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March 26, 2018

Tennessee Valley Authority
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**Engineer's Certification of Unstable Areas Demonstration
New CCR Landfill
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesboro, Kentucky**

1.0 PURPOSE

The purpose of this document is to certify that the Unstable Areas Demonstration for the TVA Paradise Fossil Plant (PAF) New Coal Combustion Residuals (CCR) Landfill is in compliance with the Unstable Areas demonstration specified in the Final CCR Rule at 40 CFR §257.64. Pursuant to § 257.64(d)(2), the owner or operator of a new CCR landfill must complete the unstable areas location demonstration no later than the date of the initial receipt of CCR in the new CCR landfill.

2.0 BACKGROUND

AECOM performed a site assessment to evaluate the current conditions and proposed design of the new landfill in accordance with the unstable area requirements of location restrictions under the USEPA CCR Rule §257.64. As part of the site assessment, AECOM has reviewed available historical information and completed site reconnaissance visits and geotechnical explorations.

3.0 SUMMARY OF FINDINGS

TVA intends to construct a new CCR landfill at the PAF facility to provide long-term disposal capacity for CCR materials (fly ash, boiler slag, and gypsum) produced by the facility.

Based upon our review of the available historical data, the results of the geotechnical investigation, and our engineering analyses, AECOM has concluded that the PAF CCR Landfill will meet the CCR Rule requirements for 40 CFR §257.64 Unstable Areas, provided the remedial actions are implemented as designed to address deep mine stability. Once the remedial actions are implemented and prior to the initial receipt of waste, AECOM will update this certification.



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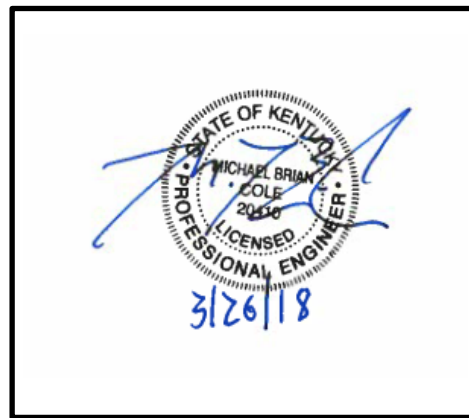
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4.0 CERTIFICATION

I, Michael Brian Cole, being a Registered Professional Engineer in good standing in the State of Kentucky, do hereby certify, to the best of my knowledge, information, and belief that the information contained in this certification has been prepared in accordance with the accepted practice of engineering and that the information contained herein is accurate as of the date of my signature below. I certify that the Unstable Area Demonstration for CCR, dated 3/26/18, for the above-referenced CCR Unit meets the unstable areas location requirements of 40 CFR § 257.64(a), as recognized and generally accepted good engineering practices have been incorporated into the design of the CCR Unit to ensure that the integrity of the structural components of the Unit will not be disrupted.

M. Brian Cole
Printed Name

3/26/18
Date



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ATTACHMENTS: Unstable Area Demonstration for CCR- New CCR Landfill

COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

**TENNESSEE VALLEY AUTHORITY – PARADISE FOSSIL PLANT
LANDFILL
DRAKESBORO, KENTUCKY**

**UNSTABLE AREA
DEMONSTRATION FOR CCR
NEW CCR LANDFILL**

Prepared for



Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

March 26, 2018 – Rev 0

Prepared by





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1.0 PROJECT BACKGROUND

Tennessee Valley Authority (TVA) owns and operates the Paradise Fossil Plant (PAF) in Drakesboro, Kentucky. The plant features three units, completed between 1963 and 1970, and three large natural-draft cooling towers. Units 1 and 2 were retired in 2017. The plant consumes about 20,000 tons of coal per day. Property of the PAF facility occupies more than 3,400 acres along the western side of the Green River. The plant is located along the west bank of the Green River along State Route 176 inside the eastern border of Muhlenberg County as depicted below in **Figure 1**.

