V COST ANALYSIS OF AMD ABATEMENT

GENERAL

In order to evaluate comparative abatement methods and costs, the cost of lime neutralization was compared with the cost of other abatement methods proposed in this report. Abatement methods that involve the neutralization of AMD in treatment plants can be used separately or in conjunction with. other methods. All the other methods proposed in this report supplement each other and are integrated into a total abatement plan.

In view of the above, cost comparison between alternative abatement methods can only be made between the neutralization of AMD in treatment plants and the combination of all other reported methods.

The major recharge sources of AMD discharges from the Buttonwood Tunnel and the South Wilkes-Barre boreholes are located outside the study area. Therefore, although the magnitude of these discharges has been determined in this study, total abatement of all these discharges by methods other than neutralization by treatment cannot be evaluated within the scope of the present study. However, partial abatement by other methods can be evaluated for AMD discharges attributed to water losses within the Solomon Creek watershed. The most economical solution for the total abatement of AMD discharges from the Buttonwood Tunnel and the South Wilkes-Barre borehole can only be determined upon the completion and evaluation of abatement studies in the adjacent watersheds. Since the cost of total AMD abatement by the neutralization method can be determined at the present time, maximum cost limits for other alternative methods can be derived. Consequently, the comparison between alternative abatement methods can, only be made for the Askam borehole discharges that originate entirely within study area watersheds of Nanticoke and Warrior Creeks.

ESTIMATED ABATEMENT COST - NANTICOKE AND WARRIOR CREEKS Pertinent data for the abatement cost analysis of the Askam borehole discharges that originate in the Nanticoke and Warrior

Creek watersheds is as follows:

Annual mean discharges	2,000 million gallons (MG)
Average (daily) discharge	5.5 MGD
Average acid concentration	630 ppm
Average acid load	29,100 lbs/day
Average concentration of total iron	384 ppm
Average total iron load	17,660 lbs/day
Maximum (daily) discharge	17.6 MGD
Minimum (daily) discharge	0.0 MGD

ABATEMENT BY NEUTRALIZATION (Treatment Plant): Cost for this alternative is based on treatment with hydrated lime. Although other types of treatment plants have been in operation, the majority of operating plants in Pennsylvania are presently using lime as the neutralization agent*. Therefore, for the purpose of cost comparison with other proposed methods of abatement, cost estimate for treatment plants are based on the hydrated lime neutralization process. If the neutralization method is selected for the abatement of the AMD discharges from the Askam borehole, consideration may be given to other competitive methods of neutralization.

