

V. DESCRIPTION OF SAMPLING STATIONS

Approximately 250 sampling stations were installed during the course of this study. Measurements were taken weekly at each station.

A total of ten gaging stations were installed on the larger streams. These stations were located, when possible, on fairly shallow and straight sections of streams where the current was swift. The contour of the stream bottoms were measured by surveyor's level and tape. The stream cross sections were plotted on graph paper. Steel rods were placed in the stream bed to measure the changes in depth. A small portable Ott current meter with an attached counter was used to determine stream velocities by wading the streams. Stream depth and velocity measurements were used to determine the flow.

A total of ten concrete block, rectangular notch weirs were constructed on the smaller main streams. Some problems were encountered from flooding and ice damage, otherwise this type of station proved quite accurate and reliable.

Approximately 230 rectangular and v-notch weirs constructed of plywood were installed on the smaller streams and points of mine discharge. These weirs, which were put in place with steel rods and sandbags, proved to be practical and efficient sampling stations. However, they required constant maintenance to repair leaks caused by flooding.

A two-man crew was kept busy the better part of the study period repairing the concrete block and plywood type sampling stations.

VI. LABORATORY ANALYSIS METHODS

The character and degree of mineralization of mine drainage and the intensity of the drainage on the waters of Two Lick Creek Watershed was analyzed and evaluated by measurement of characteristic indicators or parameters. The parameters used in this study, the method of analysis, and discussion of each are described as follows:

A. pH

Method: Glass electrode pH meter, Type II.

Reference: Manual on Industrial Water and Industrial Wastewater, Edition II, A.S.T.M., Page 494.

Discussion: pH is used to determine the degree of acidity or alkalinity of water and is defined as being the logarithm of the reciprocal of the hydrogen concentration.

Natural waters usually exhibit a pH in the range of pH 6.0 to 9.0. Acid mine drainage normally exhibits a range of pH 2.0 to 6.0 and the pH of a given receiving stream will vary with the severity of pollution and the state of reaction of the mine drainage and other existing pollutants.

Meter Standardization: To conform with A.S.T.M. specifications, Sections 7 and 8.

B. Acid (Total)

Method: Titrimetric titration using sodium hydroxide (standard solution of 0.02n) to a pH of 8.0.

Reference: A.S.T.M., Manual on Industrial Water and Industrial Wastewater, Edition II, Page 889.

Discussion: This method is intended for the routine titrimetric measurement of acidity or alkalinity in industrial water and acid mine drainage. In all determinations, the hydrogen or hydroxyl was present in water by virtue of the dissociation of hydrolysis of its solutes are neutralized by titration with standard alkali (acid) or acid (alkali) using phenolphthalein as the primary indicator.

The method determines acidity (alkalinity) due to free mineral acids and acid salts. It does not measure the contribution to acidity of carbon dioxide.

Acidity is reported as milligrams per liter of CaCO₃. This is not significantly different than reporting acidity as H₂SO₄ as the molecular weight ratio of CaCO₃ over H₂SO₄ is 1.02.

Net Acidity: The acidity that is present in excess of alkalinity.

C. Alkalinity (Total)

Method: Titrimetric titration using sulfuric acid (H₂SO₄) standard solution 0.02n.

Reference: A.S.T.M., Manual on Industrial Water and Industrial Wastewater, Page 889.

Discussion: This method measures the titrable alkalinity which is predominantly bicarbonate and/or carbonate in origin.

Titration is established with H₂SO₄ and an indicator of green methyl red is added. The resulting solution is then titrated with H₂SO₄ to the end point.

Under the conditions of the determination, a final positive alkalinity is measured when the acidity does not exceed the available alkalinity. Consequently, it is essential that reactions yielding acidity be completed before the alkalinity determination is attempted.

Alkalinity is reported as milligrams per liter of CaCO₃.

D. Sulfate (Total)

Method: Non-referee method A, turbidimetric method

Reference: A.S.T.M., Manual on Industrial Water and Industrial Wastewater, Page 264.

Discussion: A mole of sulfate accompanies each mole of sulfuric acid and sulfate is, therefore, an excellent indicator of the amount of mine drainage acidity. Unpolluted waters have concentrations of generally less than 20 mg./l.; polluted waters frequently have concentrations of several hundred milligrams per liter and greater.

In this procedure, the sulfate ion is converted to a barium sulfate suspension under controlled conditions. Glycerin solution and a sodium chloride solution are added to stabilize the suspension and minimize interference. The resulting turbidity is determined by a photoelectric colorimeter.

E. Iron :Total)

Method: Referee method A, photometric colorimeter method.

