Watershed-based plan

Muddy Creek of the Greenbrier River, West Virginia



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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

SUGGESTED REFERENCE

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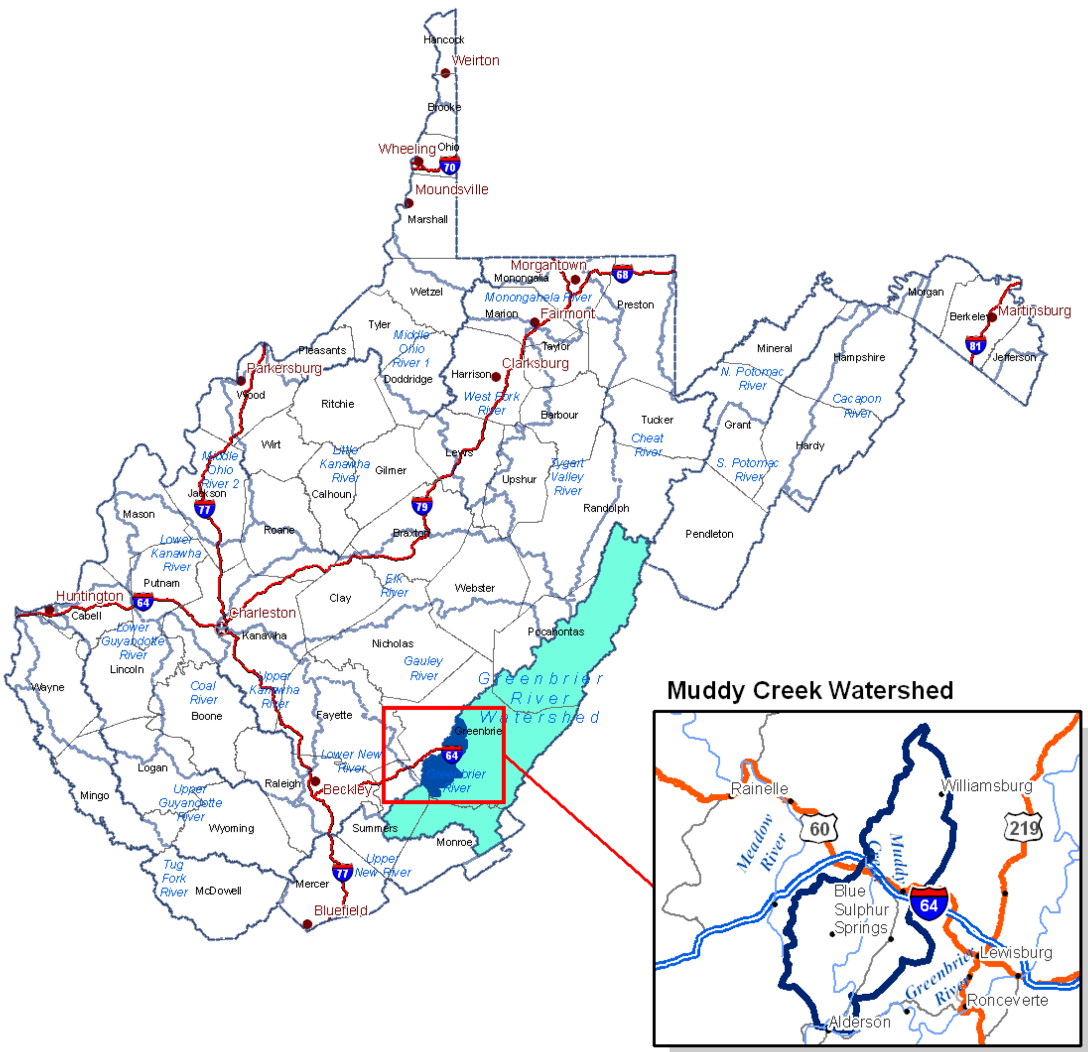
Abbreviations

AWEP	Agricultural Water Enhancement Program
BMP	best management practice
CREP	Conservation Reserve Enhancement Program
CWP	comprehensive watershed plan
EQIP	Environmental Quality Incentives Program
FOTLGR	Friends of the Lower Greenbrier River
GIS	geographic information system
GVCD	Greenbrier Valley Conservation District
LAI	Lombardo Associates, Inc.
mg/L	milligram per liter
NA	not applicable
ND	no data
NRCS	Natural Resources Conservation Service
QAPP	quality assurance project plan
STED	septic tank effluent discharge (or drain)
STEP	septic tank effluent pump
SWS	subwatershed designated in the TMDL
TMDL	total maximum daily load
UIC	underground injection control
UNT	unnamed tributary
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WHIP	Wildlife Habitat Incentives Program
WRP	Wetlands Reserve Program
WVCA	West Virginia Conservation Agency
WVDEP	West Virginia Department of Environmental Protection
WVDHHR	West Virginia Department of Health and Human Resources
WVU	West Virginia University

1 INTRODUCTION

This watershed-based plan covers the entire Muddy Creek watershed (of the Greenbrier River) in Greenbrier County, West Virginia (Figure 1). Several streams within the Muddy Creek watershed are impaired by high levels fecal coliform bacteria. Total maximum daily loads (TMDLs) have been calculated for the Muddy Creek watershed as part of a broader TMDL report for the Greenbrier River (Tetra Tech, 2008).

Figure 1: The Muddy Creek watershed in West Virginia



To correct the fecal coliform impairment so all streams in the watershed once again meet water quality standards, reductions are calculated for three types of nonpoint sources: pasture/cropland areas, onsite sewer systems, and residential runoff. Most of the load reduction will come from pasture/cropland, as shown in Table 1.

Table 1: Fecal coliform reductions by nonpoint source

Nonpoint source	Total required reduction (counts/year)	Percent of the required reductions
Pasture/cropland	3.01E+14	98
Onsite sewer systems	6.15E+12	2
Residential runoff	7.65E+11	<1

Source: (Tetra Tech, 2008). Total does not sum to 100 due to rounding.

This watershed-based plan outlines several strategies for meeting the fecal coliform TMDL. For pasture/cropland sources a variety of practices are proposed, including livestock exclusion from streams by fencing, watering system development for livestock, streambank and riparian restoration, and natural stream design. Failing onsite wastewater systems require a 100% load reduction, which means that every onsite system must be functioning properly in the watershed. An inventory of systems and potential issues will be completed and a suitable solution for remediation will ensue, based on the specifics of each site. Residential runoff reductions are relatively insignificant, and only called for in one subwatershed. This report estimates the total cost of meeting the goals of the TMDL in the watershed to be 8.2 million dollars. The agriculture remediation cost is estimated at 3.8 million dollars and the onsite septic system repair or replacement is estimated at 4.4 million dollars.

1.1 Recommendations for a Comprehensive Watershed Plan

While this watershed-based plan is an important step toward meeting the goals of the TMDL, a more intensive and interactive process has been initiated by the West Virginia Department of Environmental Protection (WVDEP) and Friends of the Lower Greenbrier River (FOTLGR). This process, known as a comprehensive watershed plan will consist of the following:

- **State of the watershed report**. Using readily available data, this report will define the study area and identify streams, subwatersheds, groundwater systems, underground streams, and karst areas. In addition, the following datasets will be compiled: land use; nonpoint sources; National Pollutant Discharge Elimination System discharges; and chemical, physical, and biological surface water data. Maps, charts, and tables would convey important information and data. In addition to a technical report, a less technical report will be produced for public dissemination.
- **Stakeholder meetings to develop a common vision.** Stakeholders will come together to define a vision for the future of the watershed and the technologies, policies, and management strategies that would be necessary to achieve this vision.
- **Data collection and analysis.** Additional data and information will allow for a more comprehensive planning process. This phase will include inventorying onsite wastewater systems and wells, identifying specific potential sites for agricultural projects, refining land use areas, calculating land use trends, compiling additional data on groundwater and underground streams, and completing a vulnerability assessment.
- **Geographic information system (GIS)-based watershed management database.** The above components will be synthesized and made available to stakeholders. Possibilities for the database

include a landowner database, educational materials, conceptual stream restoration designs, specific agricultural improvement projects, and an inventory and analysis of onsite septic systems.

Once completed, the comprehensive watershed plan will facilitate efficient selection and implementation of projects to reduce fecal coliform loads and to preserve the otherwise clean watershed. The expanded plan will help increase awareness and understanding of the Muddy Creek TMDL and watershed-based plan, generating needed support and involvement from local stakeholders.

1.2 General information

The Muddy Creek watershed is part of the larger Greenbrier River watershed. As delineated in the TMDL report, the Muddy Creek watershed is approximately 79,000 acres and includes the communities of Williamsburg, Blue Sulphur Springs, and Alderson. The approximate population of the watershed is 4,470, based on the number of occupied homes (1,788) and average household size (2.5) estimated in the TMDL (Tetra Tech, 2008).

The Muddy Creek watershed has an average elevation of 2,250 feet, characterized by dramatic valleys with steep mountains delineating its borders. Low valleys in the watershed tend to be broad with headwater regions characterized by steep confined valleys. Muddy Creek itself is predominately a meandering, slow-moving stream, only averaging 25 feet per mile of elevation change through the length of the main stem.

The Muddy Creek area is rich in history and culture. An 18th century gristmill once operated at the confluence of Mill Creek and Muddy Creek. The mill has since been disassembled and transported to Jackson's Mill, West Virginia, where recommenced operation in 1993 (WVU, 2009). While the mill had been closed for several decades before its relocation, recent literature suggests that dams associated with this and other mills continue to influence sedimentation and erosion patterns along the length of the dammed stream (Pizzuto and O'Neal, 2009; Walter and Merritts, 2008).

Blue Sulphur Springs, located at the confluence of Snake Run and Kitchen Creek, was once home to a thriving resort town before the Civil War. Visitors would visit the many spring resorts that were across the region. A large unique spring house, reminiscent of a Grecian temple, remains.

There are several major streams within the Muddy Creek watershed; approximately 165 miles of surface streams and a minimum of 12 miles of underground streams[1] drain the watershed.

Table 2 shows subwatersheds as delineated in the TMDL along with their respective lengths and drainage basin acreages.

[1] Underground length is a minimum estimate, based on the straight-line length from the point the stream disappears underground to where it reappears at the surface.

Table 2: Subwatershed statistics

Subwatershed Name	SWS	Stream feet (surface)	Stream feet (underground)*	Drainage area (acres)
Muddy Creek	2201	46,793	-	3,737
	2207	15,337	-	1,460
	2208	12,738	-	1,117
	2209	10,945	-	811
	2210	10,745	-	1,365
	2211	13,723	-	1,046
	2212	9,612	-	538
	2213	13,930	-	1,710
	2214	13,669	10,084	2,568
	2215	29,735	-	2,788
	2216	69,733	-	4,672
	2217	8,710	-	757
Mill Creek	2202	39,357	-	4,341
	2203	9,088	31,241	3,976
	2204	24,572	24,796	3,722
	2205	33,890	-	2,138
	2206	8,162	823	821
Sinking Creek	2218	15,123	16,366	1,720
	2219	18,511	-	901
	2220	14,065	-	726
	2221	7,253	-	559
	2222	53,250	3,458	3,684
	2223	4,496	-	257
	2224	11,710	-	877
	2225	13,640	-	1,541
	2226	16,805	-	2,009
	2227	27,937	1,004	2,593
	2228	33,259	-	2,030
	2229	8,033	-	630
	2230	11,904	-	1,099
	2231	28,498	-	2,275
	2232	8,705	-	213
	2233	22,440	-	1,715
	2234	20,399	-	2,079
Kitchen Creek	2235	15,921	-	1,279
	2236	39,709	-	3,764
	2237	61,303	-	4,554
	2238	5,222	-	472
	2239	15,083	-	2,388
	2240	11,910	-	893
	2241	3,432	-	253
	2242	6,499	-	472
	2243	10,729	-	731
	2244	11,931	-	1,273
-	**Total**	**843,934 (159.8 miles)**	**87,772 (16.6 miles)**	**78,554 (122.7 sq miles)**

Source: Tetra Tech Data and Downstream Strategies GIS analyses. SWS=subwatershed in the TMDL.
*Underground length is a minimum estimate, based on the straight-line length from the point the stream disappears underground to where it reappears at the surface.

Much of the area around the main stem and to the east is characterized by karst—a term used to describe the landscape formed by the dissolution of carbonate rock. Karst, and its significance to the watershed, is discussed in more detail in section 1.4.

The watershed is predominantly agricultural, with many large and small farms housing various types of livestock. There are approximately 8,000 head of livestock in the Muddy Creek watershed. Much of the livestock has direct access to the streams within the watershed.

1.3 Land use/Land cover

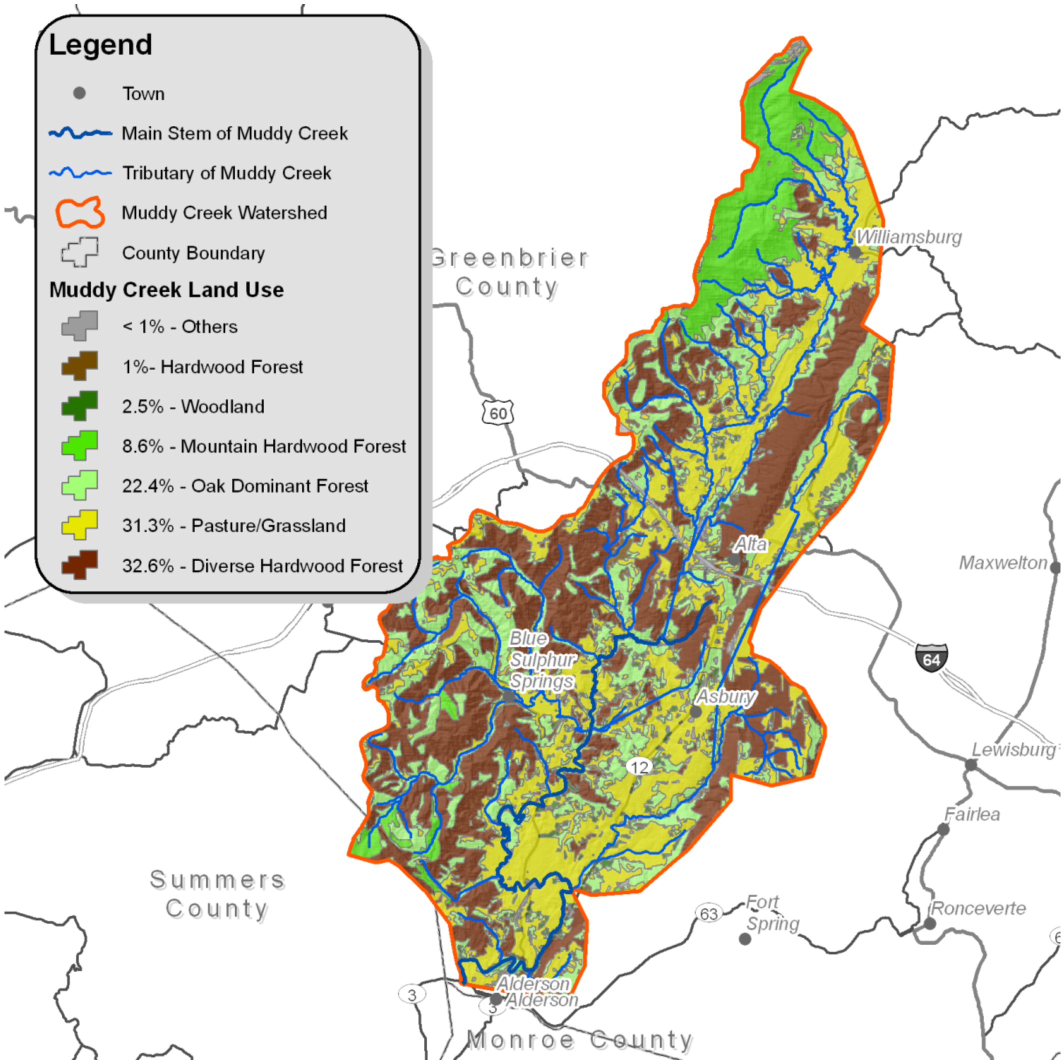
Land use in the Muddy Creek watershed has been divided into eleven categories, as shown in Table 3. Land use distribution is shown in Figure 2, with forest separated by composition. Together, the two dominant land uses—forest and pasture/grassland—comprise 98% of the watershed. No other single land use covers as much as 1% of the watershed. While forest is the predominant land use type, no fecal coliform reductions are called for in this category. All reductions will come from agricultural and residential areas.

