M E M O R A N D U M

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**Geotechnical Branch**

**DATE:** **May 31, 2022**

**SUBJECT:** **Powell, Wolfe, & Menifee Counties**
**Red River Gorge/Daniel Boone National Forest**
**Transportation Planning Study**
**Mars # 1343807P**
**Geotechnical Overview Report**

## 1.0 Project Description

The Kentucky Transportation Cabinet (KYTC) is conducting a study to identify and evaluate the Red River Gorge Geological Area in the Daniel Boone National Forest located in Powell, Wolfe, and Menifee Counties. The roadways under review surround the Red River Gorge Geological Area include: KY-15, KY-11, KY-715, and KY-77. This overview will be utilized to identify geotechnical considerations for the study area. The project location and corridor are presented in Appendix A.

The scope of work for this study consists of performing a geotechnical overview for the proposed study area base upon research of available published data and the Geotechnical Branch'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. The following sources were used to perform a literature search:

- USGS Professional Paper 1151-H: The Geology of Kentucky: Physiography;
- USGS Professional Paper 1151-H: The Geology of Kentucky: Mississippian System;
- USGS Professional Paper 1151-H: The Geology of Kentucky: Pennsylvanian System;
- Geologic Map of the Slade Quadrangle (GQ# 1183), by Gordon W. Weir, published by the USGS, 1974;
- Geologic Map of the Pomeroyton Quadrangle (GQ# 1184), by Gordon W. Weir and Paul W. Richards, published by the USGS, 1974;
- USDA Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm;
- Available KYTC Arcmap Datasets and Layers
- KYTC Projects Nearby (KYTC Geotechnical Report Number):
    - Landslides along KY-11 MP 4.9-5.0 (L-057 & 058-2021)
    - KY-11 bridge over Middle Fork of Red River (R-011-2011 & S-010-

2021)
- KY-77 rockfalls Nada Tunnel (S-017-2010)
- KY-715 over Gladie Creek (S-133-1997)

## 2.0 Topography and Drainage

The study area is on the eastern flank of the Cincinnati Arch (Figure 1), a broad regional anticline. On the eastern flank of the arch, Mississippian carbonates dip toward the southeast into the central Appalachian Basin. Eastward, progressively younger Mississippian strata and overlying Pennsylvanian strata are exposed. The outcrop limit of Pennsylvanian strata is generally used to define the western limit of the Eastern Kentucky Coal Field, which is part of the larger central Appalachian Basin. Because Lower Pennsylvanian strata contain thick conglomeratic sandstones that are resistant to erosion, the outcrop limit of Pennsylvanian strata is characterized by the rugged Cumberland (Pottsville) Escarpment.

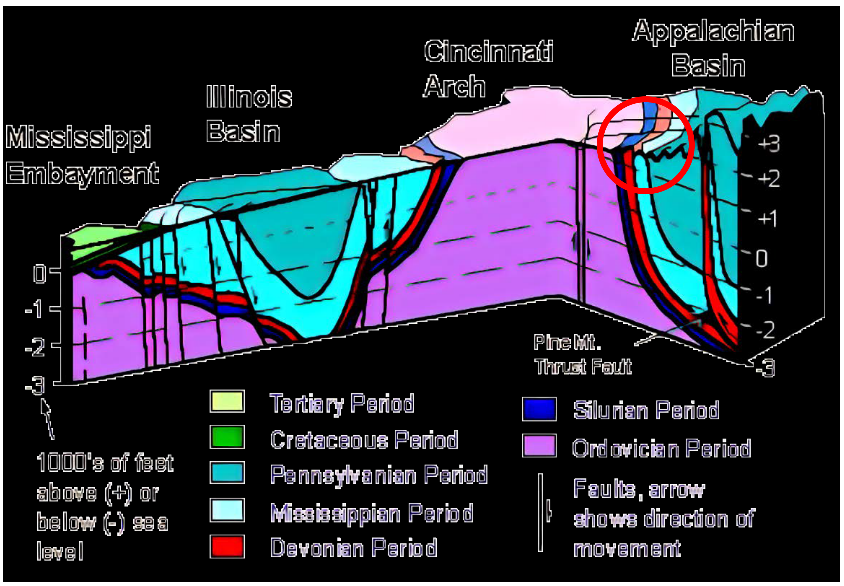



Figure 1

The hills and ridges are very rugged and highly dissected with vertical relief in the magnitude of 520 feet. Cliffs, narrow valleys, and ravines are common and characteristic. Thick, resistant Pennsylvanian quartzose sandstone caps the ridges and Mississippian limestone, shale, and siltstone are exposed on the lower slopes and in valleys.

Surface drainage is directed towards either the west flowing Red River to the north or the northwest flowing Middle Fork of the Red River to the southwest. Streams are cool and typically have moderate to high gradients, rock bottoms, and low amounts of turbidity. In general, groundwater above the river valleys is insignificant but springs commonly issue from the base of the Corbin Sandstone Member, the lower part of the Slade Formation, and the base of the Renfro Member of the Borden Formation.

## 2.1 Stratigraphy

The study area is located in the Slade (GQ# 1183) and Pomeroyton (GQ# 1184) Geologic Quadrangles. Mapping indicates the project area to be underlined, in descending order, by Lower Pennsylvanian Corbin and Grundy Formations, and Mississippian Slade and Borden Formations.

**Corbin Sandstone, Grundy Formation, Breathitt Group.** The cliff forming strata on the tops of the ridges in the Red River Gorge. This sandstone was previously considered a member of the Lee Formation but is now considered a member of the Grundy Formation. In the gorge, the Corbin is 100 to 280 feet thick. The Corbin consists of very fine to coarse-grained, crossbedded, conglomeratic quartzarenites. Conglomerates are composed of quartz pebbles. Iron staining is common in cliff exposures.

