

Research Report
KTC-89-7

EARTHQUAKE HAZARD MITIGATION OF
TRANSPORTATION FACILITIES
FOR MUHLENBERG COUNTY

by

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and

Federal Highway Administration
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| 16. Abstract Concern has grown in recent years over the seismic activity of the New Madrid seismic zone in Western Kentucky. Muhlenberg County, Kentucky is located in this region. To permit emergency medical, supply, and equipment traffic into this area after an earthquake has occurred, the Kentucky Transportation Cabinet is interested in the possibility of keeping selected routes passable. This report lists the routes that have been investigated and recommended as being the routes in Muhlenberg County that should be maintained in a passable condition. The recommended routes, US 431 and KY 176 have been visually surveyed and all seismically significant features cataloged. These features are logged by their location on strip maps contained in Appendix A and a detailed listing of all the potentially critical features is given in Appendix B. | | | | | |
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INTRODUCTION

An awareness of earthquakes and their possible effects upon the nation's infrastructure is critically important to the public, and in particular, to public officials. The nation's highway system is one of the most important components of the infrastructure. After the occurrence of an earthquake, the highway system is the primary mode of transporting emergency supplies and services into an affected area. Thus, it is important to catalog the important components of the highway system and attempt to anticipate the possible damage to these components from an earthquake.

Western Kentucky in general and Muhlenberg County in particular are in a high risk earthquake zone. In 1811-1812, three of the most severe earthquakes in American history shook the country. The location of these quakes was not on the infamous San Andreas fault nor anywhere along the well-known fault laden Pacific coast but was near a small town on the Mississippi River where the states of Kentucky and Missouri share a border (Figure 1). It is this river town, New Madrid, Missouri, that is the namesake of a region now regarded by seismologists and disaster response planners as the most hazardous earthquake zone east of the Rocky Mountains -- the New Madrid seismic zone.

In addition to these three great earthquakes, there are several other well documented factors demonstrating the susceptibility of the New Madrid region to the recurrence of major earthquakes. Through a decade of extensive research, an ancient crustal rift has

been found to underlie the relatively shallow sediments comprising the region's surface. This type of geologic structure is prone to seismic activity. The New Madrid rift has been identified as being of sufficient size to generate major earthquakes. Further evidence of the area's seismicity is the record of over 2,000 earthquakes detected in the zone since 1974. Though most have been of a magnitude below the threshold of human perception, their existence clearly indicates the high level of seismic activity occurring in the zone.

Seismologists have calculated the probabilities of recurrence of sizeable earthquakes in the New Madrid rift zone. The probability of a magnitude 6.3 earthquake (Richter scale) within 50 years is from 86 to 97 percent. The probability (1) of that same earthquake occurring within the next 15 years is from 40 to 63 percent. For comparison, the 1971 San Fernando earthquake (magnitude 6.6) killed 58 people and caused \$480 million worth of damage. The 1988 Armenian earthquake of similar magnitude killed approximately 25,000 to 30,000 people.

The probability of a magnitude 7.6 earthquake occurring within 50 years is from 19 to 29 percent. The probability for this size earthquake occurring within 15 years drops to a range of 5.4 to 8.7 percent. On February 4, 1975, the Haicheng earthquake in China had a magnitude of 7.3 and destroyed or damaged about 90 percent of the structures in a city of 90,000 people.

When comparing historical earthquakes of similar magnitude, one must take into consideration

that death totals and damage estimates will vary greatly due to the geology, population density, types of building, and quality of construction.

For a given earthquake, effects at a given location are described by the Modified Mercalli Intensity (MMI) scale (2) which ranges from I (no damage and felt only by instruments) to XII (total destruction). Details of the MMI scale are given in Table 1. Values of MMI associated with the 1811-1812 earthquakes are shown in Figure 1. The potential for damage and destruction from earthquakes in the region is significant.

In 1982, the Governor's Task Force on Earthquake Hazards and Safety was created to evaluate Kentucky's earthquake risk and to make recommendations for responding to those risks. This task force recommended increased public awareness and education programs, improved emergency response planning and training, improved building codes and seismic restraint designs, evaluation of other mitigation measures, and participation in national and regional earthquake forums and funding programs.

In 1984, Governor Collins created the Governor's Earthquake Hazards and Safety Technical Advisory Panel (GEHSTAP) to analyze scientific and engineering data regarding seismic risks in Kentucky and to make specific recommendations on mitigation, public awareness, response planning, and policy development for public health and safety. The States are dependent on their highway systems for the movement of goods and services. Due

to the possible adverse effects a major earthquake could have on this system, the Earthquake Stability and Transportation Subcommittee (ESTS) of GEHSTAP was formed.

ESTS has encouraged the Kentucky Transportation Cabinet to secure funding for generating and implementing an earthquake hazard mitigation plan in an attempt to safeguard the highway system against catastrophic earthquake failure. As a result, the Cabinet commissioned the Kentucky Transportation Center at the University of Kentucky to analyze and assess the possible effects of an earthquake on highway facilities. The study area includes the 26 western-most counties in Kentucky that are adjacent to the New Madrid seismic zone (Figure 1). To date, one of the results of that study has been the recommendation that over 1,000 miles of highways in the study area be utilized as emergency or "priority" routes. These would be the primary routes used for transporting emergency supplies and personnel after an earthquake. Also, it is anticipated that these would be the first routes repaired after an earthquake.

The initial task in identifying these priority routes was to decide where they should begin; that is, in the event of a major earthquake, the point at which the transport of goods and services would originate. Ideally, the city chosen should possess the following attributes:

1. Sufficient size to contain all necessary personnel, supplies, and facilities to respond quickly to a major emergency;
2. Proximity to the high hazard

area to speed the relief effort but not so close as to suffer the same high risk potential;

3. Easy access from other major cities in the State; and
4. Sufficient routes to provide relatively direct access to all 26 high-risk counties.

The city best fitting these criteria is Bowling Green. Located at the eastern edge of the earthquake zone in Warren County, Bowling Green meets both the size criterion (population 40,450) and the accessibility criterion (Louisville and Nashville via I 65 and Lexington via the Bluegrass Parkway). Bowling Green provides access to the 26-county area via US 68/KY 80; this road was chosen as the main east-west artery because it crosses Lake Barkley and Kentucky Lake upstream from the dams impounding those bodies of water.

As a first step towards establishing an overall policy for earthquake hazard mitigation in the highway system, these priority routes have been visually surveyed and all natural and man-made features along these routes that are considered seismically significant were cataloged. With this information, a realistic and cost-effective plan for "hardening" these routes against earthquakes can be established. Such efforts are currently under way.

PRIORITY ROUTE IN MUHLENBERG COUNTY

Muhlenberg County is located approximately 124 miles east-northeast of the center of the New Madrid Seismic Zone. Figure 1

indicates that Muhlenberg County is in the IX band of the MMI scale. This indicates considerable damage could occur in Muhlenberg County in the event of a major earthquake.

