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Development of pH TMDL for a 303(d) listed stream in Western Kentucky: Drakes Creek in Hopkins County, Kentucky

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Submitted by

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D. Executive Summary

Drakes Creek was determined as not supporting the designated uses of primary and secondary contact recreation (swimming and wading) and warm water aquatic habitat (aquatic life). Therefore, the creek was placed on the 1998 and 2002 303(d) lists for Total Maximum Daily Load (TMDL) development. The creek segment is characterized by a depressed pH, the result of acid mine drainage from strip and abandoned mining sites. In developing the TMDL for Drakes Creek, pH readings were collected at thirteen different locations within the watershed. Recent sampling supports the conclusion that several subbasins within the watershed (i.e. 2, 3, 4, and 8) do not support acceptable pH levels. Data at two downstream sites (i.e. 11 and 7) also reveal occasional impairment, however it is readily apparent that the impairment at site 11 is due to impairments in basins 2-4, while the impairment at site 7 is due to impairment from Subbasin 8. Subbasin 8 is in fact the Pleasant Run watershed, and has already been addressed through a separate TMDL. As a result, individual TMDLs are developed for Subbasins 2, 3 and 4.

Total maximum daily loads in grams H^+ ions per day were computed based on the allowable minimum pH value (6.0) for creeks and streams to meet primary and secondary contact recreation (swimming and wading) use and aquatic life use. The TMDL was done for grams of ions (subsequently converted to pounds/day) because the units for pH do not allow for the computation of a quantitatively useful load or reduction amount.

In developing a TMDL for Drakes Creek, two possible strategies were investigated. Either a cumulative aggregate TMDL may be obtained for the outlet of the watershed, or separate TMDLs (and associated load reductions) may be developed for each individual Subbasin. As a result of the availability of sampling data at multiple sampling points, individual TMDLs were developed for Subbasins 2-4. It is hypothesized that the remediation of Subbasins 2, 3, and 4 (as well as Subbasin 8 through the Pleasant Run TMDL) will lead to the restoration of the complete watershed. The TMDL and associated load reductions for Subbasins 2, 3, and 4 are shown below.

Subbasin	Incremental Upstream contributing area (mi^2)	Incremental Critical Flow (cfs)	Incremental TMDL for a pH of 6.0 (lbs/day)	Predicted Incremental load (lbs/day)	Load reduction needed (lbs/day)
2	0.90	0.56	0.0030	4.960	4.957
3	2.38	1.48	0.0080	0.760	0.752
4	4.31	2.68	0.0145	0.180	0.166

Disclaimer

This TMDL has not yet been released for public comment nor formally accepted by EPA and should not be considered the final version of the TMDL.

E. Introduction & Background

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop total maximum daily loads (TMDLs) for their water bodies that are not meeting designated uses under technology-based controls for pollution. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions. This method exists so that states can establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991). This report provides the TMDL for Drakes Creek.

Location

The Drakes Creek watershed is entirely contained within Hopkins County in southwestern Kentucky (Figure 1). Hopkins County is bounded on the west by the Tradewater River and on the east by the Pond River.

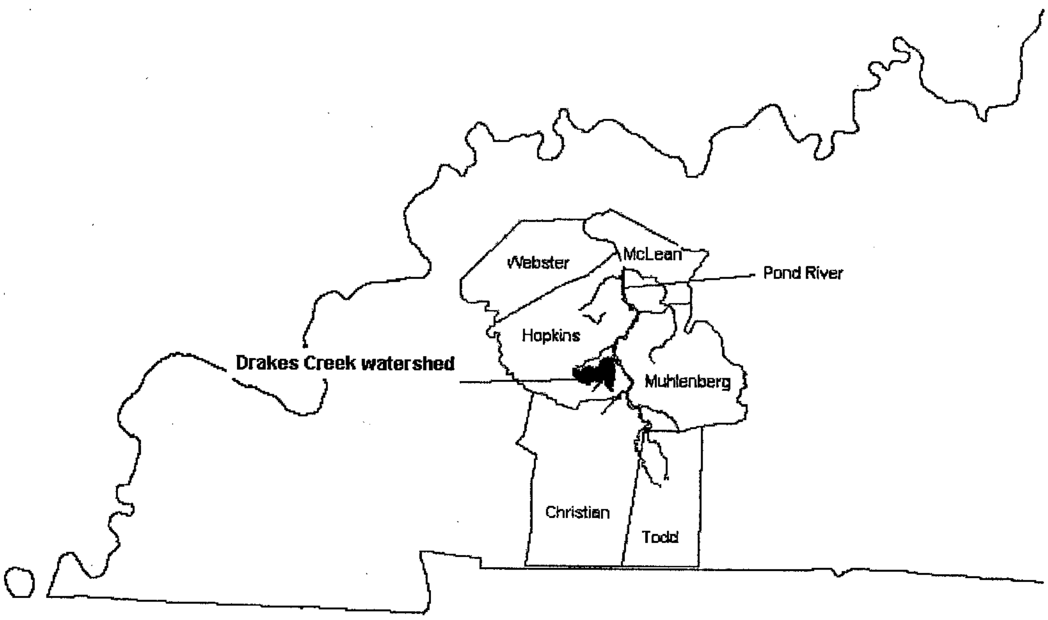

Figure 1: Location of the Drakes Creek Watershed

Hydrologic Information

Drakes Creek, a third order stream, originates in southeastern Hopkins County and flows northeast to discharge into Pond River 45.97 km (28.69 miles) upstream from its confluence with the Green River (Figure 2). The Green River carries the water northward to discharge into the Ohio River.

Drakes Creek's main stem is approximately 33.66 km (20.87 miles) long and drains an area of 41,298 acres (64.53 mi^2). The average gradient is 12.5 feet per mile. Elevations for Drakes Creek range from 195 m (640 ft) above mean sea level (msl) in the headwaters to 116 m (380 ft) above msl at the most downstream point.

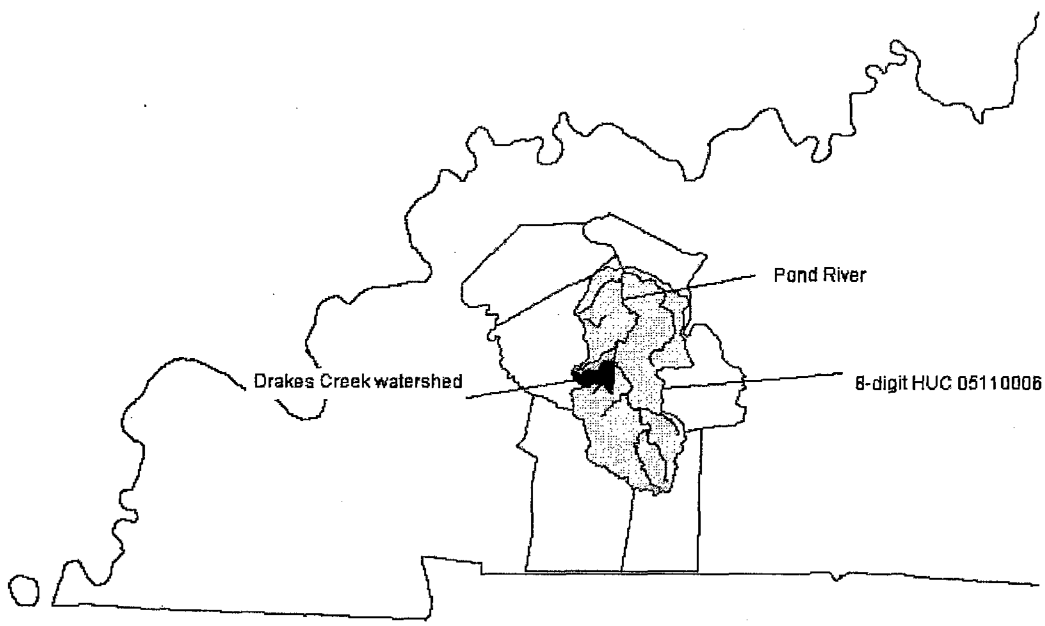

Figure 2: 8-digit HUC 05110006

Geologic Information

The Drakes Creek watershed is in the Western Coal field physiographic region. The surface bedrock is of Pennsylvanian age. Formations of the Pennsylvanian age are mostly sandstone, siltstone, coal, and interbedded limestone and shale; alluvial deposits of siltstone and crossbedded sand or sandstone underlie the extensive lowland areas (USDA, 1977). The relief of the Drakes Creek watershed ranges from nearly level to steep. Gently sloping to steep soils are found in the uplands and nearly level soils are found on the floodplain.

Landuse Information

Coal, oil, and natural gas are among the natural resources of Hopkins County. The Drakes Creek watershed contains two main landuses: resource extraction (mining and disturbed land area) and agriculture.

Soils Information

Drakes Creek watershed is dominated by nearly level loamy and clayey soils near to the mouth and level to steep loamy soils in the headwaters. The floodplains at the mouth of Drakes Creek are comprised of poorly drained soils formed in alluvium. The remainder of the watershed is dominated by Zanesville series soil, consisting of weathered shale and acid sandstone.

Mining History

Regulated mining activities in the Drakes Creek watershed have occurred since 1984. A list of the various mining permits that have been issued for Drakes Creek is provided in Table 1. Mining permits in Kentucky are classified on the basis of whether the original permit was issued prior to May 3, 1978 (pre-law permit), after January 18, 1983 (post-Kentucky primacy) or in-between these dates (interim period). An explanation of the permit numbering system is provided in Appendix C.

All permits are secured through reclamation bonds. A reclamation bond is a financial document submitted to the Office of Surface Mining prior to mine permit issuance. A bond guarantees mining and reclamation operations will be conducted by mining companies according to regulations and the terms of the approved permit. If a coal company cannot comply with these conditions, the bond is "forfeited" (paid to the Office of Surface Mining) for eventual use by the Division of Abandoned Mine Lands in reclaiming the mined area. Reclamation bonds may be submitted in the forms of cash, certificate of deposit, letter of credit or surety (insurance policy).

A reclamation bond may be returned to a coal company by either of two methods: administrative or phase (on-ground reclamation). Administrative releases occur when new bonds are substituted for the original bonds. Administrative releases are also given for areas of a mine site, which are permitted but never disturbed by mining, or for areas, which are included under a second, more recently issued permit.

Phase releases occur in three stages and according to specific reclamation criteria: Phase One – all mining is complete, and backfilling, grading and initial seeding of mined areas has occurred. Phase Two – a minimum of two years of growth on vegetated areas since initial seeding, the vegetation is of sufficient thickness to prevent erosion and pollution of areas outside the mine area with mine soils, and any permanent water impoundments have met specifications for future maintenance by the landowner. Phase Three – a minimum of five years of vegetative growth since initial seeding and the successful completion of reclamation operations in order for the mined area to support the approved postmining land use. Up to 60 percent of the original bond amount is released at phase one. An additional 25 percent is returned at phase two, with the remainder of the reclamation bond released at phase three. Once a permit is released and the reclamation bond returned, the state cannot require additional remediation action by the mining company unless it is determined that fraudulent documentation was submitted as part of the remediation process.

Table 1. History of Mining Permits in the Drakes Creek Watershed

Permit #	Permitted Area (ac)	Associated Company	Date Issued	Date Expired
6540204	414	Sextet Mining Corporation	09/18/1984	09/12/1989
8540120	419	Charolais Corporation	06/16/1987	09/12/1989
8540124	78	Circle S Coal Company Inc.	05/03/1988	05/03/1993
8540145	398.4	Warrior Coal Mining Co.	10/18/1989	05/03/1998
8540150	162.28	Charolais Corporation	08/28/1990	08/28/1995
8540173	561	Warrior Coal Mining Co.	02/16/1993	02/16/1998
8540180	360.6	Charolais Corporation	07/08/1994	07/08/1999
8540192	325.6	Charolais Corporation	04/04/1996	04/04/2001
8540198	377	Charolais Corporation	01/28/1997	01/28/2002
8540205	325.6	Centennial Resources Inc.	01/07/1998	04/04/2001
8540206	649.4	Centennial Resources Inc.	07/16/1997	01/28/2002
8540210	451.2	Centennial Resources Inc.	04/10/1998	04/10/2003
8545005	584.3	Prosperity Mining Inc.	05/08/1986	05/08/1996
8545028	294.3	Charolais Corporation	01/29/2001	01/29/2006
8547004	67	Warrior Coal Mining Co.	08/06/1990	08/06/1995

Monitoring History

The waters of Drakes Creek were monitored as early as 1978 by the DOW as reported in *The Effects of Coal Mining Activities on the Water Quality of Streams in the Western and Eastern Coalfields of Kentucky,* published in 1981 by the Kentucky Department for Natural Resources and Environmental Protection as part of an agreement with the Division of Abandoned Lands. The DOW sampled the stream on April 26, 1978, and recorded a pH value of 3.7.

