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Environmental Protection Technology Series

# Evaluation of Pollution Abatement Procedures, Moraine State Park

Office of Research and Monitoring
U.S. Environmental Protection Agency
Washington, D.C. 20460

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EPA-R2-73-140
January 1973

# EVALUATION OF POLLUTION ABATEMENT PROCEDURES
# MORAINE STATE PARK

By

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# ABSTRACT

This project was an evaluation of the various mine drainage pollution abatement techniques completed during the construction phase of the Moraine State Park, Pennsylvania. The remedial methods employed included strip mine reclamation, underground mine sealing, grouting, surface sealing, refuse pile removal, and oil and gas well plugging.

The major objective of the pollution abatement project was to insure good water quality in Lake Arthur. This was achieved; the water quality in the lake from the time of its initial inundation in 1969 to the present has had a range in analysis as follows: pH: 6.0 to 7.6, alkalinity 10 to 86 ppm, acidity: 0 to 6 ppm, iron: 0.2 to 3.0 ppm and manganese: 0 to 3.5 ppm.

Results of the underground mine hydraulic sealing and grouting work indicate an overall reduction in discharge flow rates from 146 to 57 gallons per minute, an overall reduction in net acidity from 501 to 160 pounds per day (a 68% reduction) and an overall increase in iron from 34 to 42 pounds per day. The hydraulic sealing costs in the study area were $1,266,213 for 65 mine seals and associated grouting work. These costs ranged from a low of $8,308 to a high of $58,437 per seal, for an average cost of $19,480 per seal.

Before and after data for the strip mine reclamation projects indicate a minor net decrease in the average discharge flow rates from 142 to 136 gallons per minute, an overall reduction in acidity from 50 to 22 pounds per day ( a 56% reduction) and an insignificant change in iron from 3 to 4 pounds per day. The strip mine reclamation costs were $672,208 for 462 acres. These costs ranged from a low of $420 to a high of $2700 per acre, for an average of $1455 per acre.

The cost of removing and burying 217,068 cubic yards of refuse was $294,233. Plugging 422 abandoned wells cost $378,292, surface sealing 23 mine areas cost $28,000, and an underground mine air-trap seal cost $4,165.

This report was submitted in fulfillment of Project Number 14010 DSC under the sponsorship of the Office of Research and Monitoring, Environmental Protection Agency and the Department of Environmental Resources, Commonwealth of Pennsylvania (Project CR-85), by Gwin, Dobson and Foreman, Incorporated, Consulting Engineers, Altoona, Pennsylvania 16601.

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## CONCLUSIONS

The principal objective of the pollution abatement projects in the Moraine State Park was attained with the water quality in Lake Arthur remaining at a fairly stable alkaline condition from the time the gates of the dam were closed in May 1969 to the present. During this period, the lake water has exhibited the following range of quality: pH 6.0 to 7.6, alkalinity 10 to 86 ppm, acidity 0 to 6 ppm, iron (total) 0.2 to 3.0 ppm and manganese 0 to 3.5 ppm.

At this time, there are no foreseeable reasons why the water in the lake should become polluted due to mine drainage. However, there are still several minor projects which should be performed to insure these conditions.

Evaluation of the pollution abatement techniques has been limited primarily to underground mine sealing and strip mine reclamation. The surface sealing, refuse removal and oil well sealing projects were required to eliminate a potential source of pollution since they were located in and adjacent to the inundated area of the new dam and would have caused a serious continual pollution problem. Evaluation of the reduction in pollution was impossible for these projects except as reflected in the overall quality of Lake Arthur water.

Underground (deep) mine hydraulic sealing and grouting work resulted in an overall reduction in discharge flow rates from 146 to 57 gallons per minute, an overall decrease in net acidity from 501 to 160 pounds per day (a 68% reduction) and an overall increase in iron from 34 to 42 pounds per day (not considered to be significant). The hydraulic sealing in the study area cost $1,266,213 for 65 mine seals and associated grouting work. These costs ranged from a low of $8,308 to a high of $58,437 per seal, for an average cost of $19,480 per seal.

Comparative data for the strip mine reclamation projects indicate a small net decrease in the average discharge flow rates from 142 to 136 gallons per minute, an overall reduction in acidity from 50 to 22 pounds per day (a 56% reduction) and an insignificant change in iron from 3 to 4 pounds per day. The strip mine reclamation costs were $672,208 for 462 acres. These costs ranged from a low of $420 to a high of $2700 per acre, for an average of $1455 per acre.

Precipitation and climatic conditions are factors which affect the flow and quality of mine waters; the strip mine discharges being far more erratic than the deep mines because of characteristic acid slugging effects of variable intensity. During periods of heavy precipitation, pool levels in deep mines rose significantly and discharge from the unsealed sections increased both in volume and in acid loading.

Severe erosion and run-off turbidity were adverse conditions encountered in several of the strip mine areas where construction for restoration to original contour had been employed. Control of these conditions could be obtained by converting to a combination of contour and terrace-type of restoration construction, augmented by installation of drainage ditches above the high wall and slope drain flumes across the backfill. This type of construction was used in strip mine areas reclaimed under Projects MD-8C and SL 105-1. Its effectiveness in reducing erosion was markedly evident when these areas were compared to the Northwestern Section of ASMRD-1 (where it was not used) after several months of weathering.

The deep mine sealing projects resulted in the flooding of worked out areas behind the seals. Mine observation (MO) Hole data indicate two of the mines were completely inundated under both high and low mine water conditions; seven mines were completely flooded under high mine water conditions and partly flooded under low; eight mines are partly flooded under high to normal mine water conditions and one mine had less than one foot of water under all conditions. Most of the mines had pool levels fluctuating within a range of one to five feet which varied with precipitation and infiltration. The quality of the water within the mine, determined from the samples collected in the Mine Observation (MO) holes was alkaline in all of the completely inundated mines and most of the partly flooded mines. The partly flooded mines had either acid water or both alkaline and acid waters.

At some sealing installations, total iron determinations on post abatement mine water samples indicated an increase in iron generation. An increase in iron content could be expected due to the presence of ferrous bicarbonate in the essentially neutral discharges. This iron compound, upon hydrolysis and oxidation, will generate only carbonic acid, which is not a problem for the amounts of iron involved. Actually, many of the post abatement samples are probably contaminated with iron compounds originating from the steel bore-hole casing, within which the samples are taken. Therefore, these iron determinations are not reliable indications of actual iron concentrations in the sealed mine pool water.

# SECTION II

## RECOMMENDATIONS

The following general recommendations are submitted based upon observations made and conclusions drawn during this study.

1. Prior to construction in any future abatement projects, each site (mine, strip pit, or refuse pile) should be individually examined and evaluated to determine the basic pollutant generation processes involved, and the feasibility of proposed construction methods for attaining the desired degree of abatement under final installed conditions.

2. Installation of double bulkhead seals is recommended as the best type of abatement construction for abandoned underground (deep) mines providing the conditions (extent, location, and elevation of the mined areas; maximum hydrostatic heads possible; and other geologic and topographic features of the area) are within the limits of safety to insure against the possibility of future mine water breakouts.

3. In the restoration of strip mines, terrace-type construction is recommended over backfilling to approximate original contour, particularly where final slope grades are quite steep. If contour slope restoration construction is not done in accordance with strict specifications, serious erosion problems develop which lead to extensive wash-out of the seeded soil cover and re-exposure of the refuse material to the atmosphere. Terrace-type construction (with auxiliary drainage installation as recommended in the text) eliminated erosion control problems almost completely and prevented the generation of high turbidity run-off.

4. Diversion ditches above the highwall and slope drain flumes across the backfill are recommended for strip mine restoration areas to : (a) reduce surface water infiltration of the buried refuse material, (b) minimize wash-out of the seeded surface, and (c) prevent catastrophic erosion of the surface cover. The greater the acreage above the highwall, the greater the need for diversion drainage facilities.

5. Where feasible, the recommended abatement for mine refuse piles are (a) removal and burial in strip pit restoration areas or (b) reshaping and covering in place.

6. Surface sealing of air shafts, certain portals, and caved entry areas is recommended to prevent surface waters from entering abandoned mine workings.

7. Source abatement is recommended as the initial consideration in any mine drainage control program. Treatment methods (neutralization) should be used only when source abatement plans are not economically feasible.

The following specific recommendations are made for the Moraine State Park areas:

1. Backfilling and possibly mine sealing is recommended for the small strip mine located along the park boundary near the Kildoo deep mine (see point A in Figure 4). Similar abatement should also be applied to another strip mine area outside the park boundary in the Muddy Creek watershed (see Point B in Figure 4).

2. Soil treatment and planting is recommended in several isolated barren areas where mine refuse has been removed from that location in the park area.

3. Continued surveillance is recommended in the park area. Periodic sampling and examinations on a limited scale should be carried out by competent personnel to establish long term performance effectiveness of the various types of abatement installations.

## SECTION III

## INTRODUCTION

### Background Studies

In the early 1960's, the Commonwealth of Pennsylvania began plans for the development of Moraine State Park. Because of past mining activities in the watershed of the proposed lake (Lake Arthur), pollution by acid mine drainage was considered a potential menace. In order to prevent Lake Arthur from being a polluted body of water in the Moraine State Park, the Department of Mines and Mineral Industries (now Department of Environmental Resources) retained this consultant in May 1967 to make an extensive examination and, based on this information, submit recommendations for the abatement and/or treatment of mine drainage and associated problems.

Information for the examination concerning the existing mining conditions in the park consisted of a reconnaissance of deep and strip mine areas, a search for old mine maps and contacts with persons who worked in or had knowledge of these mines.

Water samples were collected weekly from May 23, 1967 until November 1, 1967 and monthly thereafter. The water samples were analyzed for pH, alkalinity, acidity, iron, manganese and aluminum. A total of 85 weirs were installed to measure flows of all known mine drainage discharges.

A diamond core drilling program was performed consisting of 23 holes and 1858.6 feet of drilling. These holes were drilled at specific locations to determine the elevation and nature of the coal and associated strata, the extent of mined out areas, and other geologic data.

Additional field work consisted of surveys for mine drainage points and for the location, elevation and cross sections of mine refuse piles. Maps of the park area were obtained from the Department of Forests and Waters for use in the examination.

Several mine drainage projects were being performed concurrently during the period of the mine drainage examination. This work included the Appalachian Strip Mine Reclamation Project No. 1, a deep mine air-trap seal designed by the Department of Mines and Mineral Industries, and the refuse pile removal - strip mine restoration Project MD-8C.

The Report of Mine Drainage Project MD-8A was submitted to the Department of Mines and Mineral Industries on May 10, 1968.[3] This report recommended the following steps be taken to control or eliminate the acid mine drainage pollution in the watershed.

1. Removal and burial in abandoned strip mine areas of all mine refuse piles consisting of acid producing materials.

2. Install hydraulic mine seals at all deep mine openings with workings to the rise and where major discharges of acid water are emanating in order to flood the workings and prevent acid formation.

3. Sealing of mine drifts, slopes and air shafts with clay or other suitable material where the mine workings lie to the dip in order to prevent air and water from entering the mine.

4. Backfill abandoned strip mine areas to alleviate runoff and seepage through spoil areas and thus prevent pollution due to siltation and acid mine drainage.

5. Plant grass and/or trees on reclaimed strip mining areas to reduce the erosion and pyrite oxidation.

6. Construct diversion ditches and slope drain flumes in strip mine areas to direct surface water around or across affected areas.

7. Evaluate results of abatement program. If acid discharges are still objectionable, additional reclamation measures or treatment plants may be required. Treatment plants were not initially included because of perpetual maintenance and lime neutralization yields a highly flocculent hydrate and creates disposal problems.

## Location

The Muddy Creek watershed area of the Moraine State Park is situated in Franklin, Brady, Muddy Creek and Worth Townships, Butler County, Pennsylvania. This project area is located five miles south of the town of Slippery Rock, nine miles northwest of Butler and approximately 35 miles north of Pittsburgh. (see Location Map - Figure 1)

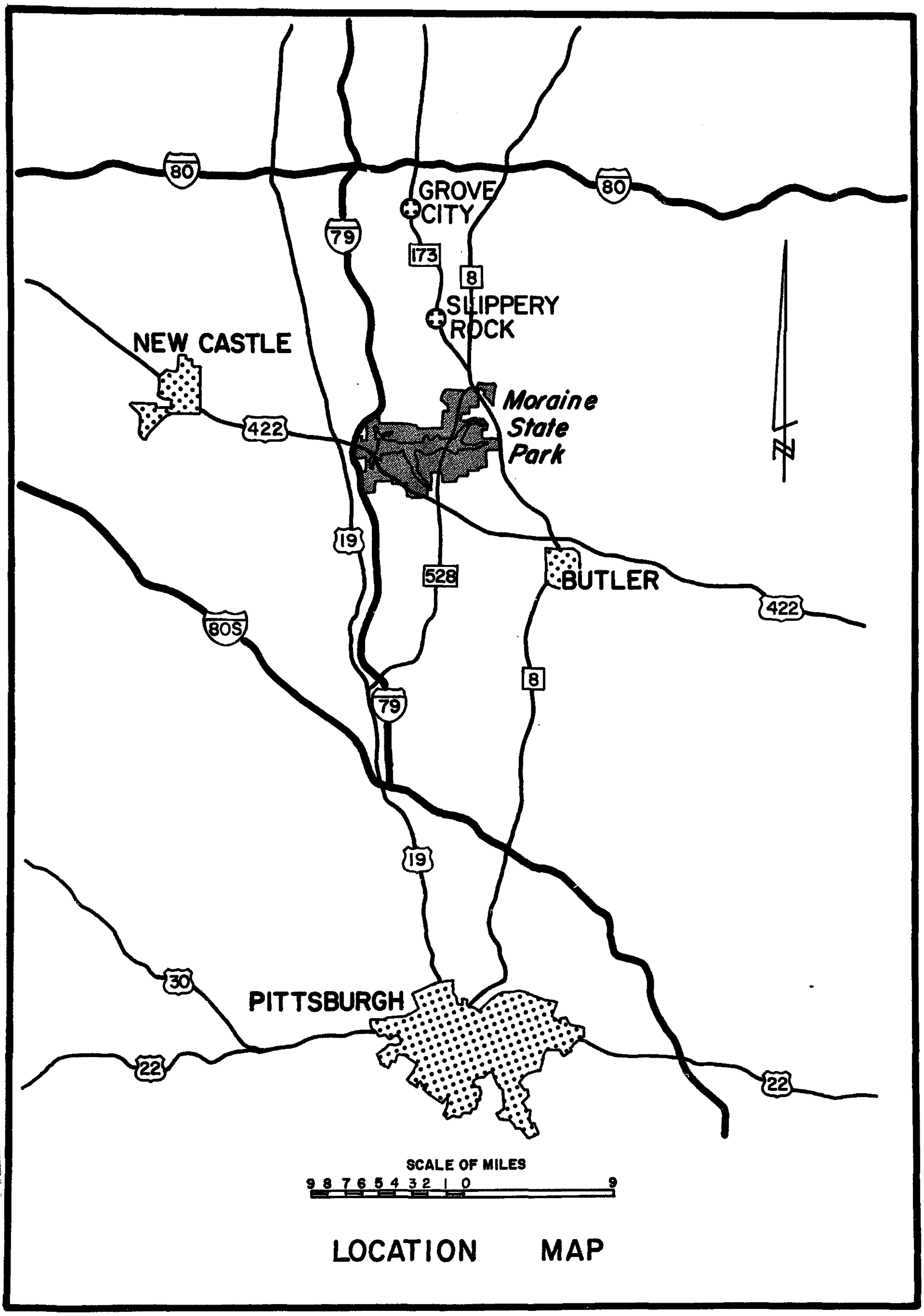

80
80
GROVE CITY
79
173
8
SLIPPERY ROCK
NEW CASTLE
Moraine State Park
422
N
19
528
BUTLER
422
80S
8
79
19
30
PITTSBURGH
22
22
SCALE OF MILES
9 8 7 6 5 4 3 2 1 0 9
LOCATION MAP

FIGURE I

## Topography

The topography consists of moderate relief, flat-topped hilly country ranging in elevation from 1160 feet at Muddy Creek to a maximum of 1525 feet at the top of the hills. The area is part of the Appalachian Plateaus Province.

## Drainage

The project area consists of about 25 of the 59 square mile watershed area of Muddy Creek. Muddy Creek is a tributary of the Slippery Rock Creek; the confluence of the two streams is about three miles west of the Moraine State Park. Muddy Creek and its tributaries flow through the flat valley system created by the Pleistocene ice sheet. The gradient on Muddy Creek through the valley is very slight, varying from an elevation of 1200 feet at the eastern limits of the park to 1160 feet at the western end. This is a vertical drop of only 40 feet over a horizontal distance of 40,000 feet. (see Figure 2)

## Geology

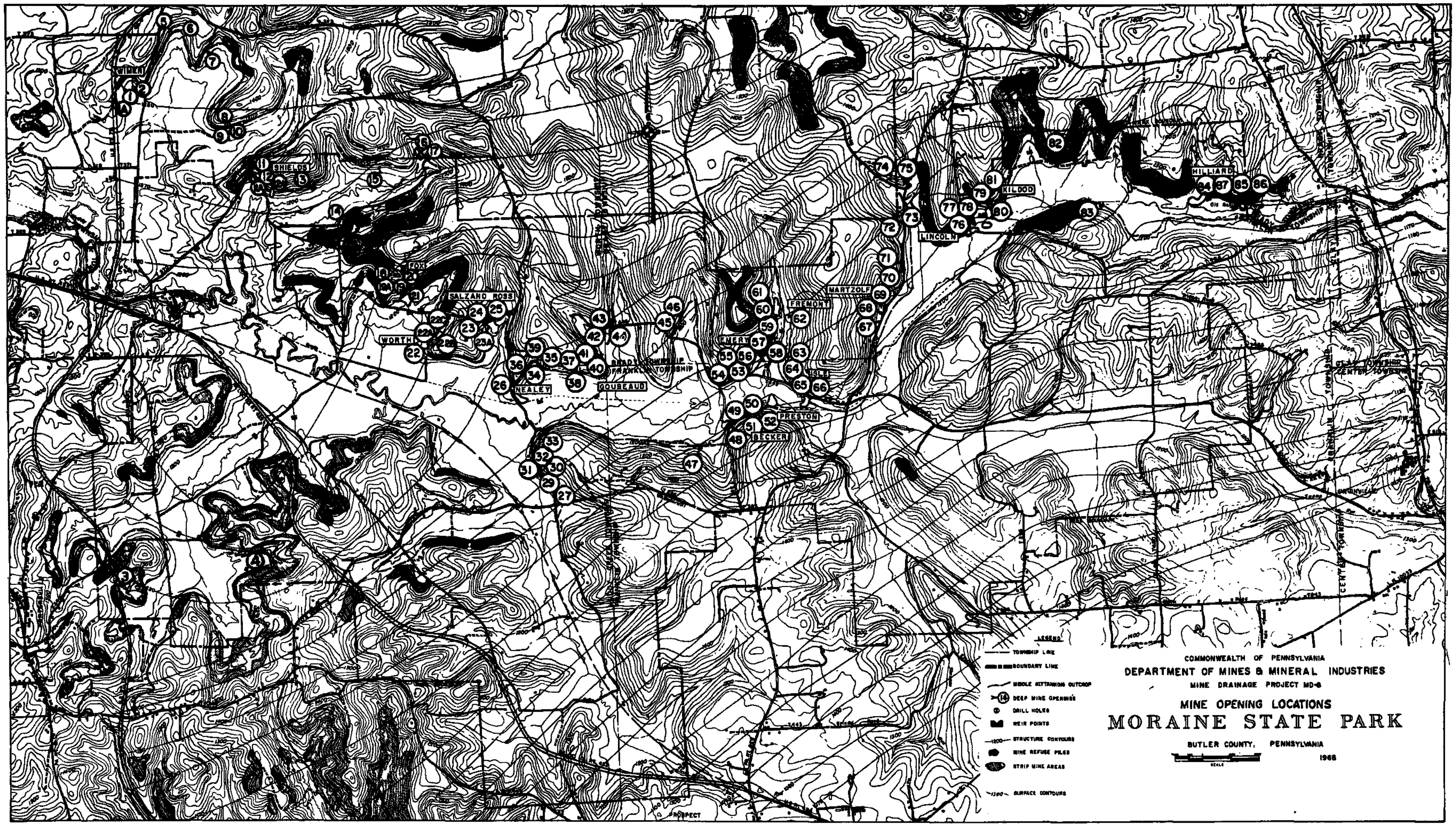
The geologic measures in the project area consist of the sedimentary strata of the Conemaugh and Allegheny Formations of the Pennsylvanian System and the unconsolidated deposits of the Pleistocene and Recent Age. The sedimentary strata dip slightly, about 3%, to the southeast and is modified by minor folds. These formations consist of a sequence of shales, siltstones, sandstones and contain several seams of coal and the Vanport limestone.

