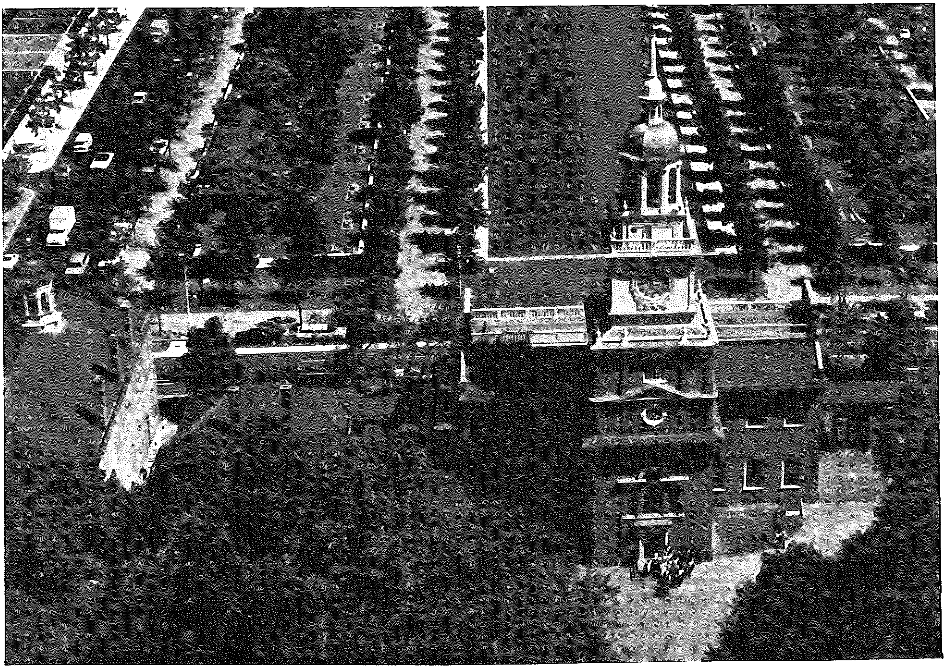
ASCE ANNUAL CONVENTION
AND EXPOSITION

PREPRINT 2770

OPERATION SCARLIFT - MINE DRAINAGE ABATEMENT

C. H. McConnell, Donald E. Fowler,
& Andrew E. Friedrich



Philadelphia, PA., September 27-October 1, 1976

$1.00

OPERATION SCARLIFT - MINE DRAINAGE ABATEMENT

By C. H. McConnell, F, ASCE, Donald E. Fowler and

Andrew E. Friedrich, AM, ASCE*

I. HISTORY OF MINING

Pennsylvania has been abundantly blessed with a variety of natural resources, not the least of which are its extensive anthracite and bituminous coal fields. For almost two centuries, these coal resources have been the base on which our highly developed industrial complex is built. In addition, millions of tons of coal have been shipped all over the world.

The history of anthracite mining is virtually the history of Northeastern Pennsylvania. The oldest coal mine in America appears to have been near Richmond, Virginia in 1750. In Pennsylvania, a blacksmith shop opened in Wilkes Barre in 1769 which used locally mined anthracite. There was a reluctance to use anthracite because it was so difficult to ignite in the then existing stoves. However, by 1820, 2,500 tons had been shipped out of the Wyoming Valley, primarily to Philadelphia.

Shipping was a problem until the canal system was built. In 1825, the Schuylkill Canal provided cheap transportation of coal to Philadelphia. By 1846, the coal canal system contained 643 miles of waterways. By 1870, the railroad had assumed a major role in the transportation of coal.

Quite naturally, the earliest mining was done by strip mining -- coal was dug out at the outcrop because this was the easiest way to obtain it. Deep mining became quite prevelant by the mid-1800s. It was in 1844 that the first mechanical breaker was used, although the slate

---

*All three employed by the Department of Environmental Resources, P. O. Box 1467, Harrisburg, Pennsylvania 17120. C. H. McConnell is Deputy Secretary for Resources Management, Donald E. Fowler, P.E. is the Special Assistant to Mr. McConnell for Land and Water and Andrew E. Friedrich, P.E., Chief, Division of Mine Area Restoration.

was still picked by hand. Thirty years later, jigs were introduced that separated the coal by specific gravity.

Anthracite production increased markedly after the Civil War -- the industrialization period of the United States. The peak annual production of 100 million tons occurred in 1917.

Strip mining, as we know it today, gained momentum during and following World War I. By 1970, 47% of the production was by surface mining, 18% by deep mining, 31% by reprocessing culm banks, and 4% by dredging. From the peak production of 100 million tons of anthracite in 1917, 1973 production had fallen to 6.3 million tons. Of this, 2.6 million tons were from the Southern Field, primarily by stripping and culm bank recovery.

It is interesting to note that in the early days of mining, a boy started his mining career between the ages of 4 and 10 years as an errand boy. He then progressed to door boy, mule driver, laborer, and finally miner. In 1905 a law was enacted that prevented minors under 16 years of age from working in an anthracite mine, and under 14 on the outside of a mine.

The history of bituminous coal mining is not as well documented as that of anthracite. Most of the bituminous records are on a county or individual mine basis. Records indicate that first mining in Fayette, Washington, and Allegheny Counties was in the late 1700s. Bituminous mining did not really blossom until the late 1800s.