Additional monitoring has been performed more recently in the Drakes Creek watershed as permits were granted to mining companies. Several sampling stations were established to monitor the water quality characteristics of the tributaries and main stem of Drakes Creek in association with the mining permits.

In 1997, the Division of Water (DOW) directed a survey of streams in the Western Kentucky Coal Fields, including Drakes Creek. A pH was collected and a habitat assessment was completed at the Kentucky Highway 70 Bridge. DOW reported that on July 3, 1997, Drakes Creek could only partially support aquatic life and swimming use. The observed cause of the pH impairment was surface mining activities and resource extraction.

In order to provide a more recent characterization of the pH levels in the watershed, the University of Kentucky (as part of the study contract with the DOW) subcontracted with Murray State University to collect additional data from the watershed. A summary of the results obtained from these sites during 2001/2002 is shown in Table 2. The Kentucky Division of Water (KYDOW) collected a new round of sampling during the summer and fall of 2003 (see Table 3). A map of the Murray State University and KYDOW sites and the watershed subbasins is provided in Figure 3. The main purpose of the KYDOW sampling was to focus on possible impairment in Subbasin 1. The recent sampling supports the conclusion that Subbasins 2, 3, 4, and 8 do not support acceptable pH levels. Data at sites 11 and 7 also reveal occasional impairment. However, it is readily apparent that the impairment at site 11 is due to impairments in Subbasins 2-4, while the impairment at site 7 is due to impairment from Subbasin 8. Subbasin 8 is in fact the Pleasant Run watershed, and has already been addressed through a separate TMDL. As shown by the values for the other sites, at least 90% of the pH values were equal to or greater than 6.0. As a result, individual TMDLs are developed for Subbasins 2, 3 and 4.

Table 2. Murray State Sampling Results

Date	Site 7		Site 8		Site 9		Site 12		Site 13	
	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH
9/22/01	36	5.5	18.2	5.9	30	5.7	2.6	5.7	<1	6.1
11/03/01	44	6.6	19.9	6.7	32	6.8	5.7	6.8	<1	6.6
12/01/01	514	6.6	27	4.4	458	6.3	42	6.3	<1	6.4
01/02/02	48	5.3	12.5	3.1	42	6.1	5.7	6.5	<1	frozen
01/20/02	50	6.6	21	3.6	48	6.6	2.8	7.2	<1	6.6
03/03/02	56	5.5	21.2	3.6	38	6.5	3.8	6.2	<1	6.6
04/07/02	56	6.6	22.7	3.5	32	7.2	2.8	7.0	<1	6.8
04/21/02	310	6.7	254	5.0	282	6.8	43.5	6.6	<1	6.8
05/10/02	44	5.8	17.2	3.9	16	5.5	13.7	6.8	<1	6.2
05/22/02	80	5.1	20	3.9	43	6.4	11.6	6.4	<1	6.2

Table 3. KYDOW 2003 Sampling Results

Date	Site 1		Site 2		Site 3		Site 4		Site 5	
	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH
8/20/2003	NM	6.70	NM	NM	0.06	2.70				
8/28/2003	NM	6.48	0.01	3.19	0.13	3.07				
9/4/2003	Flooded	6.78	1.20	3.32	1.20	3.12			NM	6.65
9/10/2003	NM	6.56	0.04	2.80	0.10	2.65	0.181	3.48	NM	7.37
9/17/2003	2.78	6.71	Pool	2.77	0.045	2.49	0.081	4.26		
9/25/2003	13.30	7.21	0.017	2.99	0.10	2.69	0.181	5.72		
10/2/2003	5.66	7.38	0.029	2.99	0.041	2.73				
10/8/2003	3.95	7.08	0.0005	2.90	0.04	2.78	Dry			
10/16/2003	7.17	7.19	0.0008	3.15	0.06	2.97	Dry			
10/23/2003	4.08	6.77	0.014	2.54	0.07	2.50	0.127	5.64		

Table 3. KYDOW 2003 Sample Results (continued)

Date	Site 6		Site 7		Site 8		Site 9		Site 10	
	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH	Flow rate (cfs)	pH
8/20/2003	Dry		NM	6.40	NM	6.60	NM	6.72	NM	6.57
8/28/2003	Dry		NM	5.65	NM	3.36	NM	6.56	NM	6.46
9/4/2003	0.06	7.25	NM	6.91	NM	4.65	NM	7.17	NM	6.94
9/10/2003	Dry		NM	6.12	NM	6.59	NM	6.56	NM	6.55
9/17/2003	Dry		NM	6.46	NM	6.62	NM	6.65	NM	6.26
9/25/2003	Dry		NM	6.96	NM	6.49	NM	7.19	NM	6.73
10/2/2003	Dry		NM	6.69	NM	5.49	NM	7.03	NM	6.66
10/8/2003	Dry		NM	6.61	NM	3.12	NM	6.92	NM	6.69
10/16/2003	Dry		NM	6.44	NM	3.15	NM	6.87	NM	6.64
10/23/2003	Dry		NM	6.07	NM	2.68	NM	6.47	NM	6.15

Table 3. KYDOW 2003 Sample Results (continued)

Date	Site 11	
	Flow rate (cfs)	pH
8/20/2003	NM	NM
8/28/2003	Stagnant	6.2
9/4/2003	Flooded	NM
9/10/2003	Stagnant	3.96
9/17/2003	0.00	5.15
9/25/2003	Stagnant	6.09
10/2/2003	Stagnant	6.44
10/8/2003	Stagnant	6.59
10/16/2003	1.43	6.54
10/23/2003	0.11	5.81

Problem Definition

The 1998 and 2002 303(d) lists of waters for Kentucky (Ky. Dept. for Environmental Protection DOW, 1998 and 2003) indicates 8.5 miles of Drakes Creek, from the upstream mile point: 8.5 to downstream mile point: 0.0 in Hopkins County, does not meet its designated uses for contact recreation (swimming) and for aquatic life. The Drakes Creek watershed provides a classic example of impairment caused by acid mine drainage (AMD). Bituminous coal mine drainage, like that found in the Drakes Creek watershed, generally contains very concentrated sulfuric acid and may contain high concentrations of metals; especially iron, manganese, and aluminum.

Acid mine drainage can (1) ruin domestic and industrial water supplies, (2) decimate aquatic life, and (3) cause waters to be unsuitable for swimming (primary contact recreation). In addition to these problems, a depressed pH interferes with the natural stream self-purification processes. At low pH levels, the iron associated with AMD is soluble. However, in downstream reaches where the pH begins to improve, most of the ferric sulfate [$Fe_2(SO_4)_3$] is hydrolyzed to essentially insoluble iron hydroxide [$Fe(OH)_3$]. The stream bottom can become covered with a sterile orange or yellow-brown iron hydroxide deposit that is deleterious to benthic algae, invertebrates, and fish.

The sulfuric acid in AMD is formed by the oxidation of sulfur contained in the coal and/or the rock or clay found above and below the coal seams. Most of the sulfur in the unexposed coal is found in a pyritic form as iron pyrite and marcasite (both having the chemical composition FeS_2).

In the process of mining, the iron sulfide (FeS_2) is uncovered and exposed to the oxidizing action of oxygen in the air (O_2), water, and sulfur-oxidizing bacteria. The end products of the reaction are as follows:

$$4\ FeS_2 + 14\ O_2 + 4\ H_20 + \text{bacteria} \rightarrow 4\ Fe + SO_4 + 4\ H_2SO_4 \qquad (1)$$

The subsequent oxidation of ferrous iron and acid solution to ferric iron is generally slow. The reaction may be represented as:

$$4\ FeSO_4 + O_2 + 2\ H_2SO_4 \rightarrow 2\ Fe_2(SO_4)_3 + 2\ H_2O \qquad (2)$$

As the ferric acid solution is further diluted and neutralized in a receiving stream and the pH rises, the ferric iron [Fe^{3+} or $Fe_2(SO_4)_3$] hydrolyses and ferric hydroxide [$Fe(OH)_3$] may precipitate according to the reaction:

$$2\ Fe_2(SO_4)_3 + 12\ H_2O \rightarrow 4\ Fe(OH)_3 + 6\ H_2SO_4 \qquad (3)$$

The brownish yellow ferric hydroxide ($Fe(OH)_3$) may remain suspended in the stream even when it is no longer acidic. Although the brownish, yellow staining of the stream-banks and water does not cause the low pH, it does indicate that there has been production of sulfuric acid. The overall stoichiometric relationship is shown in equation (4):

$$4\ FeS_2 + 15\ O_2 + 14\ H_2O \longleftrightarrow 8\ H_2SO_4 + 4\ Fe(OH)_3 \qquad (4)$$

This reaction (eqn. 4) indicates that a net of 4 moles of H+ are liberated for each mole of pyrite (FeS_2) oxidized, making this one of the most acidic weathering reactions known.

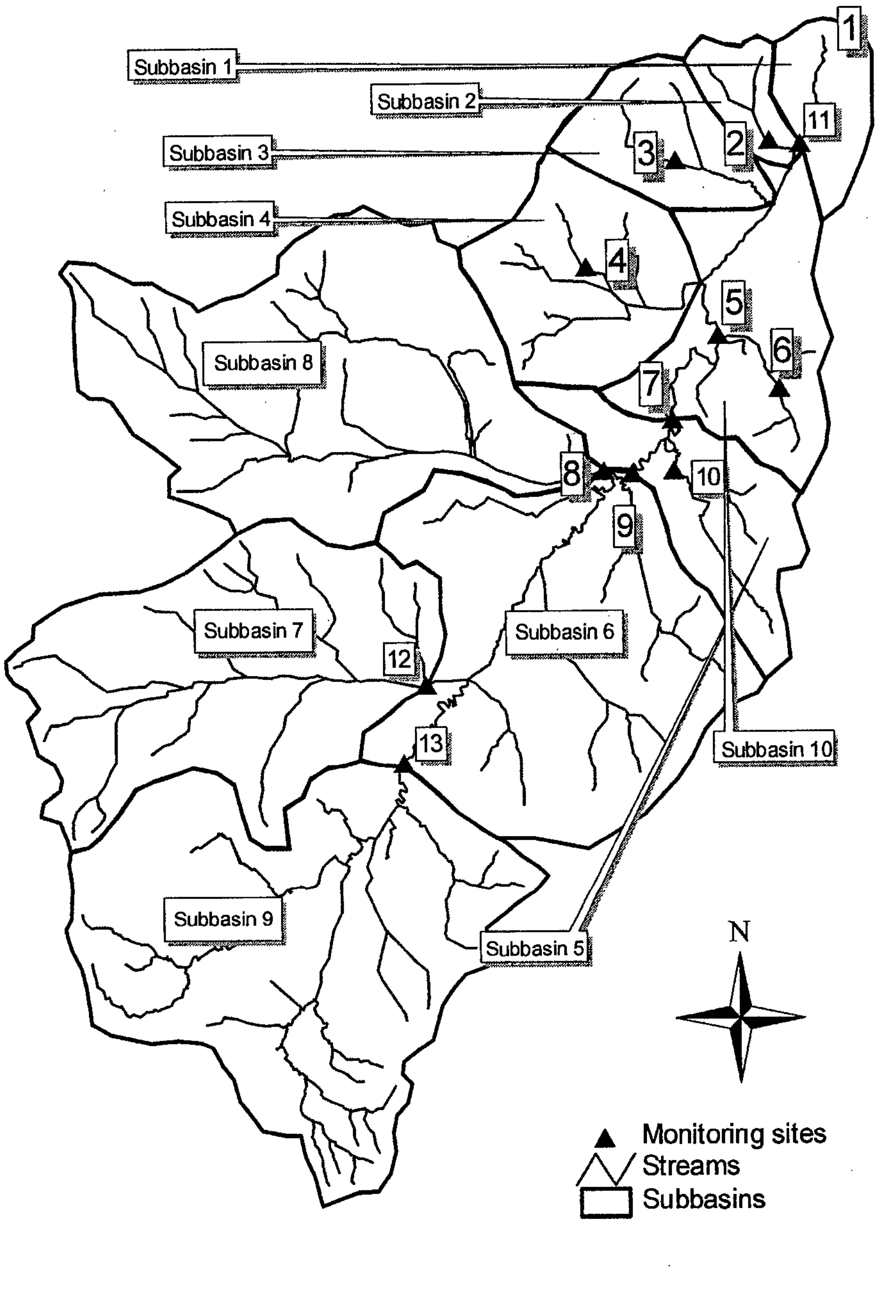

Figure 3. Sampling sites and watershed subbasins

F. Methods

1. Target Identification

The endpoint or goal of a pH TMDL is to achieve a pH concentration (and associated hydrogen ion load in lbs/day) that allows for the sustainability of aquatic life and of swimming and wading in a particular stream reach. The chronic pH criterion to protect Warm Water Aquatic Habitat Use in Kentucky requires that the pH be maintained between 6.0 and 9.0 (Title 401, Kentucky Administrative Regulations, Chapter 5:031, 2002). For a watershed impacted by AMD, the focus will be on meeting the lower criteria (pH of 6.0). Unfortunately, the current water quality criteria have not been specified in terms of a particular frequency of occurrence. As pointed out in the recent NRC TMDL report (2001), "All chemical criteria should be defined in terms of magnitude, frequency, and duration. Each of these three components is pollutant-specific and may vary with season. The frequency component should be expressed in terms of a number of allowed flow excursions in a specified period (return period) and not in terms of the low flow or an absolute "never to be exceeded" limit. The requirement of "no exceedances" for many water quality criteria is not achievable given natural variability alone, much less with the variability associated with discharges from point and non-point sources." Certainly, such is the case in developing TMDLs for pH impairment when the violations are caused by non-point sources on small intermittent streams and where the 7Q10 flow may actually be zero.

