Spire STL Pipeline Project

Resource Report 6
Geological Resources

FERC Docket No. CP17-__ -__

FERC Application
January 2017

Public

RESOURCE REPORT 6 - GEOLOGICAL RESOURCES	
SUMMARY OF FILING INFORMATION	
Information	**Found in**
1. Identify the location (by milepost) of mineral resources and any planned or active surface mines crossed by the proposed facilities - Title 18 Code of Federal Regulations (CFR) section (§) 380.12(h)(1 & 2).	Section 6.3 and Table 6.3-1.
2. Identify any geologic hazards to the proposed facilities - 18 CFR § 380.12 (h)(2).	Section 6.4 and Table 6.4-1.
3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities - 18 CFR § 380.12 (h)(3).	Section 6.2 and Table 6.2-1.
4. For liquefied natural gas (LNG) projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," National Bureau of Standards Information Report 84-2833 - 18 CFR § 380.12 (h)(5).	Not applicable.
5. For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries - 18 CFR § 380.12 (h)(6).	Not applicable.
INFORMATION RECOMMENDED OR OFTEN MISSING	
1. Identify any sensitive paleontological resource areas crossed by the proposed facilities. (Usually only if raised in scoping or if the project affects federal lands.)	Section 6.6.
2. Briefly summarize the physiography and bedrock geology of the project.	Section 6.1 and Table 6.1-1.
3. If proposed pipeline crosses active drilling areas, describe plan for coordinating with drillers to ensure early identification of other companies' planned new wells, gathering lines, and aboveground facilities.	Section 6.3 and Table 6.3-1.

RESOURCE REPORT 6 - GEOLOGICAL RESOURCES	
INFORMATION RECOMMENDED OR OFTEN MISSING	
Information	**Found in**
4. If the application is for underground storage facilities: Describe monitoring of potential effects of the operation of adjacent storage or production facilities on the proposed facility, and vice versa; Describe measures taken to locate and determine the condition of old wells within the field and buffer zone and how the applicant would reduce risk from failure of known and undiscovered wells; and Identify and discuss safety and environmental safeguards required by state and federal drilling regulations.	Not applicable.

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Acronyms and Abbreviations

CFR	Code of Federal Regulations
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information Systems
HDD	horizontal directional drill
ISGS	Illinois State Geological Survey
MDNR	Missouri Department of Natural Resources
MP	milepost
NMSZ	New Madrid Seismic Zone
PHMSA	Pipeline and Hazardous Materials Safety Administration
PGA	Peak ground acceleration
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEIA	United States Energy Information Administration
USGS	United States Geological Survey

Geologic Resources

This resource report identifies and describes the geological resources within the Spire STL Pipeline LLC ("Spire") Spire STL Pipeline Project ("Project"), the associated characteristics and limitations, and the proposed mitigation for impacts that may occur as a result of construction or operation of the Project.

6.1 Geologic Setting

Both the 24-inch pipeline and Line 880 are located within the Interior Plains Division, Central Lowland Province, and the Till Plains and the Dissected Till Plains Sections (United States Geological Survey ["USGS"] 2004).

The Central Lowland Province is the largest physiographic province extending from western New York to North Dakota and south to Texas. Characteristic features of the Central Lowlands are flat lands with geomorphic remnants of glaciation. The majority of this province is bounded by higher relief, with elevations in the region being 2,000 feet or less (United States Department of the Interior 2015).

Project facilities in Illinois, and those located east of Line 880 MP 1.0 in Missouri, are within the Till Plains Section. The Till Plains are characterized by level to gently rolling till-plain (glacial ground moraine), with broad bottomlands and associated terraces with meander scars along major river valleys. This section is overlain by a series of low, undulating ridges (glacial end moraines). Relief along the floodplain margins of major rivers and larger tributaries can be 150 feet and greater. Elevation ranges from 600 to 1,000 feet, and local relief is predominantly three to 100 feet, but can range up to 165 feet along bedrock bluffs near major streams. This section is almost entirely covered by Pleistocene till and stratified drift up to 400 feet thick. The tills are of Kansan, Illinoisan, and Wisconsinan age (oldest to youngest, exposed west to east). Up to 25 feet of loess covers till and bedrock on bluffs overlooking the Mississippi's floodplain; the loess thins to the east. Bedrock beneath the drift is composed of lower Mississippian limestones, shales, and sandstones, which is well exposed on the uplands between the lower Illinois River and the Mississippi's floodplain, and in the bluffs overlooking the rivers. Silurian and Devonian carbonates crop out along the floodplain margins farther north. Mississippian and Pennsylvanian limestones, siltstones, and sandstones are exposed in erosional windows through the till along the Wabash River and its major tributaries (United States Department of Agriculture ["USDA"]-Forest Service).

Project facilities located in the Dissected Till Plains section include the 24-inch pipeline from the Mississippi River to MP 1.0 on Line 880. The Dissected Till Plains are characterized by moderately dissected, glaciated, flat to rolling plains sloping gently toward the Missouri and Mississippi River valleys, with local relief at 20 to 65 feet. Elevation ranges from 500 to 1,500 feet. Quaternary loess (unconsolidated aeolian silt) which can be up to 25 feet thick covers most upland areas (Missouri Department of Natural Resources ["MDNR"] 2009). Pleistocene (pre-Illinoisan) till and stratified drift underlie the loess and cover most bedrock areas up to 300 feet deep. The Mississippi and Missouri floodplains have up to 150 feet of unconsolidated Tertiary and Quaternary alluvium (gravel, sand, silt, and clay) overlying bedrock. This section is mainly underlain by Pennsylvanian shale, limestone, and minor coal.

Bedrock is exposed locally along the deeper drainages and in windows eroded through the unconsolidated surficial material (USDA-Forest Service).

According to the United States Department of Agriculture, Natural Resource Conservation Service Web Soil Surveys for Greene, Jersey, and Scott Counties, Illinois, and St. Charles and St. Louis Counties, Missouri, the Project is not anticipated to cross areas of shallow bedrock where blasting may be required (i.e., areas where bedrock may be found less than five feet below the surface) (2015a and 2015b).

For topographic details including elevations relative to mean sea level along the route, see the USGS 7.5-minute series topographic quadrangle maps, located in Resource Report 1, Appendix 1-A.

6.2 Blasting

The 24-inch portion of the Project may require blasting in non-glaciated areas such as along river bluffs and bases of steep slopes in drainage ways. A Blasting Plan has been developed for the Project in order to minimize the potential for blasting-related adverse impacts, as well as address safety concerns; this plan is provided as Appendix 6-C. Though areas of shallow bedrock are not anticipated to be encountered, if required, blasting/removal of bedrock will be conducted to a depth sufficient to install the pipeline, typically six to eight feet below the ground surface. Blasting charges will be limited to the minimum number and force necessary to fracture or loosen rock to the desired depth. The explosive products selected will have the appropriate water resistance for the site conditions to minimize the potential for adverse effects of the products on groundwater.

Testing for water quantity and quality parameters will be conducted for water wells located within 200 feet of proposed blasting areas where Spire has been granted access permission by the landowners. Spire will conduct testing prior to and after construction, and a qualified independent laboratory will provide the results of the testing. Property damage resulting directly from blasting will be repaired or replaced. Spire is not aware of water main lines located within the vicinity of the potential blasting areas.

As further discussed in the Blasting Plan, in lieu of blasting in areas of shallow bedrock, rock encountered during trenching would be removed using one of the following techniques: conventional excavation with a backhoe, hammering with a pointed backhoe attachment or pneumatic rock hammer followed by backhoe excavation, or ripping with a bulldozer. Rock removal techniques would depend upon rock properties such as relative hardness, fracture susceptibility, expected volume, and location.

Table 6.2-1 provides the locations along the Project where blasting is anticipated.

Table 6.2-1. Locations of Proposed Blasting

County, State	Begin MP	End MP	Soil Type	Utilities within Blasting Radius (400 feet)[1]
24-inch Pipeline				
Jersey County, Illinois	44.94	44.95	Rock Outcrop, Limestone-Lacrescent Complex	• One Nustar ammonia pipeline is located approximately 65 feet west of the proposed pipeline; • One Ameren natural gas pipeline would cross the proposed pipeline perpendicularly; • Four fiber optic lines would cross the proposed pipeline perpendicularly; • One 72-inch steel drain pipe is located approximately 90 feet east of the proposed pipeline; • One concrete drain pipe and steel drain tile are located approximately 115 feet east of the proposed pipeline; and • One steel drain pipe and tile are located approximately 150 feet west of the proposed pipeline.
St. Louis County, Missouri	58.24	58.62	Pits, Quarry	• Utility overhead lines would run along the quarry road in close proximity to the proposed pipeline; and • There are four locations where the overhead lines would cross the proposed centerline.

Notes:

The delineation to identify locations where blasting is anticipated was performed using desktop analysis of the United States Department of Agriculture, Natural Resource Conservation Service Web Soil Surveys for Scott, Greene, and Jersey Counties, Illinois and St. Charles and St. Louis Counties, Missouri. Blasting was not assumed to be required in loam soils.

[1] A trench width of 10 feet is assumed.

6.3 Mineral Resources

6.3.1 Illinois

According to the United States Energy Information Administration ("USEIA"), Illinois' fossil fuel resources include substantial coal reserves and some crude oil (USEIA 2016a). Illinois' crude oil production and reserves are modest and are generally located in the southern half of the state (USEIA 2016a). Production peaked in the middle of the 20th century and most wells now operating in the state produce less than two barrels of crude oil per day. According to the Illinois Department of Natural Resources ["IDNR"], approximately 800 drilling permits for oil, gas, and injection wells are issued each year, with most of the production located in the southern portion of the state

(2016). The oil producing area of Illinois is part of a geologic structure known as the Illinois Basin, which covers southern Illinois, western Kentucky, and western Indiana (IDNR 2016). The Project is located on the fringe of the formation (Illinois State Geological Survey [“ISGS”] 2016e).

Illinois has few producing natural gas wells and minimal production, but is second only to Michigan in total natural gas storage capacity, with 28 natural gas fields located within the state (USEIA 2016a).

Five percent of United States coal is produced from Illinois’ 24 active bituminous coal mines (USEIA 2016a).

6.3.2 Missouri

According to the USEIA, Missouri has little fossil fuel production, but does have fossil fuel resources that have not been fully developed such as tar sands, coalbed methane, and oil shales (USEIA 2016b). Crude oil production in the state is less than 0.01 percent of the United States totals (USEIA 2016b). Presently there are three areas of current oil and gas production in Missouri - the Forest City Basin in northwestern Missouri, the Bourbon Arch in western Missouri, and the Lincoln Fold in northeastern Missouri; the Project is located within the Lincoln Fold (MDNR 2016a).

Missouri does not have natural gas reserves and only a small amount of natural gas production (USEIA 2016b). Approximately one-third of the state is underlain by coal seams that potentially could produce coalbed methane, with deposits located in the northwest, north-central, and west-central portions of the state. Missouri has one natural gas storage field located near St. Louis (USEIA 2016b). Little to no gas is produced for commercial sale in Missouri; however there are 45 registered wells for private use and two large wells produced gas for a private company (MDNR 2016a). According to the MDNR, no new wells are under construction within St. Charles and St. Louis Counties (2016b). The last recorded active wells in St. Charles and St. Louis Counties were drilled in 1975 and 2012, respectively (MDNR 2016b).

