Stantec Consulting Services Inc.
3052 Beaumont Centre Circle, Lexington KY 40513

October 5, 2018
File: rpt_003_let_175567307
Revision 0

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

RE: Fault Areas
Stilling Pond (including Retention Pond)
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Cumberland Fossil Plant
Cumberland City, Tennessee

1.0 PURPOSE

As described in 40 CFR § 257.62(a), an owner or operator of an existing CCR surface impoundment is required to demonstrate that the unit is not located in fault areas unless the unit meets certain requirements. This letter documents Stantec's certification that the Stilling Pond (including Retention Pond) at the TVA Cumberland Fossil Plant (CUF) complies with the location restrictions for fault areas in the EPA Final CCR Rule at 40 CFR § 257.62(a).

2.0 SUMMARY OF FINDINGS

The attached demonstration documents that the Stilling Pond (including Retention Pond) meets the requirements set forth in 40 CFR § 257.62(a).

3.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Stephen H. Bickel, being a Professional Engineer in good standing in the State of Tennessee, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;

2. that the information contained herein is accurate as of the date of my signature below; and

3. that the TVA Cumberland Stilling Pond (including Retention Pond) meets the requirements specified in 40 CFR § 257.62(a).

RE: Fault Areas
Stilling Pond (including Retention Pond)
EPA Final Coal Combustion Residuals (CCR) Rule
TVA Cumberland Fossil Plant
Cumberland City, Tennessee

SIGNATURE ______________________ DATE 10/05/2018

ADDRESS: Stantec Consulting Services Inc.
10509 Timberwood Circle Suite 100
Louisville, Kentucky 40223

TELEPHONE: (502) 212-5075

ATTACHMENTS: Fault Areas Demonstration

STEPHEN H. BICKEL
REGISTERED ENGINEER
AGRICULTURE
COMMERCE
No. 113134
STATE OF TENNESSEE

Fault Areas Demonstration

Stilling Pond (including Retention Pond)
Cumberland Fossil Plant
Stewart County, Tennessee

Prepared for:
Tennessee Valley Authority
Chattanooga, Tennessee

Prepared by:
Stantec Consulting Services Inc.
Lexington, Kentucky

October 5, 2018
Revision 0

Table of Contents

1.0 BACKGROUND

On April 17, 2015, EPA published the "Disposal of Coal Combustion Residuals (CCR) from Electric Utilities" final rule in the Federal Register. The Tennessee Valley Authority (TVA) contracted Stantec Consulting Services Inc. (Stantec) to evaluate the Stilling Pond (including Retention Pond) at the Cumberland Fossil Plant (CUF) regarding the requirements for the Fault Areas Location Restriction as required by the EPA Final CCR Rule, 40 C.F.R. §257.62.

As required by §257.62 of the EPA Final CCR Rule, an owner or operator of a new CCR landfill, existing or new CCR surface impoundment, or any lateral expansion of a CCR unit is required by October 17, 2018, to demonstrate that the unit is not located within 60 meters (200 feet) of the outermost damage zone of a fault that has had displacement in the Holocene time period unless the owner or operator demonstrates that measures are in place to prevent damage to the structural integrity of the CCR unit under an alternative setback distance of less than 60 meters (200 feet).

CUF is a coal-fired, electric-generating plant. The plant is located in Stewart County, Tennessee, south of the Cumberland River and approximately 60 miles northwest of Nashville. The plant is located in the Western Highland Rim of Middle Tennessee. The site is underlain by bedrock primarily of Ordovician age, with smaller amounts of Silurian and Devonian aged rock. The plant is situated in an ancient meteorite impact crater just north of the impact zone. This event has produced a complex geologic structural setting at the facility.

2.0 ASSESSMENT

This compliance demonstration was developed by conducting two tasks.

The first task was a review of available literature and published data related to the potential for faulting in the project vicinity. The result of that study, which is titled "Literature Survey and Discussion of the Geology and Seismicity of the Tennessee Valley Authority Cumberland Fossil Plant West-Central Tennessee," does not identify faults within the established minimum horizontal buffer and is presented in Appendix A.

The second task was a site specific neotectonics analysis. This study evaluates existing landforms for indications of past fault activity through a compilation of lineaments and surface drainage analysis within the project vicinity. The results of this study do not identify the presence of lineaments or drainage characteristics indicative of faults within the established minimum horizontal buffer distance. The results of the study are presented in a report titled "Tennessee Valley Authority, Cumberland Fossil Plant, West Central Tennessee, Neotectonics Analysis," and are presented in Appendix B.

3.0 CONCLUSIONS

Based on the assessment outlined herein, the Stilling Pond (including Retention Pond) at CUF meets the requirements of § 257.62 of the EPA Final CCR Rule for the 60-meter (200 foot) buffer from fault areas.

APPENDIX A
LITERATURE SURVEY AND DISCUSSION OF THE GEOLOGY AND SEISMICITY OF THE TENNESSEE VALLEY AUTHORITY CUMBERLAND FOSSIL PLANT WEST-CENTRAL TENNESSEE

Literature Survey and Discussion of the Geology and Seismicity of the Tennessee Valley Authority Cumberland Fossil Plant West-Central Tennessee

Robert D. Hatcher, Jr., Ph.D., P.G.
Department of Earth and Planetary Sciences
and Science Alliance Center of Excellence
University of Tennessee–Knoxville

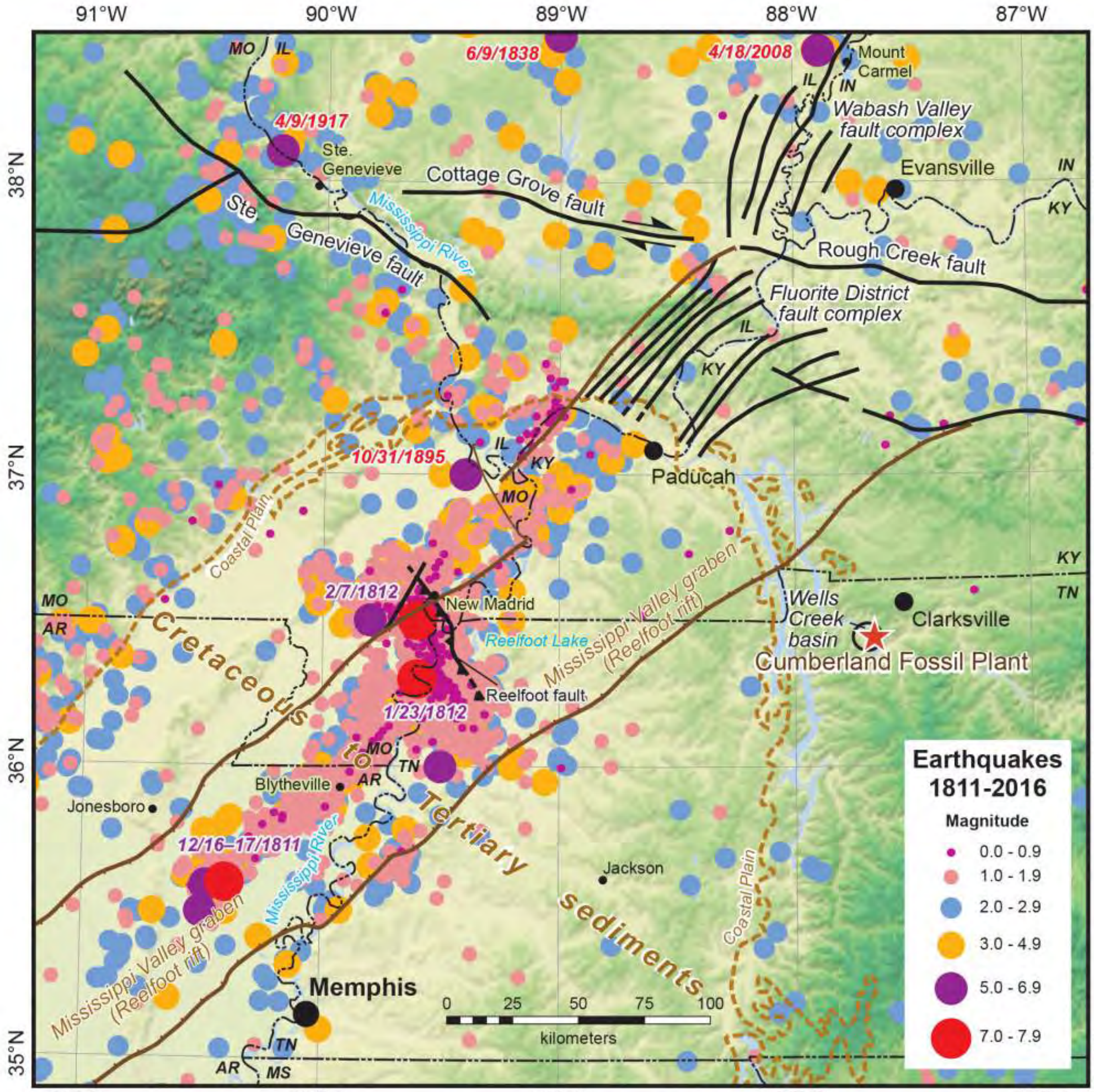
September 19, 2016
Revision January 9, 2017