Whereas anthracite marketing was pointed toward heating purposes, bituminous sales were primarily for the production of coke for iron smelting furnaces. The first successful coking plants were started in 1833. By 1873 there were over 7,200 coke ovens in Fayette County alone.

Other counties in the bituminous area started major mining in the early 1900s. The peak production year for bituminous coal was 1918 with over 177 million tons being produced. 1973 production was almost 78 million tons of which 29 million were by stripping.

The concomitant production of oil and natural gas in the bituminous area has also had a marked impact on the economy and industrialization of the State, as well as on the pollution problems.

An interesting side-light on the history of mining, and a lead-in to the following overview of mining and reclamation laws, is a 1961 law that prohibits a boy under 18 years of age from working in or about a bituminous coal mine, and also prohibits a woman or girl of any age to work in or about a mine, except for clerical work in an office.

II. - MINING LAWS

Laws relating to active coal mining in Pennsylvania go back to the mid-1800s. The first comprehensive mine safety legislation in the United States was enacted by the Pennsylvania Legislature in 1870 following the death of 108 men and boys in a mine in Luzerne County (Anthracite Area). In the same year, special legislation was enacted re mining in Mercer County (Bituminous Area). In 1877, a comprehensive Bituminous safety act was passed, very similar to the Anthracite act of 1870.

Laws governing the operation of deep mines, and governing surface support requirements for deep mines, have always been, and still are, separate for anthracite and bituminous mines. There are variations in the provisions of each set of laws but the general requirements are similar.

Mining laws similarly were separate for bituminous and anthracite surface mines. However, in 1971, the All Surface Mining Act (actually an amendment to PL 1198 of 1945 re Bituminous Strip Mining) was enacted to provide stringent mining and reclamation requirements for all surface mining in the Commonwealth (coal, stone, clay, etc.). This legislation has been hailed nationally as a model surface mining law.

A number of laws were passed through the years concerning the sealing of abandoned deep mines for various purposes: prevent entry by people; prevent entry of air to reduce oxidation and formation of acid discharge (but originally the discharge was permitted); require sealing of shafts and slopes (but once sealed, the Commonwealth was responsible for maintenance); and finally, the Clean Streams Act of 1937, as amended, required positive control of the polluting water discharge from mines.

In 1961, Pennsylvania passed the Coal Mine Subsidence Act which established a fund to provide subsidence insurance underwritten by the Commonwealth.

As early as 1965, Pennsylvania enacted laws to provide for reclamation and pollution control of abandoned mines. One half million dollars was appropriated for abating pollution from abandoned deep and strip mines; $5.5 million was appropriated to match funds in the then newly established Appalachian Regional Development Act for specific subsidence, mine fire, and strip mine reclamation projects; and another $1 million was appropriated to acquire and reclaim abandoned strip mined lands which were hazardous or a public nuisance. After reclamation, these lands could be sold at public auction and the proceeds would be returned to the revolving fund.

While Pennsylvania has been a leader in mining legislation, it has only been in relatively recent years that pollution control and land restoration have been effectively covered. The vast majority of laws up to the mid-1960s governed mining operations and State control over these operations -- particularly in the field of mine safety. Thus, Pennsylvania has a visible legacy of polluted streams and scarred landscape from the very extensive mining operations of past decades.

III. - THE NEED FOR RECLAMATION ACTION

As deep mining penetrated farther and farther into the earth, following the various workable veins, groundwater aquifers were intercepted. In digging for coal, other minerals are uncovered which when exposed to air and water form acids.

Prior to recently enacted legislation, these acid waters invariably found their way into surface streams, either by pumping or gravity flow. The hundreds of miles of brightly colored orange stream beds and banks visible today are the result of deposits of iron and other mineral particles carried into the streams by these acid mine discharges.

When deep mine workings were abandoned, water often collected in polluted underground pools which rose until they could discharge through boreholes, mine openings or fissures in the surface rocks.

Deep mining created vast labyrinths of tunnels and "rooms" under hundreds of square miles of surface area. As these workings were abandoned, the natural and artificial supports left in place deteriorate and begin to fail. Stresses and strains then develop in the overlying rock strata and they, in turn, begin to collapse, eventually leading to surface subsidence.

Subsidence potential varies from mine to mine, depending on the extent of extraction, the geological formation of the overlying rock strata and the proximity of the mining operations to the earth's surface.

Considerable areas of critical subsidence have already developed in the Wilkes Barre -- Scranton section of the anthracite region and in several sections of the bituminous region.

Fires frequently occur in the huge mountains of mine refuse material which dot our landscape. Clouds of noxious smoke and dust come from these fires, polluting the air for miles around. Other fires are burning in underground coal seams, often giving off lethal amounts of carbon monoxide gas through mine openings and rock fissures. Many of these fires have been burning for decades.

Typically, prior to the stringent laws now existing, mines were abandoned in the condition that existed at abandonment:

Gravity drainage of water

Interconnected mines left open

Subsidence was of little or no concern

Ventilation and supply shafts left open

No sealing of slope or drift entries

Storage pits left open

Outcrop barriers stripped out

Refuse left as it was.