The flat broad valley system contains the unconsolidated glacial deposits. These deposits range in thickness from several feet near the edge to 80 feet near the middle of the valley. This valley varies from about 500 feet to 3500 feet in width.

Mineable coal seams in the park consist of the Brush Creek, Freeport and Middle Kittanning seams. The Middle Kittanning or C coal seam is the most persistent seam and accounted for all of the deep mining and most of the strip mining in the park area. The Brush Creek and Freeport coal seams are erratic in nature and had only limited areas of strip mining.

## Mining History

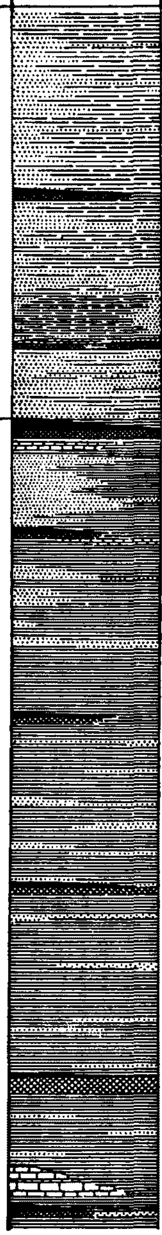
From the early 1900's, this area had supported numerous mining operations, oil and gas fields and marginal farming. The Middle Kittanning coal seam was extensively deep mined from the 1900's through the 1920's. During the 1900's there was coal production along the entire length of the Western Allegheny Railroad through the Muddy Creek Valley. Most of these deep mines were located along the outcrop on the north side



LEGEND
TOWNSHIP LINE
BOUNDARY LINE
MIDDLE KITTANNING OUTCROP
DEEP MINE OPENINGS
DRILL HOLES
WEIR POINTS
STRUCTURE CONTOURS
MINE REFUSE PILES
STRIP MINE AREAS
SURFACE CONTOURS
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF MINES & MINERAL INDUSTRIES
MINE DRAINAGE PROJECT MD-6
MINE OPENING LOCATIONS
MORAINE STATE PARK
BUTLER COUNTY, PENNSYLVANIA
SCALE
1968
WIMER
SHIELDS
FOX
SALZANO
ROSS
WORTH
HEALEY
GOUBEAUD
BRADY TOWNSHIP
FRANKLIN TOWNSHIP
EMERY
FREMONT
MARTZOLF
LINCOLN
HILLIARD
PRESTON
BECKER


FIGURE 2

# Generalized Columnar Section of the Exposed Rocks in the Watershed

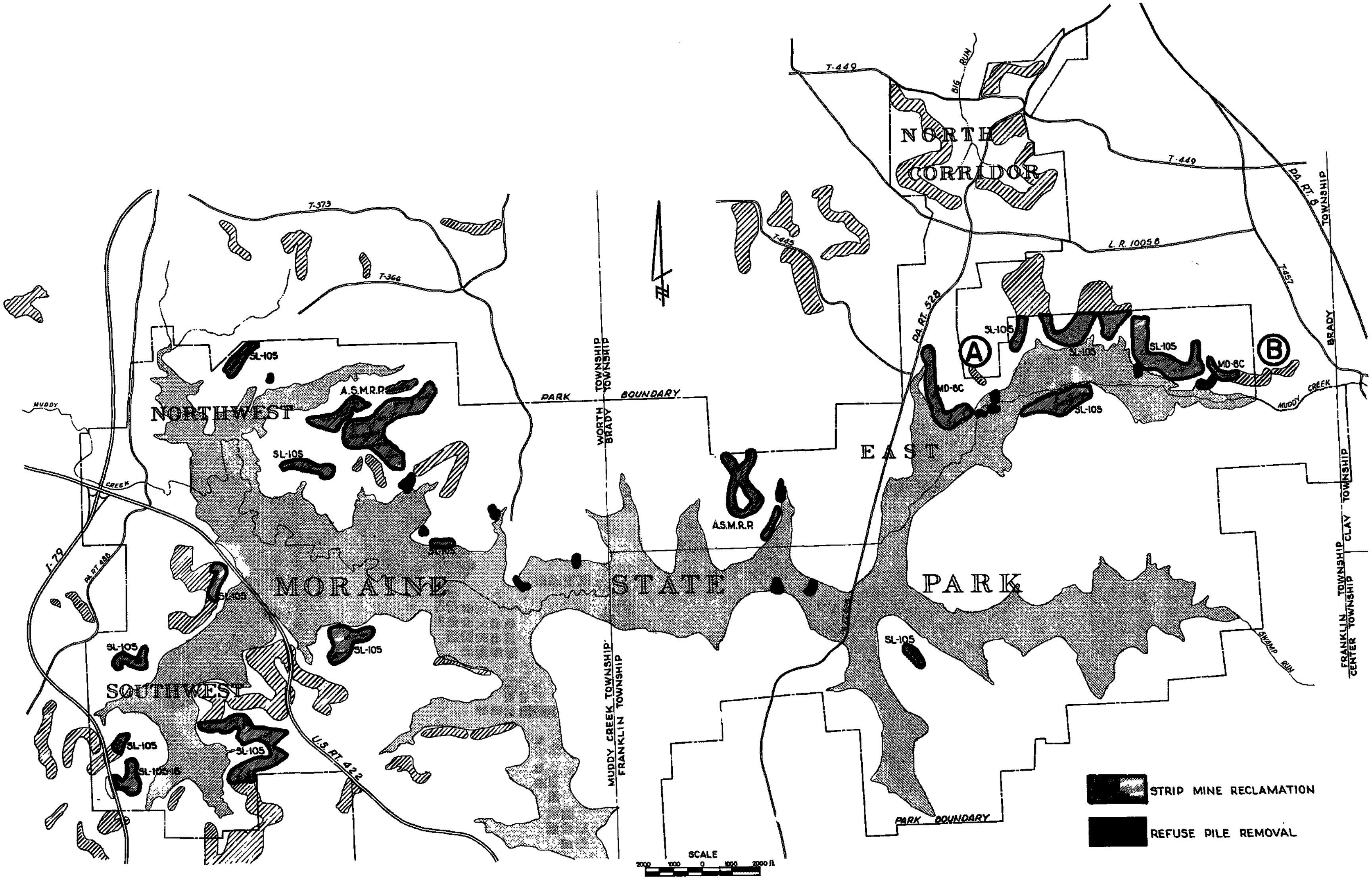
| System | Series | Formation | Member | Section | Character of member | General character of formation |
|---|---|---|---|---|---|---|
| Carboniferous. | Pennsylvanian. | Conemaugh. | Buffalo sandstone. |  | Thick- to thin-bedded arkosic sandstone and sandy shale. | Only the lower part of the formation, including about 320 feet of strata, is present. Consists of variable beds of shale and sandstone and lenses of limestone and coal. |
| | | | Brush Creek coal. | | Variable lens of coal, locally minable; 0 to more than 4 feet thick. | |
| | | | Mahoning: Red shale and Mahoning limestone. Sandstone. | | Sandstone and sandy shale, divisible into lower and upper sandy zones, separated by thin lenses of coal, clay, and limestone. Red shale occurring on an average 30 to 40 feet above Upper Freeport coal. Serves as useful horizon marker. | |
| | | Allegheny. | Upper Freeport coal. | | Widely distributed and mined, locally absent; 0 to more than 5 feet thick. | A variable sequence of shale, sandstone, limestone, clay, and valuable beds of coal; average thickness about 300 feet. |
| | | | Butler sandstone. | | Thick- to thin-bedded medium- to fine-grained arkose; 0 to 30+ feet thick. | |
| | | | Lower Freeport coal. | | Variable, locally absent; less than 2 to more than 5 feet thick. | |
| | | | Upper Kittanning coal. | | Variable and nonpersistent; in places more than 3 feet thick. | |
| | | | Middle Kittanning coal. | | Fairly persistent; prospected and mined at many places; averages between 30 and 40 inches thick. | |
| | | | Lower Kittanning coal. | | Variable; 0 to 3 feet 4 inches thick. | |
| | | | Vanport limestone. | | Massive to thin-bedded gray fossiliferous limestone 0 to 20 feet thick; valuable key bed. | |
| | | | Scrubgrass coal. | | 0 to 4 feet 10 inches thick; development known in only one area. | |

Vertical Scale
50 0 50 100 FEET

U.S. GEOLOGICAL SURVEY BULLETIN 873

FIGURE 3

of the stream and railroad which facilitated working the mine to the rise. This afforded favorable mining conditions to these early operators. The mines were developed to take advantage of gravity drainage, and underground transportation, the loaded trips were hauled out of the mine on a descending grade. Most of the deep mines were abandoned by 1930. The Salzano-Ross mine was the only active deep mine operation at the time of condemnation for the park. From the early 1940's to about 1966, strip and auger mining operations were performed extensively in the Middle Kittanning coal seam together with several strip mines being operated in the Lower Freeport and Brush Creek coal seams.




STRIP MINE RECLAMATION & REFUSE PILE REMOVAL MAP

FIGURE 4

## SECTION IV

## POLLUTION ABATEMENT METHODS

Pollution abatement projects performed in the watershed included strip mine reclamation, refuse pile removal, surface sealing, deep mine hydraulic sealing, well plugging, deep mine air-trap sealing and miscellaneous work incidental to restoration and abatement.

### Strip Mine Reclamation

Strip mine reclamation work included backfilling and regrading to terrace type restoration, approximate original contour and special restoration as required. Most of the reclamation included installation of diversion ditches and slope drain flumes. Soil treatment and planting were also included. The strip mine reclamation consisted of work performed under seven separate contracts in nineteen strip pits located throughout the park in three general areas. Table 1 on the following two pages consists of a tabulation of the various projects as to the general location, type and extent of restoration involved. The location of the strip mine reclamation areas is indicated on the map in Figure 4.

Approximate original contour restoration started at or beyond the top of the highwall and were regraded and sloped to the toe of the spoil at a maximum angle not exceeding the original contour of the land before mining, with no depressions to accumulate water. (Figure 5) For the open pits backfilled by terracing, the steepest grade of the highwall and toe of spoil was limited to forty-five degrees. The terrace was regraded to a maximum descending gradient of five degrees from the base of the highwall toward the top edge of the toe of spoil with no depressions to hold water. (Figure 5) For backfilling in all but the ASMRP-1 project, the maximum limits of work were 100 feet above the highwall of the affected area and 50 feet below the toe of spoil.

Diversion ditches were excavated above the highwalls as indicated in the applicable strip mine areas. All diversion ditches have a maximum cross-sectional area of 10 square feet and have a uniform descending gradient. Slope drain flumes were constructed across the backfill areas as indicated in the strip mine areas. (Figure 5) These flumes started at the point of intersection with the diversion ditch above the top of the highwall and extended down across the entire width of the graded backfill area to a point of discharge below the toe of spoil. The flumes were constructed with 36" - bituminized fibre 1/2 - section pipe.

TABLE 1 - MORAINE STATE PARK STRIP MINE RECLAMATION PROJECTS

| Project No. | Backfill Acreage | | Soil Treatment Acreage | Planting Acreage | | Diversion Ditches L.F. | Slope Drain Flumes L.F. |
|---|---|---|---|---|---|---|---|
| | A.O.C.① | T.B.F.② | | Grasses | Trees | | |
| NORTHWEST | | | | | | | |
| ASMRP-1 | 120.2 | ---- | 120.2 | 120.2 | 120.2 | ---- | ---- |
| SL 105-1 | 23.9 | ---- | 23.9 | 23.9 | 23.9 | 2600 | 400 |
| SL 105-1 | ----- | 6.8 | 6.8 | 6.8 | 6.8 | 1250 | 200 |
| SL 105-1 | ---- | 12.8 | 12.8 | 12.8 | 12.8 | ---- | ---- |
| SL 105-1 | ----- | ---- | ----- | ----- | ----- | 2450 | 800 |
| SL 105-1 | 2.3 | ---- | 2.3 | 2.3 | 2.3 | 800 | ---- |
| | 146.4 | 19.6 | 184.3 | 166.0 | 166.0 | 7100 | 1400 |
| | 166.0 | | | | | | |
| SOUTHWEST | | | | | | | |
| SL 105-1 | ----- | 6.3 | 6.3 | 6.3 | 6.3 | ---- | ---- |
| SL 105-1 | 17.0 | ---- | 17.0 | 17.0 | 17.0 | 3100 | 300 |
| SL 105-1 | ----- | 25.2 | 25.2 | 25.2 | 25.2 | 4400 | 600 |
| SL 105-1 | 4.7 | 6.9 | 11.6 | 11.6 | 11.6 | ---- | ---- |
| SL 105-1B | 15.6 | 2.4 ③ | 18.0 | 18.0 | 15.6 | 454 ④ | ---- |
| | 37.3 | 40.8 | 78.1 | 78.1 | 78.1 | 7954 | 900 |
| | 78.1 | | | | | | |

EAST

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ASMRP-1 | 57.3 | ----- | 57.3 | 57.3 | 57.3 | ------ | ---- |
| MD-8C | 36.0 | ----- | 36.0 | 36.0 | ----- | 3,600 | 650 |
| MD-8C | 11.0 | ----- | 11.0 | 11.0 | ----- | 2,050 | ---- |
| SL 105-1 | 4.8 | ----- | 4.8 | 4.8 | 4.8 | 1,200 | ---- |
| SL 105-1 | ----- | 29.3 | ----- | ----- | 29.3 | 2,100 | 200 |
| SL 105-1 | ----- | 23.7 | 23.7 | 23.7 | 23.7 | 2,900 | ---- |
| SL 105-1 | ----- | 46.8 | ----- | ----- | 46.8 | 4,000 | 400 |
| SL 105-1A | ----- | 8.7 | ----- | ----- | 8.7 | 1,300 | ---- |
| | 109.1 | 108.5 | 132.8 | 132.8 | 170.6 | 17,150 | 1250 |
| | 217.6 | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TOTALS | 292.8 | 168.9 | 395.2 | 376.90 | 414.7 | 32,204 | 3550 |
| | 461.7 | | | | | | |

① A.O.C. - Approximate Original Contour
② T.B.F. - Terrace Backfill
③ Special Restoration Along Highway
④ Drainage Facilities Consists of 454 L.F. of 18" Pipe Along Highway

All areas, unless designed otherwise, received soil treatment and seeding in accordance with the following:

1. Apply ground limestone at the rate of 2.5 tons per acre.
2. Apply fertilizer 10-10-10 at the rate of 300 lbs. per acre.
3. Use a disc harrow and spring tooth harrow to thoroughly mix both applications with the soil.
4. Apply seed using a tractor mounted broadcast seeder as per the following formula. The seed shall be purchased already mixed.

| Grass | Lbs. per Acre |
|---|---|
| Common Rye Grass | 8 |
| Common Timothy | 4 |
| Orchard Grass | 3 |
| Common Clover | 2 |
| Birdsfoot Trefoil | 2 |

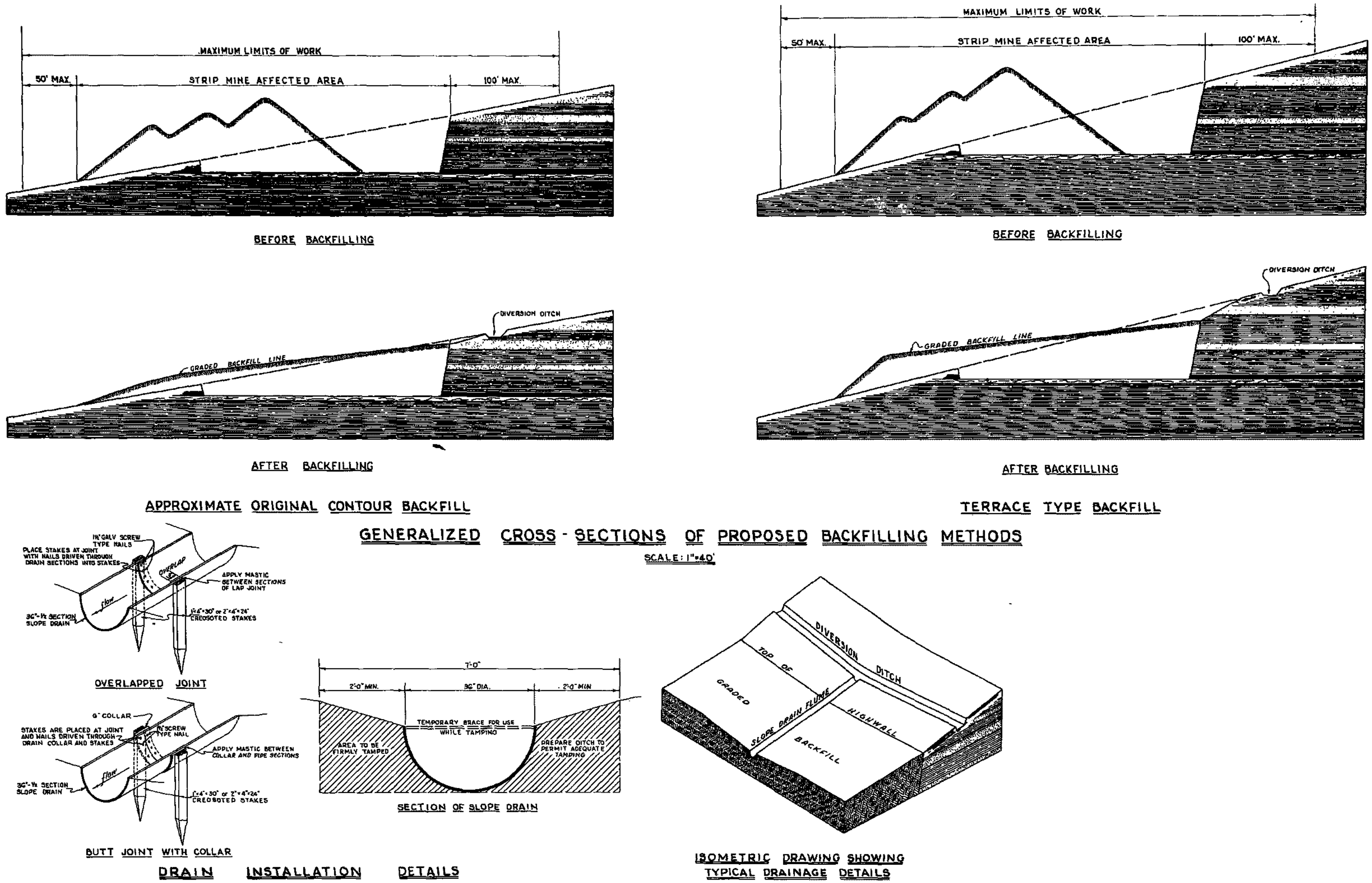
5. After seeding, go over entire area with a disc harrow and spring tooth harrow.

