APPENDIX D - TRIAD Report

A copy of the report prepared for MSHA by TRIAD Engineering, Inc., is provided on the following pages. This copy of the TRIAD report has been reformatted to appear in this text as closely as possible to the original printed version. Due to the large size of this Appendix, the full text is available only in the digital version of the MSHA Report of Investigation.

FINAL REPORT

SUBSURFACE INVESTIGATION

BIG BRANCH SLURRY IMPOUNDMENT
MARTIN COUNTY, KENTUCKY

TRIAD PROJECT NO. C00553

Prepared on behalf of:

UNITED STATES DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION

Prepared by:

TRIAD ENGINEERING, INCORPORATED
St. Albans, West Virginia

MARCH 2001

TRIAD ENGINEERING, INC.

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MARCH 2001

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March 30, 2001

United States Department of Labor
Mine Safety and Health Administration
1301 Airport Road
Beaver, WV 25813-9426

Attention: Mr. Jack Spadaro, Superintendent

Subject: **SUBSURFACE INVESTIGATION**
Big Branch Slurry Impoundment
Martin County, Kentucky
Triad Project No. C00553

Dear Mr. Spadaro:

In accordance with your request, Triad Engineering, Inc. has performed a subsurface investigation of the suspected breakthrough area for the subject project located on the facilities of Martin County Coal Corporation near Inez, Kentucky. Authorization to proceed with the investigation was provided by Contract No. J2R12004 dated November 17, 2000.

Presented in this report are the results of the field and laboratory investigation performed to determine the subsurface conditions at the subject site, as well as our interpretations and conclusions from the data.

We appreciate the opportunity to have assisted you on this project and trust this report satisfies your needs at this time. Please feel free to contact us if you have any questions concerning this report, or if we can provide any further assistance.

Very truly yours,

TRIAD ENGINEERING, INC.

Charles E. Montgomery, P.G.
Project Geologist

John E. Nottingham, P.E.
Senior Engineer

Larry C. Nottingham, Ph.D., P.E.
Principal Engineer

PROJECT DESCRIPTION

The project consists of a subsurface investigation of a portion of Martin County Coal Corporation's Big Branch coal slurry impoundment located near Inez, Kentucky. A breakthrough of the 68-acre impoundment occurred on October 11, 2000, whereby approximately 300 million gallons of coal slurry discharged into adjacent abandoned underground mine workings and ultimately into the nearby watersheds of Coldwater Fork and Wolf Creek. The mine workings are part of the 1-C Mine, located within the Coalburg Coal seam, which outcrops approximately 90 to 100 ft. below the pre-breach slurry level within the impoundment. Test borings were drilled by Triad personnel as part of a subsurface investigation to determine the location and cause of the slurry breakthrough into the mine workings. The boring locations were specified by Mine Safety and Health Administration (MSHA) personnel and located in the field by a Triad survey crew. A site plan showing the boring locations is provided on Drawing No. C00553-1.

SUBSURFACE INVESTIGATION

The subsurface investigation consisted of forty seven (47) test borings drilled in the slurry impoundment as shown on Drawing No. C00553-1. Four lines of borings were located along the centerline of four mine entries thought to be closest to the slurry breakthrough location. For the purposes of the investigation and in this report, these entries are referred to as Entry No. 1, Entry No. 2, Entry No. 3, and Entry No. 4. Borings were designated according to which line they were located along, i.e., DH3-4 would designate the fourth drill hole located along line or Entry No. 3. Borings located outside of these lines or areas were designated with an "X", i.e., DHX-1.

The borings were advanced to depths ranging from 84.4 ft. to 120.1 ft. below the existing ground surface. Prior to drill rig mobilization, a drill pad had been constructed by Martin County Coal Co. personnel along the edge of the impoundment in the general vicinity of the suspected slurry breakthrough. The pad was constructed with coarse coal refuse and other available onsite spoil material.

Full time inspection for each drill rig was provided by Triad's onsite geologist(s). The borings were advanced using two rubber tire-mounted ATV rotary drill rigs. The borings were advanced through the unconsolidated overburden material using 3.25 in. I.D. hollow stem augers or 4 in. I.D. flush-joint casing. Standard penetration testing and sampling was performed in selected borings within the unconsolidated overburden material through the hollow stem augers or casing at designated intervals. The standard penetration testing and sampling was performed in accordance with ASTM D 1586. Standard penetration testing is performed by driving a 2.0-in. O.D. split-barrel sampler into the soil with a 140-lb. hammer dropping a distance of 30 inches. The sampler is driven a distance of either 18 or 24 inches in three or four 6-inch increments and the number of blows required to produce the second and third 6-inch increments of penetration is termed the Standard Penetration Number or "N" value. These values provide an indication of the consistency or relative density of the soil. In Boring DH2-9, a portion of the unconsolidated overburden material was sampled using a 3-in. O.D. split-barrel sampler. In addition to standard penetration testing, undisturbed (Shelby tube) 3-in. I.D. samples were procured within the overburden material in designated borings at various depths.

Continuous core samples of bedrock were obtained in most of the borings using an NQ double tube core barrel equipped with a diamond-impregnated bit in accordance with ASTM D2113. Following completion of drilling, most of the borings in which mine voids were encountered were cased to bedrock with 2 in. I.D. flush-joint PVC pipe to enable sampling of the mine void material and allow video photography of the borings. The PVC casing prevented the caving of unconsolidated material into the open boreholes.