**Grundy Formation, Breathitt Group.** The Corbin is underlain by 30 to 220 feet of shale, siltstone, and thin coal. This unit was previously considered the lower tongue of the Breathitt Formation, but elevated the Breathitt to group status and named this part of the Breathitt the Grundy Formation. This part of the Grundy is not well exposed in the park, generally forming vegetated slopes beneath the Corbin cliffs. The base of the Grundy in this area is an unconformity on top of the Mississippian, which is not well exposed in the area, although can be seen on the Mountain Parkway 2 miles east of the Slade interchange.

**Slade Formation.** The Slade Formation was previously called the Newman Limestone and the Renfro Member of the Borden Formation. Several of the members of the Slade Formation are exposed in the gorge area as carbonate cliffs or ledges. Generally the formation is composed of limestone (80 percent) and shale (20 percent).

**Nada Member, Borden Formation.** The Renfro is underlain by the Nada Member. The Nada consists of 30 to 55 feet of shale (80 percent) and siltstone (20 percent). Shales are greenish-gray and are sometimes variegated red and green. Siltstones are calcitic and dolomitic. This unit is poorly exposed in the gorge and tends to form vegetated slopes.

**Cowbell Member, Borden Formation.** The Nada is underlain by the Cowbell Member. The Cowbell is 70 to 180 feet thick and consists of siltstone (70 percent) and shale (30 percent). The unit is generally differentiated from the overlying Nada by a transition to bedded siltstones. Siltstones are green to brown-gray to purple-gray. This unit is poorly exposed in the gorge and tends to form vegetated slopes. In general, where this unit forms valley bottoms, the valleys are steeper than in units floored by the underlying Nancy Member.

**Nancy Member, Borden Formation.** The Nancy is the lowermost unit exposed in the gorge. It consists of greenish-gray shales and minor siltstones. Only the upper part of the unit is exposed in the gorge area, generally forming the lowest slope above road level (0 to 100 feet). The total thickness of the unit is more than 360 feet thick. Where the Nancy forms the valley bottoms, valleys are generally wide.

### 2.3 Soils and Unconsolidated Materials

The ridgetops and gentle slopes consist of residual soils. Residual soils are derived in-place from a weathering process of the parent bedrock material. On ridgetops where is the parent material is sandstone soil depths are expected to be shallow ranging from zero (0) to a few feet. Soil depths are expected increase where lithologies change to shale on gentle slopes but still remain relatively shallow. Soil material will vary dependent on its parent material.

The hillsides and their flanks may consist of colluvium. These can appear as wedge shaped deposits with a hummocky topography. Colluvium is a locally derived residuum that has accumulated and/or migrated downslope due to gravity. Geologic mapping in the area describes the colluvium as rubble consisting of slabs and blocks, commonly a few inches to several feet across but as much as several tens of feet across, of limestone derived from the Slade Formation and of sandstone derived from the Grundy Formation. Slabs and blocks are generally loosely bound in a silty clay matrix. Thicknesses vary but are estimated to be as much as 40-feet deep.

Alluvium deposits occupy the modern stream channels and floodplains. They consist of unconsolidated sand, silt, gravel, and clay. The gravel consists mainly of subrounded to well-rounded cobbles and pebbles of siltstone from the Borden Formation, angular to rounded pebbles of chert from the Slade Formation, and well-rounded pebbles of quartz from the Grundy Formation. Thicknesses are estimated to vary from zero (0) to 40 feet, with the thickest near Red River.

## 2.4 Geologic Structures

According to geologic mapping (GQ#1083) structural contours, drawn on the base of the Slade Formation, plunge to the southeast at approximately 40 feet per mile.

Red River Gorge is located just north of the Glencairn Fault of the Irvine-Paint Creek Fault System. The Irvine-Paint Creek Fault System is an east-west oriented, down-to-the-south series of normal faults. Offsets of as much as 100 feet are recorded in the Slade quadrangle. Although in the vicinity of the study area the Geotechnical Branch does not anticipate any concerns due to the structural geology of the area.

## 2.5 Karst

According to the KYTC Arcmap Karst Potential Map the entire study area is not prone to karst potential however there are kart features within the area. Shafts and caves are present within the Slade Formation just beneath sandstone cliffs of the Grundy Formation. After a rain, water that hits the top and slopes of ridges enters the thin soil that covers the ridge. When the water passes through the soil on the ridge slopes it becomes slightly acidic. The water travels within the sandstone and soil until it reaches the less-permeable limestones and shales of the Slade Formation. The water starts to build up along the contact until it finds a fracture or weakness in the limestone. Because the groundwater is slightly acidic, it can dissolve the limestone, forming shafts and caves.

## 2.6 Mines and Quarries

Coal beds in the Grundy Formation, Breathitt Group, in this area have little commercial potential because the beds are thin and discontinuous. Coal has been mined on a small scale for local use but no mines are operating at this time.

Limestone of good quality for road construction and agricultural purposes is available from the Slade Formation. There are active and inactive quarries that surround the study area however non are inside the area of interest.

# 3.0 Geotechnical Considerations

The goal of this study is to help identify any geotechnical concerns that may affect the study corridor. Based on the available resources geotechnical concerns and considerations will be presented below.

### 3.1 Cut Slope Considerations

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. Slope configurations for rock cuts in durable bedrock can generally be 1H:2V presplit slopes on approximate 30-foot intervals of vertical height with 18 to 20-feet intermediate benches or 15-foot overburden benches. Slope configurations for non-durable bedrock or soils are generally constructed on 2H:1V slopes or flatter.