Surveys in the 1960s indicated that the magnitude of degradation in Pennsylvania by past mining was approximately as follows:

Lengths of streams polluted by mine drainage: 2600 miles continuously, + 1200 miles intermittently

(Many of these streams also were polluted by sewage and industrial wastes)

Area of unreclaimed strip mined land: 300,000 acres

Volume of burning coal refuse banks: 100,000,000± cubic yards

Volume of non-burning coal refuse banks: 2,500,000,000± cubic yards

Many underground mine fires existed and large urban areas were subject to possible future subsidence.

IV. - THE LAND AND WATER CONSERVATION AND RECLAMATION ACT OF 1968

As shown by the foregoing discussion, there was a definite need for action at least to begin to correct the land and water degradations of past mining practices. The Act of January 19, 1968, P.L. 996, as amended (Act 443) was landmark legislation in the nation to implement the cited needed action. This Act covered not only abandoned coal mine reclamation but also provided funds for sewage treatment, enhancement of public outdoor recreation, and development of county and municipal parks. The Act became known by several names, or common usage terms:

Project 500 - derived from the authorization of selling $500 million in bonds over a ten year period to enhance despoiled lands and waters.

Operation Scarlift - refers to the mine reclamation portion of the Act to remove scars of past mining.

Bond Issue Program - so called because funding was by the sale of bonds by the Commonwealth.

The intent of this Act with respect to the mining portion is not cosmetic improvements, but pollution abatement along with public safety with regard to mine fires and subsidence. The financing technique of selling bonds over a time period was the only practicable way to fund such an extensive program. Annual appropriations would be inadequate and subject to fluctuations. A major effort such as envisioned by the Legislature would have to have continuity and stability.

When Act 443 was passed in 1968, the Department of Mines and Mineral Industries was responsible for the mine restoration and abatement work. The Act of December 3, 1970, P.L. 834, (Act 275) abolished the Department of Mines and Mineral Industries, the Department of Forests and Waters and various Boards and Commissions and transferred all activities to the new Department of Environmental Resources.

The basic work authorized under Act 443 covers four distinct categories of abandoned mining reclamation. These are the abatement of stream pollution from mine drainage, which may include restoration of abandoned strip mine areas; the abatement of air pollution from abandoned burning coal refuse banks provided such land and bank material is publicly owned; and the control of surface subsidence above abandoned mine operations and the control and extinguishment of surface and underground fires from abandoned mines. Administration expenses are also authorized within the aforementioned allocation.

The original act authorized $150 million for abatement of stream pollution, $25 million for extinguishing fires in abandoned refuse banks and $25 million for control of surface subsidence and extinguishment of underground mine fires. The Acts of July 12, 1972, P.L. 857 (Act 193) and June 30, 1976 (Act 120) approved the current authorization of $140 million for the abatement of acid mine drainage, $20 million for the extinguishing fires in abandoned refuse banks and $40 million for the control of surface subsidence and control of underground mine fires.

While the Act was approved January 19, 1968, the funds were actually authorized from July 1, 1967 for a ten year period to June 30, 1977. The authorization to sell bonds would be approved by the Legislature every two years, in the amount of $40 million for the abandoned mining reclamation program. It became evident in the early 1970s that more than ten years would be required to spend properly and justifiably the $200 million as prescribed by law. The Act of July 9, 1975 (Act 104) extends the authority and funds to June 30, 1981.

The necessary time extension was due to several factors. First, the Act was approved six months after the actual effective date. Second, there had been practically no planning time prior to passage of the Act. The old Department of Mines and Mineral Industries had to initiate a very extensive program in a very short time. Third, the energy crisis of the mid-1970s caused coal prices to escalate dramatically which in turn caused re-stripping of formerly abandoned strip mines to be profitable. Since most of our acid mine drainage reclamation efforts are source-correction oriented (this technique to be described later), many of our projects, both active and planned, had to be reevaluated due to active mining. Of course, under present surface mining laws, the operator will restore the reaffected area which results in a saving to the taxpayers. Fourth, early projects concentrated on burning refuse banks, underground fires and subsidence because these were long standing, immediate problem areas for which abatement techniques were available. As a result, the legal expenditure limits were rapidly approached and the balance of the funds were almost all to be spent on acid mine drainage work.

In order to clarify ambiguous provisions of the original Act and to delineate certain legal procedures and authorizations Act No. 103, was approved on June 24, 1976. Operationally, this bill will permit performing projects on any type abandoned mine, not just abandoned coal mines as was originally specified.

It must be specifically noted that the Act does not authorize reclamation of strip mined land for the sake of reclamation or aesthetics; regrading of stripped land can only be done as a technique to abate mine drainage. Similarly, nonburning refuse banks cannot be eliminated unless it is done as an acid mine drainage abatement technique. These are two examples of the previous statement concerning the pollution abatement intent of the law vs cosmetic improvements.

V. - FORMATION OF ACID MINE DRAINAGE

Acid mine drainage is a by-product of the mining industry. For a long period of time, little control was exerted over the industry to minimize the formation of acid mine drainage. It should be noted that the acid mine drainage problems are not limited to Pennsylvania but exist in over 20 states where coal or other pollution generating minerals are mined.

