 | TRR0007 | Trap Run | 11,276 | 2,360 | 851 | 1,105 | 1,149 | 1,409 | 566 | 338 | 140 | 394 |
| BM931 | WRR0008 | White Rock Run | 5,294 | 1,009 | 1,339 | 407 | 263 | 552 | 188 | 100 | 48 | 37 |
| BM933 | WRG0003 | White Rock Glade | 4,478 | 854 | 1,299 | 490 | 276 | 784 | 209 | 116 | 49 | 45 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-5. TMDL maximum daily aluminum loads by flow percentile range (lb/d)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 140,210 | 33,702 | 33,077 | 10,812 | 12,302 | 12,157 | 7,561 | 3,500 | 1,408 | 2,310 |
| WM-2[b] | SNO0000 | Snowy Creek | 425,314 | 130,753 | 122,746 | 44,012 | 80,450 | 78,344 | 61,985 | 22,209 | 8,450 | 12,438 |
| WM-3 | CHB0005 | Cherry Bottom Run | 10,446 | 2,361 | 1,036 | 1,327 | 1,479 | 1,605 | 809 | 412 | 157 | 513 |
| WM-4 | HER0028 | Herrington Creek | 57,837 | 17,863 | 17,274 | 11,157 | 8,735 | 8,544 | 6,637 | 2,197 | 910 | 1,286 |
| WM-6[c] | MUL0001 | Murley Run | 5,918 | 1,571 | 1,180 | 686 | 469 | 422 | 234 | 147 | 99 | 72 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 319 | 77 | 76 | 62 | 37 | 51 | 17 | 12 | 8 | 8 |
| WM-8[d] | HER0014 | Herrington Creek | 63,767 | 19,068 | 18,500 | 12,624 | 11,927 | 11,965 | 8,364 | 3,148 | 1,247 | 1,592 |
| WM-10 | BUG0013 | Bull Glade Run | 890 | 222 | 206 | 164 | 99 | 129 | 45 | 31 | 23 | 21 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 421 | 105 | 98 | 78 | 47 | 61 | 22 | 15 | 11 | 10 |
| WM-12 | MLR0001 | Millers Run | 29,215 | 5,493 | 2,047 | 1,459 | 1,904 | 1,242 | 582 | 340 | 141 | 377 |
| WM-14 | TOL0001 | Toliver Run | 45,765 | 9,877 | 4,212 | 4,911 | 5,450 | 5,939 | 2,938 | 1,505 | 585 | 1,849 |
| WM-15 | LAU0013 | Laurel Run | 15,266 | 5,144 | 2,977 | 2,094 | 1,396 | 1,098 | 739 | 428 | 309 | 189 |
| WM-16 | NED0005 | Ned Run | 6,675 | 1,536 | 1,587 | 463 | 463 | 450 | 347 | 126 | 52 | 71 |

**Table 5-5. (continued)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-17[e] | MYC0018 | Muddy Creek | 115,999 | 27,079 | 28,729 | 8,806 | 6,454 | 5,125 | 3,466 | 2,008 | 1,049 | 819 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 5,700 | 1,143 | 555 | 660 | 925 | 808 | 398 | 209 | 80 | 280 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 254 | 38 | 19 | 16 | 20 | 8 | 4 | 4 | 2 | 1 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 2,893 | 925 | 884 | 672 | 436 | 264 | 193 | 162 | 131 | 91 |
| BM909 | BUF0082 | Buffalo Run | 8,914 | 1,358 | 674 | 560 | 348 | 229 | 146 | 103 | 61 | 40 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 2,060 | 383 | 175 | 185 | 198 | 264 | 94 | 51 | 22 | 54 |
| BM915 | NXB0003 | North Branch Laurel Run | 10,067 | 1,860 | 908 | 576 | 535 | 546 | 273 | 150 | 60 | 174 |
| BM928[f] | LRL0018 | Laurel Run | 47,904 | 9,288 | 3,933 | 3,542 | 3,761 | 3,868 | 2,012 | 1,091 | 401 | 1,440 |
| BM929 | LRL0034 | Laurel Run | 1,170 | 177 | 119 | 85 | 69 | 60 | 32 | 27 | 15 | 10 |
| BM930 | TRR0007 | Trap Run | 8,186 | 1,616 | 588 | 696 | 771 | 890 | 399 | 209 | 85 | 246 |
| BM931 | WRR0008 | White Rock Run | 3,764 | 925 | 846 | 481 | 316 | 387 | 162 | 92 | 65 | 49 |
| BM933 | WRG0003 | White Rock Glade | 3,708 | 1,173 | 910 | 3,040 | 603 | 610 | 282 | 174 | 131 | 112 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-6. TMDL maximum daily sulfate loads by flow percentile range (lb/d)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 2,924,016 | 716,498 | 839,934 | 335,948 | 354,683 | 326,913 | 202,596 | 137,688 | 90,335 | 66,167 |
| WM-2[b] | SNO0000 | Snowy Creek | 10,871,804 | 2,969,343 | 3,181,632 | 1,217,248 | 1,800,122 | 1,804,255 | 1,323,148 | 602,800 | 235,864 | 348,062 |
| WM-3 | CHB0005 | Cherry Bottom Run | 242,504 | 56,292 | 33,339 | 35,555 | 35,709 | 37,065 | 18,582 | 11,069 | 4,277 | 12,954 |
| WM-4 | HER0028 | Herrington Creek | 1,553,698 | 455,170 | 505,585 | 172,127 | 243,355 | 242,618 | 181,083 | 80,982 | 32,634 | 46,697 |
| WM-6[c] | MUL0001 | Murley Run | 932,376 | 261,111 | 219,654 | 116,057 | 75,619 | 96,217 | 45,362 | 32,133 | 25,296 | 19,244 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 84,620 | 19,546 | 22,349 | 13,154 | 7,094 | 14,614 | 4,313 | 2,946 | 2,481 | 2,274 |
| WM-8[d] | HER0014 | Herrington Creek | 2,034,691 | 520,608 | 572,113 | 239,224 | 384,626 | 394,665 | 255,030 | 125,498 | 47,934 | 82,087 |
| WM-10 | BUG0013 | Bull Glade Run | 235,741 | 56,529 | 60,784 | 34,869 | 19,422 | 37,185 | 11,745 | 7,997 | 6,745 | 5,970 |

