Huling Branch Mine Complex: Investigation of Acid Mine Drainage and Recommendations for Remediation

Prepared for Trout Unlimited

and the

Kettle Creek Watershed Association

by

Hedin Environmental

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Executive Summary

The goals of the project were to identify, collect, and quantify acid mine drainage (AMD) at the Huling Branch abandoned tipple site and to propose remedial alternatives. Huling Branch is a major tributary to Twomile Run, a tributary to lower Kettle Creek. The watershed is located in Sproul State Forest. Previous studies had established that Huling Branch was a primary contributor of pollution to Twomile Run. This project site is situated to the east of Huling Branch and is the source of the uppermost AMD pollution to Huling Branch. The site investigation focused on drainage produced from a complex of abandoned surface and deep mines located to the north of and abandoned tipple site (See Figures 1 and 2). This project was funded by the Pennsylvania Department of Environmental Protection's Growing Greener Program and by Trout Unlimited.

Three AMD collection systems were installed in the southeastern portion of the mine complex. Between January and August 2003, the systems collected an average 167 gpm of flow. This was 50% higher than the average flow previously measured for the site at BAMR Weir 4. The higher flows were partially attributable to the collection of two flows that previously bypassed the weir. Contaminant loadings produced by the collection systems were 2-3 times higher than loadings measured previously at the weir. As a result of the updated measurement of contaminant production by the mining complex, the estimate of treatment costs was increased considerably over previous values. A sodium hydroxide system is estimated to cost $400,000 to construct and about $300,000 per year to operate. The annual costs of a lime system might be lower, but they would still be a serious burden for the non-profit and volunteer groups in the watershed.

In addition to the "do-nothing" alternative (Alternative I) and using chemical treatment to treat the current discharges, (Alternative II), three reclamation alternatives were developed. Alternative III involves regrading and revegetation of unreclaimed mine spoils so that infiltration to the deep mine complex is decreased. The benefit of Alternative III would be a lower flow rate of AMD. The cost to reclaim 120 acres of spoil is estimated at $1.4 million.

Alternative IV involves reclamation with massive alkaline addition. The alkaline addition quantities, about 300,000 tons $CaCO_3$, were calculated from the acid producing potential of the shale/clay unit that is known to be responsible for the AMD. The alkaline addition would neutralize AMD, causing a further decrease in contaminant loading. However, the addition would likely not eliminate the AMD because of the presence of deep mines that would not be affected. The cost of the alkaline amendment alternative ranged from $10 – 13 million dollars.

Alternative V involves the mining of coal that remains in the complex. An estimated 225,000 tons of low-cover crop coal exists along with about 65,000 tons of coal remaining in the underground mines. The income produced from mining operations could lessen the project cost to $6 – 10 million. The higher cost involves the removal of the deep mines, which, in conjunction with massive alkaline addition, should permanently eliminate the AMD problem in the Huling Branch watershed.

The ideal alternative would be to remove both the deep mine and crop coal and provide massive alkaline addition using a no-cost alkaline material such as fly ash. This alternative would likely reduce the mine drainage loadings by 80 – 100% over current conditions and cost $8.6 million dollars.

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I. Introduction and Background

A. Site Description

Huling Branch is a tributary of Twomile Run in the Kettle Creek watershed. Huling Branch has a drainage area of 3.8 square miles and flows approximately 4 miles to Twomile Run (Figure 1). The entire Huling Branch watershed is located in Sproul State Forest. The Bureau of Forestry manages a popular public ATV trail system in the watershed. Huling Branch is severely impacted by mine drainage sources that begin approximately 2.5 miles upstream of the mouth. This pollution is a result of historic surface and deep mining activities in the watershed. Large areas of unreclaimed spoil are present on both sides of Huling Branch. At least two abandoned deep mines remain in the watershed. An abandoned mine tipple is present. This project focused on the area where most of the pollution is originating. Figure 2 is a map that shows the study area, a portion of Huling Branch, the mine spoils, the ATV trails, and the tipple.

B. Coal Geology and Historical Surface Mining Practices

Upper Kittanning and Lower Kittanning coal seams are present in the Huling Branch watershed. The Upper Kittanning coal is located on the highest elevations and is all that remains from the erosional processes that have shaped the region. No deep mining of Upper Kittanning coal occurred on the east side of Huling Branch. The Lower Kittanning coals are lower in elevation and occur more ubiquitously in the watershed. The Lower Kittanning was extensively deep mined in the Lower Kettle Creek watershed in the early 1900s. A very large deep mine complex were developed in the Bitumen area on the west side of lower Kettle Creek. In the Twomile watershed, deep mining occurred in the middle reaches of the Huling Branch, Middle Branch, and Robbins Hollow sub-watersheds. The Lower Kittanning coal bed is not continuous in the Twomile watershed so separate underground mines were developed. The Huling Branch watershed contains several abandoned underground mines. The underground mines shut down in the early to mid 1900’s and most of the mining records were destroyed in a fire. Essentially all of the detail that is available for the Huling Branch underground mine(s) is one map showing the general extent of the workings.

Several reasonable inferences can be made about the mining practices based on the coal structure and mining methods. The Lower Kittanning coal bed dips at approximately 5% to the southwest. The coal bed is above the regional ground water table, so flooded mine conditions were avoided through mining practices and the installation of proper drainage. It is likely that the mines were developed in an up-dip manner so that the water drained freely through the mine openings to the southwest. This mining method limited flooding of the mines, even after their closure. The humid aerated conditions created were, and continue to be, favorable for pyrite oxidation.

Surface mining occurred in the Huling Branch watershed in the 1950s and 1960s. The hilltop Upper Kittanning reserves were removed to approximately 60 feet of cover by D.G. Wertz, Richmont Coal Company and Kettle Creek Corporation. It is unknown whether Upper Kittanning reserves existed in the mine complex considered in this study. A large hilltop surface mine exists on the western side of Huling Branch that apparently removed all of the Upper

Kittanning reserves. No AMD has been identified from this mine site. Surface mining also occurred on the Lower Kittanning coal seam, but the mining was limited to areas near the crop with low overburden depths. The abandoned highwalls suggest mining was limited to areas with 60 foot cover depths or less. The surface mining intercepted deep mine workings, creating a direct hydrological connection between the deep mines and surface mines in many locations. Several abandoned deep mine entries are visible in highwalls.

Several local residents who worked for the surface mine companies were interviewed about the mining practices. The following explanation is based on those conversations and reviews of the existing conditions and coal geology.

When surface mining was occurring, two Commonwealth regulations were in place that were intended to lessen the production of acid mine drainage through inundation. First, the removal of crop coal, especially from a down-dip location, was prohibited. The reasoning was that the in-place crop would act as a hydrologic plug and cause the bottom of the mine to flood. Second, miners were required to separate the carboniferous pyritic black shale that was situated on top of the Lower Kittanning coal seam from the rest of the overburden during mining and then place it on the pit floor after the coal was removed. It was thought that the flooded conditions, caused by the presence of the coal crop barrier, would limit the oxidation of the pyritic shale and thus prevent acid production.

The regulations resulted in the surface mines beginning about 120 feet behind the crop of the coal. The mining continued up-dip until the cover became too deep or water problems were too severe (the coal prevented easy drainage of the mine on the down-dip side). In the Huling Branch watershed, it appears that mining on the down-dip side of the hills (and deep mines) was limited to one or two cuts. Mining also occurred in the up-dip side of the deep mines where the rising coal approached the land surface. More surface mining appears to have occurred in these areas, probably because of good cover ratios and because of fewer problems with water. Water in the up-dip mining pits would have readily drained into the underground mine workings, away from the surface mining activities.

Figure 3 shows a conceptual model of the hydrogeological setting that is believed to exist in the Huling Branch watershed. At a 5% slope (5 feet of rise for every 100 feet horizontally), the 4 to 5 feet thick Lower Kittanning coal seam only floods 80-100 feet of the up-dip mine or coal seam. As the combined underground and surface mining disturbance extends several hundred feet above the crop of the coal, the crop barriers have created limited inundation. The down-dip structure of the coal drains water from the pits and spoils to the northeast through the abandoned underground mine and to the pits and spoils to the southwest. Water following this path intercepts black shale placed on the bottom of the strip pits and high-sulfur coal and clay within the underground mine.

The water likely pools along the down-dip coal crop (as intended), and slowly infiltrates downslope through the coal and overlying rocks and soils. Thus, the water flows subsurface for 100-120 feet until the coal crops and the water then discharges as numerous small seeps over a wide area. Because of the highly acidic chemistry, the seeps are quite toxic and much of the surface vegetation dies. Large kill zones occur for this reason in the Huling Branch watershed and throughout the Twomile Run watershed.

