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1.0 Introduction

1.1 Background

In April of 2015, the US EPA formally published national regulations for disposal of coal combustion residuals (CCR) from electric facilities. As part of the rule, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer stating that aspects of the CCR impoundments are in accordance with the rules. Based on our understanding of the Request for Fee Estimate received from AEP on April 29, 2015, AEP specifically requested P.E. certification to fulfill the requirements of 40 CFR § 257.73(e), Periodic Safety Factor Assessments. S&ME performed the design and construction administration for the dam raising completed in 2014. Due to our familiarity with the site, S&ME was selected to perform the Safety Factor Assessment for this facility. S&ME understands that certification and/or documentation for other structural integrity criteria will be performed by AEP or other consultants.

1.2 Location and Historic Overview

The Cardinal Power Plant is located along the Ohio River, approximately 8 miles south of Steubenville in Jefferson County. Then Fly Ash Reservoir II is an on-stream reservoir within the east branch of Blockhouse Run, located approximately, three-quarters of a mile north of the plant. Completed in 1986, the original earth fill dam, referred to as Stage 1, consisted of a 180 feet high arched dam constructed as a conventional zoned earth embankment. At 925 feet NGVD, the dam featured a 70-foot wide by 1,055-feet long crest. The maximum operating pool that could be achieved with the original configuration was EL 913. Construction of the first dam raising, referred to as Stage 2, was completed in 1997 which brought the dam to a maximum height of 225 feet with a 30 foot wide crest at Elevation 970 feet and a maximum operating pool elevation of 960 feet. The dam raising was achieved through the use of an upstream soil cement block (cement stabilized bottom ash) in conjunction with a downstream earth fill along with extensions of the upstream bottom ash filter, clay core, chimney drain and downstream mine spoil shell. At the completion of the 1997 raising, the upper portion of the entire dam crest consisted of a minimum of 9 feet of RCC to both protect the dam from erosion and serve as a roadway. In 2013, the dam was raised an additional 13 feet with the construction of a double-sided mechanically stabilized earth (MSE) wall system on top of the RCC, raising the maximum operating pool to Elevation 974 feet. To control seepage, a cement-bentonite slurry wall was constructed which penetrated into the existing clay core. A non-structural vinyl sheet pile wall was then inserted full depth through the slurry wall and extended to the top of the raised dam in between the MSE reinforced zones. The raised dam also includes a modified auxiliary spillway composed of mass concrete, and a precast service spillway extension.
1.3 Previous Investigations and Design Work

In 2010, the undersigned senior engineer, when in the employment of BBC&M Engineering, Inc., completed a supplemental geotechnical assessment of the FAR-II Dam. The assessment consisted of performing slope stability analysis for various steady-state, seismic, rapid drawdown, and surcharge loading cases which were not previously addressed.

S&ME began design work for the FAR-II dam raising in 2011. In support of the design, S&ME conducted a subsurface investigation consisting of soil borings, test pits, and core samples of the soil cement block. S&ME then worked closely with AEP and state dam safety officials to permit this unique structure,
including evaluating a variety of seepage and stability failure modes as well as the potential for corrosion of the reinforced concrete wall panels. S&ME then served in a construction administration role for the duration of construction. Upon completion of the project in April of 2014, S&ME issued an Engineering Certification Letter to the Ohio Department of Natural Resources, Division of Soil and Water. S&ME also completed a First Filling Plan and updated the Operation, Maintenance, and Inspection Manual and Emergency Action Plan.

2.0 Scope of Work

In accordance with AEP’s request, the following work items were performed by S&ME:

1. S&ME completed a cursory review of the previously conducted design work for the recent dam raising, as well as a previous design reports and construction documents made available by AEP.

2. S&ME visited the site along with personnel from AEP to observe the facility. It should be noted that the ODNR Division of Soil and Water, Dam Safety Section conducted the 1-year inspection of the dam in June of 2015 and concluded that construction was performed in accordance with the terms of the permit, plans, specifications, and approved changes.

3. Action values relating to instrumentation measurements were determined based on slope stability analyses using the critical cross-section and examination of historical piezometer readings provided by AEP.

4. Upon completing Tasks 1 through 4, S&ME’s determined that there was sufficient information to certify the structural integrity of the surface impoundment in accordance with the requirements of 40 CFR § 257.73(e). A separate letter has been prepared to this effect.