Reference: A.S.T.M., Manual on Industrial Water and Industrial Wastewater, Edition II, Page 371.

Discussion: Normally mine drainage contains iron in both ferrous and ferric states. Ferric iron does not contribute to acidity. Ferrous iron is a major contributor to acidity and is usually present in high concentrations in active mine drainage discharges. The presence of ferrous iron in a receiving stream usually indicates that the reactions have not gone to completion. The ferric iron present in streams above a pH of 3 is in this particular state.

In receiving streams, measurements of the total iron concentration are complicated by sampling problems, since the amount of ferric iron present is dependent upon the stream velocity and sampling depth.

In the analysis, the sample containing insoluble iron and iron oxides are put into solution by treating with hydrochloric acid. Phenanthroline is added to form an orange-red ferrous solution which is then placed in a photometric colorimeter. The amount of iron present is measured by the intensity of the color which is directly proportional to the amount of ferrous iron in the water.

VII. WATER QUALITY CRITERIA

Certain water quality criteria for the Two Lick Creek Watershed have been determined in order to establish a goal for the improvement of stream quality for the watershed.

The criteria used are adaptations of similar criteria used by the U. S. Department of Interior, Federal Water Pollution Control Agency in their March 1968 report, "Stream Pollution by Coal Mine Drainage, Upper Ohio River Basin" and by the Pennsylvania Department of Mines and Mineral Industries.

Any criteria in relation to mine drainage analysis is extremely difficult to assess since there are many variables or constituents that may affect a given water use at one concentration and correspondingly affect another water use at a different concentration.

Then, too, the effect that combinations of various compounds has on water use varies considerably as certain compounds often are in synergism with each other. For example, the toxicity to fish by various elements or compounds varies substantially with pH.

The following criteria are used to define the concentration or range of values at which concern over water quality for all uses is indicated, assuming that each characteristic is acting alone and not in synergism with another. The characteristics listed are those common to mine drainage waters and are of concern with most water uses.

It should be noted that only the first five characteristics listed were analyzed in tests of water samples from Two Lick Creek Watershed.

<u>Characteristic</u>	<u>Area of Concern</u>
1. <u>pH</u>	Below 6.0, above 8.5
2. <u>Acidity (Hot to pH of 8.3)</u>	Exceeding the Alkalinity
3. <u>Alkalinity</u>	(See acidity and pH)
4. <u>Total Iron</u>	Higher than 1.0 mg/l.
5. <u>Sulfates</u>	Higher than 250 mg/l.
6. <u>Total Solids</u>	Higher than 750 mg/l.
7. <u>Suspended Solids</u>	Higher than 250 mg/l.
8. <u>Dissolved Solids</u>	Higher than 500 mg/l.
9. <u>Turbidity</u>	Higher than 200 units
10. <u>Specific Conductance</u>	Higher than 350 microhomas/cm.

Characteristic Continued

Area of Concern Continued

11. Manganese

Higher than 0.5 mg/l.

12. Hardness

Higher than 150 mg/l.

The quality indicators or classifications used in this study are:
(1) Polluted water - any water with an acid concentration of 13 mg/l. or greater; (2) Severely acid water - any water with an acid concentration of 178 mg/l. or greater; (3) Moderately acid water - any water with an acid concentration of 13 mg/l. to 178 mg/l.; (4) Unpolluted (uncontaminated) water - any water with an acid concentration of 13 mg/l. or less.

For the purpose of this study, we will be concerned with raising stream acid concentration levels towards 13 mg/l. and less.

Recommendations are made in the Analysis of Individual Watersheds section of this report to accomplish this objective.

The other characteristics, particularly sulfate and iron, are also considered in recommendations and when possible, abatement measures will be aimed at meeting the criteria set for their respective areas of concern regarding pollution concentrations.

VIII. DISCUSSION OF pH AND ACIDITY

In 1909, S. P. Sorenson invented the symbol pH as a convenient expression to define the concentration of hydrogen ions in an aqueous solution.

It has since been established that the concentration of hydronium, (H_3O^+), and hydroxide, (OH^-), ions in pure water are the same and are equal to 1×10^{-7} mole/liter at 25°C . Pure water is then said to be neutral.

Thus, $\text{pH} = \text{pOH} = 7.00$.

If then, in a aqueous solution, (H_3O^+) is greater than 1×10^{-7} g. ion/liter the solution is alkaline.

The larger the concentration of the hydronium ion, the more strongly acidic the solution is, and the larger the concentration of the hydroxide ion, the more strongly basic the solution is.