A detailed geotechnical exploration will be required for areas that involve widening existing cuts or creating entirely new cuts. Where the Borden and Slade formations are encountered shale with interbedded siltstone and limestone are the dominant rock types. Highway projects that intersect these formations have typically experienced slope stability and maintenance issues associated with the deep Rock Disintegration Zones (RDZ) and the rapid slaking of the newly exposed bedrock. The disintegration mainly occurs in the shale component of the formations. Slope configurations of 2H:1V or flatter should be anticipated. As the shale erodes large blocks of siltstone or limestone beds can slide and potentially reach the road. To limit falling rock hazards roadside ditch benches of 14 (non-interstate) or 18 (interstate) feet are often recommended.

Where the Grundy Formation, Breathitt Group, is encountered durable, cross-bedded sandstone are the dominant rock type. Cut slopes with pre-split slopes of 1H:2V with carefully placed intermediate benches can be anticipated. Careful attention to bedding planes, fractures, and fracture orientation must be considered when designing these slopes.

Cut slopes on ridge flanks where deep deposits of colluvium have accrued should be avoided. These areas can be subjected to groundwater seepage, erosion, creep displacement, and expansion/contraction of the shales and residual soils. The removal of toe support can accelerate the rate of creep or cause outright slope failures.

### 3.2 Embankment Considerations

Most of the anticipated excavated materials should be suitable for use in project embankments constructed on 2H:1V slope configurations or flatter up to 20-feet tall. Any embankments built 20-feet or taller will require stability analysis and may require flatter slopes.

The project area is notorious for unstable fill slopes. There are locations in the study area where embankment failure mitigations, rails/lagging and additional asphalt, have been used. The failures could be a result of poor construction techniques, poor embankment material, poor foundation material, or sharp cut/fill transitions on the steeper slopes in the area. Special shale compaction construction, flatter side slopes, partial rock embankment, and constructed embankment platforms are some of the techniques used to reduce these issues.

Material excavated from the project would most likely consist of a mix of durable sandstone and non-durable shales. Embankments principally of non-durable shale (SDI less than 95 according to KM 64-513) should be constructed using special shale compaction methods. If this construction method is not followed the shale can break down in a few years causing settlement and potential failures.

### 3.3 Saturated, Soft, or Unstable Soils

In areas where durable rock will not be in sufficient quantity to construct a rock roadbed, valley bottoms along creeks and rivers, other methods of improving subgrade can be considered. Chemical stabilization is the preferred method of subgrade improvement. In areas where lanes are being added or chemical stabilization is not feasible (such as cross-overs, tie-ins, etc.) the subgrade can be constructed with Kentucky Coarse Aggregate No. 2, No. 3, or No. 23 sized stone with geotextile fabric.

Valley bottoms tend to have high moisture contents and material that is vulnerable to high changes in volume. Working platforms and embankment working platforms may be anticipated. Where durable rock is not sufficient a 2-foot working platform consisting of Kentucky Coarse Aggregate #2's, 3's, or 23's wrapped with Geotextile Fabric may be required.

There are several stream channels and possible springs within the area. Any saturated or unstable areas encountered within embankment foundation limits may need to be stabilized and the stream channel may need to be redirected or have pipes installed.

### 3.4 Water Wells and Springs

Based on available mapping (Appendix C), several water wells and springs are noted within/near the proposed study area. These locations should be inventoried to verify their locations. Spring boxes and/or granular material may be required in the vicinity of springs. All water wells and/or cisterns within the limits of construction, whether shown on the plans or not, shall be plugged in accordance with Section 708 of the current Standard Specifications for Road and Bridge Construction.

### 3.5 Gas and Oil Well

Based on the available mapping, there are oil and gas wells in the vicinity of the project study area. These wells are depicted on the mapping in Appendix C. Any gas wells within the proposed right-of-way limits, shall be treated in accordance with Mines and Mineral Specifications.

### 3.6 Karst Conditions

Sinkholes, domes, and pits are present within the Slade Formation. Any open sinkhole and/or solution cavities within the limits of construction, whether shown on the plans or not, that are not used for drainage purposes, shall be filled and/or capped in accordance with the current edition of Section 215 of the Standard Specifications for Road and Bridge Construction.

Any sinkholes utilized for drainage purposes for new roadway construction should incorporate adequate measures to minimize water infiltration into the subgrade and erosion control measures to minimize the impact of open sinkholes.

Adequate drainage will be of primary concern with any new design or new construction in the area to minimize environmental impacts by surface runoff into the underlying karst network. Proper management of surface water will also lesson the occurrence of sinkhole dropouts during construction. Mitigation of surface runoff should be performed by silt checks, silt traps, sediment basins and lined ditches where appropriate. In situations sinkholes should be avoided, especially those that remain open after construction.

## 3.7 Structures

At this time, it is unknown as to whether the proposed roadway would require new and/or widened substructure elements. It can be anticipated that most of the bridges within the project study area are likely supported by rock bearing foundation systems. Culverts along the proposed alignments may be replaced or widened. The culverts within the study area are likely supported by either non-yielding or yielding foundation systems depending upon the location along the proposed alignment. A detailed geotechnical investigation will be required to determine the foundation support systems.

## 4.0 Site Specific Observations

Four roadways: KY-15, KY-11, KY-715, and KY-77, are the primary focus of the study corridor. A site investigation was performed on May 23, 2022 to help identify any current geotechnical deficiencies with the current alignments. A brief description with observations of each roadway will follow with the intent to highlight any geotechnical concerns.

