Appendix D. Geotechnical Overview

Report of Geotechnical Overview

I-69 Strategic Planning Corridor Study from Fulton to Eddyville, Kentucky
Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties, Kentucky

Stantec Consulting Services Inc.
One Team. Infinite Solutions
1409 North Forbes Road
Lexington, KY 40511-2050
Tel: (859) 422-3000 • Fax: (859) 422-3100
www.stantec.com

Prepared for:
Palmer Engineering
Winchester, Kentucky

February 14, 2011

Stantec

Stantec Consulting Services Inc.
1409 North Forbes Road
Lexington, KY 40511-2050
Tel: (859) 422-3000
Fax: (859) 422-3100

February 14, 2011 rpt_001_175561002

Mr. Gary Sharpe, PE, PLS
Palmer Engineering
400 Shoppers Village
P.O. Box 747
Winchester, Kentucky 40392-0747

Re: Report of Geotechnical Overview
I-69 Strategic Planning Corridor Study
from Fulton to Eddyville, Kentucky
Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties, Kentucky

Dear Gary:

Stantec Consulting Services Inc. (Stantec) is pleased to submit this geotechnical overview for the proposed Interstate 69 corridor situated between the cities of Fulton and Eddyville, Kentucky in Fulton, Hickman, Graves, Marshall, Livingston and Lyon counties. The overview is based upon research of available published data and input from various Project Team meetings.

Palmer Engineering provided Stantec with preliminary locations for the study area. The scope of work performed and results of the overview are presented in the accompanying attachment. Stantec appreciates having the opportunity to provide these engineering services and would be happy to answer any questions and further assist you concerning this project.

Sincerely,

STANTEC CONSULTING SERVICES INC.

T. Craig Barnett, PE
Geotechnical Engineer

Adam Crace, PE
Project Manager

Mark A. Litkenhus, PE
Senior Principal

/rws

Report of Geotechnical Overview

I-69 Strategic Planning Corridor Study from Fulton to Eddyville, Kentucky Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties, Kentucky

Table of Contents

Section **Page No.**

1. Project Description 1

2. Scope of Work 1

3. Physiographic and Stratigraphic Setting 2
- 3.1. Topography and Drainage 2
- 3.2. Stratigraphy 2
- 3.3. Faulting in the Area 4
- 3.4. Soils and Unconsolidated Materials 4
- 3.5. Regional Seismicity 4

4. Geotechnical Considerations 5
- 4.1. General 5
- 4.2. Karst Activity in the Area 5
- 4.3. Erosion 6
- 4.4. Cut Slope Considerations 6
- 4.5. Embankment Considerations 6
- 4.6. Structures 6
- 4.7. Seismic Concerns 7

List of Figures

Figure **Page No.**

Figure 1. Physiographic Region Overview 3

Figure 2. Earthquake Epicenters and Magnitudes in the Central and Eastern United States from 1568 - 1987 5

Report of Geotechnical Overview

I-69 Strategic Planning Corridor Study from Fulton to Eddyville, Kentucky
Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties, Kentucky

Prepared for:
Palmer Engineering
Winchester, Kentucky

February 14, 2011

Report of Geotechnical Overview

I-69 Strategic Planning Corridor Study from Fulton to Eddyville, Kentucky Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties, Kentucky

1. Project Description

The Kentucky Transportation Cabinet (KYTC) is evaluating a corridor for the proposed Interstate 69 (I-69) that would include the Purchase Parkway from the Tennessee state line to the Interstate 24 (I-24) interchange, and then east along I-24 to west of the Western Kentucky Parkway. This overview will be utilized to identify possible improvements needed to bring the corridor up to current interstate standards. It is anticipated the current alignment of the Purchase Parkway will be utilized and that significant improvements will be needed at the major interchanges. In addition, it is anticipated 10 bridge structures will require some type of widening effort to meet current interstate criteria.

The Project Team prepared an environmental footprint of the area to be studied. This area incorporates portions of Fulton, Hickman, Graves, Marshall, Livingston and Lyon Counties. The proposed I-69 corridor is approximately 68 miles in length.

