Drury Run Watershed TMDL

For Acid Mine Drainage Affected Segments

Prepared by Pennsylvania Department of Environmental Protection

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Table 1

Table 2

TMDL's
Drury Run Watershed
Clinton County, PA

Introduction

This Total Maximum Daily Load (TMDL) calculation has been prepared for segments in the Drury Run Watershed (Attachments A and B). It was done to address the impairments noted on the 1996 Pennsylvania 303(d) list, required under the Clean Water Act, and covers four segments on this list and one additional non-listed segment (shown in Table 1, page 2). High levels of metals, and in some areas depressed pH, caused these impairments. All impairments resulted from acid drainage from abandoned coal mines. The TMDL addresses the three primary metals associated with acid mine drainage (iron, manganese, aluminum), and pH.

Directions to the Drury Run Watershed

The Drury Run watershed is located in Clinton County in Northcentral Pennsylvania (Attachment A). It flows into the West Branch Susquehanna River at Drury, approximately 2.4 miles west of Renovo. Drury is at the intersection of PA. Routes 120 and 144. The stream segments addressed in this TMDL are found by traveling from the aforementioned intersection north on PA Route 144.

Segments addressed in this TMDL

There are no active mining operations in the watershed. All of the discharges in the watershed are from abandoned mines and will be treated as non-point sources. The distinction between non-point and point sources in this case is determined on the basis of whether or not there is a responsible party for the discharge. Where there is no responsible party the discharge is considered to be a non-point source. Each segment on the 303(d) list will be addressed as a separate TMDL. These TMDLs will be expressed as long-term, average loadings. Due to the nature and complexity of mining effects on the watershed, expressing the TMDL as a long-term average gives a better representation of the data used for the calculations.

The use designations for the stream segments in this TMDL can be found in PA Title 25 Chapter 93.

Watershed History

The Drury Run watershed (Attachment B) is 11.5 $mi.^2$ in area. It originates at Tamarack Swamp and flows south-southeasterly for 7.7 miles to the West Branch of the Susquehanna River. This watershed is classified as High Quality-Cold Water Fishery (HQ-CWF). Drury Run and tributaries are lightly buffered streams with little capacity to assimilate acidic discharges which may result from coal mining. These streams are characterized by the Pennsylvania Fish and Boat

Table 1. 303(d) Sub-List								
State Water Plan (SWP) Subbasin: 09-B West Branch Susquehanna River								
Year	**Miles**	**Segment ID**	**DEP Stream Code**	**Stream Name**	**Designated Use**	**Data Source**	**Source**	**EPA 305(b) Cause Code**
1996	7.3	Part C of list	23620	Drury Run	EV/HQ-CWF	305(b) Report	RE	pH
1998	No additional assessment data was collected for the 1998 303(d) list.			Drury Run	EV/HQ-CWF			
2000	1.07	980827-0900-TAS	23620	Drury Run	EV/HQ-CWF	SWMP	AMD	Metals & pH
2000	1.75	980827-1030-TAS	23620	Drury Run	EV/HQ-CWF	SWMP	AMD	Metals
1996	1.0	Part C of list	23626	Sandy Run	HQ-CWF	305(b) Report	RE	Metals
1998	No additional assessment data was collected for the 1998 303(d) list.			Sandy Run				
2000	3.76	980806-1430-TAS	23626	Sandy Run	HQ-CWF	SWMP	AMD	Metals & Ph
2000	0.47	980806-1430-TAS	23627	Sandy Run Unt	HQ-CWF	SWMP	AMD	Metals & pH
2000	0.8	980806-1430-TAS	23628	Sandy Run Unt	HQ-CWF	SWMP	AMD	Metals & pH
2000	0.53	980806-1430-TAS	23629	Sandy Run Unt	HQ-CWF	SWMP	AMD	Metals & pH
1996	1.3	Part C of List	23621	Stony Run	HQ-CWF	305(b) Report	RE	Metals
1998	No additional assessment data was collected for the 1998 303(d) list.			Stony Run				
2000	3.31	980827-1000-TAS	23621	Stony Run	HQ-CWF	SWMP	AMD	Metals & Ph
2000	0.73	980827-1000-TAS	23622	Stony Run Unt	HQ-CWF	SWMP	AMD	Metals & pH
2000	1.75	980827-1000-TAS	23625	Stony Run Unt	HQ-CWF	SWMP	AMD	Metals & pH
1996	Not currently on 303(d) List			Whiskey Run	HQ-CWF			
1998	Not currently on 303(d) List			Whiskey Run				
2000	Not currently on 303(d) List			Whiskey Run				
1996	1.7	7128	23625	Woodley Draft	CWF	305(b) Report	RE	Metals
1998	1.75	7128	23625	Woodley Draft	CWF	SWMP	RE	Metals
2000	No additional assessment data was collected for the 2000 303(d) list			Woodley Draft				

High Quality Water = HQ
Exceptional Value Water = EV
Cold Water Fishes=CWF
Surface Water Monitoring Program = SWMP
Abandoned Mine Drainage = AMD

Commission as clean but infertile freestone streams which provide the habitat for wild brook and brown trout, the invertebrates upon which they feed, and a limited variety of lower plant forms. Unaffected by mining, they typically range in pH from 5.4 – 7.0.

This watershed contains numerous smaller drainage basins. Principal of these for this report are Sandy Run, Woodley Draft, Stony Run, and Whiskey Run (Attachment B), each of which has been affected by past coal and/or clay mining. These flow into the lower half of Drury Run, degrading that section of the stream. The upper portion of Drury Run is meeting its designated uses and criteria for aluminum and manganese and is not influenced by mining. However, sampling point 1DR also indicates that iron at 1DR shows some excursions above criteria and pH between 5.3 and 5.8. The headwaters of Drury Run is the Tamarack Swamp. Sampling point 1DR is down stream of the Tamarack Swamp. The decay of organic material, a naturally occurring condition, in the swamp is responsible for the iron excursions and pH at sampling point 1DR.

Naturally reproducing populations of brook trout and brown trout are found in the unaffected and minimally affected stream lengths of the Drury Run watershed. Acid mine drainage has caused the elimination of a brook trout population in the lower half of Sandy Run. Where acid mine drainage has affected the stream water quality in Drury Run, no fish are present, and invertebrate communities are reduced to taxa tolerant of mine drainage influences.

Underground mining of the Lower Kittanning, Clarion, and Mercer coals and associated clays began within the watershed in the latter part of the 19^{th} century and continued into the 1940s. Surface mining in the watershed began in the 1940s and continued until the 1980s.

Abandoned underground and surface mines have caused depressed pH values and elevated metals concentrations in the tributaries of the above-referenced streams. Some of the surface mines were either partially backfilled and contoured or left abandoned with open pits and highwalls. Acidic pit water accumulates at a number of the abandoned mines.

TMDL Endpoints

One of the major components of a TMDL is the establishment of an instream numeric endpoint, which is used to evaluate the attainment of acceptable water quality. An instream numeric endpoint, therefore, represents the water quality goal that is to be achieved by implementing the load reductions specified in the TMDL. The endpoint allows for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The endpoint is based on either the narrative or numeric criteria found in PA's water quality standards.

Because of the nature of the pollution sources in the watershed, most of the TMDLs' component makeup will be Load Allocations (LA) that are specified above a point in the stream segment. All allocations will be specified as long-term average concentrations. These long-term average concentrations are expected to meet water-quality criteria 99% of the time. PA Title 25 Chapter 93.5(b) specifies that a minimum 99% level of protection is required. All metals criteria evaluated in these TMDLs are specified as total recoverable. The data used for this analysis report iron as total recoverable. The following table shows the applicable water-quality criteria for the selected parameters.

Table 2. Applicable Water Quality Criteria		
Parameter	**Criterion value (mg/l)**	**Total Recoverable/ Dissolved**
Aluminum*	0.1 of the 96 hour LC 50 0.75	Total recoverable
Iron	1.50 0.3	Total recoverable dissolved
Manganese	1.00	Total recoverable
PH**	6 - 9	NA

- *- This TMDL was developed using the value of 0.75 mg/l as the in-stream criterion for aluminum. This is the EPA national acute fish and aquatic life criterion for aluminum. Pennsylvania's current aluminum criterion is 0.1 mg/l of the 96-hour LC-50 and is contained in PA Title 25 Chapter 93. The EPA national criterion was used because the Department has recommended adopting the EPA criterion and is awaiting final promulgation of it.
- ** - The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission). This condition is met when the net alkalinity is maintained above zero.

Computational Methodology

A TMDL equation consists of a Wasteload Allocation (WLA), Load Allocation (LA) and a Margin of Safety (MOS). The WLA is the portion of the load assigned to Point Sources. The LA is the portion of the load assigned to Non-point Sources (NPS). The MOS is applied to account for uncertainties in the TMDL. The MOS may be expressed implicitly (documenting conservative processes in the computations) or explicitly (setting aside a portion of the allowable load).

For purposes of this TMDL, point sources are identified as permitted discharge points and nonpoint sources are other discharges from abandoned mine lands which includes tunnel discharges, seeps (although none were specifically identified), and surface runoff. Abandoned and reclaimed mine lands are treated in the allocations as nonpoint sources because there are no NPDES permits associated with these areas. As such, the discharges associated with these lands were assigned load allocations (as opposed to wasteload allocations).

For situations where all of the impact is due to non-point sources, the equations shown below are applied using data for a point in the stream. The load allocation (LA) made at that point will be for all of the watershed area that is above that point. For situations where there are only point-source impacts or a combination of point and non-point sources, the same type of evaluation is used. The point-source is mass balanced with the receiving stream, and sources will be reduced as necessary to meet the water quality criteria below the discharge

Correlations for flow and each parameter (Table 3) were calculated, using the Rsquare function in Excel, for Stony Run only. The available data for the other streams in this TMDL did not have enough paired flow/parameter data to calculate correlations. There is no significant correlation between source flows and pollutant concentrations. Analyses of the data could not determine a critical flow.

