Watershed-based versus At-source-based AMD Treatment: Costs and Benefits

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Background: Acid Mine Drainage Treatment Costs

The advent of watershed based plans, TMDLs and a renewed focus on removal of stream segments from the CWA sec. 303d list suggests we take a more systematic approach to treating AMD at the watershed scale. As the focus of acid mine drainage (AMD) treatment shifts from single source to watershed scale remediation, we need to rethink whether the methods that have served us in the past are still valid. For example, NPDES permitting, policy and the lack of operations and maintenance funds in AMD treatment programs emphasized passive treatment of individual AMD sources. Experience has shown that construction of treatment systems to treat individual sources can be expensive due to their large number, diffuse nature and spatial distribution. Moreover, landowner access agreements can be difficult or impossible to obtain and construction of access roads to remote locations are costly. Furthermore, due to the uncertainty associated with the long term effectiveness of existing passive technologies, it is becoming increasingly evident that it will take much longer and cost much more to implement the TMDL and restore watersheds through passive, at-source treatment alone.

Other AMD treatment strategies include at source chemical using water-powered lime dosers such as the Aquafix ™. This doser is also suitable for in-stream dosing and was the basis for both in-stream and at source cost comparisons.

This paper evaluates the efficacy of the various AMD remediation approaches on a watershed basis. Specifically, it uses commonly available cost estimators to estimate the most cost effective and ecologically beneficial approach to AMD watershed reclamation.

AMD Treatment Cost/Benefit Analysis

Costs were estimated using the Office of Surface Mining's AMD Treat software. This package estimates both capital and operations/maintenance (M&O) costs. These cost estimates were compared to actual costs supplied by WVDEP.
The majority of cost associated with the treatment of acid mine drainage (AMD) is controlled by the following factors:

Factor 1.	Site access	S
Factor 2.	Construction	C
Factor 3.	Alkalinity addition	A
Factor 4.	Oxidation requirement	O
Factor 5.	Sludge disposal	D

AMD treatment, like most enterprises, benefits from economies of scale. The most efficient scenario involves a single, large volume discharge with a single access point and large scale, one time construction. One time mobilization of construction equipment, construction of a single access road, relative few access agreements is obviously less expensive than treating the same amount of acid load at 10 or 100 locations. Viewed simply, in AMD treatment the metric that determines the program's effectiveness is the mass of alkalinity that is delivered to impaired streams (factor 3, above). As the number of treatment sites increases, the proportion of program cost devoted to alkalinity addition decreases as access, construction and sludge disposal costs dominate. It is generally assumed that the cost of AMD treatment equals the cost of alkalinity x 2 to account for the other four factors. Treatment for manganese generally doubles the total cost. So the cost of AMD treatment at a given site can be described by equation 1:

equation 1: $\textit{AMD Cost} = S+C+A+O+D$

There are many ways to estimate environmental benefits. In this study, recovered stream miles were used. Recovered stream miles were determined by estimating the miles of stream that would be neutralized as a result of a project. Thus, the environmental efficiency of a treatment program would be described by equation 2:

equation 2: *Environmental efficiency = AMD Cost/ Recovered stream miles*

Treatment efficiency, on the other hand, estimates the amount of AMD treatment that will be achieved per dollar invested in a project. It is determined by dividing the AMD treatment cost by the tons of acid load removed by a project. See equation 3:

equation 3: *Treatment efficiency= AMD Cost/Tons of acid load removed*

Viewed in a Statewide context, the Special Reclamation Fund is the largest of many programs that treat AMD. Others include: the AML program, 10% set aside program, Clean Streams program, Watershed Cooperative Agreements, CWA sec. 319 program. All of these programs play a role in meeting watershed remediation objectives as outlined under CWA sec 303. TMDL and TMDL implementation programs. All of these programs will ultimately be evaluated according to their environmental efficiency.

This study is meant to highlight significant differences between at source and in stream treatment. It is not meant to provide an exhaustive estimate of treatment costs at any particular site. Thus, every attempt was made to apply a consistent approach to cost estimation within the limitations of the site data.

Methods

A comparison of AMD treatment costs was made related to the following scenarios:

- Single AMD sources

- Multiple AMD sources
- Manganese sources.

