FAILURE OF DAM NO. 3

on the

Middle Fork of Buffalo Creek

near Saunders, West Virginia

on

February 26, 1972

Report prepared by

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for the

Committee on Natural Disasters
National Academy of Engineering

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BUFFALO CREEK REPORT

I. INTRODUCTION

At approximately 8 a.m. on Saturday, February 26, 1972, a coal refuse dam (designated as Dam No. 3 in this report) located near the mouth of the Middle Fork of Buffalo Creek at Saunders, West Virginia, failed (see Figure 1). The failure released approximately 176 million gallons of water into the Buffalo Creek Valley. Prior to entering Buffalo Creek, the water broke through two other dams (designated as Dam No. 1 and Dam No. 2). The flood waters flowed along Buffalo Creek Valley to Man, West Virginia, where they entered the Guyandotte River (see Figure 2).

In the three hours it took to traverse the 17-mile length of the Buffalo Creek Valley, the flood produced damage estimated to be between 30 and 50 million dollars. In addition, the flood caused 118 deaths, left approximately 4,000 homeless, and destroyed or seriously damaged approximately 850 permanent and mobile homes. Also destroyed were approximately 1,000 cars and trucks, several highway and railway bridges, sections of railroad tracks and highways, and portions of utility facilities. The Office of Emergency Preparedness estimated the cost of the flood to the 17 participating federal agencies to be approximately

$22 million, which included $7 million in disaster relief and $12 million in funds for road reconstruction.

Shortly after the Buffalo Creek flood, the Committee on Natural Disasters of the National Academy of Engineering appointed an inspection team headed by Professor T. William Lambe, Massachusetts Institute of Technology, and including Professor Roger K. Seals, West Virginia University, and Mr. W. Allen Marr, Massachusetts Institute of Technology. The team went to Buffalo Creek on March 4, 1972, to take photographs and record their personal observations. Initially, the team made an aerial observation of the dam sites, then a ground-level inspection of Buffalo Creek Valley and the dam sites along Middle Fork.

This report summarizes the observations, findings, and recommendations of the inspection team. It attempts to describe the conditions prior to the failure, the failure itself, and the consequences of the failure. Recommendations are made for further studies. In writing this report, the team has drawn upon its personal observations and experiences, and upon the following publications, articles, and newspapers:

1. Preliminary Analysis of the Coal Refuse Dam Failure at Saunders, West Virginia, February 26, 1972, U.S. Department of Interior Task Force to Study Coal Waste Hazards, March 12, 1972.

2. Results of Preliminary Examinations of Coal Waste Banks in Southern West Virginia, W. E. Davies and J. Gallaher, December 5, 1966.

3. "Design of Dams for Mill Tailings," C. D. Kealy and R. L. Soderberg, Bureau of Mines Information Circular 8410, U.S. Department of Interior, 1969.

4. "Coal Refuse Fires, An Environmental Hazard," L. M. McNay, Bureau of Mines Information Circular 8515, U.S. Department of Interior, 1971.

5. "Flow through a Tailings Pond Embankment," C. D. Kealy and R. E. Williams, Water Resources Research, Vol 7, No. 1, February 1971.

6. "Refuse Removal and Disposal," E. D. Hummer, Coal Preparation, J. W. Leonard and D. R. Mitchell (Editors), AIME, New York, 1968.

7. Charleston Daily Mail, Charleston, West Virginia, articles appearing between February 27, 1972 and March 15, 1972.

8. Charleston Gazette, Charleston, West Virginia, articles appearing between February 27, 1972 and March 15, 1972.

II. COAL REFUSE DISPOSAL BANKS AND DAMS IN THE MIDDLE FORK VALLEY

Middle Fork, located in Logan County, West Virginia, flows northwest and intersects Buffalo Creek at the community of Saunders (see Figure 2). According to the USGS Lorado Quadrangle Map, West Virginia (1968), Middle Fork actually enters Lee Fork which, in turn, flows into Buffalo Creek (see Figure 3). The elevation of Middle Fork at its headwater is 2320 ft. and at its intersection with Lee Fork is 1493 ft. Middle Fork is approximately 2 miles long and flows through a valley whose walls rise at slopes approximately 2:1 to elevations between 2400-2600 ft. The valley walls show evidence of strip mining and currently contain roads that have been used to transport mining refuse to the disposal sites.

Initial disposal of mine refuse near the intersection of Lee Fork and Middle Fork began approximately 15 years ago with the dumping

of refuse material into a waste bank. Continuing disposal by Buffalo Mining Company, a Division of Pittston Company, extended the refuse bank into the valley, reaching a distance of approximately 1500 ft. along the valley as of February 1972. The bank had an average width of approximately 400 ft. and at the mouth of Middle Fork reached more than 200 ft. above natural ground elevation.

Following the enactment of water pollution control legislation in 1964, the first wash water retention dam was constructed, using mine refuse. At the time of the failure, four dams had been constructed out of mine refuse. Dam No. 1 was approximately 1600 ft. from the mouth of the valley and was about 20 ft. in height. Dam No. 2 was also about 20 ft. high and was located another 600 ft. up the valley. The USGS Quadrangle Map published in 1968 (see Figure 3) shows the Tailings Ponds behind both Dam No. 1 and Dam No. 2. An aerial photo made on March 29, 1966 (see Figure 4) shows the impoundment behind Dam No. 1. A third dam, Dam No. 3, ranged in height from 45 to 60 ft. and was located approximately 600 ft. upstream from Dam No. 2. A fourth dam, which was not involved in the failure, was located another 2500 ft. up the valley.

Figures 5 and 6 are aerial photographs made shortly after the failure (on February 27, 1972) and show the area near the mouth of Middle Fork (Saunders). The approximate locations of Dam Nos. 1, 2, and 3 are indicated on the photographs. Remnants of Dam No. 3 are seen, but no identifiable traces of Dam Nos. 1 and 2 remain. Dam No. 4 is

too far upstream on Middle Fork to appear in the photographs. Figure 6 clearly shows the gully eroded in the refuse bank as the flood waters entered the Buffalo Creek Valley.

Dam No. 1 was constructed in 1964 to clarify effluent water pumped from the preparation plant. This dam was apparently constructed on firm, natural ground. Extensive sedimentation behind this dam and the need for additional refuse disposal capacity dictated the second dam, which was constructed in 1967. For similar reasons, a third dam was constructed in 1970. Dam Nos. 2 and 3 were constructed by dumping refuse in areas containing sedimented refuse (silt) and water. Apparently, no effort was made to remove vegetation or poor quality soils from the base and abutments of the dams.