Table 3: Land use in the Muddy Creek watershed

Land use	Acres	Percent
Forest	52,787	67
Pasture/grassland	13,693	17
Pasture/grassland over karst	10,870	14
Light intensity urban	387	<1
Wetland	202	<1
Barren land	154	<1
Row crop agriculture	94	<1
Surface water	58	<1
High intensity urban	57	<1
Shrubland	55	<1
Populated area	31	<1
Moderate intensity urban	27	<1
Total	**78,415**	**100**

Source: WV LAND GAP-NRAC-WVU 2002.

Figure 2: Muddy Creek Land Use



1.3.1 Forest

Currently 52,787 acres or two-thirds of the watershed (67 percent) are covered by forest. The majority of the forest is comprised of deciduous trees, with some pockets of dominant evergreen stands.

1.3.2 Agriculture

Approximately 24,563 acres (31 percent) of land within the watershed is pasture/grassland. While this may include some unforested non-farm land, it is assumed to be primarily agricultural—used either for active livestock grazing or as other non-productive pasture land. Approximately 94 acres (<1 percent) is modeled as cropland. Both the pasture and cropland are primarily situated at the lower elevations, spread about the numerous valleys and lowlands of the Muddy Creek watershed in close proximity to the streams. There are approximately 7,200 head of cattle, 600 sheep, and 300 horses in the Muddy Creek watershed. According to the TMDL model, agricultural land currently contributes approximately 89% of the watershed's total fecal coliform load.

Agricultural runoff in the Muddy Creek watershed is particularly difficult to monitor and reduce as much of the land is underlain by karst and pitted by sinkholes. Sinkholes provide a direct conduit to underground streams, allowing for rapid introduction of contaminants into the water network.

1.3.3 Residential

Approximately 500 acres (0.6%) of the land within the watershed are currently being used for residential purposes. This very small percentage is spread throughout the watershed, primarily as farm residences. Residential use is a similarly minor contributor to the fecal coliform impairment. Together, failing septic systems, straight-pipes, and residential runoff account for less than 2% of the total baseline fecal coliform load in the Muddy Creek watershed.

1.3.4 Commercial

Commercial and service-related uses currently occupy a small percentage of the watershed. Some of these uses include the Alta Sand quarry that comprises approximately 114 acres. This quarry is unique in that Sinking Creek subsides under the quarry and resurfaces approximately one mile downstream.

The town of Alderson at the mouth of Muddy Creek is home to several historic sites. Alderson's store, established in 1887, is now housed in a 1932 building designed by the same architect who built the Governor's Mansion (Simpson, 2007). Also in the Alderson Historic District are a restored 1896 railroad depot, a pedestrian bridge, and many historic buildings.

Route 60, the Midland Trail National Scenic Highway, passes through the middle of the watershed as it traverses the state from Kenova east to White Sulphur Springs. The scenic route hosts museums, historic houses, an amusement park, and many natural attractions and draws thousands of visitors every year.

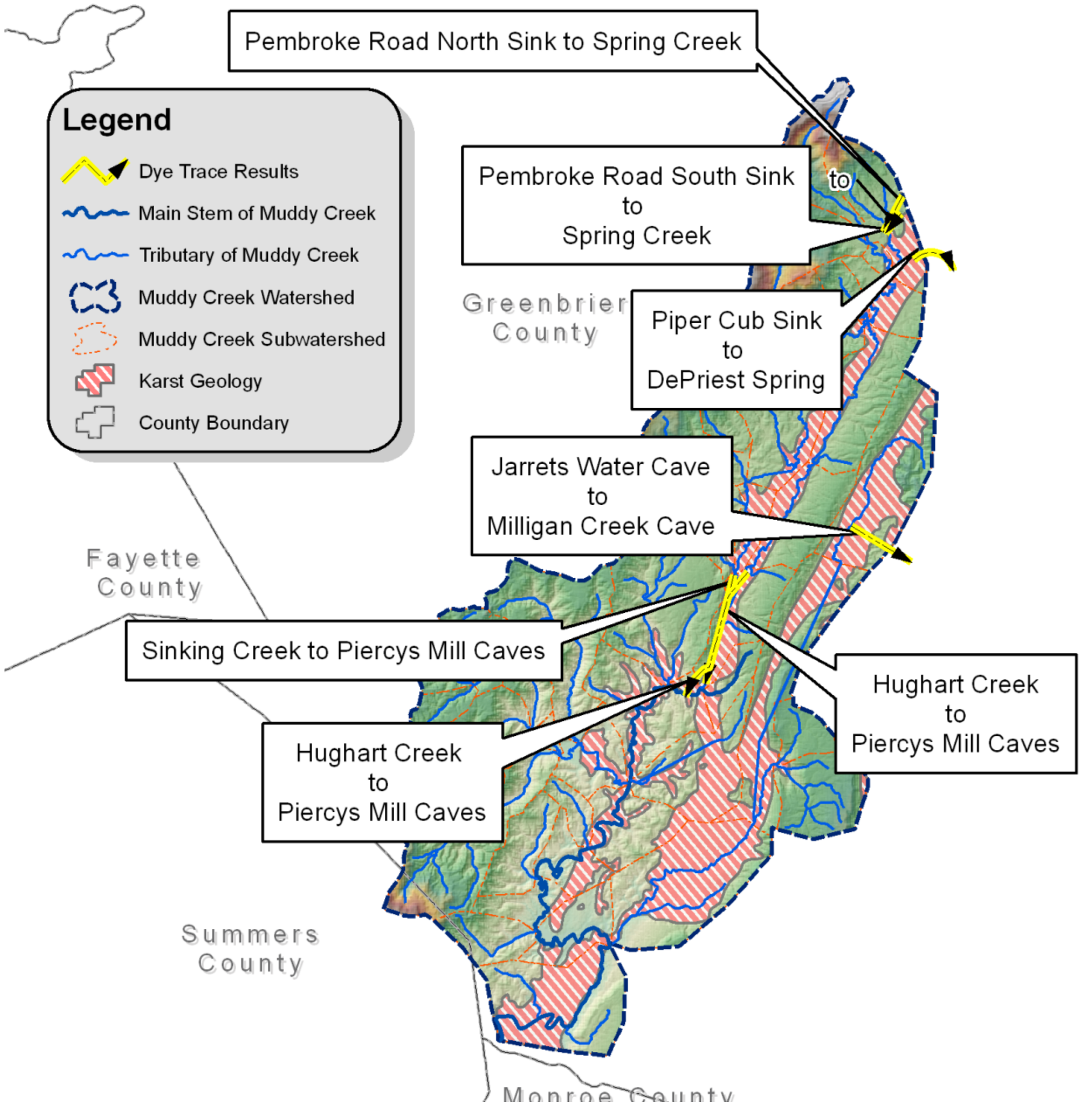
1.4 Muddy Creek watershed framework

A watershed includes all the land that drains to a common point. In the case of Muddy Creek, this point is in Alderson, where Muddy Creek joins the Greenbrier River. Since water flows downhill, watersheds are generally defined by the surrounding ridges. Computer models delineate watersheds by considering elevation, surface flow, and topography. More sophisticated models may take into account underground stream flow.

Eastern West Virginia—the area along the border with Virginia known as the Valley and Ridge Physiographic Province—is characterized by a high percentage of karst terrain as shown in Figure 3. Karst is the name given to a particular type of landscape formed by the dissolution of carbonate rocks such as limestone. Caves, sinkholes, and underground streams are all common features of karst, and result in greater hydrologic complexity compared to non-karst areas. Approximately 12% of the Muddy Creek watershed, and up to 50% of individual subwatersheds, are known to be underlain by karst.

Since the 1960s, scientists have been using fluorescent dyes in West Virginia streams to determine subsurface flow paths (Jones, 1997). Dye is added to the stream at the point where it sinks below ground and is detected with varying techniques when it re-emerges at the surface (Jones, 1997). Water tracing results are also presented in Figure 3.

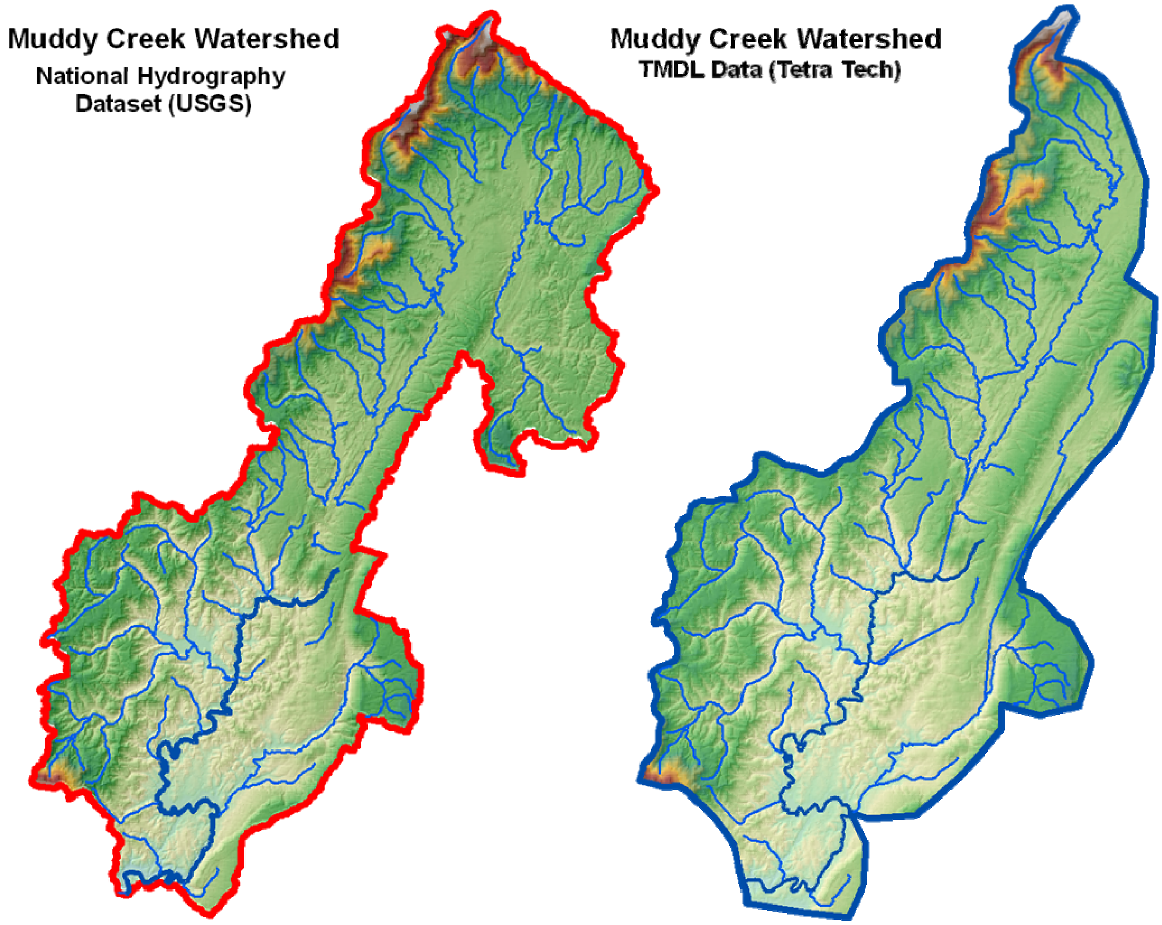
Figure 3: Karst geology and dye tracing results



The hydrologic complexity in karst regions makes watershed modeling difficult. In order to increase efficiency, modeling software often predicts flow patterns based solely on surface topography. The software is programmed to assume that water always flows downhill. However, a stream that disappears underground may flow beneath a small ridge and return to the surface on the other side. The ridge would prevent accurate modeling of the stream's path in a program which only considers surface topography. In the Muddy Creek watershed, this has resulted in discrepancies between datasets as to the exact boundaries of the watershed.