Actual field sites and their associated data were selected in conjunction with WVDEP from the list of planned Special Reclamation projects. Seven sites were selected:

- Daugherty, 192-77, Preston County
- Daugherty, 17-81, Preston County
- Rockville Mining, S-91-85, Preston County
- Hunt Coal, Inc., U-5071-86, Logan County
- Coal X, Inc., UO-396, Logan County
- C&C Co., UO-36, Logan County
- B&S O-43-84, Nicholas County

In each case, the impact on the receiving stream was estimated by calculating the acid and metal load reductions and the resulting impact on the receiving stream. Metal load reductions were assumed consistent with the site's NPDES permit. The study focused on watersheds with available in-stream monitoring data. An acid/base loading model was used to estimate recovered stream miles.

The WVDEP Special Reclamation Program relies almost solely on calcium oxide dosers. By statute DEP is required to treat discharges within the permit boundaries to technology based standards:

Table 1. Technology Based Limits-New Source Coal Mine. From USEPA Clean Water Act- NPDES Program: WV Code, ch. 20, article 5A, Water Pollution Control Act.

	Active		Post-Mining			
			Underground Mine		Surface/Prep/Refuse	
Parameter	acid	alkaline	Acid	alkaline	acid	alkaline
pH	6-9 *	6-9	6-9	6-9	6-9	6-9
Fe	3.0/6.0	3.0/6.0	3.0/6.0	3.0/6.0		
Mn	2.0/4.0	NA.	2.0/4.0	NA.		
TSS	35.0/70.0	35.0/70.0	35.0/70.0	35.0/70.0		
settlable solids					0.5	0.5

* monthly average./daily maximum

The treatment alternative included placement of dosers at strategic points in the watershed. Only dosers charged with calcium oxide were considered for both on site and in stream treatment scenarios. Cost estimates were based on the OSMRE software package AMD Treat. For at source treatment schemes the following cost centers were included in the analysis:

- Capital Costs:

  - doser installation, pond construction, roads, land access, ditching, engineering
- Annual Costs:
  - water sampling, labor, operations and maintenance, chemical, sludge removal.

The same cost centers were included for in stream schemes except that in-stream treatment implies that sludge will not be collected. Therefore, the costs of pond construction and sludge removal were not included in the in-stream option.

Definitions and Data Interpretation

Within project sites, each WVDEP sampling station was assumed to require separate treatment facilities. Each treatment unit consisted of a lime doser with either a one or a 35 ton bin as determined by the annual acid load. The cost difference between large and small dosers was $60,000 according to AMD Treat. The design included a single sludge collection pond downstream of each doser. AMD Treat relies heavily on flow and acidity to estimate chemical dosage rates and pond sizing. Dissolved metal concentrations and pH are secondary input parameters. They were used to calculate acidity based on the following formula:

$$\text{acidity (mg/L)} = 50*((3x[Fe]/56)+(3x[Al]/27)+(2x[Mn/55)+(1000*10^{-pH}))$$

where acidity is expressed in calcium carbonate equivalents.

The above formula was also used to ensure that acidity estimates and metal concentrations were consistent. The nominal water quality parameters are included in table 2. It was assumed that each site would require 3,000 ft. of road construction. The costs of piping, pipe welding and trenching were not included in the analysis.

Stream mile recovery was based on the length of the affected stream. It was taken as 100% of stream length in the case of on site treatment. In-stream treatment resulted in removal of one half mile of affected channel due to metal precipitation. In reality, this length will be a function of metal loading, flow and channel characteristics. In streams with low metal loadings the affected length will be minor whereas it may well extend beyond a half mile in heavily contaminated streams.

Results

Six cost tables were assembled using AMD Treat that included combinations of acidity from 50 to 500 mg/L and flows from 10 to 240 gpm. Output includes capital and annual costs (table 2). This allows rapid estimation of costs for each treatment unit. These treatment costs were based on WVDEP data for each site. These data were used to develop average site water qualities and flows for study sites (table 3a) and for six completed Special Reclamation sites (table 3b). The seven study sites were then classified according to the following: 1) single AMD discharge, 2) multiple AMD discharges and 3) manganese only discharges. Table 4 indicates treatment costs for each of these discharges, combined capital and annual costs over an arbitrary 20 year period, miles of stream recovered and two estimates of performance: dollars per mile of stream recovered and acid load removal efficiency.

