EPA-R2-73-151
MARCH 1973

Environmental Protection Technology Series

Feasibility Study Lake Hope Mine Drainage Demonstration Project

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

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Monitoring, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

EPA-R2-73-151
March 1973

FEASIBILITY STUDY
LAKE HOPE MINE DRAINAGE DEMONSTRATION PROJECT

Project 14010 HJQ

Project Officer

Eugene F. Harris
Environmental Protection Agency
National Environmental Research Center
Cincinnati, Ohio 45268

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

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price $1.25 domestic postpaid or $1.00 GPO Bookstore

EPA Review Notice

ABSTRACT

The purpose of the Lake Hope project is to demonstrate the reduction of acid mine drainage pollution by the removal of coal refuse, and the construction of bulkhead seals to flood underground mine workings and thus prevent the formation of acid. The Lake Hope site was chosen for the demonstration project because acidic drainage from abandoned coal mines in the watershed above Lake Hope has severely restricted water oriented activity in this prime recreational area. A total of 107 mine openings has been noted. The combined acid discharge from these openings is over 700,000 pounds per year. A multi-phase mine drainage abatement demonstration program is recommended with major elements including:

1. Removal and/or burial of coal refuse which was scattered throughout the area during active mining operations.

2. The sealing of a portion of Mine Complex 47 (Mine Openings 40 through 52 shown in Figure 2) with subsequent monitoring of the effectiveness of the mine seals.

3. Sealing of the balance of the mine openings in Mine Complex 47.

4. Sealing of Mine Opening 88 and adjacent interconnected openings if necessary to achieve the desired improvement in Lake Hope water quality.

Expansive concrete seals or alternative plain concrete plugs are recommended for the first phase mine sealing. Curtain grouting will be necessary to seal the face of the hill above and adjacent to the mine openings and at intermediate points of weakness of the geological structure.

Over a year of base line water quality information has already been accumulated to serve as a standard against which effectiveness of the demonstration project can be measured. At the present time, water in Lake Hope normally exhibits pH between 4.0 and 5.0 and the total acidity is frequently in the 20 to 30 mg/l range. Following completion of the Phase I and Phase II mine sealing programs, total acidity of the water in the lake is expected to be approximately one-half of present levels and pH should be in the 6.0 to 7.0 range.

In 1970, over 650,000 persons visited Lake Hope State Park. The improved water environment resulting from the mine drainage demonstration project will greatly improve the enjoyment of visitors to the area and will result in more extensive water-oriented recreational activities. Aquatic habitat will be greatly improved with resulting wild life management and fishing benefits. The general area aesthetics will also be improved with the removal of coal refuse and elimination of a significant portion of iron-bearing acid mine drainage from the area streams.

CONTENTS

FIGURES

TABLES

RECOMMENDATIONS

A multi-phase mine drainage demonstration project is recommended for the Lake Hope watershed in Vinton County, Ohio. To demonstrate effective procedures for reducing mine drainage pollution of Lake Hope, removal and/or covering of coal refuse which was scattered throughout the area during active mining operations is recommended. Mine sealing is also recommended, beginning with Mine Openings 40 through 52 in Mine Complex 47. Subsequent sealing will encompass all remaining openings in Mine Complex 47. Additional mine seals will be constructed in the Mine 88 Complex as warranted to demonstrate complete control of mine drainage and as available funds permit.

PART I - INTRODUCTION

Scope of Investigation

This report is a presentation of an evaluation of the feasibility of demonstrating refuse pile disposal and mine sealing in the Lake Hope area in Vinton County, Ohio. The specific scope of the investigations is as follows:

1. Review the history of mining, mine drainage problems, and mine drainage abatement measures in the study area.

2. Assess the jurisdictional framework through which a mine drainage abatement project may be carried out.

3. Inventory local physical features, hydrology, water quality, social and environmental factors, and other elements influencing the value of mine drainage demonstration projects in the study area.

4. Develop preliminary engineering features of a workable mine drainage abatement program in sufficient detail to permit evaluation of the feasibility of the proposed project.

5. Estimate the effectiveness of the project and delineate possible beneficial uses for the reconstructed area upon completion of the mine drainage abatement improvements.

6. Determine tangible and intangible benefits of the recommended program.

7. Develop an outline of scheduling and budgeting to assure adequate administrative control of the proposed project.

8. Recommend a continuing program for surveillance of mine drainage from the improved area. Delineate means for measuring the accomplishments of the demonstration program with respect to presently envisioned objectives.

Project Objectives

The study area, which is the subject of this mine drainage abatement feasibility investigation, is located in Vinton County, Ohio, in the watershed above Lake Hope. Acidic waters draining from the study area have restricted recreational activities at Lake Hope State Park and caused several fish kills in the lake. Fish reproduction in Lake Hope is severely inhibited and as a result, the lake attracts few fishermen.

Two major objectives of the mine drainage demonstration program analyzed herein are:

1. Demonstrate effective techniques of bulkhead sealing of underground mines to prevent the formation and discharge of acid mine drainage and to permit ultimate utilization of the study area in a manner which will create a measurable public benefit.

2. Demonstrate methods for reduction of mine drainage pollution from coal refuse piles through burial and/or removal.

Project Description

The Lake Hope site has been mined by both surface and drift mining techniques with the latter greatly predominating. The proposed mine drainage abatement project will demonstrate means for alleviating problems related to previous drift mining activities. Acid contribution from the strip mined area is inconsequential. The proposed project includes three parts as follows:

1. Base Line Water Quality - The initial effort which has already been undertaken by the Ohio Department of Natural Resources involves establishment of a monitoring system for surveillance of water quality in Sandy Run and tributaries, discharges from mine openings, and surface runoff. The data collected is presented in a report entitled "Base Line Water Quality," which is included in its entirety as Appendix A and summarized in "Part III - Inventory and Forecast." The complete water quality studies provide the standards against which the success of the entire program will be measured.

   Two new gaging and monitoring stations have been constructed and the existing USGS flow gaging station has been improved to permit monitoring of several parameters of water quality. Mine discharge records for a period of over one year are available and included in the base line report in Appendix A.

   Following construction and clean-up of all phases of the pollution abatement demonstration project, a minimum of two years of monitoring of the water quality will be performed to determine the effectiveness of the techniques.

2. Coal Refuse Disposal - The first phase of physical improvement in the demonstration project involves the removal and/or covering of refuse remaining from the period of active mining in the region. In addition to being unsightly, these areas of refuse are continuously leached by surface water runoff and are a source of acid contribution to the streams. This phase has already been completed by the Division of Forestry and Reclamation of the Ohio Department of Natural Resources and is discussed in detail in "Part IV - Preliminary Engineering Features." Many refuse piles have been removed and buried in suitably prepared sites outside the drainage area. Refuse accumulations in Honeycomb Hollow and several other locations

have been buried in place. Surface grading, liming, fertilization, and seeding have followed the removal or burial of refuse. General aesthetics are vastly improved as a result of this phase of the program; water quality data following completion of the refuse removal is not adequate at this time to fully define the long-term improvement to streams and Lake Hope.

3. Mine Sealing - There are currently over 100 mine openings in a small area in the upper reaches of the Lake Hope watershed. A multi-phase program will be undertaken to demonstrate the effectiveness of mine sealing in eliminating detrimental affects of mine drainage on water quality. A non-draining or bulkhead type of mine seal will be utilized and is detailed, along with several alternatives, in "Part IV - Preliminary Engineering Features." Through a continuous water quality monitoring program, the effects of the mine sealing program will be evaluated.

PART II - JURISDICTIONAL FRAMEWORK

Authority

The State of Ohio Department of Natural Resources, through the Director, pursuant to Sections 1501.01; 1501.011; 1501.02; and 1501.021 of the Ohio Revised Code may enter into cooperative or contractual arrangements with the United States or any agent or department thereof for the accomplishment of the purposes for which the department was created. Senate Bill No. 13 (1949) created the Department of Natural Resources ". . . to formulate and put into execution a long-term comprehensive plan and program for the development and wide use of the natural resources of the state to the end that health, happiness, and wholesome enjoyment of life of the people of Ohio may be further encouraged; that increased recreational opportunities and advantages be made available to the people of Ohio and visitors, that industry, agriculture, employment, investment and other economic interests may be assisted and encouraged. . . ." Legal authority is also granted to obtain land and water and mineral rights by purchase, negotiation of easements, condemnation, leases and other control techniques.

Water Quality Standards

Lake Hope is in the Raccoon Creek Watershed, which is in turn directly tributary to the Ohio River. No water quality standards have as yet been specifically set for this stream. The minimum conditions for all waters at all places and at all times are applicable, however. These conditions state that the water shall be:

1. Free of substances attributable to municipal, industrial or other discharges, or agricultural practices that will settle to form putrescent or otherwise objectional sludge deposits.

2. Free from floating debris, oil, skum and other floating materials attributable to municipal, industrial or other discharges, or agricultural practices in amounts sufficient to be unsightly or deleterious.

3. Free from materials attributable to municipal, industrial or other discharges, or agricultural practices producing color, odor or other conditions in such degree as to create a nuisance.

4. Free from substances attributable to municipal, industrial or other discharges, or agricultural practices in concentrations of combinations which are toxic or harmful to human, animal, plant or aquatic life.

Virtually the entire length of Racoon Creek is affected by acid mine drainage. Water quality standards adopted for the Hocking River Basin make special provision for those streams polluted by acid mine drainage. These provisions are generally applicable to Raccoon Creek and tributaries also. The Hocking River Standards state that the Water

Pollution Control Board and the Ohio Department of Health will encourage and assist other agencies such as the Ohio Department of Natural Resources and the U. S. Department of Interior in the development and implementation of programs for area-wide control of acid mine drainage from abandoned underground and pre-reclammation law strip coal mines.

Site and Mineral Right Acquisition

The State of Ohio has acquired virtually all property and mineral rights directly involved in drainage to Lake Hope. A few minor parcels will shortly be acquired so that no mining activities will be permitted within the project drainage area.

Funding Authority

Authority for the original funding of the Lake Hope project is contained in the appropriations H. B. No. 828 enacted by the 108th Ohio General Assembly.

Prevention of Future Pollution

When all anticipated land and mineral right acquisitions are completed, the State of Ohio will be able to exert full control over the watershed. This will assure that the project area will not be adversely affected by the influx of acid or other mine water pollution from nearby sources or from future mining operations.

A continuous program of monitoring water quality and maintenance of mine drainage control facilities will further safeguard the integrity of the water in the streams tributary to Lake Hope.

PART III - INVENTORY AND FORECAST

Physical Conditions

The Lake Hope project is located in Brown Township, Vinton County, Ohio, approximately 20 miles west of Athens, Ohio. The site is within the 22,569-acre Zaleski State Forest.

Figure 1 is a base map illustrating many of the significant physical features of the study area. This map has been prepared from U. S. Geological Survey 7 1/2 minute topographic maps and supplemented with information from other sources.

The boundary of the watershed tributary to Lake Hope is shown in Figure 1. The main stream draining into Lake Hope is Sandy Run, which is in turn fed by many tributaries reaching back up into small valleys. The outlet from Lake Hope is into Raccoon Creek, which is a major tributary of the Ohio River.

As illustrated by the contour lines in Figure 1, the entire watershed is quite rugged. The stream channels have formed deeply incised valleys into the terrain. The area is almost entirely forested and serves as a major open space recreational outlet for residents of Ohio and nearby states.

Lake Hope was constructed during 1938-1939 and filled with water during the spring of 1939. The total drainage area tributary to the lake is approximately 10 square miles. About 120 acres of water surface are provided. The lake is relatively shallow with the total storage volume at the time of construction estimated at approximately 1,500 acre-feet. This volume has been reduced somewhat by siltation.

Mining History - Coal is the only mineral resource that has been extensively exploited in the study area. Coal mining was initiated in the vicinity over 100 years ago. Activity was greatly accelerated during World War II but has rapidly declined in recent years. The State of Ohio has acquired virtually all of the land tributary to Lake Hope and is in the final negotiation stage for the remaining parcels. Few blocks of coal remain which could be economically mined and with the land in state ownership there will be no further mining in the watershed.

Mining has largely been accomplished by drifting horizontal tunnels back into the Middle Kittanning (No. 6) coal seam from the outcrop which is at or slightly above the valley floor. A total of 107 mine openings have been catalogued and locations are shown in Figure 2. Presented in Table 1 are the names of mine operations associated with the various mine openings. Consecutive identification numbers have been established purely for convenience and bear no relationship to the actual recorded number of the mine. The identification numbers as listed have been used throughout the balance of this report. The tabulation of names is not complete but represents an accumulation of

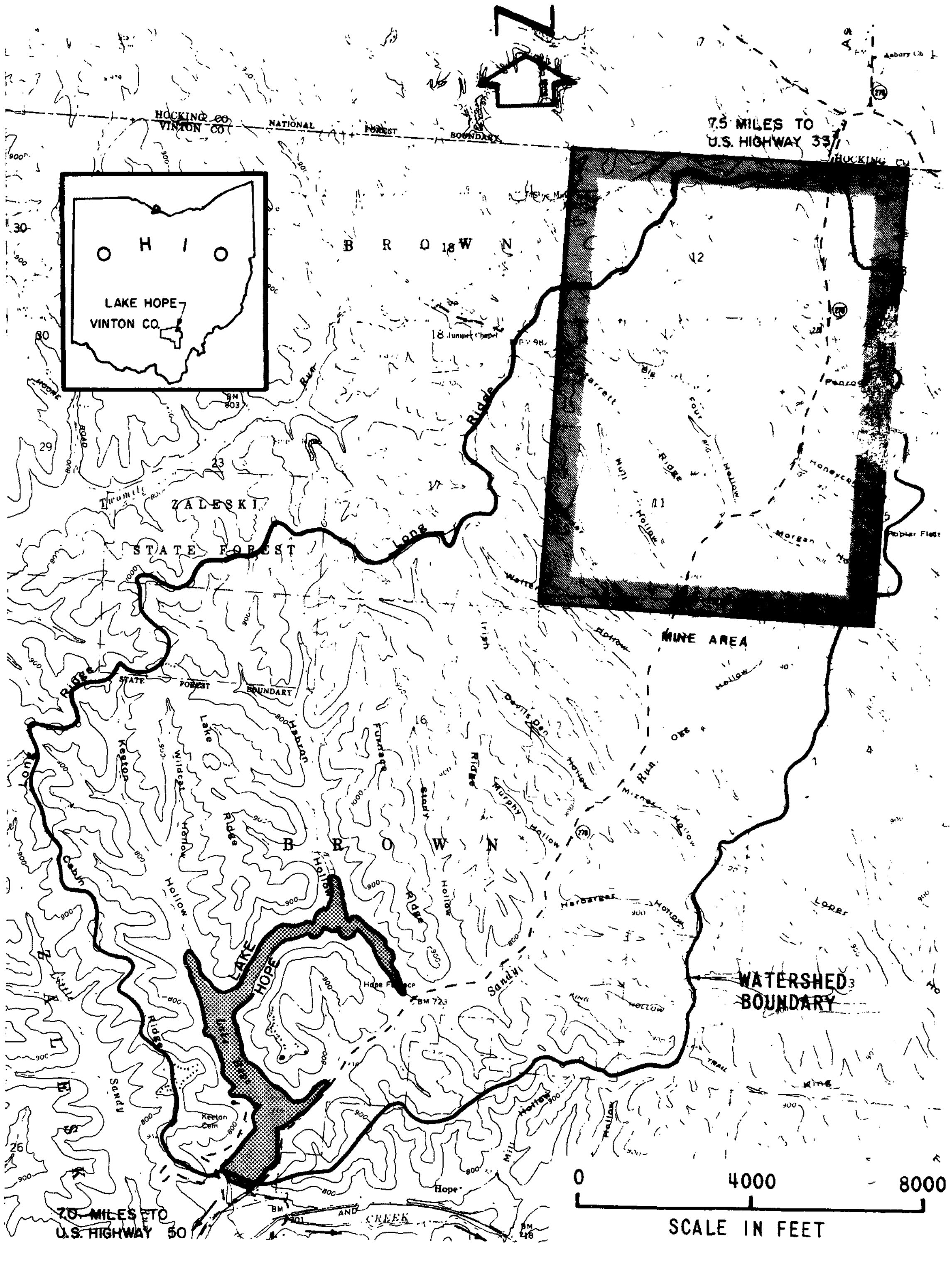


FIGURE 1 - LAKE HOPE DRAINAGE BASIN

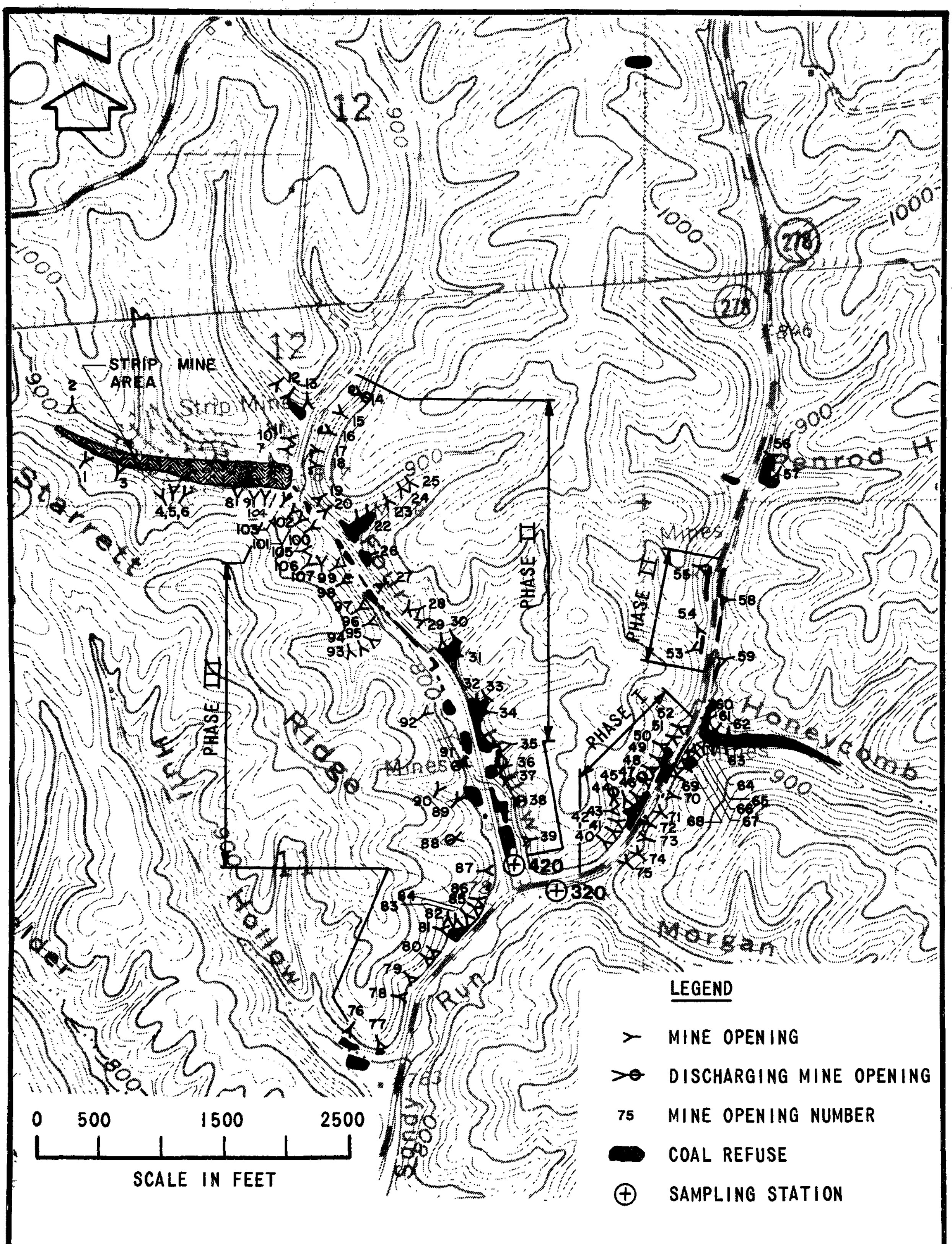


FIGURE 2 - MINE OPENINGS

TABLE 1

MINE OPENING IDENTIFICATION

Mine Opening	Name	Mine Opening	Name
1	George McDaniels	39	Largent
2	Ownership Not Available	40-47	Hope Hollow
3	Dewey McDaniels	48-50	Ownership Not Available
4-6	Jay McDaniels	51-57	John Fuller
7	Taylor	58-59	Ownership Not Available
8-9	Dude McDaniels	60-62	Ralph Fuller
10-11	Taylor	63	Ownership Not Available
12-13	Harkless	64	Jackson
14-17	Lowery	65-75	Ownership Not Available
18	Ownership Not Available	76-77	Hull
19-21	Loper	78	Ownership Not Available
22-23	Prater	79-90	Loper No. 3
24-25	Ownership Not Available	91-92	Powers
26	Loper No. 2	93-97	Largent No. 2
27	Ownership Not Available	98-99	Largent
28	Loper No. 1	100-102	Hulley
29-30	Loper No. 2	103	Bray
31	Largent	104	Ownership Not Available
32-33	Todd	105	Hulley
34-38	Ownership Not Available	106-107	Largent

readily available information. Indicated openings are not all working shafts, but include ventilation holes as well. It is probable that there are additional openings not catalogued which have sloughed in, have been bulldozed shut, or are obscured by vegetative cover.

Interconnections exist between most of the mines which have been worked into the same block of coal. Available mine maps are generally inadequate to establish extent and exact locations of interconnections. However, the maps do indicate the possibility of interconnections and discussions with previous mine operators indicate general agreement with the fact that the hill has been completely honeycombed by the various mine operations. Based on extant mine maps, the approximate mined-out areas are shown in Figure 3. The apparent interconnection of mines defines two large mined areas identified as Mine 47 Complex and Mine 88 Complex. Several smaller mined areas are seen to be independent of the major complexes.

There was a small strip mine operation in the south half of the southwest quarter of Section 12 as shown in Figure 2. The mine, which disturbed less than 20 acres in total, is abandoned and the area is now owned by the State of Ohio. Reclamation of this area is not included in the proposed demonstration project.

Areas in which coal refuse was deposited during active mining operations are also identified in Figure 2. These have been largely covered or removed as the first phase of the mine drainage abatement demonstration program.

Geologic Considerations - The mining throughout the study area has been exclusively of the Middle Kittanning (No. 6) coal seam. The overburden above the No. 6 seam is generally massive sandstone with some fracturing evident. In this location, this vein of coal is approximately 42 inches in thickness. Lower Kittanning (No. 5) coal is also present in the Lake Hope vicinity, but because of the relative thinness of the seam and since it is 25 to 30 feet below the Middle Kittanning, which would necessitate a more costly mining procedure, this resource has not been commercially developed.

The outcrop of the Middle Kittanning coal seam is shown in the Figure 3 topographic map. Also shown in Figure 3 is the structure contour drawn on the Middle Kittanning coal as developed from generalized information and old mine maps. The coal dips in the general direction of a line south 67 degrees east along which the average inclination is 33 feet per mile.

No coal drill records are available for the immediate study area. Several test borings were conducted as part of the feasibility investigation and the results obtained are presented in "Part IV - Preliminary Engineering Features" of this report.

There are no known geological faults in the study area. A search of the terrain over the mined-out areas does not reveal any indication of surface subsidence as a result of the underground mining activities.

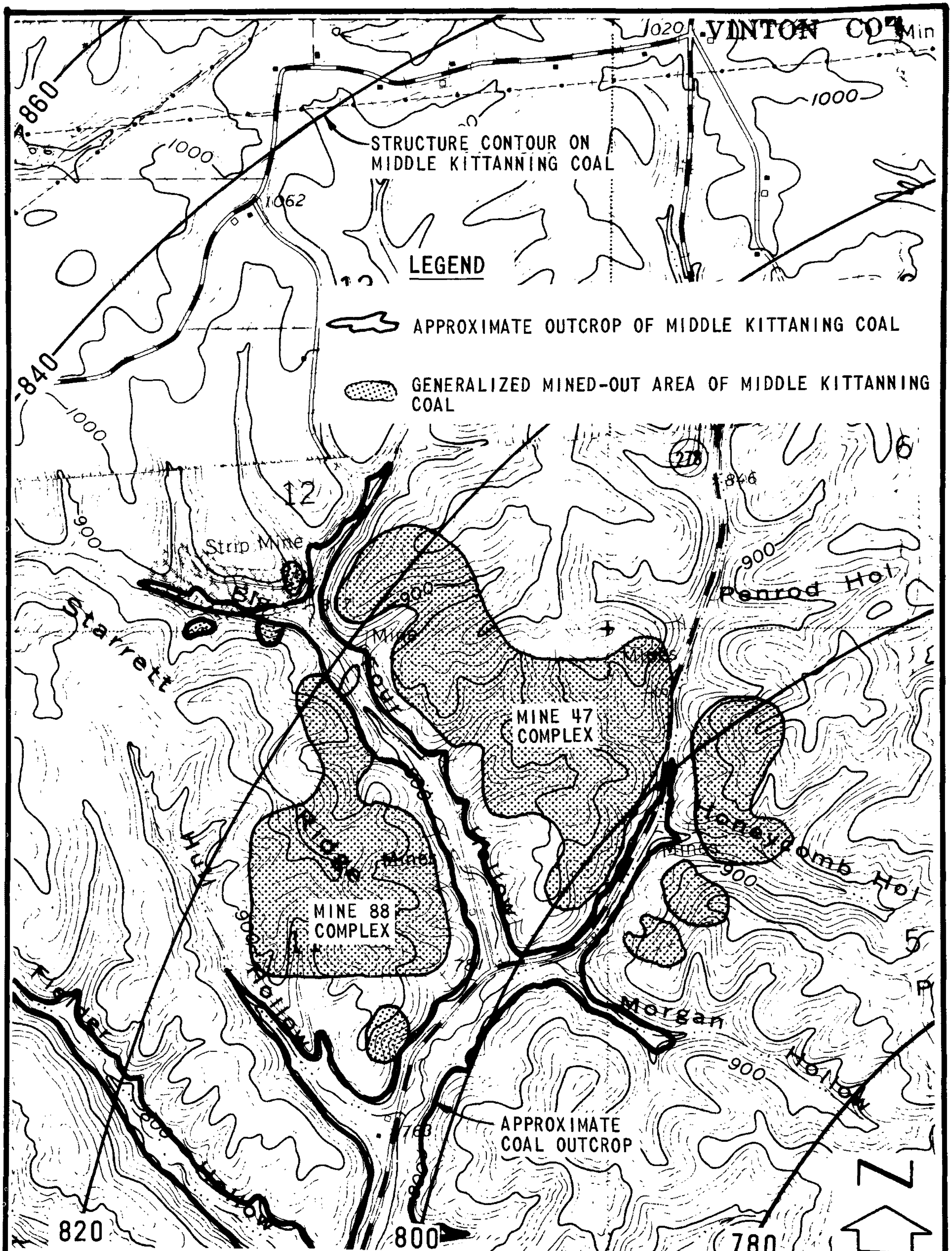


FIGURE 3 - GEOLOGICAL AND MINING FEATURES

Gas, Oil and Water Wells - Oil and gas resources may be present although data on these minerals is too sparse to evaluate. A survey by the Division of Oil and Gas of the Ohio Department of Natural Resources reports only three wells in the project watershed. These are described below and shown in Figure 4.