Introduction

The purpose of this report is to provide a literature survey and discussion of known active (surface displacement during the last 11,700 years—Holocene time) or potentially active (evidence of surface displacement during the last 1.6 m.y.—Quaternary time) faults (Bryant and Hart, 2007) near the Tennessee Valley Authority Cumberland Fossil Plant in west-central Tennessee. The plant is located some 19 miles southwest of Clarksville, at mile 103 on Lake Barkley (Cumberland River), at the west edge of Cumberland City, Stewart County, Tennessee, (Fig. 1).

The references cited in this report are considered critical for understanding the geology, paleoseismology, and modern seismicity of the region and in the vicinity of the Cumberland Fossil Plant. Many of the papers, maps, and reports cited herein contain additional citations that provide much greater detail about the surface and subsurface geology and seismicity in the region. Several of these reports and publications include Kellberg (1958), Wilson and Stearns (1968), Stearns et al. (1968a, 1968b), Tiedeman et al. (1968), Wilson et al (1968), Johnston and Schweig (1996), Julian and Danzig (1998), Obermeier (1998), McBride et al. (2002), Tavakoli, et al. (2010), Pratt (2012), and Van Arsdale et al. (2013).

This literature search is intended to summarize the available literature near and in the region surrounding the Cumberland Fossil Plant. In particular, it is important to note any active faults within a 2-mi radius of the plant, and to chronicle the seismicity of the region that might affect the plant. The definitions below are from California Geological Survey Special Report (2007 revision); this report defines a rigorous set of criteria for evaluating seismically active faults in the state that has the greatest earthquake hazard (and population) in the U.S. An active fault (or earthquake fault) is one that has been demonstrated to have moved during the Holocene (last 11,700 years). This would include the zone of deformation (damage zone) on either side of the fault, which would encompass geologic structures (folds, subsidiary faults, joints and shear fractures, etc.) that would have been produced as coseismic features during movement on the fault that produced seismicity (Bryant and Hart, 2007). The California Geological Survey defined the boundaries of "Earthquake Fault Zones" to be located ~500 ft (150 m) from a major active fault and 200 to 300 ft (60-90 m) from well-defined minor faults (Bryant and Hart, 2007, p. 42).



Sources: Linework - Natl. Atlas Data; EQs - USGS/NEIC, CERI, & Stover, C. W. and Coffman, J. L., 1993; Faults - McBride & Nelson (2001), Hough et al. (2000), and Johnston & Schweig (1996)

Figure 1. Location map for the Tennesee Valley Authority Cumberland Fossil Plant (red star), regional seismicity, major tectonic features, prominent faults, the Wells Creek basin impact structure (circle located just west of and beneath the red star), and major population centers. Dates of earthquakes of $M_w > 5$ are shown in red and purple letters.

Regional Geology and Seismicity

The Cumberland Fossil Plant is located in the Western Highland Rim along the west side (actually south bank along a convex-southward meander) of the Cumberland River (Fig. 2). Surface geology in this region consists of late Paleozoic carbonate and clastic sedimentary rocks of the Western Highland Rim exposed east of the Tennessee River and west of the Cumberland River. These rocks are unconformably overlain by thin unconsolidated Quaternary terrace, floodplain, and other river deposits (Fig. 2). Gulf Coastal Plain deposits unconformably overlie the Paleozoic stata some 30 miles farther west. The otherwise gently west-dipping sedimentary sequence is interrupted by the near-circular Wells Creek Basin impact structure (Hardeman, 1966; Wilson and Stearns, 1968). The Cumberland Fossil Plant is located on the north flank of the central uplift of the Wells Creek structure (Fig. 2). Evidence that this structure is a product of a bolide impact is chronicled by Wilson and Stearns (1968). Detailed geologic maps of the impact structure are contained in their report (Wilson and Stearns, 1968, their Plate 2) and in Stearns et al. (1968a, 1968b), Tiedeman et al. (1968), and Wilson et al. (1968).

West and southwest of the Cumberland Plant is the large early Paleozoic Mississippi Valley graben, identified by aeromagnetic data (frequently referred to as the Reelfoot rift; e.g., Hildenbrand and Hendricks, 1995; Johnston and Schweig, 1996; Van Arsdale et al., 2013). Most of the seismicity of the New Madrid seismic zone is contained within the graben (Fig. 1), and some have suggested that the seismic activity in this and other eastern U.S. intraplate seismic zones is related to early Paleozoic faults (e.g., Johnston and Schweig, 1996; Wheeler, 1996).

The active seismicity, however, only roughly parallels the graben boundaries, and is located in a northeast-trending zone of earthquakes that is truncated (or displaced by) in northwestern Tennessee and southeastern Missouri by a northwest-trending zone of seismicity, a thrust now called the Reelfoot fault (Chiu et al., 1992; Johnston and Schweig, 1996; Cox et al., 2006). The history of the New Madrid seismic zone and the 1811-1812 earthquakes is chronicled by Johnson and Schweig (1996) and Hough et al. (2000).
A major zone of seismicity continues to the northeast from near the northwest end of the

