State of Ohio
Environmental Protection Agency

Division of Surface Water

Total Maximum Daily Loads for the Sunday Creek Watershed

Final Report
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Acknowledgments

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Rural Action, www.ruralaction.org, has employed a Sunday Creek Watershed Coordinator since 2001. This position is funded partially by Ohio EPA CWA 319 and Ohio Department of Natural Resources. Jen Bowman was the original watershed coordinator and crafted a Sunday Creek Watershed Management Plan. Cara Hardesty took the position in 2004. The watershed coordinator acts as a liaison between the Sunday Creek Watershed Group, a citizen group working to improve the environment of Sunday Creek Watershed, and state and federal agencies. This organization and both coordinators are acknowledged for their contributions to the TMDL project.

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1.0 Introduction

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these waters (the Section 303(d) lists) are made available to the public and submitted to the U.S. Environmental Protection Agency (USEPA) in even-numbered years. Further, the CWA and U.S. EPA regulations require that Total Maximum Daily Loads (TMDLs) be developed for all waters on the Section 303(d) lists.

The Ohio Environmental Protection Agency (Ohio EPA) identified the Sunday Creek watershed (assessment unit 05030204 070) as an impaired water on the 1998, 2002, and 2004 303(d) lists. The causes listed in the 2004 Integrated Report are metals, pH, siltation, and flow alteration. The sources for the first three causes are surface mining and acid mine drainage. Flow alteration in related to a major impoundment on East Fork; this “cause” is described in this report but not addressed as a TMDL issue.

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio’s TMDL process is full attainment of Water Quality Standards (WQS), which would subsequently lead to the removal of the water bodies from the 303(d) list.

The 138 square mile Sunday Creek watershed lies within the coal bearing portion of the Western Allegheny Plateau ecoregion (see Figure 1). Flowing from north to south, Sunday Creek confluences with the Hocking River, which flows into the Ohio River. The topography is dominated by steep narrow valleys and narrow ridges. The dominant land cover is forest (78%). The East Fork of Sunday Creek has been dammed to produce the 644-acre Burr Oak Lake, which anchors a major state park. Much of the northwest portion of the watershed has been mined for coal using both underground and surface mining methods. In this region, coal waste is scattered on the ground, and soil is heaped and mounded in unnatural conditions. Sinkholes in the valleys send streams into underground mines to emerge elsewhere, polluted with acid mine drainage.

The Trimble Township treatment plant is the only point source discharge (sewage treatment, NPDES permitted) in the watershed. Because the facility discharges to Sunday Creek, which is not impaired by bacteria, no WLA was done for this facility. TMDLs for bacteria were calculated individually to the small subbasins found to be impaired by bacteria.

To provide a foundation for the TMDL and to assist other watershed restoration efforts in the Sunday Creek watershed, Ohio EPA conducted a watershed study in 2001 and

2002. The study found impairments to the Aquatic Life Habitat and the Recreation uses. The primary causes of impairment are pH (acidity), habitat, and bacteria. The pH, or acidity, is from acid mine drainage (AMD) a toxic combination of acidity, iron, aluminum and other metals produced when high sulfur coal is exposed to water and oxygen. Habitat degradation has numerous causes. The most significant sources of bacteria are cattle with direct access to the stream and home sewage. TMDLs were developed for pH, bacteria, and habitat (sediment).

Substantial work on implementation strategies has been completed. Using Clean Water Act Section 319 funds, the Sunday Creek Watershed Group created the *Comprehensive Watershed Management Plan for the Sunday Creek Watershed*. This plan describes present conditions and recommends actions to eliminate sources of impairment. The plan, which has been formally endorsed by the State of Ohio, can be found at http://www.sundaycreek.org/publications.html. The group also produced an Acid Mine Drainage Abatement and Treatment Plan which documents sources of AMD and describes remediation activities. The AMDAT is found at http://www.sundaycreek.org/documents/SundayCreekAMDAT2003.pdf.

This report summarizes the water quality and habitat condition of the Sunday Creek watershed, quantitatively assesses the factors causing the impairment, provides for tangible actions to restore and maintain the streams, and specifies monitoring to ensure actions are carried out and to measure the success of the actions taken. Table 1 summarizes the impairments addressed and TMDLs included in this report.

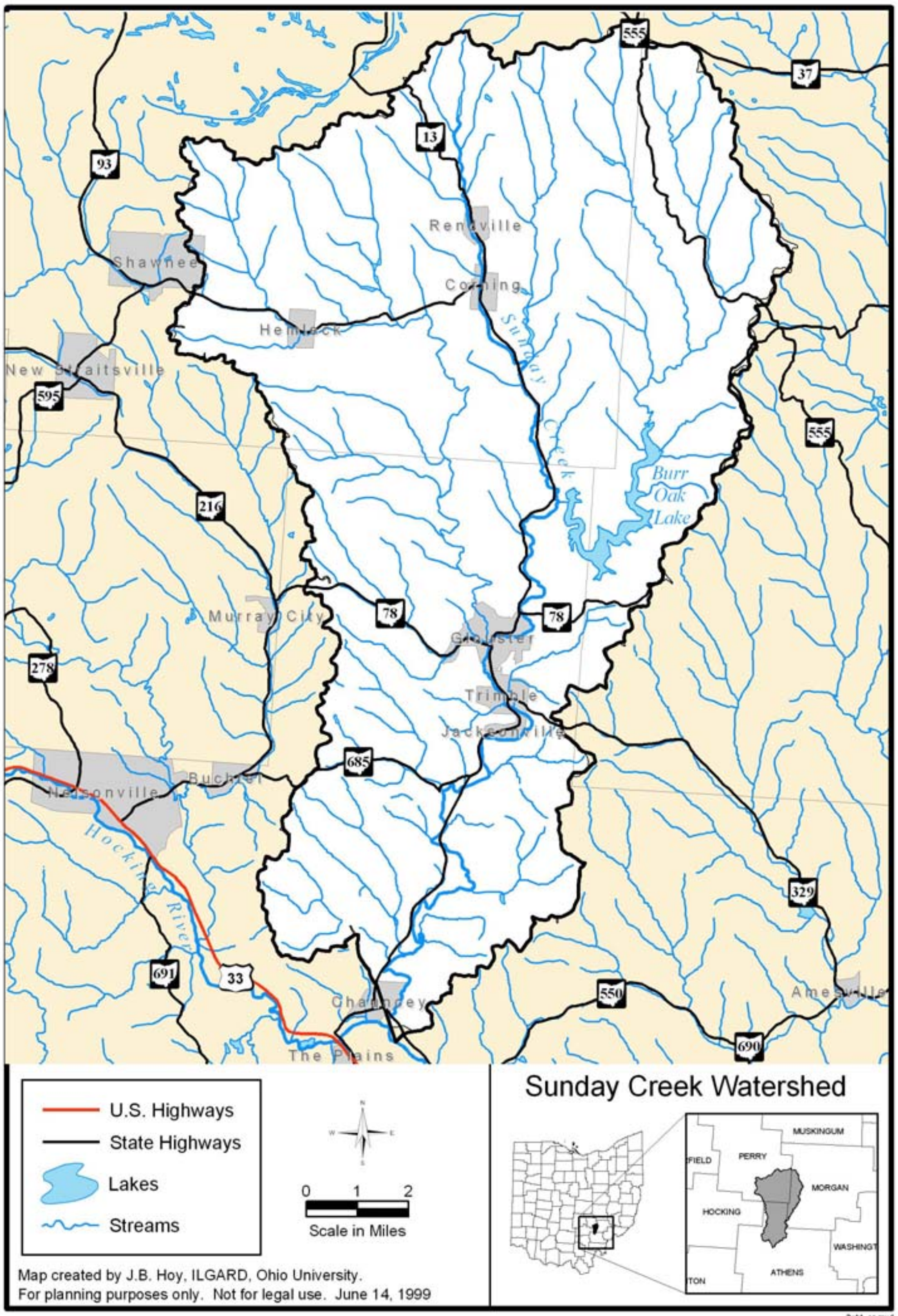

Figure 1. Sunday Creek Watershed (source: Ohio University, ILGARD)

Table 1. Summary of Sunday Creek TMDL Content

Waterbody [Identification Number]	Impairments[A]	TMDLs in this report?		
		Acidity	Bacteria	Sediment
Sunday Creek (01-200)	1) AMD 2) Upper site interstitial	✓		✓
Sunday Cr Trib. I at RM 26.4 (01-207)	1) Interstitial flow (natural) 2) Marginal habitat			
Sunday Cr. Trib II at RM 25.44 (01-202)	None			
Eighteen Run (01-256)	1) AMD, relocated channel, draining reclaimed mine lands.	✓		
Dotson Creek (01-260)	1) Oil and gas extraction at lower site. 2) Upstream impoundments. 3) Beaver influence (lower site)			✓
East Branch Sunday Creek (01-250)	1) Reservoir (flow and bottom release) lower 0.1 miles. 2) Livestock access (upstream reservoir) 3) Intermittent flow (uppermost site) 4) Modest AMD (up from reservoir)			✓
Eels Run (01-255)	None			
Cedar Run (01-252)	None			
San Toy Creek (01-208)	1) Naturally low gradient swamp/beaver affected stream.			✓
Long Run (01-209)	1) Interstitial flow (natural)			
West Branch Sunday Creek (01-240)	1) AMD (severe to moderate)	✓		
West Branch Trib. I at RM 12.41 (01-254)	1) AMD (moderate) 2) Poor habitat	✓		✓
Pine Run (01-344)	1) AMD (severe to moderate, numerous seeps) 2) Interstitial flow (upper reach). 3) Low gradient wetland/beaver influence (natural).	✓		
West Branch Trib II at RM 10.73 (01-247) ***AKA Congo Run***	1) Moderate AMD 2) Low gradient stream (natural)	✓		✓

Waterbody [Identification Number]	Impairments[A]	TMDLs in this report?		
		Acidity	Bacteria	Sediment
Trib. of West Branch Trib II at RM10.73/2.32 (01-253) ***Congo Run** (basin)*	1) AMD (severe); numerous surface and submerged seeps 2) Low gradient wetland stream. 3) Modified habitat.	✓		✓
Trib. of West Branch Trib II at RM 10.73/0.9 (01-249) ***Congo Run** (basin)*	1) Flows through reclaimed surface mine. 2) Interstitial flow, likely a result of previous mining (subsidence or modified hydrology associated with mining /reclamation efforts)	✓		
Johnson Run (01-242)	1) Poor habitat 2) True intermittent flow (natural)	✓		
Indian Run (01-243)	1) Unknown sources; some high metals, but good alkalinity level	✓		
West Br Trib. III at RM 3.45 (01-248)	1) Interstitial or possible naturally occurring intermittent flow			
Mud Fork (01-241)	1) high bacteria (failing on-site septic systems) 2) Marginal habitat	✓	✓	✓
Mud Fork Trib. I at RM 2.87 (01-246)	Bacteria	✓	✓	✓
Mud Fork Trib. II at RM 0.2 (01-245)	Bacteria	✓		✓
Congress Run (01-230)	Bacteria	✓	✓	
Sunday Creek Trib. III (01-206)	None	✓		
Greens Run (01-220)	1) Failing septic home system(s) 2) Modest AMD 3) Marginal habitat	✓	✓	
Little Greens Run (01-222)	1) Marginal habitat 2) Failing home septic system(s)	✓		
Oregon Ridge (Sunday Cr Trib. IV at RM 6.71) (01-205)	1) Severe AMD (outlet for major seep). 2) Intermittent flow	✓		

Waterbody [Identification Number]	Impairments[A]	TMDLs in this report?		
		Acidity	Bacteria	Sediment
Jackson Run (01-204)	1) Failing septic systems 2) Intermittent flow (observation made while collecting macrobenthos, not from habitat assessment)	✓	✓	
Big Bailey Run (01-210)	1) AMD modest to severe 2) Intermittent flow (upper site)	✓		✓
Middle Bailey Run (01-213)	None			
Carr Bailey Run (North Branch) (01-211)	1) Modest AMD load. 2) True Intermittent flow 3) Post surface mining landscape w/ beavers 4) Poor habitat	✓		✓
West Bailey Run (01-214)	1) Low gradient wetland/beaver influence (natural), or post-surface-mining landscape with beavers. 2) Possible losing stream. 3) Modest AMD load			✓

[A] Additional information on the condition of the watershed is contained in Appendix F.