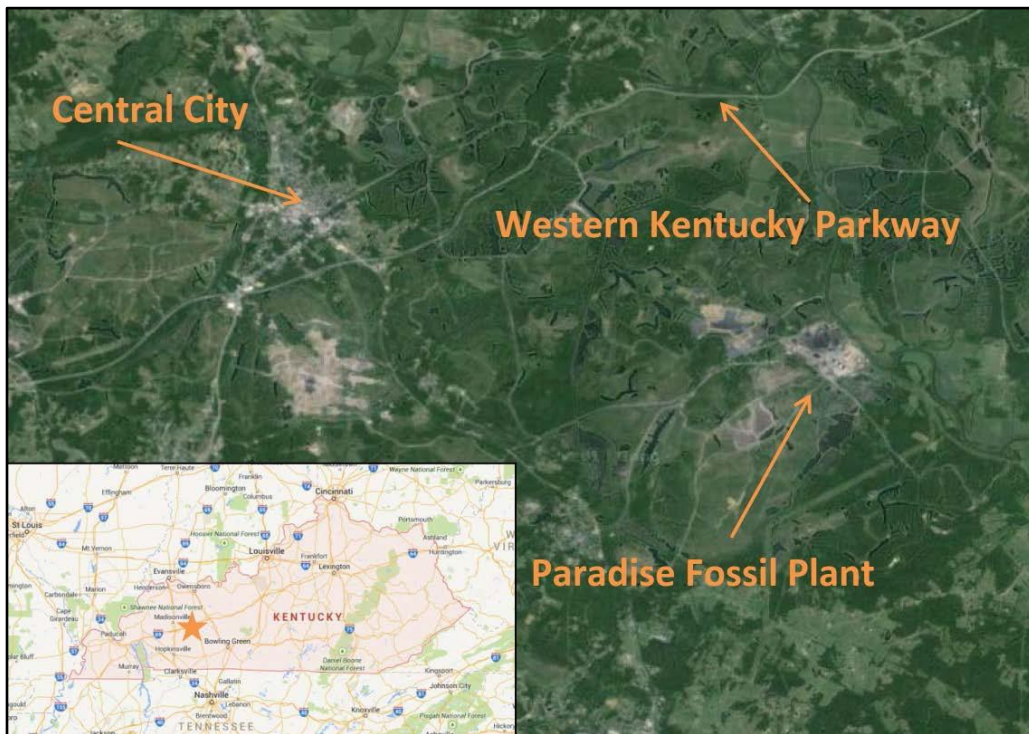


Figure 1: TVA PAF Site Location

TVA intends to construct a new CCR landfill at PAF to provide long-term disposal capacity for CCR materials (fly ash, bottom ash, and gypsum) produced by the facility. Approximately ten percent boiler slag materials are anticipated to be landfilled; whereas, the balance is anticipated to be reclaimed and marketed. The proposed landfill site (Site) covers approximately 116 acres, and planned construction will include a CCR landfill, two stormwater detention ponds, and corresponding leachate lagoons. The Site is presented in Figure 2 on the next page.



Figure 2: PAF Landfill Site Location

The Site is bounded to the south by Jacobs Creek, a tributary that bisects the PAF property from Riverside Road; the Green River to the east; a PAF facility electrical transmission line easement to the west; and the PAF power station to the north. The Site was previously used as a storage area for boiler slag fines.

2.1 SITE ASSESSMENT

AECOM performed a site assessment to evaluate the current conditions of the new CCR landfill in accordance with the unstable area requirements of location restrictions under the USEPA CCR Rule 40 CFR §257.64. As part of the site assessment, AECOM has reviewed available historical information and completed site reconnaissance visits and geotechnical explorations.

2.1 AVAILABLE HISTORIC DATA

Available historical information included a desktop review of publicly available historical mine maps, a geotechnical exploration performed in 2016 and presented in the associated Geotechnical Phase 2 Site Evaluation Report completed by AECOM in 2017, and an Underground Mine Investigation Report completed by AECOM in 2017. The details of the available historic information are presented in the following sections.

2.2 PUBLICLY AVAILABLE INFORMATION

Historical mining was performed across the majority of the PAF property. A review of available information obtained from the Kentucky Division of Mine Safety (DMS) and online maps from the Kentucky Mine Mapping Information System was previously performed by AECOM. Each known historic mine located on the PAF property is briefly summarized below.