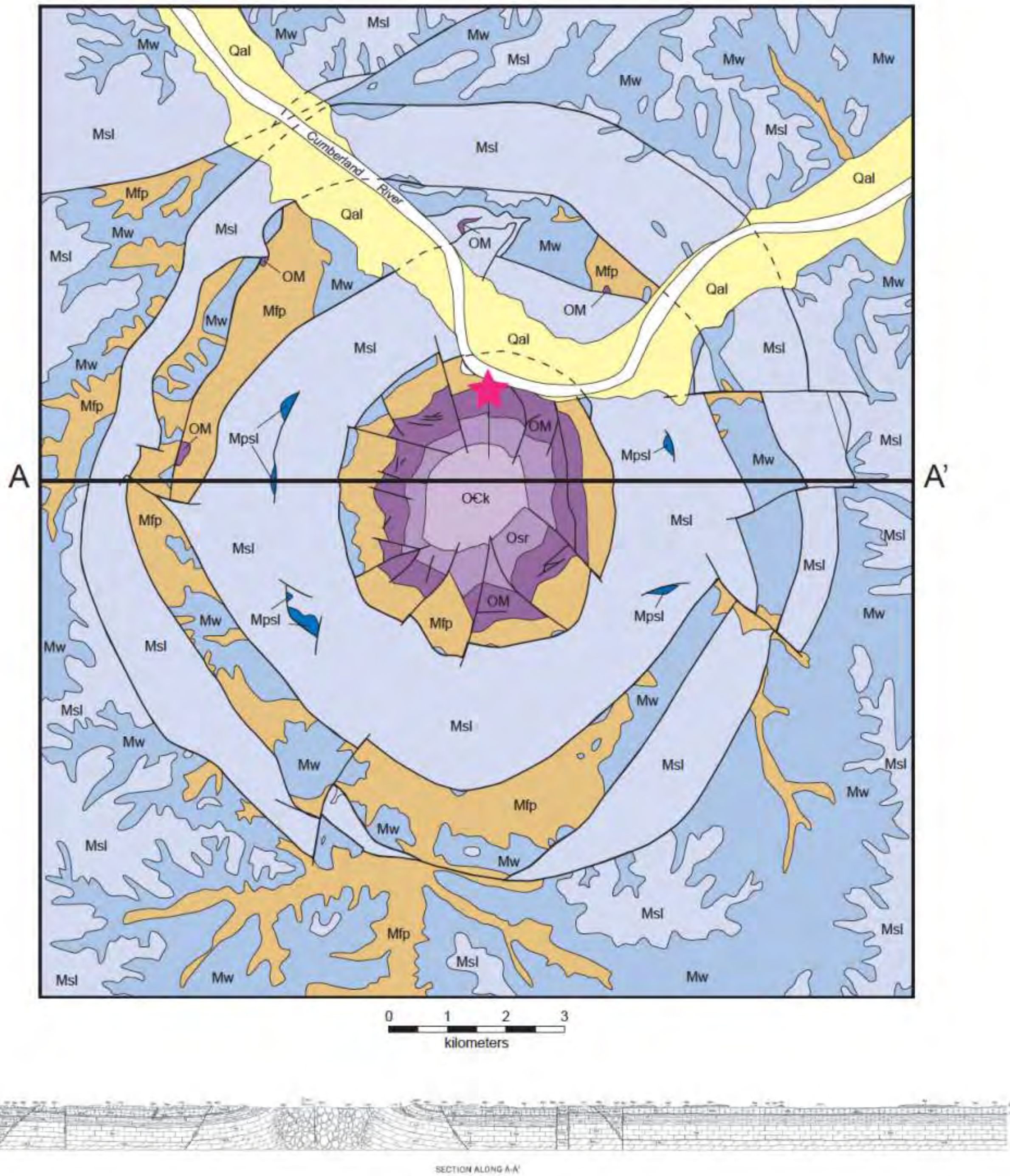


Figure 2. Geologic map of the Wells Creek structure in west-central Tennessee. The red star is the location of the Cumberland Fossil Plant. Note the circular character of the outcrop pattern produced by doming and radial and concentric faults that produced steep dips in the core of the structure. Oldest units are exposed in the central part of the structure. OCk—Knox Group. Osr—Stones River Group. OM—Nashville Group through Chattanooga Shale. Mfp—Fort Payne Formation. Mw—Warsaw Limestone. Msl—St. Louis Limestone. Mpsl—Post-St. Louis Mississippian rocks. Qal—Alluvium. A—A'–Location of cross-section line. Additional map-unit symbols in the cross section, but not in geologic map: Ofh–Fernvale through Hermitage Formations (Middle and Upper Ordovician units). S–Silurian. D–Devonian. MDc–Chattanooga Shale. (From C. W. Wilson, Jr., and R. G. Stearns, 1968, Tennessee Division of

Reelfoot fault that diminished in frequency and magnitude of earthquakes northeastward to the region in Kentucky near Paducah (Fig. 1). The northeast-trending faults that are defined by the seismicity in the New Madrid seismic zone have recently been interpreted as dextral strike-slip faults that are truncated by the Reelfoot fault (Cox et al., 2006; Tavakoli et al., 2010). The zone of greatest frequency and magnitude of historic earthquakes continues northwestward across southernmost Illinois into southeastern Missouri in a zone that parallels the strike of the Paleozoic Ste. Genevieve fault (Fig. 1). The northeastern limit of historical New Madrid earthquakes, which ends immediately southwest of Paducah, and the TVA Shawnee Fossil Plant, bounds a region of very low to no historic seismicity in southern Illinois and adjacent Kentucky to an area near the N70°W-trending Paleozoic Cottage Grove dextral fault in southern Illinois where a group of historical earthquakes mostly of $M_w < 5.0$ occurs on both sides of the Cottage Grove fault (Fig. 1). The current interpretation of the New Madrid seismic zone is that it is related to a crustal-scale dextral strike-slip fault system and flower structure (Tavakoli, et al., 2010; Pratt, 2012). This interpretation is based on earthquake, seismic reflection, and surface geologic data (Tavakoli et al., 2010), as well as computer modeling of the structure (Pratt, 2012), and fits the available data better than any previous interpretation.

McBride and Nelson (2001) and McBride et al. (2002, their Figure 2) identified a young fault suite in southern Illinois in both seismic reflection profiles and surface exposures, which displace Cretaceous and Tertiary deposits, and early Pleistocene sediments, but not the late Pleistocene sediments, and overlying Pleistocene loess and Quaternary stream deposits. These young faults (inactive for at least 55 ka) may or may not be related to the complex of Paleozoic faults in that area (McBride et al., 2002, their Fig. 2) (Fig. 1). The Paleozoic Fluorite District fault zone appears to separate the New Madrid seismic zone from the Wabash Valley fault system and seismic zone (Obermeier, 1998) (Fig. 1). A similar group of faults was imaged in seismic-reflection data by Luzietta et al. (2006) in the Crittenden fault zone in eastern Arkansas. This fault system similarly displaces Paleozoic, Cretaceous, and Tertiary sediments, but could not be demonstrated to have displaced the younger Pleistocene sediments, although they may have been folded.

Cumberland Site Geology and Potentially Active Faults Within Two Miles of the Site

The geology at the Cumberland Plant site consists of thin unconsolidated Quaternary clastic stream deposits immediately east of the confluence of Wells Creek with the

Cumberland River that rest unconformably on steeply north-dipping Ordovician, Silurian, and Mississippian limestone, shale, and calcareous silicastone (Kellberg, 1958; Julian and Danzig, 1998). The cross sections that Kellberg (1958) constructed are remarkably similar to the modern cross sections by Wilson and Stearns (1968), Stearns et al. (1968a, 1968b), Tiedeman et al. (1968), and Wilson et al. (1968), which are based on detailed geologic mapping and some drill data. These rocks are intensely brittlely deformed, especially the Knox Group dolostone in the center of the central uplift. Here, beds within the Knox cannot be traced for any appreciable distance, and abundant shattercones indicative of intense, hypervelocity brittle deformation have been recovered from the Knox (Wilson and Stearns, 1968, their Figs. 34 through 40).

The Cumberland Fossil Plant actually rests on moderately to steeply dipping Early to Late Ordovician, Silurian, Devonian, and Mississipian rocks that still maintain sufficient continuity to be mapped as stratigraphic units, in contrast to the intensely deformed Knox Group rocks in the innermost part of the central uplift. Nevertheless the rocks at the Cumberland site lie in the innermost of the radial and concentric faults that have been mapped in this structure. These faults form a series of concentric horsts and grabens, within the central uplift forming the innermost horst (Wilson and Stearns, 1968, their Plate 2) (Fig. 2). Wilson (1953) identified at least two localities where Wilcox (Paleocene-Eocene) sands occur in depressions nearby. If these sands were deposited after the Wells Creek impact, the minimum age of the impact would be pre–Wilcox deposition.

Julian and Danzig (1998) summarized the topography, geology (see their Fig. 5.9), subsurface exploration, and ground water resources of the Cumberland Fossil Plant site, flue gas desulfurization disposal area, and ash disposal sites. Ground water occurs here in fractures in the bedrock units, with some in the remnant terrace and other river deposits, and the water table is relatively close to the surface, with a local vadose zone through the weathered rocks near and at the surface. Fractures and faults may locally be enlarged by dissolution, but no major karst systems have been identified in the site area.

Conclusions

1. The Cumberland Fossil Plant is located east of the east flank of the New Madrid seismic zone, in an area of low seismicity.

2. The fossil plant is also located within the central uplift of the near-circular array of horsts and grabens forming the Wells Creek Basin impact structure. This impact structure likely formed before the deposition of the Wilcox Formation, an Eocene clastic unit of the Mississippi Embayment in the Coastal Plain of west-central Tennessee.

3. None of the literature reviewed, including published papers, TVA reports, and reports from other agencies, have indicated the existence of any active or potentially active faults within two miles of the Cumberland Fossil Plant.

References Cited

Bryant, W. A., and Hart, E.W., 2007, Fault-rupture hazard zones in California: California Geological Survey, Special Publication 42, Interim Revision 2007, 42 p.

Chiu, J. M., Johnston, A. C., and Yang, Y. T., 1992, Imaging the active faults of the central New Madrid seismic zone using PANDA array data: Seismological Research Letters, v. 63, p. 375–393.