The concentrations of hydronium or hydroxide ion\$ most commonly encountered are relatively small and cover the range $10^0 - 10^{-14}$ g. ion/liter. Since the handling of very small numbers in terms of exponents is somewhat awkward, it is convenient to use a logarithmic notation, and to define:

$$\text{pH} = -\log_{10} [\text{H}_3\text{O}^+] = -\log_{10} (c_{\text{H}_3\text{O}^+}) @ 25^\circ \text{C}.$$

or

$$\text{pH} = -\log (\text{H}_3\text{O}^+)$$

This is the definition for pH used and adopted in most textbooks on quantitative analysis.

If the pH is less than 7, the solution is acidic and conversely, if the pH is greater than 7, the solution is alkaline. Correspondingly, acidic solutions are described by pOH values larger than 7 and alkaline solutions by pOH values less than 7. The greater the departure from 7, the greater the acidity or alkalinity as the case may be. The relationships are summarized in Table 7 on the following page.

It must be emphasized that both pH and pOH are logarithmic terms and are therefore powers of 10. Consequently, the pH and pOH scales are not linear. For example, a solution of pH 1 has 10 times the concentration of hydronium of a solution of pH 2, and not twice the concentration.

Although pH and pOH are both useful, it is common practice to use only pH to indicate quantitatively either the acidity or the alkalinity of an aqueous solution.

Table 7
Relationships Among (H_3O^+) , (OH^-) ,
pH, and pOH in Dilute Aqueous
Solution at 25°C.

<u>(H_3O^+)</u>	<u>pH</u>	<u>pOH</u>	<u>(OH^-)</u>	
1.0×10^1	-1	15	1.0×10^{-15}	<p>Acidity increases</p> <p>Neutral solution Pure water</p> <p>Acidity decreases</p>
10^0	0	14	10^{-14}	
10^{-1}	1	13	10^{-13}	
10^{-2}	2	12	10^{-12}	
10^{-3}	3	11	10^{-11}	
10^{-4}	4	10	10^{-10}	
10^{-5}	5	9	10^{-9}	
10^{-6}	6	8	10^{-8}	
10^{-7}	7	7	10^{-7}	
10^{-8}	8	6	10^{-6}	
10^{-9}	9	5	10^{-5}	
10^{-10}	10	4	10^{-4}	
10^{-11}	11	3	10^{-3}	
10^{-12}	12	2	10^{-2}	
10^{-13}	13	1	10^{-1}	
10^{-14}	14	0	10^0	
10^{-15}	15	-1	10^1	

IX. DISCUSSION OF MINE DRAINAGE FORMATION

A. Sources of Mine Drainage

Deep mines and improperly backfilled and augered strip mines leave voids and expose rocks bearing sulfur compounds.

Rain water and surface water drains into these voids from groundwater storage through rock intersected by the mine. The groundwater normally enters the mine over such a large area that its actual points of entry are almost impossible to determine. If the mine is located above drainage, the amount of groundwater entering the mined area will be less, but substantiated amounts of surface runoff may find its way into the mine.

In addition to exposed rock left in the mined void, there is additional rock bearing sulfur minerals exposed from strip mining when overburden spoil is not properly buried and from coal refuse which is the end result of coal preparation plants. Coal refuse is usually piled in the general vicinity of the mine, coal preparation plant, or in other adjacent areas such as along roads and streams. Coal refuse is normally very high in sulfuric and other toxic materials.

As water enters and flows through the mine void, strip spoil, or coal refuse pile, it will, in most instances, come in contact with sulfur-bearing minerals which have been exposed to the air by the mining process. The minerals are dissolved by the water which reacts chemically to become acidic and toxic in character. The contaminated water then leaves the mine, either by gravity flow or by being pumped, to enter and contaminate the nearest water course.

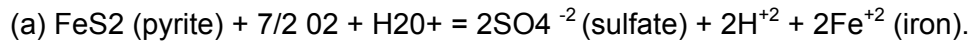
B. Chemistry

The formation of mine acid is dependent upon the presence of oxygen, sulfur-bearing material, and water.

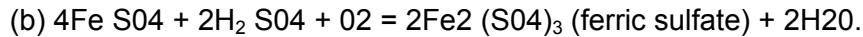
The sulfur-bearing material is present principally in the form of the minerals pyrite and marcasite which are both iron disulfide, FeS_2 , but differ in their crystalline structure. Both minerals are referred to as iron sulfides and are contained within coal seams and in associated shale and sandstones strata adjacent to the coal. The disulfide is quite variable in its physical form and is frequently present as minute particles disseminated throughout the rock, where as at other times it is present as crystals and crystal aggregates of large size.

