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Methodology for Estimating the Costs of Treatment of Mine Drainage

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ABSTRACT: Tetra Tech developed worksheets for the U.S. Department of the Interior, Office of Surface Mining (OSM) to allow a consistent, accurate, and rapid method of estimating the costs of long-term treatment of mine drainage at coal mines, in accordance with the Surface Mining Control and Reclamation Act (SMCRA) of 1977. This paper describes the rationale for the worksheets and how they can be used to calculate costs for site-specific conditions. Decision trees for selection of alternative treatments for acidic or alkaline mine drainage are presented.

1 INTRODUCTION

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) established bonding requirements for operators of coal mines. Regulations under SMCRA require that operators of coal mines prepare site-specific estimates of the costs of reclaiming areas affected by mining operations and managing any pollutants mat may emanate from them. The cost estimates are reviewed by me U.S. Department of the Interior, Office of Surface Mining (OSM) or authorized state regulatory authorities to determine the amount of bonding that is necessary for reclamation activities at each mine. OSM has determined that the estimated costs of reclamation for a number of coal mines have been significantly lower than the actual costs of completing reclamation activities at those facilities. To a large extent, such discrepancies have been the result of failures in the development of reasonable estimates for the long-term treatment of mine drainage-

Acid mine drainage (AMD) forms when sulfide minerals in rocks are exposed to oxidizing conditions. AMD is found İn coal mining and metal mining areas and also in highway embankments where sulfides in geologic materials are exposed to water and oxygen. The predominant acid-producing minerals are pyrite and marcasite. Significant work in methods of predicting, controlling, and treating AMD has been done by Skousen (1996, 1998) at West Virginia University and by the Pennsylvania Department of Environmental Resources (1998). Earle and Callaghan (1998) have described the effects of AMD on aquatic life, on potable and industrial water supplies, and on metal and concrete structures. In an effort to prevent the adverse effects of AMD in the future and hold companies that produce AMD responsible for their actions, OSM contracted with Tetra Tech EM Inc. (Tetra Tech) to develop a methodology for estimating the long-term costs of treating mine drainage. Costs determined through the use of the methodology will serve as the basis for establishing the bonding requirements for coal mine operators.

2 TECHNOLOGIES FOR PREVENTION AND REMEDIATION OF AMD

Coal mine operators are required to meet the discharge permit requirement established under the National Pollution Discharge Elimination System (NPDES). NPDES permits for coal mines generally require the monitoring of pH, total suspended solids, and concentrations of iron and manganese. Depending on the drainage quality of the particular site, monitoring of other parameters may be required. The technologies for preventing and remediating AMD include the following:

- Source control by addition of alkaline substances, capping of acid-producing materials, hydrologie controls, or grouting (for underground mines)
- Active treatment by neutralization processes and aeration basins
- Passive treatment by alkalinity-producing diversion wells, anoxic limestone drains, or aerobic or anaerobic wetlands

The life-cycle costs of the technologies vary considerably, with active treatment methods the most expensive and passive treatment systems the least. The selection of a technology depends on several site-specific conditions, including the quality and quantity of mine drainage to be treated and the discharge requirements to be satisfied. There are two types of mine drainage, net acidic and net alkaline. Net acidic mine drainage occurs under conditions under which the total acidity of the drainage exceeds its total alkalinity, while net alkaline drainage occurs under conditions under which total acidity is less than total alkalinity. Figures 1 and 2 provide decision trees to assist the user in identifying alternative treatment technologies for net acidic mine drainage and net alkaline mine drainage, respectively.

3 COST-ESTIMATING METHODOLOGY

The methodology described in this paper can be used to estimate the costs of long-term treatment of mine drainage for both new and existing mining operations.

To generate cost estimates for the treatment of mine drainage, the methodology uses third-party costs and assumes that the materials and equipment required to conduct each activity will be brought to the site. Although the operator may have equipment and materials available to conduct such activities while the facility İs operational, there is no guarantee that the same equipment or materials will be available to a regulatory autfiority once a facility has been abandoned. Therefore, use of third-party costs is essential to the development of a cost estimate that reflects a "reasonable worst-case scenario" and to ensure that financial assurance mechanisms can be counted upon to provide regulatory authorities with sufficient funds to conduct the necessary mine drainage treatment activities.

The methodology provides a variety of worksheets that can be used to estimate the costs of specific activities that are known to be conducted in treating mine drainage at coal mines. It is unlikely, however, that all of the worksheets provided in the methodology will be needed to estimate the costs for treating mine drainage for any particular site. In applying the methodology, die user must select from among the available worksheets only those that pertain to activities mat will be conducted to address mine drainage at the particular site of concern. The decision trees presented in figures 1 and 2 will assist the user in making that selection. Once the worksheets for each specific activity have been completed, the costs estimated for those activities are combined on unit summary worksheets to derive a cost estimate for each unit, then combined on a site summary worksheet to derive a comprehensive cost estimate for the site.