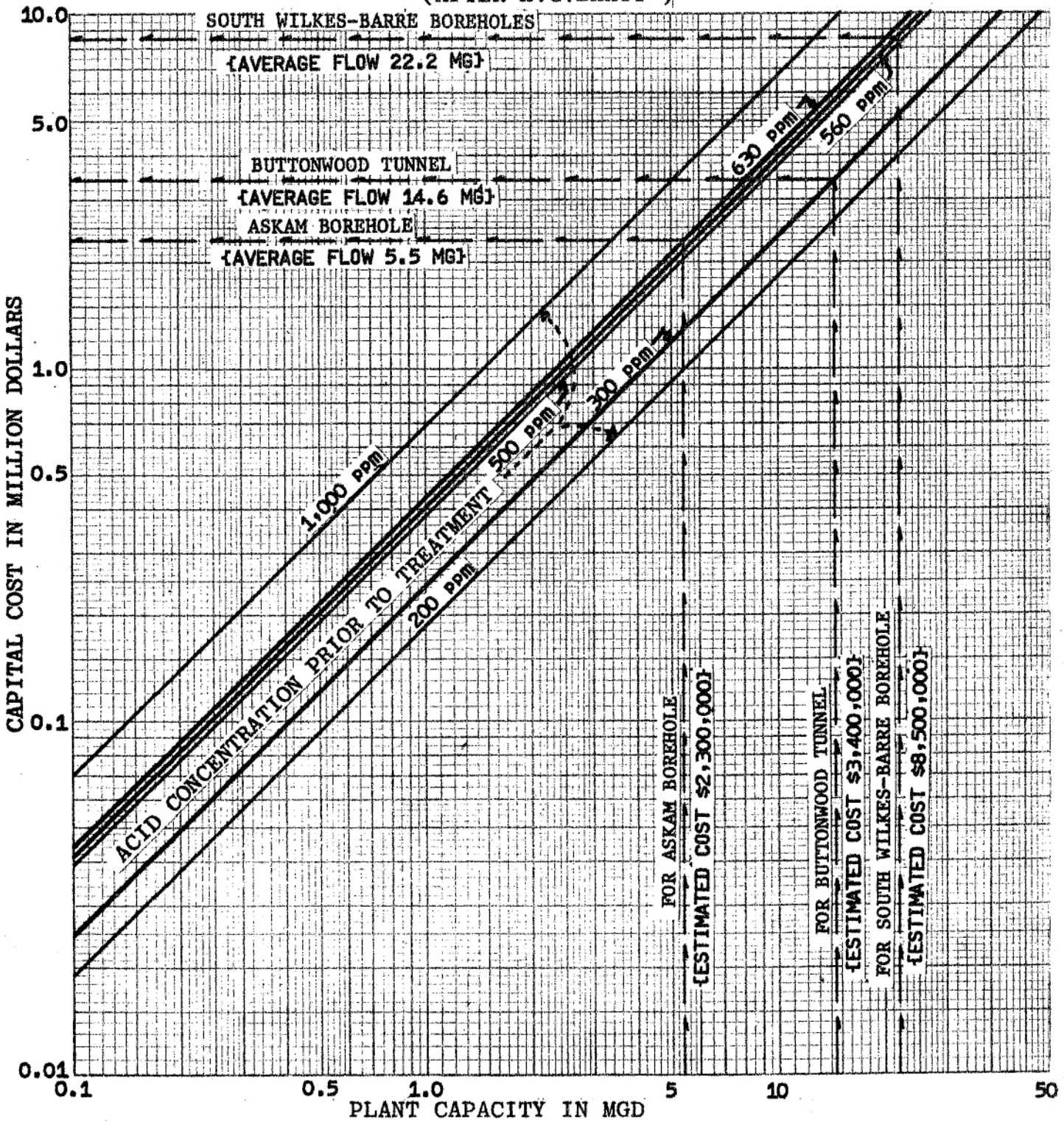
Generalized initial cost of hydrated lime treatment plants are presented in FIGURE NO. 17 (page 80). For the average discharge and acid concentration at the Askam borehole, the estimated Initial Cost (construction and installation costs) is $2,300,000.

Fairly accurate construction and operating cost of treatment facilities in the Wilkes-Barre area have already been established.

As a result of the General Assembly Legislative Act 43A (June, 1964), appropriation was made to research, design, fabricate and operate a demonstration plant for the treatment of AMD. Among the various sites selected for the demonstration of treatment by neutralization was the Blue Coal Co. Loomis No. 4 shaft at Ashley, Pennsylvania. The average rate and concentration of the AMD, treated at the Loomis site, is similar to the average rate and concentration of the AMD discharges from the Askam borehole. The major difference between these two sites is that whereas the discharge from the Loomis shaft * After H. G. Bhatt

NEUTRALIZATION OF AMD BY TREATMENT

HYDRATED LIME TREATMENT PLANT WITH SLUDGE DISPOSAL
CAPITAL COST (INITIAL CONSTRUCTION & INSTALLATION COST)
(AFTER H.G.BHATT*)



* *Economics of Coal Mine Drainage Treatment; H.G.Bhatt, Michael Baker, Jr., Inc.; Presented at the Seminar on Design of Coal Mine Drainage Treatment Facilities: The Pennsylvania State University, Nov. 14, 1973*

FIGURE 17

was at a constant rate, the discharges from the Askam borehole would vary significantly throughout the year. Therefore, for the same size of treatment plant that was demonstrated at the Loomis site, additional storage facilities would be required to equalize the flow rate into the Askam treatment plant. Since the major cost of treatment is the operation rather than the cost of construction, the cost of storage was omitted from the present discussion.