Permit No. 9-A	Total depth 3,184 feet. Plugged and abandoned October 13, 1914.
Permit No. 334-A	No record of well ever having been drilled. Permission to drill was given December 3, 1923.
Permit No. 335-A	Total depth 3,310 feet. Plugged and abandoned October 15, 1928.

Since none of the oil and gas wells are active, they will have no effect on the proposed mine drainage demonstration project. With the control of mineral rights residing with the State of Ohio, future development of gas and oil resources will also be controlled.

The water wells on file at the Division of Water of the Ohio Department of Natural Resources are also shown in Figure 4. Depth and yields are indicated for each well. All wells are on property owned by the State of Ohio and are largely used for water supply to recreational facilities. The wells are all downstream of the mined area where the demonstration project will be undertaken and therefore will not influence the proposed project.

Adequacy of Existing Information - Available physical information is generally adequate for evaluation of the proposed mine drainage feasibility project. More definitive information on the extent of mine interconnections, the depth of coal remaining between mine workings and the outcrop, and more extensive soil boring information would be helpful. It is possible, however, to proceed with the feasibility analysis based on available information, recognizing that additional physical details will have to be assembled at the time final construction plans and specifications are developed for the proposed demonstration facilities.

Water Resources

Base line water resource data is available for streams in the study area. Flow and quality characteristics of drainage from the mine openings which are the major sources of acid discharge have also been investigated extensively. A complete summary of water quality and flow data is presented in a report entitled "Base Line Water Quality" prepared for the Ohio Department of Natural Resources and dated October 14, 1971. Appendix A is a complete reproduction of this report including an updated computer printout of the water quality

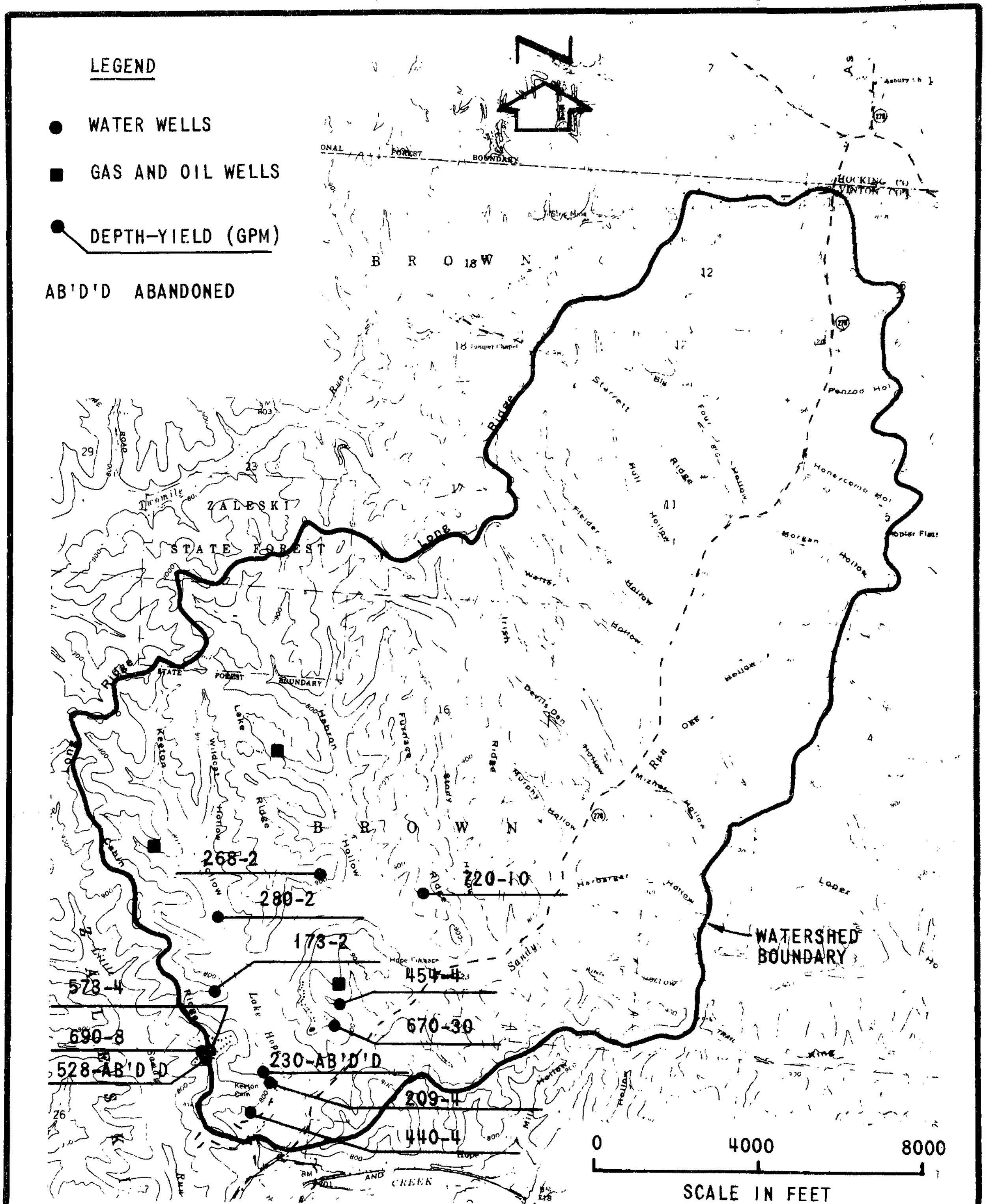


FIGURE 4 - GAS, OIL AND WATER WELL LOCATIONS

analytical results. Figure 5 presents the locations of sampling stations utilized and Table 2 contains the key for coordination of sample points with the Appendix A data.

TABLE 2

SAMPLE POINTS

Station No.	Location
200-299	Lake Hope
300-399	Sandy Run
400-499	Big Four Creek
500-699	Mine Openings (by addition of 500 to Mine Opening No. - Figure 2)
700-799	Small Streams and Drainage Tributary to Sandy Run
800-899	Small Streams and Drainage Tributary to Big Four Creek

Stream Records - A U. S. Geological Survey stream gaging station (No. 310 in Figure 5) has been in operation since October, 1957. Table 3 presents long-term flow duration data for Sandy Run as taken from Bulletin 42 "Flow Duration of Ohio Streams," 1968, Ohio Department of Natural Resources, Division of Water, Columbus, Ohio. Records from this station reveal annual runoff from the 4.99 square mile drainage area averaging 16.84 inches. This represents an average discharge of 6.19 cubic feet per second (cfs). There are periods each year during which there is no flow in the stream past the gaging station. The maximum recorded discharge at this location is 3,770 cfs on August 3, 1958.

Two new gaging stations, 320 on Sandy Run (drainage area 0.98 square mile) and 420 on Big Four Creek (drainage area 1.01 square mile), were established in October, 1970, for the specific purpose of gathering base line hydrologic and water quality data for the proposed mine drainage abatement demonstration project. All three gaging stations have been provided with analytical and recording equipment to monitor flow, temperature, pH and conductivity. Station 310 also contains equipment for continuously measuring dissolved oxygen concentrations.

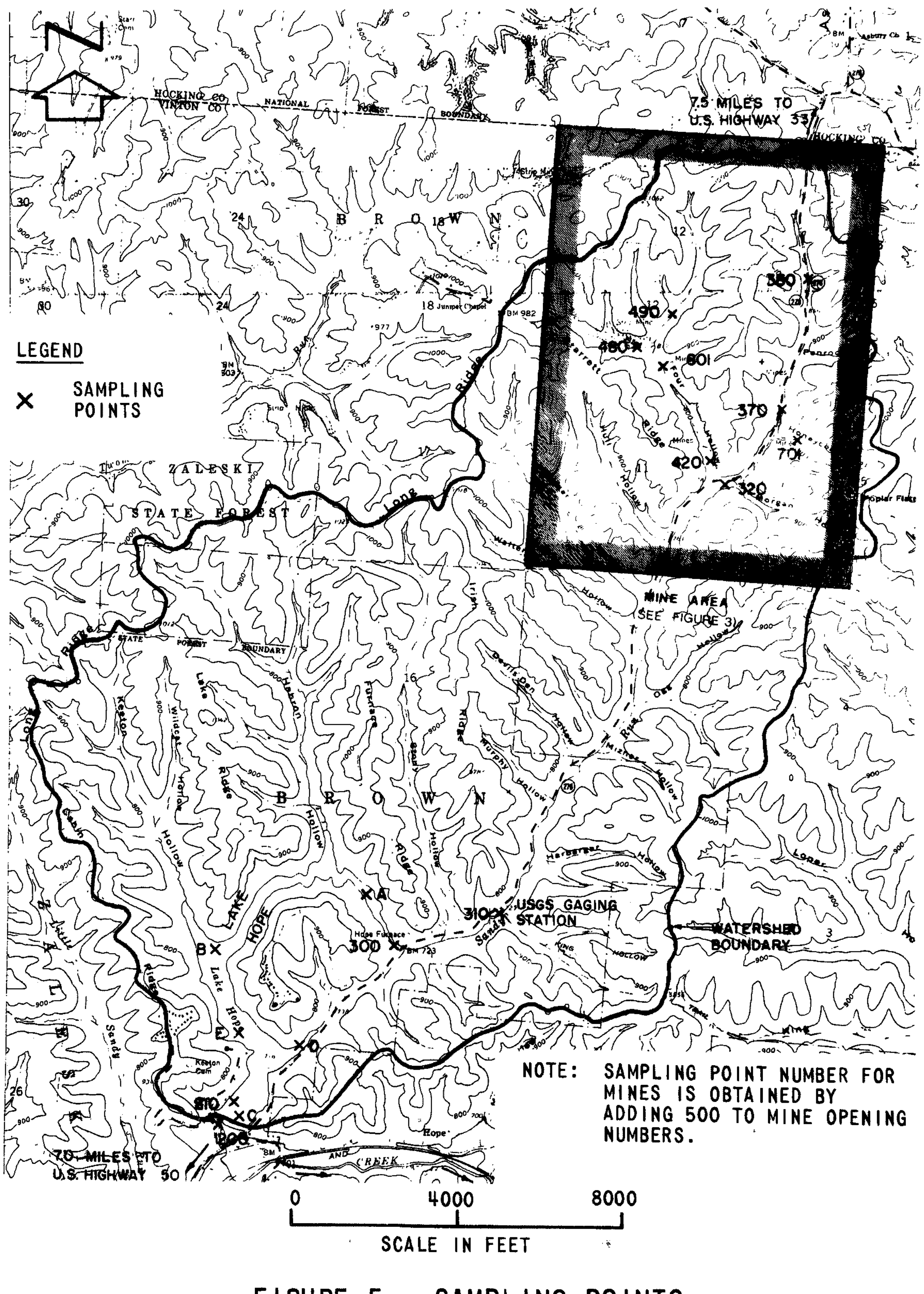


FIGURE 5 - SAMPLING POINTS

TABLE 3

SANDY RUN
FLOW DURATION DATA

Percent of Time Discharge Equalled or Exceeded	Discharge gpm	cfs	cfs/Sq. Mi.
10	6,284	14.00	2.810
20	3,142	7.00	1.400
30	1,795	4.00	0.802
40	943	2.10	0.421
50	584	1.30	0.261
60	332	0.74	0.148
70	220	0.49	0.098
80	144	0.32	0.064
90	45	0.10	0.020

In addition to the summary presented in the Base Line Water Quality Report, U. S. Geological Survey cooperatively with the State of Ohio is continuing to collect samples at Sampling Points 310, 320, and 420 at two week intervals for analysis of the following characteristics:

Iron
Manganese
Dissolved Solids (residue on evaporation at 180° C)
Total Hardness
Acidity (to pH 8.3)
Sulfate
Specific Conductance
pH
Flow

Table 4 is a summary presentation of the water quality data collected to date by the Geological Survey. A more detailed summarization of the most significant parameters is included in the Appendix A report. The Geological Survey sampling and analysis program will continue during the duration of the demonstration project. Throughout the monitoring period reports of the Geological Survey water quality investigations will be made available to the Environmental Protection Agency and other parties to the program every two weeks. Data from the continuous monitoring equipment will be reported and distributed on a monthly basis.

TABLE 4

USGS WATER QUALITY SUMMARY

STATIONS 310, 320, AND 420

	Maximum	Minimum	Average
Sampling Station 310			
Dissolved Solids, mg/l	960	93	375
Hardness, mg/l	470	51	182
Acidity, mg/l	228	5	81
Iron, mg/l	33.0	0.6	4.3
Manganese, mg/l	11.0	0.12	3.10
Sulphate, mg/l	655	57	256
pH	4.7	3.4	
Conductivity, micromhos at 25° C	1,210	182	616
Temperature, F	73	33	55
Flow, gpm	27,825	22	3,275
Sampling Station 320			
Dissolved Solids, mg/l	2,600	127	1,142
Hardness, mg/l	1,100	70	409
Acidity, mg/l	794	15	320
Iron, mg/l	120.0	1.8	46.7
Manganese, mg/l	12.0	0.43	4.87
Sulphate, mg/l	1,872	94	816
pH	4.6	2.8	
Conductivity, micromhos at 25° C	2,930	256	1,599
Temperature, F	74	33	55
Flow, gpm	4,488	18	256
Sampling Station 420			
Dissolved Solids, mg/l	1,630	110	755
Hardness, mg/l	620	64	278
Acidity, mg/l	596	5	222
Iron, mg/l	87.0	1.6	25.8
Manganese, mg/l	17.0	0.65	6.63
Sulphate, mg/l	1,144	80	524
pH	4.3	2.8	
Conductivity, micromhos at 25° C	2,100	226	1,138
Temperature, F	77	33	57
Flow, gpm	5,655	4	621

Lake Sampling - Water quality characteristics for Lake Hope proper show considerable variation. During the period between April, 1970, and June, 1971, as reported in the Base Line Water Quality Study, pH was seen to vary between 3.9 and 7.8. Acidity (to pH 8.3) ranged from a high of 100 mg/l down to less than 20. The majority of the samples collected, however, exhibited pH between 4.0 and 5.0 and total acidity between 20 and 30 mg/l.

In addition to the water quality samples, an analysis was made of the bottom muds in Lake Hope. These data are reported in Appendix A. On the basis of evaluation of both water and bottom mud characteristics, it was concluded that while some resistant species of fish can survive in water of low pH for long periods, tolerance and reproductive capability of desirable species are severely limited. The low pH also has a detrimental effect on the entire biota as it affects the complete food chain of the ecosystems.

Mine Drainage - Direct discharge from mine openings was found to be the most significant source of acid contribution to the streams above Lake Hope. Two mine openings consistently produce the greatest flow rate, highest acid concentration, and therefore the greatest acid load.

Mine Opening 47 is at the lowest elevation of all the openings into the hill west of Sandy Run and north of Big Four Hollow. As a result, all mine drainage generated in this major mine complex is discharged to Sandy Run through Opening 47. Over the period of record from April, 1970, through June, 1971, drainage discharge averaged 120 gallons per minute (gpm) with an average acid load entering Sandy Run of 1,465 pounds per day. A high flow of 341 gpm was recorded from this mine opening on May 8, 1971, with a corresponding acid load of 4,665 pounds per day. A low flow of 27.5 gpm was recorded on two separate occasions with corresponding acid loads of 379 and 388 pounds per day.

The other major mine discharge is from Mine Opening 88 which drains the complex of mine workings driven into the coal seam below Starrett Ridge southwest of Big Four Hollow. The recorded high flow from Mine Opening 88 was 265 gpm on May 5, 1971. The acid flow rate at that time was 5,374 pounds per day. The observed low flow condition from Mine Opening 88 was 12 gpm with a corresponding acid load of 281 pounds per day. Average conditions for this mine opening include a yield of 70 gpm and an acid load discharged to Big Four Creek of 1,029 pounds per day.

Figure 6 is a graph of acid flow in pounds per day versus water flow rate in gallons per minute for discharge from Mine Opening 47 into Sandy Run. Similar graphs are available for other sampling points in Appendix A. This plot indicates a general relationship between discharge and the amount of acid emitting from the mine opening. Water volume is quite dependent upon meteorlogical conditions. Therefore, the quality of water discharging from the mine and also flowing in

Sandy Run is more specifically dependent upon precipitation patterns than on purely seasonal conditions. High acid flow may occur at any season of the year if the precipitation pattern is conducive to such discharge.

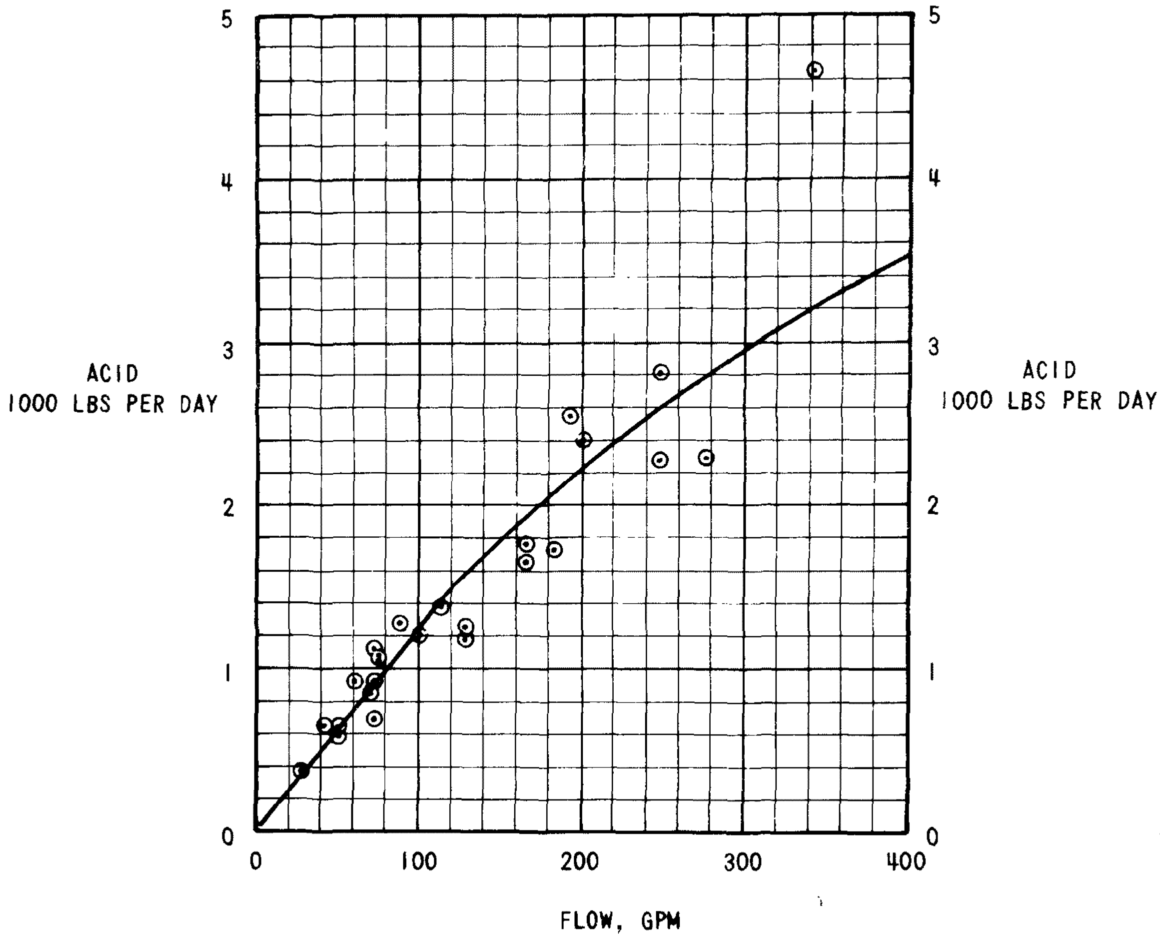


FIGURE 6 - ACID VS FLOW
SAMPLE POINT 547

The total acid discharge from the various mine openings generally exceeds the total as measured in Sandy Run at Station 310. This indicates that, on balance, natural stream flow from all sources except mine drainage contains enough alkalinity to neutralize a portion of the acidity. Laboratory testing was undertaken to verify the impact of natural drainage upon acidic discharge from mine openings. Reults of these investigations are reported in the Appendix A report. Because of the natural alkalinity of the area water, it is not necessary to eliminate all acid production in the various mines in order to achieve a marked improvement in water quality in Lake Hope. Expected improvements in water quality for specific mine drainage abatement projects are discussed in "Part IV - Preliminary Engineering Features."

Precipitation - Records of precipitation were maintained and correlated with other water volume and quality measurements during the base line investigations. In addition, maximum expected rainfall rates have been determined from the U. S. Department of Commerce Weather Bureau Technical Paper No. 40 "Rainfall Frequency Atlas of the United States." This publication indicates that the maximum one hour rainfall that might be expected yearly at Lake Hope would produce slightly over one inch of precipitation. The maximum one hour storm with a return frequency of 10 years would produce about 1.9 inches of rainfall. Average rainfall in the Lake Hope vicinity is approximately 36 inches per year.

Social and Economic Environment

Lake Hope State Park (see Figure 7), with Lake Hope as a focal point, is located deep within the 22,569-acre Zaleski State Forest. The Ohio Department of Natural Resources, through a development program dating to the early 1930's, has continually added to the park facilities and extensive recreational opportunities are now available in the area. An attractive dining lodge and numerous cabins provide basic visitor accomodations. Recreational pursuits that are readily accessible include hiking, horseback riding, boating, swimming and camping.

The state park proper encompasses 3,103 acres, including the 120-acre lake. The dining lodge, 69 cabins and 223 family campsites, marina facilities, beach and trails make this one of Ohio's comprehensive facilities. Developed park area supplemented by over 22,500 acres of forest land results in a very versatile recreation resource.

A 1970 travel survey indicates Lake Hope to be among the top areas in attracting visitors from all over the state. Visitors were reported from 64 of the 88 Ohio counties. Franklin County (Columbus) surpassed all other counties by three-fold in representation. Lake Hope is 78 miles from Columbus. Park attendance for 1970 was 658,938 visitors.

Problem and Causes - Access to easily minable coal made this area attractive over 100 years ago. Even now, old stone iron smelting furnaces remain as monuments to the industrial history and add to the heritage of the region.

Acid draining into Lake Hope has adverse affect on the extensive water-oriented recreation which centers on the lake. The low pH of the water adversely affects fishing, since fish reproduction is severely inhibited at the pH levels commonly experienced. Fish kills have been reported in the past when excessive slugs of acid reached the lake.

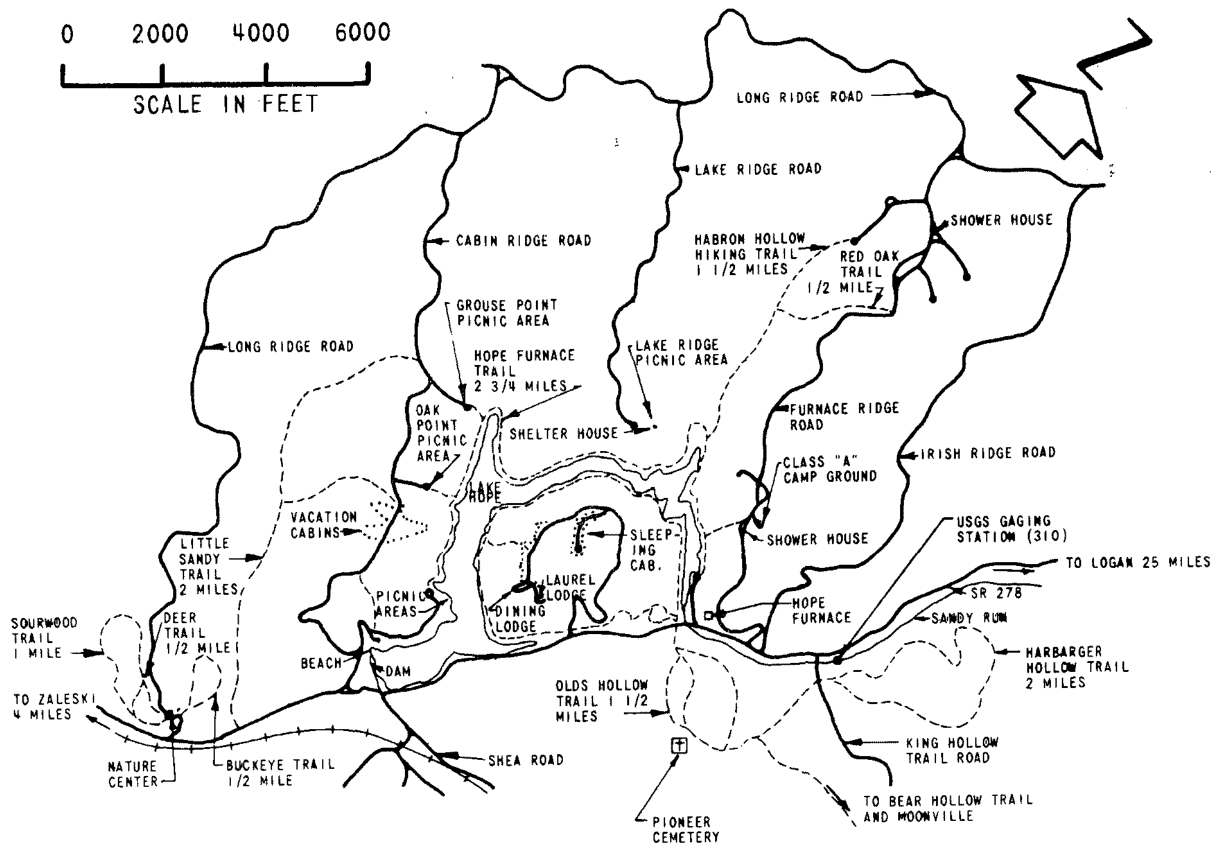


FIGURE 7 - LAKE HOPE STATE PARK FACILITIES

Attendance figures show that only 5,398 (one percent) of the park visitors in 1970 came to Lake Hope to fish. The state-wide average for fishermen utilizing state park lakes is approximately 10 percent of the total attendance. This lack of fishermen in this area has subsequent affects on camping and cabin revenues, and related other expenditures in the locale.

Recreation Needs - The central region of Ohio is already heavily populated and shows strong growth tendencies. Lake Hope State Park lies within the area strongly influenced by the central region. Water areas suitable for fishing, general boating, and small craft are one of the severe shortages. The central region needs 8,000 more acres of water to satisfy current demands, and by 1985 almost 34,000 acres (not now existing) will be required. Current shortage of shore line for sport fishing activities is 740 acres, by 1985 the shortage will be 1,094 acres unless new resources are developed. The shoreline acreages for sport fishing are based on a 20-foot depth requirement.

Space needed for picnicing, camping, hiking, and other land based activities is over 7,000 acres today, and will reach 12,000 acres by 1985. Presence of water greatly enhances this land for the activities described.

PART IV - PRELIMINARY ENGINEERING FEATURES

Abatement Project Description

Mine drainage problems in the Lake Hope area are typical of those encountered as a result of mining for coal. Iron pyrite found in the overburden and material adjacent to the coal seam, when exposed to water and air, is oxidized to form sulfuric acid and acidic iron salts. Once formed in the old mine workings, the acid may be retained for a period but ultimately drains into Lake Hope with a detrimental impact on this prime recreational facility.