Because the types of activities that may be necessary to address mine drainage may vary significantly from one site to the next, and because it might be necessary to conduct unusual or uncommon activities at some sites to address the specific circumstances at those sites, the methodology may not include worksheets that address all the activities that may be necessary at any given site. In such cases, cost estimates for unusual or uncommon activities should be developed through the use of alternative approaches.

The methodology as currently designed is a general approach to estimating costs. The issue of treatment cost versus time and reduction of acidity loading over time can be addressed by using different time frames, flow rates, and acidity to run the model, according to site-specific conditions.

Worksheets are the primary tools the methodology provides to help estimate the costs of treating the mine drainage. The methodology presents seven categories of cost worksheets, each of which corresponds to one of various activities that might be undertaken to address discharges of mine drainage at coal mines. The categories of worksheets are: 1) source control, 2) active treatment, 3) passive treatment, 4) general treatment and polishing units, 5) discharge memods, 6) system operations, and 7) support activities. A site summary worksheet also is provided to sum all the costs of treatment of mine drainage that are associated with a particular site.

Many activities performed in treating mine drainage involve basic field construction work. Therefore, in the worksheets, typical construction costs Üiat most closely resemble field construction activities are used. Although several sources of information provide estimates of typical construction costs, hourly rates for labor and equipment set forth in *Mean's Cost Guides* are used frequently in the worksheets. *Mean's Cost Guides* are recognized industry standards in the United States for cost estimating. Because the guides are updated annually, the cost components of the worksheets can be updated readily, as well. When certain costs, such as those for laboratory analysis of water or soil samples, could not be found in *Mean's,* representative costs provided by a number of vendors were obtained and averaged. Costs of activities not found in *Mean's* can be established by obtaining current quotes from vendors or by interpolation of costs of similar activities obtained from the mining industries.

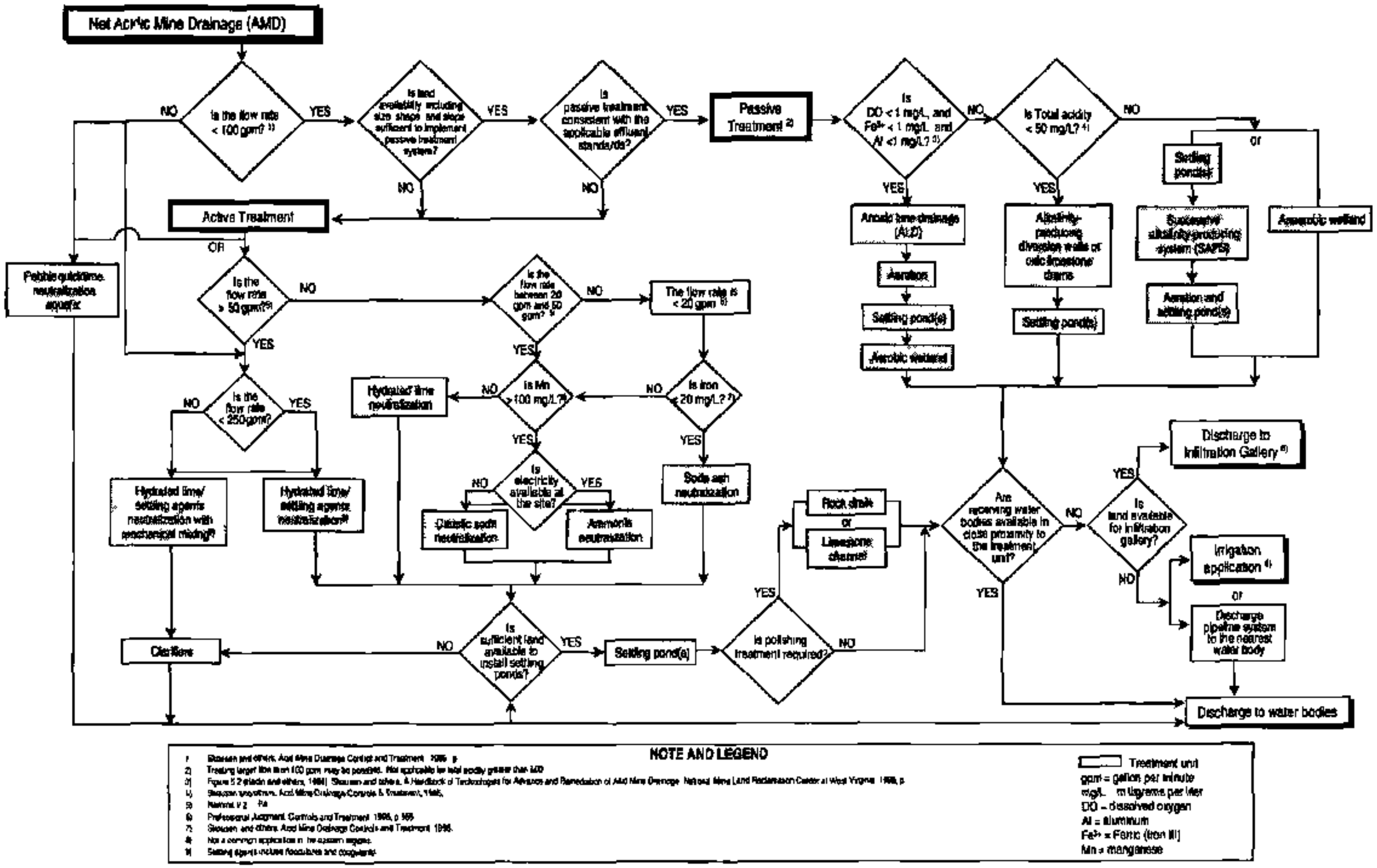

Figure 1 Decision tree for the selection of alternatives for the treatment of net acidic mine drainage

