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BUFFALO CREEK (W. VA.) DISASTER, 1972

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FOREWORD

On February 26, 1972, a dam created of mine refuse failed, releasing between 150 and 200 million gallons of sludge-filled water and thousands of cubic feet of refuse into a 17-mile-long valley known as Buffalo Creek, W. Va. The resultant flood killed 118 people, with seven still missing, injured hundreds, and left over a thousand people homeless. The emotional scar of this terror-filled morning will remain with the residents of this valley as long as they live.

In 1969, Congress enacted the Coal Mine Health and Safety Act which, among other things, was designed to give peace of mind to a large segment of our population who have for years lived in fear of their lives and the lives of their loved, due to unsafe conditions in and around our Nation's coal mines. In 1970, we held oversight hearings that dramatized the need for more stringent enforcement of the laws pertaining to safety in underground coal mines. The disaster of February 26, 1972, dramatized the need for more stringent enforcement of the regulations pertaining to surface mines and surface facilities of underground mines.

Pursuant to the legislative review responsibilities of this committee, we have undertaken a complete investigation of the circumstances surrounding this disaster.

At my request, the U.S. Army Corps of Engineers provided the Subcommittee on Labor the expert services of their engineers to assist in studying the Buffalo Creek Dams and a representative sample of similar refuse dams in the vicinity of Buffalo Creek.

The committee wishes to express its appreciation for the dedication displayed by the large number of employees of the Corps of Engineers who participated in this study. The committee is especially grateful to Mr. Garth Fuquay for his invaluable and dedicated service, often with personal hardship, to the committee and to the Nation.

HARRISON A. WILLIAMS, Jr.,
Chairman, Committee on Labor and Public Welfare.

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Part I of II

THE FAILURE OF REFUSE DAMS ON MIDDLE FORK

Buffalo Creek

U.S. SENATE SUBCOMMITTEE ON LABOR
of the
Committee on Labor and Public Welfare
Harrison A. Williams, Jr., Chairman

May 1972

Report on

An Engineering Survey of Representative Coal Mine Refuse Piles
As Related to the Buffalo Creek, West Virginia Disaster

SUMMARY

On February 26, 1972, the Buffalo Creek Valley suffered a disastrous flood when three dams built to impound coal waste failed on the Middle Fork of Buffalo Creek. The result of the flood left 118 people dead, a number of others missing, and substantial damage to the homes and surrounding area.

The Committee on Labor and Public Welfare, Harrison A. Williams, Jr., Chairman, requested the Corps of Engineers to conduct an engineering survey of the failed dams, and other coal mine refuse piles in the Buffalo Creek, West Virginia, area. The Corps of Engineers survey included on-site inspection, sampling and testing, as well as laboratory analysis of the materials used in constructing these dams.

The conclusions reached in this report are that the design, construction and operations of these dams were unsatisfactory. Specifically, the survey revealed that if refuse piles are constructed across valleys containing streams so as to form a dam, and if these dams are constructed without adequate spillways, or other measures to take care of high volume flow, these dams will eventually fail. Moreover, the failure of these dams was probably accelerated due to the lack of compaction of materials used, together with the failure to follow other basic design requirements.

The particular situation at Buffalo Creek involved three separate dams built on successfully higher stream levels upstream of a massive

refuse pile in the Middle Fork Valley. Of the three dams, the last one built, hereinafter called Dam #3, was the largest and retained the most volume of water and sludge. The size and location of Dam #3 made it the central focus of the survey, and its failure was the significant cause of the ultimate flood and disaster. That dam was built by the simple expedient of dumping coal mine refuse into the settling pond of the pool below and occasionally grading it with a bulldozer. The conclusion that was reached by the survey and analysis is that Dam #3 should never have been built. The reason is that its successful operation depended on uncontrolled seepage through the embankment and/or foundation of the dam. The analysis of the dam reflects that uncontrolled seepage and sliding of portions of the embankment, compared with other possibilities of mechanics of failure, probably was the ultimate cause of the collapse of the dam. Specifically, the failure was caused primarily by a combination of sliding of the downstream portion of the embankment progressing in separate sections upstream and of subterranean channelised flow and erosion of the foundation and/or embankment.

In addition to the conclusions regarding the failure of the dam, the engineering survey discloses that technology is presently available to assure that construction of such dams can be accomplished in a menner to assure the safety of the surrounding communities.

However, there appears to be little doubt that an adequate program of technical inspections of the Middle Fork dams would have indicated them to be in danger of failure. For example, a trained observer in an adequate inspection would have noted the piping and would have been sufficiently alarmed to do something about it.

Report on

An Engineering Survey of Representative
Coal Mine Refuse Piles as Related to the Buffalo Creek, W.Va., Disaster

PART I - DAMS ON THE MIDDLE FORK, BUFFALO CREEK

A. Authority

The engineering study and investigation was initiated upon the request of Senator Harrison A. Williams, Jr., Chairman, Committee on Labor and Public Welfare, on March 10, 1972.

B. Purpose

The Corps of Engineers was asked to make an engineering assessment of the dams which failed on the Middle Fork of Buffalo Creek as they existed prior to failure. In addition, engineering assessments were requested of other representative refuse piles or dams in the area.

The Corps was also asked for its recommendations on what should be done to make the existing refuse piles safe.

Finally, the Corps was asked for its views on measures which can be brought to bear to assure against other disasters of the type which occurred on Buffalo Creek.

C. Scope of the Investigation

General. The work was performed on the basis of sample refuse piles in the area and on the remnants of those on the Middle Fork of Buffalo Creek. The completed study was to be accomplished within 60 days. The time limitation obviated an in-depth study of the sample refuse piles. However, sufficient data was obtained to form general conclusions regarding the engineering characteristics and probable behavior of the refuse piles.

Reports of Investigation. The investigation was to be reported in two parts: Part I, as given herein, the investigation as specifically related to the dams on the Middle Fork, which failed; and a separate Part II, the investigation of representative dams within the general vicinity of Buffalo Creek.

D. General Description of the Area

The area of southwestern West Virginia in which the Middle Fork Dams were located is one of rugged topography, characterized by innumerable steep-gradient streams and valleys with steep side-slopes. Coal mining, both of the deep and strip type, is the principal industry in the area, along with allied supporting services.

For the Middle Fork of Buffalo Creek, the valley walls rise on slopes as steep as 60-70%. The valley is about 2.1 miles long with the watershed divide being at a maximum elevation of about 2,600 above mean sea level and the outlet elevation at Saunders at about 1,500 feet. The stream, as can be recognized, starts at about elevation 2,000 and falls 500 feet in 1.7 miles, for a slope of 5.5 percent. The hillside rock slopes are covered by a thin mantle, generally of less than 5 feet, of colluvial soil; vegetation consists of small trees and brush.

Typical of the entire area, mine refuse dumps are located in the valleys where they will best serve the purposes of the mines; further processing of the coal by washing has resulted in an effluent of "black water" which within the last several years has become legally objectionable for introduction into the streams. The pattern then, has been that the refuse dumps are made into dams to form settling ponds for the "black water" prior to it being released into streams or re-used as clear wash water. Regarding the area stream system of immediate concern, the Middle Fork joins Buffalo Creek at Saunders, West Virginia; about 17 miles from Saunders, Buffalo Creek joins the Guyandotte River at Man, West Virginia.

E. Failure of Dams

Three dams were constructed in tandem near the downstream terminus of the Middle Fork for the purpose clarifying the wash water from an upstream coal preparation plant, and as disposal areas for mine refuse. At about 8:00 a.m. 26 February 1972, after a three-day rainstorm in the area, the three dams failed, releasing into Buffalo Creek a torrent of mine refuse and water of such proportions as to have catastrophic effects on the area between the dams and Man, West Virginia. This disaster has resulted in 118 dead and 7 missing, and 507 homes destroyed, and 273 homes seriously damaged, with minor damage to 663 additional homes.

F. Method of Investigation

The failures on the Middle Fork have been investigated first and are reported on herein in Part I; other representative dams have been investigated and are reported on in Part II of this study. The general methods of investigation, the general hydrology, and geology, are included herein and will not be repeated elsewhere.

For an investigation of this type, some assumptions are necessary at the outset; these are as follows:

a. Extraneous material such as waste lumber, steel and timber are present generally in the refuse piles. These materials comprise such a small percentage of the volume, however, that they are considered as having no effect on the engineering behavior of the refuse.

b. At any one location, the distribution of the material is uniform throughout the cross section of the pile, unless positively indicated to the contrary, below.

c. The analysis of the dams can be obtained with satisfactory accuracy based on the use of field densities and laboratory testing of remolded samples.

d. The dimensions of the Middle Fork Dams have been established with reasonable accuracy by use of aerial photos and by corroborated eye witness accounts.

e. As the depth of sludge below dams 2 and 3 is speculative, it is shown as a thin layer for this study, but present and continuous under the base of the dams.

f. The slopes of dams 2 and 3 are based on eye witness accounts and where data are unknown, reasonable assumptions have been made conforming with observations of the remaining portions of Dam 3 or of other dams in the area.

g. All references to the right and left side of the dams and valleys are based on looking downstream.

Mapping, Geology and Hydrology

The sites were mapped by photogrammetric methods by the Huntington District, Corps of Engineers. The brief geologic report of the area and active sites has been produced, based on field trips and office studies as has the hydrology discussion. These reports are attached as Appendix A of this report.

Field Sampling, Testing and Data Collection

Field Sampling. At the upper site, Dam No. 3, field densities were taken on the upper portion of the remainder of both abutments at some two feet below the surface. A six-inch diameter sand cone was used. Sufficient material was taken near these tests for laboratory analysis; also a sample of the settled material remaining from the pond was taken for laboratory evaluation (samples 9 and 10, plate 6a). Dam 2 was not sampled since its complete failure was surely a result of occurrences at Dam 3.[1/] The location of sampling and density tests is shown on Plate 3. The field density data are as follows:

Location	Sample No.	Unit Weight #/ft^3	W.C.,%
Top, Lt. Abut.	3	104.0	4.2
" " "	4	98.4	9.0
" " "	5	81.3	8.8
" Rt. "	6	84.0	5.9
Floor after Failure	7	76.8	5.3

Data Collection. In order to obtain reliable data, a series of desired items were listed and discussions were held with the owners of the Middle Fork dams. The questionnaire and answers obtained in conference with the owners representatives are presented as Appendix B, hereto. Photographs as shown on the inset of Plate 2 were taken and an on-site examination of the deposits were made with observations and conclusions as indicated below.

1/ This hypothesis is treated further, below.

Laboratory Work. Laboratory work was performed by the Ohio River Division Laboratory, Corps of Engineers, Mariemont, Ohio. Various tests including gradation, specific gravity, consolidation shear strength and permeability were performed on remolded samples, generally using the field density tests as a base reference for the consolidation, shear strength and permeability tests.

In addition, a model of the area, 10 feet by 4 feet by 3 feet high was prepared by the Waterways Experiment Station, Corps of Engineers, and shipped to Washington, D. C. for use as a visual aid by the Senate Committee.

Office Studies. Office studies were made on sections of the dam to determine the conditions under which the embankments would fail or be stable and the probability of occurrence of failure.

g. Investigation of Sites on Middle Fork, Buffalo Creek

Description of Area of Dams and Mode of Operation. The location of the dam(s), now failed, is as shown on Plate 1, near the mouth of the Middle Fork of Buffalo Creek, Logan County, West Virginia.[2/]

Adjacent to Saunders, near the mouth of the Middle Fork, a huge waste pile existed covering the entire valley of the stream. This pile, started in 1947 and used intermittently since, is a maximum of about 200 feet high and over 1,000 feet long, measured parallel to the valley. (See Plates 2 and 3.) Positive data are not available as to the depth to which refuse of this pile blocked the valley on the northeasterly

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2/ A report, dated March 12, 1972, by the U. S. Department of Interior Task Force to Study Coal Waste Hazards, entitled "Preliminary Analysis of the Coal Refuse Dam Failure at Saunders, West Virginia, February 26, 1972" gives, among other things, details of the damage which occurred as a result of the failure and some data as to the physical characteristics of the dams and the valley prior to construction of the work.

side prior to failure of the upper dams, but this area was washed completely out and a canyon of up to 45-foot depth and 50 to 100 feet wide along this side of the valley resulted from the release of water and other materials from the upper dams.

In addition, three dams existed along the Middle Fork above the large pile at the mouth of the valley; the first, reported to have been developed from refuse materials in 1964, was constructed to form a stilling pool for clarifying effluent pumped from the upstream coal washing plant and was constructed in order to augment water supplies for coal washing by use of a collection sump downstream of the large refuse pile. According to the referenced report, it was ". . . constructed by placing the coal refuse partially across the valley at a point upstream from the then existing refuse pile. This refuse was apparently placed on firm ground." This dam (No. 1) was reported to have been about 20 feet high.

Apparently, clarification of the effluent from the coal wash water by use of only the one basin was not entirely satisfactory as related to the standards implemented in the early 1960's, so that in 1966 a second dam (No. 2) was constructed about 600 feet upstream from the first. In 1969 construction of dam No. 3 was initiated 600 feet above No. 2. These two dams were constructed by dumping refuse into the areas of impounded water and settled and/or partially settled coal washings. Dam No. 2 was about 20 feet high also and Dam No. 3 was 45 to 60 feet high at time of failure. No. 3 was used continuously for refuse disposal after its construction was initiated.

After the embankment for No. 3 was completed across the valley by dumping over the end of the fill, additional refuse was placed by trucks dumping over the edge of the embankment into the impoundment or on top of the fill. For the latter, levelling by a dozer and back-dragging of the blade, together with the hauling traffic, was the only compaction the refuse received.

Under "normal conditions," water impounded by dam No. 3 reached the pool below by seepage through the dam and foundation. From reports, a 24-inch pipe was placed in dam No. 3 seven to ten feet below the top of the embankment at its lowest elevation, on the right side, to take care of overflows. Other pipes were for discharge of clear water from dams 1 and 2 to a ditch where it was directed ". . . through two culverts to Buffalo Creek Valley where a small impoundment collected the water." It was then pumped back to the preparation plant for further use in the washing process. It has been reported that for operation of the preparation plant, 500 gallons per minute for the 12-hour normal washing period was pumped into the Middle Fork 0.9 miles above dam No. 3 and flowed into the impoundment (360,000 gallons a day.) Assuming no outflow and the same conditions in the watershed as on 25 February 1972, this volume of water from the preparation plant would be equal to a rainfall in the area for a 12-hour period of only 0.03 inches.

As can be reconstructed by use of aerial photographs, Dam No. 3 had the following dimensions:

a. 435 feet wide on left abutment; 300 feet on right abutment.

b. Its maximum length, 585 feet.

c. It slopes about 1 V on 1.5 H, both upstream and down.

It is further reported that water had been no higher than 11 feet from the top of the dam before the late February 1972 rainfall.

Dam 2 had the approximate following dimensions:

a. Slopes about 1 V to 1.5 H

b. From field observations, the crest of this dam was quite wide on the left side of the valley in the vicinity of the gob pile and roadway. It is reported to have been no more than 20 feet on the right center portion, flaring to slightly greater width at the right abutment.

Geology of Immediate Area of Middle Fork and Failed Dams

Locally, along the Middle Fork, in the area of the dams which failed, the embankment foundation under the remaining abutments consists of a thin residual and colluvial mantle of soil generally not exceeding 18 inches in thickness. This overburden consists of a brown lean clay with weathered sandstone and shale fragments. In view of the type of parent rocks and the steepness of the stream bed gradient, it is quite likely that a layer of gravel composed of sandstone, siltstone and shale overlays the stream-bottom rock.

The surface rocks exposed along the valley walls, some by erosion during the dam failures, consist of fine grained sandstones, siltstones, and shales of the Kanawha Series, Pennsylvanian age. Two coal seams have been identified downstream of the site from published county geologic reports. They are the Williamson coal seam at elevation 1675 and the Alma Coal at elevation 1565. Above the refuse dam, strip mining has been, or is being performed on the Chilton seam at elevation 2000 and the Coalburg at elevation 2200.

The strata are dipping uniformly at the rate of 100 feet per mile to the northwest.

Earthquake Activity. The Buffalo Creek area is located in Zone 1 Region of the Seismic Risk Map of the United States.3/ Within this zone minor damage is predicted. Distant earthquakes with accelerations slightly higher than 0.05 g may cause damage to structures with fundamental periods greater than 1.0 second. This corresponds to intensities V and VI of the Modified Mercalli Scale of 1931. (See Appendix C.)

On 19 November, 1969 at 8:08 p.m. EST, an earthquake occurred at the geographic location of 50 miles West of Roanoke, Virginia, and 80 miles south of Charleston, West Virginia. The epicenter at Lat. 37.4 north, Long. 80.9 west, is located approximately 45 miles SE of Buffalo Creek. The U.S.C.G.S. in Washington, D. C. ranked this tremor at an intensity of V or greater (Modified Mercalli). For comparison, the recent quake which caused considerable damage in the San Fernando Valley, California, (1971), was ranked at maximum intensity of about VII to XI.

Hydrology of Immediate Area of the Middle Fork and Failed Dams

Data used for the storm and flood has been obtained from extensive field and office investigations conducted by many agencies and from available aerial and U. S. Geological Survey 7.5 minute quadrangle maps. Using the most reliable of these sources, the conditions existing prior to the disaster at the further upstream dam No. 3 are as follows:

a. The tributary drainage area above the dam is 1.08 square miles.

b. The minimum elevation of top of dam was about 1750 feet msl.

c. The possible storage potential which may have been available behind the dam is shown on the area capacity curve, Plate 8.

3/ Corps of Engineers Engineering Technical Letter 1110-2-150, 30 July 1971, "Seismic Risk Map of the United States."

The National Weather Service had reported that during a 72-hour period prior to the breach of No. 3 dam, precipitation at Logan and other stations in the vicinity of Buffalo Creek had averaged 3.7 inches. This amount, falling in a period of three days, has a frequency of occurrence on the average of once in every two years.

Although snow cover of 6 inches or more was reported in the area on 21 February, warmer temperatures in the following days had melted this snow to the extent that only small patches remained on the northern slopes at the inception of a high intensity rainfall period during the evening of the 25th. The heavy rainfall continued throughout that night, commencing at about 8:00 p.m. on the 25th and ending 13 hours later. It was accompanied by thunder and lightning, with highest intensity occurring around midnight to 1:00 a.m. Although the greatest amount of precipitation officially recorded in the area was 1.90 inches at Logan, a bucket survey by National Weather Service personnel located two supplemental samples for the 13-hour period of about 3-3/4 inches, at about 3 miles from Dam No. 3.[4/]

Consequently, it is very possible that rainfall greater than the official station average could also have occurred above the dam and produced a greater than usual runoff.

In arriving at the storage potential for pool 3, the 24-inch corrugated outflow pipe must be considered; this pipe through the embankment was located about 6 - 8 feet below the top of the dam, or at approximately 1743 feet msl, and while the exact location, in plan, is obscure, discussions indicate it to have been located 150-200 feet from the right abutment. The pipe outlet capacity is shown on Plate 9.

4/ See also Report to Administrator, National Oceanic and Atmospheric Administration, "Buffalo Creek Disaster", April 17, 1972.

Witnesses had reported that before this storm, the outlet pipe had never carried any water through the dam. For the purposes of analysis, an assumption was made that just prior to this storm, heavy runoff from previous rainfall and snowmelt could have raised the impoundment level to the outlet pipe. The remaining capacity of the reservoir available above this level would be equal to 168 acre-feet, or approximately 2.92 inches of runoff.

Therefore, rainfall above the dam averaging 1.9 inches, as reported to be general by the Weather Service, would have been insufficient to fill the reservoir even if no leakage occurred through the dam.

Regardless of this, it was also reported by witnesses that the water was at the crest of the dam, or possibly trickling over, just before the breach.

Tributary basin runoff resulting from the 3.75 inches of rainfall was routed through the reservoir, assuming an outflow solely from the outlet pipe. The results of the routing computations showed that with those assumed conditions, the pool would have approached but still not exceeded elevation 1750 msl by the time of failure at 0800 hours on 26 February.

It cannot be definitely concluded by hydrologic analysis of known data whether overtopping occurred. However, since rainfall intensities can vary greatly throughout a storm area and unofficial records of 3.75 inches were attained in proximity to the dam, it is entirely possible that pool level could have reached or exceeded the top of the dam if outflow during the impoundment period was minimal.

Description of Failure and Conditions Before and After Failure

As indicated above, the reported general storm intensity (3-3/4 inches in 72 hours) by rainfall alone would not appear to have caused sufficient impoundment to approach the top of the dam. This simply means that one or a combination of factors occurred:

(1) The pipe outlet was not operating even near capacity,

(2) The local rainfall was more than that of the general storm of the area,

(3) There was more snow on the hills at the beginning of the storm than was generally reported by witnesses, and

(4) The level of the pool at the beginning of the storm was higher than reported, or

(5) The elevation of the low point in the crest of the dam and of the outlet pipe were actually lower than the value used in the computations.

In any case, there was sufficient runoff and pool rise to cause failure of the dam with water at or near the top of the dam.

From field observations, there is now no recognizable evidence of Dam No. 1. As shown on Plate 3 approximately 100 feet of the right portion of Dam No. 2 has been breached and entirely removed. On the left side of Dam No. 2 and parallel to its axis for a distance of about 200 feet, the upstream layer of sediment has apparently been pushed downstream toward No. 2 and, part of it, up and over the dam. This was done without apparent erosion of this highly erodible material; that is, most of the flow from the breached Dam No. 3 was directed toward the right side of the valley where the other two dams were breached. Erosion has exposed the parent rock on that side of the valley. Some pipes of about the diameter mentioned above are evident in the debris in the valley. Also evident and of speculative significance are two 5-foot ± diameter cone sinkholes on the right side of the existing stream. Similarly, on the left a large 30-foot ± sinkhole of the same general characteristics exists in what was the downstream portion of the foundation of Dam 3. The pipe overflow on Dam No. 3 was reportedly flowing about half full at the time of the failure. The slope of the pipe is not known; its flow, therefore, could have been impeded. At any rate, it was not sufficient to stop the disaster.

The entire width of Dam No. 3 has been removed except for about 50 to 75 feet on the left side of the valley and 30 or so on the right side. (See Plate 3.)

There was also no provision for seepage protection measures and no spillway was provided. Also, from reports there was no zoning of the material within the dam. This is borne out by the appearance of the remaining portions of the dam on both abutments. As is usually the case, the average abutment material also was finer than that appearing on the surface of the slopes.

The dam failed at a surprising speed; reports from presumably reliable witnesses indicated that at 0745 hours the day of the failure, the water level was at, or within 6 inches of the top of the dam and at 0800 hours electric clocks in the Village of Saunders stopped -- due, presumably, to debris from the failure rupturing the power lines. Also, one witness was on the dam, at about 0745 hours on 26 February, and reported the dam to be in an essentially unstable condition. Further, another witness was parked on the road near the huge gob-pile at about 0755 hours and reported three inches of black water flowing over the road; he moved back down the road and to a higher elevation and heard a roar from upstream at about 0805 hours, followed suddenly by an immense wall of water appearing in the area between the right side of the valley and the gob-pile, moving rapidly down the valley. It is therefore reasonable to conclude that the major portion of the failure occurred in something less than 15 minutes -- possibly 10.

There were no reports of any of these dams being on fire; however, the huge refuse pile at the mouth of the valley was burning on the right side where the by-pass flows occurred. This resultant fire, by witness account, when quenched by the failure outflow, caused several explosions. The only significant result of the explosions could have been to loosen the surface of the gob-pile and make it more erodible.

There were plans made about one-half hour before failure to install another pipe on the right abutment, directing its flow across the road and into the ditch adjacent to the hillside. While such a completed installation could have been of assistance in maintaining the pool level at the time it was proposed, it is doubtful that it could have been successfully installed. For successful installation a ditch would have been required -- water probably would have flowed in this ditch regardless of nominal efforts to stop it and an already threatening condition could have been made worse by this flow -- it even could have been the initiation of failure, but perhaps a slower failure than actually occurred. Speculation in this matter is not significant since the pipe was not installed and failure did occur.

For some time, perhaps a year or more, boils downstream of the dam in pool 2 were in evidence, at least on the left side of the valley. Since the significance of these boils was apparently not understood by those witnesses reporting them, similar conditions could have existed other than on the left side. These boils occurred with the pool at low level. and were in operation for a considerable period of time prior to the late February 1972 storm over the area. This action was described as being a noticeable emergence of black water of about the color of the pool upstream of Dam 3, in the pool of relatively clear water of pool 2, downstream of the toe of Dam 3. This seepage by its natural action had eroded a small flow path in the foundation, starting at the point of emergence, clear back under the dam and to a point of entrance to pool 3. It is entirely reasonable to assume that this "pipe" (or these pipes) had stabilized under the small normal difference in elevation between pools 2 and 3. Then came the February storm, resulting in a significant increase in the elevation of pool 3. Under this condition, the pipe or pipes would be subject to a major increase in pressure and consequent velocity, causing a corresponding significant increase in erosion and enlarging of the foundation pipe -- for three days of increasing upstream pool elevation. This foundation erosion was in progress, exposing a material which must be considered erodible, to the process. By this mechanism, at the time the storm started, the dam could be considered in an incipient state of failure. After three days of erosion in pipe or pipes in the highly erodible material and at an increasing head, a volume of material could have been removed sufficient to cause the collapse of the pipes, which by this time could have been some feet in diameter. This, in turn, could have suddenly lowered the dam in a localized area, resulting in a rush of water and effective sudden failure of the embankment. In further support of the postulated piping failure, one observer, present on the dam only minutes before failure occurred, describes in part his walk from the right abutment to the central portion of the dam as the farther he progressed from the right abutment, the softer and wetter the top of the embankment became, until by the time he reached the central area, he was sinking into the embankment to the top of his shoes, where previously he had driven in a truck. In addition, he stated that he observed the dam to be shifting slightly back and forth.

It should be noted that the location where the shaking was observed was probably well past the location of the 24-inch pipe, toward the center of the embankment. No reason for the embankment to be shaking or vibrating is known other than the water rushing with turbulence through a rough passage eroded in the embankment and/or foundation (piping). This mode of failure, therefore, is consistent with observations. The action was incipient and the rapid failure which occurred is of the type which could occur due to piping collapse.

One witness present on the dam about 0630 hours, 26 February, reports that longitudinal cracks existed on the dam at that time and that there was displacement at some of the cracks, downward on the downstream side of the crack. On return of another witness at about 0745 hours, he observed that downstream portions of the dam had disappeared and others were disappearing in pool 2. This action strongly suggests that another form of failure had been in progress for a period of at least an hour and a half before the final surge took place. This failure process is that of a progressive circle or wedge failure, beginning at the original downstream slope and working its way upstream in stages, until the upstream pool breaks through and ostensibly, sudden and massive collapse occurs.

Laboratory Testing and Results. The samples obtained in the field were sent to the Ohio River Division Laboratory in Mariemont, Ohio, for testing. The testing was as follows:

a. Moisture Content. Samples from the density testing were sent to the laboratory in sealed cans for moisture determination. The determination of water content [4/] for these samples and all others was made on the basis of oven drying at 60° Centigrade until a constant weight was reached.

b. Gradation. The grain-size determination was made by standard laboratory methods, with the addition that care was taken to reduce the somewhat fragile particles as little as practicable by keeping to a minimum hand-manipulation of the material during testing.

4/ Some research was necessary to be assured that only the moisture from the samples was being evaporated; that is, that as little as practicable of the volatiles from the coal in the samples was driven off. To this end, several trial samples were dried out under infrared lamps, several in the oven at 60° C and several at 100° C were tested. The infrared samples took some days to reach a constant weight, and less control as to air currents, humidity, and temperature was possible using this method; the 100° C samples reached a constant weight but this temperature reduced the weight somewhat of samples which had been dried to constant weight in the 60° oven, thereby indicating a possibility of driving off volatiles or organic material rather than simply moisture. It was therefore concluded that the oven at 60° C was the most desirable and reliable method of moisture content determination for these samples. This latter method was then used throughout the testing program.

c. Specific Gravity. The specific gravity was obtained on representative samples, thereby being a figure which represents the combined value of coal, shale, sandstone, etc., depending on the percentages of each in the sample.

H. Analysis of Dams on the Middle Fork

Of the several types of analysis that dams should be subjected to in the process of ensuring their safety, a most important one is that of sliding stability. In this type analysis, it is common to give the results in terms of a "factor of safety." In the analyses, the forces which tend to cause movement are applied to the section, and the forces which tend to resist this movement are similarly indicated. The forces are then summed either graphically or algebraically and the factor of safety is obtained as the ratio of the sum of the resisting forces to those which would tend to cause movement. An example of the use of the factor of safety of a dam is that for the level at which a pool is maintained during the summer for recreation purposes, the dam must have a factor of safety of not less than 1.5.

Theoretically, a factor of safety of 1.0 should indicate the embankment is barely stable but (to be ridiculous) if it were exposed to a small force, such as a wind from the wrong direction, it would fail. In theory then, the embankment under analysis would be stable if computations show a factor of safety larger than 1.0 and would be subject to failure by sliding if the factor of safety is less than 1.0.

Practically, however, a safety factor of 1.0 to 1.2 under operating conditions is rarely considered satisfactory, due to the unknown accuracy of some of the assumptions generally necessary in solving stability problems; likewise, a factor of safety of 0.9 to 0.99 may not actually mean the embankment will fail since the accuracy of the assumptions used may be responsible for the seeming instability.

It may be concluded then that for operating conditions, the range of factors of safety between 0.9 and 1.2 are generally taken as warning flags and usually adjustments in materials and section configuration will be required to improve the factor of safety and make an embankment "safe" against sliding; that is, with an acceptable factor of safety.

As an example of the flexible use of the factor of safety, Corps of Engineers practice is to require a higher value for normal conditions which will probably be encountered in day to day operation than for conditions which may not occur simultaneously or which may occur for so short a duration that the entire spectrum of potentially damaging effects will not have time to develop within the embankment. In this regard, a factor of safety of 1.5 is required for the normal operating conditions and a factor of safety of 1.2 is required for rapid drawdown of the pool from the level of the spillway; however, the possibility of earthquake and rapid drawdown of the pool occurring at the same time is considered so unlikely that an analysis of the latter conditions is not necessary, regardless of the resulting factor of safety. Similarly, experience in other areas has shown that regardless of some of the otherwise slight inaccuracies involved in the analysis, the method used in applying earthquake forces is sufficiently conservative to allow a factor of safety of 1.0 to be used when these forces are superimposed on those determined with reliability which are due to normal operating conditions.

Sliding Stability

For reasons contained herein, the failure of Dam 3 on the Middle Fork is considered more significant than the failure of the other two dams; accordingly, tests in the field and laboratory were performed only on Dam 3 material and the stability analyses reported herein were performed only for Dam 3.

From field and laboratory test results, the more significant values used in the stability analyses are shown on Plate 5. The cases analyzed for the embankment are shown in general schematic form on Plate 5, also. These include:

a. Progressive circular slice failure starting downstream and progressing upstream, full pool.

b. Progressive wedge failure, starting downstream and progressing upstream, full pool.

c. Sliding of the entire embankment on the sludge foundation, with uplift in a pervious foundation layer beneath the sludge.

d. Same as c. above, except with no pervious foundation layer beneath the sludge.

Cases a. and b. were performed by electronic computer; cases c. and d. were performed manually. The details of the computations are on file in the U. S. Army Engineer District, Pittsburgh, Pennsylvania.

Case a. For the circular surface of sliding, the factor of safety was determined as 0.54. In this case, there is no question from the analysis but that failure could occur. This factor of safety is so low that, taken with the above reported crack and displacement at 0630 hours and sliding at 0745 hours, it is almost a certainty that progressive failure, as described for b. below, was occurring. This type of failure is consistent

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with observations and analysis and had time to develop into a sudden massive collapse of the dam.

Case b. The critical wedge for failure gave a factor of safety of 0.97. If we split hairs and say that the factor of safety must be greater than 1.0 for stability, then it is obvious that the portion of the embankment downstream of the critical plane on Figure 5 would slide downstream. Practically and consistent with the discussion of factors of safety given above, the only conclusion which can be drawn in this case is that there is danger of instability. Also, if this critical wedge slid out, a wedge of the remaining downstream portion of the embankment would be critically subject to a similar failure, which process would be repeated until the entire embankment would be destroyed.

Case c. It was believed prior to the analysis that this case could possibly have been the critical one, in that it would allow a shifting and sliding of the entire embankment in a sudden manner, totally breaching the dam. However, if the conditions postulated in the analysis are reasonable, the dam did not fail in this manner, since a factor of safety against sliding of 3.+ was obtained under these conditions. This factor of safety was obtained using the entire width of the embankment; if, in the embankment, a clear path of seepage to the underlying gravel existed, a condition of instability could exist over that portion downstream of such a path. Similarly, it is clear for the conditions shown that on the downstream slope, uplift equals the downward forces so that downstream of this point the embankment was unstable. The latter conditions would result in progressive failure, again, and would appear to conform to the reports of this type failure.

Case d. This case is less critical than Case c, since uplift pressures are less; therefore, the factor of safety is larger than for Case c. No further computations were made for these conditions.

In comparing the stability criterion for normal operating conditions to the cases analyzed, it can be seen that in two standard relatively simple conditions of analysis, the dam was unsatisfactory from a sliding standpoint. However, under these conditions, a progressive series of failures would be necessary to achieve complete breaching of the embankment; such action had not been reported by observers, and appears to conform to the ultimate conditions required for the rapid failure which has been reported.

Accordingly, the more likely mode of failure would have been that due to piping of the embankment and/or foundation, combined with progressive sliding.

Piping

In the matter of a piping failure through the foundation, the mechanism of piping is sufficiently understood to determine whether it is likely to occur, and mechanics are available to provide means for forestalling such a condition. In the case of Dam 3, however, the need for such analysis does not exist; piping was occurring in the foundation and no designed means of preventing or stopping or otherwise controlling it were used. Therefore, the dam was unsafe as regards piping and its failure could have been due entirely to piping or piping could have contributed substantially to the failure by other mechanisms.

Overtopping

This type of failure is due essentially to progressive erosion of the embankment beginning with water from the pool flowing over the top of the embankment at its lowest point. In continuing this action, the stream removes the embankment material in its path, essentially as a result of stream velocity, beginning slowly and increasing the erosion as the velocity of the flow increases. In addition, the stream tends to undercut the sides of the channel, the sides shear and fall into the flow, thereby widening the breach in the embankment. This action continues until the level of the upstream and downstream pools are such that velocity of flow is reduced to the point that no further erosion occurs. Generally, this latter development results from complete breach of the dam.

Two points exist which are not compatible with this type of failure in Dam No. 3; (1) the failure must have occurred rapidly as mentioned hereinbefore and (2) almost the entire embankment was removed. On the other hand, it is quite probable that Dam No. 2 failed in this manner, since only a relatively narrow part of the dam was removed and the breach in it could have been already underway when the large rapid surge from Dam 3 struck it.

If it were not in process of failure at that time, it is known to have been considerably lower on the right side of the valley and, therefore, the surge in the pool would have probably damaged that area more than higher areas when it struck. Then, having initiated the erosion path, the flow continued through this area. The proposition of failure of Dam 2 in this manner is not inconsistent with the rapid registering of downstream damage since it would have actually been far overtopped by the surge from the rapid failure of Dam 3. Consequent erosion of the embankment of Dam 2 could have begun immediately subsequent or during the passage of the latter part of the surge. That such a surge did, in fact, take place can be observed from a portion of the remains of the sludge from pool number 2 which was obviously thrust up and over, to some extent, the embankment of Dam 2 on the left side of the valley -- that is, the surge could have pushed the material up and over the dam and then subsided as a result of the flow on the right side, as the embankment failed in that area.

As to the overtopping failure of Dam 3 being inconsistent with observed facts, such erosion would have appeared to cause a more gradual increase in the debris downstream. Such a gradual increase would result in the process taking longer than the 10 minutes or so between the time the dam was observed to be standing with water at or 1/2 foot below the crest and the report of serious damage downstream. Even more time would have been required if Dam 2 had failed in a similar manner as a result of the overtopping erosion of Dam 3. As to the second point that almost the entire embankment of Dam 3 was removed, typically, erosion does not cause removal on such a large scale; rather, the flow starts in a low area and the attacks are concentrated in that area, with widening of the breach being accomplished to some extent by velocity against the confining embankment walls plus the undercutting, shearing off and consequent removal of the sides of the breach area. The mechanics whereby such a breach would have widened to include almost the entire length of the dam are difficult to visualize and postulate and therefore cannot be seriously entertained. The relatively narrow breach of Dam No. 2, on the other hand, does conform to the visualized action and could have been formed by massive overtopping and consequent erosion.

Accordingly, failure of Dam 3 must have been caused by action other than overtopping -- one cause or contributing cause was piping of the foundation; the other, a progressive shear failure of the embankment. If the latter type failure occurred, it probably was in combination with a piping failure -- it is doubted that this shear type of failure could have been the sole cause of breaching since known condition of piping existed prior to the late February storm.

I. Discussion

Dimensions and Configuration. Data as to the precise details of topography in the valley prior to the failure of the dams are meager. The best information available is shown on Plate 2a, an enlargement of a high altitude aerial photo taken in 1971. The location of each of the two upper dams (Nos. 2 and 3) is positive; the lower (Dam No. 1) is reasonably certain and can be located with all the accuracy necessary for purposes of this study. The details of the embankments as to upstream and downstream slopes are not positive. For this study, reports and observed slopes of similar materials in the area were used. The saturation line in Dam No. 3 prior to failure was based on corroborated observations just prior to failure that the embankment was ". . . soft and wet . . . ."

As to the downstream exit of seepage through the embankment, witnesses were not aware of seepage emerging on the downstream slope. However, since these witnesses were not trained observers, and the slope was wet due to the rains, it is likely that they would not have recognized the seepage that would have been occurring. For purposes of analyzing, the upper seepage line was assumed to exit at the elevation of the downstream pool, rather than on the slope. The result of this assumption makes a slightly higher safety factor than probably existed in terms of actual seepage.

The elevation of Dam No. 3 was assumed to be at the same elevation as the roads on each side of the valley -- with straight line interpolation between these elevations. The fill for Dam No. 3 is known to have been dumped on the sediment in the pool formed upstream of Dam No. 2; a nominal depth of 5 feet of this sediment is therefore shown under Dam No. 3 on Plate 5. The elevation of the valley bottom (foundation for Dam No. 3) was determined by straight line interpolation between points of known elevation, upstream and downstream of the dams. Based on observation of the debris after failure and on upstream natural materials and on gravel in the streambed on Buffalo Creek, it appears reasonably certain that a layer of coarse pervious material underlay the sludge for Dam 3 over at least a portion of the valley floor.

Order of Failure. On 26 February 1972, the dams were observed to be intact less than an hour before major destruction in the downstream areas began. For such massive destruction to occur, Dam 3 failed at about the same time as Dams 2 and 1.

There has been some speculation that Dam No. 2 failed before Dam No. 3. Examination of the facts indicates this to be of little consequence, even if true.[5/] Whether the lower ones failed slightly before, and perhaps assisted in triggering the failure of Dam 3 or failed as a result of the failure of Dam 3 is therefore considered to be of minor importance. Accordingly, the failure mechanism of Dam 3 is the more significant since it was instrumental in causing the major amount of damage, and is the one emphasized and analyzed herein. The principles used in the analytical work on Dam 3, generally, are applicable to that of Dam 2.

Hydrologic Design. The storm which occurred, triggering the failure, was of minor intensity to that for which, by normal methods, Dam 3 should have been designed. The generally accepted engineering minimum basis for dam spillways would have been one to accommodate a storm in this area of about 22 inches rainfall in 24 hours, rather than the 3-3/4 inches in 72 hours, which is reported to have occurred.

The pool level prior to the storm appears to have been within elevations 1735-1740, or 10-15 feet below the top of Dam 3. In order for the pool to be within the six inches to one foot of the top of the dam, and rising at the rate of 3 inches per hour, at 0745, 26 February as reliably reported, with the pipe flowing and the known underseepage occurring, it was necessary that the total quantity of inflow exceed that to be expected from a 72-hour storm of 3-3/4 inches.

5/ For instance, Dam No. 2 failed in 1967 and destroyed a pump house, boy scout building, and flooded the basement of a residence. Damage was limited because of the small amount of water impounded.

It would appear that these and many of the other dams in the area were exposed to little hydrologic design. In the design of any dam it is absolutely essential that the design be based on an analysis of the conditions by a qualified hydrologic engineer. Similarly, in modifying existing structures, all engineering changes should be based on the hydrology affecting the dam. In terms of specifics to the area, all dams should have some form of spillway which would release inflow in excess of that required to serve as a settling pond for the coal washings, for those dams existing for this purpose or those proposed in the future. For small drainage areas, a higher dam could possibly store the runoff from the maximum storm; if so, then such a dam must be supplied with tower or pipe outlet which would reduce the pool, gradually, down to normal operating level. For safety, such a dam would necessarily have to be stable under the conditions of the maximum pool, and for drawdown. That is, it would have to be designed and constructed with technical adequacy, all related to the hydrologic conditions.