Table 3. Rsquare

Parameter	Rsquared
pH	0.071
Alk.	0.117
Acid.	-0.408
Fe	0.412
Mn	-0.324
Al	Al had only two data pairs

TMDLs and LAs for each parameter were determined using Monte Carlo simulation. For each source and pollutant, it was assumed that the observed data are log-normally distributed. The lognormal distribution has long been assumed when dealing with environmental data. For this TMDL the Department checked the distribution of the alkalinity, acidity, aluminum, iron and manganese concentration data at the Stony Run sampling point 8ST. The Beta distribution was identified for aluminum and manganese. The @Risk simulation was modified and run for aluminum and manganese by replacing the RiskLognorm function with RiskBeta in the existing concentrations calculations. Table 4 compares the @Risk calculations for both distributions. The Beta distribution produced less protective allowable concentrations and percent reductions.

Table 4. Comparison of RiskLognormal and Risk Beta Function Results

Parameter	Sample Concentration	Allowable Concentration	Difference in Allowable Concentration	Percent Reduction
Lognormal Al	7.11	0.498		93%
Lognormal Mn	11.81	0.591		95%
Beta Al	7.11	0.534	6.7%	92.5%
Beta Mn	11.81	0.708	16.5%	94%

Each pollutant source was evaluated separately using @Risk[1]. Five thousand iterations were performed to determine the required percent reduction so that water-quality criteria will be met in-stream at least 99 percent of the time. For each iteration, the required percent reduction is:

$$PR = \text{maximum}\{\, 0, (1 - Cc/Cd) \,\} \qquad \text{where,} \qquad (1)$$

PR = required percent reduction for the current iteration
Cc = criterion in mg/l
Cd = randomly generated pollutant source concentration in mg/l based on the observed data

[1] @ Risk - Risk Analysis and Simulation Add-in for "Micorsoft Excel", Palisade Corporation, Newfield , NY, 1990-1997

Cd = RiskLognorm(Mean, Standard Deviation) where (1a)

Mean = average observed concentration
Standard Deviation = Standard deviation of observed data

The overall percent reduction required is the 99th percentile value of the probability distribution generated by the 5000 iterations, so that the allowable long-term average (LTA) concentration is:

LTA = Mean * (1 – PR_{99}) where (2)

LTA = allowable LTA source concentration in mg/l (the mean of five thousand iterations, from the statistics portion of the @Risk program.)

Where a stream or stream segment is listed on the 303(d) list for pH, the same type of evaluation is used. This analysis cannot be performed for pH and therefore utilizes data for acidity and alkalinity. The result is a reduction in acid loading for the stream. The pH method is fully explained in Attachment C.

An example calculation, including detailed tabular summaries of the Monte Carlo results is presented for the Lorberry Creek TMDL in Attachment D.

Sandy Run Watershed

The Sandy Run watershed (Attachment B) has an area of approximately 3.6 mi.^{2} and includes 5.45 miles of streams. The headwaters of Sandy Run (1SR, 2SR, 3SR) are unaffected by mining. However, the water is moderately acidic. Sandy Run is affected by AMD in the lower half of its length (8SR, 9SR, 10SR, and 11SR). Both deep and surface mining occurred in the upper half of this watershed. Attachment B shows two areas of surface mining partially located in the watershed, both along the eastern surface divide and both part of the R.S. Carlin's Hill 4B Operation (MDP #3166BSM37). This site was permitted for mining 101.6 and 185 acres of Lower Kittanning and Middle Kittanning coals, respectively. The site was reclaimed. Deep mining in this watershed appears to have taken place prior to 1920.

Three point-source discharges D2, D3, and D5, in Attachment B, exhibiting characteristics of AMD are documented in the Sandy Run watershed. All three are located on the northeastern slopes of the watershed divide between Sandy Run and Woodley Draft. Discharges at sample points D2 and D3 originate from abandoned underground Mercer mine openings. D2 disappears into the forest floor near the discharge origin. D3 flows to Sandy Run through a channel. However, during extended droughts, this flow, too, disappears into the ground. A sample point D4 (Attachment B) represents the D3 discharge flow at its confluence with Sandy Run. D5 is a discharge, which enters Sandy Run from the east.

The combined flows of Drury Run and Sandy Run (6DR, Attachment E) produce stream water with pH values slightly less than the values in Drury Run upstream of Sandy Run (5DR).

TMDL calculations

The TMDL for Sandy Run consists of a load allocation to all of the area above sampling point 9SR (Attachment B). This is the first stream monitoring point downstream of all mining impacts. Addressing the mining impacts above this point addresses the impairment for the entire stream segment to its confluence with Drury Run.

There is currently no entry for this segment on the Pa 303(d) list for impairment due to pH. However sample data at point 9SR shows pH ranging between 4.6 and 5.0. For this reason pH will be addressed as part of this TMDL. Upstream samples taken at sampling point 1SR do not indicate mining impacts however, pH at 1SR ranges between 5.3 and 5.8. The objective is to reduce acid loading to the stream which will in turn raise the pH to the desired range. Sampling point 9SR has the lowest pH so the alkalinity at 9SR will be used in the evaluation. The result of this analysis is an acid loading reduction that equates to meeting standards for pH (see Table 2). The method and rationale for addressing pH is contained in Attachment C.

The load allocation for this stream segment was computed using water-quality sample data collected at point 9SR. In-stream flow measurements were not available for point 9SR. Flow for this point was estimated using the unit-area hydrology from a known point (11SR) on Sandy Run.

The watershed area above point 9SR is 1.52 square miles. The known flow point (11SR) on Sandy Run had an average flow of 3.19 cfs, and a watershed area of 3.6 square miles. This gives a flow yield of 0.886 cfs/sq.mi. Multiplying the flow yield for the known point (11SR) times the watershed area above point 9SR equals the flow of 1.35 cfs (0.873 MGD) at point 9SR.

An allowable long-term average in-stream concentration was determined at point 9SR for aluminum, iron, manganese and acidity. The analysis is designed to produce an average value that, when met, will be protective of the water-quality criterion for that parameter 99% of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water-quality criteria 99% of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and standard deviation of the data set, 5000 iterations of sampling were completed, and compared against the water-quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water-quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99% of the time. The mean value from this data set represents the long-term average concentration that needs to be met to achieve water-quality standards. Table 5 shows the load allocations for this stream segment.

		Table 5. Sandy Run				
		Measured Sample Data		Allowable		Reduction Identified
Station	Parameter	Conc (mg/l)	Load (lbs/day)	LTA conc (mg/l)	Load (lbs/day)	%
9SR						
	Al	0.6	4.4	0.4	3.2	28%
	Fe	0.1	0.6	0.1	0.6	0%
	Mn	0.7	5.1	0.5	3.6	30%
	Acidity	13.0	94.6	1.9	14.2	85%
	Alkalinity	6.3	46.0			

The allowable loading values shown in Table 5 represent load allocations made at point 9SR.

Margin of Safety

For this study the margin of safety is applied implicitly. A MOS is built in because the allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Another margin of safety used for this TMDL analysis results from:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long-term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.

Seasonal Variation

Seasonal variation is implicitly accounted for in these TMDLs because the data used represent all seasons.

Critical Conditions

The reductions specified in this TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis. The average flow determined from unit area hydrology was used to derive loading values for the TMDL.

Woodley Draft Watershed

The Woodley Draft watershed lies southeast of the Sandy Run watershed (Attachment B). This watershed covers less than 1.1 $mi.^2$ and includes 1.82 miles of streams. Mining has impacted the entire length of Woodley Draft. Within the watershed, portions of three surface mines drain to this stream. West of the head of the stream is a partially reclaimed Clarion coal surface mine. To the east, at or near the drainage divide, is part of the R.S. Carlin Hill 4B Operation (MDP # 3166BSM37). This site mined the Clarion coal. Mining was completed by March 1977. Southeast of Woodley Draft is Avery Coal's Hill No. 2A Operation (SMP # 18820101). This is the most recent permit application in the Drury Run watershed. Because of concerns raised by the Department and the PA Fish and Boat Commission, the permit application was withdrawn on January 26, 1984.

TMDL Calculations

The TMDL for Woodley Draft consists of a load allocation to all of the area above the point 2WD shown in Attachment B. This is the first stream monitoring point downstream of all mining impacts. Addressing the mining impacts above this point addresses the impairment for the entire stream segment to its confluence with Drury Run.

There is currently no entry for this segment on the Pa 303(d) list for impairment due to pH. No sample data are available above sample point 2WD to establish an upstream pH. Sample data at point 2WD show pH ranging between 4.3 and 4.5; pH will be addressed as part of this TMDL because of the mining impacts. The objective is to reduce acid loading to the stream which will in turn raise the pH. The result of this analysis is an acid loading reduction that equates to meeting standards for pH (see Table 2). The method and rationale for addressing pH is contained in Attachment C.

The load allocation for this stream segment was computed using water-quality sample data collected at the point 2WD. There was just one flow datum (0.245 MGD) available at sampling point 2WD.

An allowable long-term average in-stream concentration was determined at point 2WD for aluminum, iron, manganese and acidity. The analysis is designed to produce an average value that, when met, will be protective of the water-quality criterion for that parameter 99% of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water-quality criteria 99% of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and standard deviation of the data set, 5000 iterations of sampling were completed, and compared against the water-quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water-quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99% of the time. The mean value from this data set represents the long-term average concentration that needs to be met to achieve water-quality standards. Table 6 shows the load allocations for this stream segment.

		Table 6. Woodley Draft				
		Measured Sample Data		Allowable		Reduction Identified
Station	Parameter	Conc (mg/l)	Load (lbs/day)	LTA conc (mg/l)	Load (lbs/day)	%
2WD						
	Al	3.4	7.0	0.6	1.2	83%
	Fe	0.02	0.04	0.02	0.04	0%
	Mn	3.3	6.8	0.8	1.5	77%
	Acidity	24.4	49.9	4.1	8.5	83%
	Alkalinity	5.6	11.4			

The allowable loading values shown in Table 6 represent load allocations made at point 2WD.

Margin of Safety

For this study the margin of safety is applied implicitly. A MOS is built in because the allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Another margin of safety used for this TMDL analysis results from:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long-term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.