The Technical Support Document for Water Quality-Based Toxic Control (USEPA, 1991) states that daily receiving water concentrations (loads) can be ranked from the lowest to the highest without regard to time sequence. In the absence of continuous monitoring, such values can be obtained through continuous simulation or Monte-Carlo analysis. A probability plot can be constructed from these ranked values, and the occurrence frequency of any 1-day concentration of interest can be determined. Where the resultant frequency exceeds that of the stated target value (e.g. 10 years), associated load reductions will be required until the resultant concentration satisfies the stated target value and its associated exceedance frequency. Where the load and the resultant target indicator (i.e. pH) can be directly related through discharge (flow rate), the frequency of the associated discharge can be directly related to the frequency of the target value (e.g. pH).

In recognition of the inherent difficulties associated with imposition of a "no-exceedance" pH criteria on potentially intermittent streams, the Kentucky Division of Water has decided to use the lowest one year average discharge of the most recent 10-year flow record as the flow basis for setting the appropriate TMDL and associated loading reduction. Use of an average annual flow as the basis for determining the TMDL also provides a convenient mechanism for determining the total annual load; the total annual reduction that would be derived from an annual summation of both the daily TMDLs; and the associated daily load reductions for the critical year using the actual historical daily flows. The equivalent total annual load can be determined by simply multiplying the TMDL (derived by using the average annual flow) by 365 days.

Likewise, the equivalent total annual load reduction can be obtained by multiplying the average annual load reduction (derived by using the average annual flow) by 365 days. Although the 10 year average lowest flow (which roughly corresponds to the 365Q10), is typically only exceeded by approximately 20% of the days in the critical year it still provides for explicit load reductions for approximately 80% of the total annual volume of flows. For actual daily flows less than average flow, incremental load reductions may be accomplished by explicit imposition of a pH standard of 6 units.

2. Source Assessment

Point Source Loads

There are no known permitted point source loads contributing to the existing pH violations in the watershed.

Non-Point Source Loads

In order to provide a more recent characterization of the pH levels in the watershed, the University of Kentucky (as part of the study contract with the DOW) subcontracted with Murray State University to collect additional data from the watershed. A summary of the results obtained from these sites is shown in Table 2. The Kentucky Division of Water also collected a new round of sampling during the summer and fall of 2003. The main purpose of the KYDOW sampling was to focus on possible impairment in Subbasin 1 (see Figure 3). A summary of the results obtained from these sites is shown in Table 3. A map of the Murray State and the KYDOW sample sites is provided in Figure 3. Recent sampling supports the conclusion that Subbasins 2, 3, 4, and 8 do not support acceptable pH levels. Data at sites 11 and 7 also reveal occasional impairment. However it is readily apparent that the impairment at site 11 is due impairments in basins 2-4, while the impairment at site 7 is due to impairment from Subbasin 8. Subbasin 8 is in fact the Pleasant Run watershed, and has already been addressed through a separate TMDL. As a result, individual TMDLs are developed for Subbasins 2, 3 and 4.

3. Model Development

The magnitude of the associated hydrogen ion load in a water column (in terms of activity) can be determined by measuring the pH of the water. The relationship between hydrogen load and pH can be expressed as follows:

$$\{H_3O^+\} = 10^{-pH} \quad \text{or more commonly} \quad \{H^+\} = 10^{-pH} \qquad (5)$$

Where pH is the negative log of the H^+ ion activity in mol/L. To convert between the measured activity $\{H^+\}$ and the actual molar concentration $[H^+]$, the activity is divided by an activity coefficient, γ.

$$[H^+] = \{H^+\}/\gamma \qquad (6)$$

The activity coefficient, γ, is dependent on the ionic strength μ of the source water under consideration. The ionic strength of a given source water can be approximated by estimating the TDS (total dissolved solids in mg/liter or ppm) and applying the following relationship (Snoeyink and Jenkins, 1980):

$$\mu = (2.5 * 10^{-5}) * TDS \qquad (7)$$

Alternatively, the ionic strength of a given source of water may be related to the measured specific conductance (SC) through the following relationship (Snoeyink and Jenkins, 1980):

$$\mu = (1.6 * 10^{-5}) * SC \qquad (8)$$

Ionic strength can be converted to an associated activity coefficient using the functional relationship shown in Figure 4 (Snoeyink and Jenkins, 1980). In the absence of actual measured values of TDS or specific conductance, an estimate of the upper limit of the ionic strength may be obtained from an evaluation of historic values of TDS or specific conductance collected in the area. For example, an evaluation of over 1600 measurements of specific conductance obtained from streams in the eastern Kentucky Coal Fields (Grubb and Ryder, 1972; Kentucky Division of Water, 1981; and USGS, 1983) has revealed a range of values from 45 (μ mho/cm) to 5920 (μ mho/cm). Use of an upper limit of 6000 (μ mho/cm) yields an ionic strength of 0.096 or approximately 0.10. Use of a value of ionic strength of 0.10 yields an activity coefficient of approximately 0.83.

For the Drakes Creek watershed, specific conductance values were observed to vary from 55 to 2250 (μ mho/cm), which yield ionic strength values of between 0.001 to 0.036 respectively. Application of Figure 4 for the observed ionic strengths in Drakes Creek yields activity coefficients of 0.97 to 0.87.

The atomic weight of hydrogen is 1 gram per mole. Thus, the concentration of hydrogen ions in mol/L is also the concentration in g/L. Multiplying the concentration of hydrogen ions by the average flow rate for a given day results in a hydrogen ion load for that day in grams/day. As a result, for any given flow rate, there is a maximum ion load that the stream can assimilate before a minimum pH value of 6.0 is violated. Thus for any given day a TMDL may be calculated for that day using the average daily flow and a minimum pH standard of 6 units.

Because pH and equivalent hydrogen ion load can be related as a function of discharge and ionic strength, a functional relationship can be developed between discharge and the associated ion loading for a given pH value. By specifying a minimum pH value (e.g. 6) and an associated minimum activity correction factor (e.g. 0.87), an envelope of maximum hydrogen ion loads (that could still yield a pH of 6) may be obtained as a function of discharge (see the upper $TMDL_x$ curve in Figure 5). However, in the case of developing a TMDL for an impaired stream, the most conservative approach would be to assume an activity coefficient of 1.0, which would yield the lowest value for the TMDL for a given range of activity coefficients (see lower $TMDL_1$ curve in Figure 5). The difference between the maximum $TMDL_x$ (based on the observed activity coefficient) and the minimum $TMDL_1$ (based on an activity coefficient of 1.0) would thus provide an explicit margin of safety in setting the TMDL for the stream as well as for calculating the associated load reduction. Thus in developing a TMDL for the Drakes Creek Watershed, the TMDL for each subbasin will be established assuming an activity coefficient of 1.0, while the observed load will be determined using an activity coefficient of 0.87, thus providing for an upper limit for margin of safety (MOS) of approximately 13%.

Hydrogen Loading Example Calculation

In order to demonstrate the hydrogen loading conversion procedure, use the following monitoring data:

- Critical discharge (Q) = 0.56 cfs (Subbasin 1)
- Measured pH = 6.0

The pH can be converted to a mole/liter measurement (i.e. moles $[H^+]$/liter) by applying the following relationship:

$$pH = -\log \{H^+\}$$

The resulting moles of hydrogen is the anti-log of -6.0, which is 0.000001 moles/liter. The units need to be converted into grams/cubic ft. This is accomplished by applying the following conversion factors:

- There is one gram per mole of Hydrogen.
- 1 liter = 0.035314667 cubic feet

(0.000001 moles/liter)*(1 gram/mole)*(1liter/0.035314667 ft^3) = 0.0000283168 g/ft^3

The goal is to achieve a loading rate in terms of g/day, or lbs/day. If the amount of hydrogen in grams/cubic foot is multiplied by the given flow rate in cubic feet/second and a conversion factor of 86,400 s/day, then the load is computed as:

(0.0000283168 g/ft^3)*(0.56 ft^3/s)*(86400s/1day) = 1.37 g/day, or 0.0030 lbs/day

Assuming an activity correction factor of 0.87, the maximum load would be 1.57 g/day, or 0.0035 lbs/day:

1.37 g/day / 0.87 = 1.57 g/day, or 0.0035 lbs/day

Thus, by using an activity coefficient of 1.0 instead of 0.87, a margin of safety of approximately 13% would be assumed.

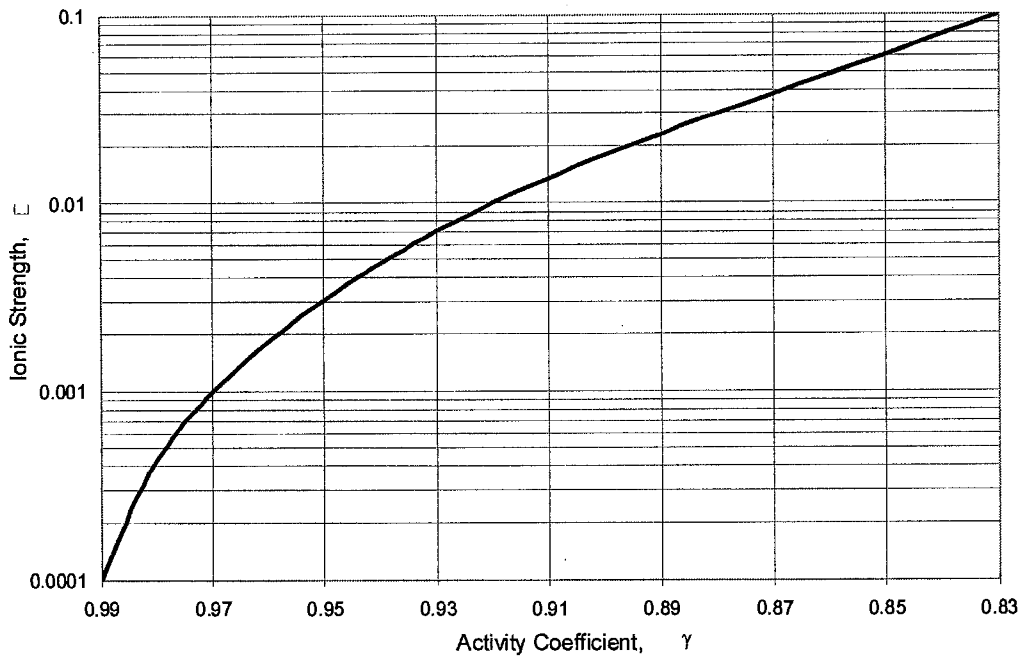

Figure 4: Activity coefficients of H+ as a function of ionic strength

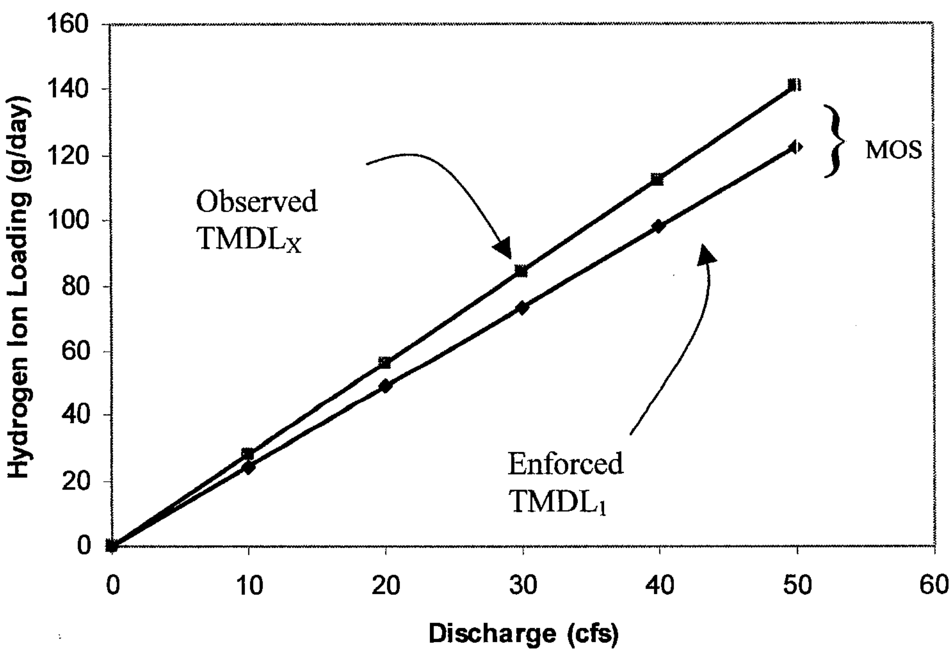

Figure 5: Relationship between discharge and maximum ion loading for a pH of 6.0

G. Results & Discussion

1. TMDL Development

Theory

The Total Maximum Daily Load (TMDL) is a term used to describe the maximum amount of a pollutant a stream can assimilate without violating water quality standards and includes a margin of safety. The units of a load measurement are mass of pollutant per unit time (i.e. mg/hr, lbs/day). In the case of pH there is no associated mass unit (pH is measured in Standard Units).