Stream recovery was based on water quality upstream of the treated discharge. Most sites contained acidic water upstream of the special reclamation site. In these cases treating the discharge to compliance levels would not result in additional recovered habitat in any of the cases evaluated. However, Hunt Coal in Logan County had sites that, appeared to be singular AMD sources to short streams that discharged directly to the Guyandotte River, so treatment of the special reclamation site was credited with recovering the full length of these tributaries to the Guyandotte River.

Only one manganese discharge site was presented: B&S Coal in Nicholas County. The discharge resulted in a Mn concentration of 0.16 mg/L downstream in Muddlety Creek and the discharge channels were less than 0.1 mi. long. Costs were developed directly from AMD Treat and are presented in table 3a.

The results were summarized and sorted according to total project cost, stream recovery, stream recovery cost and acid load removal efficiency (table 5). The lowest costs were associated with projects that had a single source of AMD, or Mn and that were treated at source. Multiple sources were more costly while in stream treatment always resulted in treatment of much higher acid loads. In-stream treatment also resulted in the highest number of recovered stream miles with many of the at source treatments resulting in little or no stream recovery.

In-stream treatment also resulted in the fewest dollars invested per recovered stream mile. Finally when the sites were sorted by acid removal efficiency, in stream treatment resulted in the lowest cost per ton of acid load removed. The lowest treatment efficiencies were observed at the manganese treatment site (B&S) and a site with multiple AMD sources treated at source (C&C Co.).

Discussion

The data presented in this study were based on the results of monitoring reports and a site topo map. The results are not meant to indicate actual site costs; rather they are presented to allow a comparison of order of magnitude costs between several treatment scenarios. Comparisons between actual site costs, and estimates based on the methods used in this study indicate large differences reflecting the strong influence of site specific factors such as topography, access, condition of the road network, piping distances and opportunities for consolidating multiple discharges into single treatment units.

AMD Treat was used throughout to estimate treatment costs. As applied, it tended to underestimate on site treatment costs (there were no comparable, actual costs for in stream dosing). For example, storage of calcium oxide in the doser hoppers is limited to about 120 days. Longer residence times may result in moisture absorption and jamming.

This, and the need to monitor multiple sites leads to the need for nearly year around access, snow plowing and other maintenance. These costs are not included in this analysis.

In addition, in stream flow data were only available for three of the seven sites limiting the number of in stream treatment assessments that could be developed. In stream options were also focused on the immediate receiving stream. It is likely that the efficiency of in stream treatment would increase with the size of the affected watershed. This would increase the number of recovered stream miles while allowing optimal placement of dosers along paved, public roads.

Nonetheless, differences among treatment settings were large enough to allow several conclusions that may influence application of the Special Reclamation Fund.

Conclusions

The study demonstrated that it is possible to classify treatment settings according to performance related to the following parameters (see table 5):

- Total treatment cost. Treatment costs were always least where single treatment units could be installed versus multiple treatment units. This applied to all on site treatment settings and to all but one in-stream treatment site. The later cost was a function of exceptionally high acid loads. Twenty year project costs ranged from $459,000 to $2,858,000. The Mn site was among the least expensive treatment sites.

- Stream miles recovered. In stream treatment resulted in much higher stream recoveries (1.5 to 2.5 miles) while at source treatment stream recoveries were always less (0.1 to 0.8 miles). The Mn treatment resulted in negligible stream recovery.

- Environmental efficiency (stream recovery cost). Stream recovery costs ranged from $14,500 to $285,000/recovered stream mile. Efficiencies were highest in the three in stream settings and were lowest on sites with multiple AMD sources treated at source. Treatment at the Mn site resulted in one of the least efficient uses of funds with a cost of $280,000/stream mile recovered.

- Acid removal efficiency. All three of the most efficient sites with respect to AMD treatment were in stream dosing units. Costs per ton of acid load treated ranged from $175 to $1,478 while at source treatment efficiencies ranged from $2,200 to $272,000.

These results indicate a strong relationship between at source treatment and lower environmental and treatment efficiencies. They also indicate that in stream treatment does not necessarily result in higher total project costs even though in stream treatment always treated higher pollutant loads.