US 431 and KY 176 have been designated as the priority routes in Muhlenberg County. US 431 starts at the Muhlenberg County-Logan County line and travels north for 18.41 miles, ending in Central City. KY 176 starts at the junction of KY 176 and KY 181 in the City of Greenville, and travels east for 7.80 miles, ending at the junction of US 431.

A number of features along these priority routes could potentially hamper rescue and relief efforts. These features included bridges, soil fills, cut slopes, gas pipelines, power lines, power lines, water towers, geologic faults, large trees, mines, water impoundments, and swamps. These features are logged by their location on strip maps contained in Appendix A and a detailed listing of all potentially critical features is given in Appendix B.

BRIDGES

Bridges are the most significant and important features on the priority route. With few exceptions, existing highway bridges in the study area have not been designed to resist motions and forces that may be generated by earthquakes. Bridges located within the seismic zone could possibly be damaged, thus reducing their load-carrying ability. In some cases, damage could be sufficiently great to cause complete collapse. Several types of damage could occur:

1. A bridge could fail at the bearing which supports the

main spans, causing the spans to fall from the bearings and possibly from the piers or abutments.

2. Failure could occur in the columns, piers, or footings which would reduce the load-carrying capacity of the bridge, if the bridge was still in place.
3. An abutment could tilt allowing the entire span to fall.
4. Soil movement or slumping could affect the bridge approach fills, damaging the abutments or piers, or making the bridge inaccessible.

There are five bridges located on US 431 and two bridges on KY 176. The bridges are located over:

US 431

1. Rocky Creek,
2. Branch of Rocky Creek,
3. Pond Creek,
4. Mine Haul Road, and
5. Western KY Parkway.

KY 176

1. Pond Creek, and
2. Mine haul road over KY 176.

Research is currently under way studying the effects that an earthquake could have on these bridges and their approach fills.

FILLS

Highway fills are particularly important because of their tendency to fail from seismically induced motions. Fills fail in one of two major modes. The first is a generalized circular or wedge-shaped failure resulting in one or both traffic lanes moving down and out. If both lanes failed, this would certainly render the route impassable and immediate repairs would be necessary. The second mode of failure is a general slumping or settling of the embankment. The roadway would probably remain passable if settlement or slumping were not severe but reduced speed limits would be required for safety.

Large fills on US 431 and KY 176 in Muhlenberg County are located as follows:

US 431

1. Approach fills for the bridge over Rocky Creek,
2. Approach fills for the bridge over Branch of Rocky Creek,
3. Approach fills for the bridge over Pond Creek,
4. 0.34 mile north of the Pond Creek bridge, and
5. Approach fills for the bridge over the mine haul road.

KY 176

1. 0.39 mile west of the Pond Creek bridge, and
2. Approach fills for the bridge over Pond Creek.

CUT SLOPES

Most cut slopes cataloged during surveys of US 431 were in rock and were less than 45 feet in height. Should any of these slopes fail, both lanes of the roadway probably would be closed. Cut slopes that have a history of failure and those that have steep slopes should be considered as problem areas.

The most critical cut slopes are located:

1. 0.11 mile south of the bridge over the mine haul road,
2. 0.29 mile north of the bridge over the mine haul road, and
3. 1.10 miles south of Central City.

GAS PIPELINES

A gas pipeline crosses under KY 176. It is possible that pipelines could fail under or near a priority route causing a temporary closure. If a pipeline failed, an explosion might destroy a section of the priority route. Repair could be delayed by further gas leaks, fire, and/or additional explosions.

It appears that most of the pipelines in Muhlenberg County were constructed with little or no seismic considerations. A Gas pipeline cross under KY 176 0.90 mile east of the junction of KY 181 and KY 176.

POWER LINES

High voltage power lines also were cataloged during the route surveys. The height of the lines above the roadway were estimated visually. Power company officials speculated

that a number of breaks along each power line would occur during a major earthquake. In most cases, fallen lines would not be transmitting power because power would be automatically cut off within a few seconds in the event of a break.

Additionally, power line support towers could potentially fall across a priority route.

Power lines cross at the following locations on US 431.

US 431

1. 0.60 mile south of junction of US 431 and KY 246 (heading west),
2. 0.31 mile south of the bridge over the mine haul road, and
3. 1.09 miles north of the bridge over the mine haul road.

WATER TOWER

A water tower is approximately 20 feet from US 431 at milepost 11.30. It is possible that the tower could fail during a major earthquake and temporarily block the priority route.

GEOLOGIC FAULTS

There are numerous geologic faults (breaks in the bedrock where movement has occurred in the past) in the study area. The faults are seismically significant since a large earthquake could trigger additional movement along one or more old slip planes. There are no precautionary measures that can be taken to reduce hazards from faults except that construction of bridges and other facilities over or near such

faults requires special consideration. The faults are included for informational purposes only. Faults which cross under US 431 and KY 176 are listed below:

US 431

1. 0.47, 1.00, 1.42, 1.76, 1.87, and 2.65 miles north of the Branch of Rocky Creek Bridge;
2. 0.23, 0.56, and 0.94 mile north of junction KY 70 (heading east) and US 431;
3. 0.45 mile south of the Pond Creek bridge; and
4. 1.01 miles north of the bridge over the mine haul road.

KY 176

1. 2.20 and 2.95 miles east of junction KY 181 and KY 176.

MINES

There are several types of mining-related activities in Muhlenberg County that could affect priority routes during a major earthquake. A large earthquake could collapse pillars in underground mines and cause rapid subsidence at the surface. Other potential hazards exist from strip mines that might have large spoil banks and/or possible water impoundments. Abandoned or current operating mines are located at the following:

US 431

1. Deep mine 0.87 mile south of junction KY 246 (west) and KY 431;
2. Deep mine 0.75 mile north of junction KY 70 (east) and KY

431;

3. Deep mine 0.33 mile south of Pond Creek bridge;
4. Strip mine 0.12 mile south of the bridge over the mine haul road and continues north for 0.52 mile;
5. Deep mine 2.25, 2.10, and 1.23 miles south of the junction of Western KY Parkway and US 431; and
6. Deep mine 0.91 mile north of the junction of Western Ky Parkway and US 431.

KY 176

1. Deep mine 2.95 miles east of the junction of KY 181 and US 431,
2. Strip mine 0.70 mile west of the Pond Creek bridge,
3. Strip mine 0.02 mile east of the Pond Creek bridge,
4. Deep mine 0.21 mile east of the Pond Creek bridge, and
5. Deep mine 0.68 mile west of the junction of US 431 and KY 176.

