TETRA TECH

September 2018

USEPA Approved Report

Total Maximum Daily Loads for the Mononganela River Watershed, West Virginia

Prepared for
West Virginia Department of Environmental Protection
Division of Water and Waste Management
Watershed Assessment Branch, TMDL Section

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On the cover:
Photos provided by WVDEP Division of Water and Waste Management

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ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

7Q10	7-day, 10-year low flow
AML	abandoned mine land
AML&R	[WVDEP] Office of Abandoned Mine Lands & Reclamation
BMP	best management practice
CFR	Code of Federal Regulations
CSO	combined sewer overflow
CSR	Code of State Rules
DEM	Digital Elevation Model

DMR	[WVDEP] Division of Mining and Reclamation
DNR	West Virginia Division of Natural Resources
DWWM	[WVDEP] Division of Water and Waste Management
GIS	geographic information system
gpd	gallons per day
HAU	home aeration unit
LA	load allocation
µg/L	micrograms per liter
MDAS	Mining Data Analysis System
mg/L	milligrams per liter
mL	milliliter
MF	membrane filter counts per test
MPN	most probable number
MOS	margin of safety
MRLC	Multi-Resolution Land Characteristics Consortium
MS4	Municipal Separate Storm Sewer System
NED	National Elevation Dataset
NLCD	National Land Cover Dataset
NOAA-NCDC	National Oceanic and Atmospheric Administration, National Climatic Data Center
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OOG	[WVDEP] Office of Oil and Gas
POTW	publicly owned treatment works
SRF	State Revolving Fund
SSO	sanitary sewer overflow
STATSGO	State Soil Geographic database
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UNT	unnamed tributary
WLA	wasteload allocation
WVDEP	West Virginia Department of Environmental Protection
WVDOH	West Virginia Division of Highways
WVU	West Virginia University

EXECUTIVE SUMMARY

This report includes a Total Maximum Daily Load (TMDL) for the Monongahela River mainstem. This modeling effort was organized into one watershed model with 116 subwatersheds representing areas adjacent to the Monongahela River feeding into a separate two-dimensional receiving water model with 1524 grid cells (3 wide and 508 long) stretching from the confluence of the West Fork and Tygart Valley Rivers to the Pennsylvania border. The West Fork, Tygart, and West Virginia direct tributaries of the Monongahela had been modeled under previous TMDLs and were treated as model inputs at baseline and TMDL condition. These TMDLs were: Total Maximum Daily Loads for Selected Streams in the Monongahela River Watershed, West Virginia (WVDEP 2014), Total Maximum Daily Loads for the West Fork River Watershed, West Virginia (WVDEP 2014), Total Maximum Daily Loads for the Tygart Valley River Watershed, West Virginia (WVDEP 2016).

WVDEP developed fecal coliform TMDLs for selected streams in the Monongahela River Watershed, which were USEPA approved in April 2014. Water bodies covered under this effort included all the impaired streams contributing to the Monongahela River, but not the mainstem itself. There were 19 direct tributaries modeled for fecal coliform under this effort. Not all direct tributaries of the Monongahela mainstem had TMDLs developed because not all direct tributaries were impaired streams. WVDEP developed fecal coliform TMDLs for selected streams in the West Fork River Watershed, which were USEPA approved in July 2014. WVDEP developed fecal coliform TMDLs for the Tygart Valley River Watershed, which were USEPA approved in June 2016 and modified in September 2016.

A TMDL establishes the maximum allowable pollutant loading for a waterbody to comply with water quality standards, distributes the load among pollutant sources, and provides a basis for actions needed to restore water quality. West Virginia's water quality standards are codified at Title 47 of the *Code of State Rules* (CSR), Series 2, and titled *Legislative Rules, Department of Environmental Protection: Requirements Governing Water Quality Standards*. The standards include designated uses of West Virginia waters and numeric and narrative criteria to protect those uses. The West Virginia Department of Environmental Protection routinely assesses use support by comparing observed water quality data with criteria and reports impaired waters every two years as required by Section 303(d) of the Clean Water Act ("303(d) list"). The Act requires that TMDLs be developed for listed impaired waters.

The Monongahela River is included on the West Virginia's 2014 Section 303(d) List and draft 2016 Section 303(d) List. Documented impairment is for numeric water quality criteria for fecal coliform bacteria.

The Environmental Fluid Dynamics Code (EFDC) model was used to model instream concentrations of fecal coliform in the Monongahela River. EFDC is a hydrodynamic model that can be used to simulate aquatic systems in one, two, and three dimensions. It has evolved over the past two decades to become one of the most widely used and technically defensible hydrodynamic models in the world. (USEPA 2017).

The Mining Data Analysis System (MDAS) was used to represent linkage between pollutant sources and instream responses for fecal coliform bacteria under previous TMDLs developed for tributaries of the Monongahela River. The MDAS is a comprehensive data management and modeling system that is capable of representing loads from nonpoint and point sources in the watershed and simulating instream processes. Loads generated with MDAS models developed for previous USEPA-approved TMDLs were used to represent the contributions of West Fork, Tygart, and select Monongahela River Watershed tributaries to the Monongahela Mainstem EFDC model. A separate MDAS model was used to simulate loads from remaining Monongahela River Watershed tributaries (not previously modeled during TMDL development), as well as direct surface runoff to the mainstem. Flow and pollutant loads from the MDAS watershed model were linked to the EFDC grid by associating loads from tributaries and diffuse flow (surface runoff from adjacent subwatersheds without a stream channel identified in the NHD) to spatially appropriate grid cells.

In general, point and nonpoint sources contribute to the fecal coliform bacteria impairments in the watershed. Failing on-site septic systems, direct discharges of untreated sewage, and precipitation runoff from agricultural and residential areas are nonpoint sources of fecal coliform bacteria. Point sources of fecal coliform bacteria include the effluents of sewage treatment facilities, and stormwater discharges from Municipal Separate Storm Sewer Systems (MS4s), and Combined Sewer Overflows (CSOs). The presence of individual source categories and their relative significance varies by subwatershed.

This report describes the TMDL development and modeling processes, identifies impaired streams and existing pollutant sources, discusses future growth and TMDL achievability, and documents the public participation associated with the process. It also contains a detailed discussion of the allocation methodologies applied for various impairments. Various provisions attempt to ensure the attainment of criteria throughout the watershed, achieve equity among categories of sources, and target pollutant reductions from the most problematic sources. Nonpoint source reductions were not specified beyond natural (background) levels. Similarly, point source WLAs were no more stringent than numeric water quality criteria.

Considerable resources were used to acquire recent water quality and pollutant source information upon which the TMDL is based. The TMDL modeling is among the most sophisticated available, and incorporates sound scientific principles. TMDL outputs are presented in various formats to assist user comprehension and facilitate use in implementation, including allocation spreadsheets, an ArcGIS Viewer Project, and Technical Report.

The applicable TMDL is displayed in **Section 7** of this report. The accompanying spreadsheets provide previously developed TMDLs and allocations of loads to categories of point and nonpoint sources that achieve the total TMDL. Also provided is the ArcGIS Viewer Project that allows for the exploration of spatial relationships among the source assessment data. A Technical Report is available that describes the detailed technical approaches used in the process and displays the data upon which the TMDL is based.

1.0 REPORT FORMAT

This report describes the overall total maximum daily load (TMDL) development process for the Monongahela River and outlines the source assessment for all pollutants for which the TMDL is presented. It also describes the modeling and allocation processes and lists measures that will be taken to ensure that the TMDL is met. The applicable TMDL is displayed in **Section 7** of this report. The report is supported by an ArcGIS Viewer Project that provides further details on the data and allows the user to explore the spatial relationships among the source assessment data, magnify streams and view other features of interest. In addition to the TMDL report, a CD is provided that contains spreadsheets (in Microsoft Excel format) that display detailed source allocations associated with successful TMDL scenarios. A Technical Report is included that describes the detailed technical approaches used in the process and displays the data upon which the TMDL is based.

2.0 INTRODUCTION

The West Virginia Department of Environmental Protection (WVDEP), Division of Water and Waste Management (DWWM), is responsible for the protection, restoration, and enhancement of the State's waters. Along with this duty comes the responsibility for TMDL development in West Virginia.

2.1 Total Maximum Daily Loads

Section 303(d) of the federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (in Title 40 of the *Code of Federal Regulations* [CFR] Part 130) require states to identify waterbodies that do not meet water quality standards and to develop appropriate TMDLs. A TMDL establishes the maximum allowable pollutant loading for a waterbody to achieve compliance with applicable standards. It also distributes the load among pollutant sources and provides a basis for the actions needed to restore water quality.

A TMDL 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 a margin of safety (MOS), implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. TMDLs can be expressed in terms of mass per time or other appropriate units. Conceptually, this definition is denoted by the following equation:

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

WVDEP is developing TMDLs in concert with a geographically-based approach to water resource management in West Virginia—the Watershed Management Framework. Adherence to the Framework ensures efficient and systematic TMDL development. Each year, TMDLs are developed in specific geographic areas. The Framework dictated that 2017 TMDLs should be pursued in Hydrologic Group D, which includes the Monongahela River. **Figure 2-1** depicts the hydrologic groupings of West Virginia's watersheds; the legend includes the target year for finalization of each TMDL.

WVDEP is committed to implementing a TMDL process that reflects the requirements of the TMDL regulations, provides for the achievement of water quality standards, and ensures that ample stakeholder participation is achieved in the development and implementation of TMDLs. A 48-month development process enables the agency to carry out an extensive data generating and gathering effort to produce scientifically defensible TMDLs. It also allows ample time for modeling, report finalization, and frequent public participation opportunities.

The TMDL development process begins with pre-TMDL water quality monitoring and source identification and characterization. Informational public meetings are held in the affected watersheds. Data obtained from pre-TMDL efforts are compiled, and the impaired waters are modeled to determine baseline conditions and the gross pollutant reductions needed to achieve water quality standards. The draft TMDL is advertised for public review and comment, and an informational meeting is held during the public comment period. Public comments are addressed, and the draft TMDL is submitted to USEPA for approval.

In 2014, WVDEP developed fecal coliform TMDLs for selected streams in the Monongahela River Watershed. Water bodies covered under this effort included all the impaired streams contributing to the Monongahela River, but not the mainstem itself. Also, in 2014, WVDEP developed fecal coliform TMDLs for selected streams in the West Fork River Watershed. Then, in 2016, WVDEP developed fecal coliform TMDLs for the Tygart Valley River Watershed. The West Fork and Tygart converge at the City of Fairmont to form the Monongahela River.

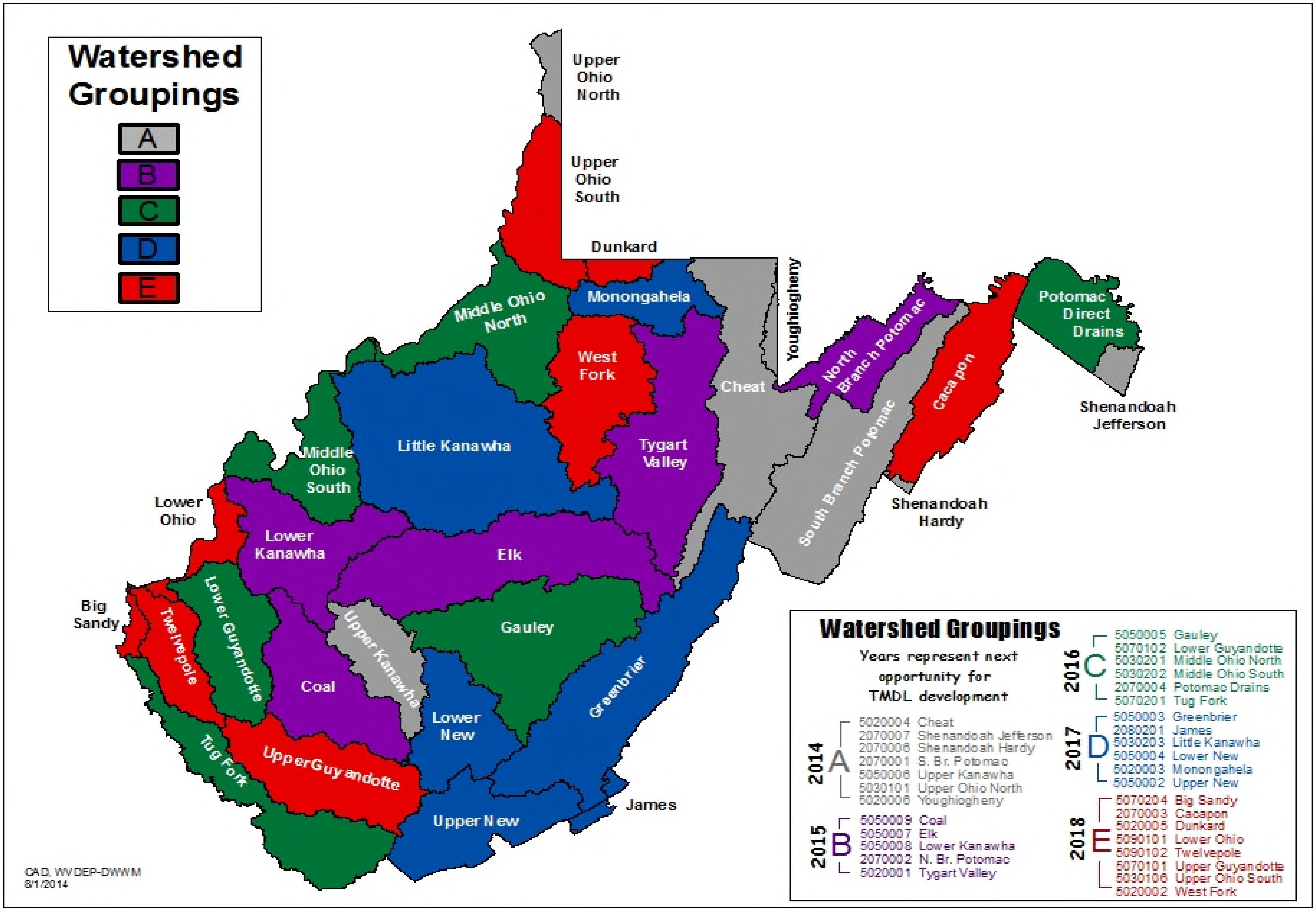


Figure 2-1. Hydrologic groupings of West Virginia's watersheds

2.2 Water Quality Standards

The determination of impaired waters involves comparing instream conditions to applicable water quality standards. West Virginia's water quality standards are codified at Title 47 of the *Code of State Rules* (CSR), Series 2, titled *Legislative Rules, Department of Environmental Protection: Requirements Governing Water Quality Standards*. These standards can be obtained online from the West Virginia Secretary of State Internet site http://apps.sos.wv.gov/adlaw/csr/rule.aspx?rule=47-02.)