**Table 5-6. (continued)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 111,076 | 26,842 | 28,815 | 16,546 | 9,212 | 17,654 | 5,572 | 3,793 | 3,199 | 2,835 |
| WM-12 | MLR0001 | Millers Run | 980,462 | 189,996 | 106,613 | 67,956 | 82,134 | 46,220 | 42,775 | 19,686 | 14,032 | 17,528 |
| WM-14 | TOL0001 | Toliver Run | 1,368,440 | 304,393 | 181,437 | 177,955 | 174,595 | 178,924 | 132,206 | 54,776 | 21,057 | 61,846 |
| WM-15 | LAU0013 | Laurel Run | 2,244,317 | 629,619 | 494,921 | 250,071 | 187,988 | 181,532 | 104,043 | 77,698 | 56,885 | 39,180 |
| WM-16 | NED0005 | Ned Run | 145,583 | 37,473 | 38,617 | 14,467 | 14,385 | 11,205 | 8,840 | 5,020 | 3,061 | 2,599 |
| WM-17[e] | MYC0018 | Muddy Creek | 2,332,409 | 630,496 | 700,280 | 276,307 | 218,335 | 190,611 | 126,334 | 103,050 | 78,730 | 54,884 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 253,908 | 49,404 | 31,735 | 30,762 | 41,697 | 32,149 | 15,266 | 9,772 | 3,579 | 11,979 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 45,131 | 8,086 | 4,828 | 3,680 | 4,111 | 2,136 | 1,415 | 978 | 704 | 464 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 111,529 | 50,525 | 58,885 | 50,150 | 38,397 | 27,197 | 23,191 | 20,895 | 16,995 | 9,957 |
| BM909 | BUF0082 | Buffalo Run | 832,033 | 128,858 | 85,371 | 63,552 | 41,178 | 29,628 | 24,401 | 16,952 | 13,382 | 8,736 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 184,419 | 35,359 | 19,872 | 17,719 | 18,048 | 24,688 | 9,374 | 5,877 | 2,527 | 5,813 |
| BM915 | NXB0003 | North Branch Laurel Run | 312,976 | 60,728 | 38,196 | 27,504 | 22,287 | 18,045 | 9,381 | 7,443 | 4,643 | 6,988 |
| BM928[f] | LRL0018 | Laurel Run | 1,118,687 | 210,633 | 105,447 | 97,692 | 88,281 | 79,768 | 38,723 | 29,595 | 16,178 | 30,725 |
| BM929 | LRL0034 | Laurel Run | 308,253 | 44,947 | 33,479 | 23,195 | 18,199 | 13,327 | 8,504 | 6,723 | 5,120 | 3,351 |
| BM930 | TRR0007 | Trap Run | 371,890 | 76,514 | 35,435 | 39,702 | 38,470 | 41,496 | 18,290 | 12,339 | 4,998 | 13,004 |
| BM931 | WRR0008 | White Rock Run | 528,604 | 134,016 | 131,726 | 61,829 | 42,662 | 59,819 | 24,047 | 16,680 | 12,887 | 9,936 |
| BM933 | WRG0003 | White Rock Glade | 853,763 | 195,936 | 238,060 | 130,071 | 76,047 | 157,959 | 48,789 | 28,158 | 23,287 | 22,253 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-7. TMDL maximum daily nitrate loads flow percentile range (lb/d)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 84,075 | 28,977 | 18,086 | 10,981 | 7,039 | 5,289 | 3,452 | 2,038 | 626 | 450 |
| WM-2[b] | SNO0000 | Snowy Creek | 228,057 | 77,279 | 54,132 | 28,515 | 18,886 | 16,252 | 59,904 | 6,023 | 966 | 934 |
| WM-3 | CHB0005 | Cherry Bottom Run | 5,394 | 916 | 1,814 | 456 | 1,511 | 146 | 84 | 55 | 28 | 127 |
| WM-4 | HER0028 | Herrington Creek | 30,945 | 11,593 | 7,854 | 4,293 | 2,819 | 2,542 | 7,781 | 900 | 137 | 118 |
| WM-6[c] | MUL0001 | Murley Run | 13,216 | 5,828 | 3,857 | 2,201 | 1,418 | 1,250 | 631 | 445 | 104 | 152 |