2. Scope of Work

The scope of work for this study consists of performing a geotechnical overview for the proposed corridor based upon research of available published data and Stantec's experience with highway design and construction within the region. General geotechnical and geologic characteristics of the study area have been identified and are discussed in this report. Stantec personnel, using a variety of sources, performed a literature search that included reviews of the following sources:

- Available topographic and geologic mapping of the project area published by the United States Geological Survey (USGS) and the Kentucky Geological Survey (KGS);
- The Geologic Map of Kentucky, published by the USGS and the KGS (1988);
- KYTC Geotechnical Data, published by the KGS and KYTC, http://kgs.uky.edu/kgsmap/kytcLinks.asp;
- United States Department of Agriculture, Soil Conservation Service (SCS) Soil Survey Publications for affected counties;
- Physiographic Regions, published by KGS, http://kgs.uky.edu/kgsweb; and
- KY Lakes, published by Kentucky Division of Geographic Information (GIS), http://kymartian.ky.gov

3. Physiographic and Stratigraphic Setting

3.1. Topography and Drainage

The proposed I-69 corridor for this study is located in Western Kentucky, situated on portions of ten USGS 7.5-minute topographic quadrangle maps. They are the Calvert City (1993), Briensburg (1969), Eddyville (1967, revised 1973), Hickory (1994), Westplains (1993), Oak Level (1969, revised 1987), Hardin (1969, revised 1986), Dublin (1969), Mayfield (1994) and Water Valley (1969, revised 1981) Quadrangles.

The study area is situated within the Mississippi Embayment and the Mississippian Plateaus Physiographic Regions of Kentucky. The eastern portion of the project alignment is situated within the Mississippian Plateaus Region. The Mississippian Plateaus contains gently to moderately rolling topography that has been partially influenced by karst weathering in some areas. The karst areas in the Mississippian Plateaus Region are characterized by the existence of sinkholes, ridgetop ponds, sinking streams, springs, and various subterranean channels. The remaining portions of the proposed project alignment are located within the Mississippi Embayment Region which consists of broad, flat flood plains along the Mississippi River to gently rolling uplands of low relief. The alluvial areas are relatively level. The limits of each Region is detailed in Figure 1.

Surface drainage within the region is directed towards numerous swales, ditches, creeks, and streams, including the Cumberland River, Tennessee River, Clarks River, Bayou du Chien River and Mississippi River, as well as karst features in the area. The Kentucky Lake and Lake Barkley reservoirs are located on the eastern side of the study area.

3.2. Stratigraphy

Corresponding USGS geologic quadrangles are available for the Calvert City (1968), Briensburg (1964), Eddyville (1963), Hickory (1965), Westplains (1967), Oak Level (1968), Hardin (1968), Dublin (1972), Mayfield (1965) and Water Valley (1963) Quadrangles.

Based on the various geologic mapping and literature reviewed, the proposed corridor is primarily underlain by alluvium, loess and continental deposits of the Tertiary and Quaternary age. The Mississippian Plateaus Region on the eastern end of the proposed corridor is primarily underlain by limestone, shale and possibly some sandstones. The bedrock consists of Mississippian age limestones, shales and isolated sandstones. The limestones are predominantly gray, medium to coarse grained, zones argillaceous, with fossiliferous and cherty zones. The shales are gray, clayey to silty, with calcareous zones. The sandstones are generally light to yellowish gray, and very fine to medium grained.

The Mississippi Embayment Region is predominantly underlain by alluvium, loess and continental deposits. Less common deposits include the Clayton and McNairy, Porters Creek Clay and the Coastal Plain deposits. The overburden soils are unconsolidated and easily eroded. Alluvial deposits of silt, sand, and gravel are also present along major streams and rivers in the area. The loess deposit consists of silt. The continental deposits consist of gravel, sand and clay. The Clayton and McNairy deposits consist of sand. The Porters Creek Clay consists of clay and sand. The Coastal Plain deposits consist of sand and clay.

The overburden soils are greater than 100 feet thick along the proposed corridor within the Mississippi Embayment Region. Bedrock is not mapped on the Dublin, Hardin, Hickory, Mayfield, Oak Level or Westplains Quadrangles.