Water quality standards consist of three components: designated uses; narrative and/or numeric water quality criteria necessary to support those uses; and an antidegradation policy. Appendix E of the Standards contains the numeric water quality criteria for a wide range of parameters, while Section 3 of the Standards contains the narrative water quality criteria.

According to 40 CFR Part 130, TMDLs must be designed to implement applicable water quality standards. The TMDL presented herein is based upon the water quality criteria that are currently effective. If the West Virginia Legislature adopts Water Quality Standard revisions that alter the basis upon which the TMDL is developed, then the TMDL and allocations may be modified as warranted. Any future Water Quality Standard revision and/or TMDL modification must receive USEPA approval prior to implementation.

In addition, according to 40 CFR Part 131.10(b), TMDLs must be designed to attain and maintain downstream quality standards. As such, the Pennsylvania Department of Environmental Protection's (DEP) fecal coliform water quality criteria have been included in Table 2-1 and is addressed within this TMDL. The criteria are similar except Pennsylvania DEP allows increased counts of bacteria in non-swimming months; while, WVDEP criteria apply the entire calendar year. As such, attainment of West Virginia fecal coliform water quality criteria at the state line will be protective of the Pennsylvania criteria.

Designated uses for West Virginia include: propagation and maintenance of aquatic life in warmwater fisheries and troutwaters, water contact recreation, and public water supply. In the Monongahela River, water contact recreation and/or public water supply use impairments have been determined pursuant to exceedances of numeric water quality criteria for fecal coliform bacteria.

The numeric water quality criteria applicable to the Monongahela River addressed by this report are summarized in **Table 2-1**.

Table 2-1. Applicable West Virginia and Pennsylvania water quality criteria

POLLUTANT	STATE	DESIGNATED USE/WATER QUALITY CRITERIA
Fecal coliform bacteria	**WV**	**Human Health Contact Recreation/Public Water Supply**: Maximum allowable level of fecal coliform content for Primary Contact Recreation (either MPN [most probable number] or MF [membrane filter counts/test]) shall not exceed 200/100 mL as a monthly geometric mean based on not less than 5 samples per month; nor to exceed 400/100 mL in more than 10 percent of all samples taken during the month.
Bac1 (Fecal coliforms/ 100 ml)—	**PA**	**Water Contact Only:** During the swimming season (May 1 through September 30), the maximum fecal coliform level shall be a geometric mean of 200 per 100 milliliters (ml) based on a minimum of five consecutive samples each sample collected on different days during a 30-day period. No more than 10% of the total samples taken during a 30-day period may exceed 400 per 100 ml. For the remainder of the year, the maximum fecal coliform level shall be a geometric mean of 2,000 per 100 milliliters (ml) based on a minimum of five consecutive samples collected on different days during a 30-day period.

3.0 WATERSHED DESCRIPTION AND DATA INVENTORY

3.1 Watershed Description

Located within the Western Allegheny Plateau ecoregion, the Monongahela River is a major tributary of the Ohio River that eventually joins the Mississippi and flows to the Gulf of Mexico. The Monongahela TMDL Project Area encompasses approximately 93 square miles in northern West Virginia. The Project Area excludes streams and drainage areas of the Monongahela River watershed for which previous TMDLs were developed. The Project Area extends from the City of Fairmont north to the Pennsylvania border, and lies in portions of Marion, Monongalia and Taylor Counties in West Virginia (**Figure 3-1**). Outside West Virginia, the Monongahela River continues northward through Pennsylvania to the City of Pittsburgh, although areas draining to that portion of the river are not discussed in this report. Cities and towns in the vicinity of the area of study include Fairmont, Morgantown, and Westover.

The average elevation in the Project Area is 1,136 feet. The highest point of the Project Area is 2,125 feet on a ridge above the headwaters of Maple Run. The minimum elevation in the Project Area is 793 feet, which is the normal pool elevation of the Monongahela River at the West Virginia state line. The total population living in the subject Project Area of this report is estimated to be 10,000 people.

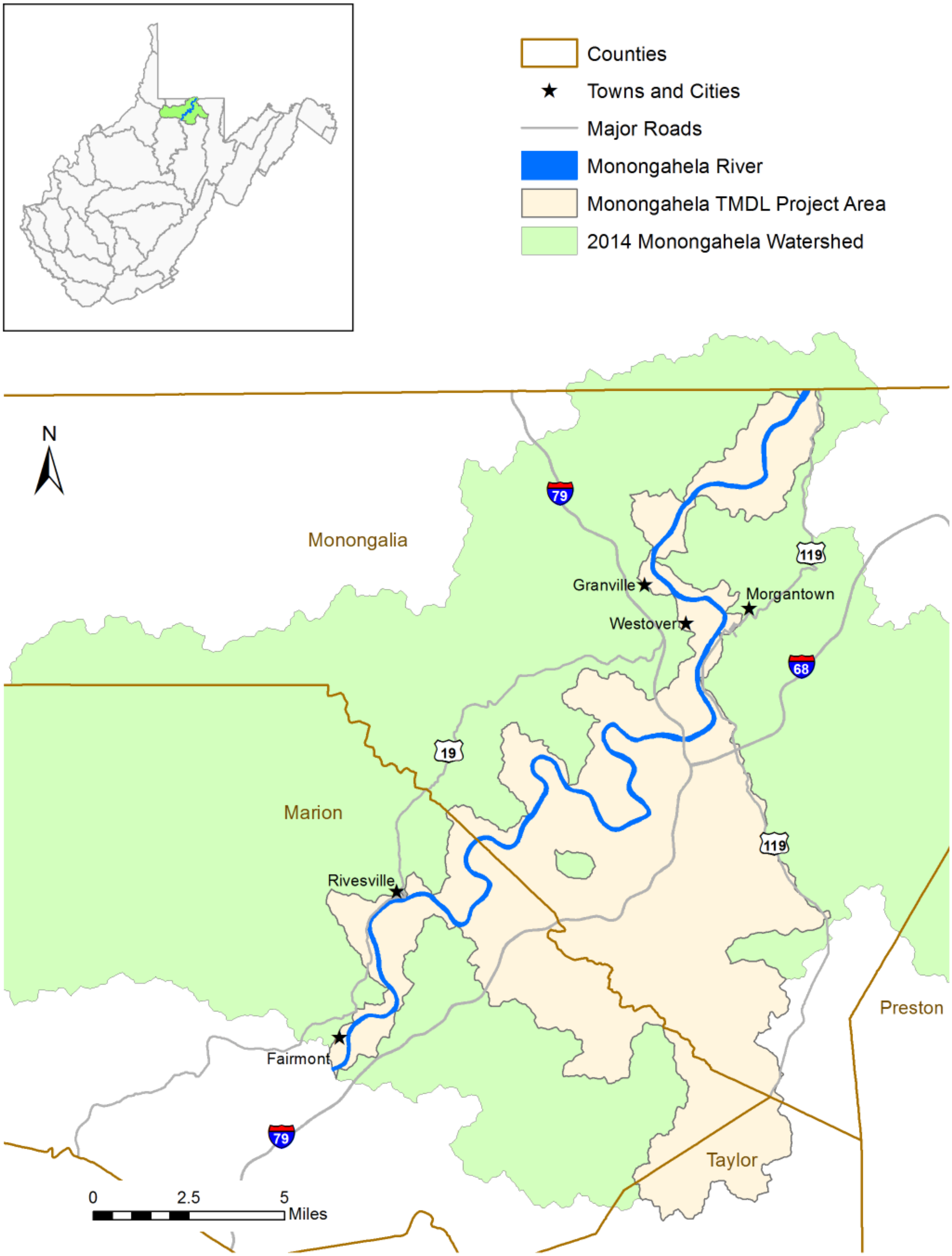


Figure 3-1. Location of the Monongahela River TMDL Project Area in West Virginia

Landuse and land cover estimates were originally obtained from vegetation data gathered from the National Land Cover Dataset (NLCD) (USGS 2011). The Multi-Resolution Land Characteristics Consortium (MRLC) produced the NLCD coverage. The NLCD database for West Virginia was derived from satellite imagery taken during the mid-2000s, and it includes detailed vegetative spatial data. Enhancements and updates to the NLCD coverage were made to create a modeled landuse by custom edits derived primarily from WVDEP source tracking information and 2011 aerial photography with 1-meter resolution. Additional information regarding the NLCD spatial database is provided in Appendix D of the Technical Report.

Table 3-1 displays the landuse distribution for the TMDL Project Area derived from NLCD as described above. The dominant landuse is forest, which constitutes 77.35 percent of the total landuse area. Other important modeled landuse types are urban areas under MS4 permit (5.32 percent), urban areas not under MS4 permit (6.17 percent), grassland (6.30 percent), and agricultural (cropland/pasture, 3.61 percent combined). Individually, all other land cover types compose less than one percent of the total watershed area each.

Table 3-1. Modified landuse for the Monongahela TMDL Project Area

Landuse Type	Area of Watershed		
	Acres	Square Miles	Percentage
Barren	343.05	0.54	0.57
Cropland	665.69	1.04	1.11
Forest	46,224.82	72.23	77.35
Grassland	3,764.19	5.88	6.30
MS4	3,181.06	4.97	5.32
Non-MS4 Urban/Residential	3,687.84	5.76	6.17
Pasture	1,492.15	2.33	2.50
Water	402.01	0.63	0.67
Total	59,760.81	93.38	100.00

3.2 Data Inventory

Various sources of data were used in the TMDL development process. The data were used to identify and characterize sources of pollution and to establish the water quality response to those sources. Review of the data included a preliminary assessment of the watershed's physical and socioeconomic characteristics and current monitoring data. **Table 3-2** identifies the data used to support the TMDL assessment and modeling effort. These data describe the physical conditions of the TMDL watershed, the potential pollutant sources and their contributions, and the impaired waterbody for which a TMDL needs to be developed. Prior to TMDL development, WVDEP collected comprehensive water quality data on the Monongahela River mainstem and several small tributaries. This pre-TMDL monitoring effort contributed the largest amount of water quality data to the process and is summarized in the Technical Report, **Appendix J**. The geographic information is provided in the ArcGIS Viewer Project.

Table 3-2. Datasets used in TMDL development

Type of Information		Data Sources
Watershed physiographic data	Stream network	USGS National Hydrography Dataset (NHD)
	Landuse	National Land Cover Dataset 2011 (NLCD)
	NAIP 2011 Aerial Photography (1-meter resolution)	U.S. Department of Agriculture (USDA)
	Counties	U.S. Census Bureau
	Cities/populated places	U.S. Census Bureau
	Soils	State Soil Geographic Database (STATSGO) USDA, Natural Resources Conservation Service (NRCS) soil surveys
	Hydrologic Unit Code boundaries	U.S. Geological Survey (USGS)
	Topographic and digital elevation models (DEMs)	National Elevation Dataset (NED)
	Dam locations	USGS
	Roads	2011 U.S. Census Bureau TIGER, WVU WV Roads
	Water quality monitoring station locations	WVDEP, USEPA STORET
	Meteorological station locations	National Oceanic and Atmospheric Administration, National Climatic Data Center (NOAA-NCDC)
	Permitted facility information	WVDEP Division of Water and Waste Management (DWWM), WVDEP Division of Mining and Reclamation (DMR)
	Timber harvest data	WV Division of Forestry
	Oil and gas operations coverage	WVDEP Office of Oil and Gas (OOG)
	Abandoned mining coverage	WVDEP DMR
Monitoring data	Historical Flow Record (daily averages)	USGS
	Rainfall	NOAA-NCDC
	Temperature	NOAA-NCDC
	Wind speed	NOAA-NCDC
	Dew point	NOAA-NCDC
	Humidity	NOAA-NCDC
	Cloud cover	NOAA-NCDC
	Water quality monitoring data	USEPA STORET, WVDEP
	National Pollutant Discharge Elimination System (NPDES) data	WVDEP DMR, WVDEP DWWM
	Discharge Monitoring Report data	WVDEP DMR, Mining Companies
	Abandoned mine land data	WVDEP DMR, WVDEP DWWM

Type of Information		Data Sources
Regulatory or policy information	Applicable water quality standards	WVDEP
	Section 303(d) list of impaired waterbodies	WVDEP, USEPA
	Nonpoint Source Management Plans	WVDEP

3.3 Impaired Waterbodies

WVDEP conducted extensive water quality monitoring in the Monongahela River from 2012 through 2013. The results of that effort were used to confirm the fecal coliform impairment identified on the West Virginia 303(d) list.

In 2014 and 2016, TMDLs were developed for impaired waters in watersheds contributing to the Monongahela River (**Figure 3-2**). These watersheds were modeled first, both to address stream impairments within those watersheds, and also to develop inputs necessary for modeling the Monongahela River mainstem. The Monongahela TMDL Project Area includes the Monongahela River mainstem and adjacent land area draining directly to the mainstem without a stream channel identified on the NHD, or to unimpaired streams not modeled under previously developed TMDLs. The Monongahela River, its adjacent land area, and unimpaired tributaries were divided into six project segments to aid in water quality assessment and TMDL implementation. All project segments were impaired for fecal coliform based on pre-TMDL monitoring.