Water seeping through Dam No. 3 was collected in the pond behind Dam No. 2 and then decanted to the lower pond through a 30-in. pipe, followed by a diversion ditch. Overflow water from Dam No. 1 was conveyed by a culvert to the Buffalo Creek Valley where it was collected in a small pond. Water from this pond was pumped to the preparation plant for reuse in the coal washing process.

The inspection team observed evidence that the refuse bank at the mouth of Middle Fork was burning both prior to and at the time of the failure. No evidence was found that any of the dams had burned or were burning at the time of the failure.

It is estimated that approximately 200,000 tons of refuse and 50,000 to 100,000 tons of silt were deposited in Middle Fork Valley annually. Water consumption by the preparation plan amounted to approxmately 500,000 gallons per day during recent operation.

Refuse disposal systems have always been part of coal mining and coal cleaning plant systems. In addition to the cost of disposal, there are several inherent environmental problems associated with coal refuse. One of the most prevalent problems is coal refuse fires which begin most commonly by spontaneous combustion. These fires produce acrid gases and particulate matter. Another pollution problem arises from the from the preparation plant effluent being pumped into nearby streams. Thus, dams were constructed to provide settling ponds for the effluent and to reduce the threat of refuse fires.

Although the investigating team concluded from their studies that these dams were built with a minimum of design and construction control, no loss of life had been reported as a result of coal refuse dam failures in this area prior to the Buffalo Creek disaster. However, property damage and loss of life have occurred as a result of pollution and landslides associated with coal waste piles. A survey of coal refuse banks in the United States was conducted by the Department of Interior (U.S. Geological Survey and Bureau of Mines) following the disaster at Aberfan, Wales, in 1966. The report based on this survey described the bank at Saunders as:

> Bank stable. Large deep lake at rear of bank. Dike at N.E. edge of lake is 15 ft. wide, 8 ft. high. Could be overtopped and breached. Flood and debris would damage church and two or three houses downstream, cover road and wash out railroad. Gully at front covers road with wash regularly. Lake contains about 5,000 cubic feet of water.

The dike described in the USGS report is Dam No. 1. Dam Nos. 2 and 3 did not exist at the time of the survey.

III. DESCRIPTION OF DAM NO. 3

The centerline of Dam No. 3 was located approximately 2600 ft. upstream from the mouth of Middle Fork. The dam varied in height from approximately 45 ft. at the right abutment to 60 ft. at the left abutment. It is probable that the dam was trapezoidal in shape, with side slopes determined by the angle of repose of the refuse material. Measurements made by the Department of Interior Task Force indicated a base width varying from 400-500 feet; the greater width existed at the left abutment and corresponded to the greater dam height. The dam spanned the entire width of the valley, which was approximately 400-500 feet at the location of the dam. As previously indicated, Dam No. 3 was constructed on a foundation of refuse sedimented from the impoundments produced by Dam Nos. 1 and 2. Subsurface borings made recently indicated that sediment deposits as great as 50 ft. in thickness existed beneath Dam No. 3.

No information was obtained concerning the amount of freeboard that existed prior to the rainstorm preceding the failure. The crest width was estimated to be 100-200 ft. A 24-in. overflow pipe was placed

in the right abutment area approximately 7-10 ft. below the crest of the dam. However, under normal conditions, flow would reach the lower pond by seepage through the dam rather than by flow through the pipe. From all indications, no provisions were made to prevent piping along the overflow pipe. In addition, none of the dams had emergency spillways.

The coal mining refuse used to construct the dam consists of a mixture of clayey shale and low quality coal. Sources of refuse include waste rock and other impurities generated during mine development and operation and impurities separated from the "run of mine" or raw coal at the preparation plant. Generally, most of the solid waste is produced at the preparation plant. Coarse refuse (greater than 1 mm particles) is usually transported to the disposal site by conveyors or trucks, whereas fine refuse (less than 1 mm particles) is usually pumped to a settling pond in a slurry.

According to the Task Force Report, refuse was continuously dumped at Dam No. 3 following its inception. It was estimated that approximately 1,000 tons of refuse were transported daily to the disposal site by 30-ton trucks. The refuse was dumped over the ends of the dam or on top of the dam. When dumped on top of the dam, layers as great as 5 ft. in thickness resulted. These layers were spread with a bulldozer to maintain a surface for the haul trucks. No special effort was made to compact the refuse material; however, some compaction resulted from the operation of the hauling and spreading equipment.

A sample of refuse was taken from the left abutment area at the time the inspection team made its visit. Specific gravity, grain size, and direct shear tests were conducted on the sample. Visually, the refuse was classified as a black granular material containing fragments of sandstone, shale, and low grade coal. Larger fragments vary from blocky to platy in shape. According to the Unified Soil Classification System, the refuse was classified as an SP material, i.e., poorly graded sand, gravelly sand, little or no fines. In the field, slabs of refuse were observed that were several feet wide and several inches thick. The grain size distribution curve for the laboratory sample is presented in Figure 7.

Middle Fork had a drainage area of approximately 800 acres, most of which contributed run-off to the impoundment behind Dam No. 3. Prior to the failure it was estimated that the impounded water had reached a height in excess of 40 ft. and extended upstream a distance of about 2500 ft. Based on these estimates, the total volume of water impounded was estimated to be 21 million cubic feet.

IV. DESCRIPTION OF FAILURE

At 8:00 a.m. on February 26, 1972, Dam No. 3 failed. The released water over-topped the two small dams, No. 1 and No. 2, below Dam No. 3 and rushed down the right side of a large waste dump of coal refuse. An aerial view of the area taken seven days after the failure is shown in Figure 8.

Only the abutments of Dam No. 3 remained. The left abutment shown in Figure 9 was estimated to be approximately 60 ft. high. At the time of failure the estimated crest width was 100-200 ft. and the base width was 400-500 ft. Trees, stumps, and natural soil present in the foundation can be seen in Figure 10. Figure 11 shows some of the coal silt and sludge which remained in the reservoir bottom.

The two small dams were completely eroded away. Figure 12 is an upstream view of the location of Dam No. 2. The left abutment of Dam No. 3 is in the center background.

The water followed a haul road down the right side of the coal waste pile and eroded the 50-ft.-deep gulley shown in Figures 13 and 14. Steam explosions occurred when portions of the waste pile which were burning were flooded by the advancing water. The flood waters emptied out of the gulley into Buffalo Creek (Figure 15) and started their devastating way downstream. It was estimated by the U.S. Department of Interior Task Force that the entire quantity of impounded water was released within a 15-minute period.