2.0 Condition of the Watershed

As part of the TMDL process, an intensive ambient assessment of the Sunday Creek watershed was conducted by the Ohio EPA during the 2001 field sampling season. The study area included the entire length of Sunday Creek, principal tributaries, and all remaining minor conveyances possessing a drainage area greater than 1.0 mile^2. A total of 83 stations were sampled throughout the catchment, evaluating 34 named and unnamed streams. Ambient biology, macrohabitat quality, water column chemistry, and bacteriological data were gathered from nearly every sampling station. Diel water quality (dissolved oxygen (DO), pH, conductivity, and temperature), and sediment chemistry (metals, organics, and particle size) were evaluated at selected stations. Cumulatively, 98.8 linear stream miles of the watershed were surveyed and assessed.

The study methods and results are summarized in this chapter. Details of the assessment are contained in Appendix F.

2.1 Assessment Methodology

A geometric site selection methodology (a systematic census) was employed to derive the initial station list. This method has proved rapid and efficient in generating an objective and comprehensive collection of potential sampling sites where an assessment of an entire catchment is desired. However, an unavoidable consequence of this method includes substantial data gaps in lower or larger stream segments. It was therefore necessary to directly target these higher order segments (or tributaries) to ensure an even distribution of sampling effort. Ohio EPA sampling resources were also allocated to selected long-term monitoring sites established by the Ohio DNR in support of the Sunday Creek Restoration Projects. Lastly, though limited in scope, areas that have been previously sampled and evaluated by the Ohio EPA were revisited for the purposes of coarse trends assessment. Locations of sampling stations and types of monitoring performed at each location are presented in Figure 2 and Table F.1.

Specific sampling objectives included the following:

1) Systematically sample and assess the principal drainage networks of Sunday Creek in support of the TMDL process,

2) Gather ambient environmental information (biological, chemical, and physical) from undesignated water bodies to objectively prescribe an appropriate suite of beneficial uses (e.g., aquatic life, recreation, water supply),

3) Verify the appropriateness of existing, unverified beneficial use designations, and recommend changes where appropriate,

4) Establish baseline ambient biological conditions at selected reference stations to evaluate the effectiveness of future pollution abatement efforts, and

5) Document any changes in the biological, chemical, and physical conditions of the study areas where historical information exists, thus expanding the Ohio EPA data base for statewide trends analysis.

The components of the TMDL process supported by this survey are principally the identification of impaired waters, verification (and redesignation if necessary) of beneficial use designations, gathering ambient information that will factor into the wasteload allocation, ascribing causes and sources of use impairment, and the derivation of basin specific pollutant loading goals or restoration targets. These data are necessary precursors to the development of effective control or abatement strategies.

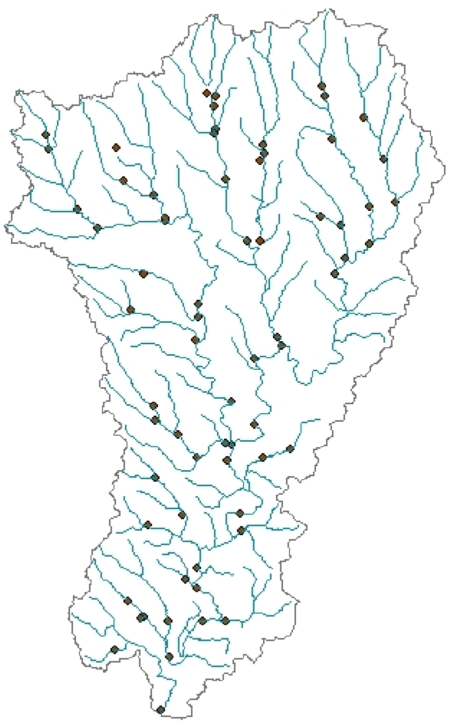

Figure 2. Location of environmental monitoring stations within the Sunday Creek watershed, 2001.

2.2 Assessment Results

The primary sources of water quality impacts within the study area are associated with mine drainage. Runoff from abandoned surface and subsurface minelands contained within the Sunday Creek basin are significant and long-standing sources of acid, sediment, and metal loads. To address these pervasive environmental problems, the

Sunday Creek Restoration Project was initiated in 2000, bringing together watershed residents, academics, and governmental agencies. To date, a hydrologic budget has been developed for the Sunday Creek watershed, all prominent sources of mine drainage within the basin have been identified and quantitatively characterized, biologically calibrated wasteload reduction targets have been established, and specific AMD remediation projects have been developed and prioritized relative to associated costs and feasibility.

Of the 98.5 aggregate linear stream miles of the Sunday Creek watershed assessed in 2001, 26.1 miles (27.2%) were found to fully support existing and recommended aquatic life uses. Partial attainment was indicated for 30.3 miles (30.8%) and non-attainment for the remaining 41.38 miles (42.0%). By far, the leading causes and sources of aquatic life use impairment (partial and non) were associated mine drainage (AMD, sedimentation, and hydrologic disruption). Taken together, these impact types accounted for 67.2% of impaired miles. Other sources included agriculture, primarily livestock (2%), natural features or phenomenon (10.6%), failing on-site septic systems (6.7%), and impact related to impoundment (13.5%). The latter, largely limited to Burr Oak Reservoir, affected stream segments up and downstream from the dam. Summarized index scores and aquatic life use attainment, by station, are presented in Table F.2. Detailed waterbody summaries for each stream assessed as part of this investigation are presented in Table F.3.

2.2.1 Sunday Creek (Mainstem)

A total of 26.6 miles of the Sunday Creek mainstem were surveyed and assessed. Twelve stations were deployed to evaluate the reach extending from the extreme headwaters in north central Perry County to the Hocking River confluence, near US 33. Varying degrees of aquatic life use impairment were indicated at all sites. Seventy-one percent (18.9 miles) were found in non-attainment. The remaining 7.7 miles (29%) supported only fair biological assemblages, and, thus, were considered in partial attainment.

Longitudinal performance of the various chemical stressor and biological response indicators clearly portrayed the influence of the most prominent sources of mine drainage within the watershed. These sources included three mine seeps discharging directly or indirectly to the mainstem: Corning, Truetown, and Big Bailey seeps, the latter via Big Bailey Run. The Corning seep is located within the headwaters, joining Sunday Creek near RM 21.0. Truetown and Big Bailey seeps are located within the lower portion of the basin affecting approximately the lower six miles of Sunday Creek. Poor to very poor fish and macroinvertebrate communities, elevated AMD chemical indicators, and low pH were found throughout the affected segments, located downstream from these sources. Stations contained within the segment sufficiently removed from Corning displayed limited recovery evidenced by improved performance of both chemical and ambient biological indicators. Moreover, two stations (RMs 10.2 and 7.3), representing approximately four stream miles, supported communities very near the WWH threshold. However, this incomplete recovery was disrupted by mine drainage emanating from the Truetown seep, and to a lessor extent Big Bailey seeps.

In response, biological performance and water quality significantly declined and remained profoundly impacted throughout the lower six miles. Although others sources of mine drainage are clearly active within the basin, and in the aggregate contribute significant quantities of mine drainage to the watershed, the prominent sources listed above appear to be the controlling influences on the health of the mainstem.

Only the upper 0.6 miles of Sunday Creek appeared to be relatively free from the influence of mine drainage. Aquatic life use impairment within this segment was associated with intermittent stream flow. As channel features, substrate quality, riparian condition and adjacent land use appeared compatible with a healthy ephemeral headwater, failure of the biology to fully meet the prescribed biocriteria appeared a result of natural conditions. Chemical indicators of the direct effect of intermittent flow included a violation of the WWH DO minimum criterion.

2.2.2 East Branch Sunday Creek

The principal drainage network of the East Branch Sunday Creek is composed of three named tributaries: Eels Run, Cedar Run and San Toy Creek. A total of 12 stations were monitored to evaluate the mainstem and direct tributaries, yielding the assessment of 19.6 linear stream miles. Full attainment of the existing and recommended aquatic life uses was indicated for 7.6 miles (38.8%). The remaining miles were found impaired, with 8.2 miles (41.8%) in partial attainment and 3.8 miles (19.4%) in non-attainment.

Leading causes and sources of aquatic life use impairment within the sub-basin were impoundment, stream intermittence or other natural features, and unrestricted cattle access. Impacted segments were found primarily on the mainstem. Cattle access and intermittence were the principal problems identified upstream from Burr Oak Reservoir. The affected downstream segment contained ample evidence of the regular anoxic, hypolimnetic releases from the reservoir. This, too, resulted in use impairment. AMD within the East Branch was considered only a tertiary source of water quality problems. No indications were found to suggest significant quantities of mine drainage are delivered to the mainstem or principal tributaries.

Eels Run, Cedar Run and the vast majority of assessed miles of San Toy Creek were found to fully support the WWH aquatic life use. Only the lower 0.7 miles of San Toy Creek were found impaired. Biometrics and chemical indicators were reflective of the low gradient, wetland/beaver influences that characterize the lower 0.7 miles of this creek. As such, the departure from the WWH biocriteria was attributed to natural causes.

2.2.3 Upper Sunday Creek Tributaries

Upper Sunday Creek tributaries included all small direct waterways that join the mainstem of Sunday Creek upstream from the West Branch Sunday Creek, excluding the East Branch. These water bodies include five named and unnamed streams: Unnamed Tributary I, Unnamed Tributary II, Eighteen Run, Dotson Creek, and Long Run. Full attainment was indicated for Unnamed Trib. I and nearly all assessed miles of Dotson Creek. The remaining tributaries were found impaired (partial or non-attainment). Eighteen Run was impacted by mine drainage. Both Long Run and Unnamed Trib. I appeared naturally limited by intermittent or interstitial flow. Cumulatively, 7.8 miles of upper Sunday Creek tributaries were evaluated. Over 70% were found to support a community fully consistent with recommended and existing aquatic life uses. Impairments were limited to the remaining 30%, with 26% partially meeting the prescribed biocriteria and 4% in non-attainment.

2.2.4 West Branch Sunday Creek

The largest of the Sunday Creek sub-basins, 26 sampling stations were allocated to evaluate the West Branch mainstem, and eleven direct and indirect tributaries. Cumulatively, 30.4 stream miles were surveyed and assessed. The leading cause of aquatic life use impairment was mine drainage, accounting for over 85% of all impaired waters. The upper portion of the mainstem and its tributaries and bore a heavy AMD load from several large mine seeps. Other impacted tributaries and mainstem segments are affected by other minor seeps or they course through reclaimed and unreclaimed minelands and mine spoil. Only the Mud Fork sub-basin appeared unaffected by AMD. All but the lower 0.2 miles of Mud Fork and all assessed miles of its principal tributaries were found to support aquatic communities fully consistent with the WWH aquatic life.