During the mining process, iron sulfide minerals are exposed to air and water and oxidized to ferrous sulfate and sulfuric acid. Flowing water carries away the ferrous sulfate and acid to form mine drainage water.

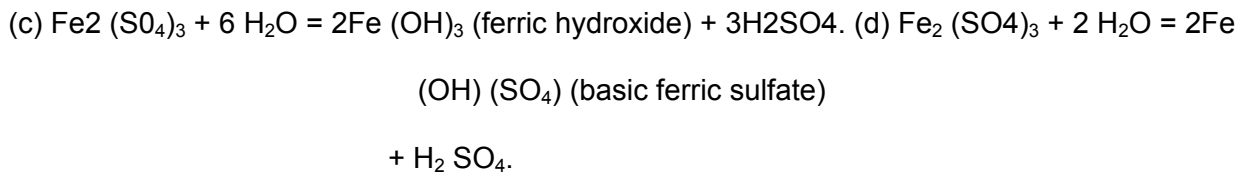
It is generally agreed that the initial phase in the production of acid is the oxidation of FeS_2 (pyrite) to release iron, sulfate and acid as shown in equation (a) on the following page.



In water, the ferrous sulfate may be further oxidized to ferric sulfate as seen in equation (b):



Depending on pH, temperature, and concentration of the various compounds, the reaction proceeds by hydrolyzation to form basic ferric sulfate or ferric hydroxide and additional sulfuric acid as shown in equations (c) and (d):



From the above equations, it can be seen that one mole of iron pyrite ultimately leads to the release of 4 moles of acidity; 2 moles from the oxidation of iron sulfate and 2 moles from the oxidation of ferrous iron.

These equations generally describe the reactions involved, however, the actual influence that numerous variables such as oxygen concentration, inhibitors, catalysts, etc., may have on the production processes and the reaction rates are not fully understood.

The variety of constituents found in mine drainage waters are produced by secondary reactions of sulfuric acid with compounds in adjacent rocks in the mines and along stream channels, and with various organic materials that are encountered in the drainage environment. It is reported that micro-organisms in organic ligands; soluble metal ions such as copper, aluminum, and manganese; and suspended material with large surface areas and high absorption capacities, such as clay particles, catalyze the oxidation of ferrous iron.

However, there are conflicting opinions among researchers as to the importance of the participation of micro-organisms in acid formation. Several bacterial species have been isolated from mine drainage waters but the exact extent of their importance in the reactions is still controversial. Silverman states that bacteria plays a dominant role in the oxidation of ferrous iron and probably accounts for the rapid oxidation noted in mining environments.

Hill reports pyrite can be oxidized without the presence of oxygen if a source of ferric iron is available. In order for the ferric iron to be present, it must either be carried to the pyrite site by water movement within the mine environment or be formed on the pyrite site by the oxidation of ferrous iron. While this reaction is of relatively minor importance, both mechanisms probably occur. The supply of ferric iron to the pyrite site would be far greater in refuse piles and surface mine spoils than in the walls and roof of an underground mine.

X. ABATEMENT METHODS AND RELATED COSTS

This section sets forth the methods that will be recommended in this report to abate the various sources of pollution and the costs related to each method.

A. Associated Deep Mine Abatement Methods

1. Watertight Mine Seal Method

a. Combination Hydraulic/Standard Seal

This method involves opening and entering the mine, drilling into the entry to be sealed, installing an acid resistant frame with steel reinforcement at the drilled location, pouring concrete through the drill hole (or holes) into the frame to form the seal (dam), curtain grouting under pressure the strata associated with the mined seam through additional drill holes. Plate 8 illustrates the above description.

The costs related to this method are based on certain minimal requirements as described below.

Table 8

Estimate of Construction Costs

Combination Hydraulic/Standard Seal

(Based on 18 foot wide entry)

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
<u>MINE SEAL</u>					
1.	Opening and entering mine	L. S.			\$ 500
2.	Timber Sets	6	Sets	\$ 50.00	300
3.	Drilling 6" Holes	250	L.F.	5.00	1,250
4.	Top, Bottom and Rib Hitches	7	C.Y.	30.00	210
5.	Brickwork	1	M	300.00	390
6.	Reinforcing Bars	500	Lbs.	0.20	100
7.	Formwork	80	S.F.	1.25	100

Table 8 Continued

Estimate of Construction Costs

Combination Hydraulic/Standard Seal

(Based on 18 foot wide entry)