Following completion of drilling, all coreholes were sealed with a Portland cement grout from the bottom of the boring to the top of rock. The remainder of the borings were backfilled with auger cuttings. In borings in which a void was encountered, a plug was installed above the void to prevent loss of grout into the mine opening. Following installation of the plug, the coreholes were grouted to the top of rock or above, followed by auger cuttings to the top of ground.

Sampling of the material encountered within the mine workings was also conducted using various methods. These include:

- 2 in. split barrel sampler w/plastic trap
- 2 in. split barrel sampler w/butterfly and flap valve
- 3 in. split barrel sampler w/ plastic trap
- 3 in. split barrel sampler w/flap valve
- 2 in. PVC sampler w/butterfly and flap valve
- 1.5 in. PVC sampler w/plastic trap
- 1.5 in. PVC sampler w/flap valve

All split spoon, rock core, and mine void samples were visually classified in the field by Triad's onsite geologists. Split spoon samples were placed in air-tight glass jars. Rock core samples were placed in partitioned wooden boxes. Mine void samples were placed in zip-lock plastic bags. All samples were delivered to the Triad laboratory in Scott Depot, West Virginia.

Groundwater level observations were made by our geologists during drilling operations, at drilling completion, and at various times thereafter. Groundwater observations are presented on the boring logs and are discussed in the "Subsurface Conditions" section of this report. The results of the subsurface investigation are provided on the boring logs (Figures 1 through 189).

LABORATORY TESTING

Laboratory tests were performed on the selected rock core, mine void, and undisturbed (Shelby tube) samples to generally classify and evaluate the materials. These tests consisted of:

- Atterberg Limits Testing
- Grain Size Distribution
- Triaxial Shear Strength
- Unit Weight
- Permeability
- Specific Gravity
- Uniaxial Compressive Strength (rock core)
- Modulus of Rupture (rock core)

Atterberg limits testing, grain size distribution, unit weight, and specific gravity determination aid in classification of the material and provide a basis for estimating their engineering properties. Triaxial shear, uniaxial compression, and modulus of rupture testing provide a basis for evaluating the strength of tested materials. Permeability testing was performed to determine the coefficient of permeability of the suspected seepage barrier material as well as natural ground material. The results of the lab testing are presented on the boring logs (Figure Nos. 1 through 189) as well as in Appendix A.

In addition to testing of the samples obtained from the borings, the grain size distribution was determined for a bulk sample of material weighing approximately 950 lbs. The material was excavated using a bulldozer and placed in sample bags for delivery to our laboratory. It is our understanding the material is representative of that which was used to construct a seepage barrier around a portion of the slurry impoundment.

Chemical analysis of selected slurry samples was performed by CT & E Environmental Services, Inc. of Charleston, West Virginia. The slurry samples consisted of material sampled from the mine void and "grab" samples obtained by MSHA personnel from various locations. The results of the chemical analysis are provided in Appendix B. The following is a summary of the samples selected for chemical analysis:

- Grab sample from Big Branch Slurry Impoundment
- Two samples from mine void in Boring DH2-9
- Grab sample from Wolf Creek
- Grab sample from Coldwater Creek
- Sample from mine void in Boring DH1-11

SURVEYING AND MAPPING

Surveying and mapping of the project site was conducted by Triad personnel employing conventional land surveying techniques. All traverse runs were "closed loop" using the direct angle measurement and closed horizon technique. Our average error of closure was 1 ft. in 100,000 ft. The surveying instrument used for the project was a Topcon GTS-311 Total Station Theodolite in combination with a Hewlett-Packard 48GX calculator equipped with SMI Version 6 CVCE software for data collection. The traverses were run using Topcon single prizms on fixed-target tripods.

Prior to commencement of drilling activities, locations and coordinates of Global Positioning System (GPS) control points used by Martin County Coal Corporation were provided to our survey personnel. It is our understanding these control points have been used by Martin County Coal for layout of their mining operations. Our survey crew verified these control points by checking bearing and distance between the points. These were also checked with recently established control points located on the property. The survey control information provided by Martin County Coal was found to be accurate.

At the request of MSHA personnel, the survey data was further verified by locating existing structures, entries, and ribs in the North Portals #1 area. These features located by the Triad survey crew accurately reflected information provided on Martin County Coal mine maps for the area.

Following verification of two older control points (MC #1 and #4462) that had been used to establish the aforementioned GPS points, new control points were established by Triad for the subsurface investigation prior to beginning drilling operations. A portion of the mine workings in the suspected failure area was then surveyed and outlined on the ground surface and several pre-determined boring locations were established. Our survey crew returned to the site periodically to locate additional borings as they were drilled.

GEOPHYSICAL INVESTIGATION

A mise-a-la-masse electrical profiling survey of the project area was conducted by Enviroscan, Inc. This method was employed in an attempt to locate the breakthrough area by energizing the mine workings by way of an electrode placed in one of the borings and mapping the electrically conductive subsurface body. The geophysical field work was conducted during the course of drilling activities by Triad. As such, several borings which were completed following the survey are not depicted on the drawings provided by Enviroscan. A copy of the geophysical report is provided in Appendix C of this report. As can be seen in the report, two primary electrical peaks or anomalies were detected during the course of Enviroscan's investigation. One peak was located adjacent to (outside) the south rib of Entry No. 1. A larger anomaly was detected near the northern edge of one of the pillars between Entry Nos. 2 and 3. Borings were drilled in these areas to investigate the findings of the electrical survey and are further discussed in the "Subsurface/Geologic Conditions" section of this report.