**Table 5-7. (continued)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 923 | 373 | 242 | 134 | 92 | 97 | 49 | 34 | 13 | 21 |
| WM-8[d] | HER0014 | Herrington Creek | 51,674 | 13,361 | 7,862 | 4,676 | 5,572 | 2,574 | 7,936 | 910 | 226 | 771 |
| WM-10 | BUG0013 | Bull Glade Run | 2,599 | 1,075 | 697 | 388 | 264 | 268 | 135 | 95 | 34 | 54 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 1,233 | 510 | 331 | 184 | 125 | 127 | 64 | 45 | 16 | 26 |
| WM-12 | MLR0001 | Millers Run | 29,481 | 5,625 | 2,810 | 2,472 | 3,257 | 870 | 437 | 222 | 49 | 129 |
| WM-14 | TOL0001 | Toliver Run | 32,754 | 5,858 | 5,641 | 2,622 | 7,111 | 926 | 464 | 286 | 133 | 590 |
| WM-15 | LAU0013 | Laurel Run | 55,412 | 20,870 | 13,637 | 7,739 | 5,089 | 4,048 | 3,351 | 1,444 | 260 | 480 |
| WM-16 | NED0005 | Ned Run | 2,683 | 1,119 | 732 | 419 | 277 | 221 | 332 | 78 | 11 | 5 |
| WM-17[e] | MYC0018 | Muddy Creek | 55,136 | 23,234 | 14,217 | 8,898 | 5,386 | 4,063 | 3,226 | 1,603 | 570 | 235 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 5,621 | 897 | 989 | 414 | 248 | 146 | 88 | 56 | 23 | 121 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 992 | 200 | 100 | 90 | 46 | 32 | 16 | 8 | 2 | 5 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 3,757 | 1,083 | 1,192 | 833 | 453 | 173 | 114 | 69 | 44 | 18 |
| BM909 | BUF0082 | Buffalo Run | 23,265 | 4,576 | 2,286 | 2,084 | 1,050 | 731 | 367 | 186 | 41 | 49 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 4,060 | 671 | 759 | 382 | 261 | 114 | 70 | 52 | 14 | 60 |
| BM915 | NXB0003 | North Branch Laurel Run | 8,356 | 1,588 | 1,451 | 868 | 433 | 251 | 126 | 64 | 15 | 57 |
| BM928[f] | LRL0018 | Laurel Run | 27,687 | 5,009 | 3,879 | 2,280 | 1,207 | 802 | 403 | 205 | 57 | 275 |
| BM929 | LRL0034 | Laurel Run | 6,595 | 1,321 | 660 | 614 | 310 | 216 | 108 | 55 | 16 | 63 |
| BM930 | TRR0007 | Trap Run | 8,804 | 1,547 | 925 | 716 | 479 | 252 | 127 | 78 | 28 | 119 |
| BM931 | WRR0008 | White Rock Run | 9,956 | 4,020 | 2,661 | 1,495 | 1,006 | 889 | 910 | 316 | 81 | 111 |
| BM933 | WRG0003 | White Rock Glade | 18,636 | 6,286 | 4,410 | 2,321 | 1,575 | 1,808 | 2,042 | 639 | 263 | 391 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-8. TMDL maximum daily ammonium loads flow percentile range (lb/d)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 21,749 | 11,228 | 7,429 | 4,028 | 2,433 | 2,058 | 1,648 | 1,458 | 228 | 182 |
| WM-2[b] | SNO0000 | Snowy Creek | 64,526 | 31,147 | 21,362 | 10,674 | 6,403 | 6,528 | 30,245 | 6,280 | 613 | 412 |
| WM-3 | CHB0005 | Cherry Bottom Run | 734 | 200 | 265 | 165 | 293 | 58 | 64 | 21 | 49 | 57 |
| WM-4 | HER0028 | Herrington Creek | 8,820 | 4,785 | 3,296 | 1,588 | 979 | 1,026 | 3,922 | 889 | 83 | 52 |
| WM-6[c] | MUL0001 | Murley Run | 4,067 | 2,343 | 1,643 | 811 | 480 | 512 | 255 | 179 | 31 | 37 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 260 | 153 | 107 | 50 | 32 | 41 | 20 | 14 | 4 | 5 |
| WM-8[d] | HER0014 | Herrington Creek | 10,030 | 4,787 | 3,298 | 1,746 | 1,187 | 1,039 | 4,019 | 898 | 204 | 342 |
| WM-10 | BUG0013 | Bull Glade Run | 753 | 440 | 308 | 146 | 92 | 113 | 56 | 39 | 11 | 13 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 356 | 209 | 146 | 69 | 44 | 53 | 27 | 19 | 5 | 6 |
| WM-12 | MLR0001 | Millers Run | 3,927 | 1,240 | 735 | 949 | 621 | 330 | 163 | 81 | 48 | 56 |
| WM-14 | TOL0001 | Toliver Run | 4,421 | 1,323 | 914 | 1,050 | 1,380 | 368 | 297 | 97 | 227 | 262 |
| WM-15 | LAU0013 | Laurel Run | 14,304 | 7,947 | 5,566 | 2,774 | 1,697 | 1,590 | 1,604 | 556 | 60 | 137 |
| WM-16 | NED0005 | Ned Run | 830 | 460 | 320 | 161 | 97 | 92 | 165 | 40 | 4 | 2 |
| WM-17[e] | MYC0018 | Muddy Creek | 15,781 | 9,014 | 5,837 | 3,257 | 1,922 | 1,572 | 1,518 | 805 | 152 | 58 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 793 | 200 | 153 | 164 | 96 | 57 | 53 | 19 | 39 | 54 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 130 | 46 | 25 | 35 | 17 | 12 | 6 | 3 | 1 | 2 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 498 | 497 | 282 | 191 | 127 | 41 | 26 | 18 | 10 | 5 |
| BM909 | BUF0082 | Buffalo Run | 2,987 | 1,016 | 565 | 785 | 390 | 272 | 135 | 67 | 13 | 15 |
| BM913 | UGB0002 | Unnamed tributary to Glade Run | 544 | 161 | 187 | 129 | 72 | 45 | 26 | 12 | 20 | 23 |
| BM915 | NXB0003 | North Branch Laurel Run | 1,099 | 384 | 350 | 286 | 147 | 99 | 49 | 24 | 21 | 25 |
| BM928[f] | LRL0018 | Laurel Run | 3,655 | 1,187 | 947 | 904 | 479 | 314 | 155 | 77 | 87 | 122 |
| BM929 | LRL0034 | Laurel Run | 825 | 306 | 173 | 237 | 117 | 82 | 41 | 20 | 4 | 20 |
| BM930 | TRR0007 | Trap Run | 1,174 | 366 | 242 | 287 | 153 | 100 | 60 | 25 | 45 | 53 |
| BM931 | WRR0008 | White Rock Run | 2,961 | 1,662 | 1,162 | 575 | 354 | 371 | 438 | 130 | 24 | 28 |
| BM933 | WRG0003 | White Rock Glade | 5,189 | 2,646 | 1,849 | 856 | 572 | 728 | 978 | 290 | 82 | 100 |