Additional Faulty Concept. With regard to the inflow of wash water from the cleaning plant, the water was released into the Middle Fork about 0.9 mile above Dam 3. The wash water, then, entered the upstream end of the pool, with settling of the coarse material beginning where the stream encountered the pool still water and finer material settling progressively downstream toward the dam, in proportion to its grain size. This procedure then would cause the poorer (structurally) materials in suspension in the water to settle out in contact with the dams or immediately adjacent to it. In turn, as the refuse materials were added to the dam and dozed over the upstream face, the foundation for the added material would necessarily be, in part, this poorer, low-strength material.

The more advisable and recommended method of deposition of water with solids suspended in it is to deposit it near the dam or the downstream end of a pool to allow the more desirable engineering material to settle out near the dam and the poorer materials as far away from the dam as practicable.

Accordingly, this was another concept of operation which was not correct.

Failure Mechanism. As to the mechanism of failure of Dam 3, Plate 5 presents the schematic details of analysis, with the results of the stability cases given above, using laboratory and field test results as the parameters for the computations involved. The case for the full width of the dam, parallel to the stream flow, indicated that it probably would not fail by the entire section sliding downstream. Similar cases were investigated, but for a slice in thickness, beginning progressively with a slice on the downstream slope and proceeding upstream. These computations indicate that failure could have occurred in these cases. The former case was investigated using a normal decreasing uplift on the base of the dam proceeding downstream, and another analysis was based on the proposition of open gravel existing below the sludge foundation, allowing almost full uplift on the entire base of the dam. The analyses indicate that failure of the entire section en masse probably did not occur from sliding.

<u>Construction Materials and Liquefaction</u>. The materials used in constructing the dam were generally fine, very light in unit weight and, at least in part, were cohesionless. The description of being fine and cohesionless is a warning flag as being highly susceptible to erosion of which piping is a form. Being very low of unit weight and fine are properties which generally affect the stability as regards sliding and flow failure. (The strength of the material under drained conditions is directly proportional to the weight of material above it. Under conditions other than drained, the strength depends to some extent on compaction and on the pore water pressures which generally are transmitted rapidly in such a material). Also, fine saturated materials of low density are notably susceptible to liquefaction and consequent flow slides, particularly in case of shock loads, such as earthquakes. Liquefaction and flow of saturated fine materials can also be caused by large strains. This type of phenomenon results in a mud wave and actually caused much of the damage along Buffalo Creek, subsequent to the failure of the dams on the Middle Fork.

<u>Compaction</u>. The method of construction, end-dumping over the edge of a reasonably high fill, resulted in low unit weights, lower strength than might have been otherwise obtained and higher permeability.

<u>Permeability</u>. The permeability of the embankment allowed it to become saturated, but did not apparently cause the seepage to exit on the slope, which could have resulted in serious erosion of the downstream slope. The more serious case of permeability appears to have been in the foundation, with possible results as described above. It should be noted that the

phreatic line shown on Plate 5 is not strictly in accord with theoretical concepts, but rather is drawn to reproduce reported conditions as nearly as possible; that is, saturated embankment with no seepage exit visible on the downstream slope. Under the reported conditions, the embankment coefficient of permeability from grain size is of the order of 150 x 10^{-4} cm/sec., and from laboratory tests, 5 x 10^{-4} cm/sec. For the time frame under discussion, the coefficient of permeability of about 80.0 x 10^{-4} cm/sec. was sufficiently low to impede flow, apparently lower than some parts of the foundation, and the overall permeability of the embankment and foundation was sufficient to balance inflow and outflow when pool 3 was reported to have been about 15 feet in depth. However, due to known paths of high seepage and lack of uniformity in the embankment and foundation, no further direct consideration of the coefficient of permeability is considered necessary.

Earthquakes. Aside from liquefaction and flow slides in the area of concern, some normal allowance should be made in the design for such shock loads. This is usually done by analyzing the effect of a horizontal force acting through the center of gravity of the section under consideration, the magnitude of the force being selected on the basis of past experience with earthquakes in the area. This was not done in the case of the Middle Fork dams.

Instrumentation and Communications. Generally, also, there is some instrumentation[6/] in dams to give advance warning of dangerous conditions within the dam and a means of direct communication from the dam to a central

6/ See, for example, ENGINEERING MANUAL 1110-2-1908 "Instrumentation of Earth and Rockfill Dams," Corps of Engineers.

office from which action could be taken in case of danger. As can be determined, neither of these installations existed on the Middle Fork.

J. Conclusions.

The conclusions have been grouped below according to whether they pertain to the failure, to design, to construction or to operations and inspection. They are:

a. Pertaining to the Failure

1. The dam was unstable under the conditions imposed upon it.

2. No known means exist to positively identify the controlling mode of failure.

3. Failure could have been due to either, or a combination of any, or all of the following:

(a) Piping through the foundation

(b) Piping of the embankment

(c) Failure in the foundation, allowing a major portion of the embankment above it to move en masse downstream

(d) Progressive failure of the downstream slope of the embankment above the foundation due to high seepage pressures and high phreatic line

(e) Overtopping and consequent erosion of the embankment.

4. There was considerable seepage through the embankment and/or foundation since, according to reports, the pool would remain stable at about 15 feet depth under normal flows (with no means of outlet other than seepage).

5. The dam was founded on a layer of sediment from No. 2 pool which would be a very poor foundation.

6. The dam was near being overtopped and the embankment was saturated.

7. The total failure was quite rapid.

8. The embankment material was only slightly cohesive, which could allow quick water-pressure effects on strength.

9. There was a real force exerted on the sediment layer of pool No. 2 to result in a considerable amount of the material being pushed up and over Dam No. 2.

10. From inception to time of failure there was a condition for foundation piping at Dam 3. Piping is reported to have been observed some months prior to failure and in light of the analysis, probably existed.

11. Considering all of the above, it would appear that failure could have resulted from a movement of the right center portion of the dam downstream, allowing the failure to occur in a sudden manner. For failure to have taken this form, the observed progressive movement of the downstream portion of the embankment would have had to take place before the major failure occurred.

To repeat for emphasis, another and likely method of failure is related to piping of the foundation.

b. Pertaining to Design

1. The basic concept of Dam No. 3 was not acceptable from an engineering standpoint. This concept, as understood from reports, was for the dam to serve as a retention structure for a pool of relatively shallow depth for settling coal washings. The key point is that the success of the operation depended on seepage from the pool through the

embankment and/or foundation to clarify the "black water." No other provision was made for passage of water except the pipe at an upper elevation which had never been in use until the February 1972 storm occurred, and, it is understood, was not intended for use during normal operations. Also, no design and construction effort was made to alleviate possible detrimental effects of the required seepage. We then have a structure the successful operation of which depended on uncontrolled seepage; unless some happy accident occurred whereby Mother Nature took care of this fundamental error of conception, the dam was doomed to failure from the time the first load of refuse was dumped. Many points of design and construction on these three dams are considered inadequate in varying degrees; these are:

a. Inadequate by-pass system for high volume flows

b. Lack of proper measures to assure adequate foundation

c. Lack of zoning in dam and other measures to assure control of seepage

d. Lack of compaction

e. Lack of erosion protection

f. Little attention to steepness of embankment slopes

g. Lack of qualified technical inspection

h. Little attention to the preparation of the abutments prior to embankment construction

i. Continued dumping of embankment material on the poor material (sludge)

j. Lack of attention to possible earthquake action

The uncontrolled seepage proposition, on the other hand, is a basic error in concept.

2. Technology is available so that dams for the purpose of those on the Middle Fork can be made safe; however, the time and expense for such design, controlled construction and subsequent inspection are such as to cast serious doubt on the economic practicality of such dams.

3. Better design and construction methods and inspections are necessary in the area in order to preclude further disasters of the type suffered by failure of the refuse dam on the Middle Fork of Buffalo Creek.

4. The materials of which Dam 3, and by extrapolation, Dams 2 and 1, were composed are considered at near-marginal suitability for dam construction. They are too light in unit weight and at least part are fine grained, cohesionless and are highly susceptible to erosion and to liquefaction. Because of these latter characteristics, unusual attention will be necessary in design and construction to assure a safe structure incorporating these materials.

5. A second fallacious design concept existed, but was not as serious as b(1) above. That is, the settled material should have been used to enhance the strength of the dam (or to detract from it as little as possible), rather than to be a serious liability. The practical step would have been to introduce the wash-water into the pool near the dam instead of at the upstream end of the pool, thereby widening the dam by deposition at the dam of the better engineering material from suspension.

c. Pertaining to Construction

1. The dam was not constructed as an engineered structure, in that —

(a) Erosion protection was absent, both upstream and downstream.

(b) The dam was not zoned.

(c) Little compaction of the material was performed and that which occurred was incidental to other required measures of construction.

(d) Proper measures were not taken to assure a good foundation.

(e) Stream was not diverted during initial embankment construction, thereby allowing material of questionable suitability to be present at the foundation-embankment interface.

(f) There was no effective spillway for flows in excess of that required for the settlement of the coal washings.

d. Pertaining to Operations

1. Successful operation of a dam is composed of the following steps:

(a) Adequate professional design

(b) Adequate construction, inspected to insure that design requirements are carried out during the work.

(c) Professional technical inspection upon completion of construction and periodically during operation.

None of these basic steps were followed at the failed Middle Fork sites.

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2. Some attention by local and Federal agencies had been given to the proposition of flood plain management within the area. However, there was almost no direct effect of this action in the entire Buffalo Creek area.

3. Expenses connected with b-2, b-3 above and e-5 below, make other methods of disposal of coal-wash material and mine waste attractive. The coal-wash material can be successfully handled by structurally designed settling basins, excavated basins or by an adequately designed series of small dams and pools which will allow recovery of the coal dust. There would appear to be a commercial market for this recovered material, as evidenced by its composition being largely coal dust. As regards the disposal of mine waste, and aside from environmental and ecological considerations, valleys can still be used as storage areas provided that the natural drainage for the watershed is taken into consideration in the design and the embankments of the material are constructed so as to be stable; that is, with proper compaction and properly designed slopes. On the other hand, the possibility of placing the material back in the mine as mining in the underground areas is completed would appear to offer a reasonable avenue for further intensive investigation.

e. Pertaining to Inspection

1. It appears that by existing law, the State had responsibility for inspection (and therefore, safety) of the dam; that the owner similarly had responsibility for the safety and inspection of the dam and the Federal Government, through the Bureau of Mines, had responsibility for safety and inspection of the dam.

2. The consequent "let-George-do-it" attitude resulted in tragedy. Accordingly, a change in the statutes should be effected to make one agency, and only one, clearly responsible for the safety of non-Federal dams of this and all other kinds. Model laws are available for this purpose which have in practice proved satisfactory. (See Appendix D.)

3. Continuing frequent technical inspection is not occurring. There appears to be little doubt that an adequate program of technical inspections of the Middle Fork dams would have indicated them to be in danger of failure. For example, a trained observer in an adequate inspection would have noted the piping and would have been sufficiently alarmed to do something about it.

4. Responsibility for continuous technical inspection is not clear; neither is the criteria for establishing whether the responsibility for dam safety should be at the State or Federal level. There is a positive need for both the criteria and the clarification of responsibility.

5. Technical inspection is expensive and, if performed by States, will probably require some Federal cost-sharing.

6. Considerable work has been performed by Civil Engineering Societies within the United States to meet the public safety problem as related to dams. The U. S. Committee on Large Dams has compiled a model law to this end and has transmitted it to each State, recommending its enactment into State law; the Pittsburgh Section, American Society of Civil Engineers, has modified the model law slightly in an effort to adapt it to Pennsylvania conditions and similarly, with other technical societies

within the Commonwealth, proposed to the state in 1970 its enactment into law.

K. Recommendations.

It is recommended that:

1. Action be taken to effect a change in statute to make one agency, and only one, clearly responsible for the safety of non-Federal dams, in accordance with conclusion e-2, above.

2. Existing dams be modified by the owner to include a spillway, the level, dimensions and other features to be provided as required by the agency of 1, above. Similarly, for these dams, all other engineering features shall be subject to review and modifications made by the owner as necessary to provide a safe embankment. As an alternate to these measures, the owner may breach the dams in a manner approved by the agency. If ownership is not clear, the agency, with funds provided by the Federal Government, should be authorized to perform the work in connection with breaching.

3. The agency of 1, above, also be authorized to review and require modifications of all refuse piles placed in valley to assure that a slide in these piles will not dam the natural drainage of the valley or otherwise endanger life and property.

4. That a program of periodic detailed engineering inspections of refuse dams during and subsequent to construction be required.

5. A program of intensive research be pursued by the Bureau of Mines, related to more attractive methods of disposal of coal-mine refuse, methods of separating undesirable dust from coal and for the disposal of this dust.

6. A Federal agency be designated and authorized to compile, publish and disseminate to the industry and state and local authority an up-to-date, comprehensive summary of the detailed engineering required to produce safe refuse dams.

7. Serious consideration be given to implementing the above recommendations, as applicable to cover all non-Federal dams.

8. Since it is evident that more restrictive (and enforced) land use regulations for the valley of Buffalo Creek would have lessened the impact of the debris from the failure of the dams on the Middle Fork, implementation of flood plain management concepts be accomplished in the area with all due haste.

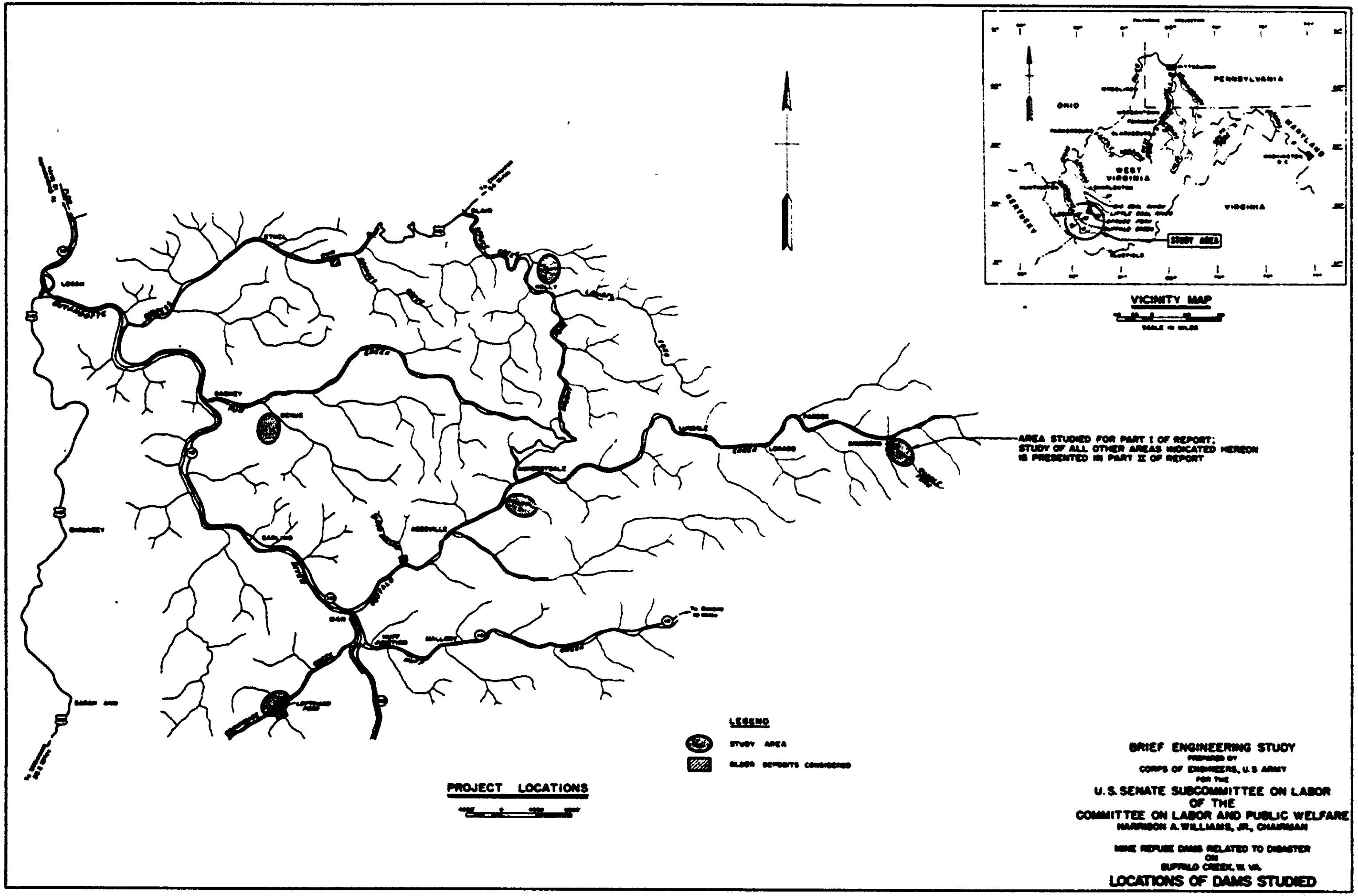
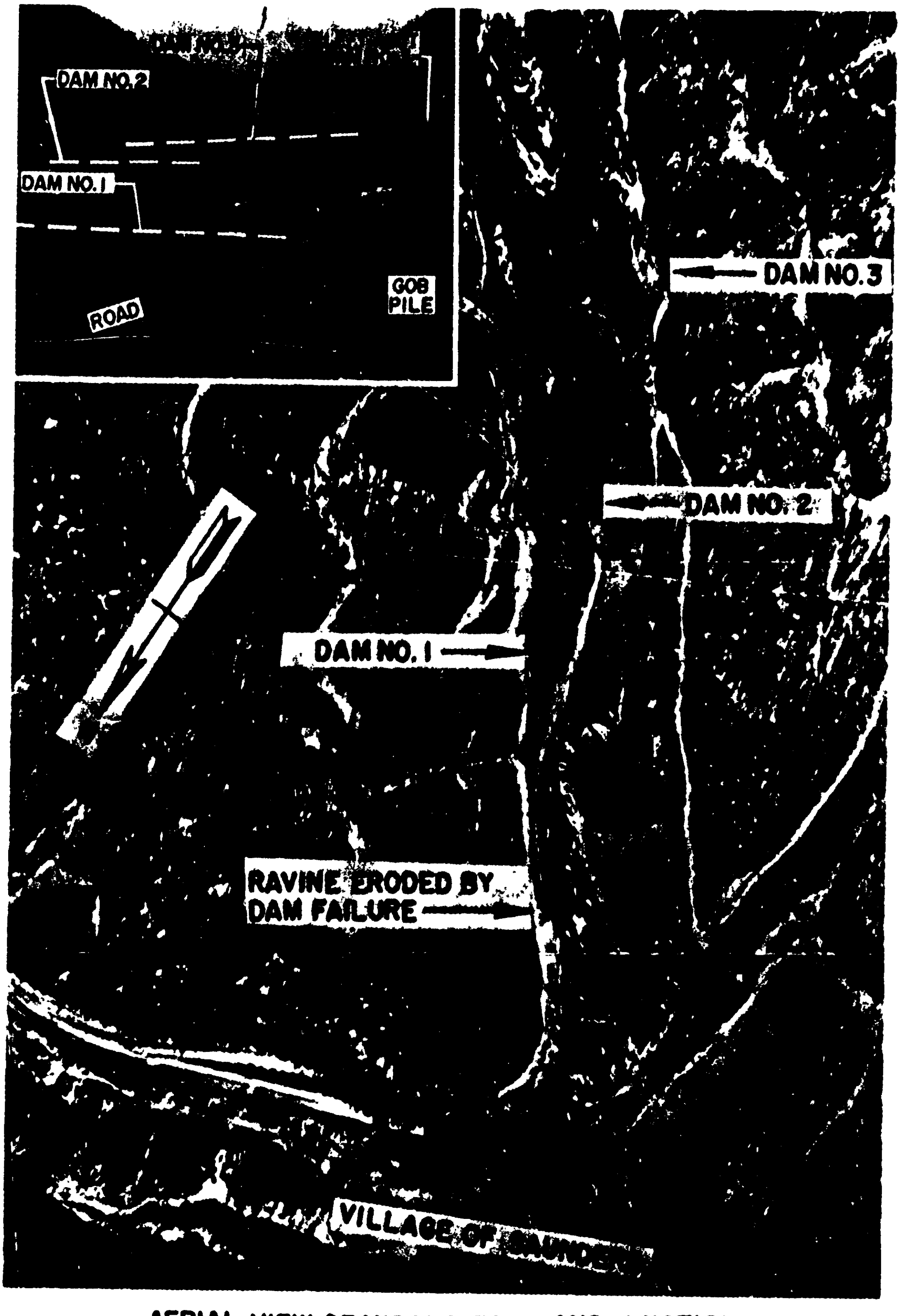

VICINITY MAP
PENNSYLVANIA
OHIO
WEST VIRGINIA
VIRGINIA
STUDY AREA
AREA STUDIED FOR PART I OF REPORT:
STUDY OF ALL OTHER AREAS INDICATED HEREON
IS PRESENTED IN PART II OF REPORT
LEGEND
STUDY AREA
PROJECT LOCATIONS
BRIEF ENGINEERING STUDY
U.S. SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
LOCATIONS OF DAMS STUDIED

PLATE NO. 1

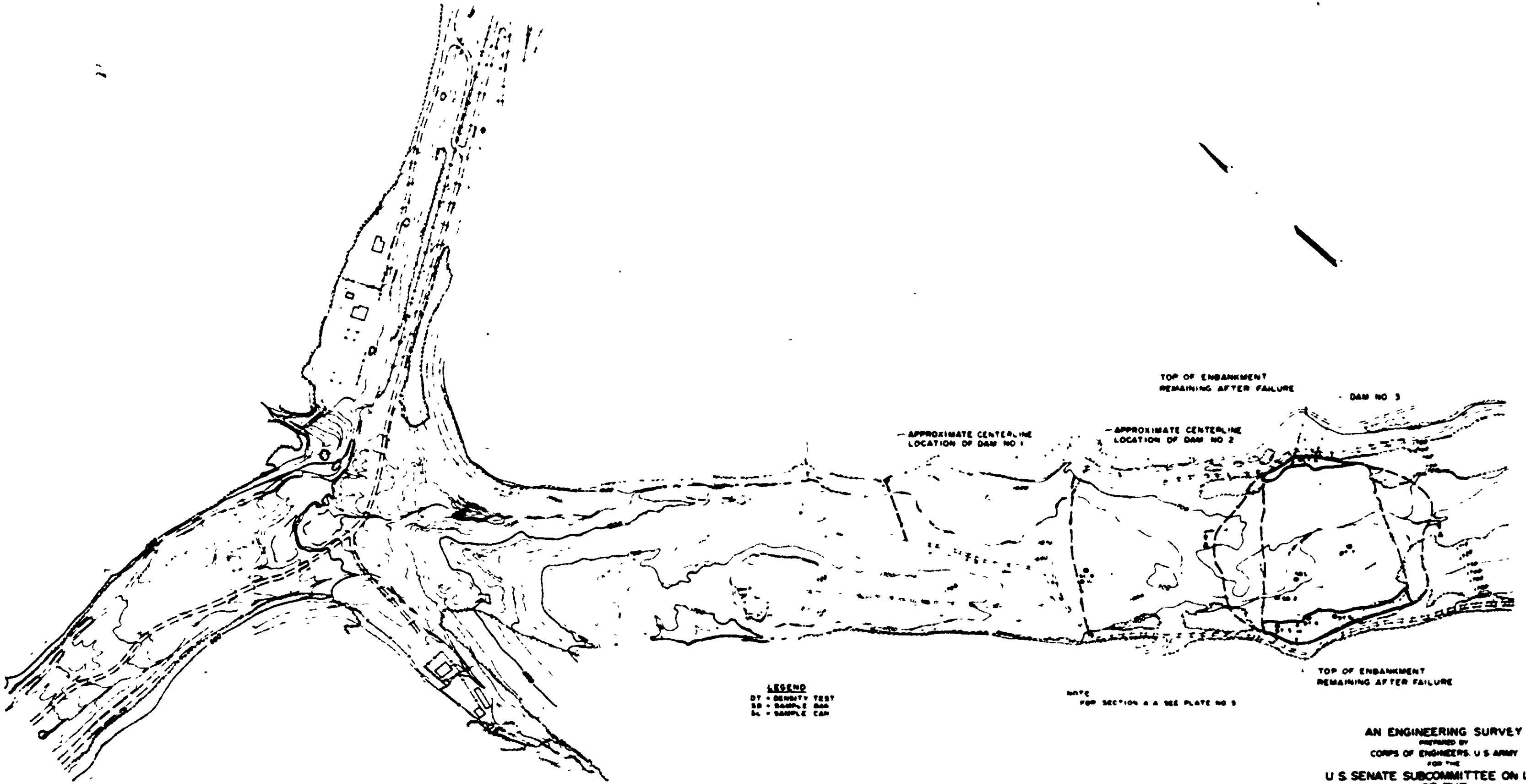
BUFFALO CREEK AREA, WEST VIRGINIA
(November 3, 1971)

Black-and white copy of an aerial infrared photograph taken at 42,000 feet for the EROS Program of the U. S. Department of the Interior.

PLATE 2A



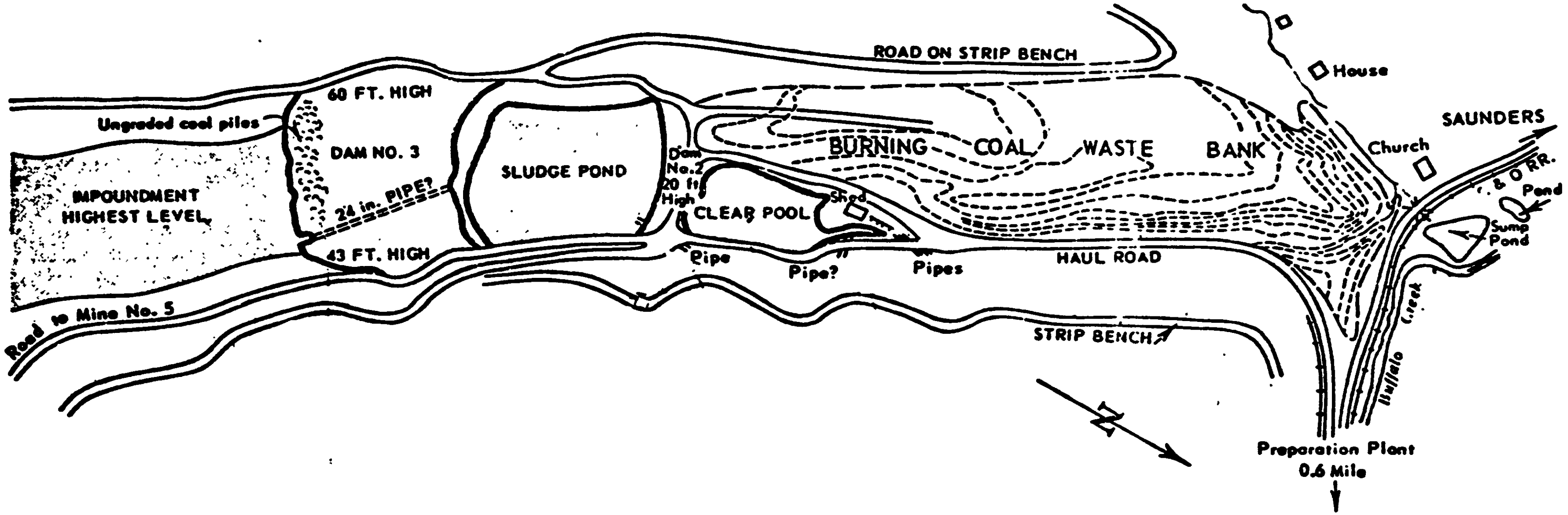
AERIAL VIEW OF MIDDLE FORK AND JUNCTION
WITH BUFFALO CREEK AFTER FAILURE OF DAMS
PLATE NO. 2



AN ENGINEERING SURVEY
PREPARED BY
CORPS OF ENGINEERS, U S ARMY
FOR THE
U S SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A WILLIAMS, JR., CHAIRMAN

TOPOGRAPHY AFTER FAILURE OF DAMS
MIDDLE FORK, BUFFALO CREEK, W. VA.

PLATE NO 3



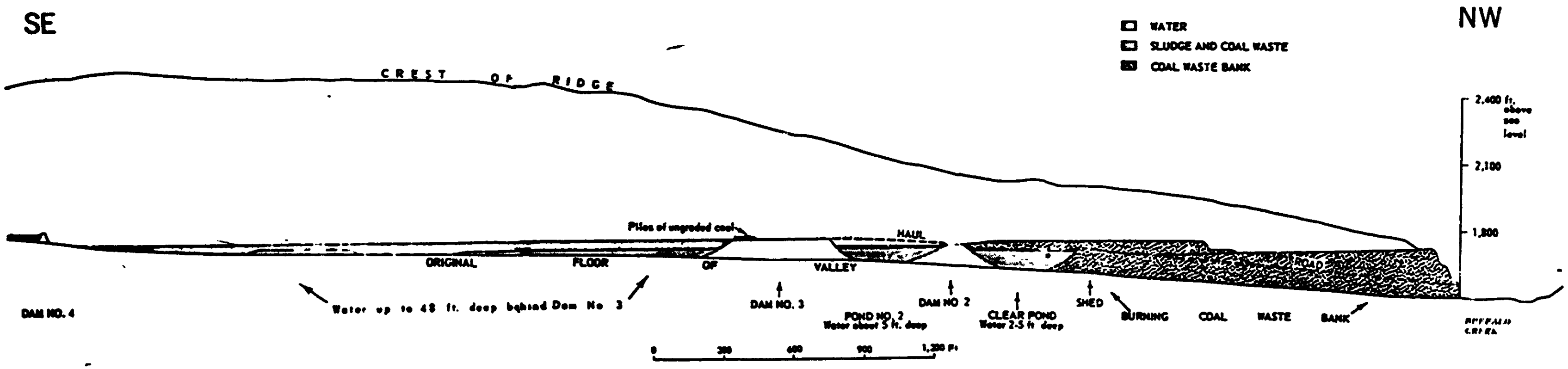
SKETCH MAP
MIDDLE FORK SAUNDERS, W. VA.

0 200 400 600 800 1000 Ft

As of late February, 1972
before dam broke

(COURTESY USGS)

PLATE NO. 4A



PROFILE ALONG MIDDLE FORK, SAUNDERS. WEST VIRGINIA

VIEW TOWARDS SOUTHWEST
FEBRUARY 26, 1972
Prior to failure of dam

(COURTESY USGS)

PLATE NO. 4B

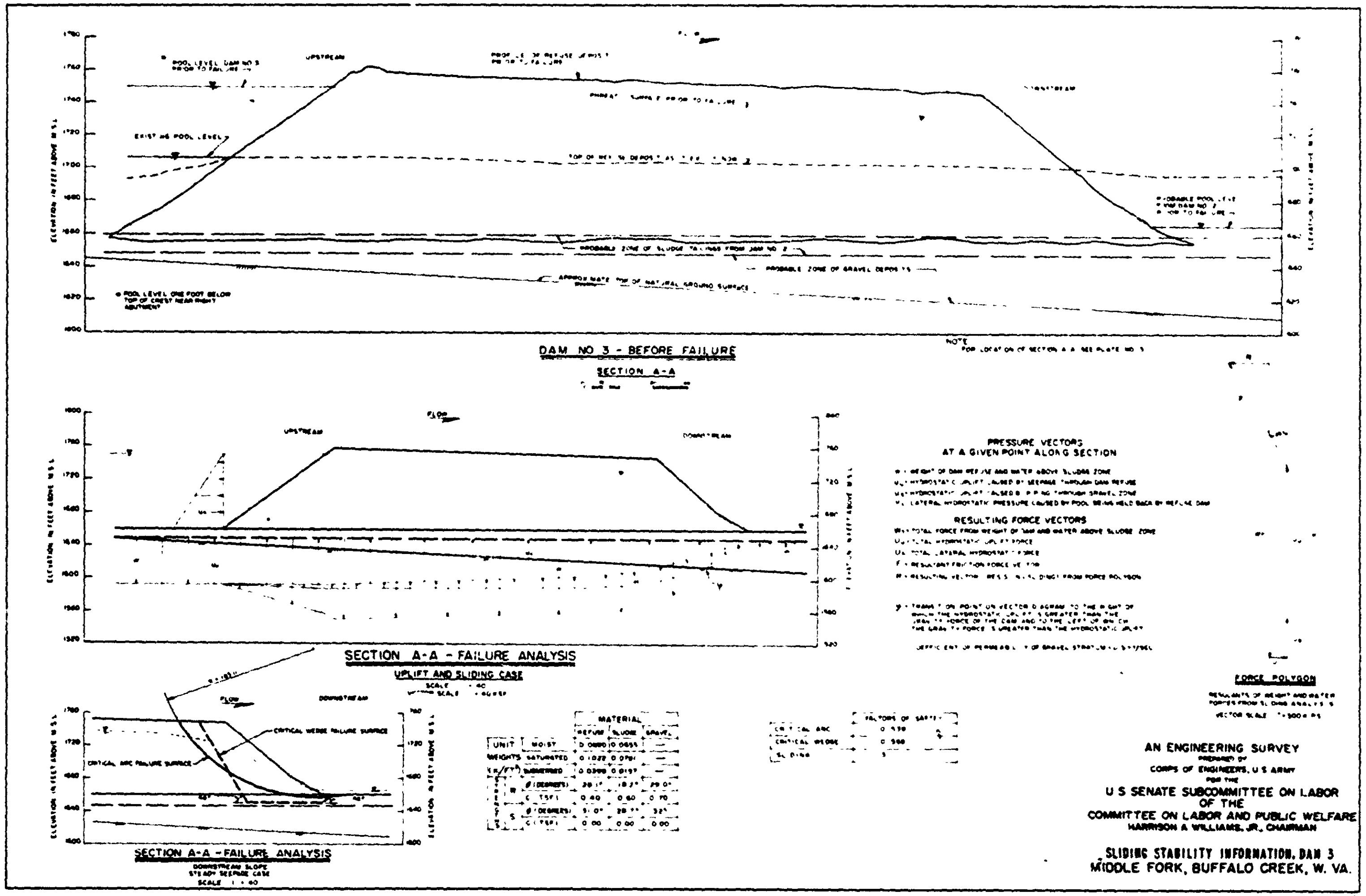

DAM NO 3 - BEFORE FAILURE
SECTION A-A
SECTION A-A - FAILURE ANALYSIS
UPLIFT AND SLIDING CASE
PRESSURE VECTORS
AT A GIVEN POINT ALONG SECTION
RESULTING FORCE VECTORS
FORCE POLYGON
SECTION A-A - FAILURE ANALYSIS
AN ENGINEERING SURVEY
CORPS OF ENGINEERS, U S ARMY
U S SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A WILLIAMS, JR., CHAIRMAN
SLIDING STABILITY INFORMATION, DAM 3
MIDDLE FORK, BUFFALO CREEK, W. VA.