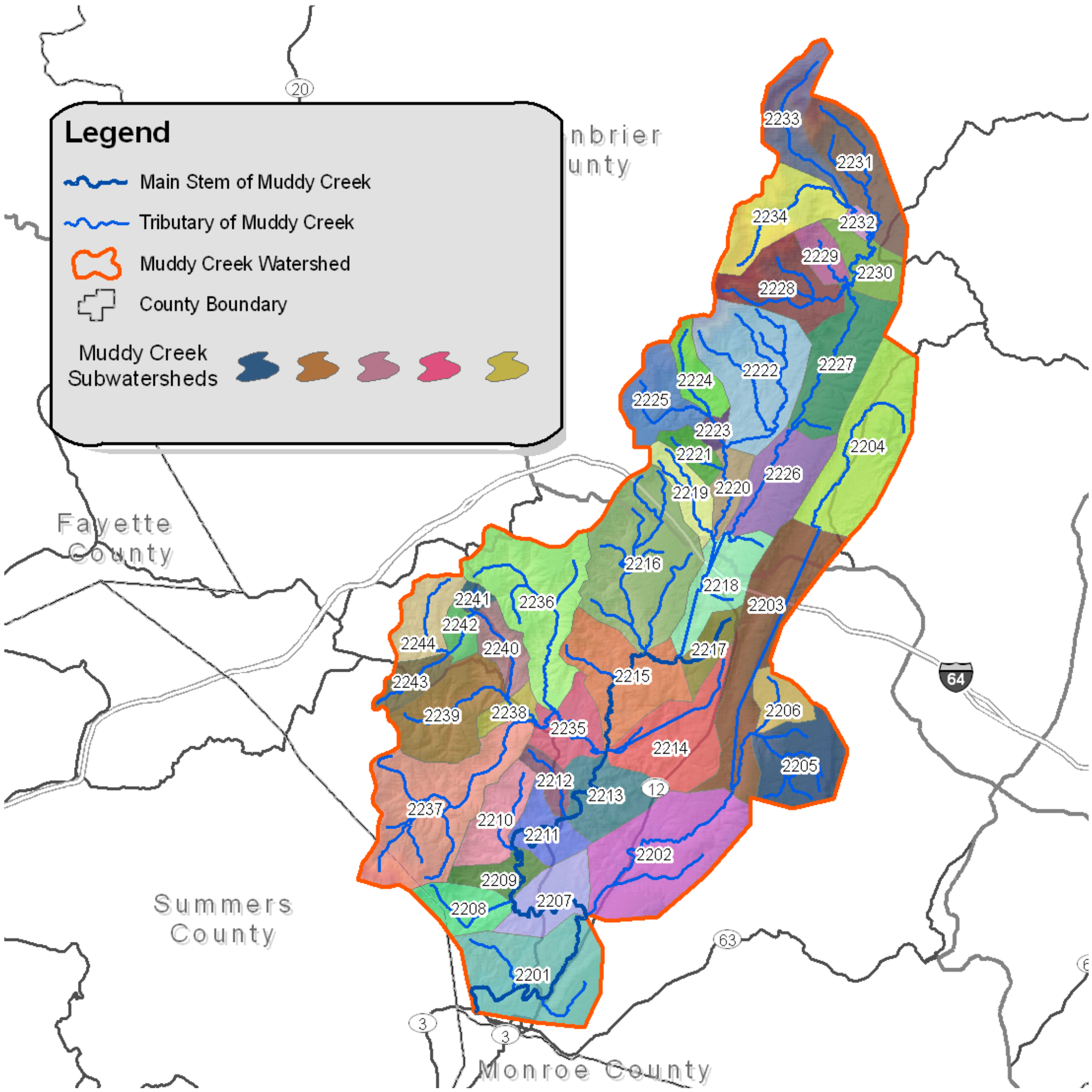
Two interpretations of the Muddy Creek watershed are depicted in Figure 4. The United States Geological Survey (USGS) model is part of a national dataset of computer-modeled watershed boundaries. Because of the scope of the project, these models are based solely on elevation data, and do not consider underground streams. The Tetra Tech model of the Muddy Creek watershed was created for use in the TMDL report, and gives more weight to stream connectivity through underground channels. Because this watershed-based plan focuses heavily on the data and recommendations presented in the TMDL, all data and analysis presented herein will be based on the watersheds as delineated in the TMDL.

Figure 4: Watershed boundary discrepancies



As part of the modeling process, the Muddy Creek drainage is divided into subwatersheds. This division allows for more precise monitoring of pollutants and evaluation of their sources. Each subwatershed is hydrologically connected, and has a unique common outlet. Figure 5 illustrates these subwatersheds, labeled with unique identification numbers. All data presented by subwatershed will refer to these identification numbers.

Figure 5: Muddy Creek modeled subwatersheds



2 MEASURABLE WATER QUALITY GOALS AND IMPAIRMENTS

The goal of this watershed-based plan is to provide a road map toward meeting West Virginia's numeric and narrative water quality criteria. Streams not meeting water quality standards are placed on a statewide list of impaired streams called the 303(d) list. Improving water quality so these streams are once again clean and can be removed from this list is the primary goal of this plan.

The fecal coliform water quality standard shown in Table 4 is the only standard relevant to the nonpoint source pollution problems addressed by this watershed-based plan.

Table 4: West Virginia water quality standard for fecal coliform

	Aquatic life		Human health		
Parameter	Category B1 (Warm water fishery streams)	Category B2 (Trout waters)	Category A (Public water supply)	and	Category C (Water contact recreation)
Fecal Coliform	None	None	Maximum allowable level of fecal coliform content for Primary Contact Recreation…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 ten percent of all samples taken during the month.		

Source: 47 Code of State Rules Series 2, Section 8.13.

As shown in Table 5 and Figure 6, Muddy Creek and several of its tributaries appear as impaired streams on the 2008 303(d) list due to high levels of fecal coliform (WVDEP, 2008). In addition to the impaired streams, many other contributing streams require reductions in fecal coliform in order to restore the impaired streams.

Table 5: Streams in the Muddy Creek watershed requiring reductions

	Stream	Stream code	TMDL Subwatershed codes
Impaired streams	Muddy Creek	WVKNG-22	2201, 2207, 2209, 2211, 2213, 2215, 2217
	Mill Creek	WVKNG-22-A	2202, 2203, 2205
	Kitchen Creek	WVKNG-22-C	2235, 2238, 2240, 2242, 2244
	UNT/Muddy Creek RM 19.8[1]	WVKNG-22-E	2218
	Sinking Creek	WVKNG-22-E-1-(S)	2226, 2227, 2230, 2232, 2234
	Hughart Creek	WVKNG-22-E-1-A-(S)	2220, 2223, 2225
Other streams requiring reductions	Raders Valley	WVKNG-22-A-0.5-A-(S)	2204
	UNT/Mill Creek RM 7.04	WVKNG-22-A-1	2206
	UNT/Muddy Creek RM 8.6	WVKNG-22-A.3	2208
	Beech Run	WVKNG-22-B	2210
	UNT/Muddy Creek RM 13.19	WVKNG-22-B.5	2212
	UNT/Muddy Creek RM 15.94	WVKNG-22-C.1	2214
	Renick Creek	WVKNG-22-C-1	2236
	Snake Run	WVKNG-22-C-2	2237
	Sawmill Hollow	WVKNG-22-C-3	2239
	UNT/Kitchen Creek RM 6.59	WVKNG-22-C-4	2241
	UNT/Kitchen Creek RM 7.83	WVKNG-22-C-5	2243
	Alum Rock Hollow	WVKNG-22-D	2216
	UNT/Hughart Creek RM 0.8	WVKNG-22-E-1-A-0.2	2219
	UNT/Hughart Creek RM 3.0	WVKNG-22-E-1-A-0.8	2221
	Tater Run	WVKNG-22-E-1-A-1-(S)	2222
	Roach Run	WVKNG-22-E-1-A-2	2224
	Stony Run	WVKNG-22-E-1-A.7	2228
	UNT/Sinking Creek RM 11.2	WVKNG-22-E-1-A.8	2229
	UNT/Sinking Creek RM 13.1	WVKNG-22-E-1-A.9	2231
	Flynn Creek	WVKNG-22-E-1-B	2233

Source: WVDEP (2008). UNT=unnamed tributary. RM=river mile. NA=not applicable.

[1] While the TMDL lists this stream as UNT/Muddy Creek RM 19.8, it is in the 303(d) list as UNT/Muddy Creek RM 20.10. Both sources list the stream code as WVKNG-22-E.

Figure 6: Impaired streams in the Muddy Creek watershed

Source: Tetra Tech (2008), WVDEP (2008).

3 FECAL COLIFORM REDUCTIONS FROM THE TMDL

The Greenbrier River TMDL—which includes Muddy Creek as one of many subwatersheds—calculates specific pollutant reductions required for nonpoint and point sources of fecal coliform. These load allocations and wasteload allocations are used as the basis for this watershed-based plan.

TMDLs are calculated for each of the fecal coliform–impaired streams in the watershed: Muddy Creek, Mill Creek, Kitchen Creek, the unnamed tributary of Muddy Creek at river mile 19.8,[2] Sinking Creek, and Hughart Creek. As shown in Table 6, load allocations for nonpoint sources are provided for all six of these subwatersheds; there are no point sources of fecal coliform in the Muddy Creek watershed.

Table 6: Fecal coliform total maximum daily loads and major components (counts/day)

Stream	Baseline	Load allocation	Margin of safety	TMDL	% Reduction
Muddy Creek	1.51E+12	6.63E+11	3.49E+10	6.98E+11	55.99
Mill Creek	3.00E+11	1.03E+11	5.43E+09	1.09E+11	65.61
Kitchen Creek/Muddy Creek	4.49E+10	3.32E+10	1.75E+09	3.49E+10	26.07
UNT/Muddy Creek RM 19.8	2.75E+11	1.89E+11	9.94E+09	1.99E+11	31.39
Sinking Creek	1.49E+11	1.01E+11	5.31E+09	1.06E+11	32.06
Hughart Creek	9.53E+10	6.68E+10	3.51E+09	7.03E+10	29.93

Source: (Tetra Tech, 2008) allocation spreadsheet. TMDL may not sum to total of other columns due to rounding. UNT=unnamed tributary. RM=river mile.

As shown in Table 7, two categories of nonpoint sources are targeted: pasture/cropland and onsite sewer systems.[3] Pasture/cropland is targeted selectively in twenty-four subwatersheds, with reductions ranging from 9.5% to 90% (Table 7 and Figure 7). The TMDL also uses West Virginia Department of Environmental Protection (WVDEP) livestock tracking data to analyze agricultural intensity, shown in Figure 8.

The subwatersheds requiring the highest percentage reductions in fecal coliform from pasture/cropland are concentrated in the lower portion of the watershed (Figure 7). These same subwatersheds are characterized by high or very high agricultural intensity (Figure 8). Implementing agricultural best management practices (BMPs) as described in 4.1 should be prioritized in these subwatersheds.

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[2] While the TMDL lists this stream as UNT/Muddy Creek RM 19.8, it is in the 303(d) list as UNT/Muddy Creek RM 20.10. Both sources list the stream code as WVKNG-22-E.

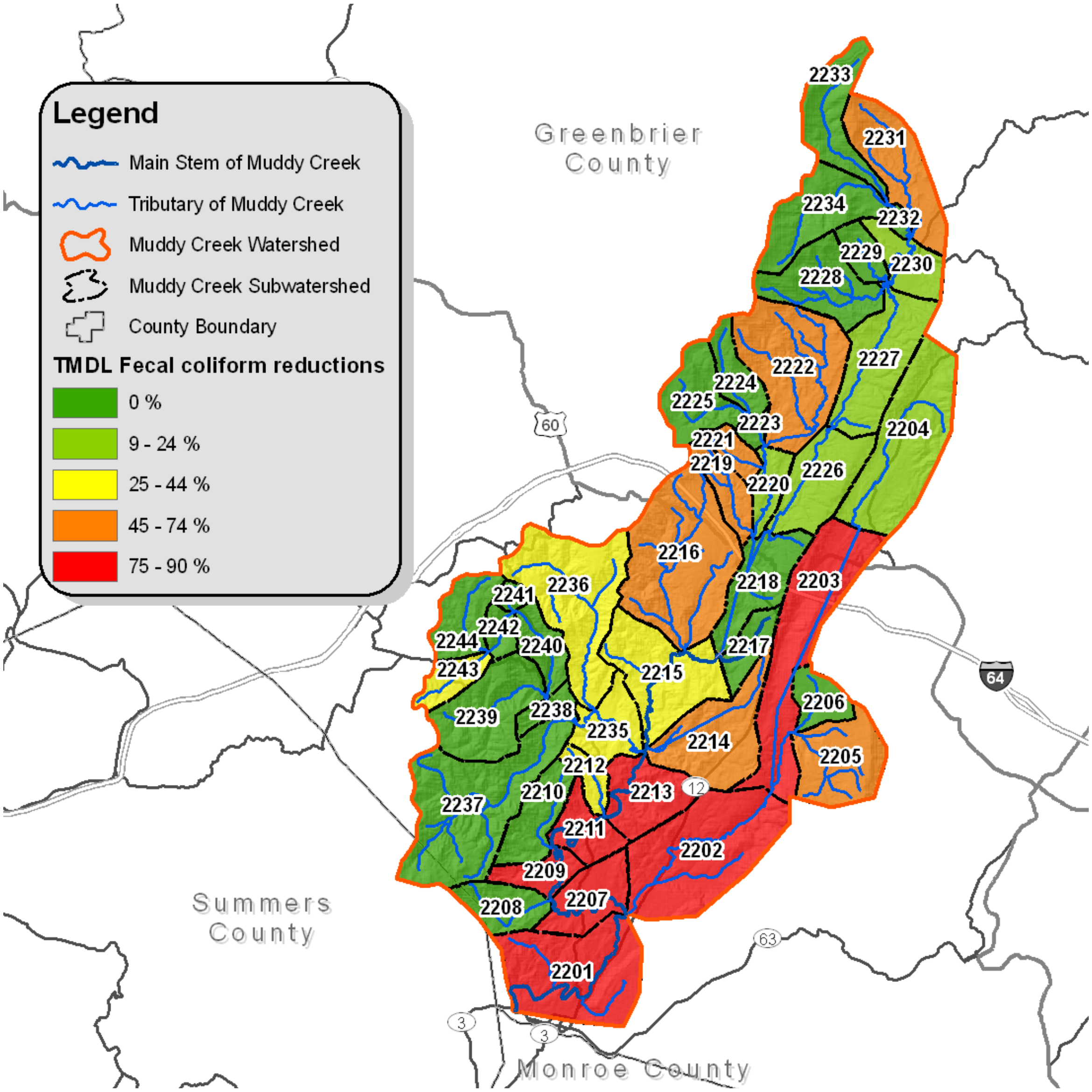
[3] Subwatershed 2201 of Muddy Creek also requires a reduction from residential stormwater runoff—Baseline: 1.53E+12; Allocation: 7.66E+11; Reduction: 50%. One other nonpoint source category is considered in the TMDL but not assigned allocations: natural background (wildlife).