In order to fully understand the problems associated with mine area restoration work, a brief review of the chemical reactions under which acid mine drainage is produced is necessary. The formation of mine drainage is dependent upon the presence of oxygen, sulfur bearing material, and water. The following description of the formation of AMD is taken from the report "Two Lick Creek Mine Drainage Pollution Abatement Project, SL 109" prepared for the Department of Environmental Resources by L. Robert Kimball, Consulting Engineers.

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.

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):

<u>(a)</u> FeS_2 (pyrite) + $7/2\ O_2 + H_2O = 2SO_4^{-2}$ + $2H^+ + Fe^{+2}$ (iron).

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

<u>(b)</u> $4Fe\ SO_4 + 2H_2SO_4 + O_2 = 2Fe_2\ (SO_4)_3 + 2H_2O$.

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

(c) $Fe_2 (SO_4)_3 + 6 H_2O = 2Fe (OH)_3$ (ferric hydroxide - "Yellowboy") + $3H_2SO_4$.

(d) $Fe_2 (SO_4)_3 + 2 H_2O = 2Fe (OH) (SO_4) + H_2 SO_4$.

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.

VI. - METHODS OF ABATING ACID MINE DRAINAGE

The acid mine drainage program is implemented in four basic steps. First, a watershed study is conducted on those watersheds where past mining has resulted in polluted streams from mine drainage. The predecessors to the Environmental Protection Agency, the Federal Water Quality Administration, and the Federal Water Pollution Control Administration made a survey, in the 1960s, of mine drainage in Pennsylvania. They identified those watersheds degraded by mine discharges. Approximately 80% of the affected watersheds in the State now have either a completed or an on-going study.

After careful analysis of the study, those recommended projects that are deemed to make significant contributions to the abatement of mine drainage within a reasonable cost are further defined. Scopes of work for these selected projects are then sent for detailed design.

In very general terms, pyrite plus oxygen plus water yields sulfuric acid and "yellowboy", the precipitate found in streams affected by mine drainage. Therefore, any project undertaken to abate acid mine drainage must address the control or elimination of either (1) the pyrite, (2) water, a reactive material and also the transporting agent, or (3) oxygen. From experience, the complete removal of the first two, that is, the pyritic material and water, is practically impossible. To resolve the problems of acid mine drainage, there are two methods of approach. That is, correction of the problem at the source or treatment of the discharge. Our program to date under Operation Scarlift has used both methods. We have used the policy of trying to correct the acid mine drainage problem through source correction to the maximum extent possible with treatment as a last resort. Under source correction, we have addressed the acid mine drainage problem resulting from abandoned deep mines, strip mines, and breaker refuse piles.

A. Source Correction (Deep Mines)

To reduce the pollution from deep mines, we have used two techniques, (1) deep mine sealing with subsequent inundation and (2) reduction of inflow of surface water into the deep mines.

1. Deep Mine Sealing:

The purpose of deep mine sealing (inundation) is to displace the oxygen medium in the mine with water. Therefore, one of the three necessary elements in the chemical reaction forming acid mine drainage is eliminated. Prior to initiating a project involving deep mine sealing, many factors must be evaluated and weighed. Mine maps must be studied to determine the extent of the workings and the amounts of inundation that would be needed to flood the mine workings. This establishes the hydraulic head that must be withstood to accomplish the complete inundation of the mine. A determination of the integrity of the crop barrier must be ascertained to see if it is sufficient size to withstand the related head that would be imposed on it. Also, the rock structure overlying the coal must be evaluated to determine the extent to which it will conduct or retard the movement of water. If the rock strata overlying the coal seam is relatively impervious, then the ultimate head that would develop on any seal would not only be dictated by the coal seam but also could be affected by any aquifers above the coal seam. Potential head in this case could be the highest ground elevation overlying the deep mine. In this case, it is generally necessary through the use of a tunnel, borehole, or entry to control the desired level of inundation. In the case where the rock strata above the mine is relatively pervious, the level of inundation can be controlled through the use of a grout curtain to the desired elevation.

In many cases, the outcrop of the deep mine is inadequate to retain the hydraulic head that must be developed to achieve the desired level of inundation. In cases where there is insufficient crop barrier due to strip mining, an impervious barrier in conjunction with strip mine reclamation is utilized. This reclamation can be designed so that it acts as a dam to retain the head that is going to be developed and control the seepage.

It should be noted that hydraulic heads of over 400 feet would be involved in some of the potential seals that have been considered. Because of the high heads involved and the serious consequence of any failure of the seals, detailed geological investigations and evaluations are essential in the design of seals.

Another method of inundation in mines with insufficient crop is the use of box cutting through the deep mines to compartmentalize the mine. The head in each compartment that would be developed can then be controlled to a practical level. Provisions must be made during this type of sealing to insure there is no interconnection between various flooded pools that are established.