**Table 5-8. (continued)**

| Station | Station code | Station name | 0–10 | 10–20 | 20–30 | 30–40 | 40–50 | 50–60 | 60–70 | 70–80 | 80–90 | 90–100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM -7, WM -10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM -16.
[f] BM928 includes upstream loads from BM929.

### *5.3.1 Wasteload Allocations*

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. On the basis of the types of activities and the minimal flow of the discharges, these permitted non-mining sources are believed to be negligible. Under these TMDLs, these minor discharges are assumed to operate under their current permit limits and are assigned WLAs that allow them to discharge at their current permit limits. Table 5-9 presents the WLAs for each point source. It was assumed that if a parameter limit was not in the permit, that the present discharge levels were not adversely affecting the stream and a WLA was not given.

**Table 5-9. WLAs for permitted facilities upstream of impaired segments**

| NPDES Permit Number | Outlet | Facility | Permit flow (mgd) | Associated station/ station code | Associated station name | Ammonia[a] (lb/yr) | Total iron (lb/yr) | Total aluminum (lb/yr) |
|---|---|---|---|---|---|---|---|---|
| MD0052850 | 001A | Swallow Falls State Park WWTP | 0.062 | WM-14/ TOL0001 | Toliver Run | 330 (S) | --[b] | -- |
| WV0033804 | 001 | Terra Alta STP | 0.25 | WM-2/ SNO0000 | Snowy Creek | 1,523 | -- | -- |
| WV0086665 | 001 | Alpine Lake STP | 0.06 | WM-2/ SNO0000 | Snowy Creek | -- | -- | -- |
| WV0119113 | 002 | Cranesville Stone | 0.077156[c] | WM-17/ MYC0018 | Muddy Creek | -- | 752 | 101 |
| WVG551149 | 001 | Alyeska, Inc. (Big Bear Lake Campground WWTP) | 0.03 | BM933/ WRG0003 | White Rock Glade | 137(S) 274 (W) | -- | -- |
| WVG610139 | 001 | Grimm Lumber, Inc. | 0.0026 | WM-15/ LAU0013 | Laurel Run | -- | 8 | -- |
| WVG640110 | 001 | Terra Alta WTP | 0.005 | WM-2/ SNO0000 | Snowy Creek | -- | 18 | 11 |