Missouri’s current coal production is modest and equals only approximately one percent of the coal consumed within the state (USEIA 2016b).

A review of the publicly available geographic information systems (“GIS”) data for Scott, Greene, and Jersey Counties in Illinois, and St. Charles and St. Louis Counties in Missouri, identified oil and gas wells within 0.25-mile of the Project facilities, as identified in Table 6.3-1. No oil and gas resources were identified within the proposed REX Receipt Station, the Laclede/Lange Delivery Station, or the MRT Bi-directional Station. One resource was identified in the vicinity of the Redman Delivery Station as shown on Table 6.3-1.

When present in a project area, mining activities could constitute a threat to the integrity of the proposed pipeline by way of surface subsidence and soil strains, as well as affect restoration efforts if mitigation measures are not implemented.

Locations of existing wells within the Project workspace will be field verified prior to construction. Spire will work with the well-operator and landowner to make minor deviations to the line to avoid impact on any oil and gas well within the Project workspace, therefore no negative affects to these wells are anticipated as a result of the Project. Because of the narrow construction footprint of the proposed Project, impacts to the recovery of aggregates are anticipated to be minimal. The proposed Project facilities are shallow, and the impacts on oil and gas resource recovery also are anticipated to be minimal.

Mineral resources that are crossed or are located within 0.25-mile of the proposed Project are also listed in Table 6.3-1, based on a review of the ISGS and MDNR GIS databases and maps (ISGS 2016a; ISGS 2016b; ISGS 2014a-c; and MDNR 2014a-d).

Table 6.3-1. Mineral Resources in the Vicinity of the Pipeline

Approximate MP	County, State	Mineral Resources	Status[1]	Distance (feet)/Direction from Construction Work Area
24-Inch Pipeline				
0.0	Scott, Illinois	Coal Slope	Abandoned	886/Northeast
0.0	Scott, Illinois	Coal Strip Mine	Abandoned	1,035/Northwest
0.0	Scott, Illinois	Clay Mine	Abandoned	0/East
11.6	Greene, Illinois	Oil/Gas Well	Unknown	366/West
11.7	Greene, Illinois	Oil/Gas Well	Unknown	177/East
11.7	Greene, Illinois	Oil/Gas Well	Unknown	1,026/West
11.8	Greene, Illinois	Oil/Gas Well	Unknown	177/East
12.2	Greene, Illinois	Oil/Gas Well	Unknown	406/Southwest
12.4	Greene, Illinois	Oil/Gas Well	Unknown	1,275/Southwest
13.6	Greene, Illinois	Oil/Gas Well	Unknown	980/West
36.5	Jersey, Illinois	Oil/Gas Well	Unknown	34/South
42.3	Jersey, Illinois	Oil/Gas Well	Unknown	941/West
42.3	Jersey, Illinois	Oil/Gas Well	Unknown	Within the workspace
44.2	Jersey, Illinois	Oil/Gas Well	Unknown	1,140/East
45.0	Jersey, Illinois	Oil/Gas Well	Unknown	13/East
53.3	St. Charles, Missouri	Oil/Gas Well	Abandoned	713/Southwest
54.3	St. Charles, Missouri	Oil/Gas Well	Plugged	1,010/Southwest
55.3	St. Charles, Missouri	Oil/Gas Well	Abandoned	418/Southwest
56.9	St. Charles, Missouri	Oil/Gas Well	Plugged	444/East
57.1	St. Charles, Missouri	Oil/Gas Well	Active	1,080/West
57.1	St. Charles, Missouri	Oil/Gas Well	Active	1,091/West
58.2	St. Louis, Missouri	Mine - Sand and Gravel Quarry	Producer	227/North
58.3	St. Louis, Missouri	Oil/Gas Well	Active	196/South
58.4	St. Louis, Missouri	Mine - Limestone Quarry	Open Pit	410/East
58.5	St. Louis, Missouri	Mine - Limestone Quarry	Producer	420/East
58.8	St. Louis, Missouri	Oil/Gas Well	Abandoned	636/West
58.8	St. Louis, Missouri	Oil/Gas Well	Active	534/Northwest

Table 6.3-1. Mineral Resources in the Vicinity of the Pipeline (Continued)

Approximate MP	County, State	Mineral Resources	Status[1]	Distance (feet)/Direction from Construction Work Area
Line 880				
0.4	St. Louis, Missouri	Mine - Limestone Quarry	Open Pit	430/East
1.0	St. Louis, Missouri	Mine - Limestone Quarry	Past Producer	1,218/East
1.6	St. Louis, Missouri	Oil/Gas Well	Active	867/Northeast
Redman Delivery Station				
5.3	St. Louis, Missouri	Oil/Gas Well	Plugged	82/West

Note:

Data is sourced from Illinois GIS sources included: Oil and Gas Fields (2016), Mines-Active (2016), Mines-All (2016), and Wells-Boring Location (2016). Missouri GIS sources included: Industrial Mineral Mines (2014), Inventory of Mine Occurrences and Prospects (2014), State Permitted Oil and Gas Wells (2014) and Wells (2015).

1 "Producer" refers to an active mine and "Past Producer" refers to a mine no longer in operation or abandoned (Mulvany 2016).

6.4 Geologic and Other Natural Hazards

Below is a discussion on geologic hazards that may exist or may potentially develop within the Project area. Geologic hazard areas that are crossed by or are located within 0.25-mile of the proposed Project are listed in Table 6.4-1.

Table 6.4-1. Geologic Hazard Areas

Nearest Milepost[1]	County	State	Hazard Type[2]	Distance/Direction from Construction Work Area (feet)[3]
24-inch pipeline				
13.5	Greene	Illinois	Karst	1,020/West
40.0	Jersey	Illinois	High Susceptibility for Landslides	0[5]
43.1	Jersey	Illinois	Karst	0[4]
58.4	St. Louis	Missouri	2 Sink Areas	1,078/West and 1,156/West
58.8	St. Louis	Missouri	5 Sink Areas	625/Northwest, 289/North, 296/North, 442/West, and 0[4]

Table 6.4-1. Geologic Hazard Areas (Continued)

Nearest Milepost[1]	County	State	Hazard Type[2]	Distance/Direction from Construction Work Area (feet)[3]
Line 880				
0.0	St. Louis	Missouri	Sink Area	1,102/Southwest
0.6	St. Louis	Missouri	Sink Area	0[4]
1.6	St. Louis	Missouri	3 Sink Areas	172/Northeast, 826/Northeast, and 229/Southeast
1.7	St. Louis	Missouri	2 Sink Areas	545/East and 0[4]
1.9	St. Louis	Missouri	Sink Area	86/East
4.3	St. Louis	Missouri	3 Sink Areas	888/Southwest, 1,204/Southwest, and 539/South
7.0	St. Louis	Missouri	St. Louis fault	172/East

Note:

Hazard areas are based on desktop review (i.e., these areas have not been field verified) of the following sources: USGS Earthquake Hazards Program, Missouri Spatial Data Information Service, and Illinois State Geological Survey Data Clearinghouse. Data available from these sources for Illinois included earthquakes, faults, and sinkhole areas (karst). Spatial data relative to flash flooding, volcanism, or landslides were not present or available in the data sources used. Data available from these sources for Missouri included earthquakes, sink areas, tectonic fault structures, and inventory of landslide incidences. Information relative to flash flooding and volcanism were not present or available in the data sources used.

1 Nearest Milepost indicates the closest milepost from where direction and distance to workspace was measured.

2 Sink areas located within the limits of another known sink area are not shown. The larger of the sink areas is presented in the table.

3 Hazard areas located within the Project workspaces will be field verified and appropriate measures will be taken if encountered in the field.

4 Work areas associated with the Project are not anticipated to occur at this location; therefore this hazard is not anticipated to be a concern to Project activities.

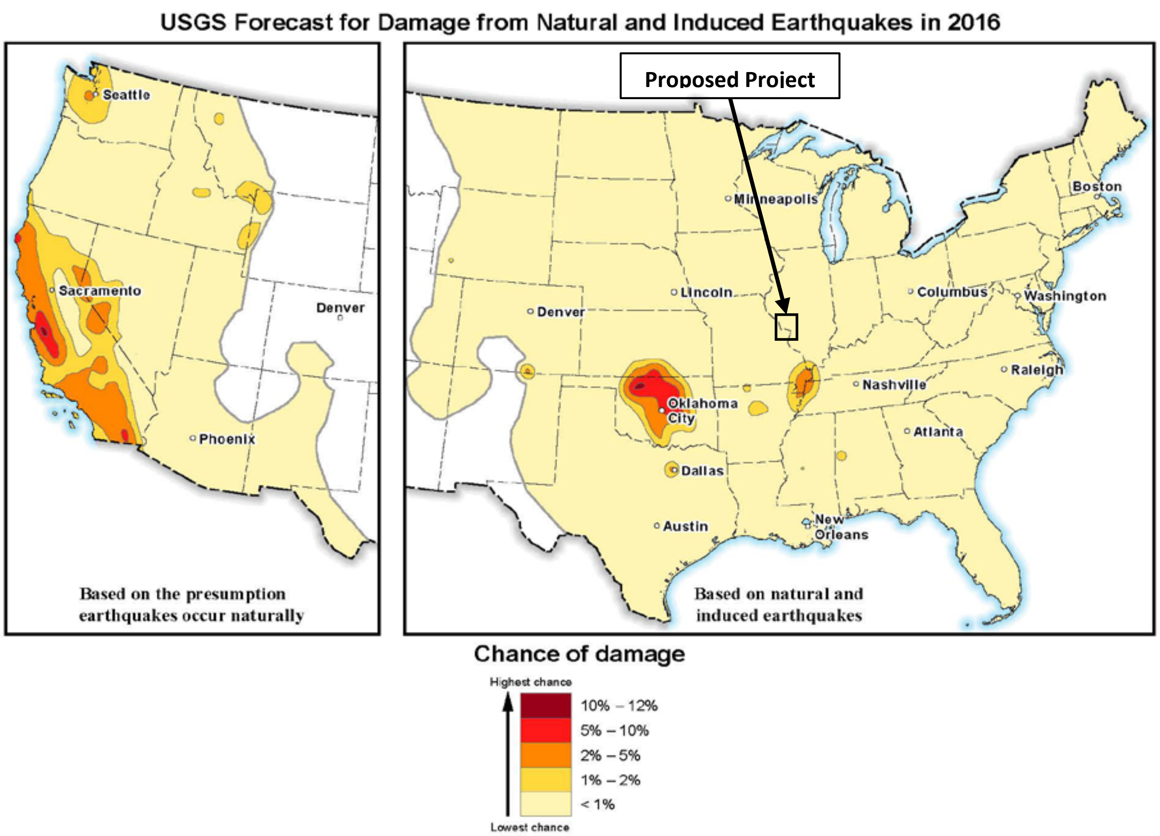
5 Landslide susceptibility is based on USGS mapping and mileposts are approximate (Godt 1997). The pipeline has been routed to avoid slopes where possible.