Comparison between the Askam borehole discharges and the reported AMD influent and the treated effluent from the Loomis demonstration plant is presented in TABLE XIII.

TABLE XIII

AMD TREATMENT FOR ASKAM BOREHOLE DISCHARGE

DESCRIPTION		ASKAM BOREHOLE AMD DISCHARGES	TREATMENT PLANT LOOMIS NO. 4 SHAFT	
			INFLUENT	EFFLUENT
pH		3.7	3.2	7.4
TOTAL ACIDITY	(ppm)	633	560	0
TOTAL IRON	(ppm)	384	360	6.4
MANGANESE	(ppm)	–	30	18
CALCIUM	(ppm)	–	349	625
MAGNESIUM	(ppm)	–	185	173
SULFATES	(ppm)	1,936	3,430	3,240
ALUMINUM	(ppm)	–	80	13
TOTAL SOLIDS	(ppm)	–	6,100	5,500
DISCHARGE	(MGD)	5.51	5.76	5.76
TOTAL ACIDITY	(LBS/DAY)	29,100	26,800	0
TOTAL IRON	(LBS/DAY)	17,660	17,300	308
ALKALI REQUIREMENTS	(LBS/DAY)	–	20,000	–
OXYGEN REQUIREMENTS	(LBS/HOUR)	–	103	–
SLUDGE PRODUCTION	(LBS/DAY)	–	43,200	–

NOTE: Based on data obtained from "Operation Yellowboy": Mine Drainage Treatment, Plans and Cost Evaluation; Dorr-Oliver, Inc. (Principal Investigator); Submitted to the Pennsylvania Coal Research Board, June, 1966.

On the basis of the data obtained from the Loomis treatment plant, the expected quality of the treated Askam effluent is as follows:

100%	reduction of Acidity
98%	reduction of Total Iron
40%	reduction of Manganese
0%	reduction of Sulfates
10%	reduction of Total Solids

It should be noted that the expected quality of the effluent would be satisfactory for direct discharges into the Susquehanna River. However, the quality of the effluent precludes such discharges into the Nanticoke Creek if the presently proposed water quality criteria for this creek are to be satisfied. Therefore, either additional treatment, or the diversion and conveyance of the effluent directly into the Susquehanna River would have to be added to the cost of treatment.

The derived costs for the treatment of the Askam borehole discharges is based on the reported cost for the Loomis treatment plant. Since the Loomis plant operation was in 1965, the reported costs were updated to reflect current (1975) prices, as shown in TABLE XIV (page 83). The total estimated annual cost of treatment at Askam is $1,011,600.

ALTERNATIVE ABATEMENT METHODS: These methods consist of lining streambed channels and the restoration of abandoned strip mines that presently cause the major surface water losses into the deep mines. The location and scope of the proposed projects, employing these abatement methods, are shown in FIGURES 15 and 16 (pages 73 and 74), and are described elsewhere in Part IV of this report. In addition to the above, the supplementary abatement methods consist of the prevention of present industrial and municipal discharges into the dep mines, as well as the interception of the groundwater, presently recharging the mine pools. The projected AMD abatement benefits, to be realized from the proposed alternatives to the neutralization by treatment are

TABLE XIV

COST OF TREATMENT - ASKAM AMD DISCHARGES

DESCRIPTION	COST OF AMD NEUTRALIZATION WITH HYDRATED LIME (DOLLARS)		
	1965 LOOMIS PLANT	COST* FACTOR	1975 PLANT AT ASKAM
CONSTRUCTION COST(1)	1,094,000	2.15	2,352,000
OPERATING COSTS:			
SUPERVISION OF LABOR	108,000	2.3	248,400
POWER	100,000	2.0	200,000
CHEMICALS	152,000	1.84	279,700
MAINTENANCE & MISC.	35,000	2.3	80,500
TOTAL OPERATING COST	395,000	(2.05)	806,600
FIXED COST:	80,500(2)	-	205,000(3)
TOTAL ANNUAL COST	475,000	(2.13)	1,011,600