Seasonal Variation

Seasonal variation is implicitly accounted for in these TMDLs because the data used represent all seasons.

Critical Conditions

The reductions specified in this TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis. There was just one flow datum available at point 2WD.

Whiskey Run Watershed

Whiskey Run originates from the higher elevations of the watershed divide between Drury Run and Shintown Run (Shintown Run is not shown on Attachment B). The headwaters have been historically degraded by drainage from abandoned underground Mercer clay and coal mines which were in operation prior to the 1930s. More recently, in the late 1970s and early 1980s, this area was the site of surface mining. Abandoned surface mine pits of the Elk Mountain Mine (MDP #4676SM8) operated by the Quinn Coal and Clay Company surround the stream origin. This 500-acre site was permitted for 312 acres of mining of the Lower Kittanning coal and clay. It affected, in part, an old abandoned strip mine of many years ago consisting of unreclaimed spoils, highwalls, and impoundments. In addition, there were several old abandoned deep mines to be stripped, on both the clay and coal seams. This site was declared abandoned on January 3, 1984. A "Bond Forfeiture Project Profile" indicated an abandoned highwall approximately 800 feet long and 45 feet high. This profile also reported that reclamation was possible and necessary for improving water quality, fish and wildlife habitats, and improve social/economic conditions. Several mining permit numbers for this site indicated that revegetation was needed on 10, 5, and unspecified acres, respectively. Pit water was also found to be acidic at abandoned surface mines of the Quinn Coal and Clay Co. Elk Mountain Mine, which removed Lower Kittanning, Clarion and Mercer coal. Acid discharges were also documented originating from the toe-of-spoil on the partially backfilled area of the Elk Mountain operation.

Whiskey Run is an unofficial, locally named, waterbody that does not appear on either the 1996 or 1998 303(d) lists nor in the fifth edition of the Pennsylvania Atlas and Gazeteer and begins as an upwelling (D6, Attachment B). We did this TMDL because Whiskey Run is a discharge from an underground mine pool. Sample Point 1WR (Attachment B) is located on Whiskey Run at a former monitoring point for the Quinn Coal and Clay operations. This point is approximately 500 feet downstream of D6.

Several discharges flow to Whiskey Run approximately 800 feet downstream of D6. These discharges, identified as the upper pond discharge (D7, Attachment B) and the lower toe discharges (D8 and D9, Attachment B), flow from the north and originate along the toe-of-spoil on the abandoned surface mine of the Quinn Elk Mountain Mine.

The cumulative effect of the discharges at the headwater of Whiskey Run is represented by 2WR (Attachment B), located on Whiskey Run at its confluence with Drury Run.

<u>TMDL calculations</u>

The TMDL for Whiskey Run consists of a load allocation to all of the area above the point 2WR shown in Attachment B. This is the first stream monitoring point downstream of all mining impacts. Addressing the mining impacts above this point addresses the impairment for the entire stream segment to its confluence with Drury Run.

There is currently no entry for this segment on the Pa 303(d) list for impairment due to pH. No sample data is available above point 2WR to establish an upstream pH value. Sample data at point 2WR shows pH ranging between 3.5 and 4.2; pH will be addressed as part of this TMDL because the cause of impairment for Whisky Run is pH and metals. The objective is to reduce acid loading to the stream which will in turn raise the pH. The result of this analysis is an acid loading reduction that equates to meeting standards for pH (see Table 2). The method and rationale for addressing pH is contained in Attachment C.

The load allocation for this stream segment was computed using water-quality sample data collected at point 2WR. The average flow, measured at sample point 2WR (0.18 MGD), is used for these computations

An allowable long-term average in-stream concentration was determined at point 2WR for aluminum, iron, manganese and acidity. The analysis is designed to produce an average value that, when met, will be protective of the water-quality criterion for that parameter 99% of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water-quality criteria 99% of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and standard deviation of the data set, 5000 Iterations of sampling were completed, and compared against the water-quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water-quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99% of the time. The mean value from this data set represents the long-term average concentration that needs to be met to achieve water-quality standards. Table 7 shows the load allocations for this stream segment

		Table 7. Whiskey Run				
		Measured Sample Data		Allowable		Reduction Identified
Station	Parameter	Conc (mg/l)	Load (lbs/day)	LTA conc (mg/l)	Load (lbs/day)	%
2WR						
	Al	11.1	16.6	0.4	0.7	96%
	Fe	0.6	0.9	0.6	0.9	0%
	Mn	5.0	8.0	0.7	1.1	86%
	Acidity	73.0	109.0	0.4	0.5	99.5%
	Alkalinity	0.8	1.2			

The allowable loading values shown in Table 7 represent load allocations made at point 2WR.

Margin of Safety

For this study the margin of safety is applied implicitly. A MOS is built in because the allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long-term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.

Seasonal Variation

Seasonal variation is implicitly accounted for in these TMDLs because the data used represent all seasons.

Critical Conditions

The reductions specified in this TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis. The average flow, measured at sampling point 2WR is used for these computations.

Stony Run Watershed

Stony Run, with an area of 4.04 mi^2, is the last major tributary to Drury Run prior to the confluence of Drury Run with the West Branch of the Susquehanna River. This watershed contains the most areas disturbed by underground and surface mining within the Drury Run watershed. In the upper parts of the Stony Run watershed, but downstream of the headwaters, is located R.S. Carlin's Hill 4B Operation (MDP # 3166BSM37). The site mined the Clarion coals on 394 acres. This acreage consisted of noncontiguous hilltops, many of which were in the subject watershed (Attachment B). A field engineers' pre-mining report documented numerous abandoned underground mines and small, abandoned surface mines within the 4B Operation. Two Avery Coal Company surface mines are located in the middle and lower sections of this watershed. These are the Hill No. 2A and Hill #2 Operations (Attachment B). Both are west of Stony Run. The application for the former was withdrawn. A permit for the latter (Attachment B) was issued in 1984 for 114.4 acres of which 26.7 coal (Mercer) acres were to be affected. Mining was completed by May 18, 1989.

Also in the lower section of this watershed is the Quinn Coal and Clay Mines West Branch Operation (MDP #4670BSM2, Attachment B). This operation was a transfer of the Peter M. Evock No. 1 Mine (MDP #3169BSM8), which removed the Upper and Middle Kittanning, coals in 1968. The West Branch Operation was permitted to mine the Lower Kittanning coal and clay. This operation affected, in part, an old completed and backfilled site, which was mined in the 1940s prior to the preservation of topsoil. Earlier mining on this site also included deep mining of the Lower Kittanning coal and underclay begun probably in the 1860s. Quinn's operation consistently failed to meet state regulations and he subsequently forfeited his bonds. By August 29, 1984, all activity on this permit had ceased.

An affected spring, 1STT2, marks the beginning of AMD pollution in the Stony Run watershed. This spring is located downslope of abandoned Clarion surface coal mines. Discharges were also documented at the headwater of Slab Hollow (D10), the headwater of a major unnamed tributary to Stony Run (D14), along Stony Run upstream of the unnamed tributary (D12, D13), and on the higher elevations of the eastern watershed slopes (D15, D15a, D16, and D17). The latter four are associated with abandoned Mercer coal underground mines.

The upper reach of Kelly Hollow shows significant degradation apparently from the stripping of Upper Kittanning coal. Other areas show the effects of Lower Kittanning coal mining. In summary, the water quality has been degraded by past mining with most of the degraded water going into Stony Run and Drury Run.

The Stony run watershed is also affected by highly acidic mine drainage which is believed to originate from abandoned underground mines on the Mercer coal and clay. All stream waters in the Stony Run watershed are affected by acid mine drainage. Abandoned underground mines produce many of the acid discharges, and it appears that the entire hydrologic system is affected by acid mine water from these same sources.

The hilltops in the Stony Run watershed were surface mined for Clarion and Mercer coals. Acidic pit water was documented at abandoned surface mine operations of the Quinn Coal and Clay West Branch Mine, which removed the Mercer coal. Several other companies also conducted surface mining of Clarion coal in the Stony Run watershed. Acidic discharges are present downslope of these mines. However, the pervasiveness of underground mines and their associated impacts on surface and groundwater quality prevents a determination of any probable adverse effects from these surface mines.

Water quality of Drury Run, from Stony Run downstream to the confluence of the West Branch of the Susquehanna River, represents the cumulative effects of the mine drainage to Drury Run. Although the larger flow in this section of Drury Run dilutes the acidic flows of Woodley Draft, Whiskey Run, and Stony Run, it is, never the less, acidic with elevated concentrations of manganese and aluminum.

<u>TMDL</u> <u>Calculations</u>

The TMDL for Stony Run consists of a load allocation to all of the area above the point 8ST shown in Attachment B. This is the first stream monitoring point downstream of all mining impacts. Addressing the mining impacts above this point addresses the impairment for the entire stream segment to its confluence with Drury Run.

There is currently no entry for this segment on the Pa 303(d) list for impairment due to pH. However sample data at point 8ST shows pH ranging between 3.6 and 5.0. For this reason pH will be addressed as part of this TMDL. Upstream samples taken at point 1ST may indicate mining impacts (slightly elevated iron levels); pH at 1ST ranges between 5.7 and 6.2. Sampling point 8ST has the lowest pH so the alkalinity at sampling point 8ST will be used in the evaluation. The result of this analysis is an acid loading reduction that equates to meeting standards for pH (see Table 2). The method and rationale for addressing pH is contained in Attachment C.

The load allocation for this stream segment was computed using water-quality sample data collected at point 8ST. The average flow, measured at sampling point 8ST (1.63 MGD), is used for these computations.

An allowable long-term average in-stream concentration was determined at point 8ST for aluminum, iron, manganese and acidity. The analysis is designed to produce an average value that, when met, will be protective of the water-quality criterion for that parameter 99% of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water-quality criteria 99% of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and standard deviation of the data set, 5000 iterations of sampling were completed, and compared against the water-quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water-quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99% of the time. The mean value from this data set represents the long-term average concentration that needs to be met to achieve water-quality standards. Table 8 shows the load allocations for this stream segment.