In conjunction with inundation, the following factors must be investigated to determine that there will be no adverse environmental effects caused by the sealing:

a. The rock structure and stratigraphy must be evaluated to ascertain what the migration of water will be after sealing.

b. A determination must be made of the elevation of the groundwater table with the possible seasonal fluctuation.

c. Aquifers above and below the coal measures must be known.

d. Based on the anticipated level of inundation, a check must be made of all residences in the area to insure there will be no basement flooding as the result of our work.

e. A check must be made of all public and private water supply in the area to determine whether there would be any adverse effects caused by our sealing project.

f. All springs in the immediate vicinity of the deep mine should be located and their elevations checked with respect to proposed future level of flooding. These springs may also give an indication of fault zones that may transect the mining complex.

g. If possible, the water quality of aquifers, both above and below the coal seam, should be ascertained. Polluted aquifers immediately below the deep mine may indicate that the underclay had been breached during mining, possibly to relieve a local drainage problem within the mine. If this is the case, a sealing project may not be feasible.

h. A check must be made of all fault zones and fracture zones in the vicinity of the deep mine complex. They must be evaluated with respect to the sealing and their connection to aquifers in the area.

i. An investigation must be made into any active mines, both deep and strip, that are operating within the area that would be affected by the proposed inundation to determine that the project would present no safety hazard to these operations.

j. In areas where there is unconsolidated material and a minimum rock coverage above the mine complex, the project must be evaluated to insure that any proposed inundation will not cause subsidence. It has been our experience, especially in the Wyoming Valley in the Anthracite area, that subsidence can occur as the result of fluctuating mine pools.

There are many uncertainities involved in trying to evaluate the above factors. However, the benefits that would be derived in pollution abatement must be weighed against potential problems that could arise. Once we have determined that the negative consequences of our project would be minimal, or tolerable, then the only items that must be determined are the degree to which the sealing must be accomplished. To insure inundation, of course, the discharge must be less than the recharge into the mine complex. However, the amount of seepage that can be tolerated from the finished project must be limited to the point that fluctuations are maintained above the coal and high pyrite zone.

Additionally, it is imperative, if a mine is inundated, that the regulatory agency within the State is advised so that no mining can take place that could unknowingly endanger life and property.

2. Reduction of Inflow Into Mines:

Another method that we are using to resolve the acid mine drainage problem from deep mines is to reduce the concentrated infiltration into the mine. The type of work involved in this method consists of (1) backfilling subsidence holes, generally in stream channels, (2) providing impervious liners in stream channel reaches where excessive water losses have been noted, (3) backfilling of strip mines that have intersected the deep mine and where concentrated overland flow is presently discharging, and (4) backfilling of slope entries where stream flows are presently being lost.

This method does not result in the dewatering the mine complex but is used merely to reduce the transportation of the acid mine drainage from the mine. It has been noted in several publications in the past that the overall reduction of pollution using this method may be minimal. We use this method mainly on marginal watersheds where only a minimum amount of additional abatement is necessary to make the stream useable, or in cases where we are proposing to provide a treatment plant for the mine discharge, in which case the size of the treatment facility can be reduced by eliminating this surcharge of surface water. Although we have not monitored our projects during a sufficient period of time to determine the long range effects using this method of abatement, it is our feeling that during periods of low natural infiltration, the reduction in inflow to the mine will minimize the acid loading into the stream. Since this normally corresponds to low stream flow periods, it can have a very pronounced effect on a stream during this period. Conversely, during periods of high infiltration into the mine, which generally corresponds to high stream flow periods, the acid mine drainage can usually be assimilated through dilution. In using the method of reducing the water inflow into the mine, essentially the only problems that must be resolved concern the potential for downstream flooding. If the stream loss into the deep mine is excessive and has occurred for a number of years, there is the possibility that the downstream reaches of the stream through siltation have reduced channel capacity. Also due to the lack of flow for many years, there may be undersized stream encroachments present. Before this method is used, and water is restored to the original channel, stream channel capacities must be checked to insure that there will be no flooding dangers caused by this type of work.

3. New Techniques Under Consideration:

There are two other methods for solving the acid mine drainage from deep mines which we feel show promise for the future. The first concerns daylighting of abandoned deep mines. This method involves stripping out and recovering the coal in the pillars. Thus, removal of the coal eliminates one source of pyritic material. However, for this method to be successful, the pyritic roof material must be selectively placed in the backfill to minimize the contact with air and water. We are presently monitoring a daylighting operation being conducted by an active mining company. Once the results are analyzed, along with the results of an on-going EPA research project on daylighting in Maryland, a decision will be made on whether we will use this method in the future.

The second method which we are presently planning to research involves dewatering of aquifer(s) above the mine roof through the use of gravity connector wells. Above mining areas, there are fracture zones which are zones of concentration for groundwater. Wells can be located at the innersection of these fracture zones to collect this water and transmit it below the mine complex. If successful, this method will only be useful on a limited basis where proper geological conditions prevail. This method involves the localized dewatering of aquifers which are presently above the mine roof and feeding the mine, and transporting this water from above the mine area to an aquifer below the mine area through the connector well. A modification of this concept, which also may be useful in the future, would involve the case where there is a high alkaline aquifer above the mine complex, which could be collected and transmitted into the mine for essential in-mine treatment. One drawback to this method is the difficulty of evaluating the aquifers to insure that the dewatering does not adversely affect water supplies in the immediate area. If successful, this method may also prove beneficial to active deep mining where excessive water problems are encountered.