Where specified, various species of trees were planted in the reclaimed areas. The deciduous and evergreen trees were planted on 8'x8' centers which allows for approximately 700 trees per acre. The species included Red Oak, Red Maple, Red Pine, White Spruce, Hybrid Poplar, White Pine, Hemlock, European Black, Alder and Norway Spruce. The shrubs (Arrowwood, Viburnum and Autumn Olive), which are a source of wild game food, were not intermixed with the trees but were planted in rows along the edges of the reclaimed areas.

In addition to the 461.7 acres backfilled under the various contracts described in this report there were 265 acres of strip mined lands backfilled by the previous mine operators. None of these areas were contributors of mine drainage pollution.

In the North Corridor of the Moraine State Park there were 167.6 acres of strip mine reclamation. However, all of this area drains into Big Run and is not considered in this study. This work, Project SL-110-2, is included in the Slippery Rock Creek mine drainage pollution abatement projects.

There is remaining a small strip mine area of five acres located partly in and partly out of the park near the Kildoo deep mine which should be included in future reclamation work. There are also about thirty acres outside of the park area but in the Muddy Creek watershed which should be considered in future abatement work.




**STRIP MINE RECLAMATION DETAILS**

**FIGURE 5**

Project ASMRP-1 | Strip Mine Reclamation | 177.5 Acres

Reclamation work for the strip mined lands in the project areas consisted of clearing, excavating, burying toxic materials, backfilling and regrading to the approximate original contour. Restoration work consisted of 57.3 acres in the North Central Section in Brady Township and 120.2 acres in Worth Township. Also included in this contract was the construction of a drainage channel in the lower seam of the North Central section and the burial of 82,347 CY of refuse pile materials in the strip mine pit during backfilling. The restoration work was the first project conducted under the Appalachian Surface Mine Reclamation Program by a cooperative agreement with the Commonwealth of Pennsylvania and the Federal Government. After completion of the restoration work, the reclaimed areas received soil treatment and planting with grasses and trees. This work was not included in the Federal-State contract and was conducted by the Pennsylvania Department of Forests and Waters. The project work was performed during 1967 and 1968 at a cost of $219,118.

Project MD-8C | Strip Mine Reclamation | 47.0 Acres

This work comprised the strip mine reclamation part of Project MD-8C. The work consisted of excavating, burying acid-producing materials including 134,721 CY of refuse pile rock, backfilling and regrading to approximate original contour of 36.0 acres of affected area in a strip mine adjacent to the Lincoln deep mine and 11.0 acres in a strip mine adjacent to the Hilliard deep mine. Also included in this work was the installation of a diversion ditch above the highwall and a slope drain flume across the backfill. After restoration work was completed, the area received soil treatment and planting with grasses. This work was performed in 1967 and 1968 at a cost of $29,964.

Project SL-105-1 | Strip Mine Reclamation | 210.5 Acres

This project included three contracts for reclamation work in three separate sections of the park. This included work in five strip areas in the Northwest Section, four strip areas in the Southwest Section and four strip areas in the Eastern Section. Reclamation work in the Northwest Section included 23.9 acres backfilled to approximate original contour in the first area; 6.8 acres and 12.8 acres in the second and third areas both with terrace type restoration; no backfill work was required in the fourth area, however, drainage ditches and slope drain flumes were required; and 2.3 acres of approximate original contour in the fifth area for a total of 45.8 acres of restoration. Work in the Southwest Section included two areas of 6.3 acres and 25.2 acres with terrace-type backfill, one area of 17.0 acres backfilled to approximate original contour and an area of 11.6 acres with a combination of terrace-type and approximate original contour backfill for a total of 60.1 acres of restoration. The Eastern Section reclamation included one area of 4.8 acres with approximate original contour and three areas of 29.3 acres, 23.7 acres and 46.8 acres with terrace-type restoration for a total of 104.6 acres. Diversion ditches were installed in four areas of the Northwest Section, two areas of the Southwest Section and all four areas of the Eastern Section. All areas received soil treatment, except for two areas in the Eastern Section. All areas were planted with grasses and/or trees except Area 4 of the Northwest Section which had adequate vegetative cover. The project work was performed in 1969 and 1970. The costs consisted of $109,628 for the 45.8 acres in the Northwest area, $120,200 for the 60.1 acres in the Southwest area and $156,900 for the 104.6 acres in the Eastern area.

Project SL-105-1A          Strip Mine Reclamation          8.7 Acres

The project consisted of reclamation of 8.7 acres of affected area in the Eastern Section of the park. Restoration included terrace-type backfilling and installation of 1300 feet of diversion ditch above the highwall. No soil treatment was required and the area was planted in trees. Work in the project was performed in 1969 and 1970 at a cost of $8,775.

Project SL-105-1B          Strip Mine Reclamation          18.0 Acres

The project area is located on and adjacent to Interstate 79 in the Southwest Section of the park. Effluent from the drainage facilities installed as part of the highway construction discharged surface water and drainage from the highway into a strip mine area along the east side of the highway. This water, along with other drainage into the strip mine, produced acid discharges. Restoration work included 15.6 acres backfilled to approximate original contour and 2.4 acres, within the right-of-way of the highway, graded and backfilled to special restoration. Drainage facilities installed as part of this contract included the installation of a storm sewer along the highway to carry the drainage formerly discharged into the strip mine to a natural drainage course below the strip mine area. After completion of the restoration work, the area received soil treatment and planting. The area within the highway right-of-way was planted with grasses and outside the right-of-way with grasses and trees. The project work was performed in 1970 at a cost of $27,623.

Refuse Pile Removal

Prior to completion of the dam for Lake Arthur, there were 14 deep mine refuse piles located throughout the park in or near the area to be inundated. If these piles were left untouched, additional pollution would result due to the inundation. Most of the piles were located on the unconsolidated glacial material which further complicated the problem. Several plans were considered, consisting of leveling, sealing and covering the piles in place with topsoil; excavating pits in the glacial moraine adjacent to the piles and burying the refuse material in the pits; or loading, transporting and burying the refuse rock in abandoned strip pits to be backfilled. Plans for sealing and covering the piles in place were not considered feasible due to possibilities of failure caused by wave action of the lake. Burying the material in the moraine posed difficult and expensive operational conditions. The plan for removal and burial of refuse in the strip pits was considered to be most feasible and as a result, Project MD-8C was initiated.

Project MD-8C | Refuse Pile Removal | 14 Refuse Piles

The project included the excavation, loading and transport of materials from 14 refuse piles for burial in strip mine areas requiring restoration. This work was performed under two contracts. During the first, 82,347 CY from seven refuse piles were removed for burial in strip mine pits being backfilled by the contractor under the Appalachian Surface Mine Reclamation Program. During the second, 134,721 CY from the remaining seven refuse piles were removed and buried in the 36.0 and 11.0 acre strip mines being reclamated as part of Project MD-8C. The project work was performed in 1967 and 1968 at a cost of $103,757 for the first contract and $190,486 for the second.

Surface Sealing

Of the ninety some deep mine openings in the Muddy Creek watershed associated with the park there were 23 deep mine areas consisting of drifts, slopes, shafts, subsidence holes and small gob areas considered for surface sealing. Although these mines were not points of actual acid mine discharges, they were areas where water could enter the mine and places that would become a possible source of pollution, particularly after inundation of the deep mines. Most of the areas considered were mines in which the deep mine workings were advanced to the dip. In order to correct the problem, Project SL-105-2 was established.

Project SL 105-2 | Surface Sealing | 23 Mine Areas

The project included removing and burying acid-producing materials from the mine area and associated refuse piles; and filling and regrading the abandoned deep mine drifts, slopes, shafts and subsidence holes. After backfilling was completed, the areas were limed, fertilized and planted with grasses.

Mine areas included in this project are indicated on the map in Figure 6.

Mine (15), a deep mine drift in the northwest section of the park.

Mines (30, 31, 32, 33), deep mine drifts of the South Nealey area near the center of the park.

Mines (39, 40, 41, 42), deep mine drifts and openings in the Nealey mine.

Mines (45, 46), deep mine drifts of a small mine located between the Goubeaud and Emery mine.

Mines (47, 48, 49, 50, 51, 52), deep mine openings of the Becker and Preston mines located along the south shoreline in the center area of the park.

Mines (70, 71, 73), deep mine drifts of small deep mines located along State Route 528 north of the Martzolf mine.

Also included in the project were small gob piles buried at Mines (33) and (46) and a test pit at Mine (15). The work was started in January 1969 and completed in May 1969 at a cost of $28,000.

Deep Mine Bulkhead Sealing

Abandoned deep mines were the major source of pollution in the park area. Before abatement, over 85% of the acidity came from these mines. Several plans were considered in the initial study for the abatement, alleviation, elimination or treatment of these deep mine discharges. One of these plans consisted of building a pipeline collection system to transport the acid mine water from the various discharges to a treatment plant. The system would require a main transmission line over eight miles in length, most of which would be buried in the glacial material below the water level in Lake Arthur. Several more miles of laterals leading from the deep mines to the main would be necessary. Due to the topography and elevation of many of the mine discharges, flows entirely by gravity would not be possible. Several lift stations would be required. Estimates for the initial construction costs for the facilities were in excess of two million dollars. In addition there would be the daily operational costs and maintenance, including the problem of sludge removal and disposal from the treatment plant. Other variations of the collection-treatment system consisted of building several smaller treatment plants throughout the park area, thus transporting the mine water from each of the applicable mines to a treatment plant in that particular area. Many of the same problems existed with this plan as well as additional problems. Proposed plans for source abatement by sealing also were taken under consideration. Plans for the installation of double bulkhead seals in the mine entries and pressure grouting in the adjacent strata were considered as a means of eliminating (or reducing) flows from the mines and at the same time flooding, or at least partly flooding, the mine workings. Previous studies have indicated that inundation of deep mine workings has the effect of reducing or preventing the formation of acidity by decreasing the air supply to the pyrite located within the mine workings.

The installation of air seals was not considered because previous installations have proven to be only partially effective. Several problems were anticipated and encountered in the construction of the mine seals. Installation in accessible entries is generally preferred as it affords the opportunity for direct insitu construction. However, all of the entries were caved at the portal and it was not feasible to re-open the entries due to major expenditures involved. As a result, remote installation of double bulkhead seals from the surface directly above the entries installation were recommended. The exact location and extent of the mined area behind the caved mine drifts were not known and required exploratory drilling for each seal. Grouting and sealing operations would be more difficult and more expensive where mining extended to areas under shallow cover near the outcrop. Mine entries having considerable flows would be more difficult to seal than those with little or no flows.

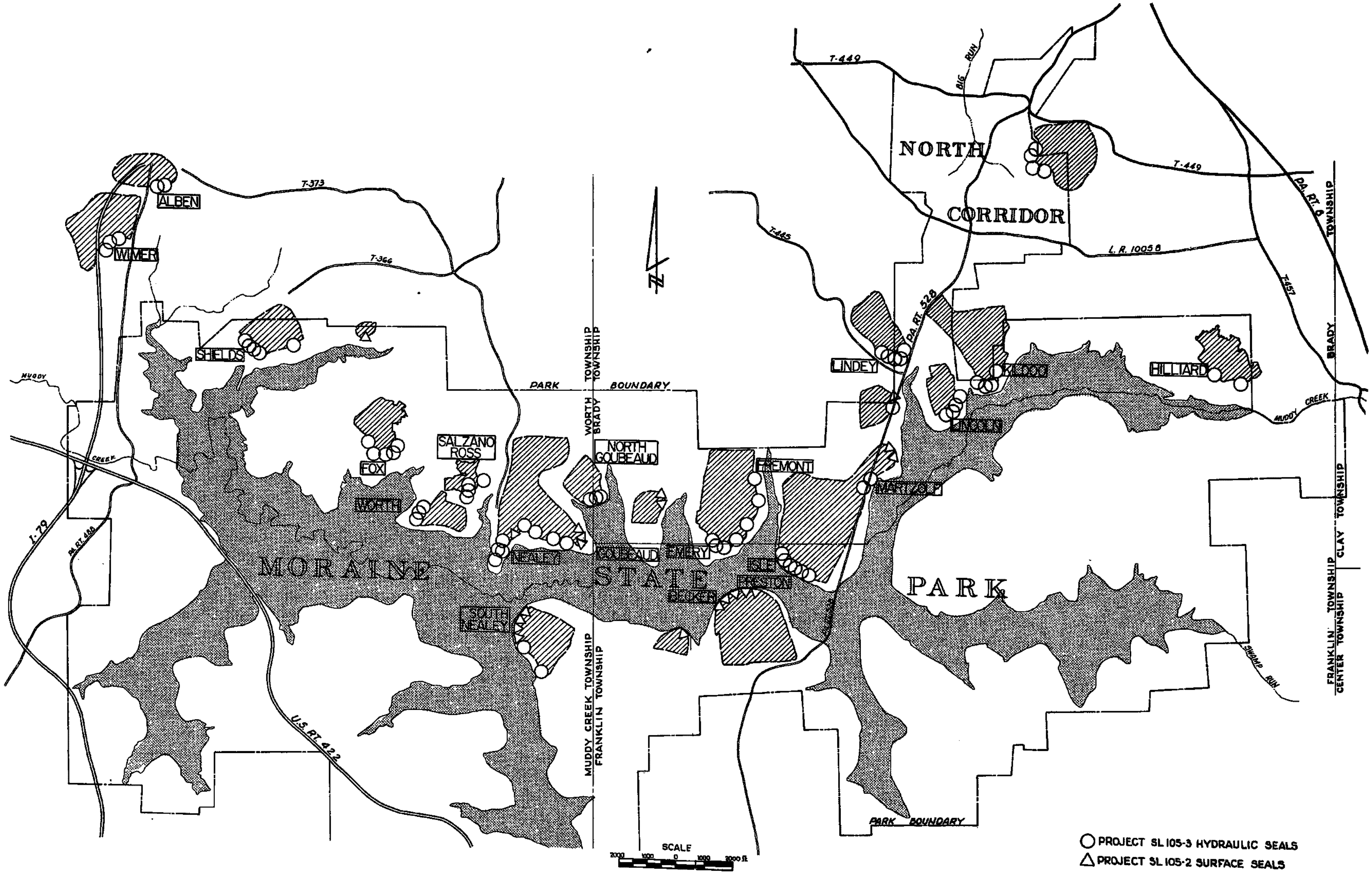
Considering all of the applicable conditions, deep mine hydraulic sealing was the most feasible of all methods studied. The major features of a mine seal and the technique of installation are shown in Figures 7 and 8. The estimated costs for sealing were about half of those for the construction of the collection-treatment methods.

Project SL-105-3 Deep Mine Bulkhead Sealing 69 Mine Openings

The project consisted of construction of double bulkhead seals installed through drill holes and pressure grouting in the area of the seal and strata adjacent to the mine entries. Curtain grouting operations in specific areas along the outcrop were included. A total of 69 mine seals were installed, 65 mine seals are in the Muddy Creek watershed and 4 mine seals are in the North Corridor of the park in the Big Run watershed area. (See Figure 6). This project was performed from February 1969 to August 1971 at a cost of $1,351,650.

Wimer Mine

The Wimer Mine is located in the northwest area of the watershed with four deep mine drift openings (1, 1A, 2, 3) all of which are approximately 2000 feet north of the park boundary. Deep mine seals were installed in three entries (1, 2, 3). An observation hole was drilled behind the mine seals. Interstate 79 crosses over the top of the mine in a north-south direction. During construction of the interstate highway, mine workings, including one of the drift openings (1A) were encountered at the south end of the mine in the area near the outcrop. In this area the caved roof rock, gob and other waste materials were removed and the area backfilled with selected material. A drain pipe




DEEP MINE SEALING MAP

FIGURE 6

was installed in the entry (1A) under the grade line of the highway. Due to these conditions, it was not possible to construct a conventional deep mine seal in the mine entry (1A). Instead, permeable plug seals consisting of limestone aggregate installed through drill holes were placed in mined areas back of the (1A) mine entry.

Prior to the hydraulic sealing, the Wimer mine was averaging 35 pounds per day of acid and after sealing 22 pounds per day.

The last bulkhead seal for this mine was not completed until the early part of 1971. Initial observations from limited data (MO-1) indicate this mine is partly flooded. Complete inundation of the mine is not probable due to the type of drainage and backfill installations performed during the construction of Interstate 79. This mine, along with the Alben mine, has the highest coal seam elevations of all the deep mines in the study area.