6.4.1 Earthquakes/Seismic Risk

Seismic hazards in the Project area are relatively low, with mapped peak ground acceleration levels corresponding to the two percent in 50-year probabilities of exceedance, ranging from eight to 20 percent of gravity in Illinois, and 20 to 30 percent of gravity in Missouri (USGS 2014). According to the USGS 2016 figure (Figure 6.4-1) depicting the forecast for damage from natural and induced earthquakes, the Project is within an area with less than one percent chance for damage from natural and induced earthquakes and therefore damages occurring to the pipeline are not anticipated to be a major concern (USGS 2016).

Additionally, the pipeline will be built to 49 CFR Part 192 standards (Pipeline and Hazardous Materials Safety Administration ["PHMSA”] 2016) which provide adequate protection for hazards that may cause the pipeline to move or sustain abnormal loads (US Government Publishing Office 2016).

Figure 6.4-1. USGS Forecast for Damage from Natural and Induced Earthquakes in 2016

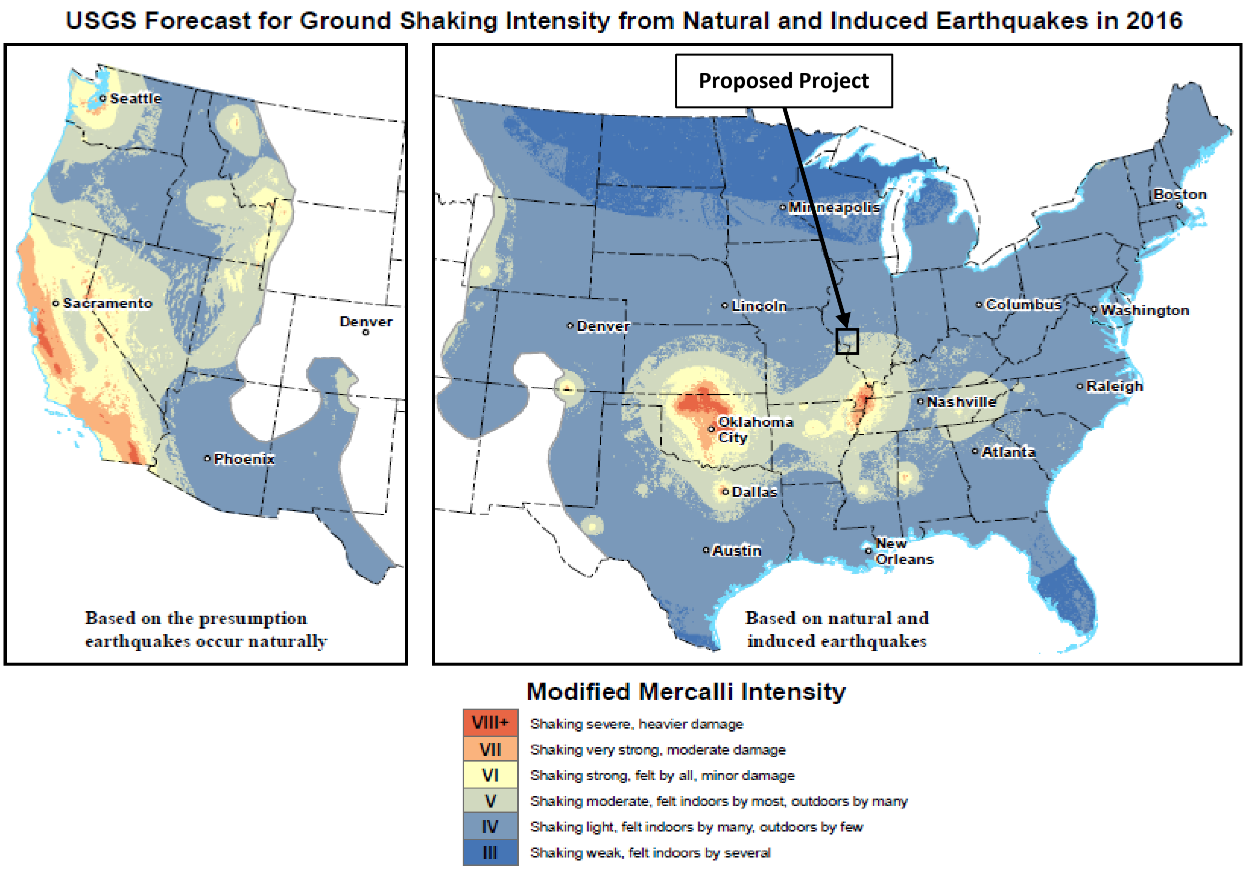


USGS map displaying potential to experience damage from natural or human-induced earthquakes in 2016. Chances range from less than 1 percent to 12 percent.

The Project is located approximately 100 miles northwest of, and was routed to avoid, an area of seismic activity referred to as the New Madrid Seismic Zone (“NMSZ”) (United States Department of the Interior 2009). According to the USGS, the NMSZ is the most active seismic area in the United States east of the Rocky Mountains. Due to the geologic conditions in the NMSZ, earthquakes in that region have the potential to damage an area approximately 20 times larger than earthquakes in California and most other active seismic areas. According to the USGS 2016 figure (Figure 6.4-2) depicting ground shaking intensity from earthquakes, the Project ranges from IV to V in Modified Mercalli Intensity. Areas of the Project may experience light ground shaking intensity described as “shaking light, felt indoors by many, outdoors by few” to moderate intensity, described as “shaking moderate, felt indoors by most, outdoors by many”. Because the potential for damage in the area of the Project is considered none to very light, damage to the Project from potential earthquakes is not anticipated to occur. Earthquakes that could occur would happen within sufficient distance away from the Project to pose significant issues or cause interruption with the service of the proposed pipelines. According to the ISGS, recent earthquakes in Illinois occurred in January 2012 and February 2010 however, these earthquakes occurred in the northeastern part of the state, and are not located near the Project area.

According to the MDNR, small earthquakes and tremors occur frequently in the state, with thousands being noted since 1795. Most are typically too small to be felt and are more frequent in the NMSZ, but also occur on other faults located in Missouri and the surrounding states. Based on the history of past earthquakes, USGS seismologists in 2009 suggested that the chance of having a magnitude 7.0-8.0 earthquake in the NMSZ within the next 50 years is about 7 to 10 percent; smaller earthquakes have a greater change of occurring (MDNR 2015).

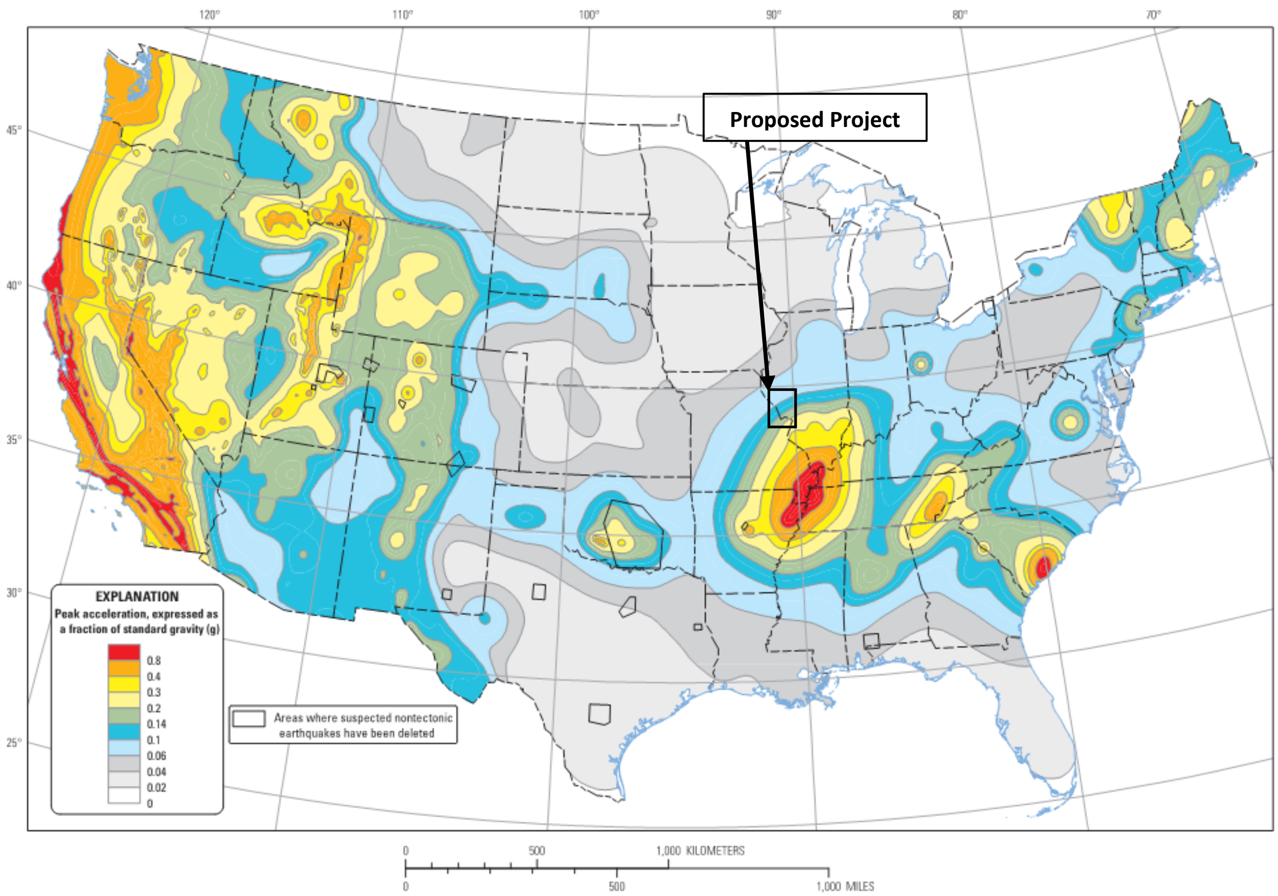
Figure 6.4-2. USGS Forecast for Ground Shaking Intensity from Natural and Induced Earthquakes in 2016



USGS map displaying intensity of potential ground shaking from natural and human-induced earthquakes. There is a small chance (one percent) that ground shaking intensity will occur at this level or higher. There is a greater chance (99 percent) that ground shaking will be lower than what is displayed in these maps.

Spire has also reviewed available published National Seismic Hazard Maps Design prepared by USGS to calculate the peak ground acceleration ("PGA") of various return periods including two and 10 percent probabilities for exceedance in 50 years. PGA is equivalent to the maximum ground acceleration that occurs during earthquake shaking at a location (i.e., how hard the earth shakes at a given geographic point). As shown on Figure 6.4-3, the Project is within an area of PGA of 0.1 to 0.3 percent of standard gravity for two percent probability for exceedance in 50 years and, as shown on Figure 6.4-4, a PGA of 0.03 to 0.1 percent of standard gravity for ten percent probability for exceedance in 50 years.