Cox, R. T., Cherryhomes, J., Harris, J. B., Larsen, D., Van Arsdale, R. B., and Forman, S. L., 2006, Paleoseismology of the southeastern Reelfoot Rift in western Tennessee and implications for intraplate fault zone evolution: Tectonics, v. 25, TC3019, doi:10.1029/2005TC001829.

Hardeman, W. D., 1966, Geologic map of Tennessee: Tennessee Division of Geology, scale 1:250,000.

Hildenbrand, T. G., and Hendricks, J. D., 1995, Geophysical setting of the Reelfoot rift and relations between rift structures and the New Madrid seismic zone: U. S. Geological Survey Professional Paper 1538–E, 30 p.

Hough, S. E., Armbruster, J. G., Seeber, L., and Hough J. F., 2000, On the modified Mercalli intensities and magnitudes of the 1811-1812 New Madrid earthquakes: Journal of Geophysical Research, v. 105, p. 23,839-23,864.

Johnston, A. C., and Schweig, E. S., 1996, The enigma of the New Madrid earthquakes of 1811-1812: Annual Review of Earth and Planetary Sciences, v. 24, p. 339-384.

Julian, H. E., and Danzig, A. J., 1998, Cumberland Fossil Plant groundwater assessment: Tennessee Valley Authority Report WR 98-1-46-110, 80 p. (plus appendices).

Kellberg, J. M., 1958, Preliminary geologic investigations for the Cumberland Steam Plant Site: Tennessee Valley Authority Geologic Branch, 19 p.

Luzietti, E. A., Kanter, L. R., Schweig, III, E. S., Shedlock, K. M., and Van Arsdale, R. B., 1995, Shallow deformation along the Crittenden County fault zone near the southeastern margin of the Reelfoot rift, northeastern Arkansas: U.S. Geological Survey Professional Paper 1530-J, 23 p.

McBride, J. H., and Nelson, W. J., 2001, Seismic images of shallow faulting, northernmost Mississippi Embayment, north of the New Madrid seismic zone: Bulletin of the Seismological Society of America, v. 91, p. 1128–139.

McBride, J. H. Nelson, W. J., and Stephenson, W. J., 2002, Quaternary-age deformation in the northern Mississippi embayment: Seismological Research Letters, v. 73, no. 5, p. 597-627.

Pratt, T.L., 2012, Kinematics of the New Madrid Seismic zone, Central United States, based on stepover models, *Geology*, v. 40, p. 371-374. doi:10.1130/G32624.

Seid, M. J., Denny, F. B., and Devera, J A., 2013, Bedrock geology of the Cave-In Rock quadrangle, Hardin County Illinois, and Crittenden County, Kentucky: Illinois State Geological Survey, Prairie Research Institute, 7 p.

Sparks, T. N., compiler, 2009, Subcrop geologic map of Cretaceous/Tertiary Section, Jackson Purchase region, western Kentucky: U.S. Geological Survey STATEMAP, Series XII, 2009, Contract Report 34, scale 1:125,000.

Stearns, R. G., Tiedeman, H. A., and Wilson, C. W., Jr., 1968a, Geologic map of the Erin quadrangle, Tennessee: Tennessee Division of Geology, GM 38–SW, scale 1:24,000.

Stearns, R. G., Tiedeman, H. A., and Wilson, C. W., Jr., 1968b, Geologic map of the Needmore quadrangle, Tennessee: Tennessee Division of Geology, GM 38–NE, scale 1:24,000.

Stover, C.W., and Coffman, J.L., 1993, Seismicity of the United States, 1568-1989 (revised), U. S. Geological Survey Professional Paper 1527, 418 p.

Tiedeman, H. A., Wilson, C. W., Jr., and Stearns, R. G., 1968, Geologic map of the Cumberland City quadrangle, Tennessee: Tennessee Division of Geology, GM 38–NW, scale 1:24,000.

Van Arsdale, R., and Cupples, W., 2013, Late Pliocene and Quaternary deformation of the Reelfoot rift: Geosphere, v. 9, 13 p. doi:10.1130/GES00906.1

Wheeler, Russell L., 1996, Earthquakes and the southeastern boundary of the intact Iapetan margin in eastern North America: Seismological Research Letters, v. 67, no. 5, p. 77-83.

Wilson, C. W., Jr., 1953, Wilcox deposits in explosion craters, Stewart County, Tennessee, and their relations to origin and age of Wells Creek Basin structure: Geological Society of America Bulletin, v. 64 p. 753-768.

Wilson, C. W., Jr., and Stearns, R. G., 1968, Geology of the Wells Creek structure, Tennessee: Tennessee Division of Geology Bulletin 68, 236 p.

Wilson, C. W., Jr., Stearns, R. G., and Tiedeman, H. A., 1968, Geologic map of the Ellis Mills quadrangle, Tennessee: Tennessee Division of Geology, GM 38–SE, scale 1:24,000.

Woolery, E., Baldwin, K., Nelson, K., Hampson, S., Givler, R., and Sundermann, S., 2009, Site-specific rupture hazard assessment—Fluorspar area fault complex, western Kentucky: Seismological Research Letters, v. 80, p. 1035–1044.

APPENDIX B
NEOTECTONIC ANALYSIS

Tennessee Valley Authority Cumberland Fossil Plant, West Central Tennessee

Neotectonics Analysis

September 24, 2018

Prepared for:

Tennessee Valley Authority

Prepared by:

Stantec Consulting Ltd.
500 – 4730 Kingsway
Burnaby, British Columbia
V5H 0C6

Project Number:
17555021.202.3/203.3

FINAL REPORT

Revision	Description	Author		Quality Check		Independent Review	
0	IFR	Sid Tsang	2016-11-03	Sid Tsang	2016-11-03	Rick Guthrie	2016-11-03
1	IFU	Sid Tsang	2018-09-24	Sid Tsang	2018-09-24	Rick Guthrie	2018-09-24

Table of Contents

LIST OF FIGURES

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the Tennessee Valley Authority (TVA) to conduct a Phase 1 Assessment for the Fault Areas demonstration of the Cumberland Fossil Plant in west central Tennessee (Figure 1). The demonstration is required by the US Environmental Protection Agency's disposal of Coal Combustion Residuals (CCR) Rule (US EPA 2015). The first task was to complete a literature review of available data of known active or potentially active (last 11,700 years) faults in the vicinity of the Cumberland Fossil Plant (Hatcher 2016). The second task comprises a neotectonics analysis within a two-mile radius of the site—the subject of this report.

1.1 SCOPE OF WORK

For the purpose of this study we define neotectonics as the study of geologically recent (last 11,700 years) movements and deformations of the Earth's crust and measurement of its local effects in order to develop techniques for predicting earthquakes. The scope of work for this neotectonics analysis comprises the following three tasks:

Task 1 builds on the literature review findings by utilizing the online 2014 U.S. Geological Survey (USGS) seismic hazard map, the online USGS interactive fault map, and the State of Tennessee TNGIS GIS Services website. Publically available maps, reports and scientific literature relevant to the terrain conditions of the site are reviewed.

Task 2 involves a lineament analysis where lineaments are mapped from air photographs, Light Detection and Ranging (LiDAR) hillshade and satellite images within at least a two-mile radius of the Cumberland Fossil Plant (study area); centered on the bottom ash pond. The mapping is carried out in ArcGIS to facilitate the plotting of maps and viewing of spatial data. Where lineaments are identified, the main directions are plotted.

Task 3 involves a drainage analysis of well-defined patterns (dendritic, parallel, trellis, rectangular, radial, annular and contorted) which are not redirected by anthropogenic activity.