PLATE NO 5

SOIL TEST DATA SUMMARY

PROJECT: Mine Waste Dam Investigation SHEET 1 OF 1

FEATURE: Physical Characteristics DATE May 1972

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	NAT. WATER CONT %	NATURAL DRY DENSITY LBS/CU FT	SPECIFIC GRAVITY	COMPACTION DATA OPT WATER %	MAXIMUM DRY DENSITY LBS/CU FT	SHEAR DATA DRY DENSITY LBS/CU FT	SAT. WATER %	TYPE TEST	C T/SQ FT	TAN ϕ	ϕ DEG.	MAXIMUM SHEAR T/SQ FT	PERMEABILITY DATA LOAD T/SQ FT	K_v, 10^{-4} FT/MIN	K_h, 10^{-4} FT/MIN	CONSOL. DATA C_c	REMARKS
BUFFALO CREEK																										*-#4=14.9, -#4=6.7
	2		Silty Gravelly SAND	44	46	10				11.3*		1.73**			80.9	11.7	R	.40	.535	28.1			8.8 (γd=	80pct)		** -#4=1.58 (4 tests)
			(SP-SM)												60.1	15.7	S	-	.600	31.0						+#4=1.93
			(50% coal, 49% shale)																							
	9 & 10 (Comp)		Sandy SILT(ML)	-	44	56				36.1		1.48			48.7	34.3	Q	.10	.250	14.0			3,600 (γd	= 48 pct)		
			(coal fines)												48.8	36.3	R	.60	.330	18.2						
															48.4	35.1	S	-	.548	28.7						
AMHERST																										
	9		Silty Gravelly SAND	11	83	6				10.1		2.38*			112.2	9.2	Q	.40	.330	18.2						*Two tests
			(SW-SM)												110.8	10.7	R	2.00	.165	9.4						
			(90% Shale, 8% coal)												112.0	9.5	S	-	.593	30.7						
POWELLTON																										
	20		Sandy SILT(ML)	1	32	67				31.1		1.42			48.6	30.2	Q	.30	.230	13.0						
			(coal fines)												49.4	31.4	R	.30	.470	25.2						
															46.4	33.5	S	-	.555	29.0						
YOUNGSTOWN																										
	3		Silty Sandy GRAVEL	56	34	10				8.2		2.27*			114.4	8.1	R	1.60	.670	33.8					.065	* -#4= 2.25
			(GP-GM)												104.1	15.6	S	-	.548	28.7						+#4 coal= 1.49, Shale = 2.58
			(43% coal; 55% shale)																							
	2 & 4 (Comp)		Sandy Clayey GRAVEL	40*	29*	31*		28.3*	18.6*	12.0*		2.67			103.3	22.0	S	-	.480	25.6					0.15	*Two tests each
			(GC)																							
ISLAND CREEK																										
	1 & 4 (Comp.)		Silty Sandy GRAVEL	63	31	6				7.7		2.23*			95.9	8.6	R	0.50	.600	31.0			640 (γd=	100 pct)		*Bag #1 +#4= 2.32
			(GP-GM)												84.2	10.7	S	-	.560	29.2						-#4= 1.93
			(coal & shale)																							Bag #4 +#4= 2.46
																										-#4 = 1.97

ORD Form 873
6 Apr 67

T-Triaxial Compression DS-Direct Shear S-Consolidated Drained
UC-Unconfined Compression Q-Unconsolidated Undrained R-Consolidated Undrained

LAB

PLATE 6A

MATERIAL BREAKDOWN

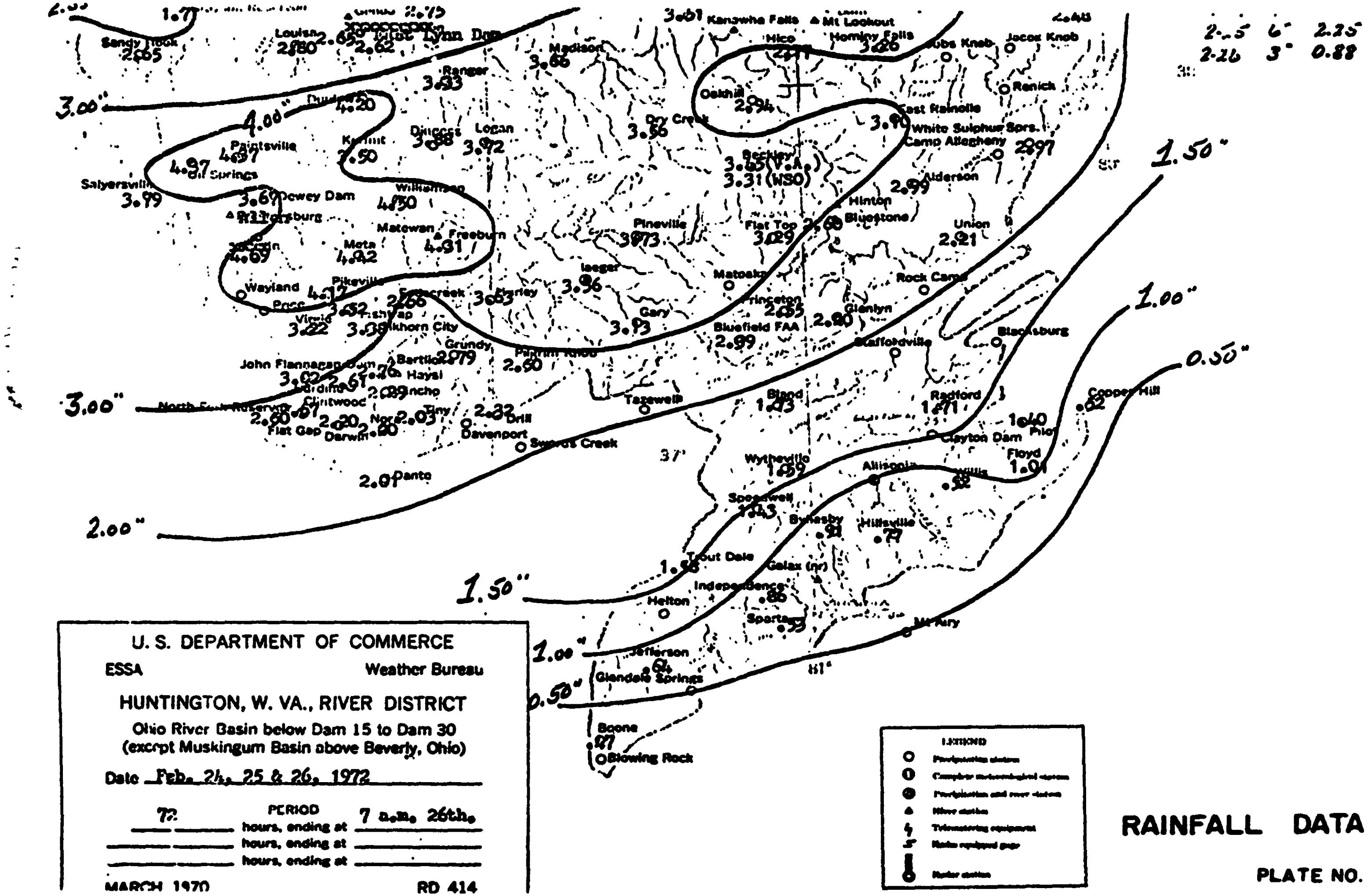
Percentages of Total Sample	10%	10%	7%	6%	4%	4%	3%	56%
SAMPLE sizes	+2"	+1½"	+1"	+¾"	+½"	+⅜"	+#4	−#4
COAL	30%	47%	47%	35%	38%	58%	63%	56%
Carbonaceous & Clayey Shale	70%	53%	51%	63%	60%	40%	37%	44%
Sandstone	0%	0%	2%	1%	1%	2%	0%	0%
Reddog	0%	0%	0%	1%	1%	0%	0%	0%

Percentages of Material in Range

Sample #9 & 10 was basically coal dust with about 10% clay

CORPS OF ENGINEERS, U.S. ARMY
OHIO RIVER DIVISION
INSTALLATION
COMPUTED BY
CHECKED BY
SUBJECT Buffalo Creek - Middle Fork
COMPUTATION Sample #2
COMPUTATION SHEET
DATE
PAGE 2 OF 2 PAGES
SHEET

PLATE 6B



RAINFALL DATA

PLATE NO. 7

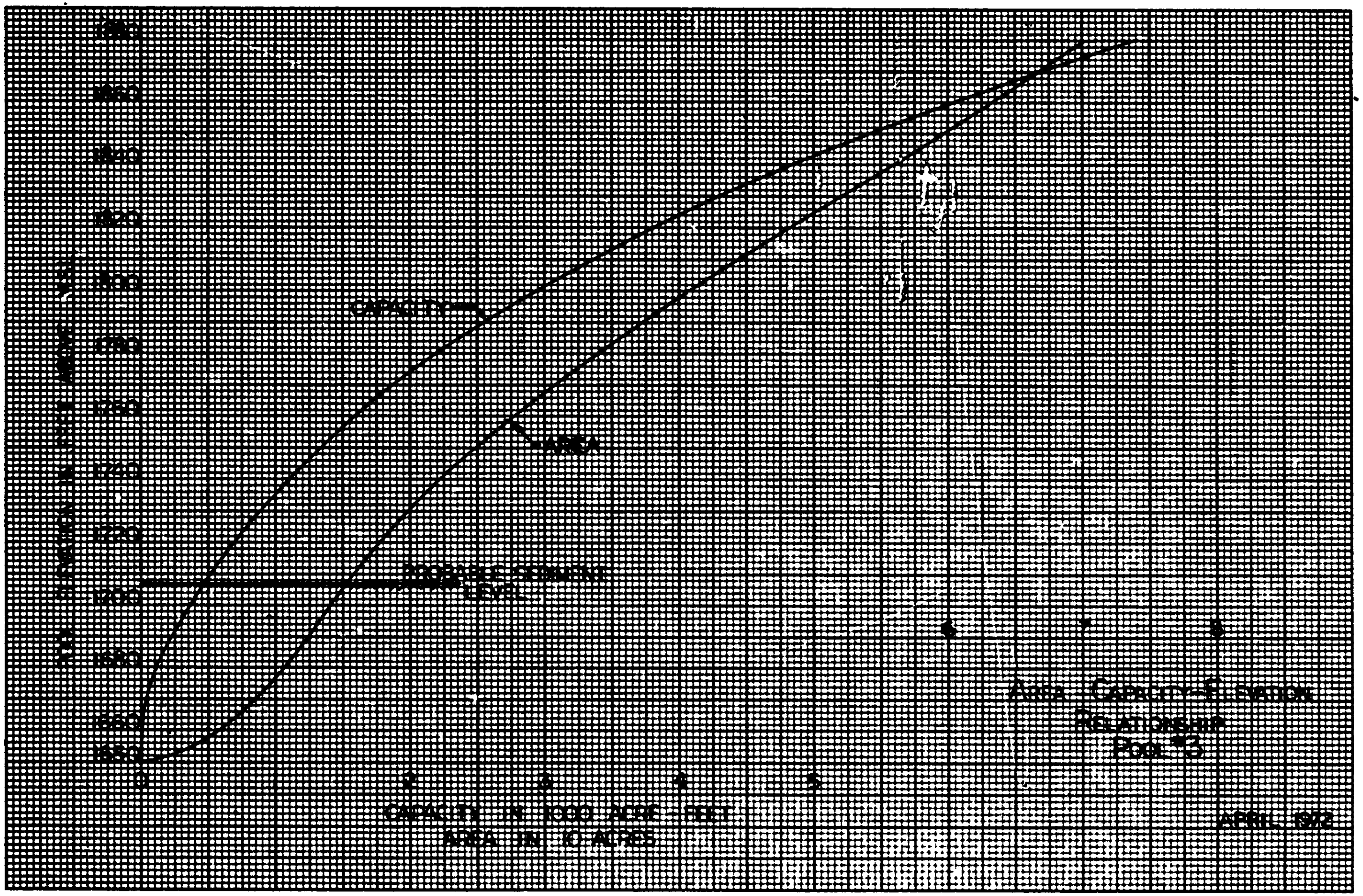
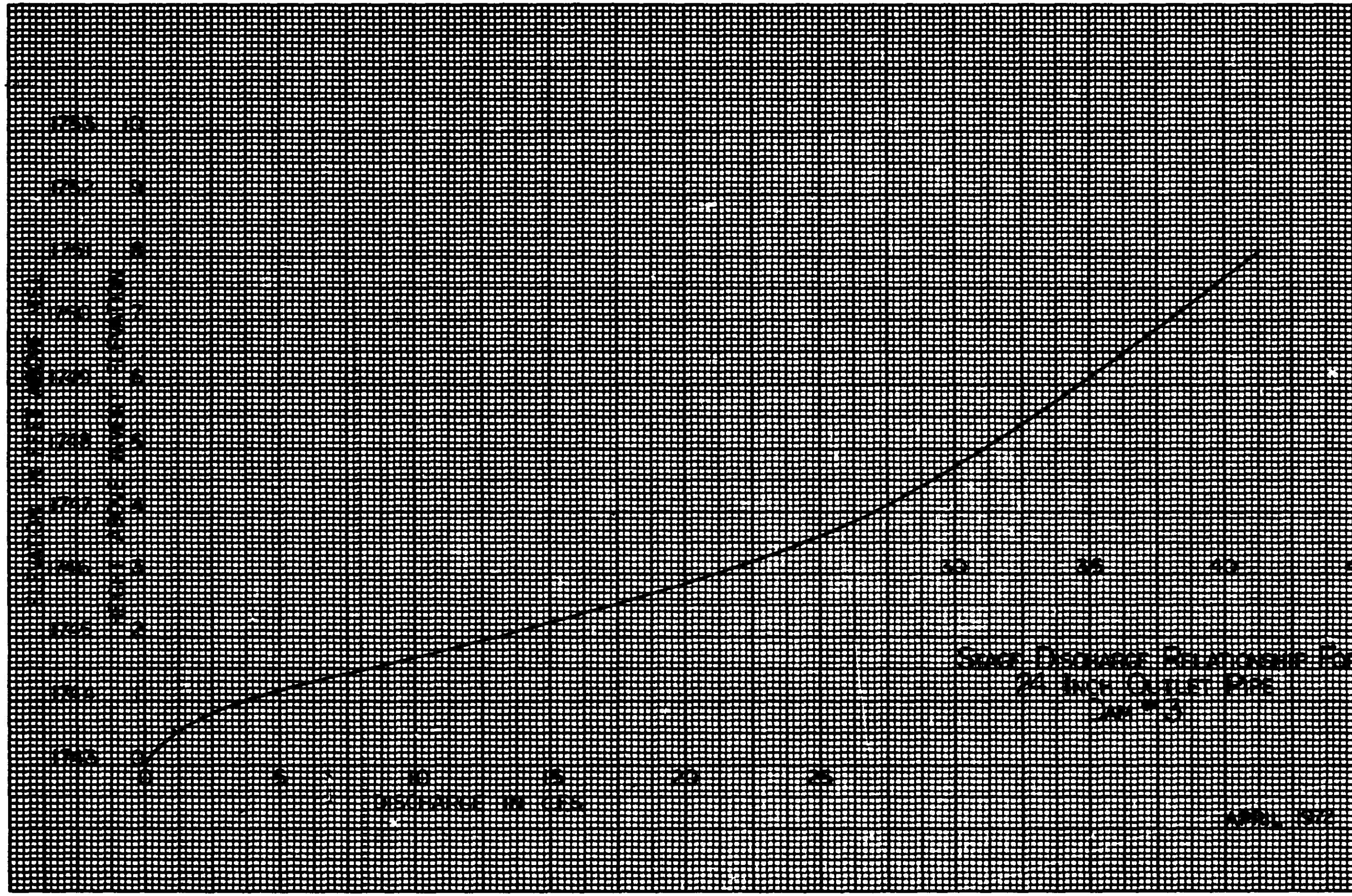

1880
1860
1840
1820
1800
1780
1760
1740
1720
1700
1680
1660
1650
0
2
3
4
5
6
7
8
CAPACITY
AREA
LEVEL
AREA - CAPACITY - ELEVATION
RELATIONSHIP
POOL #3
CAPACITY IN 1000 ACRE - FEET
AREA IN 10 ACRES
APRIL 1972

PLATE 8

76-620 O - 72 - 5



PLATE

APPENDIX A

GENERAL HYDROLOGY AND GEOLOGY OF THE AREA

APPENDIX A

General Hydrology of the Area

Climatology. The drainage system of the study area is composed of perennial streams tributary to the Guyandotte River in the Ohio River basin. It is located in Logan County in southern West Virginia in the Appalachian Plateau. The area is largely forested with some development in the valleys. Extensive coal mining operations are also predominant throughout the area, supporting many small communities located within the valleys.

The Guyandotte River flows in a general northwesterly direction from its source to its mouth at Huntington, West Virginia. The long and narrow watershed is approximately 100 miles long, with an average width of about 17 miles. Only a very small portion of the 1670 square mile drainage will be examined in this report.

The Appalachian Plateau in this area is dissected by many significant streams. Within this region, the valley sides are extremely steep with moderately sloped intermediate land. The streams are characterized by steep gradients and high velocities. Elevations within the study area vary from 700 feet above mean sea level to 2700 feet, for a total relief of 2000 feet.

Climate. The climate of the region is temperate with appreciable season variation in temperature. It is geographically in a region of variable air mass activity, being subjected to both continental and maritime air mass invasion. The weather is usually moderate but may have frequent and rapid changes resulting from the passage of fronts associated with general low pressure areas. The normal percentage of possible sunshine varies from about 35% in December and January to about 61% in July. Measurable precipitation occurs about 155 days per year and the mean length of the frost-free period in the basin is 180 days. The prevailing wind direction at Charleston, which is 40 miles north of the study area, is from the southwest at an average velocity of 7 miles per hour, but short duration velocities of above 60 miles per hour have been sustained. Although tornados may strike this area, their occurrence is very infrequent.

Temperature. Temperature data are available from the Weather Bureau station at Logan, located 10 miles northwest of the study area for 46 years and at the Weather Bureau station at Pineville, 22 miles southeast, for 27 years. The normal annual temperatures for these two stations are 56.9°F and 53.9°F, respectively. Temperature extremes of record are 104°F and -12°F at Logan and 102°F and -13°F at Pineville. The monthly normal temperature at Logan ranges from 36.6°F in January to 76.4°F in July. Pineville varies from 33.3°F to 70.0°F for the same months.

Precipitation. Normal annual precipitation based on the 60 year record at Logan is 45.43 inches. Pineville, with a shorter period of 27 years, has a normal annual value of 43.25 inches. In both cases, the precipitation is fairly evenly distributed throughout the seasons. The normal average monthly precipitation is at a maximum in July with 5.12 inches at Logan and 4.72 inches at Pineville, and at a minimum in October with 2.57 inches at Logan and 2.61 inches at Pineville. The summer rains occur mostly from thunderstorms of convectional frontal, convective or orographic origin. They are usually confined to relatively small areas and are of short duration with high intensity rates. Precipitation in the fall, winter and early spring months generally results from the passage of low pressure systems over the basin.

The average snowfall varies significantly throughout the area. As an example, Logan has an average annual snowfall of 19.5 inches, while Pineville, at a higher elevation but only 30 miles away, has an average annual snowfall of 26.5 inches. The maximum average monthly snowfall of 5.6 inches at Logan occurs in February, while the maximum monthly snowfall at Pineville is 8.5 inches during January.

A summary of climatology is given in Table 1. The information is based on data published by the U.S. Weather Bureau in "Climatological Data - West Virginia" and in "Climatic Summary of the United States - Supplement for 1951 through 1960, West Virginia".

Streamflow Records. The U. S. Geological Survey maintains several gaging stations in the Guyandotte River basin. Three of these stations have periods of record greater than ten years. One of these at Man, West Virginia, with a drainage area of 762 square miles, is located within the study area. Continuous records are available from 1929 to 1962 with only annual maximums available from 1962 to date. The average annual runoff for 33 years of record is 17.57 inches. The other two stations are both located in the lower portions of the basin. One of them is located on the Guyandotte River at Branchland, West Virginia with a drainage area of 1226 square miles. The other is located near Milton, West Virginia on the Mud River, a tributary to the Guyandotte River, with a drainage area of 256 square miles at the gate site. The average annual runoff is 17.12 inches at Branchland for a period of 43 years and 14.27 inches at Milton for a period of 32 years.

General Geology of the Area

Scructure. The geologic structure of Logan County has been only slightly disturbed by lateral or upward movements of the earth's crust.

There is a gradual rise of the rocks from the northwest to the southeast, interrupted by occasional anticlines and corresponding synclines. The dip of the rocks is nowhere excessive and in most regions is hardly perceptible to the eye, wh re levels of the coals are exposed in stripping and the nature and rate of change can be observed. The general direction of most of the anticlines and synclines is northwest and southwest, corresponding closely to the trend of the Appalachian Mountain System. In most of the County, the structure is devoid of special features.

The Campbell Creek Coal Seam or No. 2 Gas Coal is the most persistent and easily recognized coal in Logan County and has therefore been used as the key rock for determining structure.

The geologic structure has influenced the topography only to a slight degree. There are no long gentle slopes showing the structural divide along the Warfield Anticline and no through-like valley marking the course of the few synclines. The erosive work of the streams has been more rapid along the anticlines than along the synclines so that the topography is no guide to the structure. At close range, however, the narrow shale and coal benches, where exposed by clearings, are of considerable help in following structure. These benches are often obscured by the vegetative growth or by the great mass of sandy debris that frequently covers the slopes, especially near the foot of the hills.

Since the rocks of Logan County contain no unusually hard ledges but are composed largely of sandstone members of medium hardness separated by thin beds of shale and there is no consequent ponding of the streams, there are no waterfalls or extensive rapids in the streams. They show remarkably uniform profiles, having, in geologic terms, only a slight fall until near the source where the streams terminate against the steep ridges.

Stratigraphy - General Section. The surface rocks of Logan County are almost wholly contained within the Pennsylvanian Age rocks. There are Quaternary deposits along the streams and a number of oil and gas wells have been drilled down into the Mississippian and some of these have even pierced the upper part of the Devonian.

The geologic column of concern is as follows:

Pennsylvanian -	Conemaugh Series		
	Allegheny Series		
	Pottsville	Upper or	Kanawha Series
		Middle	New River Series
		Lower	Pocohontas Series
Mississippian -	Mauch Chunk Shales		
	Greenbrier L.S.		
	Pocono S.S.		
Devonian -	Catskill Series		

The most recent rocks of Pennsylvanian age found in Logan County are those of the Conemaugh Series. This series, which may have once covered the entire area of Logan, has been so nearly eroded that only a few remnants of it remain.

The lowest surface rocks of the area are represented by the great sandstone member at the top of the Middle Pottsville or New River Series which out-crops along the Guyandotte River.

The Kanawha Series, or Upper Pottsville, constitutes the great bulk of out-cropping sediments in Logan County. Probably 90% of the surface rocks of Logan are represented by Kanawha Series. This series consists of massive sandstones, coal beds, impure fire clays, sandy and argillaceous shales, buff and black in color, and several thin, impure, lenticular and marine limestones.

Sandstones predominate, probably constituting 60 percent of the stratum but the contained coals have by far the greatest economic value.

Coals. The coal beds occurring in Logan County for which coal reserves have been estimated (Bureau of Mines Report of Investigation 5259), are listed in descending order as follows:

No. 5 Block	Williamson
Stockton	Upper Cedar Grove
Coalburg	Upper Split of Cedar Grove
Buffalo Creek	Cedar Grove
Winifrede	Lower Cedar Grove
Chilton "A"	Alma
Chilton	No. 2 Gas [1](Campbell Creek)[2](Logan-Eagle)
Hernshaw	

[1] W. Va. Geological Survey Report, Logan and Mingo Counties, 1914.

[2] Bureau of Mines Report of Investigations 5259, 1956.

The No. 5 Block Bed is in the Allegheny Series and the remaining beds are in the underlying Pottsville Series, Pennsylvanian system.

Logan County coals are of a high-volatile A bituminous rank. Virtually all coals are coking and most of them are either of metallurgical grade as mined or may be prepared to meet present-day specifications for metallurgical coal.

Sandstones. The sandstones of the Kanawha Series in Logan County are nearly all of the same general type: massive, gray, micaceous, medium hard, medium coarse and much current-bedded.

Residual Clay. Residual Clay, which is derived from weathered rocks and not transported from its original location, is almost entirely lacking in the County. The thickness of overburden was less than five feet and generally was approximately 18 inches at the refuse piles investigated.

Topographic Features. The topography of Logan County is steep and rugged. The streams have cut their channels deep through the surface rocks, making sharp V-shaped valleys. In the western end of the County, the hills are from 400 to 800 feet above the valleys but their height increases rapidly southeastward so that in the southeastern region ridges 1200 to 1500 feet high are the rule.

The hillsides are broken frequently by narrow flat benches, marking the deposits of shale and coal that separate the massive ledges of sandstone that compose the greater part of the surface rocks. These benches are not readily seen from the valleys as their narrowness and the vegetation that usually covers the hills, though sparse, give the appearance of a slope that is uniformly steep. The tops of the ridges are sharp, being frequently only wide enough for narrow trails along them. There are numerous low divides and corresponding sharp points that rise several hundred feet high.

APPENDIX B

QUESTIONNAIRE ON REFUSE PILES

APPENDIX B

QUESTIONNAIRE ON REFUSE PILES

1. Owner: Buffalo Mining Company

   Division of Pittston Company

   Lyburn & Laredo, West Virginia

2. Location: Middle Fork, Buffalo Creek (Failure Area)

3. Date of Failure - 26 Feb 1972

4. Date Area Inspection - 27 Mar 1972

   a. Personnel contacted:

      (1) Mr. Murdock - Attorney

      (2) E. J. Wood - General Manager

      (3) Jim Yates - Civil Engineer, V.P. oι Engineering, Pittston Coal Group

5. How constructed

   a. Truck and dumped from near full height, across creek

   b. Dozer spread, as necessary

6. When was pile started

   a. Dam No. 1 - 1964

   b. Dam No. 2 - 1966

   c. Dam No. 3 - 1969

7. No. 3 dam was being used when failure occurred.

8. Has pile been on fire - Three dams had not; huge pile at mouth of canyon was burning on right side of valley.

9. Is it burning now - Yes, on the side exposed to the flow from the failure of the upstream dam.

10. Has any effort been made to zone pile? No. Pile dumped over end to complete across valley - then dumped on top and spread.

11. What percent of dam is red dog? No red dog.

12. Is pile used for general mine refuse or just coal refuse? - General mine refuse.

13. Distance, in elevation, from top of pile upstream to water level - When last seen before failure, reported at or about 6" below top - with 5 or 6 ft. of truck dumped material in piles on top of that.

14. Distance, in elevation, approximately, from top of pile downstream to seepage exit. No seepage reported on downstream slope.

15. Any downstream erosion protection. No.

16. Any upstream erosion protection. No.

17. Was foundation stripped or otherwise treated prior to construction. No. Material was dumped into existing sludge from Pool No. 2. On abutments no treatment; trees are exposed after failure.

18. Does spillway exist - No and did not. A 24-inch pipe about 100 feet from right abutment, 4 feet below top of dam on downstream side on day of failure; elevation upstream, not known - water covering it - was flowing about half full on 26 February 1972, projecting 10 feet, impinging on downstream slope of dam and had eroded.

19. Measures used to allow normal drainage to occur past dam, other than seepage through dam - No, except as given under 18, above.

20. Approximate amount of fill placed per month - Not known.

21. What type of material is foundation - Sludge over probable alluvial material.

22. Who does the Operator consider the regulatory authority to consult when operator wants to change dam or pile or build another - West Virginia Department of Natural Resources and the Public Utilities Commission.

23. Are inspections made by that authority - Yes.

24. Does owner consider their structure a refuse pile, a dam, or something else? An impoundment, not a dam.

25. Has owner inspected dam - They say so, but records are not available.

26. Have they had any problems with their structure - In 1971 a small failure occurred on the downstream side of the dam toward the right abutment side. The material slid into Pool 2 and was simply replaced by dumping from the top of the dam. In 1969, before No. 3 was completed, high water occurred and Dam No. 2 was overtopped allegedly before its completion, doing a minor amount of damage downstream in Saunders. The dam was repaired by dumping from the abutment.

27. The owner has never requested assistance from regulatory authority.

28. When operating, about 360,000 gallons of water and silt were discharged into the pool in 12 hours.

29. Mr. Dasovich, mining engineer with degree from West Virginia School of Mines, was in charge of dam.

78-620 O - 72 - 6

APPENDIX C

EARTHQUAKE SCALES

APPENDIX C

EARTHQUAKE SCALES

a. Common Earthquake Scales. Several scales have been utilized in the past to identify the size or effects of earthquakes. The two most common scales in use today are "Richter Magnitude" and "Modified Mercalli Intensity" values. Some confusion has existed in the public mind regarding fundamental differences in these two scales.

b. Richter Magnitude. Richter Magnitude which scales logarithimacally from 0 to less to approximately 9 (theoretically open-ended) can be related to the amount of seismic energy released by a given earthquake. Each earthquake can therefore be defined in terms of only one Magnitude value. The most recent formula for converting Richter Magnitude to energy (in ergs) is Log E=11.4 + 1.5M. This formula provides an approximate basis for comparing relative "sizes" of earthquakes. However, the relative amount of damage done is not always directly related to the absolute size of an earthquake in terms of energy release.

c. Modified Mercalli Intensity. Modified Mercalli Intensity is based on the amount of ground motion produced at a specific location within the zone of seismic influence for a given earthquake. A single earthquake can therefore produce a large number of different Mercalli Intensities within its zone of influence depending upon soil conditions, rock type, ground water elevation, topography and other environmental ground features. When the size of an earthquake is referenced to the Modified Mercalli scale, it is assigned the highest Mercalli intensity recorded within the shock area. The Intensity value assigned in this manner to a given earthquake ofter (but not always) is fairly close to the numerical value of the Richter Magnitude for the same earthquake.

What should be remembered is that in proceeding from the epicenter to the outermost shock felt areas, the Intensities will gradually fall off to zero, while the Magnitude will remain constant throughout. In addition, two earthquakes of similar Magnitude, but occurring in separate parts of the country, where different rock types and different hypocenter depths prevail, can produce great differences in the areal extent of felt areas.

d. Engineering Earthquake Scale. From paragraphs b and c above, it is evident that while Richter magnitude provides an invaluable tool in theoretical earthquake studies, Modified Mercalli intensity values are, with our present state of knowledge, more directly applicable for defining the effects of resulting ground motion on engineering structures. Attached is a list of Modified Mercalli Intensities from 1 through 12 with corresponding but abridged qualitative descriptions.

MODIFIED MERCALLI INTENSITY SCALE OF 1931

1. NOT FELT EXCEPT BY A VERY FEW UNDER ESPECIALLY FAVORABLE CIRCUMSTANCES.
2. FELT ONLY BY A FEW PERSONS AT REST, ESPECIALLY ON UPPER FLOORS OF BUILDINGS. DELICATELY SUSPENDED OBJECTS MAY SWING.
3. FELT QUITE NOTICEABLY INDOORS, ESPECIALLY ON UPPER FLOORS OF BUILDINGS, BUT MANY PEOPLE DO NOT RECOGNIZE IT AS AN EARTHQUAKE. STANDING MOTOR-CARS MAY ROCK SLIGHTLY. VIBRATION LIKE PASSING OF TRUCK. DURATION ESTIMATED.
4. DURING THE DAY FELT INDOORS BY MANY, OUTDOORS BY FEW. AT NIGHT SOME AWAKENED. DISHES, WINDOWS, DOORS DISTURBED; WALLS MAKE CREAKING SOUND. SENSATION LIKE HEAVY TRUCK STRIKING BUILDING. STANDING MOTORCARS ROCKED NOTICEABLY.
5. FELT BY NEARLY EVERYONE, MANY AWAKENED. SOME DISHES, WINDOWS, ETC., BROKEN; A FEW INSTANCES OF CRACKED PLASTER, UNSTABLE OBJECTS OVERTURNED. DISTURBANCE OF TREES, POLES, AND OTHER TALL OBJECTS SOMETIMES NOTICED. PENDULUM CLOCKS MAY STOP.
6. FELT BY ALL, MANY FRIGHTENED AND RUN OUTDOORS. SOME HEAVY FURNITURE MOVED; A FEW INSTANCES OF FALLEN PLASTER OR DAMAGED CHIMNEYS. DAMAGE SLIGHT.
7. EVERYONE RUNS OUTDOORS. DAMAGE NEGLIGIBLE IN BUILDINGS OF GOOD DESIGN AND CONSTRUCTION; SLIGHT TO MODERATE IN WELL-BUILT ORDINARY STRUCTURES; CONSIDERABLE IN POORLY BUILT OR BADLY DESIGNED STRUCTURES; SOME CHIMNEYS BROKEN. NOTICED BY PERSONS DRIVING MOTORCARS.

8. DAMAGE SLIGHT IN SPECIALLY DESIGNED STRUCTURES; CONSIDERABLE IN ORDINARY SUBSTANTIAL BUILDINGS WITH PARTIAL COLLAPSE; GREAT IN POORLY BUILT STRUCTURES. PANEL WALLS THROWN OUT OF FRAME STRUCTURES. FALL OF CHIMNEYS, FACTORY STACKS, COLUMNS, MONUMENTS, WALLS. HEAVY FURNITURE OVERTURNED, SAND AND MUD EJECTED IN SMALL AMOUNTS. CHANGES IN WELL WATER. PERSONS DRIVING MOTORCARS DISTURBED.
9. DAMAGE CONSIDERABLE IN SPECIALLY DESIGNED STRUCTURES; WELL DESIGNED FRAME STRUCTURES THROWN OUT OF PLUMB; GREAT IN SUBSTANTIAL BUILDINGS, WITH PARTIAL COLLAPSE. BUILDINGS SHIFTED OFF FOUNDATIONS. GROUND CRACKED CONSPICOUSLY. UNDERGROUND PIPES BROKEN.
10. SOME WELL BUILT WOODEN STRUCTURES DESTROYED; MOST MASONRY AND FRAME STRUCTURES DESTROYED WITH FOUNDATIONS; GROUND BADLY CRACKED. RAILS BENT. LANDSLIDES CONSIDERABLE FROM RIVER BANKS AND STEEP SLOPES. SHIFTED SAND AND MUD. WATER SPLASHED (SLOPPED) OVER BANKS.
11. FEW, IF ANY, (MASONRY) STRUCTURES REMAIN STANDING. BRIDGES DESTROYED. BROAD FISSURES IN GROUND. UNDERGROUND PIPELINES COMPLETELY OUT OF SERVICE. EARTH SLUMPS AND LAND SLIPS IN SOFT GROUND. RAILS BENT GREATLY.
12. DAMAGE TOTAL. WAVES SEEN ON GROUND SURFACES. LINES OF SIGHT AND LEVEL DISTORTED. OBJECTS THROWN UPWARD INTO AIR.

APPENDIX D

MODEL LAW FOR STATE SUPERVISION OF SAFETY OF DAMS AND RESERVOIRS

United States Committee On Large Dams
of the
International Commission On Large Dams

MODEL LAW
FOR
STATE SUPERVISION OF SAFETY
OF
DAMS AND RESERVOIRS

This model law was prepared

by the

Committee on Model Legislation

for Safety of Dams

Alfred R. Golzé, Chairman
Nicholas L. Barbarossa
L. Rees Brooks
Wallace L. Chadwick
Charles F. Corns
Clifford J. Cortright
Arthur P. Geuss
Thomas G. Harton
Clifford H. McConnell
T. W. Mermel
Karl V. Taylor
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INTRODUCTION

The United States Committee on Large Dams

of the

International Commission on Large Dams

has prepared as a public service for consideration of the Governors and Legislatures of the fifty States of the United States this Model Law for State Supervision of Safety of Dams and Reservoirs.

The objective of the Model Law is safety; protection of areas below a dam from the consequences of a failure of a dam and/or untimely release of its reservoir contents. Design and construction of a dam requires the highest degree of professional engineering performance. The foundation of the dam must be stable under all conditions and capable of carrying the weight of the structure. The dam must impound its reservoir water without undue strain and be safe under the application of external forces such as those resulting from earthquakes. The reservoir area must be water-retentive and free of the possibilities of dangerous slides. Dams and associated facilities must be maintained in excellent condition throughout their life. Operation and surveillance through the years must be conducted in such a manner that any change in the structure of the dam, including its foundation, can be detected promptly and corrections made. If abandoned at any time the dam must be removed or breached to eliminate any hazard to downstream areas. This Model Law provides a guide for states who wish to provide regulations to supervise these elements essential to safe dams and reservoirs.

In developing this Model Law advantage was taken of the forty years of experience with the California statutes enacted in

1929 following the failure of the St. Francis Dam with a heavy loss of life and major property damage. The original draft was prepared by a distinguished nationwide committee of professional engineers, experts in the design, construction and management of safe dams and reservoirs. It was submitted in draft form to the Governors of all fifty States for comment. Their comments and those of their staffs are reflected in this Model Law.

This Model Law has not been prepared with the expectation that it would be adopted without change by any state. Changes to meet constitutional and legal requirements, the organizational structure, and the financial system of the several states is to be expected. Supervision of dams in Federal ownership have been omitted from jurisdiction as the consent of Congress would be necessary to such supervision. In this connection see Arizona v. California, 283 U.S. 423.

Some states may prefer to put some of the requirements into administrative or technical rules or regulations rather than into the statute itself to provide more flexibility. Experience has shown that incorporation in the basic law removes the requirements from possible frequent changes by a succession of administrators. The definition of a dam subject to jurisdiction (Sect. 1002) is expected to vary, state by state, to meet each state's individual need. The fee schedule requirement (Chapter 6) likewise is optional by states. It is not intended to be of such magnitude as to make the supervision program self-supporting.

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MODEL LAW
FOR
STATE SUPERVISION OF SAFETY OF DAMS AND RESERVOIRS

Chapter 1. Definitions

1000. Unless the context otherwise requires, the definitions in this chapter govern the construction of this Act.

1001. "Agency" means that Agency, Department, Office, or other unit of State Government designated by State law to be responsible for implementation or direction of this Act. (This section to be replaced in enactment of the law by a reference to the State unit created or selected to implement and direct the Act which may be regular State employees or specialists and consultants, including consulting engineering firms or organizations, for any or all of the provisions of this Act.)

1002. Jurisdiction applies to any artificial barrier, herein called a "dam", including appurtenant works, which does or will impound or divert water, and which (a) is or will be 25 feet or more in height from the natural bed of the stream or watercourse measured at the downstream toe of the dam, or from the lowest elevation of the outside limit of the dam, if it is not across a stream channel or watercourse, to the maximum water storage elevation or (b) has or will have an impounding capacity at maximum water storage elevation of 50 acre-feet or more.

1003. No obstruction in a canal used to raise or lower water therein shall be considered a dam. A fill or structure for highway or railroad use or for any other purpose, which does or may impound water, shall be subject to review by the Agency and shall be considered a dam if the criteria of Section 1002 are found applicable.

1004. "Reservoir" means any basin which contains or will contain impounded water.

1005. "Owner" includes any of the following who own, control, operate, maintain, manage, or propose to construct a dam or reservoir:

(a) The State and its Departments, institutions, agencies, and political subdivisions.

(b) Every municipal or quasi-municipal corporation.

(c) Every public utility.

(d) Every district.

(e) Every person.

(f) The duly authorized agents, lessees, or trustees of any of the foregoing.

(g) Receivers or trustees appointed by any court for any of the foregoing.

"Owner" does not include any agency of the United States Government, including those who operate and maintain dams owned by the United States.

"Person" means any person, firm, association, organization, partnership, business trust, corporation, or company.

1006. "Alterations", "repairs", or either of them, mean only such alterations or repairs as may directly affect the safety of the dam or reservoir, as determined by the Agency.

1007. "Enlargement" means any change in or addition to an existing dam or reservoir, which raises or may raise the water storage elevation of the water impounded by the dam.

1008. "Water storage elevation" means the maximum elevation of water surface which can be obtained by the dam or reservoir without encroaching on the approved freeboard at maximum design flood.

1009. "Days" used in establishing deadlines, means calendar days, including Sundays and holidays.

1010. "Appurtenant works" include, but are not limited to, such structures as spillways, either in the dam or separate therefrom; the reservoir and its rim; low level outlet works; and water conduits such as tunnels, pipelines or penstocks, either through the dam or its abutments.

Chapter 2. General Provisions

1025. It is the intent of the Legislature by this Act to provide for the regulation and supervision of all dams and reservoirs exclusively by the State to the extent required for the protection of public safety.

1026. No city or county has authority, by ordinance enacted by the legislative body thereof or adopted by the people under the initiative power, or otherwise, to regulate, supervise, or provide for the regulation or supervision of any dams or reservoirs in this State, or the construction, maintenance, operation, or removal or abandonment thereof, nor to limit the size of dam or reservoir or the amount of water which may be stored therein, where such authority would conflict with the powers and authority vested in the Agency by this Act. This Act shall not prevent a city or county from adopting ordinances regulating, supervising, or providing for the regulation or supervision of dams and reservoirs that (a) are not within the State's jurisdiction, (b) are not subject to regulation by another public agency or body, or apply only to appurtenances such as roads and fences not germane to the safety of the structure.

1027. All plans and specifications for initial construction, enlargement, alteration, repair or removal of dams and supervision of construction shall be in charge of a civil engineer, licensed by this State, experienced in dam design and construction, assisted by qualified engineering geologists and other specialists when necessary.

1028. No action shall be brought against the State or the Agency or its agents or employees for the recovery of damages caused by the partial or total failure of any dam or reservoir or through the operation of any dam or reservoir upon the ground that such defendant is liable by virtue of any of the following:

(a) The approval of the dam or reservoir, or approval of flood handling plans during construction.

(b) The issuance or enforcement of orders relative to maintenance or operation of the dam or reservoir.

(c) Control and regulation of the dam or reservoir.

(d) Measures taken to protect against failure during an emergency.

1029. Nothing in this Act shall be construed to relieve an owner or operator of a dam or reservoir of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam or reservoir.

1030. The findings and orders of the Agency and the certificate of approval of any dam or reservoir issued by the State are final and conclusive and binding upon all owners, and State agencies, regulatory or otherwise, as to the safety of design, construction, maintenance, and operation of any dam or reservoir.

1031. Nothing in this Act shall be construed to deprive any owner of such recourse to the courts as he may be entitled to under the laws of this State.

1032. All records of official actions of the Agency and its correspondence pertaining to the supervision of dams and reservoirs are public documents.

1033. All owners shall notify the Agency of any change in ownership of any dam or reservoir subject to this Act at the time the transfer of ownership occurs.

Chapter 3. Administrative Provisions

1050. The Agency shall be administered and directed by a civil engineer, licensed by this State, experienced in the design and construction of dams and reservoirs, and it shall employ such clerical, engineering, and other assistants as are necessary for carrying on the work of dam and reservoir supervision in accordance with this Act.

1051. When the safety considerations pertaining to a certificate of approval, dam, reservoir, or plans and specifications require it, or when requested in writing to do so by the owner, the Agency may appoint a consulting board of two or more consultants not previously associated with the structure, to report to the Agency on its proposed action with respect to these considerations.

1052. The cost and expense of a consulting board if appointed on the request of an owner shall be paid by the owner.

Chapter 4. Powers of the Agency

Article 1. Powers in General

1075. The Agency, under the police power of the State, shall review and approve the design, construction, enlargement, alteration, repair, maintenance, operation, and removal of dams and reservoirs for the protection of life and property as provided in this Act.

1076. All dams and reservoirs in the State are under the jurisdiction of the Agency, except those dams which are Federally owned.

1077. It is unlawful to construct, enlarge, repair, alter, remove, maintain, operate or abandon any dam or reservoir coming within the purview of this Act except upon approval of the Agency, provided that this section shall not be deemed to apply to routine maintenance and operation not affecting the safety of the structure.

1078. The Agency shall adopt and revise from time to time such rules and regulations and issue such general orders as may be necessary for carrying out, but not inconsistent with, the provisions of this Act.

1079. In making any investigation or inspection necessary to enforce or implement this Act, the Agency or its representatives may enter upon such private property of the dam owner as may be necessary.

1080. In determining whether a dam or reservoir or proposed dam or reservoir constitutes or would constitute a danger to life or property, the Agency shall take into consideration the following conditions, not necessarily all inclusive: the possibility that the dam or reservoir might be endangered by overtopping, seepage, settlement, erosion, cracking, earth movement, earthquakes, failure of bulkheads, flashboard, gates and conduits, which exist or which might occur in any area in the vicinity of the dam or reservoir. Whenever the Agency deems that any conditions endanger a dam or reservoir, it shall order the owner to take such action as necessary to the satisfaction of the Agency to remove the resultant danger to life and property.

Article 2. Investigations and Studies

1081. For the purpose of enabling it to make decisions as compatible with public safety and economy as possible, the Agency shall make or cause to be made such investigations and shall gather or cause to be gathered such data including advances made in safety practices elsewhere, as may be needed for a proper review and study of the various features of the design, construction, repair and enlargement of dams, reservoir, and appurtenances.

1082. The Agency shall also make or cause to be made from time to time such watershed investigations and studies as may be necessary to keep abreast of developments affecting stream run-off and as required to facilitate its decisions.

Article 3. Action and Procedure to Restrain Violations

1083. The Agency may take any legal action proper and necessary for the enforcement of this Act.

1084. An action or proceeding under this article may be commenced whenever any owner or any person acting as a director, officer, agent, or employee of any owner, or any contractor or agent or employee of such contractor is:

(a) Failing or omitting or about to fail or omit to do anything required of him by this Act or by any approval, order, rule, regulation, or requirement of the Agency under the authority of this Act, or

(b) Doing or permitting anything or about to do or permit anything to be done in violation of or contrary to this Act or any approval, order, rule, regulation, or requirement of the Agency under this Act.

1085. Any action or proceeding under this article shall be commenced in a court of appropriate jurisdiction in which (a) the cause or some part thereof arose, (b) the owner or person complained of has its principal place of business, or (c) the person complained of resides.

Chapter 5. Applications

Article 1. New Dams and Reservoirs or Enlargements of Dams and Reservoirs

1100. Construction of any new dam or reservoir or the enlargement of any dam or reservoir shall not be commenced until the owner has applied for and obtained from the Agency written approval of plans and specifications.

1101. A separate application for each reservoir and its dams shall be filed with the Agency upon forms to be provided by it.