## 4.1 KY-15

KY-15 begins in Slade at the intersection with KY-11 in Powell County at approximate mile point 3.5. From Slade KY-15 traverses East, crosses into Wolfe County, and intersects KY-715 in the town of Pine Ridge at approximate mile point 14.8. The total length of KY-15 under review is approximately 7.4 miles.

The intersection of KY-15 and KY-11 in Slade is located in the valley bottom where the Middle Fork of the Red River and Clear Branch Creek converge. Bearing East KY-15 follows Clear Branch Creek upstream and crosses the Mountain Parkway. The two-lane road once on the southern side of the Mountain Parkway exposes the Borden Formation in a road cut that provides horizontal space between the existing roadway and the parkway. At approximate mile point 1.3 KY-15 begins to drastically curve and wind to the top of Pine Ridge near the Wolfe County border. Two sharp curves are flanked by rock cuts on the south side and steep fills on the north side. KY-15 has recently been paved and no geotechnical concerns were noted. Due to the extreme curves site lines were limited.

**Image 1: Rock cut Borden Formation, looking West, MP 2.7.**
**Image 2: Looking West, MP 0.7.**

Once KY-15 reaches the ridge top it remains in the uplands of the project area. There are two more crossings with the Mountain Parkway. There are small cuts and fills for the remainder until it intersects KY-715 in the town of Pine Ridge.

### 4.2 KY-715

The scope of interest on KY-715 begins at the intersection of KY-15 and KY-715 in the town of Pine Ridge at approximate mile point 5.8. KY-715 runs north by northeast towards for approximately 6.2 miles until it reaches Menifee County and the Red River. Once in Menifee County KY-715 takes a sharp left, west, until it reaches the intersection with KY-77 at approximate mile point 6.9. The total length of KY-715 under review is approximately 13 miles.

From Pine Ridge KY-715 winds its way on top of an unnamed ridge. The roadway is a narrow two-lane road that follows the top of the ridge with no cuts and a very shallow fills. In places, spot improvements have been made to the surface of the roadway where natural drainage may have impaired the roadway.

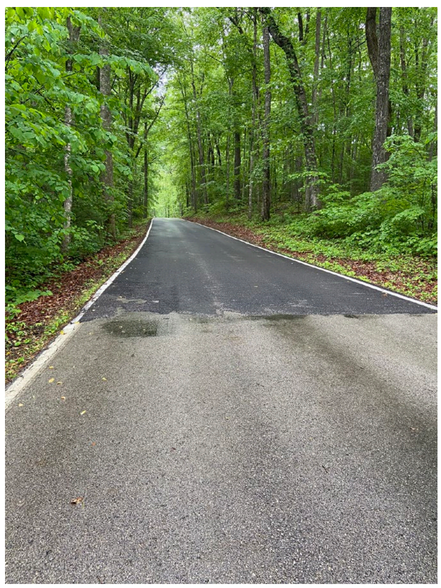


**Image 3: KY-715, spot improvement, MP 7.4.**

At approximate mile point 10.6 KY-715 begins its steep descent along the southern side of Swift Camp Creek until it reaches the intersection of the Red River and the Menifee County line. The road winds with the ridge flanks with several tall, steep, fills down the valley to Swift Camp Creek. Several slides have been previously corrected and other breaks in the pavement were noted.

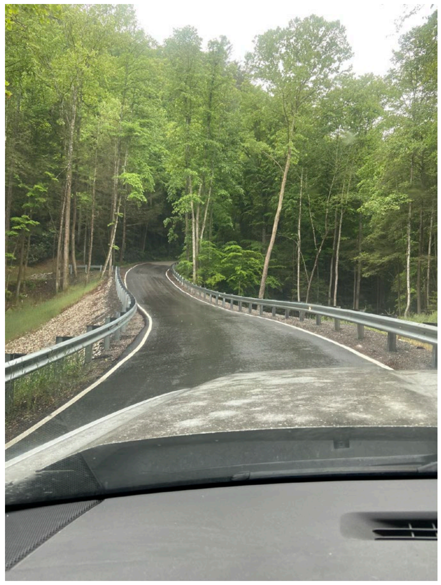


**Image 4: KY-715, looking South, road repair a drainage crossing, MP 11.1.**

Once in the Red River valley bottom KY-715 follows the Red River until its intersection with KY-77. In places, road cuts were created to provide space between the roadway and the Red River. Several places displayed embankment instability and previous remediations using rails.

**Image 5: KY-715, looking East, slide repair with rails, MP 2.2**
**Image 6: KY-715, looking East, rock cut exposing Borden and Slade formations.**

## 4.3 KY-77

KY-77 begins at the intersection with KY-11 in Powell County at mile point 0.0 where Moreland Branch Creek intersects the Middle Fork of the Red River. KY-77 has an east by northeast bearing to the Menifee County line. At the intersection with KY-715 in Menifee County, mile point 0.8, KY-77 takes a sharp turn to continue north until the end of the road's scope at approximate mile point 4.3. The total length of KY-77 under review is approximately 5.1 miles.

KY-77 begins in the valley bottom of the Middle Fork of the Red River and follows Moreland Branch Creek upstream, climbing in stratigraphic section until it reaches the 900-foot long Nada Tunnel at mile point 2.1. Moreland Branch is a small creek with a narrow valley. The roadway is a narrow two-lane road that follows the stream with several small crossings. No rock cuts were noted and very little fills were utilized because the roadway remains on the valley bottom.