TREES

The behavior of trees during an earthquake depends upon many factors including their condition, type, height, and size. Local soil conditions, geometry of the ground surface, and characteristics of the earthquake can also be important. Violent ground motions accompanied by surface rupture and perhaps permanent displacement of the soil surface produce sudden surface

accelerations of the ground which can snap and uproot large trees (3).

Trees are so numerous that, if many of them fell, US 431 and KY 176 could effectively be blocked for several hours or days before emergency crews could clear the debris. Groups of large trees are located near the road at the following sites:

US 431

1. 1.90 miles north of the Muhlenberg County-Logan County line,
2. 0.37 miles north of the Branch of Rocky Creek bridge,
3. 0.06 and 1.05 miles north of junction KY 246 (heading west) and US 431, and
4. 0.30 and 1.20 miles north of the bridge over the mine haul road.

KY 176

1. 0.10, 1.20, 1.70, 2.00, and 3.60 miles east of junction KY 181 and KY 176;
2. 0.09 mile west of Pond Creek bridge;
3. 0.95, 0.25, 0.10, and 0.0 mile west of the coal haul road bridge; and
4. 0.30, 0.92, and 1.10 miles east of the coal haul road bridge.

WATER IMPOUNDMENTS

Large impoundments of water (large recreational reservoirs or flood control dams) could threaten any

priority route located nearby. The priority route could be washed out or temporarily flooded in the event of a large impoundment failure.

Small impoundments such as large farm ponds could also be a problem area. Ponds which have large earthen dams that lie above the road surface could collapse during an earthquake and wash out a section of a priority route. Ponds which lie below the road surface and are adjacent to the toe of the fill could cause failures in the fill during an earthquake due to the high moisture content.

The impoundments are located as follows:

US 431

1. US 431 crosses the flood plain for the Lake Malone 0.11 mile north of Rocky Creek bridge, and
2. 0.07 mile north of the bridge over the mine haul road.

KY 176

1. 0.55 mile west of the Pond Creek bridge.

SWAMPS

KY 176 is constructed over a swamp approximately 0.39 mile west of the Pond Creek bridge. Priority routes that are constructed over or adjacent to swamps will probably be damaged due to failures within the soil structure during an earthquake. The high water tables penetrate the underlying road bed and weaken the soil structure. During an earthquake, the structure will be further weakened and large vertical

displacements in the road surface are likely to occur.

ALLUVIUM

Soil maps for Muhlenberg County indicate that there are moderate amounts of alluvium present throughout the county. Alluvium is a loose, fine-grain soil which is deposited by flowing water such as creeks and rivers. Due to the nature of the alluvium, ground motions at the surface of the soil can be many times greater than those within the underlying bedrock and temporary liquefaction can occur (Figure 2). An alluvium map for Muhlenberg County is shown in Figure 3.

CONCLUSIONS

In 1984, ESTS developed a fivefold plan of action for formulating and implementing a seismic mitigation policy for the western Kentucky seismic zone. To date, the Kentucky Transportation Center has established priority routes for all 26 counties in the western Kentucky seismic zone and developed seismic risk maps of all natural and man-made features that are susceptible to earthquake damage that could jeopardize the priority routes.

Current work is being conducted to analyze these features and make recommendations for hardening them against earthquake damage.

Future work involves training key personnel in the Transportation Cabinet in hazard mitigation and seismic safety; which includes bridge inspectors, district engineers, construction inspectors, designers, and maintenance personnel.

Following the education of key

personnel, the mitigation plan proposed by the Kentucky Transportation Center will be reviewed by the Kentucky Transportation Cabinet and a program will be established for implementation. The final step involves the use of relevant seismic codes for all new construction, repair, and maintenance.

REFERENCES

1. Johnson, Arch C., "A Brief Overview of the Geology, Seismicity and Seismic Hazard of the Central Mississippi Valley Area," Proceedings, A Regional Seminar on Earthquake Fundamentals for the Mississippi Valley, Earthquake Engineering Research Institute, Memphis, Tennessee, October 29, 1985.
2. Green, N. B., "Earthquake Resistant Building Design and Construction," Third Edition, Elsevier, 1987, Page No. 179-180.
3. Keller, Edward A., "Environmental Geology," Charles E. Merrill Publishing Company, A Bell and Howell Company, 1979, Page No. 157.

Additional Information

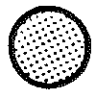
The Commonwealth of Kentucky has prepared a State Emergency Operations Procedures (State EOP) manual that is produced by the Division of Disaster and Emergency Services (DES), Department of Military Affairs, Frankfort, 40601. Annexes H. on Transportation and DD on Earthquakes give additional information on disaster preparedness and response.

A copy of the State EOP and information on local hazard mitigation activities and response preparedness are available from the AREA 2 Office of DES which is located in Hopkinsville. The phone numbers at this office are (502) 564-8602 and (502) 885-7100.

Additional information about the study discussed in this report should be directed to David L. Allen, Project Director, at the Kentucky Transportation Center, (606) 257-4513. Requests to be placed on the mailing list for updated information should be submitted on your company or agency letterhead to the Kentucky Transportation Center at the University of Kentucky, Lexington Kentucky 40506-0043.