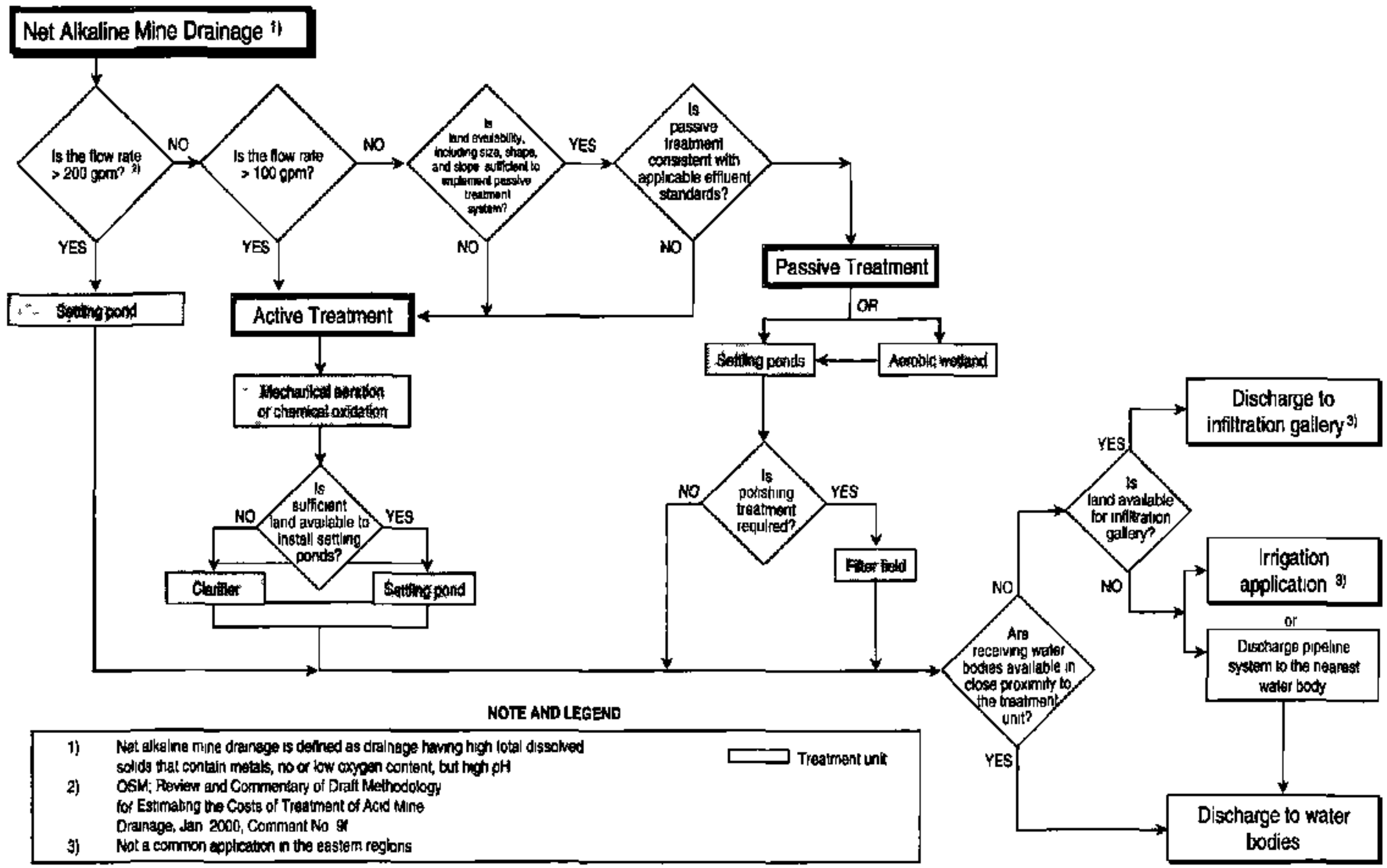

Figure 2. Decision tree for the selection of alternatives for the treatment of net alkaline mine drainage based on industry practices

In the methodology, the source control, active treatment, and passive treatment unit summary worksheets apply a factor of 16 percent to the subtotal of all capital costs to account for the costs of management and engineering design. That percentage is based on factors derived from *Mean's.* Further, in accordance with standard engineering practices, the source control, active treatment, and passive treatment unit summary worksheets apply an additional factor of 20 percent to all capital and annual operating costs to account for contingencies and unforeseen expenses that could occur during the treatment process.