Table 7: Specific nonpoint source reductions required for fecal coliform (counts/year)

Stream name	SWS	Pasture/Cropland			Onsite sewer systems		
		Baseline	Allocation	% Reduction	Baseline	Allocation	% Reduction
Muddy Creek	2201*	7.95E+13	7.96E+12	90.0	4.89E+11	0.00E+00	100
	2207	3.82E+13	4.92E+12	87.1	1.85E+11	0.00E+00	100
	2209	8.09E+12	9.85E+11	87.8	9.10E+10	0.00E+00	100
	2211	1.44E+13	3.52E+12	75.5	9.80E+10	0.00E+00	100
	2213	4.54E+13	9.65E+12	78.7	9.45E+10	0.00E+00	100
	2215	1.70E+13	1.28E+13	24.6	1.42E+11	0.00E+00	100
	2217	1.85E+12	1.85E+12	0.0	4.00E+10	0.00E+00	100
Mill Creek	2202	4.69E+13	4.75E+12	89.9	3.12E+11	0.00E+00	100
	2203	2.12E+13	2.15E+12	89.9	2.26E+11	0.00E+00	100
	2205	1.32E+13	6.66E+12	49.7	2.49E+11	0.00E+00	100
Raders Valley	2204	1.75E+13	1.44E+13	18.1	7.43E+10	0.00E+00	100
UNT/Mill Creek RM 7.04	2206	1.14E+12	1.14E+12	0.0	5.29E+10	0.00E+00	100
UNT/Muddy Creek RM 8.6	2208	7.98E+11	7.98E+11	0.0	8.33E+10	0.00E+00	100
Beech Run	2210	8.58E+11	8.58E+11	0.0	5.25E+10	0.00E+00	100
UNT/Muddy Creek RM 13.19	2212	2.56E+12	1.56E+12	39.1	2.80E+10	0.00E+00	100
UNT/Muddy Creek RM 15.94	2214	2.47E+13	9.14E+12	63.0	3.53E+11	0.00E+00	100
Alum Rock Hollow	2216	2.54E+13	1.29E+13	49.3	5.93E+11	0.00E+00	100
UNT/Muddy Creek RM 19.8	2218	1.05E+12	1.05E+12	0.0	7.31E+10	0.00E+00	100
UNT/Hughart Creek RM 0.8	2219	7.15E+12	3.64E+12	49.1	1.60E+11	0.00E+00	100
Hughart Creek	2220	3.59E+12	3.25E+12	9.5	3.40E+10	0.00E+00	100
	2223	2.10E+12	2.10E+12	0.0	1.39E+10	0.00E+00	100
	2225	2.82E+12	2.82E+12	0.0	5.73E+10	0.00E+00	100
UNT/Hughart Creek RM 3.0	2221	3.91E+12	1.97E+12	49.6	5.84E+10	0.00E+00	100
Tater Run	2222	1.62E+13	8.60E+12	46.9	3.12E+11	0.00E+00	100
Roach Run	2224	4.04E+11	4.04E+11	0.0	5.69E+10	0.00E+00	100
Sinking Creek	2226	1.59E+12	1.34E+12	15.7	1.83E+11	0.00E+00	100
	2227	3.96E+12	3.53E+12	10.9	4.79E+10	0.00E+00	100
	2230	7.18E+12	5.93E+12	17.4	3.69E+11	0.00E+00	100
	2232	0.00E+00	0.00E+00	0.0	1.26E+09	0.00E+00	100
	2234	0.00E+00	0.00E+00	0.0	3.60E+10	0.00E+00	100
Stony Run	2228	1.60E+12	1.60E+12	0.0	1.34E+11	0.00E+00	100
UNT/Sinking Creek RM 11.2	2229	1.11E+12	1.11E+12	0.0	2.30E+10	0.00E+00	100
UNT/Sinking Creek RM 13.1	2231	2.62E+13	1.17E+13	55.5	1.27E+11	0.00E+00	100
Flynn Creek	2233	0.00E+00	0.00E+00	0.0	1.44E+10	0.00E+00	100
Kitchen Creek/Muddy Creek	2235	1.57E+13	1.15E+13	26.8	7.00E+10	0.00E+00	100
	2238	3.65E+12	3.65E+12	0.0	4.84E+10	0.00E+00	100
	2240	3.29E+12	3.29E+12	0.0	1.14E+11	0.00E+00	100
	2242	1.30E+12	1.30E+12	0.0	1.71E+10	0.00E+00	100
	2244	3.17E+12	3.17E+12	0.0	8.54E+10	0.00E+00	100
Renick Creek	2236	1.29E+13	9.00E+12	30.2	2.70E+11	0.00E+00	100
Snake Run	2237	5.25E+12	5.25E+12	0.0	3.50E+11	0.00E+00	100
Sawmill Hollow	2239	3.30E+12	3.30E+12	0.0	2.02E+11	0.00E+00	100
UNT/Kitchen Creek RM 6.59	2241	4.19E+11	4.19E+11	0.0	3.98E+10	0.00E+00	100
UNT/Kitchen Creek RM 7.83	2243	2.23E+12	1.67E+12	25.1	8.54E+10	0.00E+00	100

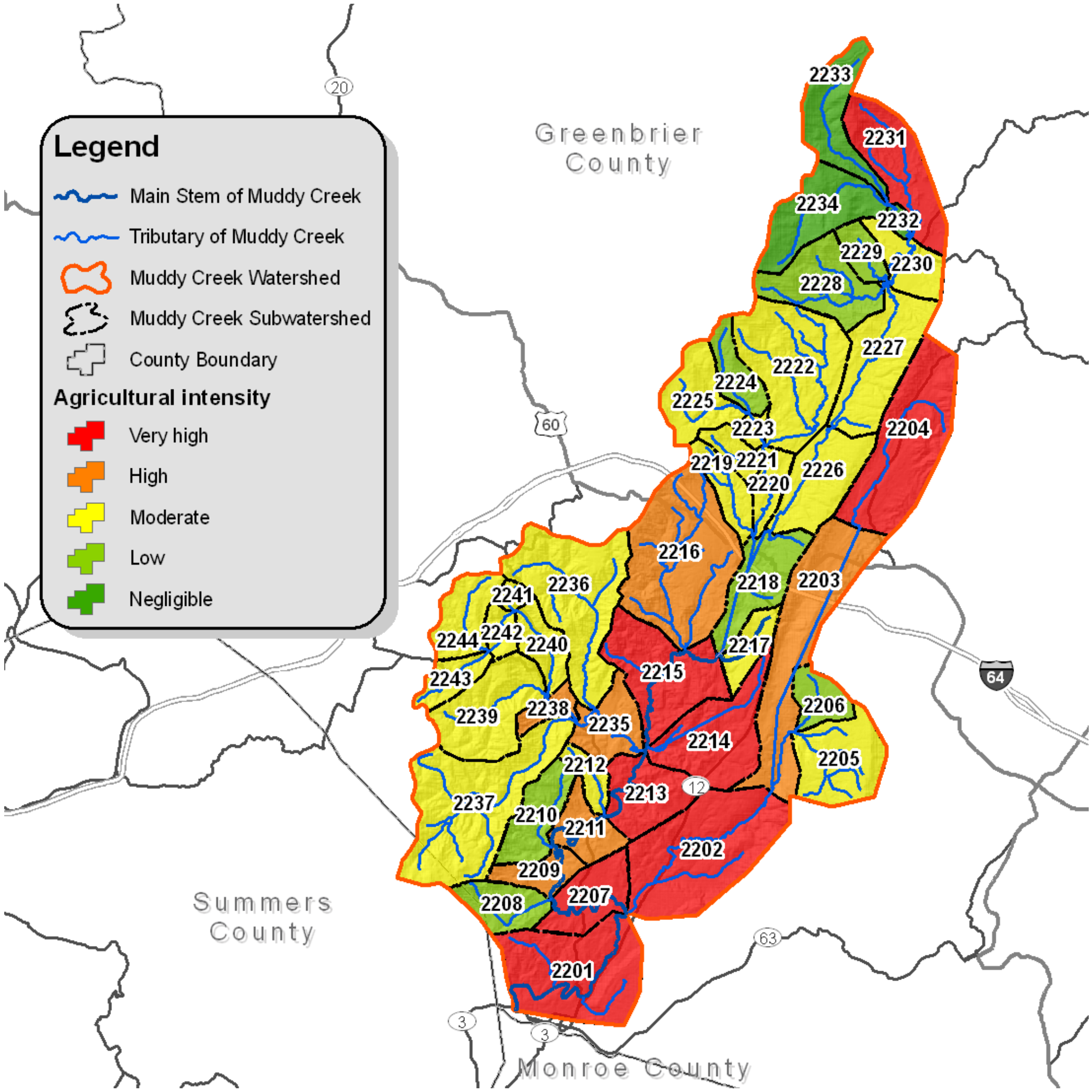
Source: Tetra Tech (2008) allocation spreadsheet. SWS=subwatershed in the TMDL.
*Subwatershed 2201 also requires a reduction from residential stormwater runoff—Baseline: 1.53E+12; Allocation: 7.66E+11; Reduction: 50%.

Figure 7: Pasture and cropland fecal coliform reductions from the TMDL by subwatershed



Source: Tetra Tech (2008).

Figure 8: Agricultural intensity

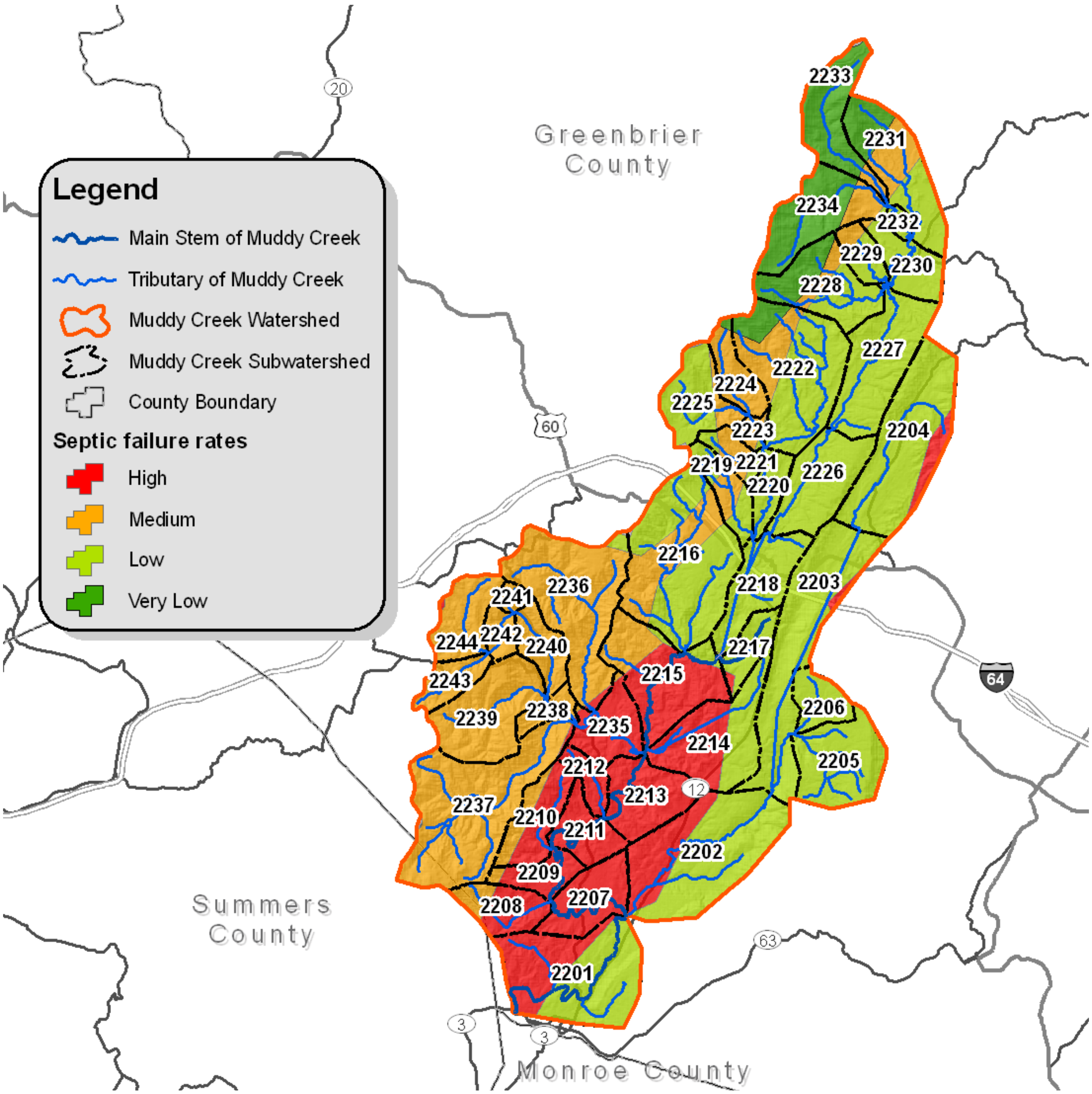


Source: Tetra Tech (2008).

In contrast to the pasture/cropland reductions, onsite sewer systems are targeted with 100% reductions across the entire watershed (Table 7). These reductions are not mapped because they are the same for all subwatersheds. The TMDL presents a model of failing septic systems, which shows varying septic failure rates across the Muddy Creek watershed (Figure 9). The areas of high septic failure are clustered around the lower reaches of Muddy Creek. This is not simply a reflection of population distribution; the TMDL models failure rates based on soil type and geologic structure and then uses instream fecal coliform data to calibrate the models.

While the septic failure rates are instructive in visualizing which regions are potentially most problematic for this issue, these are not necessarily the regions with the greatest reductions necessary in terms of bacteria count. Higher reductions may be called for in regions of lower septic failure rate due to higher concentrations of homes and the likelihood of straight pipes.

Figure 9: Septic failure rates



Source: Tetra Tech (2008).

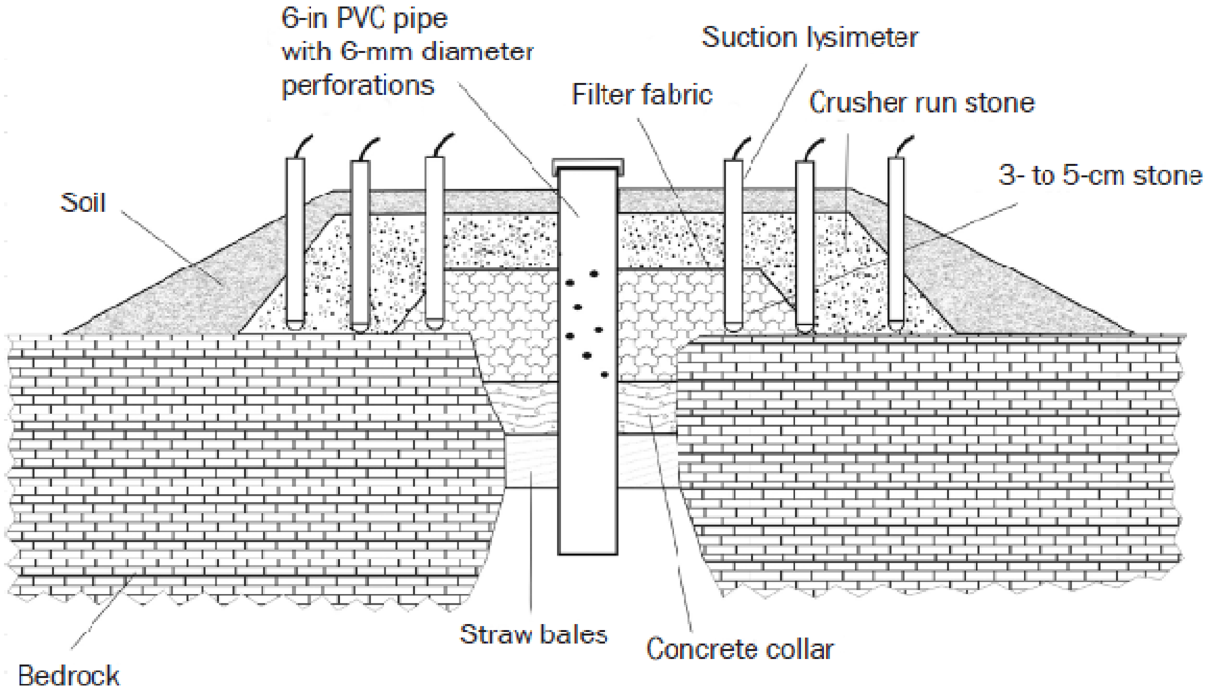
4 NONPOINT SOURCE MANAGEMENT MEASURES

4.1 Agricultural areas

In agricultural areas, several BMPs can be helpful in controlling fecal coliform runoff from pasture and cropland. Some of these BMPs prevent direct livestock access to streams, thereby protecting streambanks from disturbance. Thus, these agricultural BMPs address both streambank erosion and fecal coliform pollution.