- Drake III Mine, (KY Mine ID 06620-4): This underground deep mine targeted the Coal Seam 9 below the Dredge Cell, South Spoils Area, and Slag Mountain via pillar and partial room extraction methods. Coal seam height generally varied from 5 to 6 feet thick and mining pillars were on the order of 70-feet square. The mining efforts took place from 1971 to 1979.
- Gibraltar Mine, (KY Mine ID 04251): After the abandonment of the Drake III mine in 1979, surface mining of the Coal Seam 9 was performed from 1982 to 1991. Historic documentation suggests the deep mines of Drake III were destroyed as part these surface mining efforts to collect the remaining coal. The removal of the Drake III mine was not extensively delineated.
- Sinclair Mine, (KY Mine ID 00825-2): This mine is located below Dredge Cell, South Spoils Area, and Slag Mountain. Surface mining techniques were used to recover coal from seams 9, 11, 12, and 13 from 1962 through 1985.
- Paradise Mine, (KY Mine ID 02106): This mine is located in the same overall area as the Sinclair Mine and mined via strip mining methods between 1960 and 1979. The strip mining focused efforts to recover coal from seams 9, 11, 12, and 13. The area is mined out and topography and land cover show the area was surface mined.

The Sinclair 285 Mine, (KY Mine ID 05877), is an underground mine located south of the PAF property. Deep mining methods (underground room and pillar methods) were utilized from 1976 through 1991 to extract coal from the No. 9 seam. Historic aerial imagery indicates reworking and strip mining activities were performed south and east of the large ash pond.

2.3 SITE RECONNAISSANCE

Site reconnaissance was performed by AECOM prior to subsurface explorations across the proposed landfill footprint in 2016, and within proposed Cell 1A of the landfill in 2017. Based on observations during site reconnaissance in 2016, the proposed landfill site includes cleared areas of historic mine reclamation, with slopes and sidewalls that are vegetated to varying degrees.

TVA performed grading within the proposed landfill site during 2016 as part of the Gypsum Stack Cover Soil project. Based on observations during site reconnaissance performed within proposed Cell 1A of the landfill in August 2017 and topographic contours shown on proposed Cell 1A construction drawings, it was observed that the north, west, and south boundaries of proposed Cell 1A are located at the top of a 3H:1V slope at elevation 450 ft.

The slope grades downward toward the interior of the cell from elevation 450 ft to elevations ranging from 442 ft to 432 ft.

A gravel road is located around the north, west, and south boundaries of proposed Cell 1A at about elevation 450 ft. Grass vegetation covers the ground surface outside of the gravel road. The road slopes downward along the south boundary of proposed Cell 1A from elevation 450 ft to 432 ft. The northern portion of the eastern boundary of proposed Cell 1A is the toe of a 3H:1V slope, and the southern portion of the eastern boundary of proposed Cell 1A consists of gently sloping ground surface partially covered in grass vegetation. The ground surface within the interior of proposed Cell 1A generally slopes downward from northwest to southeast from elevation 442 ft to 432 ft.

2.4 SITE INVESTIGATIONS

As discussed in Section 2.1, AECOM completed a Geotechnical Phase 2 Site Evaluation Report and an Underground Mine Investigation Report in 2017. The explorations associated with these evaluations are discussed in the following paragraphs.

Geotechnical Phase 2 Site Investigation

The Phase 2 Site Investigation was performed in 2016, and consisted of fifty five (55) borings ranging in depth from approximately 29.5 ft below ground surface (ft bgs) to 223.7 ft bgs. Borings were advanced through subsurface materials and into bedrock with 3¼-inch or 4 ¼-inch inner diameter hollow-stem augers.

Soil samples were collected from the borings for visual classification and laboratory testing. Samples were obtained by Standard Penetration Testing (SPT) with a 2 foot long split-spoon sampler in conjunction with 2.5 foot sampling intervals in the upper 10 ft and every 5 ft thereafter. Offset borings were blind augered without sampling to desired depths to collect relatively undisturbed in-situ samples (Shelby tubes) of cohesive materials for laboratory testing.

Upon encountering bedrock at eight (8) boring locations, 3.8-inch outside diameter (HQ-size) bits were used to recover intact rock cores. A coal layer was encountered below the lower shale near the elevation of the No. 9 Coal Seam elevation. Unrecovered core losses were typically recorded in the rock core borings at the approximate elevation of the No. 9 coal seam, with the exception of boring F-6, which encountered a relatively intact layer of coal. The unrecovered core losses were interpreted as voids, which indicated the presence of deep mines below the site. Soil and bedrock information obtained during the Phase 2 Site Investigation was considered in this report.