Figure 6.4-3. USGS 2% Probability of Exceedance in 50 Years Map of Peak Ground Acceleration in 2014

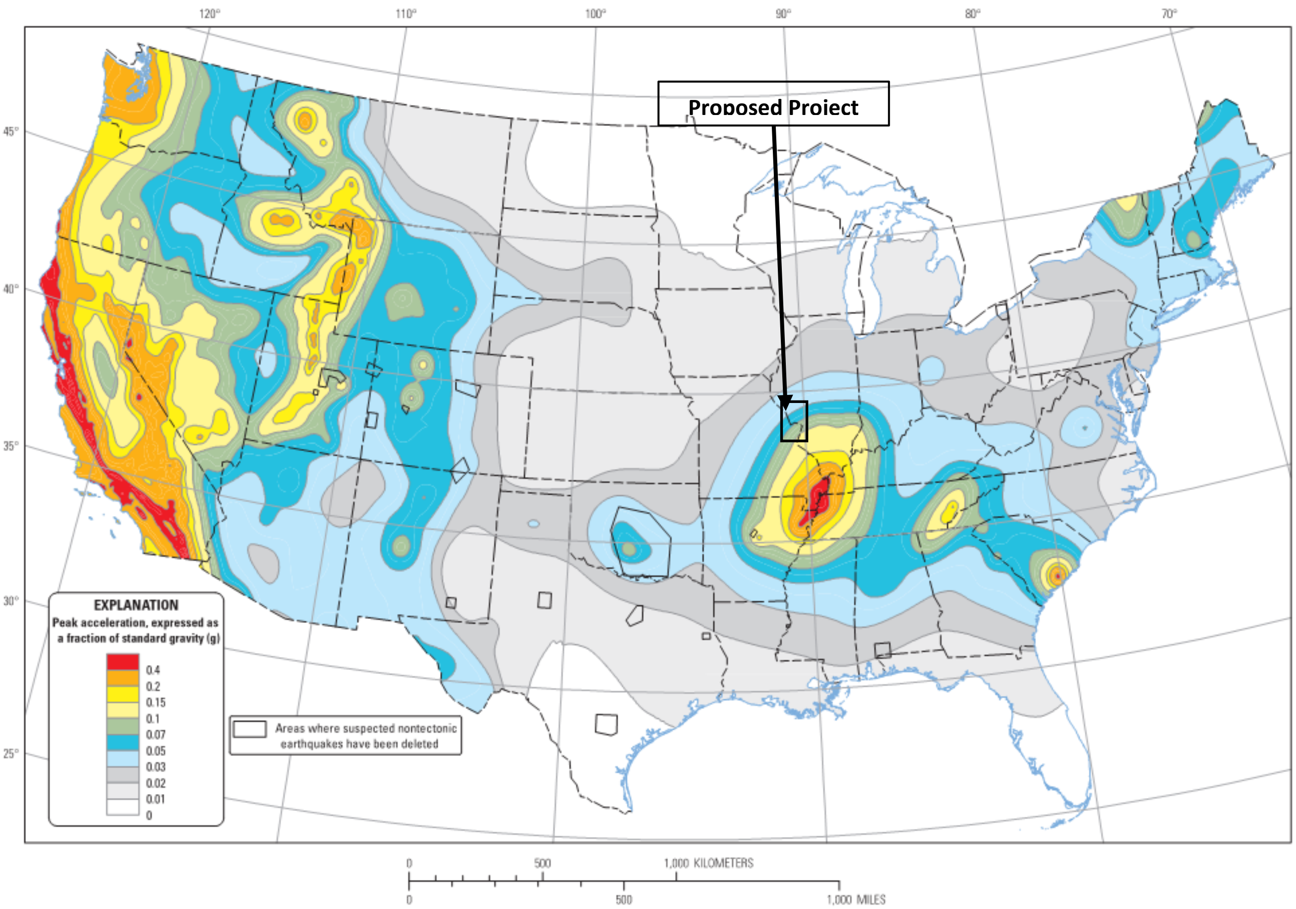


Two-percent probability of exceedance in 50 years map of peak ground acceleration

6.4.1.1 Active Faults

There are no active faults in the Project area in Illinois (ISGS 1995). The northern portion of the St. Louis fault is located east of MRT Bi-directional Station in St. Louis County, Missouri (Missouri Spatial Data Information Service 2010). Most of the fault structure is beneath the Mississippi River, therefore little information is available. Displacement is greatest in the southern portion of the fault and dissipates northward. Activity on the fault has been inconclusive; two small earthquakes since 1974 (magnitudes 3.1 and 2.4) may be attributable to the St. Louis fault zone (Harrison 1994). Due to the USGS probabilities described in Section 6.4.1, the potential for damage in the area of the Project is considered none to very light, and damage to the Project from potential earthquakes is not anticipated to occur.

Figure 6.4-4. USGS 10% Probability of Exceedance in 50 Years Map of Peak Ground Acceleration in 2014



Ten-percent probability of exceedance in 50 years map of peak ground acceleration

6.4.1.2 Soil Liquefaction

Soil liquefaction is the process by which stress exerted on soil during an earthquake can cause the soil to flow in liquid form. The probability of strong tremors from earthquakes ranges from light to moderate within portions of the Project area, according to the 2016 USGS Figure 6.4-2 depicting the forecast for ground shaking intensity from earthquakes. As previously mentioned, the Project is located outside of the NMSZ. During the winter of 1811-1812 the NMSZ experienced four earthquakes of about magnitude 8 which caused the area to experience significant disturbances that included soil liquefaction, landslides, and large fissures (Street 1990). However, the Project is located outside of the area of where significant disturbance was recorded as a result of these earthquakes and therefore this is not anticipated to be a concern to the proposed Project. Additionally, as discussed above, Spire has reviewed USGS national seismic hazard maps and determined that the Project is within an area of PGA of 0.1

to 0.3 percent of standard gravity for two percent probability for exceedance in 50 years and a PGA of 0.03 to 0.1 percent of standard gravity for ten percent probability for exceedance in 50 years. The southern portion of the Project is within an area evaluated by the USGS, and the study indicates that the geologic deposits in the area are relatively resistant to soil liquefaction (Pearce, Baldwin and Hoeft 2008). The ten percent probability of exceedance of PGA was determined to be insufficient to cause soil liquefaction. The two percent probability of exceedance of PGA was determined to be sufficient to trigger liquefaction, to about 10% liquefaction threshold exceedance. However, this is not unexpected for the conservative probability level, and the risk decreases moving northwest on the Project.

6.4.2 Underground Mining/Subsidence

According to the Coal Mines in Illinois Viewer (“ILMINES”), no abandoned underground coal or industrial mines are located beneath the proposed 24-inch pipeline, Line 880 or the proposed facilities along these areas (ISGS 2015; ISGS 2016d).

One staging area and a portion of the REX Receipt Station are within a 1,000-foot mine subsidence buffer zone as designated by ISGS (2009). This area consists of an existing access road and cultivated fields. Heavy agricultural equipment would have been previously used, with no signs of subsidence at present. Therefore, impacts from mining or subsidence on the Project are not anticipated.

6.4.3 Landslides

Landslides, slumps, and rockfalls can occur in areas where there are bluffs and steep slopes of unconsolidated materials or thick soils, and are often triggered when surficial materials are moved or modified (MDNR 2015). The vast majority of the 24-inch pipeline, including the proposed facilities, is proposed in locations with low landslide incidence. Before crossing the Mississippi River, the 24-inch pipeline traverses a short (less than one mile) area with high susceptibility and low incidence, as well as an area of around five miles with high landslide incidence. The Project area in Missouri crosses areas with moderate susceptibility and low incidence of landslides (Godt 1997).

In areas with higher landslide incidence, Spire has routed the pipeline to avoid slopes where possible. Where steep slopes with a risk of landslide are encountered, Spire will follow the procedures for slope construction described in Resource Report 1, Section 1.3.1.2 Special Construction Procedures. Additionally, none of the proposed M&R facilities along the 24-inch pipeline were located in areas of steep slopes.

Existing facilities on Line 880 were designed and installed in accordance with 49 CFR Part 192 (PHMSA 2016), and are located in an area that is relatively flat and residential. Areas of steep slope are not anticipated to be encountered.

6.4.4 Karst

Karst is a landform that develops on or in limestone, dolomite, or gypsum by dissolution, and is characterized by the presence of features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints), and caves. Karst terrains develop due to the dissolution of carbonate bedrock. Karst features and resulting karst hazards are most common in areas where carbonate rocks either outcrop at the surface, or where they are shallow and buried with unconsolidated materials generally less than 50 feet thick. Hazards common to karst regions include sinkholes, springs, erratic surface water drainage and groundwater flow, and rapid movement of materials into and through the subsurface. Sinkholes and springs can also back up and cause local flooding during high-volume rain or snowmelt events.

Table 6.4-1 indicates mapped karst features within 1,500 feet of the Project and aboveground facilities. Table 6.4-2 further describes the karst features crossed by the Project as well as planned mitigation measures. The Karst and Sinkhole Topography Map in Appendix 6-A illustrates mapped karst terrain data identified within the Project area (ISGS 2004).

Most of the hazards identified are small karst features (sinkholes) that, if encountered during construction, can either be avoided by small adjustments to the Project right-of-way or can be mitigated as described in the Karst Mitigation Plan.

Spire has proposed locations of workspaces associated with the HDD crossing of the Mississippi River and conducted geotechnical boring at these locations to determine the geology and feasibility of the drills. Geotechnical reports will be filed with the FERC. The plan and profile of the proposed river crossing is depicted in Resource Report 2, Appendix 2-D, Site Specific Waterbody Drawings. Geotechnical boring tests determined that no voids were present where geotechnical investigations took place in support of the HDD design.

Table 6.4-2. Karst Features Crossed by the Project

Karst Feature	Nearest Milepost[1]	County, State	Identified Through Field or Desktop Review	Planned Mitigation Measures
24-inch pipeline				
Karst	43.1	Jersey, Illinois	Desktop	If encountered, Spire would coordinate with a geologic expert to evaluate the feasibility of completing construction in this area.
1 Sink Area	58.8	St. Louis, Missouri	Desktop	Area is within a portion of an active mining operation; the sink area is a planned, man-made depression.
Line 880				
Sink Area	0.6	St. Louis, Missouri	Desktop	These areas are within existing facilities. Excavations are limited and no history of sink areas have been encountered.
1 Sink Area	1.7	St. Louis, Missouri	Desktop	

Public and private wells are discussed in detail in Resource Report 2, Section 2.1.2. Seven private wells are located within 150 feet of the proposed Project through Greene and Jersey Counties, Illinois. No private wells were located within 150 feet of the proposed Project in Scott County, Illinois, or in St. Charles and St. Louis Counties, Missouri.

No springs are present at the Project area. Construction, operation, and maintenance of the proposed facilities are not expected to have long-term impacts on groundwater resources. If karst areas are encountered, stormwater will be diverted upland from the excavated karst areas utilizing approved erosion and control methods. If surface waters are present near the karst excavation, then water will be flumed to minimize the potential for storm water entering the void. Sand bags or similar materials would be utilized to withhold water from entering the excavation, and water levels will be monitored to determine whether it is entering the excavation.