Table 2. Cost table used in calculating capital and operating costs for on site AMD treatment based on acidity and flow. The costs are based on OSMRE's AMD Treat software. The table lists cost centers under capital and annual costs. Calcium oxide doser technology was used in all cases. Nominal pH and metal concentrations are included to yield a given acidity value. In stream treatment costs were also calculated from AMD Treat excluding pond construction and sludge removal cost centers

Capital Costs: installation, pond construction, roads, land access, ditching, engineerin
Annual Costs: sampling, labor, O&M, chemical, sludge remova

acidity	Fe	Mn	Al	pH
501	35	1	70	3.5
acidity	flow	load	capital costs	annual costs
500	10	11	65,698	20,018
500	20	22	65,698	23,557
500	30	33	65,698	27,094
500	40	44	65,698	30,631
500	50	55	65,698	34,169
500	60	66	83,599	38,277
500	70	77	83,982	41,827
500	80	88	84,817	45,390
500	90	99	85,652	48,954
500	100	110	86,488	52,520
500	110	121	87,322	56,083
500	120	132	88,156	59,647
500	130	143	88,991	63,212
500	140	154	89,826	66,776
500	150	165	90,660	70,339
500	160	176	91,495	73,904
500	170	187	92,329	77,468
500	180	198	93,162	81,032
500	190	209	93,996	84,597
500	200	220	94,813	88,161
500	210	231	95,665	91,726
500	220	242	96,499	95,289
500	230	253	97,332	98,853
500	240	264	98,166	102,418

acidity	Fe	Mn	Al	pH
401	31	1	54	3.5
acidity	flow	load	capital costs	annual costs
400	10	9	65,698	19,912
400	20	18	65,698	23,344
400	30	26	65,698	26,755
400	40	35	65,698	30,206
400	50	44	65,698	33,638
400	60	53	83,599	37,639
400	70	62	83,599	41,071
400	80	70	84,104	44,517
400	90	79	84,850	47,971
400	100	88	85,597	51,427
400	110	97	86,342	54,882
400	120	106	87,088	58,337
400	130	114	87,834	61,792
400	140	123	88,579	65,247
400	150	132	89,324	68,702
400	160	141	90,070	72,158
400	170	150	90,815	75,612
400	180	158	91,561	79,067
400	190	167	92,305	82,523
400	200	176	93,051	85,977
400	210	185	93,796	89,433
400	220	194	94,541	92,887
400	230	202	95,286	96,342
400	240	211	96,031	99,797

acidity	Fe	Mn	Al	pH
299	22	1	40	3.5
acidity	flow	load	capital costs	annual costs
300	10	7	65,698	19,790
300	20	13	65,698	23,099
300	30	20	65,698	26,408
300	40	26	65,698	29,717
300	50	33	65,698	33,026
300	60	40	83,599	36,905
300	70	46	83,599	40,214
300	80	53	83,599	43,523
300	90	59	83,929	46,842
300	100	66	84,574	50,172
300	110	73	85,217	53,501
300	120	79	85,861	56,831
300	130	86	86,505	60,160
300	140	92	87,149	63,490
300	150	99	87,792	66,819
300	160	106	88,436	70,149
300	170	112	89,078	73,478
300	180	119	89,722	76,807
300	190	125	90,365	80,137
300	200	132	91,009	83,466
300	210	139	91,651	86,796
300	220	145	92,294	90,125
300	230	152	92,937	93,455
300	240	158	93,580	96,784

acidity	Fe	Mn	Al	pH
200	16	1	25	3.5
acidity	flow	load	capital costs	annual costs
200	10	4	65698	19678
200	20	9	65698	22876
200	30	13	65698	26073
200	40	18	65698	29270
200	50	22	65698	32468
200	60	26	83599	36235
200	70	31	83599	39433
200	80	35	83599	42630
200	90	40	83599	45827
200	100	44	83639	49026
200	110	48	84189	52240
200	120	53	84740	55455
200	130	57	85290	58670
200	140	62	85840	61885
200	150	66	86391	65094
200	160	70	86941	68309
200	170	75	87491	71524
200	180	79	88041	74737
200	190	84	88591	77953
200	200	88	89141	81167
200	210	92	89690	84383
200	220	97	90240	87597
200	230	101	90790	90812
200	240	106	91340	94033