Based on data gathered by the Task Force, it was estimated that water flow velocities ranged from 15-20 fps near Saunders to 4-5 fps at the mouth of Buffalo Creek at Man. A peak flow of 49,000 cfs was estimated at a location 4,500 ft. downstream from Saunders which corresponded to a water depth of 15-20 ft. and a flow velocity of approximately 20 fps. Farther downstream at Lorado, flood depths

approximately 6-8 ft. occurred. Downstream of Stowe, flood depths generally less than 6 ft. were experienced. (See Figure 2 for locations of Lorado and Stowe.) The flows experienced in Buffalo Creek during the flood were 2 to 40 times those which would be produced by a naturally occurring 50-year flood.

Precipitation occurring in the Buffalo Creek Valley area did not exceed 3.7 inches during the 72-hour period immediately preceding the flood. According to weather data, precipitation equal to or exceeding 3.7 inches in a 3-day period would be expected once every two years.

Several agencies and people have advanced theories about the technical cause(s) of failure. Attempts to explain the failure seem premature.

V. CONSEQUENCES OF THE FAILURE

The flood water descended down the narrow Buffalo Creek Valley. Towns along the valley from Saunders to Man were flooded with as much as 20 to 30 ft. of water. Figures 16 through 23 show damage that resulted to homes, churches, and automobiles. A total of 118 people were killed. Debris and coal silt, many times including bodies, were spread along the valley. Several railroads and highway bridges were swept from their foundations, as shown in Figures 24 through 26. Large sections of the railroad, highway, and utilities were destroyed (Figure 27).

Many animals, including dogs, horses and mules, were drowned or left wandering to scavenge for food. Snakes posed a continuous threat to the clean-up operations.

Shortly following the disaster, Governor Arch Moore of the State of West Virginia ordered that all refuse impoundments be drained. He also established an Ad Hoc Commission of Inquiry to study the disaster and its implications and to report its findings. As a direct result of the disaster, the State Legislature of West Virginia passed a bill giving control of refuse piles to the Department of Natural Resources. This bill gave the Department the power to enter private property to make tests and surveys on a continuing basis and the authority to go into circuit court to obtain an injunction against a coal operator. In cases of imminent danger, the Department can take remedial action and recover reasonable costs from the coal operator. Corrective measures not requiring immediate attention would be referred to the coal operator for his action and at his cost. The initial control of dams constructed with any material still lies with the Public Service Commission of West Virginia, but as before, the Commission cannot exercise continuing jurisdiction over such dams once constructed.

At the federal level, the Committee on Public Works of the U.S. Senate passed a resolution charging the Secretary of the Army, acting through the Chief of Engineers, to study and report on hazardous conditions associated with impoundments connected with coal mining

activities. This study is currently underway as a cooperative effort by both federal and state personnel. In addition, the Secretary is to "...provide advice and counsel to the States in the nature of timely remedial measures to mitigate or obviate the hazardous conditions."

Also at the federal level, Hollis M. Dole, Assistant Secretary of the Interior for Mineral Resources, has urged Congress to pass President Nixon's Mined Area Protection Act. This Act would require mine operators to submit reclamation plans to insure against flooding as a result of mining activity. In effect, this Act extends federal authority to potential public hazards rather than being confined to hazards to miners only as provided by the Federal Coal Mine Health and Safety Act, December 30, 1969.

An engineering study of Dam No. 3 is currently being conducted by a private consultant under a contract with the Department of Interior. Field borings and tests, laboratory tests, and detailed stability analysis are being conducted.

VI. RECOMMENDED INVESTIGATION

The failure of Dam No. 3 on the Middle Fork emphasizes that the failure of a dam retaining a relatively small height of water can be catastrophic, particularly when placed in a narrow, populated valley. In West Virginia, as well as other parts of the U.S., there are many dams which constitute a potential hazard to the health and safety of the people downstream.

To help avert future disasters similar to Buffalo Creek, we recommend an investigation of the failure of Dam No. 3. The purposes of this investigation are to determine the probable mechanism(s) causing the failure, means by which the failure could have been prevented, and procedures for inspecting and altering dams which appear to be unsafe.

This investigation should include the following aspects:

1. Construction and operating history of Dam No. 3.

2. Field and laboratory tests to determine the nature and behavior of the materials composing Dam No. 3.

3. Groundwater hydrology of the site.

4. Flow and stability analyses of Dam No. 3 to predict its performance under varying operating conditions.

5. Observations of flow and stability in similar dams.

The public should be protected from disasters like the Buffalo Creek flood. The failure of Dam No. 3 offers an opportunity to study these small, but complex, water-retaining structures.

ACKNOWLEDGEMENTS

The inspection team would like to acknowledge the efforts of the Huntington District, Corps of Engineers, in getting the team to the disaster site. Those participating in this effort included Mr. Harold Beemer, Chief, Engineering Division, Mr. Bob Lane, pilot for the District, and Mr. Bob Casey. In addition, the team would like to thank Mr. Bo Copley, Assistant Chief, Engineering Division, for his assistance in obtaining copies of both pre- and post-disaster aerial photography.

Many individuals in federal, state, and private agencies provided background information used in the preparation of this report. The team is grateful to them for their contributions. Finally, the team would like to thank Mr. Onas Aliff and Mr. Marshall Zinn, students at West Virginia University, for the laboratory testing of the refuse.