SUBSURFACE/GEOLOGIC CONDITIONS

General Overview

Rock strata in the area belong to the Breathitt Group, Princess Formation of the Pennsylvanian System. The two coal seams of primary importance at the project site are the Stockton and Coalburg Coals. These seams are included within the Broas Coal Zone and the Peach Orchard Coal Zone, respectively, as identified in Kentucky geological nomenclature. Both seams have been extensively mined in the area. The Stockton Coal, which is located approximately 100 to 125 ft. above the Coalburg Coal, lies just above the surface elevation of the slurry pond. The failure occurred when slurry broke through and discharged into mine workings in the Coalburg seam, located 90 to 100 ft. below the slurry level.

Massive sandstone units are present above the Stockton Coal and between the Stockton and Coalburg Coals. The stratum of sandstone above the Stockton Coal is exposed in the highwall adjacent to the Big Branch slurry impoundment. In appearance, it is generally gray, weathering to brown, and medium grained. It appeared to be approximately 150 to 200 ft. thick in some locations where it was exposed. Regularly spaced joints, essentially vertical, were observed throughout exposed portions of this stratum at the project site. The stratum of sandstone between the Stockton and Coalburg coals is generally gray, massive in character, and medium to coarse grained. A stratum of shale is sometimes present at the base of this sandstone and above the Coalburg Coal. This stratum was generally absent in borings which encountered a mine void. It is likely the shale was taken as "draw rock" during the mining process or may have sloughed off.

Site Conditions

As was previously mentioned, a drill pad had been constructed for the investigation prior to mobilization of the drill rigs. It is our understanding the pad was constructed with readily available spoil material consisting of a mixture of sand, clay, and sandstone fragments of varying size. This material was capped with a layer of coarse coal refuse. Standard penetration testing and sampling indicate the two layers of fill material were variable in thickness, but generally increased in thickness away from the former edge of the slurry pond.

According to information provided by MSHA personnel, a seepage barrier had been placed on the hillside around a portion of the slurry impoundment by Martin County Coal in 1995. One of the original objectives of the subsurface investigation was to delineate the seepage barrier and determine its extent and thickness in the area of the breakthrough. However, because the seepage barrier was constructed of the same material as the spoil that was used to construct the drill pad, no clear distinction between the two layers could be inferred from the drilling. However, a denser layer of soil beneath the spoil could be discerned and was identified by consistently higher standard penetration blow counts and an overall more uniform appearance than the fill above it. This separate layer is thought to be original or natural ground and is depicted on Profiles A-A through D-D (Drawing Nos. C00553-2 through C00553-5, respectively).

Entry No. 1

A total of 13 borings (DH1-1 through DH1-13) were advanced near the centerline of Entry No. 1 (please see Drawing No. C00553-1 for boring locations). Several additional borings were drilled in areas immediately adjacent to Entry No. 1 to further delineate subsurface conditions in this area. These included DHX-1 through DHX-9, DHX-11 through DHX-13, and DHX-16. Along Entry No. 1, the top layer of coarse coal refuse encountered at the ground surface ranged in thickness from less than one foot to approximately 60 ft. Many of the borings were advanced through this layer of material to the underlying layer of fill material without sampling.

Beneath the coarse refuse, a layer of fill material was encountered which extended to depths ranging from approximately 26 to 74 ft. below the existing ground surface. This fill consisted of a mixture of brown and gray clay, sand and sandstone fragments. Standard penetration testing indicates the fill layer below the coarse coal refuse is highly variable in composition and density, with some samples consisting of nearly all sandstone fragments while others consisted mostly of cohesive material. Groundwater was encountered within this layer in most of the borings. Drawing No. C00553-2 illustrates the depths at which groundwater was encountered during drilling operations.

Beneath the fill, a stratum of brown clayey sand was encountered which appeared to be natural ground. The layer extended to the top of bedrock in most of the borings. Standard penetration testing "N" values were consistently higher within this layer, and the material itself was more consistent in appearance and composition than the overlying fill material. Sandstone fragments increased in percentage and size as depth increased, with sandstone boulders often being encountered in the lower horizon of this soil stratum.

Sandstone bedrock was encountered at depths ranging from approximately 26 ft. (elev. 1031.8 ft.) in Boring DH1-11 to 81 ft. (elev. 971.4 ft.) in Boring DH1-1. Borings DH1-6, DH1-7, and DH1-9 were drilled beyond the extent of the mine roof sandstone. A zone of weathering was observed at the top of the sandstone in many of the borings, varying in extent. The weathered portion of the sandstone was generally brown in color and less hard than the unweathered material. The majority of the sandstone was gray and medium grained in texture, with occasional carbonaceous and shale laminations as noted on the boring logs.