- **Animal waste storage facilities.** Storage facilities protect animal waste from rainfall and prevent contaminated runoff from entering nearby streams.
- **Feedlot relocation.** By relocating feeding areas away from rivers, animal manure generated in these areas is less likely to run off into streams.
- **Barnyard runoff controls.** By collecting and channeling runoff from roofs via erosion-resistant channels or subsurface drains, this water will not convey fecal coliform to streams.
- **Livestock fencing.** Livestock fencing ensures that manure is not deposited directly into streams. Additionally, if livestock are kept away from the streams, they cannot trample the streambanks and disturb the riparian vegetation.
- **Armored stream crossings.** Sometimes, it is necessary to preserve stream crossings so that livestock can be moved to other locations, even after livestock fencing is built. Armored stream crossings can be built to prevent livestock from disturbing riparian areas.
- **Alternative watering sources.** If livestock are fenced away from streams that had been used for watering, alternative watering sources such as springs may need to be developed.
- **Riparian and sinkhole buffers.** Protected stream buffers help filter runoff before it reaches streams, and can therefore reduce sediment and fecal coliform concentrations in runoff from pasture and cropland. Vegetative buffers around sinkholes perform the same function for subsurface streams.
- **Stabilizing streambanks using natural stream design.** Streambank stabilization projects can promote appropriate riparian vegetation. Principles of natural stream design can ensure that stream channels are of **the** appropriate size and dimensions to handle the flows that are generated by a watershed, and that inevitable high flows are handled appropriately.
- **Sinkhole filters.** Subsurface flow can be very rapid in karst, and there is a demonstrated link between agriculture in karst regions and increased fecal coliform and nitrate levels (Boyer, 2005; Boyer and Pasquarell, 1996; 1999). It is therefore important to prevent fecal coliform from entering subsurface streams through sinkholes. Experimental sinkhole filters have been installed at three locations in nearby Greenbrier River watersheds. "The basic sinkhole filter design… consists of a thick, concrete plug over the sinkhole throat. A 15-cm (6-in) diameter perforated PVC pipe through the concrete plug allows filtered water to flow into the aquifer. The perforated section of PVC pipe is wrapped in filter fabric" (Boyer, 2008). This design is shown in Figure 10. It is thought that these filters may also trap phosphorous and pesticides in addition to fecal coliform (Boyer, 2008). One drawback is that they may increase nitrate loads. This is because nitrate is a solute, and only particulate matter is trapped by the filter; furthermore, nitrification may occur in the filter itself (Boyer, 2008).

Figure 10: Generalized sinkhole filter



Note: The suction lysimeters are for study purposes only.

Source: (Boyer, 2008, Figure 1)

4.2 Onsite sewer systems

According to the TMDL report, untreated sewage must be prevented from reaching streams to meet the onsite sewer system load allocations (Tetra Tech, 2008). Many specific measures can be taken to meet this broad goal. There are several control measures that can help solve fecal coliform discharges from onsite sewer systems, as listed below:

- **Replacing and repairing onsite systems and leach fields.** In some cases, onsite systems are the most appropriate solution but are in need of replacement or repair. Traditional septic systems and drain fields can work well if properly installed and maintained. In addition, the West Virginia Department of Health and Human Resources (WVDHHR) will consider "alternative and experimental sewer systems" on sites of at least two acres (WVDHHR, 2003). These systems, commonly referred to as "class II" may include "shallow fields, soil absorption mounds, shallow beds, low pressure pipe systems, elevated fields, evapotranspiration systems and unique systems designed for specific situations" (WVDHHR, 2003).
- **Upgrading underground injection control (UIC) permitted systems.** Some onsite wastewater systems are permitted with UIC permits. These systems may be upgraded to better control fecal coliform discharges.
- **Installing community cluster systems.** In some cases, cluster systems are a more practical or economical alternative. Cluster systems can serve multiple homes. These systems incorporate options that bridge the extremes between individual onsite systems and centralized systems.

Septic tanks are installed at each house, and the septic tank effluent is then piped to a central location for treatment and dispersal.

- **Extending lines for municipal and public service district systems.** Collection systems for large, centralized systems can be extended in some locations to take on new customers that are now discharging wastewater through failing or nonexistent onsite systems.

When lots are near wetlands or floodplains, when there is shallow depth to bedrock or water table, or when soil percolation rates are slower than 1 hour/inch, the addition or modification of onsite systems is not feasible and an offsite solution must be found (LAI, 2005a).

For an extensive review of available wastewater treatment technologies, onsite and cluster systems, and wastewater management options, see Task 6 of the *Comprehensive Wastewater Management Plan for Fayette County* (LAI, 2005b).

4.3 Residential

Stormwater runs off from land more quickly when forests and fields are developed into impervious surfaces. Measures can be taken during the development or redevelopment process to promote infiltration of rainwater. One subwatershed must reduce fecal coliform loads by addressing residential runoff. Sources of runoff from residential areas include streets, lawns, driveways, and roofs (Bannerman, et al., 1993).

The following measures reduce stormwater runoff, resulting in a corresponding reduction in fecal coliform, as well as other pollutants.

- **Rain barrels.** Rain barrels collect runoff from downspouts and hold it for later use watering lawns, washing cars and clothes, and other purposes not requiring potable water.
- **French drains.** French drains are in-ground trenches that incorporate a perforated pipe to carry surface and groundwater to rain gardens, dry wells, or other appropriate outlets.
- **Rain gardens.** Rain gardens are planted areas designed to absorb storm runoff from impervious areas such as roofs and pavement. They tend to absorb about 30% more than typical lawns. Several factors should be considered when creating a rain garden, including proximity to septic systems, soil permeability, plant selection, and runoff volume (Kassulke, 2003).
- **Wetland protection.** Wetlands are a naturally existing way to reduce runoff and flooding. Preserving wetland areas in the vicinity of urban and residential development will buffer the effects of increased runoff from impervious surfaces.
- **Proper pet waste disposal.** While pet waste is rarely the primary source of fecal coliform, it is a contributor, and one that is easily addressed. Pet waste should be collected and disposed of in the garbage or in an in-ground composting pit designed for this purpose.
- **Terracing.** Terracing reduces runoff, conserves water, and allows for landscaping or gardening on steep slopes.
- **Tree planting.** Trees can act as windbreaks, help stabilize soil, and provide shade, reducing cooling costs in the summer.

5 LOAD REDUCTIONS AND COSTS

5.1 Agricultural areas

In Section 4.1, various measures are listed for both of these land use areas. In this section, we focus on the costs of nonpoint source agricultural measures. While the percent reductions for fecal coliform are smaller in the agricultural category than in the septic category, the net reduction is an order of magnitude greater for agricultural areas.

The TMDL targets twenty-four subwatersheds for fecal coliform reductions from pasture and cropland (Table 7). Reductions of greater than 75% are required in subwatersheds of Muddy Creek and Mill Creek; additionally, reductions of greater than 45% are required in the following subwatersheds: Mill Creek, UNT/Muddy Creek RM 15.94, Alum Rock Hollow, UNT/Hughart Creek RM 0.8, UNT/Hughart Creek RM 3.0, and Tater Run (Figure 7). The BMPs discussed above in Section 4.1 will contribute to the reduction of fecal coliform in agricultural areas.

In order to most effectively reduce fecal coliform in agricultural areas, it is necessary to keep livestock out of the streams and control runoff. Riparian buffers may accelerate and protect streambank stabilization efforts while filtering runoff from pastureland. Additional measures are often necessary when livestock are fenced away from streams. These include armored stream crossings and alternative watering sources. Table 8 presents unit cost estimates for armored fencing, riparian buffer establishment, stream crossings, alternative water sources, and waste storage systems.

Table 8: Estimated costs of best management practices associated with livestock exclusion from streams

Best management practice	Unit cost	Unit
Livestock fencing	$1.14	1 linear foot
Riparian buffer establishment	$1,000	1 acre
Armored stream crossing	$1,200	18” culvert, 20’ length
	$2,800	30” culvert, 30’ length
	$5,900	48” culvert, 40’ length
Alternative watering source	$3,000	Per watering best management practice
Animal waste storage system/relocation of feedlots with runoff control	~$75,000	Per storage system/feedlot relocation

Source: (Hardy, et al., 2007), (Meyer and Olsen, 2005), (USDA, 2008).

In order to estimate the total potential cost of livestock fencing and riparian buffer establishment, a GIS analysis was conducted to determine the acreage of agricultural land in the Muddy Creek watershed, as well as the linear feet of stream passing through agricultural land. Agricultural categories cover about 25,000 acres in the Muddy Creek watershed. Table 9 shows the length of stream that flows through pasture/grassland for subwatersheds requiring agricultural fecal coliform load reductions; the length of fencing required, assuming both sides of the stream would be fenced; the acres of riparian buffer to be constructed, assuming a 35-foot buffer on each side of the stream; the number of stream crossings, assuming one per 1,000 feet of stream; and the number of necessary alternative watering sources, assuming one per 1,000 feet of stream.

Table 9: Stream length through pasture land and associated best management practices

Stream	SWS	Stream feet through pasture	Maximum feet of fencing required	Acres of riparian buffer	Stream crossings	Alternative watering sources
Watersheds containing impaired streams						
Muddy Creek	2201	10,956	21,912	19.4	22	22
	2207	12,072	24,144	20.1	24	24
	2209	8,121	16,242	13.7	16	16
	2211	12,297	24,594	20.3	25	25
	2213	11,843	23,686	19.6	24	24
	2215	14,807	29,614	24.9	30	30
Mill Creek	2202	32,025	64,050	53.0	64	64
	2203	20,103	40,206	33.3	40	40
	2205	8,757	17,514	15.0	18	18
Kitchen Creek/Muddy Creek	2235	13,454	26,908	22.1	27	27
Sinking Creek	2226	2,258	4,516	4.5	5	5
	2227	10,451	20,902	17.8	21	21
	2230	5,583	11,166	10.1	11	11
Hughart Creek	2220	9,504	19,008	15.8	19	19
Other watersheds requiring reductions						
Raders Valley	2204	15,261	30,522	25.5	31	31
UNT/Muddy Creek RM 13.19	2212	3,607	7,214	6.1	7	7
UNT/Muddy Creek RM 15.94	2214	9,555	19,110	16.2	19	19
Renick Creek	2236	10,643	21,286	17.8	21	21
UNT/Kitchen Creek RM 7.83	2243	1,011	2,022	1.9	2	2
Alum Rock Hollow	2216	17,389	34,778	30.3	35	35
UNT/Hughart Creek RM 0.8	2219	5,330	10,660	8.9	11	11
UNT/Hughart Creek RM 3.0	2221	3,503	7,006	5.7	7	7
Tater Run	2222	26,645	53,290	44.8	53	53
UNT/Sinking Creek RM 13.1	2231	13,998	27,996	23.2	28	28
Total		**279,173**	**558,346**	**470.0**	**558**	**558**

Source: (Hardy, et al., 2007), (Meyer and Olsen, 2005), (Tetra Tech, 2008). SWS=subwatershed in the TMDL.

A fecal coliform load reduction efficiency of 70% is assumed for both fencing and riparian buffer best management practices (Chesapeake Bay Program, 2007). The riparian buffer and total reductions were calculated by assuming that of the 30% of sediment still reaching the stream after fencing is in place, 70% will be trapped by the addition of a riparian buffer, for a total reduction of 91%. Based on these efficiencies, potential reductions for each subwatershed are presented in Table 10.

Constructing fences and riparian buffers on all streams would result in exceedance of the TMDL reductions, as shown in Table 10.

Table 10: Fecal coliform load reductions by stream and agricultural best management practice (counts/year)

Stream	SWS	Required reduction	Reduction by fencing	Reduction by riparian buffer	Total reduction	Percent of required reduction
Watersheds containing impaired streams						
Muddy Creek	2201	7.16E+13	5.57E+13	1.67E+13	7.24E+13	101%
	2207	3.32E+13	2.67E+13	8.01E+12	3.47E+13	104%
	2209	7.10E+12	5.66E+12	1.70E+12	7.36E+12	104%
	2211	1.09E+13	1.01E+13	3.02E+12	1.31E+13	120%
	2213	3.58E+13	3.18E+13	9.53E+12	4.13E+13	116%
	2215	4.19E+12	1.19E+13	3.57E+12	1.55E+13	369%
Mill Creek	2202	4.21E+13	3.28E+13	9.84E+12	4.26E+13	101%
	2203	1.91E+13	1.49E+13	4.46E+12	1.93E+13	101%
	2205	6.57E+12	9.26E+12	2.78E+12	1.20E+13	183%
Kitchen Creek/Muddy Creek	2235	4.20E+12	1.10E+13	3.29E+12	1.43E+13	340%
Sinking Creek	2226	2.50E+11	1.12E+12	3.35E+11	1.45E+12	580%
	2227	4.30E+11	2.77E+12	8.32E+11	3.60E+12	838%
	2230	1.25E+12	5.02E+12	1.51E+12	6.53E+12	522%
Hughart Creek	2220	3.40E+11	2.51E+12	7.54E+11	3.27E+12	961%
Other watersheds requiring reductions						
Raders Valley	2204	3.17E+12	1.23E+13	3.68E+12	1.59E+13	503%
UNT/Muddy Creek RM 13.19	2212	1.00E+12	1.79E+12	5.37E+11	2.33E+12	233%
UNT/Muddy Creek RM 15.94	2214	1.55E+13	1.73E+13	5.18E+12	2.24E+13	145%
Renick Creek	2236	3.90E+12	9.03E+12	2.71E+12	1.17E+13	301%
UNT/Kitchen Creek RM 7.83	2243	5.60E+11	1.56E+12	4.68E+11	2.03E+12	362%
Alum Rock Hollow	2216	1.25E+13	1.78E+13	5.33E+12	2.31E+13	185%
UNT/Hughart Creek RM 0.8	2219	3.51E+12	5.01E+12	1.50E+12	6.51E+12	185%
UNT/Hughart Creek RM 3.0	2221	1.94E+12	2.74E+12	8.21E+11	3.56E+12	183%
Tater Run	2222	7.60E+12	1.13E+13	3.40E+12	1.47E+13	194%
UNT/Sinking Creek RM 13.1	2231	1.45E+13	1.83E+13	5.50E+12	2.38E+13	164%
Total		**3.01E+14**	**3.18E+14**	**9.55E+13**	**4.14E+14**	**251%**

Source: Required reductions from Tetra Tech (2008). Reduction efficiencies from Chesapeake Bay Program (2007). SWS=subwatershed in the TMDL. UNT=unnamed tributary. RM=river mile.

Table 11 shows the estimated costs of fencing, riparian buffer, stream crossings, and alternative watering sources. Because some parcels may already be fenced and other parcels may not be active pastureland, the cost estimates should be considered an upper bound. The total cost is based on developing BMPs for every stream through pasture/cropland. As mentioned above, implementing the full set of BMPs would exceed TMDL reductions. These exceedances were used to estimate the minimum cost to meet the TMDL.