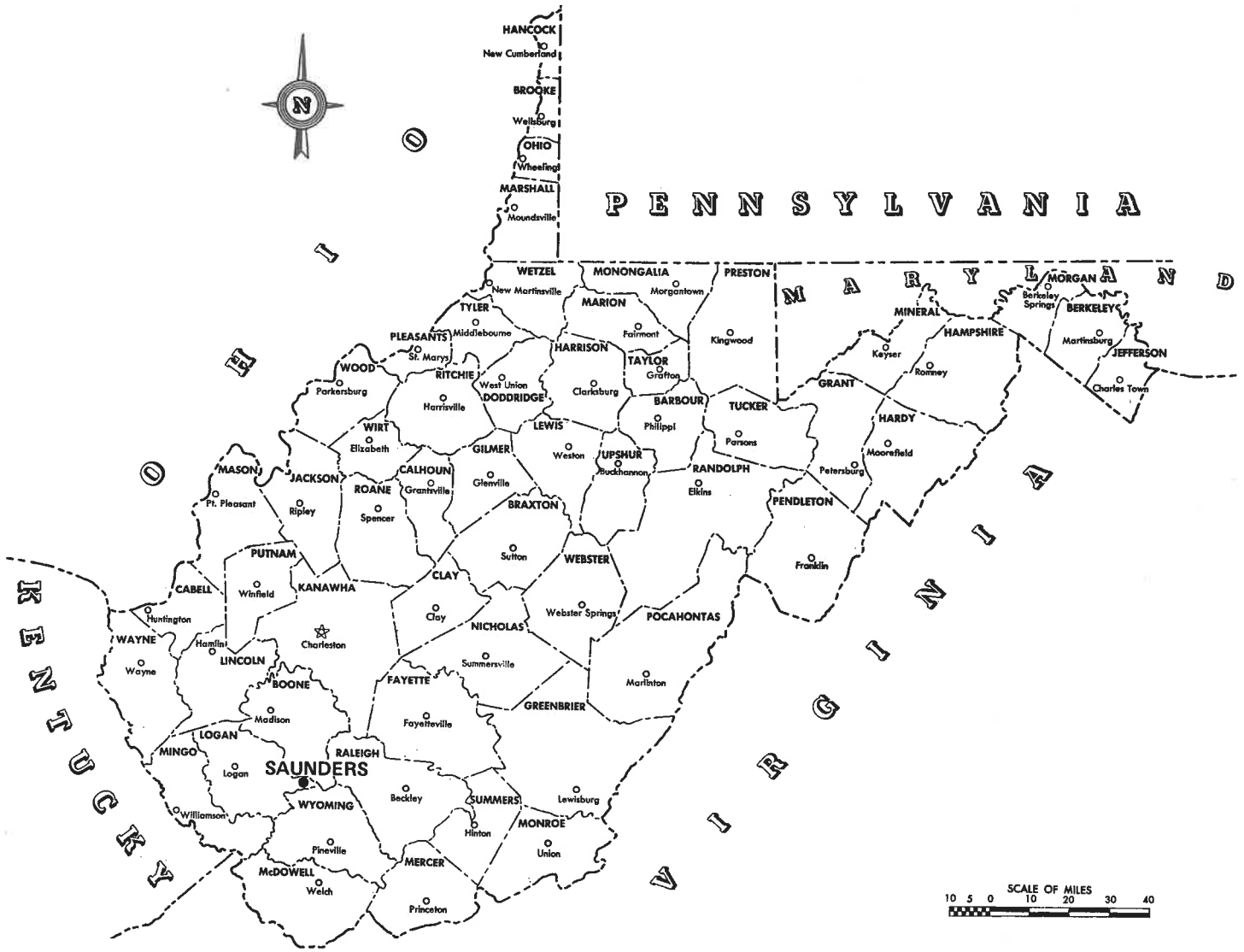

FIGURE 1 Location of Failed Dam, Saunders, West Virginia.

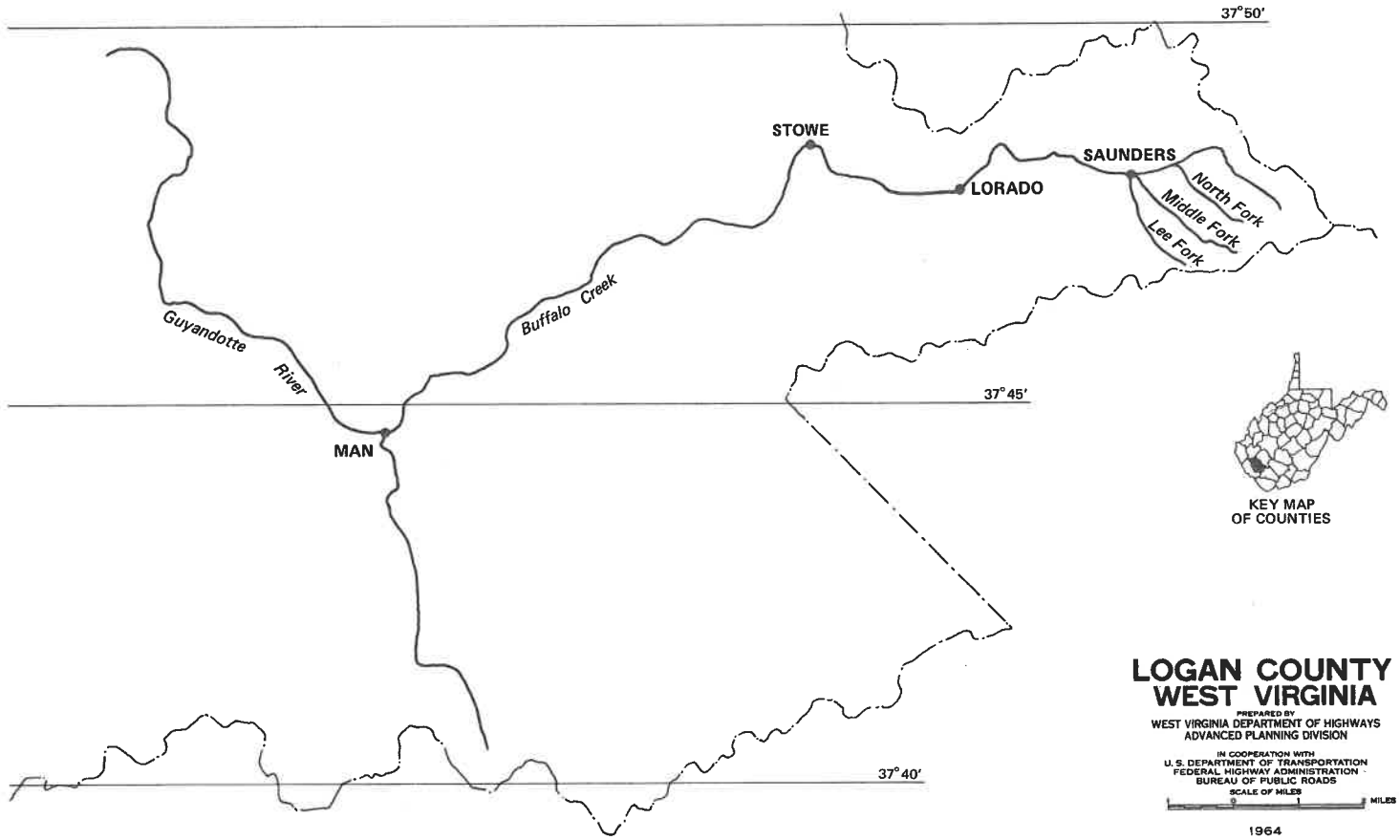

FIGURE 2 Map of Buffalo Creek from Saunders to Man, West Virginia.