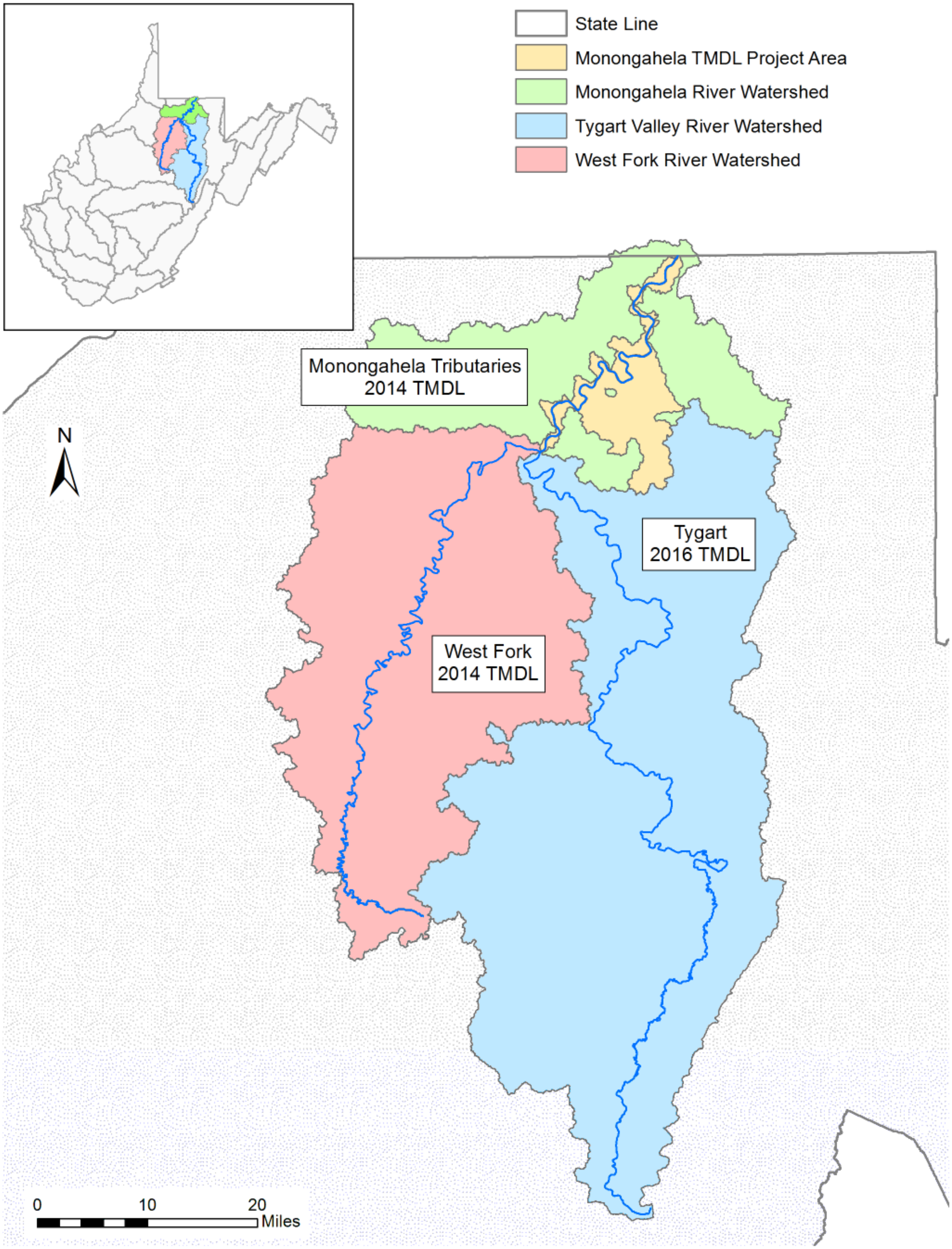


Figure 3-2. Monongahela River and Contributing TMDL Watersheds

4.0 FECAL COLIFORM SOURCE ASSESSMENT

4.1 Fecal Coliform Point Sources

Publicly and privately owned sewage treatment facilities and home aeration units are point sources of fecal coliform bacteria. Combined sewer overflows (CSOs) and discharges from MS4s are additional point sources that may contribute loadings of fecal coliform bacteria to receiving streams. The following sections discuss the specific types of fecal coliform point sources that were identified in the Monongahela River.

4.1.1 Individual NPDES Permits

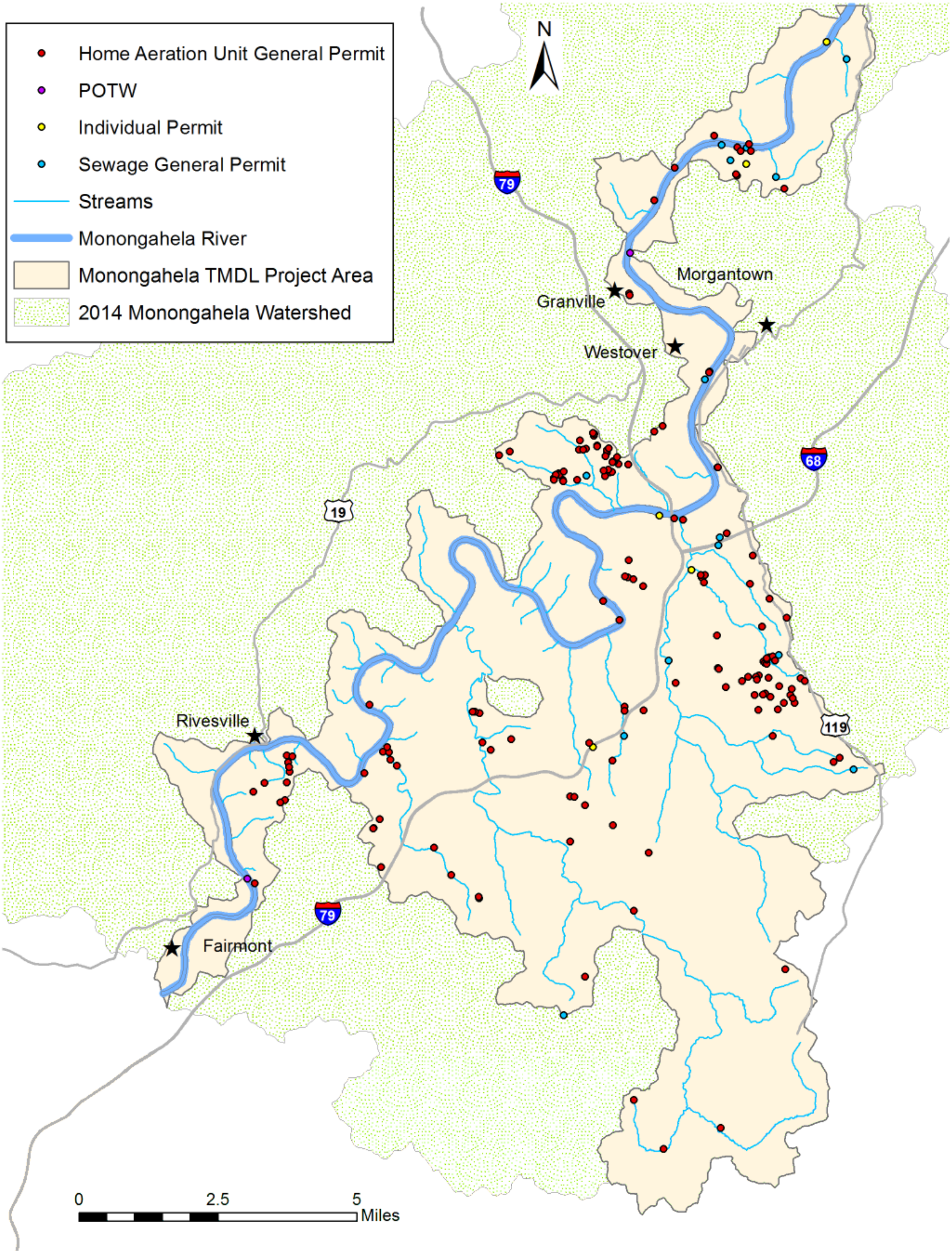
WVDEP issues individual NPDES permits to both publicly owned and privately owned wastewater treatment facilities. Publicly owned treatment works (POTWs) are relatively large sewage treatment facilities with extensive wastewater collection systems, whereas private facilities are usually used in smaller applications such as subdivisions and shopping centers. Additionally, specific discharges from industrial facilities are regulated for fecal coliform bacteria.

In the subject watersheds of this report, there are 2 individually permitted POTWs discharge treated effluent at 2 outlets (Fairmont and Morgantown). There are also 3 permitted stormwater discharges associated with the Fairmont POTW. Five additional individually permitted non-POTW wastewater treatment plants discharge from one outlet each.

These sources are regulated by NPDES permits that require effluent disinfection and compliance with strict fecal coliform effluent limitations (200 counts/100 mL [geometric mean monthly] and 400 counts/100 mL [maximum daily]). Compliant facilities do not cause fecal coliform bacteria impairments because effluent limitations are more stringent than water quality criteria.

4.1.2 General Sewage Permits

General sewage permits are designed to cover like discharges from numerous individual owners and facilities throughout the state. General Permit WV0103110 regulates small, privately owned sewage treatment plants (“package plants”) that have a design flow of 50,000 gallons per day (gpd) or less. General Permit WV0107000 regulates home aeration units (HAUs). HAUs are small sewage treatment plants primarily used by individual residences where site considerations preclude typical septic tank and leach field installation. Both general permits contain fecal coliform effluent limitations identical to those in individual NPDES permits for sewage treatment facilities. In the Monongahela River Project Area, 15 facilities are registered under the “package plant” general permit, and 157 are registered under the HAU general permit. **Figure 4-1** shows the location of NPDES permits.



Note: permits in close proximity may overlap

Figure 4-1. Modeled NPDES permit locations

4.1.3 Overflows

CSOs are outfalls from POTW sewer systems that discharge untreated domestic waste and surface runoff. CSOs are permitted to discharge only during precipitation events. Sanitary sewer overflows (SSOs) are unpermitted overflows that occur as a result of excess inflow and/or infiltration to POTW separate sanitary collection systems. Both types of overflows contain fecal coliform bacteria.

In the subject watersheds, there were a total of 34 CSO outlets associated with POTW collection systems operated by the City of Fairmont (13), Morgantown Utility Board (16), Westover Combined Sewer Collection System (4), and the Greater Paw Paw Sanitary District (1). No significant SSO discharges were represented in the model. CSO locations are shown in **Figure 4-2** below.

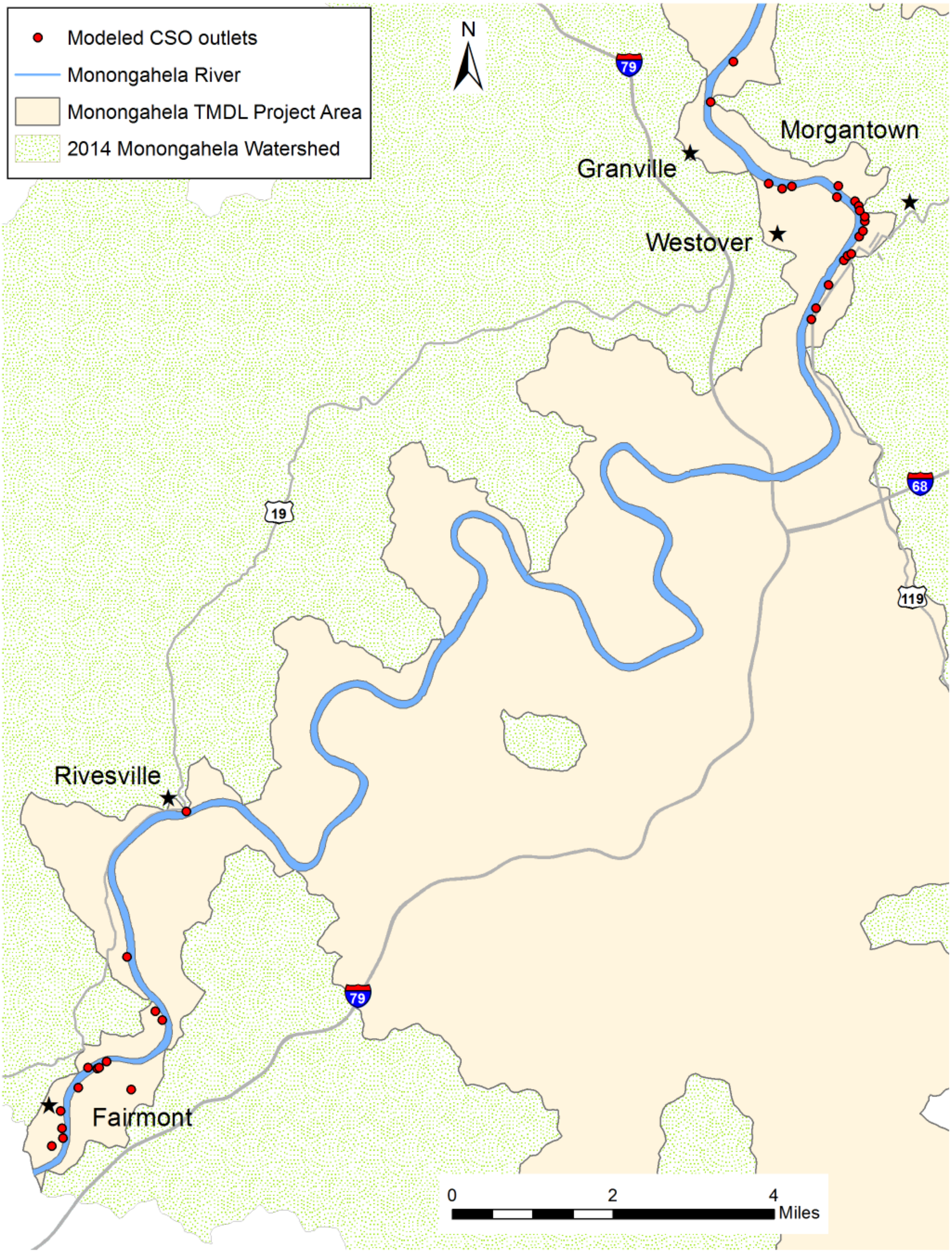


Figure 4-2. Modeled CSO locations

4.1.4 Municipal Separate Storm Sewer Systems (MS4)

Runoff from residential and urbanized areas during storm events can be a significant fecal coliform source. USEPA's stormwater permitting regulations require public entities to obtain NPDES permit coverage for stormwater discharges from MS4s in specified urbanized areas. As such, MS4 stormwater discharges are considered point sources and are prescribed WLAs.