Underground Mine Investigation

The Underground Mine Investigation was performed in order to further characterize the rock and mine conditions encountered during the Phase 2 Site Investigation. This investigation was

performed in December 2016 and January 2017 and consisted of drilling two borings, UG-1 and UG-2, within the area of proposed Cell 1A. Both of the borings were advanced through Coal Seam 9 mine interval using HQ-sized rock coring tools. Bedrock information obtained during the Underground Mine Investigation was used for this report.

3.0 FOUNDATION CONDITIONS

The foundation conditions are summarized below based on the boring logs and laboratory data from the 2016 and 2017 AECOM explorations.

3.1 SITE SPECIFIC SOIL AND ROCK CONDITIONS

In general the subsurface profile encountered during the explorations consisted of a soil layer, comprised primarily of fill, Coal Combustion Residuals (CCR) materials, and mine spoils, from the ground surface to bedrock. The bedrock is generally comprised of an upper shale unit, a sandstone unit, a lower shale unit, and the mine space. The mine space is underlain by another shale unit.

3.1.1 SOIL

Fill is assumed to be the result of grade changes that were implemented during the construction of the man-made site features such as access roadways and after strip mining was performed across the site. Fill materials were typically classified as moist, reddish brown or dark brown lean clay (CL) or sandy silt (ML) with gravel, sand and rock fragments. Fill materials were distinguished from mine spoils by relatively stiffer consistency near the ground surface and being found directly over the underlying ash materials.

CCR materials produced at the PAF were temporarily staged and stored onsite within the boundary of the proposed new CCR landfill. As a result, ash fill materials were encountered in twenty three boring locations across the proposed site. The ash fill materials were typically comprised of slag fines, typically described as moist to wet, black, silty sand (SM).

Mine spoils identified at the site were placed as a result of extensive surface mining. Mine spoils at the Site are composed of rock fragments and excavated soil that was generated as coal deposits were recovered. A majority of the borings encountered mine spoils at the ground surface or beneath the ash fill materials and extended to the underlying bedrock. The mine spoil was comprised primarily of fine-grained soils but also included intermixed granular soil layers. The fine-grained mine spoils were generally described as moist to wet, brown, lean clay (CL) with variable amounts of sand, gravel, rock fragments. Granular mine spoil layers were generally described as dry to moist, brown or dark brown, clayey gravel (GC) or clayey sand (SC) with gravel largely composed of highly weathered shale fragments with lesser amounts of sandstone or limestone fragments. Coal fragments and ash materials were also noted in both the fine-grained and granular mine spoil layers but usually in trace amounts.

Native alluvium soil was encountered below the mine spoil materials at one boring. The alluvium was classified as moist to wet, yellowish brown fat clay (CH) underlain by yellowish red and gray silt (ML), and gray and yellowish brown lean clay (CL). The alluvium soil also included varying amounts of sand with oxidation staining and black ferrous staining in trace amounts.

Native fine-grained residual soil deposits were encountered below the mine spoil materials at five boring locations. Residual soils were typically classified as moist to wet, yellowish brown or reddish brown with gray mottling, lean clay (CL) or fat clay (CH) and also included trace amounts of weathered rock fragments and cobbles.

3.1.2 SHALE

The upper shale unit encountered below the soil was described as gray or dark gray with light gray banding, fresh to slightly weathered, and moderately hard. The upper shale thickness ranged from 2.6 to 40.6 feet with an average thickness near 20 feet. The Rock Quality Designation (RQD) values recorded within the shale ranged from 0 to 100%, with an average near 76%.

A lower shale unit was encountered below the sandstone. This shale unit was described as dark gray to greenish gray, fresh, thinly to medium bedded, moderately hard, with trace amounts of pyrite and clay-ironstone nodules. The lower shale thickness ranged from about 16 to 29.5 feet with an average thickness of about 23 feet. RQD values within the lower shale unit ranged from 0 to 100%, with an average of 78%.

3.1.3 SANDSTONE

Sandstone was encountered below the upper shale layer, and was described as fine to medium grained, massively bedded, fresh, and moderately hard to hard. The sandstone ranged from about 32 to 65 feet thick with an average of about 47 feet. RQD values ranged from 57% to 100% with an average of 94%.