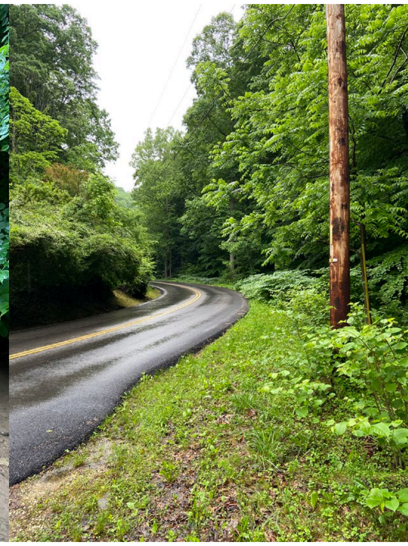




**Image 7: Moreland Branch.**
**Image 8: KY-77, looking East.**
**Image 9: Western entrance to Nada Tunnel**

Once through the Nada Tunnel KY-77 descends down Grays Branch Creek until it intersects the Red River. The roadway is placed well above Grays Branch with rock cuts on the north side and steep embankments towards the valley bottom on the south side. Rock overhangs are present where differential weathering has occurred and roadway surface breaks are present in areas with steep fill slopes.

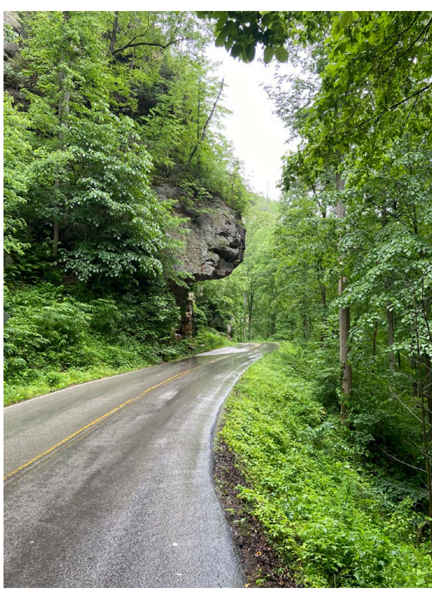



**Image 10: Rock overhang exposed on Eastern side of Nada Tunnel.**
**Image 11: Steep fill slope towards Grays Branch on East side of Nada Tunnel.**

At the valley bottom KY-77 follows the Red River approximately 0.8 miles until the intersection with Dunkan Branch Creek. KY-77 ascends with Dunkan Branch Creek and up stratigraphic section until it reaches the peak of Tarr Ridge.


**Image 12: Bridge over Red River, MP 4.3.**
**Image 13: Red River, MP 4.3.**

Similar to KY-715 along the Red River KY-77 is flanked by rock cuts on the north side and embankment fills slopes on the south side. The rock cuts exposed the Borden Formation. Several places in the roadway displayed cracks in the surface indicating fill instabilities. Repairs were noted in a few places.

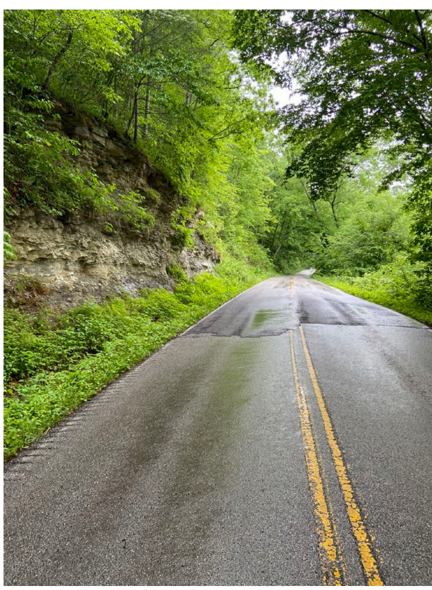
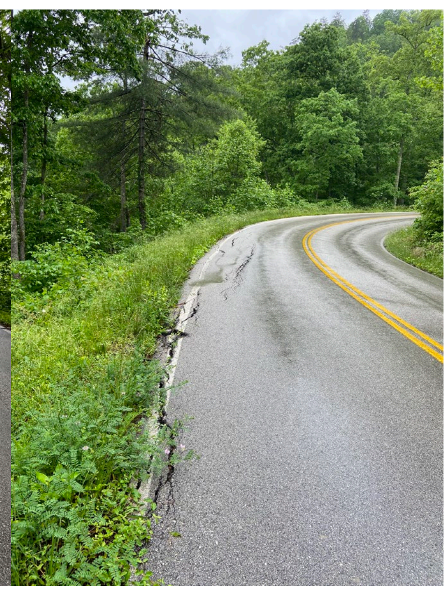



**Image 14: Rock cut exposing the Borden Formation with roadway surface repair, MP 0.3.**
**Image 15: Roadway surface cracks, Grays Branch side, MP 3.7.**

KY-77 up Dunkan Branch is extremely narrow with steep fills slopes on the Eastern side towards Dunkan Branch. The road is windy as it follows the ridge flanks steeply up the valley. Several cracks in the roadway surface were noted along with a few small-scale repairs.

## 4.4 KY-11

KY-11 begins in Slade at the intersection with KY-15 at approximate mile point 3.5. It has a north by northwest bearing along the Middle Fork of the Red River valley bottom until it reaches the intersection with KY-77 at approximate mile point 5.1. The entirety of KY-11 is along the valley bottom and the length under review is approximately 1.6 miles.

At the KY-11/KY-77 intersection the roadway is on the northeast side of the Middle Fork of the Red River. The valley bottom is wide and flat providing ample space for the two-lane road with minimal cut and fill. KY-11 crosses the Middle Fork of the Red River at mile point 4.1.


**Image 16: KY-11, looking north along the Middle Fork of the Red River valley.**
**Image 17: Middle Fork of the Red River crossing.**

To provide space between KY-11 and the Middle Fork of the Red River, mile point 4.6, a large road cut was made exposing the Borden Formation. Differential weathering between interbedded siltstone and shale was observed. Two major landslide repairs were observed where two sections of the embankment were undercut by the stream. The slide at mile point 4.7 utilized quickcrete with horizontal drains indicating water movement along the cut slope also contributed to slope stability failures.