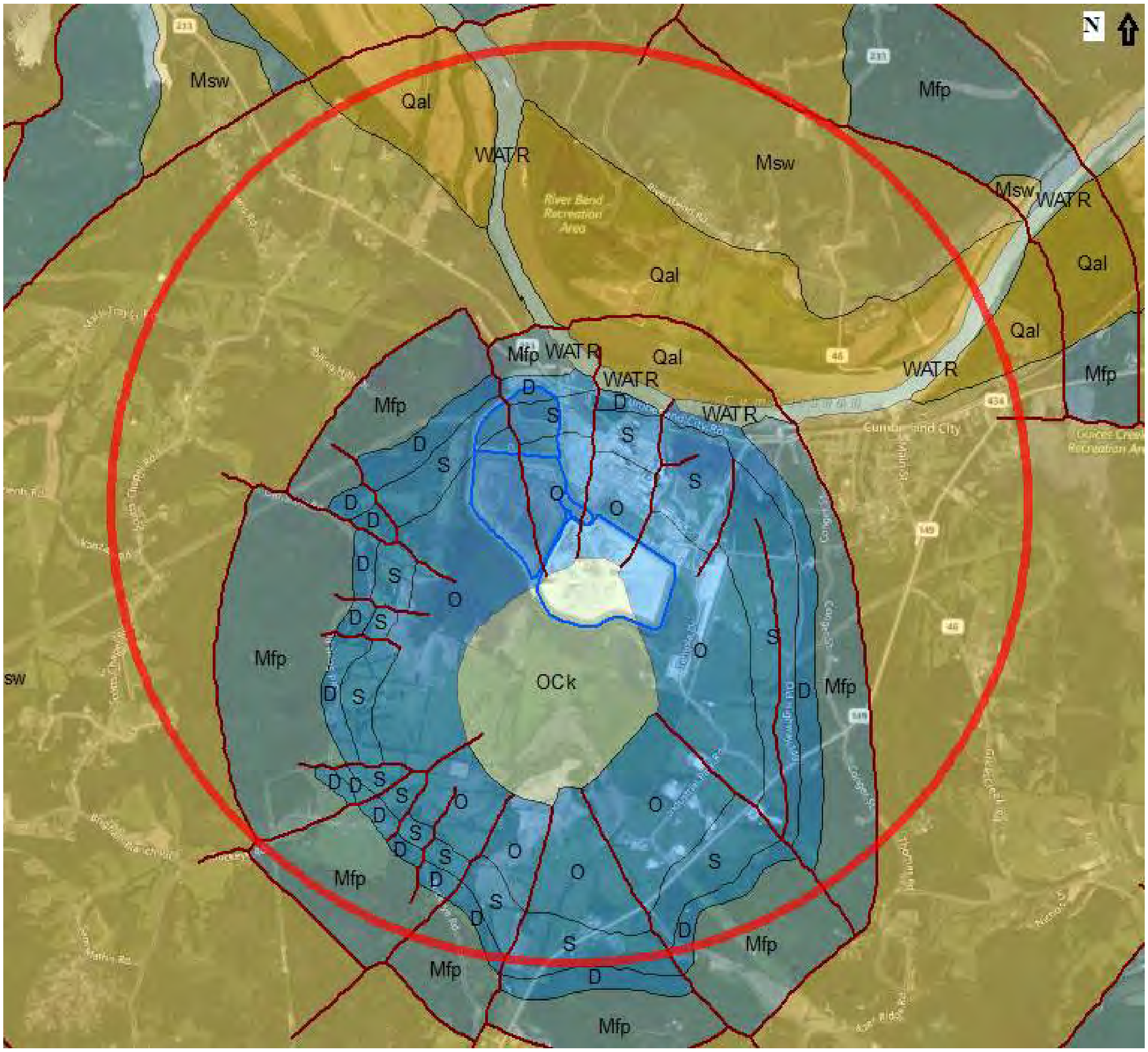


Figure 1. **TVA Cumberland Fossil Plant study area (red); Geology and inferred faults (purple) from USGS Mineral Resources On-Line Spatial Data. Image source: Bing Maps.**

Map Symbol	Age	Description
Qal	Quaternary	Alluvium - sand and silt
Msw	Mississippian	Warsaw Limestone
Mfp	Mississippian	Fort Payne Formation – chert and shale
D	Devonian	Limestone and chert
S	Silurian	Limestone and shale
O	Ordovician	Limestone and shale
OCk	Ordovician to Cambrian	Knox Group – dolomite and limestone

2.0 BACKGROUND INFORMATION

2.1 DATA SOURCES

Readily available background information of relevance to the neotectonics analysis and geological conditions of the site was gathered and reviewed. This information included:

- Geologic Map of the Cumberland City Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-NW. 1:24,000 scale. (Tiedemann et al. 1968).
- Geologic Map of the Erin Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-SW. 1:24,000 scale. (Stearns et al. 1968a).
- Geologic Map of the Needmore Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-NE. 1:24,000 scale. (Stearns et al. 1968b).
- Literature Survey and Discussion of the Geology and Seismicity of the Tennessee Valley Authority Cumberland Fossil Plant, West Central Tennessee (Hatcher 2016).
- State of Tennessee TNMAP GIS Services: Environmental/Hydrological Features
- TNGIS 2013 LiDAR for Lower Cumberland.
- US Department of Agriculture, Natural Resources Conservation Service-Soil Survey database for Houston County, Tennessee (TN083).
- US Department of Agriculture, Natural Resources Conservation Service-Soil Survey database for Stewart County, Tennessee (TN161).
- USGS data catalog: Physiographic provinces.
- USGS Mineral Resources On-Line Spatial Data: Digital Faults and Geology for Tennessee.
- 2014 USGS National Seismic Hazard Maps.

2.2 PROJECT SETTING

The study area is located within the Western Highland Rim region; an elevated region of rolling terrain, heavily dissected by low gradient creeks and small rivers. Within the study area, elevations range from 360 feet above sea level along the Cumberland River to approximately 650 feet above sea level along Sheep Ridge, immediately west of the Cumberland Fossil Plant. The underlying bedrock geology comprises Paleozoic carbonate and clastic sedimentary rocks that had been laid down in horizontal beds. Approximately 200 +/- 100 million years ago a meteorite impacted the region forming a four mile wide crater (Wilson and Stearns, 1968). The force of the impact caused the bedrock to vapourize, melt and fracture. Where the bedrock acted like a liquid crustal rebound resulted in central uplift (Figure 2). Millions of years of weathering and erosion have lowered the surface by hundreds of feet. The shattered rock in the impact crater (Knox dolomite) eroded faster and deeper than the surrounding region and formed the near-circular Wells Creek Basin. The bedrock is unconformably overlain by thin, unconsolidated Quaternary fluvial deposits. The Cumberland River meanders east to west at the north end of the study area and Wells Creek flows north through the central basin of the study area where it joins the Cumberland River at the north end of the Cumberland Fossil Plant.