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
8.	Concrete	7	C.Y.	\$ 80.00	\$ 560
9.	Backfill Outby Seal	30	C.Y.	10.00	300
<u>CURTAIN GROUTING</u>					
10.	Drilling 3" Holes	400	L.F.	3.50	1,400
11.	Cement for Grouting	240	Sacks	5.00	1,200
12.	Fly-Ash for Grouting	960	Sacks	2.00	1,920
13.	Sand for Grouting	8	Tons	50.00	400
14.	Mobilization and Demobilization	L.S.			<u>600</u>
TOTAL					\$9,230

b. Hydraulic Seal

This method is similar to the above method with the following exceptions: (1) The mine is not opened or entered; (2) No frame is constructed as such within the mine entry; (3) Drill holes are sunk to either side of the proposed seal (dam); (4) Coarse aggregate (gravel) is poured through the above holes to form bulkheads; and (5) Drilling an additional hole for observation inby from the seal. Concrete is then poured into the center of the bulkheads to form the seal (dam) itself. Curtain grouting then follows.

Plate 9 illustrates the above description on the following page. The costs related to this method are based on certain minimal requirements as described on Page 40, Table 9 .

Table 9

Estimate of Construction CostsHydraulic Seal(Based on 18 foot wide entry)

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
<u>BULKHEADS</u>					
1.	Drilling 6" Holes	900	L.F.	\$ 5.00	\$ 4,500
2.	Gravel	72	Tons	50.00*	3,600
3.	Cement for Grouting	160	Sacks	5.00	800
4.	Fly-Ash for Grouting	650	Sacks	2.00	1,300
5.	Sand for Grouting	14	Tons	50.00*	700
<u>DAM</u>					
6.	Drilling 3" Holes	150	L.F.	3.50	525
7.	Concrete	40	C.Y.	80.00	3,200
<u>CURTAIN GROUTING</u>					
8.	Drilling 3" Holes	500	L.F.	3.50	1,750
9.	Cement for Grouting	300	Sacks	5.00	1,500
10.	Fly-Ash for Grouting	1,200	Sacks	2.00	2,400
11.	Sand for Grouting	10	Tons	50.00*	500
<u>OBSERVATION DRILL HOLE</u>					
12.	Drilling 6" Holes	50	L.F.	5.00	250
13.	Casing Left in Place	25	L.F.	3.00	75
14.	Mobilization and Demobilization	L.S.			<u>\$ 600</u>
TOTAL					\$21,700

*Indicates in place cost

2. Water Diversion/Flume Discharge Method

When a watertight seal is impractical or impossible, this method is used as an alternate primarily to channel and/or divert mine drainage from a deep mine.

No attempt will be made to open the mine. A Bituminized Fibre Flume will be installed at the point of mine drainage. The flume will carry the water through or over any contaminated strip spoil or coal refuse to a desirable point of discharge.

Plate 10 illustrates the above description. The costs related to this method are based on certain minimal requirements as described below:

16 inch diameter Bituminized Fibre Flume at an in place cost of \$3.00 per lineal foot.

B. Refuse Pile Reclamation Methods

1. Coal Refuse Removal and Burial Method

This method involves physically transporting coal refuse from the site of pollution to an appropriate open strip pit where the refuse is buried. The original site of pollution and the stripped area are then regraded and revegetated as necessary.

Plate 11 illustrates the above description.

The costs related to this method are based on certain minimal requirements as described below in Table 10.

Table 10

Estimate of Construction Costs

Coal Refuse Removal and Burial Method

<u>Item Number</u>	<u>Description</u>	<u>Unit</u>	<u>Unit Price</u>
1.	Coal Refuse Burial	C.Y.	\$ 0.85
2.	Soil Cover	C.Y.	0.31
3.	Diversion Ditch	L.F.	1.00
4.	Flume	L.F.	75.00
5.	Revegetation	Acre	325.00 *

* Itemized under Section D, Revegetation.

2. Coal Refuse on Site Regrading and Cover

This method involves terrace regrading coal refuse on site and then covering it with a layer of clay which is then compacted. The area is then ditched around its periphery to prevent surface water from entering it. Culverts and flumes are installed to drain runoff from rainfall. The area is then revegetated with an appropriate cover.

The costs related to this method are based on certain minimal requirements as described below in Table 11.

Table 11

Estimate of Construction Costs

Coal Refuse on Site Regrading and Cover

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
1.	Terrace Regrading	1,700	C.Y./Acre	\$ 0.50	\$ 850
2.	Soil Cover (3')	5,000	C.Y./Acre	1.00	5,000
3.	Flume	L.S.	Acre	100.00	100
4.	Revegetation	L.S.	Acre	450.00	<u>450</u> *
			Total Acre		\$6,400

* Itemized under Section D, Revegetation.