2.2.5 Big Bailey Run

Seven sampling stations were allocated to the Big Bailey Run sub-basin. All together, approximately six stream miles were surveyed and assessed, which included Big Bailey Run mainstem, Middle Bailey Run, Carr Bailey (North Branch), and West Bailey Run. As with other areas contained within the Sunday Creek watershed, mine drainage and landscape modifications associated with unreclaimed minelands were the leading sources of aquatic life use impairment. Big Bailey Run receives a high percentage of its flow from mine drainage from one of the largest seeps in the Sunday Creek watershed which joins the stream 0.4 miles from its confluence with Sunday Creek. Impairments not related to mining were limited to the upper 0.7 miles of Big Baily Run (upstream from Middle Bailey Run), and the lower mile of both Carr Bailey Run and West Bailey Run. Departures from the prescribed biocriteria for these stream reaches were derived largely from intermittent or interstitial flow. Middle Fork Big Bailey and the middle segment of Bailey Run were found to support WWH communities.

2.2.6 Lower Sunday Creek Tributaries

Lower Sunday Creek tributaries included six small direct and indirect waterways that join the mainstem of Sunday Creek downstream from the West Branch Sunday Creek confluence: Congress Run, Unnamed Tributary III, Greens Run, and Little Greens Run, Unnamed Tributary IV, and Jackson Run. Cumulatively, nine linear stream miles were surveyed and assessed.

Full attainment of the existing and recommended aquatic life use(s) was indicated for Congress Run, Unnamed tributary III, and 0.7 miles of Little Greens Run. Unlike much of the study area, significant AMD impacts were limited to one stream: Unnamed Tributary IV. This waterbody receives the mine drainage from the largest single source of AMD within the entire Sunday Creek basin (Truetown seep). All remaining impaired waters were impacted by failing septic systems, characterized by low dissolved oxygen levels, elevated ammonia-N concentrations, and fecal coliform bacteria exceedances, or were found naturally limited, mainly by intermittent flow.

3.0 Problem Statement

The goal of the TMDL process is full attainment of the stream use designations and water quality standards (WQS). Where suitable WQS are not available, targets may be developed to provide an endpoint for the analysis of pollutant loads and to guide implementation. In this chapter, the development of the targets to address the acid mine drainage, bacteria, and sedimentation impairments is discussed.

3.1 Focus of TMDL Analysis

Acid Mine Drainage

As described in Chapter 2, the water quality and biological assessments of the Sunday Creek watershed indicate that the primary cause of non attainment is pH. This TMDL outlines the changes that must occur in the watershed so that pH does not prevent the stream from meeting the Warm Water Habitat (WWH) aquatic life use designation. Ohio has water quality standards for pH; however pH is difficult to model. As a surrogate, net acidity was selected for load calculations and modeling.

Bacteria

Fecal Coliform bacteria exceeded the primary contact recreational use designation in four waterbodies (Mud Fork 1, Mud Fork 2, and Mud Fork Trib 1 are included as one waterbody) within the Sunday Creek watershed. Data generated from bacteria sampling throughout the basin in the summer of 2001, as well as information provided by the Sunday Creek watershed coordinator was used to identify areas that have a high potential to exceed the bacteria water quality standards.

Ohio's statewide criteria for the primary contact recreational use designation requires that not less than five samples be collected in a thirty day period. A follow-up collection of five runs in a 30 day period in June of 2003 allowed a comparison of instream bacteria values to the recreational use designation water quality criteria. A comparison of the geometric mean of these five samples revealed that bacteria impairments occurred on five of the eight sample sites.

This report describes the fecal coliform model and inputs used to determine loading sources and types of implementation needed to reduce the fecal coliform loading to below target levels.

Sedimentation

As described in Chapter 2 and Appendix F, the water quality and biological assessments of the Sunday Creek Watershed (specifically the Qualitative Habitat Evaluation Index (QHEI)), indicate that a contributing cause of non attainment is sedimentation. Also, the Sunday Creek Watershed Group (SCWG) describes in detail the sedimentation problem in their Comprehensive Watershed Management Plan for the Sunday Creek Watershed (CWMP) (SCWG, 2003, pg. 78).

3.2 Target Development

Acid Mine Drainage

With respect to Ohio's biocriteria, pH is not so much the cause of impairment as it is the measure of the cause of impairment. Impairment, as observed in biological populations, is caused by acidity. In the heavily mined area of Sunday Creek, acidity is formed from hydrolyzing salts such as iron, aluminum and manganese sulfates. Any one of these parameters – pH, acidity or the concentration of metals – could be used in the TMDL as an indicator of stream quality. In streams where AMD and metals are prevalent, pH is not a reliable measurement of acidity due to the latent acidity from residual metals. For this reason, net acidity is used to quantify this pollutant load, not pH.

Ohio does not have a water quality standard for acidity, but there is one for pH. The statewide water quality criteria for the protection of aquatic life for outside mixing zone average for pH, as per Administrative Code 3745-1-07 Table 7-1, is 6.5 - 9.0. This range, 6.5 - 9.0 was used as the pH target. Figures 3 and 4 show the relationship of pH to net acidity and are comprised of 315 pH and net acidity data points from many sites throughout the Sunday Creek basin. Seventeen high net acidity values, greater than 300, were eliminated to remove extreme outliers.

The target for net acidity was based on the relationship between net acidity and the water quality standard for pH. Figure 4 shows that when the net acidity target of –67 mg/l is met, pH will be greater than the minimum pH Ohio EPA water quality standard of 6.5. For this reason -67 net acidity was selected as the target for acidity.

To summarize, the target for pH is 6.5, but because it is difficult to model pH, acidity loads were used as a surrogate for pH. Based on the relationship between net acidity and pH in Sunday Creek, it was determined that the pH target is met when the net acidity is -67 mg/l or lower.

Figure 4 shows that when the net acidity target of –67 mg/l is met, pH will be greater than the minimum pH Ohio EPA water quality standard of 6.5.

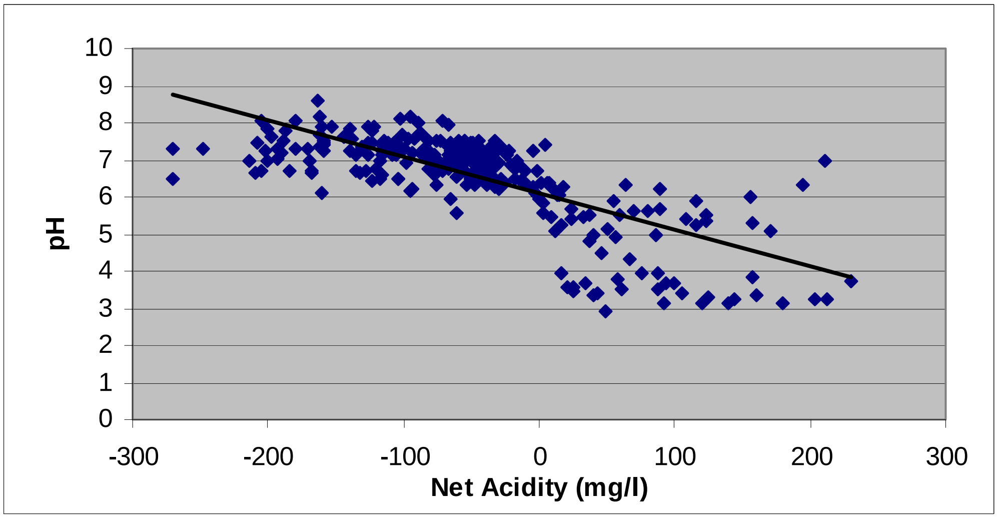

Figure 3. pH versus Net Acidity

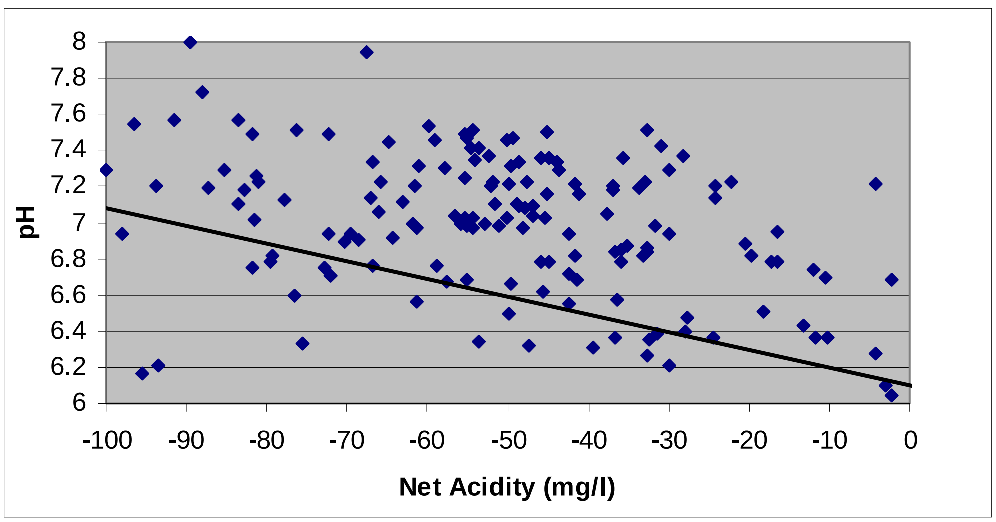

Figure 4. Detail of Figure 3 (pH versus Net Acidity)

Bacteria

Bacteria samples were collected at 66 sites during the summer of 2001 with one sample collected at 45 sites and 2 or 3 samples collected at the remainder. The statewide numerical and narrative criteria for primary contact recreational use designation requires that for each designation at least one of the two bacteriological standards (fecal coliform or e. coli) must be met. These criteria apply outside the mixing zone and for fecal coliform state; the geometric mean content most probable number (MPN), based on not less than five samples within a thirty-day period, shall not exceed 1,000 per 100 ml and shall not exceed 2,000 per 100 ml in more than 10 percent of the samples taken during any thirty-day period. Since fewer than 5 samples were taken at each site, 1000 counts/100 ml was used as the preliminary screening target to determine which sites to resample five times in a thirty day period. Eight sites were selected and resampled during a thirty day period between early June and early July in 2003. The geometric mean from these five samples (from each of the eight sites) were then compared to the WQS as described above. Six of the eight sites exceeded the WQS and are included in the TMDL (see Table 2 for sampling results).

Table 2. Sunday Creek Bacteria Sampling Results

	Bacteria Sample Results (counts/100ml)						counts/100 ml	
Basin	preliminary screening 7/17/2001	6/9/2003	6/17/2003	6/20/2003	6/23/2003	7/1/2003	geometric mean (> 1000 is an exceedance)	maximum (> 2000 is an exceedance)
Greens Run RM 1.7	87000	820	5	2600	2300	29000	934	29000
Greens Run RM 0.1	1130	1300	1130	1400	490	360	816	1400
Mud Fork RM 2.2	5100	12000	12000	2400	940	400	2647	12000
Mud Fork Trib 1 RM 0.1	1400	410	3100	690	4400	5800	1862	5800
Mud Fork RM 0.2	1200	2100	5	2800	1900	830	541	2800
Congress Run RM 1.3	1800	3700	1900	450	5800	2500	2149	5800
Jackson Run RM 0.2	2500	1600	1800	4000	1080	1200	1717	4000
Sunday Cr. trib. III RM 0.4	3000	410	580	140	70	90	184	580
Doanville Gage Flow (DA = 114 sq mis)		*290*	*1080*	*130*	*67*	*35*		
Description of flow conditions (stream flow/level)		high/ increasing	high/ increasing (presently raining)	high/ decreasing	high/ decreasing	low/ decreasing		

Sedimentation

Based on the report *Using the Qualitative Habitat Evaluation Index to Derive TMDL Targets for Sediment Impairment in Southeast Ohio* (Rankin, 2003), the substrate score target was set at 13 points. Appendix A includes a map of sites which scored less than the target of 13. Two points were added to 13 as the margin of safety (MOS), or 10% more than the target, rounded to the next whole number. Therefore the target with the MOS is a QHEI substrate subcomponent score of 15 points. See Table 3 for site deviation from the target.