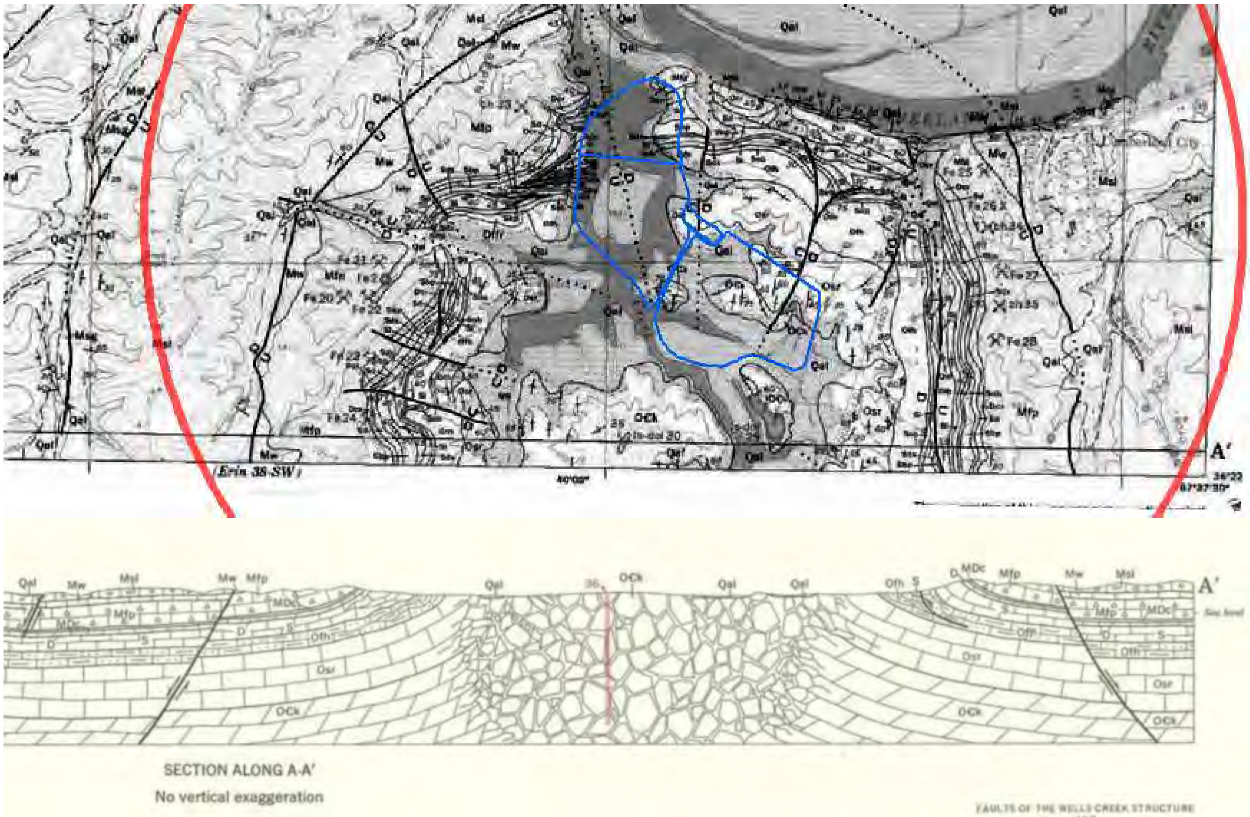


Figure 2. Excerpt from the geologic map of the Cumberland City Quadrangle, Tennessee for the Cumberland Fossil Plant study area (red) (Tiedemann at al., 1968).

The USGS fault mapping (Figure 1) shows radial and concentric faults which are a legacy of the Wells Creek Basin meteorite impact.

The 2014 USGS National Seismic Hazard Model displays the uniform probabilistic seismic hazard map with a 2-percent probability of exceedance in 50 years (Figure 3). The seismic hazard is shown as low to moderate hazard for the Cumberland Fossil Plant.

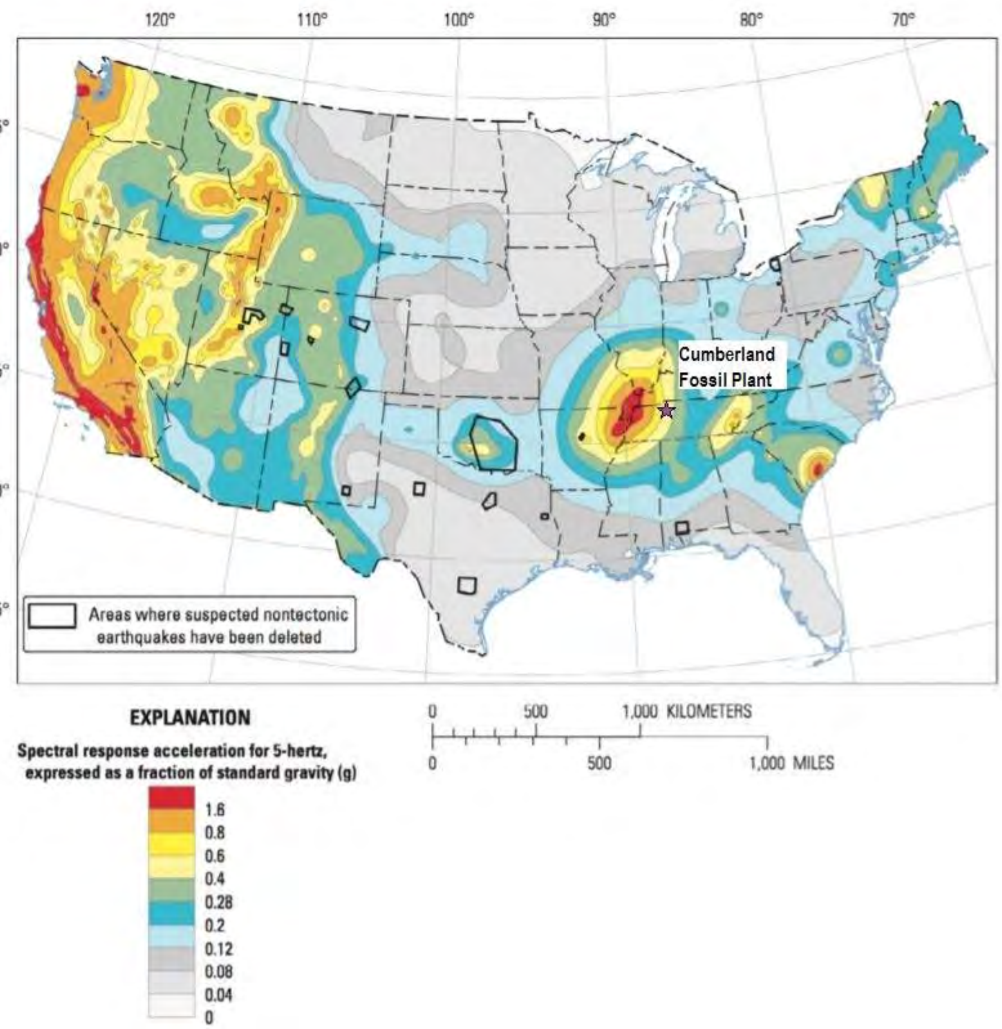


Figure 3. **2014 USGS National Seismic Hazard Map, 5-Hz spectral acceleration, 2% probability of exceedance in 50 years or 0.04% probability of exceedance in 1 year on firm rock site condition.**

3.0 LINEAMENT ANALYSIS

The desktop lineament analysis utilizes 2012 and 2014 satellite imagery and 2013 LiDAR (5 feet grid)[1] hillshade imagery. The satellite and LiDAR hillshade imagery were viewed in ArcGIS to enable the mapper to view imagery, LiDAR data and other GIS layers readily.

The lineament analysis is based on visible interpretation of mappable linear, rectilinear or curvilinear surface features that are expected to reflect subsurface phenomena (Figure 4). Without geophysical data the mapping of these surface features are subjective at best. Most of the mapped lineaments (L1-L18) are interpreted to be a legacy of the Wells Creek Basin impact structure—radial and curvilinear features. Two lineaments (L19, L20) defined by the valley axis of the Cumberland River likely represent major faults that pre-date the Holocene (Figure 4).

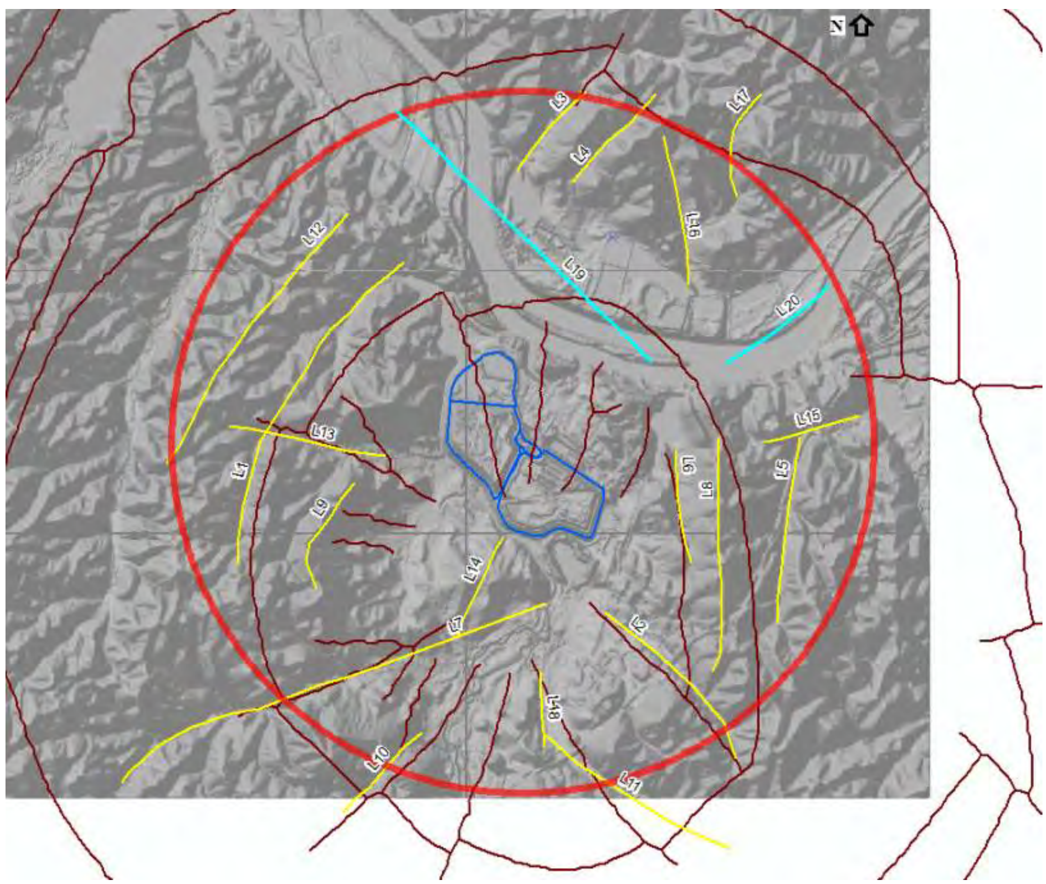


Figure 4. Mapped lineaments (yellow, blue) and USGS faults (purple) overlain on LiDAR hillshade image.