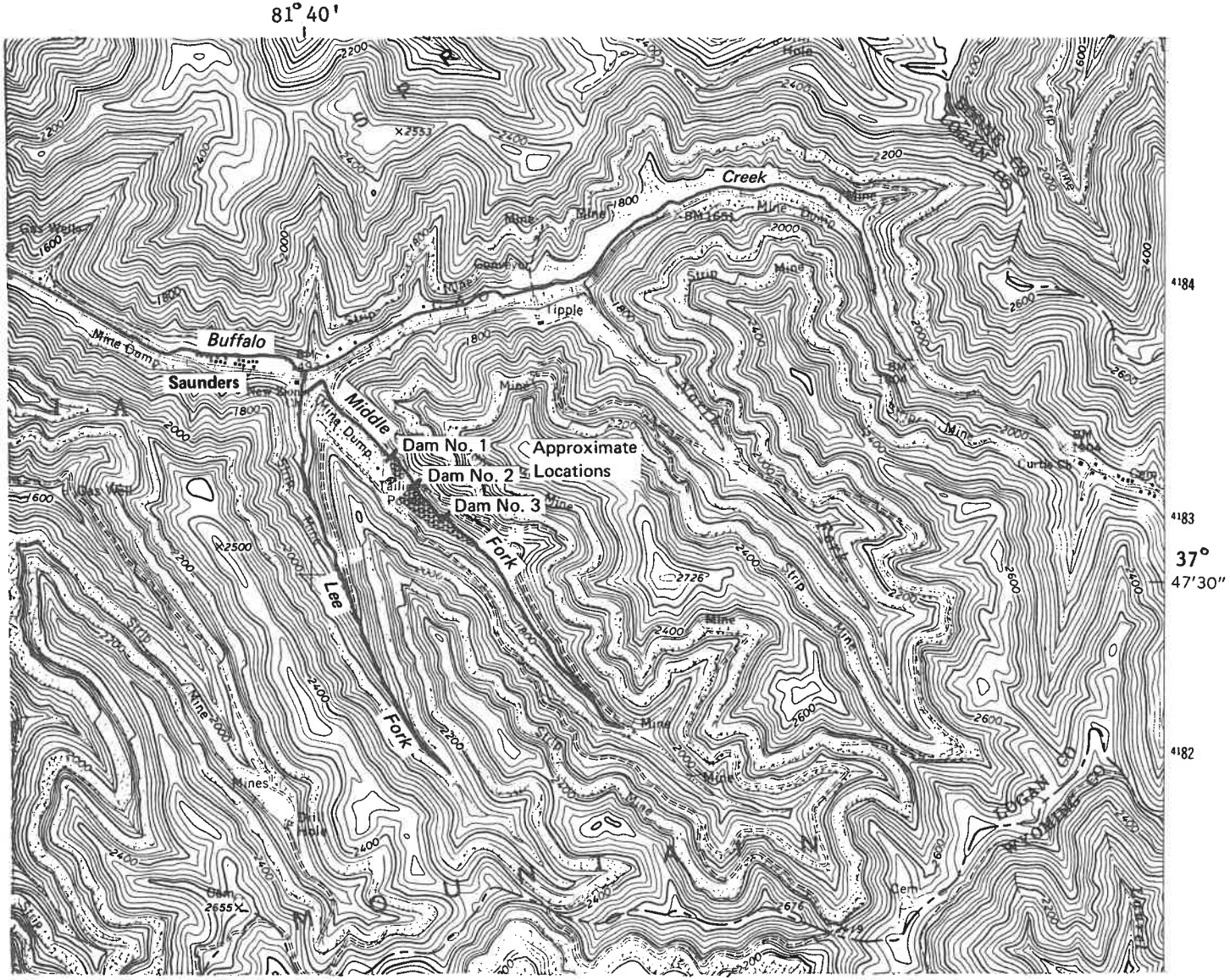

FIGURE 3 Portion of USGS Lorado Quadrangle Map showing Saunders Area.
(Scale 1:24000, Contour Interval - 40 ft.)