* BASED ON ENGINEERING NEWS RECORD " COST INDEX"
(1) EXCLUDING LAND ACQUISITION, STORAGE CAPACITY REQUIRED TO MAINTAIN FLOW AND THE DIVERSION OF EFFLUENT INTO THE SUSQUEHANNA RIVER.
(2) 20 YEAR AMORTIZATION - 4% INTEREST RATE.
(3) 20 YEAR AMORTIZATION - 6% INTEREST RATE.

summarized in TABLE XV (page 814). A cost estimate for these projects is presented in TABLE XVI (page 8b). The annual cost consists of fixed costs and operating costs. The operating costs include the cost of pumping, if pumping wells are to be used for the interception of groundwater*, as well as the periodic maintenance of channels and stream lining., The cost

**The use of artesian wells, horizontal gravity flow welts or grout curtain, which are alternative solutions to pumping wells, may reduce the estimated cost for this item. Similar cost reduction can be realized if water can be marketed for municipal or industrial uses. For a description of the groundwater interception concept, see Appendix C.*

TABLE XV

PROPOSED PROJECTS FOR THE ABATEMENT OF
THE ASKAM BOREHOLE AMD DISCHARGES

PROJECT DESCRIPTION	ESTIMATED BENEFITS		
	WATER LOSSES PREVENTED		ACID ABATED
	MG/YEAR	MGD	LBS/DAY
A. FOR DER CONSIDERATION: (1)	(1)		
WARRIOR CR. WATERSHED PROJECTS	278	0.76	4,030
NANTICOKE CR. WATERSHED PROJECTS	1,034	2.83	17,390
ALTERNATIVE TO PRESENT DISCHARGE OF BLUE COAL CO. EFFLUENT INTO THE DEEP MINES	270	0.74	3,880
GROUNDWATER INTERCEPTION	160	0.44	2,310
SUB-TOTAL ("A" PROJECTS ONLY)	1,742	4.77	27,610*
B. FOR CONSIDERATION BY LOCAL INTERESTS:			
PREVENTION OF RAW SEWAGE DISCHARGES INTO DEEP MINES	51	0.14	730
LAND RESTORATION TO UPGRADE PRESENT LAND USE	250	0.68	3,600
TOTAL PROPOSED PROJECTS	2,043	5.59	31,940

* COMPARABLE TO THE ACID REMOVAL AT THE LOOMIS PLANT, SEE TABLE XIII.

(1) EXCLUDING THE DIVERSION OF SUGAR NOTCH FLOW FROM THE SOLOMON CR. WATERSHED INTO THE WEST BRANCH OF WARRIOR CREEK; PRESENTLY IN THE DESIGN STAGE.

TABLE XVI

ESTIMATED COST OF ASKAM BOREHOLE AMD ABATEMENT
PROPOSED ALTERNATIVE METHODS TO NEUTRALIZATION

PROJECT DESCRIPTION	INITIAL COST ($)	USEFUL LIFE YEARS	CAPITAL RECOVERY FACTOR	ANNUAL COSTS ($)		
				FIXED	OPERATE	TOTAL
WARRIOR CREEK WATERSHED	(3,392,000)					
CHANNEL & STREAMBED LINING	2,492,000	40	0.06646	165,600	16,560†	182,160
BALANCE OF WORK	900,000	100	0.06018	54,200	–	54,200
NANTICOKE CREEK WATERSHED	(6,637,300)					
CHANNEL & STREAMBED LINING	4,878,400	40	0.06646	324,200	32,420†	356,620
BALANCE OF WORK	1,758,900	100	0.06018	105,850	–	105,850
ALTERNATIVE TO BLUE COAL CO. DIVERSION FROM SOLOMON CREEK	114,000	*	*	4,000	4,000	8,000
GROUNDWATER INTERCEPTION	100,000	**	**	7,800	6,000	13,800
TOTAL PROPOSED PROJECTS	10,153,300			661,650	58,980	720,630

* BASED ON LUMP SUM SETTLEMENT WITH BLUE COAL, DESCRIBED ELSEWHERE.