MMI SCALE REGIONAL INTENSITY
BOUNDARY ZONES



NEW MADRID SEISMIC
ZONE

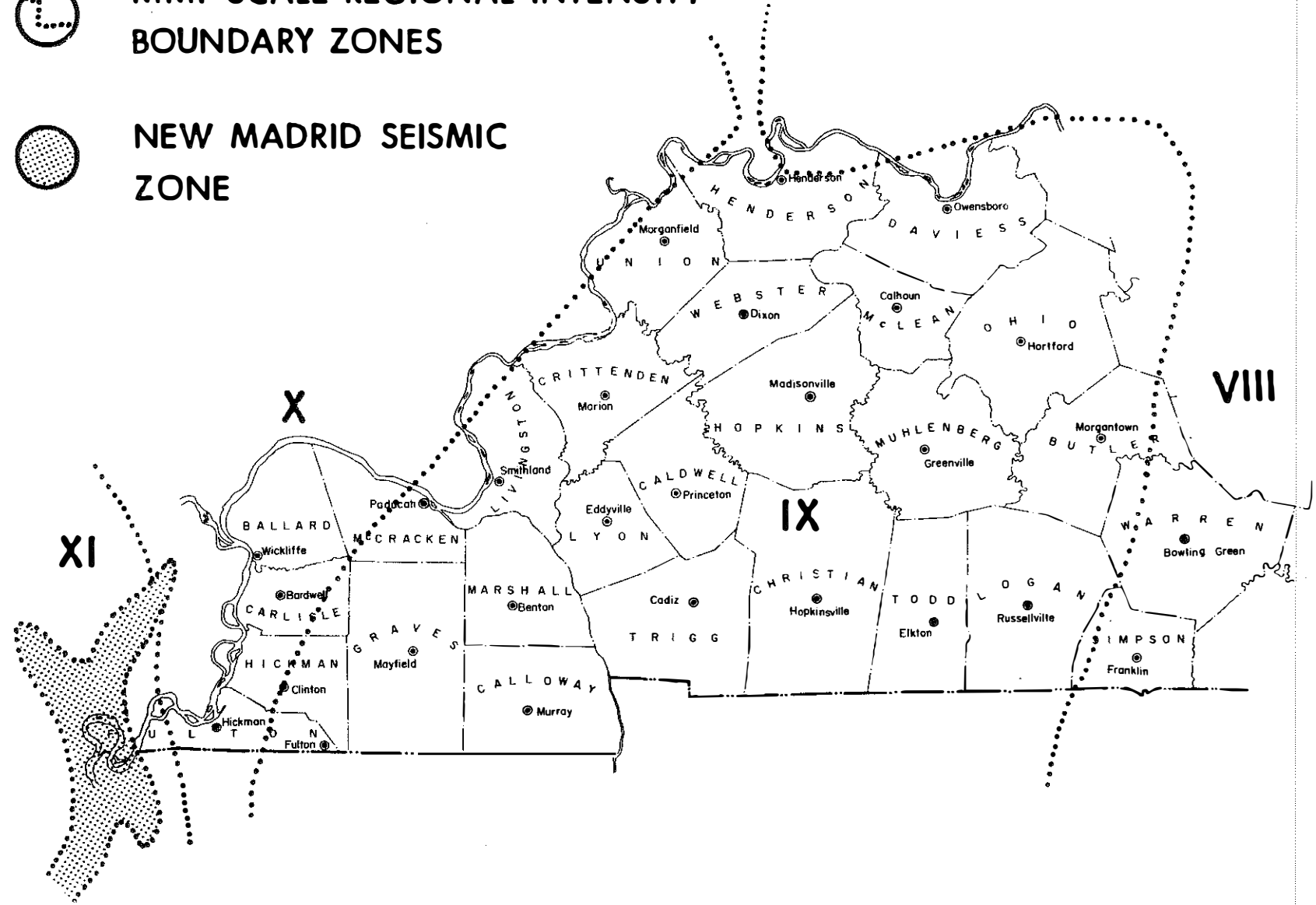


Figure 1: The twenty-six counties included in this study area.

Table 1: MODIFIED MERCALLI INTENSITY SCALE

Modified Mercalli Intensity Scale, 1956 Version

The following comments by Dr. Richter precede the published statement of the intensity scale:

...Each effect is named at the level of intensity at which it first appears frequently and characteristically. Each effect may be found less strongly, or in fewer instances, at the next lower grade of intensity; more strongly or more often at the next higher grade. A few effects are named at two successive levels to indicate a more gradual increase.

Masonry A, B, C, D. To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering.

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar, reinforced by not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weakness like failing to tie corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

The following list represents the twelve grades of the scale.

- I. Not felt. Marginal and long-period effects of large earthquakes.
- II. Felt by persons at rest, on upper floors, or favorable placed.
- III. Felt indoors, Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
- IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.
- V. Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
- VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken, Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken.
- VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices. Same cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
- VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundation if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
- IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. Frame structures, if not bolted, shifted off foundations. Frames cracked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand crater.
- X. Most masonry and frame structures destroyed with their foundations. Some will-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large land slides. Water thrown on banks of canals, river, lakes, etc. Sand and mud shifted horizontally on beaches and flat lands. Rails bent slightly.
- XI. Rails bent greatly. Underground pipelines completely out of service.
- XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.

AMPLIFICATION OF SHAKING AND DAMAGE DUE TO SHAKING

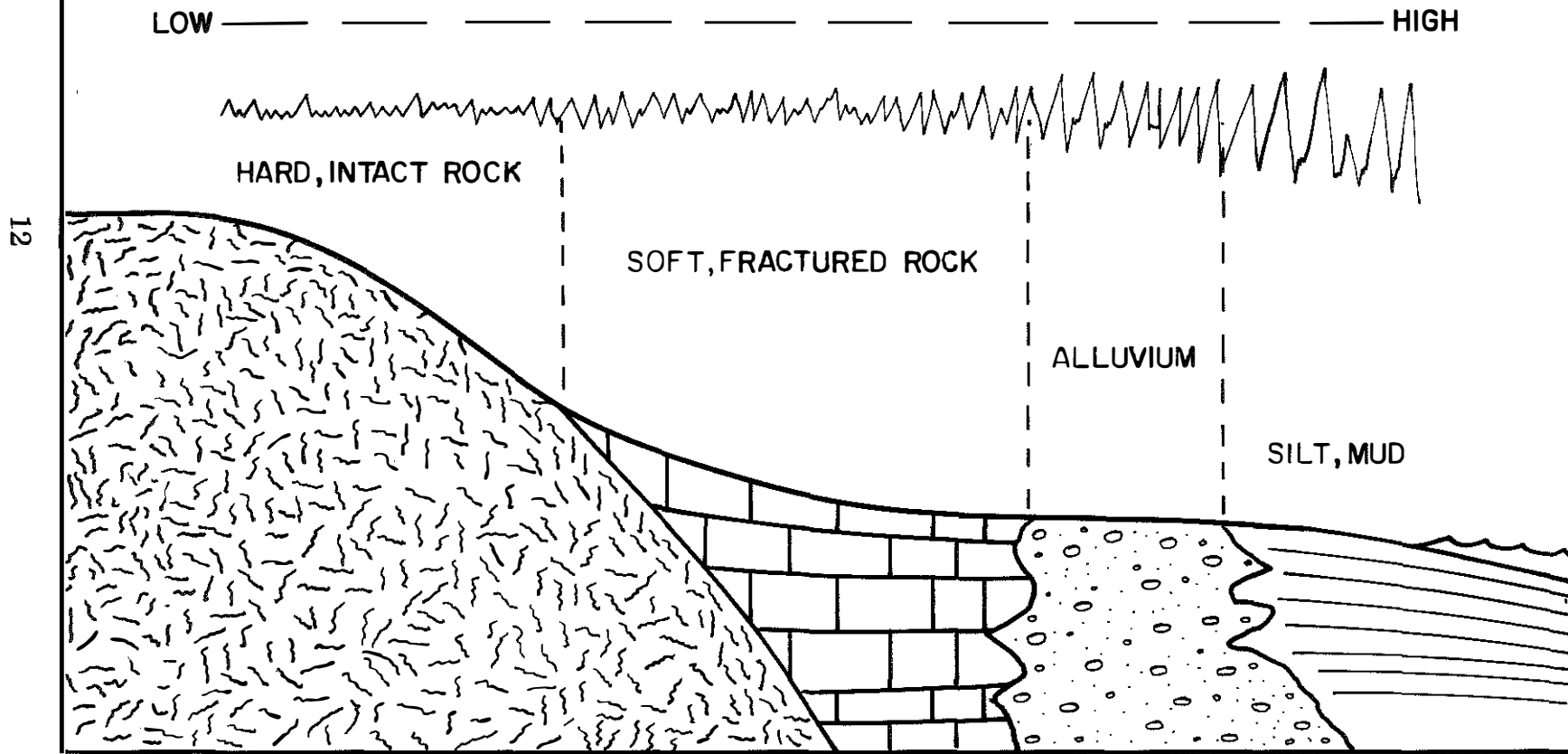
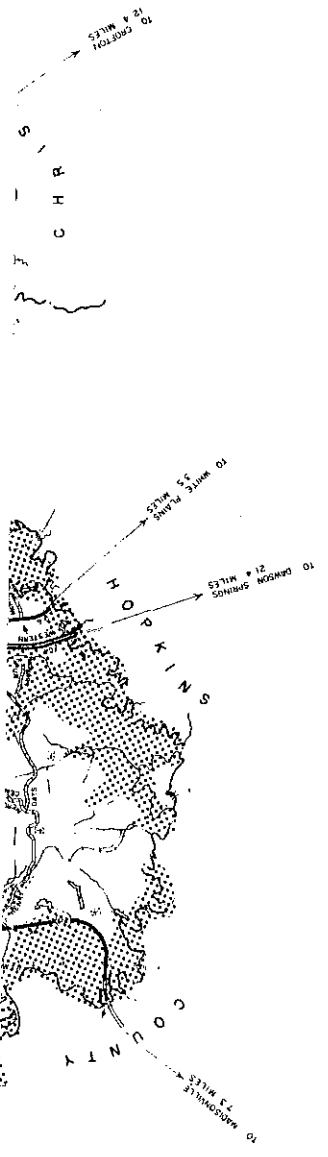