B. Source Correction (Strip Mine)

Another major area of concern in our source correction abatement program involves the pollution emanating from strip mines. Pennsylvania has the largest acreage in the United States of disturbed lands due to past mining: 370,000 acres or 1.3% of the total land in the State. Of the 370,000 acres, about 300,000 are attributable to coal mining; the other 70,000 are from stone, clay, and sand and gravel extraction. Pennsylvania's 370,000 acres of mining-disturbed land represents some 11.5% of all the mining-disturbed land in the United States; Pennsylvania's total land area is only 0.75% of the land area in the United States. Thus, Pennsylvania has a nationally high order of magnitude of surface reclamation requirements.

Prior to initiating a project involving strip mine reclamation, a determination must be made as to the nature of the pollution problem. During strip mine operations, pyritic material, which overlaid the coal seam and in some cases breaker refuse, returned to the site after coal processing, was intermingled throughout strip mine spoil banks. Acid mine drainage formation takes place both at the surface of the spoil bank during periods of runoff and from infiltration into the spoil material which subsequently leaches out. Proper grading, good water management, and providing good vegetative cover will reduce the acid mine drainage formation caused at the surface. This will also provide for increased controlled runoff and increased evapo-transportation, with a subsequent decrease in infiltration. If part of the problem of leaching was caused by impounded runoff water between the highwall and the spoil bank, the grading will significantly reduce the leaching portion of the pollution problem. If infiltration into the spoil bank is caused by a connection with groundwater aquifers, then some type of control, such as an impervious barrier, must be incorporated into the project to minimize the contact of water with the pyritic spoil material.

One matter that must be investigated prior to initiating this type of work concerns an evaluation of the potential downstream flooding as a consequence of restoring the strip mined land to an unimpeded runoff situation. As was mentioned previously, after many years of siltation and reduced flows in stream channels, the channel capacity may be restricted such that an adverse consequence of the rehabilitation work would be downstream flooding. An assessment of the potential downstream flooding must be made and weighed against the benefits that will be derived.

C. Source Correction (Refuse Banks)

A third area of concern in our abatement program deals with deep mine refuse or breaker refuse banks. With the present price of coal, we have found that many of these pollution sources are presently being eliminated by active coal operators who are reprocessing these refuse banks. However, in those cases where there is insufficient coal content in the bank, the size and/or location of the bank precludes it from being reprocessed, and if the bank is a significant stream polluter, then reclamation of these banks is considered in the abatement program. In evaluating a project to eliminate or decrease the pollution from a refuse bank, consideration must be given to minimize the contact of surface water, groundwater, and rainfall with the refuse material. The ideal solution would be to remove the material and deposit it in areas where it would have minimum contact with water. However, in many cases this is not economically practical. Therefore, piles are regraded to induce good surface runoff and thus minimize infiltration. Additionally, measures are taken to control those portions of the bank that are in contact with surface runoff.

D. Treatment

Some past mining practices defy source correction. Only after exhaustive studies of treatment plant feasibility and benefits are plants considered. Under our program, ten treatment plants have been constructed to date ranging from very sophisticated ion exchange units to very basic in-stream lime type facilities which involve a lime storage bin and lime feed mechanism (refer to Appendix A). Although much has and can be accomplished utilizing treatment facilities, they do have serious drawbacks. Treatment plants have a continuous annual operation and maintenance expense which must be born by the taxpayers. Since nothing is done to correct the source of the problem, these plants will have to be renewed at some future date to insure that the pollution abatement they are achieving will continue. Although we have not experienced significant problems, treatment plants could be subject to downtime through power failure, truckers' strikes, etc. It is possible that if this downtime is excessive, all that has been accomplished as far as establishing downstream water activities could be undone. Additionally, there is the continuous cost for disposal of sludge which is generated during the treatment process.

Utilizing a lime or limestone treatment process can eliminate the acid and iron problems pertaining to the mine discharges. However, they cannot alleviate the high sulfate concentration that is inherent in acid mine drainage. Elimination of the sulfate problem requires using either ion exchange, reverse osmosis, flash distillation, or the alumina-lime process. Unless a need for potable water is necessary, the cost for the last four processes is prohibitive.

Instead of going into a detailed explanation of the various treatment processes and their limitation, I would like to refer you to two publications, which essentially provide a resume of the state-of-the-art concerning treatment. They are:

"Analysis of Pollution Control Costs", prepared by Michael Baker, Jr., Inc., for the Appalachian Regional Commission. This document was published in February, 1973 by the Appalachian Regional Commission, 1666 Connecticut Avenue, N.W., Washington, D. C. 20235.

"Processes, Procedures, and Methods to Control Pollution From Mining Activities", prepared by Skelly & Loy for the U. S. Environmental Protection Agency. This report was published in October, 1973 and is available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

Another treatment method involves in-stream treatment with limestone. In 1970, the Department in cooperation with the Environmental Protection Agency undertook a project to evaluate the use of limestone barriers in Trough Creek, an acid polluted stream in Huntington County. The results of this study will be available soon as an Environmental Protection Agency publication entitled Trough Creek Limestone Barrier Installation and Evaluation - (Project Number 14010 FWW).

The results of this project demonstrated that limestone barriers had the capability of neutralizing the acid present and restoring the stream to conditions favorable to aquatic life. However, some problem did arise specifically involving (1) the washout of the barriers under flooding conditions, (2) the siltation of the barriers reducing effective contact surface area, and (3) the coating of the limestone with metal hydroxides and clay particles which substantially reduced their effectiveness.