acidity	Fe	Mn	Al	pH
100	10	1	10	3.5
acidity	flow	load	capital costs	annual costs
100	10	2	65698	19566
100	20	4	65698	22653
100	30	7	65698	25738
100	40	9	65698	28823
100	50	11	65698	31910
100	60	13	83599	35565
100	70	15	83599	38651
100	80	18	83599	41736
100	90	20	83599	44822
100	100	22	83599	47908
100	110	24	83599	50993
100	120	26	83617	54079
100	130	29	84074	57180
100	140	31	84532	60279
100	150	33	84988	63380
100	160	35	85455	66480
100	170	37	85902	69580
100	180	40	86359	72681
100	190	42	86815	86781
100	200	44	87272	78881
100	210	46	87728	81981
100	220	48	88185	85082
100	230	51	88641	88181
100	240	53	89098	91282

acidity	Fe	Mn	Al	pH
50	7	1	5	4.5
acidity	flow	load	capital costs	annual costs
50	10	1	65698	19566
50	20	2	65698	22653
50	30	3	65698	25738
50	40	4	65698	28823
50	50	6	65698	31910
50	60	7	83599	35565
50	70	8	83599	38651
50	80	9	83599	41736
50	90	10	83599	44822
50	100	11	83599	47908
50	110	12	83599	50993
50	120	13	83617	54079
50	130	14	84074	57180
50	140	15	84532	60279
50	150	17	84988	63380
50	160	18	85445	66480
50	170	19	85902	69580
50	180	20	86359	72681
50	190	21	86815	75781
50	200	22	87272	78881
50	210	23	87728	81981
50	220	24	88185	85082
50	230	25	88641	88181
50	240	26	89098	91282

Table 3a. Summary of flows and water quality at each of the study sites.

192-77 WVDEP sample #	DAUGHERTY	Gum Run of Cheat River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
2071	Total of seeps flowing into pond #211	1.6	487.3	1.4
2075	outlet of ALD at Site #6	2.5	377.4	2.5
207	Pond in hollow on east side of South site	14.4	335.5	12.0
51	Mouth of UNT of Gum Run	391.8	354.4	309.3
50	Mouth of Gum Run	626.7	162.2	253.4
	totals: At source treatment	14.4		12.0
	In Stream Doser in Gum Run	626.7	162.2	253.4

17-81 sample #	DAUGHERTY	Cheat River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
267	Pond on east side of North site	18.8	613.3	26.6
2671	Seep into pond #267 on South side	12.0	288.7	7.1
2672	Seep into pond #267 on West side	7.5	441.9	7.0
	totals: At source treatment	18.8		26.6
	No in stream data, cannot estimate in stream treatment option.			

S-91-85 WVDEP sample #	ROCKVILLE MINING	Martin Creek of Cheat River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
2	Discharge pond #3	4.8	1343.6	5.5
3	Discharge pond #5	8.3	271.4	5.2
4	Discharge pond #4	40.0	388.4	32.6
5	Discharge pond #5 into sediment ditch	47.4	156.5	12.0
55	seep to diversion ditch to Pond #5	2.0	610.0	2.7
	totals: At source treatment	102.5		57.9
	In Stream Doser in Martin Creek to Glade	2384.0	63.0	330

U-5071-86 WVDEP sample #	HUNT COAL, INC.	Guyanndotte River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
1	Mine Discharge	8.4	532.3	12.4
2	Seep from fill	0.3	246.3	0.2
	totals: At source treatment	8.8		12.6
	Discharges directly to Guyandotte River, No in Stream treatment option			

UO-396 WVDEP sample #	COAL X, INC.	Sandlick Ck. of Guyanndotte River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
2	Pond Discharge	9.3	120.0	2.6
3	Above on Sandlick Ck.	33.3	397.7	23.6
4	Below on Rt. Fk. Sandlick Ck.	35.0	41.8	10.1
	totals: At source treatment	9.3		2.6
	In Stream Doser in Sandlick Ck.	33.3	397.7	23.6

UO-36 WVDEP sample #	C & C COMPANY	Unnamed trib. of Guyandotte River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
1	Upstream Drain	2.0	203.0	0.9
2	Downstream Drain	2.0	6.8	0.03
3	Eliminated Pond above road crossing.	62.3	11.0	1.5

O-43-84 WVDEP sample #	B & S	Muddlety Creek of Gauley River flow (gpm)	calc acid (mg/L)	acid load (tons/year)
1	Effluent from sediment pond at O-3086-87	27.2	31.7	1.9
10	Downstream Muddlety Creek	23,511	-28.9	32.4

Table 3b. Estimated costs of six Special Reclamation Projects using the cost estimation parameters of this study.