The MS4 entities are registered under the MS4 General Permit (WV0116025). Individual registration numbers for the MS4 entities are City of Fairmont (WVR030038), Town of Star City (WVR030023), City of Westover (WVR030022), Morgantown Utility Board (WVR030030), West Virginia University (WVR030042), and the West Virginia Division of Highways (WVDOH) (WVR030004). MS4 entities and their areas of responsibility are displayed in **Figure 4-3**.

MS4 source representation is based upon precipitation and runoff from landuses determined from the modified NLCD 2011 landuse data, the jurisdictional boundary of the cities, and the transportation-related drainage areas for which WVDOH has MS4 responsibility. In certain areas, urban/residential stormwater runoff may drain to both CSO and MS4 systems. WVDEP consulted with local governments and obtained information to determine drainage areas to the respective systems and best represent MS4 pollutant loadings.

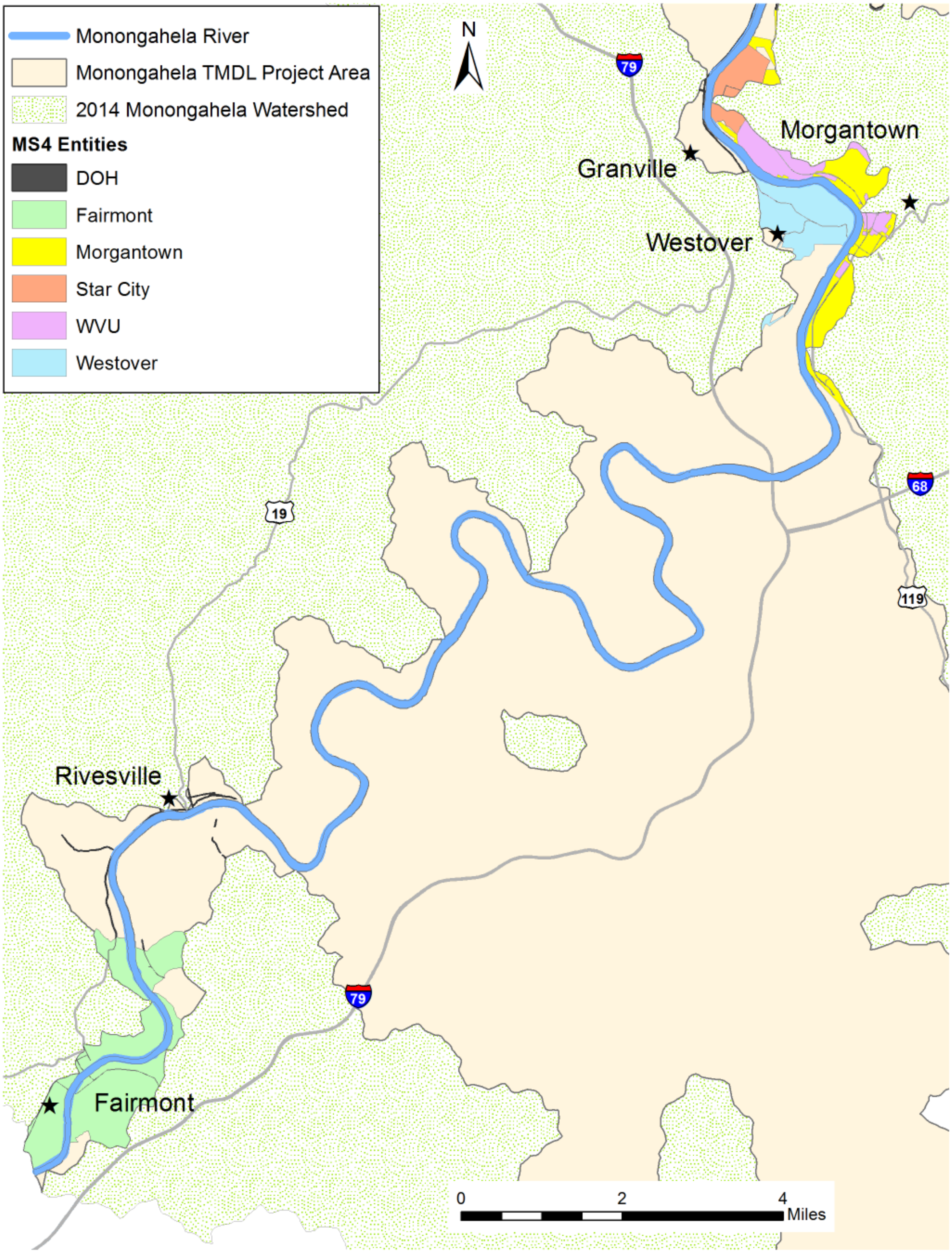


Figure 4-3. MS4 Communities in Monongahela TMDL Project Area

4.2 Fecal Coliform Nonpoint Sources

4.2.1 On-site Treatment Systems

Failing septic systems and straight pipes are significant nonpoint sources of fecal coliform bacteria. Information collected during source tracking efforts by WVDEP yielded an estimate of 200 homes that are not served by centralized sewage collection and treatment systems and are within 100 meters of a stream. Homes located more than 100 meters from a stream were not considered significant potential sources of fecal coliform because of the natural attenuation of fecal coliform concentrations that occurs because of bacterial die-off during overland travel (Walsh and Kunapo, 2009). Estimated septic system failure rates across the watershed range from 7 percent to 10 percent.

Due to a wide range of available literature values relating to the bacteria loading associated with failing septic systems, a customized Microsoft Excel spreadsheet tool was created to represent the fecal coliform bacteria contribution from failing on-site septic systems. WVDEP's pre-TMDL monitoring and source tracking data were used in the calculations. To calculate loads, values for both wastewater flow and fecal coliform concentration are needed.

To calculate failing septic wastewater flows, TMDL Project Area watersheds were assigned one of four possible septic failure zones. During the WVDEP source tracking process, septic failure zones were delineated by soil characteristics (soil permeability, depth to bedrock, depth to groundwater and drainage capacity) as shown in United States Department of Agriculture (USDA) county soil survey maps. Two types of failure were considered, complete failure and periodic failure. For the purposes of this analysis, complete failure was defined as 50 gallons per house per day of untreated sewage escaping a septic system as overland flow to receiving waters and periodic failure was defined as 25 gallons per house per day. **Figure 4-4** shows the fecal coliform counts per year represented in the model from failing septic systems relative to the total acreage for each subwatershed.

Once failing septic flows were modeled, a fecal coliform concentration was determined at the TMDL watershed scale. Based on past experience with other West Virginia TMDLs, a base concentration of 10,000 counts per 100 ml was used as a beginning concentration for failing septic systems. This concentration was further refined during model calibration. A sensitivity analysis was performed by varying the modeled failing septic concentrations in multiple model runs, and then comparing model output to pre-TMDL monitoring data. Additional details of the failing septic analyses are elucidated in the Technical Report.

For the purposes of this TMDL, discharges from activities that do not have an associated NPDES permit, such as failing septic systems and straight pipes, are considered nonpoint sources. The decision to assign LAs to those sources does not reflect a determination by WVDEP or USEPA as to whether they are, in fact, non-permitted point source discharges. Likewise, by establishing a TMDL with failing septic systems and straight pipes treated as nonpoint sources, WVDEP and USEPA are not determining that such discharges are exempt from NPDES permitting requirements.

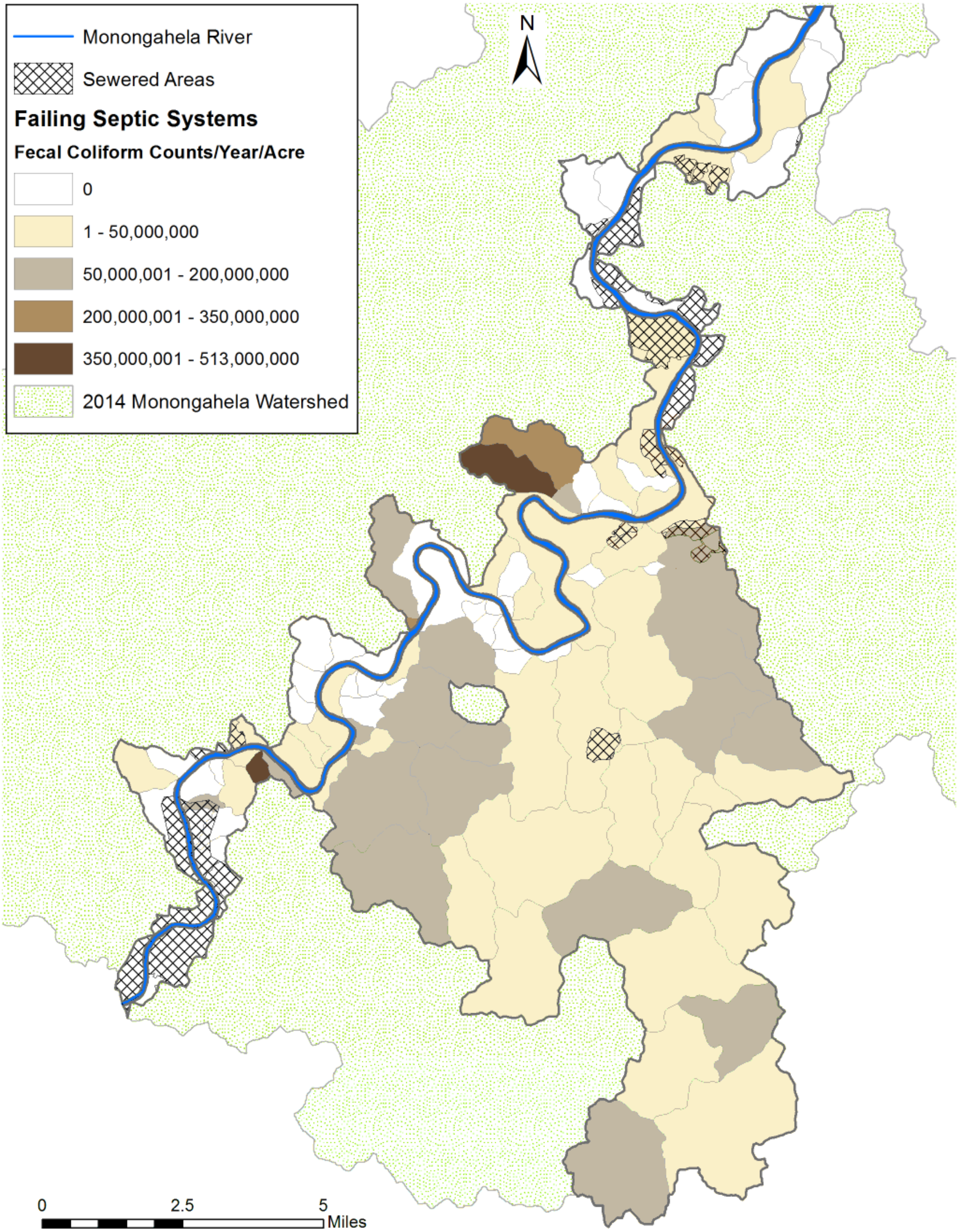


Figure 4-4. Fecal coliform counts attributed to failing septic systems per year relative to the acreage of each subwatershed in the Monongahela River as represented in modeling.

Some streams in the Project Area were not identified as being impaired for fecal coliform despite having comparatively high bacterial loading from failing onsite septic systems. One example is Brand Run (WV-MU-20). Brand Run did not have a fecal coliform TMDL developed in 2014 because pre-TMDL monitoring results did not indicate bacterial impairment. However, bacterial activity may have been suppressed by the toxicity of dissolved aluminum concentrations as high as 9.75 mg/l, and total iron concentrations as high as 12.8 mg/l.

4.2.2 Urban/Residential Runoff

Stormwater runoff from residential and urbanized areas that are not subject to MS4 permitting requirements can be a significant source of fecal coliform bacteria. These landuses are considered to be nonpoint sources and load allocations are prescribed. The modified NLCD 2011 landuse data were used to determine the extent of residential and urban areas not subject to MS4 permitting requirements and source representation was based upon precipitation and runoff.

4.2.3 Agriculture

Agricultural activities can contribute fecal coliform bacteria to receiving streams through surface runoff or direct deposition. Grazing livestock and land application of manure result in the deposition and accumulation of bacteria on land surfaces. These bacteria are then available for wash-off and transport during rain events. In addition, livestock with unrestricted access can deposit feces directly into streams.

Although agricultural activity accounts for a small percentage of the overall watershed, agriculture is a significant localized nonpoint source of fecal coliform bacteria. Source tracking efforts identified pastures and feedlots near impaired segments that have localized impacts on instream bacteria levels. Source representation was based upon precipitation and runoff, and source tracking information regarding number of livestock, proximity and access to stream, and overall runoff potential were used to develop accumulation rates.

4.2.4 Natural Background (Wildlife)

A certain “natural background” contribution of fecal coliform bacteria can be attributed to deposition by wildlife in forested areas. Accumulation rates for fecal coliform bacteria in forested areas were developed using reference numbers from past TMDLs, incorporating wildlife estimates obtained from West Virginia’s Division of Natural Resources (WVDNR). In addition, WVDEP conducted storm-sampling on a 100 percent forested subwatershed (Shrewsbury Hollow) within the Kanawha State Forest, Kanawha County, West Virginia to determine wildlife contributions of fecal coliform. These results were used during the model calibration process. On the basis of the low fecal accumulation rates for forested areas, the storm water sampling results, and model simulations, wildlife is not considered to be a significant nonpoint source of fecal coliform bacteria in the watershed.