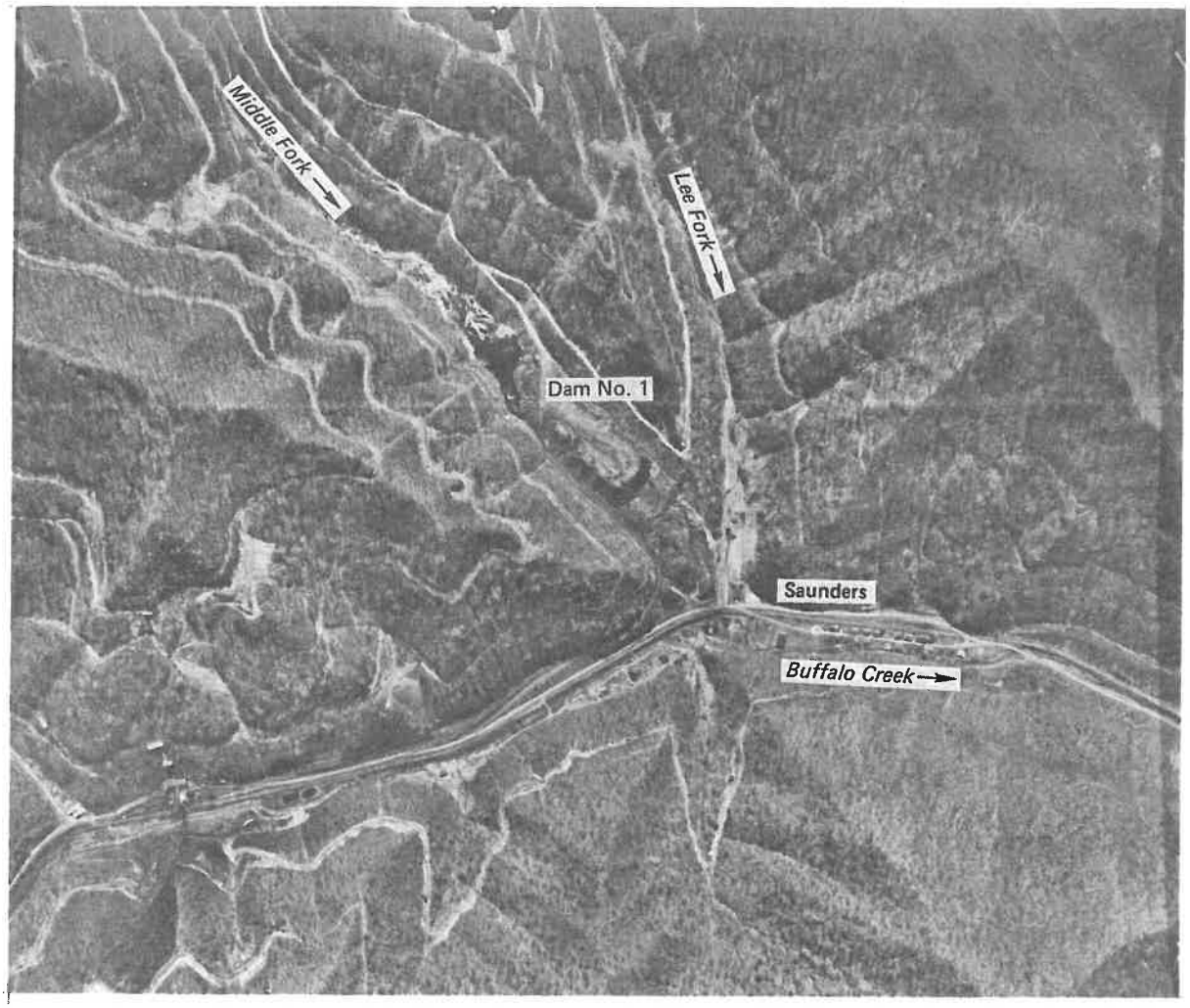

FIGURE 4 Aerial Photograph of Refuse Bank and Dam No. 1 as of March 29, 1966. Approximate Scale: 1" = 1000'.

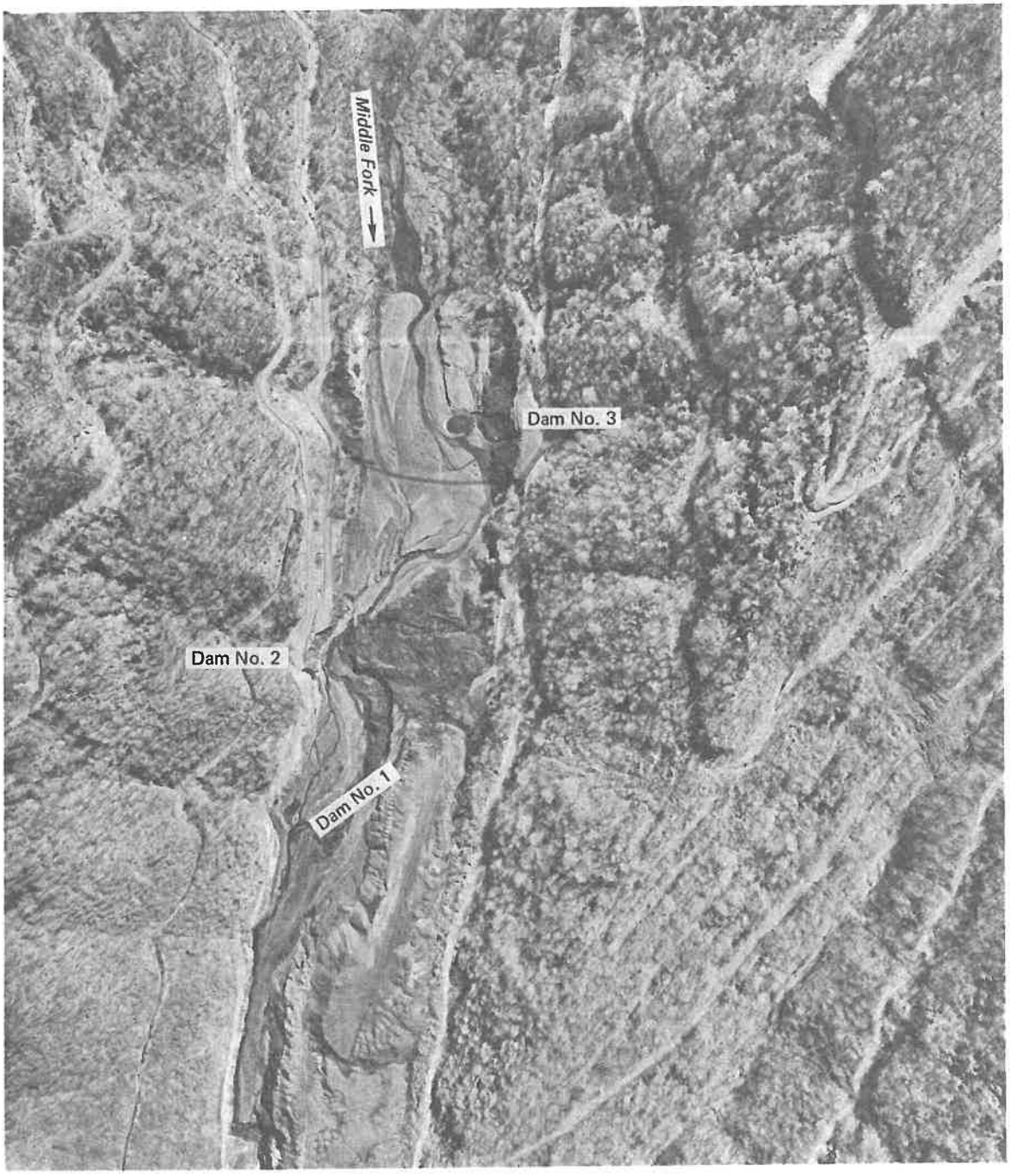

FIGURE 5 Aerial Photograph showing Approximate Locations of Dam Sites (2-27-72). Approximate Scale: 1" = 500'.

FIGURE 6 Aerial Photograph of Saunders Area (2-27-72).
Approximate Scale: 1" = 500'.