C. Surface Mining Reclamation Methods

1. Regrading

This will involve a combination of measures as follows:
(1) Regrading by use of contour and terrace backfills; (2) Diversion ditches; (3) Slope drain flumes; and (4) Revegetation.

Plates 12 and 13 illustrates the above description.

The costs related to these measures are based on certain minimal requirements as described on the following page in Table 12.

Table 12

Estimate of Construction Costs

Regrading

<u>Item Number</u>	<u>Description</u>	<u>Unit</u>	<u>Unit Price</u>
1.	Spoil Backfill	C.Y.	\$ 0.45
2.	Diversion Ditch	L.F.	1.00
3.	Slope Drain Flume	Acre	75.00
4.	Revegetation	Acre	325.00 *

* Itemized under Section D, Revegetation.

2. Impoundment

This method involves impounding water to a depth to cover the coal seam and carbonaceous shales by the construction of a dam or dams across either or both ends of an open strip cut. The costs related to this method are based on certain minimal requirements and are estimated to be \$700 per acre.

D. Revegetation

This method involves revegetation of surface mines that have been previously backfilled and ineffectively vegetated. The costs related to this method are based on certain minimal requirements as described below in Table 13.

Table 13

Estimate of Costs Per Acre

Revegetation

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
<u>METHOD 1. GRASS AND LEGUMES</u>					
1.	Fertilizer (10-20-20)	0.5	Tons	\$ 66.00	\$ 33.00
2.	Lime	2	Tons	8.00	16.00

Table 13 Continued

Estimate of Costs Per Acre

<u>Item No.</u>	<u>Description</u>	<u>Revegetation</u>			
		<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
3.	Seed Mixture #1*	77	Pounds	\$ 1.80	\$138.00
4.	Hay Mulch (Applied)	2.5	Tons	77.00	193.00
5.	Hydroseeding (Application)	1	Acre	70.00	<u>70.00</u>
				TOTAL	\$450.00

*See Table 14.

METHOD 2. GRASS AND LEGUMES

1.	Fertilizer (10-20-20)	0.5	Tons	66.00	33.00
2.	Lime	2	Tons	8.00	16.00
3.	Seed Mixture #2**	68	Pounds	0.93	63.00
4.	Hay Mulch (Applied)	2.5	Tons	77.00	193.00
5.	Broadcast and Disc Harrow Application	1	Acre	20.00	<u>20.00</u>
				TOTAL	\$325.00

**See Table 14.

METHOD 3. REFORESTATION

1.	Trees (Cuttings)***	700	Trees	0.015	10.50
2.	Hand Planting	1	Acre	39.50	<u>39.50</u>
				TOTAL	\$ 50.00

***See Table 14.

Table 14
Estimate of Cost Per Acre
Seed Mixtures and Trees

<u>Item No.</u>	<u>Description</u>	<u>Approximate Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Total</u>
<u>* MIXTURE #1</u>					
1.	Crownvetch	22	Pounds	\$ 5.50	\$121.00
2.	Perennial Rye Grass	25	Pounds	0.22	5.50
3.	Kentucky #31	20	Pounds	0.42	8.40
4.	Red Fescue	10	Pounds	0.35	<u>3.50</u>
				TOTAL	\$138.40
<u>** MIXTURE #2</u>					
1.	Crownvetch	8	Pounds	5.50	44.00
2.	Perennial Rye Grass	20	Pounds	0.22	4.40
3.	Kentucky #31	20	Pounds	0.42	8.40
4.	Birdsfoot Trefoil	10	Pounds	0.25	2.50
5.	Red Fescue	10	Pounds	0.35	<u>3.50</u>
				TOTAL	\$ 62.80
<u>***TREES</u>					
1.	Hybrid Poplar	700	Trees	0.015****	9.60

****Cost based on stock that is readily obtainable from Pennsylvania Department of Forests and Waters. Commercial nursery stock will cost approximately \$50.00 per thousand cuttings.

E. Hydrated Lime Treatment Plant Method

When all other abatement methods are impractical or impossible, treatment plants will be required. Where practical, various discharges will be gathered at one central location for treatment. The capital and operating costs related to this method are based on Holland's research project at West Virginia University.

Table 15

Hydrated Lime Treatment

Total Operating Cost With Sludge Disposal

Including Capital Costs

(Cents Per Thousand Gallons)

<u>MGD</u>	<u>600-700 PPM Acidity</u>	<u>1,400 PPM Acidity</u>	<u>2,800-4,300 PPM Acidity</u>
.25	30	44	68
.50	25	36	57
.75	23	34	54
1.00	22	33	52
1.50	21	31	50
2.00	20	30	49
4.00	19	29	48
6.00	19	29	48
8.00	19	29	47

XI. MINE SEALING IN RELATION TO STRATIGRAPHY

A. General

Due to the depositional environment associated with coal deposits, generalization of the strata associated with the important coal seams on an area basis are, at best, extremely variable. Deep mine seal locations will require an itemized geologic section for roof and floor lithology together with fracture patterns and specific criteria on permeability, migration routes, and anticipated problems on mine sealing.