Total maximum daily loads (TMDLs) are comprised of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels for a given watershed. The sum of these components may not result in exceedance of water quality standards (WQSs) for that watershed. In addition, the TMDL must include a margin of safety (MOS), which is either implicit or explicit, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \text{Sum (WLAs)} + \text{Sum (LAs)} + \text{MOS} \qquad (9)$$

Wasteload Allocations

There are no known permitted point sources in this watershed. As a result, the wasteload allocations for the Drakes Creek Watershed are assumed to be zero.

Load Allocations

Load allocations for the Drakes Creek Watershed are assumed to be directly related to acid mine drainage as a result of water leaching from abandoned mines. The total load allocation for Drakes Creek is assumed to be an explicit function of the average daily flow in the stream and an associated pH standard of 6.0 units. Predicted daily loads for Subbasins 2, 3 and 4 can be obtained using the inductive loading models shown in Figures 7-9.

Margin of Safety

The margin of safety (MOS) is part of the TMDL development process (Section 303(d)(1)(C) of the Clean Water Act). There are two basic methods for incorporating the MOS (USEPA, 1991):

1) Implicitly incorporate the MOS using conservative model assumptions to develop allocations, or

2) Explicitly specify a portion of the total TMDL as the MOS using the remainder for allocations.

In using the proposed methodology, the MOS may be incorporated explicitly through the properties of water chemistry that determine the relationship between pH and hydrogen ion concentration. In an electrically neutral solution, the activity coefficient (γ in equation 6) is assumed to be equal to 1.0, meaning that there is no quantitative difference between activity and molar concentration. In the case of AMD there obviously exists the possibility of additional ions in the water column that may affect the relationship between the measured activity and the associated ion load. Specific conductance values in Drakes Creek have been found to range from 55 – 2250 (μ mho/cm), which yield ionic strength values of between .001 and .036 respectively. Application of Figure 4 for the observed ionic strengths in Drakes Creek yields activity coefficients of 0.97 – 0.87. In developing a pH TMDL for Drakes Creek, a conservative activity coefficient of 1.0 was assumed, while an activity coefficient of 0.87 was used in calculating the actual load, thus providing for a margin of safety of approximately 13%. Even though this MOS can be deemed as an explicit MOS, for this TMDL it will be expressed as an implicit MOS because a conservative assumption has been used in the model to determine the value of the TMDL.

2. TMDL Determination

Because maximum hydrogen ion loading values can be directly related to flow via Figure 5, the associated allowable ion loading can be directly related to the flow. In order to find the lowest 10-year average annual discharge for the Drakes Creek watershed, a regional hydrologic frequency analysis was used. Regional analysis can be used to develop an inductive model using data that has been collected at streamflow gaging stations that are located in the same hydrologic region as the watershed of interest. For this study, the following USGS gaging stations were selected: 03320500, 03384000, 03383000, and 03321350. The data from these gages is used to estimate the lowest average annual flows of the most recent 10 years (see Table 4). These discharges were then regressed with watershed area to produce Figure 6. Using this figure, the lowest 10 year mean annual discharge for a given watershed area can be readily determined.

Table 4. Flow rates (cfs) for stations in regional analysis

	USGS Gaging Station Numbers			
Station	3384000	3321350	3320500	3383000
Area (mi^2)	2.10	58.20	194.00	255.00
Q (cfs)	0.69	49.10	99.70	166.00

Application of Figure 6 for the Drakes Creek watershed yields a TMDL critical average annual discharge of 0.56 cfs for Subbasin 2 assuming an upstream watershed area of 0.90 mi^2. Application of a critical discharge of 0.56 cfs with the lower $TMDL_1$ curve in Figure 5 yields a TMDL for Subbasin 2 of 0.0030 lbs/day as shown in Table 5. TMDL values for other Subbasins are also given in Table 5.

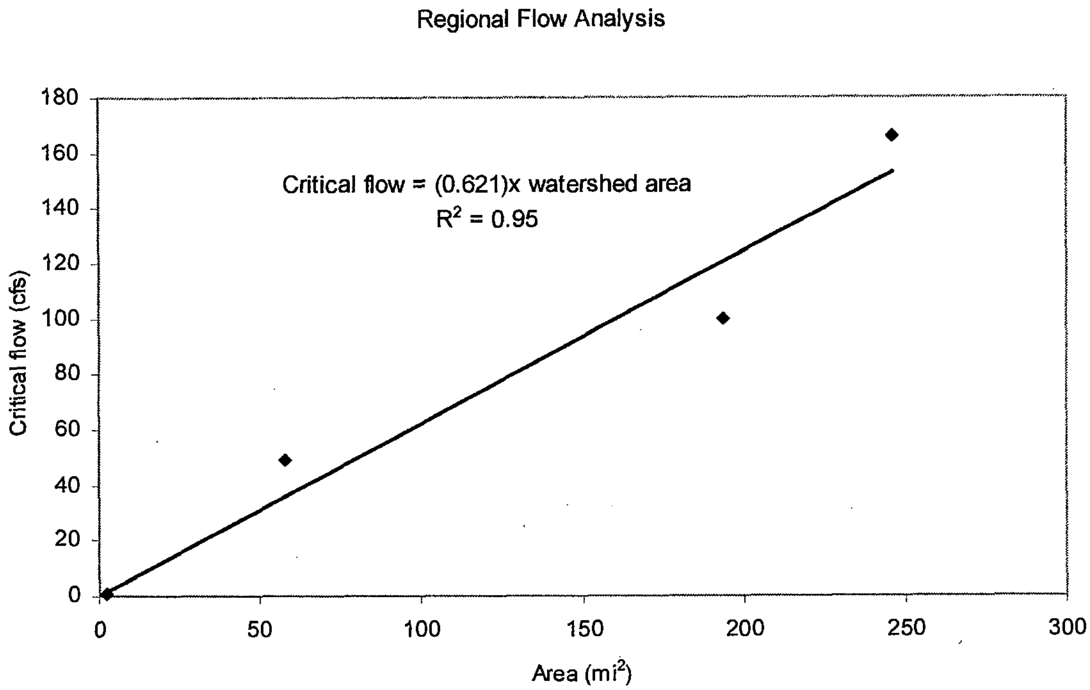

Figure 6: Relationship between basin area and the critical TMDL flow.

Table 5. Flow and Corresponding TMDLs for Subbasins 2, 3, and 4

Subbasin	Cumulative Area (mi^2)	Incremental Area (mi^2)	Cumulative Q (cfs)	Incremental Q (cfs)	Cumulative and Incremental TMDL (lbs/day)
2	0.90	0.90	0.56	0.56	0.0030
3	2.38	2.38	1.48	1.48	0.0080
4	4.31	4.31	2.68	2.68	0.0145

3. Hydrogen Ion Loading Model

There are currently no permitted point sources in this watershed that contribute to the pH impairment. As a result, the current point source load (wasteload) for the Drakes Creek Watershed is zero. Therefore, the entire hydrogen ion load can be attributed to nonpoint sources. For this watershed, the source is the AMLs.

Based on a physical inspection of the watershed, it is hypothesized that the degradation of the pH in the stream is directly related to oxidation of sulfur that occurs as runoff flows over the spoil areas associated with previous mining activities in the basin. Using the most recent monitoring data, inductive models were developed at monitoring sites 2, 3, and 4 that relate total hydrogen ion loading to flow. These models are shown in Figures 7-9, and are derived from the data in Table 3. In developing these models, a conservative value of 0.87 was assumed for the activity coefficient based on the upper limit of measured specific conductance values of 2250 (μ mho/cm). These models will be used in conjunction with the plot of the minimum $TMDL_1$ curve as shown previously in Figure 5. As discussed previously, the minimum $TMDL_1$ curve was developed assuming an activity coefficient of 1.0, thus providing for an upper limit for a margin of safety for the TMDL of approximately 13%.

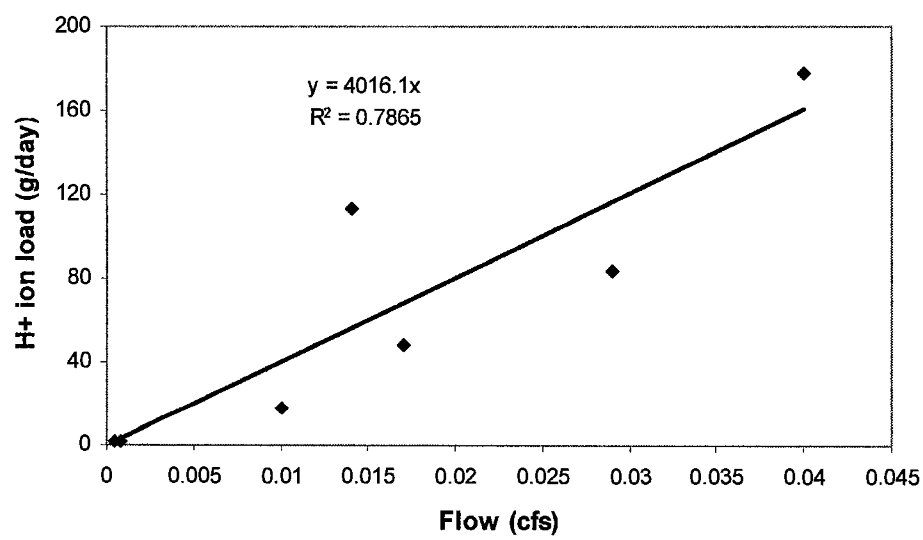

Figure 7: Relationship between flow and ion load for Site 2

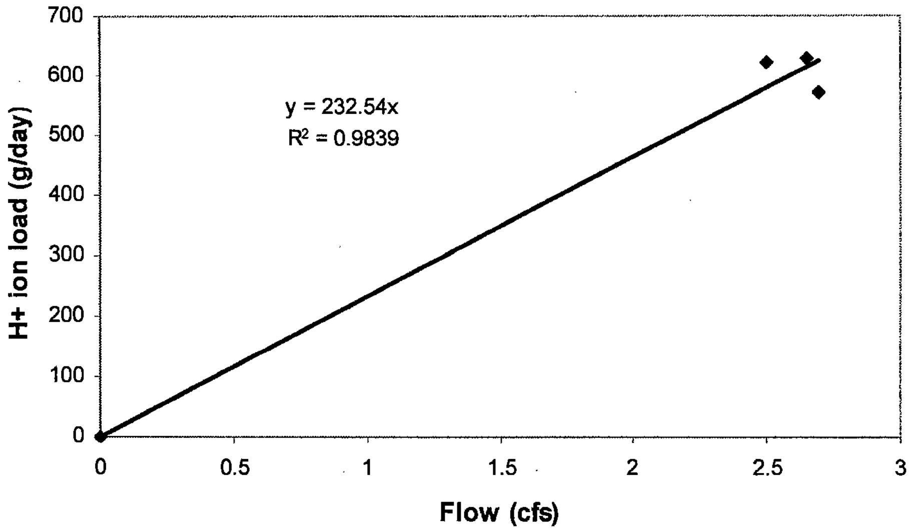

Figure 8: Relationship between flow and ion load for Site 3

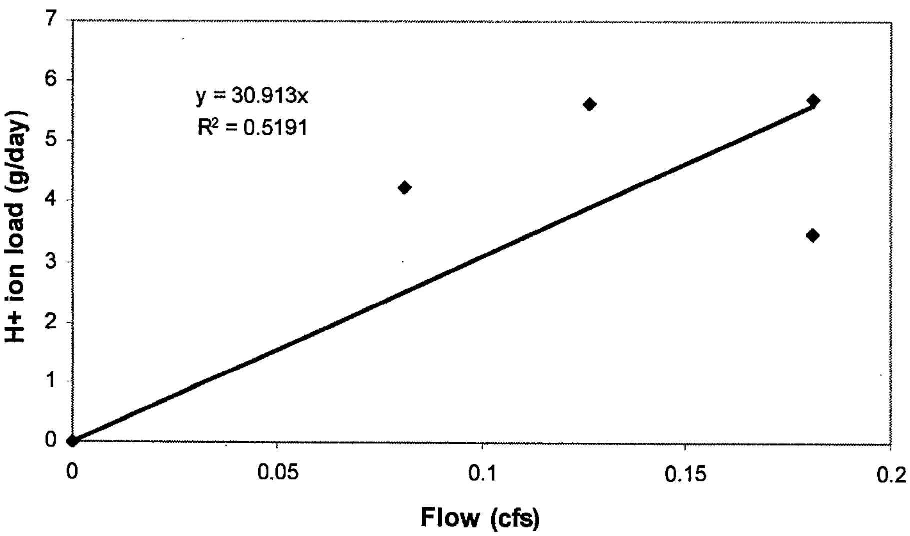

Figure 9: Relationship between flow and ion load for Site 4

4. Predicted Load

Once a TMDL is developed for a watershed, the associated load reduction must be spatially allocated. One way to accomplish this objective is through unit load reductions as associated with different land uses within the watershed. The impacts of such reductions on the associated water quality standard can then be verified through mathematical simulation. Alternatively, separate TMDLs (and associated load reductions) can be developed for individual subbasins within the watershed.