[a] Ammonia limits contain summer and winter limits. Summer loads (S) are valid from May 1 through October 31. Winter loads (W) are valid November 1 through April 30.
[b] There is no permit limit for this parameter for this facility. Persent discharge levels assumed not to be adversely affecting stream.
[c] Flow based on drainage area and average annual model output for mining land use.

Because the permits do not have limits for all parameters, during model development an analysis was performed on other data in PCS to see if this data had an affect on pH. The PCS database was searched for permits with the same Standard Industrial Classification (SIC) codes as the permits in the model. Average flow and loads from these facilities were used to calculate average effluent concentrations by SIC code. Additional information was obtained from EPA's national recommended water quality criteria (USEPA 2004). No effect was observed; therefore, these concentrations were not used in the final model.

### *5.3.2 Load Allocations*

The LA is that portion of the TMDL that is assigned to nonpoint sources. LAs were first applied to atmospheric deposition. These TMDL loads are based on the 2020 predictions under the CAIR regulation from EPA Office of Air Quality Planning and Standards at Research Triangle Park, North Carolina. After these future loads were applied to the model, the loads from known mining seeps and portals were reduced. If further reductions were required, the loads from other nonpoint sources were reduced. These loads were applied to the whole watershed and not a specific nonpoint source or land use.

Table 5-10 presents total annual load allocations at the monitoring locations, as the stream leaves the watershed. Note that the loads in these tables include atmospheric deposition loads, which are also presented separately in Table 5-11 (but as direct inputs to the land surface rather than as the stream leaves the watershed). Atmospheric deposition reductions were not found to have a significant impact on predicted pH in the watershed. The loads in Table 5-10 include background concentration and atmospheric loads that have gone through chemical reactions. These loads also include loads from mine seeps which are presented in Table 5-12. These loads represent a 99 percent reduction in flow and pollutant concentration levels for the mine seeps.

**Table 5-10. LAs for iron, aluminum, sulfate, nitrate, and ammonium yearly loads**

| Station | Station code | Station name | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|
| WM-1[a] | MYC0002 | Muddy Creek | 79,663 | 53,593 | 1,642,486 | 42,074 | 9,679 |
| WM-2[b] | SNO0000 | Snowy Creek | 198,637 | 145,025 | 5,054,641 | 115,512 | 27,127 |
| WM-3 | CHB0005 | Cherry Bottom Run | 3,261 | 2,098 | 67,721 | 1,126 | 245 |
| WM-4 | HER0028 | Herrington Creek | 27,255 | 20,193 | 717,023 | 16,869 | 4,021 |
| WM-6[c] | MUL0001 | Murley Run | 2,249 | 2,811 | 490,988 | 8,045 | 1,827 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 104 | 159 | 39,768 | 532 | 124 |
| WM-8[d] | HER0014 | Herrington Creek | 33,327 | 24,437 | 963,612 | 21,112 | 4,968 |
| WM-10 | BUG0013 | Bull Glade Run | 294 | 449 | 112,925 | 1,514 | 352 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 140 | 213 | 53,550 | 718 | 167 |
| WM-12 | MLR0001 | Millers Run | 7,931 | 5,702 | 273,935 | 5,924 | 1,202 |
| WM-14 | TOL0001 | Toliver Run | 14,172 | 9,423 | 397,953 | 6,812 | 1,422 |
| WM-15 | LAU0013 | Laurel Run | 6,021 | 8,743 | 1,252,566 | 29,377 | 6,581 |
| WM-16 | NED0005 | Ned Run | 3,183 | 2,274 | 72,552 | 1,539 | 369 |
| WM-17[e] | MYC0018 | Muddy Creek | 57,719 | 42,081 | 1,329,769 | 31,324 | 7,139 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 1,573 | 1,063 | 54,834 | 820 | 186 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 49 | 65 | 13,424 | 198 | 39 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 3,285 | 1,667 | 147,856 | 1,185 | 232 |
| BM909 | BUF0082 | Buffalo Run | 1,906 | 2,123 | 238,483 | 4,602 | 898 |
| BM913 | UGB0002 | Unnamed tributary | 504 | 420 | 45,811 | 816 | 173 |
| BM915 | NXB0003 | North Branch Laurel Run | 2,807 | 1,921 | 90,465 | 1,748 | 361 |
| BM928[f] | LRL0018 | Laurel Run | 13,478 | 8,838 | 315,092 | 5,573 | 1,152 |