S-10-81 | Ed-E Development Co., Inc. | Brains Ck. of Fields Ck. Of Three Forks Ck., of Tygart Valley R.

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Acid Load Removal Efficiency ($/ton)
Total of seeps 1,2,3	26.0	1353.9	77.4	$ 126,920	$ 24,071	$ 608,340	$ 393
Seep 4	6.0	935.0	12.3	$ 126,920	$ 19,291	$ 512,740	$ 2,077
totals: At source treatment	32.0		89.8	$ 253,840	$ 43,362	$ 1,121,080	$ 624

S-1032-86 | Ed-E Development Co., Inc. | Cheat River

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Acid Load Removal Efficiency ($/ton)
Seep	7.0	850.0	13.1	$ 126,920	$ 24,071	$ 608,340	$ 2,324
totals: At source treatment	7.0		13.1	$ 126,920	$ 24,071	$ 608,340	$ 2,324

EM-32 | Borgman Coal Co. | Heather Run of Cheat River

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Acid Load Removal Efficiency ($/ton)
UG mine seals and seeps	31.0	400.0	27.3	$ 126,920	$ 20,706	$ 541,040	$ 992
totals: At source treatment	31.0		27.3	$ 126,920	$ 20,706	$ 541,040	$ 992

S-26-85 | Wocap Energy Resources | UNT of Church Run of Cheat River

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Acid Load Removal Efficiency ($/ton)
Mine Discharge	35.0	1030.0	79.3	$ 132,631	$ 24,997	$ 632,571	$ 399
totals: At source treatment	35.0		79.3	$ 132,631	$ 24,997	$ 632,571	$ 399

S-176-77 | Interstate lumber Co. | Roaring Ck. Of Cheat River

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Acid Load Removal Efficiency ($/ton)
Mine Discharge	25.0	93.8	5.2	$ 132,340	$ 19,588	$ 524,100	$ 5,079
totals: At source treatment	25.0		5.2	$ 132,340	$ 19,588	$ 524,100	$ 5,079

S-60-84 | Hidden Valley Coal Co. | UNT of Mill Run of Little Sandy Ck.

	flow (gpm)	hot acidity (mg/L)	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Removal Efficiency ($/ton)
Mine Discharge	19.0	73.0	3.1	$ 132,420	$ 19,372	$ 519,860	$ 8,518
totals: At source treatment	19.0		3.1	$ 132,420	$ 19,372	$ 519,860	$ 8,518

Table 4. Summary of costs and evaluation parameters for each study site.

Single AMD discharge

192-77	DAUGHERTY	Gum Run of Cheat River						
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
2071	Total of seeps flowing into pond #211	1.4						
2075	outlet of ALD at Site #6	2.5						
207	Pond in hollow on east side of South site	12.0	$ 65,689	$ 23,344	$ 532,569	0.3	$ 106,514	$ 2,211
51	Mouth of UNT of Gum Run	309.3						
50	Mouth of Gum Run	253.4						
	totals: At source treatment	12.0	$ 65,689	$ 23,344	$ 532,569	0.3	$ 106,514	$ 2,211
	In Stream Doser in Gum Run	253.4	$ 146,291	$ 36,944	$ 885,171	2.0	$ 22,129	$ 175

UO-396	COAL X, INC.							
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
2	Pond Discharge	2.6	$ 65,698	$ 19,678	$ 459,258	0.5	$ 45,926	$ 8,714
3	Above on Sandlick Ck.	23.6						$ -
4	Below on Rt. Fk. Sandlick Ck.	10.1						$ -
	totals: At source treatment	2.6	$ 65,698	$ 19,678	$ 459,258	0.1	$ 229,629	$ 8,714
	In Stream Doser in Sandlick Ck.	23.6	$ 94,325	$ 30,206	$ 698,445	2.4	$ 14,551	$ 1,478

Multiple AMD discharges

17-81	DAUGHERTY	Cheat River						
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
267	Pond on east side of North site	26.6	$ 65,689	$ 23,557	$ 536,829	0.25	$ 107,366	$ 1,009
2671	Seep into pond #267 on South side	7.1	$ 65,689	$ 23,099	$ 527,669	0.25	$ 105,534	$ 3,730
2672	Seep into pond #267 on West side	7.0	$ 65,689	$ 20,018	$ 466,049	0.25	$ 93,210	$ 3,343
	totals: At source treatment	26.6	$ 197,067	$ 66,674	$ 1,530,547	0.75	$ 102,036	$ 2,875
	No in stream data, cannot estimate in stream treatment option.							