In the current case, incremental TMDLs were established for the impaired subbasins (i.e. Subbasins 2-4). The incremental load reductions for Subbasins 2-4 can then be obtained by subtracting the incremental TMDL from the incremental load for these Subbasins. Attainment of the incremental load reduction for Subbasins 2-4 should meet the TMDL requirement for the complete watershed.

The predicted hydrogen ion load for Subbasin 2 may be obtained using the critical discharge from Table 4 along with the associated load relationship shown in Figure 7. Use of a critical flow of 0.56 cfs with the fitted line in Figure 7 yields a load of 2,249 (g/day) or 4.96 (lbs/day). Therefore, for the purpose of developing the associated load reduction required for Subbasin 2, the observed critical load is assumed to be 4.96 lbs/day, as shown in Table 6. It should be noted that Site 2 is not located at the outlet of Subbasin 2, and the loading relationship at Site 2 is being extrapolated to obtain a loading at the outlet of Subbasin 2. The predicted hydrogen ion loads for Sites 3 and 4 were computed in similar way, and are given in Table 6. Also note that for Subbasins 2-4, the incremental and cumulative predicted loads are the same due to the fact that there are no upstream Subbasins that contribute to Subbasins 2-4.

Table 6. Predicted Ion Loads for Subbasins 2, 3, and 4

Subbasin	Cumulative and Incremental Critical Q (cfs)	Predicted Load Incremental and Cumulative (gm/day)	Predicted Load Incremental and Cumulative (lbs/day)
2	0.56	2,249	4.96
3	1.48	344	0.76
4	2.68	83	0.18

5. Load Reduction Allocation

Once a TMDL is developed for a watershed, the needed load reductions can be determined. One way to accomplish this objective is through the use of unit load reductions as associated with different land uses within the watershed. The impacts of such reductions on the associated water quality standard can then be verified through mathematical simulation. Alternatively, separate TMDLs (and associated load reductions) can be developed for individual Subbasins within the watershed. In the current study, an incremental TMDL and associated load reduction was developed for Subbasins 2-4 as identified in Figure 3. Attainment of the resultant load reduction should then meet the TMDL requirement for Subbasins 2-4.

Translation of the TMDLs in Table 5 into associated daily load reductions may be accomplished by subtracting the TMDLs for each Subbasin from the predicted loads for each Subbasin (Table 6). Application of this approach yields the values in Table 7.

Table 7. TMDL Summary and Reduction Needed for Subbasins 2, 3, and 4

Subbasin	Incremental Upstream contributing area (mi^2)	Incremental Critical Flow (cfs)	Incremental TMDL for a pH of 6.0 (lbs/day)	Predicted Incremental load (lbs/day)	Load reduction needed (lbs/day)
2	0.90	0.56	0.0030	4.960	4.957
3	2.38	1.48	0.0080	0.760	0.752
4	4.31	2.68	0.0145	0.180	0.166

6. Permitting

Permitting other than in Subbasins 2, 3, and 4

Permitting for locations in the Drakes Creek Watershed other than in Subbasins 2-4 (excluding the Pleasant Run Watershed) would require no special considerations related to 303(d). As shown by the values listed for the remaining sites (excluding sites 11 and 7), at least 90% of the pH values were equal to or greater than 6.0. Sites 1 and 7 are directly impacted from drainage from sites 2-4 and 8, which will be addressed through this and the Pleasant Run TMDL reports. Remediation of the abandoned mine areas in Subbasins 2-4 should thus result in improved water quality at Sites 2-4 and lead to the improvement of the water quality at Site 11. Further improvement at Site 8 (as well as site 7) is expected to be accomplished by implementation of the TMDL associated with the Pleasant Run Watershed (Subbasin 8).

New Permits

New permits (except for new remining permits) for discharges to streams in the Drakes Creek Watershed could be allowed anywhere in the watershed, contingent upon the end-of-pipe pH being permitted at a range of 7.0 to 9.0 standard units. Water quality standards state that for meeting the designated uses of aquatic life and swimming, the pH value should not be less the 6.0, nor greater than 9.0. This range of 6.0 to 9.0 for pH is generally the value assigned for end-of-pipe effluent limits. However, because stream impairment exists (low pH), new discharges cannot cause or contribute to an existing impairment. A pH of 7.0 represents a neutral state between an acidic and a non-acidic condition. As such, a discharge having a pH of 7.0 to 9.0 standard units will not cause or contribute to the existing impairment. The discharge will not cause impairment because the effluent discharge has a pH greater than 6.0 standard units. The discharge will not contribute to the existing impairment because a pH of 7.0 represents a neutral condition with respect to acidity and effectively represents a background condition. Based on limited pH data from streams in undisturbed watersheds in the area, a pH of 7.0 is generally representative of the value of background pH. The hydrogen ion load associated with a pH of 7.0 is insignificant (effectively zero) and therefore does not represent a contribution to the existing impairment. As such, new permits having an effluent limit pH of 7.0 would not be assigned a hydrogen ion load as part of a Waste Load Allocation. There are no active permits in the Drakes Creek Watershed that would contribute to the pH impairment.

Remining Permits

New remining permits may be approved on a case-by-case basis where streams are impaired because of low pH from abandoned mines. Permit approval is contingent on reclamation of the site after remining activities are completed. During remining, existing water quality conditions must be maintained or improved. Reclamation of the site is the ultimate goal, but water quality standards (pH of 6.0 to 9.0 standard units) may not necessarily be met in the interim. Remining therefore constitutes a means whereby a previously disturbed and unreclaimed area can be reclaimed.

The eventual reclamation of the remining site should result in a reduction of the overall ion load (specifically the nonpoint source load) of the subbasin where the remining was done. The reclamation should also result in an improved stream condition (increased pH) because a previously disturbed (and unreclaimed area) area will be reclaimed. Follow-up, in-stream monitoring would need to be done at the subbasin outfall to determine the effect of reclamation activities (following remining) on the overall ion load coming from the subbasin. This constitutes a phased TMDL, where a remedial measure (reclamation at the end of remining) would then need to be followed by in-stream monitoring to see how well the remedial measure did in improving the low pH condition for that subbasin. There are currently no active remining permits in the Drakes Creek watershed.

Distribution of Load

There were no point source discharges during the study period and there are currently no point source discharges in the watershed that would contribute to the existing low pH impairment. However, Table 8 splits the TMDL (which is based on meeting the minimum water quality standard value for pH of 6.0) evenly between the Waste Load Allocation and the Load Allocation for each subbasin as a means of defining a conservative approach toward any new permits and new remining permits in the watershed. As previously mentioned, the hydrogen ion load associated with a pH of 7.0 is insignificant, but is a discrete value. New permits having a minimum pH effluent limit of 7.0, and new remining permits with modified effluent limits for pH essentially represent no net change in conditions in the Subbasin with respect to pH.

Table 8. Wasteload and Load Allocation in the Drakes Creek Watershed

Subbasin	Incremental Critical Flow Rate (cfs)	TMDL for pH = 6.0 (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
2	0.56	0.0030	0.00150	0.00150
3	1.48	0.0080	0.00400	0.00400
4	2.68	0.0145	0.00725	0.00725

H. Conclusions

1. Implementation Controls

Remediation of pH-impaired streams as a result of current mining operations is the responsibility of the mine operator. The Kentucky Division of Mining Reclamation and Enforcement is responsible for enforcing the Surface Mining Control and Reclamation Act of 1977 (SMCRA). The Kentucky Division of Abandoned Mine Lands (DAML) is charged with performing reclamation to address the impacts from pre-law mine sites in accordance with priorities established in SMCRA. SMCRA sets environmental problems as third in priority in the list of AML problem types.

The Kentucky Division of Abandoned Lands proposed and conducted a two-part reclamation project in the Drakes Creek watershed from 1985 - 1986. The first part of the project addressed a landslide along the west side of Drakes Creek near its confluence with the Pond River. The second part dealt with a slurry pond and a breached dam that were damaging adjacent bottomland and contributing coal fines and pollutants to Drakes Creek. Specific reclamation activities included the reclamation of 40 acres of unstable material and associated bench areas, including two impoundments, a 14-acre slurry impoundment, restoration of 6,500 feet of clogged stream and 5.4 acres of cropland covered with fines. The total cost of the project was $750,572. More recently, during the Summer and Fall of 2003, additional reclamation was performed in subbasin 3 in an area where a vegetative cover could not be established. This reclamation project involved re-grading a hillside and re-routing a tributary of Drakes Creek to remove a gully wash, adding lime to the entire hillside, and re-seeding the area. Reclamation activities are also underway at other locations within the state where water quality is affected by acid mine drainage (AMD). Since 1985, the KDAML has spent approximately $17 million dollars on various reclamation projects in western Kentucky. These projects are summarized in Table 9.

For 2000, the total federal Kentucky AML budget allocation was approximately $17 million. However, the bulk of these funds were used to support priority 1 (extreme danger of adverse effects to public health, safety, welfare, and property) and priority 2 (adverse effects to public health, safety, and welfare) projects. Based on the cost of current remediation efforts, it would appear that a significant increase in federal funding to the AML program, as well as a rearrangement of priorities as established in SMCRA, would be required in order for the AML program to play a significant part in meeting the TMDL implementation requirement associated with pH impaired streams in the state of Kentucky.

Table 9. Kentucky Division of Abandoned Mine Lands Reclamation Projects

Watershed	Project Name	Cost
Brier Creek	Brier Creek	$522,041
	Buttermilk Road	$403,320
Crab Orchard Creek	Crab Orchard Mine	$1,038,203
	Zugg Borehole	$11,974
Pleasant Run	Pleasant Run	$2,162,085
	Pleasant Run II	$421,384
Pond Creek	Pond Creek I	$50,118
	Pond Creek II	$3,801,740
	Pond Creek III	$4,011,514
Flat Creek	East Diamond Mine	$535,000
	Flat Creek	$720,572
Rock Creek	Rock Creek I	$650,000
	Rock Creek II	$750,000
	McHenry Coop. Agreement	$130,165
Render Creek	McHenry II	$1,075,340
	Vulcan Mine	$585,359
Total		$16,868,815

2. Load Reduction Strategy

Recent studies in West Virginia (Clayton, et. al., 1998) and Kentucky (Carew, 1998) have demonstrated that limestone sand can be used as an effective agent for restoring the pH in acidified streams. For streams with a pH < 6, $CaCO_3$ may be used to neutralize free hydrogen ions based on the following relationship:

$$CaCO_3 + 2H^+ \rightarrow H_2CO_3 + Ca^{2+} \qquad (11)$$

Thus, the theoretical total mass of $CaCO_3$ required to neutralize 1 gm of H^+ ions can be obtained by dividing the molecular weight of $CaCO_3$ (100) by the molecular weight of 2 hydrogen atoms (2) to yield:

$$\text{Required mass of limestone} = 50 * \text{Mass of Hydrogen Ions} \qquad (12)$$

Or, in terms of a required annual load:

$$\text{Annual required mass of limestone} = 18{,}250 * \text{Mass of Hydrogen Ions (g/day)} \qquad (13)$$

In practice, however, this value will only represent a lower bound of the required mass as a result of two issues: 1) the fact that not all the limestone added to a stream will be readily available as soluble $CaCO_3$, and 2) the fact that an increasing fraction of the $CaCO_3$ mass will be required to neutralize other metal ions (e.g. Fe, Al, Mn) that will also most likely be present in the acid mine drainage, especially in the case of streams with pH < 4.5 (Snoeyink and Jenkins, 1980).