A multi-phase mine drainage demonstration project is proposed. Efforts already undertaken have established a water quality base line (Appendix A) which can be utilized to measure demonstration project effectiveness. Physical improvements to demonstrate means for reducing mine drainage pollution involve the following:

1. Removal or burying of random areas of coal refuse remaining from active mining operations.

2. A mine sealing program to inundate the old mine workings and inhibit acid formation and discharge into Sandy Run.

Coal Refuse Disposal

At the termination of active mining in the Lake Hope watershed, an estimated 100,000 cubic yards of coal refuse was randomly scattered near mine openings and adjacent to the area streams. These refuse piles detracted from the aesthetics of the area and were a source of acid contribution as a result of leaching of surface water.

Two alternatives were considered for improving the appearance of the area and eliminating acid production from the coal refuse.

1. Physically remove the refuse and bury outside the project watershed. This alternative would completely eliminate the objectionable material from the demonstration area; therefore, there would be no potential for future contamination of Sandy Run or Lake Hope as a result of surface water leaching.

2. Consolidate the coal refuse into several locations and provide a soil cover prior to seeding the area. This alternative is the more economical of the two for the large accumulations of refuse.

Upon considering the advantages and disadvantages of these two alternatives, a course of action utilizing both approaches was initiated. The Division of Forestry and Reclamation of the Ohio Department of Natural Resources undertook this project. Approximately 17,000 cubic yards of refuse were loaded onto dump trucks and hauled about 3 miles to disposal sites outside the Lake Hope watershed. The refuse was buried in a location and a manner which would not create any adverse effects on the environment.

The majority of the coal refuse in Honeycomb Hollow and at several other locations was buried in place. A total of 13.7 acres of refuse pile sites have been prepared and planted in accordance with the following program.

1. Areas with pH below 4.5:

    a. Scarify top 5 to 6 inches.

    b. Spread lime screenings at 5 tons per acre.

    c. Spread 6 to 8 inches of soil top dressing.

2. Areas with pH above 4.5:

    a. Scarify if required.

    b. Spread lime screenings at 3 to 5 tons per acres.

    c. Disc lime into soil.

3. Apply the following mixture as a slurry with a hydroseeder:

    a. Agricultural limestone at 2 tons per acre.

    b. Fertilizer (12-12-12), at 600 pounds per acre.

    c. Seed mixture at 36 pounds per acre containing 14 pounds Kentucky 31 Fescue, 12 pounds Sericia lespedeza and 10 pounds orchard grass.

    d. Mulch at 1,500 pounds per acre.

    e. Water as necessary to maintain proper suspension.

4. During the spring following germination of the seeded mixture, plant one year seedlings of European black alder, sweet gum, and sycamore at the rate of 700 trees per acre.

The revegetation program appears to be a success and the general aesthetics of the area are much improved. Some increase in acid production was expected and observed in the initial flush following the refuse removal and replanting activities. The water quality record to date is not sufficient to judge the magnitude of the long-term decrease in acid production from the replanted areas.

As the refuse piles in Honeycomb Hollow were being buried, Division of Forestry and Reclamation personnel noted that drainage from this small watershed was entering a subsidence near Mine Opening 62 and exiting through Mine Opening 60. This subsidence was plugged with locally available material and surface drainage was diverted away from the opening. At present there is no drainage from Mine Openings 60 or 61 and these mines are flooded to an elevation above the coal seam. This treatment has effectively eliminated a source of acid production. The quantity of acid produced in this mine complex averaged 139 pounds per day (51,000 pounds per year) over the period of record prior to the remedial work. Elimination of this quantity of acid will undoubtedly improve water quality conditions in Sandy Run. A decrease of approximately 4 mg/l of total acidity is expected with a corresponding pH increase of 0.1 unit. However, sufficient analytical data has not been accumulated following completion of the work to statistically verify the long-term impact on water quality.

Mine Sealing Program Alternatives

To assure fiscal control of the mine sealing project within available funds and to permit continuing refinement of demonstration techniques applicable to this site, a staged construction program is recommended. The two major sources of mine drainage have previously been identified as the Mine 47 Complex and the Mine 88 Complex. The initial concept of a demonstration program involved sealing the major points of acidic drainage and selected other openings as necessary for complete containment. Subsequent investigations as reported herein have better defined the extent of interconnections of the mine workings and have dictated the need for sealing all openings in a particular complex. The extent of mine sealing necessary to curtail drainage from the Mine 47 Complex is shown as Phases I and II on Figure 2. Similarly, the Mine 88 Complex is shown as Phase III. Detailed analyses have been performed to determine which mine complex should be sealed as the initial phase of the program. Results of these analyses as related to cost and mine drainage abatement effectiveness are presented at appropriate points in this text.

Following is an outline of the significant advantages which relate to proceeding initially with sealing of the Mine 47 Complex.

1. Openings in the Mine 47 Complex are more readily accessible than are the openings in the Mine 88 Complex. Construction will be somewhat easier and the impact on the natural park environment will be less since construction of roadways through forested areas will be minimized.

2. Mine Opening 47 is the most visible source of mine drainage pollution to the casual visitor in the area. Many of the openings in the Mine 47 Complex are relatively close to existing roadways. The completed mine seals will, therefore, be conveniently located for public inspection and eliminate the most noticeable mine drainage source, thus enhancing the demonstration aspects of the project.

3. The cost per unit of acid drainage eliminated is less for the Mine 47 Complex than for the alternative.

4. The largest flow of acid to Sandy Run and Lake Hope is from Mine Opening 47. Therefore, the greatest improvement in water quality can be realized upon completion of the sealing of the Mine 47 Complex.

5. It is possible and practical to break the sealing of the Mine 47 Complex into two steps as shown as Phase I and Phase II in Figure 2. Proceeding in this manner will permit flooding a good deal of the old mine workings and facilitate evaluation of the effect of hydrostatic head on the geological formations at a minimal dollar investment.

The factors which would favor proceeding initially with the Mine 88 Complex can be summarized as follows:

1. The total cost for sealing the entire complex is less than for the Mine 47 Complex. It is, therefore, possible to eliminate a substantial source of mine drainage for a lower capital expenditure.

2. The maximum hydrostatic head which must be imposed on the seals when the old mine workings are completely flooded is approximately 17 feet. The hydrostatic head for the alternative mine complex is approximately 30 feet. This difference in hydrostatic pressure will influence costs for seals and the remedial grouting required to eliminate seepage through the geological formations.

On the basis of the foregoing comparison of advantages to each alternative and the more detailed quantitative comparisons presented in subsequent sections of this report, it is recommended that the initial mine sealing be conducted in the Mine 47 Complex in a two-phase operation as illustrated in Figure 2 and subsequently described.

Core Boring Program

To better define geological factors influencing the design of mine seals, three core borings were taken in the vicinity of Mine Opening 47 as shown in Figure 8. The characteristics of the core sections removed are illustrated. As shown, the borings detailed overburden material of soft sandstone. The coal averaged nearly 4 feet in thickness and was underlain by hard fire clay. The data from the borings are felt to be generally applicable to the other mines in the demonstration project area.

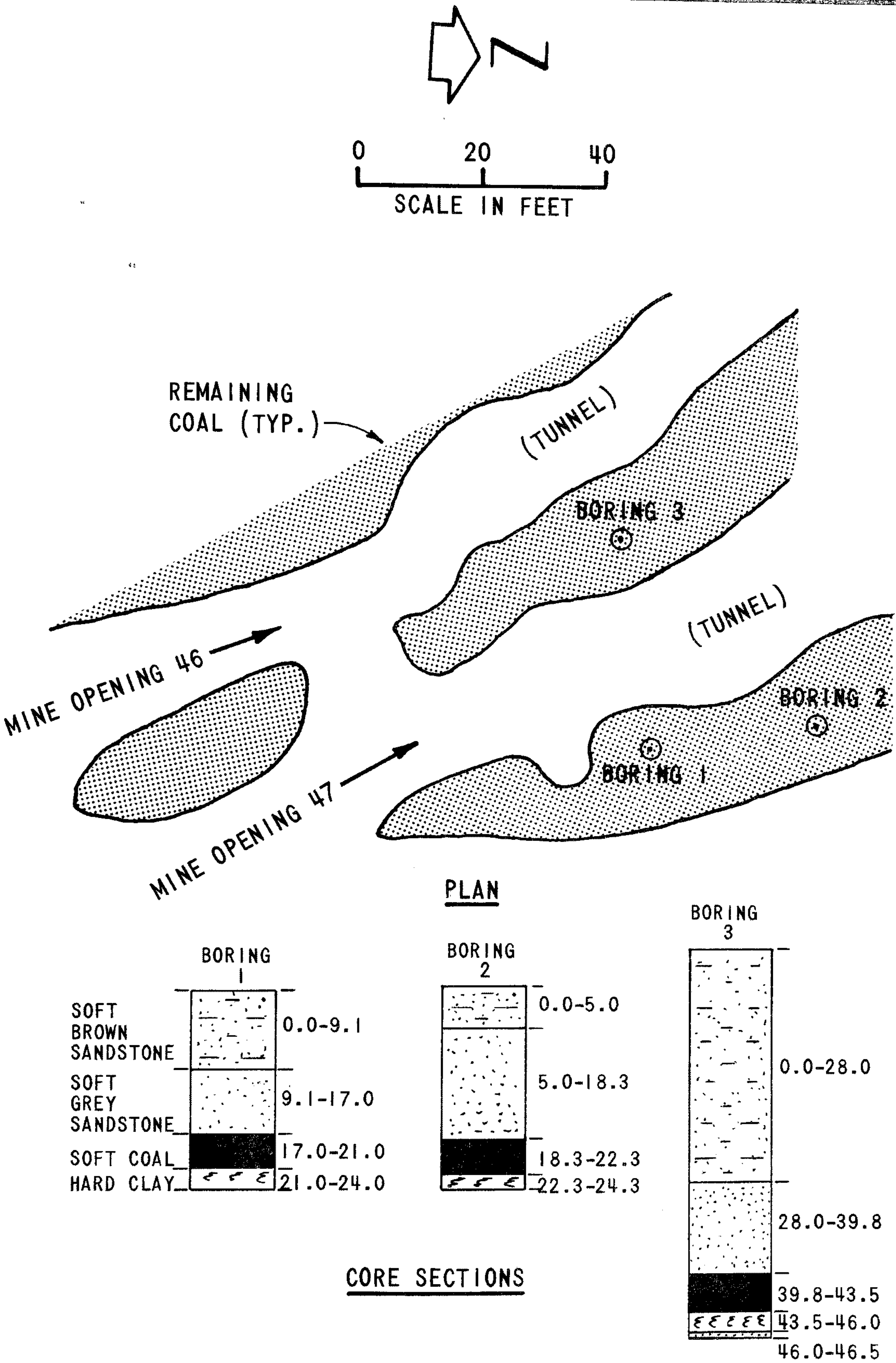


FIGURE 8 - CORE BORINGS AT MINE OPENING 47

After coring, the holes were pressure tested with water. The results of these pressure tests are as follows:

Boring No.	Depth (Ft.) From	To	Press. Gage,* psi	Time, Min.	Water Injected, Gal.
1	17.0	24.0	17.0	10	0.1
1	12.0	24.0	12.0	7	0.2
2	18.0	24.3	18.0	10	6.5
2	13.0	24.3	13.0	10	3.0
3	39.5	44.5	35.0	10	9.0
3	34.5	39.5	30.0	10	0

*Pressure gage read at top of hole.

The general observation which can be made as a result of these borings is that the coal seam and overburden are relatively tight. A limited loss of water would be expected through the geological formations. It can be further concluded on the basis of the pressure tests that a grouting procedure would be effective in reducing or eliminating localized seepage where such conditions develop. This conclusion was also verified by the drilling contractor who has had a great deal of experience with grouting of semipermeable stratas.

Inspection of the old mine roofs and the boring cores did reveal one possible defect in the geological system, however. Rather large fractures were observed which appeared to run vertically through the entire depth of the sandstone overburden. While drilling one hole (Boring 3 in Figure 8) the water used in the drilling operation was lost and observed to be entering Mine 47 through a fracture in the roof nearly 18 feet below. These defects in the sandstone will undoubtedly cause some problems in the mine sealing operation. It would appear that they can be successfully grouted, however, and therefore are not felt to be an insurmountable obstacle to the mine sealing program.

Phase 1 - Mine Sealing Program

The first phase of the recommended mine sealing program consists of construction of watertight seals on Mine Openings 40 through 52 inclusive, pressure grouting of the porous and fractured stratas above and directly adjacent to the mine seals, and remedial pressure grouting along the coal outcrop into which these openings have been driven as seepage areas appear. This first phase of activity will be accomplished in three steps:

1. Site preparation.

2. Construction of seals in mine openings.

3. Pressure grouting of porous rock formations above and directly adjacent to the mine openings and remedial pressure grouting as seepage areas appear.

Site Preparation - First efforts will be directed toward preliminary cleaning Mine Openings 40-52 inclusive, as shown in Figure 9. Additional exposure of the coal seam as necessary to locate seepage areas would be done by the general contractors during the construction phases.

Material removed from the coal face will either be dispersed throughout the area or stockpiled for utilization in dressing up the site following completion of all construction activity.

Mine Sealing - Mine Openings 40-52 and any currently unidentified intermediate openings which may be located during site preparation will be sealed as the second step of the program. This stage also includes thorough cleaning of the mine portals and any other preliminary work required preparatory to the actual sealing operation.

A number of factors which influence the design and construction of the mine seals are apparent on the basis of close visual inspection of the mine openings and the surrounding terrain. These include:

1. The coal seam is generally above grade throughout the area, although not far enough above the valley floor to present severe access problems. Little additional site work will be required of the contractor in order to locate his equipment near the mine openings.

2. Mine portals into the old workings are generally quite short. Mine operators branched out into rooms very near the entrance so that there may be less than ten feet of coal remaining behind the outcrop in some locations. This was verified in detail near Mine 47 as the survey was completed to establish locations for core borings.

3. Only the pillars remain in the mines; there is little, if any, mineable coal left.

4. Roof structure is sound with few "falls" near the mine entrances. Vertical fractures in the sandstone overburden are present in many of the area mines. At Mine 47, these are mostly perpendicular to the tunnels and occur at approximately 20-foot intervals. The fractures normally average 1 1/2 inches in width. Tree roots were observed in one fracture near the entrance to Mine 47.

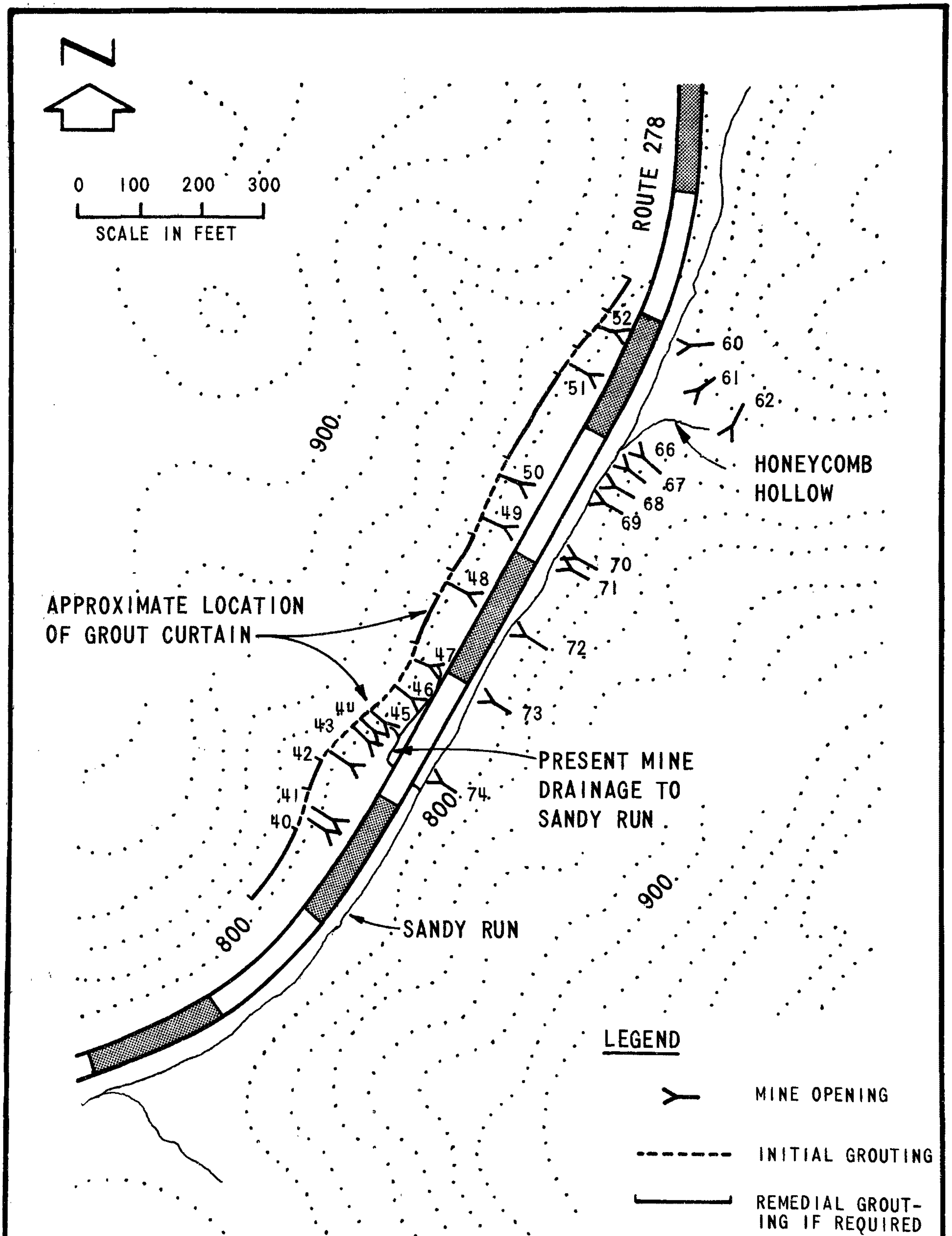


FIGURE 9 - PHASE 1, MINE SEALING MAP

5. Much of the gob was left in the mine and is piled randomly at the sides of the tunnels and back into the workings.

6. The vertical height of the coal seam and most of the openings is relatively consistent at about 3 feet 6 inches to 4 feet.

The preferred type of seal for installation in the Lake Hope area consists of front and rear bulkheads of self-supporting concrete with a light expansive-type cement placed between the bulkheads. This approach has been used successfully. A high flow mine located three miles west of Lost Creek in Harrison County, West Virginia, was closed with an expansive cement type seal. The procedure, material used, and results are outlined in "New Mine Sealing Techniques for Water Pollution Abatement" published by the Environmental Protection Agency (14010 DMO 03/70).

The expansive cement type seals can be placed from the front of the mines after the portals are cleaned. Plan and section of the recommended seal are shown in Figure 10. The rear bulkhead is placed first. A front bulkhead is then constructed with grouting pipes through the structure as necessary to install the center plug. Following completion of the front bulkhead, the expansive cement is placed between the two bulkheads to complete the mine seal.

As shown in the figure, a drain pipe is placed through the entire seal with a valve on the outside end. This will permit regulation of the rate of water accummulation behind the seal, thus assuring that the water level will not rise too rapidly before the concrete is strong enough to withstand the applied head. It will also be possible to lower the level of the impounded water to effect remedial measures if excessive seepage is noted along the face of the outcrop.

<u>Alternative Mine Sealing Technique</u> - To date, only a limited number of contractors have the technology, experience and equipment necessary to install an expansive cement type mine seal. Therefore, in order to obtain more competitive bids for the Lake Hope Demonstration Project, inclusion of an alternate mine sealing technique is considered desirable. For this alternative, plain concrete plug seals, as shown in Figure 11, are recommended. This seal is a variation of the approach selected for the Moraine State Park pollution abatement program. In Moraine State Park, mine sealing resulted in a 75 percent reduction in acid flow from drift mines similar to those at the Lake Hope site.

The alternative type of mine seal consists of a simple concrete plug in the mine opening. It is anticipated that this plug can be installed by working entirely from the front face of the outcrop. A rear form or

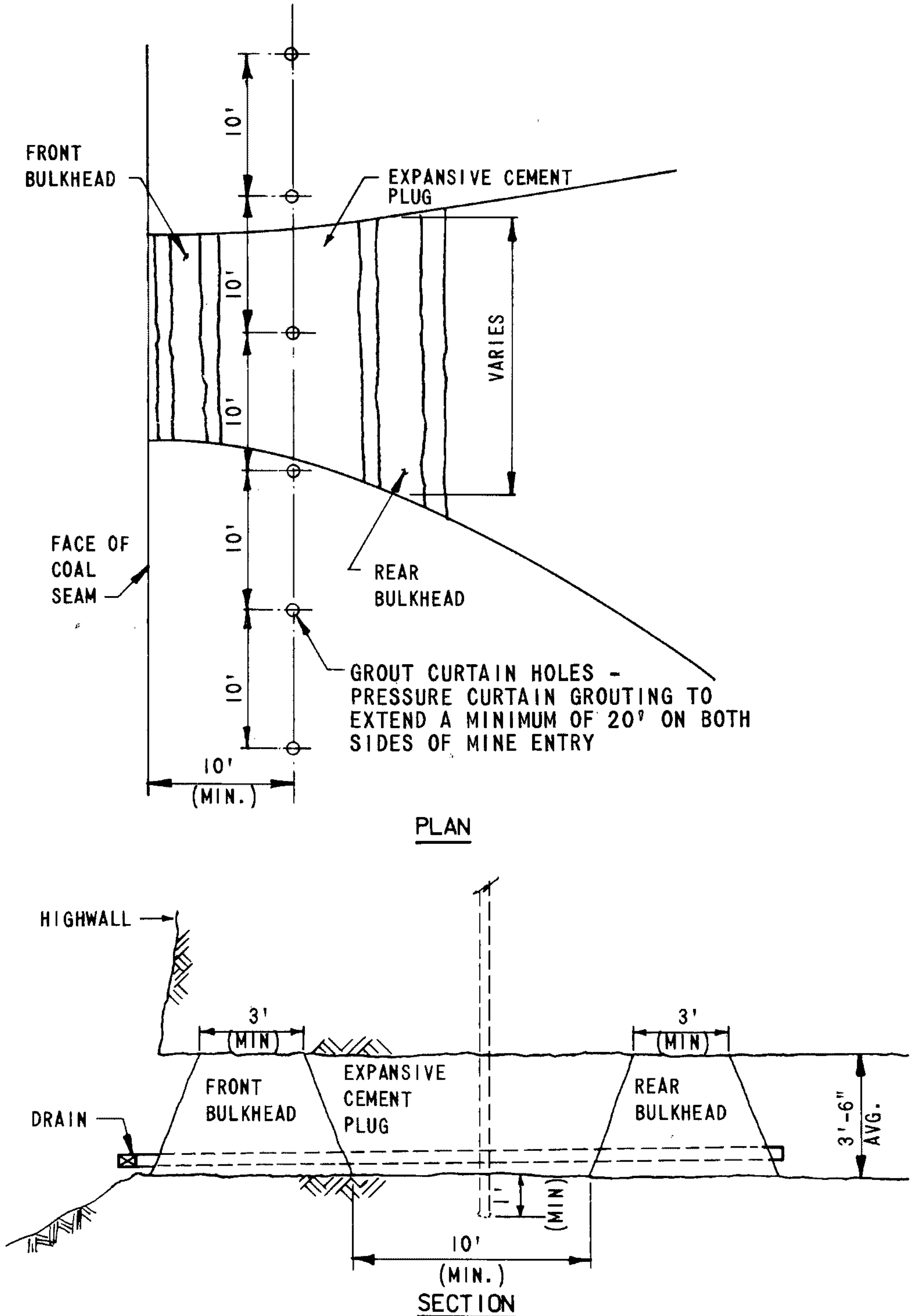


FIGURE 10 - PREFERRED MINE SEAL

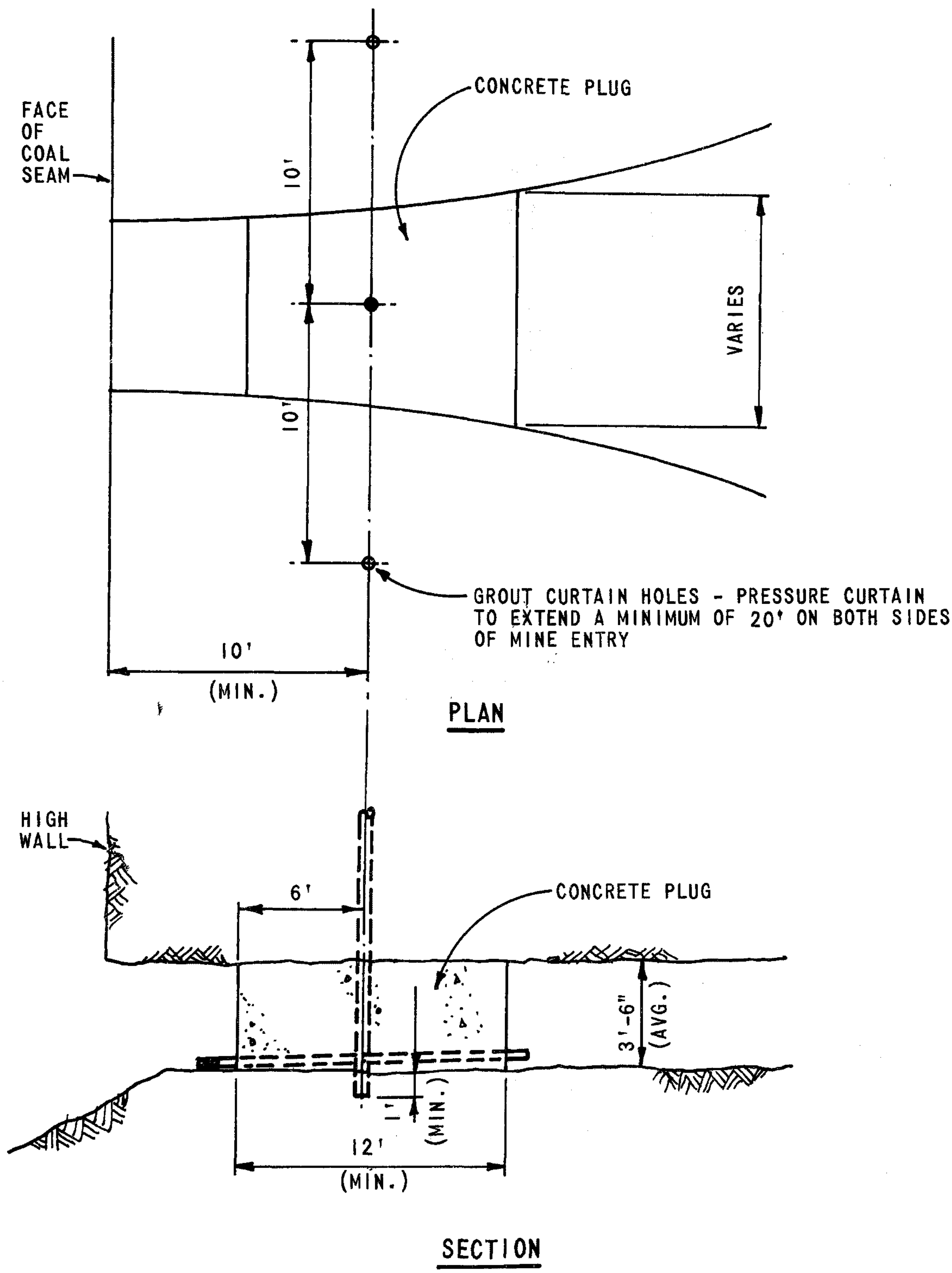


FIGURE 11 - ALTERNATE MINE SEAL

bulkhead is required behind the plug in order to hold the mass concrete in place. This could consist of a wooden form, a grouted aggregate bulkhead, or similar arrangement at the contractor's convenience. It is recommended that the front form be constructed of wood which will be removed after the concrete is set. This enhances construction and minimizes the distance required from the face of the outcrop to the face of the seal. The contractor will be required to cut filling chutes in the rock above the front form to assure that the void between the forms is completely filled and to provide a means for vibrating the concrete.