The sandstone was underlain by either the Coalburg Coal or the mine workings in the coal seam. In a few of the borings, a thin layer of shale was present above the Coalburg Coal. The top of the mine void was generally encountered between the elevations of 967 and 969 ft., with the exception of Boring DH1-10, in which a void was encountered at an elevation of approximately 971.5 ft. The top of the mine was denoted during the drilling process by a decrease in drilling water circulation pressure and/or a sudden drop in the drilling tools as they advanced during the coring process. These depths as measured during drilling were subsequently checked with core recovery for verification. After encountering the void, the drilling rods were allowed to advance, without rotation, to the floor of the mine, which was encountered at elevations ranging between approximately 957 and 959 ft. If the drilling rods encountered resistance within the void before reaching the level of the mine floor because of boulders, mine rubble, etc., rotation was resumed. The mine floor was composed of soft gray clay shale which graded into sandstone.

As can be seen in Drawing C00553-1 and C00553-2, Boring DH1-1, DH1-6, DH1-7, DH1-9, and DH1-10 were drilled in areas beyond the limits of mining as depicted on Martin County Coal mine maps, but within the zone designated as part of the outcrop barrier. In Boring DH1-10, advanced approximately 5 ft. beyond the depicted limits of mining, a void was encountered at the horizon of the Coalburg seam. In Boring DH1-1, drilled approximately 12 ft. beyond the depicted limits of mining, approximately 1.2 ft. of broken coal was recovered from the Coalburg horizon. The drill rig operator indicated that the tools advanced erratically at the elevation of the coal seam. It was initially suspected that poor core recovery in a weathered/broken zone of coal was responsible for the small amount of coal recovered, however, as will be explained later, subsequent borings drilled in immediately adjacent areas indicated that a significant portion of the coal seam was missing from this area.

In Boring DH1-7, approximately 6.5 ft. of coal was encountered. At this location, however, it appears that the Coalburg seam is not entirely present because the seam is thinning at the outcrop. There was no sandstone overlying the coal at this point. This was confirmed in Boring DH1-6, in which less than a foot of coal was encountered. Approximately 1.9 ft. of coal slurry or "filter cake" was recovered immediately above the coal in this boring. Standard penetration testing was conducted at five foot intervals in DH1-6, starting at a depth of 35 ft.

Each test extended 18 inches (except in those encountering "refusal" on a boulder or obstruction). Between the depths of 85 and 88.3 ft., continuous sampling of the material was conducted. Following split spoon refusal at a depth of 88.3 ft., continuous rock coring was conducted to the termination depth of 99.8 ft. As in the case of Boring DH1-7, there was no sandstone overlying the Coalburg Coal. In Boring DH1-9, the bedrock surface (shale) was encountered at an elevation of 958.6 ft., or at the approximate base of the Coalburg horizon. The rapid diminishing of the coal seam at the outcrop is demonstrated between Borings DH1-7, DH1-6, and DH1-9 as shown on Profile A-A on Drawing No. C00553-2.

As was previously mentioned, several "X" borings were advanced in areas adjacent to Entry No. 1 in an attempt to further delineate subsurface features encountered in the area. Borings DHX-3 through DHX-6 and DHX-8 and DHX-9 were drilled near the end of Entry No. 1 to confirm areas of missing coal. Borings DHX-12 and DHX-13 were advanced to better define the Coalburg outcrop.

In Borings DHX-4, DHX-5, and DHX-8, portions of the Coalburg Coal were found to be absent. In Boring DHX-4, drilled adjacent to Boring DH1-1, continuous split spoon sampling was conducted from a depth of 65 to a depth of 91.2 ft, where split spoon refusal was encountered at the top of rock. Standard penetration testing "N" values indicated the material between the coarse coal refuse and the top of rock was very soft. At several sample intervals, the sampler advanced under the weight of the drilling rods without hammering. Coal slurry was also found to be present in many of the samples. This material was found to be present to the depth at which split spoon refusal was obtained in the Coalburg Coal. The original/natural ground material encountered in other borings was absent at this location, as was the stratum of sandstone above the coal. Split spoon refusal was obtained in the Coalburg Coal at a depth of 91.2 ft. (elevation 960.6 ft.). Only approximately 2 ft. of coal was present at this location. This boring served to confirm the data obtained from the adjacent Boring DH1-1, in which very little coal was recovered. The continuous sampling conducted in Boring DHX-4 confirms that the sandstone roof and most of the Coalburg Coal are absent at this location. Nearly identical conditions were encountered in Boring DHX-8, advanced in a similar method as DHX-4. Again, the layer of original/natural ground was absent, as was the sandstone roof and most of the Coalburg Coal. Split spoon refusal was obtained in the coal at a depth of 90 ft. (elev. 961.4 ft.). Approximately 3 ft. of coal was present at this location. In Boring DHX-5, the sandstone roof was present, as was the layer of original ground. A void was encountered at the base of the sandstone, however, with only approximately 1.2 ft. of coal present at the bottom of the void.

In several of the borings drilled along Entry No. 1, sandstone boulders/fragments were encountered within the mine void. These borings include DH1-3, DH1-4, DH1-10, and DHX-1.

The sandstone ranged in thickness from 0.5 ft. to 3.9 ft. The possible origin of these sandstone fragments will be discussed later in the "Conclusions" section of this report.

Profile A-A illustrates the subsurface conditions parallel to Entry No. 1. Profile D-D illustrates the conditions in this area as they appear perpendicular to the outcrop of the Coalburg Coal. The coal outcrop does not run perpendicular to the mine entries in this area, therefore, profiles drawn parallel to the entries exaggerate the thickness of the outcrop barrier.