3.1.4 COAL

Coal layers were encountered near the elevations of the No. 9 and No. 11 Coal Seam elevations. Relatively intact coal was encountered near the elevation of the No. 11 Coal Seam, and ranged in thickness from about 1.5 to 4 ft. Unrecovered core losses were generally recorded in the rock core borings at the approximate elevation of the No. 9 coal seam, with the exception of boring F-6, which encountered a relatively intact layer of coal. The unrecovered core losses were interpreted as voids ranging in thickness from about 5.2 to 7.9 feet, and were indicative of the presence of deep mines below the site.

3.1.5 GROUNDWATER

The presence of groundwater was noted at the time of drilling on recovered samples and in the completed boreholes prior to backfilling. AECOM also installed a total of twelve groundwater

monitoring wells within the landfill footprint and surrounding the landfill limits. During the field investigation activities, wet materials were found to vary from 5 to 79 feet below the ground surface, generally between Elevation 376 and Elevation 410 feet.

3.2 NATURAL UNSTABLE AREAS

Based on review of historical data and observations in the borings performed during the geotechnical explorations, the majority of the area within the proposed landfill footprint was surface mined, and a relatively small amount of native soil remains above bedrock. As discussed in Section 3.1.1, native alluvium soil was encountered below the mine spoil materials at one boring location. The alluvium was classified as moist to wet, yellowish brown fat clay (CH) underlain by yellowish red and gray silt (ML), and gray and yellowish brown lean clay (CL). The SPT N- values recorded within the alluvium deposit ranged from 4 to 11 bpf, with an average near 8 bpf, indicating medium stiff to stiff consistency.

Native fine-grained residual soil deposits were encountered below the mine spoil materials at five boring locations. Residual soils were typically classified as moist to wet, yellowish brown or reddish brown with gray mottling, lean clay (CL) or fat clay (CH) and also included trace amounts of weathered rock fragments and cobbles. The SPT N-values recorded within the residual materials varied from 9 to 22 bpf, with an average near 15 bpf, indicating a stiff to very stiff consistency.

Considering the medium-stiff to very stiff consistency of the native soils at the site, natural unstable areas were not encountered during the explorations performed at the site. There are no observed karst features, natural springs, or evidence of landslides at the site where the new CCR landfill is proposed.

3.3 MAN-MADE UNSTABLE AREAS

The primary considerations for man-made unstable areas are presented in the following paragraphs.

3.3.1 Settlement

Based on the results of the settlement analysis performed along the leachate alignments as part of the Phase 2 Site Investigation, the anticipated total subgrade settlement will generally vary from 4 to 42-inches given typical surcharge loads from CCR materials estimated to be equivalent to 30 to 230 ft. Total settlements of this magnitude are typical for this type of subgrade material and can be accommodated in the design of liner and leachate collection systems. The settlement analysis did not include provisions for determining effects of deep mine subsidence, which is discussed further in Section 3.3.3.

3.3.2 Liquefaction Potential

As part of the Geotechnical Phase 2 Site Investigation Report, a preliminary screening analysis was performed to determine if the proposed landfill subgrade soils are subject to

liquefaction. Liquefaction generally occurs primarily in clean fine sands, non-plastic silty sands, non-plastic silt, gravels, and has been observed in sensitive clays.

Based on the results of the preliminary analysis, in isolated areas across the Site, ash fill materials and some granular minespoil layers were found to meet generally accepted criteria for liquefaction potential. These locations include borings B-7, C-7, and F-5, within the south, central, and western portions of the Site.

In order to demonstrate the stability of the landfill expansion to earthquake loading, a post-earthquake analysis was performed at Section 2-2', located at the southwest slope of the landfill. This section was selected due to a relatively thick layer of ash in the foundation. For this evaluation, a minimum factor of safety (FS) of 1.2 was used for the post-earthquake condition, which is consistent with standard geotechnical engineering practice. This analysis was performed assuming the slag fines material layer below the water level classically liquefies as a result of the earthquake, and residual strength values were assigned to this material.

The slag fines residual strength was estimated following procedures in Idriss and Boulanger (2008) and shown on Figure 5. The value for the equivalent clean sand SPT corrected blow count, $(N_1)_{60CS-Sr}$, for the ash and slag fines was considered as the average value of 14 bpf.

Based on the $(N_1)_{60CS-Sr}$ of 14 bpf, the liquefied ash materials were assigned a residual shear strength ratio of 0.12 in the slope stability analytical models.

The factor of safety for the post-earthquake slope stability condition was 1.81 for the cross-sections analyzed. This factor of safety is well above the target value of 1.20, and indicates the landfill will be stable in the event of the design earthquake.