C. Previous Work

In 1982 a drilling program was conducted by Pennsylvania Department of Environmental Protection Bureau of Abandoned Minelands Reclamation (BAMR) in order to quantify the amount of coal remaining in the Twomile watershed. Most of the drill holes penetrated the Lower Kittanning coal seam and at least two other coal seams found below the Lower Kittanning. These seams are most likely associated with the Clarion/Brookville coals and were determined to be of little or no economic value. There were no alkaline strata or limestone beds encountered in the drilling program. The DEP concluded that reclamation through remining was not a viable option because the acid overburden conditions would require incorporation of huge amounts of alkaline rock that were not locally available.

Overburden data for a hole drilled in the Huling Branch watershed was obtained and reviewed. The hole was drilled through 70 feet of solid overburden into the Lower Kittanning deep mine where a 5 foot void was encountered. The overburden was sampled as the drilling progressed and the samples were identified (sandstone, shale, clay, etc.) and subjected to acid/base chemical analyses. A copy of the summary table produced from the drill log is presented as Table 1. The entire overburden had a neutralization deficit of 14 tons $CaCO_3$ per 1,000 tons of overburden. The deficit resulted from the presence of highly acidic clay and shale layer directly above the coal (and the roof of the underground mine). The top 62 feet of the overburden were essentially non-reactive sandstone. The drilling encountered 44 feet of sandstone with a weak net alkaline chemistry (about 5 tons per 1,000 tons (NP)). The next 18 feet were weak net acid sandstone with a net NP (acidic potential minus neutralization potential) of about -5 tons/1,000 tons. The final eight feet were highly acidic clay and shale. This zone had an average sulfur content of 3.6%, an acid production potential of 114 tons/1,000 tons, an NP of 6 ton/1,000 tons, and an NNP of -108 ton/1,000 tons. (The minus number indicates that acid potential exceeds neutralization potential.) This is the black shale that was reportedly placed on the pit floors during mining.

A geophysical conductivity survey was performed by BAMR and Trout Unlimited during summer/fall of 2001. The purpose of the survey was to identify shallow subsurface flowpaths of contaminated water. The survey concentrated on the areas north of the tipple site between Boyer Road and the road to Middle Branch ATV parking area. Results of the survey were applied to a base map of the Huling Branch tipple area. The survey indicated that shallow groundwater with high conductivity was present on two southwestern facing slopes containing the down-dip edge of the Lower Kittanning coal seams above the tipple area. Extremely high conductivity was measured near the unnamed tributary above the tipple zone. All areas with high conductivity readings had large kill zones associated with them.

Table 1. Geochemistry of Core in the Huling Branch Watershed.

OVERBURDEN ANALYSIS SPREAD SHEET CALCULATION SUMMARY

OPERATOR
PERMIT NO.
DRILL HOLE B6-22

COUNTY LONG
TOWNSHIP

TOTAL DEPTH	TOP ACREAGE	BOTTOM ACREAGE
75	1	1

THRESHOLD VALUES

SULFUR	NP	FIZZ
1	30	1

MPA, NP -TH = With Thresholds

	TONS MPA -TH	TONS MPA	TONS NP -TH	TONS NP	NET NP TONS -TH	NET NP TONS	TONS OB
TOTAL (TONS):	3849	4827	0	1219	-3849	-3608	2810
TOTAL (TONS/THOUSAND):	14	17	0	4	-14	-13	

Without Thresholds @ 31.25

MPA (Total Tons)	4827	Tons/1000 tons	17
NP (Total Tons)	1219	Tons/1000 tons	4
Net Tons NP	-3608	Tons/1000 tons	-13
NP/MPA Ratio	0		
Available NP	3608		
(Tons per acre)	DEFICIENT		
NP Available to	6981		
achieve 1.2% NNP	DEFICIENT		

With Thresholds @ 31.25

MPA (Total Tons)	3849	Tons/1000 tons	14
NP (Total Tons)	0	Tons/1000 tons	0
Net Tons NP	-3849	Tons/1000 tons	-14
NP/MPA Ratio	0		
Available NP	3849		
(Tons per acre)	DEFICIENT		
NP Available to	5536		
achieve 0.6% NNP	DEFICIENT		

Without Thresholds @ 31.25

Net NP Requirement	Alk. Additon Rate (t/ac)
1 ton/1,000 tons net NP	3889
2 ton/1,000 tons net NP	4170
3 ton/1,000 tons net NP	4452
4 ton/1,000 tons net NP	4733
5 ton/1,000 tons net NP	5014
6 ton/1,000 tons net NP	5295
7 ton/1,000 tons net NP	5576
8 ton/1,000 tons net NP	5857
9 ton/1,000 tons net NP	6138
10 ton/1,000 tons net NP	6419
11 ton/1,000 tons net NP	6700
12 ton/1,000 tons net NP	6981

With Thresholds @ 31.25

Net NP Requirement	Alk. Additon Rate (t/ac)
1 ton/1,000 ton net NP	4130
2 tons/1,000 tons net NP	4412
3 tons/1,000 tons net NP	4693
4 tons/1,000 tons net NP	4974
5 tons/1,000 tons net NP	5255
6 tons/1,000 tons net NP	5536

An AMD collection plan was developed based on the geophysical results. The plan included an array of collection systems that targeted 13 separate seepage areas and connected into one trunk line that carried the acidic water below the tipple site. A meeting was held at the site on March 29, 2002 with TU, KCWA, Sproul State Forest and Hedin Environmental to review plans for the implementation of the collection system. The meeting participants expressed mixed views on the proposed collection system. While the group toured the site, several observations were made that caused a reappraisal of the collection plan. Water was observed flowing from abandoned pit floors and deep mine entries, but much of this flow infiltrated into spoil and disappeared. Kill zones were apparent below several of these infiltration areas. There was evidence in several areas that flow ponded within pits, but did not discharge. Again, kill zones were evident below these infiltration areas.

A plan was developed to investigate the possibility of collecting water in the pits and transporting it away from the abandoned spoils before it had an opportunity to infiltrate. If this approach proved feasible, then it might be possible to eliminate the kill zones by eliminating the source of toxic water.

The Bureau of Forestry agreed to supply a backhoe for one day to investigate soils at the site. On April 17, 2002 the backhoe excavated several pits in abandoned pit floors, and along coal crops above the abandoned tipple site. The excavation pits that were located in spoil quickly became inundated with water due to the saturated conditions of the spoil. It was not possible to observe the presence or condition of coal, underclay or original ground due to flooding and instability of the pits. Coal crop excavations were also conducted. These excavations did not produce appreciable amounts of water.

The coal bed structure, available coalmine mapping and the excavation pits indicated that spoil on the down-dip side of the deep mines was saturated. This shallow ground water was flowing through the unmined permeable coal crop, and discharging as seeps downgradient of the mine spoils. This acidic water created kill zones. During periods of low flow, the porosity of the spoil and coal crop was sufficient to carry the deep mine discharge subsurface to the kill zones. During periods of high flow, the spoil became saturated with water, causing the water table in the pits to rise to the surface, creating ephemeral pools of acidic water. Several of these pools were trapped within the spoil and thus became sources of acidic water during dry periods.

The AMD collection plan was redesigned based on this conceptual hydrologic model (See Figure 3). A plan was developed to collect water as it discharged from the deep mine by installing french drains in pits known to have water flowing in them. The water would be transported through the spoil in solid pipe and discharged downgradient of kill zones. This collection/transport plan would bypass kill zones and, if the model is correct, eliminate the toxic conditions that support the kill zones. This plan also had the potential to separate the AMD from uncontaminated surface water. This would prevent the contamination of clean surface runoff, lessen the amount of water that needed to be treated, and decrease the variability in flow rates.

II. Collection of AMD

Four areas were targeted for water collection and were labeled A, B, C, and D. These sites are shown on Figure 2. All four sites had flowing or standing water during wet weather and all had downgradient kill zones associated with discharge points.

The collection systems were installed in November and December of 2002. The contractor, Smith Lumber of Renovo, installed the systems with an excavator, bulldozer, rubber tire highlift and laborers. Pipe and fittings were supplied by Catalone Pipe Supply of Penfield. Both 6" and 8" SDR 35 PVC pipe were used for the collection and conveyance of AMD. Factory supplied perforated pipe was used in areas of 6" water collection. 8" pipe was perforated on site.