After the concrete plug is completed, grout will be injected from above to compensate for shrinkage effects. A minimum plug length of 12 feet is recommended to allow for complete pressure grout sealing.

In Moraine State Park, this type of seal was constructed utilizing both front and rear bulkheads of grouted aggregate with the center plug of plain concrete. At that location, however, it was necessary that the entire seal be placed from above, rather than from the front as is possible at Lake Hope. The seals at Moraine State Park have successfully impounded heads up to 30 feet of water, which is comparable to what will be required at Lake Hope.

Pressure Grouting - The final step in the first phase operation will consist of sealing the face of the coal outcrop and the porous overburden material. A grout curtain will be installed above and approximately 20 feet on either side of each mine seal. The relationship of the grout curtain to the mine seals is shown in an isometric view of a typical opening in Figure 12.

As shown in the figure, the grout curtain will extend across the mine seal and to the full height of the overburden material. The grout curtain at the mine opening is necessary to seal the void caused by shrinkage between the sandstone overburden and the concrete mine seal. The material on either side of the mine seal will probably be fractured and some grouting should be done in this area. A grout curtain over and adjacent to the mine seal will be necessary regardless of whether the expansive cement type of seal or the alternate concrete plug seal is selected.

Pressure grouting will also be done as a remedial measure between openings as seepage areas become apparent. For cost estimating purposes, it has been assumed that pressure grouting will be required along the entire construction area beginning at a point approximately 50 feet southwest of Mine 40 and extending some 50 feet north of Mine 52. The vertical cracks in the sandstone formation will be washed and filled with grout. The grouting will continue throughout the sealing program until the mines are filled with water to the desired final elevation.

Phase 2 - Mine Sealing Program

Phase 2 activities will follow by three to four months and expand upon the procedures and results obtained in the Phase 1 operation. Assuming

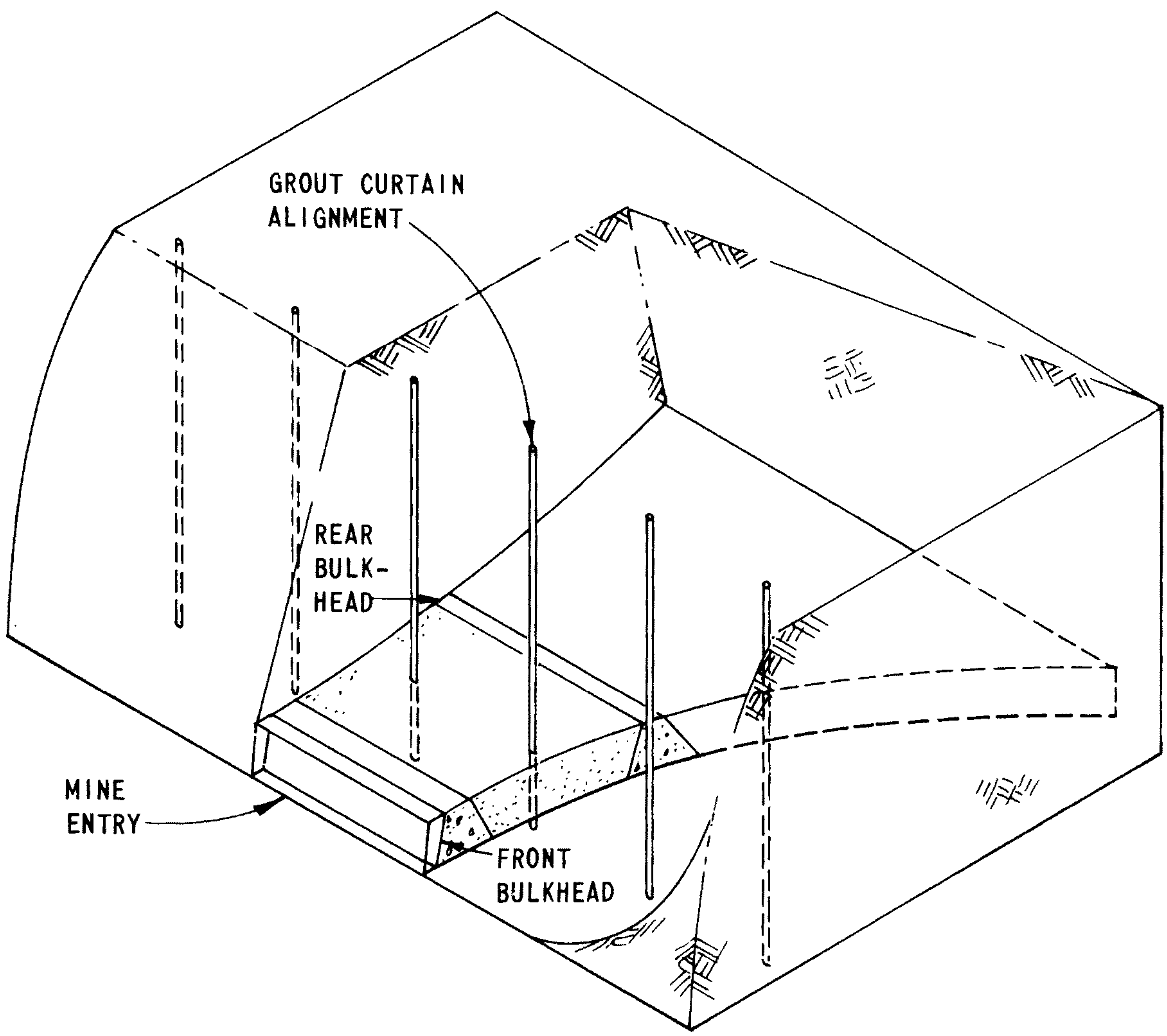


FIGURE 12 - ISOMETRIC DRAWING OF MINE SEAL

the Phase I sealing is successful in impounding water in the old mine workings, it will then be necessary to seal all other mines which have an interconnection with those previously sealed. In general terms, Phase 2 operation (Mine Openings 14-39 and 53-55) will proceed through the same three steps as Phase I.

Due to the slope on the coal seam, openings in the vicinity of Mine 39 are approximately 14.6 feet higher than the openings sealed in the first phase program. The slope of the seam continues upward to the northwest along Big Four Hollow so that openings around Mine 26 are some 26.6 feet higher than Mine 47 and openings in the vicinity of Mine 14 are approximately 32.8 feet higher than Mine 47.

Openings will be sealed utilizing one or both of the alternative approaches previously presented, except Mine Openings 14 through 26. Due to the relatively low hydrostatic head which will be applied at these openings, it may be possible to achieve greater economy by utilizing a permeable type of mine seal as shown in Figure 13. The procedure, materials used, and results are outlined in "New Mine Sealing Techniques for Water Pollution Abatement," published by the Environmental Protection Agency (14010 DMO 03/70). Full evaluation of the application of this type of seal to the Lake Hope Project is deferred until results of the Phase I activity.

Field survey has located several mine openings (20 and 21) in the area that are already sealed with concrete block. These seals will be utilized to the extent possible in the design of the complete Phase II sealing program.

At Mine Openings 53, 54, and 55, the coal is some 15 feet below the surface and access is gained through steeply inclined shafts. These openings are presently flooded to a level above the top of the coal seam. It is anticipated that as Mines 40-52 are sealed, the water level will rise in these mines and they will also have to be sealed. Slightly different procedures will have to be utilized in placing mine seals under water in these three openings. The same general type of seal can be utilized with modification of the placement procedure to account for the unique entrance conditions.

A grout curtain will extend to the maximum hydrostatic elevation over and adjacent to mine seals except at Mine Openings 14-26. The elevation of the coal seam at these mine openings precludes the need for excessive hydrostatic head on the mine seals. Remedial pressure grouting will be undertaken as necessary to eliminate points of seepage.

Economies in the total program cost will be realized if the geological strata are tight enough to eliminate remedial pressure grouting in some areas. For cost estimating purposes, it has been assumed that grouting will not be necessary in the area between Mine Openings 14 through 26.

Vents

The mine complex will have a drain installed at an elevation above the highest point in the coal seam in the series of Mines 14 through 55.

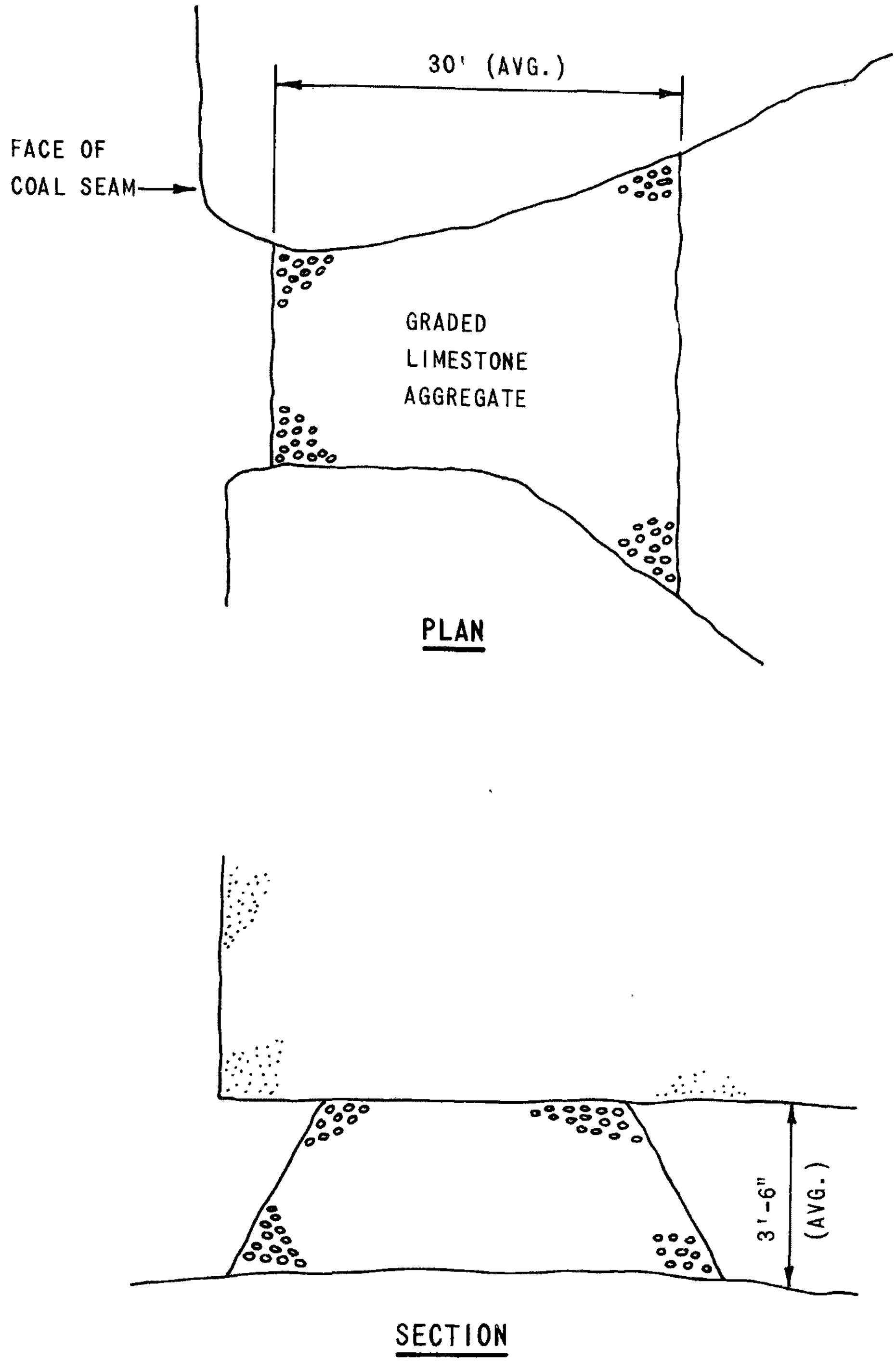


FIGURE 13 - PERMEABLE MINE SEAL

This venting of the mines will insure that the seals will not be subjected to an excessive head of water. The top of the vent will be about 33 feet above the top of the coal seam at Mine 47 (Elevation 833). Water standing to this elevation will submerge all the reactive components through all of the old workings in this mine complex. Vents will consist of several 6-inch diameter vertical holes drilled into the workings from the slope above the mine openings in the 40-52 series. An overflow will be provided at Elevation 833. Clay pipe will carry overflow from the mines to the bottom of the hill.

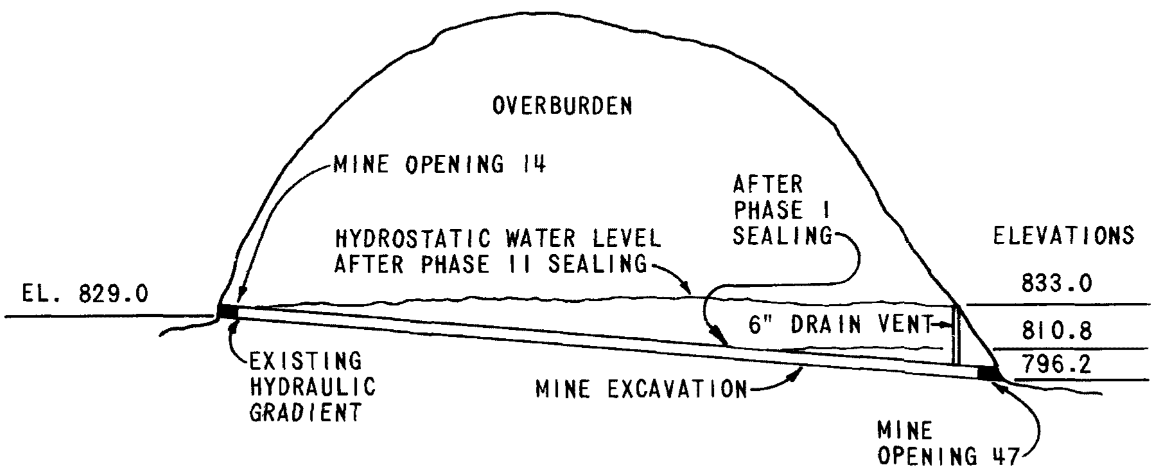


FIGURE 14 - CROSS-SECTION AND WATER ELEVATIONS

One 3-inch diameter sampling hole will be drilled from the top of the hill into the mine complex at a location designated by the Division of Geological Survey of the Ohio Department of Natural Resources. This 3-inch diameter hole will be equipped for sampling air and water within the mine.

The anticipated water surface elevation in the mines following the completion of Phase I and Phase II is shown on Figure 14.

Phase 3 - Mine Sealing

Sealing Mine Openings 76 through 103 has been considered both as an alternative to sealing Mine Openings 14 through 55 and as a portion of a total program for the entire area. This series of mines is located southeast of Big Four Hollow Road. At present, drainage emits from Mine Openings 88 and 91.

Core borings taken at Mine Opening 45 are believed to be typical of this area also. Factors influencing the design and construction of mine seals in this area based on visual inspection of the mine openings and the surrounding terrain are the same as previously outlined relative to Phases I and II except that the coal outcrop and mine openings are generally located nearly 20 feet above the valley floor. This presents a severe access problem which has added to the estimated cost of this phase.

A sealing program in the Mine Opening 88 Complex could be accomplished in two parts. First efforts would seal Mine Openings 76 through 92 excluding 81, 82, and 83. Field inspection has shown that Mine Openings 81, 82, and 83 are not physically connected to the Mine 88 Complex although a small amount of seepage was noted on the backwall at Mine Opening 81.

The solid plug-type Mine Seal previously described is recommended for this complex. Pressure grouting will be provided over and directly adjacent to the mine seals. Remedial pressure grouting will seal seepage areas that develop as water levels build up in the abandoned mines.

The second part of Phase III mine sealing would begin after the period required to evaluate the initial activity and would involve sealing Mine Openings 93 through 107. Maximum hydrostatic head developed in this series would be at an elevation approximately 17.0 feet above Mine Opening 88.

Based upon results from the initial sealing, permeable mine seals could be considered as an alternative for Mine Openings 98 through 107 where the hydrostatic head is not excessive. Pressure grouting over and adjacent to Mine Openings 98 through 107 has not been included in the comparative cost estimates developed for Phase III.

Cost Estimates

A cost estimate has been prepared for each of the elements in the total mine drainage abatement program. These costs are summarized in Table 5. Figures presented are based upon funds expended to date where applicable and on anticipated 1972 cost levels for the remaining elements. The cost of mine seals has been varied to reflect field conditions and the type and size of bulkhead which will be provided.

TABLE 5

PROGRAM COST ESTIMATE

Land Acquisition Costs

Name	Interest	Acres	Cost
Harkless	Fee	39.60	$ 5,000
Yates	Fee	160.00	15,100
Sheffield	Fee	941.75	67,800
Fuller	Fee	45.00	50,000
Eggleston	Fee	70.00	7,100
Powers	Fee	80.00	5,100
Taylor	Fee	147.00	15,200
Bray	Fee	390.00	35,000
McDaniel	Fee	100.04	21,500
McDaniel	Fee	182.00	18,200
Mead	Surface	1,030.00	69,195
Ogan Heirs	Mineral	1,030.00 (1)	52,000 (2)
Fuller	Fee	20.00	30,000
White	Fee	48.00	30,320
McDaniel	Fee	55.00	25,000 (3)
Ogan Heirs	Fee	114.00 (4)	37,000 (3)
Total			$431,515 (5)

(1) In watershed - total parcel is 2,637.00 acres.
(2) Not included in request for matching funds.
(3) Estimated cost - transaction not finalized.
(4) In watershed - total parcel is 247.00 acres.
(5) Funds expended.

Refuse Removal

Equipment Operators	$ 13,920	
Supervision	6,080	
Lowboy and Tractor	1,273	
Bulldozer	4,400	
Grader	2,550	
Belt Loader	665	
Dragline	1,800	
Dump Truck	9,120	
Hydroseeder	192	
Total		$ 40,000 (1)

Consultant Services
(Not including design fees or resident supervision)

Base Line Water Quality Study	$ 19,000 (1)	
Feasibility Study	16,500	
Post Construction Studies and Report	30,000	
Total		$ 65,500
Flow Monitoring Installation and Equipment Total		$ 58,616 (1)

Phase I Mine Sealing

Preliminary Location of Outcrop	$ 4,500
Mine Openings 40, 41, 42, 46, 48 49, 50, 51, & 52	
Site Preparation	13,500
Mine Seals - 9 @ 6,000 each	54,000
Mine Openings 43, 44, & 45	
Site Preparation	6,000
Mine Seals - 3 @ 8,000 each	24,000
Mine Opening 47	
Site Preparation	2,500
Mine Seal	15,000
Mine Seal and Remedial Grouting	
Site Preparation	2,500
Drilling	19,800
Grouting	40,000
Subtotal	$181,800

(1) Funds expended.

Program Surveillance	5,000	
Administration, Engineering and Contingency	40,200	
TOTAL		$227,000

Phase 2 Mine Sealing

Preliminary Excavation of Outcrop	7,000	
Mine Openings 53, 54, & 55		
Site Preparation	7,500	
Mine Seals - 3 @ 9,000	27,000	
Mine Openings 14 through 39		
Site Preparation	36,400	
Mine Seals - 7 @ 4,900	34,300	
Mine Seals - 21 @ 6,000	126,000	
Mine Seal and Remedial Grouting		
Site Preparation	6,100	
Drilling	46,300	
Grouting	99,600	
Subtotal	$390,200	
Program Surveillance	15,000	
Administration, Engineering and Contingency	82,300	
TOTAL		$487,500
Total Estimated Project Cost		$1,310,131

Cost Comparison

To arrive at the most cost effective mine drainage demonstration program, a comparison was made of the several alternatives available for sealing mines in the study area. The comparison evaluated sealing Mine 47 Complex as contrasted to Mine 88 Complex. In both cases a reduction of acid discharge as a result of the mine sealing program was estimated to be 60 percent. In the case of the Mine 47 Complex, an acid reduction of 321,000 pounds per year or 46 percent of the total acid entering Lake Hope would be contained. Based on the estimated $714,500 cost of sealing this complex as previously presented, unit costs for the program amount to $2.23 per pound of acid reduction.

The estimated cost of the Phase III sealing program as an alternative to Phases I and II previously presented is developed in Table 6.

A cost-effectiveness evaluation for the Mine 88 Complex indicates a reduced acid load of 225,000 pounds per year (32 percent of the total entering Lake Hope) at a cost of $601,900. The unit cost of acid reduction for this series of mine openings is $2.57 per pound.

Based on the foregoing analysis, sealing of the Mine 47 Complex was deemed to be the most cost effective. This conclusion forms the basis for establishing the recommended program as outlined herein. Water quality improvements which further justify proceeding in the recommended manner are discussed in "Part V - Project Effectiveness."

TABLE 6

PHASE III COST ESTIMATE

Initial Mine Sealing - Mine Openings 76-80 and 84-92.		
Site Preparation	$ 48,000	
Mine Seals - 15 @ 6,000	90,000	
Mine Seal and Remedial Grouting		
Site Preparation	10,500	
Drilling	40,500	
Grouting	81,000	
		$270,000
Second Stage Mine Sealing - Mine Openings 93-107		
Site Preparation	$ 42,000	
Mine Seals - 14 @ 6,000	84,000	
Mine Seal and Remedial Grouting		
Site Preparation	6,500	
Drilling	26,000	
Grouting	53,000	
		$211,500
Administration, Engineering and Contingency		120,400
TOTAL ESTIMATED PHASE III COST		$601,900

Program Surveillance

The U. S. Geological Survey stream gaging and sampling program conducted in cooperation with the State of Ohio has previously been outlined. This program will be continued to provide the basic data for evaluation of program effectiveness.

As outlined, the stream at points 310, 320, and 420 will be monitored *continuously for flow, pH, temperature and conductance.* Dissolved oxygen will also be continuously determined at gaging station 310. In addition, samples will be collected at each of the three stations twice a month for analysis for the list of parameters presently being evaluated as specified in "Part III - Inventory and Forecast."

Upon completion of Phase I and Phase II mine sealing, there should be no free flowing discharge from the sealed mine complex except for the vents or high level drains which will be provided to relieve hydrostatic pressure at an elevation above all of the old mine workings. Provision will be made for monitoring this discharge from the mined area either on a continuous or periodic basis depending upon the flow conditions which develop.

The combination of the continuous monitoring of stream flow and collection of data related to the vented discharge from the mined area will adequately establish the effectiveness of the mine drainage abatement project.

The final aspect of program surveillance will involve an evaluation of all data collected and preparation of a summary report on the abatement project. Additional intensive sampling of sources and amount of continuing mine drainage discharges will be undertaken at that time. This phase of activity will be deferred until adequate records are available to establish trends in mine drainage production from the project site. A minimum of two and possibly as many as four or five years from the completion of construction is recommended to provide time for the system to stabilize and for adequate records to be accumulated.

Emergency Procedures

All possible precautions will be taken during the period of construction to assure that no slugs of acid contaminated water are discharged into the streams at the project site. If it becomes necessary to reduce the volume of water impounded in the old mines at any point during or after the construction activity, discharge rate will either be controlled so that there are no detrimental effects or lime will be added to maintain the desired pH.

As previously noted, all discharges from the area will be routinely monitored. Developing hazarous conditions will be noted and appropriate emergency measures undertaken if necessary to cope with a particular situation.

PART V - PROJECT EFFECTIVENESS

Water Quality Improvements

The effectiveness of a mine sealing project is related to a number of natural variables, most notably hydrologic and geologic factors. The complexities inherent in such a natural system compounded by man's disruption of natural phenomena through mining and construction of mine seals make rigorous evaluation of the expected mine drainage pollution reduction extremely difficult. A number of mine sealing programs has been undertaken in recent years. However, at the present time published data on the reduction in acid load to area streams attributable to mine sealing is quite limited.

The Moraine State Park project as reported at the Third Symposium on Coal Mine Drainage Research at Pittsburgh in May, 1970, has yielded preliminary results indicating 70 to 80 percent reduction in mine drainage discharge as a result of a mine sealing program. Limited data on other projects indicates this to be a reasonable order-of-magnitude expectation for mine sealing effectiveness.

For the purpose of this report, an overall reduction in acid load to the stream from a mine sealing project has been taken as 60 percent of the present average discharge. This is probably a conservatively low percentage and there is a good possibility that better results will be realized.

On the basis of 60 percent reduction of the acid load from sealing Mine 47 and the interconnected complex, a total of 321,000 pounds less of acid will reach Sandy Run than at the present time. The anticipated net result of this reduced acid discharge will be reflected in an approximate 26 mg/l reduction in the average acid concentration in Sandy Run at the USGS gaging station and 14 mg/l in Lake Hope. The average present acid concentration in Lake Hope as reported in the Base Line Water Quality Report is 31 mg/l with the concentration frequently ranging between 20 and 30 mg/l. Therefore, when the effects of the mine sealing program are fully realized, the average net acidity in Lake Hope will nearly be cut in half from present levels.

The pH increase corresponding to the indicated reduction in total acidity is impossible to predict, since there is no practical mathematical correlation between acidity and pH. Some improvement in pH is certain, however, and a reasonable estimate of the prevalent pH range in Lake Hope after completion of recommended mine sealing improvements is 6.0 to 7.0. An average pH increase in Sandy Run of 1.0 units is also expected.

Comparatively, if the Mine 88 Complex is sealed, a net reduction of 18 mg/l of acidity in Sandy Run and 10 mg/l in Lake Hope might be expected. This would yield a pH improvement in the order of 0.5 units less than could be achieved by sealing the Mine 47 Complex. In view of relatively minor cost differential between the two alternatives and the substantially better water quality results which can be achieved, the recommendation for proceeding initially with Phases I and II appears fully justified.

The total estimated cost for the recommended Phase I and Phase II Lake Hope mine drainage demonstration program has previously been presented as $1,310,131. Amortizing this cost at 5 percent interest over a 50-year period yields an annual capital recovery cost of $71,769. For the estimated acid load reduction of 321,000 pounds per year, an annual unit cost for the mine drainage abatement program is calculated at $447 per ton of acid discharge reduction.