The total calculated costs of source control, treatment, and system operations are adjusted to net present value to determine the long-term costs of treatment in current dollars. This method is used widely to evaluate the value of long-term investments and is useful in this analysis for determining the amount of bonding that is necessary for reclamation activities at a particular site. The three main components used m completing the net present value adjustment are:

- The number of years during which the system is expected to operate
- The annual inflation rate
- The estimated annual discount rate, which represents the cost to the owner of the facility of borrowing money

The use of different figures for years of treatment, die inflation rate, or the discount rate could have a significant effect on the cost estimate generated for an individual facility. The cost estimates are highly sensitive to small variations İn those parameters, and the user should select values carefully for the calculation of net present value to obtain the most realistic cost estimate.

4 USING THE WORKSHEETS TO ESTIMATE COSTS

The methodology is designed to offer a flexible and rapid means of generating reasonable and accurate estimates of the costs of treating mine drainage. The methodology prescribes the following four basic steps in using the worksheets to develop cost estimates.

1, Using information in the reclamation plan or other information available about the site, the user must determine the specific treatment processes that are to be conducted to address mine drainage at the site and the specific source control techniques (if any) that will be implemented. The user must also identify any conditions at the site (for example, difficult access to the site) that might require the conduct of additional activities or require capital expenditures that will add to the expense of implementing the selected treatment processes. In addition, the user must identify related data that are lacking and must be generated or assumed if a reasonable cost estimate is to be developed.

2. The user must identify and assemble all the worksheets needed to calculate the cost estimate. Table 1 identifies the worksheets for specific activities that are addressed in the methodology and that might be appropriate for the treatment of mine drainage at surface mines, underground mines, and coal refuse facilities, respectively. The user should review the applicable worksheets to become familiar with the data inputs necessary to use them and the assumptions upon which the cost data incorporated into the worksheets are based.

3. Using information in the reclamation plan or other information available about the site, the user must obtain the data that are required to use the worksheets and enter those data. The user should review all cost data that are incorporated into the worksheets to ensure that those data accurately reflect me potential tasks to be performed at the site. If necessary, the user can adjust the costs incorporated into the worksheets or replace them with other cost data that are more accurate for the site. Once all appropriate data have been entered, the user can estimate the costs of each activity by applying the method prescribed İn the worksheets.

4. The user must transfer the estimated cost of each activity to the source control, active treatment, or passive treatment summary worksheet, as appropriate, to derive cost estimates for each unit; apply allowances to those estimates to account for engineering expenses and contingencies; and adjust those estimates to net present value. The user should review the default factors applied on the source control, active treatment, or passive treatment summary worksheet to ensure that those factors are appropriate. If necessary, the user can adjust the default factors or replace them with more appropriate factors. Finally, the user must transfer the costs for each unit to the site summary worksheet to derive a comprehensive cost estimate for the site. Figure 3 provides example worksheets for active treatment; figure 4 provides example worksheets for passive treatment. Details of other worksheets are available in *Methodology for Estimating the Costs of Treatment of Mine Drainage,* prepared by Teta Tech.

Table 1. Worksheets applicable to the treatment of mine drainage at surface mines, underground mines, and coal refuse piles.

Worksheet	Code	Surface Mines			Underground Mines			Coal Refuse Piles		
		Source Control	Active Treatment	Passive Treatment	Source Control	Active Treatment	Passive Treatment	Source Control	Active Treatment	Passive Treatment
Capping of Acid-Producing Material	SC-2	•						•		
Regrading and Backfilling	SC-3	•						•		
Grouting and Mine Seals	SC-4				•					
Stormwater and Runoff	SC-5	•			•			•		
Alkaline Addition for Spoils	SC-6A/B	•			•			•		
Soda Ash Neutralization	AT-2A/B		•			•			•	
Caustic Soda Neutralization	AT-3A/B		•			•			•	
Hydrated Lime or Pebble Quicklime Neutralization	AT-4A/B		•			•			•	
Ammonia Neutralization	AT-5A/B		•			•			•	
Aeration Basins	AT-6A/B		•			•			•	
Pebble Quicklime Neutralization – Aquafix System	AT-7		•			•			•	
Alkalinity-Producing Diversion Wells	PT-2A/B			•			•			•
Anoxic Limestone Drains (ALD)	PT-3A-C			•			•			•
Successive Alkalinity-Producing Systems (SAPS)	PT-4A/B			•			•			•
Aerobic and Anaerobic Wetlands	PT-5A/B			•			•			•
Ponds	GTU-1A/B		•	•		•	•		•	•
Clarifiers	GTU-2A/B		•			•			•	
Rock Drains	GTU-3A/B		•	•		•	•		•	•
Filter Fields	GTU-4A/B		•	•		•	•		•	•
Open Limestone Channels (OLC)	GTU-5A-C		•	•		•	•		•	•
Infiltration Galleries	DM-1A/B		•	•		•	•		•	•
Irrigation Applications	DM-2A/B		•	•		•	•		•	•
Pipe Systems	DM-3		•	•		•	•		•	•
Chemical Consumption	OP-1		•	•		•	•		•	•
System Maintenance and Replacement	OP-2	•	•	•	•	•	•	•	•	•
Electricity	OP-3		•	•		•	•		•	•
Sludge Removal	OP-4		•	•		•	•		•	•
Sampling and Analysis	OP-5	•	•	•	•	•	•	•	•	•
Land Access	SW-1	•	•	•	•	•	•	•	•	•
Monitoring Wells	SW-2	•	•	•	•	•	•	•	•	•
Site Security	SW-3	•	•	•	•	•	•	•	•	•
Access Roads	SW-4		•	•		•	•		•	•