Aggregate was placed around perforated pipes to facilitate water collection. The aggregate was a #57 dry screened river gravel aggregate obtained from Glenn O. Hawbaker's aggregate plant in Shinglehouse, PA. A noncalcareous aggregate was specified so that it would *not* increase the pH of collected mine water and thus would *not* promote the precipitation of metal hydroxide solids within the collection system.

The water collection drains were excavated through spoil and coal and placed several inches into the bottom clay. This created an impervious "liner" around the perforated pipe and aggregate that prevented water from bypassing the collection systems. The width of water collection trenches was generally three feet. In general, the collection systems were dug in an upslope direction. This allowed sources of water to be readily identified (and followed if necessary) and allowed intercepted water to drain away from the excavation face.

A. Collection Site A

Collection Site A is located along Boyer Road above the tipple site and just east of Huling Branch. The site is a partially backfilled deep mine entry. During the spring of 2002, water was observed flowing from the entry and across spoil where it infiltrated and disappeared. No distinct kill zone was visible in the vicinity of this site. The AMD was likely discharging into Huling Branch as groundwater base flow. This discharge was the furthest upstream source of AMD to Huling Branch.

The Site A collection system was constructed by excavating a trench through spoil and into the abandoned deep mine opening. The trench penetrated 6" into the bottom clay. Two 6" perforated pipes laid side-by-side extended from the entry into 50' of spoil. The pipes were connected to a single 6" solid pipe that transferred the collected water approximately 200' to Boyer Road, and then approximately 2000'down Boyer Road to a discharge point below the Site B kill zone. The pipe was buried at least three feet deep the entire length along Boyer Road.

B. Collection Site B

Collection Site B is located on the northwestern edge of tipple site approximately 900' southeast of Site A. Prior to collection, water discharged into an open pit and flowed down-dip along the mined out coal bed for approximately 250' before disappearing into porous spoil. A kill zone is located 200' below the end of an open cut which had been left open by surface mine operators to prevent the accumulation of pit water. The kill zone is approximately 50' lower in elevation than the surface mine. After water surfaced in the kill zone, it flowed on the surface for 200' down to Boyer Road, crossed the roadway, and continued in a defined flow path/channel to Huling Branch.

The Site B collection system consists of two separate 6" collection networks, B_1, and B_2. The B_1 excavation started at the base of spoil above the large kill zone along Boyer Road. The 8" solid transfer pipe extended upslope approximately 300 feet to abandoned spoils and pits. During installation of the transfer pipe, 120' of crop coal was encountered. The coal seam (Lower Kittanning) was 5' thick. Once through the coal, water-producing spoil was encountered in the pit at the base of an unreclaimed highwall. Two 6" laterals that branched off along the base of the highwall were placed. The perforated water-collection lateral was placed that extended 20' to the east. A lateral was placed that extended 70' to the northwest to AMD-producing deep mine entries. A collection system (perforated pipe and aggregate) was installed at these mine openings.

B_2 is located 200' northwest of B_1 and also penetrated 120' of coal crop. B_2 paralleled the base of the highwall for 250' using two 6" perforated pipes placed side by side. No deep mine openings were encountered, but a small dip in the underclay measuring 100' wide by 18" deep, trending in a northeasterly direction, produced 2-3 gallons per minute of water. Prior to water collection, this water was observed flowing to the end of the open pit in the area of water collection at B_1 where it seeped into the spoil and disappeared through the porous spoil and coal crop. At the end of the water-bearing zone, the lateral was reduced to one single 6" pipe for another 250' to the eventual end of the collection system. To collect the water into the pipe, aggregate was placed around the perforated pipe and a clay barrier was installed downstream of the water-bearing zone to force water into the pipe. There was very little water encountered in the last 250'.

B_1 and B_2 were connected together above the Site B kill zone with an 8" pipe. The single line was trenched through the kill zone. The 8" line terminated at the down slope edge of the kill zone along Boyer Road.

C. Collection Site C

Site C is located north of the tipple site. At this site water appears at the surface intermittently only during very wet periods. Water in this area could be flowing subsurface in the spoil in a down-dip direction towards collection Site B. Due to the low flow, this site was the lowest priority of the four chosen locations. Collection was not performed at this site due to time and monetary restrictions and the uncertainty of success.

D. Collection Site D

The Site D is located at the base of an abandoned highwall above the eastern side of the unnamed tributary to Huling Branch approximately 1000 feet north of abandoned tipple area. During times of wet weather, water can be observed to be flowing on the surface flowing south to a lower water filled depression. This depression is down-dip of the collection area and was thought to collect water from the porous spoil.

The Site D excavation started at the base of the slope above the eastern side of the unnamed tributary to Huling Branch and extends north approximately 800’ to an unreclaimed highwall. The excavation encountered 100’ of Lower Kittanning crop coal and spoil placed on top of the coal in the excavated pits. The collection system consisted of 50’ of 8” perforated pipe placed through spoil to the base of the highwall. Water flowed into the trench from the northeast, which is an area that has many acres of open pit spoils located in the up-dip direction of the discharge point.

III. Collection Results

The following sections discuss the effectiveness of collection efforts and water chemistry results.

A. Collection Success

The collection systems were sampled for flow and chemistry in 2003 (Table 2). Low flows were observed in January, July, and late August, while very high flows were observed in March. Inspections were made of the areas around and downslope of the collection systems in March. No water was observed below Site A or Site B. Several seeps that previously caused a kill zone below Site B were conspicuously dry in March. It appears that the Site A and Site B systems were successful in the collection of most of the AMD produced in these areas. Because A and B carry the AMD down to the tipple site, they enter Huling Branch about 2,500 feet lower than was the case before the collection systems were installed. This change should result in substantial improvements to Huling Branch above the tipple.

The collection system at Site D was also successful. It produced the most water (see results below). However, acidic water continued to be produced in the channel of an unnamed tributary south of the Site D area. When the final reclamation plan for Huling Branch is developed, the installation of a collection system to the east of Site D should be considered.

The Site C system was not installed because it required considerable excavation and cost, and because it was reasoned that the water from Site C should follow the dip and flow to the southeast to the B1 system. No large seeps have been identified below the Site C area. This area should be inspected further to determine whether the final reclamation plan should include the Site C collection system.

B. Water Quality

Monitoring of the collection system occurred between January and August of 2003. During this time, a total of 28.9 inches of precipitation fell on the Lock Haven weather station, located approximately 30 miles southeast of the site. The mean precipitation for this period is 26.9 inches, indicating that the sample period is representative of a normal year.

Highlighted cells are estimated flows and were in excess of 300 gpm. March flows and chemistry were collected during normal spring snow melt and rain events. The total average flow for the three collection systems was at least 167 gpm. The flows varied substantially, depending on recent precipitation conditions. This suggests that the mine complex hydrology is largely controlled by surface infiltration and shallow groundwater flow. Rough infiltration calculations suggest the feasibility of this conceptual hydrologic model. The acreage of spoil within the mine complex is 120 acres (pink shaded area in Figure 2). Because of the structural dip, most of this acreage is above the collection systems. Between January and August 2003, approximately 94 million gallons of liquid precipitation fell on the spoils. If all of the 75% of the precipitation that fell on these 120 acres between January and August 2003 (243 days) infiltrated the spoil and flowed to the collection systems, then the average total flow rate attributable to infiltration would be 202 gpm. As noted above the measured average flow as at least 167 gpm, and some flow was not collected. This general concurrence supports the belief that up-dip infiltration is a major component of the mine complex hydrology.

The three collection systems were samples 3-4 times. All of the water samples were highly contaminated acid mine drainage with acidity concentrations that generally varied 900 – 1100 mg/L acidity. Sulfate concentrations were 700-1800 mg/L. There was little indication of neutralization of the AMD with its flow through the spoil and deep mines. Pure pyrite oxidation should produce 100 mg/L acidity (as $CaCO_3$) for each 96 mg/L sulfate, or approximately a 1:1 ratio.

$$FeS_2 + H_2O + O_2 \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

Most acid mine drainage samples have an acidity:sulfate ratio far below the 1:1 ratio. The average of the Huling Branch samples 0.82 acidity to 1.00 sulfate. Very little neutralization is occurring.

All of the samples had very high aluminum concentrations, with concentrations ranging up to 115 mg/L. Al is toxic fish and macroinvertebrates at concentrations greater than 0.2 mg/L. Al is also difficult to treat with passive procedures (see later discussion).

The systems collect water as it discharges from the deep mine, before it contacts down-dip spoil, coal crop, or underclay. It is clear that contamination of the groundwater has already taken place within the up-dip mined areas. Remediation of spoils on the down-dip side of the mine will not have a significant effect on water quality. Remediation efforts should focus on up-dip spoils and the abandoned deep mine.