To develop more precise cost estimates for agricultural areas, it will be necessary to initiate a process with agencies and local organizations that interface with the agricultural community.

Table 11: Estimated costs of best management practices by stream

Watershed name	SWS	Fencing	Riparian buffer	Stream crossings	Alternative watering sources	Total cost	Cost to meet TMDL
Watersheds containing impaired streams							
Muddy Creek	2201	$43,824	$129,281	$65,736	$19,365	$258,206	$255,334
	2207	$48,288	$142,450	$72,432	$20,075	$283,244	$271,127
	2209	$32,484	$95,828	$48,726	$13,744	$190,782	$184,112
	2211	$49,188	$145,105	$73,782	$20,309	$288,384	$239,376
	2213	$47,372	$139,747	$71,058	$19,594	$277,771	$240,362
	2215	$59,228	$174,723	$88,842	$24,885	$347,678	$94,112
Mill Creek	2202	$128,100	$377,895	$192,150	$52,962	$751,107	$741,781
	2203	$80,412	$237,215	$120,618	$33,274	$471,519	$465,585
	2205	$35,028	$103,333	$52,542	$14,997	$205,900	$112,395
Kitchen Creek/Muddy Creek	2235	$53,816	$158,757	$80,724	$22,061	$315,358	$54,352
Sinking Creek	2226	$9,032	$26,644	$13,548	$4,507	$53,731	$15,826
	2227	$41,804	$123,322	$62,706	$17,812	$245,644	$29,311
	2230	$22,332	$65,879	$33,498	$10,103	$131,812	$25,230
Hughart Creek	2220	$38,016	$112,147	$57,024	$15,840	$223,028	$23,211
Other watersheds requiring reductions							
Raders Valley	2204	$61,044	$180,080	$91,566	$25,524	$358,214	$71,224
Raders Valley	2212	$14,428	$42,563	$21,642	$6,085	$84,717	$36,422
UNT/Muddy Creek RM 13.19	2214	$38,220	$112,749	$57,330	$16,194	$224,493	$155,316
UNT/Muddy Creek RM 15.94	2236	$42,572	$125,587	$63,858	$17,779	$249,796	$82,989
Renick Creek	2243	$4,044	$11,930	$6,066	$1,889	$23,929	$6,603
UNT/Kitchen Creek RM 7.83	2216	$69,556	$205,190	$104,334	$30,348	$409,428	$221,715
Alum Rock Hollow	2219	$21,320	$62,894	$31,980	$8,940	$125,134	$67,467
UNT/Hughart Creek RM 0.8	2221	$14,012	$41,335	$21,018	$5,674	$82,039	$44,738
UNT/Hughart Creek RM 3.0	2222	$106,580	$314,411	$159,870	$44,799	$625,660	$322,643
Tater Run	2231	$55,992	$165,176	$83,988	$23,194	$328,351	$200,114
Total		**$1,116,692**	**$3,294,241**	**$1,675,038**	**$469,952**	**$6,555,924**	**$3,961,347**

Source: Downstream Strategies calculations based on data in Table 8 and Table 9. SWS=subwatershed in the TMDL.

5.2 Onsite sewer systems

The TMDL targets every subwatershed within the Muddy Creek watershed for 100% reductions of fecal coliform loads from onsite sewer systems (Table 7).

As discussed in Section 4.2, possible solutions include replacing or repairing onsite systems, upgrading UIC permitted systems, installing cluster systems, and extending lines for municipal and public service district systems.

Table 12 presents initial installation and annual maintenance costs for various components of these wastewater treatment options. Individual site conditions (soil type, depth to bedrock or water table) and location (proximity to other homes and to municipal systems) will determine the most appropriate solution for each site.

Table 12: Estimated costs of treatment systems

Technology	Includes installation and:	Initial cost per house	Annual cost per house
Individual onsite systems			
New individual onsite septic system, traditional drain field	New tank and drain field	$5,000	$50
Septic tank		$1,000	
Alternative systems			
Textile filter		$11,000	$240
Peat filter		$8,500	$240
Recirculating sand filter		$7,000	$240
Sand filter-single pass		$2,500	$240
UV treatment	Home-sized unit	$800	$150
Drain field	Area 0.2 gallons/ft^2 for individual home	$2,500	
Drip field	For individual home	$8,000	
Low pressure pipe	For individual home	$5,000	
Recirculating sand filter with direct discharge	For individual home	$5,040	$200
Cluster systems			
Package plant with direct discharge	Treatment plant only	$2,800	$425
Septic tank effluent pump (STEP) system	New septic tank with street-side hookup	$9,000	$180
Septic tank effluent discharge (or drain) (STED) system	New septic tank with street-side hookup	$6,000	$50
Vacuum valve pit	Valve pit can handle 2-4 homes	$2,000	$50
Vacuum collection station		$325,000	
Centralized system hook-ups			
Connection tap fee		$300	
8" Line installed per foot	Includes manholes, no lift station	$100	
4" Line installed per foot		$50	

Source: WTCMC et al (Undated).

According to the TMDL, there are 3,311 structures beyond the reaches of public sewers in the Muddy Creek watershed (Tetra Tech, 2008). For the purposes of modeling fecal coliform baseline loads, the TMDL assumes that 54% (1,788) of these structures are occupied homes. Table 13 presents the number of homes by subwatershed and likelihood of septic failure.

Table 13: Modeled septic failure of homes by subwatershed

Subwatershed	SWS	Homes by likelihood of septic failure				
		Very Low	Low	Medium	High	Total
Muddy Creek	2201		136		26	163
	2207				29	29
	2209				14	14
	2211				15	15
	2213				15	15
	2215		2		21	23
	2217		16		1	16
Mill Creek	2202		3		37	68
	2203		97			97
	2205		17			107
Raders Valley	2204		32			32
UNT/Mill Creek RM 7.04	2206		23			23
UNT/Muddy Creek RM 8.6	2208			1	12	13
Beech Run	2210				8	8
UNT/Muddy Creek RM 13.19	2212				4	4
UNT/Muddy Creek RM 15.94	2214		95		21	115
Alum Rock Hollow	2216		143	49		192
UNT/Muddy Creek RM 19.8	2218		31			31
UNT/Hughart Creek RM 0.8	2219		9	26		35
Hughart Creek	2220		15			15
	2223		1	2		3
	2225		22	1		23
UNT/Hughart Creek RM 3.0	2221		9	7		16
Tater Run	2222		95	17		112
Roach Run	2224			11		11
Sinking Creek	2226		78			78
	2227		21			21
	2230		153	2		156
	2232		1			1
	2234	2		6		8
Stony Run	2228		45	5		51
UNT/Sinking Creek RM 11.2	2229		9	1		9
UNT/Sinking Creek RM 13.1	2231		24	14		37
Flynn Creek	2233	3		2		5
Kitchen Creek/Muddy Creek	2235				11	11
	2238			9		9
	2240			22		22
	2242			3		3
	2244			16		16
Renick Creek	2236		6	49		55
Snake Run	2237			66		66
Sawmill Hollow	2239			38		38
UNT/Kitchen Creek RM 6.59	2241			8		8
UNT/Kitchen Creek RM 7.83	2243			16		16
Total		**4**	**1,198**	**372**	**214**	**1,788**

Source:(Tetra Tech, 2008). SWS=subwatershed in the TMDL.

The TMDL then assigns rates to each septic failure zone—both for seasonal and complete failure. These percentages are presented in Table 14, and are then used in Table 15 to calculate the number of homes with failing septic systems and the cost to repair these units.

Table 14: Modeled percentages of homes with failing septic systems

Type	Seasonal failure	Complete failure	Seasonal or complete failure
Very Low	3	5	8
Low	7	10	17
Medium	13	24	37
High	19	28	47

Source:(Tetra Tech, 2008). SWS=subwatershed in the TMDL.

Assuming a per-system repair/replacement cost of $10,000 (LAI, 2005c, p 6), the total estimated cost to repair all seasonally and completely failing septic systems in the Muddy Creek watershed is $4.42 million (Table 16).

Table 15: Modeled septic failure of homes by subwatershed

Subwatershed	SWS	Homes experiencing septic failure			
		Low	Medium	High	Total
Muddy Creek	2201	23		12	36
	2207			13	13
	2209			7	7
	2211			7	7
	2213			7	7
	2215			1	1
	2217	3			3
Mill Creek	2202	5		18	23
	2203	16			16
	2205	18			18
Raders Valley	2204	5			5
UNT/Mill Creek RM 7.04	2206	4			4
UNT/Muddy Creek RM 8.6	2208			6	6
Beech Run	2210			4	4
UNT/Muddy Creek RM 13.19	2212			2	2
UNT/Muddy Creek RM 15.94	2214	16		1	26
Alum Rock Hollow	2216	24	18		43
UNT/Muddy Creek RM 19.8	2218	5			5
UNT/Hughart Creek RM 0.8	2219	1	1		11
Hughart Creek	2220	2			2
	2223		1		1
	2225	4			4
UNT/Hughart Creek RM 3.0	2221	2	3		4
Tater Run	2222	16	6		22
Roach Run	2224		4		4
Sinking Creek	2226	13			13
	2227	3			3
	2230	26	1		27
	2232				
	2234		2		2
Stony Run	2228	8	2		1
UNT/Sinking Creek RM 11.2	2229	1			2
UNT/Sinking Creek RM 13.1	2231	4	5		9
Flynn Creek	2233		1		1
Kitchen Creek/Muddy Creek	2235			5	5
	2238		3		3
	2240		8		8
	2242		1		1
	2244		6		6
Renick Creek	2236	1	18		19
Snake Run	2237		25		25
Sawmill Hollow	2239		14		14
UNT/Kitchen Creek RM 6.59	2241		3		3
UNT/Kitchen Creek RM 7.83	2243		6		6
Total		**204**	**138**	**101**	**442**

According to the model, there are no failing septic systems in the Very Low septic failure zones. SWS=subwatershed in the TMDL.

Table 16: Septic system upgrade costs by subwatershed

Subwatershed	SWS	Low	Medium	High	Total
Muddy Creek	2201	$240,000	$0	$120,000	$360,000
	2207	$0	$0	$130,000	$130,000
	2209	$0	$0	$70,000	$70,000
	2211	$0	$0	$70,000	$70,000
	2213	$0	$0	$70,000	$70,000
	2215	$0	$0	$100,000	$100,000
	2217	$30,000	$0	$0	$30,000
Mill Creek	2202	$50,000	$0	$170,000	$220,000
	2203	$170,000	$0	$0	$170,000
	2205	$180,000	$0	$0	$180,000
Raders Valley	2204	$50,000	$0	$0	$50,000
UNT/Mill Creek RM 7.04	2206	$40,000	$0	$0	$40,000
UNT/Muddy Creek RM 8.6	2208	$0	$0	$50,000	$50,000
Beech Run	2210	$0	$0	$40,000	$40,000
UNT/Muddy Creek RM 13.19	2212	$0	$0	$20,000	$20,000
UNT/Muddy Creek RM 15.94	2214	$160,000	$0	$100,000	$260,000
Alum Rock Hollow	2216	$240,000	$180,000	$0	$420,000
UNT/Muddy Creek RM 19.8	2218	$50,000	$0	$0	$50,000
UNT/Hughart Creek RM 0.8	2219	$20,000	$90,000	$0	$110,000
Hughart Creek	2220	$20,000	$0	$0	$20,000
	2223	$0	$10,000	$0	$10,000
	2225	$40,000	$0	$0	$40,000
UNT/Hughart Creek RM 3.0	2221	$20,000	$30,000	$0	$50,000
Tater Run	2222	$160,000	$60,000	$0	$220,000
Roach Run	2224	$0	$40,000	$0	$40,000
Sinking Creek	2226	$130,000	$0	$0	$130,000
	2227	$30,000	$0	$0	$30,000
	2230	$260,000	$10,000	$0	$270,000
	2232	$0	$0	$0	$0
	2234	$0	$30,000	$0	$30,000
Stony Run	2228	$80,000	$20,000	$0	$100,000
UNT/Sinking Creek RM 11.2	2229	$20,000	$0	$0	$20,000
UNT/Sinking Creek RM 13.1	2231	$40,000	$50,000	$0	$90,000
Flynn Creek	2233	$0	$10,000	$0	$10,000
Kitchen Creek/Muddy Creek	2235	$0	$0	$50,000	$50,000
	2238	$0	$30,000	$0	$30,000
	2240	$0	$80,000	$0	$80,000
	2242	$0	$10,000	$0	$10,000
	2244	$0	$60,000	$0	$60,000
Renick Creek	2236	$10,000	$180,000	$0	$190,000
Snake Run	2237	$0	$250,000	$0	$250,000
Sawmill Hollow	2239	$0	$140,000	$0	$140,000
UNT/Kitchen Creek RM 6.59	2241	$0	$30,000	$0	$30,000
UNT/Kitchen Creek RM 7.83	2243	$0	$60,000	$0	$60,000
Total		**$2,040,000**	**$1,370,000**	**$1,010,000**	**$4,420,000**

SWS=subwatershed in the TMDL.

5.3 Residential area runoff

Subwatershed 2201, at the mouth of Muddy Creek, requires a 50% reduction in fecal coliform from residential stormwater runoff. This can be achieved by educating the public and implementing some of the practices outlined in section 4.3. Aside from the education/outreach component, some of these practices—proper pet waste disposal and wetland protection, for example—can be cost-free on private lands. Cost estimates for other practices are provided in Table 17 (Schueler, et al., 2007, p 134).

Table 17: Estimated costs of select stormwater management techniques (in 2006 dollars per cubic foot treated)

Rooftop retrofit technique	Median cost	Range	Design & engineering (%)
Rain barrel[1]	$25.00	$12.50 to $40.00	5
French drain/drywell[2]	$12.00	$10.50 to $13.50	5
Owner-installed rain garden	$4.00	$3.00 to $5.00	5
Professionally-installed rain garden	$10.00	$5.00 to $10.00	32

1. Average cost for eight cubic foot barrel serving one typical roof leader.
2. Three foot deep stone trench serving two roof leaders.
Source: Modified from Table 2 (Schueler, et al., 2007, p 134).

The reduction in fecal coliform from residential runoff is only 0.25% of the total reductions required in the watershed and the reductions are only required in one of 44 subwatersheds. Furthermore, coarse delineation of the subwatersheds in the TMDL appears to have resulted in a higher estimate of developed land than actually drains to Muddy Creek. For these reasons, this report recommends that efforts be focused on projects with greater potential impact on fecal coliform reduction. Therefore, residential runoff costs are not included in the total cost estimate. The issue of residential runoff will be revisited in the course of the comprehensive watershed plan.

5.4 Total cost for all remediation efforts

Based on the calculations in Table 11 and Table 16, the total estimated cost to meet the fecal coliform TMDL in the Muddy Creek watershed is 8.2 million dollars.