3.3. Faulting in the Area

Based on USGS Geologic mapping, several unnamed faults are near the footprint studied on the eastern part of the corridor near the Western Kentucky Parkway. USGS Geologic mapping also indicates a series of concealed probable faults near the proposed roadway between Calvert City and Benton Kentucky. A series of hypothetical faults are noted between Benton and Mayfield Kentucky on the USGS Geologic mapping. Faults are not noted on the section of the proposed corridor between Mayfield and Fulton Kentucky. These faults are mapped within portions of the western portion of the studied corridor. The study area is near the New Madrid Fault Zone and discussed further in 3.5.

3.4. Soils and Unconsolidated Materials

Alluvial materials are the predominate soil type along the proposed alignment within the Mississippi Embayment Region and are comprised of sands, silts, clays and gravels covering the floodplains of major streams and tributaries in the study area. Major streams within the environmental footprint include Cumberland River, Tennessee River, Clarks River, Bayou du Chien River and Mississippi River. The Kentucky Lake and Lake Barkley reservoirs are located on the eastern side of the study area.

Residual soils are the predominate soil type within the eastern portion of the study area near the Western Kentucky Parkway. Soil descriptions contained herein are based upon SCS soil surveys and on Stantec's knowledge of the study area. Soils within the Mississippian Plateaus Region along the corridor are predominantly a clayey to silty clay and range in depths from four feet to greater than twelve feet. Soils can become very thin to very deep in karst areas within a relatively short distance.

3.5. Regional Seismicity

Seismicity within the Commonwealth of Kentucky varies widely depending on location. The western portion of the state is dominated by the New Madrid and Wabash Valley source zones. In general, these zones are fairly active with many documented historical seismic events. Central and eastern portions of the state experience less frequent earthquakes because the source zones are quite distant from these areas. To assist designers in the Commonwealth of Kentucky, the KYTC began a research project in conjunction with the University of Kentucky and the Kentucky Transportation Center (KTC) in 1996. The products of this effort are documents in the publication "Source Zones, Recurrence Rates, and Time Histories for Earthquakes Affecting Kentucky", Research Report KTC-96-4, by Ron Street, et al., (1996). This document and other information available from the Kentucky Geological Survey (KGS) were reviewed in relation to the Interstate 69 Corridor.

An Earthquake Epicenters and Magnitudes Map for the Central and Eastern United States from 1568 to 1987 is presented in Figure 2. This map indicates that the I-69 Corridor area could be affected by earthquake events, particularly the New Madrid Seismic Zone (NMSZ). The NMSZ lies within the Central Mississippi Valley, extending from northeast Arkansas, southeast Missouri, western Tennessee, western Kentucky, and southern Illinois. The NMSZ is the most seismically active region in the United States east of the Rocky Mountains.