Table 2: Collection System Samples

Site	Date	Cond (uS)	Flow (gpm)	pH	Net Acidity (mg/L)	Fe (mg/L)	Mn (mg/L)	Al (mg/L)	SO4 (mg/L)	Loading (pounds per day) Net Acid	Fe	Mn	Al
Site A	01/30/03	2665	0.1	2.5	1212	8.0	8.9	66.3	1879	2	0.0	0.0	0.1
	03/21/03	2383	115.0	2.6	885	145.3	10.4	53.6	1376	1226	201.3	14.4	74.3
	05/31/03	1708	21.0	2.6	621	91.5	4.0	26.7	474	157	23.2	1.0	6.8
	07/03/03		1.0										
	08/01/03		24.0										
	08/21/03		1.5										
	A Average	**2252**	**27**	**2.6**	**906**	**82**	**8**	**49**	**1243**	**462**	**74.8**	**5.1**	**27.1**
Site B	01/23/03	4290	7.0	2.3	1382	200.0	23.4	89.3	1864	116	16.8	2.0	7.5
	01/30/03	3295	4.3	2.4	1264	209.1	24.5	93.8	1956	65	10.7	1.3	4.8
	03/21/03	1706	300.0	2.8	575	103.9	3.8	28.8	739	2072	374.5	13.7	103.8
	05/31/03	2560	32.5	2.5	743	73.9	10.0	41.0	736	290	28.9	3.9	16.0
	07/03/03		10.0										
	08/01/03		100.0										
	08/21/03		18.0										
	B Average	**2963**	**67**	**2.5**	**991**	**147**	**15**	**63**	**1324**	**636**	**107.7**	**5.2**	**33.0**
Site D	01/23/03	3090	1.3	2.4	1239	124.0	10.9	113.0	1335	19	1.9	0.2	1.7
	01/30/03	2125	0.6	3.1	981	119.9	6.3	99.1	1176	7	0.9	0.0	0.8
	03/21/03	1983	300.0	2.8	936	49.6	8.5	97.1	1103	3372	178.8	30.6	350.0
	05/31/03	2620	12.0	2.5	1160	71.4	12.6	115.0	1090	167	10.3	1.8	16.6
	08/01/03		120.0										
	08/21/03		7.0										
	D Average	**2455**	**73**	**2.7**	**1079**	**91**	**10**	**106**	**1176**	**891**	**48.0**	**8.2**	**92.3**
TOTAL*	**Average**		**167**		**1016**	**112**	**12**	**80**	**1246**	**1989**	**228**	**24**	**163**
										2070	**231**	**19**	**152**

* concentrations are flow-weighted averages; total loadings are calculated from total flow times flow-weighted average

Table 3 summarizes data collected at the Huling Branch BAMR Weir 4 between 1995 and 2000. Flow from Collection Site A and Site B never flowed through Weir 4. These flows entered Huling Branch upstream of the tipple site. Site D flow and other flows from the tipple area passed through Weir 4.

Table 3: BAMR Weir 4 Average Chemistry, Flow and Loading (August 1995 – May 2000)

	Flow (gpm)	**Lab pH**	**Acid mg/l**	**Fe mg/l**	**Fe2 mg/l**	**Mn mg/l**	**Al mg/l**	**SO4 Mg/l**	**Acid lb/d**	**Fe lb/d**	**Al lb/d**
Average	110	2.7	692	72	4	23	54	845	751	68	62
Minimum	9	2.4	398	10	1	3	33	323	93	4	8
10%	22	2.5	464	38	2	14	42	431	240	25	16
Median	73	2.8	647	69	4	22	55	855	536	56	40
75%	137	2.9	862	88	5	29	59	1000	971	87	80
90%	228	2.9	967	116	6	36	70	1327	1327	118	126
Maximum	571	3.1	1142	139	11	40	75	1756	3823	303	325
count	38	46	46	46	46	46	46	46	38	38	38

The contaminant loadings estimated for Site D in March 2003 were approximately equal to those measured at Weir 4 between 1995 and 2000. In March 2003, Sites A and B together produced approximately the same loading as Site D. The combined flows and loadings of the collection systems was considerably larger than the Weir 4 measurements. The 2003 flows were 50% higher (167 vs. 110 gpm), the acidity loadings were 2.7 times higher (1989 vs. 845 lb/day), the Fe loadings were 3.3 times higher (228 vs. 68 lb/day) and the Al loadings were 2.6 times higher (163 vs. 62 lb/day). These differences were not due to unusual climatic conditions because, as noted earlier, the precipitation during the 2003 monitoring program was average. The differences are due to the more effective collection of mine water from the Huling mine complex.

IV. Remediation Alternatives

Five alternatives were considered in the remediation analysis. The first alternative is “no action” which provides no improvements over current conditions. The remaining four alternatives provide pollution remediation. The second alternative is treatment of the AMD using the best available technology (chemical treatment). The third, fourth, and fifth alternatives involve varying levels of reclamation which are assumed to offer varying remedial effects on AMD production and thus require varying amounts of follow-up AMD treatment to eliminate the residual AMD.

A. Alternative I: No Action

The no action alternative maintains the current conditions. Huling Branch and Twomile Run below the Huling Branch will remain lifeless, and impacts to Kettle Creek will continue. There is, of course, a limited amount of pyrite available for oxidation in the Huling Branch watershed that will eventually be exhausted. Long-term studies of AMD production from deep mines generally indicate that this natural remediation will take centuries.

B. Alternative II: AMD Treatment

This project established the feasibility of collecting the mine discharges. Table 2 presented the sampling results for the three installed collection systems. We believe that these data represent a large majority of the AMD produced by the Huling mine complex. The treatment evaluations made below are based on the 2003 collection system data. If the final reclamation plan includes treatment, the missed water should be collected and treated. This should not change the quantities and costs presented below by more than 10-20%. Table 4 represents the amount of pollution measured from the existing collection systems that would require treatment assuming no reclamation activities take place.

Table 4: Flow and AMD loadings estimated for the Huling Mine Complex.

	Average	**High**
Acidity, mg/L	1,000	Unknown
Fe, mg/L	110	Unknown
Al, mg/L	80	Unknown
Flow, gpm	167	>715
Acidity, lb/day	1,989	>6,670
Fe, lb/day	228	>754
Al, lb/day	163	>527

Passive Treatment

In the 2000 *Restoration Plan,* it was noted that the Huling Branch discharges were not suitable for passive treatment. That assessment has not changed. The combined waters contain approximately 1,000 mg/L acidity, 110 mg/L Fe, and 80 mg/L Al. This water chemistry far exceeds recommended limits for passive treatment.

If passive treatment was feasible, the highly variable flow rates would make the technology very expensive. Generally, passive systems must be designed for high loading conditions. This usually translates into substantially higher capital costs for systems with variable influent flows and loadings. The Huling collections system flow rates ranged in 2003 between 8 gpm and >715 gpm. If a passive treatment technology is identified, reduction of flow rate and flow variation through up-dip reclamation of the spoils would likely be very cost-effective.

Chemical Treatment

Two chemical treatment systems, liquid NaOH and pebble lime, are discussed below. Both of these treatment systems are suitable for remote sites without electricity or daily access. In both cases, alkaline chemicals are used to neutralize the mine water acidity, which causes the metals to precipitate in treatment ponds as hydroxide solids. The resulting metal-rich sludge is periodically pumped from the treatment ponds into either a sludge drying bed or a borehole that disposes of the alkaline sludge into the deep mine voids.

Treatment costs for the systems were estimated using Hedin Environmental's experience with chemical treatment systems and using OSM's AMD Treat software.

Sodium Hydroxide

Sodium hydroxide is a liquid reagent that is stored in large metal tanks (5,000 – 20,000 gallons) and is dripped into the AMD stream. The dosing rate of the chemical is either adjusted manually every few days by the operator, or it is automatically adjusted by a flow-controlled water wheel or flushing device. Sodium hydroxide treatment is the most reliable chemical treatment method available and is preferred for remote sites where access is limited.

We assume that the treatment system would be constructed at the tipple site. There is adequate room and, as noted earlier, most of the mine water has already been collected and is convenient to the site. The possibility that the acidic water would be piped down Huling Branch to a treatment area near Kettle Creek was not explored. Placement of the system near Kettle Creek would lessen road maintenance costs and storage tank requirements. Sludge costs could increase if the material had to be trucked back to the minesite for disposal. All other costs would be similar.