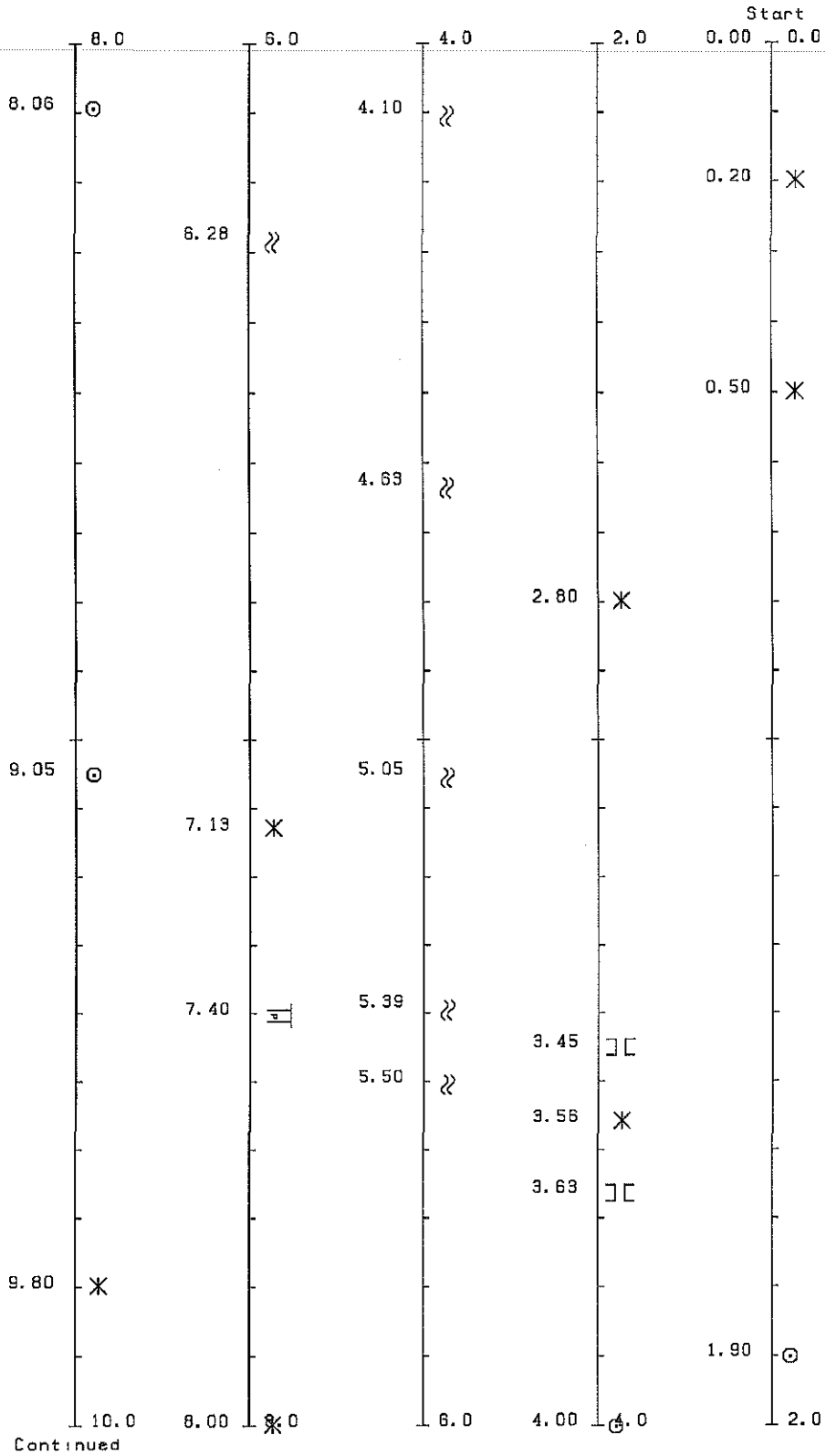
Figure 2 : Amplification of shaking in softer rock & soil during an earthquake.