One way to deal with the first limitation is to simply add more limestone to the stream. Recent studies in both West Virginia and Kentucky have found that application rates of 2 to 4 times the theoretical limestone requirement have been found to be effective in restoring AMD streams. The most effective way to deal with the second limitation is to determine the additional amount of limestone that must be added to neutralize both the hydrogen ions and the additional ions that might be present. One way to approximate this quantity is by calculating the total acidity in the water column (as expressed directly as $CaCO_3$).

Total acidity is normally defined as a measure of the concentration of acids (both weak and strong) that react with a strong base. Acidity may be determined analytically by titrating a water sample with a standard solution of a strong base (e.g. NaOH) to an electrometrically observed end point pH of 8.3. (For waters associated with acid mine drainage it is important that any ferric salts present must first be oxidized prior to the determination of the total acidity). The required mass of NaOH required to raise the sample pH to 8.3 can then be expressed directly in terms of $CaCO_3$ as follows:

$$\text{Acidity, as mg } CaCO_3 = \frac{50{,}000*(\text{mL of NaOH})*(\text{Normality of NaOH})}{\text{Weight of sample used (mg)}} \quad (14)$$

In general, a relationship between pH (or the associated mass of free hydrogen ions), and the total acidity can be readily developed for a given stream using measured values of pH and acidity (Clayton, et. al, 1998). Using measured streamflow data, an additional relationship between the required hydrogen ion reduction (required to raise the pH up to 8.3) and the corresponding load of $CaCO_3$ (required to neutralize both the hydrogen ions and other free ions) can also be determined such as the one shown in Figure 10. In this particular case, Figure 10 was constructed from an analysis of data from five separate watersheds in the western Kentucky Coal Fields, and thus provides a regional curve for application to similar watersheds in the area. A similar curve could be developed for application to watersheds in other areas using regional data for that area. Alternatively, a site-specific curve could be developed for an individual watershed using measured values of flow, pH, specific conductance, and total acidity.

For the case of Drakes Creek, site-specific stream acidity data were not collected as part of the overall sampling effort. As a result, the required $CaCO_3$ loading was determined using the regional curve. It should be recognized that the loading values produced by application of Figure 10 should theoretically increase the pH to 8.3 (based on the definition of total acidity), although pragmatically the achieved value will likely be less. As a result, Figure 10 is likely to provide a conservative estimate of the initial required $CaCO_3$ loading for a particular stream. Subsequent applications of additional limestone can be further refined through follow-up monitoring.

Application of Figure 10 using the required hydrogen ion load reduction values shown in Table 7 yields the corresponding values of $CaCO_3$ loadings shown in Table 10. A corresponding approximation of the annual loading required can be obtained by simply multiplying the daily values by 365. Based on the work of Clayton, et. al., (1998), it is recommended that the values in Table 10 be multiplied by a factor of 2 in order to provide a conservative estimate of the initial loading. Loading values for subsequent years can be modified by an analysis of pH values obtained from subsequent field monitoring.

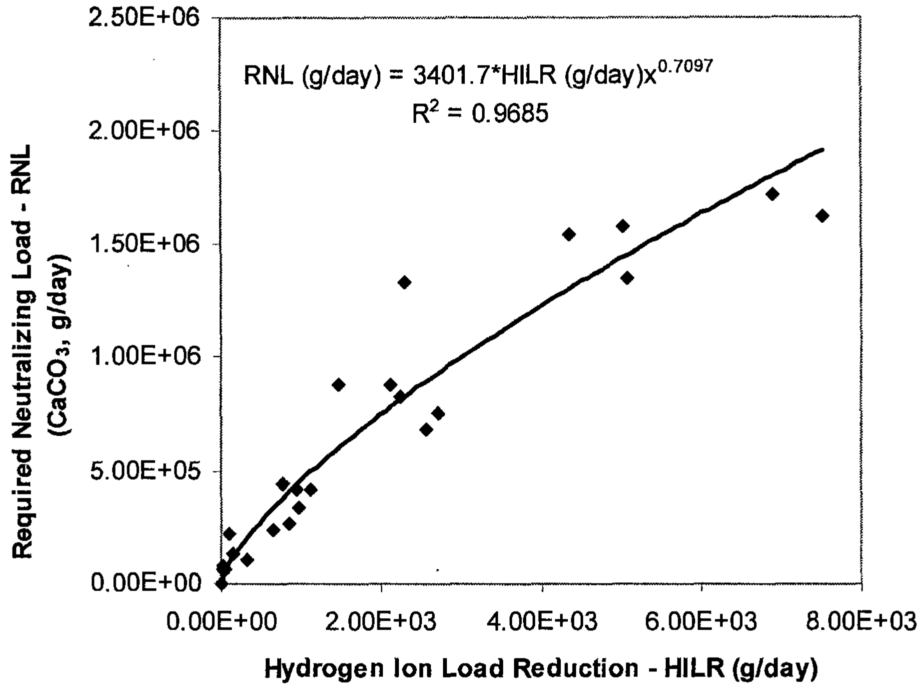

Figure 10: $CaCO_3$ loading vs. required hydrogen ion reduction

Table 10. $CaCO_3$ loadings for Drakes Creek

Subbasin	Required reduction (lbs/day)	Required reduction (g/day)	$CaCO_3$ loading (g/day)	$CaCO_3$ loading (lbs/day)	$CaCO_3$ loading (tons/yr)
2	4.957	2248	813,703	1,794	327
3	0.752	341	213,399	471	86
4	0.166	75	72,850	161	29

I. LITERATURE CITED

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J. APPENDICES

A. **Financial and Administrative Close-out**

B. **QA/QC for Water Monitoring**

C. **Mining Permits Numbering System**

D. **TMDL Facts Sheet**

E. **Index of TMDL Submittal Documentation**

APPENDIX A: FINAL ADMINISTRATIVE CLOSE-OUT

OUTPUTS (MILESTONES)

Milestone	Expected Begin Date	Expected End Date	Actual Begin Date	Actual End Date
1. Submit all draft materials to the Division of Water, Nonpoint Source Section for review and acceptance	Duration			
2. Submit Annual Reports and/or participate in Division of Water sponsored NPS Conference(s)	Duration			
3. Request most current Final and Close Out Report Guidelines	Jan-02	Jan-02		Apr-04
4. Submit three copies Final and Close Out Reports and submit three copies of all products produced by this project	Jun-02	Jun-02		Jun-04
5. Collect the necessary data	Feb-01	Jul-01	Sep-01	Oct-03
6. Develop discharge frequency models	Feb-01	Apr-01	Oct-01	Dec-01
7. Perform data analysis	Jun-01	Jul-01	Oct-03	Nov-03
8. Develop loading models	Aug-01	Sept-01	Nov-03	Dec-03
9. Compute TMDLs	Sept-01	Oct-01	Nov-03	Dec-03
10. Compute loading reductions/allocations	Oct-01	Nov-01	Nov-03	Dec-03
11. Prepare final TMDL documents	Nov-01	Dec-01	Nov-03	Dec-03
12. Submit TMDLs for DOW/EPA approval (Initial draft of TMDL was submitted to DOW on 1/14/2003, initial review comments were received on 8/8/2003, DOW initiated additional sampling during August – October of 2003, revised draft was then submitted to DOW on 12/30/2003. Final 319 Report was submitted on 6/30/2004)	Dec-01	Jan-02	Jan-03	
13. Submit TMDLs for public comment (TMDL has not yet been released for public comment pending review comments from EPA)	Feb-02	Mar-02		

ORIGINAL PROJECT BUDGET

Budget Summary:

Budget Categories	Project Activity Categories						
	BMP Imple-mentation	Project Manage-ment	Public Education	Monitoring	Technical Assistance	Other	Total
Personnel						$ 27,500.00	$ 27,500.00
Supplies							
Equipment						$ 2,325.00	$ 2,325.00
Travel							
Contractual				$9,583.00			$ 9,583.00
Operating Costs						$ 14, 963.00	$14,963.00
Other							
TOTAL				$ 9,583.00		$ 44,788.00	**$54,371.00**

Detailed Budget:

Budget Categories	Section 319(h)	Non-Federal Match	Total
Personnel	$16,500.00	$ 11,000.00	$27,500.00
Supplies			
Equipment	$ 2,325.00	$	$ 2,325.00
Travel			
Contractual	$ 5,750.00	$ 3,833.00	$ 9,583.00
Operating Costs	$ 7,425.00	$ 7,538.00	$14,963.00
Other			
TOTAL	**$32,000.00**	**$22,371.00**	**$54,371.00**
	59%	41%	100%

ACTUAL EXPENSES

Budget Summary:

Budget Categories	Project Activity Categories						
	BMP Imple-mentation	Project Manage-ment	Public Education	Monitoring	Technical Assistance	Other	Total
Personnel						$ 31,893.40	$ 31,893.40
Supplies						$71.68	$71.68
Equipment							
Travel							
Contractual				$7,385.12			$ 7,385.12
Operating Costs						$ 13,832.09	$13,832.09
Other							
TOTAL				$ 7,385.12		$ 45,797.17	**$53,182.89**

Detailed Budget:

Budget Categories	Section 319(h)	Non-Federal Match	Total
Personnel	$16,779.79	$ 15,113.61	$31,893.40
Supplies	$ 71.68		$71.68
Equipment	$	$	$
Travel			
Contractual	$ 7,385.12		$ 7,385.12
Operating Costs	$ 7,061.18	$ 6,770.90	$ 13,832.09
Other			
TOTAL	**$31,297.77**	**$21,884.51**	**$53,182.29**
	58.85%	41.15%	100%

No equipment was purchased by UK as part of this contract. There were no special grant conditions for this contract.

APPENDIX B:

QA/QC for: Development of pH (H^+ Ion Mass) TMDL a 303(d) Listed Stream in Western Kentucky: Drakes Creek in Hopkins County, Kentucky

By

Lindell Ormsbee, Kentucky Water Resources Research Institute

Andrew Kellie, Murray State University

January 28, 2000

For pH Impairment

PROJECT ORGANIZATION AND RESPONSIBILITY

Field Sampling Supervisor: Andrew Kelly, Murray State University, College of Industry and Technology, Department of Industrial and Engineering Technology, P.O. Box 9, Murray, Kentucky 42071-0009, (270) 762-3393

WATERSHED INFORMATION

1. Waterbody: Drakes Creek:
   Waterbody #KY21007882-01
   River Basin: Green
   USGS 8-digit HUC#:05110006
   Stream Order: 3
   County: Hopkins
   USGS Quads: St. Charles, Nortonville, Madisonville East, Crofton, Dawson Springs SE
   Milepoints: 0.0 to 8.5

MONITORING OBJECTIVES

To collect flow and pH readings from selected sites in Drakes Creek watershed.

STUDY AREA DESCRIPTION

Drakes Creek

Drakes Creek runs through the southeastern section of Hopkins County in southwestern Kentucky. This report will examine its status preceding a thorough investigation and monitoring of the Creek.

Location

The Drakes Creek watershed is contained mostly within Hopkins County, in southwestern Kentucky (Figure 1). Hopkins County is bounded by the Tradewater River in the west, the Pond River in the east, Webster County in the northwest, and Christian County in the south. This watershed contains the Pleasant Run Craborchard Creeks. Major highways that traverse the watershed are the Western Kentucky Parkway and U.S. Route 41. The Drakes Creek watershed houses few cities, Nortonville and Oak Hill being the most sizable. The 7.5 minute quadrangle maps on which Drakes Creek can be found are Crofton, Dawson Springs SE, Saint Charles, Nortonville, Madisonville East, and Graham.

Hydrologic Information

Drakes Creek, a fourth order stream, originates in south Hopkins County and flows north to discharge into the Pond River 57.5 km (35.7 miles) upstream of its confluence with the Green River. The Green River, along with the Tradewater, carries the runoff from the county northward to discharge into the Ohio River.

The mainstem of Drakes Creek is approximately 33.66 km (20.87 miles) long and drains an area of 41,298 acres (64.53 mi^2). The average gradient is 8 feet per mile. Elevations for Drakes Creek range from 201 m (660 ft) above mean sea level (msl) in the headwaters to 115 m (380 ft) above msl at the mouth. Like most of the smaller watersheds, many of the tributary streams are intermittent. Drakes Creek contributes to the Pond Watershed, HUC # 05110006.

Geologic Information

The Drakes Creek watershed is in the Western Coal field physiographic region. The surface bedrock is of Pennsylvanian age. Formations of the Pennsylvanian age are mostly sandstone, siltstone, coal, and interbedded limestone and shale; alluvial deposits of siltstone and crossbedded sand or sandstone underlie the extensive lowland areas (USDA, 1980). The relief of the Drake Creek watershed ranges from nearly level to steep. Gently sloping to steep soils are found in the uplands and nearly level soils are found on the floodplain.

Landuse Information

Coal, oil, and natural gas are among the natural resources of Hopkins County. Coal is the county's most important revenue-producing natural resource. The Drakes Creek watershed employs two main landuses: resource extraction (mining and disturbed land area) and agriculture.