5.0 WATERSHED MODELING

Establishing the relationship between the instream water quality targets and source loadings is a critical component of TMDL development. It allows for the 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. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses with flow and loading conditions. This section presents the approach taken to develop the linkage between sources and instream response for TMDL development in the Monongahela River.

5.1 Model Selection

Selection of the appropriate analytical technique for TMDL development was based on an evaluation of technical and regulatory criteria. The following key technical factors were considered in the selection process:

- Scale of analysis
- Point and nonpoint sources
- Fecal coliform bacteria impairments are temporally variable and occur at low, average, and high flow conditions
- Time-variable aspects of land practices have a large effect on instream pollutant concentrations
- Pollutant transport mechanisms are variable and often weather-dependent

The primary regulatory factor that influenced the selection process was West Virginia's water quality criteria. According to 40 CFR Part 130, TMDLs must be designed to implement applicable water quality standards. The applicable water quality criteria for fecal coliform bacteria in West Virginia and Pennsylvania are presented in **Section 2.2**, **Table 2-1**. West Virginia numeric water quality criteria are applicable at all stream flows greater than the 7-day, 10-year low flow (7Q10). The approach or modeling technique must permit representation of instream concentrations under a variety of flow conditions to evaluate critical flow periods for comparison with criteria.

The TMDL development approach must also consider the dominant processes affecting pollutant loadings and instream fate. In the Monongahela River, an array of point and nonpoint sources contributes to the various impairments. Most nonpoint sources are rainfall-driven with pollutant loadings primarily related to surface runoff, but some, such as inadequate onsite residential sewage treatment systems, function as continuous discharges. Similarly, certain point sources are precipitation-induced while others are continuous discharges. While loading function variations must be recognized in the representation of the various sources, the TMDL allocation process must prescribe WLAs for all contributing point sources and LAs for all contributing nonpoint sources.

The MDAS was developed specifically for TMDL application in West Virginia to facilitate large scale, data intensive watershed modeling applications. The MDAS is a system designed to support TMDL development for areas affected by nonpoint and point sources. The MDAS component most critical to TMDL development is the dynamic watershed model because it provides the linkage between source contributions and instream response. The MDAS is used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and instream water quality. It is capable of simulating different flow regimes and pollutant loading variations. A key advantage of the MDAS' development framework is that it has no inherent limitations in terms of modeling size or upper limit of model operations. In addition, the MDAS model allows for seamless integration with modern-day, widely available software such as Microsoft Access and Excel. Fecal coliform bacteria coming from sources in watersheds and tributaries draining to the Monongahela River were modeled using the MDAS. These MDAS watershed model outputs were in turn used as inputs to the Monongahela River EFDC receiving water model to simulate instream water quality dynamics.

5.2 Model Setup

5.2.1 General MDAS Configuration

Configuration of the MDAS model involved subdividing the TMDL watershed into subwatershed modeling units connected by stream reaches. Physical characteristics of the subwatersheds, weather data, landuse information, continuous discharges, and stream data were used as input. Flow and water quality were continuously simulated on an hourly time-step.

Two grid-based weather data products were used to develop MDAS model weather input files for TMDL modeling. The Parameter-Elevation Regressions on Independent Slopes Model (PRISM) and the North American Land Data Assimilation System (NLDAS-2) are both publicly available weather datasets. PRISM data features daily weather on 4 km grid spatial scale, and NLDAS-2 data has hourly weather on a 12 km grid scale. Both datasets combine rain gauge data with radar observations to predict hourly weather parameters such as precipitation, solar radiation, wind, and humidity. For more information on PRISM and NLDAS-2, refer to **Section 2.2.2** of the Technical Report.

PRISM daily weather data and NLDAS-2 hourly precipitation data were obtained and processed to create a time series for each 4 km x 4 km grid cell that intersected modeled TMDL watersheds. Using the precipitation and temperature time series, a model weather input file was developed for each PRISM grid cell. Given that slight variability was observed between the grid cells at the12-digit Hydrologic Unit Code (HUC) scale and in order to allow more feasibility when executing the models, one centrally located weather input file per HUC was identified as representative of the weather in the area. Model subwatersheds falling within each 12-digit HUC were then assigned the appropriate weather input file for hydrologic modeling purposes.

The portion of the Monongahela Watershed in West Virginia for which TMDLs had not been previously developed was broken into 116 separate subwatershed units as shown in **Figure 5-1**. Some of these subwatersheds contained streams draining directly to the Monongahela River mainstem. Modeled flows from these streams were added to the receiving stream model as a time series with variable flow and fecal coliform concentration. Other subwatersheds adjacent to the Monongahela River mainstem did not contain a stream channel according to NHD Reach stream data. Precipitation runoff from these subwatersheds was calculated as surface runoff and added to the receiving stream model.

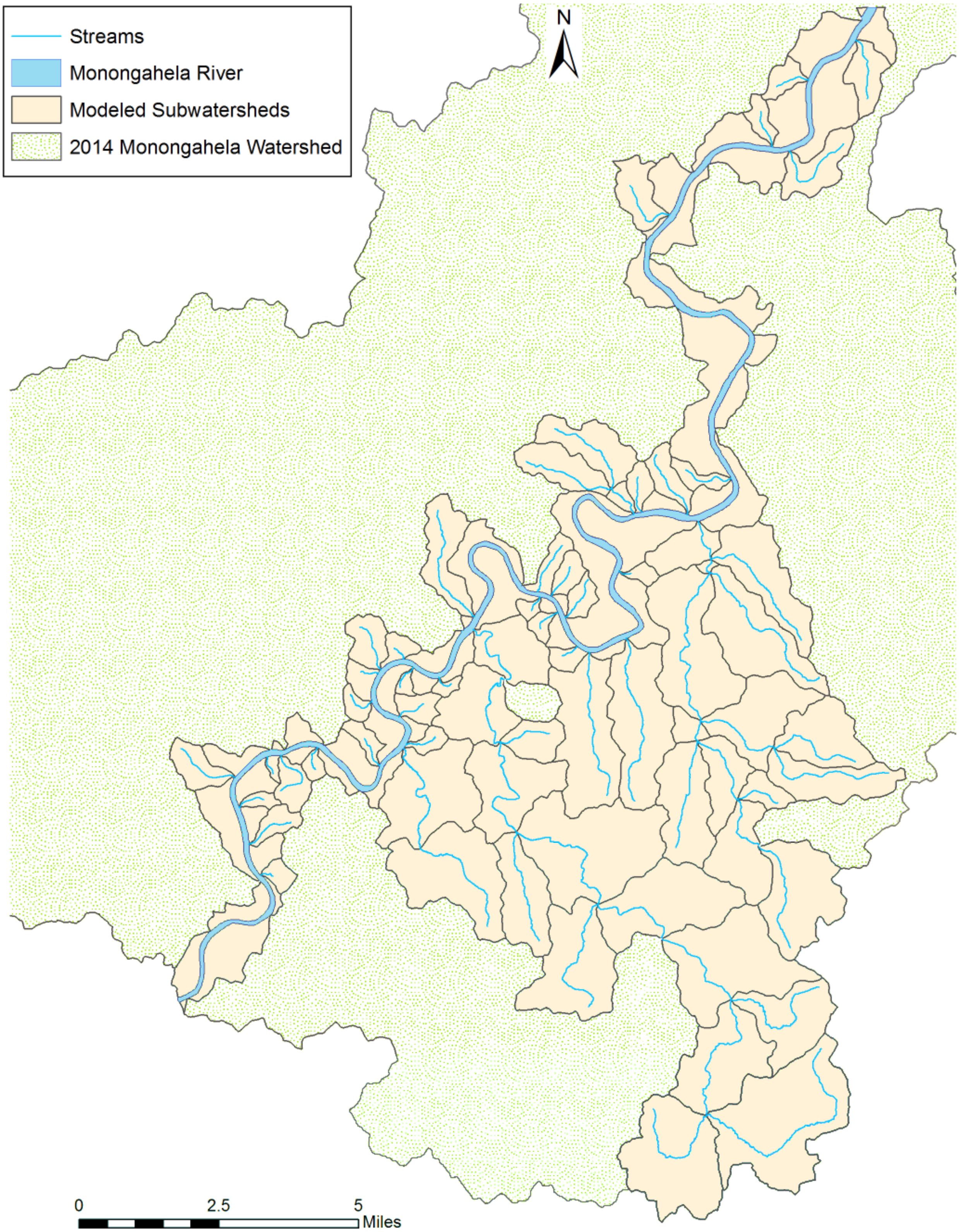


Figure 5-1. Modeled Subwatersheds

5.2.2 Fecal Coliform Configuration

Modeled landuse categories contributing bacteria via precipitation and runoff include pasture, cropland, urban/residential pervious lands, urban/residential impervious lands, grassland, forest, barren land, and wetlands. Other sources, such as failing septic systems, straight pipes, and discharges from sewage treatment facilities, were modeled as direct, continuous-flow sources in the model.

The basis for the initial bacteria loading rates for landuses and direct sources is described in the Technical Report. The initial estimates were further refined during the model calibration. A variety of modeling tools were used to develop the fecal coliform bacteria TMDL, including the MDAS, and a customized spreadsheet to determine the fecal loading from failing residential septic systems identified during source tracking efforts by the WVDEP. **Section 3.1.4** of the Technical Report describes the process of assigning flow and fecal coliform concentrations to failing septic systems.

5.3 Model Parameterization

Hydrology and water quality parameters were assigned to the model using a reference approach. Streams in the adjacent watershed were too small to have USGS gages that could have been used to inform hydrologic calibration. Available pre-TMDL water quality monitoring focused on the Monongahela River mainstem, and water sampling data from unimpaired streams in the Project Area was too limited in quantity to be used for meaningful comparisons of loading rates in modeled landuses. Instead, the Project Area adjacent to the Monongahela River was expected to have characteristics similar to watersheds modeled under the 2014 Monongahela Tributaries TMDL (Group D2) effort in neighboring streams. Hydrologic and water quality parameters from the MDAS model developed for the Monongahela Tributaries TMDL were applied to landuses in the unimpaired 116 subwatersheds directly draining to the Monongahela River mainstem.

6.0 RECEIVING WATER MODELING

6.1 Model Selection

Multiple computer models have been developed to simulate water quality in large rivers. To select the most suitable model for fecal coliform water quality simulation in the Monongahela River, the following factors were considered:

- A model from public domain
- Two or three dimensional simulation capability
- A model with integrated hydrodynamics and water quality modeling capability

A number of public domain water quality models are available that contain the basic framework for river model development such as WASP, CE-QUAL-W2, or the latest version of HEC-RAS. Among these models, only EFDC is able to simulate three dimensional hydrodynamics and water quality, and it is an integrated model which does not require external linkage between hydrodynamics and water quality.

The EFDC model is a public domain hydrodynamic and water quality modeling system developed by Tetra Tech. Tetra Tech continues to maintain and enhance the model with primary external support from USEPA. The EFDC is readily available to the general public at http://www.epa.gov/ceampubl/swater/efdc/index.htm. EFDC is unique among current surface water modeling systems in that it incorporates hydrodynamics, salinity, temperature, sediment, toxic contaminant, and eutrophication simulation capabilities in a single internally linked framework. EFDC incorporates sediment and adsorptive toxic contaminate fate and transport formulations. Its eutrophication module is based on CE-QUAL-ICM and is capable of representing primary production and nutrient cycling at multiple levels.

The EFDC model also includes a wide range of simulation capabilities for incorporating flow control and navigational structures including culverts, pressure conduits, spillways, weirs, dams and pumping operations as well as time-dependent barriers appropriate for representing lock operations. The operation of the various flow linkages and controls can be specified in a time varying manner or their operation can be controlled by simulation variables such as water surface elevation. The EFDC modeling system also includes a variety of pre- and post-processing, and decision support tools that will greatly improve linkage capabilities.

6.1 Model Setup

6.1.1 Grid Generation

An EFDC model framework was developed for the Monongahela River, from the confluence of the Tygart Valley River and West Fork River to the West Virginia/Pennsylvania State line. An additional segment was added to the grid to extend the domain to the USGS gage at the Point Marion Lock and Dam at RM 90.8.

Several foundational datasets were used to develop a computational grid framework for the EFDC model. Horizontal dimensions and extent of the model domain was matched to river boundaries derived from aerial photos interpreted with GIS techniques, while the vertical extent of the water column was derived from 1990 bathymetry data available from the U.S. Army Corps of Engineers as GIS data. These datasets are described below.

The river boundary was then segmented laterally into a grid of 3 lateral cells, and longitudinally into segments of variable length. The longitudinal cell dimensions were varied based on the density of sources, such as POTWs, CSOs, and MS4s in urbanized areas. Longitudinal lengths vary between 45 m and 150 m, and transition smoothly between resolution areas. The finer resolution grid cells (i.e., 45 m) were developed in the areas with the most dense pollutant sources (e.g., permit outlets, urban stormwater runoff, residences), allowing the model to more accurately identify the relative contributions from the sources. Lateral lengths vary with the width of the river. There were four navigational lock and dam structures on the modeled portion of the Monongahela River. The Opekiska, Hildebrand, Morgantown, and Point Marion locks and dams created four pools on the Monongahela River. The EFDC grid cell boundaries were adjusted to break where dams crossed the river channel.

The 1990 West Virginia Monongahela River bathymetry dataset was of sufficient resolution to calculate average elevations for each the EFDC cells. Some cells did not contain a bathymetry observation. In the case of cells missing bathymetry data, linear interpolation was used to fill the data gaps. One vertical layer was used in this model.

6.1.2 Weather Data

Weather conditions directly impact the hydrodynamics and water temperature in the river. Weather stations were explored from various sources including NOAA weather service to identify the stations nearby the river. The EFDC model requires air pressure, air temperature, dew point temperature or relative humidity, rainfall, evaporation, solar radiation, cloud cover and wind. Hourly weather data from October 2013 to September 2016 were downloaded and used in creation of the meteorological input files for the EFDC model. PRISM daily weather data and NLDAS-2 hourly precipitation data were obtained and processed to create a precipitation time series. Weather data development methodologies were very similar to those described in **Section 5.2.1.** Surface airways data were available from NOAA's Local Climatological Network. The closest hourly surface airways station in the Monongahela watershed was the Morgantown Hart Field Airport (WBAN 13736).