**Image 18: Rock cut, exposing Borden Formation, KY-11 MP 4.6.**
**Image 19: Slide repair, quickcrete and horizontal drains, KY-11 MP 4.7.**
**Image 20: Slide repair, rails, KY-11 MP 5.0.**

## 5.0 Conclusions

The purpose of this overview was to provide a general summary of the bedrock, soil, and geomorphic features likely to be encountered within the proposed area; and to identify geotechnical features that may have an adverse impact on the project.

Geotechnical drilling will be needed for roadway cut/fills and structures. If a portion of this project will be a widening project, information on existing pavement structure should be obtained to assist the team in pavement design. Due to the high volume of traffic chemical modification may not be feasible so a granular subgrade could be utilized. Sampling of foundation soils should be performed for embankment situations.

The information presented in this overview should be reviewed in the general nature in which it was intended. A thorough geotechnical exploration of the proposed alignment and grade will be required to properly anticipate and plan for special requirements necessary for the design and construction of the proposed alignment.

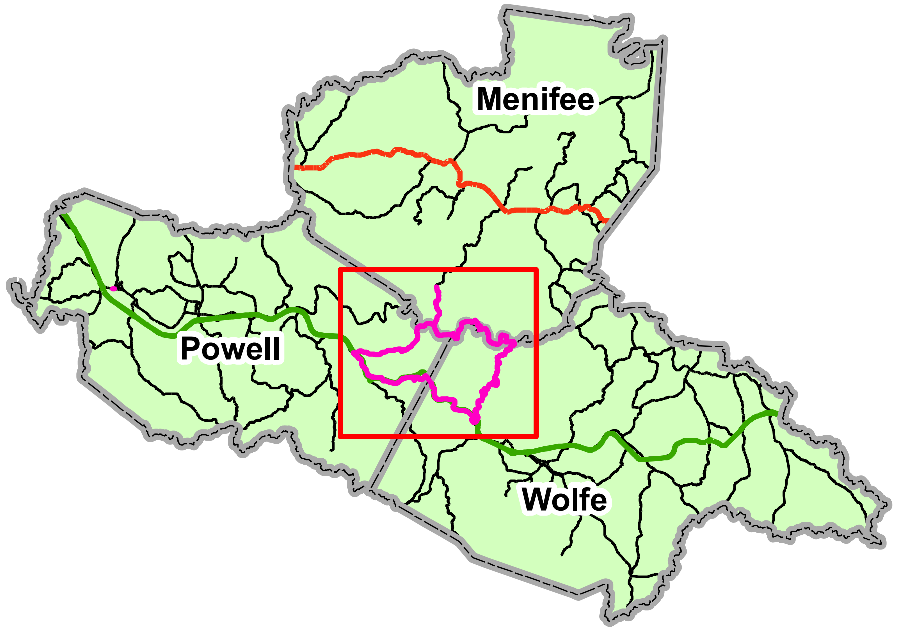
**APPENDIX A (Study Area Corridor)**
**APPENDIX B (Geologic Map)**
**APPENDIX C (Water, Gas, Oil Wells, and Springs)**