Spire has prepared a Karst Mitigation Plan included in Appendix 6-A, describing the general measures to be implemented during construction to ensure that correct measures for construction in karst formations are taken. As described in the Karst Mitigation Plan, pre-construction review of the available datasets regarding karst information provides a possibility that a geophysical formation may be present in Illinois. The dataset for Missouri indicated the possibility of sink areas, but no indication of karst features. If an unanticipated karst feature is discovered during construction activities, work in the immediate area would stop and the appropriate contractor supervisors would be alerted. If karst mitigation is required, Spire will notify and coordinate with applicable agencies to ensure any necessary and appropriate agency review or approvals are acquired. A copy of this Karst Mitigation Plan will be retained on-site, and it will be made available to the federal, state, and local agencies upon request.

6.4.5 Flooding and Scour

Streams in the Project area may be affected by flash floods due to narrow river valleys, steep slopes, and rock-bottomed streams. Flash floods have the potential to cause damage to proposed facilities.

Within Illinois, portions of the 24-inch pipeline will be located within the 100-year FEMA floodplains of Apple Creek and Macoupin Creek in Greene County, Illinois, and Otter Creek and the Mississippi River in Jersey County, Illinois. Impacts are unavoidable due to the long linear nature of the floodplain and the route of the Project. Construction of the pipeline throughout these areas will not result in any permanent fill in the floodplains.

Within Missouri, a portion of the 24-inch pipeline will be located within the 100-year FEMA floodplain and FEMA regulatory floodway of the Mississippi River, Missouri River, and tributaries to the Missouri River. This includes the crossing of the Mississippi River and the crossing of the Missouri River, as well as the proposed 24-inch pipeline alignment approximately between MP 45.0 through MP 58.1. No permanent fill is associated with construction of the pipeline, and Spire will install the 24-inch pipeline with a minimum seven feet of cover within the floodplains of the Mississippi and Missouri Rivers. A portion of the replacement pipeline on Line 800 will be located within the 100-year FEMA floodplain and FEMA regulatory floodway of Coldwater Creek. No permanent fill associated with construction of Line 880 is proposed in the floodplains.

For the pipelines, the trench will be excavated at least 12 inches wider than the diameter of the pipe, though the width may increase depending on the stability of the native soils. Spire is proposing to provide a minimum depth of cover of approximately five feet over the pipeline across waterbodies, with two feet of cover in areas of consolidated rock. The proposed cover will generally provide adequate scour protection from high flows and flooding. Prior to construction, field observations will be conducted to determine stability of the banks and appropriate bank stabilization techniques. In order to handle increased flows, additional pumps will be on standby for dam-and-pump crossings, and appropriately sized flumes will be available to handle the storm flows as needed. After construction is completed, each crossing will be inspected periodically for signs of erosion and remediated as necessary.

The MRT Bi-directional Station will be located within a 100-year FEMA floodplain. Spire is currently developing the detail design for the MRT Bi-directional Station. A combination of several options are being considered to prevent potential flood water come into contact with sensitive equipment or hazardous materials, which may include designing platforms or raising the earth elevation to be higher than the flood elevation; designing the structures that surround sensitive equipment to be water proof as not allow flood waters to enter; and/or installing physical barriers around the site to block the flood waters is being considered but will likely not be implemented in final design due to their restrictiveness of allowing access to the site. If necessary, Spire will perform a hydrologic and hydraulic analysis as part of local permit submittals.

Additionally, MLV 3 will be located within a 100-year FEMA floodplain, which is not expected to change the based flood elevation. Spire proposes to design aboveground facilities and pipelines as such to prevent and minimize impacts from potential high velocity flows. The REX Receipt Station, the Redman Delivery Station, and the Laclede/Lange Delivery Station are not located within a 100-year FEMA floodplain.

Additional information regarding floodplains, including anticipated permitting applications, is provided in Resource Report 2, Section 2.2.3 Floodplains.

6.5 Liquefied Natural Gas Facilities in Seismic Risk Areas

No Liquefied Natural Gas facilities are proposed as part of this Project, and therefore, this section is not required.

6.6 Paleontology

Federal lands are crossed by the Project in Missouri. The United States Army Corps of Engineers (“USACE") property is held in fee title by the USACE St. Louis District and is located on the south side of the Mississippi River. Spire is proposing to install the pipe via horizontal directional drill (“HDD”) at this property as part of its crossing of the Mississippi River. Construction workspaces will be placed outside of the property, therefore no earth disturbance of the USACE property is anticipated.

Illinois regulates paleontological resources on state and publically owned land, according to the Illinois Archaeological and Paleontological Resources Protection Act (20 ILCS 3435/.02) (from Chapter 127, paragraph 133c.02) (Illinois General Assembly). Properties crossed by the Project that qualify for these conditions are state owned road rights-of-way; however as these rights-of-way are previously disturbed, no impacts to these state regulated resources are anticipated.

In Illinois, the Project crosses areas where Mississippian age rocks, which can contain fossils of common prehistoric aquatic organisms such as bryozoans, trilobite, and brachiopods, may be located at outcrops or beneath drift (ISGS

2016f). Areas with underlying Pennsylvanian age rocks, which may commonly contain fossils of gastropods, trilobites, and corals, may also be crossed by the Project. The paleontological sites included by ISGS are not crossed by the Project, and other known paleontological sites publically available online are not located in the Project area (ISGS 2016f; Paleontology Portal 2016). However, there is record of a wholly mammoth fossil discovery on the campus of Principia College, which is located over one mile east of the Project (Principia News 2013).

Missouri's Code of State Regulations does not specify regulations for paleontological resources on state or local land. The MDNR indicates that fossils such as brachiopods, bryozoans, trilobite parts, etc. in shaly limestones of the Middle Ordovician Plattin and Decorah Formations, and bryozoans, brachiopods, etc. in shaly limestone of the Meramecian Warsaw Formation may be present near the portion of the Project located in St. Louis County (MDNR 2008).

Should a potential paleontological find be discovered during construction, Spire would follow applicable regulations and coordinate with the appropriate agency(ies) pursuant to their applicable jurisdiction.

6.7 Geotechnical Investigations

Spire has conducted geotechnical investigations at the Mississippi and Missouri River crossings to determine the feasibility of conducting a HDD of these rivers. These geotechnical investigations included land and water bores. Spire will file this report with the FERC in January 2017. Based on these primary evaluations, the proposed Mississippi River and Missouri River are determined to be feasible with a high probability of successful completion.

While not anticipated, if an attempted HDD installation is unsuccessful, the proposed HDD alignment could be modified beneath the river using the same general location to accommodate an additional HDD attempt, depending on the condition/cause contributing to the original HDD failure. Prior to attempting a second HDD crossing, a risk mitigation workshop should be held with all parties to determine the cause of the initial failure and any mitigation measures that could be adopted to reduce the risk(s) during the second HDD attempt.

Additionally, four soil borings were performed in St. Charles County, Missouri at equal spacing between the proposed Mississippi and Missouri River crossings in support of the buoyancy evaluation for the pipeline. These borings will be included in the HDD geotechnical report with the crossings investigations, to be filed with the FERC in January 2017.

An additional investigation for the facility sites will be initiated in January 2017 and will include 15 borings. Results of these investigations will be provided to the FERC in February 2017.

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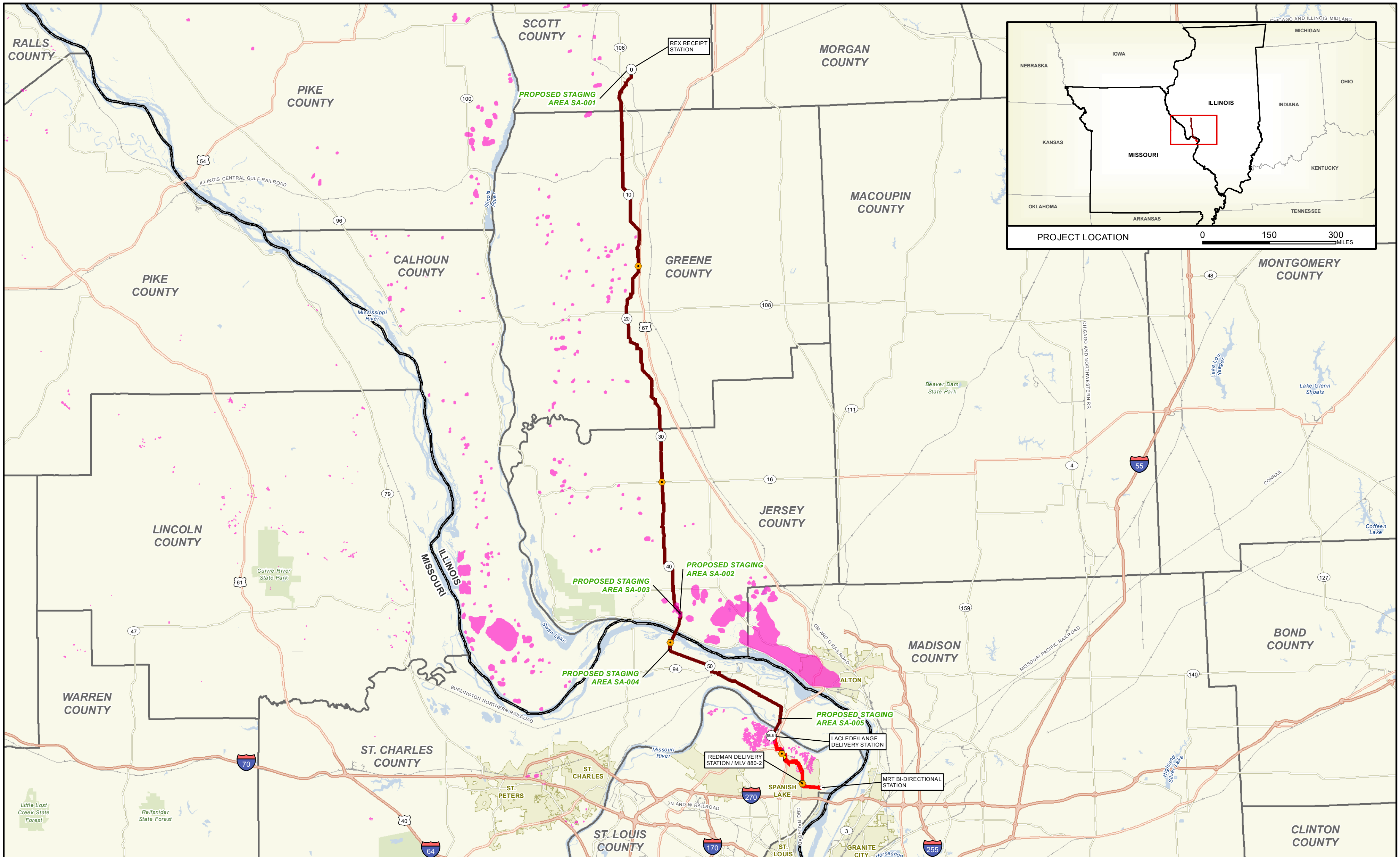
APPENDIX 6-A

Karst and Sinkhole Topography Map and Karst Mitigation Plan



- MILE POST
- PROPOSED M&R SITE
- PROPOSED MAINLINE VALVE SITE
- PROPOSED 24-INCH DIAMETER PIPELINE
- LINE 880 20-INCH DIAMETER RELOCATION
- EXISTING LINE 880 20-INCH DIAMETER PIPELINE
- INTERSTATE
- HIGHWAY
- MAJOR ROAD
- RAILROAD
- PROPOSED CONTRACTOR YARD/STAGING AREA
- KARST & SINKHOLE AREA
- PARK BOUNDARY
- WATERBODY
- COUNTY BOUNDARY
- STATE BOUNDARY

KARST DATA OBTAINED FROM THE ILLINOIS STATE GEOLOGICAL SURVEY.