Table 3. TMDL QHEI Substrate Subcomponent Table

				SUBSTRATE**		
River	**RM**	**Year**	**QHEI**	**Existing Conditions**	**Target***	**Target Deviation**
Carr Bailey Run	0.70	2001	30.5	-1.0	15.0	16.0
East Branch Sunday Creek	12.60	2001	28.0	2.0	15.0	13.0
San Toy Creek	0.70	2001	54.5	4.5	15.0	10.5
Trib. to W. Br. Sunday Creek (10.73)	0.10	2001	58.5	5.0	15.0	10.0
Trib to W. Br. Sunday Creek (10.73/2.32)	0.10	2001	46.5	5.0	15.0	10.0
Sunday Creek	10.20	2001	55.5	9.0	15.0	6.0
Big Bailey Run		2001	56.0	9.0	15.0	6.0
East Branch Sunday Creek	9.90	2001	59.5	9.0	15.0	6.0
Dotson Creek	0.30	2001	57.5	10.0	15.0	5.0
Sunday Creek	4.20	2001	56.0	10.5	15.0	4.5
Sunday Creek	7.30	2001	59.5	11.0	15.0	4.0
Sunday Creek	24.00	2001	50.5	11.0	15.0	4.0
Trib. to Mud Fork (1.06)	0.20	2001	46.0	11.0	15.0	4.0
Trib. to W. Br. Sunday Creek (12.41)	0.10	2001	45.0	11.0	15.0	4.0
Mud Fork	0.20	2001	50.5	11.5	15.0	3.5
West Bailey Run	0.50	2001	54.0	12.0	15.0	3.0
Trib. to Mud Fork (2.87)	0.10	2001	45.5	12.0	15.0	3.0
Sunday Creek	26.00	2001	57.0	13.0	15.0	2.0

* 13 is the target with 2 pts. added for the MOS

** Units for the scores are points. The maximum score for substrate is 20 points.

For the silt and embeddedness subcomponents of the QHEI score a qualitative measure is used both as a score and target. From this a deviation is developed, see Tables 4 and 5.

Table 4. TMDL QHEI Silt Subcomponent Table

				SILT		
River	**RM**	**Year**	**QHEI**	**Existing Conditions**	**Target**	**Target Deviation**
Carr Bailey Run	0.70	2001	30.5	heavy	normal	yes
East Branch Sunday Creek	12.60	2001	28.0	heavy	normal	yes
San Toy Creek	0.70	2001	54.5	moderate	normal	yes
Trib. to W. Br. Sunday Creek (10.73)	0.10	2001	58.5	moderate	normal	yes
Trib to W. Br. Sunday Creek (10.73/2.32)	0.10	2001	46.5	mod. and heavy	normal	yes
Sunday Creek	10.20	2001	55.5	moderate	normal	yes
Big Bailey Run		2001	56.0	mod. and heavy	normal	yes
East Branch Sunday Creek	9.90	2001	59.5	moderate	normal	yes
Dotson Creek	0.30	2001	57.5	mod. and heavy	normal	yes
Sunday Creek	4.20	2001	56.0	mod. and heavy	normal	yes
Sunday Creek	7.30	2001	59.5	moderate	normal	yes
Sunday Creek	24.00	2001	50.5	moderate	normal	yes
Trib 2 to Mud Fork (1.06)	0.20	2001	46.0	moderate	normal	yes
Trib. to W. Br. Sunday Creek (12.41)	0.10	2001	45.0	moderate	normal	yes
Mud Fork	0.20	2001	50.5	moderate	normal	yes
West Bailey Run	0.50	2001	54.0	normal and mod.	normal	yes
Trib 1 to Mud Fork (2.87)	0.10	2001	45.5	normal and mod.	normal	yes
Sunday Creek	26.00	2001	57.0	moderate	normal	yes

Table 5. TMDL QHEI Embeddedness Subcomponent Table

River	RM	Year	QHEI	EMBEDDEDNESS Existing Conditions	EMBEDDEDNESS Target	EMBEDDEDNESS Target Deviation	Other
Carr Bailey Run	0.70	2001	30.5	extensive	low	yes	coal fines
East Branch Sunday Creek	12.60	2001	28.0	extensive	low	yes	
San Toy Creek	0.70	2001	54.5	mod. and extensive	low	yes	
Trib. to W. Br. Sunday Creek (10.73)	0.10	2001	58.5	moderate	low	yes	
Trib to W. Br. Sunday Creek (10.73/2.32)	0.10	2001	46.5	mod. and extensive	low	yes	
Sunday Creek	10.20	2001	55.5	moderate	low	yes	
Big Bailey Run		2001	56.0	mod. and extensive	low	yes	
East Branch Sunday Creek	9.90	2001	59.5	moderate	low	yes	
Dotson Creek	0.30	2001	57.5	mod. and extensive	low	yes	
Sunday Creek	4.20	2001	56.0	moderate	low	yes	
Sunday Creek	7.30	2001	59.5	moderate	low	yes	
Sunday Creek	24.00	2001	50.5	moderate	low	yes	
Trib 2 to Mud Fork (1.06)	0.20	2001	46.0	moderate	low	yes	
Trib. to W. Br. Sunday Creek (12.41)	0.10	2001	45.0	moderate	low	yes	
Mud Fork	0.20	2001	50.5	low and moderate	low	yes	
West Bailey Run	0.50	2001	54.0	low and moderate	low	yes	
Trib1 to Mud Fork (2.87)	0.10	2001	45.5	low and moderate	low	yes	
Sunday Creek	26.00	2001	57.0	low	low	no	coal fines

3.3 Current Deviation from Target

Acid Mine Drainage

Using important sites or marker points in the basin as determinants of impairment, the target is compared to existing conditions, see Table 6. The very headwaters of Sunday Creek are not impaired.

Table 6. Acid Mine Drainage Target Deviation

	Target	Existing Conditions	Meets Target?	Deviation from Target
		Net Acidity Concentrations (mg/l) (negative acidity is alkaline)		
Beginning of Headwaters	**-67**	**-119**	**yes**	**na**
End of Headwaters upst. E Br.	**-67**	**-25**	**no**	**-42**
Mainstem just upst. West Br.	**-67**	**-41**	**no**	**-26**
West Branch at mouth	**-67**	**-45**	**no**	**-22**
Mainstem at mouth	**-67**	**-4**	**no**	**-63**

Bacteria

Of the eight sites that were sampled (i.e., five times in a thirty day period), six exceeded WQS as shown in Table 7. These six sites occur on four streams, so four models were built to assess bacteria loading. The Mud Fork model encompassed all three Mud Fork sites.

Table 7. Bacteria Target Deviation

Basin	**Geometric Mean Target (counts/ 100 ml)**	**Geometric Mean (> 1000 is exceedance)**	**Deviation from Geo Mean Target**	**Maximum Target (counts/ 100 ml)**	**Maximum (> 2000 is exceed ance)**	**Deviation from Max Target**
Greens Run RM 1.7	1000	934	-66	2000	29000	27000
Mud Fork RM 2.2	1000	2647	1647	2000	12000	10000
Mud Fork Trib 1 RM 0.1	1000	1862	862	2000	5800	3800
Mud Fork RM 0.2	1000	541	-459	2000	2800	800
Congress Run RM 1.3	1000	2149	1149	2000	5800	3800
Jackson Run RM 0.2	1000	1717	717	2000	4000	2000

Sedimentation

Target development for sediment target deviation is discussed in Section 3.1, Tables 3, 4 and 5.

4.0 TMDL Modeling

4.1 Method of Calculation

Acid Mine Drainage
Shimala (1997) stated that in the Sunday Creek watershed, “budgets produced from time-variant and single-time data show that the exact amount of any concentration can not be calculated precisely at any given point due to the complexity of the water chemistry, there are many conditions that affect the concentrations of metals and acidity in the stream” (Shimala, pg. 57, 1997). To calculate the instream acid concentration at a given point, a model that simulates the complex chemical reactions would be needed. Data for such a model is not available. Instead, a spreadsheet that calculates the mass balance of net acidity for the entire basin was developed. To compensate for the difficult-to-model chemical reactions that occur, adjustment checkpoints at several mainstem and tributary points were included in the spreadsheet.

Establishing instream numeric targets is a significant component of the TMDL process. The numeric targets serve as a measure of comparison between observed instream conditions and conditions that are expected to restore the stream to its designated uses. The TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards.

For the purposes of this report, the entire modeled segment will be considered to be meeting the applicable WQS or target when the net acidity goal of -67 mg/l is met at all mainstem and main tributary sites. However, it should be noted that in order to meet targets at the main sites, most of the secondary sites must also meet.

A spreadsheet was used to calculate existing and post remediation net acidity instream concentrations in the Sunday Creek study area. The major inputs consisted of the adjusted site flow, net acidity concentration, net acidity load and cumulative instream concentration. The net acidity load was calculated for each site by multiplying the site net acidity concentration by the site discharge. The load was then added to the next downstream site load, then that total added to the next downstream site and so on. In the same manner the site flows were determined. Then the cumulative loads were divided by the cumulative flows at each site to determine the “cumulative concentration” at each site. This site cumulative concentration was then compared to the net acidity target of -67 mg/l to determine impairments. If the cumulative concentration was less than -67 mg/l there was an impairment, if it was greater than -67 mg/l the target was met.

The net acidity concentration is calculated by subtracting the acidity concentration by the alkalinity concentration, i.e., acidity – alkalinity = net acidity. The net acidity load is calculated by multiplying the net acidity concentration by the discharge. No conversion is used to bring it to a commonly measured load such as lbs/d or kg/d. The load is simply used as an adding mechanism so that the concentration can be calculated for each site as discussed.

Allocations of pH to point source discharges are not included (i.e., wasteload allocations are zero). There are only two minor permitted dischargers in the basin: Buckingham No. 2 mine with 3 outfalls and Trimble Township waste water treatment plant with one outfall (see Table 8 for details). Any water entering the study area with a pH equal to or greater than 6.5 would be beneficial in terms of buffering the acidity. Permit limits for these facilities already include a pH range of 6.5 to 9. A wasteload allocation would be needed only if the pH range were being lowered below 6.5. In reality, discharges from these facilities can be considered an implicit margin of safety.

Table 8. Permitted Dischargers in the Sunday Creek Basin

Facility & outfall	**# obs**	**Data Start Date**	**Data End Date**	**pH Minimum**	**pH 50th percentile**	**Flow 50th percentile (cfs)**
Buckingham Mine no. 2 001	194	10Mar99	25Dec02	6.63	7.8	0.018
002	153	15Dec99	25Dec02	6.78	8.0	0.100
003	140	01Mar00	25Dec02	not given	7.75	0.001
Trimble WWTP 001	1257	02Jan98	31Dec02	5.9	7.0	0.246

It is difficult to predict acidity at any given point of a stream because of complex instream chemical changes occurring due to constant acid additions, buffering, and oxidation. The model compensates for this by using data to adjust the calculated acidity concentrations and flows to measured acidity concentrations and flows at various mainstem and main tributary points. If the cumulative concentrations, which are calculated from cumulative loads and flows, moving downstream do not match a mainstem or main tributary site, the difference is added or subtracted to the cumulative load/concentration. The same is done to balance the flows. In the model these are called unknown concentrations and unknown flows, respectively. The calculated unknown concentration and flow values account for the changes in water chemistry, unmeasurable subsurface flow additions, missed seeps and/or variability due to the averaging of concentrations and flows at sites with multiple samples.

