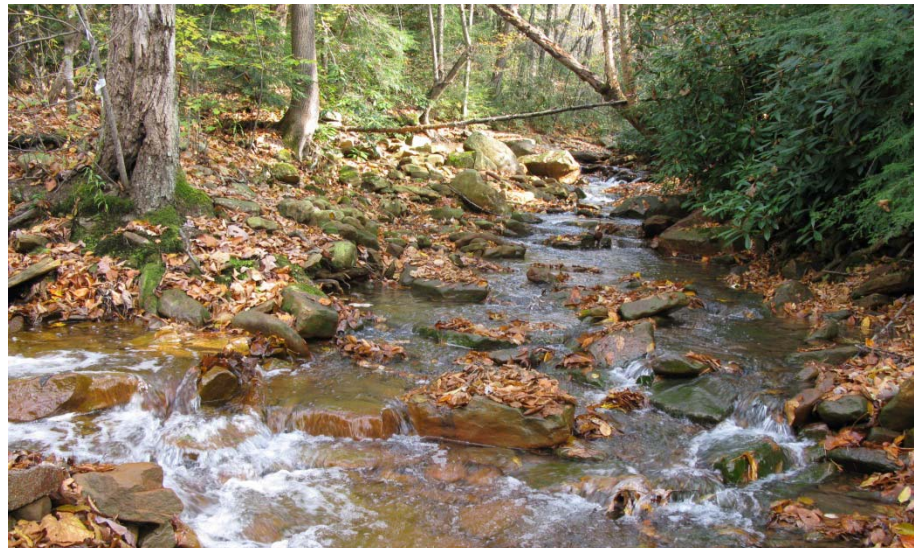


Twomile Run Water Quality Monitoring Kettle Creek Watershed, Clinton County, Pennsylvania

**Technical Report Developed for Trout Unlimited and the
Kettle Creek Watershed Association by Hedin Environmental**

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HedinEnvironmental

Background

Twomile Run is a tributary to Kettle Creek in Clinton County that has been polluted with acid mine drainage since the early 1900s. During the last 10 years, significant remediation projects have been undertaken in the watershed. As projects have been implemented, comprehensive sampling rounds have been conducted in order to quantify changes in water quality. Each of these “snapshot” sampling events was conducted in a single day and included flow measurements so that the loading contributions of each monitoring point could be determined and compared. The benchmark to which these sampling rounds are compared is the Twomile Run Total Maximum Daily Load (TMDL) study conducted by DEP in 1999-2000 before the restoration effort began. The TMDL provides goals for contaminant reduction that, combined with reestablishment of a viable trout fishery, should allow stream sections to be removed from the Commonwealth’s list of degraded streams. This report provides an assessment of progress towards those goals.

Methods

Water samples have been collected from stream locations over the last 45 years by various parties. Samples were analyzed by standard methods in use when the samples were collected. Analytical methods have changed over the last 45 years which complicates specific comparisons of recent and old data. But evaluations of major changes in water chemistry over the last 30 years are certainly reasonable. All chemical data in this report is presented as mg/L. Alkalinity and acidity are presented at mg/L CaCO₃. Flow rates were determined from measurements made at installed weirs and by stream gaging with a velocity meter. Flow rates are presented as gallons per minute (gpm). Data were entered into a master spreadsheet that is available from Trout Unlimited. Loadings were calculated from the product of flows rates and concentrations and are expressed in this report as pounds per day (ppd). Every study of Twomile Run has found non-point AMD inputs to the stream section between Robbins Hollow and Huling Branch. This contaminant loading was calculated from the difference of Twomile Run above Huling Branch and the sum of Robbins Hollow, Middle Branch, and Twomile Run above Middle Branch. Remediation of Twomile Run beyond Huling Branch was not considered in this assessment because Huling is severely polluted with AMD and no remediation had occurred in the watershed when this report was prepared. (Reclamation activities began in the fall 2013.)