5 CONCLUSIONS

The methodology developed by Tetra Tech for OSM is user-friendly and allows an accurate determination of the amount of funds that should be provided to ameliorate AMD at coal mine sites. Recognizing that current mine operators may not be available to conduct treatment activities, the methodology reflects costs for an independent third-party to perform these activities. The methodology can be used for both new and exciting mining operations and for active and passive treatment processes. Because many treatment activities involve basic field construction work, *Means Cost Guides,* a recognized standard İn the construction industry, was selected as the basis for information for the worksheets. The worksheets also provide the flexibility for the user to modify the information for site-specific conditions.

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SODA ASH (SODIUM CARBONATE) NEUTRALIZATION

[illegible]			
	Assume that soda ash briquettes will be used		
a	Design flow rate	0.0 gpm	
b	Total acidity of mine drainage acidity	0.0 mg/L as $CaCO_3$	
c	Molar acid equivalents loading (multiply line 1a times 3 785 L/gal, times line 1b, times 0 01 mole $CaCO_3$/g $CaCO_3$, times 0 001 g/mg, times 512,640 min/year)		0 equivalents of acid/year
d	Theoretical amount of soda ash needed per equivalent of acid[a]		0 389 lb/equivalent
e	Factor to account for excess alkalinity required in the effluent (20 to 30% - OSM)	0%	
f	Actual annual amount of soda ash needed (add line 1e to 1, multiply the result by line 1c and by line 1d)		0 lbs
g	Density of soda ash briquettes	157.05 lb/ft³	
h	Annual volume of soda ash briquettes (divide line 1f by line 1g and y 27)		0 yd³
[illegible]			
	Reaction pond is assumed to be a small circular pond with the bottom diameter equal to its depth. Alternate setups are possible		
a	Porosity of soda ash briquettes (professional judgement)	40%	
b	Actual volume of reaction pond required (divide line 1h by line 1a)		0 yd³
c	Side wall slope (S)	0.5 ft rise/ft run	
d	Depth of open pit (d), calculate as $\left[\sqrt{\frac{1}{\pi\left(1+\frac{2}{S^2}\right)}}\right]$		0 ft
e	Surface area of open pit, calculate as $2\pi\left(0.5 + d\sqrt{\frac{1+S}{S^2}}\right)$		0 ft²
f	Depth of excavation (add lines 2d 3a, and 3b)		0 ft
g	Excavation volume, calculate as $\frac{\pi}{S^1}$ (then divide by 27 to yield cubic yard)		0 yd³
h	Excavation footprint, calculate as $d\,\pi\left(\frac{S+}{S}\right)$		0 ft²

Figure 3. (page 1 of 2) Example worksheet for active treatment.

SODA ASH (SODIUM CARBONATE) NEUTRALIZATION

[illegible]			
a	Thickness of clay liner (a minimum of 0 5 ft)	0 ft	
b	Thickness of liner cover	0 ft	
c	Surface area of reaction pond (line 2e)		0 ft²
d	Volume of clay compacted (multiply line 3a by line 3c and divide by 27)		0 yd³
e	Swelling factor[b]	40%	
f	Volume of clay required (add 100% to the percentage in line 3e and multiply that percentage by line 3d)		0 yd³
g	Volume of liner cover (multiply line 3b and 3c and divide by 27)		0 yd³
h	Include synthetic liner? (Y or N)	Y	
i	Surface area of synthetic liner (multiply line 2e by 1 25, a factor that accounts for liner anchor)		0 ft²
[illegible]			
a	Volume to be excavated (Line 2g)		0 yd³
b	Multiplier for clearing and grubbing (professional judgement. 200% for small site and 25% for regular site)	200%	
c	Area to be cleared in ft² (multiply line 2h by line 4b)		0 ft²
d	Area to be cleared in acres (divide line 4c by 43,560)		0 acres
e	Area to be surveyed (equal to line 4c)		0.00 acres
f	Survey rate	1 acre/day	
g	Days required to conduct survey (multiply line 4e by line 4f)		0.00 days

[a] 106 g/mole*1 mole/mole / 6 efficiency / 1000g/kg * 2 2 lb/kg

[b] U S Environmental Protection Agency *Final Guidance Manual Cost Estimates for Closure and Post-Closure Plans (Subparts G and H)* January 1987 EPA/530-SW-87 009, Volume III, pg. 7-10. Compaction factor provided is for off-site clay