The proposed mine drainage abatement project would eliminate approximately one percent of the total acid mine drainage presently generated within the Raccoon Creek Basin as reported in the November, 1967, "Recommendations for Water Pollution Control, Raccoon Creek Basin, Ohio" prepared by the Ohio Basin Region of the Federal Water Pollution Control Administration.

Other Demonstration Values

The proposed mine drainage abatement demonstration project is located within a widely used state park. As a result, there is a considerable exposure of the public to efforts by state and federal agencies to abate mine drainage pollution and improve the environment.

With the existing state park facilities as a focal point, interpretive facilities could be developed to illustrate mining techniques, sources of acid mine drainage, pollution abatement techniques, and to put the entire field of coal extraction and mine drainage abatement in proper perspective.

Benefits

The greatest single benefit attributable to the proposed mine drainage demonstration project will relate to the improved recreational value of Lake Hope and indirectly, of all other facilities in Lake Hope State Park. The Lake Hope site is extremely beneficial to the general public, as 658,938 visitors visited the park in 1970.

At similar parks throughout the state of Ohio, approximately 10 percent of the visiting public utilizes the water resource for fishing. By improving the aquatic environment of Lake Hope, fish reproduction will return to normal and fisherman visitations to Lake Hope might increase by as much as 55,000 persons annually. As a result, utilization of the entire Lake Hope State Park and Zaleski State Forest complex could be expected to increase. This would have a significant positive influence on the local economy as a result of increased visitor days of activity.

Swimming and recreational boating would also be directly benefitted by improved water quality in Lake Hope. Although both activities are presently carried on in the lake, enjoyment is impaired due to the acidic conditions of the water.

Removal of the random coal refuse remaining from active mining operations greatly enhances the aesthetics of the area. The coal refuse generally did not support a vegetative cover and, therefore, was a visual detraction from the general natural setting of the area. With removal or burying of the coal refuse and surface restoration of the affected sites, the entire region will soon be restored to a more natural and pleasing condition.

General area visual conditions will also be improved as a result of the mine sealing efforts. Mine drainage normally carries a high iron concentration which precipitates out to create a rust colored coating on stream banks and objects in contact with the water. Partial relief of this condition will be realized in Sandy Run as a result of the proposed program.

PART VI - IMPLEMENTATION AND OPERATION

Project Responsibility

Responsibility for initiation and follow-through on all aspects of the mine drainage abatement demonstration project is the responsibility of the Ohio Department of Natural Resources. All divisions of the department have assisted in the accumulation and evaluation of the preliminary development of the proposed project. Other state and federal agencies have also been involved in the planning and design of a workable program.

Jurisdictional authority is clearly available to the Department of Natural Resources to carry out the mine drainage abatement program. Land is in state ownership and therefore succeeding phases of the project can and will proceed immediately.

The mine seals are anticipated to require very little routine maintenance. Ohio Department of Natural Resources personnel now assigned to Lake Hope can regularly monitor the physical condition of the seals as they go about their regular duties at the site. Responsibilities and procedures for water quality surveillance has previously been outlined.

Program Schedule

Figure 15 outlines a schedule under which the various elements of the mine drainage abatement demonstration project may be undertaken. As shown, the period between December, 1971, and June, 1972, is allotted to finalizing the feasibility report and preparing construction plans and specifications. The project will be advertised for bidding during July, 1972.

Phase I mine sealing is scheduled for August, 1972, through January, 1973. This will be followed by a minimum of four months of evaluation of the initial sealing, during which decisions will be made regarding the remedial grouting in Phase I and development of the details of Phase II mine seal. This second phase of sealing will be undertaken during the June, 1973, through February, 1974, period.

The final project report is scheduled for production in February through June, 1976. This will allow two full years for data collection following completion of Phase II mine sealing. However, as has been previously mentioned, it may be desirable to increase or decrease the time for data accumulation prior to producing the final project document.

Water quality monitoring is seen to be a continuing effort throughout the span of project activity. Monitoring of water quality characteristics will continue up to five years beyond the period supported by demonstration grant funds.

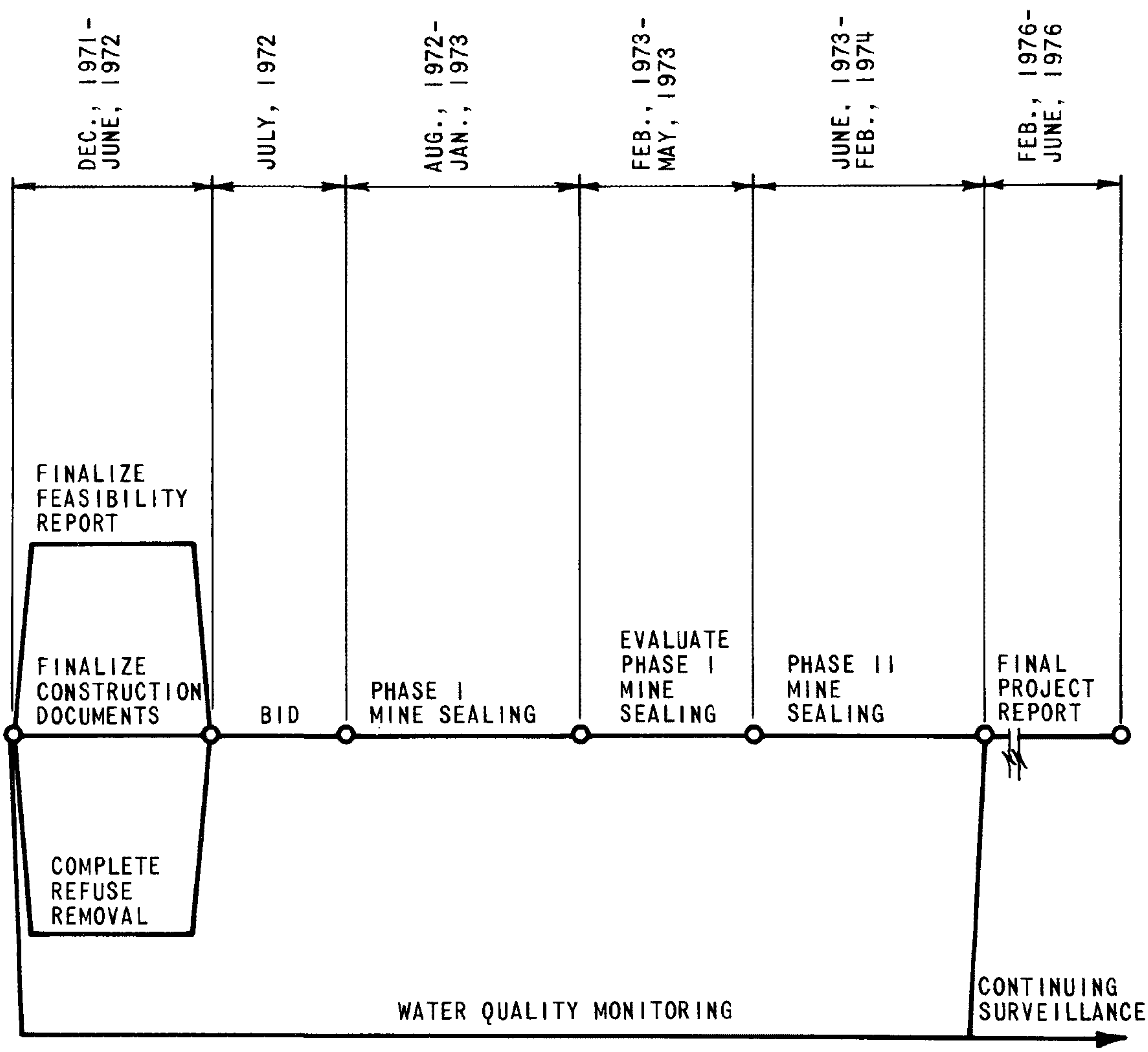


FIGURE 15 - PROGRAM SCHEDULE

APPENDIX A

Lake Hope Base Line Water Quality

PART I - INTRODUCTION

Scope

Presented herein are the results of studies made to characterize the origin, quantity, and methods of control for acid mine drainage to Lake Hope from tributary streams. It is the principal objective of this study to quantify the acid production to serve as a basis for corrective action. The major factor involved is the planning and implementation of a sampling and testing program to produce the required data.

Specific items included in the scope of studies are as follows:

1. Participate in the selection of sites for two temporary flow monitoring and sampling stations.
2. Prepare design drawings of the flow measuring structures and associated housing for instrumentation and sampling of the two new stations, as well as supplemental facilities at an existing USGS gaging station on the main stem of Sandy Run.
3. Conduct a preliminary sampling and testing program prior to monitoring station construction for a period of three months. The purpose of this program is to provide analytical data not only on the Sandy Run and tributary streams, but also individual sources of acid mine drainage. Subsequent to installation of monitoring stations, a second three-month program is to be implemented.
4. On the basis of field investigation and data compiled, the quantity and composition of acid mine drainage is to be determined. This also is correlated with precipitation events.
5. Identify and quantify acid production from various strip mine areas and refuse piles.
6. Determine the contribution of acid mine drainage into Lake Hope resulting from unmined areas.
7. Evaluate Lake Hope bottom muds to determine the effect of acid mine drainage on present and future ecology of the lake.

8. Develop a specific recommendation for a program of mine sealing or other remedial techniques to be implemented.
9. Establish guidelines for future utilization of data collected.

Study Area

Lake Hope is located in Vinton County, Ohio, some 60 miles southeast of Columbus. Access to the area is generally from U. S. Highway 50 which runs east and west, south of the lake and by U. S. Highway 33 which connects Athens and Columbus. State Highway 278 connects these two major routes and passes directly adjacent to Lake Hope and parallel to Sandy Run in the valley above the lake. Figure 1 is a map showing Lake Hope and the tributary drainage basin.

Lake Hope State Park with Lake Hope as the focal point is located deep within the 19,000-acre Zaleski State Forest. The Department of Natural Resources, through a development program which dates back to the early 1930's, has continually added to the park facilities so that extensive recreational opportunities are now available in the area. The attractive dining lodge and numerous cabins provide basic visitor accommodations. Park facilities provide for hiking, horseback riding, boating, swimming and camping.

Lake Hope was constructed during 1938-1939 and filled with water during the spring of 1939. The total drainage area tributary to the Lake is slightly over 10 square miles. Approximately 126 acres of water surface are provided; the estimated total storage volume in the lake at the time of construction was something over 1,500 acre-feet.

Previous Report

The studies reported herein are a further development following the study "Lake Hope - Report on Acid Mine Drainage Program" prepared for the Department of Natural Resources by Stanley Consultants. That report documents a number of previous studies and reports on field investigations and previous program considerations. It also describes potential means of providing an acid mine drainage abatement program. The data and the various prior reports referenced therein have been used as background material for these studies.

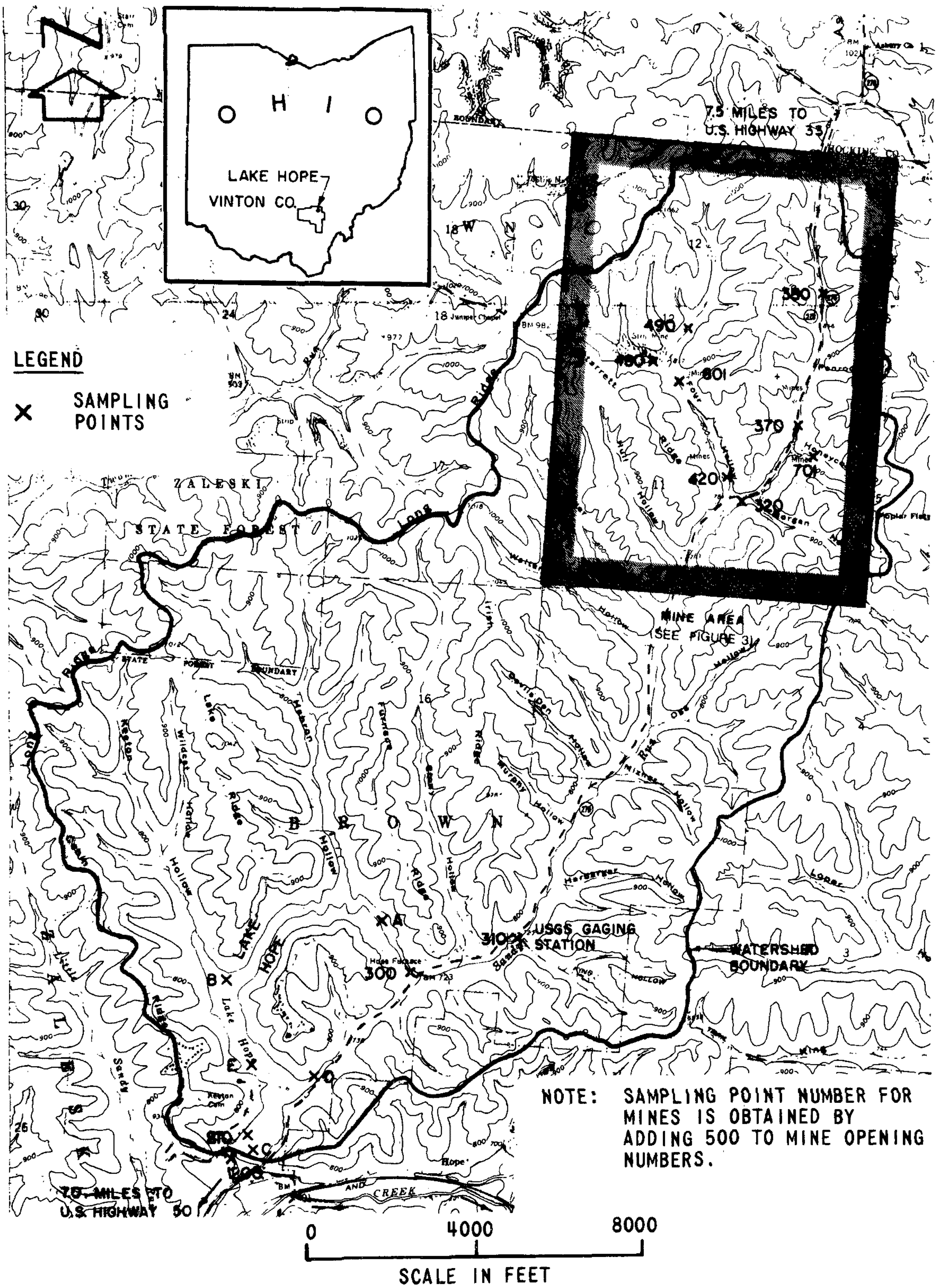


FIGURE 1 - LAKE HOPE DRAINAGE BASIN - VICINITY MAP

PART II - WATER CHARACTERISTICS

Data Requirements

It is necessary that sufficient data be obtained to quantify the acid contribution of Sandy Run to Lake Hope. Also, significant acid contributions to Sandy Run from major tributary sources must be defined. Supplemental information in the form of data on iron, sulfate and dissolved oxygen content as well as temperature and conductivity will aid in a more complete characterization of water quality.

In prior reports, a considerable amount of data has been presented which show results of pH tests made on water samples from Lake Hope and tributary sources. However, information on total acid content has been very limited.

The pH parameter measures only the concentration of hydrogen ion. It does not measure total acid concentration. An example of the lack of correlation between pH and acidity is shown on Figure 2 where pH and acidity of samples from Lake Hope are compared. Analyses of samples from other points where acid concentration is higher would show even less correlation. Therefore, the major thrust in obtaining data was to measure both water flows and acid concentration to arrive at acid quantities on a weight basis.

Sampling and Gaging Programs

The sampling and gaging surveillance program was initiated in April, 1970. It consisted of two parts: one executed by United States Geological Survey (USGS), and the second by Stanley Consultants.

Initially, the USGS program consisted of flow measurement and sampling at two-week intervals from three points shown on Figure 3:

1. Sandy Run at an existing gaging station a short distance upstream from Lake Hope (Sample Point 310)
2. Big Four Creek near the point where this stream enters Sandy Run. (Sample Point 420)
3. Sandy Run a small distance upstream from the point at which Big Four Creek enters (Sample Point 320)

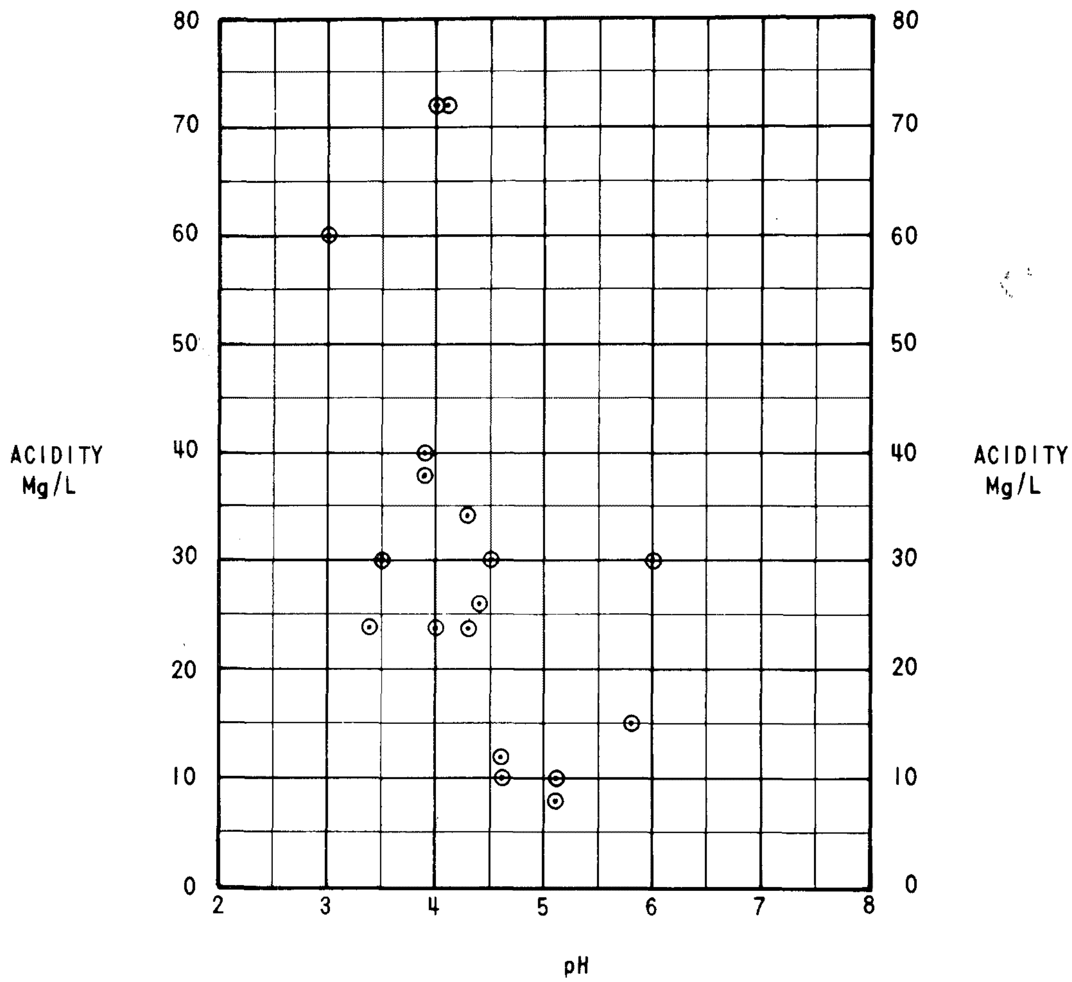


FIGURE 2 - ph VS ACIDITY
LAKE HOPE

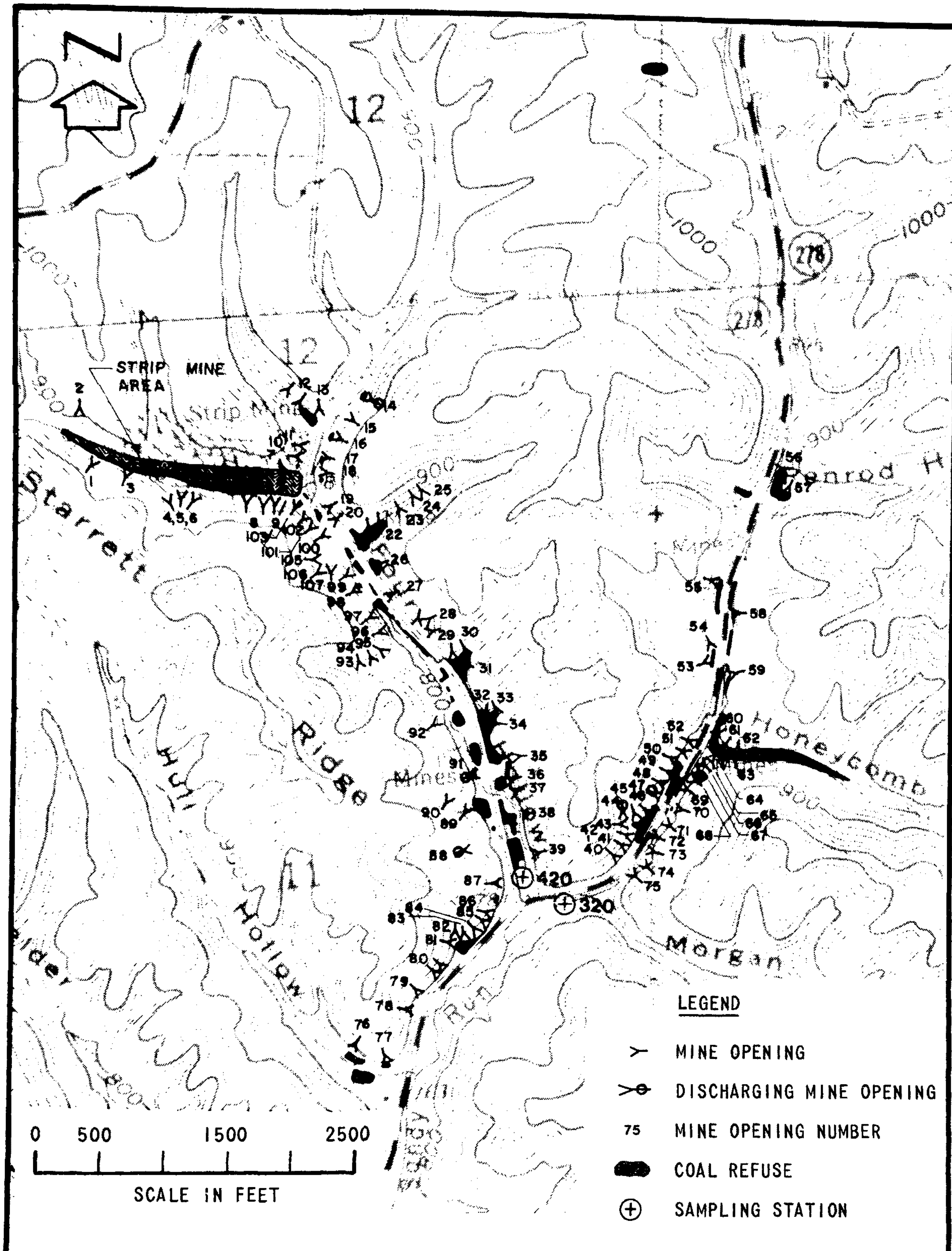


FIGURE 3 - LAKE HOPE DRAINAGE BASIN - MINE OPENINGS

Flows at Sample Point 320 have been determined from a continuous stage recorder at that location. Prior to installation of monitoring stations, flows in Big Four Creek (Sample Point 420) and in Sandy Run upstream from Big Four Creek (Sample Point 320) were obtained by means of a current meter. Samples were taken manually from each of these three points for subsequent laboratory analysis. Temperature and pH measurements were made at the time of sampling. After installation of monitoring stations described later herein, all flow measurements were taken at these points from stage recorders. Samples continued to be taken at two-week intervals for more complete laboratory analysis, while other parameters were measured on-site from continuous monitoring units.

The second phase of the gaging and sampling program was performed by Stanley Consultants. The initial scope of the project contemplated two sampling periods in this phase. The first period was to be an intensive three-month sampling program followed by a reduced program for a three-month period. To coordinate with later than anticipated construction of the monitoring stations, the order of sampling was reversed. The initial period from April, 1970, through June, 1970, including sampling at approximately two-week intervals. The subsequent stage, initiated in early March, 1971, and extending through May, 1971, consisted of samples taken twice weekly.

The intent of this phase of the program was to gage and sample sources of acid mine drainage such as mine openings and refuse areas. A survey of mine openings was made which revealed that only three had flows in excess of a few gallons per minute. These three mine openings were provided with 90 degree V-notch wiers for flow measurement. Such measurements have been made and samples have been taken throughout the two sampling periods. In addition, stream samples and other small flows entering the stream were sampled. These included one sample point on Sandy Run upstream from the acid mine drainage area. Occasional samples have been taken from other mine openings and refuse areas.

Monitoring Stations

To provide a continuing record of water flow and water characteristics, monitoring stations were constructed. Design of these facilities was included as a part of the studies reported herein.

Facilities were added to an existing USGS gaging station on Sandy Run to provide a continuous sample for monitoring. In-line analytical equipment is arranged to measure temperature, pH, conductivity and dissolved oxygen. Location of these facilities is at Sample Point No. 310 shown on Figure 3.

Two other monitoring stations were constructed. One is located on Big Four Creek just upstream from the point at which it flows into Sandy Run. This is the same location as that of Sample Point No. 420. The other station is located on Sandy Run just upstream from the point at which Big Four Creek enters. This is the same location as Sample Point No. 320. These stations sample and measure pH, conductivity and temperature. In addition, they are provided with a primary measuring flume and gaging facility to measure flow.

Testing Programs

Procedures used in obtaining samples for testing have been described previously.

On those samples which are obtained at two-week intervals by the United States Geological Survey, the following tests have been run:

1. Iron
2. Manganese
3. Dissolved Solids (Residue on evaporation at 180 C.)
4. Total Hardness
5. Acidity (to pH = 8.3)
6. Sulfate
7. Specific Conductance
8. pH
9. Flow

Since the automatic monitoring stations have been placed in operation, these stations have been continuously recording data on river stage, pH, specific conductance, and temperature. Dissolved oxygen is also monitored at Sample Point 310. Data on river stage (flow), pH, and temperature would be required under any sampling program. Continuous monitoring provides more complete data.

Information on dissolved oxygen is desirable to make sure that no critical oxygen deficit exists. Iron content of the mine drainage is for the most part present in the ferrous form which is an effective reducing agent, particularly when the pH is increased to near the neutral point. Such ferrous iron can therefore reduce the dissolved oxygen content of the water. Organic matter present as vegetation degradation products can also exert an oxygen demand.

Although not specifically measuring acid content, conductivity does provide a means for approximate appraisal of acid content. The acidity-conductivity relationship is shown on Figure 4 for three sampling points.

The program of manual sampling at the three stream locations by USGS is continuing at two-week intervals. Analysis of these samples will provide more complete data to supplement the continuously recorded parameters.