** SEE COST ESTIMATES FOR WELLS, PREVIOUSLY DESCRIBED.

† BASED ON 10% OF INITIAL COST.

estimate of groundwater interception is based on the following conservative assumptions:

6 wells (50 GPM, each) @ $10,000/well	$ 60,000
Electrical connections (if provided by DER)	30,000
Connections to receiving streams	10,000
Total Initial Cost	$ 100,000

Pumping Cost (power)

Installed capacity $\frac{(300 \text{ GPM} \times 200 \text{ feet})}{3{,}960 \times 0.7}$ = 25 HP = 17.5 K

153,300 KWHR (per year) x $0.03/KWHR	=	$ 4,600
Estimated annual maintenance cost	=	1,400
Total Annual Operating Cost		$ 6,000

Annual costs are derived as follows:

ITEM	INITIAL COST ($)	USEFUL LIFE (YEARS)	CAPITAL * RECOVERY FACTOR	ANNUAL FIXED COST ($)
PUMPS, MOTORS & CONTROLS	12,000	10	0.13587	1,630
ELECTRICAL CONNECTIONS	30,000	25	0.07823	2,347
WELLS, HOUSING & PIPING	58,000	40	0.06646	3,853
SUB-TOTAL, FIXED COSTS	100,000			7,830
OPERATING COST				6,000
TOTAL ANNUAL COST	- - - - - - - - - - - - - -			13,830

* *At 6% INTEREST RATE*

For all other projects, the annual operating costs are only related to the maintenance of channels and stream improvements. The useful life of channels and streambed lining is 40 years. Although land restoration is a permanent improvement, a useful life of 100 years was assumed for these projects, to compensate for any additional work that may be caused by isolated subsidence areas.

COMPARISON BETWEEN ALTERNATIVE ABATEMENT METHODS: The total estimated annual cost of neutralization by treatment is $1,012,000 whereas the total annual cost of the proposed alternative abatement methods is $720,600. Consequently, the cost of alternative methods is 30 percent lower than the cost of neutralization by treatment. Moreover, since the operating cost of the alternative abatement methods is only 8 percent of the estimated total annual costs, the projected cost for these methods is less susceptible to cost escalation of labor and materials than the cost projected for the neutralization method. Cost comparison for the duration of the expected useful life is illustrated in FIGURE NO. 18 (page 87).