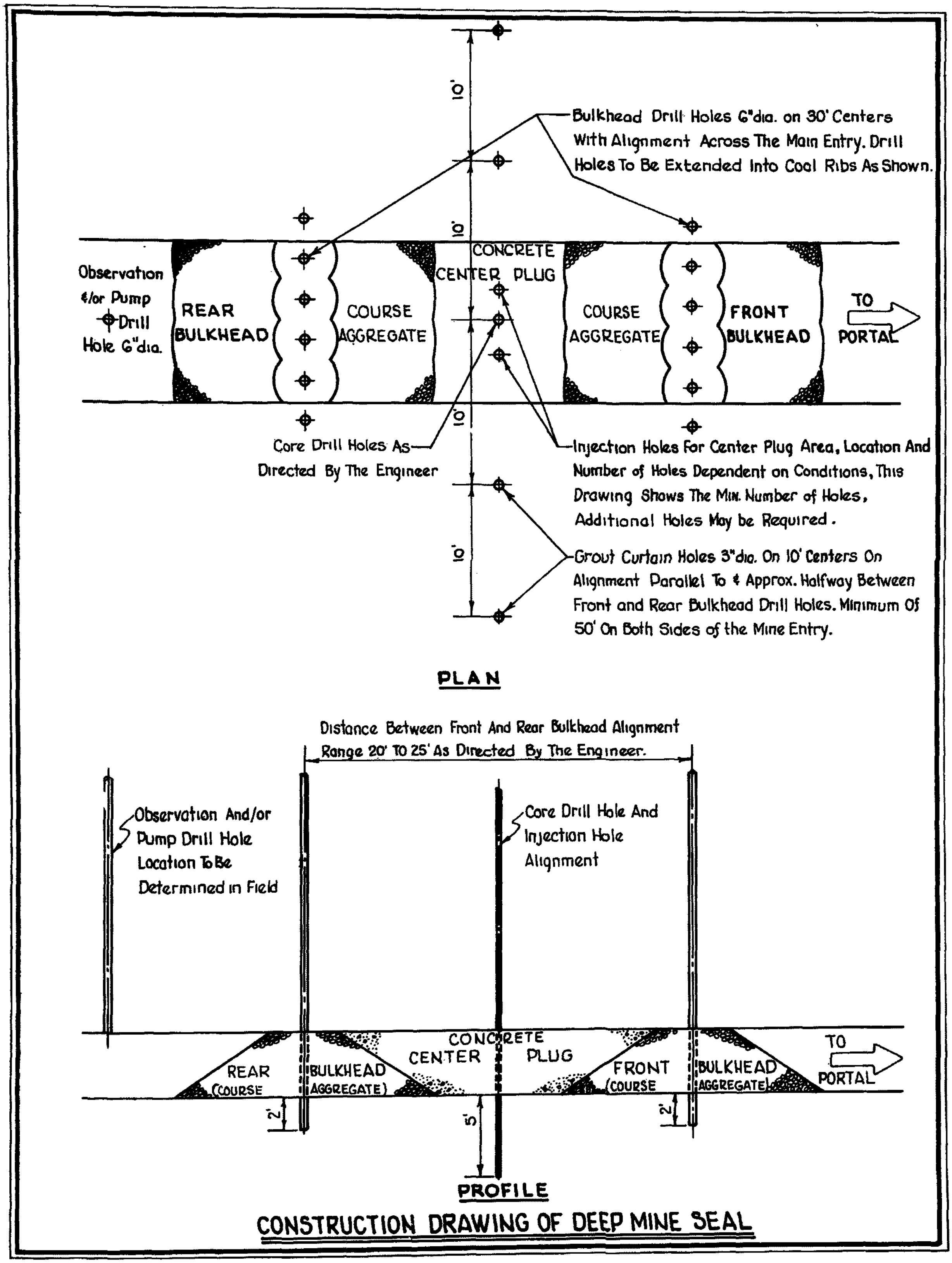
Alben Mine

The Alben Mine is located approximately 4000 feet north of the park boundary in the northwest area of the watershed. The deep mine bulkhead sealing work in this mine consisted of two hydraulic seals in entries (5, 5A) and sealing an airshaft. This work was completed in early 1971. Prior to the sealing work, this mine had an average acid production of 35 pounds per day. Since completion of the hydraulic sealing, there have been no flows from the mine.

Shields Mine

The Shields Mine is located in the northwest section of the park approximately 6000 feet southeast of the Wimer and Alben Mines. The construction work for the five mine entries (11, 12, 12A, 13, 13A) was completed in February 1970.

Conditions relative to flooding behind the seals in the Shields mine is indicated by observation holes (MO-11, 13). (MO-11) is located behind the sealed main entries while (MO-13) is behind a sealed drift about 2000 feet east of the main entries. Observations at (MO-11) indicate the mine to have fluctuating pool levels with the mine flooded under high mine water conditions. Readings at (MO-13) indicated the mine to be flooded initially to the same maximum elevation (1281 feet) as (MO-11) reached at a later date. During the third quarter of 1970, the entry at (MO-13) went dry, indicating a dam caused by roof fall or some other type of interference inby the observation hole. The entry remained dry until the last half of 1971 when the mine entry was again flooded to an elevation of 1280 feet.



10'
Bulkhead Drill Holes 6"dia. on 30' Centers With Alignment Across The Main Entry. Drill Holes To Be Extended Into Coal Ribs As Shown.
10'
CONCRETE CENTER PLUG
Observation &/or Pump Drill Hole 6"dia.
REAR BULKHEAD
COURSE AGGREGATE
COURSE AGGREGATE
FRONT BULKHEAD
TO PORTAL
10'
Core Drill Holes As Directed By The Engineer
Injection Holes For Center Plug Area, Location And Number of Holes Dependent on Conditions, This Drawing Shows The Min. Number of Holes, Additional Holes May be Required.
10'
Grout Curtain Holes 3"dia. On 10' Centers On Alignment Parallel To ℄ Approx. Halfway Between Front and Rear Bulkhead Drill Holes. Minimum Of 50' On Both Sides of the Mine Entry.
PLAN
Distance Between Front And Rear Bulkhead Alignment Range 20' TO 25' As Directed By The Engineer.
Observation And/or Pump Drill Hole Location To Be Determined in Field
Core Drill Hole And Injection Hole Alignment
CONCRETE CENTER PLUG
REAR (COURSE
BULKHEAD AGGREGATE)
FRONT (COURSE
BULKHEAD AGGREGATE)
TO PORTAL
2'
5'
2'
PROFILE
CONSTRUCTION DRAWING OF DEEP MINE SEAL


FIGURE 7

Fox Mine

The Fox mine is located in the northwest area of the park. The bulkhead mine sealing work in this mine consisted of sealing five entries (18, 19, 19A, 20, 21). The initial reduction of acid from these deep mine entries in 1968 and 1969 was attributed to the strip mine reclamation work preventing water from entering the deep mine. The deep mine sealing work was completed in June 1970. Prior to the abatement work the average acid production was 28 pounds per day. After completion, the average decreased to one pound per day of acidity.

Two observation holes (MO-18, 20) were installed in the Fox mine. (MO-18) is at an elevation ten feet higher than (MO-20). The data from these holes indicate the mine to be partly flooded and the mine water to be alkaline.

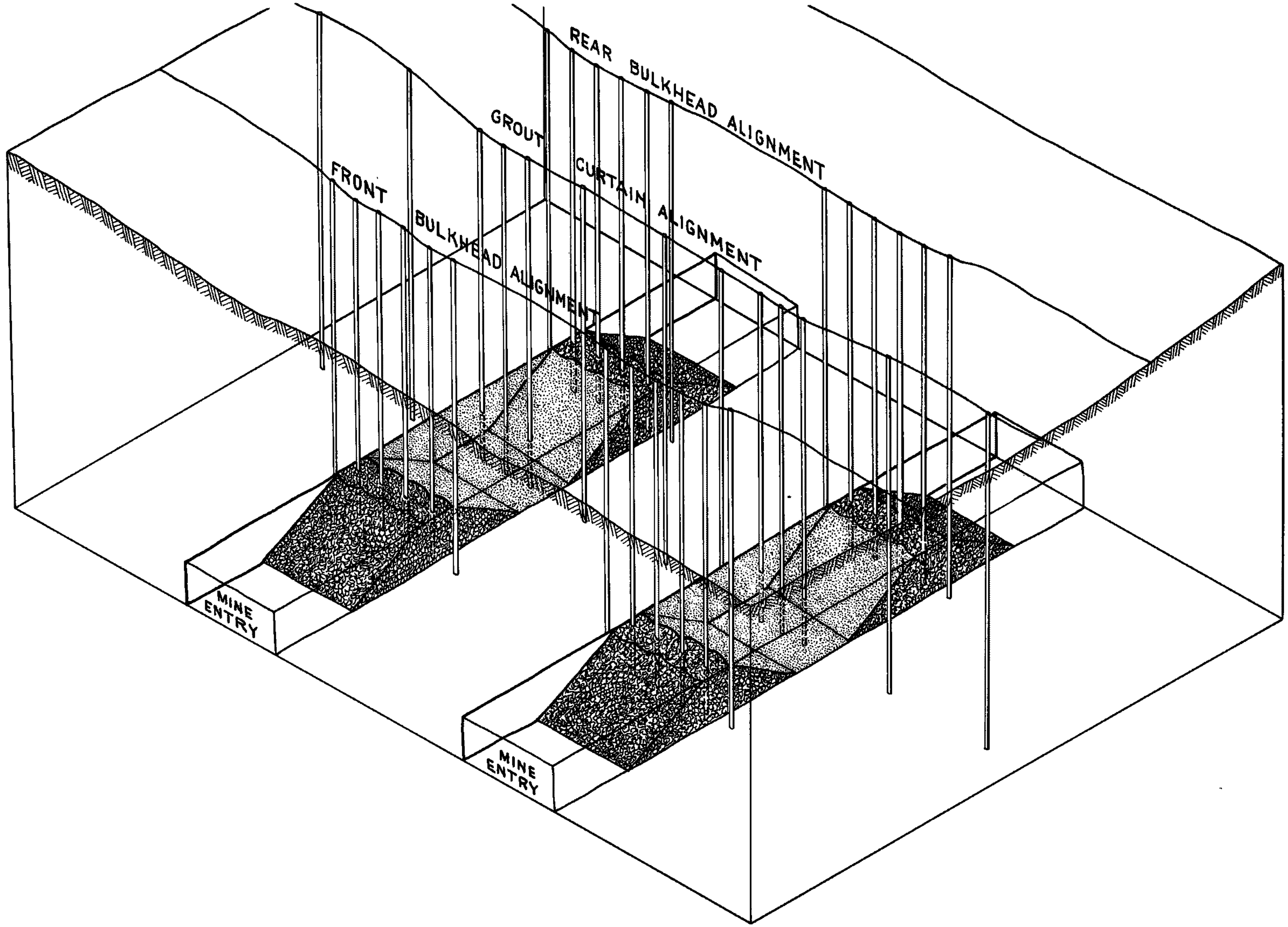
Worth Mine

The Worth mine is located adjacent to and southwest of the Salzano Ross mine. The distance between the Worth and Salzano Ross drifts is about 2000 feet across the hill. The elevation of the Worth drifts is about six feet higher than the Salzano Ross drifts. Although there were no flows from the Worth entries, sealing work was performed in three entries (22, 22A, 22C) due to the possibilities of the interconnection with the Salzano Ross mine and probable inundation of both mines. After completion of the sealing work, there has been no flow from the Worth entries.

Observation hole (MO-22) was drilled into the Worth mine. During the initial test period the water rose to a height of 22.4' in (MO-22) indicating complete inundation of the mine. The chemical analysis indicated the mine water to be alkaline.

Salzano Ross Mine

The Salzano Ross mine is located in the northwest section of the park. The drift openings for Salzano Ross are about 3500 feet southeast of the drifts for the Fox mine and about 2000 feet northeast of the drifts for the Worth mine. There has been some discussion, both pro and con, that the Salzano Ross mine and Worth mine are cut through to each other and thus, have a common underground pool. There has been nothing revealed in our research to either confirm or deny the existence of an underground connection between the two mines. The Salzano Ross mine was the largest acid-producing deep mine area in the watershed. Initially, an air seal was installed in 1967 with only limited success. Prior to the deep mine hydraulic sealing work which started in June 1969, the mine was averaging 147 pounds per day of acid. Since completion of the bulkhead sealing project, the average acid effluent loading has been reduced to 13 pounds per day.




ISOMETRIC DRAWING OF DEEP MINE SEALS

NO SCALE

FIGURE 8

The mine water conditions for Salzano Ross are designated by the data of (MO-23). This information indicates the mine to be completely flooded and the mine water alkaline. Under conditions of complete inundation in the mine, fluctuating water levels in (MO-23) are noted.

## South Nealey Mine

The South Nealey mine is located about 7000 feet south of Salzano Ross. Two drifts (27, 29) of the mine had discharges with an erratic production of acidity averaging 3 pounds per day. These entries were sealed in June 1969 and since that time, there has been no flow from the mine.

The underground water conditions in the small deep mines in the South Nealey area are denoted by (MO-29). Although the water levels vary from 9 to 13 feet in the observation hole, the mine is only partly flooded under both high and low mine water conditions. Tests show the mine water to be acid.

## Nealey Mine

The Nealey mine drifts are located about 2500 feet southeast of the Salzano Ross drifts. Six drifts (26, 34, 35, 36, 36A, 36B) were sealed in August 1969. Prior to the sealing, the mine had an average acid production of 4 pounds per day. There have been no acid discharges or flows since sealing.

The data at each of the mine observation holes (MO-34, 36) indicate the same pool elevations for both locations and the same change in elevations of the pool levels from high to low mine water conditions. This would indicate the interconnected mine workings to be relatively free of barriers or internal dams between the two observation holes. The mine is partly flooded under all mine water conditions and the mine water is predominantly acid.

## Goubeaud Mine

The Goubeaud mine entries are located along the northern shoreline of the lake approximately 2000 feet east of the Nealey drifts. Two entries (37, 38) were sealed in August 1969. This mine had acid discharges averaging 2 pounds per day prior to sealing and no acidity after sealing.

Observation hole (MO-38) data indicated the conditions relative to the Goubeaud mine. This information revealed the mine to be partly flooded with fluctuating pool levels. The mine water shows a tendency to change from acid to alkaline with increased inundation.

North Goubeaud Mine

These three drifts (43, 44, 44A) are located about 2000 feet northeast of the Goubeaud drifts. Due to proximity to the Goubeaud-Nealey deep mine areas, these drifts were sealed in September 1969.

There is no water quality data for (MO-44); measurements in the observation hole indicated less than one foot of water in the area behind the seal.

West Emery Mine

These entries (53, 54, 56) are located along the shoreline at the southwestern end of the Emery deep mine area. Construction work consisted of sealing the three entries and a 400 foot grout curtain. This work was performed in the last half of 1969. Flows and production of acid prior to the construction had been erratic. The discharges are still somewhat erratic; however, there is an improvement in water quality.

Observation hole (MO-54), located behind a sealed mine drift in the southwest side of the Emery mine, denotes a partly flooded mine with fluctuating pool levels and alkaline mine water.

Emery Mine

Mine drifts (57, 58) are located in the center of the Middle Kittanning area of the North Central Section of the Appalachian Surface Mine Reclamation Project. These entries were sealed in September 1969. Since sealing, these entries have been averaging an acid production of 2 pounds per day.

Observation hole (MO-58) in the northeast side of the Emery mine area indicates a completely flooded mine with an alkaline mine water. There is further evidence that the Emery deep mines either are not interconnected or there is a great amount of interference from one area of the deep mine to the other. The mine pool elevation in the Emery mine is about 35 feet higher than the mine pool for West Emery.

Fremont Mine

The Fremont mine entries (60, 61) are located 600 feet north of the Middle Kittanning area of the North Central Section of the Appalachian Surface Mine Reclamation Project. The water quality from this mine prior to sealing was erratic with the production of both acidity and alkalinity in the low range. These entries were sealed due to their relative location to the Emery deep mine areas and possible inundation caused by an interconnection between the mines. There has been no real change in the quality of the discharge since sealing.

Data from the Fremont observation hole (MO-60) indicate a deep mine area with a limited amount of flooding. Since sealing, the maximum height of water measured in the observation hole was 2.7 feet. However, all mine water samples from the observation hole indicated alkaline water.

Isle Mine

The Isle mine entries are located along the north shoreline in the central area of the park about 2000 feet west of the new highway bridge for Route 528. The deep mine sealing work consisted of installing mine seals in six entries (64A, 64B, 65A, 65B, 66A, 66B) and grouting 1000 lineal feet of outcrop in the area. This work was performed from May through November in 1969. Prior to the sealing work, the mine was producing an average of 2 pounds of acid per day. Since sealing there have been no acid flows from these entries.

Conditions related to the mine water in the Isle mine after sealing are indicated by the data from three observation holes (MO-64, 65, 66). The mine pool elevations are at the same level for all three locations and denote the same change in elevation from high to low mine water conditions; indicating all three areas are interconnected with a minimum of interference. This mine also has a fluctuating mine pool. The mine is flooded under the high mine water conditions and partly flooded under low. The mine water has been both acid and alkaline in low water conditions and alkaline when the mine is completely flooded.

Martzolf Mine

The Martzolf entries are located along Route 528 approximately 4000 feet north of the new highway bridge. Sealing work for the Martzolf mine included the installation of mine seals in two entries (68, 69) and an airshaft; the work being performed during the last half of 1969. Prior to sealing, this mine was producing an average of 2 pounds per day of acid. There has been no flow of acid water from this mine since sealing.

Mine observation hole (MO-69) is located in the Martzolf mine. The data at this location indicate a fluctuating pool level with the mine flooded in high mine water conditions and partly flooded in low mine water. The mine water is alkaline under all conditions of flooding.

Lindey Mine

The Lindey mine is located in the northeast section of the watershed near the intersection of State Route 528 and Township Route 445. The deep mine sealing work consists of five entries (74, 75, 75A, 87, 88), an airshaft and 1000 lineal feet of grout curtain. This was one of the more difficult mines to seal. The sealing work started in August 1969 and was finally completed in August 1970. Initially the mine produced an average of 18 pounds of acid per day. After sealing, an average of 12 pounds per day was produced in the effluent from the unsealed section of the mine.

Two mine observation holes (MO-75, 87) are in the Lindey mine. Data from these holes indicate pool elevations at the same level for both locations. The mine is flooded in high mine water conditions and partly inundated in low mine water conditions. The mine water from the observation hole behind the barrier in contrast to the acid effluent discharge ahead of the barrier is alkaline.

## Lincoln Mine

The Lincoln mine entries are located along the north shoreline in the northeast end of the park, approximately 2000 feet east of State Route 528. Prior to any reclamation work, the Lincoln mine was producing about 112 pounds per day of acid. The initial reduction in acidity was due to the refuse pile removal and strip mine reclamation work in reducing the quantity of water from entering the mine. Additional reduction of acidity was the result of the mine sealing project. This mine complex was one of the more difficult mines to seal. The deep mine sealing work started in February 1969 and was completed in October 1970. This work included deep mine seals in four entries (76A, 76B, 77A, 77B) and 2000 feet of grout curtain. Acid production after reclamation and sealing has averaged 70 pounds per day.

The underground waters of the Lincoln mine are denoted by (MO-76). This data indicate the mine to be completely flooded under high mine water conditions and at least 90% inundated under low mine water conditions. Samples taken from the mine observation hole indicated the deep mine waters to be alkaline in four out of the six quarters of the examination.