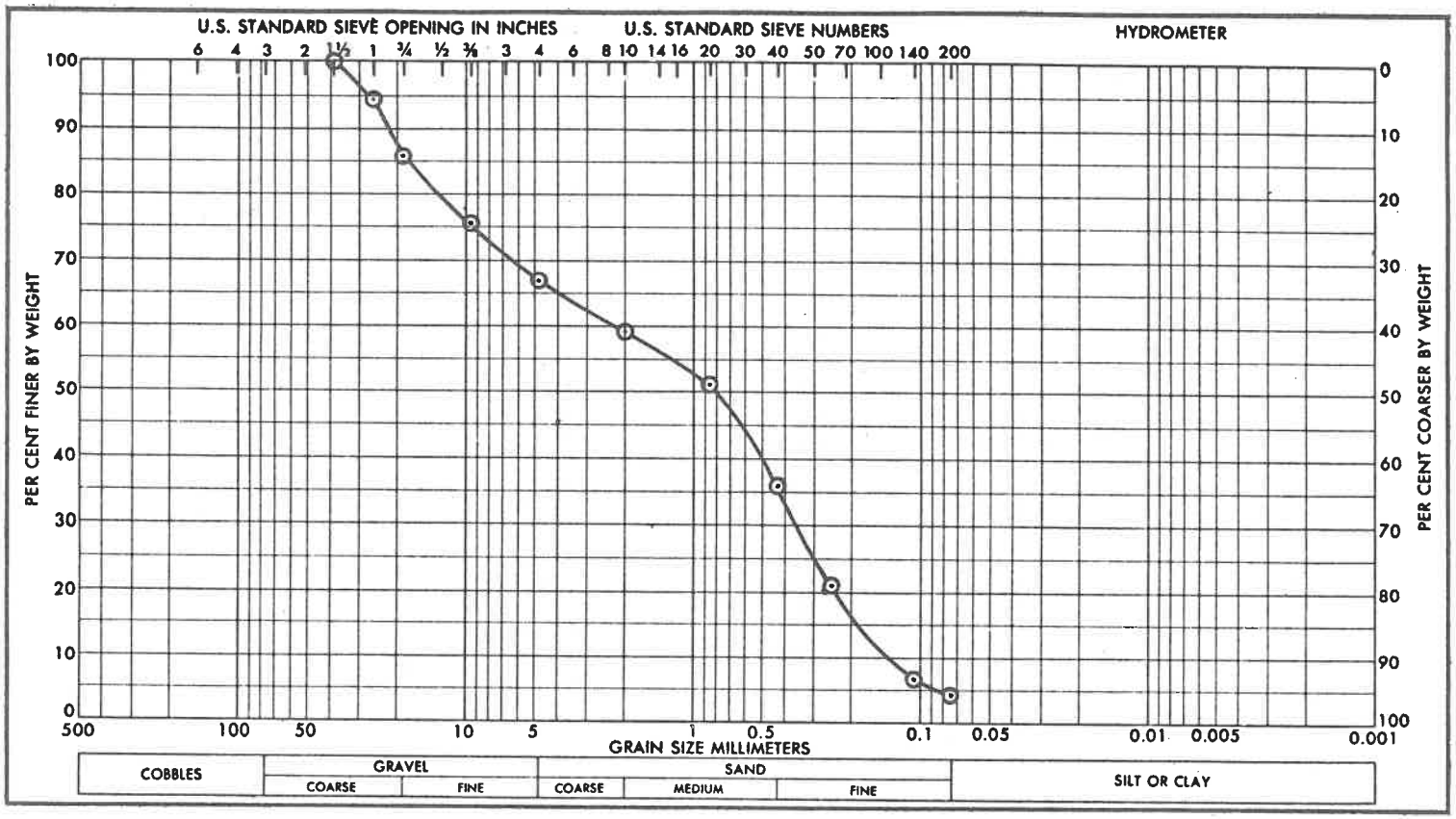

FIGURE 7 Grain Size Distribution Curve for Coal Refuse Sample Taken at Dam No. 3 Site.

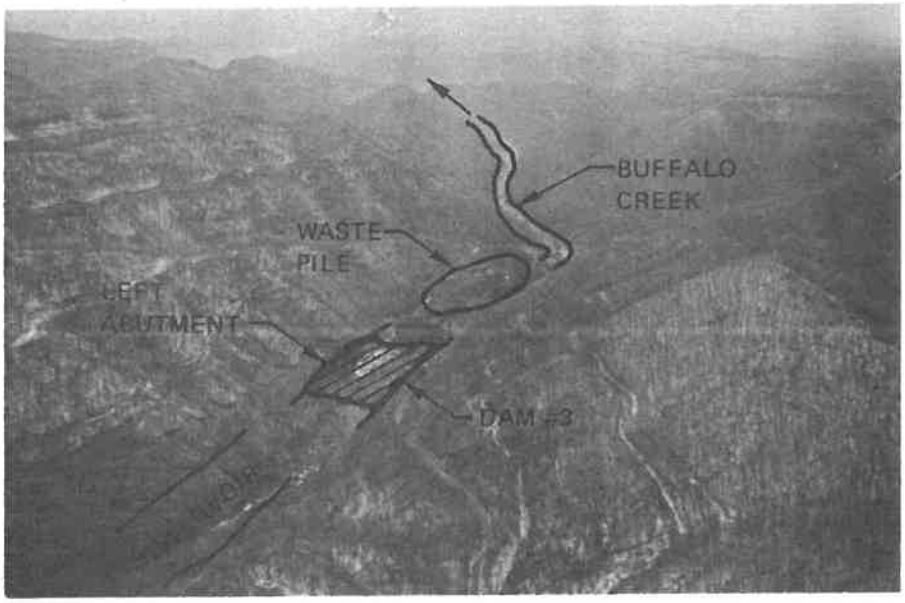

FIGURE 8 Downstream View of Reservoir in Foreground, Left and Right Abutments of Dam No. 3 (at arrow), Waste Pile, and Buffalo Creek.

FIGURE 9 Looking Downstream from Left Abutment.

FIGURE 10 Looking at Right Abutment of Dam No. 3 from Left Abutment.

FIGURE 11 Looking Upstream at Reservoir Area from Center of Dam.

FIGURE 12 Looking up at Left Abutment. Dam No. 2 Formerly in Foreground.

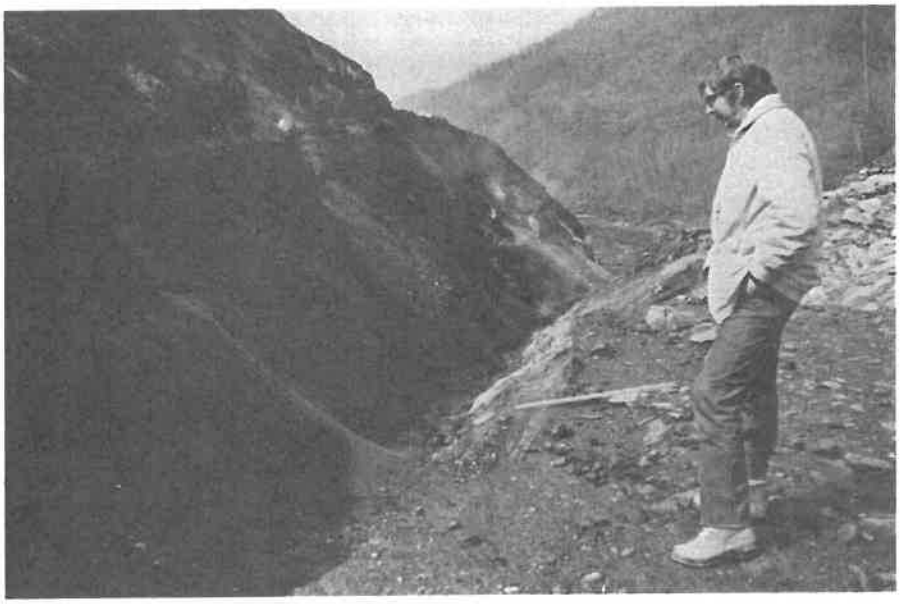

FIGURE 13 Looking Downstream at Washed Out Gulley by Waste Pile.