The parameters used from the data available from each station were atmospheric pressure, air temperature, relative humidity, wind speed, wind direction and sky condition description. An evaluation of data gaps using associated missing data flags indicated that there were approximately less than 1 percent data that were missing. The missing data typically spanned a few hours. Any missing data was filled in using data from the previous hour. The atmospheric pressure, air temperature, relative humidity, precipitation, wind speed and wind direction were directly incorporated into the meteorological files after applying appropriate unit conversions. The evaporation effects were assumed to be negligible due to the relatively small surface area and was assumed to be zero. The solar radiation time series was derived from the sky condition description of cloud cover. See the Technical Report for more information on weather data and filling data gaps.

6.1.3 Watershed Contributions

Flow and pollutant loads were linked to discrete EFDC grid cells to represent spatial variation in sources. Sources of pollutant loading include MDAS model results, CSO overflow estimates, permitted facilities contributing at their permit limits, and estimated septic system contributions. MDAS model results for both tributary and diffuse sources were used. A total of 200 flow time series, 3 temperature time series, and 111 fecal coliform time series were developed based on the available data. The conversion of each source to EFDC input format is described in the following subsections.

Flow and pollutant loads from the MDAS watershed model were linked to the EFDC grid by associating loads from tributaries and diffuse flow (surface runoff from adjacent subwatersheds without a stream channel identified in the NHD) to spatially appropriate grid cells. Components of MDAS output including tributary flow, diffuse flow, fecal coliform concentration, and temperature were converted to EFDC inputs.

A total of 59 tributary time series and 50 diffuse flow time series were converted to EFDC format. Tributaries were as follows: West Fork River (1), Tygart Valley River (1), Monongahela River direct drains modeled under the 2014 TMDL effort that received a fecal coliform TMDL (19), Monongahela River direct drains modeled under the 2014 TMDL effort that did not receive a fecal coliform TMDL (9), and Monongahela direct drains modeled for the 2018 TMDL effort (29). Diffuse flows were derived from surface runoff calculated from subwatersheds without a stream channel identified in the NHD (50). Each tributary and diffuse source was assigned a discrete time series for flow and fecal coliform. MDAS temperature results for the West Fork and Tygart tributaries were applied as individual time series at those locations. A single time series for temperature was applied to the remaining tributary and diffuse sources based on the average daily temperatures from all MDAS subwatersheds.

6.1.4 Failing Septic Systems

Flow and pollutant loads from modeled failing septic sources were linked to the EFDC grid by associating loads to specific grid cells. A total of 19 failing septic source locations were converted to EFDC format. These 19 failing septic sources were in diffuse flow subwatersheds lacking a tributary stream, where it was necessary to route failing septic loads directly to the Monongahela River. Septic sources in subwatersheds with a direct drain tributary had their failing septic loads assumed into the tributary time series load. Not every subwatershed was modeled with a failing septic source. Some subwatersheds served by sanitary sewer were not modeled with a failing septic source. Each septic source was assigned a discrete constant flow and fecal coliform concentration. A single time series for temperature was applied to all outfalls based on the average daily temperatures from all subwatersheds. All outfalls were assigned a constant fecal coliform concentration of 10,000 counts/100mL.

6.1.5 Combined Sewer Overflows

Flow and pollutant loads from CSOs were linked to the EFDC grid by associating loads to specific grid cells. The following components were converted to EFDC input format. Thirty-three CSO outlets were converted to EFDC format. Each CSO was assigned an individual flow based on estimates of drainage area and timing developed from information provided by municipal dischargers. Flow volumes for 32 CSOs were derived from MDAS modeled estimates of precipitation runoff draining to combined sewer systems during rain events. One CSO was modeled using daily flows made available by the discharger. A single time series for temperature was applied to all outfalls based on the average daily temperatures from all subwatersheds, and all outfalls were assigned a constant fecal coliform concentration of 100,000 counts/100mL.

6.1.6 NPDES Permitted Point Sources

Flow and pollutant loads from the permitted facilities were linked to the EFDC grid by associating loads to specific grid cells. Permitted flows and fecal coliform concentrations from 40 outfalls were converted to EFDC input format. Each outfall was assigned a discrete constant flow. A single time series for temperature was applied to all outfalls based on the average daily temperatures from all subwatersheds and a constant fecal coliform concentration of 200 colonies/100mL.

6.2 Model Calibration

6.2.1 Hydrology and Water Temperature Calibration

Model calibration consisted of the process of adjusting model parameters within expected ranges to provide a match to observed conditions. The EFDC hydrodynamic model was calibrated for flow and temperature using graphical comparisons of model predicted flows and water temperature to available monitoring data for a three year period from October 1, 2013 to September 30, 2016. Observed flow data from USGS 03062235 Monongahela River at Flaggy Meadow, WV was used for hydrology calibration. Water temperature was calibrated by comparing model output to water temperature observations collected in the field by WVDEP during pre-TMDL water quality monitoring.

Adjustable parameters and forcing functions for the hydrodynamic model include bottom roughness, and also solar radiation reaching the water surface. Solar radiation can be highly variable as it is a function of multiple factors such as topographic shading, shading from tree canopy, and hourly cloud conditions.

6.2.2 Water Quality Calibration

After hydrodynamics and water temperature calibration was complete, the model was calibrated for fecal coliform bacterial concentration. Fecal coliform bacteria are modeled with two processes, transport and die-off. Transport of fecal bacteria through the model is determined by the flow which is a function of model hydrodynamics. Die-off is the other mechanism that determines fecal coliform concentrations over time as they decrease in the water column. The die-off rate is adjusted iteratively during calibration so that modeled fecal coliform concentrations match pre-TMDL monitoring observations as closely as possible. Recently collected pre-TMDL monitoring data were available for the time period July 2014 to June 2105.

The Monongahela EFDC model simulated water quality in the Monongahela mainstem for a three year period from October 1, 2013 to September 30, 2016. This three year period provides results for both calibration within the 2014-2015 time period when pre-TMDL monitoring data were collected, as well as with additional two years of run time to provide model validation over variable weather conditions.

Similar to the calibration of water temperature, the fecal bacteria calibration was based on visual inspection of graphical comparisons between model predictions and pre-TMDL monitoring observations. Goodness-of-fit statistics were not calculated because of the insufficient amount of observed data. During the calibration of fecal coliform, the die-off rate was adjusted iteratively after the visual inspection of the model results. The final die-off rate was set to 0.5 per day at 20^{o}C with a temperature adjustment coefficient at 1.08. It should be noted that modeled fecal coliform concentrations were primarily dependent on proximity to modeled sources. Four major sources contributed the majority of fecal coliform bacteria to the model: upstream tributaries, failing septics, CSOs, and other permitted point sources. Fecal bacteria loading levels from upstream tributaries were determined by MDAS model outputs under baseline and allocated conditions for previously developed TMDLs. For failing septics, CSOs, and other permitted point sources, estimates and assumptions concerning constant values for flow or concentration might have contributed to the model error as fecal bacteria from these sources more than likely have significant variability. A graphic representation of fecal coliform concentrations in the Monongahela River while receiving CSO discharges is show in **Figure 6-2.**

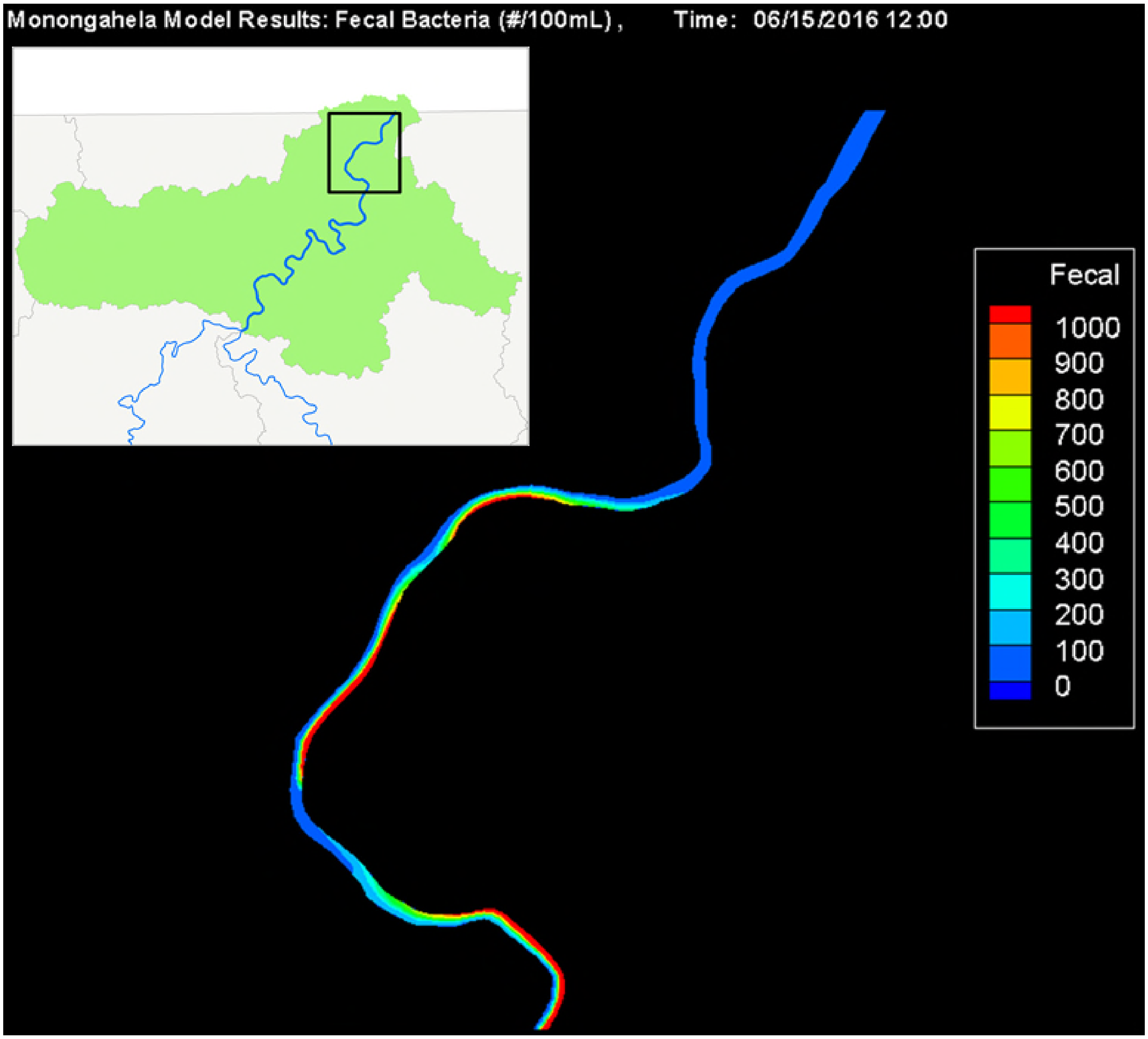


Figure 6-1. Spatial distribution of fecal coliform bacteria in the lower portion of the model domain during CSO discharge event

Throughout water quality calibration, fecal coliform model output correlated closely with pre-TMDL monitoring observations in terms of spatial trends and magnitudes. The model results showed that the fecal coliform loading from the West Fork and Tygart Valley River strongly impact the fecal concentration in the upper portion in the model domain. The bacteria levels gradually decrease as the Monongahela River flows north toward Morgantown. Below Morgantown, fecal coliform concentrations again increase due to CSO contributions and inputs from urban streams with significant fecal coliform loads.

7.0 TMDL AND SOURCE ALLOCATIONS

7.1 Allocation Strategy

As explained in **Section 2**, a TMDL is composed of the sum of individual WLAs for point sources, LAs for nonpoint sources, and natural background levels. In addition, the TMDL must include a MOS, implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. TMDLs can be expressed in terms of mass per time or other appropriate units. Conceptually, this definition is denoted by the equation:

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

To develop the TMDL for the fecal coliform impairment in the Monongahela River, the following approach was taken:

- Define TMDL endpoints
- Simulate baseline conditions
- Assess source loading alternatives
- Determine the TMDL and source allocations

7.1.1 TMDL Endpoints

TMDL endpoints represent the water quality targets used to quantify TMDLs and their individual components. In general, the West Virginia and Pennsylvania numeric water quality criteria for the subject pollutants and an explicit five percent MOS were used to identify endpoints for TMDL development. The TMDL endpoints for fecal coliform criteria are displayed in **Table 7-1**.

The five percent explicit MOS was used to counter uncertainty in the modeling process. Long-term water quality monitoring data were used for model calibration. Although these data represented actual conditions, they were not of a continuous time series and might not have captured the full range of instream conditions that occurred during the simulation period.

Table 7-1. TMDL endpoints

Water Quality Criterion	Designated Use	Criterion Value	TMDL Endpoint
Fecal Coliform	Water Contact Recreation and Public Water Supply	200 counts / 100 mL(Monthly Geometric Mean)	190 counts / 100 mL (Monthly Geometric Mean)
Fecal Coliform	Water Contact Recreation and Public Water Supply	400 counts / 100 mL (Daily, 10% exceedance)	380 counts / 100 mL (Daily, 10% exceedance)

The TMDL is presented as an average daily load that was developed to meet TMDL endpoints under a range of conditions observed throughout the year. For most pollutants, analysis of available data indicated that critical conditions occur during both high- and low-flow events. To appropriately address the low- and high-flow critical conditions, the TMDL was developed using continuous simulation (modeling over a period of several years that captured precipitation extremes), which inherently considers seasonal hydrologic and source loading variability.

7.1.2 Baseline Conditions and Source Loading Alternatives

The calibrated model provides the basis for performing the allocation analysis. The first step is to simulate baseline conditions, with existing nonpoint source loadings at calibrated conditions and point source loadings at permit limits. Baseline conditions allow for an evaluation of instream water quality under the highest expected loading conditions.