S-91-85	ROCKVILLE MINING							
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
2	Discharge pond #3	5.5	$ 65,698	$ 18,026	$ 426,218	0.1	$ 213,109	$ 3,895
3	Discharge pond #5	5.2	$ 65,698	$ 19,790	$ 461,498	0.1	$ 230,749	$ 4,468
4	Discharge pond #4	32.6	$ 125,698	$ 30,206	$ 729,818	0.1	$ 364,909	$ 1,120
5	Discharge pond #5 into sediment ditch	12.0	$ 125,698	$ 32,468	$ 775,058	0.1	$ 387,529	$ 3,238
55	seep to diversion ditch to Pond #5	2.7	$ 65,698	$ 20,018	$ 466,058	0.1	$ 233,029	$ 8,596
	totals: At source treatment	57.9	$ 448,490	$ 120,508	$ 2,858,650	0.5	$ 285,865	$ 2,468
	In Stream Doser in Martin Creek to Glade	330.4	$ 94,325	$ 91,601	$ 1,926,345	2.5	$ 38,527	$ 291

U-5071-86	HUNT COAL, INC.							
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
1	Mine Discharge	12.4	$ 65,698	$ 20,018	$ 466,058	0.1	$ 466,058	$ 1,873
2	Seep from fill	0.2	$ 65,698	$ 19,790	$ 461,498	0.1	$ 184,599	$ 132,834
	totals: At source treatment	12.6	$ 131,396	$ 39,808	$ 927,556	0.2	$ 265,016	$ 3,676
	Discharges directly to Guyandotte River, No in Stream treatment option							

UO-36	C & C COMPANY							
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
1	Upstream Drain	0.9	$ 65,698	$ 19,678	$ 459,258	0.5	$ 45,926	$ 25,514
2	Downstream Drain	0.03	$ 65,698	$ 19,566	$ 457,018	0.5	$ 45,702	$ 765,141
3	Eliminated Pond above road crossing.	1.5	$ 83,599	$ 35,565	$ 794,899	0.5	$ 79,490	$ 26,288
	totals: At source treatment	2.4	$ 214,995	$ 74,809	$ 1,711,175	1.5	$ 57,039	$ 272,314
	Unsufficient upstream flow to allow in stream option							

Manganese only discharges

O-43-84	B & S							
WVDEP sample #	SITE_DESC	acid load (tons/year)	Capital cost	Annual cost	Cost of Treatment ($/20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
1	Effluent from sediment pond at O-3086-87	1.9	$ 65,689	$ 24,779	$ 561,269	0.10	$ 280,635	$ 14,635
10	Downstream Muddlety Creek	32.4						
	totals: At source treatment	1.9	$ 65,689	$ 24,779	$ 561,269	0.10	$ 280,635	$ 14,635

Table 5. Results of cost and benefit analyses sorted according to total 20 year project costs, stream miles recovered, cost per stream mile recovered and acid removal efficiency.