3.0 Information Review and Site Visit

To support the safety factor assessment, S&ME conducted a cursory review of previous documents relating to the FAR-II Dam and conducted a site visit at the facility. While not a comprehensive list, AEP provided S&ME with the following documents during the course of our involvement with this facility:

- Construction Plans, Fly Ash Dam 2
- Construction Plans, Dam Raising of Fly Ash Retention Dam II, March 1997
- 1997 Failure Repair Report
- 1999 Post Construction Performance Report
- 2004 Seepage Report

On August 18, 2015, the undersigned S&ME personnel met with Dr. Mohammad Ajlouni (AEP Civil Engineering) and Mr. Randy Sims (Landfill Operations) at the Cardinal Plant and conducted a site visit at the FAR-II Dam. The participants observed the site and discussed recent monitoring results, as well as
tentative plans to raise the pool level by adding additional stop logs. S&ME observed slight rutting along the wheel path on top of the dam, as well as minor settlement of the granular infill adjacent to the panels. Instrumentation readings from 12 tiltmeter sensors placed on the MSW wall panels indicate that both the upstream and downstream MSE wall panels are leaning outward slightly, however the rate of movement has now generally leveled off. This outward tilt appears to be an expression of the rotational movement needed to fully engage the geogrid reinforcement. S&ME understands that AEP is closely monitoring the ongoing instrumentation readings. While the site visit was not a formal inspection, visual observations of the FAR-II Dam did not reveal any dam safety concerns, and the downstream slopes appear to be in a similar condition as observed during construction of the recent dam raising.

4.0 Safety Factor Assessment

As part of the safety factor assessment, S&ME completed Parts 1 and 2 of Section 257.73(e) of the Final Rules for the Disposal of Coal Combustion Residuals from Electric Utilities published on April 17, 2015 in the Federal Register. In accordance with the Rule, the analysis was performed for the critical cross-sections(s) that are anticipated to be most susceptible of all cross-sections to structural failure based on appropriate engineering considerations. The Rule specified the following loading conditions for analysis:

i. Static Factor of Safety under the long-term, maximum storage pool loading condition must equal or exceed 1.50.
ii. Calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.50
iii. The calculated seismic factor of safety must equal or exceed 1.00
iv. For dikes constructed of soils susceptible to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.

4.1 Limit Equilibrium Analyses

Our 2013 Dam Raising Design Report discusses in detail the subsurface investigation, laboratory testing, parameter justification, seepage analyses and limit equilibrium slope stability analyses that were performed to develop safety factors for the FAR-II Dam Raising design. S&ME focused on evaluating the cross-section through the high point of the dam with additional slope stability runs performed for the section through the existing emergency spillway. Two dimensional slope stability analyses were performed under End of Construction, Long Term Maximum Pool (Static), Maximum Surcharge Pool, Rapid Drawdown, and seismic loading conditions in conformance with the US Army Corps of Engineers Manual 1110-2-1902 entitled Slope Stability. The phreatic surface was modeled based on current piezometer data collected from at the site and the results of the finite element seepage analysis. However, the phreatic surface was entered manually to minimize the potential for computation uncertainty as compared to directly using the finite element analysis output pressures.

Shear strength parameters representing the existing dam zones were developed by AEP and their consultants for the design of the Stage 1 and Stage 2 dams. These values were used as the starting point for the Stage 3 global stability analyses but were modified in some cases to reflect the results of the current investigation or to investigate particular failure modes. Additionally, the Stage 3 raising included several new material zones: the MSE wall reinforced zone (No. 57 stone), ODOT Item 304 surface course,
the cement-bentonite slurry wall, and the vinyl sheet pile wall. The shear strength parameters for these new materials were estimated based on past experience. It should also be noted that the strength of these materials does not appreciably impact the global stability analyses. Additional discussion of the shear strength values for the most critical zones is provided in the 2013 Final Design Report.

### 4.2 Liquefaction Potential of Embankment Soils

S&ME reviewed the material and compaction specifications of the embankment fill for the original dam construction and subsequent raisings. The dam was constructed entirely of engineered materials and was designed in accordance with the methods used to design conventional water reservoirs. The embankment fill consists of fine grained overburden soil and mine spoil fill from near the project site. With the exception of the blanket drain, chimney drain, and rip rap zone, all earthen material was compacted to 100% of the standard proctor compaction test. Based on this understanding, the embankment soils are considered non-liquefiable. Furthermore, liquefaction of the foundation soils is not a concern as the overburden beneath the dam was removed prior to fill placement, with the dam supported directly on bedrock.