Weighted tape measurements taken within the mine voids following drilling indicated that most of the void space was filled with soil and/or slurry. As was explained in the "Subsurface Investigation" section of this report, several methods were employed to sample the material within the void. However, the presence of cobble and boulder size material in the void (which was larger in diameter than the sampling devices) hindered sample recovery efforts. Table No. 1 presents a summary of sampling efforts within the mine void along and adjacent to Entry No. 1. Laboratory tests (including grain size analyses) were conducted on several of the samples listed in Table No. 1. The laboratory results are presented in Appendix A of this report.

TABLE NO. 1 - ENTRY NO. 1 MINE VOID SAMPLES

Boring No.	Sample Depth (ft.)	Sample Description
DH1-5	87.3 - 90.6	Brown Sand and Gravel
DH1-8	85.0 - 91.4	Brown Sand and Gravel
DH1-10	80.6 - 85.7	Brown Silty Sand with Gravel
DH1-11	91.8 - 95.8	Brown Sand with trace Gravel
DH1-11	92.6 - 96.2	Brown Silty Sand with Gravel
DH1-11	96.1 - 97.1	Coal Slurry and Sand
DH1-12	89.4 - 99.4	Brown Silty Sand with trace Coal Slurry, Gravel
DH1-12	90.1 - 99.7	Brown Silty Sand with trace Coal Slurry, Gravel
DH1-12	90.7 - 99.2	Brown Silty Sand with trace Gravel, Plant Roots
DH1-13	85.7 - 87.7	Brown and gray Silty Sand with Gravel
DH1-13	87.7 - 89.7	Brown and gray Silty Sand with Gravel

TABLE NO. 1 (CONTINUED)

Boring No.	Sample Depth (ft.)	Sample Description
DH1-13	89.7 - 91.7	Brown and gray Silty Sand with Gravel
DH1-13	91.7 - 93.7	Brown and gray Silty Sand with Gravel
DH1-13	93.7 - 95.6	Brown and gray Silty Sand with Gravel
DHX-1	89.4 - 91.9	Brown Silty Sand with Gravel
DHX-2	N/A	Coal Slurry, with Silty Sand and trace Gravel
DHX-5	79.7 - 82.7	Brown Sand

Entry No. 2

A total of nine borings (DH2-1 through DH2-9) were drilled near the centerline of Entry No. 2 (please refer to Drawing No. C00553-1 for boring locations). The general subsurface stratigraphy encountered along Entry No. 2 was essentially the same as along Entry No. 1. The Coalburg Coal, however, was found to be present at the end of the entry approximately as depicted by the mining limits on the Martin County Coal mine map provided to Triad.

As in the area of Entry No. 1, the coal barrier at the end of Entry No. 2 appears to be considerably thinner than that which is depicted on documents provided by Martin County Coal. In Borings DH2-4 and DH2-5, split spoon refusal on shale bedrock was obtained below the horizon of the Coalburg Coal. Drilling data indicates the coal seam thins out in the area between Borings DH2-5 and DH2-6. Approximately 3.5 ft. of outcrop coal was encountered in Boring DH2-6. Profile B-B (Drawing No. C00553-3) illustrates the subsurface conditions encountered in this area.

Mine void samples collected from borings along Entry No. 2 are described in Table No. 2.

TABLE NO. 2 - ENTRY NO. 2 MINE VOID SAMPLES

Boring No.	Sample Depth (ft.)	Sample Description
DH2-9	89.8 - 91.8	Coal Slurry with Sand and Gravel
DH2-9	91.8 - 93.8	Coal Slurry with Sand and Gravel

TABLE NO. 2 (CONTINUED)

Boring No.	Sample Depth (ft.)	Sample Description
DH2-9	93.8 - 95.8	Coal Slurry with Sand and Gravel
DH2-9	95.8 - 97.8	Sand and Gravel
DH2-9	97.8 - 99.9	Coal Slurry with Sand and Gravel

Entry No. 3

A total of four borings were drilled near the centerline of Entry No. 3 (Borings DH3-1 through DH3-4). Subsurface conditions encountered in the area of Entry No. 3 were similar to those encountered along Entry No. 2. The Coalburg Coal was found be intact at the end of the entry as depicted on mine maps provided to Triad. However, as in Entries No. 1 and 2, the thickness of the coal barrier is less than that depicted on Martin County Coal documents. Profile C-C (Drawing No. C00553-4) illustrates the subsurface conditions found in this area. The mine void encountered in Boring DH3-4 was sampled. Material collected from the void was a mixture of coal slurry and sand.

Entry No. 4

One boring (DH4-1) was drilled in the area of Entry No. 4 to confirm the presence of the coal barrier beyond the entry. The full Coalburg seam overlain by approximately 5 ft. of sandstone was encountered at this location.

"P" Borings

Two borings DHP-1 and DHP-2, were advanced to confirm the presence of pillars as depicted on mine maps (please refer to Drawing No. C00553-1 for boring locations). The pillars were found to be intact in both borings. Some fracturing of the sandstone above the pillars was observed and is noted on the boring logs.