6 TECHNICAL AND FINANCIAL ASSISTANCE

Technical assistance is needed for the following tasks related to fecal coliform bacteria:

- collecting data at bacteria sources in preparation for the design and implementation of remediation projects;
- creating conceptual designs of remediation projects;
- creating detailed engineering designs of remediation projects;
- performing project management, including putting projects out for bid, managing projects, and tracking their progress,
- monitoring instream and source water quality following the installation of remediation projects to document their effectiveness, and
- managing decentralized onsite systems after installation.

A combination of federal and state agencies, academic institutions, watershed organizations, consultants, and citizens will be involved in providing technical and financial assistance for Muddy Creek watershed projects. Specific technical and financial resources are provided for fecal coliform reductions from pasture/cropland and onsite sewer systems.

6.1 Pasture/Cropland

6.1.1 West Virginia Department of Environmental Protection

The Division of Water and Waste Management provides technical assistance for the use of BMPs, educates the public and land users on nonpoint source issues, enforces water quality laws that affect nonpoint sources, and restores impaired watersheds through its Nonpoint Source Program (WVDEP, 2009). Once a watershed-based plan is approved for Muddy Creek, the watershed will be eligible for funds from the 319 program through the USEPA. These grants can be used to help implement nonpoint source pollution control projects such as those that address fecal coliform. A 40% match is required.

6.1.2 Stream Partners Program

The Stream Partners Program offers grants of up to $5,000 to watershed organizations in West Virginia. Grants can be used for range of projects including small watershed assessments and water quality monitoring, public education, stream restoration, and organizational development. Stream Partners grants may be pursued in the future to compliment nonpoint source research, education, and reclamation projects in the watershed.

6.1.3 Local governments

Greenbrier County will be approached to provide in-kind support for Muddy Creek. The County may also be approached to support and enforce ordinances related to stormwater management that have the potential for reducing the fecal coliform impairment in Muddy Creek.

6.1.4 West Virginia Conservation Agency

The West Virginia Conservation Agency (WVCA) provides support to local watershed organizations across West Virginia. WVCA helps coordinate and implement 319 projects, especially those related to agriculture and streambank stabilization.

The Greenbrier Valley Conservation District (GVCD), a division of WVCA, has several programs specifically for the Greenbrier River and its tributaries. These programs include a cost-share program to eradicate multiflora rose, and a pilot program to increase productivity while conserving resources and improving water quality (WVCA, 2009).

6.1.5 US Department of Agriculture/Natural Resources Conservation Service Farm Bill Programs

There are several US Department of Agriculture (USDA)/ Natural Resources Conservation Service (NRCS) programs with relevance to the Muddy Creek watershed. These programs can help address fecal coliform impairments in Muddy Creek by establishing riparian buffers, protecting wetlands, and conserving water resources.

The voluntary Wildlife Habitat Incentives Program (WHIP) provides funds to private landholders who wish to devote some of their land to the development of habitat areas. Wildlife habitat may include upland, wetland, riparian, and aquatic habitat. The projects must target a specific species for habitat improvement, generally require an agreement of 5-10 years, and offer up to 75% cost-share assistance.

The Environmental Quality Incentives Program (EQIP) has a stated goal of promoting agricultural production while maintaining or improving environmental quality. The program provides payments of up to 75% of project costs and associated foregone income. Specific priorities to be addressed are:

- Impaired water quality;
- Conservation of ground and surface water resources;
- Improvement of air quality;
- Reduction of soil erosion and sedimentation; and
- Improvement or creation of wildlife habitat for at-risk species (USDA, 2009b).

One specific sub-program of EQIP is the Agricultural Water Enhancement Program (AWEP). AWEP provides technical and financial assistance to help farmers plan and implement projects aiming to conserve water and improve water quality.

The Wetlands Reserve Program (WRP) is a source of support for farmers who are willing to retire marginal farmland acreage in order to restore, protect, or enhance wetland areas. Program options include permanent and 30-year easements, and easement-free restoration. (USDA, 2007)

Technical service providers are certified by NRCS to provide technical assistance to farmers who have received funding for NRCS conservation projects.

Some landowners may be interested in participating in the NRCS floodplain easement purchase program. Through the Emergency Watershed Protection Program, the NRCS purchases floodplain easements for active restoration. The original landowner retains the right to control public access to the property and to use the easement for undeveloped recreational uses (USDA, 2009a).

6.1.6 Farm Service Agency

The Conservation Reserve Enhancement Program (CREP) is a voluntary program in which landholders agree to retire some portion of their land from agricultural production for a period of 10-15 years. Eligible land includes cropland or marginal pasture land that has been owned and operated for at least a year and that demonstrates a need, such as wildlife habitat restoration or erosion control. The government pays the rental value of the retired land plus $100/acre, as well as some portion of the costs for necessary improvements. If the project includes active restoration (as opposed to natural regeneration), a cost-share incentive is offered. CREP enrollment is limited to specific geographic areas and practices; therefore, communication with the Greenbrier County Farm Service Agency will be required to confirm whether these funds can be used in the Muddy Creek watershed.

6.1.7 Partners for Fish and Wildlife

The Partners for Fish and Wildlife Program is sponsored by the United States Fish and Wildlife Service. This voluntary program primarily involves streambank fencing, tree-planting, and invasive species control. The United States Fish and Wildlife Service offers technical and financial assistance to conserve or restore native ecosystems.

6.1.8 Resident participants

Voluntary contributions, both monetary and in-kind, from watershed residents will be used to meet match requirements for other fund sources.

6.1.9 Private developers

As the Muddy Creek watershed develops, private developers will play a key role in determining the biological impacts that will result from their actions. Partnerships with developers will likely be important for maintaining and improving the biological health of the creek.

6.2 Onsite sewer systems

6.2.1 Section 319 funds

Clean Water Act Section 319 funds may be available for reclamation of nonpoint sources of fecal coliform bacteria. This watershed-based plan is being developed so that these funds can be allocated to the Muddy Creek watershed. WVDEP's Nonpoint Source Program will determine whether or not funds will be allocated to Muddy Creek for projects addressing fecal coliform bacteria pollution (WVDEP, 2009).

6.2.2 Local governments

Greenbrier County will be approached to provide in-kind support for Muddy Creek. The County may also be approached to support and enforce ordinances related to stormwater management that have the potential for reducing the fecal coliform impairment in Muddy Creek.

6.2.3 Onsite System Loan Program

The West Virginia Housing Development Fund has partnered with WVDEP to make this low-interest available to home owners and those on long-term leases. Loans of up to $10,000 are to be used to replace or repair existing septic tanks or to connect to a public water treatment system.

6.2.4 Section 504 very low-income housing repair program

This loan and grant program through USDA's Rural Development office is available for rural homeowner-occupants who earn less than 50% of the area median income. The low-interest loans are to be used specifically to render the home more safe or sanitary. Homeowners over 62 years old may be eligible for grants.

6.2.5 Additional funding sources

A number of funding source may be pursued to install and repair onsite and centralized wastewater treatment systems including:

- Clean Water State Revolving Funds,
- Housing and Urban Development Small Cities Block Grants,
- Appalachian Regional Commission funds,
- special appropriations from the United States Congress,
- USDA Rural Utility Service funds,
- funds from a private purveyor of wastewater treatment services interested in an operations and maintenance contract on the system. (LAI, 2005c)

6.3 Residential

Again, reductions from residential use are minor, and thus a low priority. As described in Section 5.3, most of the techniques to abate residential runoff are low-cost. Education and outreach efforts will be integrated into current programs organized by FOTLGR.

7 PAST AND CURRENT PROJECTS

7.1 Kitchen Creek streambank stabilization

In 2008, a project was implemented in Kitchen Creek to address streambank erosion. The project was sponsored by numerous state and federal agencies and implemented with the help of the landowner. There were multiple facets to the project in the areas of livestock exclusion and streambank work.

A total of 2.5 acres was designated for livestock exclusion. To this end, more than 2,800 feet of fencing were installed along the stream in accordance with CREP guidelines. Additionally, one stream crossing was installed for the livestock and an alternate watering source for livestock was developed onsite by drilling a well and providing a two watering troughs.

The project also included approximately 1,800 feet of stream work. This involved grading the slope of the streambank in four locations; temporarily stabilizing the banks with straw erosion-control blankets; and planting these areas with grass and dogwood, ironwood, and elderberry trees for long-term stabilization (Figure 11). Two log veins were installed to create riffles and pools, redirecting flow away from the eroding bank. Additionally, the project addresses erosion around a bridge by using large boulders to reinforce the bank immediately downstream of the bridge.

In 2009, the project site was revisited; additional fencing was installed and riparian areas re-vegetated on a small portion of a tributary upstream of the initial work that was experiencing erosion problems.

Figure 11: Kitchen Creek stabilization project, before and after

8 IMPLEMENTATION SCHEDULE, MILESTONES AND MEASURABLE GOALS

The measurable goal for fecal coliform is to meet the instream water quality criterion. Partnerships will be formed, projects implemented, and receiving streams monitored. Implementing the Muddy Creek watershed-based plan will involve a concerted effort by the local watershed organizations, GVCD, WVDEP, and the watershed community. Successful implementation will require a variety of skill sets and interests. These can include, but are not limited to project management, technical analyses, facilitation, public relations, heavy machinery operation, and manual labor. The key is to pull all of these talents to the table; this will help to ensure a positive and productive implementation process.

Developing partnerships with existing groups is essential. In Muddy Creek, GVCD and others have begun to develop projects and implement load reductions on a numbers of streams. In order to meet water quality standards, a significant effort must be placed on planning, creating milestones and measurable goals, developing a timeline, and creating a process for measuring progress. All of these practices take significant effort for all interested parties; this plan represents a living document, a guidance manual to achieve a clean watershed.

Each section below describes the implementation plan and approach for each type of pollution reduction. It is important that representatives from all agencies working in the watershed coordinate with one another for efficient use of project resources.

8.1 Pasture/Cropland

8.1.1 Step 1: Form partnerships with agriculture agencies and organizations, local businesses, farmers, and watershed residents

The first step in addressing fecal coliform discharges from agricultural land will be to form strong partnerships with agriculture agencies and organizations such as the Natural Resources Conservation Service, GVCD, Farm Service Agency, Farm Bureau, and other organizations that have a significant stake in the Muddy Creek and lower Greenbrier River Watershed. These entities are already actively working with farmers on projects that often involve environmental improvements, including stream bank restoration and fencing projects.

A crucial step in the process is to identify and engage relevant stakeholders in the watershed community. The success of the project depends on the willingness of residents to partake in the planning process and begin to develop projects on their property. Having a TMDL that is focused solely on fecal coliform requires that the planning process integrate the stakeholders through the watershed planning process and address their particular needs—while also addressing water quality issues.

This process has already begun; the watershed association sponsored a watershed community meeting which drew over 60 residents, agency members, and interested people. Over 20 watershed residents completed a survey that inquired about certain land use issues and interest in participating in any type of conservation project. GVCD has begun to perform site visits to assess the project feasibility and interest. This process will continue and the plan will be used as a management and funding mechanism for those potential projects.

Project implementation will depend heavily upon landholder interest, but subwatersheds will be preferentially targeted based on the net reduction in fecal coliform from agricultural runoff as calculated from the TMDL. The top ten priority subwatersheds are shown in Table 18. This prioritization is reflected in the schedule proposed in Section 8.4.

Table 18: Ranked subwatersheds for agricultural best management practices

SWS	Stream Name	Stream Code	Agricultural load reduction (counts/yr)	Rank
2201	Muddy Creek	WVKNG-22	7.16E+13	1
2202	Mill Creek	WVKNG-22-A	4.21E+13	2
2213	Muddy Creek	WVKNG-22	3.58E+13	3
2207	Muddy Creek	WVKNG-22	3.32E+13	4
2203	Mill Creek	WVKNG-22-A	1.91E+13	5
2214	UNT/Muddy Creek RM 15.94	WVKNG-22-C.1	1.55E+13	6
2231	UNT/Sinking Creek RM 13.1	WVKNG-22-E-1-A.9	1.45E+13	7
2216	Alum Rock Hollow	WVKNG-22-D	1.25E+13	8
2211	Muddy Creek	WVKNG-22	1.09E+13	9
2222	Tater Run	WVKNG-22-E-1-A-1-(S)	7.60E+12	10

SWS=subwatershed in the TMDL.

8.1.2 Step 2: Develop and implement projects

Based on partnerships, interest, and rank, specific farm land projects will be planned and developed that will reduce fecal coliform loads. This process will involve communication with farmers and will also require soliciting funding. An initial public meeting was held April 23, 2009 at the Asbury community center on Route 12. This meeting reviewed what a watershed based plan is and recruited land owners to participate. As mentioned above, 20 residents filled out surveys and are interested in developing projects on their property. GVCD has begun the process of making site visits to these interested watershed residents. The watershed association will collaborate with GVCD and other entities to develop and implement projects throughout the Muddy Creek watershed. Some funding sources such as Section 319 funds may cover a range of projects, while other sources such as Farm Bill programs will be focused on specific farms. Initial project development is likely to start in the fall of 2009, with the goal of implementing projects by the summer of 2011.

8.1.3 Step 3: Conduct monitoring to evaluate progress

Monitoring will be required to confirm baseline fecal coliform levels in receiving streams, and to evaluate the effectiveness of agricultural BMP projects. Recommendations for subsequent projects will be based on the success of initial projects. Monitoring will continue until data for an entire year show that water quality standards are being met for fecal coliform. This monitoring process is explained in more detail in Section 9.

8.2 Onsite sewer systems

8.2.1 Step 1: Create an inventory of onsite systems

A detailed inventory and database of onsite septic systems will be necessary before final decisions can be made as to the most effective septic system solutions. In combination with water quality monitoring, this will allow for the prioritization of communities targeted for upgrades. A preliminary ranking has been established based on the significance of potential reductions by subwatershed. Once the plan is implemented, individual land owners will be contacted and a survey will be performed to gather support for onsite wastewater system repair.

Table 19 lists the top ten subwatersheds for onsite wastewater treatment repair or replacement. This ranking is based on baseline loads presented in the TMDL.

Table 19: Ranked subwatersheds for onsite septic replacement or repair

SWS	Stream Name	Stream Code	Baseline load (counts/yr)	Rank
2216	Alum Rock Hollow	WVKNG-22-D	5.93E+11	1
2201	Muddy Creek	WVKNG-22	4.89E+11	2
2230	Sinking Creek	WVKNG-22-E-1-(S)	3.69E+11	3
2214	UNT/Muddy Creek RM 15.94	WVKNG-22-C.1	3.53E+11	4
2237	Snake Run	WVKNG-22-C-2	3.50E+11	5
2202	Mill Creek	WVKNG-22-A	3.12E+11	6
2222	Tater Run	WVKNG-22-E-1-A-1-(S)	3.12E+11	7
2236	Renick Creek	WVKNG-22-C-1	2.70E+11	8
2205	Mill Creek	WVKNG-22-A	2.49E+11	9
2203	Mill Creek	WVKNG-22-A	2.26E+11	10

SWS=subwatershed in the TMDL.