Table 8. Stony Run

		Measured Sample Data		Allowable		Reduction Identified
Station	Parameter	Conc (mg/l)	Load (lbs/day)	LTA conc (mg/l)	Load (lbs/day)	%
8ST						
	Al	7.1	96.6	0.5	6.8	93%
	Fe	0.3	3.9	0.3	3.9	0%
	Mn	11.8	160.0	0.6	8.0	95%
	Acidity	67.3	915.0	1.0	13.7	98.5%
	Alkalinity	2.8	37.6			

The allowable loading values shown in Table 8 represent load allocations made at point 8ST.

Margin of Safety

For this study the margin of safety is applied implicitly. AMOS is built in because the allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long-term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.

Seasonal Variation

Seasonal variation is implicitly accounted for in these TMDLs because the data used represent all seasons.

Critical Conditions

The reductions specified in this TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis. The average flow, measured at sampling point 8ST, was used for these computations.

Drury Run

Upstream of point 5DR (Attachments B and E), Drury Run is unaffected by AMD and is attaining its designated uses above that point. Sampling point 1DR shows some excursions above criteria for iron and pH between 5.3 and 5.8. The headwaters of Drury Run is the Tamarak Swamp. Sampling point 1DR is down stream of the Tamarak Swamp. The decay of organic material, a naturally occurring condition, in the swamp is responsible for the iron excursions and pH at sampling point 1DR. Downstream of Sandy Run, Drury Run is impaired due to the influences from Sandy Run and other tributaries. There are no known direct inputs of AMD to Drury Run. All tributaries to Drury Run have been evaluated and are included in this TMDL. Upon implementation of these TMDLs, the main stem of Drury Run will no longer be impaired. There are no reductions necessary for the main stem of Drury Run.

Summary of Allocations

This TMDL will focus remediation efforts on the identified numerical reduction targets for each watershed. As changes occur in the watershed, the TMDL may be re-evaluated to reflect current conditions.

Table 9 presents the estimated reductions identified for all points in the watershed.

Station		Table 9. Summary Table - Drury Run Watershed				
		Measured Sample Data		Allowable		Reduction Identified
	Parameter	Conc (mg/l)	load (lbs/day)	LTA Conc (mg/l)	load (lbs/day)	%
9SR	**In-stream monitoring point located on Sandy Run**					
	Al	0.61	4.44	0.44	3.20	28%
	Fe	0.08	0.58	0.08	0.58	0%
	Mn	0.70	5.1	0.49	3.57	30%
	Acidity	13.00	94.65	1.95	14.2	85%
	Alkalinity	6.33	46.09			
2WD	**In-stream monitoring point located on Woodley Draft near its mouth**					
	Al	3.45	7.05	0.59	1.2	83%
	Fe	0.02	0.04	0.02	0.04	0%
	Mn	3.32	6.78	0.76	1.55	77%
	Acidity	24.4	49.85	4.39	8.97	82%
	Alkalinity	5.60	11.44			
2WR	**In-stream sampling point located on Whiskey Run at its mouth**					
	Al	11.09	16.65	0.44	0.66	96%
	Fe	0.62	0.93	0.62	0.93	0%
	Mn	5.30	7.96	0.74	1.11	86%
	Acidity	73.00	109.68	0.364	0.54	99.5%
	Alkalinity	0.83	1.25			
8ST	**In-stream monitoring point located on Stony Run at its mouth**					
	Al	7.11	96.65	0.5	6.79	93%
	Fe	0.29	3.94	0.29	3.94	0%
	Mn	11.81	160	0.59	8.0	95%
	Acidity	67.35	915.	1.01	13.73	98.5%
	Alkalinity	2.77	37.6			

All allocations are load allocations to non-point sources. The margin of safety for all points is applied implicitly through the methods used in the computations.

Recommendations

In the study area, several locations have been identified that could benefit from remediation. The goal is to prevent or reduce AMD from reaching the receiving streams. This remediation may include: removal of abandoned highwalls, filling-in abandoned pits, regrading and replanting, plugging pre-act deepmine openings, and passively treating discharges.

Abandoned highwall removal in conjunction with filling-in pits is recommended because these practices eliminate surface water accumulations. Such accumulations commonly exhibit characteristics of AMD. An ancillary benefit of highwall removal is the elimination of a safety hazard. An example in the study area where this is recommended is in the Whiskey Run watershed. At least 800 feet of abandoned highwall and associated impoundments have been identified on Quinn Coal and Clay's Elk Mountain Mine, MDP #4676BSM8 (Attachment B).

Regrading and replanting abandoned areas is also recommended in the study area. The former may be in conjunction with highwall removal and filling-in of impoundments or it may involve old mining in which there are no abandoned highwalls. Regrading is beneficial because it reroutes surface water and eliminates low areas in which surface water can become impounded. Replanting is a necessary follow-up to regrading. It aids in stabilizing reclaimed spoil and preventing silt and sedimentation from entering receiving streams. Abandoned mine lands have been identified in the Woodley Draft, Whiskey Run, and Stony Run watersheds.

Plugging pre-act deepmine openings is recommended but would be implemented only when practical and environmentally advantageous. Most of the deep mining in the study area is very old, in some cases dating back to the 1800s. As a result, most portals are now collapsed and can not be identified. If actual deep mine entries are identified in the future, these should be evaluated for possible sealing. Discharge-specific assessments are recommended.

Passive treatment of discharges in the study area should be considered. Discharge-specific assessments are recommended. These assessments will consider all technical factors in determining whether passive treatment is practical or, if it is, which type is best suited for a specific discharge. Considerations will be given to water chemistry, topographical setting, and upfront and long-term costs, including maintenance. Discharges exhibiting characteristics of AMD have been identified in the Sandy Run, Whiskey Run, and Stony Run watersheds.

Some of the practices discussed above have already been implemented. For example, the Bureau of Abandoned Mine Lands (AML) completed a reclamation project (BF-224) on Quinn Coal and Clay's Elk Mountain Mine (Attachment B). Old pre-act deep mine openings were backfilled and plugged, pits were filled in, and regrading and replanting was done. The site is now grassland.

Presently, AML's BF-432 project in the study area involves filling-in abandoned pits and regrading old spoil on Quinn Coal and Clay's West Branch Operation (Attachment B). The existing pit has 12 feet of water in it. This project will be sent out for bids.

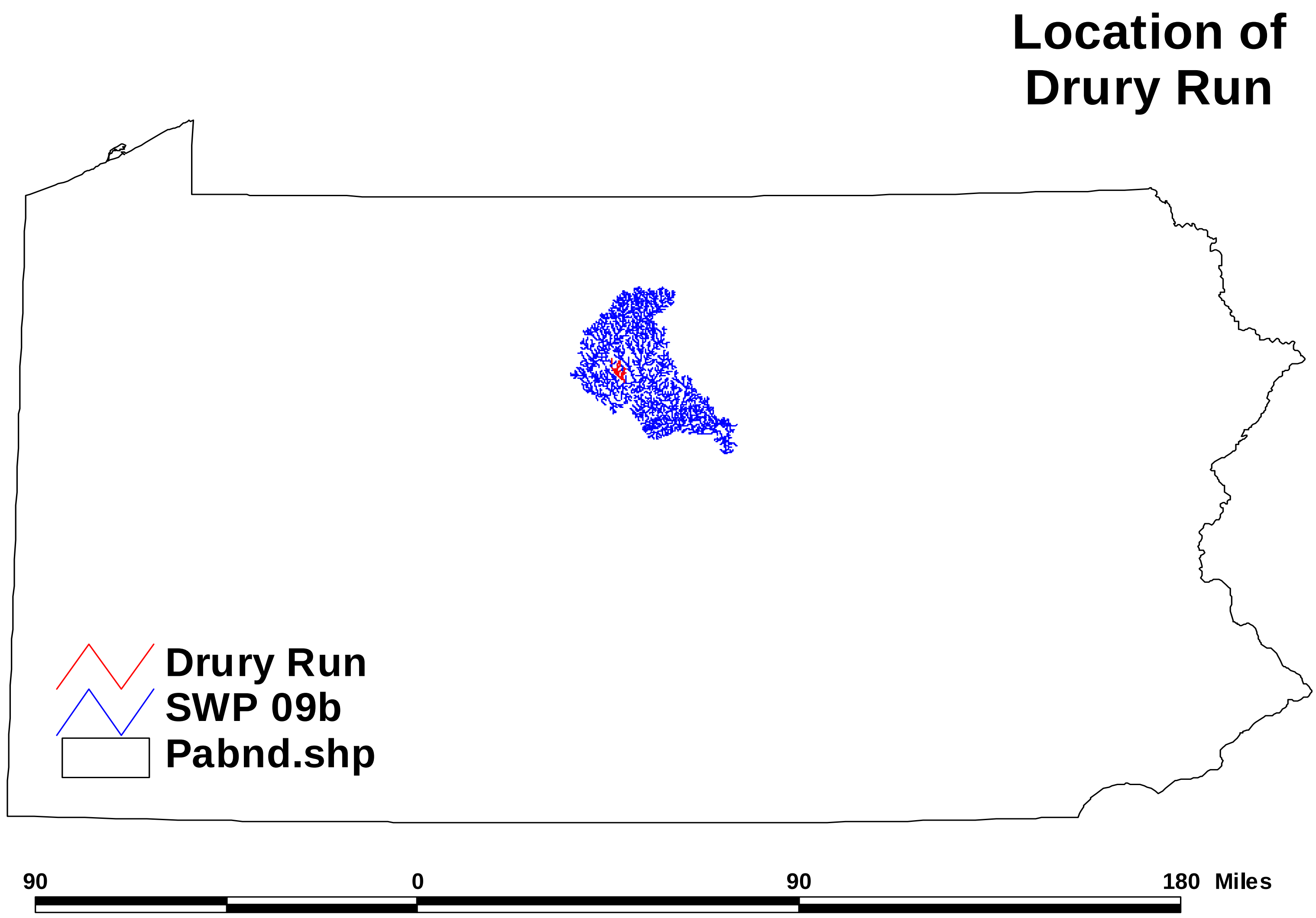
As previously discussed, the use of passive treatment systems will be determined on a case-by-case basis. The determining factors are: water chemistry, topography, as well as construction and long-term costs, including maintenance.