Analysis made by Stanley Consultants on samples taken from mine openings, refuse piles, and streams include the following:

1. Flow
2. pH
3. Temperature
4. Acidity
5. Sulfate
6. Iron

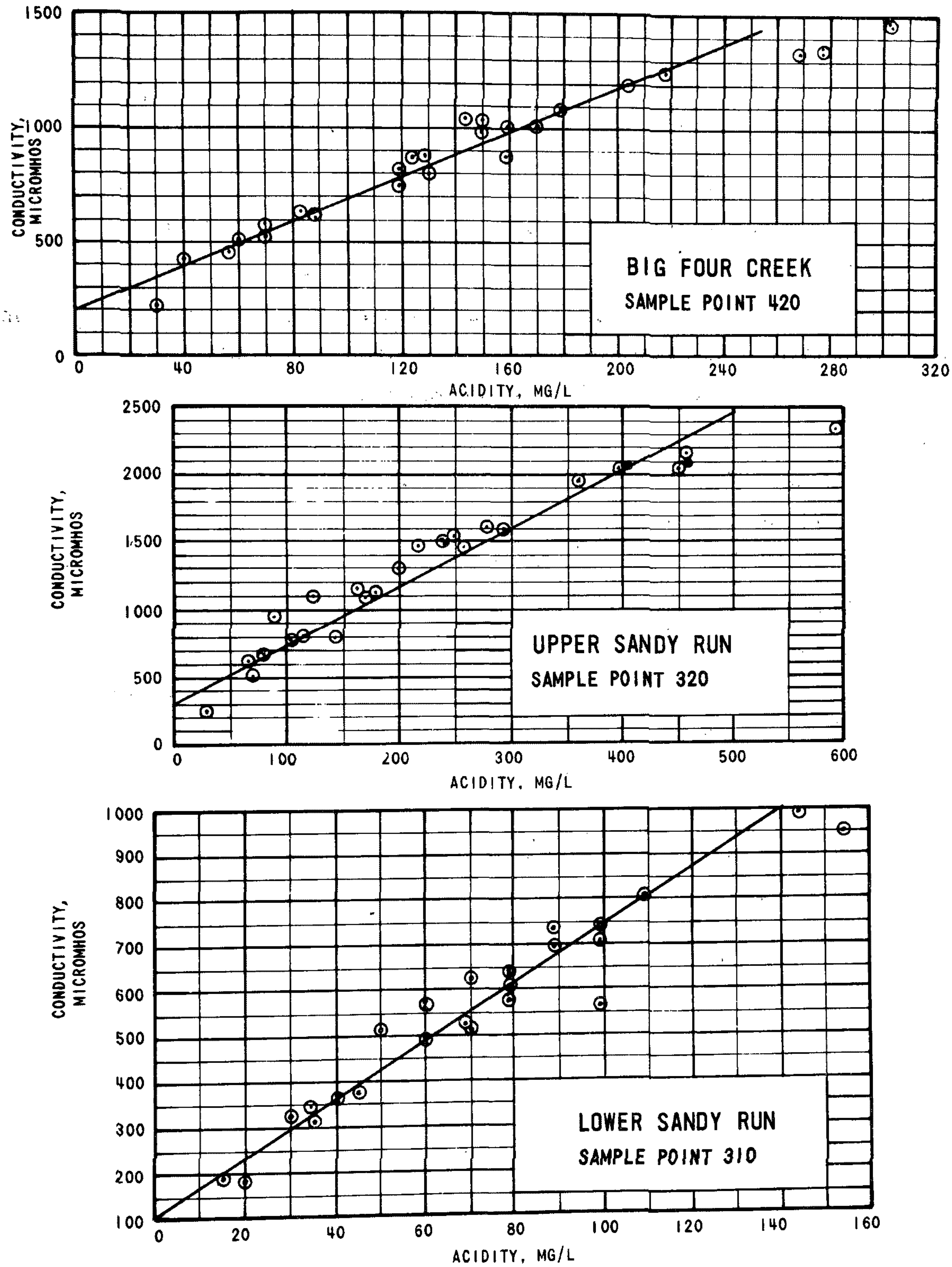


FIGURE 4 - CONDUCTIVITY VS ACID CONTENT

PART III - DATA DEVELOPMENT

Analytical Methods

Samples taken at two-week intervals by the United States Geological Survey were analyzed by standard procedures.

All samples taken by Stanley Consultants were analyzed either in a field laboratory set up in the Nature Center of Lake Hope State Park or at facilities of Ohio University in Athens. Temperature measurements were made at the time samples were taken. Other analyses were made within several hours after sample collection.

Procedures used in analysis of samples collected by Stanley Consultants are as follows:

1. pH was determined by an electric pH meter, standardized on each day of use with buffer solutions of pH = 4.0 and pH = 7.0.
2. Acidity was determined by titration with 0.02N, sodium hydroxide to the phenolphthalein end point (pH = 8.3). This end point was checked during the test on some samples by means of the pH meter. Sample preparation included addition of four drops of 30 percent hydrogen peroxide followed by boiling for two minutes with subsequent cooling to room temperature before titration. This procedure accelerates oxidation of iron to the ferric form. By cooling prior to titration, the interference from magnesium and aluminum encountered with titration at the elevated temperature is minimized. The technique used is essentially the same as Method 2 described by Payne and Yeates in "The Effects of Magnesium on Acidity Determination of Mine Drainage," (Third Symposium on Coal Mine Research - 1970). The end point of 8.3 was selected in the interest of standardization. Titration to a lower pH end point may have been desirable. However, titration curves are presented later herein which illustrate the difference in acidity measured to other end points.

3. Iron concentration was determined by a colorimetric technique using 1, 10 - phenanthroline to produce a color related to concentration. The colorimeter used was equipped with a filter to provide light at a wavelength of 510 millimicrons. A commercial reagent marketed as Ferro Ver was used. This method is in essential agreement with Standard Methods, 12th Edition, page 156.
4. Sulfate was determined by a turbidimetric method based on precipitation of the sulfate ion in an acid media with barium chloride. Silica was present at a concentration below the interference level of 500 mg/l. The colorimeter used in this determination was equipped with a filter to produce light at a wavelength of 420 millimicrons. A commercial preparation, Sulfa Ver III, was used. This method is in essential compliance with that shown in Standard Methods, 12th Edition, page 291.

Analytical Data

A detailed tabulation of flow and chemical data is shown in Appendix A. This table is a computer printout in which all flows are converted to gallons per minute. The weight of each constituent in pounds per day is computed for those instances where both a flow and concentration are available.

Data shown is as follows:

1. The first column indicates the date. The designation 052870 is May 28, 1970.
2. The second column indicates sample location. The location of sample points other than mine openings are shown on Figure 1 and Figure 3.

Samples are designated as follows:

Number	Location
200-299 (*)	Lake Hope
300-399	Sandy Run - Main Stem
499	Big Four Creek
500-699	Mine Openings (by addition of 500 to opening on Figure 3)
700-799	Small Streams tributary to Sandy Run
	Small Streams and refuse drainage tributary to Sandy Run
800-899	Streams and refuse drainage tributary to Big Four Creek
(*)	Samples A through E from the lake are special samples.

3. The third column indicates the source of data and the sample number taken on that day. The letter "G" indicates data by USGS. The letter "S" indicates data collected by Stanley Consultants. The "S2" indicates the data is from the second sample by Stanley Consultants on that day.
4. Flow shown in column 4 is in gallons per minute. Data from USGS in cubic feet per second has been converted.
5. Temperatures shown are in degrees Fahrenheit.
6. Concentrations shown are as follows:

Acidity	mg per liter as $CaCO_3$
Iron	mg per liter as Fe
Sulfate	mg per liter as $CaCO_3$

7. Data in columns 8, 10 and 12 show pounds per day of the respective constituents.
8. All other data can be interpreted from column headings.
9. The use of an asterisk (*) indicates that data is not available or could not be computed from available data.

Table 1 is a compilation of chemical analysis made during July, 1971 at various locations on Lake Hope. A sample was taken from the surface and from the bottom of the lake at each point. The location of these sample points is shown on Figure 1.

TABLE 1

SAMPLES FROM LAKE HOPE

	Depth (ft)	pH	Temperature (C)	H_2S (mg/l)	Dissolved Oxygen (mg/l)
Surface Samples					
A	-	3.75	24	-0.1	8.0
B	-	4.1	27		8.0
C	-	4.1	27		8.0
D	-	4.1	27		8.0
E	-	4.1	27		8.0
Bottom Samples					
A	3	3.75	24	-0.1	8.0
B	10	4.5	27	-0.1	8.0
C	20	4.5	23	-0.1	8.0
D	6	4.3	27	-0.1	8.0
E	18	4.5	24	-0.1	8.0

Interpretation of Test Results

The main thrust of corrective actions necessary to control the influence of acid mine drainage is aimed at acidity control. With this factor corrected, the iron content of such drainage would automatically be controlled. With the pH of the water near the neutral point, and adequate natural aeration, iron will be precipitated as ferric hydroxide. The sulfate content of the water, particularly that coming from some mine openings, is quite high. However, concentration in the water from Sandy Run entering the lake has ranged from 65 to 450 mg/l. This in itself would pose no particular problem assuming that the sulfate anion were associated with a cation other than hydrogen. Nevertheless, any corrective action controlling acid entry into the lake, except neutralization, will also control the quantity of sulfate.

An attempt has been made to correlate weight flow of acid with stream flow at several points. Figure 5 shows the relationship of acid weight per day versus stream flow based on data taken at the original USGS gaging station (Sample Point No. 310) located on the main stem of Sandy Run. A curve indicating the apparent relationship between these parameters has been added, however, deviations are quite large. This is undoubtedly due to the prior history of precipitation and drainage flow. Likewise, a similar correlation has been attempted for the flow from Mine Opening No. 47 (Sample Point No. 547), which is the single largest source of acid mine drainage. Data presented on Figure 6 shows significant deviations from the apparent best fit of the curve. Such deviations indicate that the weight of the acid produced is a function of factors other than flow.

Recognizing that the oxidation of the iron sulfides is to some extent a time dependent reaction, increased flows, after a long dry period, would tend to dissolve and remove more acidic materials than a similar flow after a previous rainy period.

Stream flow measured at Sample Point No. 310 and rainfall data are shown on Figure 7 along with conductivity.

The quantity of acid in a stream reported herein is based on titration of a sample with standardized reagent to an end point of pH = 8.3. To correct acidity of flow going to the lake, an increase in pH to the range of 6.5 to 7.0 would be adequate. Therefore, the computed acid quantities could have been determined on the basis of sample neutralization to the end point of pH = 7.0. To characterize the difference between titration to these end points, a series of titration curves were prepared. Typical curves are shown on Figure 8. While the configuration of titration curves will change, even for samples collected at different times from the same source, those shown are generally representative.

The difference in acidity due to titration to different end points can be illustrated by data from Figure 8.

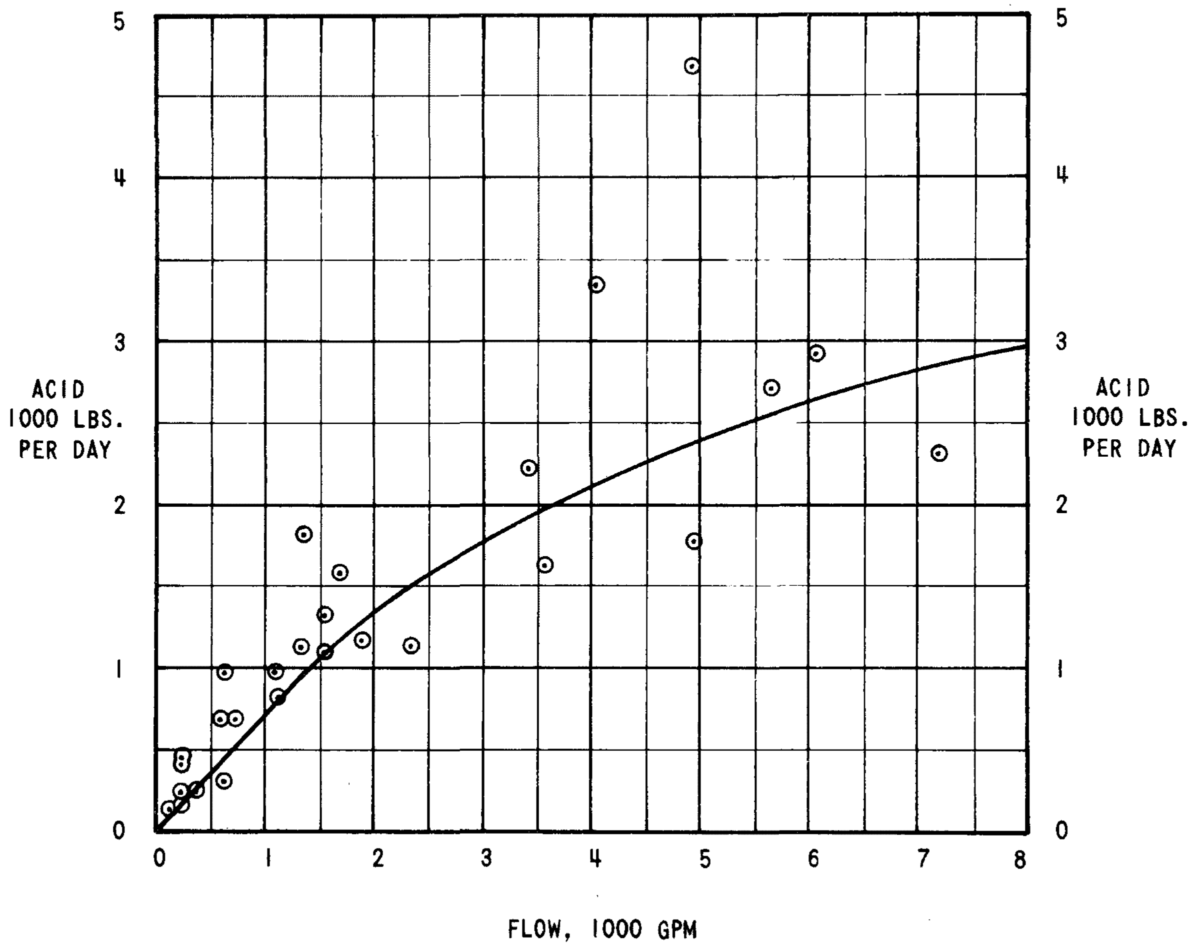


FIGURE 5 - ACIDITY VS FLOW
SANDY RUN -
SAMPLE POINT 310

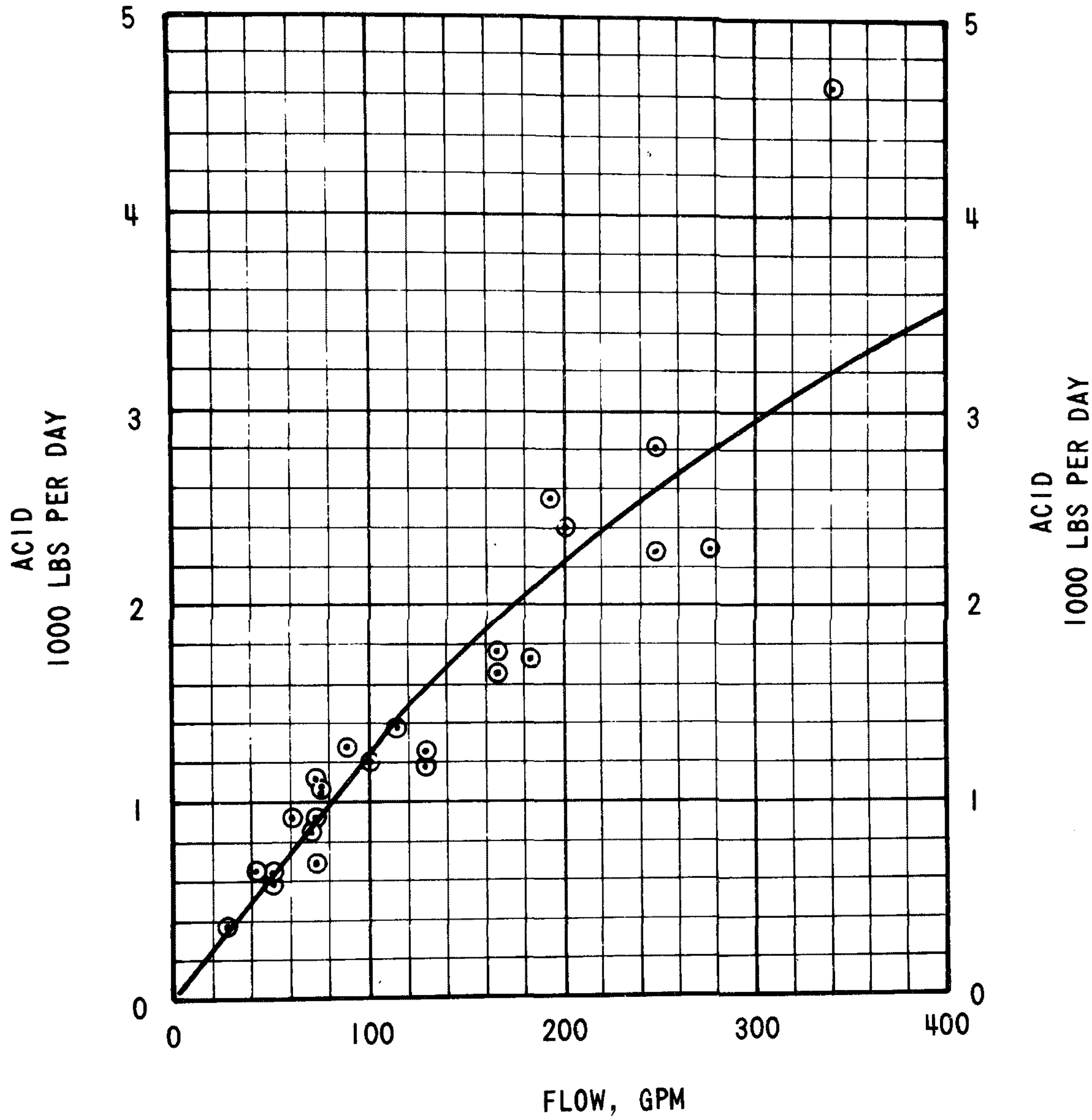


FIGURE 6 - ACIDITY VS FLOW
SAMPLE POINT 547

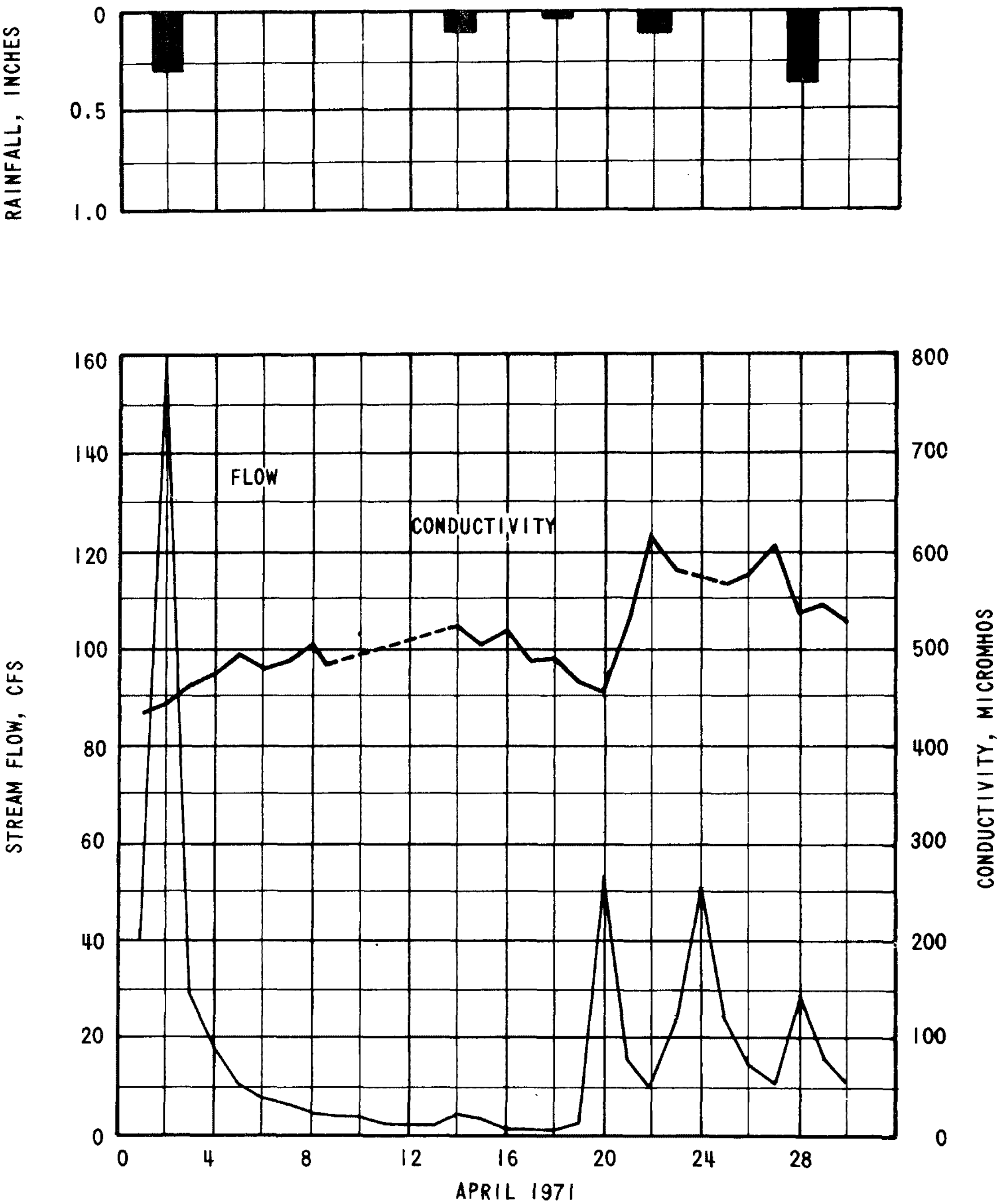


FIGURE 7 - FLOW, RAINFALL AND CONDUCTIVITY - SAMPLE POINT 310

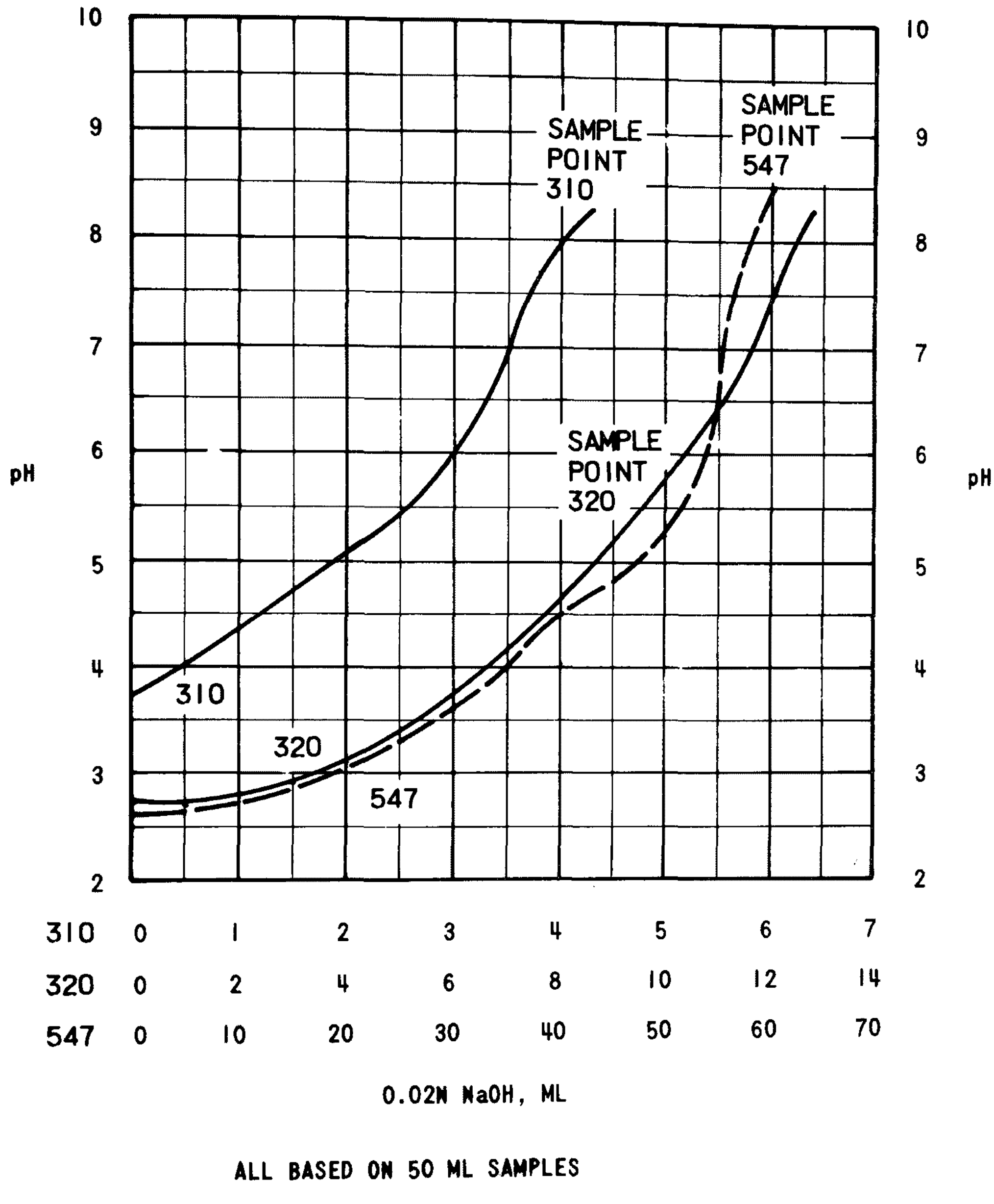


FIGURE 8 - TITRATION CURVES

For Sample Point No. 547 with titration to an end point of pH = 8.3, 59 ml of 0.02N sodium hydroxide is required. This is equivalent to an acid concentration of 1,180 mg/l expressed as calcium carbonate. Titration to an end point of pH = 7.0 requires only 55 ml of sodium hydroxide which is equivalent to an acid concentration of 1,100 mg/l. The acid concentration represented by the difference between the titration end points is less than 7-percent.

For Sample Point No. 310 titration to pH = 8.3 requires 4.3 ml of sodium hydroxide while titration to pH = 7.0 requires only 3.6 ml. These are equivalent to acid concentrations of 86 mg/l and 72 mg/l. The difference in this instance is slightly more than 16 percent.

Analysis of Lake Bottom Muds

Bottom samples were taken at various lake locations representing potentially different biological environments. These sites are as follows:

A. Near the point where Sandy Run enters the lake.

B. A point on the opposite side of the lake which receives drainage from an area free of acid mine water drainage.

C. Near the dam at the lower end of the lake.

D. A small cove opposite the boat dock.

E. A point near the widest and possibly the deepest part of the Lake.

These locations are shown on Figure 1.

The survey of Lake Hope revealed a scarcity of benthic fauna when compared to Tycoon Lake in Gallia County, Lake Catherine in Jackson County and similar aquatic ecosystems in the same geographic area which lack acid mine drainage.

The relative abundance of organisms found at the different sampling sites is shown in Table 2. The greatest abundance and widest diversity of species were found at Site D. Chironomid (midge) larvae were the most abundant organisms at all sites. These larvae are capable of living in an extremely polluted environment. On the other hand, dragon flies, a group usually quite abundant when water is near the neutral point are rare in this lake.