Sodium hydroxide is delivered in 4,400 gallon tankers. Four-wheel drive tri-axle tankers are available for accessing remote sites. Despite the existence of these trucks, winter access to the site will be difficult. Unless the road into the tipple site is maintained on a regular basis throughout winter, the NaOH storage capacity must be at least two months. Under average flow and loading conditions, the system will consume about 900 gallons per day of 20% NaOH. Thus, at least 55,000 gallons of storage capacity is recommended.

A treatment system consisting of a series of treatment ponds and a sludge disposal/drying pond could be constructed at the abandoned tipple site. Water bypassing the Site D collection system should be collected. Three ponds are recommended that are each capable of holding water for 24 hours and retaining six months of sludge. The number and size of the ponds is conservative, but difficulties accessing the site and managing sludge during winter months warrant conservative sizing. Because of the public's use of the area, the treatment system would need to be fenced and secured. The cost to the design and construct the system is estimated at $368,000 (Table 5).

Based on the average loadings in Table 4, the system would consume approximately 340,000 gallons of sodium hydroxide per year. At $0.60 per gallon delivered, the reagent will cost approximately $197,000 per year. Sodium hydroxide pricing is highly volatile, and price swings to $1.00/gallon should be expected.

The sludge ponds would need to be pumped out twice a year. We assume that each sludge pumping event will take 80 hours and that the cost to hire a sludge pumping contractor (mobile pump and support equipment, operator and at least one laborer) will be $200/hr. The annual sludge management cost is estimated at $32,000/yr.

The site would require inspection and general operation and maintenance three times a week. Assuming that each site visit takes 4 hours and that labor costs are $30/hr, then the annual personnel cost is approximately $20,000/yr. Annual equipment and miscellaneous system repairs are estimated at $20,000/yr. The cost to keep the access road open for tanker trucks is estimated at $20,000/yr.

The total estimated costs for a NaOH system are:

- Capital costs to design and construct system: $368,000
- Annual costs to operate the system: $289,000/yr

Table 5 summarizes these costs.

Table 5: Chemical Treatment System Capital Cost Estimate: NaOH

Item	Basis	Cost
Access road from Middle Branch Road to Huling	Estimate	$15,000
Collection system to collect water at Site C	Estimate	$25,000
NaOH storage tanks	Six 10,000 gallons at $1 per gallon	$60,000
Lined chemical treatment ponds	Primary Pond, 1.5 million gal	$55,000
Lined chemical treatment ponds	Secondary Pond, 1.4 million gal	$50,000
Lined chemical treatment ponds	Tertiary Pond, 1.4 million gal	$50,000
Sludge disposal pond	15,000 ft^2 at $1/$ft^2$	$15,000
Fence around system	Estimate	$50,000
Construction Total		**$320,000**
Design, permitting, and construction oversight	Estimate at 15% of construction costs	$48,000
Project Total		**$368,000**

The convention method of analyzing the economics of treatment systems is to perform a present value analysis. A trust fund sufficient to provide for the $289,000 per year in annual costs is $6.2 million (50 years, 4% net return). Thus, the total present value cost to treat the Huling Branch AMD with sodium hydroxide is $6.6.million.

<u>Pebble Lime System</u>

Pebble lime systems that use water wheels for metering chemical into the water have become standard treatment technology on remote sites in West Virginia. The systems are popular because they use pebble lime, a much cheaper reagent than sodium hydroxide. The pebble lime reagent costs for a system at Huling are about $30,000 per year, a fraction of the sodium hydroxide costs. The pebble lime system requires a large a lime silo and a heavy waterwheel that turns an auger and dispenses the pebble lime. These items increase the capital costs of the system. Pebble lime systems require more O&M and repairs. Also, the reagent efficiency (assumed at 90% in the $35,000/yr cost estimate) is strongly influenced by the mixing of the water. Poor mixing will result in unreacted lime and greatly increased lime consumption and also increase sludge pumping costs because of the extra sludge produced by unreacted lime.

The total estimated costs for a pebble lime system are:

- Capital costs to design and construct system: $300,000
- Annual costs to operate the system: $100,000/yr

Hedin Environmental is not as experienced with pebble lime systems as it is with NaOH systems. If TU decides to pursue the chemical treatment option more fully, an engineering firm experienced in the design, construction and operation of pebble lime systems should be consulted.

C. Alternative III: Reclamation of Spoils

This alternative focuses on reclamation of up-dip spoils in a manner that lessens infiltration and flow through the deep mine workings. Four observations make this alternative reasonable.

1. The up-dip spoils are unreclaimed and existing conditions promote the trapping and infiltration of surface water.
2. The local structure dips at about 5% to the southwest. This structure directs spoil infiltration through the deep mines.
3. The flow rate of discharges from the down-dip side of the deep mine are highly variable. The variability suggests a major surface water and infiltration component to the deep mine hydrology.
4. The collection of mine water from the down-dip side of the deep mines indicates that the water was already highly contaminated. The down-dip spoils are not responsible for the contamination. If spoil reclamation occurs, it should focus on up-dip spoils.

Approximately 120 acres of unreclaimed spoil exist in the Huling mine complex (the shaded area in Figure 2). Certainly, portions of the spoil are more responsible for infiltration and contamination than other portions. Sufficient information is not available to make a confident assessment of which spoils require reclamation and which spoils do not. We recommend reclamation of all 120 acres of spoil in the Huling mine complex. Our estimates could be decreased if reliable information relating to infiltration and groundwater contamination could be collected from the mine complex.

The reclamation of surface mines to reduce infiltration and increase surface runoff is a common activity on abandoned mine lands. An appropriate reclamation plan can be developed by the Bureau of Abandoned Mine Reclamation or by one of its approved engineering consultants. Several elements of the reclamation plan presented below.

- Limestone-lined diversion channels should be constructed upstream of the spoil area. This will prevent surface flows from entering the spoil area and becoming contaminated. If the collected water is clean, these channels should flow directly to Huling Branch and Middle Branch as appropriate. However, if the water has already become contaminated, the channels could flow to the tipple area, where a treatment system may eventually be located.

- The spoils should be regraded to establish positive drainage over the entire site by filling in pits and leveling out spoil piles. The regrading plan should allow for ATV trails that will provide fun for the riders, protect sensitive site vegetation, and allow for positive drainage.
- Once the final contour of the land has been obtained, vegetation should be established. It will be necessary to add lime, fertilizer, and mulch to the site spoils in order to establish grassy vegetation. If woody vegetation is desired, topsoil or other soil substitute must be placed on the top of the re-graded spoil and adequate lime and fertilizer must be applied.

The permanent establishment of vegetative cover will be enhanced by the development of an alkaline, fertile, fine textured soil. The establishment of a fine grained soil will also assist in slowing infiltration and promoting runoff. Fine soil could be produced onsite by screening spoil and adding limestone sand. Organic substrates can be imported for use in the development of fertile topsoil.

Soil could be obtained from the dredging of the Alvin R Bush Dam Lake. The lake covers approximately 130 acres. Much of the lake has accumulated many feet of sediment, reducing the capacity of the lake and hindering some recreation activities. Because the Kettle Creek watershed is forest and farmland, the sediment is generally good-quality topsoil and would be an excellent reclamation material. Samples of the Lake sediment were collected in 2000 by TU and analyzed by DEP and a private laboratory. No chemical concerns were identified. Covering all 120 acres of surface mines with one foot of topsoil would require 194,000 cubic yards of material, a fraction of the sediment currently contained in the lake. Additional sediment could be used on other reclamation areas throughout the watershed. Currently, there are no plans to dredge the lake. However, if plans are developed, the opportunity to make good use of the sediments should be fully explored.

The reclamation efforts proposed in Alternative III are similar to the activities currently underway in the Twomile Run watershed at the Robbins Hollow surface mine. Trout Unlimited and the KCWA, with assistance from BAMR, the PADEP Growing Greener Program, and the Office of Surface Mining, are regrading and revegetating abandoned mine spoils so that infiltration is decreased and flows in the Swamp kill area are lessened. The project also includes the use of a manufactured soil made from local tannery wastes.

The cost of the construction component of the Robbins Hollow reclamation is $626,712. This cost does not include the regarding plan that was prepared by BAMR. Assuming that the design cost is 10% of the construction cost, then the total project cost is estimated at $689,383. The project will reclaim 57 acres, for a per acre cost of $12,094/acre. Assuming similar project costs in the Huling Branch watershed, the cost of the Reclamation Alternative is estimated to be $1,450,000.

The project will lessen the quantity of AMD discharging at the down-dip side of the deep mine, but it is unlikely to improve the chemistry of the water. The primary benefit is expected to be lessening of AMD flow rates and decreasing of the flow variation. Quantitative benefits are impossible to predict with certainty. Several reasonable calculations are presented below.