Public Participation

Notice of the draft TMDLs will be published in the *PA Bulletin* and The Record, Renovo, PA, newspaper with a 60 day comment period ending December 7, 2000. A public meeting with watershed residents was held on November 9, 2000 beginning at 7:00 p.m. at the Western Clinton Sportsman Association in Clinton County, PA to discuss the TMDLs. Notice of final TMDL approval will be posted on the Department website.

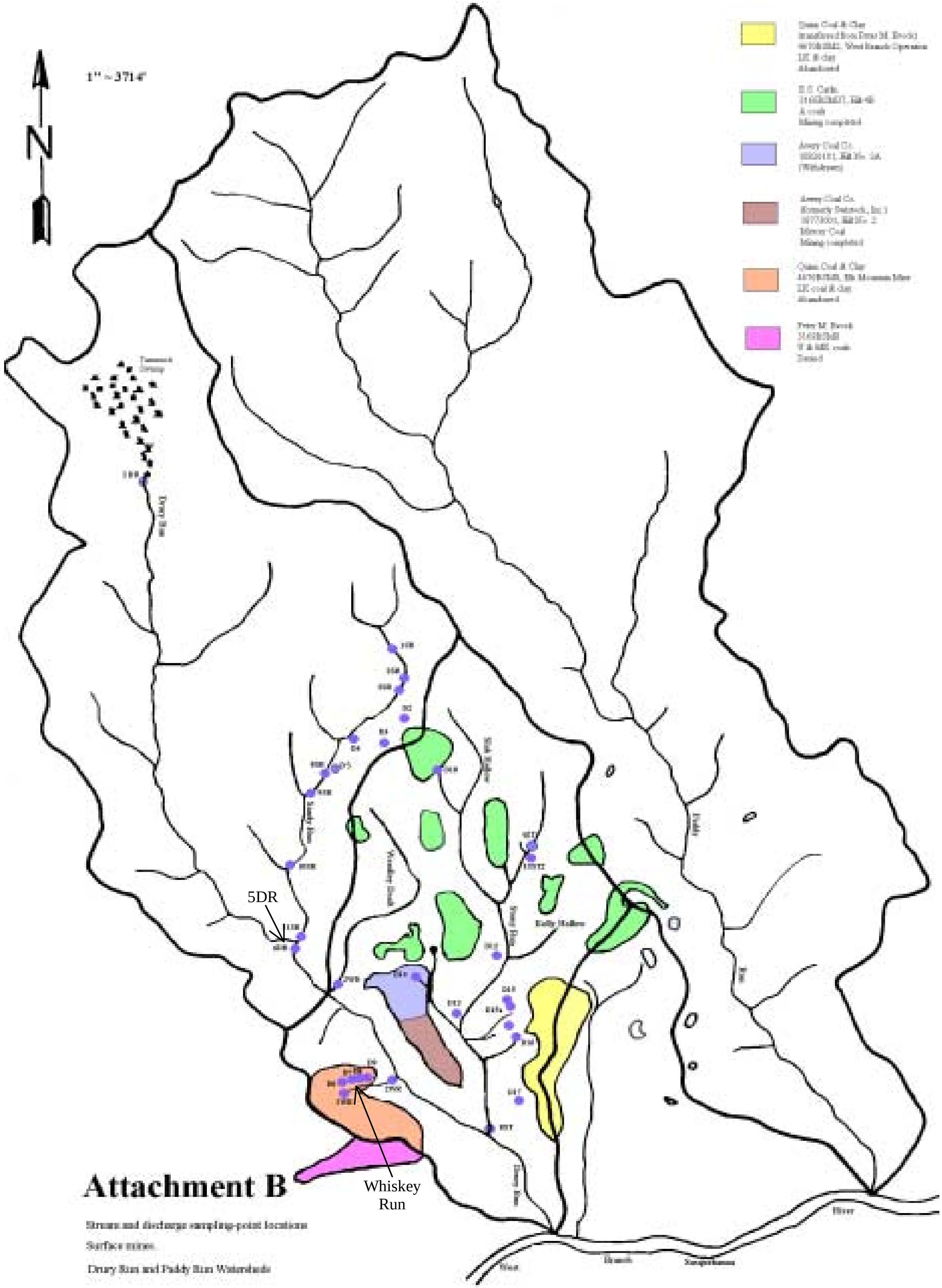
Attachment A

Location of Drury Run


Location of
Drury Run
Drury Run
SWP 09b
Pabnd.shp
90
0
90
180 Miles

Attachment B

Drury Run Watershed

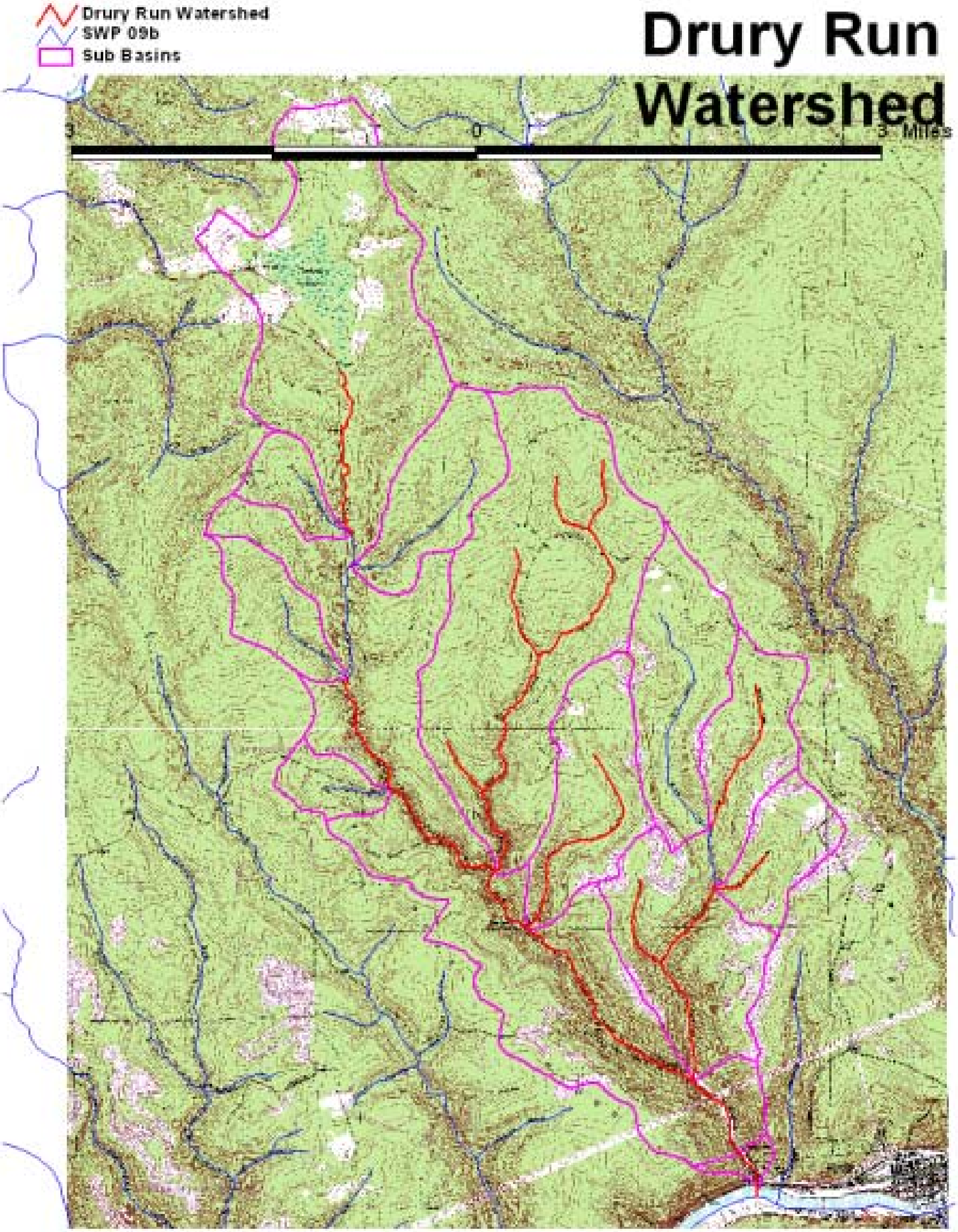


Attachment B

Stream and discharge sampling-point locations

Surface mines

Drury Run and Paddy Run Watersheds


Drury Run Watershed
SWP 09b
Sub Basins
Drury Run
Watershed
3
1
0
3 Miles

Attachment C

The pH Method

Method for Addressing 303(d) listings for pH

There has been a great deal of research conducted on the relationship between alkalinity, acidity, and pH. Research published[1] by the PA Department of Environmental Protection demonstrates, that by plotting net alkalinity vs. pH for 794 mine sample points, where net alkalinity is positive (greater or equal to zero), the pH range is most commonly 6 to 8, which is within the EPA's acceptable range of 6 to 9, and meets Pennsylvania water quality criteria in Chapter 93. The included graph (page 3) presents the nonlinear relationship between net alkalinity and pH. The nonlinear positive relation between net alkalinity and pH indicates that pH generally will decline as net alkalinity declines and vice versa; however, the extent of pH change will vary depending on the buffering capacity of solution. Solutions having near-neutral pH ($6 < pH < 8$) or acidic pH ($2 < pH < 4$) tend to be buffered to remain in their respective pH ranges.[2] Relatively large additions of acid or base will be required to change their pH compared to poorly buffered solutions characterized by intermediate pH ($4 < pH < 6$) where the correlation between net alkalinity and pH is practically zero.