## Kildoo Mine

The Kildoo mine is located 1200 feet northeast of the Lincoln mine. Prior to sealing, the Kildoo mine had produced an average of 102 pounds of acid per day. Mine sealing work in the Kildoo mine was started in February 1969 and completed in November 1970. This construction consisted of sealing four entries (79, 79A, 80, 81), an airshaft and installing several hundred feet of grout curtain. This mine and the Lincoln mine were the two most difficult mines to seal. Both mines required a considerable amount of additional work. Since sealing, the Kildoo mine has had a fairly steady flow with an average production of acidity of 30 pounds per day. However, the discharge, as examined during the final inspection of Deep Mine Sealing Project No. SL 105-3, indicated a pH 6.2.

The Kildoo mine water conditions are indicated by (MO-79). This mine is partly flooded under both high and low mine water levels. The deep mine water has been both acid and alkaline.

## Hilliard Mine

The Hilliard deep mine entries are located in a strip mine area in the northeast corner of the park. Prior to sealing, this mine had erratic discharges with an acid production averaging 6 pounds per day. The deep mine sealing work consisted of the installation of seals in two entries (85, 86) and a 1000 foot grout curtain. The construction work was started in January 1970 and completed in June 1970. Since completion of the sealing work, the mine has had a production of acidity averaging 4 pounds per day.

Mine observation hole (MO-84) is in the Hilliard mine. The data from this hole indicates a fluctuating mine water level with the mine flooded in high water conditions and partly flooded in the low water levels. The mine water is alkaline.

## North Corridor Mines

Four mine entries (89, 89A, 90, 91) were sealed under Deep Mine Sealing Project SL 105-3 in the North Corridor of the park. This section of the park is in the Big Run watershed area. The flows and discharges relative to these mines were not considered in this study because they are not part of the Muddy Creek watershed.

## Well Plugging, Air Sealing and Miscellaneous

Other pollution abatement projects performed in the park included plugging 422 oil, gas and water wells. Associated with the well plugging project was the excavating and removal of 5,000 CY of oil saturated soils from the well sites.

A deep mine air-trap seal was placed in the Salzano-Ross mine in 1967 by the Department of Mines and Mineral Industries. Because of its limited effectiveness, this air seal was replaced in 1969 by a double bulkhead hydraulic mine seal. Additional landscaping and planting projects were performed in the park area in order to prevent erosion and reduce turbidity.

## SECTION V

## METHOD OF INVESTIGATION

The periodic water sampling and flow measurements which were started in May 1967 under the Mine Drainage Project MD-8 were continued in this study from August 1968 through June 1971. Eighty-five (85) weirs were installed in 1967 at all the known mine drainage discharge points. Since that time, many of the sampling points were either moved or eliminated due to the construction in the abatement projects and due to the inundation of the lake. Water samples were collected at least once a month. These samples were analyzed and tabulated indicating the flow in gallons per minute, pH; and the alkalinity, acidity, iron and manganese in both milligrams per liter and pounds per day. The mine drainage data have been compiled into the various deep mine and strip mine areas, and this information divided into eight periods of six months duration each, starting with July 1, 1967 and ending with June 30, 1971.

After examining the mine drainage data over a period of three years, acidity was considered to be the major component. The principal criteria for evaluating the effectiveness of the mine drainage abatement projects was the examination and comparison of the discharge flow rates, and average pounds per day of net acidity and iron before and after abatement. As supplemental information, the average pounds per day of alkalinity and acidity on a six months basis for the various mining complexes in the watershed area were computed and tabulated.

The investigation and evaluation of the pollution abatement procedures were limited chiefly to the deep mine sealing and strip mine reclamation projects. Although it was not possible to compute the pounds of acid and iron that would have been generated by the refuse piles, the subsidence areas, the mining appurtenances and oil and gas well sites, it was estimated that serious and continuous pollution would have resulted if the refuse pile removal, surface sealing and well plugging projects were not performed prior to the inundation of the lake. The data for Lake Arthur are an indirect indication of their effectiveness.

The gates of the dam were closed on May 15, 1969. Starting in September 1969, water samples were taken from six locations in the lake and analyzed. This information was compiled and reported on a quarterly basis from the third quarter of 1969 through the second quarter of 1971.

Visual observations and evaluations were made during the study relative to the erosion and turbidity, particularly in the areas of strip mine reclamation.

The flooded heights and water quality for the 24 mine observation holes were reported on a periodic basis starting in 1970 or after completion of the applicable mine seal. The last measurements and tests were performed during the fourth quarter of 1971.

# SECTION VI

# ABATEMENT PROJECT COSTS

## Deep Mine Hydraulic Sealing

The total construction costs for the 69 deep mine bulkhead seals and grouting in Project SL 105-3 were $1,351,650; however, these costs included sealing and grouting work outside of the study area in the North Corridor of the park which amounted to $85,437. The costs for the 65 mine seals and grouting work in the study area amounted to $1,266,213. The average cost per mine seal, including grouting, was $19,480. The range in cost per mine seal varied from a low of $8,308 for a seal in a mine entry along State Route 528 to a high of $58,437.25 for a mine seal and grouting in a drift in the Lindey mine.

## Deep Mine Air Sealing

The construction costs for the air-trap deep mine seal installed in the Salzano Ross mine in 1967 was $4,165.

## Deep Mine Surface Sealing

The surface sealing costs for the 23 mine areas in Project SL 105-2 amounted to $28,000.

## Strip Mine Reclamation

The strip mine reclamation costs for 461.7 acres in Projects ASMRP-1, MD-8C, SL 105-1, SL 105-1A, and SL 105-1B were $672,208. These costs varied from a low of $420 per acre to a high of $2700 per acre and included all incidental work such as soil treatment, planting, and special requirements.

## Refuse Pile Removal

This work, part of Project MD-8C, was performed under two contracts for a total of $294,233. In the first contract, 82,347 CY were removed for $103,757 and in the second, 134,721 CY were removed for $190,486. The cost per cubic yard of material removed varied from $1.00 to $1.54. The greatest distance the refuse had to be transported was 3 miles.

## Well Plugging

These projects, including plugging 422 abandoned oil, gas and water wells and the removal of 5000 CY of oil-saturated soils from the well sites were performed for a total of $378,292. The average cost per well site amounted to $896.

Summary of Project Costs

The following is a tabulation of the project costs performed in the study area.

| | |
|---|---|
| Deep Mine Hydraulic Sealing | $1,266,213 |
| Deep Mine Air Sealing | 4,165 |
| Deep Mine Surface Sealing | 28,000 |
| Strip Mine Reclamation | 672,208 |
| Refuse Pile Removal | 294,233 |
| Well Plugging | 378,292 |
| Total Project Costs | $2,643,111 |

## SECTION VII

## DISCUSSION OF RESULTS

### General Considerations

Averages, analyses and flow volumes as associated with mine drainage conditions, are difficult to ascertain accurately and can be misleading due to variations in precipitation and infiltration from one period to another. Without continuous monitoring, the duration of both maximum or peak flows as well as minimum and no-flow periods were estimates and; as a result, have a certain margin of error. However, the periodic sampling on a monthly basis, supplemented with adjustments for abnormal variations or conditions have produced fairly reliable values which can be used for comparison in determining the effectiveness of an abatement program.

In the evaluation, acidity, alkalinity and iron in average pounds per day and mine discharge flow rates in gallons per minute are used as a measure for comparison. These averages, in many cases, are several times less than the maximum during high flows and do not indicate the effects of "slugging" which often accompany high flows.

Seepage from most of the refuse pile areas, some strip mine areas and the abandoned well sites were practically impossible to monitor. However, the pollution potential from these sites was recognized and abatement measures were performed to alleviate the possibilities of pollution, particularly after inundation of the lake.

The average pounds per day of both alkalinity and acidity at six month intervals have been computed for the various mine discharges. A tabulation of these values is included in the appendix of the report. Figures 9, 10, 11 and 12 on the following pages are graphs indicating these results. Figure 9 is a graph indicating the values for the total deep and strip mine discharges, Figure 10 for the total deep mine discharges, and Figure 11 for the total strip mine discharges.

### Rainfall Data

In order to correlate observed mine water pollutant loadings with atmospheric precipitation, official monthly rainfall data for the two nearest gauging stations (at Butler and Slippery Rock) were compiled for the years 1967 thru 1971. This data is included in the Appendix. The rainfall for the Moraine State Park area was estimated by averaging the monthly values from the two stations. This data is plotted in Figure 12 to show the relationship of rainfall intensity and generation of net acidity by both deep mines and strip mines.

Effectiveness of Deep Mine Sealing

Of all the pollution abatement projects performed in the watershed area, the deep mine sealing was the most effective and, at the same time, the most expensive. The general conditions associated with each of the deep mine areas sealed and a statement of the effectiveness of these individual seals are included in the Pollution Abatement Methods Section of the report.

A tabulation indicating the applicable deep mines, number of hydraulic seals, and the average values before and after mine sealing for the discharge flow rates, net acidity and iron is presented in Table 2. A comparison of these values indicate an overall reduction in flow rates from 146 to 57 gallons per minute, a reduction in net acidity from 501 to 160 pounds per day and an increase in iron from 34 to 42 pounds per day. This latter value probably is not a significant difference (see subsequent discussion).

The discharge flow rates after sealing indicate that eight mines have no flows, one mine has an average flow of less than one gallon per minute, eight mines have reduced flow rates, one mine has the same flow rate as before and one mine increased from one to two gallons per minute.

Acid loading after sealing indicates eight mines with no acid production, two mines with an average of less than one pound per day and a reduction in acidity in all of the other mines except one, where the average acid production remained the same at 6 pounds per day. Substantial reductions are indicated in all of the larger acid producers with the exception of the Lincoln mine.

A reduction in iron was indicated in most areas with the exception of the Lindey and Lincoln mines. Both of these mines had an increase in iron. Probable reasons for this are discussed in a subsequent section on iron chemistry.

Table 5 is information compiled from the Mine Observation (MO) Hole data. This table includes the name of the mine; the estimated minimum and maximum elevations of the mine; the Mine Observation (MO) Hole number and elevation at the bottom of the coal or mine in the (MO) Hole; and the minimum and maximum water elevations in the mine as measured in the (MO) Hole as the inundation elevations. This information indicates that two mines are completely flooded under both high and low mine water conditions; seven mines are completely flooded under high mine water conditions and partly flooded under low; eight mines are partly flooded under high to normal mine water conditions and one mine is reported with less than one foot of water under all conditions. Mine observation hole measurements were reported on a periodic basis starting in 1970 or after completion of the applicable mine seal.

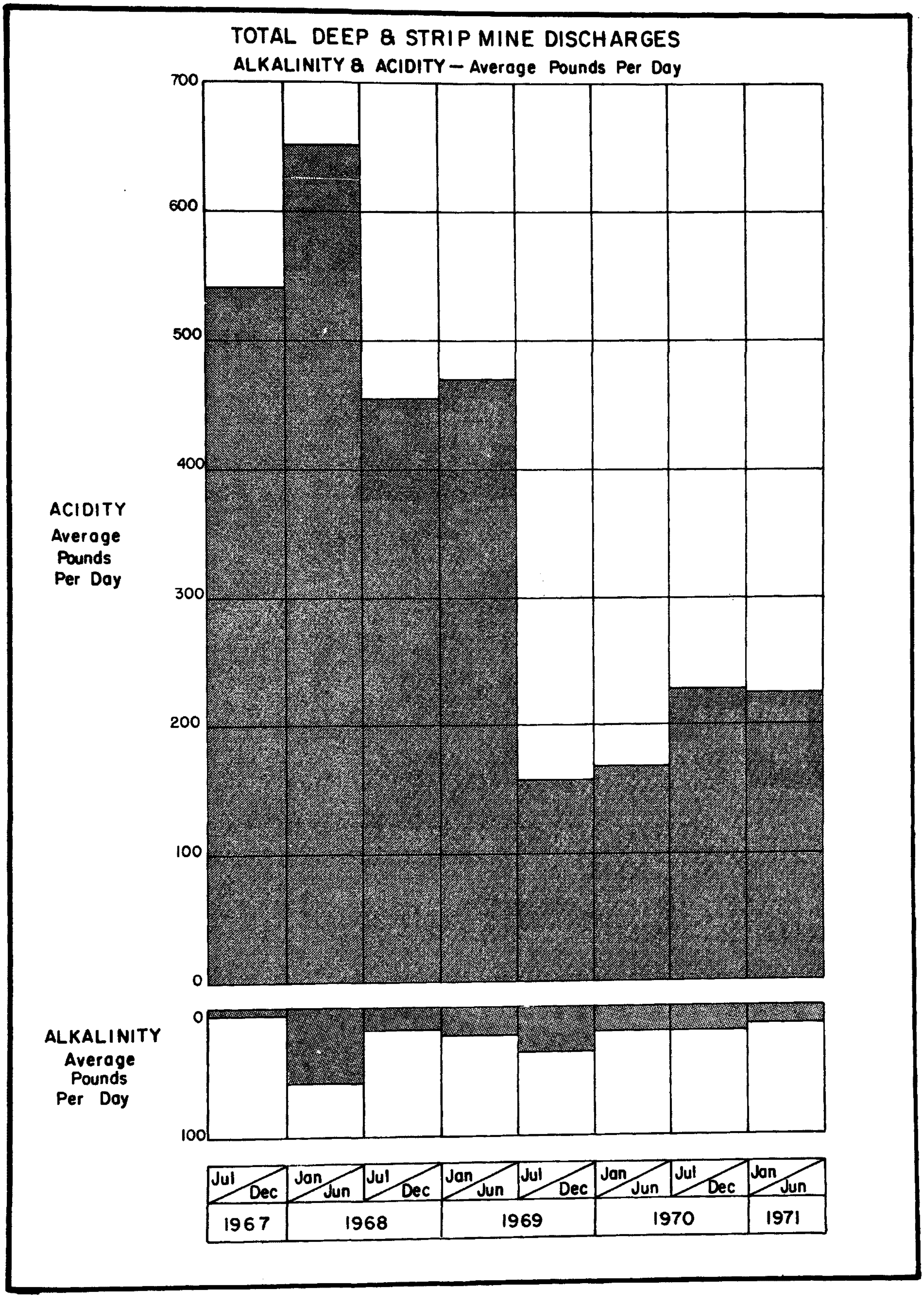

TOTAL DEEP & STRIP MINE DISCHARGES
ALKALINITY & ACIDITY — Average Pounds Per Day
ACIDITY Average Pounds Per Day
700
600
500
400
300
200
100
0
ALKALINITY Average Pounds Per Day
0
100
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
1967
1968
1969
1970
1971

FIGURE 9

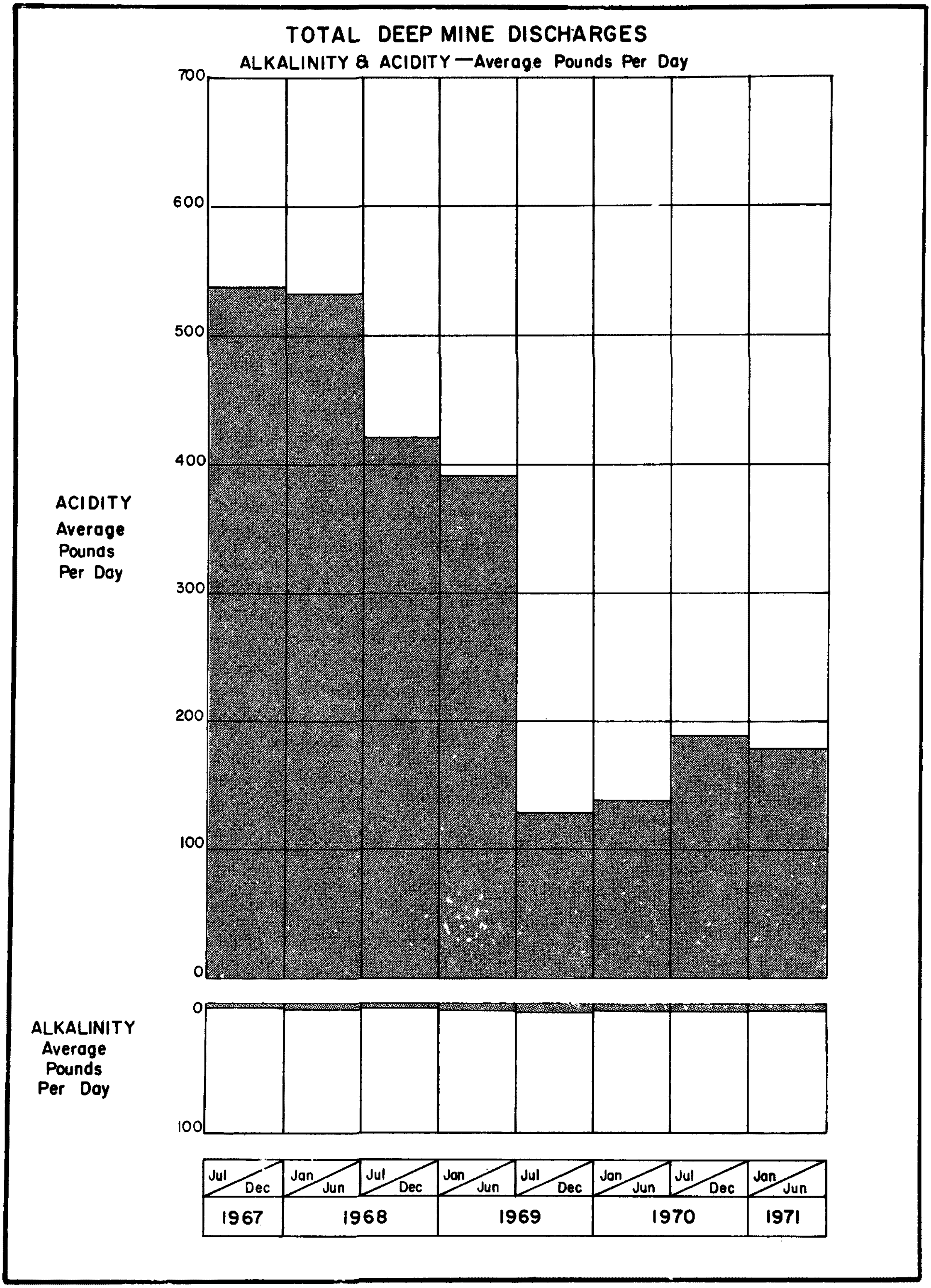

TOTAL DEEP MINE DISCHARGES
ALKALINITY & ACIDITY—Average Pounds Per Day
ACIDITY
Average
Pounds
Per Day
700
600
500
400
300
200
100
0
ALKALINITY
Average
Pounds
Per Day
0
100
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
1967
1968
1969
1970
1971