8.2.2 Step 2a: Repair/replace existing onsite systems

The onsite inventory will help to identify systems in need of repair and replacement. Some of these systems will likely be candidates for alternative individual systems or cluster systems. It is expected that these efforts will begin in 2009, after the onsite inventory is completed.

8.2.3 Step 2b: Extend municipal sewer system

One potential solution to some of the failing septic systems is to extend public sewer service. The feasibility of this option still needs to be evaluated in the Muddy Creek watershed.

8.3 Residential

As mentioned in section 5.3, residential runoff contributing to fecal coliform loads is rather insignificant in this watershed, and thus projects in this sector are not a priority. However, an outreach and education program could consist of workshops sponsored by FOTLGR that will promote practices to reduce residential runoff. As part of the comprehensive plan, a more refined delineation of residential areas will be established, allowing for a more focused strategy.

8.4 Schedule

Table 20 consolidates the milestones and goals set forth in Sections 8.1 and 8.2. Water quality monitoring as specified in Section 9.2 will continue through this time period. Community outreach will also be an ongoing effort.

Subwatersheds were prioritized for projects based on their potential contribution to the necessary reductions in fecal coliform.

Reductions presented in Table 7 were used to calculate the cumulative percent attainment of fecal coliform load reductions required by the TMDL for the entire Muddy Creek watershed.

Table 20: Implementation schedule and reductions for fecal coliform

Year	Planning Goals	Pasture Cropland Action	Onsite wastewater Treatment Action	Percent Attainment
2009	• Develop EPA Approvable watershed-based plan • Form partnerships • Hold at least two watershed meetings with stakeholders • Begin to Develop a ***Comprehensive Watershed Plan (CWP)*** for the Muddy Creek Watershed • Secure office space	• Identify watershed residents interested in developing projects • Identify riparian owners in Muddy Creek watershed and mail a survey • Develop one conceptual project based on project participation	• Develop information and public education materials about onsite wastewater management • Identify residents wanting to participate in onsite system repair	-
2010	• Publish a ***State of the Watershed*** document • Define a **Vision** for the watershed • Identify other issues in the watershed • Hire VISTA volunteer • Hire FOTLGR Executive Director • Publish ***CWP***	• Develop conceptual projects designs for first round of projects in SWS 2201 and 2202. • Write proposals for 319 funding of projects	• Inventory actual onsite wastewater treatment systems projects. • Repair/replace onsite systems in SWS 2216, 2201, and 2230	0%

Year	Planning Goals	Pasture Cropland Action	Onsite wastewater Treatment Action	Percent Attainment
2011	• Implement ***CWP*** • Develop GIS-based watershed management system • Develop water quality monitoring program	• Implement first round of projects		37%
2012		• Develop conceptual projects designs for second round of projects in SWS 2207 and 2213 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2214, 2237, and 2202	38%
2013		• Implement second round of projects		60%
2014		• Develop conceptual projects designs for third round of projects in SWS 2203 and 2214 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2222, 2236, and 2205	60%
2015		• Implement third round of projects		72%
2016		• Develop conceptual projects designs for fourth round of projects in SWS 2231 and 2216 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2203, 2239, and 2207	72%
2017		• Implement fourth round of projects		81%
2018		• Develop conceptual projects designs for fifth round of projects in SWS 2211 and 2222 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2226, 2219, and 2215	81%
2019		• Implement fifth round of projects		87%
2020		• Develop conceptual projects designs for sixth round of projects in SWS 2209 and 2205 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2228, 2231, and 2240	87%
2021		• Implement sixth round of projects		91%
2022		• Develop conceptual projects designs for seventh round of projects in SWS 2235 and 2215 • Write proposals for 319 funding of projects	• Repair/replace onsite systems in SWS 2211, 2213, and 2209	91%
2023		• Implement seventh round of projects		94%

Year	Planning Goals	Pasture Cropland Action	Onsite wastewater Treatment Action	Percent Attainment
2024		- Develop conceptual projects designs for eighth round of projects in SWS 2236 and 2219 - Write proposals for 319 funding of projects	- Repair/replace onsite systems in SWS 2243, 2244, and 2208	94%
2025		- Implement eighth round of projects		97%
2026		- Develop conceptual projects designs for ninth round of projects in SWS 2204 and 2221 - Write proposals for 319 funding of projects	- Repair/replace onsite systems in SWS 2204, 2218, and 2235	97%
2027		- Implement ninth round of projects		98%
2028		- Develop conceptual projects designs for tenth round of projects in SWS 2230 and 2212 - Write proposals for 319 funding of projects	- Repair/replace onsite systems in SWS 2221, 2225, 2206, 2210,2238, and 2224	98%
2029		- Implement tenth round of projects		99%
2030		- Develop conceptual projects designs for eleventh round of projects in SWS 2243 and 2227 - Write proposals for 319 funding of projects	- Repair/replace onsite systems in SWS 2227, 2217, 2241, 2234, 2220, and 2212	99%
2031		- Implement eleventh round of projects		100%
2032		- Develop conceptual projects designs for twelfth round of projects in SWS 2220 and 2226 - Write proposals for 319 funding of projects	- Repair/replace onsite systems in SWS 2229, 2242, 2233, 2223, and 2232	100%
2033		- Implement twelfth round of projects		100%

9 MONITORING

Instream monitoring is important to gage the recovery of streams after remediation projects are installed, and is also crucial to support partners as they engage in periodic strategic planning of reclamation priorities.

9.1 Quality assurance project plans

A Quality assurance project plan (QAPP) will be developed to name objectives for sampling and outline procedures for documenting that the quality of the observations are sufficient to answer the appropriate questions. Monitoring associated with this watershed-based plan will have the following objectives:

- To verify that loads of nonpoint source pollutants have been reduced following implementation of the measures outlined in this plan, and
- To verify that streams are no longer impaired by nonpoint source pollutants.

The most intractable sources of variation are likely to be changes over time. Since the primary source of fecal coliform in the watershed is agricultural runoff, the concentration of fecal coliform will vary seasonally and with variations in precipitation. The most important quality assurance measure will be to sample many times throughout a range of hydrologic conditions. Additional standard quality assurance methods such as analysis of duplicates, field blanks, and samples with known concentrations will be included in QAPPs as well.

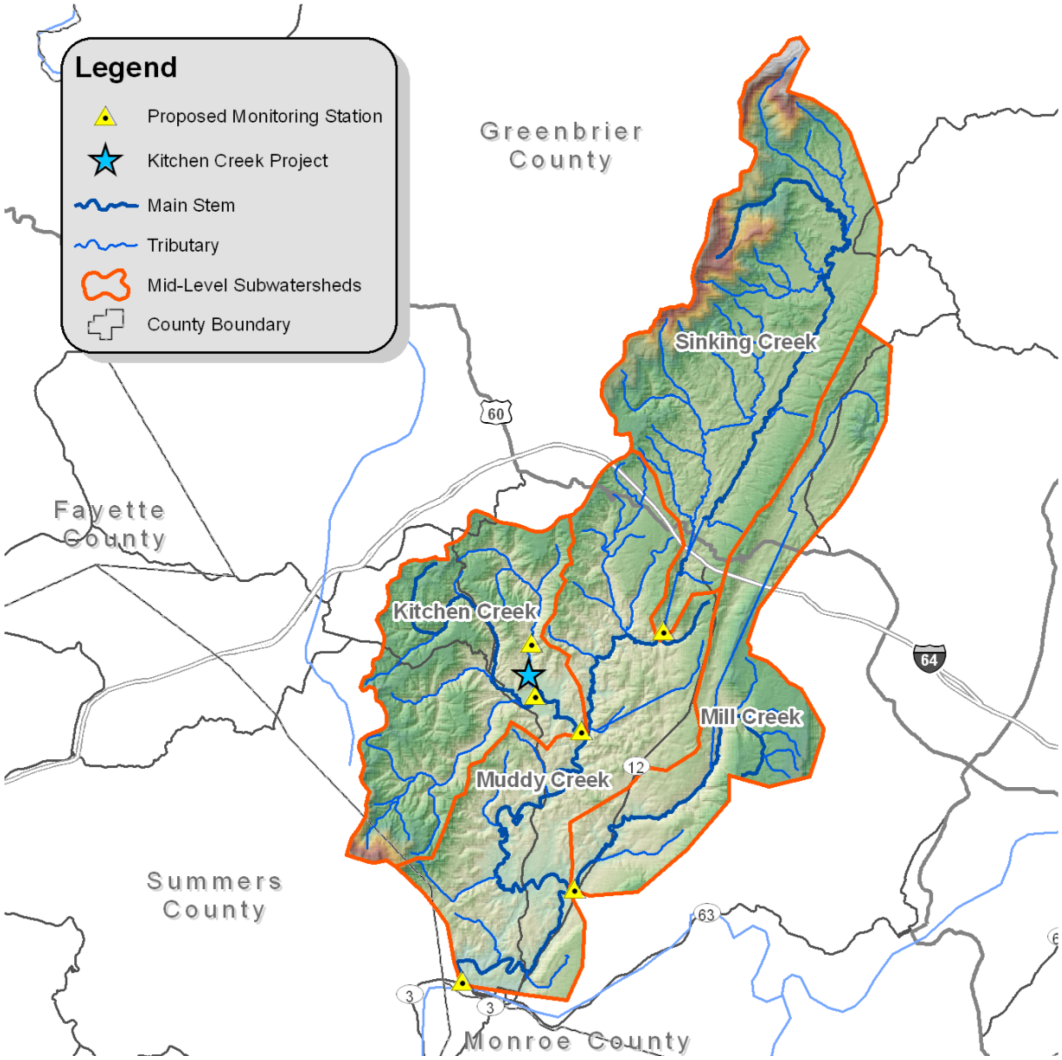
9.2 Instream monitoring

Instream monitoring is important to gage the recovery of streams after remediation projects are installed, and is also crucial to support partners as they engage in periodic strategic planning of reclamation priorities.

Quarterly monitoring will occur near the mouth of each of the four subwatersheds—Sinking Creek, Mill Creek, Kitchen Creek, and Muddy Creek. These locations are approximated in Figure 12. Monitoring dates will be chosen to capture a variety of hydrologic conditions, per the QAPP. As remediation projects are implemented, additional monitoring locations will be established both up- and downstream of these projects. All monitoring results will be analyzed on a quarterly basis to identify trends, sources, and the effects of any remediation activity. This is demonstrated in Figure 12 in relation to the Kitchen Creek project discussed in Section 7. The monitoring results will be measured against the evaluation criteria of fecal coliform. Additionally, results will be used to determine percent attainment relating to water quality goals.

WVDEP monitors Muddy Creek as part of its watershed assessment program. FOTLGR plans to conduct more frequent monitoring in locations chosen to demonstrate the effectiveness of implemented projects.

Figure 12: Proposed monitoring stations



9.2.1 Watershed Assessment Program

According to WVDEP's five-year watershed management framework cycle, the agency performs in-depth monitoring of the state's watersheds every five years. When the next round of monitoring takes place in Muddy Creek in 2013, these data will be helpful to show whether streams are improving or declining in quality. In addition to water chemistry, technicians collect benthic macroinvertebrates to determine biological impairments and fecal coliform data to determine bacteria impairments. Technicians also perform sediment-related assessments. WVDEP will then use these data, plus data collected by other agencies and organizations, to make impairment decisions for the next 303(d) list.

9.2.2 Friends of the Lower Greenbrier River

FOTLGR board members and volunteers plan to conduct a range of instream monitoring of the Muddy Creek Watershed with the assistance of any staff and VISTA workers that may be hired in the interim. A GIS database will be developed to house analysis results and manage the sampling program. Funding will be provided by various grants and through fundraising activities. A monitoring program will be developed that will follow the protocols developed and set forth in the QAPP.

11 **OUTREACH AND EDUCATION**

11.1 Friends of the Lower Greenbrier River

11.1.1 Organization

FOTLGR is concerned with the issues that affect the lower part of the Greenbrier River Watershed. The Muddy Creek watershed, located in the lower part of the Greenbrier drainage, offers a unique opportunity to facilitate the remediation of a polluted tributary. FOTLGR will monitor and act on issues affecting this part of the river, its watersheds, and the people who use it. In addition, FOTLGR will help educate the people who use and appreciate the Greenbrier River and its tributaries.

Short term goals:

- Attracting a broader membership representing the entire Lower Greenbrier River watershed from approximately Ronceverte to Hinton
- Raising awareness in the community about good water maintenance practices through school and civic club presentations and distribution of literature
- Performing stream and river-road cleanups twice each year
- Developing public information signage on preserving and protecting the Lower Greenbrier River to be erected at public entry and pull-over points along the river

Long Term Goals:

- Hiring a water quality expert to regularly check for pollutants associated with sewage, farm runoff, and other river conditions that may pose a threat
- Conducting long-range strategic planning sessions on how to involve visitors and residents in protecting the watershed and groundwater
- Training additional members to conduct water quality data collection
- Involving local communities in semi-annual river clean-ups and on-going river improvement projects
- Promoting tourism and recreation through a healthier, more beautiful river

11.1.2 Newsletters

FOTLGR publishes several newsletters each year and distributes them to over 250 members. Newsletters will continue to update the readers about current developments throughout the area, both positive and negative.

11.1.3 Public education

FOTLGR uses a number of efforts to provide public education and is actively involved in educating the local community in the Lower Greenbrier watershed. FOTLGR has invested in several educational tools. These tools help the residents of the watershed gain a more in-depth knowledge of how a watershed works and the different organisms that can provide an index of stream health.

Enviroscape:
FOTLGR's new Enviroscape tool is a three-dimensional watershed in a box that allows the organization to present a hands-on display to schools and civic organizations. This model demonstrates how water run-off from farms and homes picks up contaminants as it flows into our rivers and streams. FOTLGR can make presentations up to an hour in length with the children participating through the use of a toy tractor, barn, cows, homes and a factory. This gives students a first-hand look at how pollution gets into rivers and drinking water.

Macroinvertebrate Study:
FOTLGR owns tools for testing macroinvertebrate life in the Greenbrier River. Samples are collected in nets and catalogued to help determine the health of the Greenbrier and its tributaries. Members have received special training in the use of these tools.

11.1.4 Stream-side cleanups

FOTLGR has committed to organizing two stream-side cleanup days per year.

11.1.5 Web site

FOLTGR maintains a Web site, www.lowergreenbrierriver.org, with information about the entire Lower Greenbrier Watershed.

11.2 West Virginia Department of Environmental Protection

Local stakeholders are encouraged to become a part of WVDEP's Save Our Streams program. Through this program, citizen volunteers are trained by WVDEP to collect and identify benthic macroinvertebrates and monitor chemical and physical conditions in order to assess changes in the health of the stream. More information on the program and how to get involved is available at http://www.wvdep.org/item.cfm?ssid=11&ss1id=202.

11.3 West Virginia Conservation Agency

Educators and students in the Greenbrier Valley have participated in WVCA programs in the past and their participation will be encouraged in the future. WVCA programs include various academic competitions and curriculums designed to increase students' awareness of conservation and environmental issues. More information about these programs can be found at http://www.wvca.us/education/.

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