**Table 5-10. (continued)**

| Station | Station code | Station name | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr) |
|---|---|---|---|---|---|---|---|
| BM929 | LRL0034 | Laurel Run | 205 | 347 | 89,098 | 1,366 | 265 |
| BM930 | TRR0007 | Trap Run | 2,251 | 1,597 | 100,301 | 1,743 | 372 |
| BM931 | WRR0008 | White Rock Run | 1,602 | 1,751 | 259,344 | 5,754 | 1,359 |
| BM933 | WRG0003 | White Rock Glade | 1,291 | 2,227 | 380,867 | 9,839 | 2,215 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

**Table 5-11. Projected (2020) yearly loads from atmospheric deposition for TMDL scenario**

| Station | Station code | Station name | Dry (lb/yr) | | | Wet (lb/yr) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Sulfate | Nitrate | Ammonium | Sulfate | Nitrate | Ammonium |
| WM-1[a] | MYC0002 | Muddy Creek | 86,590 | 881 | 8,397 | 133,277 | 65,265 | 22,970 |
| WM-2[b] | SNO0000 | Snowy Creek | 154,943 | 1,576 | 15,025 | 238,484 | 116,784 | 41,103 |
| WM-3 | CHB0005 | Cherry Bottom Run | 2,494 | 25 | 242 | 3,839 | 1,880 | 662 |
| WM-4 | HER0028 | Herrington Creek | 21,519 | 219 | 2,087 | 33,121 | 16,219 | 5,708 |
| WM-6[c] | MUL0001 | Murley Run | 20,238 | 206 | 1,962 | 31,149 | 15,254 | 5,369 |
| WM-7 | ZWE0001 | Unnamed tributary to Bull Glade Run | 1,598 | 16 | 155 | 2,460 | 1,205 | 424 |
| WM-8[d] | HER0014 | Herrington Creek | 30,846 | 314 | 2,991 | 47,477 | 23,249 | 8,183 |
| WM-10 | BUG0013 | Bull Glade Run | 4,600 | 47 | 446 | 7,081 | 3,467 | 1,220 |
| WM-11 | UBL0000 | Unnamed tributary to Bull Glade Run | 2,186 | 22 | 212 | 3,365 | 1,648 | 580 |
| WM-12 | MLR0001 | Millers Run | 12,366 | 126 | 1,199 | 19,034 | 9,321 | 3,280 |
| WM-14 | TOL0001 | Toliver Run | 15,942 | 162 | 1,546 | 24,538 | 12,016 | 4,229 |
| WM-15 | LAU0013 | Laurel Run | 46,589 | 474 | 4,518 | 71,708 | 35,115 | 12,359 |
| WM-16 | NED0005 | Ned Run | 2,447 | 25 | 237 | 3,766 | 1,844 | 649 |
| WM-17[e] | MYC0018 | Muddy Creek | 60,972 | 620 | 5,912 | 93,846 | 45,956 | 16,174 |
| WM-21 | ZWI0000 | Unnamed tributary to Bear Creek | 1,895 | 19 | 184 | 2,916 | 1,428 | 503 |
| WM-22 | ZWL0005 | Unnamed tributary to Little Bear Creek | 712 | 7 | 69 | 1,096 | 537 | 189 |
| WM-26 | ZWH0000 | Unnamed tributary to Mill Run | 7,507 | 76 | 728 | 11,554 | 5,658 | 1,991 |
| BM909 | BUF0082 | Buffalo Run | 12,697 | 129 | 1,231 | 19,542 | 9,570 | 3,368 |
| BM913 | UGB0002 | Unnamed tributary | 1,837 | 19 | 178 | 2,827 | 1,384 | 487 |
| BM915 | NXB0003 | North Branch Laurel Run | 4,418 | 45 | 428 | 6,800 | 3,330 | 1,172 |
| BM928[f] | LRL0018 | Laurel Run | 15,072 | 153 | 1,462 | 23,198 | 11,360 | 3,998 |
| BM929 | LRL0034 | Laurel Run | 4,801 | 49 | 466 | 7,390 | 3,619 | 1,274 |
| BM930 | TRR0007 | Trap Run | 4,280 | 44 | 415 | 6,588 | 3,226 | 1,135 |
| BM931 | WRR0008 | White Rock Run | 8,877 | 90 | 861 | 13,663 | 6,691 | 2,355 |
| BM933 | WRG0003 | White Rock Glade | 11,731 | 119 | 1,138 | 18,055 | 8,842 | 3,112 |

[a] WM-1 includes upstream loads from WM-17.
[b] WM-2 includes upstream loads from WM-15.
[c] WM-6 includes upstream loads from WM-7, WM-10, and WM-11.
[d] WM-8 includes upstream loads from WM-4.
[e] WM-17 includes upstream loads from WM-16.
[f] BM928 includes upstream loads from BM929.