In an attempt to provide generalized sections for anticipated lithology, numerous diamond drill hole (DDH) core logs in possession of CBC and R. & P. Coal Companies were evaluated. Selected DDH logs are incorporated in this report as representative of the lithology within an area. Following is a brief resume of anticipated roof conditions together with evaluated sealing characteristics. The coal seams mined in the area list "Fire Clay", "Slate" or "Shale" underlying the mined seams throughout the entire drainage basin. The numbers on the descriptions correspond to hole numbers assigned to core holes by the coal companies.

B. Diamond Drill Hole Log Evaluations

1. DDH #447

In an area covering the northwest quarter of the Two Lick Creek Watershed, extending 2.65 miles south of the borough of Clymer to 24 miles north of Clymer and about 2 mile east, good roof conditions with good sealing characteristics are anticipated. In this area the coal seams, particularly the "B" seam, are overlain by dark shale units. The shale units are thick, impervious, and have very little fracturing.

2. DDH #2

In the extreme northeast portion of the Two Lick Creek Watershed immediately north of the borough of Commodore encompassing an area of approximately 2 square miles, good roof conditions for sealing are anticipated for the "D" coal seam, because of the presence of thick, impervious shale overlying the coal. The roof conditions are not as good for sealing "B" seam mines in this area. The "B" seam is overlain with sandstone which is pervious and tends to contain fractures and voids.

3. DDH #91

The next area, 3 miles north of Wandin Junction and about one mile west of Commodore, is in the central part of Map Sheet #1 and comprises an area of 6 square miles. In this area, roof conditions for sealing mines is anticipated as being good because of the pressure of dense impervious shale overlying both the "D" and "B" coal seams.

4. DDH #291 and #528

In the areas shown on Map Sheets #5 and #6 near Indiana, conditions for sealing are anticipated as being good in both the "E" and "B" coal seams because of the presence of dense impervious shale overlying the coal seam.

5. DDH #1444 and #1447

In the areas near Homer City as shown on Map Sheets #9, #10, #12, and #13, roof conditions are good for sealing coal mines for the "B" seam because of shale overlying the coal. However, the conditions for sealing coal mines in the "E" seam are not as good in the area because of the presence of sandstone overlying the coal. The sandstone is pervious and contains fractures and voids.

Table 16

Drill LogsClymer Field

<u>Boring Number</u>	<u>Lithology</u>	<u>Thickness</u>		<u>Depth</u>			
		<u>Feet</u>	<u>Inches</u>	<u>Feet</u>	<u>Inches</u>		
#2	Dk. Sandy Shale	22'	8"	118'	2"		
	Bl. Slate	0'	10"	119'	0"		
	COAL	4'	3"	123'	3"	"D"	
	Dk. Sandy Shale	21'	9"	145'	0"		
	SLATE & COAL SPARS	0'	5"	145'	5"		
	COAL	1'	0"	146'	5"		
	Fire Clay	4'	10"	151'	3"		
	Dk. Sandy Shale	35'	4"	186'	7"		
	Sandy Shale	41'	9"	266'	2"		
	Sandstone	16'	0"	282'	2"		
	BONEY COAL	0'	1"	282'	3"		
	COAL	2'	11"	285'	2"		
	Fire Clay	1'	3"	286'	5"	"B"	
	Dk. Fire Clay	0'	5"	286'	10"		
	Fire Clay	4'	4"	291'	2"		
	#91	Sandy Shale	16'	4"	599'	7"	
		Sandstone	6'	4"	605'	11"	
		Dk. Shale	0'	4"	606'	8"	
		COAL	3'	1"	609'	9"	"D"
Fire Clay		6'	3"				
Dk. Shale		11'	6"	35'	0"		
Sandy Shale		1'	0"	36'	0"		
COAL		0'	6"	36'	6"	"D"	
BONEY/COAL		0'	6"	37'	0"		
Fire Clay		12'	0"	49'	0"		
Lt. Sandy Shale		12'	6"	61'	6"		
Dk. Shale		10'	3"	196'	3"		
HARD, STREAKED COAL AND BONEY		0'	2"				
CLEAN COAL		0'	1/8"	199'	7"		
COAL		0'	1 1/2"				
SULFUR STREAKS		0'	3/8"			"B"	
COAL		1'	4"				
Fire Clay		5'	0"	204'	7"		
Lt. Shale		7'	5"	212'	0"		