1102. The application shall give the following information:

(a) The name and address of the owner.

(b) The location, type, size, and height of the proposed dam and reservoir and appurtenant works.

(c) The storage capacity and reservoir surface areas for normal pool and maximum high water.

(d) Plans for proposed permanent instrument installations in the dam.

(e) As accurately as may be readily obtained, the area of the drainage basin, rainfall and streamflow records and flood-flow records and estimates.

(f) Maps and general design drawings showing plans, elevations, and sections of all principal structures and appurtenant works or other features of the project in sufficient detail, including design analyses, to determine safety, adequacy and suitability of design.

(g) Such other pertinent information as the Agency requires, such as proposed time for commencement and completion of construction.

1103. The Agency shall, when in its judgment it is necessary, also require the following:

(a) Data concerning subsoil and rock foundation conditions and the materials entering into construction of the dam or reservoir.

(b) Investigations of, and reports on, subsurface conditions, involving such matters as exploratory pits, trenches and adits, drilling, coring, geophysical surveys, tests to determine leakage rates, and physical tests to measure in place and in the laboratory the properties and behavior of foundation materials at the dam or reservoir site.

(c) Investigations of, and reports on, the geology of the dam or reservoir site and its vicinity, possible geologic hazards, including seismic activity, faults, weak seams and joints, availability and quality of construction materials, and other pertinent features.

(d) Such other appropriate information as may be necessary in a given instance.

1104. In instances wherein the physical conditions involved and the size of the dam or reservoir are such as to render the above requirements as to drainage areas, rainfall, streamflow, floodflow, and drilling or prospecting of site unnecessary, the Agency may waive the requirements.

1105. The application shall set forth the purpose or purposes for which the impounded or diverted water is to be used.

Article 2. Repairs, Alterations, or Removals

1106. Before commencing the repair, alteration or removal of a dam or reservoir, including the alteration or removal of a dam or reservoir so that it no longer constitutes a dam or reservoir as defined in this Act, the owner shall file an application and secure the written approval of the Agency, except as provided in this article. Repairs shall not be deemed to apply to routine maintenance and operation not affecting the safety of the structure.

1107. The application shall give such pertinent information or data concerning the dam or reservoir, or both, as may be required by the Agency and such information as to other matters appropriate to a thorough consideration of the safety of such a change as may be required by the Agency.

1108. The application shall state the proposed time of commencement and of completion of remedial construction.

1109. The application shall give the name and address of applicant, shall adequately detail, with appropriate references to the existing dam or reservoir, the changes which it is proposed to effect, and shall be accompanied by maps and plans and specifications which shall be a part of the application and which shall be of such character and size and set forth such pertinent details and dimensions as the Agency may require. The Agency may waive any of the requirements of this section if found by it unnecessary.

1110. In case of an emergency where the Agency declares repairs or breaching of the dam are immediately necessary to safeguard life and property repairs or breaching shall be started immediately by the owner, or by the Agency at the owner's expense, if he fails to do so. The Agency shall be notified at once of proposed emergency repairs or breaching and of work under way when instituted by the owner.

1111. The proposed repairs, breaching and work shall be made to conform to such orders as the Agency issues.

Article 3. Approval of Applications

1112. Upon receipt of an application the Agency shall give its consideration thereto and shall approve or disapprove the same within the time provided in Section 1114.

1113. If an application is defective, it shall be returned to the applicant for such action as necessary to correct the defects, endorsed so that in order to retain its validity, it must be corrected and returned to the Agency within 30 days or such further time as may be given by the Agency. If the application is not so returned, it shall be rejected.

1114. No applications shall be approved or disapproved in less than 30 days after the receipt of the fee required by Section 1125, but all applications shall be approved or disapproved as soon as practicable thereafter. At the discretion of the Agency hearings may be held on each application.

1115. Approvals shall be granted under terms, conditions, and limitations necessary to safeguard life and property.

1116. Actual construction shall be commenced within one year after date of approval; otherwise the approval becomes void.

1117. The Agency may, upon written application and for good cause shown, extend the time for commencing construction.

1118. Notice shall be given to the Agency at least ten days before construction is to be commenced and such other notices shall be given to the Agency as it may require.

Chapter 6. Fees

1125. The application for a new dam and reservoir or enlargement shall set forth the estimated net cost, as defined in this chapter, of the dam and reservoir or enlargement and shall be accompanied by a filing fee based upon the estimated cost and according to the following schedule: (Schedule below will of necessity vary in each State.)

(a) For the first one hundred thousand dollars ($100,000) a fee of 2 percent of the estimated cost.

(b) For the next four hundred thousand dollars ($400,000) a fee of 1½ percent.

(c) For the next five hundred thousand dollars ($500,000) a fee of 1 percent.

(d) For all costs in excess of one million dollars ($1,000,000) a fee of one-half of 1 percent.

In no case, however, shall the fee be less than one hundred dollars ($100) or more than fifty thousand dollars ($50,000).

1126. One fee only shall be collected for an enlargement to be effected by flashboards, sandbags, earthen levees, gates, or other works, devices, or obstructions which are, from time to time, to be removed and replaced or opened and shut and thereby operated so as to vary the surface elevation of the impounded water.

1127. For the purposes of this Act, the estimated net cost of the dam and reservoir or enlargement involved shall include the following:

(a) The cost of all labor and materials entering into the construction of the dam and appurtenant works or reservoir, including right of way.

(b) The cost of preliminary investigations and surveys.

(c) The cost of the construction plant properly chargeable to the cost of the dam or reservoir.

(d) Any and all other items entering directly into the cost of the dam or reservoir.

1128. Excluded from the cost listed in Section 1127 shall be:

(a) Costs of right of way for other than the dam and reservoir.

(b) Detached or underground powerplants, including switchyards and substations.

(c) Electrical generating, or pump-generating machinery.

(d) Roads, railroads, helioports and landing strips affording access to the dam or reservoir.

1129. An application shall not be considered by the Agency until the filing fee is received. All or part of the filing fee may be returned to the applicant only if he withdraws or cancels the application any time prior to the start of construction. The amount of the refund will be determined by the Agency with due regard to funds actually expended by the Agency in consideration of the application.

1130. As soon as possible after giving the notice of completion required in Section 1150, the owner shall file an affidavit with the Agency stating the actual cost of the dam and reservoir or enlargement thereof in such detail as the Agency requires to determine whether a further fee is due. In the event the owner of a new or enlarged dam or reservoir, because of loss of records, recent change of ownership, or other causes beyond his control, is unable to report the actual cost of construction or enlargement, he shall file an affidavit to this effect, stating the reasons therefor, within thirty days after receiving a written request therefor from the Agency. The Agency shall then make its own appraisal of the cost of construction or enlargement and determine what further fee, if any, is required.

1131. In the event the actual cost exceeds the estimated net cost by more than 15 percent, a further fee shall be required by the Agency computed under the schedule set forth in Section 1125 upon the actual cost, plus a penalty of 15 percent of the actual cost. No further fee shall be required, however, if such fee is to be computed at less than twenty dollars ($20). Upon making a determination that a further fee is required, the Agency shall notify the owner by certified mail of the amount of such fee and shall notify the owner that he may appear within sixty days thereafter before an authorized representative of the Agency to protest the amount of the fee, in whole or in part, determined by the Agency to be required, and the sufficiency of the appraisal upon which such determination was based.

1132. All filing fees and other charges collected under the provisions of this Act shall be paid into a special fund in the State Treasury immediately after the Agency has certified

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as to the correctness of the amounts received, to be available to the Agency for expenditure for the purposes authorized by this Act.

1133. The fees provided for in this article shall be required of all enumerated in the definition of owner in Chapter 1 of this Act.

Chapter 7. Inspection and Approval

Article 1. New or Enlarged Dams and Reservoirs

1150. Immediately upon completion of a new dam and reservoir or enlargement of a dam and reservoir the owner shall give a notice of completion to the Agency, and as soon thereafter as possible shall file with the Agency a certificate signed by the responsible engineer supervising construction for the owner, certifying that the project was constructed in conformance with approved plans and specifications, accompanied by supplementary drawings or descriptive matter showing or describing the dam or reservoir as actually constructed, which shall include but not be limited to the following:

(a) A record of all geological boreholes and grout holes and grouting.

(b) A record of permanent location points, benchmarks and instruments embedded in the structure.

(c) A record of tests of concrete or other material used in the construction of the dam and reservoir.

(d) A record of seepage flows and embedded instrument readings.

1151. In connection with the enlargement of a dam and reservoir, the supplementary drawings and descriptive matter need apply only to the new work.

1152. A certificate of approval shall be issued by the Agency upon a finding by the Agency that the dam and reservoir are safe to impound water within the limitations prescribed in the certificate. No water shall be impounded by the structure prior to issuance of the certificate.

Article 2. Certificates of Approval

1153. Each certificate of approval issued by the Agency under this Act may contain such terms and conditions as the Agency may prescribe.

1154. The Agency may revoke or suspend any certificate of approval whenever it determines that the dam or reservoir constitutes a danger to life and property. Whenever it deems such action necessary to safeguard life and property, the Agency may also amend the terms and conditions of any such certificate by issuing a new certificate containing the revised terms and conditions.

1155. Before any certificate of approval is revoked by the Agency, the Agency shall hold a hearing. Written notice of the time and place of the hearing shall be mailed, at least twenty days prior to the date set for the hearing, to the holder of the certificate. Any interested persons may appear at the hearing and present their views and objections to the proposed action. Any petition to a court of appropriate jurisdiction to inquire into the validity of action of the Agency revoking a certificate of approval shall be commenced within thirty days after service of notice of the revocation on the holder of the certificate.

Article 3. Repaired or Altered Dams and Reservoirs

1156. Immediately upon completion of the repair or alteration of any dam or reservoir, the owner shall give notice of completion to the Agency and as soon thereafter as possible shall file with the Agency a certificate signed by the responsible engineer supervising the work for the owner that the repairs or alterations were completed in accordance with the approved plans and specifications, accompanied by supplementary drawings or descriptive matter showing or describing the dam or reservoir as actually repaired or altered together with such maps, data, records, and information pertaining to the dam or reservoir as repaired or altered as the Agency requires.

1157. A certificate of approval shall be issued by the Agency upon a finding by the Agency that the dam and reservoir are safe to impound water within the limitations prescribed in the certificate. Pending issuance of a new certificate of approval, the owner of the dam or reservoir shall not, through action or inaction, cause the dam or reservoir to impound water beyond the limitations prescribed in the existing certificate.

1158. The certificate of approval shall supersede any previous certificate of approval issued for the dam or reservoir so repaired or altered.

Article 4. Removal of Dams and Reservoirs

1159. Upon completion of the removal of a dam or complete drawdown of a reservoir such evidence as to the manner in which the work was performed and as to the conditions obtaining after the removal as the Agency requires shall be filed with the Agency.

1160. This evidence shall show that a sufficient portion of the dam has been removed to permit the safe passage of floods down the watercourse across which the dam was located, within flooding criteria required by the Agency, and that adequate provision has been made by the owner to prevent damage downstream from the remaining portion of the dam by subsequent flooding of downstream areas under such criteria.

1161. Before final approval of the removal of a dam or reservoir is issued, the Agency shall inspect the site of the work and determine that all danger to life and property as a result thereof has been eliminated.

Article 5. Complaints as to Unsafe Conditions

1162. Upon receipt of a written complaint alleging that the person or property of the complainant is endangered by the construction, enlargement, repairs, alterations, maintenance, or operation of any dam or reservoir the Agency shall cause an inspection to be made unless the data, records, and inspection reports on file with it are found adequate to make a determination whether the complaint is valid.

1163. If the Agency authorizes an inspection the complainant shall deposit with the Agency a sum estimated by it to be sufficient to cover costs of the inspection. The Agency may utilize independent consultants of its selection to make the inspection and a report to the Agency.

1164. If it is found that an unsafe condition exists, the Agency shall notify the owner to take such action as is necessary to render or cause the condition to be rendered safe, including breaching or removal of any dam found beyond repair, and any money deposited to secure an inspection shall be returned.

1165. If, after an inspection is made on account of a complaint, the complaint is found by the Agency to have been without merit, the cost therefor shall be payable into the Special Fund in State Treasury from the money deposited, with any excess returned to the complainant. The complainant will be provided with a copy of the official report of the inspection.

Article 6. Inspection During Progress of Work

1166. During the construction, enlargement, repair, alteration, or removal of any dam or reservoir the Agency shall make either with its own engineers or by consulting engineers or engineering organizations, periodic inspections at State expense for the purpose of ascertaining compliance with the approved plans and specifications. The Agency shall require the owner to perform at his expense such work or tests as necessary, provide adequate supervision during construction by a civil engineer registered or licensed by the laws of this State, and to disclose information sufficient to enable the Agency to determine that conformity with the approved plans and specifications is being secured.

1167. If, after any inspections, investigations, or examinations, or at any time as the work progresses, or at any time prior to issuance of a certificate of approval it is found by the Agency that amendments, modifications, or changes are necessary to ensure safety, the Agency may order the owner to revise his plans and specifications, provided, however, the owner may, pursuant to Section 1051, request an independent consulting board to review the order of the Agency.

1168. If conditions are revealed which will not permit the construction of a safe dam or reservoir the Agency's approval shall be revoked.

1169. In the event that conditions imposed may be waived or made less burdensome in its judgment without sacrificing safety, the Agency may authorize an owner to revise the plans and specifications accordingly.

1170. If at any time during construction, enlargement, repair, or alterations of any dam or reservoir the Agency finds that the work is not being done in accordance with the provisions of the original approved plans and specifications or in accordance with the approved revised plans and specifications, it shall give a written notice thereof and order compliance by registered mail or by personal service to the owner.

1171. The notice and order shall state the particulars in which the original approved plans and specifications or the approved revised plans and specifications are not being or have not been complied with and shall order the immediate compliance with the original approved plans and specifications or with the approved revised plans and specifications as the case may be.

1172. The Agency may order that no further work be done until such compliance has been effected and approved by the Agency.

1173. A failure to comply with the approval and approved plans and specifications shall render the approval subject to revocation by the Agency, if compliance is not made in accordance therewith after notice and order from the Agency as provided in this article. If compliance is not forthcoming in a reasonable time, the Agency may order the incomplete structure removed sufficiently to eliminate any safety hazard to life or property.

Chapter 8. Maintenance, Operation and Emergency Work

Article 1. Maintenance and Operation

1174. Supervision over the maintenance and operation of dams and reservoirs in this State, other than those owned by the Federal Government, insofar as necessary to safeguard life and property from injury by reason of the failure thereof is vested in the Agency.

1175. The Agency shall require owners or their agents to keep available and in good order records of original and any modification construction and to report annually with respect to maintenance, operation and engineering including piezometric data and geologic investigations. The Agency shall issue such rules and regulations and orders as necessary to secure adequate maintenance, operation and inspection by owners or their agents and shall require engineering and geologic investigations by owners or their agents which will safeguard life and property.

In addition, the owner of a dam or reservoir or his agent shall fully and promptly advise the Agency of any sudden or unprecedented flood or unusual or alarming circumstance or occurrence existing or anticipated which may affect the dam or reservoir.

1176. The Agency, from time to time, but not less often than once every five years, either with its own engineers, or by consulting engineers or engineering organizations, shall make inspections of dams and reservoirs at State expense for the purpose of determining their safety but shall require owners to perform at their expense such work as may reasonably be required to disclose information sufficient to enable the Agency to determine conditions of dams and reservoirs in regard to their safety and to perform at their expense other work which may reasonably be required, including installation of instruments necessary to secure maintenance and operation which will safeguard life and property.

Article 2. Emergency Work

1177. The Agency shall be responsible for determining that an emergency exists and through normal disaster communication channels shall warn the public, immediately employing any remedial means necessary to protect life and property, if in its judgment either:

(a) The condition of any dam or reservoir is so dangerous to the safety of life or property as not to permit of time for the issuance and enforcement of an order relative to maintenance or operation.

(b) Passing or imminent floods or any other condition which threaten the safety of any dam or reservoir.

1178. In applying the remedial means provided for in this article, the Agency may in emergency with its own forces, or by other means at its disposal, do any of the following:

(a) Take full charge and control of any dam or reservoir.

(b) Lower the water level by releasing water from the reservoir.

(c) Completely empty the reservoir.

(d) Perform any necessary remedial or protective work at the site.

(e) Take such other steps as may be essential to safeguard life and property.

1179. The Agency shall continue in full charge and control of such dam or reservoir, or both, and its appurtenances until they are rendered safe or the emergency occasioning the action has ceased and the owner is able to take back such operations. The Agency's take over will not operate to relieve the owner of a dam or reservoir of liability for any negligent acts of the owner or his agents.

1180. The cost and expense of the remedial means provided in this article, including cost of any work done to render a dam or reservoir or its appurtenances safe, shall be collected by presentation of bills to owners in the same manner as other debts to the State are recoverable, provided that if such bills are not promptly paid by the owners the cost shall be recovered by the State from the owner by action brought by the Agency in a court of appropriate jurisdiction.

Chapter 9. Offenses and Punishment

1185. Every person who violates any of the provisions of this Act or of any approval, order, rule, regulation, or requirement of the Agency is guilty of a misdemeanor and punishable by a fine of not more than _________________($________) or by imprisonment in _______________. In the event of a continuing violation each day that the violation continues constitutes a separate and distinct offense.

1186. Any person who wilfully obstructs, hinders, or prevents the Agency or its agents or employees from performing the duties imposed by this Act or who wilfully resists the exercise of the control and supervision conferred by this Act upon the Agency or its agents or employees is guilty of a misdemeanor and punishable as provided in this article.

1187. Any owner or any person acting as a director, officer, agent, or employee of an owner, or any contractor or agent or employee of a contractor who engages in the construction, enlargement, repair, alteration, maintenance, or removal of any dam or reservoir, who knowingly does work or permits work to be executed on the dam or reservoir without an approval or in violation of or contrary to any approval as provided for in this Act, or any inspector, agent, or employee of the Agency who has knowledge of such work being done and who fails to immediately notify the Agency thereof is guilty of a misdemeanor and punishable as provided in this article.

Chapter 10. Dams and Reservoirs Existing Prior to the Effective Date of this Law

Article 1. Dams and Reservoirs Completed Prior to Effective Date of this Law

1200. Every owner of a dam or reservoir that falls within the definition of a dam or reservoir in this Act that was completed prior to the effective date of this Law shall immediately file an application with the Agency for the approval of such dam or reservoir.

1201. A separate application for each reservoir and its dams shall be filed with the Agency upon forms to be supplied by it and shall include or be accompanied by such appropriate information concerning the dams or reservoir as the Agency requires.

1202. The Agency shall give notice to file an application to owners of such dams or reservoirs who have failed to do so as required by this article, and a failure to file within thirty days after such notice shall be punishable as provided in this Act.

1203. The notice provided for in this article shall be given by certified mail to the owner at his last address of record in the office of the county assessor of the county in which the dam is located and such mailing shall constitute service.

1204. The Agency shall make inspections of such dams or reservoirs at State expense.

1205. The Agency shall require owners of such dams or reservoirs to perform at their expense such work or tests as may reasonably be required to disclose information sufficient to enable the Agency to determine whether to issue certificates of approval or to issue orders directing further work at the owner's expense necessary to safeguard life and property. For this purpose, the Agency may require an owner to lower the water level of, or to empty, the reservoir.

1206. If, upon inspection or upon completion to the satisfaction of the Agency of all work that may be ordered, the Agency finds that the dam and reservoir are safe to impound water, a certificate of approval shall be issued. The owner of the dam or reservoir shall not, through action or inaction, cause the dam or reservoir to impound water following receipt by the owner of a written notice from the Agency that a certificate will not be issued because the dam or reservoir will not safely impound water. Before such notice is given by the Agency, the Agency shall hold a hearing. Written notice of the time and place of the hearing shall be mailed, at least twenty days prior to the date set for the hearing, to the owner of the dam or reservoir. Any interested persons may appear at the hearing and present their views and objections to the proposed action.

Article 2. Dams and Reservoirs Under Construction Before Effective Date of this Law

1207. Any dam or reservoir that falls within the definition of a dam or reservoir in this Act and which the Agency finds was under construction and based on its findings not 90 percent constructed on the effective date of this Law shall, except as provided in Section 1208, be subject to the same provisions in this Act as a dam or reservoir commenced after that date. Every owner of such a dam or reservoir shall file an application with the Agency for the Agency's written approval of the plans and specifications of the dam or reservoir.

1208. Construction work on such a dam or reservoir may proceed, provided an application for approval of the plans and specifications therefor is filed, until a certificate of approval is received by the owner from the Agency approving the dam and reservoir or an order is received by the owner from the Agency specifying how the construction must be performed to render the dam or reservoir safe. After receipt of an order specifying how construction of the dam or reservoir must be performed, work thereafter must be in accordance with the order.

1209. Such dams or reservoirs as are based on Agency findings 90 percent or more constructed on the effective date of this Law shall be subject to the same supervision as dams or reservoirs which were completed prior thereto.

Article 3. Fees for Dams or Reservoirs Under Construction Before Effective Date of this Law

1210. The owners of dams or reservoirs that, based on Agency findings, are 90 percent or more constructed on the effective date of this Act and that are subject to the provisions of this Act shall not be required to pay a fee but shall submit an application for approval and issuance of a State certificate as provided in Section 1209. Applications for the approval of dams and reservoirs that are made subject to this

Act that are found by the Agency to have been less than 90 percent constructed on the effective date of this Law shall be accompanied by fees as much less than provided for dams and reservoirs commenced after that date as the percentage of construction found by the Agency to have been completed on that date.

UNITED STATES COMMITTEE

INTERNATIONAL COMMISSION ON LARGE DAMS

An Engineering Survey of Representative Coal Mine Refuse Piles as Related to the Buffalo Creek, West Virginia, Disaster

Part II of II

REPRESENTATIVE DAMS IN THE AREA OTHER THAN THOSE ON MIDDLE FORK, BUFFALO CREEK

U.S. SENATE SUBCOMMITTEE ON LABOR
of the
Committee on Labor and Public Welfare

Harrison A. Williams, Jr., Chairman

May 1972

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REPORT ON

An Engineering Survey of Representative Coal Mine Refuse Piles as Related to the Buffalo Creek, W. Va. Disaster

Part II of II

REPRESENTATIVE DAMS IN THE AREA, OTHER THAN THOSE ON THE MIDDLE FORK, BUFFALO CREEK

SUMMARY

The conclusions and recommendations of Part I of this report are supported firmly by the studies of this Part. For instance, lack of adequate design and construction measures, as well as the poor planning of operations, make all the dams presently in use a serious hazard, one even of potentially catastrophic proportions, to life and property downstream. The dams are, in general, only barely stable under present conditions; the study indicates that all will fail under reasonably high pool conditions. A majority of the refuse dams presently in use, termed active hereinafter, are composed of materials in a relatively loose condition and of a type which is susceptible to liquefaction and therefore to mud flows as occurred in the case of the Middle Fork dams.

The reconnaissance of the area during selection of the dams for study and the study per se, indicated no dams with conditions identical to those on the Middle Fork -- there may be some -- they simply were not observed. Some are similar, with only minor differences; most, however, were significantly different -- with better foundation conditions and generally in method of

construction. Although different, none of the dams observed are considered safe structures; they were not designed and constructed to withstand the natural destructive action to which they can be exposed. Since the dams surveyed all show evidence of some prior failure and the dams studied are believed to be representative of those in the area, it is reasonable to assume that sometime during their construction almost all of the other dams in the area have failed, with varying degrees of gravity. None, yet, have failed with the catastrophic consequences of those on the Middle Fork. However, contemplation of the appalling possible results in the area of a deluge normally associated with a hurricane of major proportions or of a moderately severe earthquake in the early spring when the embankments would be more nearly saturated than at other seasons, is stupifying, in that the recent Buffalo Creek disaster could be multiplied manyfold.

In order to assess the modifications necessary to existing structures due to earthquakes and the measures required in design of future dams, the agency responsible for dam safety should, by a detailed study, have criteria determined by eminent experts in the fields concerned, the criteria taking into account the data from instrumentation obtained during the recent San Fernando, California earthquake.

The following statements are similar to those contained in Part I, and are set out here simply for emphasis; technology is avilable to assure the safety of all the dams in the area, providing corrective measures are taken and to assure safety of dams constructed in the future. These measures will be expensive and will probably result in the dams being considered uneconomical.

Existing statutes as to safety of dams overlap and their technical adequacy in some cases is questionable. This should be corrected and one agency made clearly responsible for supervision and dam safety. Model laws are available for guidance in establishing technically adequate statutes. (See Appendix D, Part I).

REPORT ON

An Engineering Survey of Representative Coal Mine Refuse Piles as Related to the Buffalo Creek, W. Va. Disaster

Part II of II

REPRESENTATIVE DAMS IN THE AREA, OTHER THAN THOSE ON THE MIDDLE FORK, BUFFALO CREEK

A. Authority, Purpose and Scope of the Investigation. All of these items are as set forth in Part I of this report.

B. Compilation of Report. General. In order that as early use as possible could be made of the results of the investigation, it was agreed that the report should be divided into two parts. Part I should be concerned only with the work specifically related to the dams of the Middle Fork, Buffalo Creek. Part II, as given herein, should relate to the examination of representative refuse piles in the area.

C. Selection of Sites for the Study and Sites Chosen

1. General. **The study area on the Middle Fork of Buffalo Creek, which was covered in Part I had only remnants of the impoundment dams. The primary emphasis in part II was placed on a study of active piles (those presently in use) which have existing pools behind them. Some superficial examination was made of three sites not presently in use and which did not have pools. The latter were included to balance the overall study as to construction treatment required when the refuse piles are not in the active category.**

2. Criteria for Selection of Active Sites for Study. The sites **were** near the Middle Fork of Buffalo Creek to insure as far as

practical that the mine refuse material will be geologically similar. The sites had, or were capable of retaining, a pool of either runnoff or coal cleaning water or a mixture of both. Some cases were studied which, if rupture occurred, would be disastrous in terms of loss of life and major property damage. The number of dams selected were small in order to furnish representative engineering information in the least practicable length of time. An attempt was made to locate at least one dam as similar in purpose and construction as possible to that which failed in the Middle Fork of Buffalo Creek. In order to accomplish the selection, a map study was made to delineate deposits for observation and two helicopter flights were made over the area and one trip into the area by automobile.

3. Sites Selected and Locations. Using the guidelines indicated above, the following refuse dams were selected for investigation, as are indicated on Plate 1.

a. The Amherst Coal Company disposal pile and pool, located adjacent to Dick Branch of Buffalo Creek. The pool is actually in a small unnamed tributary of Dick Branch, with the dam at the mouth of this small tributary and the base of the dam extending into Dick Branch. Dick Branch is a tributary of Buffalo Creek; the dam and pool are near the town of Fanco, West Virginia, which was partially demolished by the failure of the dams on the Middle Fork.

b. The Youngstown Mining Corporation refuse dam located at the mouth of an unnamed tributary of Right Hand Fork which, in turn, is a tributary of Rum Creek. The dam is about 1¼ miles above the junction of Rum Creek with the Guyandotte River and is located at the town of Dehue, West Virginia.

c. The Island Creek Coal Company refuse dam across Little White Oak Branch of Spruce Fork, being a part of the Kanawha River System. It is located about 2½ miles upstream along Spruce Fork, southeast of Blair, West Virginia.

d. The Powellton Company dam and impoundment on Rockhouse Creek, a tributary of the Guyandotte River. The dam is located about 2 miles upstream (southwest) of the junction at Man, West Virginia, of the Creek with the river. This impoundment was selected as being the most similar in size, construction and use, of those observed, to that of the Middle Fork, Buffalo Creek.

4. Older Sites. A cursory examination was made of the following sites:

a. Powellton Coal Company refuse pile across the valley from site 3(d) above, on the Left Hand Fork of Rockhouse Creek.

b. A refuse pile in Bingo Hollow, of vague ownership, near Kestler, West Virginia. Bingo Hollow is a tributary of Buffalo Creek.

c. A refuse pile, again of vague ownership, adjacent to Route 119, 1.4 miles east of Ethel, West Virginia, on an unnamed tributary of Dingess Run.

D. Details of Report Coverage

1. Items Identical for Both Parts of Report. The methods of preparation of the geology and hydrology, map preparation, methods of data collection, the general assumptions, and office studies are identical for both parts of the report; these items are covered in Part I and will not be set forth herein. Laboratory work and methods, similarly, are identical and are stated only in Part I except that part of the testing work only is included herein as Appendix 5; the general field investigations are also identical except that larger density tests were taken on the active sites

than on that of the Middle Fork in order to take into account the effect on unit weight of the larger size pieces of rock and coal.

The report on the general geology and hydrology, the rainfall data, and the Earthquake scales are contained in Part I and are not repeated herein, though they are applicable to the several sites discussed in this part. Similarly, the discussion of factors of safety is contained only in Part I.

2. <u>Items Contained Herein (Part II)</u>

a. Details as to the coverage of the several active dams and of the older inactive refuse piles.

b. Specific conclusions and recommendations on each site not common to all sites.

c. General conclusions and recommendations only in addition to those given in Part I.

E. Investigation of Sites

1. Amherst Coal Company, Dick Branch Refuse Dam and Impoundment.

a. Site Investigation

(1) Location. The facility, operated in conjunction with the company's Cleaning Plant No. 1, is located near the mouth of Dick Branch on the left side of the Branch Valley on an unnamed small tributary. The facility is across Buffalo Creek from the small partially destroyed village of Franco, West Virginia. See Plates 1 and 10.

(2) Questionnaire. The completed questionnaire is given as Appendix 3.

(3) Results of Field Tests. Field density tests were taken at locations shown on Plate 11, together with samples for laboratory testing.

The results of the field density tests are as follows:

Sample No.	Type Material	Dry Unit Weight, #/ft^3	W.C. %
1	Refuse	116.2	9.6
2	Refuse	114.1	7.0
3	Refuse	112.2	7.7
4	Refuse	106.6	7.6
5	Refuse	106.7	8.4
6	Refuse	94.5	8.5
7	Refuse	120.9	7.5
8	Refuse	107.2	9.1
9	Sludge	111.5	10.1
10	Sludge	111.4	9.7

b. Topography, Including Local Geology. As elsewhere in the area of Buffalo Creek, the valley is one of rugged terrain. The height of the upstream divide of the unnamed tributary on which the dam and pool are located is about elevation 2020; the valley drops 820 feet in 0.4 miles, giving an awesome gradient of about 39%. Fortunately, the 0.4 mile is the length of the valley and the watershed is only 0.12 square miles in area, so that, while runoff may have high velocity, its quantity is limited due to this watershed size.

The embankment is founded on a residual and colluvial mantle which does not usually exceed 18 inches in depth. The overburden consists of brown lean clay with weathered sandstone and shale fragments. Vegetation is composed of small trees and brush.

Side-slopes of the valley are as steep as 1 V to 1.5 H or, in other terms, a 67% slope.

The surface rocks exposed along the valley walls consist of sandstones, shales and several coal seams of the Kanawha Series, Pennsylvania Age. The coal were identified in the field as the Chilton at elevation 1418, the Island Creek (Cedar Grove) at elevation 1140 and the Eagle (No. 2 Gas) at elevation 895. This sequence of coal correlates well with the data presented in the West Virginia Geological Survey Report - Logan and Mingo Counties, 1914.

The strata are dripping uniformly at the rate of 50 feet per mile to the northwest.

Evidence obtained from personnel of the Amherst Coal Company and limited field investigation indicates that at least part of the seepage from the sludge impoundment is entering bedrock and is discharging out of the hillside at a point which correlates with the outcrop of the Island Creek (Cedar Grove) coal seam. This discharge is outside the base of the dam.

c. Hazard Created by Facility's Possible Failure. The gradient from the dam and pool to Buffalo Creek is truly forbidding; rapid failure of the dam would obliterate the downstream portion of Amherstdale and the reconstructed part of the valley of Buffalo Creek from that point downstream to Man, West Virginia, where Buffalo Creek joins the Guyandotte

River. It appears probable that such failure would also cause loss of life and serious property damage in Man, and property damages for some distances on the river past Man.

d. Description of Facility. The dam is semi-circular in plan and at the crest is about 1660 feet long. At maximum thickness, it is about 350 feet, assuming the valley slope above the pool continues down to the bottom of Dick Branch and the refuse slopes are about 1 V on 1.5 H. The base of the dam extends into the valley of Dick Branch. If the pool were full it would contain in excess of 12,225,000 gallons of water above the sediment. The combined cubic yardage of dam and sediment is of the order of 7,710,000 cubic yards. The maximum height of the dam from crest to the downstream toe is about 500 feet.

The embankment is composed of minus 5-inch coal refuse; the sediment of minus 5/16-inch coal washings. The dam is presently on fire in several small areas and has burned intermittently for several years; however at present it is estimated that only a minor percentage of the embankment is red dog.

There is at present, evidence of two small slides in the main embankment. Also, there appears to be two levels of seepage outlets on the downstream slope; the upper level at about elevation 1300 and the lower at about 1200. At this lower level three main outlets are in evidence; two supply an intermediate level impoundment at elevation 1140, and the third flows into a lower level impoundment formed by a small dam across the mouth of Dick Branch. All have eroded quite deeply into the embankment. The upper level has, as yet, not produced serious damage.

During the time of the field work, sludge was only 3.5-4 feet below the top of the embankment. The settled material slopes downward, roughly upstream, at an estimate 1.5 - 2.0% and at the time, water covered only about one half the impoundment.

There is no spillway for the facility nor is there other means to by-pass the embankment with high-volume flows.

e. Method of Operating the Facility. The embankment and impoundment areas have apparently grown somewhat like Topsy over the years, being started by truck dumping up Dick Branch in 1946. This material in the main valley, see Plate 10, has been on fire and is now red dog; it has been eroded by flow in the Branch to a considerable extent also. The belt conveyor system was started in 1953; it has also been used to supply refuse for enlarging the lower level of the main refuse pile, to construct an impoundment at intermediate level (near the base of the main embankment in the valley of Dick Branch), to construct the main embankment in the mouth of the unnamed tributary of Dick Branch and is now being used to convey refuse into a small unnamed tributary, farther upstream. The material for the latter appears to be dumped from the conveyor; the material for the main embankment is furnished only as the rise in settled material makes raising the embankment necessary and is hauled from the conveyor to the embankment, dumped and spread by dozer.

The wash material is screened to remove particles larger than 5/16-inch, then pumped up the hillside from the cleaning plant via an 8-inch pipe, entering the pool through the northwesterly part of the embankment, and exiting near the embankment. The settled solids slope downward gently to the southwesterly end of the pool, away from the embankment, to standing water.

On the date of the photography at the end of March 1972, the water was reported to be as high as it ever was, see Plate 10. Also according to the reports it fluctuates about 18 inches per week, but all the water seeps out of the pool in 4 or 5 days if the washing plant is shut down. The operators estimate that 2,000 gpm is pumped to the pool in a 10-12 hour day carrying about 15% solids by volume. Further, the plant operates an estimated 220 to 230 day year. This reduces to about 5000 to 6000 cubic yards of solid waste added to the interior of the impoundment per year.

The operator feels that much of the water seeps into the hillsides and impoundment foundation from the pool; it exits downstream at the locations mentioned above. Most of the water is reported to be settled out in the intermediate pool at elevation 1140. The clearer water from this pool and some seeping directly from the impoundment and spilling from the conveyor are clarified further in the impoundment at the mouth of Dick Branch for use in washing; or is released directly into Buffalo Creek if not needed and the quality is satisfactory.

As to the waste, it is reported that about 30,000 tons per month is belted up the hillside.

It is of interest to note that according to the operators, the storm of late February 1972 which resulted in the disaster in Buffalo Creek, made only a very small difference in the level of the water in this impoundment. However, there are no means by which the run-off from a really heavy storm would by-pass the impoundment nor is there means of lowering the pool after such a storm occurred, even if the height of the embankment was such that the run-off could be contained.

f. Analysis of Dam.

Hydrology. See Appendix 6.

Seepage. The seepage exits have eroded the base of the embankment in varying degrees; the center of the three appears to have caused a partial failure of the base of the embankment. From action of these three exits, it can be inferred that under proper conditions, serious erosion of the base of the embankment could occur leading eventually to failure of the dam.

As to quantity of seepage; it has been stated that about 20,000 gallons per day is pumped into the pool and that there is an approximate 18-inch fluctuation in pool level during the week; a reasonably constant pool level is maintained within this 18-inch range. Excluding rainfall affects, this pool condition can be ascribed then only to pumping in of wash water and seepage out through the foundation. By simple computations this seepage then amounts to about 15,000 gallons per day from approximately half the possible pool area, or if the entire area were just covered it could be reasonably taken as 30,000 gal/day or slightly less than 0.05 cubic feet per second. Assuming rainfall and increase of the pool to a minimum 5-foot depth (cannot be more or it would overtop); the foundation seepage would compute at about 0.25 cfs or to be entirely conservative, not more than 0.5 cfs. This quantity of seepage, if as reported, in the rock and coal seams, would appear to cause no major damage, except at the exit where the refuse piles could be eroded. This latter is unquestionably occurring.

For a sustained heavy rain the above quantity of foundation seepage will not approach that required to balance inflow from run-off.

The importance of this observation, is that if the only outlet for run-off is foundation seepage it would take a considerable length of time for the pool to return to "normal" operating level; a pattern of seepage through the embankment would then have time to develop, which could have serious consequences on the embankment stability, as indicated below.

As to whether this embankment seepage could, as a practical matter, develop, there is evidence that such seepage had taken place, with exits being observed at two levels in the embankment, the one at about elevation 1200 and the other near the top of the embankment at elevation 1300. Since this pattern did not result in failure, it must be reasoned that the entire embankment below the seepage exits did not become saturated. That is, the quantity of water in the pool was small enough to be relieved before a full seepage pattern within the embankment could occur. However, in a longer period of time, such a pattern could unquestionably take place. This reasoning emphasizes the critical need for a stand-pipe or other means to reduce to pool level in a rapid manner at this installation.

The seepage through the foundations and hillside is causing some detrimental erosion, which could ultimately cause serious damage to the embankment where it exits. This problem should be dealt with before it causes more serious problems with the embankment.

The most serious matter is that of a heavy storm where the seepage pattern within the embankment will be established - seepage and piping.will be a problem - the embankment will simply fail under these conditions as shown on Plate 12. However, a problem intermediate to this

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does exist, to wit - if the flow of water entering the impoundment on the surface of the settled material is ever in the direction of the embankment, instead of away from it, serious consequences could result. If the embankment is less pervious than the settled material, pore pressures could build up behind the thin embankment shell and blow the embankment off, resulting in a failure, the magnitude of which could be catastrophic if the pressures were uniform throughout the length of the embankment and the permeability of both the embankment and the sludge at the contact are uniform. Probably they would not be, so the failure probably would not be of such major proportions, but a failure would result nevertheless. Since these properties of uniformity are not known and could not be determined in the time available for the investigation, it is imperative that the owner establish piezometers at close intervals along the crest of the dam down into the underlying sludge to assess water pressures that may be acting on the embankment.

If, on the other hand, the embankment is substantially more pervious than the sludge, and surface flow is toward the embankment, water will enter the embankment from the sludges and flow downward through the embankment without causing any problems provided there are means to drain the embankment at its base, without erosion. No such means have been observed at the Dick Branch embankment.

While the operator feels that the three seepage exits where erosion is taking place may be due to seepage through the foundation, there appears to be major reasons to doubt the source of this seepage. The first is as indicated in the paragraph immediately above; the other is that water from the pool and the surface flows to it, has to be seeping downgrade through the settled material toward the embankment. To repeat, it has to be doing this or it defies a fundamental natural law for flow of water; such a condition is shown, ignoring the seepage from suffface flows, on the section for present conditions, Plate 12. This seepage from the pool must exit on the slope of the embankment or, blow-out, depending on the relative permeabilities for the thin shell and the sludge, the embankment, causing a failure as indicated above. Since the only damage on the downstream slope of the embankment that can be observed is the erosion, (no blow-out) the water from the pool seeping downstream must be emerging at these exits. With a build up in pool, this seepage would increase until by erosion it could cause the dam to fail; in which case the failure would be slower than that which occurred on the Middle Fork, but disastrous, nevertheless.

According to the test results, Plate 20, the coefficient of permeability of the sludge is about 750×10^{-4} cm/sec, based on grain-size and also from the grain-size and permeability tests of the embankment material, its' coefficient is approximately 80×10^{-4} cm/sec.

These results then show that there is danger of there being more water flowing from the sludge than can be drained away by the shell of embankment and that there is a possibility of pressures being built up in the sludge adjacent to the shell, perhaps verging on sufficient to cause a serious failure. This possibility should be checked by a piezometer installation as indicated above. These permeabilities should also be checked by a detailed investigation. The embankment at this point, as with the Middle Fork dams prior to the storm of late February 1972, is in an incipient state of failure, due to the seepage through the embankment.