3.3.3 Deep Mine Stability

As discussed in Section 3.1.4, unrecovered core losses were typically recorded in the rock core borings at the approximate elevation of the No. 9 Coal Seam. The unrecovered core losses were indicative of voids associated with the presence of deep mines below the Site.

The stability of the mine was analyzed with respect to failure of the roof beam, pillar crushing, and a bearing capacity failure of the mine floor. Factors of safety against roof beam failure, pillar crushing, and bearing capacity of the mine floor generally meet acceptable safety factors for existing conditions. Loads from landfill construction, however, would cause the factors of safety against pillar crushing to fall below the recommended values as the landfill height progresses.

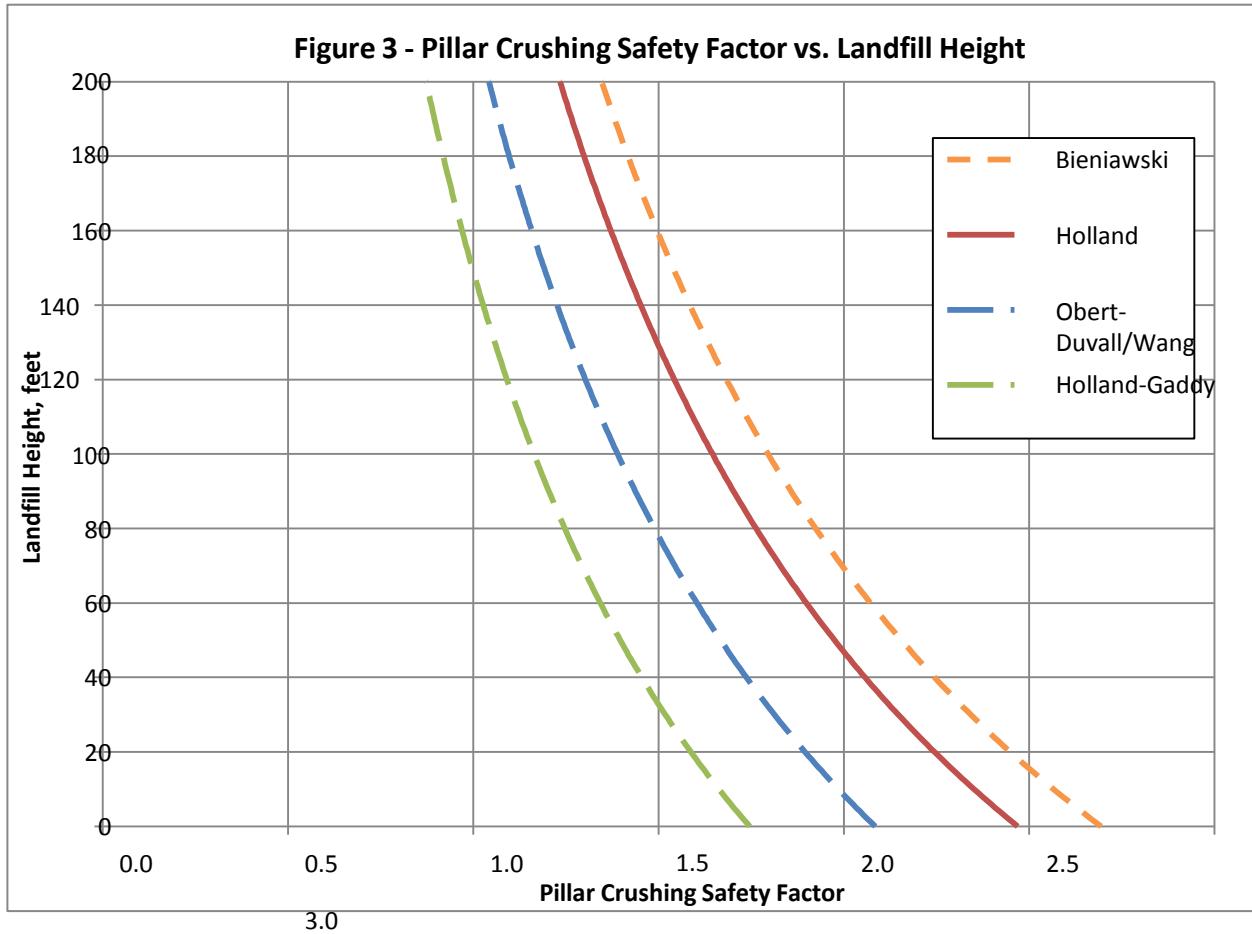
Calculating the safety factors with respect to pillar crushing was performed using the tributary method which consists of dividing the pillar strength, calculated using one of four pillar strength formulas, by the overburden load carried by the pillar. The four pillar strength formulas used for this analysis consisted of the following:

- Bieniawski Formula (1992);
- Holland Formula (1973);
- Holland-Gaddy Formula (1956); and

- Obert-Duvall/Wang Formula (1967).