---

[1] Publically available 2013 LiDAR data was downloaded from the TNGIS LiDAR for Lower Cumberland website.

4.0 DRAINAGE ANALYSIS

Drainage analysis is useful in structural geology interpretation—it includes consideration of drainage patterns, drainage texture, individual stream patterns and drainage anomalies. Deviations from an expected pattern such as flow in a direction that is oblique to the regional topographical gradient could be related to structural or lithological discontinuities.

Similar to the lineament analysis, ArcGIS was used for drainage analysis to view satellite imagery, LiDAR hillshade imagery, and the State of Tennessee TNMAP GIS Services Hydrological Features Dataset. The LiDAR hillshade was effectively used to delineate the drainage network of streams at viewing scales ranging from 1:2,000 to 1:5,000 (Figure 5). A comparison of the State of Tennessee TNMAP GIS Services Hydrological Features Dataset flowlines and mapping from the drainage analysis are shown in Figure 6.

In the study area, the drainage network has a primarily dendritic drainage pattern which is consistent with the underlying horizontal strata of sedimentary bedrock. There is a secondary curvilinear (annular) drainage pattern in the east and west portions of the study area which are interpreted to be related to the Wells Creek Basin (meteorite) impact structure.

Approximately 0.6 miles southwest of the Cumberland Fossil Plant a potential 50 foot offset in the drainage pattern has been identified (36º22.349'N, 87º39.898'W) (Figure 7). A site investigation would be required to verify if this location is a fault. If there is a fault then trenching across the fault would be needed to determine if this was an active fault.

Other visible deviations from well-defined drainage patterns are the result of redirection by anthropogenic activity. No fault scarps or other tectonic features (e.g., spreading ridges, convergent boundaries) associated with active (Holocene-aged) faults were observed within the study area.

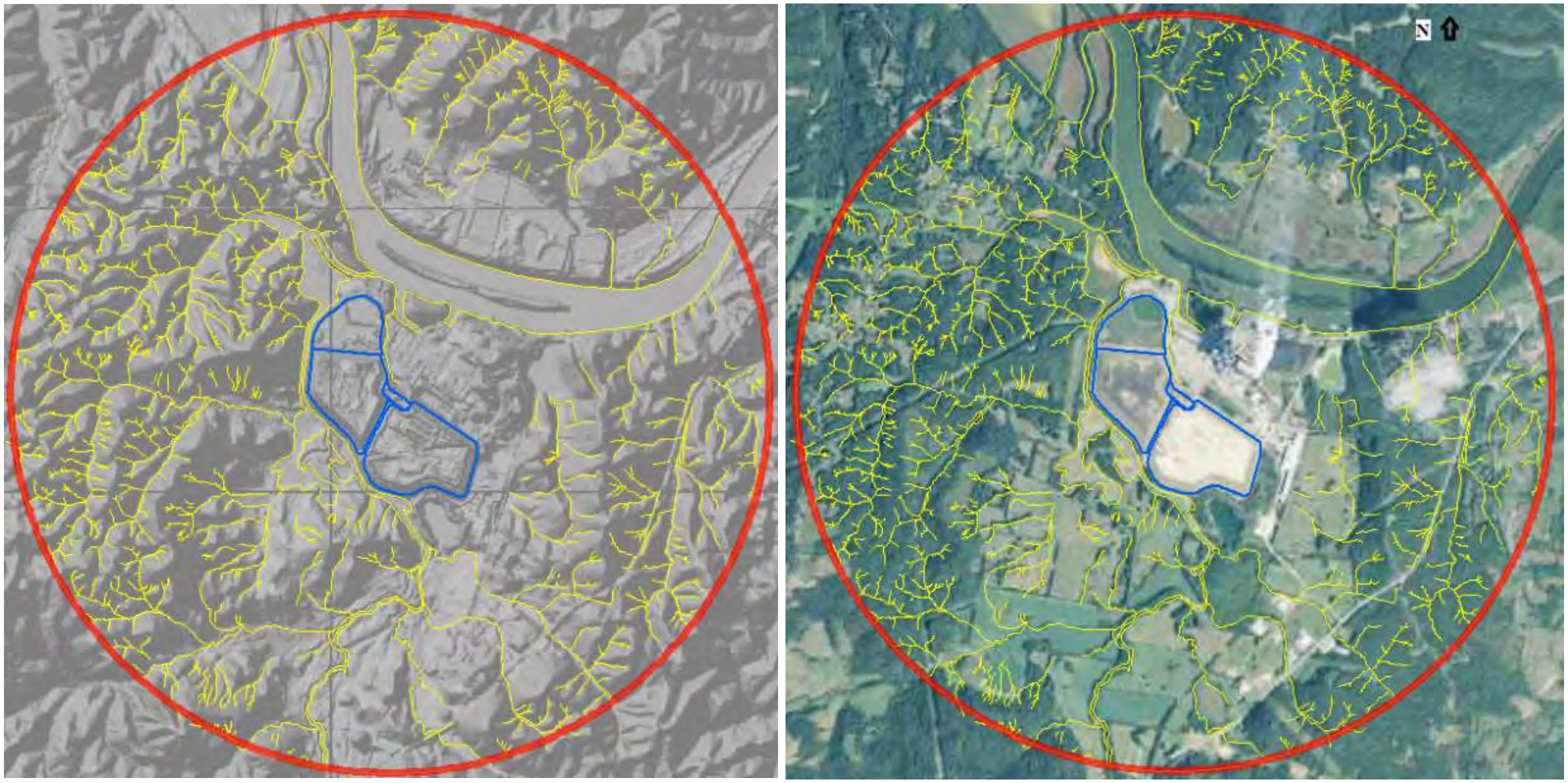


Figure 5. Drainage network mapping on 2013 LiDAR hillshade (left) and overlay on 2014 National Agriculture Imagery Program satellite imagery (right).