Soils Information

Drakes Creek watershed is dominated by nearly level loamy and clayey soils near to the mouth and level to steep loamy soils in the headwaters. The area is comprised mostly of Zanesville soils, with acidic tendencies and moderate to low permeability.

MONITORING PROGRAM/TECHNICAL DESIGN

Sampling sites in the watershed were selected so as to provide a basis for the development of loading models for the associated tributary basins. Exact locations of planned sites are provided in Table 1.

Flow and pH monitoring on the watersheds specified requires some ten samples. These will be obtained at two to three week intervals throughout the duration of the project. Specific dates on for sampling will be set to ensure that a variety of flow conditions (high, low, and moderate) are included in the sampling campaign.

Three students from Murray State University will constitute the sampling team for the work proposed for western Kentucky. Two students will perform each sampling trip. The third student is available to substitute in the event of sickness of one of the other team members. All three students will be trained in field procedures by the Murray State faculty members participating in this project.

Monitoring of pH will be done using Cole-Parmer model 590000-05 portable pH meters. The meters will be calibrated against a Cole-Parmer certified pH standard (model 55360-00, pH 4.01) at the beginning of each set of samples. Field personnel will average three measurements of pH at each sample location on each date using the above meters.

Stream flow field data will include both cross sectional area and velocity measurements at each sampling station. Current velocity will be measured using a Global model FP101 current meter. This meter will be calibrated against known flow velocities obtained using an Armfield model F1-10 hydraulics bench equipped with Armfield model F1-13 rectangular and v-notch weirs. Calibration of the current meter will be done prior to commencement, at mid-point, and at the termination of the sampling campaign.

Cross sectional areas will be surveyed during the first sampling run and plotted to scale using AutoCAD. Thereafter, cross sectional areas for discharge computations will be determined by measuring channel depth using a leveling rod held vertically during each sampling run. Volumetric flow rate (discharge) will be computed from the measured velocity and cross sectional area for each sample location.

Table 1. Proposed Sampling Locations for Drakes Creek

(1) Drakes Creek above Pleasant Run (at river mile 8.55 at US Hwy 62),
(2) Pleasant Run near the mouth (at river mile 0.3 at US Hwy 62),
(3) Drakes Creek below Pleasant Run (at river mile 7.05 at State Hwy 813),
(4) UT (at river mile 0.6) to Drakes Creek (at river mile 5.45 to Drakes Creek),
(5) UT (at location as close to mouth as possible) at Drakes Creek (at river mile 4.70 to Drakes Creek) but may need to sample multiple sites due to access constraints,
(6) UT (at river mile 0.9) to Drakes Creek (at river mile 3.35 to Drakes Creek),
(7) UT (at river mile 0.4) to Drakes Creek (at river mile 2.15 to Drakes Creek), and
(8) Drakes Creek at river mile 1.9 at jeep trail.

CHAIN OF CUSTODY PROCEDURES

All collected data will be recorded in the field on a field data log and then transferred into an Excel Spreadsheet for subsequent storage and dissemination. The field data log will contain fields for the following information:

1. Monitoring Location
   a. County
   b. Monitoring location type
   c. Stream name
   d. Lat/Long (including method to acquire lat/long)
   e. Physical description of site

2. Unique Sample Identifier
   a. Person collecting the sample
   b. Date and time of sample
   c. Weather conditions

1. Sample Analysis Units
   a. Depth
   b. Velocity
   c. pH

4. Additional comments

QUALITY CONTROL PROCEDURES

The quality control/quality assurance plan proposed for this project includes (a) personnel training, (b) equipment calibration, (c) sampling oversight, and (d) data verification components. These are detailed below.

Training

Students participating in the program will be trained by Murray State faculty in all tasks to be performed during sampling prior to commencing the sampling. A faculty member will accompany the team on the first sampling round in order to verify correct field procedures. Instruction will include specifics of all techniques needed to measure (a) current velocity, (b) channel depth, and (c) pH. Students will participate in the initial survey of the cross sectional area of each sample site. Safety requirements for sampling will be discussed and demonstrated.

To ensure consistency in sampling, each sample site will be plotted on a U.S. Geological Survey 7 ½ minute topographic quad. These will be furnished to the student team. In addition, each sample station will be photographed during the initial sample session. Photos will be mounted in vinyl and furnished to the field crews. Finally, the field crews will be supplied with the survey field notes describing each site as obtained during the initial sample session.

Equipment Calibration

Equipment calibration will be conducted as described above to ensure that field data is valid. A spare pH meter as well as sample bottles will be carried on each sampling session.

Sampling Oversight

General sampling oversight will be provided by the Murray State faculty members participating in this project. This oversight will include (a) issuing prior approval (or selecting) dates for each sampling session, (b) verifying proper operation of field equipment prior to each session, and (c) reviewing data following session completion and enter data into spreadsheet.

DATA MANAGEMENT AND DATA REPORTING STANDARDS

All collected data will be recorded in the field on a field data log and then transferred into an Excel Spreadsheet for subsequent storage and dissemination. The Excel spreadsheet will be designed on the same format as the chain of custody form. For each sampling event, a separate row will be prepared which will include the following information:

1. Monitoring Location
   a. County
   b. Monitoring location type
   c. Stream name
   d. Lat/Long (including method to acquire lat/long)
   e. Physical description of site

2. Unique Sample Identifier
   a. Person collecting the sample
   b. Date and time of sample
   c. Weather conditions

2. Sample Analysis Units
   a. Depth
   b. Velocity
   c. pH

4. Additional comments

APPENDIX C: MINING PERMITS NUMBERING SYSTEM

XXXX-XX Permit issued prior to May 3, 1978. Ex. 1357-76. The first four numbers represent the mine number. The last two numbers represent the year of issuance.

XXX-XXXX Permit issues after May 3, 1978. The first three numbers indicate the location of the mine by county and the timing of the original permit issuance. (Ex. Hopkins County = 54).

If the first three numbers correspond to the county number, the permit was originally issued during the interim program.

If 200 has been added to the county number, the permit was originally issued prior to May 3, 1978, and carried through into the interim program. Ex. 254 (Hopkins)

If 400 has been added to the county number the permit was issued prior to the Permanent Program and was to remain active after January 18, 1983. Ex. 454 or 654 (Hopkins)

If 800 has been added to the county number: (1) the application is for a permit after January 18, 1983 or (2) two or more previously permitted areas have been combined into a single permit. Ex. 854 (Hopkins)

The last four numbers indicate the type of mining activity being permitted.

COAL

0000-4999	Surface Mining
5000-5999	Underground Mine
6000-6999	Crush/Load Facility
7000-7999	Haul Road Only
8000-8999	Preparation Plant
9000-9399	Refuse Disposal

NON COAL

9400-9499	Limestone
9500-9599	Clay
9600-9699	Sand/Gravel
9700-9799	Oil Shale
9800-9899	Flourspar

APPENDIX D: TMDL Fact Sheet

Drakes Creek, Kentucky

Project Name:	Drakes Creek
Location:	Hopkins County, Kentucky
Scope/Size:	Drakes Creek, watershed 41,298 acres (64.43 mi^2)
Land Type:	Forest, agricultural, barren/spoil
Type of Activity:	Acid Mine Drainage (AMD) caused by Strip/Abandoned Mines
Pollutant(s):	H^+ Ion mass, Sulfuric Acid
TMDL Issues:	Non-point sources
Water Quality Standard/Target:	pH shall not be less than six (6.0) or more than nine (9.0) and shall not fluctuate more than one and zero-tenths (1.0) pH unit over a 24-hour period. This standard is found within regulation 401 KAR 5:031.
Data Sources:	KPDES Permit Historical Sampling Data, Murray State University Sampling Data, Kentucky Division of Water
Control Measures:	Kentucky non-point source TMDL implementation plan, Kentucky Watershed Framework

Summary:

Drakes Creek was determined as not supporting the designated uses of primary and secondary contact recreation (swimming and wading) and warm water aquatic habitat (aquatic life). Therefore, the creek was placed on the 1998 and 2002 303(d) lists for Total Maximum Daily Load (TMDL) development. The creek segment is characterized by a depressed pH, the result of acid mine drainage from strip and abandoned mining sites. In developing the TMDL for Drakes Creek, pH readings were collected at thirteen different locations within the watershed. Recent sampling supports the conclusion that Subbasins 2, 3, 4, and 8 do not support acceptable pH levels. Data at sites 11 and 7 also reveal occasional impairment, however it is readily apparent that the impairment at site 11 is due to impairments in basins 2-4,

while the impairment at site 7 is due to impairment from Subbasin 8. Subbasin 8 is in fact the Pleasant Run watershed, and has already been addressed through a separate TMDL. As a result, individual TMDLs are developed for Subbasins 2, 3 and 4.

TMDL Development:

Total maximum daily loads in grams H^+ ions per day were computed based on the allowable minimum pH value (6.0) for creeks and streams to meet the primary and secondary contact recreation (swimming and wading) use and the aquatic life use. The TMDL was done for grams of ions (subsequently converted to pounds/day) because the units for pH do not allow for the computation of a quantitatively useful load or reduction amount.

In recognition of the inherent difficulties associated with imposition of a "no-exceedance" pH criteria on potentially intermittent streams, the Kentucky Division of Water has decided to use the lowest one year average discharge of the most recent 10-year flow record as the flow basis for setting the appropriate TMDL and associated loading reduction. Use of an average annual flow as the basis for determining the TMDL also provides a convenient mechanism for determining the total annual load, the total annual reduction that would be derived from an annual summation of both the daily TMDLs, and the associated daily load reductions for the critical year using the actual historical daily flows.

TMDL for Drakes Cr:

In developing a TMDL for Drakes Creek, there are two possible strategies. Either a cumulative aggregate TMDL may be obtained for the outlet of the watershed, or separate TMDLs (and associated load reductions) may be developed for each individual Subbasin. As a result of the availability of sampling data at multiple sampling points, individual TMDLs were developed for Subbasins 2-4. It is hypothesized that the remediation of Subbasins 2, 3, and 4 (as well as Subbasin 8 through the Pleasant Run TMDL) will lead to the restoration of the complete watershed. The TMDL and associated load reductions for Subbasins 2, 3, and 4 are shown below.

Subbasin	Incremental Upstream contributing area (mi^2)	Incremental Critical Flow (cfs)	Incremental TMDL for a pH of 6.0 (lbs/day)	Predicted Incremental load (lbs/day)	Load reduction needed (lbs/day)
2	0.90	0.56	0.0030	4.960	4.957
3	2.38	1.48	0.0080	0.760	0.752
4	4.31	2.68	0.0145	0.180	0.166

Permitting Other Than in Subbasins 2-4:

Permitting for locations in the Drakes Creek Watershed other than in Subbasins 2-4 (excluding the Pleasant Run Watershed) would require no special considerations related to 303(d). As shown by the values listed for the remaining sites (excluding sites 11 and 7), at least 90% of the pH values were equal to or greater than 6.0. Sites 11 and 7 are directly impacted from drainage from Subbasins 2-4 and 8, which will be addressed through this and the Pleasant Run TMDL reports. Remediation of the abandoned mine areas in Subbasins 2-4 should thus result in improved water quality at Sites 2-4 and lead to the improvement of the water quality at Site 11. Further improvement at Site 8 (as well as site 7) is expected to be accomplished by implementation of the TMDL associated with the Pleasant Run Watershed (Subbasin 8).

New Permits:

New permits (except for new remining permits) for discharges to streams in the Drakes Creek Watershed could be allowed anywhere in the watershed, contingent upon the end-of-pipe pH being permitted at a range of 7.0 to 9.0 standard units. Water quality standards state that for meeting the designated uses of aquatic life and swimming, the pH value should not be less the 6.0, nor greater than 9.0. This range of 6.0 to 9.0 for pH is generally the value assigned for end-of-pipe effluent limits. However, because stream impairment exists (low pH), new discharges cannot cause or contribute to an existing impairment. A pH of 7.0 represents a neutral state between an acidic and a non-acidic condition. As such, a discharge having a pH of 7.0 to 9.0 standard units will not cause or contribute to the existing impairment. The discharge will not cause impairment because the effluent discharge has a pH greater than 6.0 standard units. The discharge will not contribute to the existing impairment because a pH of 7.0 represents a neutral condition with respect to acidity and effectively represents a background condition. Based on limited pH data from streams in undisturbed watersheds in the area, a pH of 7.0 is generally representative of the value of background pH. The hydrogen ion load associated with a pH of 7.0 is insignificant (effectively zero) and therefore does not represent a contribution to the existing impairment. As such, new permits having an effluent limit pH of 7.0 would not be assigned a hydrogen ion load as part of a Waste Load Allocation. There are no active permits in the Drakes Creek Watershed that would contribute to the pH impairment.