APPENDIX A
STRIP MAP FOR MUHLENBERG COUNTY
US 431 and KY 176

US431

MUHLENBERG



LEGEND OF FEATURES

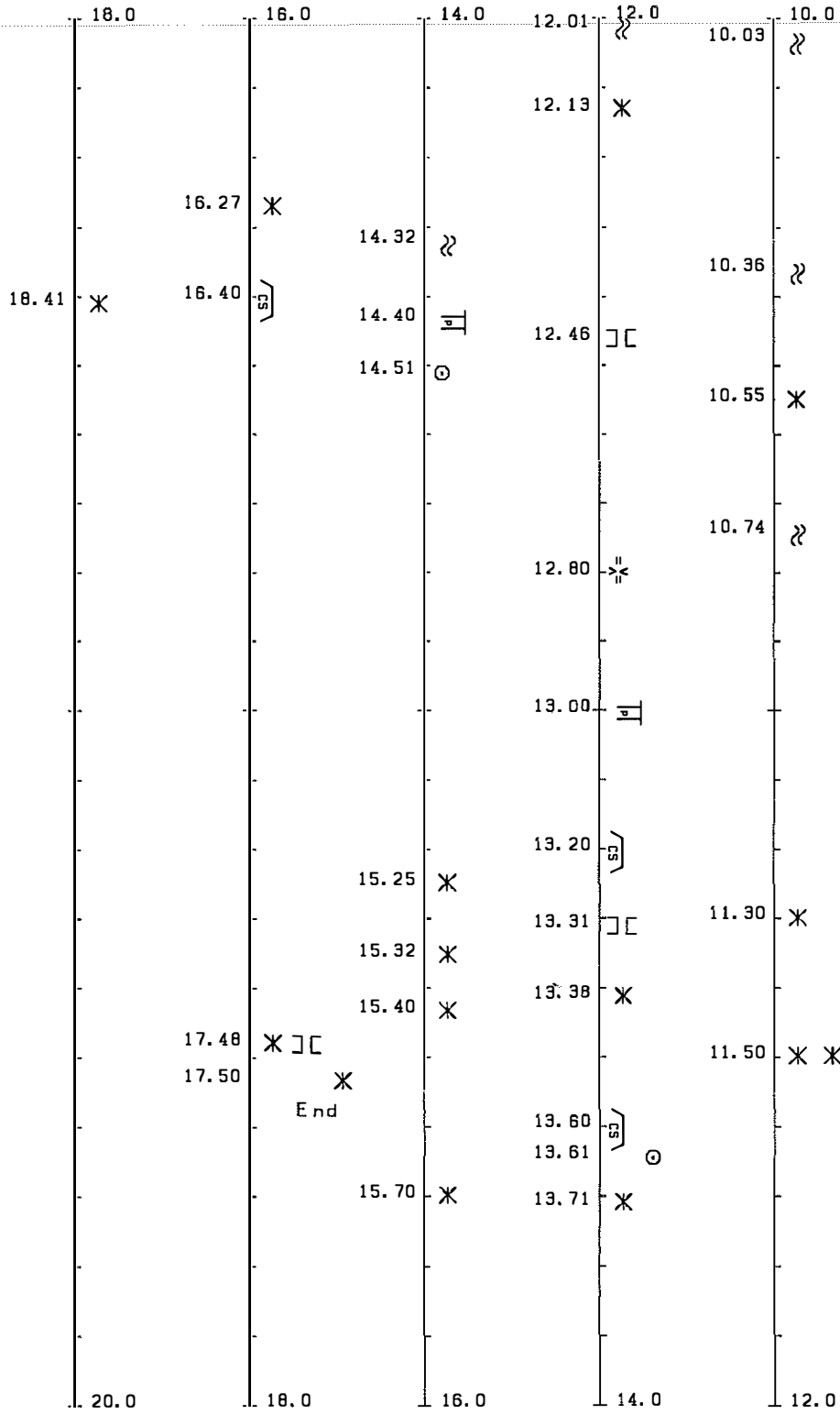
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|--|----------|--|------------|--|----------|--|-------|--|-------|
| | BRIDGE | | CUT SLOPE | | BUILDING | | FILL | | OTHER |
| | TREE | | POWER LINE | | SIGN | | FAULT | | |
| | PIPELINE | | MINE | | TANK | | DAM | | |

SEE REPORT FOR DESCRIPTIONS OF OTHER

US431

MUHLLENBERG

Continued



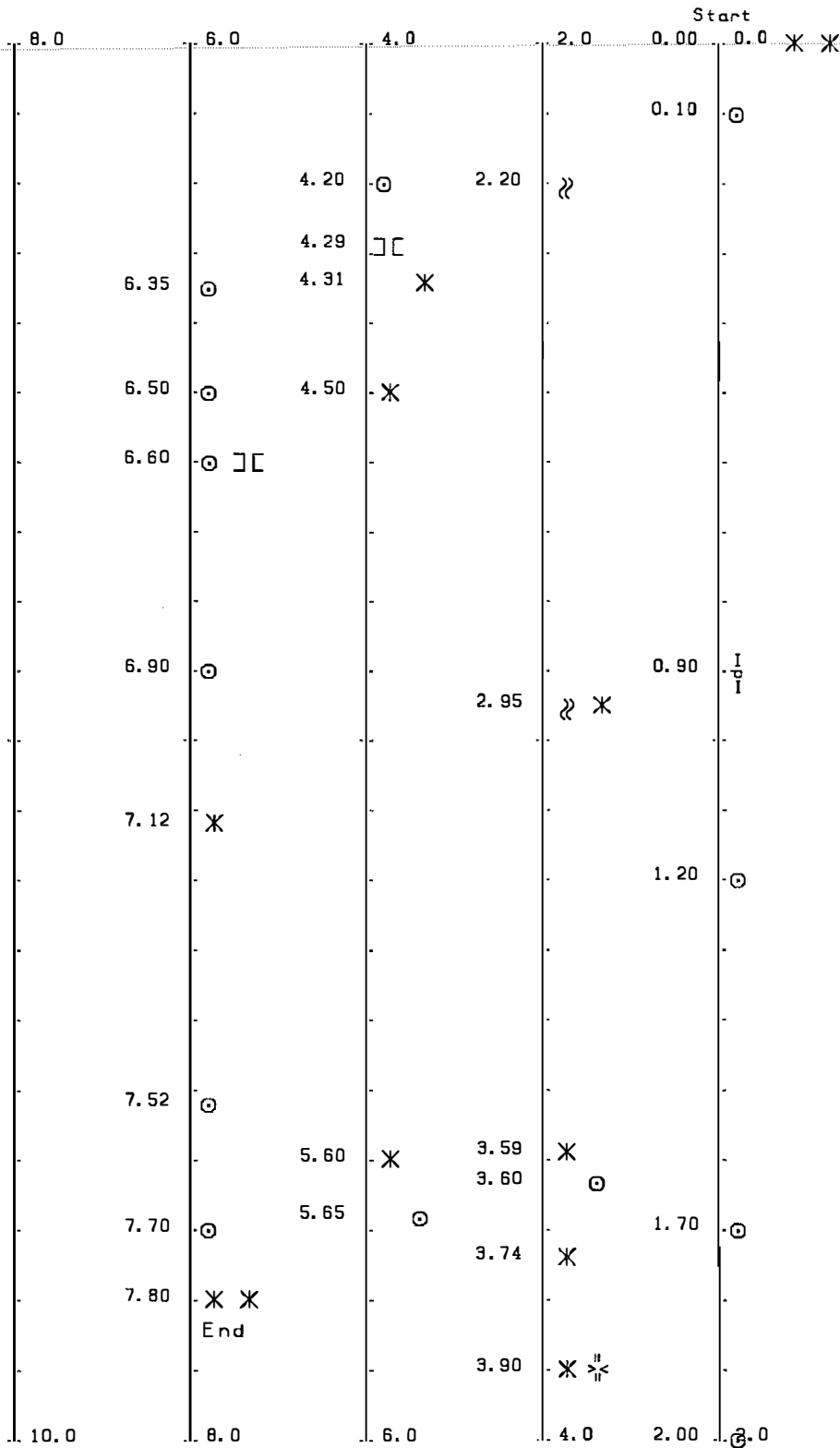
LEGEND OF FEATURES

| | | | | | | | | | |
|--|----------|--|------------|--|----------|--|-------|--|-------|
| | BRIDGE | | CUT SLOPE | | BUILDING | | FILL | | OTHER |
| | TREE | | POWER LINE | | SIGN | | FAULT | | |
| | PIPELINE | | MINE | | TANK | | DRM | | |