ACTIVE TREATMENT **AT-2B**

INSTALLATION - Page 1 of 1

SODA ASH (SODIUM CARBONATE) NEUTRALIZATION

[illegible]				
a	Volume to be excavated (from AT-2A, line 4a)	0	yd^3	
b	Excavation footprint (from AT-2A, line 4c)	0	ft^2	
c	Unit cost of clearing and grubbing[a]	0.380	$\$/ft^2$	
d	**Total cost of clearing and grubbing (multiply line 1b by line 1c)**	0.00	$	
e	Unit cost of excavation[b]	4.330	$\$/yd^3$	
f	**Total cost of excavation (multiply line 1a by line 1e)**	0.00	$	
g	**Total Cost to Excavate Reaction Pit (add lines 1d and 1f)**			$0.00
[illegible]				
a	Volume of clay required (from AT-2a, line 3f)	0	yd^3	
b	Unit cost of purchase and placement of clay[c]	17.28	$\$/yd^3$	
c	**Total cost of clay liner (multiply line 2a by line 2b)**	0.00	$	
d	Volume of liner cover (from AT-2a, line 3g)	0	yd^3	
e	Unit cost of purchase and placement of liner cover[d]	6.57	$\$/yd^3$	
f	**Total cost for liner cover (multiply line 2d by line 2e)**	0.00	$	
g	Include synthetic liner? (Y or N)	Y		
h	Surface area of synthetic liner (from AT-2A, line 3i)	0	ft^2	
i	Unit cost of purchase and placement of synthetic liner[e]	1.73	$\$/ft^2$	
j	**Total cost of synthetic liner (multiply line 2h by line 2i)**	0.00	$	
k	**Total Cost to Line Reaction Pit (add lines 2c, 2f, and 2j)**			$0.00
[illegible]				
a	Quantity of soda ash for one year (from AT-2a, line 1f)	0	lbs	
b	Unit cost of purchase and delivery of soda ash briquettes[f]	0.140	$/lb	
c	Unit cost of filling and spreading by dozer[g]	0.0003	$/lb	
c	**Total Cost of Purchase and Delivery of a One Year Supply of Neutralization Chemical (add lines 3b and 3c, and multiply the result by line 3a)**			$0.00
TOTAL COST OF SODA ASH NEUTRALIZATION SYSTEM (add lines 1g, 2k, and 3c)				**$0.00**

[a] R.S. Means Company, Inc., *Environmental Remediation Unit Cost Data* 1999 pg. 4-1 & 4-9 Item No. 17 01 0103 and 17 03 0101 The cost is that for medium brush with average grub and some trees, clearing and rough grading with a D6 dozer

[b] R.S. Means Company, Inc., *Environmental Remediation Unit Cost Data*, 1999 pg. 4-15 Item No. 17 03 0276 The cost is that for excavation with a $1\text{-}yd^3$ crawler-mounted, hydraulic excavator

[c] R.S. Means Company, Inc., *Environmental Remediation Unit Cost Data* 1999, pg. 9-78 Item No. 33 08 0507 The cost is that for construction of a clay liner of 10e-7 conductivity, with 6" lifts and purchase and delivery of clay material from an off-site location

[d] R.S. Means Company, Inc., *Environmental Remediation Unit Cost Data*, 1999 pg. 4-23, Item No. 17 03 0422 The cost is that for unclassified fill 6" lifts on-site with spreading and compaction

[e] R.S. Means Company, Inc., *Environmental Remediation Unit Cost Data*, 1999 pg. 9-81, Item No. 33 08 0572 The cost is that for purchase, delivery and installation of a 60 mil polymeric HDPE liner

[f] Rumine Version V 1.21 Unit cost of caustic soda was obtained from Midstate Chemical Pennsylvania. The cost is that for purchase *and delivery within a 50-mile radius.*

[g] R.S. Means Company, Inc., *Site Work and Landscape Cost Data*, 1999 pg. 53 Item No. 022 262 0010 The cost is that of spreading dumped material by dozer with no compaction

Figure 3. (page 2 of 2) Example worksheet for active treatment

PASSIVE TREATMENT **PT-5A**

INVENTORY Page 1 of 2

AEROBIC AND ANAEROBIC WETLANDS

1 AMD CHARACTERISTICS		
a Iron concentration of mine drainage	0 mg/L	
b Manganese concentration of mine drainage	0 mg/L	
c Design flow rate	0 gpm	
d Design i on removal (grams of iron removed per square meter per day of wetland) 20 gmd for alkaline drainage and 5 gmd for acidic drainage[a]	20 gmd	
e Design manganese removal (grams of iron removed per square meter per day of wetland)[a]	0.5 gmd	
f Iron loading (multiply line 1a by line 1c 3 785 l/gal and 1 440 min/day and divide the product by 1 000 mg/g)		0 grams
g Manganese loading (multiply line 1b by l ne 1c 3 785 l/gal and 1 440 min/day and d vide the product by 1,000 mg/g)		0 grams
2. SURFACE AREA OF WETLAND		
a Surface area of wetland required for iron removal (div de ine 1f by line 1d and multiply the result by 10 76 square feet/square meter)		0 ft²
b Surface area of wetland required for manganese remova (d vide line 1g by line 1e and multiply the result by 10 76 square feet/square meter)		0 ft²
c Total surface area of wetland (add lines 2a and 2b)		0 ft²
3. HUMUS OR COMPOST LAYER REQUIREMENT		
a Thickness of compost layer (0 5 to 1 ft Skousen 12 to 18 inch Brod e)	0.00 ft	
b Surface area of compost layer in ft² (from line 2c)		0 ft²
c Surface area of compost layer (multiply line 3b by 0 111)		0 yd²
d Volume of compost required (multiply line 3a by line 3b and d v de the product by 27)		0 yd³
4 LIMESTONE LAYER (FOR ANAEROBIC WETLAND ONLY)		
Th ckness of l mestone layer (0 5 to 1 ft Skousen)	0 0 ft	
b E t mated volume of limestone (multiply line 4a by line 2c)		0 00 ft³
c Density of limestone	168.02 lbs/ft³	
d Efficiency[b]	0%	
e Purity of limestone	0%	
Estimated limestone weight o limestone (multiply line 4b by l ne 4c)		0 lbs