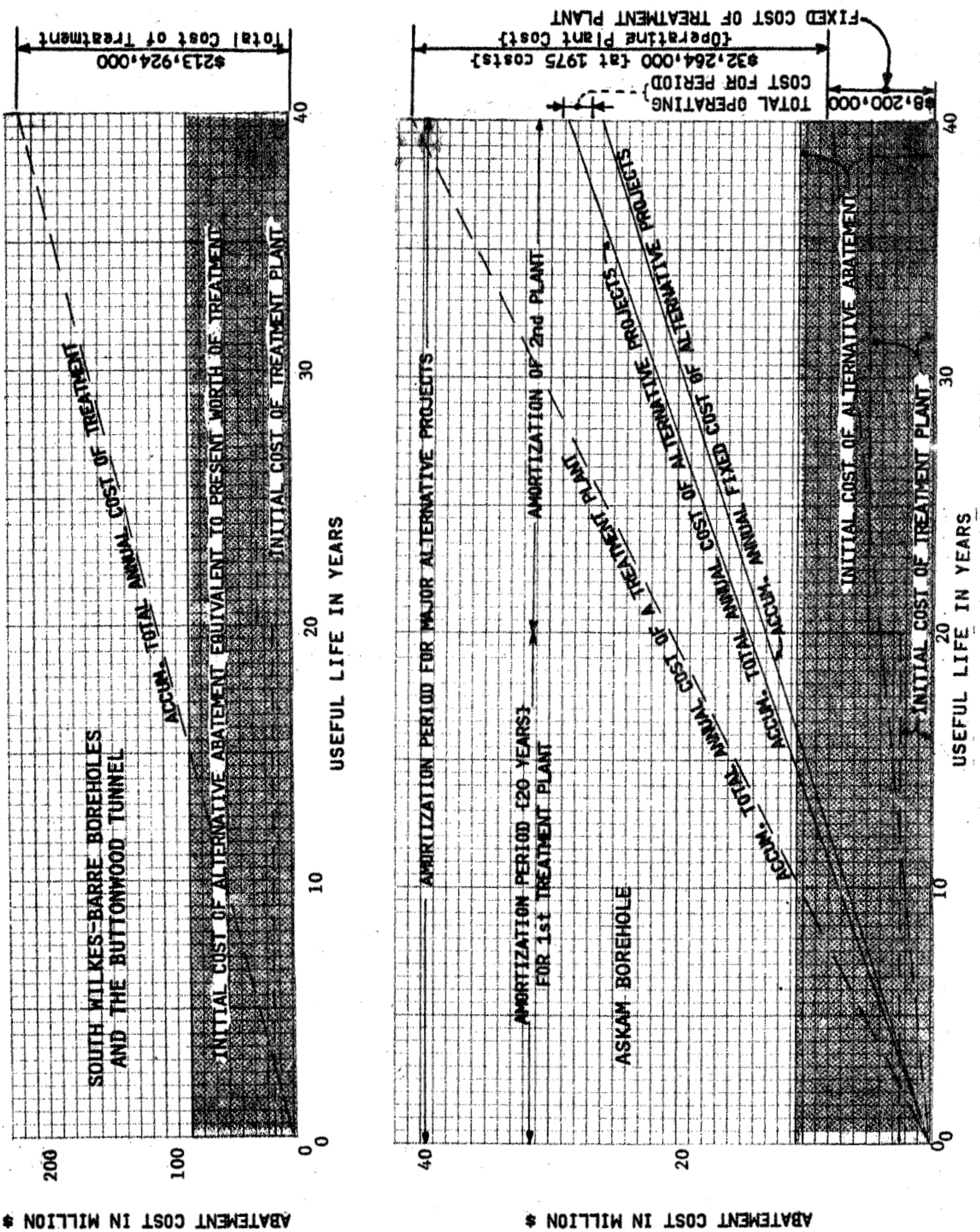
In addition to the cost factor, the proposed alternative methods would limit the formation of AMD by preventing loss and contamination of surface water and groundwater. Furthermore, it is expected that these methods will reduce basement flooding, as well as subsidence hazards in the Nanticoke and Warrior Creek watersheds.

ESTIMATED ABATEMENT COST - SOLOMON CREEK

ABATEMENT WITHIN THE STUDY AREA LIMITS: A similar approach can be applied for the comparison between the proposed abatement measures within the Solomon Creek Watershed and the cost of AMD neutralization by treatment.

Discharges from the three South Wilkes-Barre boreholes that are attributed to water losses within the Solomon Creek watershed are equivalent to 21,760 pounds of acid per day. The estimated total annual cost of treatment for the removal of 26,800 lbs/day of acid from the Askam borehole is $1,011,600 (see TABLES XIII and XIV - Pages 81 and 83). Therefore, the estimated total annual cost of treatment for the removal of 21,760 lbs/day acid from the South Wilkes-Barre boreholes is $821,358.80.

Applying these annual costs to the cost of alternative abatement projects and assuming that the operating cost of these alternative projects are 8% of the total annual cost (see Cost Analysis for the Askam borehole), the equivalent annual fixed cost of those



COST COMPARISON OF ABATEMENT METHODS

FIGURE 18

projects is $755,650. For a useful life of 40 years, the Present Worth of $755,650 at 6% interest rate is $11,369,734 0.06

Consequently, the cost of the proposed abatement projects within the Solomon Creek watershed is $11,369,734 which is 60% of the equivalent cost of treatment.

ABATEMENT OF ALL AMD DISCHARGES: On the basis of the Comparative Cost Anaylsis of the Askam borehole, the maximum cost of abating the discharges from the South Wilkes-Barre boreholes and the Button wood Tunnel can also be determined, as shown in FIGURE NO. 18 (page 87) and TABLE XVII.