Portions of the Youghiogheny River watershed originate in West Virginia. Several of these streams flow into streams listed as impaired by Maryland. The portion of the total allocation, including load allocations and the margin of safety, in Table 5-2 that is attributed to areas in West Virginia is presented in Table 5-13. These loads are area-weighted to the portion of the watershed that is in West Virginia. In addition, the mine seep, MY-00037, from Table 5-12, is in West Virginia. The TMDLs do not prescribe specific load allocations for the contributing area of West Virginia. Instead, they allow West Virginia and its stakeholders to determine appropriate and necessary source reductions.

**Table 5-12. Yearly loads from mine seeps and portals**

| Mine Seep | Associated station | Associated station code | Associated station name | Aluminum (lb/yr) | Iron (lb/yr) | Sulfate (lb/yr) |
|---|---|---|---|---|---|---|
| AMD-WV1 | WM-15 | LAU0013 | Laurel Run | 2.34 | 4.44 | 80.4 |
| OK-01-P1 | WM-2 | SNO0000 | Snowy Creek | 0.09 | 0.88 | 17.6 |
| OK-01-P2 | WM-2 | SNO0000 | Snowy Creek | 0.09 | 0.88 | 17.6 |
| SR-02-P3 | BM930 | TRR0007 | Trap Run | 0.22 | 9.87 | 44.1 |
| SR-02-S2 | BM930 | TRR0007 | Trap Run | 0.09 | 0.88 | 17.6 |
| Y-10-O1 | BM928 | LRL0018 | Laurel Run | 0.09 | 0.88 | 17.6 |
| Y-10-O2 | BM928 | LRL0018 | Laurel Run | 0.09 | 0.88 | 17.6 |
| Y-10-S1 | BM928 | LRL0018 | Laurel Run | 0.44 | 4.39 | 88.2 |
| Y-11-S1 | BM928 | LRL0018 | Laurel Run | 0.13 | 1.32 | 26.4 |
| Y-18-S1 | BM931 | WRR0008 | White Rock Run | 0.04 | 0.44 | 8.8 |
| Y-24-S1 | WM-3 | CHB0005 | Cherry Bottom Run | 0.09 | 1.67 | 18.9 |
| Y-24-S2 | WM-3 | CHB0005 | Cherry Bottom Run | 0.04 | 0.44 | 8.8 |

### *5.3.3 Margin of Safety and Future Allocation*

The MOS is the portion of the pollutant loading reserved to account for uncertainty in the TMDL development process. There are two ways to incorporate the MOS (USEPA 1991): (1) implicitly incorporate the MOS by using conservative model assumptions to develop allocations or (2) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. For this TMDL, a 5 percent explicit MOS was used to account for uncertainty in the modeling process. The MOS loadings are presented in Table 5-2.

While the MOS is an allocation for scientific uncertainly, the FA is an allocation for growth. Ten percent of the load was allocated for future allocation in the area covered by the TMDL. This growth includes future urban development, including point sources, coal mining areas, agriculture, and other nonpoint sources. The FA could also be used for sources not accounted for or unknown and therefore not otherwise included in the TMDL. The FA loadings are presented in Table 5-2.

**Table 5-13. TMDL yearly loads from West Virginia**

| Station | Station code | Station name | TMDL fraction | Iron (lb/yr) | Aluminum (lb/yr) | Sulfate (lb/yr) | Nitrate (lb/yr) | Ammonium (lb/yr)[a] |
|---|---|---|---|---|---|---|---|---|
| WM-2[b] | SNO0000 | Snowy Creek | Baseline | 300,697 | 217,871 | 6,010,047 | 223,029 | 28,364 |
| | | | TMDL | 207,159 | 151,247 | 5,271,439 | 120,466 | 28,528 |
| | | | % reduction | 31.1 | 30.6 | 12.3 | 46.0 | -0.6 |
| WM-4 | HER0028 | Herrington Creek | Baseline | 16,697 | 11,840 | 325,352 | 12,450 | 1,593 |
| | | | TMDL | 10,853 | 8,041 | 285,519 | 6,717 | 1,601 |
| | | | % reduction | 35.0 | 32.1 | 12.2 | 46.0 | -0.5 |
| WM-15 | LAU0013 | Laurel Run | Baseline | 69,614 | 57,309 | 1,635,928 | 62,732 | 7,632 |
| | | | TMDL | 6,961 | 10,106 | 1,447,959 | 33,960 | 7,608 |
| | | | % reduction | 90.0 | 82.4 | 11.5 | 45.9 | 0.3 |
| WM-17 | MYC0018 | Muddy Creek | Baseline | 53,627 | 39,035 | 1,233,075 | 29,046 | 6,620 |
| | | | TMDL | 53,627 | 39,035 | 1,233,075 | 29,046 | 6,620 |
| | | | % reduction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BM909 | BUF0082 | Buffalo Run | Baseline | 1,597 | 1,779 | 199,777 | 3,855 | 752 |
| | | | TMDL | 1,597 | 1,779 | 199,777 | 3,855 | 752 |
| | | | % reduction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BM929 | LRL0034 | Laurel Run | Baseline | 201 | 341 | 87,524 | 1,341 | 260 |
| | | | TMDL | 201 | 341 | 87,524 | 1,341 | 260 |
| | | | % reduction | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BM933 | WRG0003 | White Rock Glade | Baseline | 11,448 | 8,443 | 231,386 | 9,741 | 1,211 |
| | | | TMDL | 687 | 1,185 | 202,625 | 5,235 | 1,211 |
| | | | % reduction | 94.0 | 86.0 | 12.4 | 46.3 | -0.1 |