SPIRE STL PIPELINE

KARST & SINKHOLE TOPOGRAPHY

SCOTT, GREENE, & JERSEY COUNTIES, ILLINOIS AND
ST. CHARLES & ST. LOUIS COUNTIES, MISSOURI

MILES 10 5 0 10

N W E S

ABSOLUTE SCALE: 1:633,806

REFERENCE SCALE: 1 IN = 10 MILES

Spire STL Pipeline

MOTT MACDONALD

DRAWN BY:	JTP 12/07/2016
CHECKED BY:	NDK 12/19/2016
APPROVED BY:	JW 12/19/2016
REV. DATE:	01/2017
REVISION:	1
DESC:	ISSUE FOR FERC
PAGE:	1 OF 1

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Spire STL Pipeline Project

Karst Mitigation Plan

FERC Docket No. CP17-__-__

January 2017

Public

Table of Contents

Acronyms and Abbreviations

CFR	Code of Federal Regulations
NRCS	Natural Resources Conservation Service
Plan	FERC’s Upland Erosion Control, Revegetation, and Maintenance Plan
Procedures	FERC’s Wetland and Waterbody Construction and Mitigation Procedures
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC
USDA	United States Department of Agriculture

spire

Karst Mitigation Plan

1.1 Introduction

This Karst Mitigation Plan describes the general measures to be implemented by Spire STL Pipeline LLC ("Spire") and its contractors to ensure that correct measures for construction in karst formations are taken during construction of the Spire STL Pipeline Project ("Project"). Measures identified within this Karst Mitigation Plan outline methods that will be used in all work areas including temporary workspaces and access roads. Additionally, this plan outlines the recommended records to be maintained onsite during construction.

1.2 Pre-Construction Review

For the 24-inch pipeline construction, geotechnical hazard information was gathered utilizing Illinois Geospatial Data Clearinghouse. This information is from multiple sources and is compiled within their dataset. This dataset is considered general in nature, but provides the possibility that a geophysical formation may be present. A similar review was conducted utilizing the Missouri Spatial Data Information Service. While the dataset indicates the possibility of sink areas, there was no indication of karst features. Additionally, Laclede Gas Company, a related company of Spire Inc., has a long history of working along Line 880 and has not encountered issues related to sink holes or karst features.

For the trenchless crossings of the Missouri and Mississippi Rivers, a geotechnical investigation was conducted. No indicators of a hazardous geological formation were identified within the planned path of the horizontal directional drill installations.

1.3 Training and Awareness

Spire will conduct awareness training for karst-like features, including portals, voids, or sinkholes. Prior to construction, the contractor's field supervisory personnel and the Spire's supervisory personnel including the Chief Inspector, Craft Inspectors and the Environmental Inspectors will be trained on unanticipated karst features that could be discovered during trenching operations. The training will also provide the protocol for work stoppage if a karst feature is discovered in the immediate area and a communication plan to alert the appropriate Spire and contractor supervisors of such discovery. This training will comply with 49 Code of Federal Regulations ("CFR") Part 192.613 which requires the surveillance during construction.

1.4 Inspection, Monitoring and Surveillance

As required by 49 CFR Part 192.613, Spire will conduct route surveillance during construction and operation of the facilities, along with training of surveillance personnel, to monitor the pipeline right-of-way for evidence of subsidence, surface cracks, or depressions which could indicate sinkhole formation. Should any of these conditions be identified, Spire will implement corrective actions.

1.5 Construction Phase and Karst Remediation

If an unanticipated karst feature is discovered during trenching or other construction activities, work in the immediate area will be stopped immediately and the communication plan will be implemented to alert appropriate Spire and contractor supervisors. Erosion and sedimentation controls will be modified at the direction of an Environmental Inspector to install the measures necessary to minimize the potential for surface water runoff intrusion into the karst feature. A designated Project geotechnical engineer will be contacted and directed to the feature to conduct a detailed evaluation. The Project geotechnical engineer will develop specific design and mitigation measures depending on the site conditions and nature of the karst feature.

The mitigation methods detailed by the Project geotechnical engineer would provide enhanced stability to the void and increase the long term stability and integrity to the pipeline right-of-way. The principal approach to avoid aggravating dormant sinks or possible areas of subsidence and karst activity is to maintain rates of recharge and discharge in the subsurface at the desired natural levels. In this context, desired natural levels refer to the pre-development recharge and discharge rates. Final grading of contours and any necessary permanent erosion and sediment controls will be designed to prevent runoff from accumulating in the area of the void. In addition, during the discharge of any hydrostatic test water from the pipeline, a discharge location will be selected that will prevent the discharged water from encountering any unanticipated karst features discovered during trenching activities. These methods will help control the flow of water into underlying karst areas, which meets the intent of maintaining rates of subsurface recharge and discharge to pre-development conditions. Stormwater control measures in areas of known and verified karst terrain will be enhanced to include detention, diversion, or containerization to prevent construction influenced stormwater from flowing to the karst feature drainage point.

In the event that an unanticipated karst feature or void is discovered during construction or post-construction monitoring and karst mitigation is required, the Class 1 pipe specified for the 24-inch pipeline is capable of spanning a 28 foot void, should one unexpectedly occur, and continue to operate safely. During construction of the project, should an unanticipated cavern feature or sinkhole be encountered of size less than the maximum unsupported span length, a mitigation strategy as identified in Sections 1.5.1 or 1.5.2 below may be implemented by the Project geotechnical engineer. Should the karst feature approach or exceed the size of the maximum unsupported length, an investigation and mitigation strategy as identified in Section 1.5.3 may be implemented. It should be noted that the mitigation strategies identified below are provided as options, and each mitigation measure to be employed will be specifically selected by the Project geotechnical engineer at the time of intersection.

1) Mitigation Measures for Sinkhole Throats

   If new sinkhole throats develop within the construction area while work is commencing, work in the area will be halted and the sinkhole area will be isolated and cordoned off to an area extending 100 feet radially from the feature. The sinkhole will be inspected by a geotechnical engineer and remedial measures such as filling of the sinkhole using inverted filter approach or adjustment of the pipeline alignment may be implemented. The inverted filter approach is often used for sinkhole repair, especially when the sinkhole is not located near structures. The sinkhole area is excavated to expose either bedrock or the throat of the sinkhole. A course of rock large enough to bridge the throat of the sinkhole is placed at the bottom of the excavation. Courses of progressively finer rock and gravel are compacted above the base course. A geotextile fabric may be placed above the finest gravel course to prevent excessive loss of the uppermost course, which may consist of sand and/or soil. The inverted filter method provides filtration treatment of storm water and allows controlled storm water infiltration and groundwater recharge.

2) Mitigation Measures for Subsurface Voids and Caverns

If an existing subsurface void is intersected within the work area, work will similarly be halted and cordoned off for further evaluation by a qualified geotechnical engineer. As indicated earlier, the principal approach to maintain rates of recharge and discharge at pre-development conditions, a filter fabric secured over the void may be implemented in addition to an inverted filter.

Methods to mitigate sinkhole collapses and similar subsurface voids have been recommended by the United States Department of Agriculture ("USDA") Natural Resources Conservation Service ("NRCS"). These typical details are provided as Attachment A through C and may also be implemented depending on the karst feature encountered. The mitigation methods would provide enhanced stability to the void and increase the long term stability and integrity to the pipeline right of way. Final grading of contours and any necessary permanent erosion and sediment controls will be designed to prevent runoff from accumulating in the area of the void. In addition, during the discharge of any hydrostatic test water from the pipeline, a discharge location will be selected that will prevent the discharged water from encountering any unanticipated features discovered during trenching activities.

3) Mitigation Strategies for Karst Features Greater than Maximum Unsupported Span Length

If a karst feature greater than 50 feet long in largest measured dimension is intercepted during work activities including drilling, blasting, excavation, or trenching, all work within a 300 foot radius will immediately be stopped and Spire and Contractor Supervisors will be notified. The Project geotechnical engineer will be subsequently contacted and directed to the feature to conduct a detailed evaluation to review suspected features for evidence of areas of soft soils, highly fractured bedrock, ground subsidence, surface water flow toward the feature, and diminishing flow in nearby surface streams or waterbodies. At this time, Project geotechnical engineer may increase or decrease the work stoppage buffer based on the observation of site conditions and in consultation with state or regulatory agencies, as necessary.

Should any of the abovementioned indicators be identified and, the Project geotechnical engineer will commence a characterization program to determine the full extents of the feature along and within proximity to the pipeline alignment. The characterization method may consist of, but not be limited to, one or more of the following strategies:

a. Visual Assessment (field inspection) or Aerial Assessment (drone or aerial);
b. LiDAR or field topographic survey;
c. Installation of geotechnical instrumentation or survey monuments to determine movement;

d. Geophysical Investigation (microgravity, multi-channel analysis of surface waves, or electrical resistivity);
e. Track drill probing and/or geotechnical drilling;
f. Test pit excavation; and/or
g. Infiltration or dye trace testing.

Once sufficient detail is achieved to delineate the extents of the feature, it is anticipated that several options may be considered as a mitigative strategy including subsurface grouting within the right-of-way, structurally supporting (cradling) the pipeline on a deep foundation system, or relocating the pipeline to a less sinkhole-prone portion of an adjacent property. As each karst feature is unique, the mitigative strategy selected will be on a case-by-case basis by the Project geotechnical engineer and in consultant with project stakeholders.

Under any situation, in the event that an unanticipated karst feature or void is discovered during construction or post construction monitoring and karst mitigation is required, Spire will notify and coordinate with applicable agencies to ensure any necessary and appropriate agency review or approvals are acquired.

1.6 Post-Construction Monitoring

Spire will conduct visual, post-construction inspections of the right-of-way to evaluate the success of any mitigation activities performed for any karst features or voids discovered and mitigated during construction. The frequency of inspections will generally comply with those required under the FERC's Upland Erosion Control, Revegetation, and Maintenance Plan ("Plan") and Wetland and Waterbody Construction and Mitigation Procedures ("Procedures"), but would more specifically be based on the severity of the mitigation activities and the Project geotechnical engineer recommendations with a decreasing frequency over the two year monitoring period. As required by the Plan and Procedures, monitoring will be conducted for up to two years after construction completion. If a new karst feature or void were to develop within the right-of-way as a result of Spire's subsequent construction activities, Spire would contact the Project geotechnical engineer to evaluate the feature and make additional remedial recommendations. Spire will provide updates on the status of all discovered and mitigated karst features or voids in its bi-weekly and quarterly activity reports. During operation of facilities, staff performing routine inspections of facility and related assets will be made aware in areas of carbonate formations that the potential for sinks and karst features exists, and that surface expressions of sinks, disappearing streams or runoff, and change in topography should be noted and brought to the attention of the Project geotechnical engineer for further review and consideration. Should the potential for karst be documented, a mitigation measure as identified in Section 1.5 may be implemented.