The data used is time-variant data (data collected over a long period of time) from January 2000 to June 2002. This presents a challenge; for example, it doesn't make sense to compare the loads from two similar-sized tributaries if the sample from one tributary was taken during a low-flow condition and the sample from the other tributary was taken during a high-flow condition. In order to calculate an acidity mass balance, flow conditions need to be normalized throughout the study area. The 50th percentile of 19 flow measurements from the mouth of Sunday Creek, a reference site where frequent samples and flow measurements were taken, was derived for the duration of the sampling. On dates where flows were not measured but samples were taken, the flow was calculated using a drainage area yield based on the USGS Doanville gage 03158200 in adjacent Monday Creek. The 50th percentile flow of the Sunday Creek reference site, 28 cfs, then became the normalizing condition to be assumed for the mass balance calculations throughout the basin. Flows, from which site loads were calculated, were normalized to this condition. For instance if the measured flow at site A, a headwater tributary site, is 0.435 cfs on June 16, 2001 and the reference site flow on that day is 56 cfs and the model flow is 28 cfs at the reference site, the normalized site flow is 0.435/56 * 28 = 0.218 cfs. For sites with multiple samples and flows each sample flow is normalized then the normalized flows are averaged. Doing this normalized the flow conditions of the entire basin and makes loads from sites throughout the basin comparable.

The site flows were normalized and averaged when multiple flow values existed for a site. These two actions have the potential of adding error. To test the reliability of this method, averaged mainstem site flows where charted to see if, as one would expect, the flow values increase while moving downstream. Figure 5 shows the flows graphed moving downstream, and with the exception of one site at river mile (RM) 7.3, all the averaged and normalized flows continue to increase. The deviation at RM 7.3 may have been caused by some unknown loss of water downstream of the site, such as a subsidence, or may be an introduced error resulting from averaging. Possibly the flows at that site, on average, were higher then at the next two downstream sites. In the model the “extra” flow was removed from the next downstream site in the adjustment that occurs before each mainstem or main tributary site.

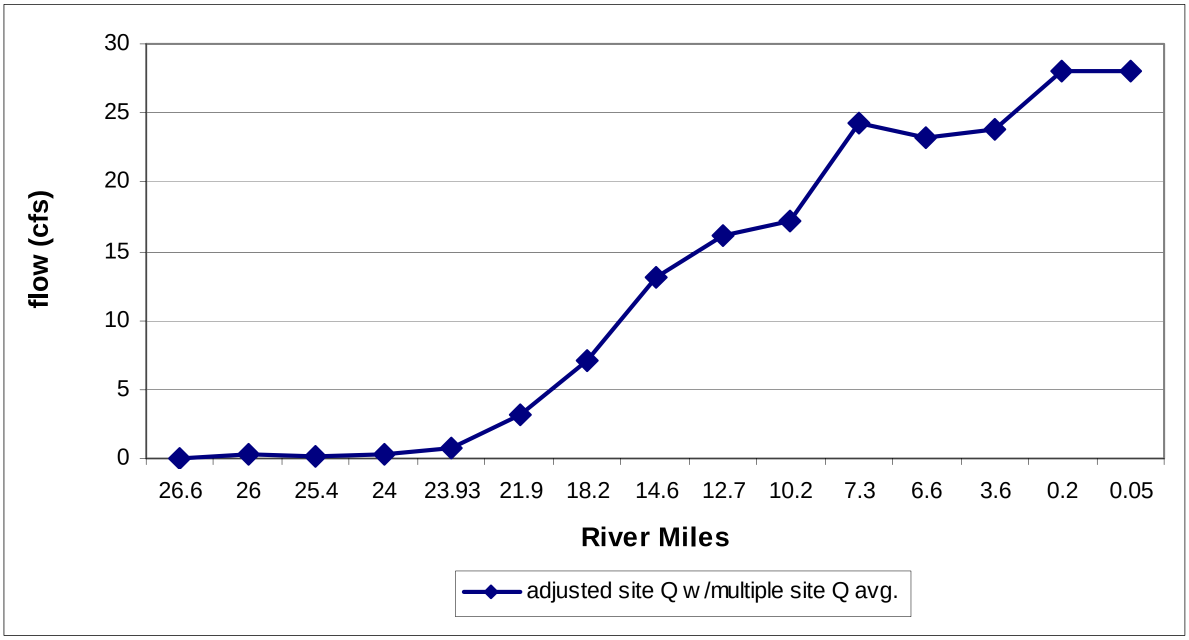

Figure 5. Sunday Creek Mainstem Flows

In order to make the net acidity mass balance spreadsheet work logically the basin was divided into segments that would allow the loads to be added and accumulate. The segments from upstream to downstream are: mainstem headwaters to just upstream East Branch, the East Branch contribution, Sunday Creek mainstem from just below the East Branch to just upstream the West Branch, West Branch and mainstem from just downstream the West Branch to the mouth.

Bacteria

The model used is the United States Environmental Protection Agency's (USEPA's) Bacterial Indicator Tool, a spreadsheet that estimates the fecal coliform bacteria contribution from multiple sources. The tool is designed to make the output that it generates available for use as input to WinHSPF and the Hydrological Simulation Program Fortran (HSPF) water quality model in BASINS. However, due to the small areas in the problem subbasins it was used as a stand alone model for this project. The tool estimates the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forested, built-up, and pastureland), as well as the asymptotic limit for the accumulation should no washoff occur. The tool also estimates the direct input of fecal coliform bacteria to streams from grazing agricultural animals and failing septic systems (USEPA, 2000).

The following text, from the model User's Guide (U.S. EPA, 2000) describes the Bacterial Indicator Tool model. The entire User's Guide is included in Appendix B.

> *The Bacterial Indicator Tool is based on a modeling study of 10 subwatersheds, composed of four land uses (cropland, forest, built-up, and pastureland)... The tool contains the following worksheets:*
>
> > *Land Use - Lists the distributions of built-up land, forestland, cropland, and pastureland in up to 10 subwatersheds.*
> >
> > *Animals - Lists the number of agricultural animals in each subwatershed (beef cattle, dairy cattle, swine, chickens, horses, sheep, and other [user-defined]), and the densities of wildlife by land use category (ducks, geese, deer, beaver, raccoons, and other [user-defined]).*
> >
> > *Manure Application - Calculates the fraction of the annual manure produced that is available for washoff based on the amount applied to cropland and pastureland in each month and the fraction of manure incorporated into the soil (for hog, beef cattle, dairy cattle, horse, and poultry manure).*
> >
> > *Grazing - Lists the days spent confined and grazing for beef cattle, horses, sheep, and other. Beef cattle are assumed to have access to streams while grazing. References Lists literature and assumed values for manure content, wildlife densities, and built-up fecal coliform accumulation rates. These values are used in calculations in the remaining worksheets.*

Wildlife - Calculates the fecal coliform bacteria produced by wildlife by land use category. Cropland Calculates the monthly rate of accumulation of fecal coliform bacteria on cropland from wildlife, hog, cattle, and poultry manure.

Forest - Calculates the rate of accumulation of fecal coliform bacteria on forestland from wildlife.

Built-up - Calculates the rate of accumulation of fecal coliform bacteria on built-up land using literature values.

Pastureland - Calculates the monthly rate of accumulation of fecal coliform bacteria on pastureland from wildlife, cattle, and horse manure, and cattle, horse, sheep, and other grazing.

Cattle in Streams - Calculates the monthly loading and flow rate of fecal coliform bacteria contributed directly to the stream by beef cattle.

Septics - Calculates the monthly loading and flow rate of fecal coliform bacteria from failing septic systems.

ACQOP&SQOLIM (for land uses) - Summarizes the monthly rate of accumulation of fecal coliform bacteria on the four land uses; calculates the build-up limit for each land use. Provides input parameters for HSPF (ACQOP/MON-ACCUM and SQOLIM/MON-SQOLIM).

The following information must be input by the user:

- *Land use distribution for each subwatershed (built-up, forest, cropland, and pastureland, including, to the extent possible, the breakout of built-up land into commercial and services, mixed urban or built-up, residential, and transportation/communications/utilities)*
- *Agricultural animals in each subwatershed*
- *Wildlife densities for forest, cropland, and pastureland in the study area (built-up land is assumed not to have wildlife)*
- *Number of septic systems in the study area*
- *Number of people served by septic systems in the study area*
- *Failure rate of septic systems in the study area*

Default values are supplied for the following inputs, but they should be modified to reflect patterns in the study watershed:

- *Fraction of each manure type that is applied each month*
- *Fraction of each manure type that is incorporated into the soil*
- *Time spent grazing and confined by agricultural animals (and in stream for beef cattle only)*

Literature values are supplied for the following inputs, but they may be replaced with user values if better information is available for the study watershed:

- *Animal waste production rates and fecal coliform bacteria content*
- *Fecal coliform bacteria accumulation rates for built-up land uses*
- *Raw sewage fecal coliform bacteria content and per capita waste production*

The Bacterial Indicator Tool was developed to provide starting values for model input, however a thorough calibration of the model is still recommended. (USEPA, 2000).

Sedimentation

Linking sedimentation to biological stress and calculating sediment load is relatively simple compared with quantifying to what degree sediment loading stresses stream biology. USEPA's *Protocol for Developing Sediment TMDLs*, recognizes that it is "difficult or impossible to relate sediment mass loading levels to designated or existing use impacts or to source contributions." Thus, USEPA encourages the use of "creative approaches and expressing targets in terms of substrate or biological indicators," (pgs. 2-3 and 2-4, USEPA, 1999). In the unglaciated hill region of Ohio gross erosion rates can be high; however, the high stream gradient and natural stream habitats in these areas enables the stream to assimilate higher amounts of sediment than lower gradient streams (Rankin, 2003). So one may incorrectly conclude that a high sediment load calculated using RUSLE or some other common sediment load calculator may cause impairment. A better way in the Sunday Creek watershed to link biological measures to sediment loading to is use a developed relationship between biological indexes and QHEI. The report *Using the Qualitative Habitat Evaluation Index to Derive TMDL Targets for Sediment Impairment in Southeast Ohio* (Rankin, 2003), demonstrates this relationship and develops targets based on it. The relationships in the Rankin report provide the modeling for this TMDL report (Appendix C). The Rankin report links biological measures with sediment and habitat stressors demonstrated in a series of figures, setting a target of 13 to 14 for substrate, a QHEI subcomponent. This target was used to determine which sites out of 77 sampled in the Sunday Creek basin are impaired by sedimentation.

The sites were sorted first by ascending QHEI score. All sites with QHEI scores 60 or greater were eliminated because they meet the minimum Warmwater Habitat (WWH) QHEI score of 60. The remaining sites were sorted by substrate score. Sites that scored higher than 13, the substrate target developed by the Rankin report, were discarded. Rankin recommended a target between 13 and 14; 13 was selected as the target for the Sunday Creek TMDL because it is more conservative than 14. Only sites that achieved less than the minimum WWH QHEI score and less than the minimum substrate score remained. A total of 18 sites were determined to be impaired by sedimentation.

4.2 Critical Conditions and Seasonality

Acid Mine Drainage

Flows in the low to normal range are considered the critical condition for most AMD sites and this Sunday Creek TMDL. The Upper Raccoon Creek TMDL report found that net acidity decreased with increasing flow after an upper flow threshold was met (*Upper Raccoon Creek TMDL Report*, Ohio EPA, 2002). The threshold for the upper Raccoon Creek, a basin similar in size and topography to Sunday Creek, was 300 cfs. Common belief is that as flow increases beyond the threshold the acidity becomes diluted so acid concentration drops.

This information was relayed to the people collecting data for the Sunday Creek AMDAT and TMDL prior to the TMDL sampling. As a result, the Sunday Creek Acid Mine Drainage (AMD) data was collected under stable conditions, and high flows were avoided. This maximized work efficiency and reduced the elimination of data. Figure 6 shows the flow to net acidity concentration relationship from all the Sunday Creek data. Since an effort was made to avoid high flows with diluted acid concentrations none of the data were negatively affected by the flows so all the data collected was able to be used.