Miscellaneous "X" Borings

Borings DHX-10, DHX-14, and DHX-15 were advanced to confirm the presence of coal as depicted on mine maps. A void was encountered in Boring DHX-10 at the elevation of the Coalburg Coal in an area depicted as being beyond the limits of mining. Solid coal was subsequently encountered in DHX-14. Likewise, a void was encountered in Boring DHX-15, indicating mining in Entry No. 4 was conducted beyond the limits as depicted on mine maps. Boring DHX-18 was drilled in a cross-cut adjacent to Entry No. 1 for the purpose of sampling the material in the mine void. Silty sand and gravel was sampled from the mine void at this location.

As was previously mentioned, several borings were drilled in the areas identified by Enviroscan as possible slurry breakthrough locations based on electrical voltage peaks detected during their survey. These include Borings DH2-9, DHP-2, DHX-16, and DHX-17. There was no evidence found in any of these borings of a possible slurry breakthrough at these locations. In Boring DHP-2, however, a significant amount of weathering and iron-stained fracturing was encountered in the sandstone above the Coalburg Coal. It is our opinion the large electrical anomaly in this area is due to the fracturing observed in Boring DHP-2. As noted in Enviroscan's report, voltage peaks "can occur along natural mineralized or oxidized near-vertical joints or fractures intersecting the mine workings." The other smaller electrical anomaly adjacent to Entry No. 1 is also likely related to subsurface fracturing or jointing.

Groundwater Conditions

Two separate groundwater levels were encountered during the subsurface investigation. An upper groundwater level was encountered while advancing through the fill/spoil material. A second (lower) level was measured in those borings which encountered mine voids. This level was generally 3 to 4 ft. above the top of the mine. Groundwater measurements are provided on the boring logs (Figure Nos. 1 through 189), in Table No. 3 below, and on Drawing Nos. C00553-2 through C00553-5. It should be noted that the final groundwater measurements for those borings which did not encounter mine voids may not be representative of actual conditions since large volumes of water were introduced into the borehole during the coring process and the water level may not have had sufficient time to stabilize. Initial groundwater levels were recorded during drilling before coring water was introduced into the borehole, and therefore may be more representative of actual groundwater conditions.

TABLE NO. 3 - BORING GROUNDWATER MEASUREMENTS

Boring Number	Initial Groundwater Level Depth/Elevation (ft.)	Final Groundwater Level. Depth/Elevation (ft.)
DH1-1	50.0/1002.4	80.7/971.7
DH1-2	50.0/1002.4	79.8/972.6
DH1-3	40.0/1015.6	84.2/971.4

TABLE NO. 3 (CONTINUED)

Boring Number	Initial Groundwater Level Depth/Elevation (ft.)	Final Groundwater Level. Depth/Elevation (ft.)
DH1-4	N/A	83.6/971.3
DH1-5	31.5/1022.9	83.0/971.4
DH1-6	40.0/1011.4	29.6/1021.8
DH1-7	50.0/1002.1	N/A
DH1-8	50.0/1003.2	81.5/971.7
DH1-9	50.0/1001.1	29.0/1022.1
DH1-10	50.0/1002.1	79.2/972.9
DH1-11	N/A	86.7/971.1
DH1-12	N/A	84.9/971.3
DH1-13	N/A	77.0/911.0
DH2-1	39.0/1013.4	81.5/970.9
DH2-2	35.0/1018.4	82.2/971.2
DH2-3	N/A	83.9/971.0
DH2-4	40.0/1009.5	26.0/1023.5
DH2-5	45.0/1006.2	23.4/1027.8
DH2-6	50.0/1002.0	29.4/1022.6
DH2-7	45.0/1006.7	24.5/1027.2
DH2-8	N/A	N/A
DH2-9	N/A	N/A
DH3-1	45.0/1005.0	26.0/1024.0
DH3-2	40.0/1011.4	29.2/1022.2
DH3-3	35.0/1017.7	17.7/1035.0
DH3-4	35.0/1018.9	83.0/970.9

TABLE NO. 3 (CONTINUED)

Boring Number	Initial Groundwater Level Depth/Elevation (ft.)	Final Groundwater Level. Depth/Elevation (ft.)
DH4-1	43.0/1007.9	34.4/1016.5
DHP-1	N/A	75.5/980.5
DHP-2	45.0/1010.7	N/A
DHX-1	N/A	84.6/971.2
DHX-2	N/A	83.9/971.6
DHX-3	50.0/1002.3	31.7/1020.6
DHX-4	67.0/984.8	80.1/971.7
DHX-5	65.0/986.2	78.0/973.2
DHX-6	65.0/986.8	47.5/1004.3
DHX-7	77.0/975.4	26.8/1025.6
DHX-8	65.0/986.4	55.6/995.8
DHX-9	60.0/992.0	N/A
DHX-10	N/A	84.0/971.3
DHX-11	N/A	20.3/1034.2
DHX-12	60.0/991.5	14.3/1037.2
DHX-13	60.0/991.1	28.1/1023.0
DHX-14	N/A	N/A
DHX-15	N/A	85.0/968.1
DHX-16	60.0/992.9	81.9/971.0
DHX-17	N/A	N/A
DHX-18	N/A	85.2/971.6

CONCLUSIONS

Based on the results of the subsurface investigation, it is our opinion the slurry breakthrough occurred at the end of what has been designated Entry No. 1. Test borings drilled in this area indicate that the Coalburg Coal is either partially or completely missing beyond the limits of mining as depicted on documents provided to Triad Engineering and the actual coal outcrop barrier is nearly non-existent. These borings included DH1-1, DH1-10, DHX-4, DHX-5, and DHX-8.