While some resistent species of fish can survive in water of low pH for long periods, direct tolerance to low pH water by desirable species is only a part of the problem in lake management. Also, to be considered is the effect of low pH on the entire biota as it effects the complete food chain of the ecosystems.

TABLE 2

RELATIVE ABUNDANCE OF BOTTOM ORGANISMS FOUND

	A	B	C	D	E
Coleoptera (Bettles)					
Dyticidae (larvae & adults)	xx		xx	xx	
Gyrinidae (larvae & adults)	x		xxx	x	
Diptera (Flies)					
Chaoborus (larvae)		xxx	xxx	xx	xx
Chironomids (larvae)	xxx	xxx	xxx	xxx	xx
Megaloptera					
Sialis (Alderfly)	x				
Odonata - dragonflies/damaelflies (Naiads)					
Coenagrion		xx	x	xx	x
Ishnura		x	x		
Gomphus		x		x	x
Macromia		x	x		
Libellulidae		xxx	xx	xx	
unidentified		x			
Trichoptera (caddisflies)					
Hydropsyche				x	
Hemiptera					
Corixidae (water boatman)	xx		x	xxx	x
Notonectidae (backswimmer)	x				
Oligochaeta (earthworms)	xx	xx		x	
Nematoda (roundworms)	x			x	
Crustacea					
Crayfish		x	xxx	xx	xx

x = only one or two per sample

xx = small numbers

xxx = abundant in sample

Samples were obtained using (Eckmann) Dredge and dip nets.

Mechanisms of Acid Formation

The source of both iron and sulfur in acid mine drainage is the iron sulfides found in the overburden and material adjacent to the coal seams. While other forms of iron and sulfide compounds may be present, the most common materials are pyrite and marcasite. Contact of this material with air and water produces sulfuric acid and the iron sulfates.

A detailed description of the oxidation processes are available from a number of sources, however, they are described briefly below:

(1) $2\ FeS_2 + 7\ O_2 + 2\ H_2O \longrightarrow 2\ FeSO_4 + 2\ H_2SO_4$

If sufficient dissolved oxygen is present, the ferrous sulfate is oxidized to ferric sulfate:

(2) $4\ FeSO_4 + O_2 + 2\ H_2SO_4 \longrightarrow 2\ Fe_2(SO_4)_3 + 2\ H_2O$

If the pH of the solution is low, this oxidation takes place very slowly. Hydrolysis of the ferric sulfate in water can take place producing ferric hydroxide and sulfuric acid.

(3) $Fe_2(SO_4)_3 + 6\ H_2O \longrightarrow 2\ Fe(OH)_3 + H_2SO_4$

This latter reaction requires a pH of 5.5 or higher to progress at a significant rate.

In the samples taken at Lake Hope, all were relatively clear indicating that any products of reaction (3) were deposited within the mine area. It should be emphasized that the above equations are useful for illustrating acidity production in the acid mine drainage. However, more complex mechanisms are undoubtedly involved. In some instances, bacteria have been reported to catalyze the oxidation reaction.

The total acid content represents the sulfuric acid formed directly as well as that formed by the hydrolysis of the ferric hydroxide and ferrous hydroxide. In the analytical tests, the ferrous hydroxide is oxidized to ferric hydroxide to simulate oxidation which would occur naturally if the pH of the acid mine drainage were increased to 8.3.

Natural Corrective Factors

There are several natural environmental factors which tend to neutralize the acidity formed and precipitate the iron. Two of these factors deserve particular mention:

1. The normal buffering action of other ground and surface waters when mixed with the acid mine drainage water.
2. The sulfate-sulfide biochemical reaction which would produce the divalent sulfide ion.

The buffering action of natural waters is due to the alkalinity present in the form of the bicarbonate ion. When the pH of the final mixture is less than 6.0, this can best be represented by the following equation:

(4) $Ca(HCO_3)_2 + H_2SO_4 \longrightarrow CaSO_4 + 2\ H_2O + 2\ CO_2$

The anerobic production of the sulfide ion is described by Decker and King.* A simplified equation is as follows:

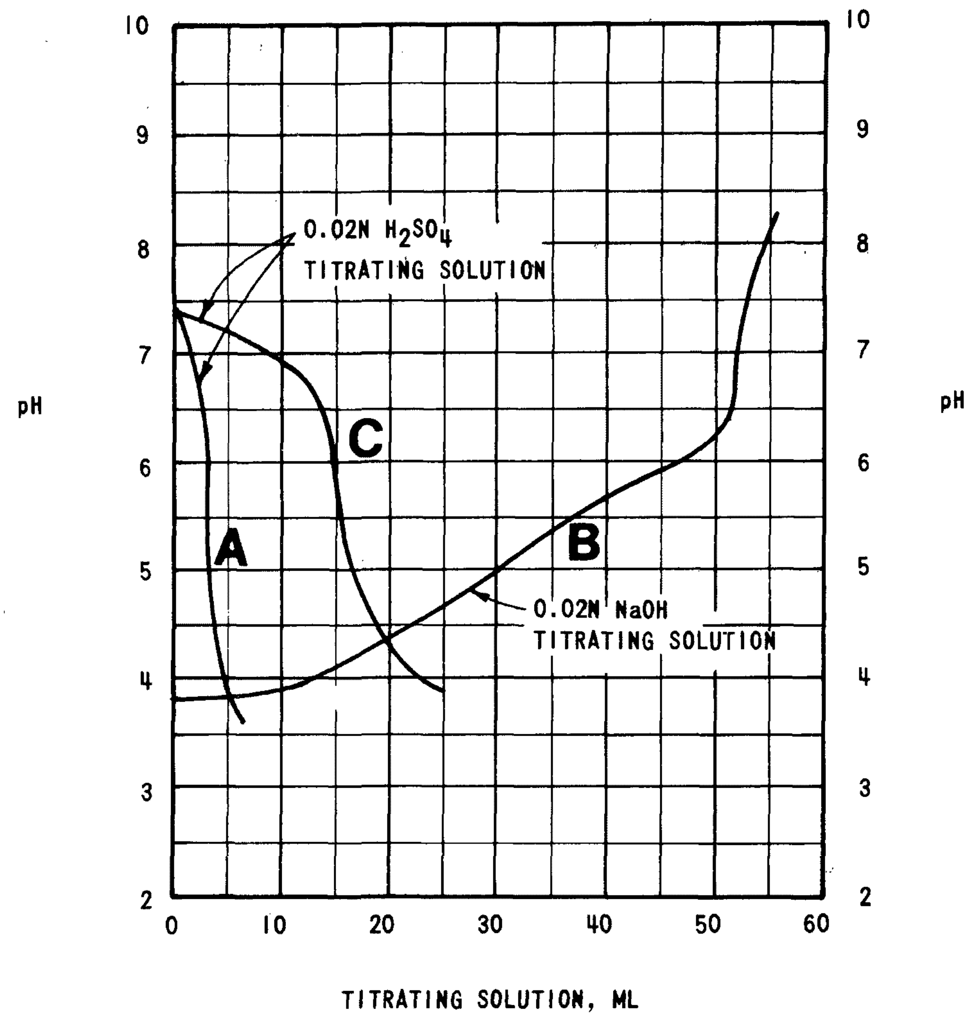
(5) $H_2SO_4 + C(Organic) \longrightarrow H_2S + H_2O + CO_2$

The organic carbon in the above equation can be in the form of vegetation degradation products or similar materials. In this anaerobic reaction, a part of the hydrogen sulfide formed escapes to the atmosphere, while another part reacts with iron present and precipitates as an insoluble iron sulfide. The environment required for such a reaction is normally that of a deep lake wherein stratification occurs. Without mixing the hypoliminon provides a desirable substrate

Undoubtedly the effect of acid mine drainage on Lake Hope has been tempered by the buffering action of other ground and surface waters. More than half of the total watershed consists of land which does not contribute acidic runoff. Therefore, a significant quantity of water containing at least a small amount of alkalinity will mix with the acid mine drainage in Lake Hope.

Buffering action can be illustrated by reference to Figure 9. Titration curves represent equivalent acid (or alkalinity) at various pH levels. When titrating solutions are of the same normality, curve intersection points represent the pH which would be obtained by mixing the designated quantity

* Decker and King, "Accelerated Recovery of Acid Strip Mine Lakes," 26th Purdue Industrial Waste Conference (May, 1971)



A 50 ML SAMPLE - SANDY RUN ABOVE MINE OPENINGS (SAMPLE POINT NO. 380)

B 50 ML SAMPLE - SAMPLE POINT NO. 547

C SAME AS "A" EXCEPT 250 ML SAMPLE

FIGURE 9 - EFFECT OF MIXING MINE DRAINAGE WITH STREAM WATER

of acid mine drainage with a designated volume of water which contains alkalinity in the form of the bicarbonate ion.

The intersection of Curve A with Curve B shows that if equal quantities of water from Sample Point No. 547 and from Sample Point No. 380 were mixed, the resulting pH would be 3.7. The intersection of Curve C with Curve B indicates that when water from Sample Point No. 380 and Sample Point No. 547 are mixed at a ratio of 5:1, the resulting pH will be 4.35.

In the case of the sulfate-sulfide biochemical reaction, it appears that the depth of Lake Hope and other environmental factors are not optimum. This is borne out by the high dissolved oxygen concentration throughout the lake at all depths, as well as the absence of the sulfide ions from all lake samples. The environment is aerobic rather than anaerobic.

<u>Extent of Correction Required</u>

Based on a series of 18 separate samples taken between May, 1970, and April, 1971, the pH of Lake Hope measured at the dam spillway varied from 3.0 to 6.0. During this same period, the acidity based on titration to a pH of 8.3 varied from 8 to 72 mg/l with an average concentration of 31 mg/l.

The lake as initially constructed consisted of 126 acres with a total estimated volume of 1,500 acre-feet. Some silting of the lake has occurred. In the fall of 1970 approximately 15 acre-feet of material was removed by dredging. A net volume reduction due to silting equivalent to 250 acre-feet has occurred since construction 22 years ago. Present storage volume of the lake is estimated at 410 million gallons.

With an average acidity concentration of 31 mg/l the total acid content of the lake is about 105,000 pounds. This can be expressed by another means. Using hydrated lime of approximately 93 percent purity, it would take about 83,500 pounds of lime to neutralize the acidity of the lake to a pH equal to 8.3 or about 40 tons of lime would be sufficient to increase the pH of the lake to 7.0. This is not offered as a suggested means of controlling acidity, but rather as an alternate quantitative means of expressing lake acidity.

Based on average flow into the lake from Sandy Run of 6.0 cfs and an average of flow-acid relationship shown on Figure 5, annual acid flow is about 625,000 pounds.

Random samples were checked for sixteen days during May, 1970; June, 1970; March, 1971; and April, 1971. Twelve of these indicated more acid was produced from Mine Opening No. 47 (Sample Point No. 547) than was measured at Sample Point No. 310. Although Sample Point No. 310 is upstream on Sandy Run a short distance from the Lake, composition of the water at that point is close to that of water entering the lake. The above data represents daily flows at Point No. 310 up to 15 cfs (6,750 gpm). This indicates that acid flow from Mine Opening No. 47 is undoubtedly the largest single source of acid mine drainage.

In most instances the sum of acid content of streams at Sample Point No. 320 and Sample Point No. 420 is more than that at Sample Point No. 310.

Both of the situations illustrates the entry of spring water or runoff into the main stream with the alkalinity of these waters exerting a buffering action.

Unfortunately it has not been possible to measure flow from mine openings at the time of high stream flows to correlate with stream acidity. However, it appears from data collected that acid from Mine Opening No. 47 during such periods is a much smaller part of total acid produced.

It is recognized that many mine openings are interconnected and that sealing one would not completely arrest flow. Sealing openings as required to stop flow now produced by Opening No. 47 would solve a great portion of the total problem.

Methods of Reducing Acid Input to the Lake

Reduction of acid entering Lake Hope from Sandy Run must be of a magnitude such that the lake pH is maintained at 6.5 or higher.

A three-part program for acid mine drainage is proposed:

1. Refuse removal or covering.
2. Sealing of those mine openings which are the major producers of acid drainage.
3. Sealing of certain other mines which do not currently produce acid drainage or produce only a small amount.

The location and relative area of the refuse piles are shown on Figure 3. Due to the wide dispersion and heterogeneous nature of the exposed coal refuse, definitive quantification of the total acid contribution from this source has not been obtained.

During dry periods contribution is essentially nil and acid flow is generally all from two or three mine openings. During heavy precipitation periods refuse pile contributions increases in significance.

Implementing an abatement program to evaluate benefits would follow this pattern:

1. Excavate and remove refuse piles. An alternate approach would be to provide a sealing cover to some refuse piles such as that in Honeycomb Hollow.
2. Seal Mine Opening No. 47 as well as those connected with it which would provide an alternate path for drainage flow.
3. Seal other major mine drainage contributors such as Mine Opening No. 89, if they are not linked directly with Mine Opening No. 47. Follow this with a short surveillance program.
4. Seal other mine openings as required.

Future Data Collection

It is necessary that data output from monitoring stations be continued to be tabulated and analyzed. This information includes stream stage (flow), pH, specific conductance, dissolved oxygen and temperature. Likewise chemical data from the samples obtained at each of these three monitoring stations should be analyzed at normal two-week intervals.

All of this data should be collected at least through the period when the abatement program is implemented. In addition, samples should be collected from the lake and analyzed not less frequently than every two-weeks.

The total of this data should meet most of the testing requirements and provide a measure of the abatement programs success. It can be used also to determine the effect of each step of the program.

Some supplemental tests will be required but these can best be defined as implementation of the program progresses.

Respectfully submitted,

STANLEY CONSULTANTS

By J. L. Thomas
J. L. Thomas

Approved L G Koehrsen
L. G. Koehrsen

APPENDIX A
LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE DATE	POINT	NO	FLOW GPM	TEMP	PH	ACIDITY MG/L	LB/D	IRON MG/L	LB/D	SULFATE MG/L	LB/D
052070	200	S1	*	72	4.0	72	*	.9	*	225	*
052170	200	S1	*	70	4.1	72	*	.9	*	225	*
060370	200	S1	*	62	3.9	38	*	.2	*	700	*
060370	200	S2	*	62	3.9	40	*	.2	*	700	*
060470	200	S1	*	62	3.5	30	*	.2	*	640	*
062370	200	S1	*	*	4.6	10	*	.2	*	80	*
030671	200	S1	*	42	5.8	15	*	15.0	*	55	*
031171	200	S1	*	40	5.1	8	*	10.0	*	168	*
031371	200	S1	*	42	5.1	10	*	16.0	*	338	*
031771	200	S1	*	45	4.6	12	*	1.0	*	72	*
032071	200	S1	*	42	3.0	60	*	5.0	*	10	*
032371	200	S1	*	43	3.4	24	*	9.0	*	100	*
032671	200	S1	*	46	4.0	24	*	6.0	*	75	*
033071	200	S1	*	48	6.0	30	*	3.0	*	25	*
040371	200	S1	*	50	4.4	26	*	2.0	*	75	*
040771	200	S1	*	50	4.3	24	*	1.0	*	25	*
041071	200	S1	*	67	4.5	30	*	3.0	*	100	*
041471	200	S1	*	56	4.3	34	*	10.0	*	100	*
042471	200	S1	*	60	6.0	34	*	3.0	*	75	*
042971	200	S1	*	55	6.0	*	*	6.0	*	25	*
050171	200	S1	*	64	6.5	52	*	5.0	*	50	*
050371	200	S1	*	53	7.8	30	*	5.0	*	25	*
050571	200	S1	*	56	6.2	36	*	2.0	*	75	*
050871	200	S1	*	61	4.5	28	*	1.0	*	25	*
051571	200	S1	*	65	4.7	30	*	.5	*	78	*
052371	200	S1	*	72	5.0	14	*	2.0	*	75	*
060271	200	S1	5	73	5.2	22	*	3.0	*	60	*
050670	210	S1	*	60	4.0	60	*	2.7	*	100	*
050770	210	S1	*	58	4.0	100	*	2.8	*	98	*
050670	300	S1	*	60	4.1	48	*	.5	*	75	*
050770	300	S1	*	58	4.0	80	*	.5	*	75	*
052070	300	S1	*	72	3.6	106	*	.5	*	60	*
052170	300	S1	*	70	3.6	106	*	.5	*	60	*
060370	300	S1	*	62	3.4	94	*	3.0	*	250	*
060370	300	S2	*	62	3.5	100	*	3.0	*	250	*
060470	300	S1	*	62	3.5	90	*	3.0	*	250	*
040771	300	S1	*	50	3.1	68	*	5.0	*	50	*
041071	300	S1	*	64	3.5	72	*	3.0	*	55	*
041471	300	S1	*	56	3.2	106	*	6.0	*	175	*
042171	300	S1	*	60	3.4	156	*	6.0	*	125	*
042471	300	S1	*	58	3.8	108	*	8.0	*	150	*
042971	300	S1	*	51	*	*	*	6.0	*	100	*
050171	300	S1	*	59	4.0	114	*	9.0	*	15	*
050371	300	S1	*	49	4.3	84	*	7.0	*	50	*
050571	300	S1	*	51	4.4	64	*	1.0	*	75	*
050871	300	S1	*	58	5.5	32	*	125.0	*	25	*

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
051571	300	S1	*	64	5.3	38	*	2.0	*	140	*
052371	300	S1	*	65	4.5	66	*	3.0	*	100	*
060271	300	S1	*	74	4.4	78	*	14.0	*	75	*
040170	310	G1	5654.8	44	3.7	40	2714	3.7	251	121	8211
041570	310	G1	1323.9	56	3.6	70	1112	3.9	62	163	2590
042870	310	G1	22978.5	61	4.2	15	4136	1.3	358	66	18199
051270	310	G1	1669.5	63	3.4	79	1583	2.8	56	212	4247
052070	310	S1	*	72	3.5	232	*	.9	*	93	*
052170	310	S1	*	70	3.6	112	*	.7	*	95	*
052670	310	G1	6058.8	64	3.8	40	2908	2.6	189	123	8943
060370	310	S1	*	62	3.2	38	*	2.7	*	300	*
060370	310	S2	*	62	3.2	40	*	2.8	*	300	*
060470	310	S1	*	62	3.6	128	*	3.3	*	300	*
061170	310	G1	233.3	73	3.6	79	221	2.2	6	243	681
062370	310	G1	89.7	62	3.4	89	96	1.7	2	302	325
062370	310	S1	*	*	3.5	93	*	2.2	*	300	*
071070	310	G1	718.0	64	3.6	79	681	3.4	29	222	1913
072170	310	G1	112.2	67	3.5	99	133	4.3	6	298	401
080370	310	G1	*	69	3.5	79	*	.0	*	236	*
081870	310	G1	224.4	73	3.6	60	162	2.2	6	208	560
083170	310	G1	67.3	72	3.6	79	64	2.0	2	276	223
091570	310	G1	242.3	72	3.4	154	448	2.8	8	427	1242
092970	310	G1	237.8	55	3.4	144	411	5.4	15	441	1259
101670	310	G1	*	55	3.5	99	*	33.0	*	291	*
102770	310	G1	*	*	3.5	109	*	2.8	*	322	*
110970	310	G1	583.4	52	3.5	99	693	4.1	29	218	1526
112770	310	G1	4936.8	46	3.5	79	4680	4.2	249	229	13566
120870	310	G1	*	36	3.5	89	*	5.4	*	270	*
122170	310	G1	4039.2	41	3.5	69	3344	.6	29	177	8579
010671	310	G1	*	35	3.7	40	*	4.2	*	125	*
012271	310	G1	1525.9	35	3.6	60	1099	5.2	95	166	3040
020571	310	G1	27825.6	33	4.7	20	6678	1.2	401	57	19033
030671	310	S1	*	42	2.6	100	*	10.0	*	125	*
031171	310	S1	*	40	3.9	34	*	7.0	*	96	*
031371	310	S1	*	48	3.9	28	*	8.0	*	188	*
031571	310	G1	8976.0	*	4.0	35	3770	1.5	162	102	10987
031771	310	S1	*	41	3.8	38	*	4.0	*	96	*
032071	310	S1	*	38	3.7	40	*	3.0	*	125	*
032371	310	S1	*	39	2.9	52	*	16.0	*	100	*
032671	310	S1	*	44	3.0	72	*	7.0	*	75	*
032971	310	G1	1122.0	47	3.6	60	808	4.0	54	166	2235
033071	310	S1	*	48	3.2	76	*	8.0	*	100	*
040371	310	S1	*	50	3.8	76	*	2.0	*	75	*
040771	310	S1	*	52	3.8	86	*	1.0	*	100	*
041071	310	S1	*	63	3.2	169	*	5.0	*	125	*
041471	310	S1	*	56	3.0	116	*	11.0	*	150	*

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
041571	310	G1	628.3	54	3.6	99	746	3.0	23	208	1568
042471	310	S1	*	58	4.1	118	*	4.0	*	150	*
042771	310	G1	350.0	52	3.5	70	294	2.8	12	229	962
042971	310	S1	*	52	3.8	*	*	6.0	*	100	*
050171	310	S1	*	60	4.0	114	*	3.0	*	100	*
050371	310	S1	*	46	3.6	80	*	9.0	*	75	*
050571	310	S1	*	50	3.7	86	*	1.0	*	75	*
050871	310	S1	*	55	4.4	42	*	2.0	*	50	*
051471	310	G1	4936.8	54	3.9	30	1777	3.8	225	114	6754
051571	310	S1	*	62	4.4	54	*	625.0	*	125	*
052371	310	S1	*	64	4.5	82	*	4.0	*	150	*
052771	310	G1	628.3	56	3.6	5	38	1.7	13	177	1335
060271	310	S1	*	68	4.4	82	*	14.0	*	100	*
061071	310	G1	493.6	*	3.8	60	355	1.4	8	208	1232
070971	310	G1	22.4	73	3.7	55	15	1.5	*	198	53
072271	310	G1	22.4	66	3.8	65	18	3.2	1	250	.67
080471	310	G1	13464.0	64	4.5	15	2424	1.1	178	88	14218
081871	310	G1	31.4	72	3.7	55	21	2.4	1	250	94
083171	310	G1	44.8	70	3.6	79	43	27.0	15	322	173
091771	310	G1	67.3	64	3.6	109	88	6.0	5	406	328
093071	310	G1	89.7	66	3.6	144	155	3.0	3	510	549
101471	310	G1	44.8	54	3.7	114	61	2.8	2	437	235
102971	310	G1	40.3	55	3.7	228	111	4.3	2	655	317
110971	310	G1	35.9	36	3.7	179	77	4.6	2	645	278
112271	310	G1	58.3	35	3.7	184	129	4.7	3	645	452
120771	310	G1	13912.8	49	4.2	30	5009	1.5	250	125	20869
122071	310	G1	1301.5	39	3.4	89	1390	5.5	86	281	4389
011072	310	G1	5385.6	43	4.2	30	1939	2.0	129	114	7368
011972	310	G1	807.8	33	3.7	119	1154	3.9	38	218	2113
040170	320	G1	1000.8	45	3.2	109	1309	18.0	216	260	3123
041570	320	G1	363.5	64	3.0	179	781	26.0	113	422	1841
042870	320	G1	4488.0	59	4.0	30	1616	4.7	253	94	5062
042870	320	S1	*	*	3.7	56	*	4.5	*	160	*
050670	320	S1	*	60	3.3	250	*	35.0	*	400	*
050770	320	S1	*	58	3.3	300	*	45.0	*	360	*
051270	320	G1	291.7	63	3.2	124	434	19.0	67	335	1173
052070	320	S1	*	72	3.2	353	*	35.0	*	300	*
052170	320	S1	*	70	3.2	234	*	40.0	*	300	*
052670	320	G1	1382.3	62	3.3	84	1393	11.0	182	235	3898
060370	320	S1	*	62	2.9	460	*	35.0	*	550	*
060370	320	S2	*	62	2.9	1610	*	40.0	*	650	*
060470	320	S1	*	62	2.9	460	*	30.0	*	600	*
061170	320	G1	58.3	73	2.8	452	316	60.0	42	1071	750
062370	320	G1	40.3	61	2.8	47	23	76.0	37	1435	696
062370	320	S1	*	*	2.9	525	*	50.0	*	*	*
071070	320	G1	125.6	64	2.9	278	419	37.0	56	707	1066

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE DATE	POINT	NO	FLOW GPM	TEMP	PH	ACIDITY MG/L	ACIDITY LB/D	IRON MG/L	IRON LB/D	SULFATE MG/L	SULFATE LB/D
072170	320	G1	22.4	64	2.8	596	160	69.0	19	1300	350
080370	320	G1	*	66	2.8	451	*	.0	*	1061	*
081870	320	G1	35.9	70	2.8	397	171	65.0	28	990	427
083170	320	G1	*	71	2.8	645	*	75.0	*	1477	*
091570	320	G1	67.3	74	2.8	407	329	36.0	29	1003	810
092970	320	G1	62.8	55	2.8	477	360	94.0	71	1123	847
101670	320	G1	*	49	3.0	238	*	22.0	*	603	*
102770	320	G1	*	*	2.9	362	*	51.0	*	874	*
110970	320	G1	130.1	49	2.9	293	458	55.0	86	666	1040
112770	320	G1	161.5	46	3.0	258	500	46.0	89	582	1128
120870	320	G1	130.1	36	3.0	238	372	52.0	81	603	942
122170	320	G1	718.0	41	3.2	114	982	1.8	16	289	2490
010671	320	G1	*	34	3.2	104	*	20.0	*	270	*
012271	320	G1	332.1	37	3.1	169	674	31.0	124	406	1618
020571	320	G1	897.6	33	3.3	89	959	13.0	140	239	2574
030671	320	S1	686.6	40	2.9	150	1236	25.0	206	275	2266
031171	320	S1	1988.1	42	4.0	42	1002	15.0	358	120	2863
031371	320	S1	1377.8	49	3.3	82	1356	10.0	165	338	5588
031571	320	G1	1436.1	53	3.6	69	1189	5.9	102	187	3223
031771	320	S1	866.1	45	3.4	88	915	8.0	83	228	2370
032071	320	S1	637.3	41	3.3	120	918	6.0	46	250	1912
032371	320	S1	444.3	41	3.0	140	746	12.0	64	300	1600
032671	320	S1	350.0	48	3.1	176	739	7.0	29	325	1365
032971	320	G1	242.3	46	3.0	164	477	3.7	11	416	1210
033071	320	S1	251.3	52	2.8	188	567	7.0	21	250	754
040371	320	S1	273.7	56	3.0	208	683	8.0	26	350	1150
040771	320	S1	233.3	55	3.3	230	644	12.0	34	500	1400
041071	320	S1	175.0	65	3.0	256	538	11.0	23	550	1155
041471	320	S1	161.5	58	2.7	296	574	13.0	25	650	1260
041571	320	G1	125.6	64	3.0	199	300	24.0	36	520	784
042471	320	S1	130.1	62	4.0	304	475	19.0	30	700	1093
042771	320	G1	80.7	48	3.0	248	240	47.0	46	645	625
042971	320	S1	130.1	49	3.2	*	*	24.0	37	575	898
050171	320	S1	130.1	62	3.6	286	447	14.0	22	1025	1601
050371	320	S1	390.4	46	3.4	130	609	7.0	33	175	820
050571	320	S1	273.7	51	3.5	178	585	4.0	13	350	1150
050871	320	S1	1377.8	58	3.8	98	1620	8.0	132	75	1240
051471	320	G1	852.7	64	3.4	79	808	8.3	85	239	2446
051571	320	S1	753.9	62	3.7	134	1212	25.0	226	250	2262
052371	320	S1	233.3	69	4.0	270	756	13.0	36	350	980
052771	320	G1	94.2	60	2.9	218	247	32.0	36	562	636
060271	320	S1	103.2	68	4.1	414	513	22.0	27	650	805
061071	320	G1	22.4	69	2.9	457	123	62.0	17	1144	308
070971	320	G1	17.9	74	2.8	695	150	74.0	16	1560	336
072271	320	G1	17.9	63	2.9	596	128	94.0	20	1560	336
080471	320	G1	1346.4	65	4.6	15	242	3.4	55	96	1551