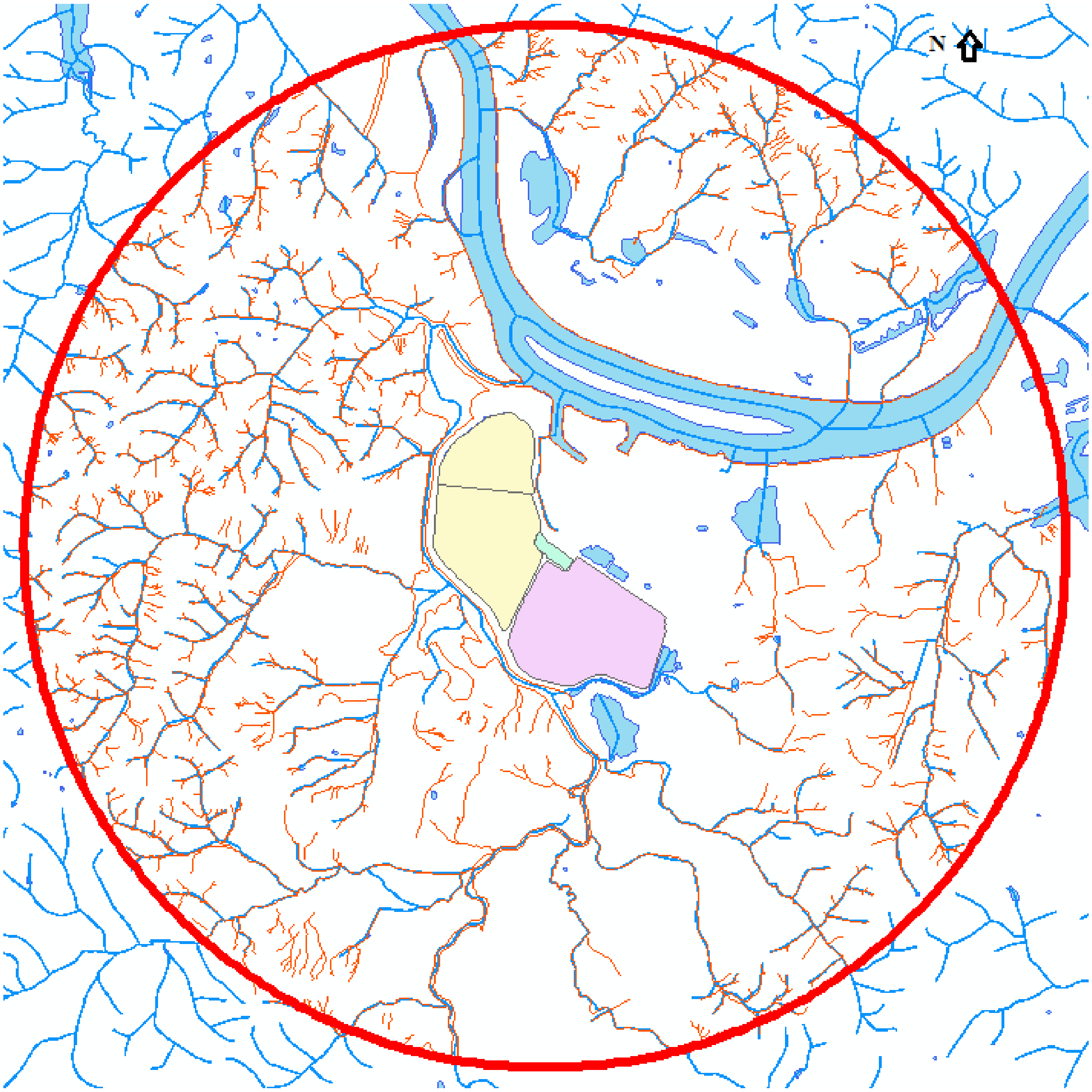


Figure 6. State of Tennessee TNMAP GIS Services Hydrological Features Dataset (blue) compared with this detailed drainage analysis mapping (orange).

Figure 7. **Potential active fault approximately 0.6 miles southwest of the Cumberland Fossil Plant (left). Close-up showing mapped drainage pattern and interpreted off-set (right).**

5.0 CONCLUSIONS

In conclusion, a neotectonics analysis of the Tennessee Valley Authority Cumberland Fossil Plant in west central Tennessee was completed within a two mile-radius centered on the bottom ash pond. The neotectonics analysis involved an extended review of published information (geology, hydrology, soils, fault, and seismic hazard), lineament analysis and drainage analysis. The findings from a separate literature review show that the study area is located east of the east flank of the New Madrid seismic zone in an area of low seismicity (Hatcher 2016). However, none of the literature reviewed have indicated the existence of any active (Holocene-aged) faults within two miles of the Cumberland Fossil Plant.

A significant feature within the study area is the Wells Creek Basin (meteorite) impact structure which occurred 200 +/- 100 million years ago forming a four mile wide crater (Wilson and Stearns, 1968). The impact penetrated to a depth of 2,000 feet causing the bedrock to vapourize, melt and fracture. The design of the Cumberland Fossil Plant should consider the geologic conditions (i.e., fractured rock) below the Wells Creek Basin.

The lineament analysis identified eighteen radial and curvilinear linear features that have been interpreted as being a legacy of the Wells Creek Basin impact structure; therefore, not active. Two lineaments are defined by the valley axis of the Cumberland River and likely represent major faults that pre-date the Holocene.

Drainage analysis of the study area shows a primarily dendritic drainage pattern which is consistent with the underlying horizontal strata of sedimentary bedrock. A secondary curvilinear (annular) drainage pattern in the east and west portions of the study area are interpreted to be related to the Wells Creek Basin impact structure.

Approximately 0.6 miles southwest of the Cumberland Fossil Plant a potential 50 foot offset in the drainage pattern has been identified near 36º22.349'N, 87º39.898'W. A site investigation would be required to verify if this location is a fault. If there is a fault then trenching across the fault would be needed to determine if this was an active fault.

Other visible deviations from well-defined drainage patterns are the result of redirection by anthropogenic activity. No fault scarps or other tectonic features (e.g., spreading ridges, convergent boundaries) associated with active (Holocene-aged) faults were observed within a 2 mile-radius of the Cumberland Fossil Plant.

6.0 CLOSURE

This document entitled "Tennessee Valley Authority Cumberland Fossil Plant, West Central Tennessee" (Report) was prepared by Stantec Consulting Services Inc. ("Stantec") for the Tennessee Valley Authority. This Report supports the fault area demonstration only for the TVA Cumberland Fossil Plant and the conclusions are not valid for other applications. This Report is based on a literature review of cited references, a desktop lineament and drainage mapping exercise based on interpretation of DEM hillshade and satellite imagery. The material in this Report reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the Report. The opinions in the Report are based on conditions and information existing at the time the Report was published and do not take into account any subsequent changes.

Yours truly,

STANTEC CONSULTING LTD.

Prepared by ______________________________

(signature)

Sid Tsang, P.Geo. (AB, BC, MB)

Reviewed and Approved by ______________________________

(signature)

Richard Guthrie, M.Sc., Ph.D., P.Geo. (AB, BC)

7.0 REFERENCES

Hatcher Jr., R.D. 2016. Literature Survey and Discussion of the Geology and Seismicity of the Tennessee Valley Authority Cumberland Fossil Plant, Western Central Tennessee; Department of Earth and Planetary Sciences and Science Alliance Center of Excellence, University of Tennessee–Knoxville. September 19, 2016.

Stearns, R.G., Tiedemann, H.A., and Wilson, C.W., Jr. 1968a. Geologic Map of the Erin Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-SW. 1:24,000 scale.

Stearns, R.G., Tiedemann, H.A., and Wilson, C.W., Jr. 1968b. Geologic Map of the Needmore Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-NE. 1:24,000 scale.

Tiedemann, H.A., Wilson, C.W., Jr., and Stearns, R.G. 1968. Geologic Map of the Cumberland City Quadrangle, Tennessee. State of Tennessee, Department of Conservation, Division of Geology. GM 38-NW. 1:24,000 scale.

US Environmental Protection Agency. 2015. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule. Part II. CFR Parts 257 and 261. Federal Register Vol. 80, No. 74. April 17, 2015.

Wilson, C.W., Jr., and Stearns, R.G. 1968. Geology of the Wells Creek Structure, Tennessee. Tennessee Division of Geology Bulletin 68, 236 p.

- 2014 USGS Seismic Hazards Maps and Site-Specific Data
  https://earthquake.usgs.gov/hazards/hazmaps/
  Accessed November 1, 2016

- State of Tennessee TNMAP GIS Services: Environmental/Hydrological Features
  http://tnmap.tn.gov/arcgis/services
  Accessed October 6, 2016

- TNGIS 2013 LiDAR for Lower Cumberland
  http://www.tngis.org/lidar-lower-cumberland
  Accessed October 6, 2016 and October 21, 2016

- US Department of Agriculture, Natural Resources Conservation Service-Soil Survey database for Houston County, Tennessee (TN083).
  http://websoilsurvey.nrcs.usda.gov
  Accessed October 21, 2016

- US Department of Agriculture, Natural Resources Conservation Service-Soil Survey database for Stewart County, Tennessee (TN161).
  http://websoilsurvey.nrcs.usda.gov
  Accessed October 21, 2016

References

- USGS Data Catalog: Physiographic provinces
  https://catalog.data.gov/dataset/superfund-gis-physiographic-provinces-aquifer-outcrops-and-recharge-rates-in-tennessee
  Accessed October 6, 2016

- USGS Mineral Resources On-Line Spatial Data: Digital Faults and Geology for Tennessee
  http://mrdata.usgs.gov/geology/state/
  Accessed October 6, 2016