Safety factors against pillar crushing were calculated for both the existing conditions and the future conditions where the landfill was constructed above the mine space.

The recommended minimum safety factor for the Bieniawski Formula is 1.5, for the Holland Formula is 2.0, the Holland-Gaddy Formula is 1.8, and the Obert-Duvall/Wang Formula is 2.0. **Figure 3** below illustrates the safety factor against pillar crushing as a function of the proposed landfill height:



The stability analysis indicated pillar crushing would result in subsidence of the mine on the order of about 2 to 3 feet following construction of the landfill, which in addition to settlement of overburden materials would result in total settlement of up to 6 feet in some areas. Although the liner strain is not anticipated to be large enough to damage the geomembrane itself, the settlement could cause localized ponding of leachate on the bottom liner system by de-sloping of the landfill floor away from the leachate sump if the subsidence is not remediated.

4.0 REMEDIAL ACTIONS

In order to provide an acceptable factor of safety against pillar crushing, remedial measures were proposed, which consisted of pumping a slurry from the ground surface into the mine space. Based on the results discussed in the Underground Mine Investigation Report, filling approximately 60 percent of the mine space would satisfy the recommended safety factors against pillar crushing when subjected to maximum landfill loads.

A test backfill placement was performed from August to October 2017 within 1.4 acres of Cell 1A of the proposed landfill. The purpose of the test backfill placement was to better predict performance of a full scale backfill grout placement program performed within the mine space located below the proposed landfill. Backfill was placed through a grid of thirty-two (32) borings. A total of over 7,400 cubic yards of backfill material was placed in the mine space through placement borings.

Six (6) confirmation borings were strategically located within the test backfill area in order to confirm the presence of grout within the mine space. The confirmation borings encountered grout and steady drilling effort at the mine elevation, which is indicative of substantially filled mine space. Rod drops of about 2 and 6 inches were observed in Borings CB-1 and CB-3. The rod drop at boring CB-1 was near the mine roof elevation, and the rod drop at boring CB-3 was at depth 131 ft bgs, about 10 ft above mine roof elevation and likely indicated a localized roof delamination.

Based on observations during the test backfill and conditions in the confirmation borings, the backfill mix used as part of the test backfill program was effective in substantially filling the mine space. Results of compressive strength testing indicate the backfill material has sufficient strength to provide acceptable factor of safety against pillar crushing. A full scale backfill grout placement program based on mix designs and practices refined during the test backfill is planned to be completed within Cell 1A.