In addition, sampling of the mine void along Entry No. 1 as well as areas where the coal is missing beyond the depicted mined limits of Entry No. 1 indicate the entry is nearly full of sand, gravel, and sandstone cobbles and boulders. According to accounts by Martin County Coal personnel, material was bulldozed into the impoundment for several hours in an attempt to plug the slurry leak. This material was composed of readily available onsite material consisting of a mixture of sand and silt, clay, and sandstone fragments ranging in size from gravel to boulders. This material eventually stopped the flow of slurry into the adjacent mine workings. The material sampled in the mine workings in Entry No. 1 is representative of the type of material that was bulldozed into the impoundment the night of the failure. The large fragments of sandstone encountered within the mine void in Borings DH1-3, DH1-4, DH1-10, and DHX-1 noted in the "Subsurface Conditions" section of this report are most likely boulders that were bulldozed into the impoundment and drawn into Entry No. 1 while the breakthrough was occurring. By contrast, slurry was present in other areas of the mine. According to information provided to Triad Engineering, slurry was previously pumped into the mine workings in this area by Martin County Coal. The material sampled from areas outside of Entry No. 1 may be the slurry originally present in the mine or slurry which entered during the breakthrough.

On the Boring Location Plan (Drawing No. C00553-1) three lines are drawn which represent the Coalburg Coal. The purple line represents the outcrop as defined by the Martin County Coal maps. The green line represents the "line of zero coal thickness" as determined from the drilling data. According to our drilling data, the Coalburg coal did not have a surficial expression in this area (at the time it was mined) because it was covered by natural unconsolidated material (soil).

Of perhaps greater significance is the red line on Drawing No. C00553-1, which represents the point at which the Coalburg seam begins its transition from full thickness (8 to 10 ft.) to zero thickness. This is also the point at which unconsolidated material instead of sandstone overlies the coal seam. As interpreted from our subsurface investigation, there was approximately 15 to 18 ft. of "full thickness" coal between the end of the mine workings in Entry No. 1 as depicted on Martin County Coal mine maps and unconsolidated material (pre-breakthrough). As was previously mentioned, however, a significant portion of that coal was found to be either partially or completely missing. Possible causes for the missing coal include:

- It was mined beyond the depicted limits.
- It was washed away during the slurry breakthrough
- A combination of the two

Since the Coalburg seam did not have a surficial expression in this area and did not have an "outcrop" as typically defined, the effective outcrop (and for the purposes of this report) is the point at which the coal seam comes in contact with unconsolidated material. It is clear from the drilling that the end of Entry No. 1 is substantially closer to the outcrop of the Coalburg seam (as defined for this report) than what is depicted on Martin County Coal mine maps. Such close proximity to the outcrop, in addition to resulting in a smaller coal outcrop barrier, presents additional consequences.

- The amount of weathering increases significantly near the outcrop. Because the outcrop barrier is significantly thinner at this location, the barrier that is present is more weathered and therefore weaker.

- The sandstone above the Coalburg Coal thins out rapidly and exhibits increased weathering as it nears the outcrop. The remaining coal barrier is substantially weakened when it no longer has a sandstone roof. Based on our subsurface information, the sandstone roof appears to have thinned to 12 ft. or less at the end of the depicted mining limits. If the workings extended beyond the depicted mining limits as they did in Borings DHX-10 and DHX-15, the roof would have been even thinner, or possibly non-existent. An isopach map illustrating the thickness of the sandstone above the mine workings is provided on Drawing No. C00553-6.

The aforementioned conditions are the primary factors which significantly increased the chances of a slurry breakthrough. We believe a process referred to in geotechnical literature as "piping" triggered the breakthrough. Over an extended period of time, groundwater and water seeping from the impoundment flowed through the weathered coal outcrop via fractures, joints, cleats, etc. commonly present in coal. As the water flowed, it dislodged particles from the walls of the flow channels and carried them into the mine void. The groundwater flow increased the oxidation and deterioration along the avenues of infiltration, enlarging them and allowing increased infiltration and piping. The increasing coal slurry level also acted to increase piping due to increased hydrostatic pressure. The infiltration eventually eroded and weakened the barrier to a point where it could no longer withstand the pressure being exerted by the coal slurry, resulting in a catastrophic failure and rapid discharge of the slurry into the mine workings. The rush of material into the mine workings removed a portion of the coal barrier, which was found to be absent in several borings advanced just beyond Entry No. 1. In addition, the removal of a portion of the coal outcrop barrier may have resulted in the collapse of a portion of the thin lip of sandstone above the Coalburg Coal beyond the end of Entry No. 1, allowing an even greater discharge of coal slurry into the mine workings.