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
081871	320	G1	22.4	64	2.8	645	174	90.0	24	1591	428
083171	320	G1	17.9	64	2.8	645	139	93.0	20	1560	336
091771	320	G1	22.4	63	2.8	546	147	75.0	20	1352	364
093071	320	G1	17.9	68	2.8	596	128	82.0	18	1456	314
101471	320	G1	17.9	59	2.9	596	128	83.0	18	1456	314
102971	320	G1	17.9	52	2.9	794	171	120.0	26	1872	403
110971	320	G1	17.9	38	2.8	645	139	96.0	21	1664	358
112271	320	G1	17.9	35	2.8	695	150	120.0	26	1664	358
120771	320	G1	2827.4	50	4.0	35	1188	6.4	217	145	4920
122071	320	G1	233.3	41	3.2	104	291	18.0	50	354	991
011072	320	G1	897.6	44	3.8	50	539	6.0	65	187	2014
011972	320	G1	121.1	38	3.2	164	238	29.0	42	458	666
062370	370	S1	*	*	6.3	*	*	1.5	*	125	*
062370	380	S1	*	*	7.0	6	*	.0	*	40	*
062470	380	S1	*	*	7.4	*	*	.0	*	*	*
031171	380	S1	*	40	6.2	4	*	5.0	*	156	*
031371	380	S1	*	47	6.6	20	*	.5	*	100	*
031771	380	S1	*	41	6.2	8	*	3.0	*	72	*
032071	380	S1	*	42	3.7	26	*	6.0	*	100	*
032371	380	S1	*	41	6.3	12	*	9.0	*	75	*
032671	380	S1	*	54	5.5	12	*	1.0	*	38	*
033071	380	S1	*	43	7.0	18	*	1.0	*	38	*
040371	380	S1	*	60	6.0	14	*	1.0	*	38	*
040771	380	S1	*	62	6.0	8	*	1.0	*	40	*
041071	380	S1	*	67	5.6	*	*	.8	*	39	*
041471	380	S1	*	62	5.9	18	*	1.5	*	44	*
042171	380	S1	*	60	5.6	12	*	9.0	*	48	*
042471	380	S1	*	66	8.0	6	*	2.0	*	44	*
042971	380	S1	*	55	*	*	*	2.0	*	41	*
050171	380	S1	*	62	7.2	8	*	1.0	*	55	*
050371	380	S1	*	52	6.3	6	*	2.5	*	38	*
050571	380	S1	*	56	6.4	6	*	.3	*	34	*
050871	380	S1	*	60	7.7	14	*	1.0	*	27	*
051571	380	S1	*	68	7.6	8	*	.2	*	38	*
052371	380	S1	*	70	5.0	10	*	2.0	*	100	*
060271	380	S1	*	69	5.6	18	*	2.0	*	32	*
040170	420	G1	906.5	45	3.2	89	968	14.0	152	216	2350
041570	420	G1	242.3	53	3.1	159	462	19.0	55	343	998
042870	420	G1	5654.8	56	4.2	30	2036	2.0	136	80	5429
042870	420	S1	*	*	3.6	50	*	6.0	*	90	*
050670	420	S1	*	60	3.4	238	*	16.0	*	500	*
050770	420	S1	*	58	3.3	240	*	20.0	*	480	*
051270	420	G1	287.2	63	3.2	129	445	7.8	27	297	1024
052070	420	S1	*	72	3.2	248	*	45.0	*	475	*
052170	420	S1	*	70	3.2	228	*	45.0	*	500	*
052670	420	G1	1700.9	63	3.3	70	1429	9.0	184	183	3735

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
060370	420	S1	*	62	3.0	380	*	14.0	*	400	*
060370	420	S2	*	62	3.1	420	*	14.1	*	480	*
060470	420	S1	*	62	3.0	400	*	16.0	*	400	*
061170	420	G1	26.9	76	2.9	278	90	16.0	5	618	200
062370	420	G1	26.9	63	3.0	27	9	15.0	5	668	216
062370	420	S1	*	*	3.0	325	*	10.0	*	450	*
071070	420	G1	94.2	64	3.1	179	202	18.0	20	447	506
072170	420	G1	22.4	64	2.9	372	100	27.0	7	782	211
080370	420	G1	*	69	2.9	303	*	.0	*	674	*
081870	420	G1	40.3	70	3.0	218	106	6.4	3	545	264
083170	420	G1	*	72	2.9	422	*	34.0	*	894	*
091570	420	G1	62.8	71	3.0	303	228	19.0	14	691	521
092970	420	G1	49.3	55	3.0	323	191	33.0	20	736	436
101670	420	G1	*	52	3.1	144	*	22.3	*	416	*
102770	420	G1	*	*	3.0	278	*	23.0	*	614	*
110970	420	G1	125.6	50	3.1	169	255	16.0	24	395	596
112770	420	G1	161.5	47	3.2	124	240	14.0	27	322	624
120870	420	G1	103.2	36	3.2	149	185	20.0	25	395	489
122170	420	G1	762.9	41	3.2	119	1090	20.0	183	260	2380
010671	420	G1	*	36	3.3	84	*	1.6	*	218	*
012271	420	G1	246.8	35	3.2	119	352	21.0	62	291	862
020571	420	G1	942.4	33	3.7	40	452	5.2	59	146	1651
030671	420	S1	637.3	42	2.9	75	574	15.0	115	200	1530
031171	420	S1	1624.6	40	4.8	27	526	6.0	117	180	3509
031371	420	S1	1041.2	49	3.5	70	875	15.0	187	312	3898
031571	420	G1	1032.2	52	3.6	55	681	8.6	107	166	2056
031771	420	S1	637.3	39	3.4	94	719	7.0	54	180	1377
032071	420	S1	538.5	37	3.3	100	646	10.0	65	200	1293
032371	420	S1	390.4	39	2.9	126	590	15.0	70	250	1171
032671	420	S1	291.7	48	3.0	132	462	11.0	39	200	700
032971	420	G1	206.4	49	3.1	129	320	1.8	4	302	748
033071	420	S1	201.9	52	2.9	160	388	6.0	15	275	666
040371	420	S1	233.3	56	3.1	152	426	9.0	25	175	490
040771	420	S1	201.9	55	3.4	166	402	6.0	15	575	1394
041071	420	S1	143.6	64	2.9	180	310	11.0	19	350	603
041471	420	S1	130.1	60	2.7	216	337	12.0	19	450	703
041571	420	G1	98.7	55	3.0	149	177	24.0	28	374	443
042471	420	S1	103.2	63	3.9	226	280	15.0	19	425	526
042771	420	G1	62.8	46	3.0	204	154	38.0	29	468	353
042971	420	S1	116.6	50	3.3	*	*	19.0	27	325	455
050171	420	S1	103.2	62	3.3	244	302	13.0	16	550	681
050371	420	S1	390.4	46	3.4	102	478	8.0	37	125	586
050571	420	S1	233.3	50	3.6	114	319	3.0	8	150	420
050871	420	S1	1377.8	58	4.0	74	1224	3.0	50	75	1240
051471	420	G1	897.6	55	3.4	70	754	8.3	89	198	2133
051571	420	S1	637.3	62	4.1	120	918	625.0	12427	250	1912

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE DATE	SAMPLE POINT	SAMPLE NO	FLOW GPM	TEMP	PH	ACIDITY MG/L	ACIDITY LB/D	IRON MG/L	IRON LB/D	SULFATE MG/L	SULFATE LB/D
052371	420	S1	116.6	70	3.5	270	378	13.0	18	250	350
052771	420	G1	89.7	64	3.0	159	171	27.0	29	395	425
060271	420	S1	103.2	71	3.2	342	424	23.0	28	390	483
061071	420	G1	17.9	73	2.9	338	73	43.0	9	759	164
070971	420	G1	4.4	77	2.8	596	32	83.0	4	1144	62
072271	420	G1	13.4	73	2.8	467	75	81.0	13	946	153
080471	420	G1	4936.8	65	4.3	5	296	2.2	130	104	6161
081871	420	G1	8.9	68	2.8	596	64	87.0	9	1071	115
083171	420	G1	17.9	73	2.8	417	90	63.0	14	905	195
091771	420	G1	17.9	64	2.9	347	75	42.0	9	811	175
093071	420	G1	17.9	78	3.0	308	66	30.0	6	738	159
101471	420	G1	17.9	66	2.9	367	79	44.0	9	894	193
102971	420	G1	13.4	67	2.9	491	79	52.0	8	1144	185
110971	420	G1	13.4	39	3.0	402	65	45.0	7	967	156
112271	420	G1	13.4	40	2.9	432	70	45.0	7	978	158
120771	420	G1	4443.1	48	4.3	25	1333	2.0	107	114	6078
122071	420	G1	296.2	42	3.2	99	352	16.0	57	302	1073
011072	420	G1	987.3	42	3.5	59	699	9.7	115	198	2346
011972	420	G1	170.5	37	3.2	129	264	20.0	41	364	745
040170	480	G1	*	46	4.1	20	*	3.9	*	102	*
052070	480	S1	*	72	3.9	95	*	.5	*	80	*
052170	480	S1	*	70	3.9	95	*	.5	*	80	*
060370	480	S1	*	62	3.8	76	*	5.0	*	250	*
060370	480	S2	*	62	3.8	42	*	5.0	*	250	*
060470	480	S1	*	62	3.8	76	*	5.0	*	250	*
062470	480	S1	*	*	*	149	*	.0	*	*	*
031171	480	S1	*	41	4.4	22	*	10.0	*	180	*
031371	480	S1	*	51	3.7	36	*	19.0	*	525	*
031771	480	S1	*	39	4.9	26	*	5.0	*	72	*
032071	480	S1	*	40	4.6	40	*	8.0	*	175	*
032371	480	S1	*	39	4.5	46	*	17.0	*	25	*
032671	480	S1	*	47	4.7	48	*	7.0	*	100	*
033071	480	S1	*	47	3.4	68	*	5.0	*	25	*
040371	480	S1	*	50	3.8	76	*	7.0	*	175	*
040771	480	S1	*	55	4.0	64	*	7.0	*	175	*
041071	480	S1	*	66	3.8	160	*	5.0	*	175	*
041471	480	S1	*	60	5.2	86	*	6.0	*	150	*
042171	480	S1	*	55	3.5	120	*	14.0	*	250	*
042471	480	S1	*	62	4.0	108	*	6.0	*	300	*
042971	480	S1	*	50	*	*	*	9.0	*	100	*
050171	480	S1	*	64	4.0	146	*	1.0	*	175	*
050371	480	S1	*	46	4.8	62	*	8.0	*	75	*
050571	480	S1	*	51	4.8	60	*	3.0	*	100	*
050871	480	S1	3040.0	59	4.9	24	876	2.5	91	75	2736
051571	480	S1	*	69	5.0	50	*	125.0	*	175	*
052371	480	S1	*	66	5.0	60	*	10.0	*	75	*

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE DATE	SAMPLE POINT	NO	FLOW GPM	TEMP	PH	ACIDITY MG/L	ACIDITY LB/D	IRON MG/L	IRON LB/D	SULFATE MG/L	SULFATE LB/D
060271	480	S1	*	74	4.6	116	*	22.0	*	100	*
040170	490	G1	*	45	7.1	*	*	.2	*	56	*
062470	490	S1	*	*	*	13	*	.0	*	*	*
031171	490	S1	*	40	6.0	4	*	10.0	*	108	*
031371	490	S1	*	46	6.5	4	*	11.0	*	350	*
031771	490	S1	*	39	5.4	10	*	5.0	*	72	*
032071	490	S1	*	43	5.1	12	*	7.0	*	75	*
032371	490	S1	*	39	4.8	8	*	14.0	*	25	*
032671	490	S1	*	45	5.2	16	*	7.0	*	75	*
033071	490	S1	*	48	3.5	36	*	6.0	*	70	*
040371	490	S1	*	53	5.5	14	*	4.0	*	50	*
040771	490	S1	*	52	4.2	14	*	1.0	*	84	*
041071	490	S1	*	65	7.6	18	*	1.7	*	89	*
041471	490	S1	*	56	7.0	14	*	1.3	*	99	*
042171	490	S1	*	54	5.2	40	*	5.0	*	130	*
042471	490	S1	*	60	5.2	30	*	1.0	*	110	*
042971	490	S1	*	50	6.8	*	*	4.5	*	125	*
050171	490	S1	*	62	7.1	10	*	3.5	*	110	*
050371	490	S1	*	47	6.3	8	*	2.5	*	93	*
050571	490	S1	*	51	6.0	10	*	1.5	*	90	*
050871	490	S1	4120.0	55	7.6	12	593	1.3	64	48	2373
051571	490	S1	*	61	7.5	18	*	.5	*	70	*
052371	490	S1	*	72	4.5	14	*	2.5	*	50	*
060271	490	S1	*	66	5.5	24	*	5.0	*	95	*
042970	547	S1	*	*	2.7	940	*	147.0	*	2070	*
043070	547	S1	140.0	*	2.8	950	1596	.0	*	*	*
050670	547	S1	50.3	60	3.0	980	592	40.0	24	3000	1811
050770	547	S1	50.3	58	3.0	1020	616	45.0	27	2880	1738
052070	547	S1	70.2	72	2.8	1110	935	50.0	42	2650	2232
052170	547	S1	70.2	70	3.0	1344	1132	50.0	42	2650	2232
060370	547	S1	41.8	62	2.8	1300	652	45.0	23	2500	1254
060370	547	S2	41.8	62	2.8	1310	657	50.0	25	2500	1254
060470	547	S1	193.0	62	2.8	1100	2548	40.0	93	2500	5790
062370	547	S1	27.5	*	3.0	1150	379	40.0	13	2500	825
062470	547	S1	27.5	*	2.6	1175	388	.0	*	*	*
030671	547	S1	247.0	48	2.3	950	2816	85.0	252	1875	5557
031171	547	S1	276.0	47	3.1	692	2292	80.0	265	1680	5564
031371	547	S1	247.0	49	3.1	768	2276	78.0	231	1875	5557
031771	547	S1	129.0	48	2.8	766	1186	69.0	107	1584	2452
032071	547	S1	183.0	46	2.9	792	1739	67.0	147	1650	3623
032371	547	S1	166.0	45	2.3	826	1645	78.0	155	1725	3436
032671	547	S1	166.0	46	2.6	888	1769	77.0	153	1825	3635
033071	547	S1	129.0	47	2.7	812	1257	67.0	104	1800	2786
040371	547	S1	129.0	49	2.6	910	1409	77.0	119	2100	3251
040771	547	S1	114.0	52	2.6	1006	1376	76.0	104	2200	3010
041071	547	S1	100.0	60	2.6	1000	1200	125.0	150	2450	2940

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE DATE	POINT	NO	FLOW GPM	TEMP	PH	ACIDITY MG/L	ACIDITY LB/D	IRON MG/L	IRON LB/D	SULFATE MG/L	SULFATE LB/D
041471	547	S1	88.0	48	2.7	1218	1286	88.0	93	2400	2534
042471	547	S1	53.0	52	3.5	1102	701	85.0	54	2450	1558
042971	547	S1	53.0	48	3.2	*	*	114.0	73	2225	1415
050171	547	S1	61.0	52	3.0	1250	915	102.0	75	2350	1720
050371	547	S1	61.0	48	3.6	2420	1771	85.0	62	2625	1922
050571	547	S1	71.0	51	3.9	1000	852	100.0	85	2025	1725
050871	547	S1	341.0	54	3.3	1140	4665	86.0	352	2175	8900
051571	547	S1	200.0	53	2.8	1000	2400	78.0	187	2050	4920
052371	547	S1	76.0	51	2.5	1128	1029	58.0	53	1875	1710
060271	547	S1	76.0	52	2.8	1166	1063	74.0	67	2125	1938
042970	560	S1	130.0	*	3.3	96	150	30.0	47	120	187
050670	560	S1	2.2	60	3.2	664	18	3.5	*	2000	53
050770	560	S1	2.2	58	3.3	664	18	3.5	*	1800	48
052070	560	S1	21.7	72	3.6	424	110	2.5	1	2000	521
052170	560	S1	12.4	70	3.7	140	21	2.2	*	1200	179
060370	560	S1	12.4	62	3.3	250	37	1.5	*	3000	446
060370	560	S2	12.4	62	3.3	290	43	1.5	*	3000	446
060470	560	S1	34.2	62	3.5	142	58	5.0	2	300	123
062470	560	S1	*	*	3.9	20	*	4.0	*	100	*
030671	560	S1	*	46	2.9	150	*	10.0	*	300	*
031171	560	S1	*	44	3.9	68	*	18.0	*	156	*
031371	560	S1	166.0	45	4.0	28	56	10.0	20	225	448
031771	560	S1	65.0	45	3.5	58	45	4.0	3	96	75
032071	560	S1	37.0	44	5.2	30	13	4.0	2	175	78
032371	560	S1	37.0	43	3.8	28	12	13.0	6	50	22
032671	560	S1	53.0	47	3.5	80	51	12.0	8	100	64
033071	560	S1	45.0	46	4.4	22	12	5.0	3	25	14
040371	560	S1	37.0	48	2.5	39	17	3.0	1	125	56
040771	560	S1	37.0	47	2.6	92	41	8.0	4	175	78
041071	560	S1	*	69	3.4	52	*	4.0	*	100	*
041471	560	S1	*	48	3.8	62	*	6.0	*	125	*
042471	560	S1	6.0	66	4.3	82	6	4.0	*	100	7
042971	560	S1	*	48	3.9	*	*	16.0	*	50	*
050171	560	S1	52.0	52	4.3	94	59	12.0	7	125	78
050371	560	S1	36.0	46	5.6	160	69	13.0	6	125	54
050571	560	S1	71.0	49	5.0	174	148	20.0	17	200	170
050871	560	S1	341.0	58	3.6	214	876	20.0	82	225	921
051571	560	S1	162.0	56	3.7	90	175	18.8	37	125	243
052371	560	S1	45.0	61	3.5	138	75	5.0	3	75	40
060271	560	S1	6.0	72	3.3	70	5	8.0	1	25	2
042870	588	S1	*	*	2.6	700	*	50.0	*	1250	*
050670	588	S1	*	60	2.8	1080	*	2.9	*	2500	*
050770	588	S1	*	58	2.8	1100	*	3.0	*	2500	*
052070	588	S1	12.4	72	2.7	2186	325	40.0	6	2800	417
052170	588	S1	*	70	2.6	2046	*	40.0	*	2600	*
060370	588	S1	12.4	62	2.7	1800	268	35.0	5	2000	298

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
060370	588	S2	12.4	62	2.8	1890	281	50.0	7	3000	446
060470	588	S1	34.2	62	2.6	1360	558	40.0	16	2750	1129
030671	588	S1	129.0	46	2.3	650	1006	65.0	101	1250	1935
031171	588	S1	204.0	43	3.3	510	1248	65.0	159	1032	2526
031371	588	S1	129.0	51	3.2	904	1399	121.0	187	2350	3638
031771	588	S1	76.0	46	2.9	916	835	105.0	96	1632	1488
032071	588	S1	76.0	43	2.8	942	859	111.0	101	1700	1550
032371	588	S1	100.0	44	2.4	970	1164	108.0	130	1925	2310
032671	588	S1	65.0	47	2.6	972	758	98.0	76	1700	1326
033071	588	S1	53.0	49	2.6	1146	729	105.0	67	2150	1367
040371	588	S1	53.0	54	2.7	1340	852	123.0	78	2750	1749
040771	588	S1	45.0	50	2.6	1474	796	146.0	79	2875	1552
041071	588	S1	37.0	62	2.7	1630	724	166.0	74	3500	1554
041471	588	S1	37.0	54	2.4	2112	938	188.0	83	3750	1665
042471	588	S1	30.0	59	3.0	2564	923	225.0	81	4500	1620
042971	588	S1	37.0	49	3.0	*	*	260.0	115	4375	1943
050171	588	S1	29.0	62	2.7	3120	1086	260.0	90	5000	1740
050371	588	S1	43.0	46	3.4	1950	1006	100.0	52	1975	1019
050571	588	S1	36.0	51	3.5	970	419	185.0	80	4500	1944
050871	588	S1	265.0	57	3.0	1690	5374	173.0	550	3000	9540
051571	588	S1	95.0	58	3.1	1286	1466	120.0	137	2375	2707
052371	588	S1	45.0	63	3.0	1180	637	98.0	53	2100	1134
060271	588	S1	37.0	61	3.2	1852	822	134.0	59	3250	1443
030671	589	S1	*	41	2.3	590	*	55.0	*	1125	*
031171	589	S1	20.0	40	4.0	90	22	20.0	5	312	75
031371	589	S1	12.0	46	3.9	305	44	39.0	6	863	124
031771	589	S1	*	43	3.1	568	*	7.0	*	1152	*
032071	589	S1	*	40	2.7	712	*	68.0	*	1300	*
032371	589	S1	*	41	2.5	1112	*	123.0	*	2375	*
032671	589	S1	*	49	2.4	1496	*	136.0	*	2600	*
033071	589	S1	*	51	2.5	1696	*	167.0	*	4000	*
040371	589	S1	*	50	2.8	1594	*	163.0	*	2875	*
040771	589	S1	*	54	3.0	1788	*	168.0	*	3500	*
041071	589	S1	2.0	66	2.5	1978	47	177.0	4	4325	104
041471	589	S1	1.5	58	2.2	2000	36	164.0	3	4000	72
042471	589	S1	5	66	3.4	2348	14	200.0	1	4375	26
042971	589	S1	8	52	3.0	*	*	220.0	2	3675	35
050171	589	S1	5	62	2.8	2824	17	205.0	1	4500	27
050371	589	S1	1.5	46	3.2	1888	34	124.0	2	4000	72
050571	589	S1	1.0	52	4.1	1744	21	157.0	2	4500	54
050871	589	S1	35.0	56	3.9	68	29	4.0	2	100	42
051571	589	S1	21.0	64	3.9	336	85	55.0	14	800	202
052371	589	S1	2.0	79	2.0	2314	56	195.0	5	5000	120
060271	589	S1	*	78	2.2	2188	*	160.0	*	4500	*
062470	591	S1	*	*	2.9	825	*	50.0	*	2000	*
042870	701	S1	*	*	4.7	20	*	.5	*	44	*

LAKE HOPE SURVEILANCE PROGRAM
WATER QUALITY DATA

RUN DATE 021572

SAMPLE			FLOW			ACIDITY		IRON		SULFATE	
DATE	POINT	NO	GPM	TEMP	PH	MG/L	LB/D	MG/L	LB/D	MG/L	LB/D
052070	701	S1	*	72	3.3	156	*	1.5	*	60	*
052170	701	S1	*	70	3.3	112	*	.9	*	60	*
060370	701	S1	*	62	3.0	300	*	5.0	*	3000	*
060370	701	S2	*	62	3.0	350	*	5.0	*	3000	*
060470	701	S1	*	62	3.0	200	*	3.0	*	300	*
062370	701	S1	*	*	3.2	137	*	4.5	*	300	*
032671	701	S1	*	44	6.4	28	*	9.0	*	60	*
033071	701	S1	*	53	3.7	38	*	6.0	*	68	*
040371	701	S1	*	48	4.0	42	*	1.0	*	69	*
040771	701	S1	*	47	3.7	52	*	1.0	*	77	*
041071	701	S1	*	56	3.6	60	*	3.0	*	84	*
041471	701	S1	*	46	3.6	74	*	8.0	*	101	*
042171	701	S1	*	48	3.5	104	*	9.0	*	135	*
042471	701	S1	*	51	3.9	90	*	5.0	*	120	*
042971	701	S1	*	48	*	*	*	5.0	*	148	*
050171	701	S1	*	52	3.7	120	*	10.0	*	180	*
050371	701	S1	*	46	4.4	128	*	8.0	*	170	*
050571	701	S1	*	49	4.5	100	*	3.0	*	210	*
050871	701	S1	*	58	6.8	14	*	1.0	*	44	*
051571	701	S1	*	64	6.7	28	*	.5	*	62	*
052371	701	S1	*	56	4.8	70	*	3.5	*	75	*
060271	701	S1	*	61	4.8	84	*	9.0	*	75	*
031171	801	S1	*	40	5.5	4	*	6.0	*	156	*
031371	801	S1	*	46	6.5	80	*	11.0	*	275	*
031771	801	S1	*	39	5.1	8	*	4.0	*	96	*
032071	801	S1	*	39	4.3	24	*	3.0	*	100	*
032371	801	S1	*	39	4.5	34	*	10.0	*	50	*
050871	801	S1	1125.0	63	7.4	6	81	1.3	18	166	2241
051571	801	S1	*	64	7.1	26	*	.2	*	125	*

☆U.S. GOVERNMENT PRINTING OFFICE: 1973 514-153/230 1-3

1 Accession Number	2 Subject Field & Group	
W	Ø4E, Ø5F	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM

5 *Organization*

State of Ohio, Dept. of Natural Resources

6 *Title*

FEASIBILITY STUDY, LAKE HOPE MINE DRAINAGE DEMONSTRATION PROJECT

10 *Author(s)*

N.A.

16 *Project Designation*

EPA Grant 14010 HJQ

21 *Note*

22 *Citation*

Environmental Protection Agency Report
Number EPA-R2-73-151

23 *Descriptors (Starred First)*

Acid Mine Drainage*, Mine Sealing,* Refuse Piles*

25 *Identifiers (Starred First)*

*Feasibility Study, *Lake Hope, Ohio

27 *Abstract*

The Lake Hope project will demonstrate the control and elimination of mine drainage pollution by refuse pile disposal and/or covering and underground mine sealings. Acid producing coal refuse will be removed and buried in suitably prepared sites. These sites will be finished graded and seeded. Non-acid producing coal mine refuse piles will be reshaped to existing contours, covered and reclaimed by appropriate seeding and tree planting for erosion control and aesthetic enhancement. The mine sealing demonstration program will be undertaken in two phases. The first phase will seal those mine openings which have been determined the most significant acid discharges and those openings immediately adjacent to or suspected of having connecting with the high acid concentration discharge openings. The second phase will seal selected remaining mine openings as determined by the continuous water quality monitoring data obtained. Continuous water quality monitoring systems will obtain data to be evaluated over the life of the project and after all construction has been completed.

Abstractor E. F. Harris | *Institution* Environmental Protection Agency