[a] The CAIR model predicts that ammonium in atmospheric deposition will increase in some areas.
[b] WM-2 includes upstream loads from WM-15.

## 6 REASONABLE ASSURANCE

Section 303(d) of Clean Water Act (CWA) and current EPA regulations require reasonable assurance that TMDLs will be implemented. TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Youghiogheny River TMDL identifies the necessary overall load reductions for those pollutants causing use impairments and distributes those reduction goals to the appropriate sources. Reaching the reduction goals established by these TMDLs will occur only through changes in current land use practices, including the remediation of acid mine drainage and the implementation of the CAIR. Although the derived TMDLs are based on best professional judgment using current data in the calibrated model, meeting these TMDLs might not be necessary if alternative remediation and future monitoring prove that pH is being corrected without reducing these parameters.

The Maryland Bureau of Mines (BOM) is responsible for protecting the environment from potential impacts from active mining and promoting the restoration of abandoned mine lands and water resources. In issuing new or updated permits in the TMDL area, BOM will ensure that permit limits will not adversely affect the pH in impaired waters. BOM also reclaims abandoned mine lands. These lands are prioritized on the basis of health, safety, and environmental impacts. Within the BOM, the Acid Mine Drainage Abatement Section's mission is to improve the waters of the state that are impaired by AMD from abandoned coal mines. This is an ongoing process that is limited by the amount of funding available and may be aided by partnerships with industries, watershed groups, other government agencies, and other interested parties.

On March 10, 2005, EPA issued the CAIR, which places caps on emissions for sulfur dioxide and nitrogen dioxides in the eastern United States. It is expected that CAIR will reduce sulfur dioxide emissions by more than 70 percent and nitrogen oxides emissions by more than 60 percent from the 2003 emission levels (USEPA 2005d). Because these pollutants are highly mobile in the atmosphere, emission reductions in West Virginia, Ohio, Pennsylvania, and possibly Michigan are expected to improve the quality of precipitation in the Youghiogheny River watershed.

The West Virginia Department of Environmental Protection (WVDEP) plans to develop a TMDL report for the West Virginia portion of the Youghiogheny River basin during its 2009 TMDL schedule. Reasonable assurance for maintenance and improvement of water quality in the affected watershed rests primarily with three separate programs. Two of these programs are wholly within WVDEP, and the third program is a cooperative effort involving many state and federal agencies. Within WVDEP, the programs involved in the effort include the NPDES Permitting Program and the Abandoned Mine Lands Program. In addition, WVDEP is involved with the West Virginia Watershed Management Network/Watershed Management Framework, which includes many state and federal agencies dealing with the protection and restoration of water resources. The framework process allows the resources of many entities to focus on the protection or restoration of water quality in selected streams.

Individuals or local groups, such as the Youghiogheny River Watershed Association, interested in improving conditions in the watershed are strongly encouraged to review funding sources available through MDE and other state and federal agencies. Numerous state programs, including section 319 programs, are available. Other Maryland programs include the Small Creeks and Estuaries Restoration Program and the State Revolving Loan Fund. For more information, visit http://www.mde.state.md.us/AboutMDE/grants/index.asp (MDE 2006).

Several remediation projects are already underway in the impaired reaches. Constructed and planned projects in the watersheds include

- The Crellin School Wetland Treatment Remediation Project on Snowy Creek treats 20 gpm.
- The Crellin-Rice Pyrolusite Remediation Project on the Laurel Run tributary to Snowy Creek treats 20 gpm.
- The Interstate #335 Anoxic Limestone Drain on White Rock Run treats 70 gpm.
- The Winding Ridge CCB Injection Project on Bear Creek treats 30 gpm.
- The Crellin Borehole Doser Project the Laurel Run tributary to Snowy Creek will treat 550 gpm.

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