Remining Permits:

New remining permits may be approved on a case-by-case basis where streams are impaired because of low pH from abandoned mines. Permit approval is contingent on reclamation of the site after remining activities are completed. During remining, existing water quality conditions must be maintained or improved. Reclamation of the site is the ultimate goal, but water quality standards (pH of 6.0 to 9.0 standard units) may not necessarily be met in the interim. Remining therefore constitutes a means whereby a previously disturbed and unreclaimed area can be reclaimed. The authority for remining is defined in Section 301(p) of the Federal Clean Water Act; Chapter 33, Section 1331(p) of the U.S. Code – Annotated (the Rahall Amendment to the Federal Clean Water Act); and the Kentucky Administrative Regulations (401 KAR 5:040 and 5:029).

The eventual reclamation of the remining site should result in a reduction of the overall ion load (specifically the nonpoint source load) of the subbasin where the remining was done. The reclamation should also result in an improved stream condition (increased pH) because a previously disturbed (and unreclaimed area) area will be reclaimed. Follow-up, in-stream monitoring would need to be done at the subbasin outfall to determine the effect of reclamation activities (following remining) on the overall ion load coming from the subbasin. This constitutes a phased TMDL, where a remedial measure (reclamation at the end of remining) would then need to be followed by in-stream monitoring to see how well the remedial measure did in improving the low pH condition for that subbasin. There are currently no active remining permits in the Drakes Creek watershed.

Distribution of Load:

There were no point source discharges during the study period and there are currently no point source discharges in the watershed that would contribute to the existing low pH impairment. The table given below splits the TMDL (which is based on meeting the minimum water quality standard value for pH of 6.0) evenly between the Waste Load Allocation and the Load Allocation for each impaired subbasin as a means of defining a conservative approach toward any new permits and new remining permits in the watershed. As previously mentioned, the hydrogen ion load associated with a pH of 7.0 is insignificant, but is a discrete value. New permits having a minimum pH effluent limit of 7.0, and new remining permits with modified effluent limits for pH essentially represent no net change in conditions in the subbasin with respect to pH.

Wasteload and Load Allocation in the Drakes Creek Watershed

Subbasin	Incremental Critical Flow Rate (cfs)	TMDL for pH = 6.0 (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
2	0.56	0.0030	0.00150	0.00150
3	1.48	0.0080	0.00400	0.00400
4	2.68	0.0145	0.00725	0.00725

Implementation Controls: Remediation of pH-impaired streams as a result of current mining operations is the responsibility of the mine operator. The Kentucky Division of Surface Mining Reclamation and Enforcement is responsible for enforcing the Surface Mining Control and Reclamation Act of 1977 (SMCRA). The Kentucky Division of Abandoned Mine Lands (DAML) is charged with performing reclamation to address the impacts from pre-law mine sites in accordance with priorities established in SMCRA. SMCRA sets environmental problems as third in priority in the list of AML problem types.

The Kentucky Division of Abandoned Lands proposed and conducted a two-part reclamation project in the Drakes Creek watershed from 1985-1986. The first part of the project addressed a landslide along the west side of Drakes Creek near its confluence with the Pond River. The second part dealt with a slurry pond and a breached dam that were damaging adjacent bottomland and contributing coal fines and pollutants to Drakes Creek. Specific reclamation activities included the reclamation of 40 acres of unstable material and associated bench areas, including two impoundments, a 14-acre slurry impoundment, restoration of 6,500 feet of clogged stream and 5.4 acres of cropland covered with fines. The total cost of the project was $750,572.

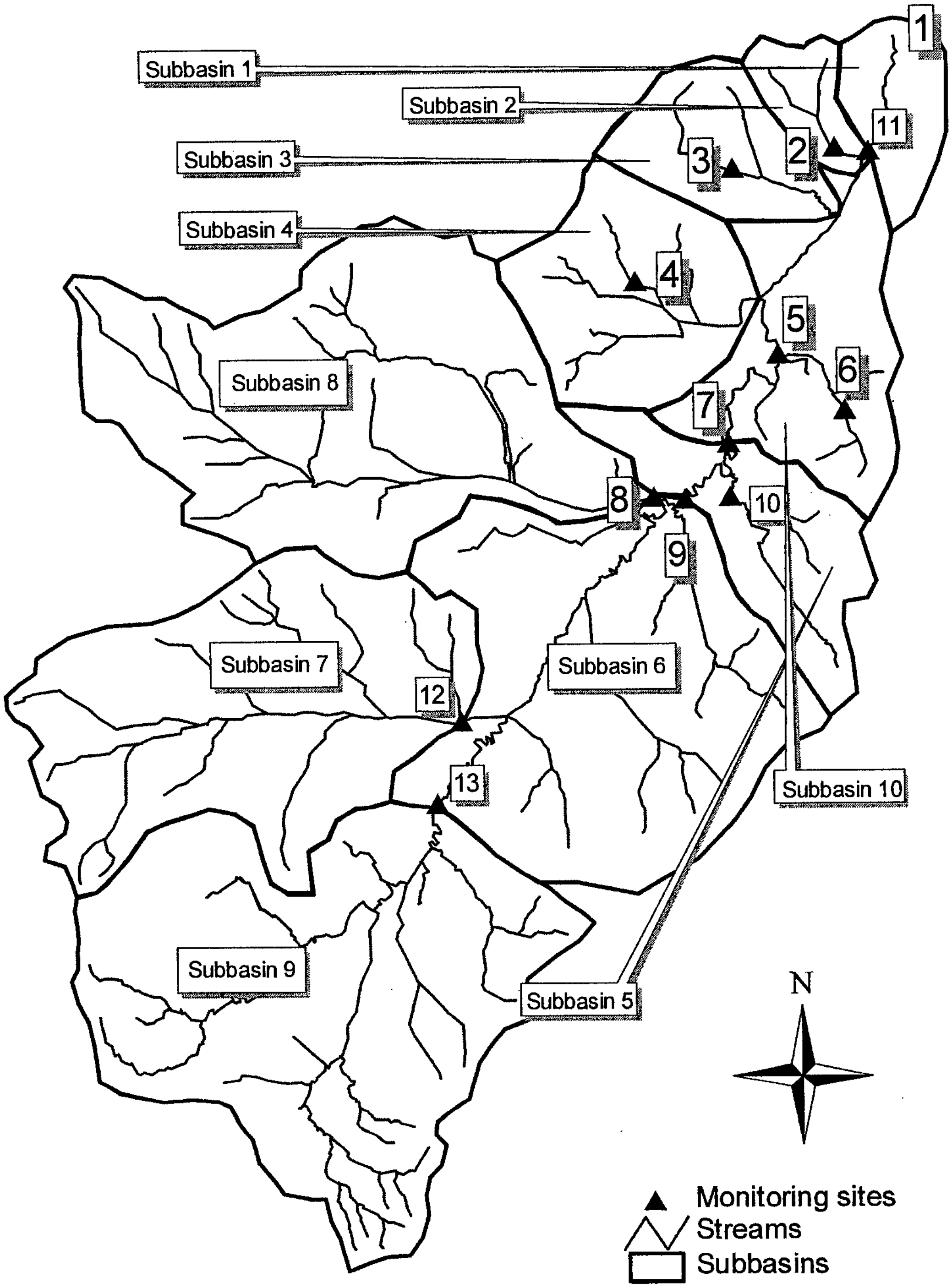
More recently, during the Summer and Fall of 2003, additional reclamation was performed along the west side of Drakes Creek near its confluence with the Pond River in an area where a vegetative cover could not be established. This reclamation project involved re-grading a hillside and re-routing a tributary of Drakes Creek to remove a gully wash, adding lime to the entire hillside, and re-seeding the area.

Reclamation activities are also underway at other locations within the state where water quality is affected by acid mine drainage (AMD). Since 1985, the KDAML has spent approximately $17 million dollars on various reclamation projects in western Kentucky. These projects are summarized below.

For 2000, the total federal Kentucky AML budget allocation was approximately $17 million. However, the bulk of these funds were used to support priority 1 (extreme danger of adverse effects to public health, safety, welfare, and property) and priority 2 (adverse effects to public health, safety, and welfare) projects. Based on the cost of current remediation efforts, it would appear that a significant increase in federal funding to the AML program, as well as a rearrangement of priorities as established in SMCRA, would be required in order for the AML program to play a significant part in meeting the TMDL implementation requirement associated with pH impaired streams in the state of Kentucky.

Kentucky Division of Abandoned Mine Lands Reclamation Projects

Watershed	Project Name	Cost
Brier Creek	Brier Creek	$522,041
	Buttermilk Road	$403,320
Crab Orchard Creek	Crab Orchard Mine	$1,038,203
	Zugg Borehole	$11,974
Pleasant Run	Pleasant Run	$2,162,085
	Pleasant Run II	$421,384
Pond Creek	Pond Creek I	$50,118
	Pond Creek II	$3,801,740
	Pond Creek III	$4,011,514
Flat Creek	East Diamond Mine	$535,000
	Flat Creek	$720,572
Rock Creek	Rock Creek I	$650,000
	Rock Creek II	$750,000
	McHenry Coop. Agreement	$130,165
Render Creek	McHenry II	$1,075,340
	Vulcan Mine	$585,359
Total		**$16,868,815**



Monitoring Sites and Subbasin Delineation in Drakes Creek Watershed

APPENDIX E: INDEX OF TMDL SUBMITTAL DOCUMENTATION

303(d) LIST INFORMATION

State	Kentucky
Name of 303(d) listed waterbody	Drakes Creek (Hopkins County)
Segment as identified from 303(d) list	River Mile 0.0 to 8.5
City/County	Hopkins County
Watershed(s)/11-digit cataloging unit code	05110006040
Length (mi) or area (acres) of impairment	8.5 miles
Water quality standards being violated	pH<6.0
Water use classification	Primary contact recreation (swimming) and warm water aquatic habitat (aquatic life)
Pollutant of concern	pH from acid mine drainage
Location description of waterbody	Located in Western Kentucky
Sources of impairment	Acid mine drainage (AMD) caused by strip/abandoned mines

PUBLIC NOTIFICATION INFORMATION

Form of public notification	press release and draft on the web	
Beginning/ending dates of public notice*	____ / ____	
Notice mentioned TMDL proposal	____yes	____no
Comments received from public	____yes	____no
Responsiveness summary prepared	____yes	____no

*Will provide public notification after having received the informal review comments back from EPA Region IV and having incorporated those changes in the report.

INDEX OF TMDL SUBMITTAL DOCUMENTATION (cont.)

TMDL INFORMATION

Critical Conditions ___high flow ___low flow

X other: max load at high, min pH at low

Seasonality X Annual_Summer/Winter_Monthly

TMDL development tool(s) ___Water quality model(s)

X Mass balance equations

X Other: Intensive synoptic survey

Supporting Models/Documents: Technical Support Document for Water Quality-based Toxics Control, Compendium of Tools for Watershed Assessment and TMDL Development

TOTAL MAXIMUM DAILY LOADS

Subbasin	Incremental Upstream contributing area (mi^2)	Incremental Critical Flow (cfs)	Incremental TMDL for a pH of 6.0 (lbs/day)	Predicted Incremental load (lbs/day)	Load reduction needed (lbs/day)
2	0.90	0.56	0.0030	4.960	4.957
3	2.38	1.48	0.0080	0.760	0.752
4	4.31	2.68	0.0145	0.180	0.166

Loadings
Wasteload Allocation (WLA)
(Point Sources)

New permits in Subbasins 2, 3, and 4 of the Drakes Creek Watershed need to meet an end-of-pipe pH of 7.0 to 9.0. The Hydrogen ion load associated with a pH of 7.0 is insignificant, but is a discrete value. As a means of defining a conservative approach toward any new permits and remining permits, the allowable WLA is 50% of the TMDL for a pH of 6.0. The table below shows the allowable wasteload for Subbasins 2, 3, and 4.

Load Allocation (LA)
(Nonpoint Sources)

For the Drakes Creek Watershed, the allowable LA is 50% of the TMDL for a pH of 6.0. The table below shows the allowable load for Subbasins 2, 3, and 4.

Other

Remining Permits may be approved on a case-by-case basis

NOTE: The TMDL has been split evenly between the Waste Load Allocation and the Load Allocation for Subbasins 2, 3, and 4 in the Drakes Creek Watershed as a means of defining a conservative approach toward any new permits and new remining permits in each subbasin. As previously mentioned, the Hydrogen ion load associated with a pH of 7.0 is insignificant, but is a finite value. New permits having a minimum pH of 7.0, and new remining permits essentially represent no net change in conditions in the subbasin with respect to pH.

Wasteload and Load Allocation for Subbasins 2-4 in the Drakes Creek Watershed

Subbasin	Incremental Critical Flow Rate (cfs)	TMDL for pH = 6.0 (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
2	0.56	0.0030	0.00150	0.00150
3	1.48	0.0080	0.00400	0.00400
4	2.68	0.0145	0.00725	0.00725

Margin of Safety

__Explicit None

*_Implicit TMDL determined using an ion activity (γ=0.87) (conservative assumptions used)