Results

Loading Reduction - Snapshot Comparisons

Over the last 15 years, twelve snapshots have been conducted to document conditions in the Twomile Run watershed. The baseline for data interpretation is the TMDL conducted in 1999-2000. The TMDL includes the main stem of Twomile Run and all major tributaries. For this report, the relevant stations were: Twomile Run above Middle

Branch, Middle Branch Mouth, Robbins Hollow Mouth, and Twomile Run above Huling Branch. These stations were resampled in 2005, 2010, and 2013. Table 1 shows the average acidity loading at each station for the four sampling efforts. The TMDL found highly acidic conditions at every station. When the 2005 snapshots were made, the Robbins Hollow headwaters passive treatment systems were providing partial treatment of AMD in Robbins Hollow and the Middle Branch treatment system was providing partial treatment of AMD in Middle Branch. Five years later in 2010 the Middle Branch system had been rehabilitated and the mouth of Middle Branch was net alkaline. When the 2013 sampling occurred, the Swamp and Robbins Hollow passive treatment systems had been recently installed and all of the upper monitoring stations were net alkaline.

The major remaining contributor of AMD to Twomile Run above Huling Branch is contaminated groundwater entering the stream as baseflow. The collection and treatment of these groundwater inputs is not economically feasible. The only means of passively addressing the contaminated groundwater is through reclamation. A major reclamation project is underway in the Huling Branch watershed which could lessen the impact of contaminated groundwater on Twomile Run. Future monitoring will bear this out.

Site	TMDL (1999-2000)	2005	2010	2013
Number of snapshots	6	2	2	2
Twomile above Middle Branch	312	85	663	-135
Middle Branch mouth	90	59	-54	-4
Robbins Hollow mouth	59	18	23	-1
Contaminated groundwater*	80	182	124	207
Twomile above Huling Branch	540	344	756	67

* calculated from: (Twomile above HB) – (Twomile above MB + MB + RH)

TMDL Loading Reduction

The comparison of snapshots of stream chemistry is complicated by unavoidable differences in flow rate. During high flow events, inflows of uncontaminated water can dilute AMD concentrations and partially neutralize acidity. The effect of restoration efforts on Twomile Run water quality above Huling Branch was evaluated by comparing the historic flow and acidity relationships to those measured in 2013. Figure 2 shows the relationship between flow and acidity between 1999 and 2005 (open diamonds) before substantial remediation occurred. Acidity concentrations decrease asymptotically as flow increases. The curve fit to these points can be used to calculate the instream acidity concentration at a known flow rate. The results of the calculation are shown in Table 2. The measured 2013 acidity concentrations are 70-81% lower than predicted from pre-remediation data. The relative difference is largest under higher flow conditions. This is likely because at high flow the larger alkalinity loads produced by the passive systems are capable of neutralizing most of the acidic groundwater inputs. Under low flows the treatment systems discharge much lower loads of alkalinity which are not sufficient to neutralize the groundwater inputs. If this explanation is correct, restoration of lower

Twomile Run under all flow conditions will require lessening the contaminated groundwater input. The Huling Branch reclamation project may provide this benefit.

Date	Flow (gpm)	Acidity (mg/L)	1999-2005 Acidity* (mg/L)	Reduction Achieved	Reduction Needed
Jun-13	3,151	7	36	81%	99%
Oct-13	215	21	69	70%	100%

*calculated acidity, see text and Figure 2

Fishery Recovery

The ability for aquatic ecosystems to recover in Twomile Run will be determined largely by improvements in water chemistry (not just decreased loading). The key chemical parameters are pH, acidity, iron (Fe) and aluminum (Al). The following section will describe the changes in water quality over time at key locations in the watershed. For each station a table provides average chemical conditions historically, when remediation efforts were initiated, and during the last two years. Graphs showing key parameters over the 20-45 year monitoring period are provided at the end of the report.

Twomile Run above AMD (Swamp)

This station is located on the main stem of Twomile Run above any known inflows of AMD. Figures 3 and 4 show pH and concentrations of alkalinity. Table 3 shows average chemical characteristics. The stream is acidic and poorly buffered. The chemistry is typical of freestone streams in northcentral PA where there is an absence of carbonate strata. The pH and alkalinity have not changed in the last 45 years. This section of Twomile Run supports native brook trout.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1968-1983	5.91	6	8	0.26	na	na	31
1999-2009	5.91	7	2	0.11	nd	0.31	13
2009-2013	6.04	6	2	nd	nd	nd	8

na: no data available. nd: below detection.