- Assuming that infiltration through the 120 acre spoil area decreases from 75% to 40%, then the down-dip AMD flow rate should decrease by about 100 gpm. This represents about 50% of the estimated average flow of AMD from the Huling mine complex.
- Infiltration into the unreclaimed spoils is likely episodic. If one inch of rain flows though the spoil and deep mine system in a three-day period, the result is a short-term increase in flow of 750 gpm. The presence of vegetation and less permeable subsoil should provide some water storage capacity in the surface 12-24 inches of the site surface. This storage would reduce the overall infiltration rate and distribute the remaining infiltration over a longer period of time, lessening peak flows from the collection system.

The elimination of flow from the mine complex will result in lower acidity loadings and decrease annual treatment costs. If the above calculations are accurate, then annual treatment costs may decrease by 50%. The moderation of flow variation would justify a smaller treatment system, decreasing capital costs by perhaps 30%.

D. Alternative IV: Reclamation of Up-dip Spoil and Alkaline Addition

This alternative includes reclamation as in Alternative III and alkaline addition. The alkaline materials are intended to neutralize acidic spoil and inhibit further pyrite oxidation in the spoils. The alternative is proposed because of several observations and predictions.

1. Analyses of samples from the collection systems indicate that contamination occurs up-dip – in the deep mine and/or in the up-dip spoils.
2. Acidic materials were reportedly buried on the pit floor in the up-dip surface mines and are probably a major source of AMD.
3. The reduction of infiltration is not expected to substantially decrease pyrite oxidation in the spoils and deep mine or the leaching of acidity from in-place toxic materials.

Alkaline addition is a common practice used in the mining of coal that has an overburden with insufficient neutralization potential. The goal would be to neutralize the spoil and the toxic black shale. The spoils would be graded to expose the pit bottoms. Alkaline addition would occur as the grading occurs.

Alkaline amendment to the entire 120 acre area is recommended. Investigation of the site to identify especially toxic spoil may be cost-effective.

The cost of alkaline addition will depend on the alkaline materials selected, the rate of application, and the depth of incorporation. Several alkaline materials are presented in Table 6 and discussed below. BAMR has recently completed several reclamation projects where alkaline amendment rates were several hundred tons per acre. (The standard amendment rate for vegetation establishment is 5-10 tons per acre.) For a reclamation project, low-value waste alkaline materials can be suitable. Several types of alkaline material are described below.

- <u>Limestone Fines</u> During the mining and processing of limestone for aggregate or lime production, unsaleable wastes are typically produced that can be obtained for minimal costs. The waste may be an unmarketable size fraction (often fines or sand) or material that is dirty (with clay). The characteristics of waste limestone varies between quarrying and processing operations. Generally, waste materials can be obtained for $1-2 per ton. There are several limestone quarries within 70 miles of Huling Branch.

- <u>Coal Combustion Ash</u> During the combustion of coal, ashes are produced that are often alkaline. The amount of alkalinity varies with the type of ash (bottom or fly) and the combustion process. Fluidized bed combustion uses limestone and produces an ash with a high lime content (CaO). Many ashes have been chemically characterized and have been approved for use in reclamation projects. Producers of combustion ash typically pay for its disposal, so it might be obtained for no cost. Trucking will be an issue for ash because currently there are no large producers are within 100 miles of Huling Branch. However, a coal-burning power plant has been proposed for Karthaus, only 40 miles away the Huling Branch watershed.
- <u>Lime Processing Wastes</u> During the calcination of limestone ($CaCO_3$) to lime (CaO) it is common to collect wastes in a wet form that is commonly referred to as “baghouse lime.” The material is generally 50% water and 50% CaO. Because the waste product tends to solidify, its use as an amendment may require some processing. Baghouse lime is usually available for $1 per ton. Several lime plants exist in the Pleasant Gap area, about 70 miles from Huling Branch.
- <u>Low Quality Limestone</u> The Dents Run project in Benezette, PA is producing hundreds of thousands of tons of alkaline rock with 40-80% $CaCO_3$ content. The material is being used for reclamation in the Dents Run project. The mining operation will produce more alkaline rock than is needed. The cost of the mined material is not clear, but is probably $4-5 per ton. A weight limit on the SR 555 bridge over the West Branch in Driftwood prevents direct trucking between the locations. The problem could probably be corrected, if this source of alkaline material proved suitable and affordable.

Table 6: Sources of Alkaline Material

Material	**Source(s)**	**Mine cost ($/ton)**	**% $CaCO_3$**
Limestone (marketable)	Local limestone quarries	$7-10	85 – 95%
Limestone (fine waste)	Local limestone quarries	$1-2	0 – 95%
Dent’s Run Limestone	Dent’s Run USACE Project	$4-5	40 – 80%
Fly Ash	Power plants	$0	40 – 50%
Wet Lime Wastes	Local lime producers	$1-2	50 – 60%

At this time, the most likely source of alkaline material for a Huling Branch reclamation project is waste limestone from quarries located within 70 miles. Table 7 shows the mileage between several limestone-producing areas and Westport. A reasonable trucking cost assumption is $1 for the first mile plus $0.10 per mile per ton plus a $2 per ton premium because of the remote location of the project. Assuming that waste materials are available for $1 per ton (loaded), then the estimated delivered cost for alkaline materials ranges $8 – $10 per ton.

A 250 megawatt power plant is proposed for Karthaus PA, 30 miles to the southeast of Westport. The plant will be constructed by River Hill Power Company and will be fueled by River Hill Mining Company. The plant will burn 2 million tons per year of coal, waste coal, and refuse using a fluidized bed technology. The targeted fuel blend will be 8,500 – 9,000 BTU. The plant will produce an alkaline bottom ask that will be used for reclamation. River Mill Power plans to have permits submitted by mid-2004, start construction in 2005, and be operating in 2008.

If the Karthaus power plant is constructed as scheduled it could provide both a market for on-site coal (See Alternative V below) and alkaline bottom ash for on-site reclamation. In western PA, alkaline ash is generally available for no cost. Some reclamation projects near the Scrubgrass Power Plant (Venango County, PA) have been partially funded by fees paid by the power plant to the operator to dispose of the ash. The feasibility of using Karthaus ash in Huling Branch would depend on the Company's ash disposal options and the feasibility of producing fuel for the plant in the Huling area. This option should be reappraised as the certainty of the power plant's construction increases.

Table 7: Driving Distances To Local Limestone Quarries

Location	**Alkaline source**	**One-way mileage to Westport**
Pleasant Gap	Limestone fines, up to 95% $CaCO_3$	63
Bellefonte	Limestone fines, up to 95% $CaCO_3$	59
Salona	Limestone fines, up to 50% $CaCO_3$	40
Jersey Shore	Limestone fines, up to 90% $CaCO_3$	51
Benezette	Limestone, 40-80% $CaCO_3$	38

The trucking costs assume that trucks return to the quarry empty. If a backhaul could be identified, trucking costs would be less. The possibility of mining coal and using the trucks to deliver coal to a southern site (near a limestone quarry) is presented in Alternative V.

The depth of incorporation is an important parameter. It is thought that the acid-producing shale is likely at the bottom of the abandoned surface mine pits. The simplest (and least costly) strategy is to place the alkaline material near the surface. It would neutralize the surface spoils and add some alkalinity to infiltrating water. The alkalinity generated would not be enough to significantly neutralize acid producing processes occurring deeper in the spoil. Therefore, Alternative IV includes the deep incorporation of alkaline materials. If local reports that the black shale was placed on the pit floors are accurate, then it will be necessary to incorporate alkaline amendments the full depth of the mines. We recommend the complete excavation of suspect spoils.

Table 8 shows the assumptions and calculations used to estimate the cost of Alternative IV. Rates of alkaline addition were based on the overburden core (Table 1), which indicated that virtually all of the toxic, acidic material is in eight feet of clay/shale above the coal. These eight feet of clay and shale were approximately 100 tons $CaCO_3$ per 1000 tons of overburden deficient in neutralization potential. The calculations in Table 7 assume that the goal is to locate and neutralize this toxic material.

The calculation assumes that the spoil is an average of 50 feet deep and regrading costs to push the spoil and expose the toxic materials are $1 per CY. The calculations assume that the alkaline addition costs $10 per ton to obtain on site. The net effect of these calculations is an estimate that earthmoving costs are about $9.7 million and alkaline amendment costs are about $2.9 million.