Baseline Conditions for MDAS

The MDAS model was run for baseline conditions using hourly precipitation data for a representative three year simulation period (January 1, 2014 through December 31, 2016). The precipitation experienced over this period was applied to the landuses and pollutant sources as they existed at the time of TMDL development. Predicted instream concentrations were compared directly with the TMDL endpoints. This comparison allowed for the evaluation of the magnitude and frequency of exceedances under a range of hydrologic and environmental conditions, including dry periods, wet periods, and average periods. **Figure 7-1** presents the annual rainfall totals for the years 2006 through 2016 at the Morgantown Hart Field (WBAN 13736) weather station in West Virginia. The years 2014 to 2016 are highlighted to indicate the range of precipitation conditions used for TMDL development in the Monongahela River.

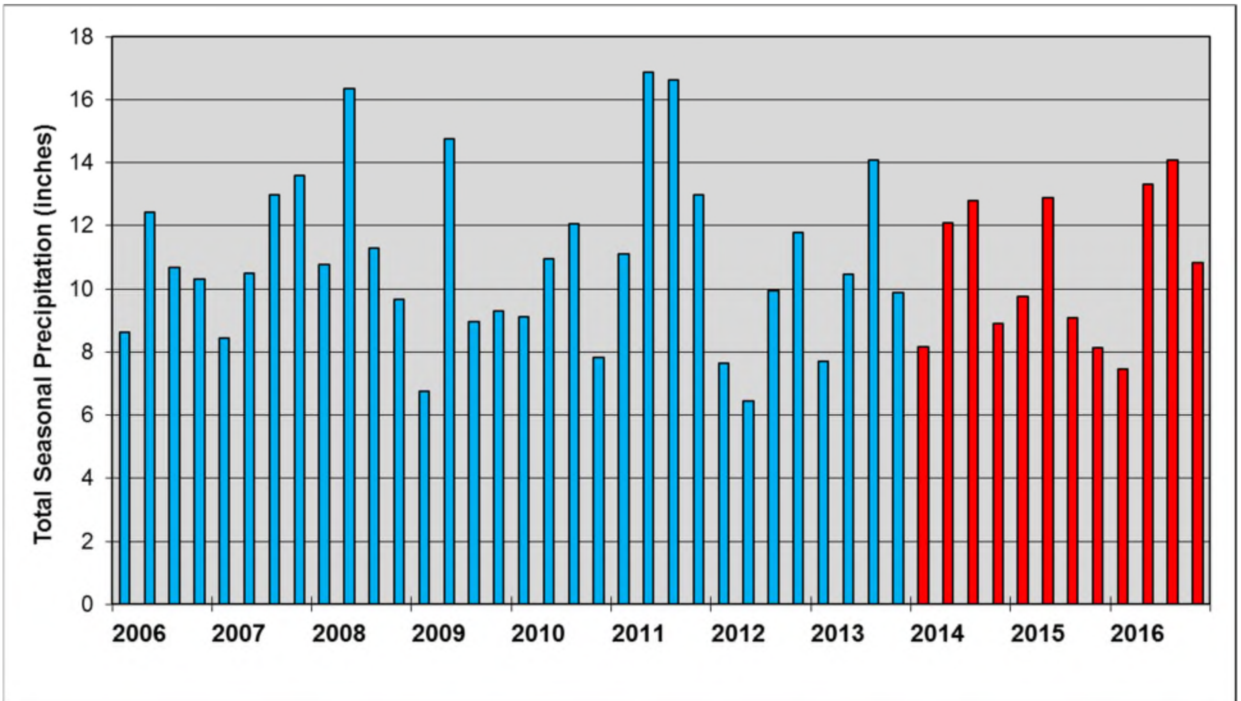


Figure 7-1. Seasonal precipitation totals for the Morgantown Hart Field (WBAN 13736) weather station

Effluents from sewage treatment plants were represented under baseline conditions as continuous discharges, using the design flow for each facility and the monthly geometric mean fecal coliform effluent limitation of 200 counts/100 mL. Baseline characteristics for non-stormwater industrial wastewater sources were obtained from effluent limitations and other permitting information.

CSO outlets were represented as discreet point sources in the model. CSO flow and discharge frequency was derived from overflow data supplied by the POTWs, when available. This information was augmented with precipitation analysis and watershed modeling to develop model inputs needed to build fecal coliform loading values for a ten-year time series from which annual average fecal coliform loading values could be calculated. CSO effluent was represented in the model at a concentration of 100,000 counts/100 mL to reflect baseline conditions for untreated CSO discharges. MS4, nonpoint source and background loadings for fecal coliform were represented using drainage area, precipitation, and pollutant accumulation and wash off rates, as appropriate for each landuse.

Baseline Conditions for EFDC

The EFDC receiving water model was developed to examine the cumulative effect of all contributing sources of fecal coliform under baseline conditions. By simulating hydrology, temperature, and bacterial concentrations for the entire river on an hourly basis, the EFDC model was used to determine whether source reductions made under TMDL allocation conditions allowed the Monongahela River to meet state water quality standards. Except for sources such as CSOs discharging directly to the mainstem, baseline and allocated conditions explored in EFDC are a direct product of outputs from MDAS models developed for previous TMDLs, plus new MDAS modeling to characterize the TMDL Project Area.

Baseline condition was modeled in EFDC by feeding MDAS outputs for each tributary stream under baseline conditions as EFDC model inputs to the portion of the EFDC model (grid cell) nearest the stream confluence. Permitted point sources discharging directly to the mainstem were modeled to discharge to the grid cell nearest the outlet location and represented at flows and concentrations determined by their permit limits. CSO inputs were also discharged to the nearest grid cell and run at baseline flows and concentrations described above. Reductions under TMDL allocation conditions were tested by replacing tributary MDAS baseline outputs with MDAS allocated condition outputs and reducing CSO effluent concentrations.

Source Loading Alternatives

Simulating baseline conditions allowed for the evaluation of each stream's response to variations in source contributions under a variety of hydrologic conditions. This sensitivity analysis gave insight into the dominant sources and the mechanisms by which potential decreases in loads would affect instream pollutant concentrations. The loading contributions from the various existing sources were individually adjusted; the modeled instream concentrations were then evaluated.

Multiple allocation scenarios were run for the impaired waterbodies, described below. The first three runs did not result in attainment of water quality criteria. The successful scenario (Run 4) achieved the TMDL endpoints under all flow conditions throughout the modeling period. The averaging period and allowable exceedance frequency associated with West Virginia and Pennsylvania water quality criteria were considered in these assessments. In general, loads contributed by sources that had the greatest impact on instream concentrations were reduced first. If additional load reductions were required to meet the TMDL endpoints, less significant source contributions were subsequently reduced.

- Run 1. All point, nonpoint, and tributary sources were modeled at baseline concentrations except CSO fecal coliform bacteria concentrations were reduced from 100,000 counts/100 ml to 200 counts/100 ml.

- Run 2. All point, nonpoint, and tributary sources were modeled at baseline concentrations except CSO fecal coliform bacteria concentrations were reduced from 100,000 counts/100 ml to 200 counts/100 ml, and flows from local urban tributaries were removed from the model to better observe the localized effects of CSOs on receiving cells.

- Run 3. Tributaries with previously developed TMDLs were set to allocation conditions, modeled failing onsite septic fecal coliform concentrations were reduced to 0 counts/100 ml. Permitted point sources and CSOs were left at baseline concentrations.

- Run 4. Tributaries with previously developed TMDLs were set to allocation conditions. Modeled failing onsite septic fecal coliform concentrations were reduced 100 percent to 0 counts/100 ml, to be consistent with state laws prohibiting failing septic systems. Permitted point sources were left at their baseline concentrations. CSO fecal coliform bacteria concentrations were reduced from 100,000 counts/100 ml to 200 counts/100 ml. MS4 areas within the project area were not reduced. Neither were non-MS4 landuses such as urban or agricultural areas.

7.2 Source Allocation

All Monongahela River tributaries with previously developed TMDLs, including the West Fork and Tygart Valley Rivers, were modeled at TMDL allocated conditions. Source allocations described below only affect portions of the Monongahela River Project Area that had not received a TMDL under the 2014 effort. Source allocations developed for this report do not change or supersede 2014 TMDLs.

The TMDL and source allocations were developed for the Monongahela River using the following methodology when allocating to fecal coliform bacteria sources:

- The effluents from all NPDES permitted sewage treatment plants were set at the permit limit (200 counts/100 mL monthly geometric mean)
- Because West Virginia Bureau for Public Health regulations prohibit the discharge of raw sewage into surface waters, all illicit discharges of human waste (from failing septic systems and straight pipes) were reduced by 100 percent in the model.
- All CSO discharges were assigned WLAs at the value of the fecal coliform water quality criterion (200 counts/100ml) to be protective of local water quality.
- MS4s, and non-point source loadings from agricultural lands and residential areas were assigned loads equal to their calibrated condition because reductions beyond those associated with illicit septic systems and CSOs were not necessary to attain water quality criteria.

Wasteload Allocations (WLAs)

WLAs were developed for all facilities permitted to discharge fecal coliform bacteria, including MS4s, as described below.

Sewage Treatment Plant Effluents

The fecal coliform effluent limitations for NPDES permitted sewage treatment plants are more stringent than water quality criteria; therefore, all effluent discharges from sewage treatment facilities were given WLAs equal to existing monthly fecal coliform effluent limitations of 200 counts/100 mL.

Municipal Separate Storm Sewer System (MS4)

USEPA's stormwater permitting regulations require municipalities to obtain permit coverage for stormwater discharges from MS4s. In the areas adjacent to the Monongahela River there are 6 designated MS4 entities described in **Section 4.1.4**. Each entity will be registered under, and subject to, the requirements of General Permit Number WV0110625. The stormwater discharges from MS4s are point sources for which the TMDL prescribes WLAs.

Load Allocations (LAs)

Fecal coliform LAs are assigned to the following source categories:

- Pasture/Cropland
- On-site Sewage Systems — loading from all illicit discharges of human waste (including failing septic systems and straight pipes)
- Residential — loading associated with urban/residential runoff from non-MS4 areas
- Background and Other Nonpoint Sources — loading associated with wildlife sources from all other landuses (contributions/loadings from wildlife sources were not reduced)

7.3 Seasonal Variation

Seasonal variation was considered in the formulation of the modeling analysis. Continuous simulation (modeling over a period of several years that captured precipitation extremes) inherently considers seasonal hydrologic and source loading variability**.** The pollutant concentrations simulated on a daily time step by the model were compared with TMDL endpoints. Allocations that met these endpoints throughout the modeling period were developed.

7.4 Critical Conditions

A critical condition represents a scenario where water quality criteria are most susceptible to violation. Analysis of water quality data for the impaired streams addressed in this effort shows high pollutant concentrations during both high- and low-flow thereby precluding selection of a single critical condition. Both high-flow and low-flow periods were taken into account during TMDL development by using a long period of weather data that represented wet, dry, and average flow periods.

Nonpoint source loading is typically precipitation-driven, and impacts tend to occur during wet weather and high surface runoff. During dry periods little or no land-based runoff occurs, and elevated instream pollutant levels may be due to point sources (Novotny and Olem, 1994).

7.5 TMDL Presentation

To better insure implementation of the TMDL, the river has been divided into project segments based on confluences of major tributaries and locks and dams. **Figure 7-2** displays the 6 project segments. The TMDL for the Monongahela River is shown in **Section 7.6** of this report. The TMDL for fecal coliform bacteria is presented in average number of colonies per day. The TMDL was developed to meet TMDL endpoints under a range of conditions observed over the modeling period. The TMDL and its components are also presented in the allocation spreadsheets associated with this report. The filterable spreadsheets also display detailed source allocations and include multiple display formats that allow comparison of pollutant loadings among categories and facilitate implementation.

The fecal coliform bacteria WLAs for sewage treatment plant effluents and CSOs are presented both as annual average loads, for comparison with other pollutant sources, and equivalent allocation concentrations. The prescribed concentrations are the operable allocations for NPDES permit implementation.

The WLAs for precipitation induced MS4 discharges are presented in terms of average annual daily loads as the average number of colonies per year (FC) and the percent pollutant reduction from baseline conditions. The “MS4 WLAs Fecal” tab of the allocation spreadsheet contains the operable allocations expressed as percent reductions. The MS4 tab also provides drainage areas of various land use types represented in the baseline condition (without BMPs) for each MS4 entity at the subwatershed scale.