The problem regarding seepage erosion can be cured, at considerable expense, by pumping the lake dry, allowing the seeps to dry up, placing a designed filter layer on the downstream slope and weighting it as required, with rock, collecting the seepage so that it will no longer damage any of the embankment, and drain it by pipes or lined ditch into Dick Branch or preferably, Buffalo Creek, The problem of general stability, and the possibility of dangerous pressures on the upstream side of the embankment, however, would remain even after this work.

Stability. Stability analyses have been performed on only one section. This section proved to be sufficiently critical as to cause grave concern about the embankment. Other sections would appear to be of as much concern, but were not investigated inasmuch as they would add little to the conclusions regarding embankment stability and due to time limitations.

The location of the section investigated is shown on Plate 11; the section is as shown on Plate 12. The values of strength, etc., are also shown on Plate 12. Laboratory examination of materials for the dam indicated that the material from this dam and that of sample 2, Middle Fork, Dam No. 3, were quite similar and the strengths determined for sample 2 could be used with sufficient accuracy for purposes of the study to represent the strength of the Amherst Dam. The strengths shown, therefore, are those from sample 2, Middle Fork, representing Amherst. The results of the investigation indicated that, as expected, the embankment barely is stable with an unsatisfactory factor of safety of 1.1, as opposed to desirable one of 1.5 under normal operating pool conditions; however, under full pool conditions with the seepage pattern fully developed as described above, the results (Factor of Safety of 0.46) show the embankment to be highly unstable, and that a catastrophic failure could occur.

This latter analysis was performed with a full pool - with a partial pool, the embankment could probably be stable, but this type of study should be performed by the owner with more detailed data than obtained in this survey. Such a study would suggest a limit of elevation for the pool. This also would more clearly define the magnitude of the seepage problem and solution.

Configuration. As indicated, the closure section on the left abutment is semi-circular, convex downstream. Being of such configuration encourages the formation of cracks, beginning on the downstream face; this could lead to eventual failure due to pool pressures. The accepted practice is to have curvature, if at all, convex upstream; this treatment tends to put the entire dam along its axis in compression, as regards pool pressures, discouraging vertical cracks.

Earthquake. As can be determined, no attention has been given in the dam to possibility of earthquake occurrence. The dam is unstable under full pool conditions, without earthquake forces; at some lower level of pool it could be stable, from a strength standpoint. This, however, is only one of the points to be considered; another is that the embankment was constructed essentially without compaction. The materials are of a type susceptible to liquefaction, being at least in part, cohesionless and relatively loose in place. This means that there is a distinct possibility that under the shock loading of an earthquake those portions of the settled material and of the embankment which would be saturated would liquefy and a mud-flow failure occur, and utterly destroy life and property in the downstream portions of the valley of Buffalo Creek.

The last reported earthquake in the area, see Part I, had a magnitude of 4.75 (Richter). The West Virginia Department of Natural Resources reports that little damage resulted to refuse dams and impoundments for this scale quake. On the other hand, there are published reports[3/] that quakes in South America of 7.2 to 8.3 caused failure of mine tailings dams due to liquefaction of the sludges material retained by the dam.

The entire subject of earthquake analysis of dams is currently being reassessed in a multi-discipline effort as a result of the wealth of data obtained from the 1971, San Fernando Valley, California earthquake. Some changes from past methods of analysis appear quite certain to occur; however, at this point in time, May 1972, the extent of adviseable changes is not clear.

The liquefaction of both dams and impounded sludge by earthquake action in the coal mining areas is an awsome possibility to

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3/ Vol 94, No. SM5, September 1968 Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineer, pp 1055-1122, "Landslides during Earthquakes Due to Soil Liquefaction", by H. Bolton Seed.

contemplate in terms of destruction, and only a detailed study of the proposition by eminent authorities on seismology, geology and engineers can determine the criteria advisable for use in the area. The agency responsible for mine dam safety should consider such a study. If the results of such a study are that, among other things, the dams, both existing and future, should be stable from the consequences of liquefaction due to earthquakes, technology is available to take care of the requirements.

Effects of Flood. Some of the aspects of flooding are of interest as related to this dam:

a. Flooding for the normally used storms would fill the pool, overtop the embankment and as stated above, would cause failure by embankment sliding, and

b. A flood would raise Dick Branch, destroying the two impoundment dams on the Branch which would of course, cause some damage along Buffalo Creek. However, flow in Dick Branch from the design flood would also wash out at least a part of the downstream toe of the main refuse dam under study. This would also affect the stability, depending on which happened first, the flow on Dick Branch or filling the pool to the level required for embankment instability.

Overtopping. The data indicated that overtopping probably will occur: it is understood that the owner currently has a mandate from the State to increase the height of the embankment. This would assist in taking care of the possibility of overtopping, but the dam would still be overtopped by a major rain storm.

Erosion from Rainfall of the Design Storm. The erosion of the embankment from this storm of 22 inches of rainfall in 24 hours falling on it and draining along the surface is a matter of serious concern also. These materials are unusually susceptible to erosion; this is evidenced by the three areas near the base of the downstream slope which have eroded just from gentle seepage. Also, see Plate 22 for the photograph of the inactive refuse pile near Ethel, W. Va.; this erosion was caused by a concentration of flow from a minute part of a drainage area. Such erosion could, conceivably, be of such magnitude, due to some form of concentration, that if the dam did not fail from a strength standpoint, it could materially assist the failure due to pool seepage by substantially reducing the length and to the same extent, direction of seepage flow. The solution to this problem would require the slopes to be flattened and compacted, the refuse screened and the slope covered with a layer of the coarser of the available material, collecting the water suitably at the base of the dam and draining it away from the dam.

This latter treatment, if the coarse layer were of suffieient thickness could be a solution for the possible build-up of pressure on the upstream side of the embankment.

Burning. Same comments as for the Island Creek Structure.

Conclusions.

1. The dam is not stable under the natural destruction forces to which it will be subjected.

2. A means must be provided in the dam to rapidly reduce the pool level caused by runoff from rainfall.

3. Piezometers are necessary in the embankment to allow the water pressure to be assessed.

4. Protective measures are necessary to make the dam safe against surface erosion and piping.

Recommendations.

It is recommended that immediate measures be taken by the owner to effect the above inidcated modifications.

2. Youngstown Mines Corp., Dehue Impoundment

a. Site Investigation

(1) Location. The Dehue Impoundment is located on Right Hand Fork of Rum Creek which joins the Guyandotte River near the Village of Dabney, West Virginia. It is situated on a small unnamed tributary on the left side of Right Hand Fork above the Village of Dehue, West Virginia (see Plates 1 and 15).

(2) Questionnaire. The completed questionnaire is attached as Appendix 4.

(3) Results of Field Tests. Field densities were taken at locations on the embankment as shown on Plate 16, together with samples for laboratory testing. The results of the density tests are as follows:

Sample No.	Type Material	Dry Unit Wt. #/ft.	W.C.%
1	Refuse (red dog)	79.8	0.1
2	Clay cap	116.2	12.0
3	Refuse	114.1	8.2
4	Clay cap	115.3	12.0
5	Sludge	65.6	25.2
6	Refuse	77.0	15.2
7	Refuse	77.7	7.4
8	Refuse	106.6	7.1

b. Topography, Including Local Geology

As elsewhere in the vicinity of Buffalo Creek, the valley of the Right Hand Fork is one of rugged terrain. The hills on each side of the Fork rise at slopes as steep as 1 vertical on 1-1/2 horizontal to elevations approximately 2,000 feet above mean sea level. The valley of the unnamed tributary on which the impoundment is located drops 1,000 feet in 1/2 mile giving an awesome gradient of about 38%. Fortunately, the half mile is the length of the valley and the watershed is only 0.12 square miles in area so that while runoff may have high velocity, its quantity is limited due to the watershed size. The embankment foundation consists of a thin residual and colluvial mantle generally not exceeding 3 feet in thickness. This overburden consists of a brown lean clay with weathered sandstone and shale fragments.

The surface rocks exposed along the valley walls consist of sandstones, shales and several coal seams of the Kanawha Series, Pennsylvanian Age. These coal seams were identified in the field as the Chilton at elevation 1200, outcropping approximately 5 feet below the crest of the embankment and the Cedar Grove at elevation 1040.

The strata are dipping uniformly at the rate of about 50 feet per mile to the northwest.

c. Hazard Created by Facility's Possible Failure

The dam and impoundment are actually almost above the Village of Dehue; failure of the embankment would essentially destroy the village. In addition, downstream are schools and other public facilities as well as additional residences. The village of Hutchinson would be damaged and the village of Dabney probably obliterated before the waste from the failure joins the Guyandotte River. Further, it appears probable that if a sudden failure of this enormous deposit occurred, serious damage could be the result on the river in McConnell, Stollings and low-lying areas within the city of Logan, West Virginia.

d. Description of Facility

The dam, having been placed from a conveyor, has a straight-line crest. The material has been dumped from some height and no effort made at compaction other than simply falling on the existing pile. The exception to the straightline crest occurs at the northerly end of the embankmen where material has been dozed in a semi-circular fashion to make closure with the side of the valley. In this area some compaction by dozers has been accomplished. A clay "cap" has been placed by dozer on this semi-circular closure section.

The refuse is, at present, on fire at several locations.

At its maximum height the refuse material is about 350 feet thick and the refuse slopes are about 1 vertical on 1-1/2 horizontal and in some places 1 on 1. The northerly end of the embankment where it ties into the hillside appears to be the more critical as regards overtopping, since there is only 6-1/2 feet of freeboard existing at that point. A large percentage of the embankment is composed of red dog and there are evidences of slides having occurred in the embankment. The volume of the embankment and sludge combined is about 2,260,000 cubic yards.

The embankment is composed of piles of material deposited in two periods; the older portion of the pile, nearer the Village of Dehue, was deposited between 1917 and 1920; the remainder was deposited beginning in 1949 and continuing until recently; there is no waste being deposited at present but the dam is being actively used to form an impoundment for "black water." Impounding of the black water began in 1960.

The effluent is pumped from the cleaning plant and enters the impoundment about 1,000 feet upstream of the main embankment. This point of discharge allows the poorer material in the effluent to settle out adjacent to the dam so that with additional height, part of this sludge will be incorporated into the embankment foundation.

There is a 36" corrugated metal pipe just below the top of the dam in the area mentioned above as having been placed by a dozer. Other areas of the crest are lower in elevation than the pipe, thereby making the pipe essentially ineffective.

Other than for this pipe, there are no measures evident for passing high volume flows from rainfall around the dam.

e. Method of Operating the Facility

As indicated above, no refuse is being added to the embankment at present. As regards the impoundment of black water, the cleaning plant located near the junction of Right Hand Fork and Rum Creek, pumps the material up into the impoundment at the rate of 400 gpm for 14 hour operation per day. The plant operated about 210 to 215 days per year. The only outlet for this water is seepage through the embankment and/or foundation.

f. Analysis of the Dam.

Hydrology (See Appendix 6)

Seepage. In view of the embankment having been constructed by dumping, there is no zoning of materials within the structure. An approximation of the phreatic line from the pool through the embankment is shown on Plate 17 for the time of Field Investigation and at possible full pool elevation. These surfaces shown on the Plate could be refined and the phreatic surface under such a refinement probably would exist well up the height of the slope. This point will be expanded further, below. There is some evidence of seepage exits at the northerly end of the embankment and on the slope in the vicinity of the road on the downstream side of the pile. The quantity of seepage existing just below the road is estimated at about 40 gpm.

Regardless of the upper seepage line shown on the steady seepage case, Plate 19, for a storm just sufficient to fill the pool (far less than design storm), the seepage would probably exit on the embankment slope. If this happened, serious erosion of the highly erodible embankment would occur, and a real possibility of piping and consequent failure of the dam result.

Similarly, there are no provisions for disposal of the water pumped into the pool except by seepage through the embankment and/or foundation. There is presently erosion being caused by this latter seepage and while not serious at this time, eventually it will beome serious unless corrective measures are taken. These corrective measures should consist of placing a suitably designed filter at the exit and a layer of rock suitably sized and the proper thickness to retain the erodible material and allow the water to escape. In combination with these measures, suitable means will necessarily have to be taken to collect the seepage and dispose of it away from the embankment without erosion. Without these measures, the dam would eventually fail due to piping.

Stability

Sliding. The sludge samples were examined in the laboratory and those for the Powellton Dam and Youngstown Dam were quite similar. Therefore, the strength results obtained on the Powellton sludge were used for this analysis and sludge for Youngstown was not tested for strength.

The cases analyzed[1a/] are shown on Plate 17 with the conditions for the analysis set up as well as the results of the analysis. It will be noted that the friction angles used were possibly refined more than it generally justified in an analysis of this type but nevertheless their use in the form shown is considered satisfactory for forming judgments as to the sliding stability of the embankment. In a like vein, the phreatic line could be refined to some extent but conforms reasonably well to known conditions of seepage. However, as indicated above, under full pool the phreatic line most probably will exit on the embankment slope. Use of such a phreatic surface in the analysis would result in a somewhat lower factor of safety than that shown, which is already of a critical nature. This factor of safety - 0.66 - for full pool conditions, indicates the dam to be highly unstable for those conditions. Further, it is noted that the circular slice method of analysis is more critical than the wedge analysis. This simply means that if failure occurred it would probably be by a form of circular movement rather than by a wedge moving downstream.

It will be noted further that the critical factor of safety obtained for the embankment at the time of the investigation is 0.92. Consistent with the description of factors of safety in Part I, this factor of safety indicates that action should be taken at present to reinforce the embankment because it is in danger of failing under operating conditions.

1a/ Generally in accordance with EM1110-2-1902, 1 April 1970, "Engineering and Design, Stability of Earth and Rock-Fill Dams", Corps of Engineers.

If no steps are taken to immediately reinforce the embankment, measures should be taken to lower the pool to safe condition (F.S. = 1.5) and base operations on this level or lower.

Piping. The concept of operation of the impoundment is fallacious. This concept consists of clarifying the water by seeping through the embankment and/or foundation. Unless the measures indicated above for protecting against possible piping, beginning at the downstream portion of the dam, are instituted the embankment will eventually fail from this cause.

Configuration. As can be seen on Plate 15, the left abutment closure section is roughly semi-circular, convex downstream. Being of such configuration encourages the formation of cracks in the embankment, beginning on the downstream face; this could lead to eventual failure due to pool pressures. The accepted practice is to have curvature, if at all, convex upstream; this treatment tends to put the entire dam along its axis in compression, as regards pool pressure, discouraging vertical cracks.

Clay Cap. Placing the clay cap on the surface of the closure section is not an advisable practice, since it tends to concentrate the seepage in the refuse, just at the base of the cap. This concentration can accelerate the seepage erosion leading to piping. Another adverse affect is that being essentially impervious, the entire cap is subject to hydrostatic forces, and, if of insufficient weight, could be subject to movement and eventual blow-out.

Earthquake and Liquefaction. The entire matter of design for safety against earthquake shocks is in a state of flux at this point. See discussion of this point for the Amherst Dam.

Erosion from Flooding. The erosion of the embankment from the design storm of 19" of runoff in 24 hours flowing along the surface of the slope is a matter of serious concern also. These materials are highly susceptible to erosion and a concentration of flow such as that which caused to erosion of the inactive refuse pile near Ethel, West Virginia, (see Plate 22) can be of serious proportions. Such erosion could conceivably be of sufficient magnitude due to some form of concentration that if the dam did not fail from a strength standpoint, it could materially assist the failure due to pool seepage. This could be effected by substantially reducing the length and to some extent the direction of seepage flow.

The solution to this problem is an expensive proposition. The slopes should be flattened and compacted and an outer layer of coarse material not subject to likely erosion placed on the slope. The slope drainage should then be collected at the base of the dam and drained away from the dam by some means that will not cause erosion.

Overtopping. The dam will overtop and fail from the maximum flood; however, the addition of five feet of fill, plus the requirement for free board, will remove this danger for the present. When the level of the sludge rises, the same amount in height should also be added to the five feet plus free board.

Conclusions.

1. This coal refuse dam at Dehue is at present in a dangerous state of stability. Immediate action of either lowering the pool or changing the section as necessary to provide stability should be undertaken.

2. The dam is seriously unstable if the pool becomes full. Continued operation of the impoundment should be contingent upon provisions of means to bypass high volume flows from rainfall. If such action is not taken, the design and lesser storms will destroy the dam. This spillway or outlet should be constructed only if the dam is strengthened to improve its safety under present conditions.

3. If the owner chooses not to strengthen the dam for its present condition of pool level, no further impoundment should be allowed and the dam should be breached.

Recommendations

It is recommended that immediate action be taken to implement the necessary measures outlined in the above Conclusions.

3. Island Creek Coal Company, Guyan No. 5 Refuse Dam & Impoundment

a. Site Investigation

(1) Location. The dam is located on Little White Oak Branch of Spruce Fork, near Kelly, West Virginia, a distance of about 3-3/4 miles southeast of Blair. (See Plates 1, 5 & 6)

(2) Questionnaire. The completed questionnaire is given as Appendix 2.

(3) Results of Field Tests. Field densities were taken at locations on the embankment as shown on Plate 6, together with samples for laboratory testing. The results of the field density tests are as follows:

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Sample No.	Type Material	Dry Unit Weight $\#/ft.^3$	W.C. %
1	Refuse	99.3	6.3
2	Red dog	70.0	0.8
3	Red dog	67.3	0.0
4	Refuse	94.2	9.2

b. Topography, Including Local Geology

The valley of Little White Oak Branch is one of rugged terrain but with gradients less steep than in other areas discussed herein. For instance, the valley walls rise at slopes of about 1 vertical on 2 horizontal rather than, as others, 1 on 1.5. The stream, as recognizable, starts about 0.6 mile above the dam (easterly) at about elevation 1800 and falls to 1220 at the dam for a stream gradient of about 18%, much flatter than the Dehue and Amherst facilities.

The watershed for the dam comprises 0.29 square miles.

The embankment foundation consists of a thin residual and colluvial mantle generally not exceeding two feet in thickness. This overburden consists of a brown lean clay with weathered sandstone and shale fragments. The surface rocks exposed along the valley walls consist of sandstones, shales and several coal seams of the Kanawha Series, Pennsylvanian Age. These coal seams were identified from published county geologic reports as the Chilton seam at elevation 1359 and the Coalburg at approximate elevation 1600. The strata are dipping uniformly at the rate of 50 feet per mile to the northwest.

c. Hazard Created by Facility's Possible Failure

Being of lesser gradient than elsewhere in the vicinity, flow of a mudwave down Little White Oak into Spruce Fork would probably not do as much damage as Dehue and Amherst failures. However, the villages of Sovereign, Blair, Sharples, Dobra and Mifflin would probably receive severe damage and possible loss of life.

d. Description of Facility

The dam has been constructed by dumping from an aerial tramway and therefore has a straightline crest. No effort has been made to compact the material.

The coal refuse is, at present, on fire at several locations and is estimated to be more than 50% red dog.

At the time of the investigation the water upstream was about 25 feet below the lowest point of the embankment crest. An effort is being made to bypass normal flows around the dam; about 2000 feet upstream from the axis a small diversion dam has been installed to intercept the flow from the main stream of Little White Oak and a small tributary to it. The water is channeled from this diversion dam in a 36" pipe on the right side of the valley, past the dam, continuing downstream some distance before discharging into a ditch, thence back into the Little White Oak.

There was a 36" pipe placed in the embankment but it has been covered with refuse.

The dam is about 2200 feet long and with sludge, comprises a volume of approximately 2,080,000 cubic yards. About 15,000 tons of refuse per month are placed on the pile.

Black water was being pumped into the impoundment and the pool has been about 10 feet higher than at present but the operators are currently pumping the wash water into mined-out sections of the mine. About 15 gpm is flowing into the pool and about the same amount seeping out.

A failure of the dam, apparently from overtopping, occurred in 1962-1963. It appears that thousands of yards of refuse were deposited in the valleys downstream as a result of this failure.

e. Analysis of the Dam

Hydrology (See Appendix 6)

Seepage. There is no zoning of the materials in the embankment; there is no spillway or other effective means of taking care of really high volume flows. There is seepage occurring through the dam and/or foundation. In this highly erodible material failure of the dam could result from piping if measures to control it are not adopted. The main exits of current seepage are at the downstream deeper points of the valley.

The coefficient of permeability of the embankment is of the order of 300×10^{-4} cm/sec, which is sufficiently high to allow reasonably swift reaction to variations in head. This permeability rate is the same as that generally associated with clean sand and gravel mixtures.[5/]

In the event of a major storm in the area, the small diversion dam upstream would undoubtedly be destroyed and with it the entrance to the 36-inch corrugated metal pipe diversion conduit. No outlet would be available for drawing the pool down under such circumstances so that the seepage pattern within the embankment, approximately as shown on Plate 7, would develop, resulting in the above-mentioned downstream embankment seepage erosion.

Stability

Sliding. The cases analyzed as shown on Plate 7 indicate the circular sliding surface to be the more critical one. The results of the analysis show a factor of safety under operating conditions of 1.01 and for full pool, of 0.74. To be assured of safe conditions as pertains to sliding stability, these factors of safety should not be less than 1.5. On this basis, the dam is presently in a dangerous state of stability and for a major rainstorm, would fail.

5/ See page 55, "Soil Mechanics in Engineering Practice," 2nd Edition, Terzaghi and Peck

Piping. Since there is no outlet for the flows bypassing the diversion dam and for storm flows, a condition of uncontrolled seepage presently exists and unless remedial action is taken the dam will eventually fail from piping.

Earthquake and Liquefaction: Erosion from Flooding

See discussion under Youngstown Mines Corporation, Dehue Impoundment.

Overtopping. For the conditions discussed herein there appears to be serious danger of this dam overtopping. The maximum pool, which will be established for flood conditions, is at elevation 1386 and the lowest point on the crest of the dam is at elevation 1362. Therefore, a spillway should be provided.

Burning. The refuse pile is on fire. Under flood conditions these fires, if located at an unfortunate location, would be subject to quenching by the rising pool. This could lead to an explosion, as at the Middle Fork old refuse pile; removal of a part of the crest by the explosion and the initiation of failure due to the pool being higher than the new low point of the crest. Another possible adverse effect of burning is that the area which has burned can slump seriously and lose elevation and again, if located in an unfortunate position, will result in early overtopping. In this regard also, fires at lower elevations can cause a shortening and concentration of seepage paths, with attendant danger to stability of the structure.

f. Conclusions

(1) The dam is in a dangerous state of stability at present as regards sliding and piping and potentially as regards erosion of the embankment. Also potentially it is in a catastrophic state of instability

if a major rainfall occurs in the area and would overtop as well.

(2) The seepage, the spillway problem and potential embankment erosion should be controlled by the owner and the embankment modified to provide adequate stability regarding sliding by additional construction.

(3) If the owner chooses not to take the measures indicated above, the dam should be breached and no further impoundment allowed.

g. Recommendations

It is recommended that immediate action be taken to implement the necessary measures outlined in the above conclusions.

4. Powellton Company, Basin #1 Sludge Impoundment

a. Site Investigation

(1) Location. The dam and impoundment under consideration are located adjacent to Rockhouse Creek about 2 miles upstream to the southwest of Man, W. Va. (See Plate 1 for location of the facility)

(2) Questionnaire. The completed questionnaire is given as Appendix 1.

(3) Results of Field Tests. Field density tests were taken at locations shown on Plate 3 together with samples for laboratory testing. The results of the Density Tests are as follows:

Sample No.	Type Material	Dry Unit Weight-#/ft.^{3}	W. C. %
1	Refuse	82.6	23.2
2	Refuse	84.9	18.6
3	Refuse	84.5	7.5
4	Refuse	99.0	11.6
5	Refuse	74.1	6.7
6	Refuse	71.1	7.6
7	Refuse	79.6	11.0
8	Creek bed material	127.9	7.7
9	Refuse (red dog)	89.3	12.6
10	Sludge	48.21	31.1

b. Topography Including Local Geology

As elsewhere in this portion of West Virginia, this area is one of rugged terrain; the valleys rise with side walls as steep as 1 vertical to 1½ horizontal and the relief in the area is of the order of 1200 feet. The entire sludge impoundment area, however, is within the somewhat broader valley bottom of Rockhurst Creek. The gradient of the natural ground surface in the immediate vicinity of the impoundment is relatively gentle, being approximately 2-1/4%. (See Plates 2 and 3)

Rockhouse Creek, which flows by the impoundment in a northeasterly direction, joins the Guyandotte River in the southerly part of the City of Man, W. Va.

The embankment foundation consists of silty gravels overlaying bedrock. The surface rocks exposed along the walls of the valley consist of sandstones, shales and several coal seams of the Kanawha Series, Pennsylvanian Age. These coal seams were identified from published County geologic reports as the Cedar Grove, elevation 1250 and the #2 Gas (Campbells Creek) at elevation 1000.

The strata are slightly folded around a weak synclinal axis running northeast to southwest and dipping 50 feet per mile to the northeast.

c. Hazard Created by Facility's Possible Failure

The downstream gradient within the valley in which the impoundment is located is relatively gentle. The impoundment is small and there is no habitation between the dam and Man, W. Va., about 2 miles away. It is therefore doubted that appreciable damage would be done by the failure of this structure, other than perhaps flooding out a downstream coal company warehouse, some tool sheds and a sawmill.

d. Description of Facility

The dam, in essence, is a semi-circular structure creating an impoundment against a railroad embankment. The basin is about 80% full of sludge; total volume of the basin, with embankment, is slightly more than 137,000 cubic yards.

The site was selected because from its physical appearance it seemed approximately the same height and apparently was functioning more like the dams on the Middle Fork than any of the others observed. This, however, on more thorough investigation, proved to be an incorrect assumption because its construction and operation is substantially different from those on the Middle Fork.

As is shown on Plates 2 and 3, on the northerly side of the impoundment is a railroad switching yard which serves the cleaning plant just upstream of the impoundment. On the southerly side immediately adjacent to the dam is a small diversion ditch and adjacent to that, a well traveled paved road leading upstream to the cleaning plant and mines and downstream, to Man.

The dam at its maximum is about 40 feet high which compares favorably with the height of the #3 dam on the Middle Fork. The impoundment's overall length is about 850 feet and its maximum width is about 140 feet. The watershed, including the pond, is only about 2 acres.

At the time of the field investigation the coal sludge was approximately 6 feet from the top of the embankment.

There are two general areas where seepage exits from the embankment. One is at the northeast end with a flow of about 2 gpm and several small areas along the toe of slope paralleling Rockhouse Road with a total flow of about 1 gpm.

Near the northeast corner of the embankment there is a 2 to 3-foot zone of red dog which apparently was placed at the time of construction. There is no red dog other than this in the pile nor is the pile on fire. The starter dike for the facility was about 10 feet high and consisted of stream gravels and colluvial overburden. The remainder of the embankment has been built in stages and is composed of coal refuse.

No facilities exist for bypassing rainfall drainage, however an 18" corrugated metal pipe exists in the pond wall at near the top of the embankment and serves as a skimmer for clear water.

As regards the method of construction of the facility, an initial starter dike, about 10 feet high, was dozed up from the existing gravel and overburden in the vicinity. As the level of sludge rose in the pond, coal refuse was periodically dumped and dozed on top of the starter dike. This method of construction then results in a successive layering of pond sludge and coal refuse for the embankment as shown by the sketch on Plate 4. This type of construction results in a relatively thin shell of coal refuse for the embankment with both the outside and inside embankment slopes being somewhat parallel. It further results in the foundation for the substantial portion of the embankment being coal sludge.

e. Method of Operating the Facility

The black water from the cleaning plant flows directly into the impoundment. The sediment is allowed to build up almost to the crest of the impoundment and then the black water is diverted to a #2 sludge basin in the vicinity. The material is allowed to settle out of the water; the water is either pumped out or drained through the skimmer pipe in the northeast corner of the basin and then the basin is cleaned out by clamshell and the material is hauled across the road into a large disposal area on the Left Hand Fork of Rockhouse Creek.

Approximately 7,000 gallons per day of two shifts are discharged into the basin. The plant is in operation 5 to 6 days a week and for the year, 50 weeks' operation; to quote the operator, "less any strike time."

It should be noted that a cyclone is used at the cleaning plant and therefore this coal cleaning operation does not require the large amounts of water that may be used at some other installations.

f. Analysis of the Dam

Hydrology (See Appendix 6)

Configuration. As indicated, the dam is semi-circular; the curvature is convex outward. Being of such configuration encourages the formation of cracks on the outside of the embankment and could cause eventual failure due to pool pressures. This is contrary to accepted practice which is to have the convex curvature on the inside of the dam next to the pool; this accepted treatment tends to put the entire dam in compression, causing vertical cracks to seal.

Seepage. Seepage does not appear to be a major problem in this installation in that the installation is so small that periodic repairs will take care of damage to the embankment due to seepage. There is, however, seepage occurring as indicated above at several locations of the embankment and some evidence of overtopping or blow-outs having occurred in the past. Since the lower exterior part of the embankment was built of sand and gravel and overburden, this material would probably tend to be of assistance in controlling the effects of seepage.

As on other analyses, the phreatic line of the section of Plate 4 is drawn to accommodate the seepage exit which has been observed. However, under sustained full pool conditions there is little doubt that the seepage exit would move up and emerge on the slope. Under such conditions the factor of safety would be slightly lower than that obtained from the analysis with the phreatic line as shown on Plate 4.

The coefficient of permeability of the sludge, by grain size, is of the order of 0.1×10^{-4} cm/sec., and of the embankment, 10 to 100×10^{-4} cm/sec. On this basis, it would appear that the embankment may drain the sludge without blow-outs of the embankment under high pool conditions, but this should be checked by installation of piezometers on the pool side of the embankment to see if the sludge pressures are being dissipated. Action should be taken to perform remedial work if data from these piezometers indicate it to be necessary.

<u>Stability</u>

<u>Sliding.</u> From an examination in the laboratory of the materials from the various sites, it was determined that sample #2 of Buffalo Creek was so similar to the refuse materials from this site that the shear tests performed on that sample could be used in the stability analysis for the Powellton site, thereby reducing the length of time necessary for the testing program.

It will be noted from Plate 4 that the circular arc method of analysis is more critical than the wedge analysis; therefore, the failure surface would probably be somewhat circular. Further, it will be noted that under the conditions at the time of the Field Investigation the factor of safety for the embankment was 1.2, which should be no less than 1.5 for safety under operating conditions. Also, it is to be noted that the phreatic line at the time, determined by an excavation within the basin, was quite low. During the time that black water is discharging into the pool and left to settle, it would appear reasonable to assume a substantial increase in the height of this phreatic line. With this increase a substantial reduction in the factor of safety will occur. Therefore during this period, the embankment is in substantial danger of failure. The owner should be required to investigate this matter further and take action as necessary depending on the results of his investigation.

Under full pool conditions which can happen apparently by natural flow or through operations, the dam will fail according to the analysis performed. (F.S. = 0.41) It is understood that the pool has been full several times without failure. This simply means that the period of time that the dam was full was not sufficient for the steady seepage condition to develop or the strengths used in the analyses were slightly conservative. At any rate, there is little doubt that under full pool conditions the dam is in dangerous condition. The owner should be required to perform a detailed investigation and take action as necessary depending on the results of that investigation.

Piping. While piping is a problem, it is felt that frequent inspection and corrective action from time to time can take care of this problem. If it is not taken care of, however, the dam will eventually fail.

Earthquake. See discussion under the Amherst dam.

Erosion. As with piping, ordinary maintenance can take care of this problem. It is doubted that erosion from rainfall will cause failure.

g. Conclusions

(1) The dam is in a dangerous condition for operations with the water level reasonable low and even more dangerous with the operational pool high. The owner should perform a detailed investigation and take corrective action as is shown to be necessary by that investigation.

(2) Piezometers should be installed to determine the potential for embankment blow-out, as discussed under "Seepage" and action taken as required.

h. Recommendation

It is recommended that action be taken to perform the work indicated by the conclusions.

5. Inactive Breached Refuse Dams

From observations in the area, some refuse piles located in valleys across the natural water course of the valley have been breached without significant loss of life or damage to property. The proposition immediately arises as to how and why these dams have been obliterated and still have not created the havoc which occurred at Buffalo Creek.

In pursuing this proposition, three refuse piles which had in the past formed dams were observed in some detail. The locations of these refuse piles are shown on Plate 1, with pictures of the dams on Plates 21, 22 and 23.

The refuse pile of the Powellton Coal Company, Plate 21, is located about 1/2 mile up Left Hand Fork from its junction with Rockhouse Creek. It was reported to have been started in 1951, had reached sizable proportions by 1963 and formed a dam across the valley about 50 feet in height.

No coal wash water was pumped behind it; only the natural runoff water from a drainage area of about 1,000 acres was impounded. In the area storm of 1963 runoff exceeded the capacity of the impoundment and according to eyewitness accounts, the dam was overtopped. The initial flow over the dam occurred in midafternoon and continued into the evening before the entire pool was drained by the dam eroding down to original stream bed. The water reached a depth of about 4 feet in the warehouse just downstream of the junction of Lefthand Fork with Rockhouse Creek and caused minor property damage in Man, West Virginia, before it discharged into the Guyandotte River.

The drainage area, height of dam, and construction methods compare favorably with those of the dam on the Middle Fork of Buffalo Creek. Also the slope of the creeks and general topography are generally similar. The significant differences, as can be determined, were that the Powellton dam had a better foundation and, since it was reported to have been on fire for some time, was composed almost entirely of red dog. (Field observations of the remains of the dam bear out this latter difference.) Also there were no reports of major boils downstream and no "black water" was impounded. These differences resulted in the major effective difference in that failure of the Powellton dam occurred over a substantially longer time interval, a matter of hours rather than minutes.

The dam in Bingo Hollow, Plate 23, is reported to have been started as long ago as forty years by the Utilities Coal Company and then some years later used as a refuse pile by the Spice Creek Cpal Company. It has not been actively used as a dump for mine refuse for 10 years or more and its ownershop (and therfore responsibility) is subject to some question.

Generally, the natural drainage in the area by-passed the pile but occassionally the drainage was stopped by spilling of the refuse over into the water course on the left side of the valley. From observation, it appears that several dams of 5 to 10 feet high occurred at different times and in one area a dam approximately 25 feet high appears to have existed. The pile consists almost entirely of red dog as do the remnants of the dams. It is reported that failures of these dams have caused some damage to property and a flow of water and refuse across the road just before it enters Buffalo Creek, of from one to one and one half feet deep, but resulted in no major property damages or loss of life.

While the dams in this Hollow were smaller than on Middle Fork, the proximaty of a large housing area to the dams would make this pile more dangerous. As with the Powellton dam, this creek and its dams had no black water from coal washing entering it. That the failure of the Bingo Hollow dams caused no major damage or loss of life can be partly due to the fact that they were not as large as those on Buffalo Creek, but also due to their being red-dog, the release of water and erosion of material simply was not rapid as that on the Middle Fork.

The third dam observed was deliberately chosen because it had not been on fire. It is located about 1-1/2 miles east and slightly south of Ethel, West Virginia, near U. S. Route 119, Plate 22. It developed on closer observation that its damming of an unnamed small tributary of Dingess Run is minimal. However, with a miniscule drainage area over one part of the pile, a considerable amount of erosion of the pile has occured, although with little damage to downstream property. In this case, the coal company has taken some pains in the other part of the pile to divert the major portion of the runoff flow by means of dikes and grading to the side of the valley where a small presently existing stream runs on rock. This pile indicates that for normal rainfall and small drainage areas, with a minimal amount of care in handling the deposition of refuse piles, even one that has not been on fire and therefore highly erodible, an impoundment can be averted and serious downstream damage need not occur.

In the cases observed, a fundamental reason for lack of serious consequences of the breaching is one of fortunate meteorological circumstances. That is, the rainfall which caused the failures did not have the required intensity and duration to produce a catastrophic amount of transporting fluid.

Another observed characteristic of the refuse piles in general is that those composed of red dog appear to be far more resistant to erosion than the freshly deposited gob. Two obvious changes occur during the burning operation which converts the refuse to red dog. One, the individual particles are made more stable and less subject to weathering and two, some masses within the pile are semi-solidified into a huger clinker, that is the already more stable particles tend to be at least partially semi-fused together, giving the mass much more strength and resistance to erosion than the initial fresh refuse pile. In this regard, the huge gob pile at the mouth of the Middle Fork on Buffalo Creek has at present vertical sides adjacent to the washed out portion of the valley which could not possibly be in existence had the piles not been at least partially converted to red dog by burning. Further, it is the writer's opinion that if this gob pile had not contained a significant amount of burned or burning refuse, and along the side where flow of water was torrential, an unbelievably greater amount of the refuse from this pile would have been eroded and washed into Buffalo Creek.

The inescapable conclusion with regard to these older dams is that when no spillway exits and the proper amount and intensity of rainfall takes place, these dams will fail, with considerable damage in loss of life and major property damage to downstream populated areas. It appears reasonable, however, that such damage would not be as great as would occur had these piles been composed of fresh dumped mine refuse.

It is recommended that these no longer used refuse piles, when constructed across a valley, at least potentially forming a pool, be breached so that their rapid failure will not be a danger to areas downstream of them. Where such dams do not have the potential of causing damage, that is, when they are located some miles measured along the valley from populated areas, the requirement for breaching is less urgent; however, no cases of this type have been noted in this survey.

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F. GENERAL CONCLUSIONS

1. The survey data show that all of the active dams covered in this survey in their present operating conditions:

a. are not safe as regards sliding stability;

b. are subject to eventual failure due to uncontrolled seepage;

c. as can be determined, have had some form of failure of slight to moderate consequence in the past;

2. Similarly, the survey data show that potentially all the active dams covered in this survey:

a. do not have adequate spillways and are subject to overtopping and consequent failure. The Powellton dam drainage area, however, is small enough that adequate equipment on a standby basis could control the water level and avoid overtopping of that dam;

b. will fail by sliding with catastrophic consequences; Powellton is the exception as to consequences;

c. will have the failures of a. and b. accelerated by erosion of the embankments;

3. If the dams studies are accepted as representative of those in coal mining areas, major changes in construction and operation are necessary for the entire industry's active refuse dams and impoundments. Similarly, major construction is necessary to make those in existence safe.

4. Owners of existing refuse dams and impoundments should be required to make a detailed engineering study of such facilities. Based on these studies, immediate remedial construction should be initiated to correct the deficiencies revealed by the study.

5. The current state of the art of design as related to earthquakes is in a state of flux. Expert opinion as related to criteria for the area under consideration is necessary before design and construction measures can be undertaken to forestall damaging effects which may be caused by earthquakes.

6. If earthquakes of major magnitude are to be considered, their results on the dams would be catastrophic. Earthquakes in the past have not been of major magnitude and have caused little damage.

7. With regard to the poor configuration on three out of four dams studied, for existing dams, continuous thorough technical inspection by the owner and the responsible agency are necessary to insure that remedial action is taken immediately if the adverse affects of the convex downstream curvature develop. For proposed dams, this configuration should not be allowed.

8. Most of the dams in the area are burning; this could lead to failure of the dams. Aside from environmental considerations, fires on the existing refuse dams which are forming impoundments should be extinguished and the dams maintained in that condition. Proposed structures should be so constructed as to minimize the possibility of the embankment burning and should be maintained in this inert state.

9. If owners decline to take action to make the dams and impoundments safe, the dams should be breached, left in a safe condition and no further impoundment allowed at that installation.

10. There apparently is less tendency for inactive red dog dams to fail with disastrous affects but they cannot be considered safe simply because they are composed of red dog.

11. Inactive dams in the area should be breached.

G. GENERAL RECOMMENDATIONS

It is recommended that the agency responsible for the safety of these and other dams:

1. Require the detailed engineering investigation of Conclusion 4 above, and require action of the owner as indicated to be necessary as a result of the investigation. Similarly, the agency should implement the necessary measures of Conclusion 7 and 8, above. If no action is taken by the owner, breaching, as indicated in Conclusion 9, above, should be undertaken.

2. Take immediate action to convene a board of consultants composed of eminent experts in seismology, geology, engineering and others as considered necessary to study the problem of earthquakes in the area and formulate design criteria for these and other dams.

APPENDIX I

QUESTIONNAIRE ON REFUSE PILES

1. Owner — Powellton Company, Rt. 10, Mallory, W. Va. (took ownership from Princess Coal Co. 4 years ago)

2. Location — S.E. of Man, W. Va. on Rockhouse Road at confluence of Rockhouse Creek and Lick Branch Sludge Pond No.1

3. Date Inspected — 29-30 March 1972

3.a. Interviewed Mr. L. Hurtle Brown, V. P. of Operations and Mr. Thomas Cook, Engineer

4. How Constructed

   a. Truck & Dozer (See 16)

   b. Conveyor & Dozer

   c. Dumped & Spread

   d. Just spread

   e. Other

5. When was pile started 1952

6. Is it actively used at present? - Not for dumping refuse but used for periodic sludge impoundment

7. Has pile been on fire? No

8. Is it burning now? No

9. Has any effort been made to zone pile? They doubt if any effort was made to zone pile

10. Rough percent volume which may be red dog as result of fire

Along the foundation near the NE corner of the embankment there appears to be a 2-3 foot zone of red dog which might have been laid down prior to construction. No red dog in pile.