Inflow of AMD from the Swamp

The first major input of contaminated mine water to the main stem of Twomile Run has its origins in a large kill zone that is referred to as the “Swamp.” The AMD is funneled into a channel that crosses three high pressure gas lines before flowing to Twomile Run approximately 1,900 ft upstream of the Robbins Road bridge. Figures 5 and 6 show pH and concentrations of acidity over the full monitoring period at the pipeline crossing. pH values have ranged between 2.5 – 3.5 over the full period. Acidity concentrations were substantially higher in the 1970s. While a portion of the difference (especially the spread

in data) may be due laboratory methodological changes, it is certain that acidity concentrations were much higher 40 years ago. Table 4 shows recent AMD chemistry. While contaminant concentrations are decreasing, the flow is still severe AMD.

Table 4. Average chemistry (mg/L) and flow (gpm) of the Swamp AMD measured at the gasoline crossing and, since 2012, at the inflow of the passive treatment system.

Point	Period	Flow	pH	Alk	Acid	Fe	Mn	Al	SO4
Pipeline	1970-1983	84	2.9	0	1238	82.5	na	na	1692
Pipeline	1995-2004	74	3.1	0	522	79.9	31.3	41.1	906
Pipeline/system	2005-2013	73	3.0	0	417	73.7	25.0	35.5	1141

na: no data available

The inflow of the Swamp AMD to Twomile Run has been periodically sampled. Figures 7 and 8 show pH and acidity concentrations. In 2011/12 a passive system was installed to treat the Swamp AMD. The system has discharged alkaline water since October 2012. The improved water chemistry is apparent. The difference in AMD chemistry is shown in Table 5.

Table 5. Chemistry (mg/L) of the inflow of Swamp AMD to Twomile Run. Average values before and after the installation of the passive treatment system are shown.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
Pre-system (2004-2010)	3.03	0	282	14.5	17.2	29.6	844
System (2013)	7.71	194	-151	0.6	7.9	0.3	618

Twomile Run above Middle Branch

The “Twomile Run above Middle Branch” station is located at the Robbins Road bridge which is about 1,900 ft below the inflow of the Swamp AMD and about 50 feet upstream of the mouth of Middle Branch. Twomile Run has been sampled above the Middle Branch inflow since the 1970s. Figure 9 shows acidity concentrations over the entire period. (No pH values are available for 1970s and 1980s.) The stream was acidic with elevated concentrations of acidity until 2012 when the Swamp treatment system was installed. Figures 10 and 11 focus on data collected since 1999. Table 6 shows the average chemistry before and after the system’s installation. The stream chemistry over this short monitoring period is greatly improved.

Table 6. Average chemistry (mg/L) of Twomile Run above Middle Branch.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1966-1983	3.9	na	146	3.3	na	na	313
1999-2004	4.0	1	64	0.9	5.5	7.7	150
2005-2012	3.9	0	46	1.2	2.4	4.9	141
2013	6.3	15	-2	0.3	1.6	1.1	76

na: no data available

Middle Branch

Middle Branch is a major tributary that is impacted by AMD. No mining exists in the headwaters of Middle Branch but the lower mile passes through abandoned mine lands. Figures 12 and 13 show pH and alkalinity for the headwaters. Table 7 shows average chemistry. The stream is acidic and weakly buffered. Concentrations of alkalinity are ranging higher in the last three years than in 2001-2005. The cause is unknown.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
2001-2006	5.6	3	9	0.1	0.0	0.2	23
2007-2013	5.3	4	5	0.1	0.0	0.1	10

Middle Branch receives AMD from abandoned deep mines and surface mines. A passive treatment system was installed in 2000 that provided inconsistent treatment because of very high contaminant loading rates. In 2007 the system was rehabilitated and one of the sources of AMD was diverted into the Huling Branch watershed. Since the rehabilitation, the treatment system discharge has always been alkaline with low metals.