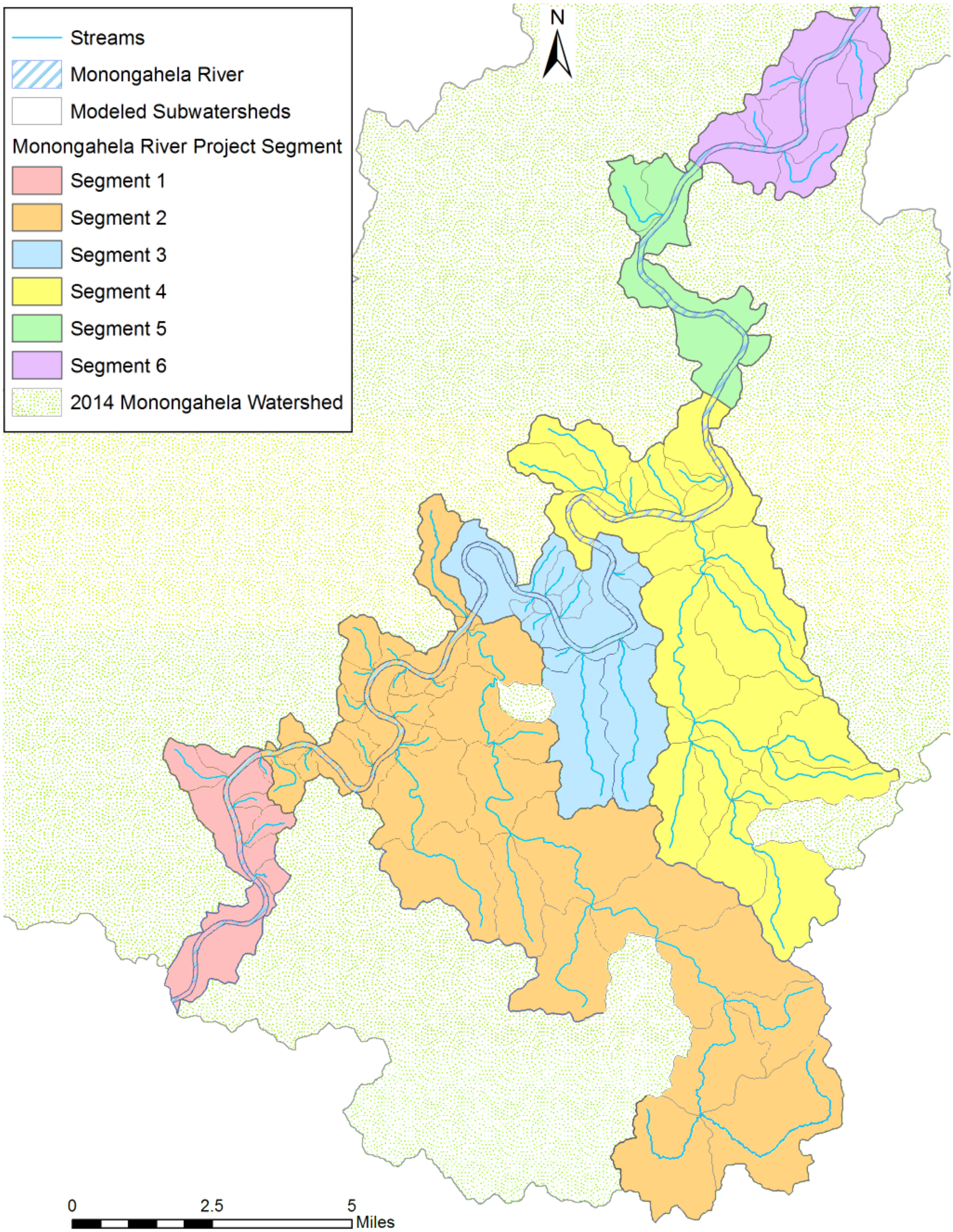


Figure 7-2. TMDL project segments

7.6 TMDL Result

Table 7-2. Fecal Coliform Bacteria TMDL

TMDL Watershed	NHD Code	Stream Name	WV Code	Load Allocations (counts/day)	Wasteload Allocation (counts/day)	Margin of Safety (counts/day)	TMDL (counts/day)
Monongahela River	WV-MU	Monongahela River	WVM-up	2.9367E+15	2.5495E+14	1.67982E+14	3.36E+15

NA = not applicable; UNT = unnamed tributary; RM = river mile.

"Scientific notation" is a method of writing or displaying numbers in terms of a decimal number between 1 and 10 multiplied by a power of 10. The scientific notation of 10,492, for example, is 1.0492×10^4 or 1.0492E+4.

8.0 FUTURE GROWTH

8.1 Fecal Coliform Bacteria

Specific fecal coliform bacteria future growth allocations are not prescribed. The absence of specific future growth allocations does not prohibit new development in the watersheds of streams for which the fecal coliform bacteria TMDL has been developed, or preclude the permitting of new sewage treatment facilities.

In many cases, the implementation of the TMDL will consist of providing public sewer service to unsewered areas. The NPDES permitting procedures for sewage treatment facilities include technology-based fecal coliform effluent limitations that are more stringent than applicable water quality criteria. Therefore, a new sewage treatment facility may be permitted anywhere in the watershed, provided that the permit includes monthly geometric mean and maximum daily fecal coliform limitations of 200 counts/100 mL and 400 counts/100 mL, respectively. Furthermore, WVDEP will not authorize construction of combined collection systems nor permit overflows from newly constructed collection systems.

9.0 PUBLIC PARTICIPATION

9.1 Public Meetings

An informational public meeting was held on May 14, 2014 at Fairmont State University (Falcon Room) in Fairmont, WV. The meetings occurred prior to pre-TMDL stream monitoring and pollutant source tracking and included a general TMDL overview and a presentation of planned monitoring and data gathering activities. A public meeting was held to present the draft TMDL on June 7, 2018 at Fairmont State College. The meeting started at 6:00 PM and provided information to stakeholders intending to facilitate comments on the draft TMDL.

9.2 Public Notice and Public Comment Period

The availability of the draft TMDL was advertised in various local newspapers beginning on May 24, 2018. Interested parties were invited to submit comments during the public comment period, which began on May 24, 2018 and ended on June 25, 2018. The electronic documents were also posted on the WVDEP's internet site at www.dep.wv.gov/tmdl.

9.3 Response Summary

The West Virginia Department of Environmental Protection received written comments on the draft TMDL from one member of the public. Comments have been compiled and responded to in this response summary. Comments and comment summaries are in boldface and italic. Agency responses appear in plain text.

The commenter expressed concern relative to pollutant sources of TDS, iron, sulfate, ions, siltation, TSS, and AMD in streams in the Monongahela River watershed.

TMDLs addressing water quality impairments for metals and sediment are presented in the Total Maximum Daily Loads for Selected Streams in the Monongahela River Watershed, West Virginia (WVDEP 2014), Total Maximum Daily Loads for the West Fork River Watershed, West Virginia (WVDEP 2014), Total Maximum Daily Loads for the Tygart Valley River Watershed, West Virginia (WVDEP 2016). The effect of ionic strength on aquatic life is the subject of ongoing studies and is not pertinent to this fecal coliform TMDL. Abandoned mine lands and land disturbances from mining and oil/gas development are not considered significant sources of fecal coliform, thus are not included in this TMDL.

The commenter also expressed concerns relative to water withdrawals and increased flow and water temperature in streams due to climate change.

As described throughout this report, the models selected to develop the TMDL for the Monongahela River allows for calibration based measured flows from the U.S. Army Corps of Engineers. The U.S. Army Corps of Engineers manages to maintain a minimum flow in the Monongahela River. There are ongoing efforts at the WVDEP to improve upon the Water Withdrawal Guidance Tool to provide information about when it is environmentally safe to withdrawal from streams.

Visit https://dep.wv.gov/WWE/wateruse/Pages/WaterWithdrawal.aspx to see the tool.

The projected loads in this TMDL are based on a range of precipitations events from dry periods, wet periods and average periods. Temperature was monitored and used as input to the EFDC model. The TMDL predicts expected loads based on current understanding of precipitation and temperature ranges. Concerns expressed by the commenter relative to climate change are beyond the purview of this TMDL.

10.0 REASONABLE ASSURANCE

Reasonable assurance for maintenance and improvement of water quality in the affected watershed rests primarily with two programs. The NPDES permitting program is implemented by WVDEP to control point source discharges. The West Virginia Watershed Network is a cooperative nonpoint source control effort involving many state and federal agencies, whose task is protection and/or restoration of water quality.

10.1 NPDES Permitting

WVDEP's Division of Water and Waste Management (DWWM) is responsible for issuing non-mining NPDES permits within the State. WVDEP's Division of Mining and Reclamation

(DMR) develops NPDES permits for mining activities. As part of the permit review process, permit writers have the responsibility to incorporate the required TMDL WLAs into new or reissued permits. New facilities will be permitted in accordance with future growth provisions described in **Section 8**.

Normally, both the permitting and TMDL development processes have been synchronized with the Watershed Management Framework cycle, such that TMDLs are completed just before the permit expiration/reissuance time frames. Permits for existing OWR NPDES facilities in the Monongahela River began being reissued in July 2018.

The MS4 permitting program is being implemented to address stormwater impacts from urbanized areas. West Virginia has developed a General NPDES Permit for MS4 discharges (WV0110625). All of the cities with MS4 permits in subject waters of this report, plus the West Virginia Department of Transportation, WVDOH are registered under the permit. The permit is based upon national guidance and is non-traditional in that it does not contain numeric effluent limitations, but instead proposes Best Management Practices that must be implemented. At permit reissuance, registrants will be expected to specifically describe management practices intended for implementation that will achieve the WLAs prescribed in applicable TMDLs. A mechanism to assess the effectiveness of the BMPs in achieving the WLAs must also be provided. The TMDLs are not intended to mandate imposition of numerical effluent limitations and/or discharge monitoring requirements for MS4s. Reasonable alternative methodologies may be employed for targeting and assessing BMP effectiveness in relation to prescribed WLAs. The "MS4 WLA Detailed" tabs on the allocation spreadsheets WLAs provide drainage areas of various land use types represented in the baseline condition (without BMPs) for each MS4 entity at the subwatershed scale. Through consideration of anticipated removal efficiencies of selected BMPs and their areas of application, it is anticipated that this information will allow MS4 permittees to make meaningful predictions of performance under the permit.

DWWM also implements a program to control discharges from CSOs. Specified fecal coliform WLAs for CSOs will be implemented in accordance with the provisions of the national Combined Sewer Overflow Control Policy and the state Combined Sewer Overflow Strategy. Those programs recognize that comprehensive CSO control may require significant resources and an extended period of time to accomplish. The WLAs prescribed for CSOs are necessary to achieve current fecal coliform water quality criteria. However, the TMDL should not be construed to supersede the prioritization and scheduling of CSO controls and actions pursuant to the national CSO program. Nor are the TMDLs intended to prohibit the pursuit of the water quality standard revisions envisioned in the national policy. TMDLs may be modified to properly implement future water quality standard revisions (designated use and/or criteria), if enacted and approved by the USEPA.

10.2 Watershed Management Framework Process

The Watershed Management Framework is a tool used to identify priority watersheds and coordinate efforts of state and federal agencies with the goal of developing and implementing watershed management strategies through a cooperative, long-range planning effort.

The West Virginia Watershed Network is an informal association of state and federal agencies, and nonprofit organizations interested in the watershed movement in West Virginia. Membership is voluntary, and everyone is invited to participate. The Network uses the Framework to coordinate existing programs, local watershed associations, and limited resources. This coordination leads to the development of Watershed Based Plans to implement TMDLs and document environmental results.

The principal area of focus of watershed management through the Framework process is correcting problems related to nonpoint source pollution. Network partners have placed a greater emphasis on identification and correction of nonpoint source pollution. The combined resources of the partners are used to address all different types of nonpoint source pollution through both public education and on-the-ground projects.

Among other things, the Framework includes a management schedule for integration and implementation of TMDLs. In 2000, the schedule for TMDL development under Section 303(d) was merged with the Framework process. The Framework identifies a six-step process for developing integrated management strategies and action plans for achieving the state's water quality goals. Step 3 of that process includes "identifying point source and/or nonpoint source management strategies - or Total Maximum Daily Loads - predicted to best meet the needed [pollutant] reduction." Following development of the TMDL, Steps 5 and 6 provide for preparation, finalization, and implementation of a Watershed Based Plan to improve water quality.

Each year, the Framework is included on the agenda of the Network to evaluate the restoration potential of watersheds within a certain Hydrologic Group. This evaluation includes a review of TMDL recommendations for the watersheds under consideration. Development of Watershed Based Plans is based on the efforts of local project teams. These teams are composed of Network members and stakeholders having interest in or residing in the watershed. Team formation is based on the type of impairment(s) occurring or protection(s) needed within the watershed. In addition, teams have the ability to use the TMDL recommendations to help plan future activities. Additional information regarding upcoming Network activities can be obtained from the Watershed Improvement Branch Basin Coordinator, Martin Christ (Martin.J.Christ@wv.gov)

There are several active citizen-based watershed associations representing several tributaries of the Monongahela River. These groups are the Friends of Deckers Creek, West Run Watershed Association, and White Day Creek Watershed Association. For additional information concerning the associations, contact the above mentioned Basin Coordinator or visit https://dep.wv.gov/WWE/getinvolved/WSA_Support/Pages/WGs.aspx

10.3 Public Sewer Projects

Within WVDEP DWWM, the Engineering and Permitting Branch's Engineering Section is charged with the responsibility of evaluating sewer projects and providing funding, where available, for those projects. All municipal wastewater loans issued through the State Revolving Fund (SRF) program are subject to a detailed engineering review of the engineering report, design report, construction plans, specifications, and bidding documents. The staff performs periodic on-site inspections during construction to ascertain the progress of the project and compliance with the plans and specifications. Where the community does not use SRF funds to undertake a project, the staff still performs engineering reviews for the agency on all POTWs prior to permit issuance or modification. For further information on upcoming projects, a list of funded and pending water and wastewater projects in West Virginia can be found at http://www.wvinfrastructure.com/projects/index.php.

11.0 MONITORING PLAN

The following monitoring activities are recommended:

11.1 NPDES Compliance

WVDEP's DWWM and DMR have the responsibility to ensure that NPDES permits contain effluent limitations as prescribed by the TMDL WLAs and to assess and compel compliance. Compliance schedules may be implemented that achieve compliance as soon as possible while providing the time necessary to accomplish corrective actions. The length of time afforded to achieve compliance may vary by discharge type or other factors and is a case-by-case determination in the permitting process. Permits will contain self-monitoring and reporting requirements that are periodically reviewed by WVDEP. WVDEP also inspects treatment facilities and independently monitors NPDES discharges. The combination of these efforts will ensure implementation of the TMDL WLAs.

11.2 Nonpoint Source Project Monitoring

All nonpoint source restoration projects should include a monitoring component specifically designed to document resultant local improvements in water quality. These data may also be used to predict expected pollutant reductions from similar future projects.

11.3 TMDL Effectiveness Monitoring

TMDL effectiveness monitoring should be performed to document water quality improvements after significant implementation activity has occurred where little change in water quality would otherwise be expected. Full TMDL implementation will take significant time and resources, particularly with respect to the abatement of nonpoint source impacts. WVDEP will continue monitoring on the rotating basin cycle and will include a specific TMDL effectiveness component in waters where significant TMDL implementation has occurred.

12.0 REFERENCES

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