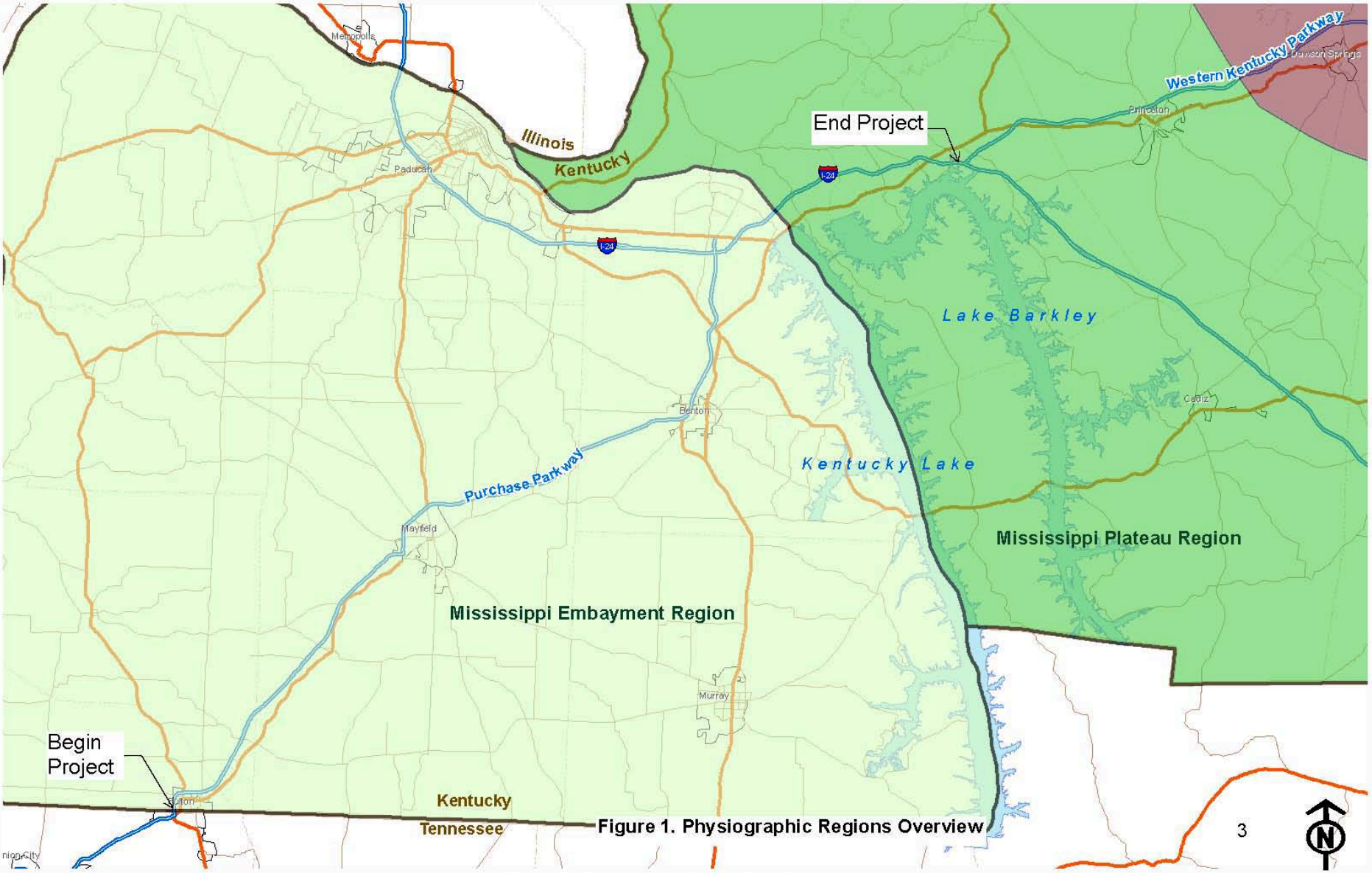

Figure 1. Physiographic Regions Overview

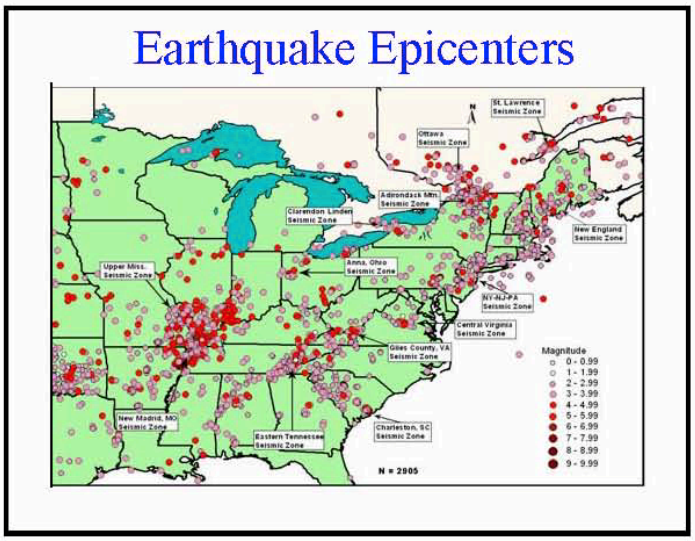

Figure 2. Earthquake Epicenters and Magnitudes in the Central and Eastern United States from 1568 - 1987

The KTC-96-4 research report indicated that a Central Kentucky earthquake event occurred on February 28, 1854 and assigned a Modified Mercalli intensity of V. The most severe effects of that earthquake was reported in Lebanon, where dishes and windows rattled. The earthquake was felt at numerous other locations in Kentucky including Bardstown and Harrodsburg.

4. Geotechnical Considerations

4.1. General

Based on discussions with the Project Team, it is not anticipated that there will be many new cuts or fills required along the existing roadways for the proposed I-69 alignments. However, it does appear that several interchanges will need to be reworked / realigned to meet the current interstate standards. The revisions to the interchanges will include lengthening ramps and changing horizontal / vertical alignments. As the interchanges are reworked, the Project Team should consider the geotechnical considerations that are included in Section 4 as they pertain to karst activity, erosion, cut slopes, embankments, widened structures and seismicity.