FIGURE 10

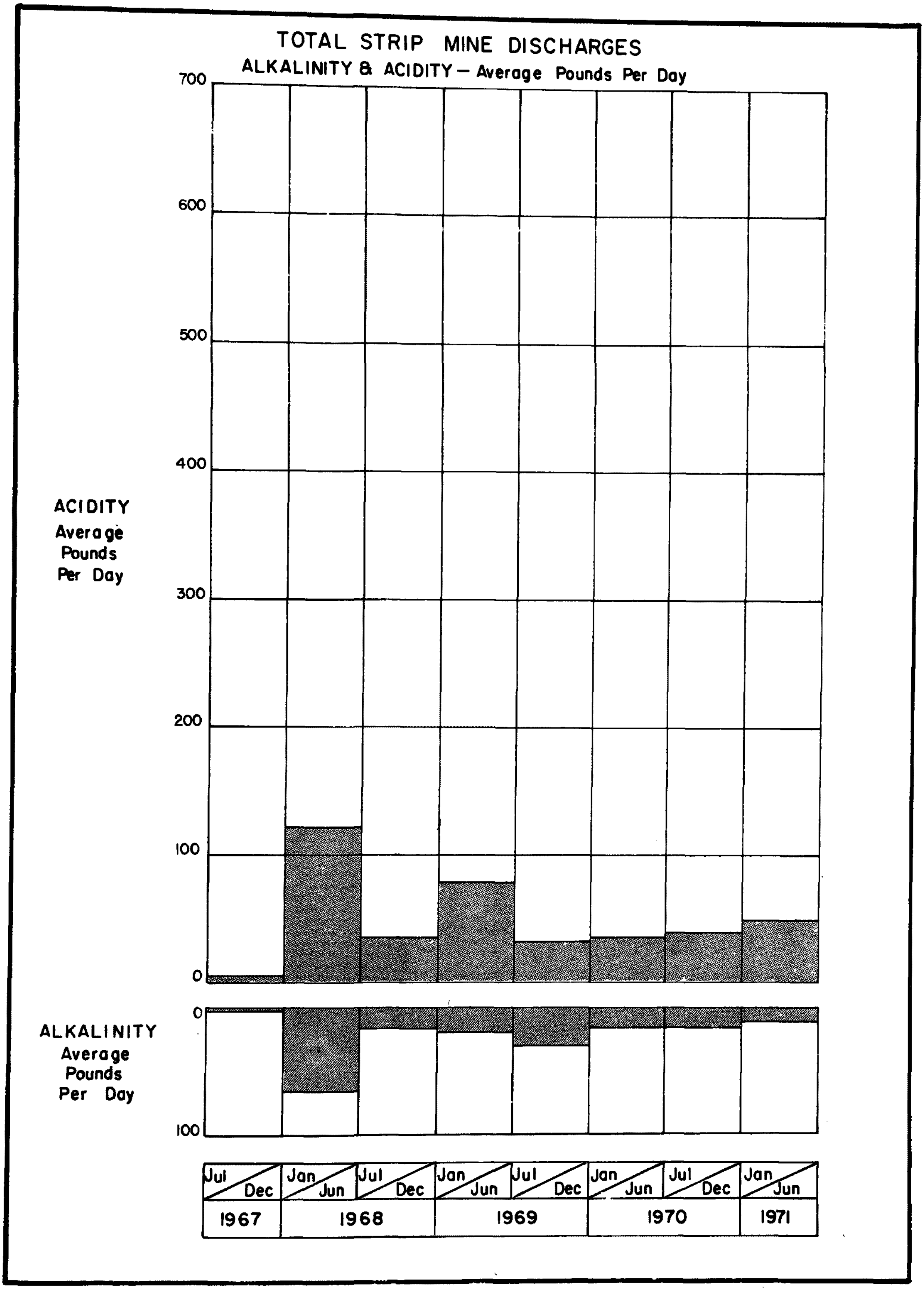

TOTAL STRIP MINE DISCHARGES
ALKALINITY & ACIDITY – Average Pounds Per Day
ACIDITY
Average
Pounds
Per Day
700
600
500
400
300
200
100
0
ALKALINITY
Average
Pounds
Per Day
0
100
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
1967
1968
1969
1970
1971

FIGURE II

The mine observation hole data for the individual mines are included in the appendix of the report. This information indicates fluctuating pool levels in most of the mines. Generally the pool levels will vary following changes in precipitation and infiltration. The majority of the mines had changes in pool levels in the range between one to five feet. The highest recorded head on a seal was 38 feet.

Water quality information indicates that the two mines that are completely flooded have alkaline mine water. Eight of the partly flooded mines have alkaline water, three of the partly flooded mines have acid water and five partly flooded mines have had both acid and alkaline mine waters. Several of the mines indicated a trend of acid water in low pool levels and alkaline water with the high pool levels. Two mines indicated a trend from acid to alkaline mine waters.

Strip Mine Reclamation

The strip mine discharges were far more erratic than the deep mine discharges; however, their contributions have always been less than 21% of the total pollution load. The production of both alkalinity and acidity in the strip mine discharges is directly affected by the climatic conditions, particularly precipitation. The production of acidity from strip mines has ranged from less than 1% of the total acid production during dry periods to 21% during wet periods throughout the four year study. (See Figure 11)

Table 3 indicates average values before and after strip mine reclamation. A comparison of these values indicates a reduction in discharge flow rates from 142 to 136 gallons per minute (probably an insignificant difference), an overall reduction in net acidity from 50 to 22 pounds per day and a minor increase in iron from 3 to 4 pounds per day (probably not significant).

The Northwest Area, consisting of 166.0 acres of backfill reclamation, had an average reduction in discharge flow rates from 26 to 13 gallons per minute (50%). In this area, the test data indicate only a minor net acidity and iron production both before and after reclamation. Representative values for the "before" reclamation conditions in the area were not possible as the 120.2 acres in the ASMRP-1 project were in the process of being backfilled during the initial periods of the study.

A comparison of values in the Southwest Area (78.1 acres) indicates an overall reduction in discharge flow rates from 24 to 3 gallons per minute (88%), an overall reduction in acidity from 21 to 2 pounds per day (90%) and a reduction in iron from one to less than one pound per day.

The strip mine reclamation in the East Area consisted of 217.6 acres of backfill. A comparison of values in this area indicates an increase in discharge flow rates from 92 to 120 gallons per minute (30%), a reduction in acidity from 28 to 19 pounds per day (32%) and a minor increase in iron from 2 to 4 pounds per day.

Both terrace-type restoration and approximate contour backfilling methods were performed in the park area (See Table 1). Except for Project ASMRD-1, contour backfilling was restricted to relatively flat areas with limited surface drainage above the highwall. Strip mine reclamation performed under Projects MD-8C, SL 105-1, SL 105-1A, and SL 105-1B included the construction of diversion ditches above the highwall and slope drain flumes across the backfill at specific locations. This was the principal reason for the reduction in the slug discharge flow rates after reclamation in the applicable areas.

Terrace-type backfill with diversion ditches and slope drain flumes are the preferred methods for reclamation because they provided maximum control of erosion and turbidity.

Erosion occurred at several locations in the backfilling; the most prominent being the Northwestern Section of ASMRD-1, an area of contour backfill without diversion ditches or slope drain flumes. Additional erosion occurred in several locations at the intersections of the diversion ditch with the slope drain flume. These conditions are being corrected by the installation of concrete or masonry construction at the intersections.

Water Quality in the Lake Area

In examining the conditions prior to inundation, flows and water quality data were obtained on Muddy Creek at Weir #85 near Nealey from 1967 to July 1969. At that time, this sampling point was inundated due to the rising pool level. The water quality at this point ranged between pH 6 and pH 7 for the two-year period. During the years 1963 to 1966, Muddy Creek varied from a pH 5 to pH 7, as indicated by data from other sources.

Periodic water sampling was started in September 1969, at six locations in the pool area. From that time through June 1971, this information indicated the water quality in Lake Arthur remained alkaline, with little change from month to month. The range in analysis, as compiled from this data, indicated the following: pH 6.0 to pH 7.6, alkalinity 10 to 86 ppm, acidity 0 to 6 ppm, iron 0.2 to 3.0 ppm and manganese 0 to 3.5 ppm. The tabulation indicating the range in analysis on a quarterly basis is shown on Table 6.

Water quality in the lake has remained good since the initial inundation in 1969 and aquatic life is flourishing. The Pennsylvania Fish Commission has stocked the lake with largemouth bass, catfish, musky, black crappies and alewives. The lake has been open for boating, fishing and swimming for the past two seasons.

TABLE 2

MUDDY CREEK WATERSHED - MORAINE STATE PARK
AVERAGE VALUES BEFORE AND AFTER MINE SEALING

| | No. of Hydraulic Seals | DISCHARGES Gallons per Minute | | ACIDITY Pounds per Day | | IRON Pounds per Day | |
|---|---|---|---|---|---|---|---|
| | | Before Sealing | After Sealing | Before Sealing | After Sealing | Before Sealing | After Sealing |
| WIMER | 3 | 18 | 8 | 35 | 22 | 4 | 2 |
| ALBEN | 2 | 5 | 0 | 35 | 0 | 3 | 0 |
| SHIELDS | 5 | (A) | (A) | (B) | (B) | (C) | (C) |
| FOX | 5 | 14 | 3 | 28 | 1 | 3 | (C) |
| WORTH | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| SALZANO ROSS | 4 | 10 | 5 | 147 | 13 | 4 | 4 |
| SOUTH NEALEY | 2 | 2 | 0 | 3 | 0 | 1 | 0 |
| NEALEY | 6 | 5 | 0 | 4 | 0 | (C) | 0 |
| GOUBEAUD | 2 | 2 | 0 | 2 | 0 | (C) | 0 |
| NORTH GOUBEAUD | 3 | 8 | 0 | (B) | 0 | (C) | 0 |
| WEST EMERY | 3 | 4 | 3 | 2 | 2 | 1 | (C) |
| EMERY | 2 | 6 | 3 | 6 | 6 | 1 | (C) |
| FREMONT | 2 | 1 | 2 | 1 | B | (C) | (C) |
| ISLE | 6 | 6 | 0 | 2 | 0 | 1 | 0 |
| MARTZOLF | 2 | 4 | 0 | 2 | 0 | 1 | 0 |
| LINDEY | 5 | 5 | 5 | 18 | 12 | 2 | 6 |
| LINCOLN | 4 | 20 | 9 | 108 | 70 | 5 | 23 |
| KILDOO | 4 | 25 | 15 | 102 | 30 | 8 | 7 |
| HILLIARD | 2 | 11 | 4 | 6 | 4 | (C) | (C) |
| | 65 | 146 | 57 | 501 | 160 | 34 | 42 |

(A) Variable flows - Average less than 1 G.P.M.
(B) Sporadic acid discharge - Average less than 1 P.P.D.
(C) Sporadic iron discharge - Average less than 1 P.P.D.

TABLE 3

MUDDY CREEK WATERSHED
MORAINE STATE PARK
AVERAGE VALUES BEFORE AND AFTER STRIP MINE RECLAMATION

| Strip Mine Areas | Backfill Reclamation Acreage | DISCHARGES Gallons per Minute | | ACIDITY Pounds per Day | | IRON Pounds per Day | |
|---|---|---|---|---|---|---|---|
| | | Before SMR | After SMR | Before SMR | After SMR | Before SMR | After SMR |
| NORTHWEST | 166.0 | 26 | 13 | 1 | 1 | © | © |
| SOUTHWEST | 78.1 | 24 | 3 | 21 | 2 | 1 | © |
| EAST | 217.6 | 92 | 120 | 28 | 19 | 2 | 4 |
| | 461.7 | 142 | 136 | 50 | 22 | 3 | 4 |

© Sporadic iron discharge - Average less than 1 P.P.D.
SMR Strip Mine Reclamation

TABLE 4

TABULATION OF DEEP MINE SEALING AND STRIP MINE RECLAMATION
AVERAGE VALUES BEFORE AND AFTER ABATEMENT

| | DISCHARGES Gallons per Minute | | ACIDITY Pounds per Day | | IRON Pounds per Day | |
|---|---|---|---|---|---|---|
| | Before MDA | After MDA | Before MDA | After MDA | Before MDA | After MDA |
| DEEP MINE SEALING | 146 | 57 | 501 | 160 | 34 | 42 |
| STRIP MINE RECLAMATION | 142 | 136 | 50 | 22 | 3 | 4 |
| TOTAL | 288 | 193 | 551 | 182 | 37 | 46 |

MDA Mine Drainage Abatement

## Comparison of Effectiveness and Costs

A summary of the average values before and after abatement for both deep mine sealing and strip mine reclamation is indicated on Table 4.

The average discharge rates for both types of mines before abatement were nearly equal: 146 gallons per minute (deep mine sealing) to 142 gallons per minute (strip mine reclamation). The deep mine sealing indicated a reduction in the discharge rates from 146 to 57 gallons per minute (60%) while strip mine reclamation had a slight reduction of 142 to 136 gallons per minute (4%). The overall reduction for total abatement was 288 to 193 gallons per minute (33%).

Values for net acidity indicated that the deep mines were producing an average of ten times more acid than the strip mines before abatement (501 pounds per day - deep mines to 50 pounds per day - strip mines). After abatement, the average net acidity from the deep mines was 160 pounds per day indicating a reduction of 68%, and the strip mine reclamation reduced the average acidity to 22 pounds per day indicating a reduction of 56%. Total overall reduction in net acidity varied from an average of 551 pounds per day (before) to 182 pounds per day (after), indicating a reduction of 67% for the combined abatement.

Average total values for both the deep mine sealing and strip mine reclamation indicated increases in production of iron after abatement. Deep mine sealing increased from 34 to 42 pounds per day and the strip mine reclamation from 3 to 4 pounds per day. As in the case of acidity, the deep mines were producing about 10 times more iron than the strip mines. However, the total increase from 37 to 42 pounds per day of iron did not cause any serious problems in the watershed area.

## Iron Chemistry in Abated Ground Waters

Analyses of many observation hole samples taken after abatement construction has been completed indicate an increase in the total iron content of the abated waters involved. These increases could be due to three different mechanisms:

1. the total iron reported includes suspended insoluble iron compounds, such as hydrous iron oxides, ferric hydroxide sols, iron oxide scale inadvertently knocked off the sides of the 6" steel casings which line the observation boreholes, iron corrosion products which accumulate at the air-water interface in the borehole, etc. Unfortunately, any or all of these compounds are determined in the total iron analysis, which is the standard iron method for reporting mine water quality. Obviously,

TABLE 5

SEALED DEEP MINE INFORMATION
IN
MORAINE STATE PARK
FROM
MINE OBSERVATION HOLE DATA

| Deep Mine | Estimated Mine Elevations | | MO Number | MO Coal Elevation | Inundation Elevations | |
|---|---|---|---|---|---|---|
| | Min. | Max. | | | Min. | Max. |
| WIMER | 1274 | 1295 | 1 | 1276 | (1278) | (1278) |
| SHIELDS | 1272 | 1280 | 11<br>13 | 1275<br>1272 | 1278<br>1272 | 1281<br>1281 |
| FOX | 1230 | 1254 | 18<br>20 | 1240<br>1230 | 1240<br>1238 | 1241<br>1243 |
| WORTH | 1225 | 1235 | 22 | 1230 | (1252) | (1252) |
| SALZANO ROSS | 1224 | 1235 | 23 | 1224 | 1232 | 1239 |
| NEALEY | 1216 | 1240 | 34<br>36 | 1216<br>1218 | 1222<br>1222 | 1224<br>1224 |
| GOUBEAUD | 1215 | 1238 | 38 | 1215 | 1215 | 1218 |
| NORTH GOUBEAUD | 1218 | 1230 | 44 | 1218 | 1218 | 1218 |
| WEST EMERY | 1196 | 1222 | 54 | 1196 | 1199 | 1203 |
| NORTH EMERY | 1198 | 1222 | 58 | 1198 | 1235 | 1236 |
| FREMONT | 1204 | 1220 | 60 | 1204 | 1204 | 1207 |
| ISLE | 1180 | 1200 | 64<br>65<br>66 | 1195<br>1183<br>1182 | 1197<br>1197<br>1197 | 1200<br>1200<br>1200 |
| MARTZOLF | 1190 | 1200 | 69 | 1190 | 1198 | 1212 |
| LINDEY | 1205 | 1230 | 75<br>87 | 1207<br>1208 | 1220<br>1220 | 1230<br>(1230) |
| LINCOLN | 1195 | 1210 | 76 | 1195 | 1209 | 1214 |
| KILDOO | 1200 | 1225 | 79 | 1202 | 1206 | 1210 |
| HILLIARD | 1210 | 1224 | 84 | 1210 | 1219 | 1225 |

TABLE 6

RANGE IN ANALYSIS

OF

WATER QUALITY IN LAKE ARTHUR

MORAINE STATE PARK

| RANGE \ YEAR / QUARTER | 1969 | | 1970 | | | | 1971 | |
|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 |
| pH | 7.0-7.6 | 6.9-7.3 | 6.9-7.2 | 6.9-7.3 | 6.8-7.5 | 6.8-7.3 | 6.0-7.0 | 6.8-7.3 |
| Alkalinity | 68-86 | 24-71 | 24-70 | 16-30 | 22-58 | 24-50 | 10-24 | 12-28 |
| Acidity | 0 | 0 | 0 | 0 | 0 | 0 | 0-6 | 0 |
| Iron | 0.5-1.9 | 0.7-1.1 | 0.5-1.5 | 0.2-1.0 | 0.4-1.1 | 0.4-0.9 | 0.4-0.9 | 0.2-3.0 |
| Manganese | 0-3.5 | 0-0.8 | 0-2.5 | 0-2.2 | 0-1.4 | 0-0.9 | 0-1.5 | 0-1.2 |

this method does not permit one to distinguish between the iron being produced in the mine waters in situ (from the decomposition of pyrite) and various other forms of iron introduced locally at the sample point by mechanical means (agitation, scuffing, air-water interface accumulation, etc.).

2. once an effective abatement structure is functional, the waters controlled or influenced by it normally undergo an increase in pH, and bicarbonate content. They are also excluded from contact with air, which helps to retain all soluble iron in the ferrous state. Under these conditions, the situation is ideal for the formation of ferrous bicarbonate, which has a solubility ranging from 25 to 710 ppm depending upon the bicarbonate iron concentration and the partial pressure of carbon dioxide in the mine atmosphere. (Solubility product of ferrous carbonate s.p. = 4 x 10-3). Where iron concentrations were very low before abatement was instituted, it would be logical to expect that ferrous ion concentrations would increase. The chemical mechanisms responsible for the presence of iron, however, are entirely different than those involved in the decomposition of pyrite to produce both acid and iron sulfate.

3. with waters upgraded to the pH range of 6 to 8 and excluded from contact with air, normal ferrous ion can attain very high solubility levels; 200 to 300 ppm being very common values experienced in the neutralization of ferrous sulfate solutions at pH 6.

In summary, it is perfectly logical to expect that the iron content of "abated" waters will increase slightly, but this does not indicate that acid mine water generating processes are still at work. In short, the foregoing discussion points up the fact that iron analyses per se as determined by the standard total iron method are quite meaningless for evaluating the effectiveness of an abatement method especially where the iron contents are less than 10 ppm. A more significant index would be to make ferrous iron determinations on filtered samples, which method would eliminate the interference of mechanically entrained iron compounds and give more positive indications of the iron producing mechanism involved.