Bacteria

The critical stream condition for bacteria concentration depends on the location and source of the bacteria. The first inch of rainfall typically removes most of the bacteria available for entrainment in runoff (Moore et al., 1982). If the source is pastured livestock, crop-field applied manure or wildlife, rains will wash manure off fields and elevate bacteria counts in the vicinity of the source shortly after the water begins to runoff. If the source is far upstream of the sampling site, due to the time of travel the bacteria counts may not elevate until after the first flush. If the source is failing aeration systems which are actively flowing to the stream or homes which have no treatment and are straight piped to the stream the critical condition occurs during low stream flows. If the source is failing leach bed systems the bacteria may not reach the stream until it is flushed out during a rain event.

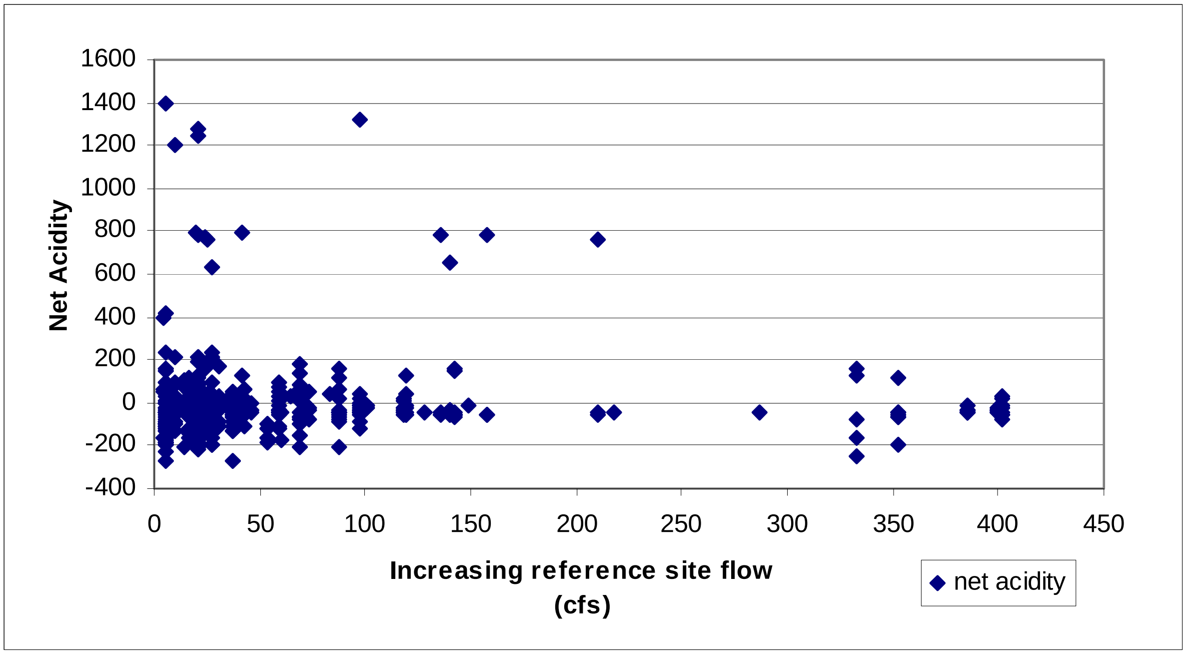

Figure 6. Relationship of Site Flow to Net Acidity for All Sites

Horsley and Whitten found that the first flush from areas adjacent to a stream will enter the stream more quickly than the first flush from areas higher in the watershed. The net result is the water quality trend exhibited in the stream data (bacteria concentrations increasing with increasing flow). As more bacteria reach the stream from higher in the watershed the stream bacteria concentration increases (Horsley and Whitten, 1996).

The source of bacteria is believed to be home sewage treatment systems (HSTSs), but samples collected during low-flow conditions did not yield significantly higher bacteria concentrations than those collected under high-flow conditions. This situation is contrary to what would be expected if the HSTS problems are linked only to pipe discharges such as failed aeration systems or bypassed leached fields. However, improperly working leach fields that cause surface ponding primarily contribute bacteria following runoff events. A combination of these modes of HSTS failure as well as significant bacteria contributions from other sources than originally thought (e.g., pasture runoff) may explain the bacteria concentration signatures across different flow conditions. Figures 7 and 8 show the bacteria data in relation to flows measured in the adjacent Monday Creek watershed.

Sedimentation

The sediment analysis for this report is based on the QHEI substrate subcomponent score. The substrate score is determined by existing substrate make up. Therefore there is no critical condition.

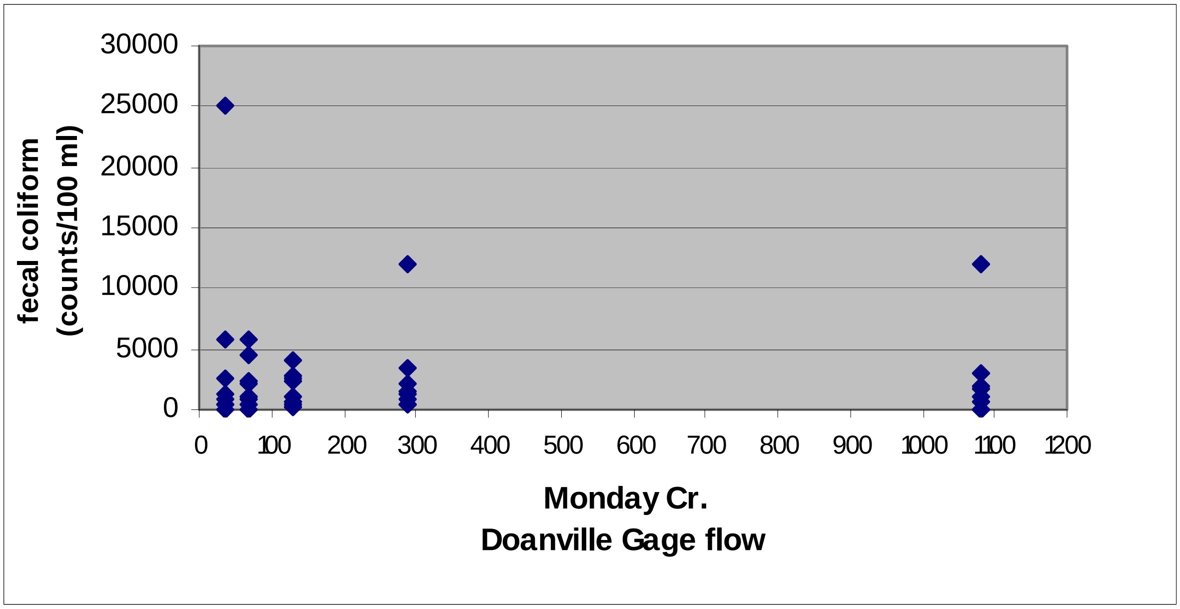

Figure 7. Comparison of Monday Creek Flows to Sunday Creek Fecal Coliform Concentrations

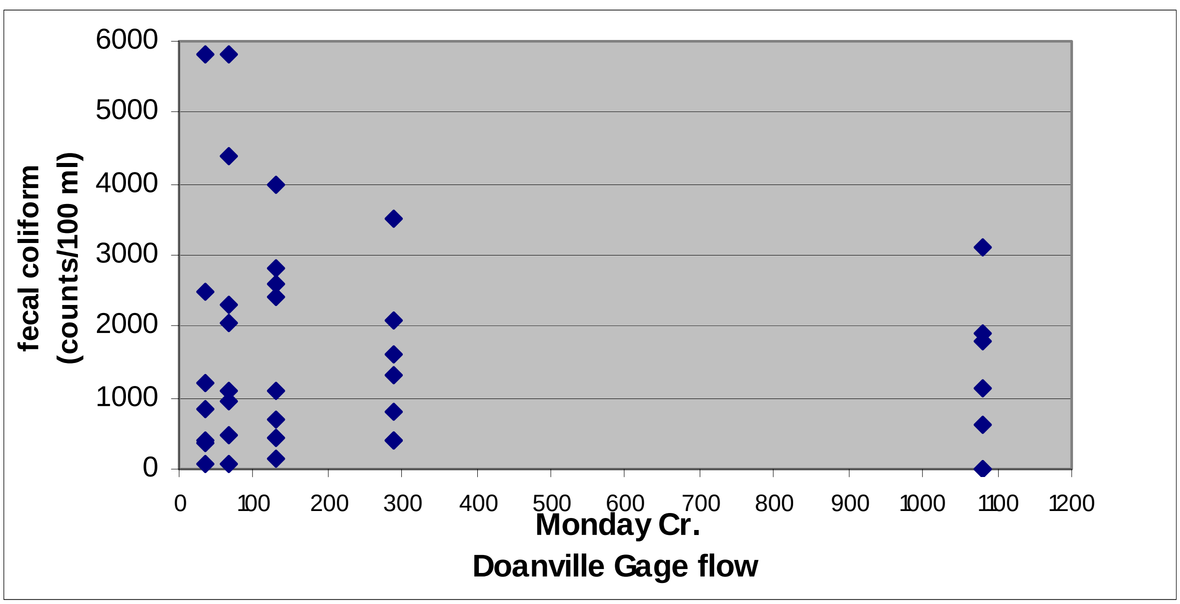

Figure 8. Figure 8 is the same as Figure 7 with the three highest values removed to better define the lower values

4.3 Margin of Safety

Acid Mine Drainage

The margin of safety (MOS) for the Sunday Creek AMD modeling is explicit (10%) and results from setting the target using the 90th percentile of data from the sites that presently meet the WWH criteria. This allows a 10 percentile buffer to the least acceptable net acidity from the WWH sites. Of 42 samples from sites in 12 different streams that meet the WWH use designation the target and 90th percentile net acidity is -67 mg/l, the 99th percentile is -53 mg/l. The margin of safety between the target of -67 and -53 is protective of water quality without being overly stringent. Further evidence of a margin of safety is demonstrated in Figure 3. Here, the -67 mg/l net acidity target correlates to a pH greater than the minimum pH WQS of 6.5, demonstrating that there is a buffer.

An implicit margin of safety stems from the four point source outfalls shown in Table 8. Since these outfalls discharge water with pH greater than the target pH of 6.5, there provide a margin of safety.

Bacteria

The premise of the bacteria model was to quantify the problem of failing home septic treatment systems in and around the Glouster area. This bacteria TMDL shows that correcting the problem will result in decreased instream bacteria and improved water quality for recreation use and shows how much improvement will occur if 93% -100% (varies depending on site) of the HSTS failures are corrected.

The MOS for the Sunday Creek bacteria modeling is explicit, based on correcting more failing HSTSs than is absolutely necessary to meet the target. For consistency among the models, each basin's post treatment model assumed that only 5% of the HSTSs would continue to fail after a localized effort was made to repair failing systems. Five percent of the HSTSs would continue to operate improperly if 93% of the systems were repaired. The exception is Greens Run, where 100% of HSTSs need to be corrected in order to meet the target. Results which show the MOS for each subbasin are shown in Table 9. This table compares the post treatment instream fecal coliform loads to the target loads, the difference of which is the percent margin of safety. Also shown is the percentage of remaining failing HSTSs after repairs are made to local HSTSs.

By assuming that only 5% of the systems would continue to fail after area wide repairs are made, the bacteria load to the stream was actually less than required by the target for all basins except Greens Run. For instance in Congress Run the existing instream bacteria load is 1.47E+10 (cnts/hr) (Table 11), if after repairs only 5% continue to fail the model predicts the instream bacteria load to be 5.31E+09 (cnts/hr) (Table 9). The target for Congress Run is 6.70E+09 (cnts/hr) (Table 9). The post treatment load then is 1.39E+09 (cnts/hr) less than the target which is a 21 percent (Table 9) "buffer." This "buffer" is the explicit margin of safety.