Figure 4 (page 1 of 2) Example worksheet for passive treatment

PASSIVE TREATMENT **PT-5A**

INVENTORY Page 2 of 2

AEROBIC AND ANAEROBIC WETLANDS

5 CLAY LINER		
a Thickness of clay liner (a minimum of 0 5 ft)	0 ft	
b Estimated volume of compacted clay (multiply line 2c by line 5a)		0 ft³
c Swelling factor[c]	40%	
d Actual volume of clay required (add 100% to the percentage in line 5c and multiply line 5b by that percentage and divide the result by 27)		0 yd³
6 DIMENSION OF WETLAND		
a Free board (1 to 3 inch Skousen)	0 ft	
b Effective depth (add lines 3a, 4a, 5a, and 6a)		0 ft
c Total volume of wetland (multiply line 2c by line 6b)		0 ft³
d Total volume of wetland in cubic yard (divide line 6c by 27)		0 yd³
e Average width (depends on availability of land)	0 ft	
f Average length (divide line 3c by the product of lines 6b and 6e)		0 ft
7 PIPING REQUIREMENT		
a Distance from influent or previous treatment unit	0 ft	
b Distance from wetland to discharge point or next treatment unit	0 ft	
c Estimated length of influent and effluent piping required (50% safety factor)		0 ft
7 PLANT AND VEGETATION		
a Density of cattails	1 plant/ft²	
b Number of cattails required (multiply line 7a by line 2c)		0 plants
c Labor rate (default)	250 plants/hrs	
d Labor hours required		0 hrs
8 SITE WORK		
a Volume to be excavated in ft³ (with 20% design factor)		0 ft³
b Volume to be excavated in yd³ (divide line 8a by 27)		0 yd³
c Area to be cleared in ft² (50% inflated) (multiply line 2c by 1.5)		0 ft²
d Area to be cleared in areas (divide line 8c by 43 560)		0 00 acres
e Area to be surveyed (same as Line 8d)		0 00 acres
f Survey rate	1 acre/day	
g Days required to complete survey (multiply line 8e by line 8f)		0 000 day

a Skousen and others 1995 Acid Mine Drainage Control and Treatment. Second Edition West V rginia University P 253 254

b Skousen and other 1996. Acid Mine Drainage Control and Treatment Second Edition West V rginia University Pg 238

c U S Environmental Protection Agency *Final Guidance Manual Cost Estimates for Closure and Post-Closure Plans (Subparts G and H)* January 1987 Volume II EPA/530-SW-87-00g Pg 7 10