Site	Treatment Scenario	acid load (tons/year)	Cost of Treatment ($ per 20 years)	Stream recovery (miles)	Stream Recovery Cost ($/mile/year)	Acid Load Removal Efficiency ($/ton)
Sort by 20 year treatment cost						
COAL X, INC. UO-396	single AMD, at source	2.6	$ 459,258	0.1	$ 229,629	$ 8,714
DAUGHERTY 192-77	single AMD, at source	12.0	$ 532,569	0.3	$ 106,514	$ 2,211
B&S O-43-84	Mn, at source	1.9	$ 561,269	0.1	$ 280,635	$ 14,635
COAL X, INC. UO-396	single AMD, in stream	23.6	$ 698,445	2.4	$ 14,551	$ 1,478
DAUGHERTY 192-77	single AMD, in stream	253.4	$ 885,171	2.0	$ 22,129	$ 175
HUNT COAL, INC. U-5071-86	multiple AMD, at source	12.6	$ 927,556	0.2	$ 265,016	$ 3,676
DAUGHERTY 17-81	multiple AMD, at source	26.6	$ 1,530,547	0.8	$ 102,036	$ 2,875
C&C Co. UO-36	multiple AMD, at source	2.4	$ 1,711,175	1.5	$ 57,039	$ 272,314
ROCKVILLE MINING S-91-85	multiple AMD, in stream	330.4	$ 1,926,345	2.5	$ 38,527	$ 291
ROCKVILLE MINING S-91-85	multiple AMD, at source	57.9	$ 2,858,650	0.5	$ 285,865	$ 2,468
Sort by stream miles recovered						
COAL X, INC. UO-396	single AMD, at source	2.6	$ 459,258	0.1	$ 229,629	$ 8,714
B&S O-43-84	Mn, at source	1.9	$ 561,269	0.1	$ 280,635	$ 14,635
HUNT COAL, INC. U-5071-86	multiple AMD, at source	12.6	$ 927,556	0.2	$ 265,016	$ 3,676
DAUGHERTY 192-77	single AMD, at source	12.0	$ 532,569	0.3	$ 106,514	$ 2,211
ROCKVILLE MINING S-91-85	multiple AMD, at source	57.9	$ 2,858,650	0.5	$ 285,865	$ 2,468
DAUGHERTY 17-81	multiple AMD, at source	26.6	$ 1,530,547	0.8	$ 102,036	$ 2,875
C&C Co. UO-36	multiple AMD, at source	2.4	$ 1,711,175	1.5	$ 57,039	$ 272,314
DAUGHERTY 192-77	single AMD, in stream	253.4	$ 885,171	2.0	$ 22,129	$ 175
COAL X, INC. UO-396	single AMD, in stream	23.6	$ 698,445	2.4	$ 14,551	$ 1,478
ROCKVILLE MINING S-91-85	multiple AMD, in stream	330.4	$ 1,926,345	2.5	$ 38,527	$ 291
sort by stream recovery cost						
COAL X, INC. UO-396	single AMD, in stream	23.6	$ 698,445	2.4	$ 14,551	$ 1,478
DAUGHERTY 192-77	single AMD, in stream	253.4	$ 885,171	2.0	$ 22,129	$ 175
ROCKVILLE MINING S-91-85	multiple AMD, in stream	330.4	$ 1,926,345	2.5	$ 38,527	$ 291
C&C Co. UO-36	multiple AMD, at source	2.4	$ 1,711,175	1.5	$ 57,039	$ 272,314
DAUGHERTY 17-81	multiple AMD, at source	26.6	$ 1,530,547	0.8	$ 102,036	$ 2,875
DAUGHERTY 192-77	single AMD, at source	12.0	$ 532,569	0.3	$ 106,514	$ 2,211
COAL X, INC. UO-396	single AMD, at source	2.6	$ 459,258	0.1	$ 229,629	$ 8,714
HUNT COAL, INC. U-5071-86	multiple AMD, at source	12.6	$ 927,556	0.2	$ 265,016	$ 3,676
B&S O-43-84	Mn, at source	1.9	$ 561,269	0.1	$ 280,635	$ 14,635
ROCKVILLE MINING S-91-85	multiple AMD, at source	57.9	$ 2,858,650	0.5	$ 285,865	$ 2,468
Sort by acid removal efficiency						
DAUGHERTY 192-77	single AMD, in stream	253.4	$ 885,171	2.0	$ 22,129	$ 175
ROCKVILLE MINING S-91-85	multiple AMD, in stream	330.4	$ 1,926,345	2.5	$ 38,527	$ 291
COAL X, INC. UO-396	single AMD, in stream	23.6	$ 698,445	2.4	$ 14,551	$ 1,478
DAUGHERTY 192-77	single AMD, at source	12.0	$ 532,569	0.3	$ 106,514	$ 2,211
ROCKVILLE MINING S-91-85	multiple AMD, at source	57.9	$ 2,858,650	0.5	$ 285,865	$ 2,468
DAUGHERTY 17-81	multiple AMD, at source	26.6	$ 1,530,547	0.8	$ 102,036	$ 2,875
HUNT COAL, INC. U-5071-86	multiple AMD, at source	12.6	$ 927,556	0.2	$ 265,016	$ 3,676
COAL X, INC. UO-396	single AMD, at source	2.6	$ 459,258	0.1	$ 229,629	$ 8,714
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C&C Co. UO-36	multiple AMD, at source	2.4	$ 1,711,175	1.5	$ 57,039	$ 272,314