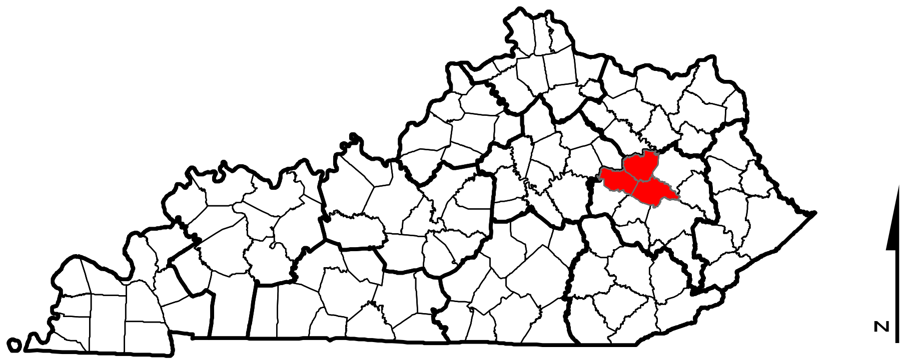
# District 10 Planning Study

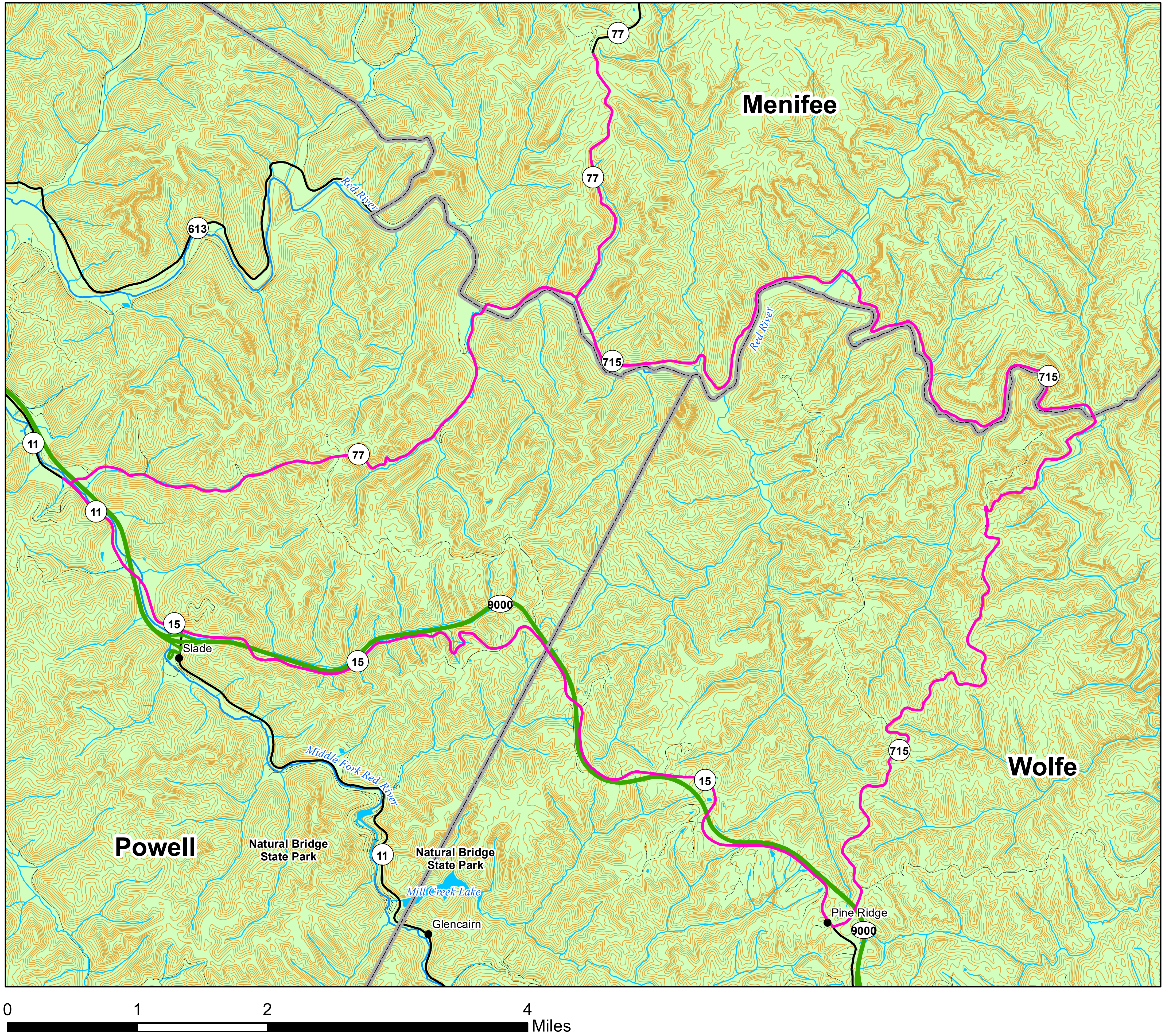
Powell - Menifee - Wolfe
10-0000.00
Location Map

**Legend**

- Routes of Study
- KY 9000 - Mountain Parkway
- US 460
- State Roads
- Local Roads
- Lakes
- Rivers and Streams
- Elevation Contours (40 ft intervals)
- Study Area
- Towns





# District 10 Planning Study

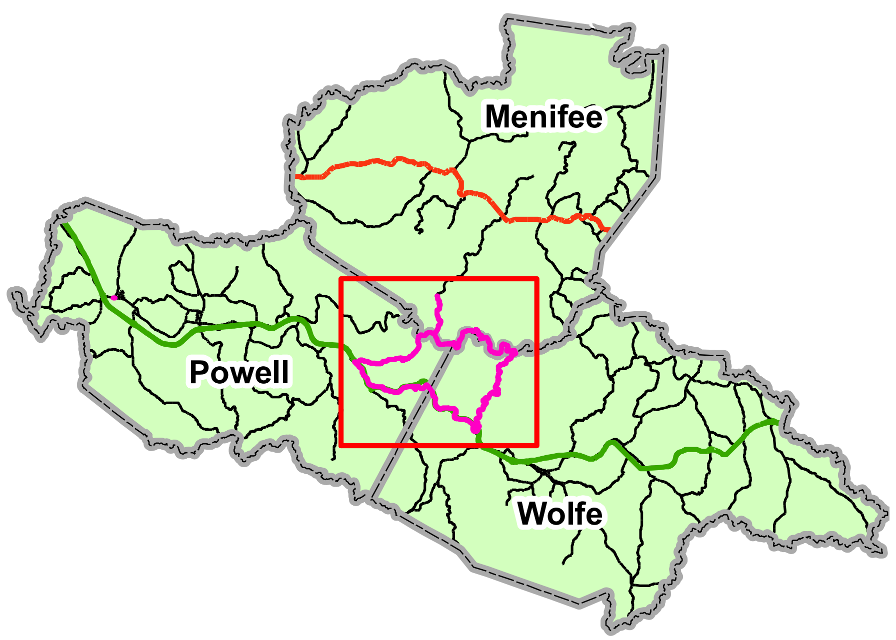
Powell - Menifee - Wolfe
10-0000.00
Geologic Map