11. Is pile used for general mine refuse or just for coal refuse?

General mine refuse. There was more underclay present at this refuse pile than at Island Creek or Dehue.

12. Distance in elevation from top of pile upstream to water level.

Approximately 6 feet to the top of the coal sludge. 80% of the impoundment is filled to the top of the embankment with coal tailings from the preparation plant. The remainder is cleaned out periodically and used as a sludge pond.

13. Distance in elevation approximately from top of pile, downstream, to seepage exit. Approximately 38 ft. from the crest to the seepage exit at the NE end of Basin No. 1, at the interface between the coal refuse and the granular creek deposit. The flow was approximately 2 gpm. In addition along the toe 20 ft. from the crest paralleling Rockhouse Road in vicinity of liquid impoundment, the flow emanated at four points at approximately 1 gpm.

14. Any downstream erosion protection? None, discharge pipe (18" corrugated metal pipe in pond wall and laid on slope) used as skimmer.

15. Any upstream erosion protection? No.

16. Was foundation stripped or otherwise treated prior to construction? If so, describe. Dozer began pushing up basin walls to about 10 ft. The material consisted of stream gravels and soil overburden. Later the basin was enlarged by dumping mine refuse from the preparation plant by truck, then shaping embankment to its present configuration.

17. Does spillway exist? Overflow pipe at NE end of sludge pond. No spillway.

18. Are any measures present to allow normal drainage to occur past dam, other than seepage thru embankment (pipe or low weir, etc.)?

Diversion ditches to other sludge ponds.

If so, give location, size and elevation referenced to top of dam. (See maps for permit) Normal drainage is channeled around sludge pond.

19. Approximate amount of fill placed per month - or 6 months. No material being placed at present and there are no plans to add additional refuse to impoundment.

20. Is pool as high as it has ever been or has it been higher; if higher, how high. "The sludge pool is as high as it has ever been." Comment - They allow the sediments to build up to the crest of the impoundment then divert the washings to No. 2 sludge basin. The basin is cleaned out to the size it currently is.

21. What type material is foundation? Creek gravel and soil (See 16)

22. Who does the Operator consider the regulatory authority to consult when the Operator wants to change a dam or pile, or build another?
Department of Natural Resources - Water Diversion

23. Are inspections made by that authority? Yes. No regular schedule but approximately 2 per month check for "black water."

24. Does the Owner consider their structure a refuse pile or a dam, or does he consider it something else? Sludge pond.

What was its initial purpose? Collection of sludge.

25. Owners are expected to inspect their dams once a week - look at owners' inspection book and see what has been noted (go back a couple of years).
They conduct regular daily inspections looking for "black water." No inspection book is kept.

26. Have they had problems with their structures (refuse pile, dam, deposit) in the past; if so, what remedial measures did they take? No problems with structures. Only minor remedial work to stop black water.
Comment - It appears that both No. 1 and No. 2 sludge ponds have been overtopped and were repaired with available fill material. (Creek gravel and clay and coal refuse)

27. Determine what coal seams were (are) mined. Six mines supply coal to the preparation plant. There are 4 mines operating in the Cedar Grove seam (48" to 50") and 2 mines operating in the Powellton seam (38" to 40"). Approximately 20% of the Cedar Grove requires washing and all of the Powellton requires washing.

28. Has the Owner ever requested any assistance prior to or after inspection, and if so, did he get this assistance? No assistance requested.

29. Obtain a statement from the Owner (from what he has calculated or deduced) as to the volume of water discharged into the pool from the processing plant on a daily basis.

Approximately 7,000 gpd (for two shifts) 350 gpm x 20 min.

Before installation of Cyclone system, they would discharge 20,000 gpd.

Comment - The flow into the sludge pond was approximately 20 gpm continuously flowing. This comes from leakage from the processing plant.

b. Determine (by some means) discharge from seepage downstream of dam.

(See 13)

30. Obtain number of days plant operates in a year. 5 to 6 days per week less 2 weeks vacation and any strikes.

31. Determine depth of deposit in pool. 21.5 ft. from the foundation to the overflow.

32. Ask Operator what drainage area contributes to the pool. Surface area around tipple and preparation plant.

b. Have any hydrology studies been performed by the Company?

None have been made.

33. Has the Company developed any emergency plans to assuage any contingent problems should they occur?

Should any emergency occur, they would divert drainage and sludge to alternate ponds.

34. Has the Company studied any alternative means of keeping the streams clean?

No studies have been made; using Cyclone recovering device which discharges for about 20 min. per day into the sludge ponds.

35. Have communications and/or illumination been installed at the deposit site? No.

b. If communications exist, to where and to whom are they linked?

Communications do exist at the warehouse below the sludge basin No. 1.

36. Have any sealants been used in construction of the deposit to make it more impervious?

Limited data on construction. Most likely they did not use sealants.

37. Who is in charge of construction of dam and what ~~is~~ are his qualifications?

There was a registered Engineer on the property when the ponds were constructed but they do not know if he had any part in their construction.

38. Who is the inspector of this dam and what ~~is~~ are his qualifications?

Mr. L. Hurtle Brown - Vice President of Operations. No degree.

Preparation Plant Superintendent. No degree.

39. If the dam suffers an accident, what is their (company) appraisal if damage or loss of life occurs?

None because of the little water.

NOTES We were given 5 plan maps and sections of sludge basins and drainage retention dams around Jane Ann preparation plant No. 1. (No. 2 burned down)

Received Xerox copy of Water Co. Pollution Control Permit No. 4043 dated 5 October 1970. Permit Application No. P-215 not available.

The Cyclone system of cleaning coal is common practice in the coal fields. It is about 90% effective. The closed system is almost 100% effective and requires no sediment ponds. It is not possible to use the closed system on all coal seams since some coals could not stand the additional fines in the coal.

APPENDIX 2

QUESTIONNAIRE ON REFUSE PILES

1. Owner — Island Creek Coal Company, Holden, W. Va.

2. Location — Guyan No. 5 - Little White Oak Branch off Spruce Fork

3. Date Inspected — 24-25 March 1972

3.a. Interviewed: — Allen S. Pack, President
George Reynolds, Director of Preparations
Ray Taliaferro, Director of Engineering
Charles Dickerson, Engineer (Title) Foreman

4. How Constructed

   a. Truck & Dozer

   b. Conveyor & Dozer

   c. Dumped & Spread

   d. Just spread

   e. Other - Aerial Tram - no compaction

5. When was pile started? 1955

6. Is it actively used at present? Yes

7. Has pile been on fire? Yes

8. Is it burning now? Yes

9. Has any effort been made to zone pile? No

10. Rough percent volume which may be red dog as result of fire. 80%

11. Is pile used for general mine refuse or just for coal refuse?

    General coal refuse.

12. Distance, in elevation, from top of pile upstream to water level.

    Varies; see topo map. 24.6 ft. from lowest point on crest of pile (panel LWV-1) to pool on upstream side.

13. Distance, in elevation, approximately from top of pile downstream to seepage exit. Varies - See topo map.

14. Any downstream erosion protection? No

15. Any upstream erosion protection?

None on the embankment. Diversion ditches above impoundment and 36" diversion pipe around right abutment.

Comment - Diversion ditches would not bypass water.

16. Was foundation stripped or otherwise treated prior to construction? If so, describe. Started dumping on natural ground.

17. Does spillway exist? No. At one time there existed a 36" pipe (overflow) through the embankment on the right side. It has since been covered over.

18. Are any measures present to allow normal drainage to occur past dam, other than seepage through embankment (pipe or low weir, etc.) ? If so, give location, size and elevation referenced to top of dam.

Diversion ditches and 36" diversion pipe (See comment under No. 15) Right abutment, 36 inch overflow buried below lowest point of refuse pile.

19. Approximate amount of fill placed per month or 6 months

750 tons per day 20 days per month 15,000 tons per month at present production.

20. Is pool as high as it has ever been or has it been higher; if higher, how high

It has been 10 feet higher when they were pumping washing water in to impoundment and the diversion ditch was not constructed. (3 months ago)

21. What type material is foundation? Colluvial material and weathered rock; less than 10 feet of cover over rock.

22. Who does the Operator consider the regulatory authority to consult when the Operator wants to change a dam or pile, or build another?

1. Department of Natural Resources - Coal Division
2. Air pollution Commission

23. Are inspections made by that authority?

Inspections are made by both of the above. Company gets report quarterly from Department of Natural Resources.

24. Does the Owner consider their structure a refuse pile or a dam, or does he consider it something else? Refuse disposal area.

... b. What was its initial purpose? Same as above.

25. Owners are expected to inspect their dams once a week. Look at owners' inspection book and see what has been noted (go back a couple of years).

They are in the process of setting up an inspection book.

Island Creek has two impoundments - Elk Creek and Coal Mountain 9B. Records are kept. Inspected daily and signed. This was started last summer or fall. We did not see these records.

26. Have they had problems with their structures (refuse pile, dam, deposit) in the past; if so, what remedial measures did they take?

A washout occurred on the right side of the embankment in 1962-1963. Diversion ditches were then installed.

Water pollution, requiring control facilities.

Comment - The evidence of the washout can be seen all down the valley and there appears to be thousands of yards of refuse deposited at the bottom of the valley (White Oak Branch).

27. Determine what coal seams were (are) mined.

Guyan No. 5 Mine Preparation Plant

Cedar Grove bed)
) deep mines
Chilton bed)

Stockton bed)
) strip and auger
Dorothy)

28. Has the Owner ever requested any assistance prior to or after inspection, and if so, did he get this assistance?

Department of Natural Resources inspects quarterly; gives no solutions to problems.

Comment - I do not think they request engineering assistance; only compliance with State water pollution regulations.

If they want to build or change an impoundment they check with the Public Service Commission.

Comment - (Believe they meant Public UTILITIES Commission)

29. Obtain a statement from the Owner (from what he has calculated or deduced) as to the volume of water discharged into the pool from the processing plant on a daily basis.

No water being pumped into impoundment. They pump into old mined-out sections of mine.

b. Determine (by some means) discharge from seepage downstream of dam. Approximately 18 gpm.

c. Inflow into pool. Approximately 15 gpm.

30. Obtain number of days plant operates in a year. 240 days.

31. Determine depth of deposit in pool. 20 feet on the left abutment to zero on the right.

32. Ask Operator what drainage area contributes to the pool. The area upstream of the impoundment.

b. Have any hydrology studies been performed by the Company?

Stated yes, but no acreage was given.

33. Has the Company developed any emergency plans to assuage any contingent problems should they occur? No; they believe that none is required.

34. Has the Company studied any alternative means of keeping the streams clean?

Thickeners and Filters. They are expensive. These methods are being used on the newer plants and on some older preparation plants. These methods are not being used at Guyan No. 5.

35. Have communications and/or illumination been installed at the deposit site? No.

b. If communications exist, to where and to whom are they linked? N/A

36. Have any sealants been used in construction of the deposit to make it more impervious? No.

37. Who is in charge of construction of Refuse Pile and what are his qualifications?

Mine Superintendent - Guyan No. 5. Mining Engineer.

39. If the dam suffers an accident, what is their (company) appraisal if damage or loss of life occurs? "No damage to property or life"

40. What is the ash content of the coal in this pile? 60-85% ash.

41. Dimensions of downstream impoundment? (Sediment pond)

200' x 75' x 25' deep. 2,805,000 gallons with 24 inch overflow.

42. Does Island Creek - Guyan No. 5 have a water pollution control permit?

No. They have filed application No. P-130 dated 31 August 1971. Maps and questionnaire on file with the Department of Natural Resources.

Stuart B. Long

APPENDIX 3

Questionnaire on Refuse Piles

1. Owner - Amherst Coal Company

2. Location - No. 1 Cleaning Plant, Dicks Branch of Buffalo Creek

3. Date Inspected - 31 March 1972 - 1 April 1972

3. a. Interviewed

Herbert Jones Jr., President, Chemical or Mechanical Engineer

Vance Price - Mining Engineer

J. Robert Rowe - Plant Superintendent

4. How Constructed

a. Truck & Dozer -

b. Conveyor & Dozer - X

c. Dumped & Spread -

d. Just Spread -

e. Other - Utilize 14 yd. scraper

5. When was pike started - Belt started 1953, started filling Dicks Branch in 1946 (truck dumped). This material has since turned to "Red Dog".

6. It is Actively used at present - Yes, only to increase embankment free-board. Majority of refuse being dumped up the valley side walls.

7. Has Pile Been on Fire - Yes 7a. The pile caught fire last Aug 1971

8. Is it burning now - Yes

9. Has any effort been made to zone pile - No

10. Rough percent volume which may be "red-dog" as result of fire - 25% of total pile. The old pile at the foot of the valley is completely burned out.

11. Is pile used for general mine refuse, or just for coal refuse - Coal refuse and impoundment for fine (0-5/16") coal refuse from the preparation plant.

12. Distance, in elev., from top of pile upstream, to water level - Distance, check aerial photo - 200-300 ft.
Elevation, check aerial photo - 10 to 20 feet, less to the top of the sediment, maybe 4 feet.

13. Distance, in elev., approx., from top of pile, downstream, to seepage exit -

Distance, check aerial photo -

Elevation - 278' (represents the interval between the Chilton seam and the Cedar Grove Island Creek seam.)

14. Any downstream erosion protection - No

15. Any upstream erosion protection - No

Comment - The distance from the top of the embankment to the top of the silty coal deposition is 3.4' at the lowest point. In the vicinity of the discharge pipe the measurement was 4.5' and erosion was occurring.

16. Was foundation stripped or otherwise treated prior to construction - Vegetation removed and began placement.

If so, describe - On natural ground which consists of clay and weathered rock. The mantle of soil cover is very thin (18").

17. Does spillway exist - No

18. Are any measures present to allow normal drainage to occur past dam, other than seepage thru embankment (pipe or low weir, etc.) - No

If so, give location, size and elev. referenced to top of dam - They don't consider that the embankment is holding a large impoundment of water, and the drainage area is small (46 acres). (USGS map shows 80 acres.)

19. Approx. amount of fill placed per month - or 6 months - 1,500 tons/day (30,000 tons/month) are being belted up the hillside. However, no material is being belted to the embankment. There is sufficient material stock-piled nearby to raise the embankment when required.

20. Is pool as high as it has ever been or has it been higher; if higher, how high.- the pool is as high as it has been.

Comment - The water level fluctuates about 18" per week. During the weekend, it drops to its lowest point. A gage was installed after the flood or 26 February 1972.

21. What type material is foundation - Colluvial - clay and rock (thin mantle) 18".

22. Who does the Operator consider the regulatory authority to consult when the Operator wants to change a dam or pile, or build another -

Department of Natural Resources - Water Division

23. Are inspectors made by that authority - Yes, inspect for violations of water pollution permit. Monthly inspections,

24. Does the Owner consider their structure a refuse pile or a dam, or does he consider it something else - Refuse pile

b. What was its initial purpose - Cleaning plant refuse disposal.

25. Owners are expected to inspect their dams once a week - look at owner's inspection book and see what has been noted (go back a couple of years) - The plant superintendent inspects daily as part of his concern for the water supply requirements of the plant. Recently they have started an inspection book which is signed by the superintendent.

The refuse pile is also inspected by the dozer and maintenance personnel.

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26. Have they had problems with their structures (refuse pile, dam, deposit) in the past; if so, what remedial measures did they take -

No problems or leakage; the fire is their only problem.

27. Determine what coal seams were mined - deep

Seam	% Production	Other Name
Chilton	5%	
Island Creek	35%	Split of the Cedar Grove
Eagle	30%	Logan Eagle or No. 2 Gas Bed
Dorthy	30%	

28. Has the Owner ever requested any assistance prior to or after inspection, and if so, did he get this assistance - No. The Department has informally requested that the top of the embankment be raised 3-4 feet.

29. Obtain a statement from the Owner (from what he has calculated or deduced) as to the volume of water discharged into the pool from the processing plant on a daily basis - 2,000 GPM approx. 10-12 hours/day carrying 15% solids.

b. Determine (by some means) discharge from seepage downstream of dam - They estimate they are recovering all of the seepage. In 4-5 days all water seeps out of the upper impoundment.

30. Obtain number of days plant operates in a year - 220-230 days per year.

31. Determine depth of deposit in pool - must calculate from aerial photo.

32. Ask operator what drainage area contributes to the pool - they calculated for me 46 AC.

b. Have any hydrology studies been performed by the Company - No

33. Has the Company developed any emergency plans to assuage any contingent problems they should occur - They are in the process of hiring an A/E (R. Kimbell) to investigate the stability and flood potential of their structures. They plan to drill the silt deposit and embankment.

Talked to Chuck Alexander, 4/17/72, R. Kimbell Associates.

34. Has the Company studied any alternative means of keeping the streams clean - Yes, Closed plant.

35. Has communications and/or illumination been installed at the deposit site - Paging phones are installed at all belt heads on the conveyor system, 6 stations.

b. If Communications exist, to where and to whom are they linked - They are connected to the processing plant.

36. Have any sealents been used in construction of the deposit to make it more impervious - No.

37. Who is in charge of construction of dam and what are his qualifications - J. Robert Rowe, Plant Superintendent, experience over all responsibility, company engineers.

38. Who is the inspector of this dam and what are his qualifications -

Plant Superintendent - no degree

Dozer & maintenance personnel

Plant personnel

39. If the dam suffers an accident, what is their (company) appraisal if damage or loss of life occurs - Damage to plant from sliding refuse pile, blockage of RR. or creek (Buffalo Creek).

40. Low sulpher coal 0.7%

41. They pump up 15% solids

42. Elev. coal seams Chilton 1418

Island Cr. 1140

Eagle 895

43. Little rise in the pool was noted during the heavy rains of 1963 or of 26 Feb 72.

44. Fill was placed on the breastworks as late as 28 Mar 72.

45. Pumping sludge with 8-inch pipe.

46. Cracks have been noted in the sediment after a prolonged shut-down. These cracks are reportedly the outlet points for the impounded water.

47. They do not plan to raise the embankment above the Chilton seam elev. 1418.

48. Coal in place = 80 lbs./cu.ft.

Loose coal = 52 lbs./cu.ft.

49. They feel that burned out red dog pile is more stable than an unburned refuse pile.

50. The company refers to the impoundments as follows:

No. 1 on top of the hill

No. 2 or middle pond

No. 3 fresh water just above plant

APPENDIX 4-

QUESTIONNAIRE ON REFUSE PILES

1. Owner — Youngstown Mines Corp., Dehue, West Virginia

2. Location — Dehue Mine, First right hand fork of Rum Creek

3. Date Inspected — 27-28 March 1972

3.a. Interviewed: Jerry Sommers, Superintendent
Joe Klimer, Preparation Engineer
Jerry Taylor, Resident Engineer
Robert Lilly, Preparation Plant Supt.

4. How Constructed

a. Truck & Dozer

b. Conveyor & Dozer

c. Dumped & Spread

d. Just spread

e. Other

Aerial tram - no compaction. Left abutment section - mine refuse spread with dozer and impervious clay cap built on refuse and compacted with dozer.

5. When was pile started? 1917-1920 old original pile started; 1949 new pile started up slope of old pile. (See attached plan)

6. Is it actively used at present? No déposition of mine refuse but impounding washing water.

7. Has pile been on fire? Yes

8. Is it burning now? Yes - partially.

9. Has any effort been made to zone pile? No; main pile not zoned, just dumped. Currently they are increasing height of embankment with a clay and stone combination.

10. Rough percent volume which may be red dog as result of fire.

90-95% red dog.

11. Is pile used for general mine refuse or just for coal refuse?

General mine refuse.

12. Distance, in elevation, from top of pile upstream to water level.

6.5 feet from the lowest point on crest to sludge.

13. Distance, in elevation, approximately from top of pile, downstream, to seepage exit.

Effluent discharges from a 36-inch corrugated metal pipe approximately 1000 feet down valley, approximately 40 gpm. Pipe is not coated with Bitumen. Algae is growing at pipe exit.

14. Any downstream erosion protection? No.

15. Any upstream erosion protection? None

16. Was foundation stripped or otherwise treated prior to construction? If so, describe.

Some vegetation was removed at the start but vegetation was covered later.

17. Does spillway exist? No. 36 inch overflow installed just below top of dam.

18. Are any measures present to allow normal drainage to occur past dam other than seepage through embankment (pipe or low weir, etc.). If so, give location, size and elevation referenced to top of dam.

Utilizing haul roads for diversion.

Comment: These measures would not prevent runoff from watershed.

19. Approximate amount of fill placed per month - or 6 months.

Not actively used. They are transferring the mine refuse to the next valley by conveyor.

20. Is pool as high as it has ever been or has it been higher; if higher, how high? The sludge impoundment has not been higher than it is now. It is slowly filling up. They have installed gage and monitor sediment filling.

21. What type material is foundation? Overburden consisting of clay and weathered rock.

22. Who does the Operator consider the regulatory authority to consult when the Operator wants to change a dam or pile, or build another?

Department of Natural Resources

Public Utilities Commission

Bureau of Mines

23. Are inspections made by that authority?

Dept. of Natural Resources - twice a month

State Department of Mines

Bureau of Mines

24. Does the Owner consider their structure a refuse pile or a dam, or does he consider it something else?

Impoundment for refuse tailings from preparations plant.

b. What was its initial purpose?

Refuse pile - 1949, when started.

Impoundment - 1960, when pumping started.

25. Owners are expected to inspect their dams once a week. Look at owners' inspection book and see what has been noted (go back a couple of years).

They have started an inspection book but it only records inspections and signature of inspector.

26. Have they had problems with their structures (refuse pile, dam, deposit) in the past? If so, what remedial measures did they take?

No problems.

27. Determine what coal seams were (are) mined.

Eagle seam or No. 2 gas bed - deep mine.

28. Has the Owner ever requested any assistance prior to or after inspection and, if so, did he get this assistance? No assistance requested.

29. Obtain statement from the Owner (from what he has calculated or deduced) as to the volume of water discharged into the pool from the processing plant on a daily basis.

14 hours operations x 400 gpm.

b. Determine (by some means) discharge from seepage downstream of dam.

Approximately 40 gpm.

30. Obtain number of days plant operates in a year. 210-215 days per year.

31. Determine depth of deposit in pool. Check aerial photo and topo map.

32. Ask Operator what drainage area contributes to the pool.

They estimate 20 acres but on their water pollution control application, they said 100 acres.

b. Have any hydrology studies been performed by the Company?

"Most likely have"

33. Has the Company developed any emergency plans to assuage any contingent problems should they occur?

None other than to provide proper maintenance.

34. Has the Company studied any alternative means of keeping the streams clean? They have checked alternate methods and consider this the best for this site.

35. Have communications and/or illumination been installed at the deposit site?

No. It is inspected daily.

b. If communications exist, to where and to whom are they linked?

They are planning on installing phones to the transfer point above the impoundment.

36. Have any sealants been used in construction of the deposit to make it more impervious? No.

37. <u>Who is in charge of construction of dam and what are his qualifications?</u>

Bob Lilly - foreman

38. <u>Who is the inspector of this dam and what are his qualifications?</u>

Bob Lilly - foreman

Dozer operator above impoundment

Transport area operator above impoundment

39. <u>If the dam suffers an accident, what is their (company) appraisal if damage or loss of life occurs?</u>

Mining town at Dehue directly below impoundment and the coal company.

<u>NOTES</u> They plan to increase breast works as needed as sediments increase.

They want to abandon the impoundment within a year.

APPENDIX 5

ADDITIONAL LABORATORY TESTING

In addition to those tests described in Part I, the following were performed in the Ohio River Division Laboratory:

a. Determination of Composition. From each screen used in the grain-size determination, a sample was taken and examined in detail by petrographic methods to determine the percentages of coal, shale, sandstone, etc. These values were then combined in proportion, according to weights on the various screens, to a single value for the entire material.

b. Shear Testing. Tests were performed in the 1.4" triaxial apparatus of minus No. 4 material if it were clear that the plus No. 4 material was not present in sufficient quantity to influence the strength. Otherwise, the 2.8 triaxial was used.

1. The Q tests were performed only as a measure to judge the validity of the R&S tests.

2. The R tests were saturated under back-pressure, and performed, generally with pore-pressure measurements, in the 1.4 or 2.8 inch triaxial.

3. The S tests were performed in the direct shear machine in the standard method, on samples 3-1/4 inches square.

c. Consolidation. Tests were performed on minus No. 4 material using specimens 4-1/4 inches in diameter and 1-1/4 inches initial height. Final loads of 13.0 tsf were used.

d. Permeability. Tests were performed on specimens of 6" diameter and 5 inches on total material.

The detailed results are on file in the U. S. Army Engineer District, Pittsburgh.

Test Results Summary is shown on Plate 20.

Unless specifically noted to the contrary, all tests reported in both Parts I and II were performed in accordance with the procedures given in the Engineer Manual EM 1110-2-1906, 30 November 1970, "Laboratory Soils Testing," Corps of Engineers.

APPENDIX 6

HYDROLOGY

1. Area - Capacity Curves. The U. S. Geological Survey 7.5 minute series topographic maps were used to derive the area curves for the ponding sites. The scale of the topographic maps is 1 to 24,000 with 40-foot contour intervals. Values for the area curves were derived by planimetering the area of each contour. A computer program utilizing the conical method was used to determine the intermediate areas at one-foot intervals. The capacity curves were developed by averaging values at one-foot intervals by the end-area method. The curves showing elevation versus capacity for Youngstown Mines Corp., Island Creek Coal Guyan No. 5, and Amherst Coal Co. sediment ponds are shown on Plates 1, 2 and 3. No curves are shown for the Powellton Coal Co. pond on Rockhouse Creek, since it is a diversion pond with negligible tributary area. Total depth of flood impoundment will approximate the number of inches of storm precipitation. The three curves reflect the storage capacity of the natural valleys. The level of present silt deposition is indicated on the curves as well as the top of dam. These were obtained by recent field surveys. Total presently available storage potential lies between these two limits.

2. Probable Maximum Storm and Flood. The maximum probable flood used in this report for the areas tributary to the dams has been based on rainfall rates and duration from Hydrometeorological Report No. 33 (April 1965), "Seasonal Cariation of Probable Maximum Precipitation East of the 105th Meridian," prepared by the Hydrometeorological Section of the U. S. Weather Bureau. In development of this storm, consideration was also given to the Engineer Circular No. 1110-2-27, from the officer of the Chief of Engineers, ENGCW-EY, 1 August 1966.

The magnitude and intensity of rainfall shown for the month of August were most critical for the size of the areas above these dams. Storms at this time are caused by stagnant anti-cyclonic eddies in the air masses which carry potentially unstable moist currents over the upper Ohio Valley. Such storms usually occur in regions in which normal or less than normal precipitation has been occurring. An antecedent rain, however, could occur within a short span prior to the maximum storm rainfall.

3. Top of Embankment Determination. To minimize the possibility of embankment failures due to overtopping, storage of probable maximum storm runoff was presumed to occur after the maximum storage obtained by routing the 10 year, 6 hour storm through the various impoundments with recommended drainage facilities in place. This total storage was used to determine the minimum elevation needed to prevent overtopping of the embankment. The computed 24 hour rainfall for the design storm was 22 inches. Total losses were assumed as 3.0 inches with a resultant runoff of 19.0 inches. The following tabulation for the four dams gives a comparison of the lowest elevation on the top of the existing embankment and the minimum elevation which should be provided for storage without overtopping of assumed maximum runoff. The required embankment elevation does not include free board.

Company Name and Stream	Existing Emb. Elev.	Required Emb. Elev.
Youngstown Mines Corp. - Right Hand Fork	1,205	1,216
Island Creek Coal Co. - Little White Oak Branch	1,362	1,386.5
Amherst Coal Co. - Dick Branch	1,416.5	1,421.5
Powellton Coal Co. - Rockhouse Creek	9,630	965

The required top elevation shown in the above tabulation is applicable for presently existing sediment conditions. When future settlement deposition usurps a significant portion of storage capacity, the embankment must be raised to provide the capacity needed to retain maximum flood runoff.

4. Standard Project Flood. The Standard Project Flood is defined as one resulting from rainfall of high intensity which, although extremely rare, has a reasonably probable chance of occurrence in the local area. It is frequently considered to be of about half the magnitude of the maximum probable flood. Reservoir impoundment during this flood consequently would raise the water level to about 2/3 of total embankment height above the bottom.

5. Discharge Outlet Control Requirements.

As a means of assuring passage in a safe manner of runoff from rainfall and snowmelt, a drop inlet type spillway can be provided; this type structure appears to offer the best solution to the problem for each dam. A drop inlet spillway is one in which the water enters over a horizontally positioned lip, drops through a vertical or sloping shaft, and then flows downstream through a horizontal or near horizontal conduit through the embankment. With this type of structure, sections of pipe could be added to the vertical or sloping shaft as the sediment accumulates and rises around it. This type of control has additional advantages as it provides automatic storage and release of inflow water without need of manual operation. The spillway must be dimensioned so that it will have a flow capacity which will enable impoundment and release of tributary inflow to be made without excessive storage but with sufficient retention time for effective deposition of sediment during passage of the water.

Ten year, 6 hour, storm runoff conditions have been adopted for normal operational design purposes. The size of the spillways were chosen so that they would be large enough to limit storage to about 10% of total runoff capacity during this flood and would balance outflow and storage so that maximum flow velocity through the reservoir would not exceed about .05 foot per second. At all other times when inflow has decreased, velocities through the impoundment would be less because of the lower storage level and smaller outflow rate and the greater ratio of total depth to flow rate resulting from normal pondage below the spillway lip. Average annual runoff in this area is about 1.2 cfs per square mile. An initial height of 4 feet has been allowed for top of spillway above the reservoir bottom. No allowance for area below the spillway level has been used in computation of flow rates through the reservoir as sedimentation could rise to near this height before the spillway lip was raised. The spillways so selected, as previously mentioned, were used in routing of the Probable Maximum and Standard Project Floods.

a. The 10-year 6-hour storm for each site was routed through storage using several sizes of drop inlets for each. This rainfall was determined from the Rainfall Intensity Frequency data of the U. S. Weather Bureau (Technical Report No. 40, "Rainfall Frequency Atlas of the United States," May 1961). The inflow for each impoundment was computed by use of the method as outlined in S.C.S. National Engineering Handbook No. 4, Chapter 21, with the rainfall so obtained. The 10-year 6-hour rainfall for the area under study is 3.00 inches. The loss rate will vary due to several factors some of which are: type of soil, ground moisture, ground cover and time of year. An assumed loss of 0.8 inch was used in the computations.

b. The various sites investigated are:

(1) Youngstown Mines Corporation
Right Hand Fork near Dehue, W. Va.

(2) Island Creek Coal Company - Guyan No. 5
Little White Oak Branch

(3) Amherst Coal Company
Dick Branch

(4) Powellton Coal Company
Rockhouse Creek

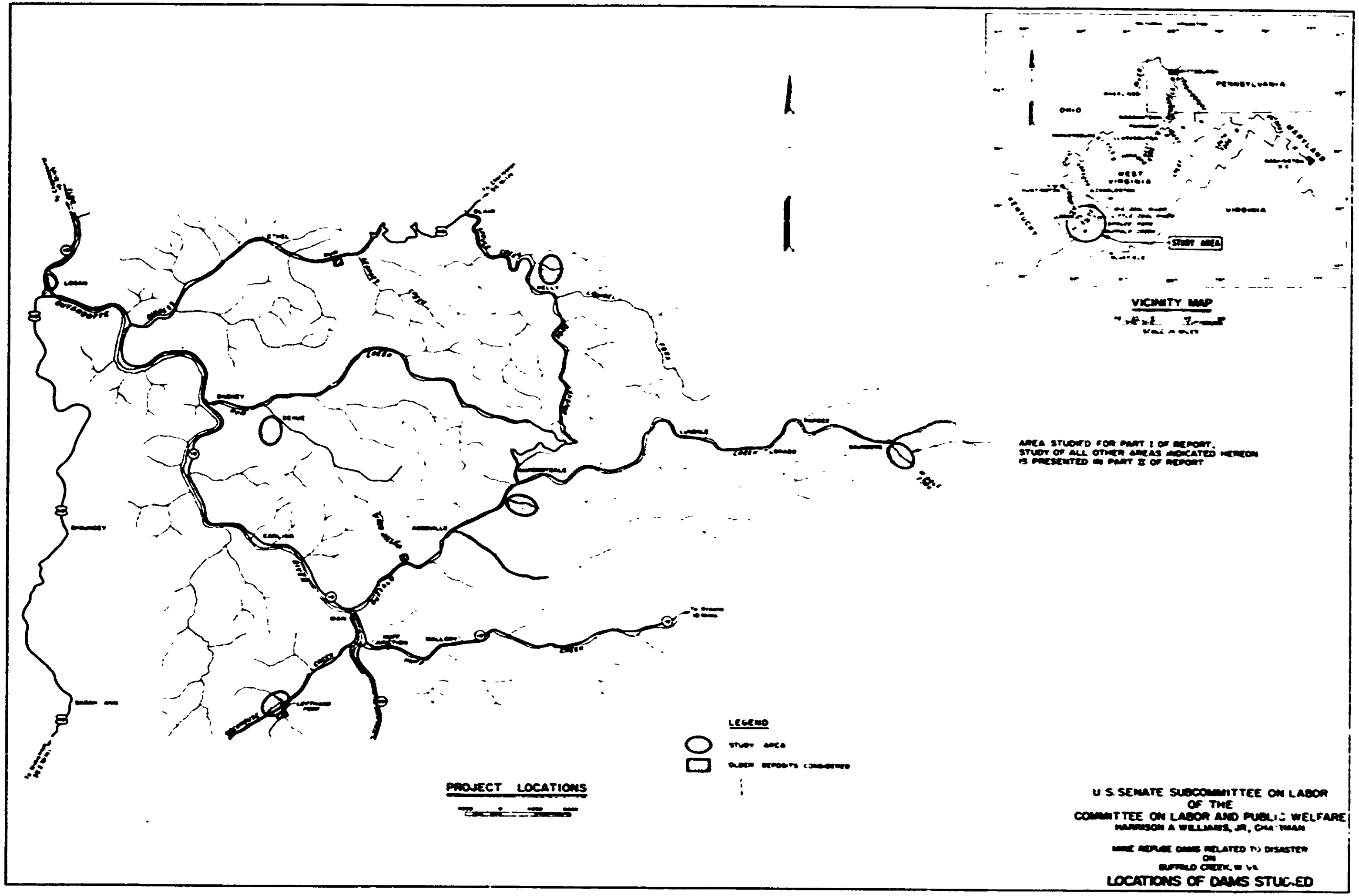
c. Youngstown Mines Corporation. This company's sediment pond is situated on Right Hand Fork near Dehue, W. Va. The contributing area behind the impoundment is 0.12 square mile. The original ground at the present dam location is approximately at elevation 1030. The embankment and siltation has raised the minimum elevation to 1198. With a spillway riser four feet high a permanent settling pond at elevation 1202 would be formed. This pond would have an area of about 9 acres and an overall length of about 1000 feet. Total present impoundment at this level is 36 acre-feet. The diameter of the spillway pipe would be 2 feet. During the 10-year 6-hour storm maximum inflow is 150 cfs. The water would rise one foot above spillway to elevation 1203.1, occupying 7% of the dam height above the spillway. Maximum outflow discharge is 13 cfs. Time of travel of this magnitude of flow through surcharge storage would be at the rate of .04 ft./sec. The head discharge relation for the 2-foot spillway is shown as Plate 4.

d. Island Creek Coal Company - Guyan No. 5. This sediment pond is located on Little White Oak Branch approximately 4.5 miles north of Amherstdale. The area draining into this pond is 0.29 square mile. The dam embankment and siltation has raised the bottom elevation from 1225 to 1343. With a spillway riser 4 feet high a permanent settling pond at elevation 1347 would be formed. This pond would have an area of about 5 acres and an overall length of about 1000 feet. Total present impoundment at this level is about 21 acre-feet. During the 10-year 6-hour storm maximum inflow was computed to be 280 cfs. The water would rise 3.5 feet above spillway to elevation 1350.5, occupying 9% of the dam height above the spillway. Maximum outflow discharge is 50 cfs. Time of travel of flow of this magnitude through surcharge storage would be at the rate of .06 ft./sec. The head discharge relation for this 3-foot diameter spillway is shown on Plate 5.

e. Amherst Coal Company. The sediment pond used by this company is situated on Dick Branch approximately one mile south of Amherstdale. The drainage area contributing to this pond is 0.12 square mile. Sediment and embankment has raised the pond bottom elevation from 1100 to 1408. With a spillway riser 4 feet above the bottom, a permenent settling pond at elevation 1412 would be formed. This pond would have an area of about 14 acres and an overall length of about 1300 feet. Total present impoundment at this level is about 58 acre-feet. During the 10-year 6-hour storm maximum inflow was computed as 150 cfs. The water would rise about 0.8 foot above spillway to elevation 1412.8, occupying about 8% of the dam height above the spillway. Maximum outflow discharge is 10 cfs. Time of travel of flow of this magnitude through surcharge storage would be at the rate of .033 foot per second. The head discharge relation for this 2-foot diameter spillway is shown as Plate 6.

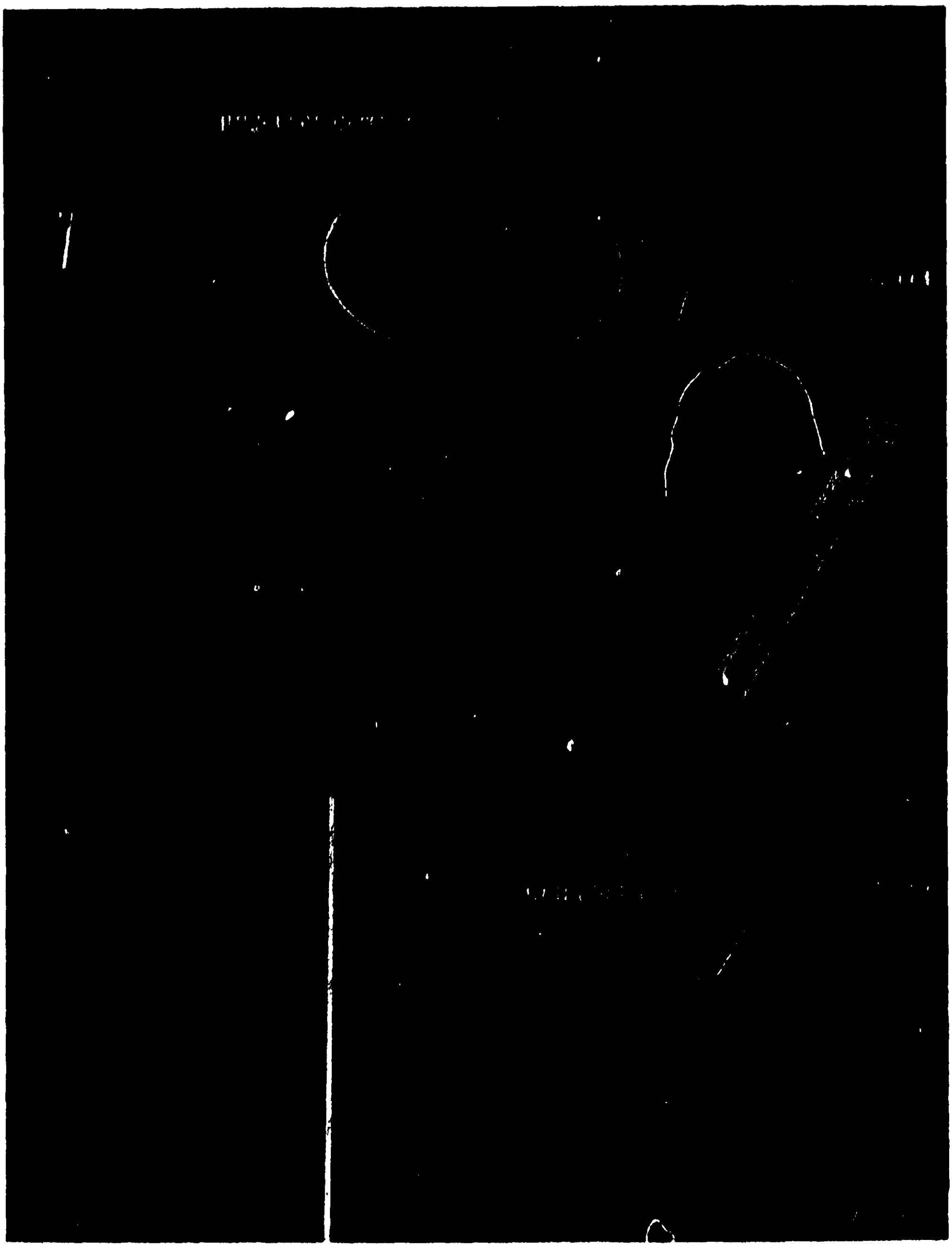
f. Powellton Coal Company. This sediment pond is located on the right bank of Rockhouse Creek, approximately 2.5 miles southwest of Man, West Virginia. It has only a peripheral drainage area. Its total area including the pond is about 2 acres. Since this pond has a very small area beyond its own limits, the inflow into the pond will closely approximate the rainfall. The pond is now provided with a 2-foot drain. The probable maximum storm could raise its level about 2 feet, consequently pondage should never be permitted.