TABLE XVII

ESTIMATED MAXIMUM ABATEMENT COSTS FOR SOUTH WILKES-BARRE BOREHOLES & BUTTONWOOD TUNNEL

PERTINENT DATA		ASKAM BOREHOLE	S. WILKES-BARRE BOREHOLES	BUTTONWOOD TUNNEL
AVERAGE DISCHARGE	{MGD}	5.5	22.2	14.6
AVERAGE ACID LOAD	{#/DAY}	23,100	104,400	36,500
AVERAGE IRON LOAD	{#/DAY}	17,660	70,150	18,500
ALKALI REQUIREMENT	{#/DAY}	20,000	71,750	25,100
CONSTRUCTION COST	{$}	2,352,000	8,500,000	3,400,000
ESTIMATED ANNUAL COST	{$}			
OPERATING COST:				
SUPERVISION & LABOR	{$}	248,400	625,500{1}	453,900{1}
POWER	{$}	200,000	807,300	530,900
CHEMICALS	{$}	279,700	1,003,400{2}	351,000{2}
MAINTENANCE & MISC.	{$}	80,500	325,000{3}	213,700{3}
TOTAL OPERATING COST	{$}	806,600	2,761,200	1,549,500
FIXED COST:	{$}	205,000{4}	741,000{4}	296,400{4}
TOTAL ANNUAL COST	{$}	1,011,600	3,502,200	1,845,900

{1} OUT OF A TOTAL OF 15 MEN REPORTED FOR ASKAM, ONLY 7 MEN WERE PRORATED ON THE BASIS OF DAILY DISCHARGES (50% OF THE ANNUAL LABOR COSTS).
{2} BASED ON THE ALKALI REQUIREMENTS.
{3} PRORATED ON THE BASIS OF PLANT CAPACITY.
{4} 20 YEAR AMORTIZATION, 6% INTEREST RATE.

The total estimated annual cost for the abatement of the South Wilkes-Barre boreholes and the Buttonwood Tunnel discharges is $5,348,100. If the annual cost of alternative abatement methods, yet to be determined, would be similar to the estimated cost of neutralization, the construction cost of these alternatives can be determined as follows:

Assumed 0perating Cost of Alternative Abatement Measures: Assumed operating cost of the alternatives is 8% of the total annual cost (see Askam Borehole). Therefore, the maximum annual fixed cost of the alternative abatement measures would be

0.92 x $5,348,100 = $4,920,250

For a useful life of 40 years, the present worth of $4,920,250 annual fixed cost, at 6% interest rate, can be derived by the following formula:

Where P, is the present worth

A, is the equal annual payment i, is the interest rate

N, is the number of annual payments

$$P = \frac{A \times \{(1 + i)^N - 1\}}{i \times (1 + i)^N}$$

Therefore the Present Worth

$$P = 4{,}920{,}250 \times \frac{(1 + 0.06)^{40} - 1}{0.06 \times (1 + 0.06)^{40}} = \$74{,}031{,}542$$

Assuming that the maximum construction cost for the abatement of the boreholes and tunnel discharges is $74,000,000, then for the average daily acid load of 140,900 lbs., the cost per lb. of acid removal is therefore 74,000,000 : 140,900 = $525.2/lb/day.

A watershed study is presently being conducted in the Mill Creek watershed. Preliminary observations indicate that the scope of abatement projects in the Mill Creek watershed would predominantly consist of projects related to the prevention of streambed losses into the deep mines. If similar conditions also exist in

the watersheds, overlying the North-West Mine Pool Complex, the cost of alternative abatement projects for the Buttonwood Tunnel and South Wilkes-Barre boreholes discharges, is anticipated to be significantly lower than the cost of AMD neutralization by treatment.

Assuming that the cost ratio between water loss prevention and AMD neutralization by treatment would be similar to the ratio obtained in the Solomon Creek watershed, the cost of abatement AMD discharges from the Tunnel and the boreholes is not expected to exceed 0.6 x $74,000,000 = $44,400,000. Consequently, the cost per pound of acid removal is expected to be $44,400,000:140,900 lbs.

$315.12/lb/day.