The first two publications cited on page 21 also give an excellent resume of costs for all acid mine drainage abatement techniques to date; that is, for both treatment plant costs and source correction costs. Much of the information concerning cost was developed from projects conducted under our Scarlift program. There are no general rule of thumb costs for acid mine drainage abatement procedures but each project must be weighed to determine the amount of work needed to accomplish the abatement objective.

VII. - STATUS OF OPERATION SCARLIFT

I would like to briefly state the magnitude of the problem of acid mine drainage pollution in Pennsylvania, and also resumé what has been accomplished to date towards resolving this problem. There are now approximately 2200 miles of streams continuously affected by acid mine drainage, plus an additional 1200 miles which are intermittently affected by acid mine drainage. Our efforts to date have resulted in a complete cleanup of 48 stream miles and a significant reduction in the pollution of an additional 140 miles. Essentially, this abatement is attributable to the restoration of over 2600 acres of strip mined land, the construction of 10 treatment facilities, sealing of 32 deep mine complexes, and reclamation of 37 refuse banks.

At present a monitoring program is being conducted in order to determine the effects of abatement work. It is difficult to ascertain on major Pennsylvania streams the amount of stream quality improvement that can be attributed specifically to acid mine drainage abatement projects versus improvement that is also being conducted by active mining operations, and the elimination of sewage and industrial waste.

As of this date, we have tentative reports on three specific watersheds where significant results have been accomplished: the Youghiogheny River, downstream of the town of Confluence; Moraine State Park, Butler County; and Mahantango Creek, Dauphin County.

In the Youghiogheny River watershed, the Shaw Mines Complex extends over an area of approximately 1900 acres in Summit and Elk Lick Townships, Somerset County - approximately 65 miles southeast of Pittsburgh. Deep mining was carried out in the Pittsburgh and Redstone Seams from the 1880's to the 1940's.

To develop the full potential of Eastern Fayette and Western Somerset Counties, as an outstanding tourist, historical and public recreation region, an adequate supply of clean water is required. The purpose of the projects at the Shaw Mine Complex was to minimize the drainage of acid waters into the Casselman River. The mine drainage from this complex was particularly severe in the Spring of 1963, when the pH value of the Youghiogheny River at Connellsville dropped to 4.5 - killing most of the aquatic life and resulting in a contamination of water supplies at Connellsville - 26 miles downstream.

The following abatement measures have been undertaken under our Bond Issue program:

1. Backfilling and leveling of subsidence areas caused by deep mining to reduce seepage of water into the underground workings.
2. Construction of 8000 l.f. of box cuts and installation of clay seals in the cuts to prevent the flow of water through the coal seam. In addition, contour backfilling was conducted above the clay seals, along with construction of permanent diversion ditches to decrease the groundwater infiltration.

3. Construction of 3500 l.f. of grout curtain to prevent the flow of water through the abandoned mines.

4. Construction of five hydraulic mine seals and related grout curtains to back up the water in the mines.

This work with a total cost of $3.1 million was initiated in December 1969 and was completed in July 1973.

In accordance with FWPCA Ohio River Basin Project, "Work Document 21", based on 1965-66 data, the average net acid load per day for the Casselman River was 60,000 lbs. After abatement work had been in progress at the Shaw Mine Complex, the average acid load per day for 1972 was 33,000 lbs. Samples taken in the Casselman River directly below the Shaw Mine Complex, before and after all work was completed, have shown an average increase in pH from 3.9 to 4.5, an average decrease in acidity from 72 mg/l to 36 mg/l and an average reduction in iron concentrations from 8.1 mg/l to 4.0 mg/l.

This acid mine drainage work has sufficiently improved the water quality in the Youghiogheny River from its confluence with the Casselman River to Connellsville so that the Pennsylvania Fish Commission stocked 160,000 fingerling brown trout in this reach of the river on August 22, 1973.

Another area where inundation of deep mines through sealing has successfully taken place is in Moraine State Park. Before any work was undertaken, the acid mine drainage from adjacent mining complexes degraded the water quality in many tributaries to such an extent that Lake Arthur would not be able to support aquatic life. Now, after the work has been accomplished, we find that the water quality in the lake is sufficient to support aquatic life and permit full recreational use. The results of this abatement program (which also included strip mine reclamation, refuse pile removal, and abandoned oil and gas well plugging, in addition to deep mine sealing) showed a 67% abatement of the pollution problem. This work, which was conducted in cooperation with the Appalachian Regional Commission, began in 1967 and was completed in 1971. The cost of abating the pollution problem was $2,643,100, which included sealing 19 deep mine complexes, plugging 422 oil and gas wells, reclaiming 462 acres of abandoned strip mines, and removal of 217,100 yd.^{3} of refuse piles.

The third watershed which we have cleaned up is Mahantango Creek, which is located in Schuylkill, Northumberland and Dauphin Counties. A lime treatment plant was constructed on Rausch Creek, an upstream tributary to Mahantango Creek. The treatment facility is located in Hegins Township, Schuylkill County, south of Valley View. The plant was designed to clean up approximately 28 miles of stream from western Schuylkill County to the Susquehanna River. This lime treatment plant, which had a capital cost of $2.1 million, was put into operation in 1974. This on-stream plant has a capacity of 20 million gallons per day, with normal operating flows ranging from 6 to 10 million gallons per day. The Pennsylvania Fish Commission conducted a survey of Mahantango Creek in June 1975. They found various invertebrate in the stream that illustrated that Mahantango Creek was recovering from the effects of acid mine drainage. In 1976 the Pennsylvania Fish Commission approved and stocked trout in a 10.5 mile stretch of the stream. Additionally, local sportsmen's groups have conducted private stocking of additional stretches of the stream. The balance of the stream is a warm-water fishery.