4.2. Karst Activity in the Area

Karst activity exists over portions of the project area near the Western Kentucky Parkway. Based on existing occurrences of known karst in the area, bedrock in the Mississippian Plateaus Region is considered to have a moderate to high potential for karst development. The potential for moderate to high karst activity is greater near the Western Kentucky Parkway and I-24.

An inventory of karst features is recommended during the next phase of study in areas where there is potential for karst activity. The inventory may be utilized to refine alignments and account for environmental related concerns such as water runoff into such features.

4.3. Erosion

The Mississippi Embayment Region consists of broad, flat flood plains along the Mississippi River to gently rolling uplands of low relief. The gently rolling terrain formed as streams gradually eroded the loess and continental deposits. The areas of erosion have exposed the less common Porters Creek Clay formation. Erosion concerns will affect the cut slope configuration and is further discussed in Section 4.4.

4.4. Cut Slope Considerations

The majority of the roadway cuts within the Mississippian Plateaus Region are likely to be shallow cuts in soils and bedrock. As previously discussed, rock types will consist of limestones, shales, and possibly sandstones. Cut slope configurations in rock are generally controlled by bedrock lithology, bedrock quality, results of Slake Durability Index (SDI) tests in shales and siltstones, and by the presence of any fractures and/or joints. In general, if joint/fracture angles are high (as measured from horizontal), steeper cut slopes can be constructed and an acceptable level of stability can be maintained. If discontinuities exhibit low angles and steep cut slopes are utilized, large block failures may occur along the open cut face.

Slope configurations for rock cuts in durable or Type I non-durable rock generally range from 1H:4V to 1H:2V pre-split slopes on approximate 30-foot intervals of vertical height. These types of cuts could be anticipated within the Mississippian Plateaus Region. Shallow cuts in bedrock may be best handled on 2H:1V slopes, covered with a soil layer and vegetated.

Slope configurations for soil cuts in alluvial deposits are generally constructed on a 2H:1V or flatter. Due to erosion concerns within the Mississippi Embayment Region, soil cuts in alluvium may be best handled on a 3H:1V or flatter and covered with vegetation.

4.5. Embankment Considerations

Embankments constructed of durable rock materials generally exhibit adequate stability at 2H:1V slope configurations. However, flatter embankment slopes may be required for tall embankments or in areas where embankments are founded on alluvial materials. Alluvial soils can be expected throughout the majority of the study area from the Tennessee state line to I-24. Since most of the improvements will be focused at interchanges, it is anticipated the embankments will be constructed from borrow and offsite sources.

Low shear strengths and high settlement potentials are generally associated with alluvial deposits. Consolidation settlements and short-term embankment stability problems are common for roadway embankments in alluvial floodplains, and controlled embankment construction rates and/or flatter embankment side slopes should be anticipated for these areas.

4.6. Structures

Based on discussions with the Project Team, it is anticipated that approximately 10 mainline structures will need to be widened to meet horizontal clearance requirements for an interstate. At this time, it is unknown as to whether the widening would require new and/or widened substructure elements. Based on Stantec's knowledge of the area, it can be anticipated that the majority of the structures within the project corridor are likely supported

on deep foundation friction elements. It can be problematic at times to install new deep foundation elements for widened structures due to access and existing battered pile elements. In addition, deep foundation elements may be difficult to install because of the presence of dense chert or gravel layers. Therefore, piles may need to be outfitted with pile points or pre-drilling may be warranted. Therefore, the Project Team should be prepared to study the structures on a case-by-case basis and anticipate special foundation designs in the next phase of the design process.

4.7. Seismic Concerns

The seismic hazard at a bridge site shall be characterized by the acceleration response spectrum for the site and the site factors for the relevant site class. A comprehensive geotechnical investigation will be required to determine the site class. The 2010 AASHTO LRFD Bridge Design Specifications provides guidelines for selecting a seismic performance category and a soil profile type for bridge sites. This information establishes the elastic seismic response coefficient and spectrum for use in further structural design and analyses. Refer to Section 3.10.2 for specifications.