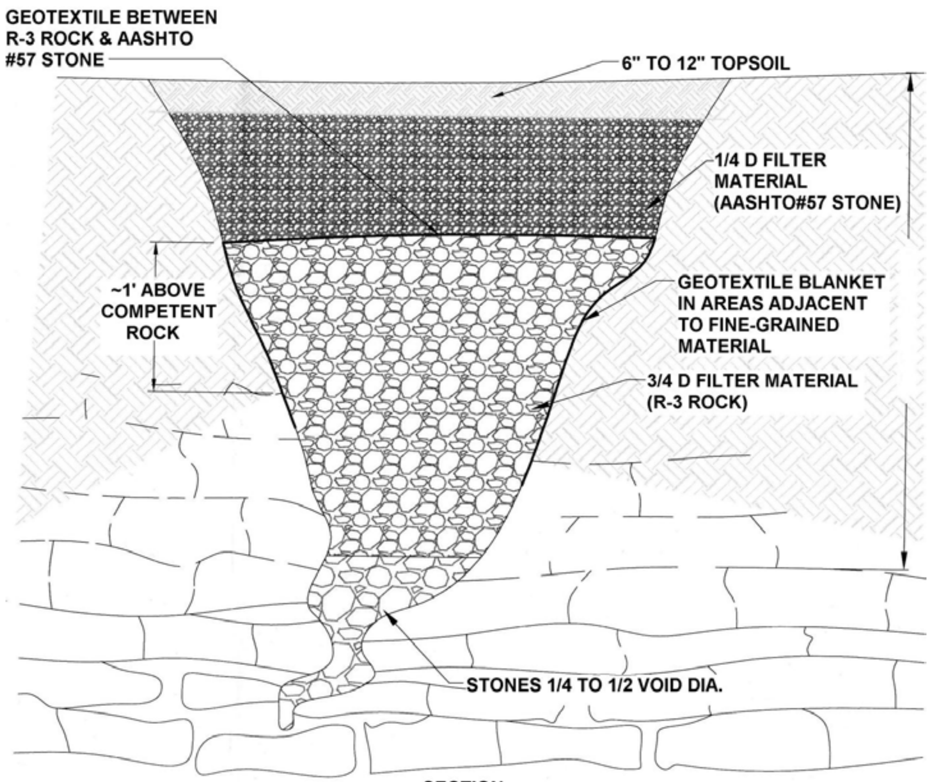
1.7 Plan Maintenance

A copy of this Karst Mitigation Plan will be retained onsite, and will be made available to the federal, state, and local agencies upon request.

ATTACHMENT A

USDA NRCS Sinkhole Repair with Pervious Cover Detail

USDA NRCS Sinkhole Repair with Pervious Cover Detail



Source: Adapted from USDA NRCS

Notes

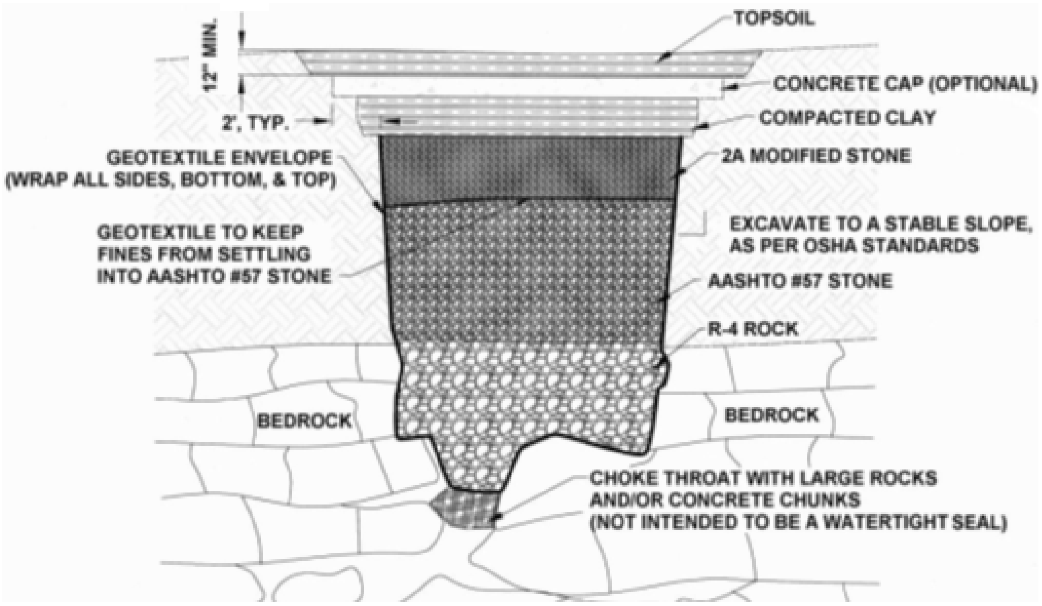
1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

ATTACHMENT B

USDA NRCS Sinkhole Repair with Impervious Cover Detail

USDA NRCS Sinkhole Repair with Impervious Cover Detail



Source: Adapted from USDA NRCS

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Geotextile shall be non-woven with a burst strength between 100 and 200 psi.

3. Select field stone(s) about 1.5 times larger than solution void(s) to form “bridge.” Place rock(s) so no large openings exist along the sides. Stones used for the “bridge” and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

4. Minimum thickness of R-4 rock is 18.” AASHTO #57 stone thickness shall be ¼ to ½ that of the R-4 rock. Minimum thickness of 2A modified crushed stone shall be 9” AASHTO #57 stone and 2A modified crushed stone shall be compacted after each placement.

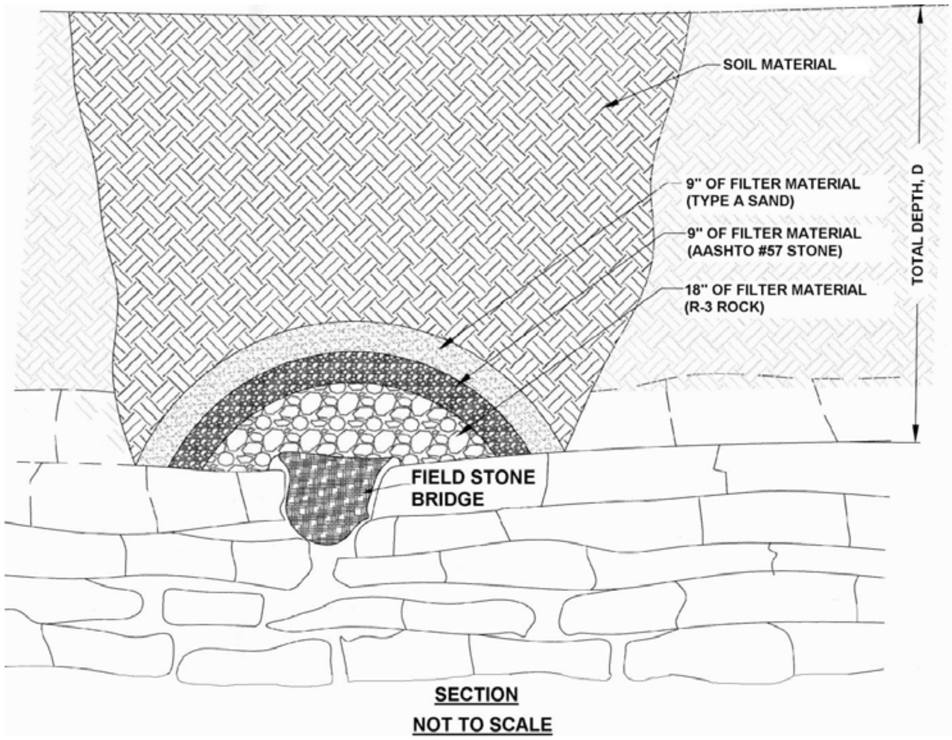
5. Compacted clay seal shall be a minimum of 12” thick. Clay shall be placed in 6” to 9” lifts and thoroughly compacted. Concrete cap, which is optional, shall be a minimum of 8” thick. Use 4,000 psi concrete with 6” X 6” - 6 gauge welded wire fabric, or # 3 rebar on 18” O.C. both ways.

Topsoil shall be a minimum of 12” thick. Grade for drainage away from sinkhole area.

ATTACHMENT C

USDA NRCS Sinkhole Repair with Soil Cover Detail

USDA NRCS Sinkhole Repair with Soil Cover Detail



Source: Adapted from USDA NRCS

Notes:

1. Loose material shall be excavated from the sinkhole and expose solution void(s) if possible. Enlarge sinkhole if necessary to allow for installation of filter materials. OSHA regulations must be followed at all times during excavation.

2. Select field stone(s) about 1.5 times larger than solution void(s) to form "bridge." Place rock(s) so no large openings exist along the sides. Stones used for the "bridge" and filters shall have a moderately hard rock strength and be resistant to abrasion and degradation. Shale and similar soft and/or non-durable rock are not acceptable.

3. Minimum thickness of R-3 rock is 18" AASHTO #57 stone thickness shall be a minimum of 9" thick. Minimum thickness of type A sand shall be 9". NOTE: A non-woven geotextile with a burst strength between 100 and 200 psi may be substituted for the AASHTO#57 stone and type A sand.

4. Soil shall be mineral soil with at least 12% fines and overfilled by 5% to allow for settlement. Suitable soil from the excavation may be used. Any available topsoil shall be placed on top surface.

spire

APPENDIX 6-B

Geotechnical Investigation Report

(to be provided January 2017)

APPENDIX 6-C

Blasting Plan

Spire STL Pipeline Project

Blasting Plan

FERC Docket No. CP17-__-__

January 2017

Public

Table of Contents

Attachments

A	Spire Blasting Specifications
B	Explosives Safety Program

Acronyms and Abbreviations

CFR	Code of Federal Regulations
CSR	Code of State Regulations
Engineer	Company Engineer
FERC	Federal Energy Regulatory Commission
lb	pound
mm/s	millimeters per second
NRCS	Natural Resources Conservation Service
OSHA	Occupational Safety and Health Administration
PPV	peak particle velocity
Project	Spire STL Pipeline Project
Spire	Spire STL Pipeline LLC

Blasting Plan

Spire STL Pipeline LLC ("Spire") is seeking authorization from the Federal Energy Regulatory Commission ("FERC") pursuant to Section 7(c) of the Natural Gas Act to construct and operate the proposed Spire STL Pipeline Project ("Project") located in Scott, Greene, and Jersey Counties, Illinois, and St. Charles and St. Louis Counties, Missouri.

1.1 Introduction

This Blasting Plan has been prepared to outline the procedures and safety measures to which the Contractor will adhere where blasting is required for installation of the pipeline. It should be noted that the contractor will be required to submit a detailed blasting plan to Spire prior to construction that is consistent with the provisions in this Blasting Plan and Spire Blasting Specifications, provided as Attachment A.