Piping through the seepage barrier and natural ground likely occurred through zones of higher permeability within these layers. Although testing of undisturbed samples from these areas indicate relatively low permeabilities, these samples are likely not representative of the permeability conditions in general. Undisturbed (Shelby tube) samples were only successfully obtained within the more cohesive zones with a lower percentage of rock fragments. Although several Shelby tube samples were attempted, only a small percentage were usable. The majority were damaged due to large rock fragments or could not be advanced more than a few inches due to the percentage of rock fragments. Standard penetration testing indicated the fill material contained a large percentage of rock fragments. The results of the grain size analysis on the bulk sample representative of the seepage barrier construction material, when compared to published data, correlates to permeabilities on the order of 10^{-3} cm/sec, which is 3 orders of magnitude greater than that obtained in the Shelby tube.

In summary, the results of our investigation indicate the impoundment failure is a consequence of mining operations in the Coalburg Coal advancing in close proximity to the outcrop of the coal seam. The August 8, 1994 plan view drawing submitted by Martin County Coal as part of the impoundment sealing plan indicated that a minimum scaled distance of approximately 70 ft. (as measured perpendicular to the Coalburg outcrop) existed between the end of Entry No. 1 and the Coalburg outcrop line. The test borings indicate that the net distance between the end of Entry No. 1 as depicted on Martin County Coal maps and the actual coal seam outcrop (point at which the top of the coal seam meets unconsolidated material) was on the order of 15 to 18 ft. Considering that some entries were found to extend beyond the depicted limits of mining in other nearby locations of the mine, the actual coal barrier at the end of Entry No. 1 may have been less than 15 ft. This minimal thickness of solid coal barrier combined with the continually increasing hydrostatic pressure as a result of the rising slurry level resulted in piping/erosion of the barrier and eventual breakthrough of slurry into the mine workings.

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Triad Engineering, Inc.

May 22, 2001

United States Department of Labor
Mine Safety and Health Administration
5012 Mountaineer Mall
Morgantown, WV 26501

Attention: Mr. Timothy Thompson, District Manager

Subject: Big Branch Slurry Impoundment
Martin County, Kentucky
Triad Project No. C00553

Dear Mr. Thompson:

Pursuant to our May 21, 2001 phone conversation regarding the subject project, we would like to submit the following clarifications regarding our conclusions outlined in the March 30, 2001 Final Report of the Big Branch Slurry Impoundment Subsurface Investigation. It has come to our attention that certain erroneous conclusions may be inferred from our statements concerning our opinions as to the cause of the impoundment failure. The areas of concern include statements contained within the final paragraph of Page 17 as noted below:

- "In summary, the results of our investigation indicate the impoundment failure is a consequence of mining operations in the Coalburg Coal advancing in close proximity to the outcrop of the coal seam." The purpose of this statement is to indicate that the ultimate cause of the failure, in our opinion, was the minimal amount of solid, competent coal/bedrock between the end of the mine workings in Entry No. 1 and unconsolidated material at the base of the impoundment. We are aware that the mining in the Coalburg seam occurred before the construction of the slurry impoundment and did not intend to infer otherwise.

- The second sentence references an August 8, 1994 plan view drawing submitted by Martin County Coal. We understand that this document is only a portion of an impoundment sealing plan that was developed to limit the amount of seepage into the mine workings and to create a blockage in the event of a breakthrough. Triad was provided with the referenced drawing at the outset of the investigation, as well as a typical seepage barrier section. No other portion of the impoundment sealing plan was provided. The existence or absence of an impoundment sealing plan does not alter our opinion regarding the cause and likely mechanism of failure.

- The Martin County Coal plan view drawing was referenced to indicate the discrepancy between the Coalburg outcrop line as indicated on the drawing and the actual amount of competent, effective coal/bedrock present between the end of the mine entries and the impoundment as determined by our subsurface investigation. Although there may have been 70 horizontal feet of material between the end of Entry No. 1 and the base of the slurry impoundment, only a fraction of this material was competent coal/bedrock.

- It should not be inferred from our report that we believe the failure path of the slurry into Entry No. 1 was entirely along a horizontal path. We suspect the failure path of the slurry through the unconsolidated strata (natural soil and seepage barrier material) was at an angle. This flow path probably corresponded to the shortest distance between the bottom of the slurry impoundment and the point where the coal seam (coal barrier for Entry No. 1) met unconsolidated material. After penetrating the unconsolidated material, we believe the slurry flowed basically horizontally through the remaining portion of the coal (coal barrier) or along the interface between the top of the coal seam and overlying sandstone bedrock. We suspect prolonged seepage over an extended period of time caused erosion and deterioration of the coal barrier, leading to a piping condition and subsequent catastrophic failure. As discussed in our report, the amount of coal barrier present beyond the end of Entry No. 1 was at most 15 to 18 ft. thick, measured horizontally. If the end of Entry No. 1 were extended beyond the limits depicted on Martin County Coal drawing, as was the case in other areas of the mine, the actual coal barrier would have been less than 15 to 18 ft. During the rapid inflow of slurry into the end of Entry No. 1, the force of the flowing slurry eroded away all but a small portion of the coal barrier and a portion of the sandstone roof, as depicted on Drawing No. C00553-5 (Profile D-D) of our report.

We hope this letter clarifies the conclusions presented in our report and addresses the concerns brought to our attention. Please feel free to contact us if you have any questions concerning this report, or if we can provide any further assistance.

Very truly yours,

TRIAD ENGINEERING, INC.

Charles E. Montgomery, P.G.
Project Geologist

John E. Nottingham, P.E.
Senior Engineer

Larry C. Nottingham, Ph.D., P.E.
Principal Engineer