The parameter of pH, a measurement of hydrogen ion acidity presented as a negative logarithm of effective hydrogen ion concentration, is not conducive to standard statistics. Additionally pH does not measure latent acidity that can be produced from hydrolysis of metals. For these reasons PA is using the following approach to address the stream impairments noted on the 303(d) list due to pH. The concentration of acidity in a stream is partially dependent upon metals. For this reason, it is extremely difficult to predict the exact pH values which would result from treatment of acid mine drainage. Therefore, net alkalinity will be used to evaluate pH in these TMDL calculations. This methodology assures that the standard for pH will be met because net alkalinity is able to measure the reduction of acidity. When acidity in a stream is neutralized or is restored to natural levels, pH will be acceptable (>6.0). Therefore, the measured instream alkalinity at the point of evaluation in the stream will serve as the goal for reducing total acidity at that point. The methodology that is applied for alkalinity, (and therefore pH) is the same as that used for other parameters such as iron, aluminum and manganese that have numeric water quality criteria.

Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both being in units of mg/L $CaCO_3$. The same statistical procedures that have been described for use in the evaluation of the metals is applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for mine waters is not a true reflection of acidity. This method assures that PA's standard for pH is met when the acid concentration reduction is met.

There are several documented cases of streams in Pennsylvania having a natural background pH below six. If the natural pH of a stream on the 303-(d) list can be established from its upper unaffected regions, then the pH standard will be expanded to include this natural range. The acceptable net alkalinity of the stream after treatment/abatement in its polluted segment will be the average net alkalinity established from the stream's upper, pristine reaches. In other words, if the pH in an unaffected portion of a stream is

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[1] Rose, Arthur W. And Charles A.Cravotta, III, 1998. Geochemistry of Coal Mine Drainage. Chapter 1 in *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*. PA Dept. Of Environmental Protection, Harrisburg, PA.

[2] Stumm, Werner, and Morgan, J.J., 1996, Aquatic Chemistry--Chemical Equilbria and Rates in Natural Waters (3rd ed.), New York, Wiley-Interscience, 1022p.

found to be naturally occurring below 6, then the average net alkalinity for that portion of the stream will become the criterion for the polluted portion. This “natural net alkalinity level” will be the criterion to which a 99% confidence level will be applied. The pH range will be varied only for streams in which a natural unaffected net alkalinity level can be established. This can only be done for streams that have upper segments that are not impacted by mining activity. All other streams will be required to meet a minimum net alkalinity of zero.

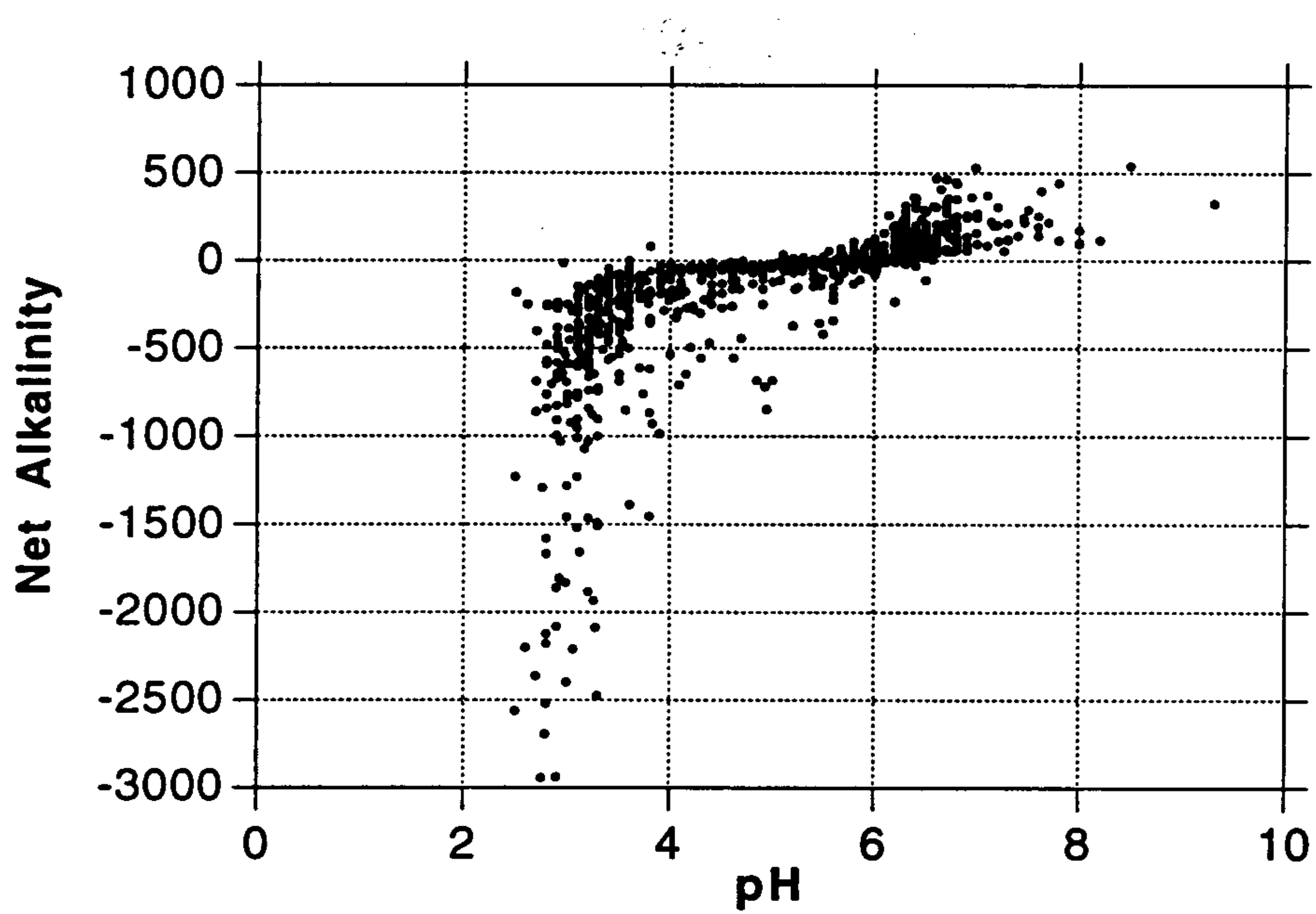

Figure 1.2, Graph C, net alkalinity vs. pH, page 1-5, of Coal Mine Drainage Prediction and Pollution Prevention in PA

Attachment D

Example Calculation: Lorberry Creek

Example Calculation: Lorberry Creek

Lorberry creek was evaluated for impairment due to high metals contents in the following manner. The analysis was completed in a stepwise manner starting at the headwaters of the stream and moving to the mouth. The Rowe Tunnel (Swat-04) was treated as the headwaters of Lorberry Creek for the purpose of this analysis.

1. A simulation of the concentration data at point Swat-04 was completed. This estimated the necessary reduction needed for each metal to meet water quality criteria 99% of the time as a long-term average daily concentration. Appropriate concentration reductions were made for each metal.

2. A simulation of the concentration data at point Swat-11 was completed. It was determined that no reductions in metals concentrations are needed for Stumps Run at this time, and therefore no TMDL for metals in Stumps Run is required at this time.

3. A mass balance of loading from Swat-04 and Swat-11 was completed to determine if there was any need for additional reductions as a result of the combining the loads. No additional reductions were necessary.

4. The mass balance was expanded to include the Shadle discharge (L-1). It was estimated that BAT requirements for the Shadle discharge were adequate for iron and manganese. There is no BAT requirement for aluminum. A wasteload allocation was necessary for aluminum at point L-1.

There are no other known sources below the L-1 discharge. However, there is additional flow from overland runoff and one unnamed tributary not impacted by mining. We believe it is reasonable to assume the additional flow provides assimilation capacity below the L-1 discharge and no further analysis is needed downstream.

The calculations are detailed in the following section and Table 9 shows the allocations made on Lorberry Creek

1. A series of 4 equations were used to determine if a reduction was needed at point Swat-04, and, if so the magnitude of the reduction.

Table 1. Equations Used for Rowe Tunnel Analysis

	Field Description	Equation	Explanation
1	Swat-04 initial Concentration Value (equation 1A)	= Risklognorm(mean,StDev)	This simulates the exisitng concentration of the sampled data.
2	Swat-04 % Reduction (from the 99^{th} percentile of PR)	= (input a percentage based on reduction target)	This is the percent reduction for the discharge.
3	Swat-04 Final Concentration Value	= Sampled Value x (1 - %reduction)	This applies the given percent reduction to the initial concentration.
4	Swat-04 Reduction Target (PR)	= maximum(0, 1- Cd/Cc)	This computes the necessary reduction, if needed, each time a value is sampled. The final reduction target is the 99^{th} percentile value of this computed field.

2. The reduction target (PR) was computed taking the 99th percentile value of 5000 iterations of the equation in row 4 of Table 9. The targeted percent reduction is shown, in boldface type, in the following table.

Table 2. Swat-04 Estimated Target Reductions			
Name	**Swat-04 Aluminum**	**Swat-04 Iron**	**Swat-04 Manganese**
Minimum =	0	0.4836	0
Maximum =	0.8675	0.9334	0.8762
Mean =	0.2184	0.8101	0.4750
Std Deviation =	0.2204	0.0544	0.1719
Variance =	0.0486	0.0030	0.0296
Skewness =	0.5845	-0.8768	-0.7027
Kurtosis =	2.0895	4.3513	3.1715
Errors Calculated =	0	0	0
Targeted Reduciton % =	**72.2%**	**90.5%**	**77.0%**
Target #1 (Perc%)=	99%	99%	99%

3. This PR value was then used as the % reduction in the equation in row 3. It was tested by checking that the water quality criterion for each metal was achieved at least 99% of the time. This is how the estimated percent reduction necessary for each metal was verified. The following table shows, in boldface type, the percent of the time criteria for each metal was achieved during 5000 iterations of the equation in row 3 of Table 9.