AEROBIC AND ANAEROBIC WETLANDS

1. SURVEYING				
a	Unit cost of surveying[a]	848 36	$/day	
b	Days required to conduct survey (from PT 5A, line 9g)	0 00	days	
c	**Cost of surveying (multiply line 1a by line 1b)**			$0.00
2. CLEARING AND GRUBBING				
a	Unit cost of clearing and grubbing[b]	5 830 00	$/acre	
b	Area to be cleared and grubbed (from PT 5A, line 9d)	0 00	acres	
c	**Total Cost of Clearing and Grubbing (multiply line 2a by line 2b)**			$0 00
3. PURCHASE AND DELIVERY OF CLAY				
a	Volume of clay required (from PT 5A line 4f)	0	yd^3	
b	Unit cost of clay purchase[c]	5 00	$/yd^3	
c	Unit cost of delivery of clay (20-mile radius)[d]	19 40	$/yd^3	
d	**Total Cost of Purchase and Delivery of Clay (multiply line 3a by the sum of lines 3b and 3c)**			$0 00
4. PURCHASE AND DELIVERY OF LIMESTONE (FOR ANAEROBIC WETLAND ONLY)				
a	Quantity of limestone (from PT 5A, line 4e)	0	lbs	
b	Unit cost of purchase and delivery of limestone (50 miles radius)[e]	0 040	$/lbs	
c	**Total Cost of Purchase and Delivery of Limestone (multiply line 4a by line 4b)**			$0 00
5. INSTALLATION OF HUMUS PEAT OR COMPOST LAYER				
a	Volume of humus peat or compost (from PT 5A line 3d)	0	yd^3	
b	Unit cost of purchase and spreading of the layer[f]	60 12	$/yd^3	
c	Unit cost of delivery of humus peat or compost (20 miles radius)[g]	19 40	$/yd^3	
d	**Cost of Purchase and Delivery Compost (multiply line 5a by the sum of lines 5b and 5c)**			$0.00
6. EXCAVATION				
a	Volume to be excavated (from PT-5A line 9b)	0	yd^3	
b	Unit cost of excavation[h]	2 05	$/yd^3	
c	**Total Cost of Excavation (multiply line 6a by line 6b)**			$0 00
7. SPREADING AND COMPACTING OF CLAY LAYER				
a	Volume of clay layer (from PT 5A line 4f)	0	yd^3	
b	Unit cost of filling and spreading the clay by dozer[i]	1 39	$/yd^3	
c	Unit cost of compacting the clay layer[j]	1 16	$/yd^3	
d	Unit cost of compaction testing by nuclear method[k]	0 85	$/yd^3	
e	Unit cost of compaction testing by sand cone method	0 33	$/yd^3	
f	**Total Cost of Spreading and Compacting Clay Layer (multiply line 7a by the sum of lines 7b through 7e)**			$0.00
8. INSTALLATION OF LIMESTONE LAYER (FOR ANAEROBIC WETLAND ONLY)				
a	Quantity of limestone (divide PT 5A line 4b by 27)	0	yd^3	
b	Unit cost of filling and spreading limestone[m]	1 39	$/yd^3	
c	**Total Cost of Installation of Limestone Layer (multiply line 7a by line 7b)**			$0.00

Figure 4 (page 2 of 2) Example worksheet for passive treatment

AEROBIC AND ANAEROBIC WETLANDS

9. PLANTS AND VEGETATION				
a	Labor hours required (from PT-5A line 8d)	0	hrs	
b	Unit cost of planting of cattails[n]	86 50	$/hr	
c	**Total Cost of Plants and Vegetation (multiply line 9a by line 9b)**			$0.00
10. INSTALLATION OF INFLUENT AND EFFLUENT PIPING				
a	Length of piping (from PT 5A line 7c)	0	ft	
b	Unit cost of purchase deliver and install 1" to 4" PVC	17 40	$/ft	
c	Allowance factor for fittings and insulation (default)[p]	15%		
d	Unit cost for fittings and insulation (multiply line 10b by line 10c)	2 61	$/ft	
e	**Total Cost of Installation of Piping (multiply line 10a by the sum of lines 10b and 10d)**			$0.00
TOTAL COST OF WETLAND INSTALLATION (add lines 1c, 2c, 3d, 4d, 5d, 6d, 7d, 8c, and 10e)				$0 00

a R.S. Means Company Inc *Environmental Remediation Data Unit Cost* 1999 pg 10-10 item No 99 24 1201 The cost is that for surveying with a two-person crew

b R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 39 item No 021 104 0260 The cost is that for clearing and grubbing of dense brush including stumps

c R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 46 item No 022 216 6000. The cost is that for purchasing clay fill or blasted rock, and loading onto a dump truck

d R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 54 item No 022 216 6000. The cost is that for hauling with a 12 yd^3 dump truck for a 20-mile roundtrip

e Ponina Version V 1 21 Average cost of pebble lime from Graybeck Lime (Bellefonte PA) and Corastone (Ehrenburg PA) The cost is that for purchase and delivery within a 50-mile radius

f R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 128, item No 029 516 0400 The cost is that for purchase delivery and placement of 1 deep push spreader Convert the cost into per cubic yard unit by dividing 1 67 $/yd^2 by 9 ($ft^2/yd^2$) times (1/12) then multiply the results by 27

g R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 54 item No 022 216 6000 The cost is that for hauling with a 12 yd^3 dump truck for a 20-mile roundtrip

h R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 49 item No 022 242 20200 The cost is that for bulk common earth excavation with a 75 HP 50-ft hauling dozer

i R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 53 item No 022 262 0010 The cost is that for spreading dumped material by dozer no compaction

j R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 45 item No 022 226 6220 The cost is that for compaction using towed vibrating roller with 6 lifts and 4 passes per lift

k R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 11 item No 014 108 4735 The cost is that for soil density testing using nuclear method ASTM D2922 71 One test per 50 yd^3 compaction is assumed

R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 11 item No 014 108 4740 Cost includes soil density testing using sand cone method ASTM D1556064 One test per 100 yd^3 compaction is assumed

m R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 pg 53 item No 022 262 0010 The cost is that for spreading dumped material by dozer without compaction

n This cost is an engineering estimate based on the use of a crew consisting of two skilled workers The hourly rate for a skilled worker was taken from R.S. Means Company Inc *Site Work and Landscape Cost Data* 1999 back cover

o *R.S. Means Company Inc Mechanical Cost Data 1999 pg 123 item No 151 550 1000 through 1150*

p The cost is that for purchase and delivery of Sch 80 high impact/pressure PVC pipes with a range of 1" through 4