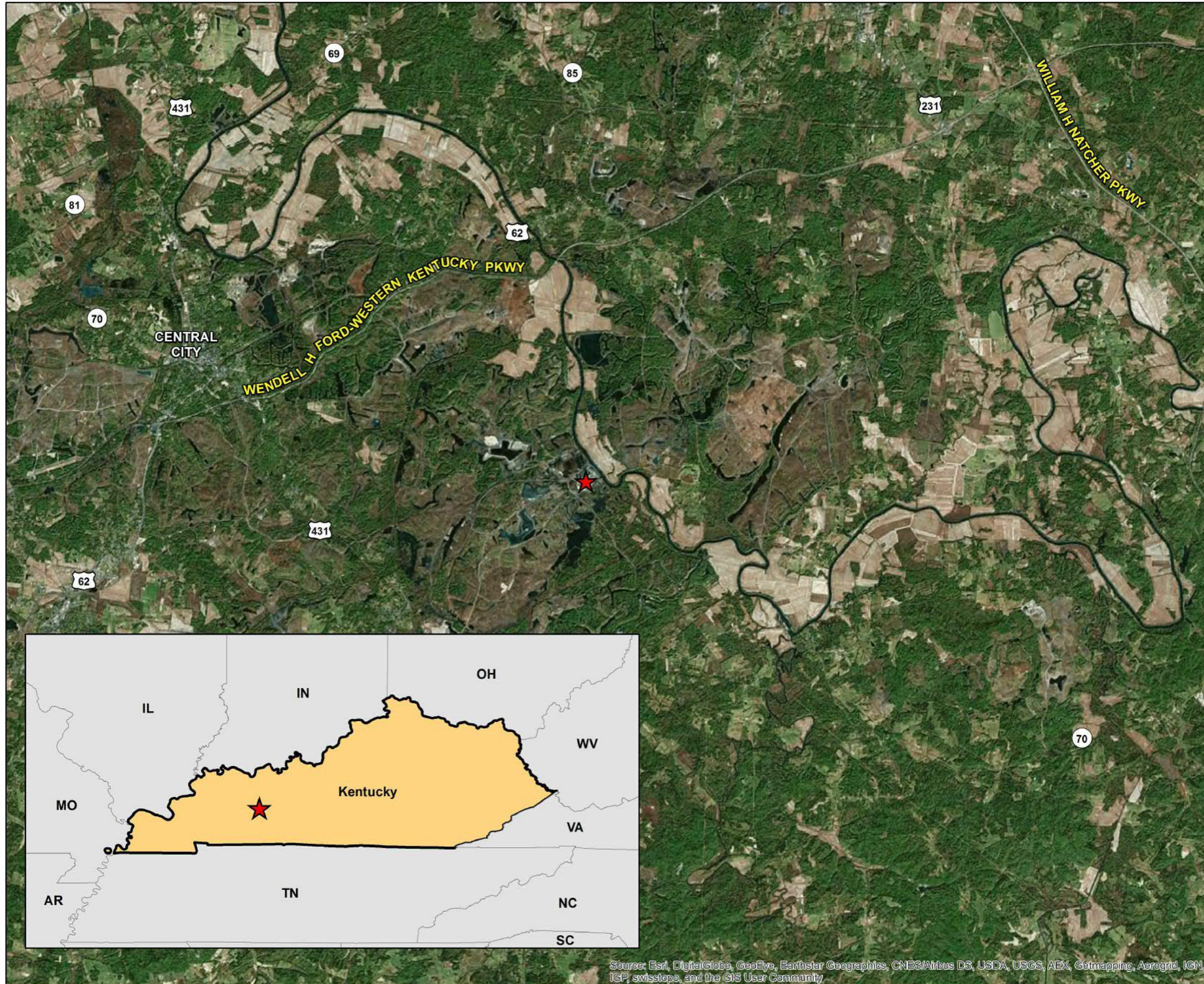
5.0 CONCLUSIONS

Based upon our review of the available historical data, the results of the supplementary investigation, our engineering analyses, and provided that the remedial actions in Section 4.0 are implemented to address deep mine stability, AECOM has concluded that the proposed PAF Landfill will meet the CCR Rule requirements for 40 CFR §257.64 Unstable Areas.

6.1 REFERENCES

1. AECOM, 2017. Deep Mine Evaluation Memorandum. Paradise Fossil Plant, Muhlenberg County, Kentucky, March 10, 2017.
2. AECOM, 2017. Geotechnical Site Evaluation, Proposed CCR Landfill, Paradise Fossil Plant, Muhlenberg County, Kentucky, dated June 27, 2017.

APPENDIX A



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, ICP, swisstopo, and the GIS User Community

AZCOM				
TVA PARADISE FOSSIL PLANT PARADISE, KENTUCKY				
FIGURE 1 SITE LOCATION MAP				
DRAWN BY: DAS	CHECKED BY: MSK	PROJECT No: 60478473	DATE: 03/08/2017	FIGURE No: 1

APPENDIX B



AZCOM				
TVA PARADISE FOSSIL PLANT PARADISE, KENTUCKY				
FIGURE 2 PROJECT VICINITY MAP				
DRAWN BY: DAS	CHECKED BY: MSK	PROJECT No: 60478473	DATE: 03/08/2017	FIGURE No: 2

APPENDIX C



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TVA PARADISE FOSSIL PLANT PARADISE, KENTUCKY				
FIGURE 3 HISTORICAL MINE MAP - NO. 9 SEAM				
DRAWN BY: DAS	CHECKED BY: MSK	PROJECT No: 60478473	DATE: 03/08/2017	FIGURE No: 3