The Greens Run 1 site has the smallest MOS. No livestock were counted in this basin and there are zero failing HSTSs in the post treatment model simulation. Thus, the entire source of fecal coliform load is from wildlife. Therefore, given the assumptions of the model the MOS for this site cannot be increased. The other study areas have a comfortable MOS and should meet the WQS with the correction of the failing HSTSs.

Table 9. Margin of Safety

Study Area	**Target fecal coliform load based on 1000 cnts/hr WQS fc load (cnts/hr)**	**Percentage of failing HSTSs after improvements**	**Post treatment instream fecal coliform loads fc load (cnts/hr)**	**Percent margin of safety (1-(model result/target))*100**
Greens Run 1	3.98E+09	0	3.92E+09	1.5
Mud Fork 1 (hw to RM 2.2)	1.15E+10	5	1.06E+09	91
Mud Fork Trib 1	1.43E+09	5	1.37E+09	4
Mud Fork 2 (RM 2.2 to mouth)	1.88E+10	5	2.84E+09	85
Congress Run	6.70E+09	5	5.31E+09	21
Jackson Run	1.05E+10	5	9.58E+09	9

Sedimentation

Based on Rankin (2003), the substrate score target should be, “a useful baseline metric score of about 13 - 14”. For this TMDL the target was set at 13 points. Two points, or more than 10% of the target, were added to 13 as the explicit MOS in order to ensure the the outer range of the suggested target (14) was exceeded. Therefore, the target with the MOS is a QHEI substrate subcomponent score of 15 points (see Table 3).

4.4 TMDL Calculations

Acid Mine Drainage

Surface mining is the source of the high stream pH which is causing impairment in the Sunday Creek watershed. The Ohio EPA water quality standard for pH is 6.5 – 9.0. Instream pH is difficult to predict because the water chemistry is constantly changing as it moves downstream. Net acidity is used in the model as a surrogate for pH, because unlike pH, loads can be developed and accumulated. Using the same data set as was used in the model it was shown that when net acidity equals or exceeds –67 mg/l (the target) pH is greater than the minimum allowed pH of 6.5, therefore net acidity is a valid surrogate for pH.

The model was first set up with the existing site net acidity concentrations and site flows adjusted for a reference site flow of 28 cfs to depict the existing conditions (see Appendix D, Existing Instream Net Acidity Conditions, for details). Using information about treatments from the AMDAT plan (SCWG, 2003), subsidence capture fill sites and treatment sites were located in the model. For the subsidence capture sites the flows and concentrations were altered to reflect changes after the subsidences are filled. This resulted in greater flow and a lower acidity concentration for these sites. Then the net acidity concentrations at the treatment sites were changed to reflect the reduction in acidity after the treatments are to be installed. This resulted in still more acid reduction at the sites and consecutive downstream sites.

However, the AMDAT did not specify treatments for the two big acid contributors, the Corning and Truetown discharges. No solutions to these sources had been selected. There are ongoing discussions regarding whether pollution prevention (i.e., preventing the creation of AMD in situ) or treatment of the AMD discharge is more suitable. An experimental pollution prevention technique has been selected for Corning and is partially funded with CWA Section 319 funds. The model revealed that until those two contributors of acid are dealt with, the target of -67 mg/l net acidity cannot be met within the basin. For specific discussion on the location of various treatments used, their effect and cost, and discussion on future work to the Corning and Truetown seeps, refer to the 2003 Sunday Creek AMDAT plan.

Using the model it was determined that if the Corning Seep acidity, in the headwaters, is reduced from a net acidity concentration of 103 mg/l to 18 mg/l and the Truetown Seep, closer to the mouth, is reduced from 1289 mg/l to 585 mg/l the target can be met throughout the basin, see Figure 9 and Appendix E, Post Treatment Instream Net Alkalinity.

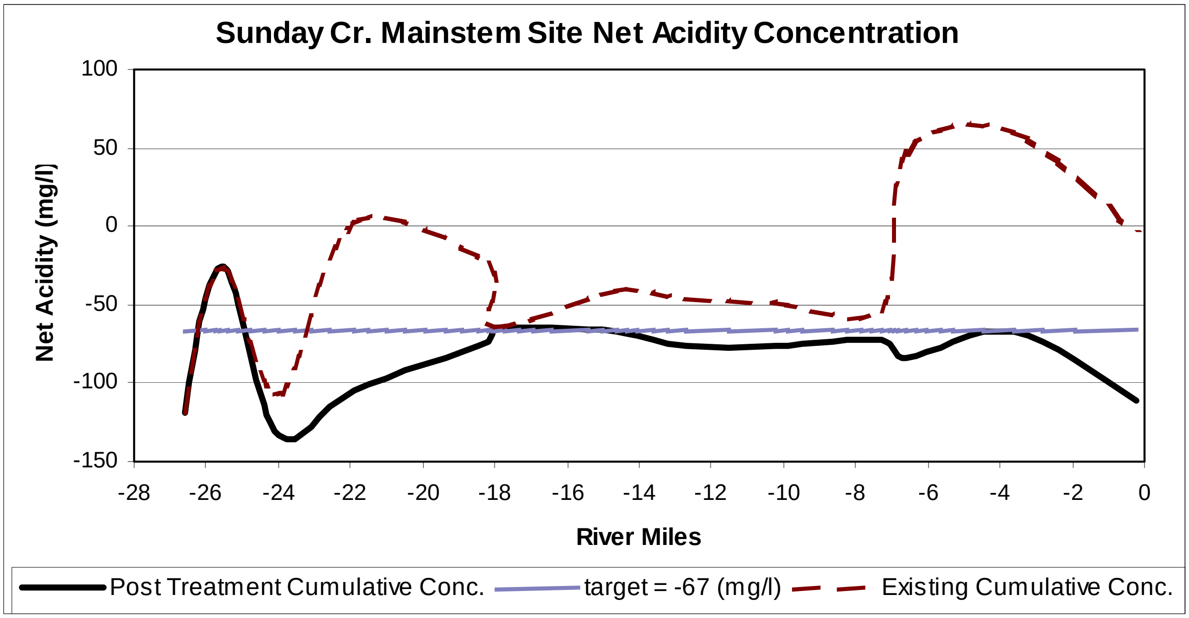

Figure 9. Comparison of Existing Net Acidity to Post Treatment Net Acidity

To compare site by site changes in net acidity load or concentration from existing conditions to post treatment conditions, the model results in Appendix D can be compared to those in Appendix E.

The post treatment modeling assumes that the treatments listed in the AMDAT are made including subsidence closures and that the Corning and Truetown Seeps are treated to a net acidity of 18 mg/l and 585 mg/l, respectively.

The post treatment net acidity only fails to meet the target of -67 mg/l at the headwaters. In this area there is a large gob pile which is listed in the AMDAT as a site to be treated. However, it is difficult to know exactly how the flow from the gob pile will be affected. Now, the gob pile absorbs rain water then slowly releases it. Though there is a main channel exiting the gob pile (which was sampled and measured for flow), there is much diffuse flow out of the gob that was not measured. As a result the gob pile flow in the model misses a portion of what is actually discharged. The effect in the model of capping the gob pile may be understated since the model underestimates a portion of the flow. Capping the pile will be an important step in allowing the headwaters to meet the target; follow-up monitoring will be needed to determine if additional remediation is needed.

Bacteria
Units for counting and reporting bacteria are “bacteria per 100 ml” or “colony-forming units per 100 ml” or “counts per 100 ml” for heterotrophic plate count. Fecal coliform concentration is expressed as “counts / 100 ml.” The concentration used for comparison to the WQSs was the geometric mean of the five samples collected at eight

sites. The load, in counts / hour, for each study area was determined by multiplying the concentration in counts/100 ml by the flow for the site in ml/hr, i.e. ((2309 counts/100 ml) * 6.70E+08 mls/hr = 1.55E+10 counts/hr). The flow was calculated by taking the flow yield from the Doanville USGS gage in the adjacent Monday Creek basin and multiplying by the drainage area of the site. This is the same method used in the acid mine drainage modeling.

The Bacterial Indicator Tool model, described in Section 4.1 and Appendix B, is sensitive to a number of inputs. Some of the inputs are supplied with the model; of these some can be adjusted to local conditions (i.e., they could be used to calibrate the model). For the model's runoff sheets these inputs include fraction of manure incorporated into soil in the manure application sheet, number of animals from the animal sheet, and the percentage of each type of urban land in the basin from the built up sheet. From the septic sheet the two important inputs are the failure rate of home sewage treatment systems and the assumed fecal coliform concentration reaching the stream.

The value for "fecal coliform concentration reaching the stream" (on the septic sheet) is important to the outcome of the model yet is difficult to measure because it changes with temperature, soil radiation, soil moisture, residence time, filtration adsorption and degree of treatment system failure. A variety of recommended values were cited in literature:

- The study "An Analysis of the Potential Impacts on Groundwater Quality of On-Site Wastewater Management Using Alternate Management Practices" cites three references with values for fecal coliform septic tank effluent concentrations ranging from 10E+6 to 10E+8 Most Probable Number (MPN) (Venhuizen, 1995).

- In "Identification and Evaluation of Nutrient and Bacterial Loading to Maquoit Bay Brunswick," the range of literature values found were from 10E+4 to 10E+7 fecal count (FC)/100 ml and selected for use in their model was 10E+6 FC/100ml (Horsley and Whitten, 1996). The cited range of values is for septic concentration which may differ from the fecal concentration that leaks, seeps or drains to the stream.

To be consistent with the literature values, the lower end of the range was used to calibrate the five subbasin models. The range of values used in these models is 1.50E+5 FC/100ml to 6.00E+5 FC/100ml. To avoid giving too much importance to this estimated large and variable concentration, model calibration was done by trying to stay within one order magnitude of the average of the five field measurements for the five subbasins (see Table 11). Using values consistently in the five subbasins and staying within an order magnitude range of fecal concentration helped to place more emphasis on the other more measurable variables such as number of homes, number of livestock and landscape makeup.

Table 10. Important Model Sensitive Inputs

Study Area	Important Model Inputs: % Available for Runoff (As Effected by Fraction Incorporated into Soil)	% of Fc Buildup from Wildlife That Runs off	Breakdown of % Areas of Built up (Comm,mxd Urban,resid,transport)	Septics Fc Conc (Cnts/100 Ml) Which Reaches the Stream	Percentage of Failing Septic Systems
Greens Run 1	na	40	.1,.1,.2,.6	2.50E+05	10
Mud Fork 1 (hw to RM 2.2)	50	40	.1,0,.3,.6	2.50E+05	75
Mud Fork Trib 1	50	40	0,0,.1,.9	2.50E+05	75
Mud Fork 2 (RM 2.2 to mouth)	50	40	.1,0,.3,.6	2.50E+05	75
Congress Run	na	40	0,0,.5,.5	6.00E+05	75
Jackson Run	50	40	.1,.1,.2,.6	1.50E+05	75

The models for each of the basins were calibrated by first inputting the known and assumed values into the model then comparing the model output to the average of the measured values at the study area. After a comparison of modeled values to measured values was done for each of the basins the fecal coliform concentration reaching the stream variable was adjusted until the model output approached the average of the measured values for the subbasin, see Table 11.

Table 11. Comparison of Calibration Model Results to Field Values and Target

Study Area	Target Load Based on WQS (1000 Cnts/hr)	Average of 5 Measured Field Samples (Cnts/hr)	Calibration Model Results of Fecal Coliform Load (Cnts/hr)
Greens Run 1**	3.98E+09	3.92E+09	4.20E+09
Mud Fork 1 (hw to RM 2.2)	1.15E+10	3.04E+10	6.33E+09*
Mud Fork Trib 1	1.43E+09	2.66E+09	2.03E+09*
Mud Fork 2 (RM 2.2 to mouth)**	1.88E+10	1.02E+10	1.15E+10
Congress Run	6.70E+09	1.44E+10	1.47E+10
Jackson Run	1.05E+10	1.80E+10	1.84E+10

* Model results from these sites were included however, importance was placed on calibration of the mouth of Mud Fork (the Mud Fork 2 site).