FIGURE 14 Looking Upstream at Edge of Waste Pile.

FIGURE 15 Looking Downstream at Buffalo Creek from Lower Right Edge of Waste Pile.

FIGURE 16 Looking Upstream at Buffalo Creek, 5 Miles Below Dam.

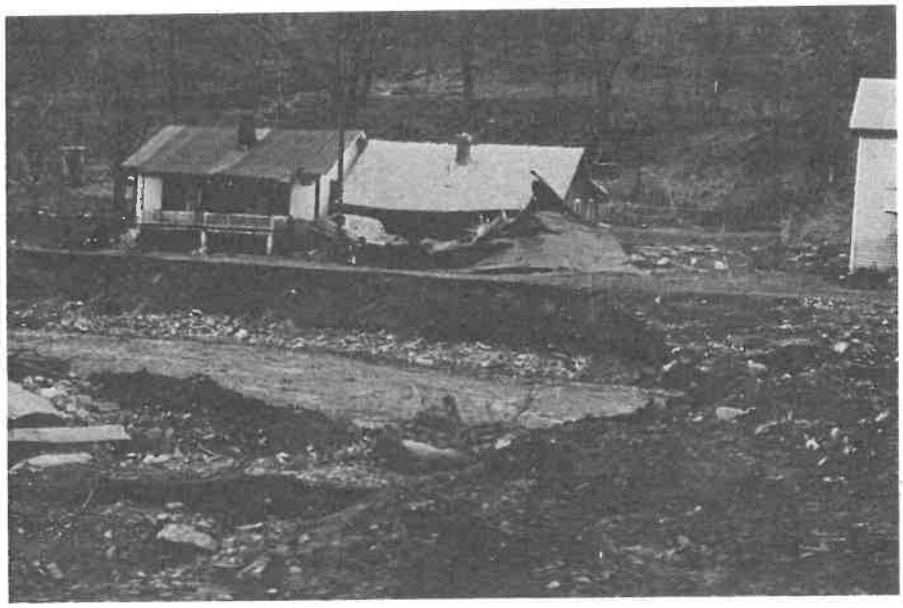

FIGURE 17 Home Removed from its Foundation and Damaged Automobile 5 Miles Below Dam.

FIGURE 18 Town 8 Miles Below Dam.

FIGURE 19 Homes 10 Miles Below Dam.

FIGURE 20 Church Removed from its Foundation. (X on Building indicates Condemned.)

FIGURE 21 General Damage.

FIGURE 22 Debris 14 Miles Below Dam.

FIGURE 23 Guardsmen Searching Debris for Missing Bodies. Fourteen Miles Below Dam.

FIGURE 24 Destroyed Bridge.

FIGURE 25 Destroyed Bridge.

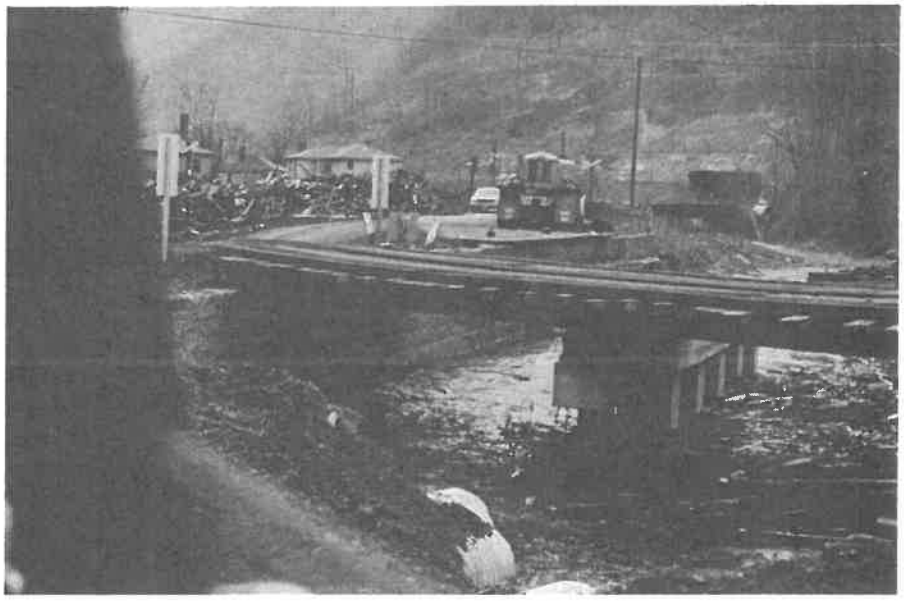

FIGURE 26 Temporary Bridge on Abutments of Destroyed Highway Bridge. Note Debris in Background.

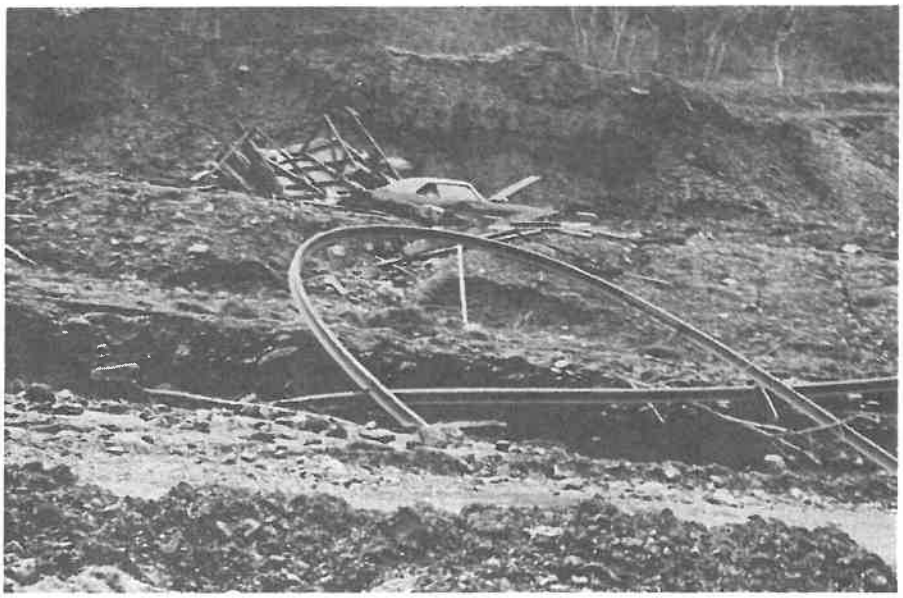

FIGURE 27 Bent Railroad Rails 5 Miles Below Dam.