Table 16 Continued

Drill Logs

Clymer Field

<u>Boring Number</u>	<u>Lithology</u>	<u>Thickness</u>		<u>Depth</u>		
		<u>Feet</u>	<u>Inches</u>	<u>Feet</u>	<u>Inches</u>	
#447	Dk. Shale	24'	0"	226'	0"	
	Slate	0'	4"	226'	4"	
	COAL	2'	7"	228'	11"	"B"
	SLATE & SULFUR	0'	5"	229'	5"	
	Fire Clay	7'	4"	237'	7"	
	Boney Clay	0'	3"	236'	10"	
	Sandstone	25'	2"	262'	0"	

Table 17

Drill LogsLucerne Field

<u>Boring Number</u>	<u>Lithology</u>	<u>Thickness</u>		<u>Depth</u>		
		<u>Feet</u>	<u>Inches</u>	<u>Feet</u>	<u>Inches</u>	
#291	Dk. Sandy Shale	19'	8"	43'	11"	
	SLATE & BONEY	0'	4"	44'	3"	"E"
	Dk. Sandy Shale	3'	0"	47'	3"	
	Dk. Sandy Shale	2'	9"	239'	9"	
	Sandstone	3'	3"	243'	0"	
	COAL @/SULFUR STREAKS	3'	2"	243'	0"	"B"
	Fire Clay	4'	4"	250'	6"	
#528	Sandstone	26'	3"	190'	8"	
	Dk. Shale	4'	10"	195'	6"	
	COAL	1'	4"	196'	10"	
	BINDER	0'	8"	197'	6"	
	COAL	3'	7"	201'	1"	"E"
	SLATE BINDER	0'	2"	201'	9"	
	COAL BONEY	0'		201'	9"	
	Fire Clay	2'	0"	203'	9"	
	Sandstone	3'	6"	207'	3"	
	Sandy Dk. Shale	14'	0"	405'	10"	
	Dl. Slate	13'	2"	419'	0"	
	BONE	0'	4½"	419'	4½"	
	COAL	2'	3"	421'	7½"	"B"
	SULFUR	0'	1½"	421'	9"	
	COAL	0'	2"	421'	11"	
	Fire Clay	3'	1"	425'	0"	
#1444	Sandstone	45'	11"	406'	11"	
	Dk. Shale	0'	4"	407'	3"	
	Sandstone	9'	1"	416'	4"	
	BONEY	0'	2½"	416'	6¼"	
	COAL	1'	2½"	417'	8 3/4"	
	BINDER	0'	5½"	418'	2¼"	"E"
	COAL	0'	7¼"	422'	5½"	
	Dk. Fire Clay	0'	3½"	422'	9"	
	Fire Clay	1'	3"	424'	9"	
	Sandstone	0'	10"	424'	10"	
	Dk. Shale	0'	11½"	425'	9½"	
	Sandstone	1'	0"	426'	9½"	
	Dk. Sandy Shale	3'	0"	429'	9½"	
	Dk. Shale	2'	11½"	432'	9"	
	COAL	0'	5"	433'	2"	

Table 17 Continued

Drill LogsLucerne Field

<u>Boring Number</u>	<u>Lithology</u>	<u>Thickness</u>		<u>Depth</u>		
		<u>Feet</u>	<u>Inches</u>	<u>Feet</u>	<u>Inches</u>	
#1444	Dk. Shale	20'	0"	615'	0"	
	BONEY	0'	8 $\frac{1}{2}$ "	615'	8 $\frac{1}{2}$ "	
	COAL	3'	5 $\frac{1}{2}$ "	619'	2"	"B"
	Dk. Fire Clay	0'	5"	619'	7"	
	Fire Clay	2'	5"	622'	0"	
#1447 (New Outcrop)						
	Sandstone	76'	10"	32'	10"	
	BONEY	0'	6"	33'	4"	
	COAL	4'	4 $\frac{1}{2}$ "	37'	8 $\frac{1}{2}$ "	"E"
	Fire Clay	2'	3 $\frac{1}{2}$ "	40'	0"	
	Sandstone	3'	0"	43'	0"	
	Dk. Shale	12'	4"	226'	4"	
	BONEY	0'	6 $\frac{1}{2}$ "	226'	10 $\frac{1}{2}$ "	
	COAL	2'	7 $\frac{1}{2}$ "	229'	6"	
	Fire Clay	3'	6"	233'	0"	