** The geometric mean of values from this site did not exceed the 1000 cnts/100 ml WQS, however at least one sample did exceed the maximum WQS of 2000 cnts/100 ml. Since comparisons were made to the geometric mean WQS the field value and resultant calibrated value do not exceed the target.

The rate of manure runoff has a very dramatic impact on instream fecal coliform concentration and loadings. This was true even though these small builtup basins had limited livestock, for numbers of animals per subbasin see Table 12. The assumed rate of manure runoff based on best professional judgement and model calibration was 50 percent, see Table 10.

The assumed percent available runoff of wildlife manure fecal coliform based on best professional judgement and model calibration was 40 percent, see Table 10. It is assumed that the fecal coliform concentration that reaches the stream from wildlife will be less than the runoff from livestock manure since wildlife waste is more widely scattered and smaller and therefore more susceptible to drying.

The Director of Environmental Health for Athens County estimated that the failure rate of the home sewage treatment systems in that county were between 75 and 80 percent, (Eichenburg, 2003). With the exception of the Greens Run 1 headwaters model, where a 10 percent failure rate was needed to calibrate the model, these rates were used in the model for calibration, see Table 10.

Table 12. Subbasin Livestock and Wildlife Populations

	Basin Specific Count/Estimation					
Study Area	**Houses**	**Dairy Cattle**	**Chickens**	**Dogs**	**Deer**	**Raccoons**
Greens Run 1	***46***	nc	nc	*55*	*21*	*11*
Mud Fork 1 (hw to RM 2.2)	***100+***	nc	nc	*120*	*60*	*32*
Mud Fork Trib 1	***3***	nc	***3***	*4*	*8*	*4*
Mud Fork 2 (RM 2.2 to mouth) to m	***100+***	nc	***5***	*120*	*31*	*16*
Congress Run	***92***	nc	***1****	*110*	*35*	*19*
Jackson Run	***344+***	***5***	***5***	172	55	29

Bolded and italicized numbers were actually counted during a “windshield” survey, all others are an estimation.

nc = none counted

Note: Dog numbers are based on a per house assumption; in rural areas 12 dogs/10 houses, in dense house areas 5 dogs/10 houses (BPJ), and deer and raccoon numbers are based on an animal/mi. sq. assumption as such; deer = 15/mi2 (BPJ) and Raccoons = 8/mi2 (Rodewald, Amanda, 2001).

* Assumed zero in the model

The results of the modeling show that by reducing the failing HSTSs in each basin the bacteria load WQS based on a concentration of 1000 counts/100 ml can be met, see

Table 13. The Greens Run and Mud Fork 2 sites had geometric mean sample values less than the target, however their maximum values exceeded the maximum target. The HSTS failure rate reductions, 10 percent for Greens Run and 70 percent for Mud Fork 2, will eliminate the maximum WQS exceedances.

Table 13. Post Treatment Model Results

Study Area	HSTS Failure Rate after Treatments	Target Load Based on WQS (1000 Cnts/hr)	Post Treatment Model Results of Fecal Coliform Load (Cnts/hr)
Greens Run 1	0	3.98E+09	3.92E+09
Mud Fork 1 (hw to RM 2.2)	5	1.15E+10	1.06E+09
Mud Fork Trib 1	5	1.43E+09	1.37E+09
Mud Fork 2 (RM 2.2 to mouth)	5	1.88E+10	2.84E+09
Congress Run	5	6.70E+09	5.3E+09
Jackson Run	5	1.05E+10	9.58E+09

Sedimentation

See sedimentation in Section 4.1 for details on TMDL calculations.

5.0 Public Participation

Public involvement is key to the success of any TMDL project. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an advisory group in 1998 to assist the Agency with the development of the TMDL program in Ohio. The group met multiple times over eighteen months and in July 2000 issued a report to the Director of Ohio EPA on their findings and recommendations. The Sunday Creek watershed TMDL project has been completed using the process endorsed by the advisory group.

In the Sunday Creek watershed specifically, Ohio EPA has regularly participated in ongoing watershed activities as part of and beyond the TMDL effort, drawing connections to the TMDL as appropriate.

Rural Action, www.ruralaction.org, has employed a Sunday Creek Watershed Coordinator since 2001. This position is funded partially by Ohio EPA CWA 319 and Ohio Department of Natural Resources. The watershed coordinator acts as a liaison between the Sunday Creek Watershed Group, a citizen group working to improve the environment of Sunday Creek Watershed, and state and federal agencies. The group has already created both a watershed management plan and an Acid Mine Drainage Abatement and Treatment (AMDAT) Plan for the Sunday Creek watershed.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was public noticed in May 2005, and a copy of the draft report was posted on Ohio EPA's web page (www.epa.state.oh.us/dsw/tMDL/index.html). In addition, copies of the report were distributed to the following local libraries:

- New Straitsville Public Library, 102 East Main Street, New Straitsville, Ohio
- Logan-Hocking County District Library, 230 East Main Street, Logan, Ohio
- Nelsonville Public Library, 95 West Washington, Nelsonville, Ohio

No comments were received on the draft report.

6.0 Implementation and Monitoring Recommendations

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both.

6.1 Implementation Strategies

Acid Mine Drainage
As described in Chapter 2, the primary cause of impairment in the Sunday Creek is pH. An effective restoration strategy must quantify the relationship between reclamation of coal mines and their wastes and water quality improvements. This has been done for pH in the Sunday Creek AMDAT plan (SCWG, 2003). The implementation options recommended in the AMDAT plan are adequate to meet the TMDL objectives.

Bacteria
To eliminate the bacteria impairments emphasis will need to be placed on education about HSTS maintenance and funding for HSTS improvements will need to be provided as an incentive to the residents of this somewhat economically depressed area.

Failing home sewage treatment systems (HSTS) are the identified source of water quality impairments from various subbasins in the Glouster area. Solutions to HSTS problems have traditionally fallen into two general categories: individual HSTS repairs/upgrades or replacement of individual HSTS with a centralized collection and treatment system.

Individual HSTS repairs or upgrades are feasible where local soils, groundwater, and bedrock conditions are favorable and lot sizes are adequate for on-site treatment. Where the above-mentioned local conditions are not available, the only feasible long-term solution to pollution problems is centralized wastewater collection and treatment. However, the small number of homes among which the cost of such a project must be distributed often makes this option cost-prohibitive, unless there is already a local centralized system nearby that can serve the area.

Ohio EPA is not aware of any published information regarding the details of the HSTS situation in this area. However, the watershed action plan currently being developed for the Sunday Creek Watershed is expected to address specific pollution problems in this area as described in the next section.

Future Planning
In 2001 Rural Action received a grant to fund a full time watershed coordinator for six years. A combination of funds from the Ohio EPA 319 program and the Ohio Department of Natural Resources (ODNR) are used to fund this position. State grant funds finance 100% of the personnel costs for the watershed coordinator position in

year one and then decrease to a level where the local watershed group finances 100% of the position in year six.

The purpose of the watershed coordinator program is to fund watershed action plan development and implementation to solve priority nonpoint source pollution problems. To obtain Ohio EPA endorsement of a final watershed action plan, the following key items must be included: a) a watershed inventory section that provides enough information to identify and quantify the sources of pollution impairing water resource quality in the watershed; b) problem statements that link each water quality impairment cause with its source(s), the load estimate, or relative pollutant contribution from each source by stream segment; the problem statement is expected to contain an actual projected loading number and units (i.e., gallons of untreated waste); and c) impairment reduction goals for each stressor on each individual stream segment to move that segment towards water quality improvement.

Rural Action has received a CWA 319 grant, part of which, is to repair failing home sewage systems. $112,500 in CWA 319 funds were secured for Sunday Creek to repair and upgrade 25 failing septic systems in the watershed. This is on a cost share basis with 319 funding up 75% of the cost up to $6,000. As a condition of this grant a Sunday Creek Home Sewage Treatment System (HSTS) plan was developed. This plan details where failing systems are causing non attainment of Recreation Use designation and activities that must occur in order for Sunday Creek to meet attainment criteria.

Low interest loan funds from the Ohio Water Pollution Loan Fund (WPCLF) linked deposit loan program administered by the Division of Environmental and Financial Assistance (DEFA) are also available. Through the linked deposit system, local banks can offer interest rates that are generally 5% below market rates to credit-worthy homeowners for the upgrade or replacement of home sewage treatment systems, as approved by the County Health Department. Terms of the loan are typically three, five, or seven years.

Funding is available only to counties that have produced an Ohio EPA approved county-wide or watershed-wide HSTS Plan. The approved contents of the plan will drive the activities which occur during the entire WPCLF loan project and will be used to evaluate the county’s progress during the funding period.

Frequently home sewage treatment systems are discharging systems. Ohio EPA does not provide funding for HSTS upgrades or repairs that result in a discharging system. Therefore in order for a homeowner to access sources of funding provided by Ohio EPA, the correction will need to result in a system that does not discharge.

Sedimentation

Initial investigation of sediment sources and source locations began in June 2003. Areas with QHEI sub component substrate scores below the target of 14 were explored and potential sources of sediment were noted. Sources included; cattle and horse stream access, gob piles, treeless stream banks and riparian zones, vehicle crossing and muskrats.

More information needs to be collected by the Sunday Creek Watershed Group regarding sources of sedimentation before specific implementation plans can be made. Once the sources are known coordination with appropriate landowners or agencies such as the Soil and Water Districts should be made to remove or reduce the sedimentation sources.

6.2 Reasonable Assurances

Reclamation of abandoned mine land has proven to be effective in reducing AMD which will improve the aquatic resource quality in Sunday Creek. The Sunday Creek AMDAT plan discusses implementation. Treatment methods and cost estimates are described in pages 33-106 of that report and should be considered the implementation plan for the acid mine drainage impairments.

The existing concentrations for selected sites from the AMDAT were replaced with remediation outputs designed to yield net alkalinity concentrations based on the type and design of treatment. The result is greatly increased net alkalinity concentrations throughout the basin. See Figure 9 for the net acidity concentration decreases throughout the mainstem. The expected net acidity decreased depicted in the after treatment scenario by the model assumes that the discharges from the Corning and Truetown seeps are treated. Currently there are no plans for treatment at the Truetown discharge. Volume of flow and location of these sites will make treatment a challenge. More work is needed to assess what can be done to treat these sites.

Many agencies, individuals, non-profit organizations and corporations are working together to improve the Sunday Creek watershed. The high interest generated by and strong support for the Sunday Creek Watershed Coordinator, along with the completion of watershed action plan, provide an impetus for change in the watershed. The following groups are among those focusing on improving the aquatic resource quality in the Sunday Creek watershed:

- Ohio EPA
- Ohio Department of Natural Resources
    - Division of Mineral Resource Management
    - Division of Wildlife
    - Division of Natural Areas and Preserves
- U.S. Department of Interior, Office of Surface Mining
- Rural Action
- Sunday Creek Watershed Group
- Ohio University
    - Institute for Local Government Administration and Rural Development,
    - Department of Geology

- Department of Biology

6.3 Process for Monitoring and Revision

The adaptive management approach is recommended for the restoration of Sunday Creek. Adaptive management suggests that a hypothetical restoration plan be developed and implemented, and then the stream reassessed. If at that time the stream is not meeting use designations another restoration plan will be developed incorporating most recent data.

For the acid mine drainage impairments, the AMDAT plan discusses long term as well as pre and post monitoring of the aquatic resource on pages 105-107. This schedule should be followed with the utilization of adaptive management.

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