SEE REPORT FOR DESCRIPTIONS OF OTHER

KY 176

MUHLENBERG



LEGEND OF FEATURES

| | | | | | | | | | |
|--|----------|--|------------|--|----------|--|-------|--|-------|
| | BRIDGE | | CUT SLOPE | | BUILDING | | FILL | | OTHER |
| | TREE | | POWER LINE | | SIGN | | FAULT | | |
| | PIPELINE | | MINE | | TRUNK | | DAM | | |

SEE REPORT FOR DESCRIPTIONS OF OTHER

APPENDIX B
SEISMICALLY SIGNIFICANT FEATURES

Report by Road and Milepoint
for Muhlenberg County - Kentucky
KY 176

| Milepoint | Feature | Data |
|-----------|----------|---|
| 0.00 | Other | Junction KY 181 Heading North-South Road Surface Type - Flexible |
| 0.00 | Other | Begin KY 176 Quake Study at Greenville Road Surface Type - Flexible |
| 0.10 | Trees | Number of Trees 200 Height 45 feet Diameter 15 in. Ending Milepoint 1.00 Distance From Road 10 feet Road Surface Type - Flexible |
| 0.90 | Pipeline | Pipeline Type - Gas Road Surface Type - Flexible |
| 1.20 | Trees | Number of Trees 15 Height 25 feet Diameter 24 in. Ending Milepoint 1.10 Distance From Road 10 feet Road Surface Type - Flexible |
| 1.70 | Trees | Number of Trees 1 Height 55 feet Diameter 36 in. Ending Milepoint 1.70 Distance From Road 15 feet Road Surface Type - Flexible |
| 2.00 | Trees | Number of Trees 20 Height 40 feet Diameter 8 in. Ending Milepoint 2.10 Distance From Road 15 feet Road Surface Type - Flexible |
| 2.20 | Fault | North Rocky Ford Fault Road Surface Type - Flexible |
| 2.95 | Fault | Fault Road Surface Type - Flexible |
| 2.95 | Other | Deep Mining (1,000 feet North of Road) Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
KY 176

| Milepoint | Feature | Data |
|-----------|---------|---|
| 3.59 | Other | Strip Mining (500 feet South of Road) Road Surface Type - Flexible |
| 3.60 | Trees | Number of Trees 30 Height 25 feet Diameter 24 in. Ending Milepoint 3.70 Distance From Road 10 feet Road Surface Type - Flexible |
| 3.74 | Other | Water Impoundment (600 feet North of Road) Road Surface Type - Flexible |
| 3.90 | Other | Swampland for 1,000 feet Road Surface Type - Flexible |
| 3.90 | Fill | Material Type - Soil Height 10 feet Side slope 2:1 Length 2000 feet Crest 25 feet Type Fill - Other Road Surface Type - Flexible |
| 4.20 | Trees | Number of Trees 300 Height 45 feet Diameter 36 in. Ending Milepoint 5.40 Distance From Road 10 feet Road Surface Type - Flexible |
| 4.29 | Bridge | Number of Spans 9 Over Stream Concrete T-Beam Bridge Bearing Type Unknown Deck Type - Concrete Length 297 feet Width 23 feet Pier Type - Open SPC Rating - B Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown |
| 4.31 | Other | Strip Mining Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
KY 176

| Milepoint | Feature | Data |
|-----------|---------|--|
| 4.50 | Other | Pond Creek Shafts (1,400 feet North of Road) Road Surface Type - Flexible |
| 5.60 | Other | Junction KY 246 Heading Southeast Road Surface Type - Flexible |
| 5.65 | Trees | Number of Trees 150 Height 50 feet Diameter 18 in. Ending Milepoint 6.00 Distance From Road 15 feet Road Surface Type - Flexible |
| 6.35 | Trees | Number of Trees 2 Height 50 feet Diameter 18 in. Ending Milepoint 6.35 Distance From Road 15 feet Road Surface Type - Flexible |
| 6.50 | Trees | Number of Trees 4 Height 50 feet Diameter 18 in. Ending Milepoint 6.50 Distance From Road 15 feet Road Surface Type - Flexible |
| 6.60 | Trees | Number of Trees 6 Height 50 feet Diameter 18 in. Ending Milepoint 6.60 Distance From Road 15 feet Road Surface Type - Flexible |
| 6.60 | Bridge | Number of Spans 1 Steel Girder I-Beam Bridge Type Unknown End 1 Fixed End 2 Fixed Deck Type - Concrete Length 60 feet Width 18 feet Pier Type - Unknown SPC Rating - A Surface Type - Flexible Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown |
| 6.90 | Trees | Number of Trees 100 Height 35 feet Diameter 30 in. Ending Milepoint 7.30 Distance From Road 10 feet Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
KY 176

| Milepoint | Feature | Data |
|-----------|---------|---|
| 7.12 | Other | Black Diamond Shafts (1,400 feet South of Road) Road Surface Type - Flexible |
| 7.52 | Trees | Number of Trees 8 Height 50 feet Diameter 20 in. Ending Milepoint 7.50 Distance From Road 15 feet Road Surface Type - Flexible |
| 7.70 | Trees | Number of Trees 8 Height 50 feet Diameter 20 in. Ending Milepoint 7.72 Distance From Road 15 feet Road Surface Type - Flexible |
| 7.80 | Other | Junction KY 431 Heading NW-SE Road Surface Type - Flexible |
| 7.80 | Other | End of KY 176 Quake Study at Drakesboro Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|---------|--|
| 0.00 | Other | Muhlenberg Co - Logan Co Boundary Road Surface Type - Flexible |
| 0.20 | Other | Junction KY 1293 Heading Southeast Road Surface Type - Flexible |
| 0.50 | Other | Junction KY 973 Heading Northwest Road Surface Type - Flexible |
| 1.90 | Trees | Number of Trees 150 Height 30 feet Diameter 24 in. Ending Milepoint 2.00 Distance From Road 20 feet Road Surface Type - Flexible |
| 2.80 | Other | Junction KY 949 Heading East Road Surface Type - Flexible |
| 3.45 | Bridge | Number of Spans 7 Over Stream Concrete T-Beam End 1 Rocker Pier 1 Rocker Pier 2 Rocker Pier 3 Rocker Pier 4 Rocker Pier 5 Rocker Pier 6 Rocker End 2 Rocker Deck Type - Concrete Length 227 feet Width 20 feet Pier Type - Solid SPC Rating - B Surface Type - Flexible Expansion Type - Finger Dam End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Pile |
| 3.56 | Other | Lake Malone Flood Plain Lake Malone Dam 3.03 miles from Road Road Surface Type - Flexible |
| 3.63 | Bridge | Number of Spans 1 Over Stream Concrete T-Beam End 1 Fixed End 2 Fixed Deck Type - Concrete Length 48 feet Width 19 feet Pier Type - Open SPC Rating - B Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown |

Report by County and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|---------------|---|
| 4.00 | Trees | Number of Trees 350 Height 40 feet Diameter 28 in. Ending Milepoint 6.60 Distance From Road 15 feet Road Surface Type - Flexible |
| 4.10 | Fault | Fault Road Surface Type - Flexible |
| 4.63 | Fault | Twin Tunnel System Road Surface Type - Flexible |
| 5.05 | Fault | Twin Tunnel System Road Surface Type - Flexible |
| 5.39 | Fault | Twin Tunnel System Road Surface Type - Flexible |
| 5.50 | Fault | Fault Road Surface Type - Flexible |
| 6.28 | Fault | Belton Fault Road Surface Type - Flexible |
| 7.13 | Other | Belton Shaft (2,000 feet East of Road) Road Surface Type - Flexible |
| 7.40 | Power Line | Electrical Power Line 27 Lines Height 40 feet Steel Support Structure Unknown Volts Road Surface Type - Flexible |
| 8.00 | Other | Junction KY 246 Heading West Road Surface Type - Flexible |
| 8.06 | Trees | Number of Trees 75 Height 25 feet Diameter 18 in. Ending Milepoint 8.70 Distance From Road 20 feet Road Surface Type - Flexible |

Report by Road and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|---------|---|
| 9.05 | Trees | Number of Trees 100 Height 30 feet Diameter 12 in. Ending Milepoint 10.00 Distance From Road 15 feet Road Surface Type - Flexible |
| 9.80 | Other | Junction KY 70 Heading East Road Surface Type - Flexible |
| 10.03 | Fault | South Browder System Road Surface Type - Flexible |
| 10.36 | Fault | South Browder System Road Surface Type - Flexible |
| 10.55 | Other | Browder Shaft (750 feet East of Road) Road Surface Type - Flexible |
| 10.74 | Fault | North Browder System Road Surface Type - Flexible |
| 11.30 | Other | Water Tower Road Surface Type - Flexible |
| 11.50 | Other | Junction KY 176 Heading Northeast Road Surface Type - Flexible |
| 12.01 | Fault | Fault Road Surface Type - Flexible |
| 12.13 | Other | Inclined Shaft Road Surface Type - Flexible |
| 12.46 | Bridge | Number of Spans 7 Over Stream Concrete T-Beam End 1 Fixed Pier 1 Fixed Pier 2 Fixed Pier 3 Fixed Pier 4 Fixed Pier 5 Fixed Pier 6 Fixed End 2 Fixed Deck Type - Concrete Length 266 feet Width 29 feet Pier Type - Open SPC Rating - B Surface Type - Flexible Expansion Type - Other End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown |

Report by County and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|------------|---|
| 12.80 | Fill | Material Type - Soil Height 10 feet Side slope 2:1 Length 2,000 feet Crest 30 feet Type Fill - Other Road Surface Type - Flexible |
| 13.00 | Power Line | Electrical Power Line 3 Lines Height 20 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible |
| 13.20 | Cut Slope | Cut Slope Type - Rock Height 40 feet Length 200 feet Backslope 1:1 Road Surface Type - Flexible |
| 13.31 | Bridge | Number of Spans 1 Overpass Concrete I-Beam End 1 Fixed End 2 Fixed Deck Type - Concrete Length 98 feet Width 42 feet Pier Type - Unknown SPC Rating - A Surface Type - Flexible Expansion Type - Poured Compression End 1 Substructure - Stub End 2 Substructure - Stub Foundation Type - Unknown |
| 13.38 | Other | Water Impoundment Road Surface Type - Flexible |
| 13.60 | Cut Slope | Cut Slope Type - Rock Height 35 feet Length 500 feet Backslope 1:1 Road Surface Type - Flexible |
| 13.61 | Trees | Number of Trees 200 Height 30 feet Diameter 28 in. Ending Milepoint 13.80 Distance From Road 10 feet Road Surface Type - Flexible |
| 13.71 | Other | Strip Mine Runs to 13.19 milepoint Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|------------|--|
| 14.32 | Fault | Fault Road Surface Type - Flexible |
| 14.40 | Power Line | Electrical Power Line 3 Lines Height 25 feet Wood Support Structure Unknown Volts Road Surface Type - Flexible |
| 14.51 | Trees | Number of Trees 200 Height 30 feet Diameter 18 in. Ending Milepoint 14.70 Distance From Road 10 feet Road Surface Type - Flexible |
| 15.25 | Other | Clinton Shaft Road Surface Type - Flexible |
| 15.32 | Other | Pond (West of Road) Road Surface Type - Flexible |
| 15.40 | Other | Mine Road Surface Type - Flexible |
| 15.70 | Other | Railroad Crossing Road Surface Type - Flexible |
| 16.27 | Other | Holt Shaft Road Surface Type - Flexible |
| 16.40 | Cut Slope | Cut Slope Type - Rock Height 20 feet Length 150 feet Backslope 1:1 Road Surface Type - Rigid |
| 17.48 | Other | Junction Western KY Parkway Heading NE-SW Road Surface Type - Flexible |

Report by County and Milepoint
for Muhlenberg County - Kentucky
US 431

| Milepoint | Feature | Data |
|-----------|---------|---|
| 17.48 | Bridge | Number of Spans 4 Underpass Concrete T-Beam End 1 Rocker Pier 1 Rocker Pier 2 Rocker Pier 3 Rocker End 2 Rocker Deck Type - Concrete Length 255 feet Width 30 feet Pier Type - Solid SPC Rating - A Surface Type - Flexible Expansion Type - Other End 1 Substructure - Full End 2 Substructure - Full Foundation Type - Unknown |
| 17.50 | Other | Central City Road Surface Type - Flexible |
| 18.41 | Other | Central City Shaft Road Surface Type - Flexible |