The mouth of Middle Branch has been monitored since 1995. Figures 14, 15, and 16 show pH, acidity and alkalinity concentrations, respectively. Before the treatment system was installed, the station always had low pH, elevated acidity, and negligible alkalinity. Since the system was constructed and rehabilitated, the pH has risen to near 6, acidity concentrations are near zero, and metal concentrations are less than 1 mg/L (Table 8). Since 2007 alkalinity has always been detected and concentrations have averaged 10 mg/L, which is higher than the upstream monitoring station.

The improvement in chemistry has resulted in reestablishment of native brook trout in lower Middle Branch.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1995-2000	4.21	1	42	0.2	1.7	5.0	66
2001-2006	5.29	3	16	0.1	0.6	0.7	69
2007-2013	6.00	10	3	0.1	0.1	0.2	30

Robbins Hollow

Robbins Hollow is a small drainage that is heavily impacted by AMD that enters Twomile Run about 400 feet downstream of the Robbins Road bridge. Unlike Huling Branch, Middle Branch and Twomile Run itself, the entire length of Robbins Hollow is impacted by AMD with abandoned mine lands encircling the watershed. For this reason,

the goal of restoration work in Robbins Hollow is focused primarily on lessening pollution to Twomile Run rather than restoration of Robbins Hollow as a fishery. The stream was not sampled as part of historic monitoring activities. Several passive treatment systems have been installed in the drainage. In 2004 three passive systems were installed which significantly improved water quality. However, the largest AMD discharges were not treated until two passive systems were installed in the summer 2013. Because of dry conditions in summer 2013, the systems did not discharge treated water until fall 2013.

Figures 17 and 18 show water quality changes over time. A single sample of the Robbins Hollow flow after installation of the latest treatment systems is available. The sample was collected under dry conditions when one of the treatment systems was not discharging and little diluting surface water was present. The sample is the highest pH and lowest acidity sample collected to date from the station. Table 9 shows water quality improvement over time.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1995-2004	3.8	0	79	2.3	7.5	8.8	216
2005-2010	4.5	1	58	1.3	7.0	6.5	307
2013	5.3	6	18	0.4	4.9	2.9	303

Twomile Run above Huling Branch

Twomile Run flows 8,000 ft between the inflow of Robbins Hollow to the next major stream inflow, Huling Branch. In this stretch of stream, inflows of contaminated groundwater are visually apparent in several sections. One artesian Fe-contaminated discharge has been known for years because of its distinctive orange staining on the stream bank and bed. With the recent improvement of upstream water chemistry, inflows of contaminated groundwater to the streambed have become more visually apparent (through stream discoloration from Fe and Al solids). Contaminated groundwater can be seen entering Twomile Run just downstream of Robbins Hollow.

Prior to the upstream water quality improvements, the contaminated groundwater could only be inferred by the presence of unaccounted loading that appears with no apparent source. Several studies have indicated the presence of a significant input of contaminated groundwater, but the recent improvement in upstream water quality has eliminated any other AMD that would mask its presence and it is now undeniable. The most likely source of the contaminated groundwater is the abandoned mines on the ridge between Huling Branch and Middle Branch. If correct, the reclamation project that is currently occurring in the Huling Branch watershed may lessen this AMD inflow.

Twomile Run has been monitored above the inflow of Huling Branch since 1966. Figures 19 and 20 show pH and acidity concentrations. Table 10 shows average

conditions over various periods. The chemistry of the stream slowly improved between 1999 and 2011, likely to due to the remediation projects on Middle Branch and Robbins Hollow. A large change is apparent in 2012/13 when the Swamp passive system became operational. pH values increased by a full unit and alkalinity was measurable for the first time in 50 years.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1966-1982	3.6	na	135	6.0	na	na	283
1999-2011	4.0	1	51	0.3	5.1	5.4	199
2012-2013	5.4	4	10	0.3	1.8	1.4	123

na: no data available

Huling Branch

Huling Branch is a major tributary that enters about 1,600 ft upstream of the mouth of Twomile Run. The lower 2.2 miles of Huling Branch is severely polluted by AMD. The stream's headwaters are above the mining activity and the water quality is good. Figures 21 and 22 show pH and alkalinity at the upstream monitoring station. The stream is acidic and weakly buffered with 2-10 mg/L alkalinity. The chemistry (Table 11) is similar to that existing in the headwaters of Middle Branch and Twomile Run and has not changed over the last 30 years. The stream above mining supports native brook trout.