Table 3. Swat-04 Verification of Target Reductions			
Name	**Swat-04 aluminum**	**Swat-04 iron**	**Swat-04 manganese**
Minimum =	0.0444	0.2614	0.1394
Maximum =	1.5282	2.0277	1.8575
Mean =	0.2729	0.7693	0.4871
Std Deviation =	0.1358	0.2204	0.1670
Variance =	0.0185	0.0486	0.0279
Skewness =	1.6229	0.8742	1.0996
Kurtosis =	8.0010	4.3255	5.4404
Errors Calculated =	0	0	0
Target #1 (value) (WQ Criteria)=	0.75	1.5	1
Target #1 (Perc%)=	**99.15%**	**99.41%**	**99.02%**

4. These same four equations were applied to point Swat-11. The result was that no reduction was needed for any of the metals. The following two tables show the reduction targets computed for, and the verification of, reduction targets for Swat-11.

Table 4. Swat-11 Estimated Target Reductions			
Name	**Swat-11 Aluminum**	**Swat-11 Iron**	**Swat-11 Manganese**
Minimum =	0.0000	0.0000	0.0000
Maximum =	0.6114	0.6426	0.0000
Mean =	0.0009	0.0009	0.0000
Std Deviation =	0.0183	0.0186	0.0000
Variance =	0.0003	0.0003	0.0000
Skewness =	24.0191	23.9120	0.0000
Kurtosis =	643.4102	641.0572	0.0000
Errors Calculated =	0	0	0
Targeted Reduciton % =	**0**	**0**	**0**
Target #1 (Perc%) =	99%	99%	99%

Table 5. Swat-11 Verification of Target Reductions			
Name	**Swat-11 Aluminum**	**Swat-11 Iron**	**Swat-11 Manganese**
Minimum =	0.0013	0.0031	0.0246
Maximum =	1.9302	4.1971	0.3234
Mean =	0.0842	0.1802	0.0941
Std Deviation =	0.1104	0.2268	0.0330
Variance =	0.0122	0.0514	0.0011
Skewness =	5.0496	4.9424	1.0893
Kurtosis =	48.9148	48.8124	5.1358
Errors Calculated =	0	0	0
WQ Criteria =	**0.75**	**1.5**	**1**
% of Time Criteria Achieved =	**99.63%**	**99.60%**	**100%**

5. The following table shows variables used to express mass balance computations.

Table 6. Variable Descriptions for Lorberry Creek Calculations	
Description	**Variable shown**
Flow from Swat-04	Q_{swat04}
Swat-04 Final Concentration	C_{swat04}
Flow from Swat-11	Q_{swat11}
Swat-11 Final Concentration	C_{swat11}
Concentration below Stumps Run	C_{stumps}
Flow from L-1(shadle discharge)	Q_{L1}
Final Conc From L-1	C_{L1}
Concentration below L-1 discharge	C_{allow}

6. Swat-04 and Swat-11 were mass balanced in the following manner.

The majority of the sampling done at point Swat-11 was done in conjunction with point Swat-04 (20 matching sampling days). This allowed for the establishment of a significant correlation between the two flows, the R squared value was 0.85. Swat-04 was used as the base flow and a regression analysis on point Swat-11 provided an equation for use as the flow from Swat-11.

The flow from Swat-04 (Q_{swat04}) was set into an @RISK function so it could be used to simulate loading into the stream. The cumulative probability function was used for this random flow selection. The flow at Swat-04 is as follows

Q_{swat04} = RiskCumul(min,max,bin range,cumulative percent of occurrence)

The RiskCumul function takes 4 arguments: minimum value, maximum value, the bin range from the histogram, cumulative percent of occurrence)

The flow at Swat-11 was randomized using the equation developed by the regression analysis with point Swat-04.

$Q_{swat11} = Q_{swat}04 \times 0.142 + 0.088$

The mass balance equation is as follows:

$$Cstumps = ((Q_{swat04} * C_{swat04}) + (Q_{swat11} * C_{swat11}))/(Q_{swat04}+Q_{swat11})$$

This equation was simulated through 5000 iterations and the 99th percentile value of the data set was compared to the water quality criteria to determine if standards had been met. The results show there is no further reduction needed for any of the metals at either point. The simulation results are shown in the following table.

Table 7. Verification of Meeting WQ Standards below Stumps Run			
Name	Below Stumps Run Aluminum	Below Stumps Run Iron	Below Stumps Run Manganese
Minimum =	0.0457	0.2181	0.1362
Maximum =	1.2918	1.7553	1.2751
Mean =	0.2505	0.6995	0.4404
Std Deviation =	0.1206	0.1970	0.1470
Variance =	0.0145	0.0388	0.0216
Skewness =	1.6043	0.8681	1.0371
Kurtosis =	7.7226	4.2879	4.8121
Errors Calculated =	0	0	0
WQ Criteria =	**0.75**	**1.5**	**1**
% of Time Criteria Achieved =	**99.52%**	**99.80%**	**99.64%**

4. The mass balance was then expanded to determine if any reductions would be necesssary at the L-1 (Shadle discharge).

   The L-1 discharge originated in 1997 and there are very little data available for it. The discharge will have to be treated or eliminated. It is the current site of a USGS test remediation project. The data that were available for the discharge were collected at a point prior to a settling pond. We currently do not have data for effluent from the settling pond.

   Modeling for iron and manganese will start with the BAT required concentration value. The current effluent variability based on limited sampling will be kept at its present level. There is no BAT value for aluminum, so the starting concentration for the modeling is arbitrary. The BAT values for iron and manganese are 6 mg/l and 4 mg/l. The following table shows the BAT adjusted values used for point L-1

Table 8 Shadle Adjusted BAT Concentrations				
Parameter	**Measured Value**		**BAT adjusted Value**	
	Average Conc.	Standard Deviation	Average Conc.	Standard Deviation
Iron	538.00	19.08	6.00	0.21
Manganese	33.93	2.14	4.00	0.25

The average flow, 0.048 cfs, from the discharge will be used for modeling purposes. There was not any means to establish a correlation with point Swat-04.

The same set of four equations used for point Swat-04 were set up for point L-1. The following equation was used for evaluation of point L-1.

$C_{allow} = ((Q_{swat04}*C_{swat04})+(Q_{swat11}*C_{swat11})+(Q_{L1}*C_{L1}))/(Q_{swat04}+Q_{swat11}+Q_{L1})$

This equation was simulated through 5000 iterations and the 99th percentile value of the data set was compared to the water quality criteria to determine if standards had been met. It was estimated that an 81 % reduction in aluminum concentration is needed for point L-1.

The following table shows the simulation results of the equation above

Table 9. Verification of Meeting WQ Standards Below Point L-1			
Name	**Below L-1 / aluminum**	**Below L-1 / Iron**	**Below L-1 Manganese**
Minimum =	0.0815	0.2711	0.1520
Maximum =	1.3189	2.2305	1.3689
Mean =	0.3369	0.7715	0.4888
Std Deviation =	0.1320	0.1978	0.1474
Variance =	0.0174	0.0391	0.0217
Skewness =	1.2259	0.8430	0.9635
Kurtosis =	5.8475	4.6019	4.7039
Errors Calculated =	0	0	0
WQ Criteria=	**0.75**	**1.5**	**1**
Percent of time achieved=	**99.02%**	**99.68%**	**99.48%**

Table 10 presents the estimated reductions needed to meet water quality standards at all points in Lorberry Creek.

		Table 10. Lorberry Creek				
		Measured Sample Data		Allowable		Reduction Identified
Station	Parameter	Conc (mg/l)	Load (lbs/day)	LTA Conc (mg/l)	load (lbs/day)	%
Swat 04						
	Al	1.01	21.45	0.27	5.79	73%
	Fe	8.55	181.45	0.77	16.33	91%
	Mn	2.12	44.95	0.49	10.34	77%
Swat 11						
	Al	0.08	0.24	0.08	0.24	0%
	Fe	0.18	0.51	0.18	0.51	0%
	Mn	0.09	0.27	0.09	0.27	0%
L-1						
	Al	34.90	9.03	6.63	1.71	81%
	Fe	6.00	1.55	6.00	1.55	0%
	Mn	4.00	1.03	4.00	1.03	0%

All values shown in this table are Long-Term Average Daily Values

The TMDL for Lorberry Creek requires that a load allocation is made to the Rowe Tunnel abandoned discharge for the three metals listed, and that a wasteload allocation is made to the L-1 discharge for aluminum. There is no TMDL for metals required for Stumps Run at this time.

Margin of safety

For this study the margin of safety is applied implicitly. The allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

- None of the data sets were filtered by taking out extreme measurements. The 99% level of protection is designed to protect for the extreme event so we felt it pertinent not to filter the data set.

- Effluent variability plays a major role in determining the average value that will meet water quality criteria over the long term. Our analysis maintained that the variability at each point would remain the same. The general assumption can be made that a treated discharge would be less variable than an untreated discharge. This implicitly builds in another margin of safety.

Attachment E

Data Used To Calculate the TMDLs

Table 1. Sandy Run Data									
9SR									
Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
4/6/83		nr	4.80		6	12	0.63	0.01	0.32
4/25/90		nr	5.00	59	7	12	0.43	0.03	0.65
6/25/90		nr	4.80	66	6	6	0.52	0.27	0.71
6/26/90		nr	4.80	68	6	6	0.61	0.06	0.67
8/15/90		nr	4.60	87	6	16	0.87	0.05	1.07
9/28/90		nr	4.90	68	7	26	0.61	0.05	0.8
Avg.					6.33	13.00	0.61	0.08	0.70
Std. dev.						7.46	0.15	0.10	0.24

Table 2. Woodley Draft Data									
2WD									
Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
4/25/90		nr	4.50	221	6	24	3.33	0.01	3.04
6/26/90		170	4.30	243	4	24	3.38	0.01	3.20
8/16/90		nr	4.40	252	6	26	3.44	0.03	3.5
9/27/90		nr	4.40	252	6	28	4.03	0.02	3.94
11/8/90		nr	4.40	220	6	20	3.06	0.01	2.94
Avg.					5.60	24.40	3.45	0.02	3.32
Std. dev.						2.97	0.36	0.01	0.40

Table 3 Whiskey Run Data									
2WR									
Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
6/10/76		nr	4.20	nr	5	10	nr	0.13	nr
6/21/90		nr	3.50	496	0	94	12.80	0.85	5.52
6/26/90		100	3.50	482	0	80	11.10	0.62	5.60
8/16/90		nr	3.50	530	0	92	11.40	0.73	5.41
9/27/90		nr	3.50	490	0	96	12.50	0.75	5.91
11/8/90		150	3.60	424	0	66	7.64	0.65	4.08
Avg.					0.83	73	11.09	0.62	5.30
Std. dev.						32.86	2.06	0.25	0.71