. As the impoundment is located between Rockhouse Creek and Left Hand Fork, precautions should be also taken to eliminate any possibility of erosion of the embankment which would permit high flows from either stream to enter the impoundment.



VICINITY MAP
PENNSYLVANIA
OHIO
WEST VIRGINIA
VIRGINIA
STUDY AREA
AREA STUDIED FOR PART I OF REPORT.
STUDY OF ALL OTHER AREAS INDICATED HEREON
IS PRESENTED IN PART II OF REPORT
LEGEND
STUDY AREA
PROJECT LOCATIONS
U.S. SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A WILLIAMS, JR, CHAIRMAN
MINE REFUSE DAMS RELATED TO DISASTER
ON
BUFFALO CREEK, W VA
LOCATIONS OF DAMS STUDIED

PLATE NO. 1



AERIAL VIEW AND PHOTO OF
REFUSE PILE AND IMPOUNDMENT
POWELLTON CO. ROCKHOUSE CREEK

PLATE NO. 2

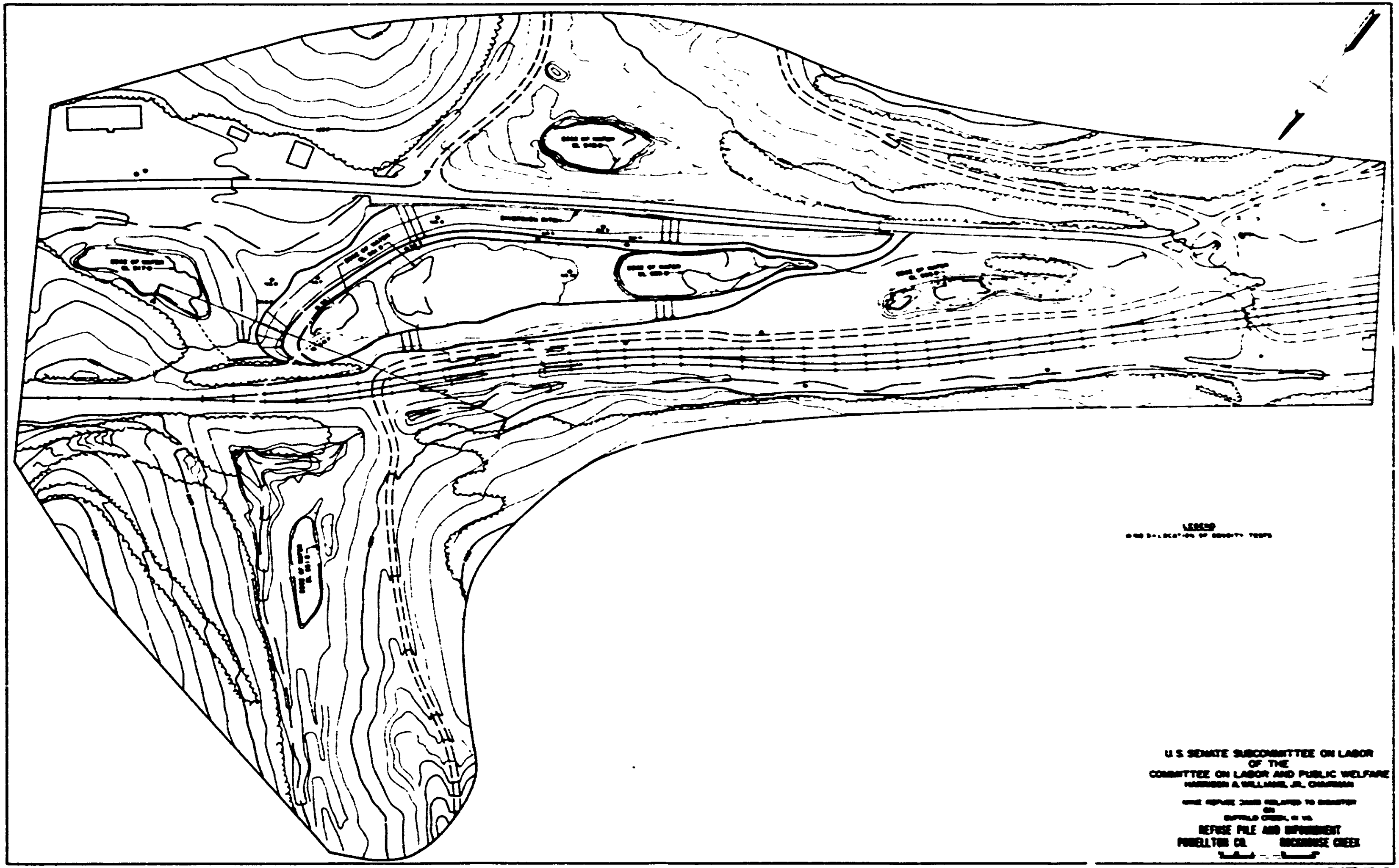
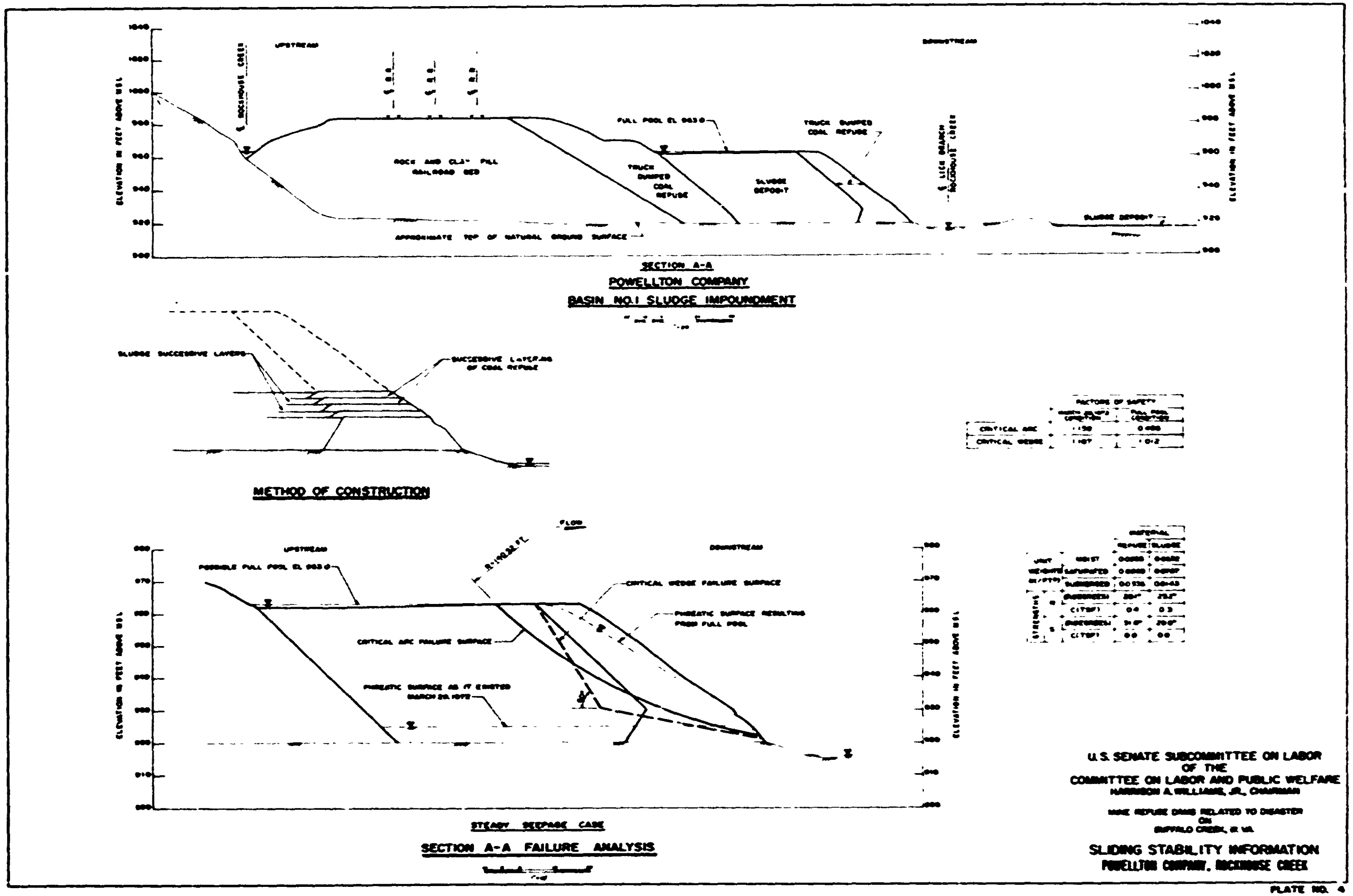
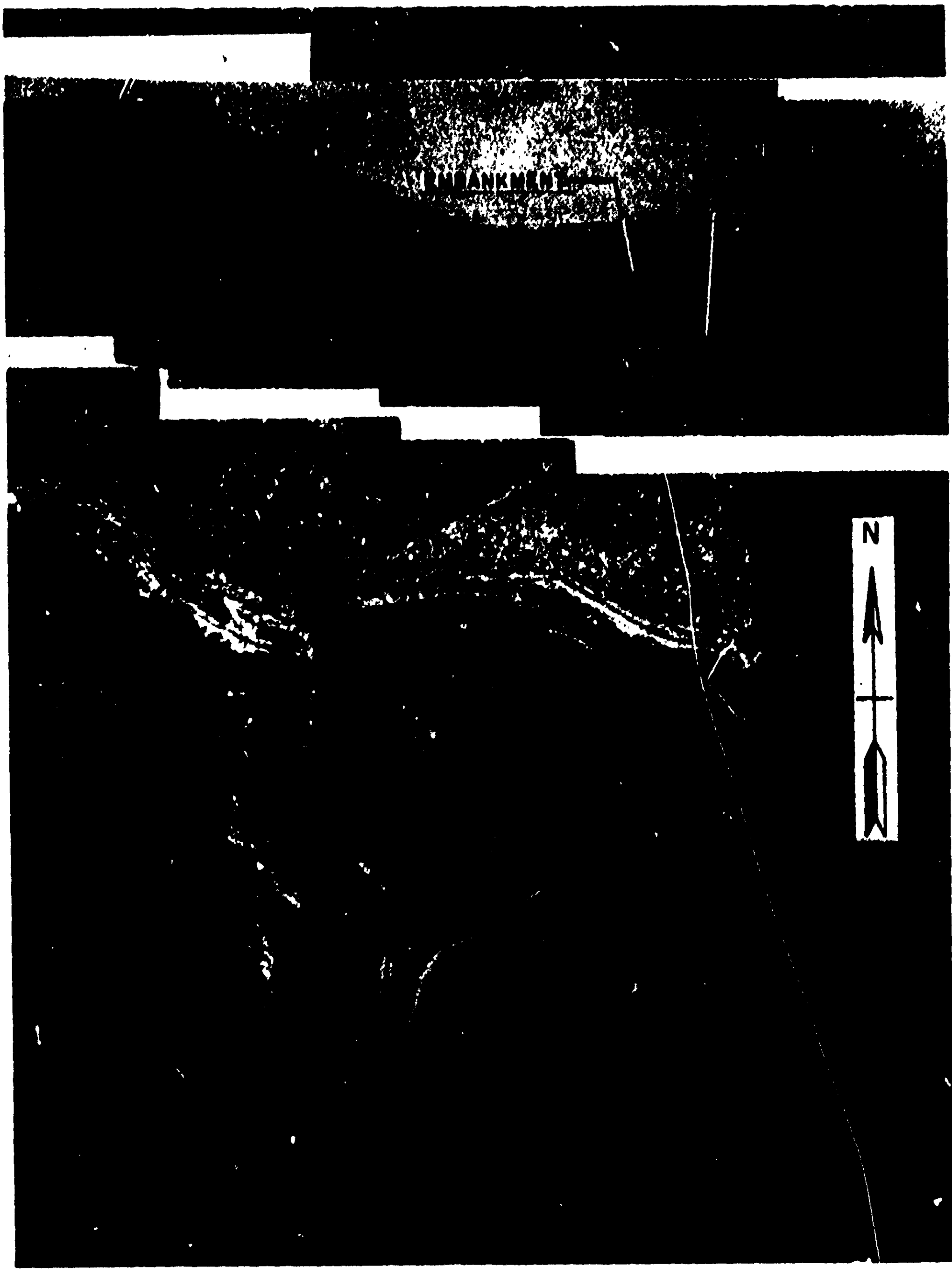

U S SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
REFUSE PILE AND IMPOUNDMENT
POWELLTON CO. ROCKHOUSE CREEK

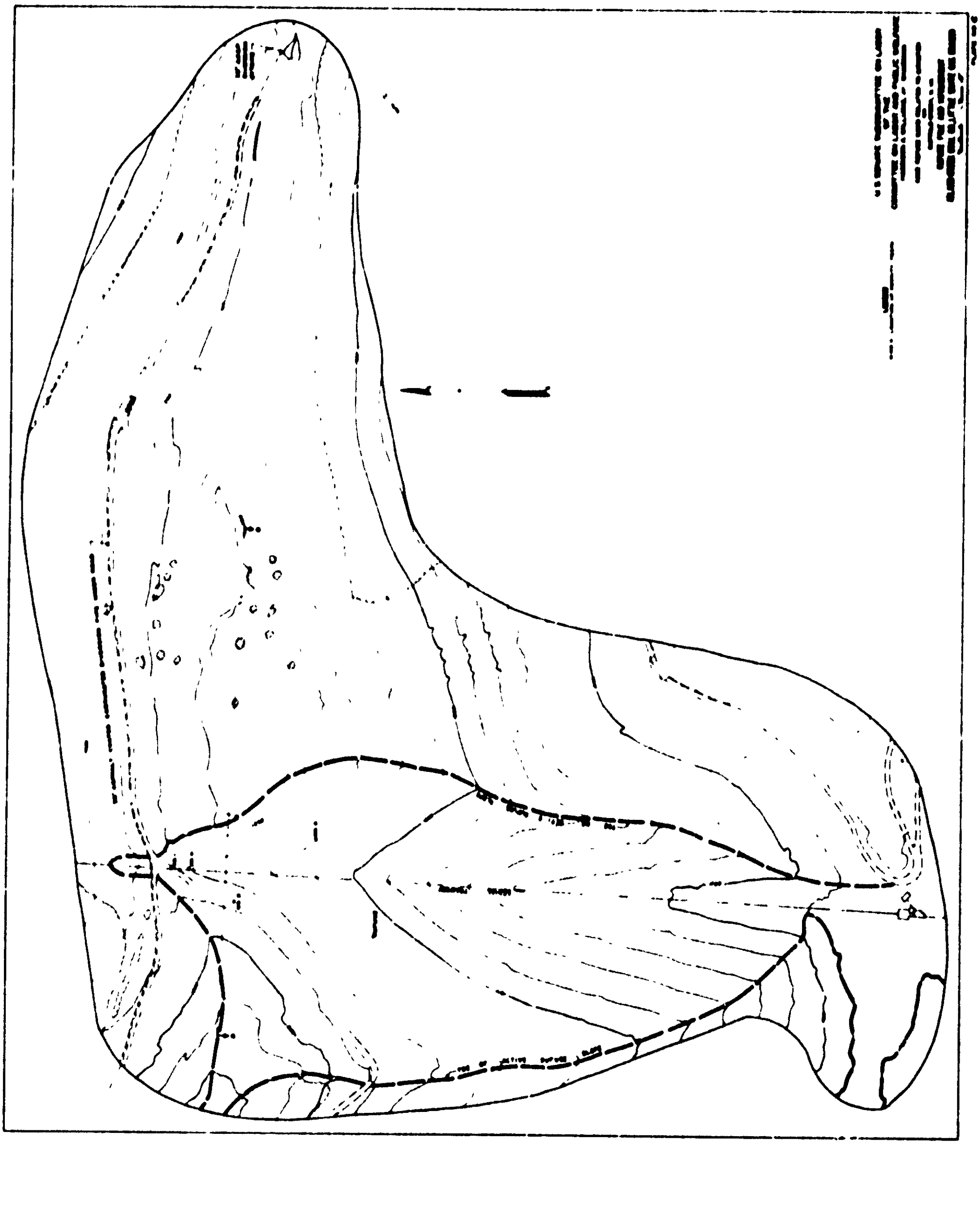
PLATE NO. 3

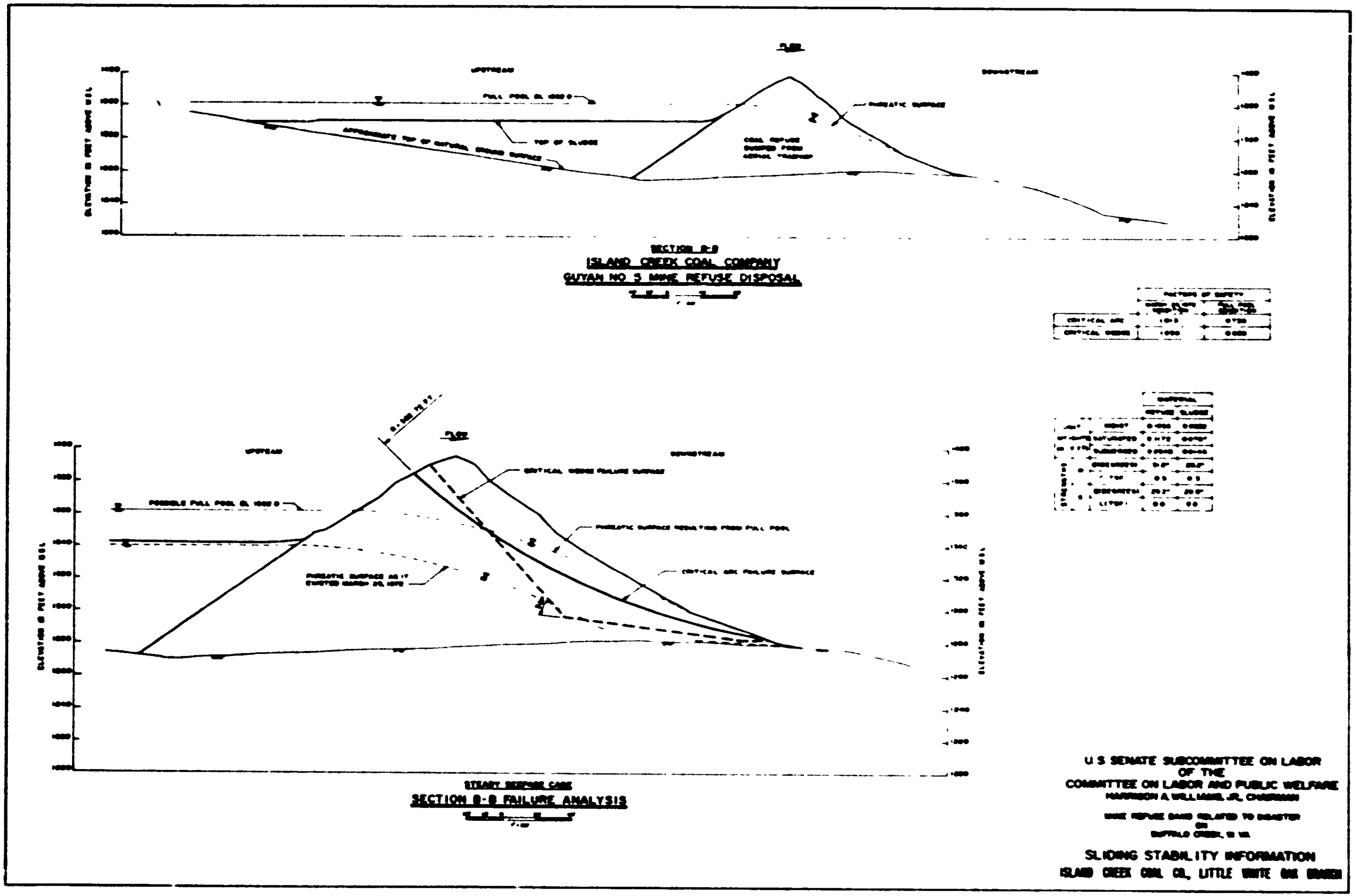

UPSTREAM
DOWNSTREAM
ROCKHOUSE CREEK
FULL POOL EL 963.0
TRUCK DUMPED COAL REFUSE
ROCK AND CLAY FILL RAILROAD BED
TRUCK DUMPED COAL REFUSE
SLUDGE DEPOSIT
SLUDGE DEPOSIT
APPROXIMATE TOP OF NATURAL GROUND SURFACE
ELEVATION IN FEET ABOVE MSL
SECTION A-A
POWELLTON COMPANY
BASIN NO.1 SLUDGE IMPOUNDMENT
SLUDGE SUCCESSIVE LAYERS
SUCCESSIVE LAYERING OF COAL REFUSE
METHOD OF CONSTRUCTION
FACTORS OF SAFETY
CRITICAL ARC
CRITICAL WEDGE
FLOW
POSSIBLE FULL POOL EL 963.0
CRITICAL WEDGE FAILURE SURFACE
PHREATIC SURFACE RESULTING FROM FULL POOL
CRITICAL ARC FAILURE SURFACE
PHREATIC SURFACE AS IT EXISTED MARCH 20, 1972
MATERIAL
REFUSE
SLUDGE
UNIT WEIGHTS
MOIST
SATURATED
SUBMERGED
STRENGTHS
STEADY SEEPAGE CASE
SECTION A-A FAILURE ANALYSIS
U.S. SENATE SUBCOMMITTEE ON LABOR OF THE COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A. WILLIAMS, JR., CHAIRMAN
MINE REFUSE DAMS RELATED TO DISASTER ON BUFFALO CREEK, W. VA.
SLIDING STABILITY INFORMATION
POWELLTON COMPANY, ROCKHOUSE CREEK
PLATE NO. 4



AERIAL VIEW AND PHOTO OF
REFUSE PILE AND IMPOUNDMENT
ISLAND CREEK COAL CO.
LITTLE WHITE OAK BRANCH

PLATE NO. 5




UPSTREAM
DOWNSTREAM
FLOW
PHREATIC SURFACE
TOP OF SLUDGE
COAL REFUSE DUMPED FROM AERIAL TRAMWAY
SECTION B-B
ISLAND CREEK COAL COMPANY
GUYAN NO 5 MINE REFUSE DISPOSAL
CRITICAL WEDGE FAILURE SURFACE
CRITICAL ARC FAILURE SURFACE
STEADY SEEPAGE CASE
SECTION B-B FAILURE ANALYSIS
U S SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A. WILLIAMS, JR., CHAIRMAN
MINE REFUSE DAMS RELATED TO DISASTER
ON
BUFFALO CREEK, W. VA.
SLIDING STABILITY INFORMATION
ISLAND CREEK COAL CO., LITTLE WHITE OAK BRANCH
PLATE NO. 7

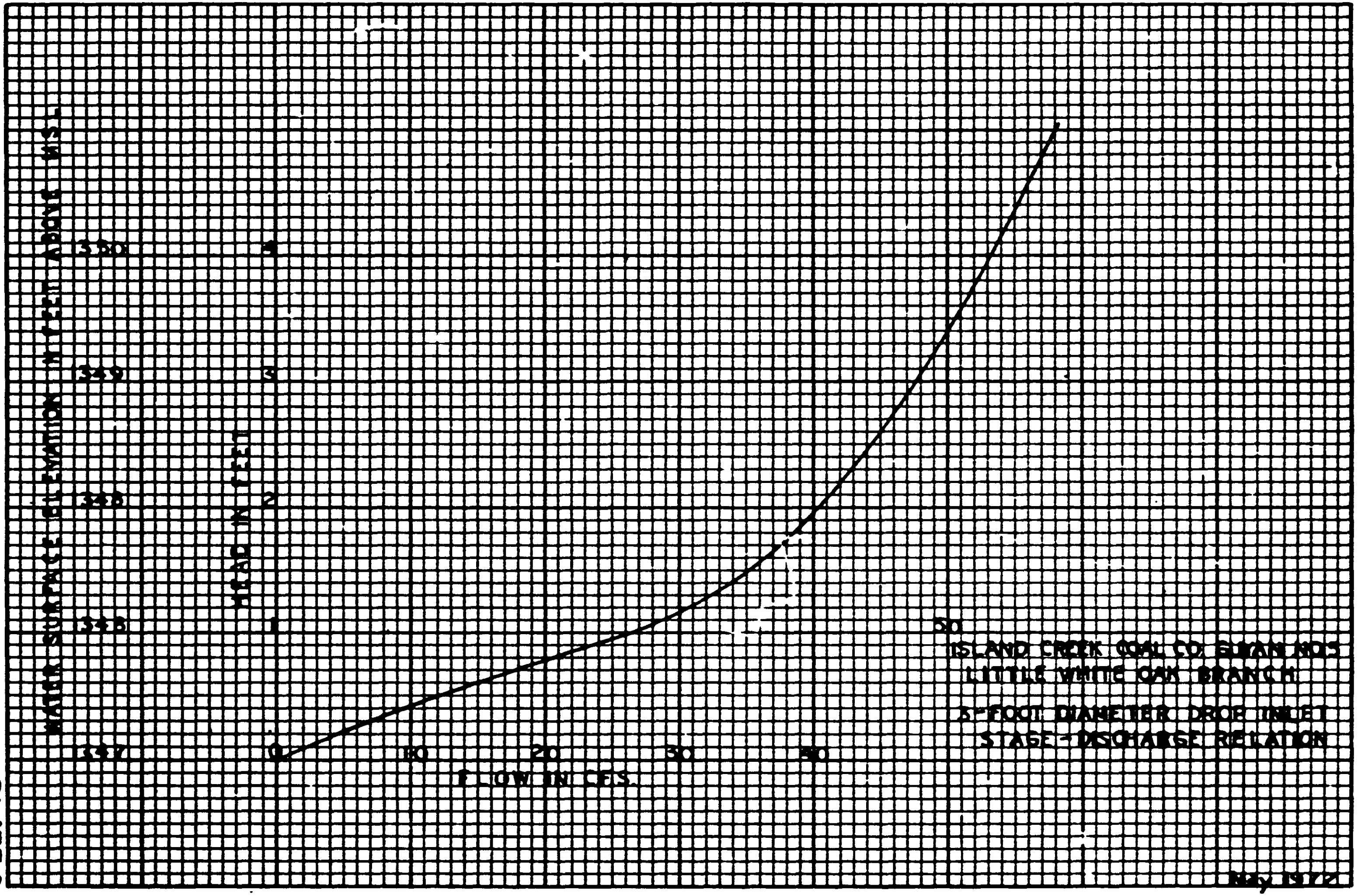

WATER SURFACE ELEVATION IN FEET ABOVE MSL
HEAD IN FEET
1350
1349
1348
1347
4
3
2
1
0
10
20
30
40
50
FLOW IN CFS
ISLAND CREEK COAL CO.
LITTLE WHITE OAK BRANCH
3-FOOT DIAMETER DROP INLET
STAGE - DISCHARGE RELATION
May 1972

PLATE 8

210

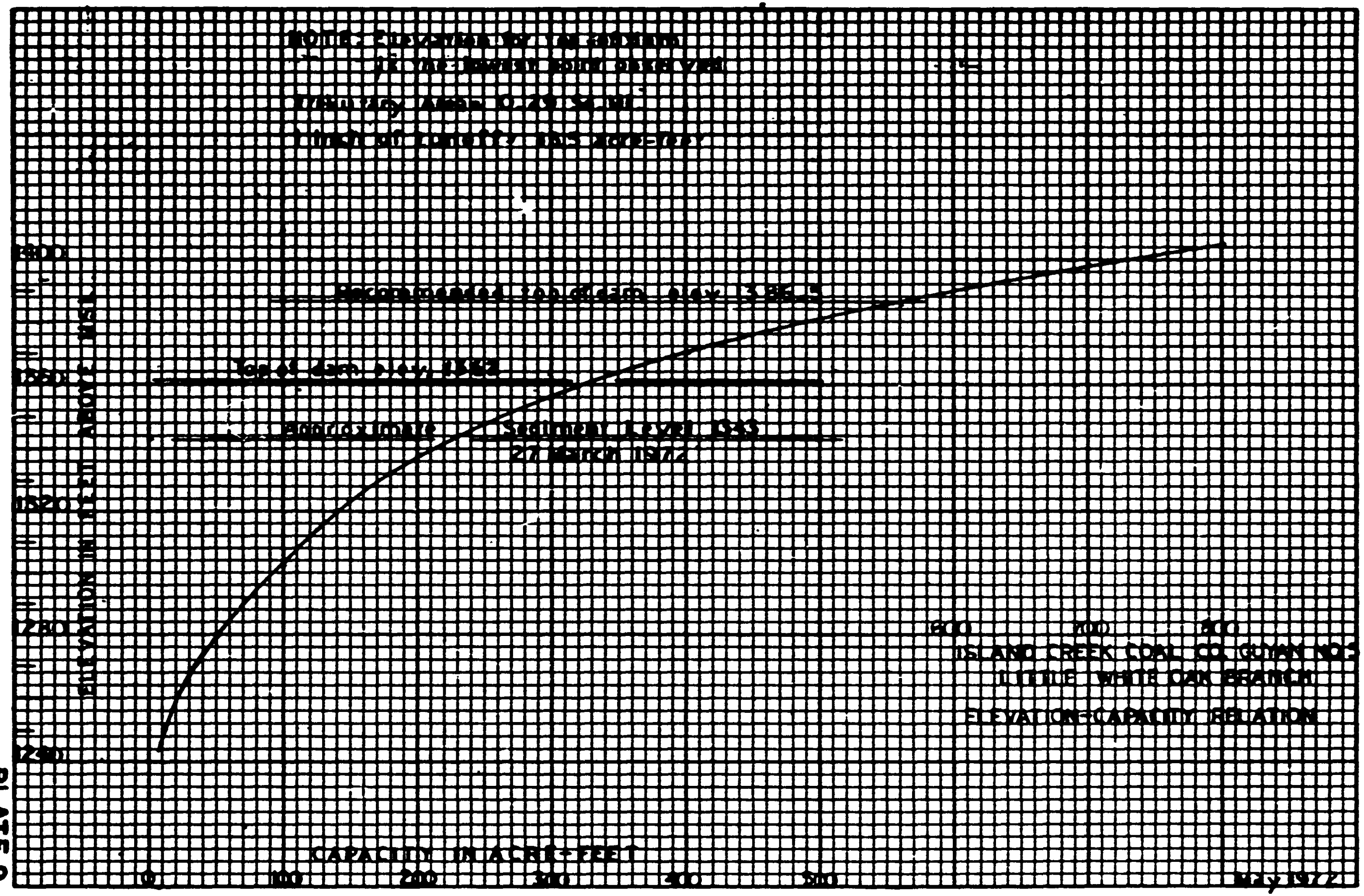
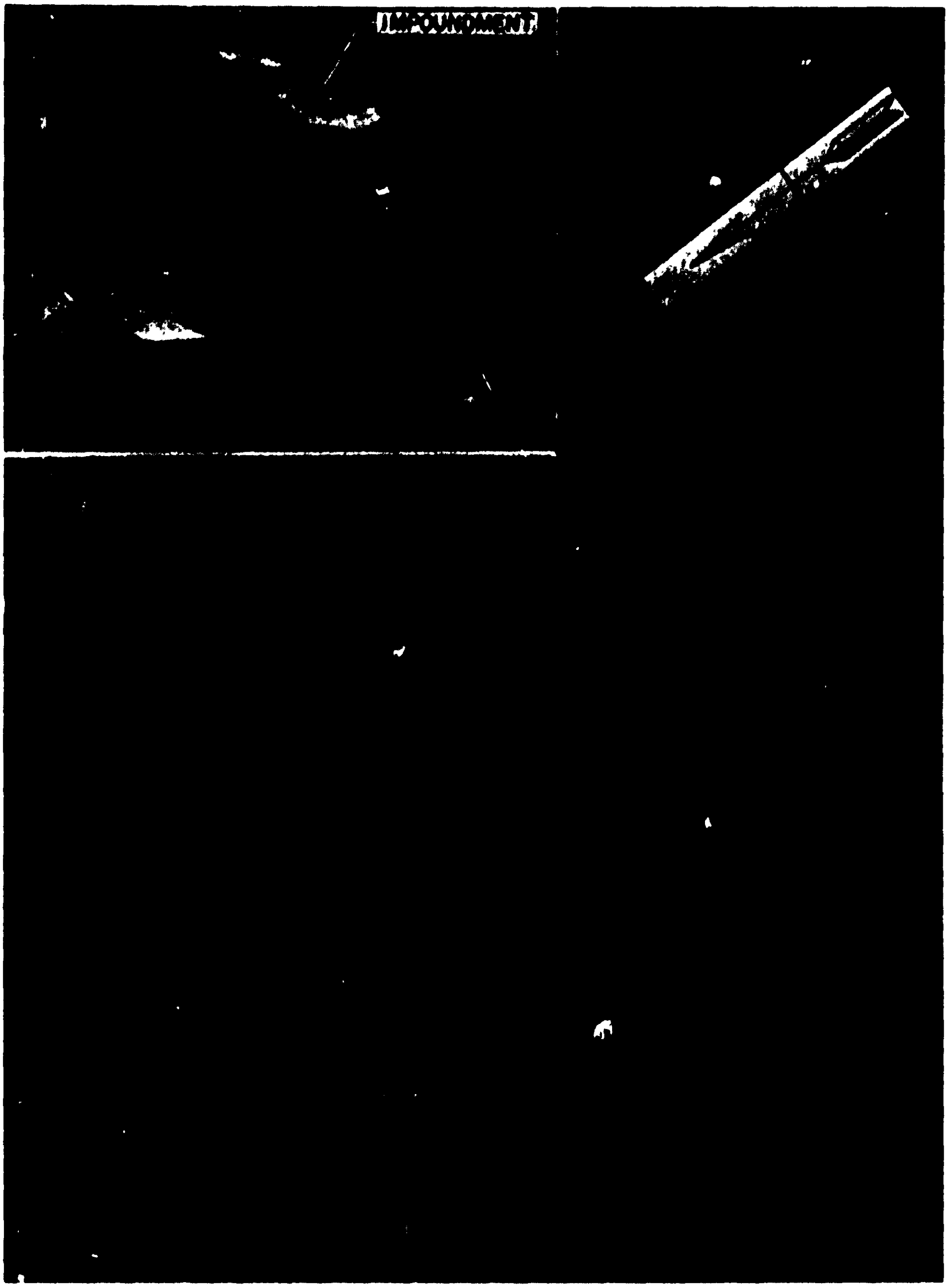
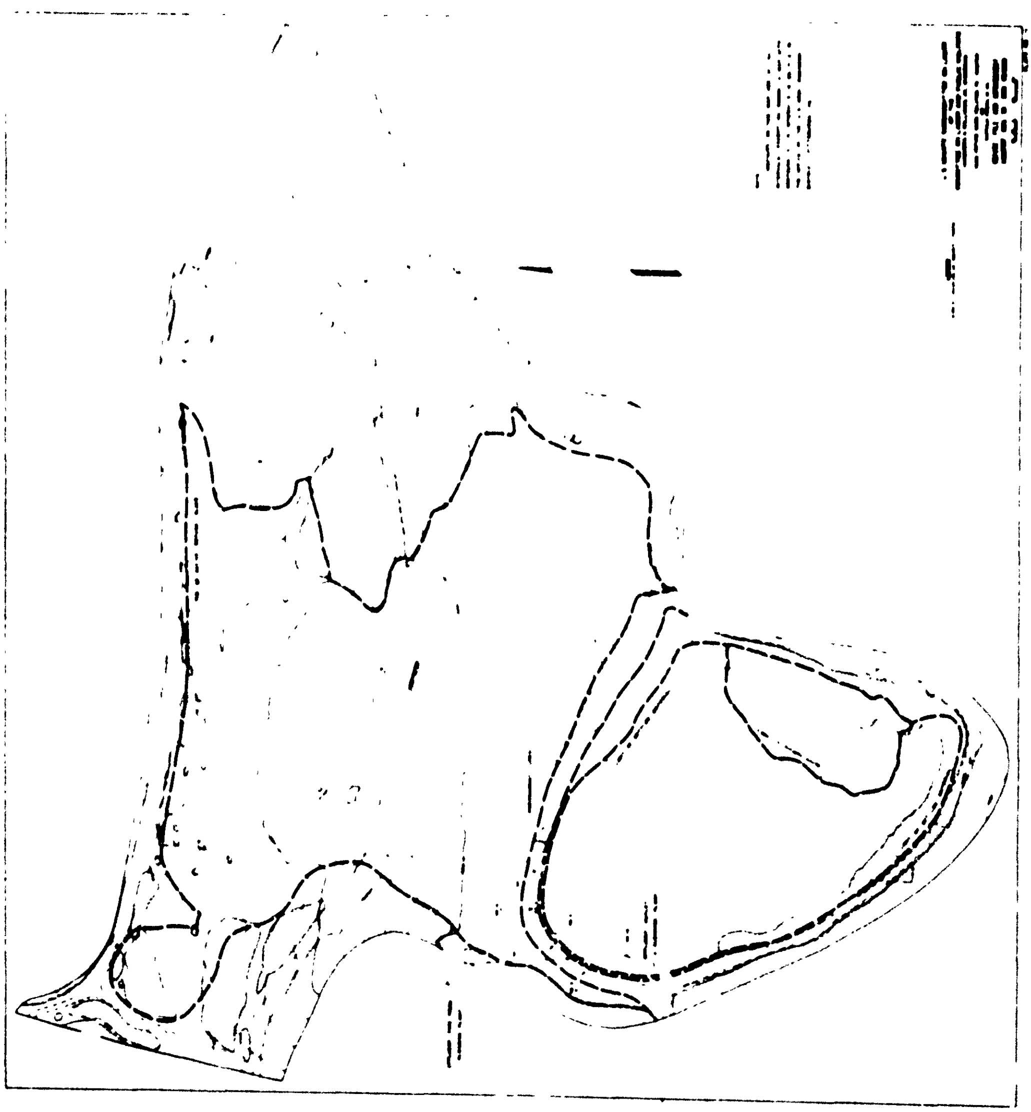

Approximate Sediment Level 1343
27 March 1972
CAPACITY IN ACRE-FEET
0
100
200
300
400
500
600
700
800
ISLAND CREEK COAL CO. GUYAN NO.3
LITTLE WHITE OAK BRANCH
ELEVATION-CAPACITY RELATION
May 1972