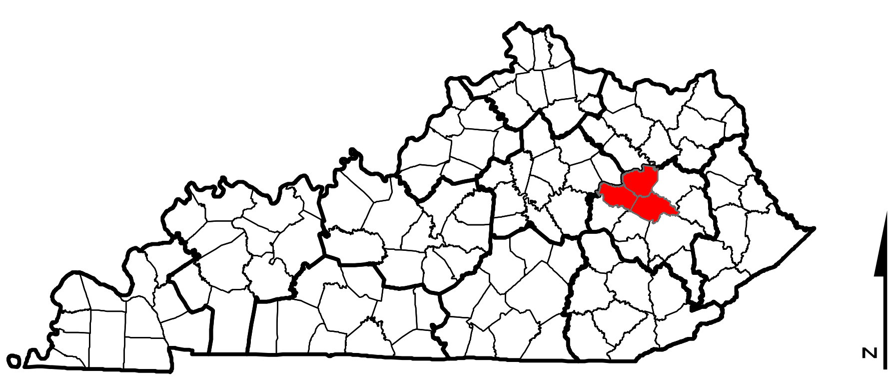
**Legend**

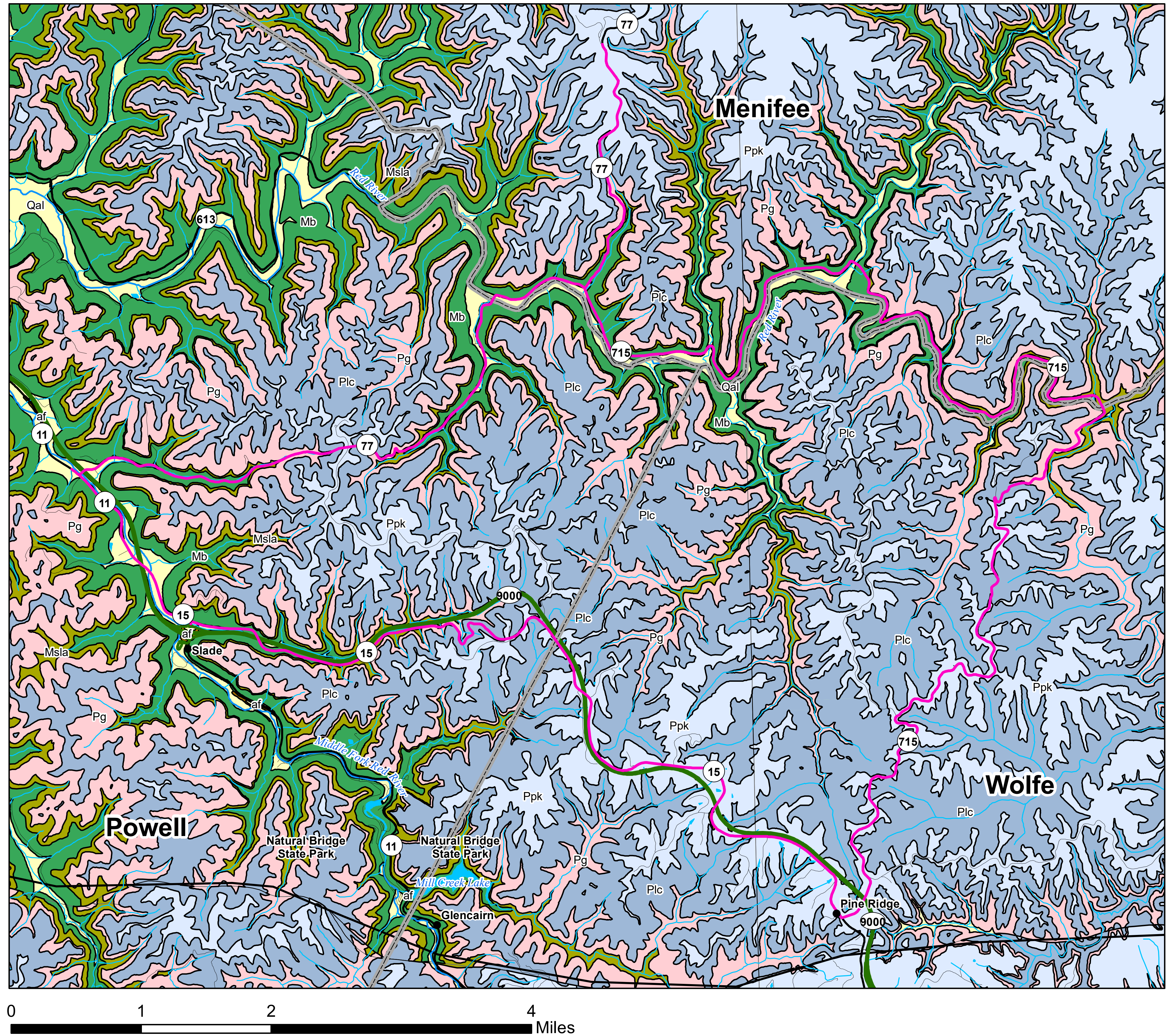
- Routes of Study
- KY 9000 - Mountain Parkway
- US 460
- State Roads
- Local Roads
- Faults
- Lakes
- Rivers and Streams
- Elevation Contours (40 ft intervals)
- Study Area
- Towns

**Geologic Formations**

- Qal - Alluvium
- Qt - Terrace Deposit
- af - Artifical Fill
- Ppk - Pikeville Formation
- Pg - Grundy Formation
- Plc - Corbin Sandstone
- Msla - Slade Formation
- Mb - Borden Member





# District 10 Planning Study

Powell - Menifee - Wolfe
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Wells and Springs Map

## Legend

- Oil Well
- Combined Oil && Gas Well
- Gas Well
- Dry and Abandoned Well
- Secondary (Service) Well
- Miscellaneous Well
- Stratigraphic Core, Public
- Abandoned Well
- Well Location
- Parkways
- US Highways
- State Roads
- Local Roads
- Lakes
- Rivers
- Monitoring Wells (Monitoring)
- Monitoring Wells (Plugged)
- DOW Groundwater - Springs
- Water Wells (Agriculture)
- Water Wells (Domestic)
- Water Wells (Other)
- Water Wells (PWS)
- Water Wells (Plugged)
- Towns
- Sinkholes
- Sinkhole Drainage Areas
- Fault
- Study Area
- Routes of Study