Table 8: Alkaline Amendment Calculations For Up-dip Surface Mines

Item	**Source**	**Result**
Spoil acreage	Measured from Figure 2	120 acres
Spoil depth, average	Estimated from Figure 2	50 feet
Spoil volume	Calculated	9,680,000 CY
Original toxic clay/shale depth	From drill log	8 feet
Clay/shale density	ABA accounting table	3,500 ton/acre-ft
Toxic shale tonnage	Calculated	2,880,000 tons
Toxic clay/shale NNP	From drill log	-100 ton $CaCO_3$/1000 tons
Alkaline amendment needed	Calculated	288,000 tons $CaCO_3$
Alkaline amendment unit cost	Estimated	$10/ton
Earthmoving unit cost	Estimated	$1.00/CY
Earthmoving total cost	Calculated	$9,680,000
Alkaline amendment cost	Calculated	$2,880,000
Total Cost	Calculated	$12,560,000

The cost estimates provided in Table 8 could be high for several reasons. The toxic materials may not be spread uniformly around the site. If a pattern to the placement of the materials can be determined, then grading quantities could be greatly decreased. Those areas found to not contain toxic materials could be reclaimed using the regrading procedures proposed in Alternative III. This would lower the regrading and revegetation costs for non-toxic spoils from about $100,000 per acre to about $12,000 per acre. Alternative IV costs would also be less if a cheaper source of alkaline material was found. The opportunity to obtain free alkaline ash from the proposed Karthaus power plant should be fully investigated and has the potential to reduce the cost of this alternative by $2.9 million.

E. Alternative V: Remining of Remaining Coal Reserves

Reserves of coal remain within the Huling Branch mine complex that could be mined to offset reclamation costs. The benefits of remining abandoned mine lands are well recognized and Pennsylvania has implemented regulations encouraging the activity. It is not expected that coal mining can fully finance the proposed reclamation and alkaline amendment activities. However, extraction of marketable coal would generate income that would lessen the total cost of the reclamation project. Alternative V would likely be implemented in conjunction with one of the reclamation alternatives (III or IV).

The two primary coal reserves are solid crop coal that is thought to ring the mine complex and pillars remaining in the deep mines. The two reserves are treated separately in this analysis.

Mining of Crop Coal

This crop coal was left in accordance with regulations at the time the mining occurred. While these regulations were intended to provide pollution abatement, there is no evidence that the coal improves water quality or that its removal will cause increased contamination of the water. The actual removal of the coal is probably neutral with respect to water quality at the site.

Crop coal was encountered at three locations during the installation of the collection systems in the southeastern lobe of the mining complex. The coal seam was 5' thick and intact for 100' to 120' feet in width. The drill hole log also reported 5 foot of coal (actually, a 5 foot void). Assuming that the conditions found at the southeastern lobe are representative of the crop conditions in the western portion of the complex, then an estimated 9,100 ft of crop coal exists around the mine complex. Figure 4 shows the areas where crop coal is assumed to be intact. If the crop is 120 ft wide and 5 ft thick, then approximately 225,000 tons of coal are present.

The coal crop was only investigated in Areas A, B, and D. While the results were similar at all three sites, full development of a mining option would require additional investigation of the crop, especially in the western lobe of the mining complex.

Two samples of the coal were collected during the collection system excavations and submitted to a laboratory for standard analyses. Results are shown in Table 9. The coal is a medium BTU low sulfur product that is marketable. The River Hill Mining Company projects that the Karthaus power plant will consume about 160,000 tons/yr of market coal with 12,000 – 14,000 BTU, <2% sulfur, and 12-14% ash. The Huling crop coal could fit within these standards. Assuming a value of $25 per ton, the reserve could generate $5.6 million in gross sales. The cost to mine the coal would be low because of the low overburden cover. At an average depth of 25 ft, the overburden to coal ratio (CY of overburden divided by tons of coal), is only 5. Ratios less than about 20:1 are generally considered profitable for mining. Because of the presence of the toxic clay and shale, mining would require special handling and alkaline amendment. If the coal was being sold to the proposed Karthaus plant, alkaline ash would likely be delivered at no cost.

Table 9: Results of Coal Analysis (measurements by G&C Coal Analysis Lab)

	Site B Sample		**Site D Sample**	
Parameter	**As Received**	**Dry Basis**	**As Received**	**Dry Basis**
% Moisture	11.69		3.99	
% Ash	10.92	12.36	17.43	18.15
% Sulfur	.86	.97	1.08	1.12
B.T.U.	10,217	11,569	11,870	12,360
BTU (Moisture-ash free)	13,201		15,104	
Lbs. Sulfur/mil. BTU	0.84		.91	
Lbs. Ash/mil. BTU	10.69		14.68	

These analyses were provided by John Prushnok of P&N Coal Company.

A cost estimate for mining crop coal is presented in Table 10. The estimate assumes that the average cost to remove the overburden and coal is $1.50/CY. The cost is higher than considered in Alternative IV because the material must be moved to expose the coal and again to regrade and reclaim the mine site. The alkaline addition rate assumes complete neutralization of 8 feet of toxic clay/shale. Approximately 30 acres will be affected. Because of the shallow overburden, the clay/shale may be partially missing or weathered. Both situations would lessen the alkaline amendment requirement.

Table 10: Estimate of the Costs and Values of Crop Mining Operation

Item	Source	Result
Coal crop length	Measured from Figure 4	9,100 feet
Coal crop width	Measured in field	120 feet
Coal depth	Measured in field	5 feet
Coal density	ABA accounting table	1,800 ton/acre-ft
Coal quantity	Calculated	225,620 tons
Overburden depth, average	Estimated from Figure 2	25 feet
Overburden and coal volume	Calculated	1,213,333 CY
Toxic clay/shale depth	From drill log	8 feet
Clay/shale density	ABA accounting table	3,500 ton/acre-ft
Toxic shale tonnage	Calculated	701,928 tons
Toxic clay/shale NNP	From drill log	-100 ton $CaCO_3$/1000 tons
Alkaline amendment needed	Calculated	70,193 tons $CaCO_3$
Earthmoving unit cost	Estimated	$1.50/CY
Earthmoving total cost	Calculated	$1,820,000
Alkaline amendment cost	Calculated	$701,928
Total Cost	Calculated	$2,521,928
Coal value	Current market	$25/ton
Value of Mined Coal	Calculation	$5,640,496
Net Cost of Project	Calculation	(3,118,568)

The calculations assume that the alkaline addition must be purchased at a cost of $10/ton. Removal of the coal crop and reclamation of the disturbed 30 acres results in a net profit of approximately $3.1 million. If free alkaline ash is used as an amendment, the net profit of this work becomes $3.8 million. This profit could then be used to fund Alternative III or Alternative IV on the spoil that will not be affected by crop mining.

Removal of Abandoned Deep Mines

In addition to the crop coal, deep mined areas likely retain approximately 30% of their original coal reserves. These reserves were left in place to support the roof rock. Figure 4 shows the areas of likely deep mine reserves shaded in yellow. Two deep mines are apparent in the Huling mine complex. The eastern mine is estimated to encompass 7.5 acres, while the western mine encompasses 17 acres. Assuming 5 foot of coal thickness and 70% historic extraction, then the remaining reserve is approximately 66,000 tons.

The quality of the coal in deep mine is likely of similar, or superior, quality to the coal sampled during the crop excavations. The deep mines, however, have substantially higher overburdens. We estimated that the overburden depths are 60-70 ft. The overburden core drilled through 70 feet of overburden before intercepting the mine void. The high overburden cover and low coal recovery would make mining of the deep mines uneconomical. Table 11 shows calculations of general costs and coal values.

Table 11: Estimate of the Costs and Values of Mining the Two Abandoned Deep Mines

Item	**Source**	**Result**
Size of eastern mine	Measured from Figure 4	7.5
Size of western mine	Measured from Figure 4	17.1
Coal depth	Measured in field	5 feet
Coal density	ABA accounting table	1,800 ton/acre-ft
Coal remaining	Estimate	30%
Coal quantity	Calculated	66,421 tons
Overburden depth, average	Estimated from Figure 2	70 feet
Overburden and coal volume	Calculated	2,837,692 CY
Toxic clay/shale depth	From drill log	8 feet
Clay/shale density	ABA accounting table	3,500 ton/acre-ft
Toxic shale tonnage	Calculated	688,800 tons
Toxic clay/shale NNP	From drill log	-100 ton $CaCO_3$/1000 tons
Alkaline amendment needed	Calculated	68,880 tons $CaCO_3$
Earthmoving unit cost	Estimated	$1.50/CY
Earthmoving total cost	Calculated	$4,256,538
Alkaline amendment cost	Calculated	$688,800
Total Cost	Calculated	$4.945,338
Coal value	Current market	$25/ton
Value of Mined Coal	Calculation	$1,488,300
Net Cost of Project	Calculation	$3,457,038

The cost of the mining operation is estimated at approximately $3.5 million more than the value of the coal. This estimate is strongly affected by the estimate of the coal reserve. If alkaline amendment material can be obtained at no cost, the net cost of this work would be approximately $2.8 million. If solid coal is present, or if extraction was only 50%, the coal value could substantially increase.