PLATE 9



AERIAL VIEW AND PHOTO OF
REFUSE PILE AND IMPOUNDMENT
AMHERST COAL CO., DICK BRANCH

PLATE NO. 10



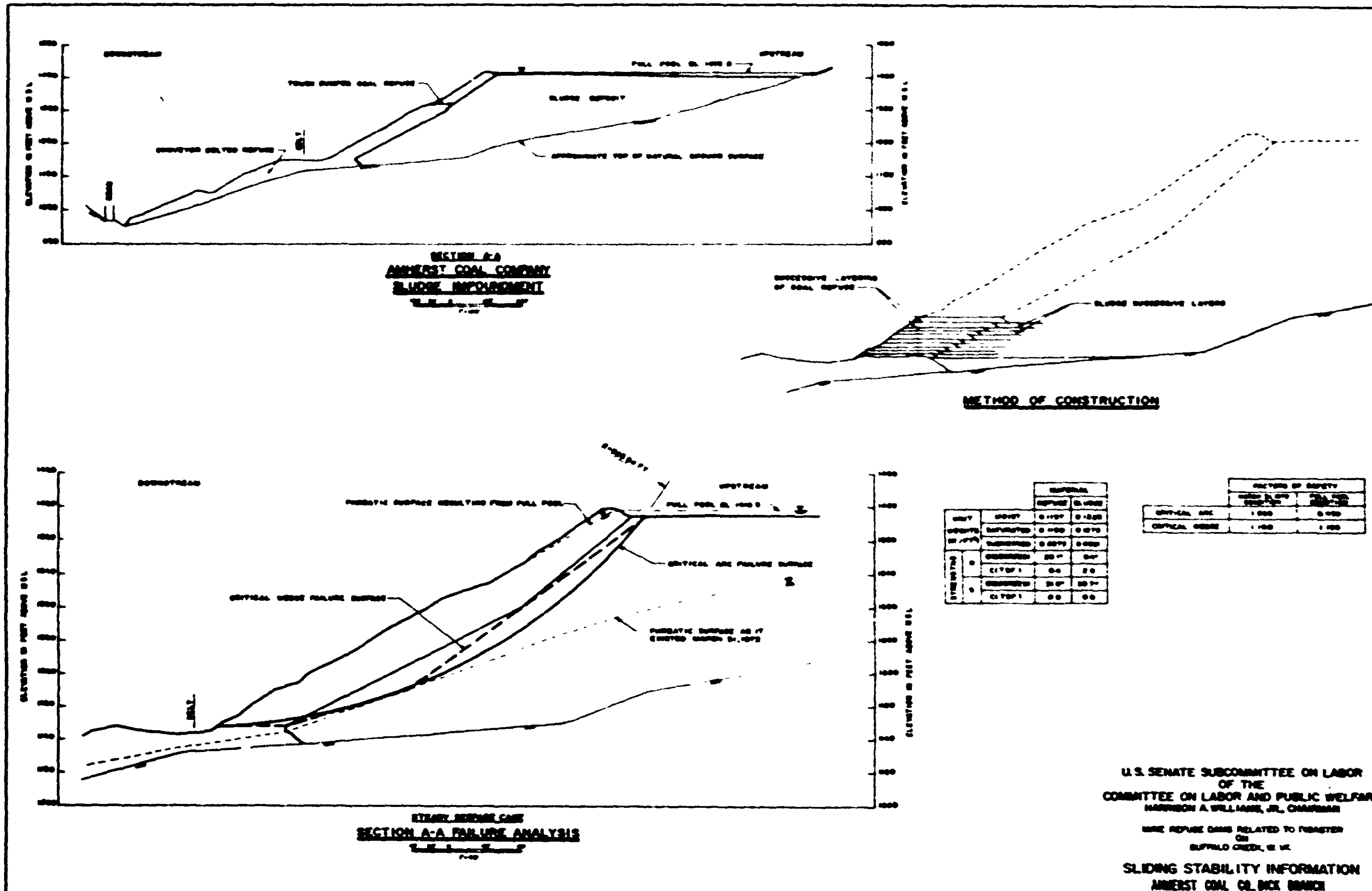

SECTION A-A
AMHERST COAL COMPANY
SLUDGE IMPOUNDMENT
METHOD OF CONSTRUCTION
SECTION A-A FAILURE ANALYSIS
U.S. SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
SLIDING STABILITY INFORMATION
AMHERST COAL CO., DICK BRANCH

PLATE NO. 12

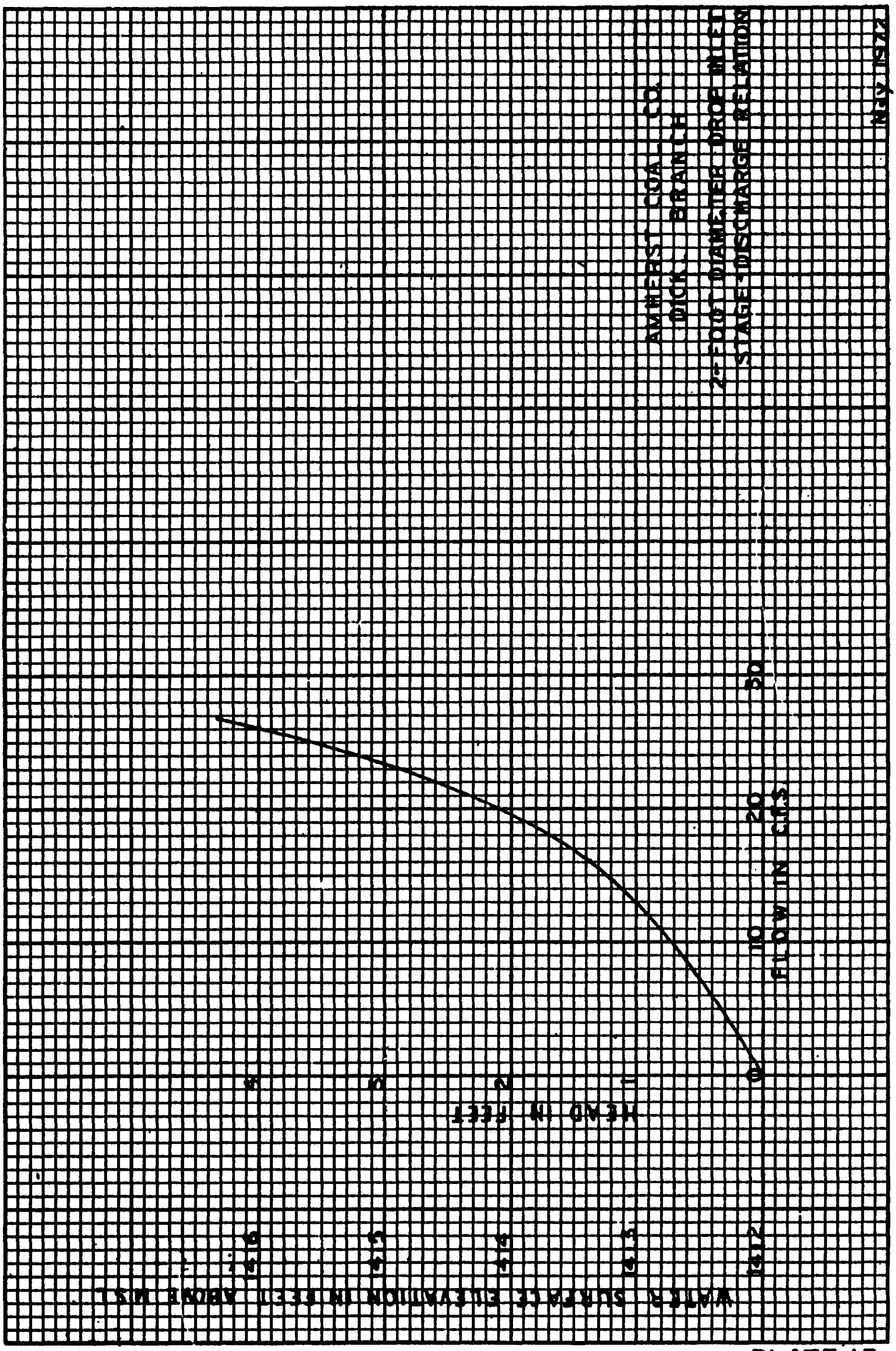
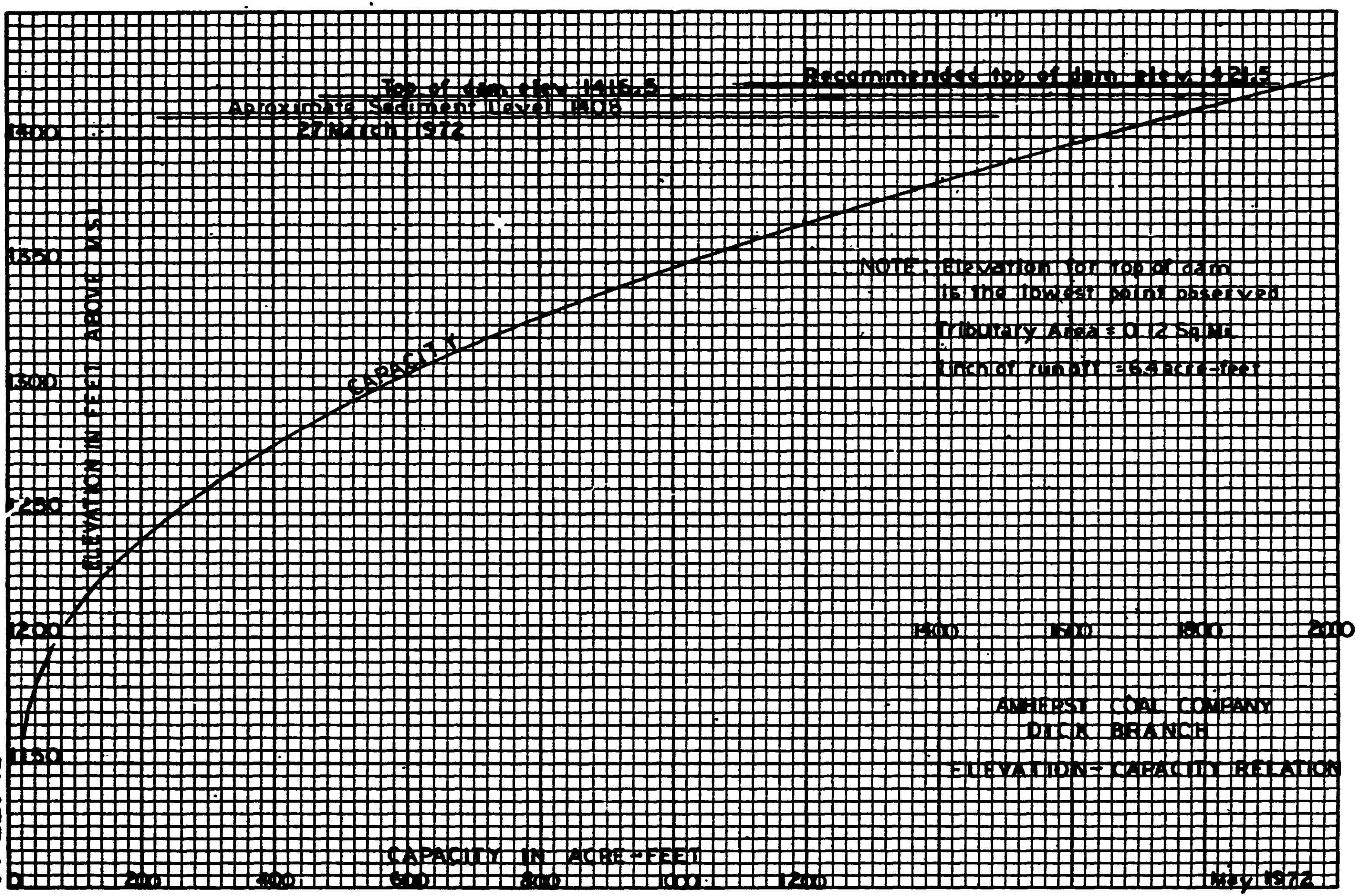
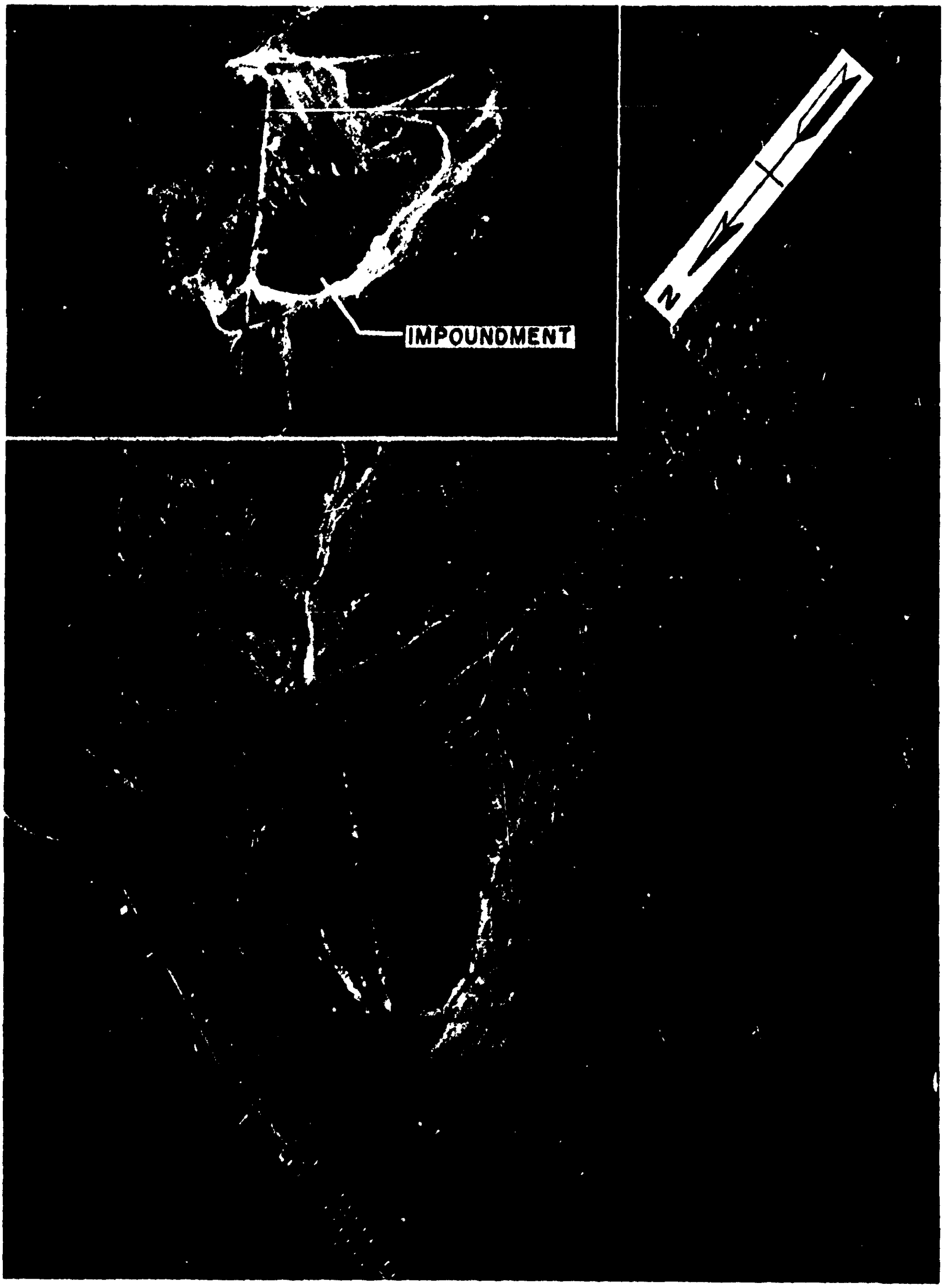

AMHERST COAL CO.
DICK BRANCH
2-FOOT DIAMETER DROP INLET
STAGE-DISCHARGE RELATION
May 1972
WATER SURFACE ELEVATION IN FEET ABOVE MSL
1412
1413
1414
1415
1416
HEAD IN FEET
0
1
2
3
4
10
20
30
FLOW IN CFS

PLATE 13

PLATE 14



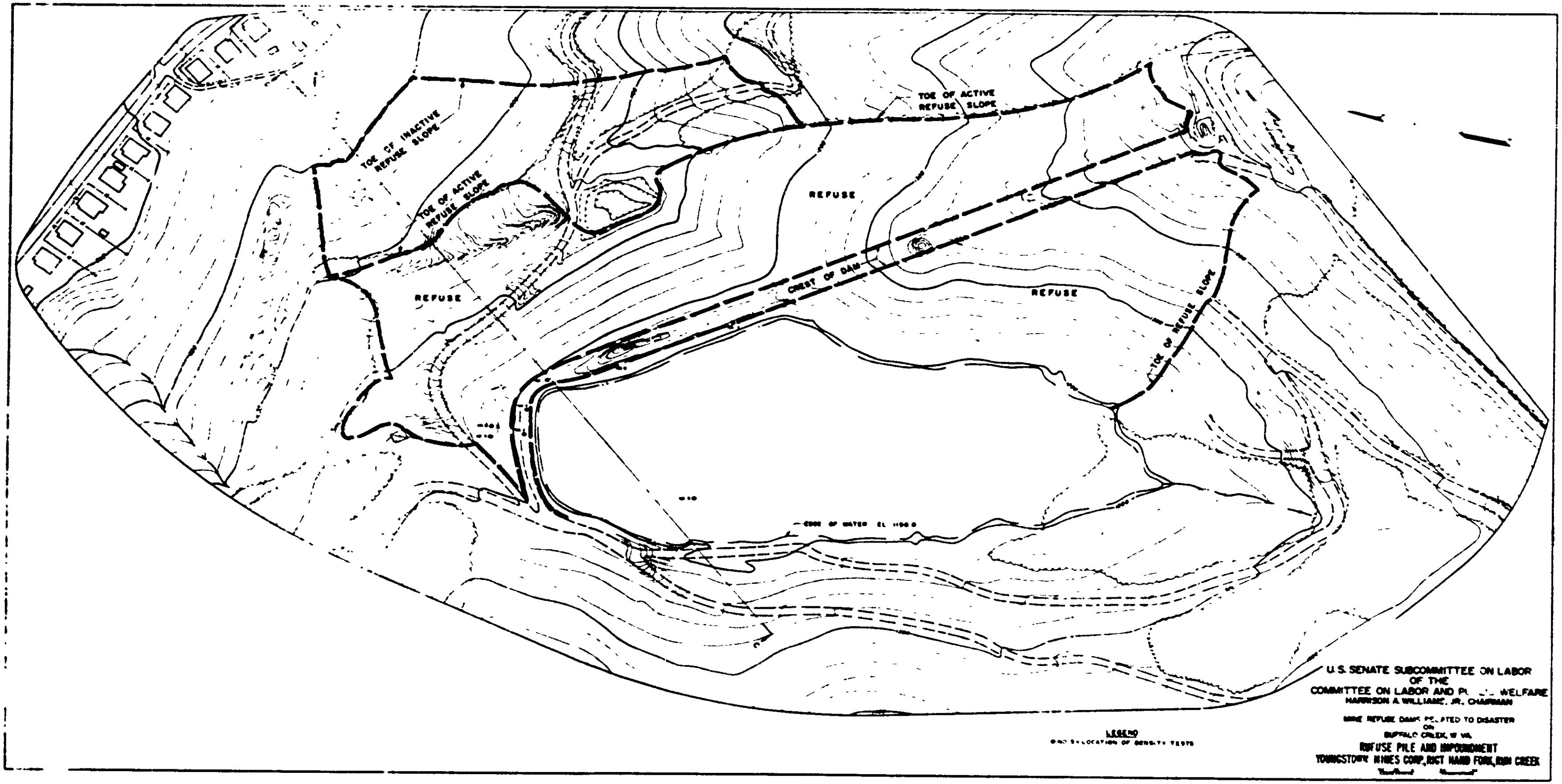
Top of dam elev 1416.5
Recommended top of dam elev 1421.5
Aproximate Sediment Level 1408
27 March 1972
1400
1350
1300
1250
1200
1150
ELEVATION IN FEET ABOVE M.S.L.
CAPACITY
NOTE: Elevation for top of dam
is the lowest point observed
Tributary Area = 0.12 Sq.Mi.
1 inch of runoff = 6.4 acre-feet
1400
1600
1800
2000
AMHERST COAL COMPANY
DICK BRANCH
ELEVATION - CAPACITY RELATION
CAPACITY IN ACRE-FEET
0
200
400
600
800
1000
1200
May 1972

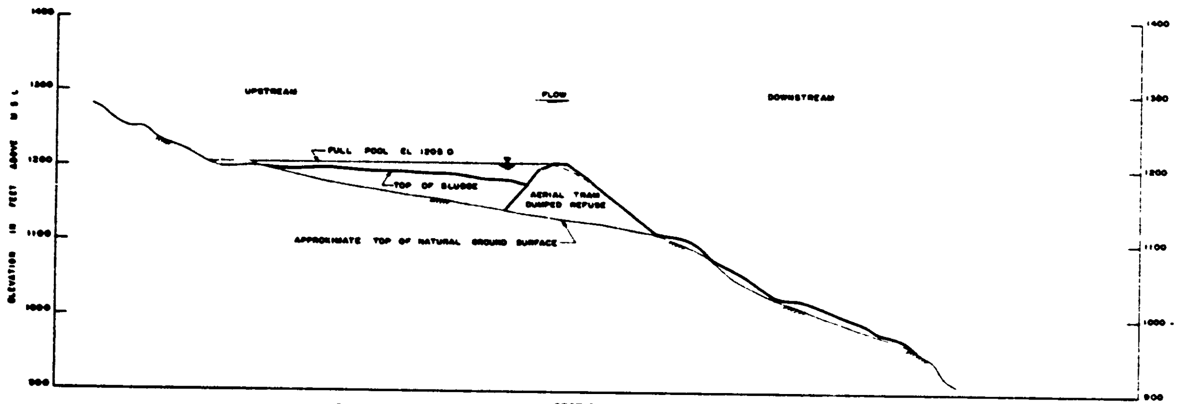


AERIAL VIEW AND PHOTO OF
REFUSE PILE AND IMPOUNDMENT
YOUNGSTOWN MINES CORP.
RIGHT HAND FORK, RUM CREEK

PLATE NO. 15

78-620 O - 72 - 15

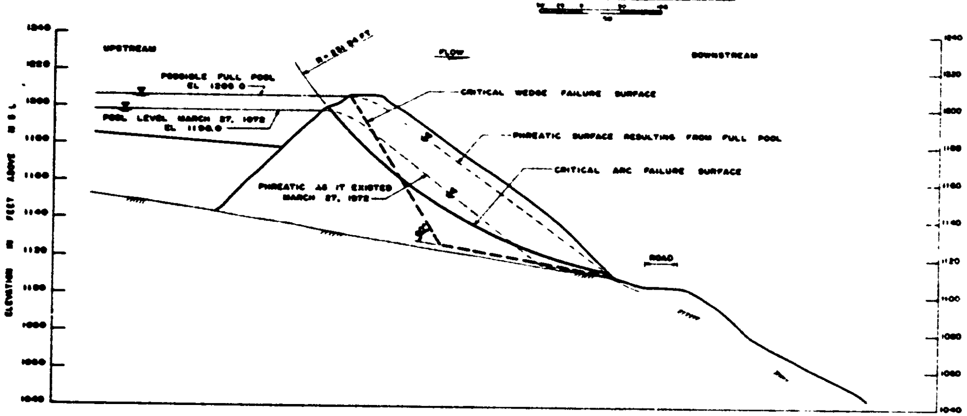

TOE OF INACTIVE REFUSE SLOPE
TOE OF ACTIVE REFUSE SLOPE
TOE OF ACTIVE REFUSE SLOPE
REFUSE
REFUSE
REFUSE
CREST OF DAM
TOE OF REFUSE SLOPE
U.S. SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A. WILLIAMS, JR., CHAIRMAN
MINE REFUSE DAMS RELATED TO DISASTER
ON
BUFFALO CREEK, W. VA.
REFUSE PILE AND IMPOUNDMENT
YOUNGSTOWN MINES CORP., RICT HAND FORK, RUN CREEK
LEGEND
PLATE NO. 16



SECTION C-C

YOUNGSTOWN MINES CORP.

DEHUE MINE REFUSE IMPOUNDMENT



STEADY SEEPAGE CASE

SECTION C-C FAILURE ANALYSIS

			MATERIAL	
			REFUSE	SLUDGE
UNIT WEIGHTS (K/FT³)		MOIST	0.1235	0.0822
		SATURATED	0.1240	0.0822
		SUBMERGED	0.0616	0.0196
STRENGTHS	R	Ø (DEGREES)	33.6°	29.2°
		C (TSF)	1.6	0.3
	S	Ø (DEGREES)	26.7°	26.0°
		C (TSF)	0.0	0.0

	FACTORS OF SAFETY	
	MARCH 27 1972 CONDITION	FULL POOL CONDITION
CRITICAL ARC	0.919	0.863
CRITICAL WEDGE	0.934	0.890

U.S SENATE SUBCOMMITTEE ON LABOR
OF THE
COMMITTEE ON LABOR AND PUBLIC WELFARE
HARRISON A. WILLIAMS, JR., CHAIRMAN

MINE REFUSE DAMS RELATED TO DISASTER
ON
BUFFALO CREEK, W. VA

SLIDING STABILITY INFORMATION
YOUNGSTOWN MINES CORP. RIGHT HAND FORK, RUM CREEK

PLATE NO. 17

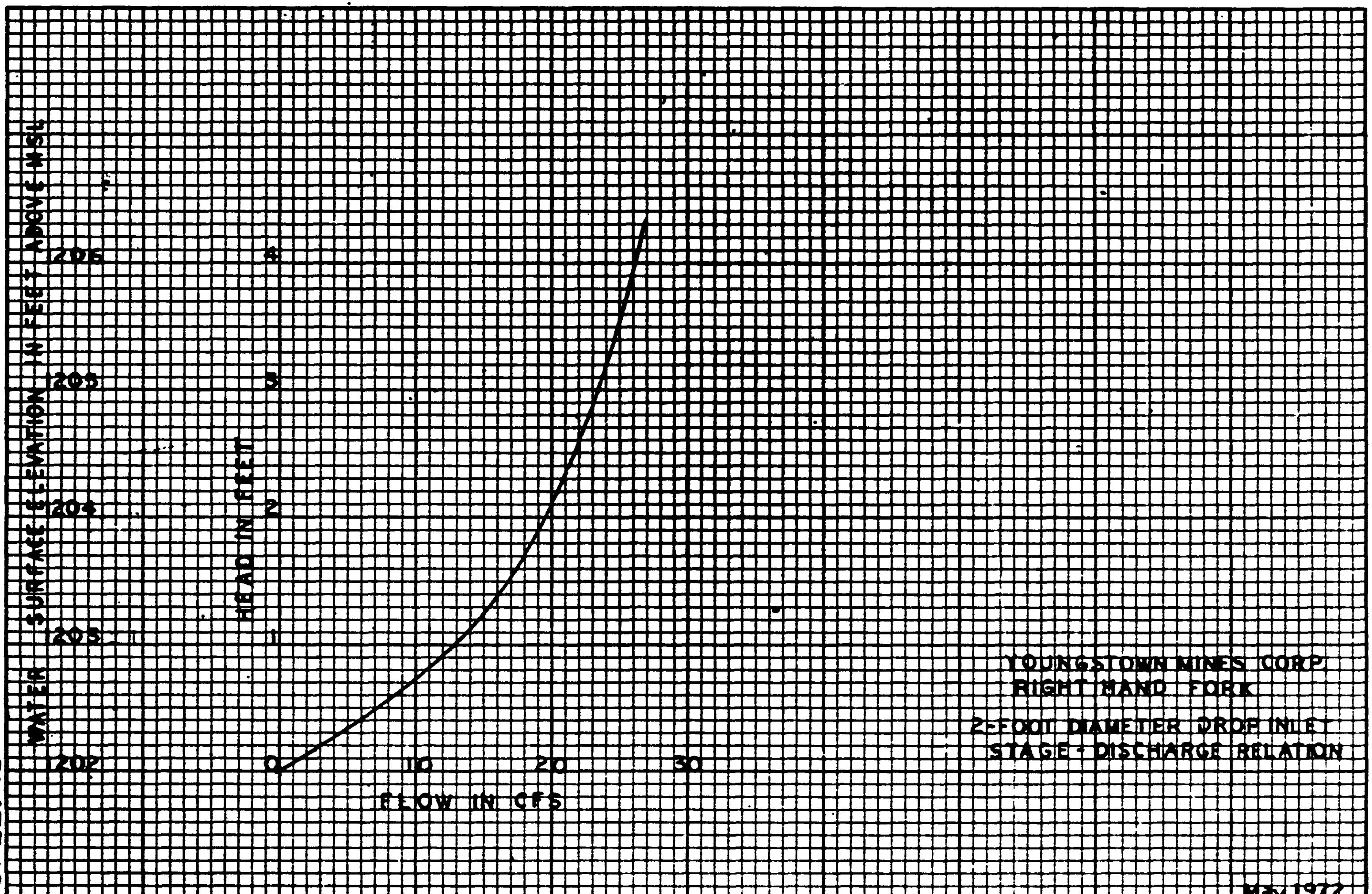

WATER SURFACE ELEVATION IN FEET ABOVE MSL
1206
1205
1204
1203
1202
HEAD IN FEET
4
3
2
1
0
10
20
30
FLOW IN CFS
YOUNGSTOWN MINES CORP.
RIGHT HAND FORK
2-FOOT DIAMETER DROP INLET
STAGE - DISCHARGE RELATION
May 1972

PLATE 18

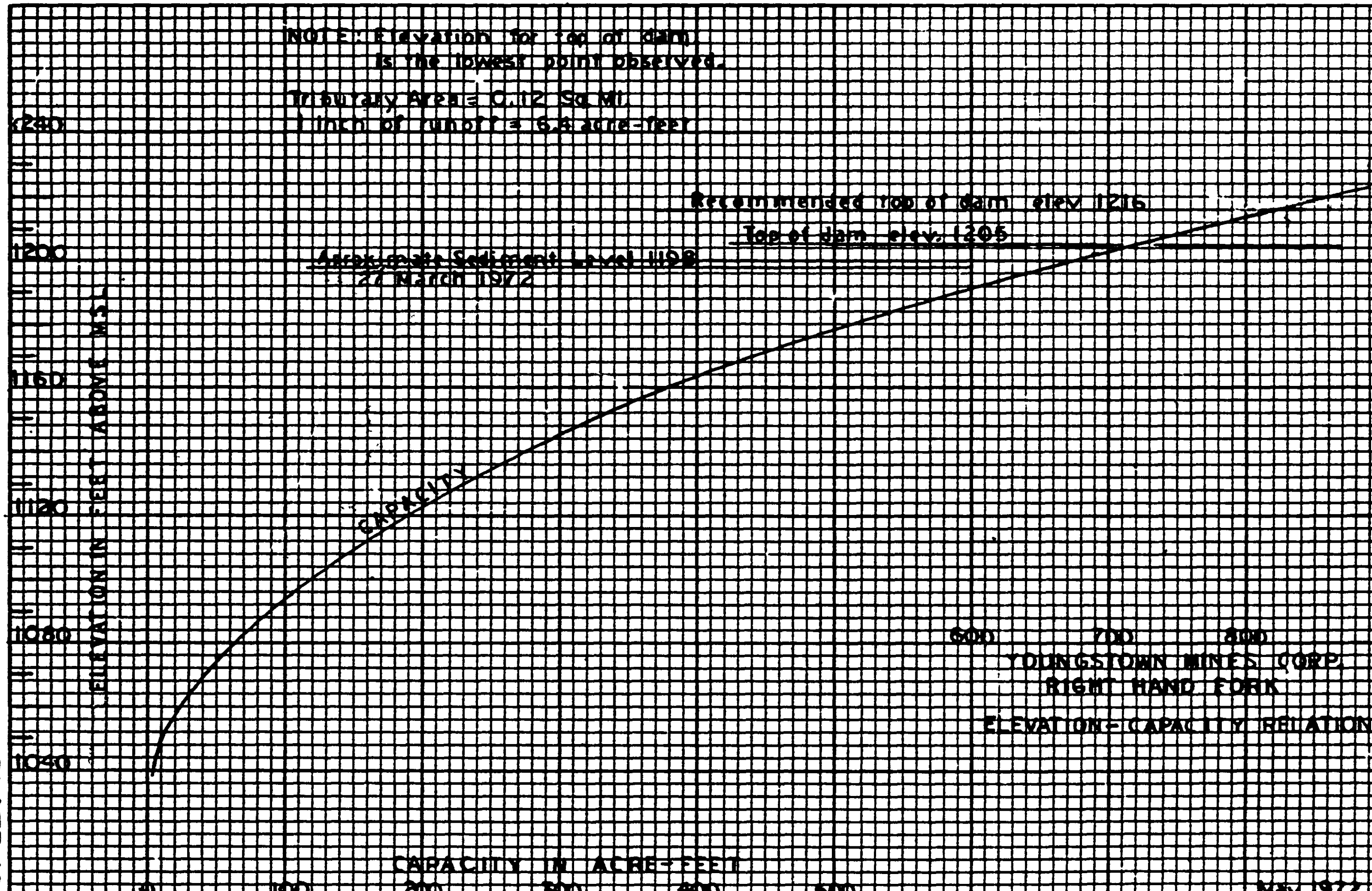

NOTE: Elevation for top of dam
is the lowest point observed.
Tributary Area = 0.12 Sq. Mi.
1 inch of runoff = 6.4 acre-feet
Recommended top of dam elev 1216
Top of dam elev. 1205
Approximate Sediment Level 1198
27 March 1972
CAPACITY
ELEVATION IN FEET ABOVE M.S.L.
1240
1200
1160
1120
1080
1040
CAPACITY IN ACRE-FEET
0
100
200
300
400
500
600
700
800
YOUNGSTOWN MINES CORP.
RIGHT HAND FORK
ELEVATION-CAPACITY RELATION
May 1972

PLATE 19

SOIL TEST DATA SUMMARY

PROJECT: Mine Waste Dam Investigation SHEET 1 OF 1

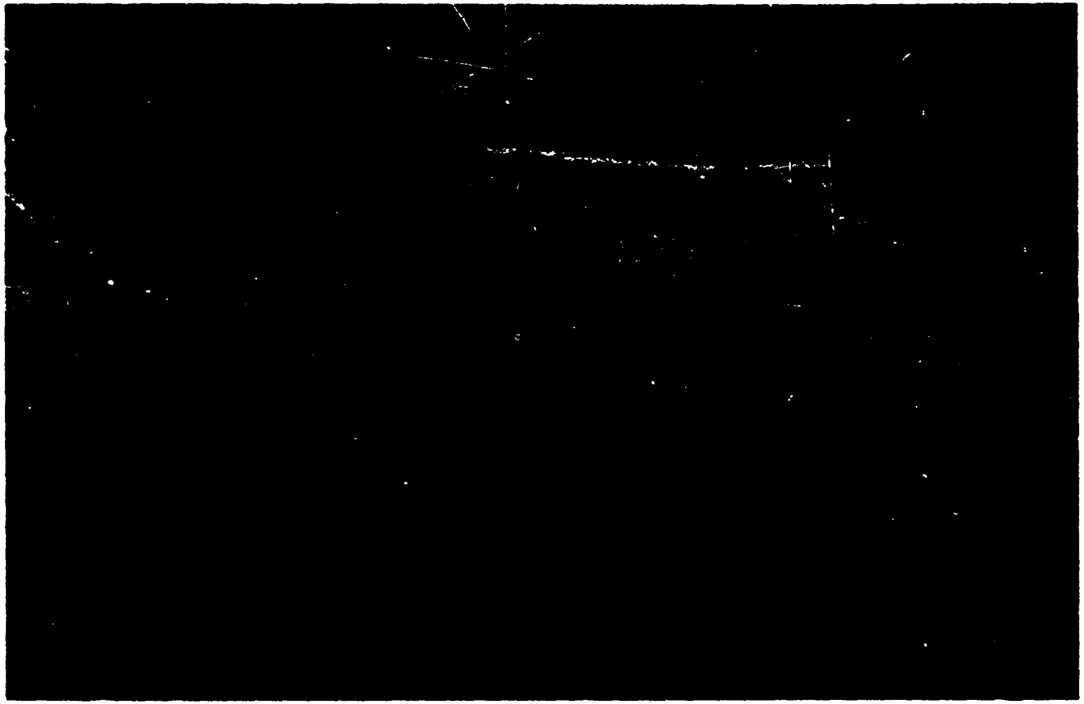
FEATURE: Physical Characteristics DATE: May 1972

BORING NO.	SAMPLE NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS: GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS: LL	PL	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS/CU FT	SPECIFIC GRAVITY	COMPACTION DATA: OPT. WATER %	MAXIMUM DRY DENSITY LBS/CU FT	SHEAR DATA: DRY DENSITY LBS/CU FT	SAT. WATER %	TYPE TEST	C T/SQ FT	TAN ø	ø DEG.	MAXIMUM SHEAR T/SQ FT	PERMEABILITY DATA: LOAD T/SQ FT	K_V, 10^{-4} FT/MIN	K_H, 10^{-4} FT/MIN	CONSOL DATA C_C	REMARKS
BUFFALO CREEK																										*+#4=14.9, -#4=6.7
	2		Silty Gravelly SAND	44	46	10				11.3*		1.73**			80.9	11.7	R	.40	.535	28.1			8.8 (γd= 50pct)			** -#4=1.58 (4 tests)
			(SP-SM)												60.1	15.7	S	-	.600	31.0						+#4=1.93
			(50% coal, 49% shale)																							
	9 & 10 (Comp)		Sandy SILT(ML)	-	44	56				36.1		1.48			48.7	34.3	Q	.10	.250	14.0			3,600 (γd = 48 pct)			
			(coal fines)												48.8	36.3	R	.60	.330	18.2						
															48.4	35.1	S	-	.548	28.7						
AMHERST																										
	9		Silty Gravelly SAND	11	83	6				10.1		2.38*			112.2	9.2	Q	.40	.330	18.2						*Two tests
			(SW-SM)												110.8	10.7	R	2.00	.165	9.4						
			(90% Shale, 8% coal)												112.0	9.5	S	-	.593	30.7						
POMELITON	20		Sandy SILT(ML)	1	32	67				31.1		1.42			48.6	30.2	Q	.30	.230	13.0						
			(coal fines)												49.4	31.4	R	.30	.470	25.2						
															46.4	33.5	S	-	.555	29.0						
YOUNGSTOWN																										
	3		Silty Sandy GRAVEL	56	34	10				8.2		2.17*			114.4	8.1	R	1.60	.670	33.8					.065	* -#4= 2.25
			(GP-GM)												104.1	15.6	S	-	.548	28.7						+#4: coal= 1.49, Shale = 2.58
			(43% coal; 55% shale)																							
	2 & 4 (Comp)		Sandy Clayey GRAVEL	40*	29*	31*		28.3*	18.6*	12.0*		2.67			103.3	22.0	S	-	.480	25.8					0.15	*Two tests each
			(GC)																							
ISLAND CREEK																										
	1 & 4 (Comp.)		Silty Sandy GRAVEL	63	31	6				7.7		2.23*			95.9	8.6	R	0.50	.600	31.0			640 (γd= 100 pct)			*Bag #1 +#4= 2.32
			(GP-GM)												84.2	10.7	S	-	.500	29.2						-#4= 1.93
			(coal & shale)																							Bag #4 +#4= 2.46
																										-#4 = 1.97

ORD Form 873
6 Apr 67

T-Triaxial Compression
UC-Unconfined Compression
DS-Direct Shear
Q-Unconsolidated Undrained
S-Consolidated Drained
R-Consolidated Undrained

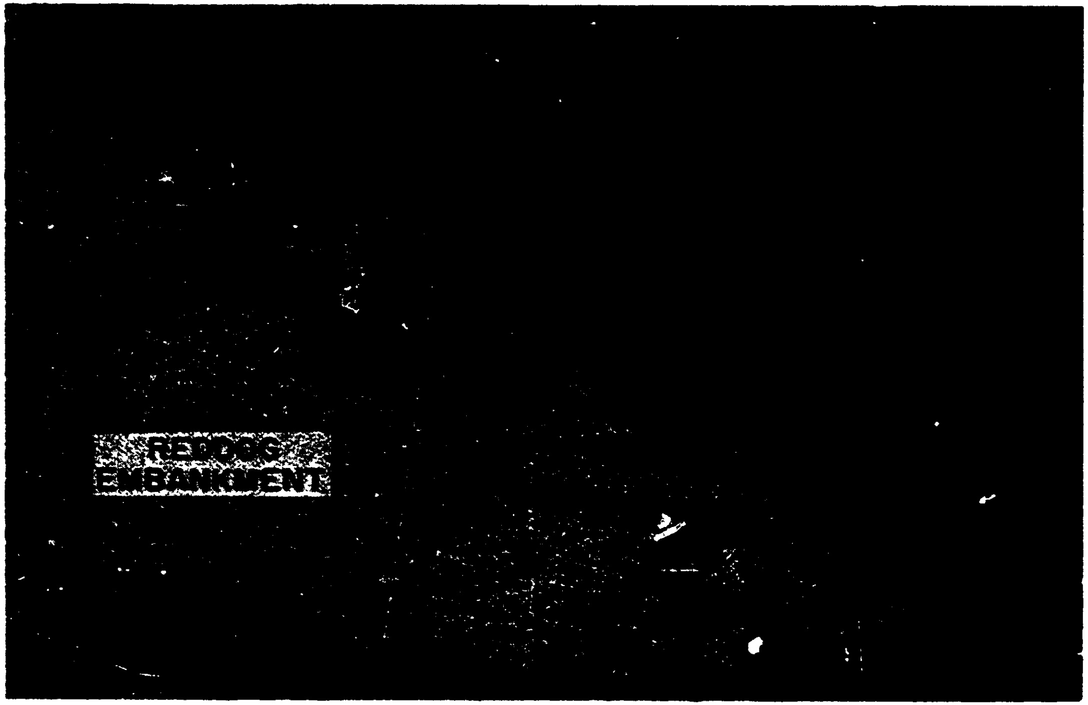
LAB
PLATE 20



INACTIVE BREACHED REFUSE DAMS
LEFTHAND FORK, ROCKHOUSE CREEK

PLATE NO. 21

PLATE NO. 23



INACTIVE BREACHED REFUSE DAMS
BINGO HOLLOW

PLATE NO. 22

INACTIVE BREACHED REFUSE DAMS
ETHEL, W. VA.