## Effect of Land Inundation (Lake Filling) on Pollutant Generation

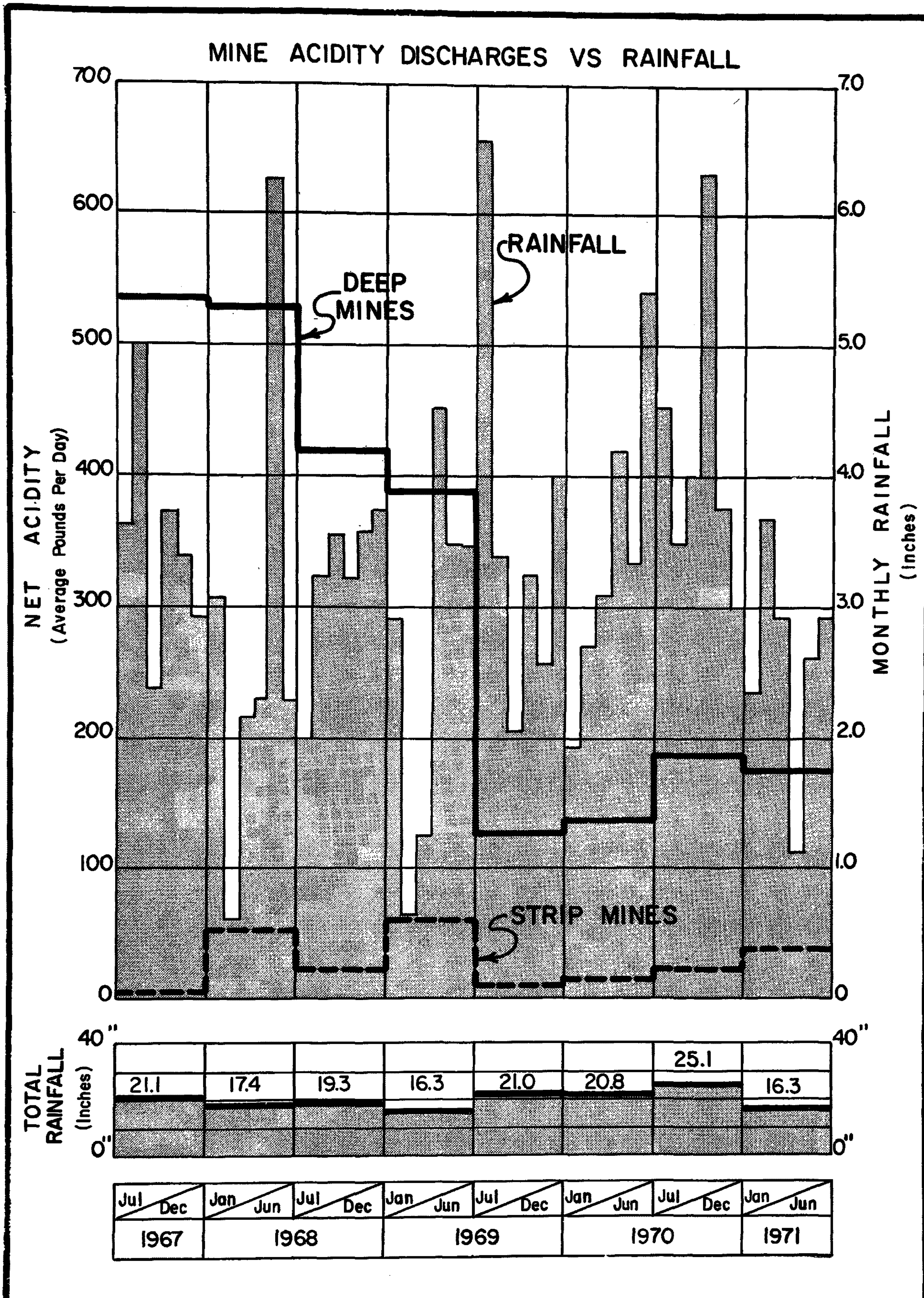
In several sections of this report, reference has been made to a potential increase in pollutant generation as the result of ultimate inundation. The inundation referred to was that of the land being covered by the impounded waters to form Lake Arthur with an average depth of 10 to 15 feet. When this hydraulic head is finally developed, the water table surrounding the lake rises an equivalent amount, inducing a higher ground water flow rate in the abandoned mines. In the case of the sealed mines, the open sections in front of the barriers are still producing an amount of mine "make" water proportional to the mined area remaining unsealed.

This is related to the apparent trend of an increase in acid production of the abated mine water sources during 1970 and 1971. The increase in ground water flow (due to water table rise) plus an increase in rainfall during 1970 and 1971 would both contribute to increased flow in the unsealed portions of the mined areas, thus increasing the total acid loading. These two meterological effects should also increase the flow and alkalinity loading of the alkaline streams in the area, so that the two effects should easily counteract each other, leaving the lake unimpaired.

## Treatment Trends and Stability

Sometimes effective responses to abatement treatment can be observed from a study of the data obtained during the relatively short period of operation. These can be subdivided according to attendant causative factors:

1. Rainfall Effect: Figure 12 illustrates the interrelationship of monthly rainfall and average total mine discharges of the two major classes. The greatly diminished discharge acidities for the deep mines follow the rainfall intensity pattern very closely as would normally be expected, since the mine "make" water in the unsealed sections should be proportional to total rainfall. However, the total amounts of acid being generated remain at a low level (less than 200 ppd) even during periods of excessive rainfall (July to Dec. 1970). The reclaimed strip mine areas do not show any direct correlation to rainfall intensity, primarily because the sampling of these areas was not timed to correspond to periods of rainfall. The obvious (but unquantified) effect of abatement treatment was the diversion of large volumes of surface run-off from these sites, thus greatly reducing the magnitude of acid slugs normally produced. The graph does show very clearly,



MINE ACIDITY DISCHARGES VS RAINFALL
NET ACIDITY (Average Pounds Per Day)
MONTHLY RAINFALL (Inches)
700
600
500
400
300
200
100
0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
RAINFALL
DEEP MINES
STRIP MINES
TOTAL RAINFALL (Inches)
40"
0"
21.1
17.4
19.3
16.3
21.0
20.8
25.1
16.3
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
Jul Dec
Jan Jun
1967
1968
1969
1970
1971


FIGURE 12

however, that after abatement treatment, acid generation in these areas remains very small and undergoes very little change under varying conditions of atmospheric precipitation. This demonstrates the establishment of a significant degree of pollutant generation control.

2. Rising Water Table Effect: As mentioned previously, the filling of Lake Arthur to a maximum depth of 15 feet would be accompanied by a corresponding rise in the ground water table level. This would be sufficient in several places to increase the average ground water flow thru untreated portions of unsealed mines and thru the lower levels of restored strip mines. The end result would be a slight increase in acid generation rate from both of these sources. The data in Figure 12 shows evidence of this type of trend. The annual increases shown are not very great and would be expected to peak very close to the levels shown for the period January-June 1971.

3. Natural Alaklinity Generation and Storage: Of paramount importance to the overall abatement concept for the area is the ability of the regional streams to generate compensating alkalinity. This capacity and reserve storage have been estimated in the following table:

TABLE 7

ALKALINE RESERVES IN LAKE ARTHUR SYSTEM

ALKALINITY RESERVE IN LAKE

(3,225 acres - 10 ft. average depth - 50 ppm average alkalinity)

32,225 AF x 0.326 MG/AF x 50 x 8.34 = 4,380,000 lbs. alkalinity
2,190 tons alkalinity

NATURAL ALKALINITY GENERATION RATES

Estimated from flow rates and analyses of Muddy Creek at Portersville Station, 0.5 miles downstream from Lake Arthur dam:

| | | |
|---|---|---|
| Flow Rates: | Average: | 35 cfs |
| | Minimum: | 0.5 cfs |
| Alkalinity: | 50 ppm (average) | |

TABLE 7 (CONTINUED)

AVERAGE ALKALINITY GENERATION RATE

35 cfs x .65 MGD/cfs x 50 x 8.34 = 9,500 lbs. alkalinity per day

MINIMUM ALKALINITY GENERATION RATE

0.5 cfs x .65 MGD/cfs x 50 x 8.34 = 136 lbs. alkalinity per day

NOTE: See Lake Arthur water analyses in Table 6.

The preceding calculations indicate that there is a tremendous alkalinity reserve in Lake Arthur (about 2,200 tons) and that the net average alkalinity generation rate of the Lake Arthur stream system is about 5 tons per day. This large compensating alkalinity supply is in great excess of any known future acid source and provides a high degree of stability insofar as water quality in the lake is concerned.

In summary, there are indications that a slight increase in acid generation (above the maximum abatement level attained in July-Dec. 1969) has occurred. This, however, is to be expected for the reasons cited above and should peak out at a level of about 200 ppd. The increase is very small and is essentially insignificant in view of the large alkalinity reserves available in the lake and its alkaline feed streams.

Cost Effectiveness of Abatement Methods

Comparison in terms of acid reduction versus costs indicates the deep mine hydraulic sealing work to be 6.5 times more effective than strip mine reclamation in the watershed area. Total costs for the deep mine hydraulic sealing were $1,266,213 and for strip mine reclamation $672,208. The average pounds per day of acid removed for the deep mine sealing were 341 pounds and for strip mine reclamation 28 pounds. The following is a tabulation of the cost per pound of acid removed per day.

Deep Mine Sealing: $\frac{\$\ 1,266,213}{341\ \#/day} = \$\ 3,713$

Strip Mine Reclamation: $\frac{\$\ 672,208}{28\ \#/day} = \$24,007$

$\frac{\text{Strip Mine Reclamation Cost/Pound/Day}}{\text{Deep Mine Sealing Cost/Pound/Day}} = \frac{\$\ 24,007}{3,713} = 6.5$

In making a comparison of effectiveness of the abatement projects, several factors have been considered. The benefits of the deep mine hydraulic sealing is limited primarily to acid reduction. In strip mine reclamation, other benefits such as land use and esthetics plus erosion and turbidity control have been regarded as important for the recreational usage of the park. The covering, recontouring and draining of the strip mine areas has also eliminated their greatest environmental impact effect, the generation of strong acid slugs during periods of heavy rainfall.

# SECTION VIII

## ACKNOWLEDGMENTS

The study described in this report was performed by the Mining Department of Gwin, Dobson and Foreman, Inc. for the Pennsylvania Department of Environmental Resources and Environmental Protection Agency. Dr. David R. Maneval and Mr. John J. Buscavage were the project directors for the contract. The report was authored by Messrs. John W. Foreman and D.C. McLean with assistance from the technical staff of Gwin, Dobson and Foreman, Inc.

The cooperation of the personnel from the Pennsylvania Department of Environmental Resources (formerly Department of Mines and Mineral Industries and Department of Forests and Waters) and from the contractors and their employees who performed the construction contracts in the abatement projects is gratefully acknowledged.

The support of the project by the Environmental Protection Agency and the guidance and assistance by Messrs. Ronald D. Hill, Donald J. O'Bryan, Eugene Harris and Ernst P. Hall were greatly appreciated.

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# SECTION X

# GLOSSARY

Air-Trap Seal - Deep mine seal to exclude air from entering the mine but permitting normal flow of water at the discharge.

Coal Outcrop - Coal which appears at or near the surface, the intersection of a coal seam with the surface.

Deep Mine Sealing - Closure of mine entries, drifts, slopes, shafts, subsidence holes, fractures and other openings into underground mines with clay, earth, rock, timber, concrete blocks, brick steel, concrete, fly ash, grout and other suitable material.

Diversion Ditch - An open channel excavated in a location, usually above the highwall, to prevent or alleviate surface drainage from entering the affected areas of a strip mine.

Dry Seal - Deep mine seal to prevent air and water from entering the mine.

Grout Curtain - An area into which grout has been injected to form a barrier around or along a deep mine area through which ground water cannot seep or flow.

Grouting - The process of injecting grout, consisting of neat cement or a mixture of neat cement, fly ash and/or admistures, usually into a borehole to seal crevices in rock formations to prevent water seepage.

Observation Hole - A borehole drilled from the surface into a deep mine entry at a location back of the mine seals. This drill hole is used to obtain mine water samples and record the height of inundation in the mine.

Slope Drain Flume - A semi-permanent open conduit installed across the backfill to intercept surface drainage from the diversion ditch above the highwall.

Wet or Hydraulic Seal - Deep mine seal to create a hydraulic head to flood the mine. Air is excluded by inundation.

# SECTION XI

# APPENDICES

# APPENDIX A

## TABULATION OF AVERAGE POUNDS PER DAY

| | 1967 | | 1968 | | | |
|---|---|---|---|---|---|---|
| | July - Dec. | | Jan. - June | | July - Dec. | |
| | ALK. | ACD. | ALK. | ACD. | ALK. | ACD. |
| **DEEP MINE AREAS** | | | | | | |
| WIMER | 0 | 22 | 0 | 29 | 0 | 18 |
| ALBEN | 0 | 30 | 0 | 34 | 0 | 41 |
| SHIELDS | (A) | (A) | (A) | (A) | (A) | (A) |
| FOX | 0 | 35 | 0 | 20 | 0 | 17 |
| WORTH | 0 | 0 | 0 | 0 | 0 | 0 |
| SALZANO ROSS | 0 | 144 | 0 | 171 | 0 | 148 |
| SOUTH NEALEY | 0 | 10 | (A) | 29 | (A) | (A) |
| NEALEY | 0 | 5 | (A) | 1 | 0 | 4 |
| GOUBEAUD | 0 | 1 | 0 | 1 | 0 | 3 |
| NORTH GOUBEAUD | (A) | (A) | (A) | (A) | (A) | (A) |
| WEST EMERY | 0 | 5 | 1 | (A) | (A) | 3 |
| EMERY | 1 | 17 | 1 | 2 | (A) | 2 |
| FREMONT | 1 | 0 | (A) | (A) | (A) | (A) |
| ISLE | (A) | 1 | 1 | 1 | (A) | 1 |
| MARTZOLF | (A) | 2 | (A) | 1 | (A) | 2 |
| LINDEY | 0 | 24 | (A) | 25 | 0 | 18 |
| LINCOLN | 0 | 141 | (A) | 111 | 0 | 69 |
| KILDOO | 0 | 100 | 0 | 101 | 0 | 94 |
| HILLIARD | (A) | 1 | (A) | 6 | 1 | 1 |
| | 2 | 538 | 3 | 532 | 2 | 420 |
| **STRIP MINE AREAS** | | | | | | |
| NORTHWEST | (A) | (A) | 38 | (A) | 6 | (A) |
| SOUTHWEST | (A) | (A) | 4 | 33 | 1 | 8 |
| EAST | 1 | 0 | 24 | 70 | 7 | 18 |
| EAST (OUTSIDE) | 0 | 3 | 0 | 17 | 0 | 8 |
| | 1 | 3 | 66 | 120 | 15 | 34 |
| TOTALS | 3 | 541 | 69 | 652 | 17 | 454 |

(A) - Average less than 1 pound per day

OF ALKALINITY AND ACIDITY

| 1969 | | | | 1970 | | | | 1971 | |
|---|---|---|---|---|---|---|---|---|---|
| Jan. - June | | July - Dec. | | Jan. - June | | July - Dec. | | Jan. - June | |
| ALK. | ACD. | ALK. | ACD. | ALK. | ACD. | ALK. | ACD. | ALK. | ACD. |
| 0 | 17 | 0 | 12 | 0 | 19 | 0 | 40 | 0 | 38 |
| 0 | 30 | 0 | 35 | 0 | 27 | 0 | 15 | 0 | 0 |
| (A) | (A) | (A) | (A) | (A) | (A) | (A) | (A) | 0 | 0 |
| (A) | 12 | 0 | 4 | 0 | 9 | (A) | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 192 | (A) | 0 | (A) | (A) | (A) | 2 | (A) | 9 |
| 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (A) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | (A) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (A) | A | (A) | (A) | 0 | 0 | 0 | 0 | 0 | 0 |
| (A) | 1 | (A) | 1 | 1 | (A) | (A) | 4 | 1 | 1 |
| 1 | 2 | 1 | 6 | 1 | 6 | (A) | 9 | 0 | 7 |
| (A) | 1 | (A) | (A) | 1 | (A) | 1 | (A) | (A) | 1 |
| 1 | 1 | 2 | 0 | (A) | 0 | 0 | 0 | 0 | 0 |
| (A) | 1 | (A) | 1 | (A) | (A) | 0 | 0 | 0 | 0 |
| (A) | 11 | 0 | 12 | 1 | 7 | (A) | 5 | 1 | 13 |
| 0 | 56 | 0 | 27 | 0 | 33 | 0 | 83 | 0 | 82 |
| 0 | 62 | 0 | 29 | 0 | 32 | 2 | 26 | 0 | 25 |
| 1 | 3 | (A) | 1 | (A) | 4 | (A) | 4 | 0 | 4 |
| | | | | | | | | | |
| 4 | 392 | 5 | 128 | 4 | 138 | 4 | 191 | 3 | 180 |
| | | | | | | | | | |
| 10 | (A) | 9 | (A) | 6 | 1 | 2 | 2 | 2 | 1 |
| 2 | 26 | 5 | 12 | 1 | 1 | 4 | 4 | (A) | (A) |
| 4 | 30 | 15 | 13 | 6 | 27 | 7 | 20 | 8 | 32 |
| (A) | 22 | 0 | 6 | (A) | 3 | (A) | 11 | 1 | 16 |
| | | | | | | | | | |
| 17 | 78 | 29 | 31 | 14 | 32 | 14 | 38 | 11 | 49 |
| | | | | | | | | | |
| 21 | 470 | 34 | 159 | 18 | 170 | 18 | 229 | 14 | 229 |