### 4.3 Summary of Results

Based on our previous investigations and current assessment of the Bottom Ash Pond facility, S&ME certifies that this assessment meets the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments*. A summary of the computed safety factors for the critical cross-section is provided in Table 5-1. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv). Graphical output corresponding to the analysis cases are presented in Appendix II.

**Table 4-1 – Safety Factor Summary**

<table>
<thead>
<tr>
<th>Analysis Case</th>
<th>Minimum Safety Factor</th>
<th>Computed Safety Factor</th>
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<tr>
<td>Long-term, maximum storage pool</td>
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<td>Embankment Liquefaction</td>
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<td>Non-liquefiable</td>
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5.0 Certification

Based on our previous investigation, design, and construction administration work associated with the Fly Ash Reservoir II Dam, S&ME certifies that this assessment meets the requirements of 40 CFR § 257.73(e), Periodic Safety Factor Assessments. A summary of the computed safety factors for the critical cross-section is provided in the table below. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv).

Michael T. Romanello, P.E.
Project Engineer
Registration No. 74384

Michael G. Rowland, P.E.
Senior Engineer
Registration No. 65559
Appendices
Appendix I – Safety Factor Assessment Figures
Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio

- Steady-State Stability Analysis
- Global Stability
- Downstream Slope
- Circular Failure Surface

Method: Spencer
Scale: 1" = 150'

Safety Factor
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00+

Material Name | Color | Unit Weight (lbs/ft³) | Cohesion (psf) | Phi (deg)
--- | --- | --- | --- | ---
RCC | | 95 | 14400 | 0
Saturated Mine Spoil | | 128 | 0 | 30
Chimney Drain | | 100 | 0 | 38
Saturated Clay Core | | 128 | 0 | 28
Rock Toe Buttress | | 110 | 0 | 38
Mine Spoil - Downstream Shell | | 125 | 0 | 30
Brown Clay | | 125 | 0 | 26
Mine Spoil - 97 Raising | | 125 | 0 | 30
Blanket Drain | | 100 | 0 | 38
Transition Zone | | 128 | 0 | 30
Overburden | | 123 | 1000 | 15
Bottom Ash Filter Zone | | 100 | 0 | 38
Item 304 | | 130 | 0 | 38
Reinforced Zone - Coarse Aggregate | | 100 | 0 | 38
Cement Bentonite Cutoff | | 100 | 720 | 0
Vinyl Sheet Pile | | 120 | 92400 | 0

260.00 lbs/ft²
### Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio

- Steady-State Stability Analysis
- Downstream Slope
- Proposed Max Operating Pool EL 974

- Composite Failure Surface Modeled with Tension Crack Along Sheet Pile Interface

Method: Spencer
Scale: 1" = 100'

---

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<th>Material Name</th>
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<th>Cohesion (psf)</th>
<th>Phi (deg)</th>
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Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio

- Steady-State Stability Analysis
- Downstream Slope
- Proposed Max Operating Pool EL 974

- Composite Failure Surface Modeled with Tension Crack Along Sheet Pile Interface

Method: Spencer
Scale: 1" = 100'

Tension Crack
Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio

- Steady-State Stability Analysis
- Surcharge Pool Loading Condition
- Global Stability
- Downstream Slope
- Circular Failure Surface

Method: Spencer
Scale: 1" = 150'
### Cardinal FAR-II Dam Raising
Cardinal Plant / Brilliant, Ohio

- Seismic Stability Analysis
- Psuedostatic Force Approach
- Downstream Slope
- Circular Failure Surface

**Method:** Spencer  
**Scale:** 1" = 150'  
**Safety Factor**

#### Material Properties

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Appendix II – Action Value Recommendation Figures
Cardinal FAR-II Dam

- Piezometer Reading Action Level Determination
- Global Stability / Static Loading
- Critical Cross-Section
- Simulated Phreatic Surface to Reduce Factor of Safety To 1.0

Method: Spencer

Modeled phreatic surface based on 2011 piezometer readings