Table 4. Stony Run Data									
8ST									
	Days	Flow (gpm)	pH	Spec Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
12/1/66		nr	4.50	nr	6	20		0.00	
6/4/68		nr	4.50	nr	12	2		0.00	
5/13/70		nr	4.60	nr	0	12		0.43	
11/19/70		nr	4.70	nr	24			0.50	
1/7/71		nr	5.00	nr	0	2		0.12	
5/17/71		nr	4.50	nr	0	29		0.23	
10/14/71		nr	4.20	nr	0	4		0.10	
1/20/72		nr	4.20	nr	0	2		0.10	
4/12/73		nr	4.10	nr	2	46		0.40	
5/1/73		nr	4.10	nr	0	42		0.40	
6/29/73		nr	4.40	nr	4	78		0.12	
7/12/73		nr	4.40	nr	4	98		0.14	
8/16/73		nr	4.30	nr	4	70		1.50	
12/30/74		nr	4.40	nr	4	46		0.25	
3/22/76		nr	4.30	nr	-5	52		0.14	
4/19/79		2864	3.65	nr	0	55		0.90	7.87
12/12/79		1200	3.80	nr	0	72		0.49	11.18
4/29/80		2300	3.85	nr	0	55		0.52	8.64
7/24/80		400	3.60	nr	0	80		0.15	11.40
9/13/80		280	3.60	720	0	76		0.10	8.90
10/28/80		600	4.20	nr	3	50		0.21	8.15
3/3/81		2000	4.30	nr	4	64		0.85	10.10
6/2/81			4.10	nr	3	90	5.14	0.39	9.28
6/11/81			4.80	470	nr	nr			
6/15/81		2500	4.11	nr	2	58		0.85	10.00
6/18/81			3.80	560	nr	60	8.68	0.77	12.23
8/25/81			4.04	nr	2	28		0.55	15.50
10/20/81		2864	4.20	630	2	78		0.32	14.80
3/15/82			4.37	nr	4	45		0.65	8.00
4/22/82		251	4.90	nr	6	16		0.10	12.00
8/16/82		56	4.03	nr	2	132		0.10	13.40
10/19/82		250	3.60	nr	0	81		0.10	12.02
1/7/83		250	4.32	nr	6	66		0.10	10.82
1/28/83			4.30	nr	5	80	6.59	0.12	10.01
3/28/83		1000	4.30	540	8	78		0.57	8.62
4/22/83		700	4.10	nr	4	94		0.48	12.06
8/15/83		400	3.95	nr	1	134		0.17	16.42
11/21/83			4.40	nr	6	70	5.11	0.24	7.72
11/23/83		600	4.30	nr	5	47		0.11	10.26
3/16/84		550	4.15	nr	3	88		0.12	11.80

Table 4. Stony Run Data									
8ST									
	Days	Flow (gpm)	pH	Spec Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
6/30/84		480	4.10	nr	2	96		0.16	13.20
9/11/84		375	3.90	nr	0	121		0.20	15.90
12/20/84		450	4.10	nr	2	90		0.14	12.70
3/30/85		600	4.40	nr	6	80		0.10	10.80
6/29/85		1500	3.65	nr	0	73		0.22	13.10
9/4/85		1500	3.90	nr	0	108		0.18	16.64
10/28/85		1000	3.90	nr	0	96		0.08	15.50
3/10/86			4.10	nr	3	62	10.10	0.3	14.20
3/21/86		1200	3.90	nr	0	103		0.23	14.56
6/24/86		800	3.90	nr	0	111		0.36	16.50
9/18/86		450	3.80	nr	0	130		0.41	16.90
12/13/86		1400	4.20	nr	1	81		0.45	11.90
2/23/87		1000	3.90	nr	0	89		0.18	16.00
4/23/87		nr	4.10	nr	4	54	5.76	0.3	10.20
5/30/87		850	4.30	nr	4	80		0.20	16.90
7/18/87		850	3.80	nr	0	126		0.39	14.80
12/19/87		800	3.90	nr	0	101		0.27	15.70
3/12/88		1000	4.10	nr	2	81		0.16	14.90
6/24/88		100	3.95	nr	2	91		0.15	11.56
7/16/88			4.00	nr	0	76	8.85	0.13	11.36
12/7/89		1795	4.30	nr	4	57		0.26	9.88
3/30/90		2300	4.25	495	5	43		0.12	6.58
4/25/90			4.20	503	4	50	7.92	0.12	10.00
6/13/90		3740	4.25	735	6	55		0.12	8.94
6/26/90		600	4.10	566	3	46	6.92	0.17	10.80
9/27/90			4.10	567	4	76	6.98	0.18	11.80
9/29/90		2244	4.15	860	5	67		0.06	13.86
11/8/90		2300	4.10	537	3	54	7.48	0.12	10.40
12/12/90		nr	4.20	nr	4	52	6.4	0.3	9.46
1/10/92		nr	4.30	nr	4	48	5.98	0.3	7.88
6/11/92		nr	4.10	nr	2	50	7.81	0.3	8.97
12/8/93		nr	4.10	nr	4	68	7.00	0.3	8.39
Avg.			4.15		2.77	67.35	7.11	0.29	11.81
Std. dev.						31.07	1.40	0.25	2.85

Table 5. Headwaters of Sandy Run

1SR

Date	Days	Flow (gpm)	pH	Spec Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
7/1/74		nr	5.30	nr	4	4	nr	0.24	nr
4/6/83		nr	5.40	nr	5	14	nr	0.01	nr
4/25/90		nr	5.60	21	7	10	0.14	0.01	0.02
6/25/90		nr	5.40	28	7	2	0.08	0.03	0.04
8/15/90		nr	5.80	20	8	4	0.05	0.01	0.01
9/28/90		nr	5.80	20	8	3	0.14	0.03	0.02
11/8/90		245	5.60	21	8	4	0.14	0.01	0.01
Avg.			5.557		6.71	5.857	0.11	0.0486	0.02
Std. dev.						4.41	0.04	0.08	0.01

Table 6. Headwaters of Stony Run

1ST

Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
6/21/90		nr	6.00	22	9	30	0.40	2.10	0.26
6/28/90		nr	6.20	23	11	0	0.21	3.19	0.16
8/16/90		nr	5.70	22	8	2	0.14	0.77	0.10
9/27/90		nr	6.20	20	8	4		0.54	0.09
11/7/90		nr	5.70	22	8	0	0.14	0.17	0.12
Avg.			5.96		8.8	7.2	0.22	1.35	0.15
Std. dev.					1.30	12.85	0.12	1.26	0.07

Table 7. Headwaters of Drury Run

1DR

Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
4/25/90		nr	5.30	44	8	8	0.09	0.61	0.07
6/27/90		nr	5.80	nr	6	36	0.53	1.67	0.11
8/16/90		nr	5.80	41	12	14	0.25	1.66	0.14
9/27/90		nr	5.50	41	10	10	0.21	0.98	0.07
Avg.			5.60		9.00	17.00	0.27	1.23	0.10
Std. dev.						12.91	0.19	0.52	0.03

Table 8. Drury Run Above Confluence with Sandy Run 5DR								
			Spec.					
Date	Flow (gpm)	pH	Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
4/25/90	nr	6.30	35	10	0	0.04	0.13	0.02
5/17/90	nr	6.10	37	8	2	0.30	0.60	0.06
6/14/90	nr	6.50	38	11	0	0.19	0.2	0.02
6/26/90	1500	7.20	36	14	0	0.15	0.29	0.02
6/26/90	nr	6.30	nr	8	4	0.60	0.31	0.03
8/16/90	nr	6.40	37	12	0	0.14	0.20	0.02
9/28/90	1600	6.70	35	12	0	0.07	0.20	0.02
11/8/90	3700	6.20	30	11	0	0.14	0.14	0.01
Avg.		6.46		10.75	0.75	0.20	0.26	0.03
Std. dev.					1.49	0.18	0.15	0.02

Table 9. Drury Run Below Confluence with Sandy Run 6DR							
Date	pH	Spec. Cond.	Alk (mg/l).	Acidity (mg/l)	A (mg/l)l	Fe (mg/l)	Mn (mg/l)
6/26/90	6.4	42	9	2	0.22	0.18	0.15
8/16/90	6.4	34	11	0	0.14	0.24	0.02
9/28/90	6.3	44	8	3	0.22	0.13	0.18
11/8/90	5.9	37	9	2	0.14	0.04	0.13
Avg.=	6.25		9.25	1.75	0.18	0.148	0.12
Std. Dev=				1.258	0.046	0.085	0.070

Table 10. Stony Run

11SR

Date	Days	Flow (gpm)	pH	Spec. Cond.	Alk. (mg/l)	Acid. (mg/l)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
8/30/73		nr	5.40	nr	6	8	nr	0.01	nr
4/6/83		nr	4.90	nr	6	12	0.27	0.01	0.20
4/25/90		nr	5.10	54	7	4	0.33	0.02	0.41
5/17/90		nr	4.90	48	5	4	0.32	0.13	0.28
6/14/90		nr	4.90	59	6	8	0.42	0.05	0.32
6/26/90		800	4.70	59	6	6	0.40	0.06	0.36
8/15/90		nr	4.90	91	7	14	0.54	0.09	0.58
9/28/90		1600	5.10	60	7	26	0.30	0.03	0.42
11/8/90		1900	5.00	37	7	3	0.34	0.07	0.46
8/10/94		nr	4.90	nr	2	7	0.43	0.21	0.28
Avg.		1433.3	4.92		5.8	11.28	0.402	0.092	0.42
Std. dev.			0.148		2.17	9.159	0.0923	0.0694	0.1122
	MGD=	2.064							
	cfs=	3.193							

Attachment F

Comment and Response

DEP received no official comments on this TMDL. Minor language edits may have been made since the draft document was public noticed.