APPENDIX B

MORAINE STATE PARK DEEP MINE SEALS
OBSERVATION HOLE WATER DATA

| Year Quarter | Water Height | milligrams per liter | | | | |
|---|---|---|---|---|---|---|
| | | pH | Alk. | Acd. | Fe | Mn |
| **MO-1 WIMER** | | | | | | |
| 1971 - 4 | 2.0 | 3.0 | 0 | 298 | 157 | 3 |
| **MO-11 SHIELDS** | | | | | | |
| 1970 - 2 | 3.6 | | | | | |
| 1970 - 3 | 3.5 | 5.1 | 10 | 116 | 27.7 | 10.7 |
| 1970 - 4 | 5.7 | 4.6 | 4 | 208 | 29.4 | 12.6 |
| 1971 - 1 | 5.5 | 3.6 | 0 | 218 | 164 | 11.0 |
| 1971 - 2 | 2.7 | 3.6 | 0 | 172 | 143 | 14.0 |
| 1971 - 4 | 4.0 | 3.9 | 0 | 272 | 95 | 13.0 |
| **MO-13 SHIELDS** | | | | | | |
| 1970 - 2 | 9.3 | | | | | |
| 1970 - 3 | 0 | | | | | |
| 1970 - 4 | 0 | | | | | |
| 1971 - 1 | 0 | | | | | |
| 1971 - 2 | 0 | | | | | |
| 1971 - 4 | 7.7 | 4.0 | 0 | 196 | 260 | 1.7 |
| **MO-18 FOX** | | | | | | |
| 1970 - 2 | 0 | | | | | |
| 1970 - 3 | 0 | | | | | |
| 1970 - 4 | 0 | | | | | |
| 1971 - 1 | 0 | | | | | |
| 1971 - 2 | 0.9 | | | | | |
| 1971 - 4 | 0 | | | | | |
| **MO-20 FOX** | | | | | | |
| 1970 - 2 | 7.9 | 6.8 | 22 | 0 | 20.1 | 1.0 |
| 1970 - 3 | 9.6 | 6.6 | 50 | 0 | 26.5 | 2.0 |
| 1970 - 4 | 10.7 | 6.5 | 26 | 0 | 21.3 | 1.6 |
| 1971 - 1 | 12.5 | 6.8 | 16 | 0 | 77 | 0.5 |
| 1971 - 2 | 12.5 | 6.6 | 18 | 0 | 348 | 1.5 |
| 1971 - 4 | 9.9 | 6.7 | 12 | 0 | 320 | 0 |

APPENDIX B (CONTINUED)

| Year Quarter | Water Height | pH | milligrams per liter Alk. | Acd. | Fe | Mn |
|---|---|---|---|---|---|---|
| **MO-22 WORTH** | | | | | | |
| 1970 - 2 | 22.4 | 8.4 | 102 | 0 | 1.1 | 0 |
| 1970 - 3 } | X | | | | | |
| 1971 - 4 } | X | | | | | |
| **MO-23 SALZANO-ROSS** | | | | | | |
| 1970 - 2 | 8.4 | 6.8 | 48 | 0 | 23.7 | 1.2 |
| 1970 - 3 | 9.2 | 6.6 | 54 | 0 | 21.6 | 0.5 |
| 1970 - 4 | 15.0 | 9.6 | 22 | 0 | 4.3 | 0 |
| 1971 - 1 | 14.6 | 7.0 | 16 | 0 | 135* | 1.0 |
| 1971 - 2 | 10.6 | 7.3 | 26 | 0 | 388* | 1.7 |
| 1971 - 4 | 9.3 | 6.8 | 32 | 0 | 402* | 0.4 |
| **MO-29 SOUTH NEALEY** | | | | | | |
| 1970 - 2 | 10.2 | 4.2 | 0 | 130 | 44.0 | 3.5 |
| 1970 - 3 | 8.8 | 3.7 | 0 | 144 | 23.8 | 3.5 |
| 1970 - 4 | 12.6 | 4.8 | 6 | 68 | 35.2 | 1.2 |
| 1971 - 1 | 12.4 | 3.8 | 0 | 128 | 175 | 2.0 |
| 1971 - 2 | 9.8 | 2.8 | 0 | 172 | 163 | 2.6 |
| 1971 - 4 | 7.4 | 3.4 | 0 | 124 | 158 | 1.5 |
| **MO-34 NEALEY** | | | | | | |
| 1970 - 2 | 6.3 | 3.8 | 0 | 38 | 22.4 | 1.0 |
| 1970 - 3 | 6.1 | 5.6 | 6 | 12 | 32.7 | 1.2 |
| 1970 - 4 | 7.2 | 7.0 | 18 | 0 | 17.4 | 0 |
| 1971 - 1 | 8.4 | 3.6 | 0 | 30 | 83 | 0.7 |
| 1971 - 2 | 7.0 | 3.2 | 0 | 78 | 165 | 2.2 |
| 1971 - 4 | 4.7 | 3.0 | 0 | 172 | 49 | 1.8 |
| **MO-36 NEALEY** | | | | | | |
| 1970 - 2 | 4.4 | 3.7 | 0 | 28 | 1.7 | 2.0 |
| 1970 - 3 | 3.9 | 3.0 | 0 | 116 | 27.9 | 7.0 |
| 1970 - 4 | 5.2 | 5.8 | 10 | 0 | 4.4 | 0.2 |
| 1971 - 1 | 6.4 | 5.2 | 8 | 8 | 32 | 1.2 |
| 1971 - 2 | 5.1 | 5.2 | 0 | 72 | 79 | 3.1 |
| 1971 - 4 | 2.9 | 2.8 | 0 | 246 | 184 | 4.0 |

X = Unable to reach water level due to caved or blocked hole.

* = These high total iron are probably due to iron scale contamination from steel casing of the sample test hole.

## APPENDIX B (CONTINUED)

| Year Quarter | Water Height | milligrams per liter | | | | |
|---|---|---|---|---|---|---|
| | | pH | Alk. | Acd. | Fe | Mn |
| **MO-38 GOUBEAUD** | | | | | | |
| 1970 - 2 | 0.5 | 4.7 | 6 | 8 | 5.9 | 0.8 |
| 1970 - 3 | 0 | | | | | |
| 1970 - 4 | 2.3 | 3.7 | 0 | 27 | 14.0 | 1.2 |
| 1971 - 1 | 2.5 | 6.7 | 22 | 0 | 26.0 | 0 |
| 1971 - 2 | 0.7 | 5.8 | 18 | 0 | 36.0 | 0 |
| 1971 - 4 | 0 | | | | | |
| **MO-44 NORTH GOUBEAUD** | | | | | | |
| 1970 - 2 | 0.4 | | | | | |
| 1970 - 3 | 0 | | | | | |
| 1971 - 4 | 0 | | | | | |
| **MO-54 WEST EMERY** | | | | | | |
| 1970 - 2 | 3.4 | 5.7 | 18 | 0 | 5.1 | 0 |
| 1970 - 3 | 4.7 | 6.0 | 24 | 0 | 0.2 | 0.5 |
| 1970 - 4 | 6.8 | 6.6 | 12 | 0 | 1.8 | 0 |
| 1971 - 1 | 6.3 | 6.7 | 14 | 0 | 0.8 | 0 |
| 1971 - 2 | 4.3 | 6.8 | 26 | 0 | 8.3 | 0 |
| 1971 - 4 | 4.8 | 6.7 | 10 | 0 | 2.4 | 0 |
| **MO-58 NORTH EMERY** | | | | | | |
| 1970 - 2 | 37.3 | 6.7 | 28 | 0 | 21.6 | 1.2 |
| 1970 - 3 | 38.3 | 7.3 | 42 | 0 | 0.6 | 0 |
| 1970 - 4 | 38.4 | 7.9 | 36 | 0 | 7.2 | 0 |
| 1971 - 1 | 38.1 | 7.0 | 34 | 0 | 126 | 0.5 |
| 1971 - 2 | 37.3 | 6.9 | 50 | 0 | | 1.4 |
| 1971 - 4 | 37.4 | 7.3 | 22 | 0 | 97 | 0 |
| **MO-60 FREMONT** | | | | | | |
| 1970 - 2 | 0.5 | 6.1 | 24 | 0 | 0.6 | 0 |
| 1970 - 3 | 0 | | | | | |
| 1970 - 4 | 0 | | | | | |
| 1971 - 1 | 0 | | | | | |
| 1971 - 2 | 2.7 | 6.4 | 24 | 0 | 203 | 0.5 |
| 1971 - 4 | 0.6 | 6.5 | 24 | 0 | 182 | 0 |

APPENDIX B (CONTINUED)

| Year Quarter | Water Height | milligrams per liter | | | | |
|---|---|---|---|---|---|---|
| | | pH | Alk. | Acd. | Fe | Mn |
| **MO-64 ISLE** | | | | | | |
| 1970 - 2 | 1.9 | 3.3 | 0 | 48 | 15.8 | 1.6 |
| 1970 - 3 | 2.2 | 4.1 | 0 | 14 | 13.7 | 1.6 |
| 1970 - 4 | 4.5 | 5.7 | 12 | 0 | 0.9 | 0 |
| 1971 - 1 | 4.9 | 7.7 | 40 | 0 | 205 | 1.0 |
| 1971 - 2 | 2.0 | 4.5 | 4 | 6 | 39 | 1.1 |
| 1971 - 4 | 1.6 | 4.1 | 0 | 64 | 179 | 0.8 |
| **MO-65 ISLE** | | | | | | |
| 1970 - 2 | 13.8 | 6.1 | 18 | 8 | 4.4 | 3.8 |
| 1970 - 3 | 14.1 | 5.6 | 22 | 0 | 0.9 | 1.6 |
| 1970 - 4 | 16.5 | 6.6 | 44 | 0 | 39.4 | 3.5 |
| 1971 - 1 | 17.0 | 7.8 | 36 | 0 | 36.0 | 1.2 |
| 1971 - 2 | 13.8 | | | | | |
| 1971 - 4 | X | | | | | |
| **MO-66 ISLE** | | | | | | |
| 1970 - 2 | 14.7 | 7.6 | 20 | 0 | 14.5 | 0 |
| 1970 - 3 | 15.0 | 7.2 | 24 | 0 | 0.8 | 0 |
| 1970 - 4 | 17.3 | 9.6 | 20 | 0 | 1.7 | 0 |
| 1971 - 1 | 17.8 | 7.7 | 36 | 0 | 55 | 1.7 |
| 1971 - 2 | X | | | | | |
| 1971 - 4 | X | | | | | |
| **MO-69 MARTZOLF** | | | | | | |
| 1970 - 2 | 8.1 | 6.8 | 20 | 0 | 1.7 | 11.2 |
| 1970 - 3 | X | | | | | |
| 1970 - 4 | 15.8 | 7.0 | 20 | 0 | 20.6 | 1.6 |
| 1971 - 1 | 22.4 | 7.2 | 26 | 0 | 49 | 0 |
| 1971 - 2 | 9.7 | 6.8 | 48 | 0 | ---- | 0 |
| 1971 - 4 | 6.7 | 7.1 | 26 | 0 | 16 | 0 |
| **MO-75 LINDEY** | | | | | | |
| 1970 - 3 | 12.6 | 5.4 | 12 | 16 | 18.9 | 3.3 |
| 1970 - 4 | 20.0 | 6.4 | 12 | 3 | 2.1 | 0.2 |
| 1971 - 1 | 23.0 | 8.0 | 22 | 0 | 46 | 2.0 |
| 1971 - 2 | 17.9 | 6.8 | 24 | 0 | 179 | 3.3 |
| 1971 - 4 | 16.5 | 5.7 | 4 | 4 | 41 | 0 |

X = Unable to reach water level due to caved or blocked hole.

APPENDIX B (CONTINUED)

| Year Quarter | Water Height | milligrams per liter pH | Alk. | Acd. | Fe | Mn |
|---|---|---|---|---|---|---|
| **MO-76 LINCOLN** | | | | | | |
| 1970 - 2 | 15.0 | 7.1 | 26 | 0 | 4.6 | 1.0 |
| 1970 - 3 | 14.2 | 3.7 | 0 | 82 | 22.4 | 5.8 |
| 1970 - 4 | 17.8 | 6.4 | 10 | 5 | 28.2 | 2.6 |
| 1971 - 1 | 18.5 | 6.6 | 10 | 0 | 191 | 1.1 |
| 1971 - 2 | 15.3 | 7.1 | 18 | 0 | 164 | 0 |
| 1971 - 4 | 15.3 | 3.5 | 0 | 22 | 87 | 0.2 |
| **MO-79 KILDOO** | | | | | | |
| 1970 - 2 | 3.9 | 3.6 | 0 | 136 | 29.3 | 7.9 |
| 1970 - 3 | 0 | | | | | |
| 1970 - 4 | 5.5 | 6.1 | 28 | 0 | 30.6 | 6.5 |
| 1971 - 1 | 8.0 | 4.1 | 0 | 124 | 76 | 11.5 |
| 1971 - 2 | 4.8 | 6.9 | 134 | 0 | ---- | 5.1 |
| 1971 - 4 | 4.2 | 7.9 | 62 | 0 | 72 | 0 |
| **MO-84 HILLIARD** | | | | | | |
| 1970 - 3 | 7.9 | 6.9 | 114 | 0 | 2.4 | 1.6 |
| 1970 - 4 | 13.5 | 6.9 | 84 | 0 | 18.5 | 2.1 |
| 1971 - 1 | 15.4 | 6.9 | 28 | 0 | 37 | 0 |
| 1971 - 2 | 9.3 | 6.9 | 28 | 0 | 90 | 0.4 |
| 1971 - 4 | 7.9 | 7.8 | 34 | 0 | 18 | 0 |
| **MO-87 LINDEY** | | | | | | |
| 1970 - 3 | 11.5 | 9.9 | 32 | 0 | 15.3 | 0 |
| 1970 - 4 | 18.8 | 10.9 | 34 | 0 | 15.4 | 1.6 |
| 1971 - 1 | X | | | | | |
| 1971 - 2 | X | | | | | |
| 1971 - 4 | X | | | | | |
| **MO-91 NORTH CORRIDOR** | | | | | | |
| 1970 - 3 | 3.8 | 5.9 | 28 | 0 | 19.8 | 2.1 |
| 1970 - 4 | 11.2 | 6.2 | 6 | 30 | 16.9 | 4.7 |
| 1971 - 1 | 11.2 | 5.9 | 24 | 54 | 133 | 5.4 |
| 1971 - 2 | 9.7 | 7.9 | 26 | 0 | 104 | 0 |
| 1971 - 4 | 4.7 | 7.6 | 30 | 0 | 147 | 0 |

X = Unable to reach water level due to caved or blocked hole.

## APPENDIX C

### RAINFALL DATA - MORAINE STATE PARK

Data compiled from Annual Climatological Data for Pennsylvania, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service in cooperation with Commonwealth of Pennsylvania, Department of Forests and Waters.

| 1967 | BUTLER PRECIPITATION Inches | SLIPPERY ROCK PRECIPITATION Inches |
|---|---|---|
| January | 0.80 | 0.89 |
| February | 2.76 | 3.23 |
| March | 4.70 | 4.27 |
| April | 3.48 | 2.82 |
| May | 5.47 | 3.45 |
| June | 1.42 | 1.22 |
| July | 3.51 | 3.81 |
| August | 3.51 | 6.47 |
| September | 2.34 | 2.25 |
| October | 3.53 | 4.02 |
| November | 3.41 | 3.32 |
| December | 3.30 | 2.75 |
| TOTAL | 38.23 | 38.50 |

| 1968 | BUTLER PRECIPITATION Inches | SLIPPERY ROCK PRECIPITATION Inches |
|---|---|---|
| January | 2.78 | 4.44 |
| February | .69 | .65 |
| March | 3.42 | 1.06 |
| April | 2.72 | 1.87 |
| May | 6.86 | 5.73 |
| June | 1.88 | 2.64 |
| July | 1.77 | 2.22 |
| August | 3.26 | 3.29 |
| September | 2.51 | 4.55 |
| October | 3.20 | 3.22 |
| November | 3.14 | 3.96 |
| December | 3.35 | 4.03 |
| TOTAL | 35.58 | 37.66 |

APPENDIX C (CONTINUED)

| 1969 | BUTLER PRECIPITATION Inches | SLIPPERY ROCK PRECIPITATION Inches |
|---|---|---|
| January | 3.01 | 2.78 |
| February | .66 | .59 |
| March | 1.31 | 1.16 |
| April | 4.88 | 3.94 |
| May | 3.62 | 3.50 |
| June | 4.03 | 3.06 |
| July | 7.54 | 4.69 |
| August | 3.46 | 3.20 |
| September | .90 | 2.31 |
| October | 3.02 | 3.50 |
| November | 2.52 | 2.81 |
| December | 4.09 | 3.91 |
| TOTAL | 39.04 | 35.45 |
| 1970 | | |
| January | 1.89 | 1.94 |
| February | 3.10 | 2.34 |
| March | 3.16 | 3.17 |
| April | 4.60 | 3.81 |
| May | 2.89 | 3.73 |
| June | 5.05 | 5.88 |
| July | 3.81 | 5.39 |
| August | 2.85 | 4.05 |
| September | 5.72 | 2.20 |
| October | 6.02 | 6.62 |
| November | 4.19 | 3.39 |
| December | 3.14 | 2.85 |
| TOTAL | 46.42 | 45.37 |

APPENDIX C (CONTINUED)

| 1971 | BUTLER PRECIPITATION Inches | SLIPPERY ROCK PRECIPITATION Inches |
|---|---|---|
| January | 2.46 | 2.18 |
| February | 3.15 | 4.32 |
| March | 2.68 | 3.16 |
| April | 1.00 | 1.18 |
| May | 2.72 | 2.69 |
| June | 3.15 | 3.86 |
| July | 3.95 | 4.56 |
| August | 3.51 | 2.45 |
| September | 4.81 | 3.23 |
| October | 1.36 | 1.12 |
| November | 2.85 | 2.48 |
| December | 4.69 | 5.41 |
| TOTAL | 36.33 | 36.64 |

| 1 Accession Number | 2 Subject Field & Group | |
|---|---|---|
| W | Ø 5F | **SELECTED WATER RESOURCES ABSTRACTS** **INPUT TRANSACTION FORM** |

**5 Organization**

Gwin, Dobson & Foreman, Inc.
Altoona, Pennsylvania 16601

**6 Title**

Evaluation of Pollution Abatement Procedures
Moraine State Park

**10 Author(s)**

John W. ~~Foreman~~ Foreman
Daniel C. McLean

**16 Project Designation**

EPA Grant 14010 DSC

**21 Note**

**22 Citation**

Environmental Protection Agency report
number, EPA-R2-73-140, January 1973.

**23 Descriptors (Starred First)**

Acid Mine Drainage*, Mine Sealing*, Surface Mines*
Bulk Head Seals, Cost-Effectiveness

**25 Identifiers (Starred First)**

Pennsylvania*, Moraine State Park*, Lake Arthur

**27 Abstract**

This project was an evaluation of the various mine drainage pollution abatement techniques completed during the construction phase of the Moraine State Park, Pennsylvania. The remedial methods employed included strip mine reclamation, underground mine sealing, grouting, surface sealing, refuse pile removal and oil and gas well plugging. Results of the underground mine hydraulic sealing and grouting work indicate an overall reduction in discharge flow rates from 146 to 57 gallons per minute, an overall reduction in net acidity from 501 to 160 pounds per day. The hydraulic sealing costs ranged from a low of $8,308 to a high of $58,437 per seal, for an average cost of $19,480 per seal.

Before and after data for the strip mine reclamation projects indicate a minor net decrease in the average discharge flow rates from 142 to 136 gallons per minute, an overall reduction in acidity from 50 to 22 pounds per day. The strip mine reclamation costs ranged from a low of $420 to a high of $2700 per acre, for an average of $1455 per acre.

| Abstractor | Institution |
|---|---|
| R. D. Hill | Environmental Protection Agency |

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