Period	pH	Alk	Acid	Fe	Mn	Al	SO4
1980-1983	5.7	6	7	0.2	na	na	23
2000-2002	6.0	3	4	<0.1	nd	<0.1	5
2010-2013	5.6	5	6	0.1	nd	0.1	8

na: no data available. nd: below detection.

Huling Branch passes through a large AML area and receives multiple AMD discharges from underground mines, surface mines, and a coal tippie. Figures 23 and 24 show pH and acidity near the mouth of Huling Branch. The figures include measurements made below the tippie as part of a proposed re-mining project. This location is 9,200 ft upstream of the mouth, but is below all the known major inflows of AMD to the stream. Table 12 shows average conditions over the last 38 years. There have not been any AMD remediation efforts in the Huling Branch watershed that would improve the water quality. Unsurprisingly, no improvement in chemistry is apparent. The data shown in the Figures 23 and 24 and Table 12 predate remedial activities by the current reclamation project and provide a good baseline for evaluating its eventual success.

Table 12. Average chemistry (mg/L) and flow (gpm) of Huling Branch downstream of AMD inputs.									
Point	Period	Flow	pH	Alk	Acid	Fe	Mn	Al	SO4
HB Mouth	1976-1983	2,189	3.29	0	179	10.6	na	na	333
HB Mouth	1999-2013	1,301	3.29	0	109	8.8	5.6	8.7	250
HB below tipple	2010-2012	4,906* (1,816)	3.44	0	70	5.8	2.5	5.7	128

* 39,000 gpm flow in April 2011; value in parentheses is average without this value
na: no data available

Summary of Chemistry Data

Table 13 summarizes the results of this assessment of water quality changes in the Twomile Run watershed. The water quality in segments of Twomile Run, Middle Branch, and Huling Branch that are above mining has not changed. These waters have an acidic poorly buffered chemistry that supports native brook trout. The water quality in streams downstream of mining activity has been improved where remediation projects have been implemented. Lower Middle Branch is alkaline with low metals and now supports brook trout. Upper Twomile Run between the Swamp inflow and Middle Branch is alkaline with low metals. Twomile Run below Middle Branch and Huling Branch is greatly improved. In 2013 pH values were above 5 and acidity concentrations were 75% lower than existed in 1999-2000. There have been no improvements in Huling Branch, where no remediation has occurred (as of 2013).

Table 13. Summary findings of the Twomile Run reassessment.				
	Period	pH	Alk	Acid
<i>Stations Above Mining</i>				
Twomile Run Headwaters	1999-2000	5.8	9	0
Twomile Run Headwaters	2013	6.0	7	0
Huling Branch Headwaters	1980-83	5.7	6	7
Huling Branch Headwaters	2011-12	5.4	4	6
Middle Branch Headwaters	2001-05	5.6	3	9
Middle Branch Headwaters	2011-12	5.4	4	5
<i>Stations Below Mining</i>				
Swamp Mouth	2004-06	3.0	0	287
Swamp Mouth	2013	7.8	194	-151
Twomile Run above Middle	1999-2000	3.9	1	64
Twomile Run above Middle	2013	6.2	13	-2
Middle Branch Mouth	1995-2000	4.2	1	42
Middle Branch Mouth	2011-13	6.0	13	1
Robbins Hollow Mouth	1999-2000	3.8	0	91
Robbins Hollow Mouth	2013	4.7	1	21
Twomile Run above Huling	1999-2000	3.9	1	58
Twomile Run above Huling	2013	5.8	3	13
Huling Branch Mouth	1999-2000	3.4	0	119
Huling Branch Mouth	2013	3.1	0	111