<u>Backhaul Opportunities for the Mining Alternative</u>

The mining operation could provide backhaul opportunities that would lower the cost of trucking in alkaline amendments. The amount of crop coal estimated to be present, 225,000 tons, is about 75% of the alkaline amendment estimated in Table 8 (as pure $CaCO_3$). As the amendment purity decreases, the percentage of alkaline material potentially balanced by coal backhauling decreases. The major opportunities that could develop if the Karthaus power plant is constructed have been discussed. If this does not occur, a market can probably be found for the coal in the Lock Haven or Bellefonte area and a cost-decreasing backhaul is possible for limestone quarries in these areas.

F. Additional Reclamation Alternatives

Several other remediation technologies have been considered. These technologies do not constitute a full alternative. They could be incorporated into the final reclamation plan.

- Alkaline recharge galleries (ponds/trenches) Some success has been achieved in the addition of alkalinity to contaminated aquifers by directing clean surface water into an infiltration gallery that contains a reactive alkaline material. The water picks up alkalinity which neutralizes groundwater acidity. It is thought that the alkaline inflows might also inhibit pyrite oxidation. Researchers in West Virginia report success using waste slag as the alkaline product, which can yield a leachate with 500-1,000 mg/l alkalinity. The water directed into the infiltration gallery must be free of metals (Fe and Al) and sediment, because both these contaminants decrease the porosity of the alkaline material. The alkaline recharge gallery idea differs from conventional remediation thinking by its emphasis on the injection of water into the mine. The reclamation efforts described in the previous section have a primary goal of *decreasing* the amount of water flowing through the mine. The goal of eliminating flow through the mine is based on the general observation that contaminant loading from deep mines is strongly correlated with flow rate. This approach would only be recommended if concentrations of alkalinity in the recharge water can be sustained at very high levels. If this is possible, then the galleries should be located above the deep mine.

- Grouting of the Deep Mine The deep mine appears to be a primary conduit of AMD to Huling Branch. Elimination of the mine through remining is a preferred option. If this is not cost-effective, then filling of the mine with grout might be considered. The goal of the grouting would be eliminate the moist aerobic conditions that support pyrite oxidation. A portion of the pyritic shale has probably collapsed onto the mine floor and would be encapsulated with grout injection. However, shale remaining in the roof will be difficult to encapsulate. Efforts to eliminate deep mine discharges through grout injection have achieved variable success. In all cases, the costs were very high because of the extensive drilling program necessary to assure filling of the mine with grout. The absence of deep mine maps would make this solution very difficult.

- Deep Mine Injections The inhibition of pyrite oxidation in the deep mine should eliminate AMD production. Inhibition is generally attempted through the application of bactericides or the modification of environmental conditions so that pyrite oxidation is not favored. All products require injection, which is complicated by the absence of mine maps. Inhibitors such as bactericides require contact between the pyrite and the inhibitor. Generally, repeated treatments are necessary and the cost is prohibitive for deep mines. Modification of the environmental conditions in the mine would most likely involve the addition of an oxygen sorbant that would create anaerobic conditions in the mine. This concept has been proposed for partially flooded deep mines where a pool of water with high biological oxygen demand (BOD) might be created through the addition of soluble organic compounds. An extensive mine pool does not exist in the Huling mine.

G. The ATV Factor and Opportunity

One important factor to consider during the development of any reclamation plan is the presence of the ATV recreation area. The ATV trails are shown on Figure 2. The Bureau of Forestry has expressed the desire to retain the present number of trail miles, with the possibility of additional trail miles in the future. The current site conditions (open spoil piles with steep slopes and water in shallow pits) are attractive to many ATV riders. The users of this area would likely find a uniform, gently sloping grassy area much less satisfying. In addition, such a site would promote the creation of “unofficial” trails, which would damage vegetation and increase infiltration. It is vital that the reclamation plan be acceptable to the Bureau of Forestry and accommodates existing and expanding ATV use.

The site could be reclaimed in a manner that provides a safe, enjoyable experience for the ATV users. It is possible that funding from the Commonwealth’s ATV fund could be used to design and construct a premier ATV facility in the Huling watershed, after the mine spoils are regraded and reclaimed.

The high numbers of visitors to the site for ATV riding, hunting, and other recreation may also result in conflicts during construction and increased vandalism both during and after construction. These conflicts can be minimized by including stakeholders in the planning and design process, educating site users about the project, scheduling project activities around popular hunting seasons, and by taking measures to prevent and deter vandalism.

V. Summary of Alternatives

Table 12 is provided as summary of the major reclamation alternatives discussed above. For alternatives IV and V, several options are presented that vary based on the availability of a free alkaline reclamation material and the extent of coal removal.

Table 12: Summary of Reclamation Alternatives

Alternative	Option	Potential Benefits	Cost Estimate
III	Surface reclamation only on 120 acres	Reduce infiltration, decrease loadings by 50%	$1.4 million
IV	A. Reclamation of 120 acres with 288,000 tons alkaline addition ($10/ton)	Reduce infiltration, decrease flow rates and acidity concentrations, decrease loadings by 50 – 80%	$12.6 million
	B. Reclamation of 120 acres with no-cost alkaline addition provided by alkaline power plant ash		$9.7 million
V	A. Coal Crop Removal and sale, reclamation of 120 acres with 288,000 tons alkaline addition ($10/ton)	Use coal proceeds to subsidize reclamation, reduce infiltration, decrease flow rates and acidity concentrations, decrease loadings by 50 – 80%	$9.4 million
	B. Coal Crop Removal and sale, reclamation of 120 acres with no-cost alkaline addition provided by alkaline power plant ash		$5.8 million
	C. Coal Crop and Deep Mine removal and sale, reclamation of 120 acres with no-cost alkaline addition provided by alkaline power plant ash	Decrease AMD loadings by 80 – 100%	$8.6 million

The ideal solution is the complete removal of crop and deep mine coal and enough alkaline addition to neutralize the acidic toxic clay/shale that remains in the mine complex (Alternative V.C above). This solution would probably eliminate or greatly reduce the AMD problem. If the alkaline material from this alternative is obtained free, then the total estimated cost of the solution is $8.6 million. The cost of this solution could be decreased if alkaline amendment could be targeted towards specific areas, and non-toxic spoils could simply be regraded and revegetated. If half of the spoils could be reclaimed by the low-intensity method (Alternative III), the cost of the project could decrease by approximately $3 million.

The net cost of the project will be strongly affected by the amount of marketable coal that can be profitably mined in the complex. If the void space in the deep mines is 50% instead of 70% (as we assumed), then an extra $1 million in coal can be mined.

VI. Conclusions

The original goals of this project were to collect AMD from the Huling mine complex, make better measurements of contaminant loading, and provide treatment recommendations. These goals were generally achieved. Most of the water from the mine complex has been collected, and it has been learned that actual contaminant loadings produced by the complex are 2-3 times higher than was originally estimated. The collected water is highly contaminated and is not suitable for passive treatment. Chemical treatment is the only option available today. A sodium hydroxide system would cost about $368,000 to construct and about $289,000 per year to operate and maintain. These annual costs are not reasonable for a volunteer-based watershed association.

During the collection of the AMD, the hydrogeology of the mining complex was investigated. The results of this investigation suggest reclamation options that, if implemented, would decrease the AMD production and chemical treatment costs. Considerable coal remains in the mining complex whose mining could offset a portion of the reclamation costs. Installation of the collection systems revealed the presence of 120 feet of quality crop coal. If these crop conditions exist throughout the site, approximately 225,000 tons of low-cover coal could be available. Another 65,000 tons of coal likely remains in the abandoned deep mines, although the cover on these reserves is much higher and it probably cannot be profitably mined. The proposed construction of a 250 MW power plant only 30 miles from the project area could provide a valuable market for coal mined from the complex and free alkaline ash that could be used for reclamation. Progress on the plant's permitting and financing should be monitored and the feasibility of linking a Huling mine complex mining and reclamation project to the plant should be investigated. In the event that the plant does not develop as planned, sources of low-cost alkaline material should be further investigate so that reclamation and major alkaline addition can eventually proceed in the watershed.