Tremendous engineering and financial problems exist in some of the drainage basins in Pennsylvania. For example, the Kiskiminetas River Basin, containing approximately 1900 square miles, contributes a net acid load of approximately 720,000 pounds per day to the Allegheny

River. Our studies to date have covered 1100 square miles of the 1900 square miles in the basin. If we find that source correction is not achievable then we are faced with the construction of treatment plants. There are about 60 major mine discharges in the basin that would have to be considered. These major sources are those that contribute more than 1000 pounds of acid per day. To construct 60 treatment plants, at an estimated average cost of $1 1/2 million per plant, would require a $90 million capital cost. With an average of $200,000 to $300,000 per year to operate each plant, operation and maintenance costs would be between $12 million and $18 million per year.

Even with the construction of the plants, we would not have completely clean streams as there are many minor sources that would not be treated. As of this date, we have studied approximately 60% of the basin. We estimate that there are 1600 to 1800 sources that would cause problems in the basin that would not be corrected by plant construction. Preliminary estimates indicate that complete source correction, if possible, would be approximately $200 million on top of the treatment costs. However, serious engineering problems exist in the source correction plans because of extremely high hydraulic heads and problems associated with continuing active mining. Deep mine interconnections in several watersheds would require sealing subsurface complexes that may be 10 miles long and 10 miles wide with potential heads of 400 feet. Sealing these complexes would flood existing coal measures and would preclude future mining in the area. From these facts, it is apparent that mine area restoration is difficult, costly and must extend over long periods of time.

In the future, we anticipate continuing our program under the present philosophy of utilizing source correction first, with treatment as a last resort. Additionally, we are striving to return to public usage the maximum number of stream miles that our program will allow. By necessity, we do not anticipate achieving complete cleanup in the immediate future of the severely polluted streams or in the main stems of the major rivers in Pennsylvania. We do foresee, however, cleanup of portions of watersheds within the coal measures. We are coordinating our program with the Pennsylvania Fish Commission to better determine areas of need for fisheries within the State. Also, we are striving to coordinate and accelerate our programs on streams where industrial and municipal sewage problems are being corrected. Additionally, we are striving to protect and improve the water quality conditions in reservoirs, both water supply and recreation, which are presently polluted by acid mine drainage. Our program will also tie into those watersheds affected by mine drainage, which are being considered under both the Federal Wild and Scenic Rivers Act and the Pennsylvania Wild and Scenic Rivers Act.

The abatement of acid mine drainage does not lend itself to a standardized procedure. The solution to each problem must be handmade depending on the variables at the site. When one deals with inadequate and many times erroneous mine maps, fractured foundations, backfilled mine openings, underground mine pools, acid seeps, and similar conditions, it is difficult to formulate a project. Valued judgements must be made in order to determine the best and most economical solution to the problem. Professional judgements are based on experience; geotechnical, mining and civil engineering; and good common sense.

While Pennsylvania's abandoned mine reclamation will continue, at least until 1981 when the Bond Issue expires, it is absolutely essential that proper restoration be accomplished following current mining. Future generations must not be burdened with our careless restoration practices. Pennsylvania has excellent laws and regulations governing active mining practices which include deep mine surface support and closure, surface mine restoration, and refuse bank deposits. Restoration by the operator of each operation as it closes is relatively inexpensive and precludes cumulative degradations. For example, in the past, as described by the conditions in the Kiskiminetas Basin, deep mines were simply abandoned with no closure or drainage control. Mine refuse piles and breaker refuse piles were left scarring the landscape and later surface mining added open pits and spoil banks. It is most important that at least general restoration parameters be prescribed nationally for uniformity and for equal economic competition, as well as for the geographical fact that coal seams do not confine themselves to political boundaries.

APPENDIX A

1975 OPERATING COSTS FOR ACID MINE DRAINAGE TREATMENT PLANTS

Plant	Treatment Method	Capital Cost	Design Capacity MGD	Total Operation & Maintenance Costs	Remarks
Altoona	Lime Soda-Ash	$4,903,326	15	O&M cost provided by the City of Altoona	
Hawk Run	Ion Exchange	2,335,025	0.5	$118,926	
Little Scrubgrass	Lime	35,000	2.5	9,290	
Slippery Rock	Lime	752,134	12	59,939	
Swamp Creek	Lime	70,729	10	18,035	
Hollywood	Lime Limestone	579,024	0.5	4,674	Research only
Rausch Creek	Lime	2,151,934	20	186,005	
Buck Mountain	Lime	40,025	5	54,182	
Sandy Run	Lime	48,516	15	25,135	
Wildwood	Hydrogen Peroxide	220,884	3	25,000*	Iron removal only

*This plant was not in full operation during 1975; however, this is an estimate of what the yearly operation and maintenance costs will be.