1.1.1 Objective

This Blasting Plan is intended to identify blasting operations, including safety, use, storage, and transportation of explosives, that are consistent with minimum safety requirements, as defined by applicable federal [e.g., Title 27 Code of Federal Regulations ("CFR") 181 - Commerce in Explosives; Title 49 CFR 177 - Carriage by Public Highway; Title 29 CFR 1926.900 et seq. Subpart U - Safety and Health Regulations for Construction - Blasting and Use of Explosives; Title 29 CFR 1910.109 - Explosives and Blasting Agents; 29 CFR 1926.900 - General Provisions and Standards Nos. 901, 902, and 904-912], state, and local regulations consistent with the conditions of the FERC Certificate.

Prior to commencing any blasting activities, Spire's Contractor will also contact and coordinate with the Missouri Division of Fire Safety, Illinois Department of Natural Resources, and county and local municipalities and stakeholders such as code enforcement officials and fire protection officials, as necessary, prior to the start of work. Work shall be conducted in accordance with State of Missouri 11 Code of State Regulations ("CSR") 40-7: Rules of Department of Public Safety Division 40 - Division of Fire Safety - Chapter 7 - Blasting; as well as the State of Illinois Explosives Act contained within 225 Illinois Compiled Statutes 210.

1.1.2 Potential Blasting Locations

The Natural Resources Conservation Service ("NRCS") defines shallow depth to bedrock as being within five feet of the ground surface (NRCS 2015). Rock encountered during trenching will be removed using one of the following techniques, typically in the order listed below:

- conventional excavation with a backhoe;
- hammering with a pointed backhoe attachment or a pneumatic rock hammer, followed by backhoe excavation;
- ripping with a bulldozer; and
- blasting followed by backhoe excavation.

The rock removal technique will depend on rock properties, such as relative hardness, fracture susceptibility, expected volume, and location. Areas of shallow depth to bedrock crossed by the Project were determined by review and analysis of published soil survey data from the NRCS Soil Data Mart program which includes the NRCS *Soil Survey Geographic (SSURGO) Database* and *Web Soil Survey* (NRCS 2015). At locations where conventional methods of rock removal are not considered feasible, Spire anticipates rock removal will be required as defined in the following plan.

1.2 Types of Blasting

The primary type of blasting will be for ditch excavation. Blasting may also be required during the right-of-way grading operation. Blasting for grade or trench excavation will be utilized only after all other reasonable means of excavation have been used and are unsuccessful in achieving the required results. Spire may specify locations (e.g., foreign utility line crossings, roadways and near-by structures) where consolidated rock must be removed by approved mechanical equipment, such as rock-trenching machines, rock saws, hydraulic rams, or jack hammers instead of blasting.

If any streams and wetland areas require blasting to perform the ditch excavation, the streams and wetland areas will be tested for rock and shot by the mainline trenching crew except when not specifically possible due to timing completion requirements. A final determination on the need for in-stream blasting will be made at the time of construction. In the event in-stream blasting is required, Spire will apply for and receive a permit for use of explosives for each perennial waterway that is proposed to be impacted by the Project. Stream beds impacted by the use of explosives will be restored to their original contour by backfill of the top one-foot of trench with clean gravel or native cobbles.

1.3 Pre-Blast Inspection

If the contractor has to blast near buildings or wells, as required by FERC, Spire's Blasting Contractor will retain an independent firm to conduct pre-blast surveys, with owner permission, to assess the conditions of structures (interior and exterior), wells, springs, and utilities within 150 feet of the proposed construction right-of-way. Should local or state ordinances require inspections in excess of 150 feet from the work area, the local or state ordinances will prevail.

As per State of Missouri 11 CSR 40-7(8)(A)(3), "Any person using explosives, which will conduct blasting within the jurisdiction of a municipality, shall notify the owner or occupant of any residence or business located within a scaled distance of fifty-five from the site of blasting prior to the start of blasting at any new location." Also, as per State of Missouri 11 CSR 40-7(8)(A)(7), the blasting contractor shall, "Make at least three documented attempts to contact the owner of any uncontrolled structures within a scaled distance of thirty-five from the blast site in order to conduct a pre-blast survey of such structures. A pre-blast survey is not required if the owner of any such structure does not give permission for a survey to be conducted."

For structures, this survey will include:

- discussions with adjacent owners and receptors to familiarize them with the activities to be conducted and planned precautions to be taken including pre-blast and post-blast condition surveys and vibration monitoring;
- determination of the existence and location of structures, utilities, septic systems, and wells at the nearby property location;
- detailed examination, photographs, and/or video records of adjacent structures and utilities; and
- detailed mapping and measurement of large cracks, crack patterns, and other evidence of structural distress.

For wells and springs utilized for extraction of water, this survey will include:

- discussion with adjacent owner to identify the type of well, water bearing zone, and end-use of water from the well or spring system; and
- determination of pre-blasting flow rate and sampling for pre-blasting total dissolved solids.

For buried utilities, this survey will include:

- discussion with utility owner/operators to identify the type of utility, number and size of utility structures, material type and construction date, depth to utility, and protective coatings, if applicable; and
- if required, exposure of section of utility within closest radial distance to proposed blasting activities to conduct pre-blasting visual condition assessment.

The results will be summarized in a condition report that will include:

- description of construction and condition of existing structure, well, or utility;
- photo documentation; and
- any structure-specific precautions such as vibration limit or air blast limit thresholds to be implemented for nearby blasting activities to be completed.

Post-blast inspections by a Spire representative will also be performed as warranted and discussed in Section 1.16.

1.4 Monitoring of Blasting Activities and Blasting Procedure

The potential for blasting along the pipeline segments to affect any structure, utility, well, septic system, spring, or other sensitive feature will be minimized by controlled blasting techniques and by using mechanical methods for rock excavation as much as possible.

Controlled blasting techniques have been effectively employed by Spire and other companies to protect active gas pipelines up to within 12 feet of trench excavation. The following sections present details of procedures for blasting that will be implemented in areas requiring blasting:

1.4.1 General Provisions

During blasting, Spire's blasting Contractor will take precautions to minimize damage to adjacent areas and structures. The Contractor will provide all personnel, labor, and equipment to perform necessary blasting operations related to the work. The Contractor will provide a permitted/licensed blaster who possesses all permits and licenses required by the states in which blasting is required during construction, and having a working knowledge of all federal, state, and local laws and regulations that pertain to the storage, use and transportation of explosives. Any failure to comply with the appropriate law and/or regulations is the sole liability of the contractor. The contractor and the contractor's permitted/licensed blaster shall be responsible for the conduct of all blasting operations, which shall be subject to inspection requirements.

1.4.2 Storage of Explosives and Related Materials

Explosives and related materials shall be stored in approved facilities required under the provisions contained in 27 CFR Part 555 and all other applicable federal, state, and local regulations pertaining to blasting and the transportation, storage and use of explosives. The handling of explosives may be performed by the person holding a permit to use explosives or by other employees under his or her direct supervision provided that such employees are at least 21 years of age.

1.4.3 Pre-Blast Operations

The contractor is required to submit a planned schedule of blasting operations to the Company Engineer ("Engineer") or his designated representative for approval, prior to commencement of any blasting or pre-blast operation, which indicates the maximum charge weight per delay, hole size, spacing, depth, and blast layout. As per notification requirements of the State of Missouri codified in 11 CSR 40-7(8)(A), "Any person using explosives that will conduct blasting within the jurisdiction of a municipality shall notify the appropriate representative of the municipality in writing or by telephone at least two business days in advance of blasting at that location." As per 11 CSR 40-7(8)(A)(1) and (2), "Any appropriate representative shall be deemed to be the city's public works department, code enforcement official, or an official at the main office maintained by the municipality" and "In any area where blasting will be conducted, whether in a municipality or in an unincorporated area, the person using explosives also shall notify the appropriate fire protection official for the jurisdiction where blasting will occur, which may be a city fire department, fire protection district, or volunteer fire protection association."

The blasting schedule is to include the blast geometry, hole spacing, burden, drill hole dimensions, type and size of charges, explosive product data, stemming materials, and delay timing patterns and should also include a location survey of any dwelling or structures that may be affected by the proposed operation. Face material shall be carefully examined before drilling to determine the possible presence of unfired explosive material. Drilling shall not be started until all remaining butts of old holes are examined for unexploded charges, and if any are found, they shall be re-fired before work proceeds. No person shall be allowed to deepen the drill holes that have contained explosives.

For blasting in vicinity of utility lines, the blasting Contractor shall make every reasonable effort to verify the exact location of utility lines located in the vicinity of such operations. When the blasting Contractor has no verification of the location of utility lines in the vicinity of such operations, but it is reasonable to assume that there are utility lines, the Contractor conducting the blasting operations shall make a concentrated effort to locate the lines with regard to their horizontal distance from the nearest blast hole and their depth below the earth's surface.

Whenever blasting is being conducted within 50 feet of electric, water, sewer, fire alarm, telephone, telegraph, or steam utilities, the blasting Contractor shall notify the appropriate representatives of such utilities at least 72 and 24 hours in advance of such blasting. Verbal notice shall be confirmed with written notice.

Whenever blasting is being conducted within 200 feet of any pipe distributing liquefied petroleum, manufactured, mixed or natural gas, the blasting Contractor shall notify the gas utility company having control of such gas at least three full working days (excluding Sundays or holidays) prior to blasting. Such notice shall be in writing and served personally or by registered mail.

If blasting is to be conducted adjacent to an existing Spire/Laclede pipeline, approval must be received from Spire. The contractor shall provide this schedule to the Engineer at least three working days prior to any pre-blast operation for approval and use. Where residences are within 50 feet of the blasting operation, the Engineer may require notification of 10 business days.

Whenever blasting is being conducted within 200 feet of a railroad, the blasting Contractor shall notify the appropriate representative of the railroad 24 hours in advance of such blasting. Verbal notice shall be confirmed with written notice.

A maximum loading powder factor shall not exceed the site-specific allowable pounds ("lbs") of explosive per cubic yard of rock to be excavated. However, should the loading fail to effectively fragment the rock, a higher powder factor may be allowed if the charge weight per delay is reduced by a proportional amount and approved by the Engineer.

1.4.4 Discharging Explosives

The following list of steps will be performed by the Contractor for all blasting. These steps represent a minimum requirement and give a general order to the blasting procedure:

a. Completion of all necessary pre-blast surveys will be confirmed prior to blasting activity to document existing conditions before blasting and any other physical factors that blasting could affect.

b. The contractor shall obtain Spire's approval and provide Spire at least 72-hour notice prior to the use of any explosives. The contractor shall comply with local and state requirements for pre-blast notifications, such as "One Call", which requires a 72-hour notice.

c. Whenever blasting is being conducted in the vicinity of gas, electric, water, fire alarm, telephone, telegraph, and steam utilities, the blaster shall notify the appropriate representatives of such utilities a minimum of 72 hours in advance of blasting. Verbal notice shall be followed-up with written notice. In an emergency, the local authority issuing the original permit may waive this time limit.

d. A safety meeting will be held prior to any blasting activities. All Project personnel involved with the blasting in any way must attend. Safety rules and signalling will be reviewed.

e. Warning signs will be erected.

f. Lightning detectors will be set up.

g. Drilled holes will be measured accurately for depth and location.

h. Seismic equipment will be set-up to measure velocities at any structures 150 feet or less from the blast.

i. Distances to any nearby structure (aboveground or below ground) suspected of being less than 300 feet from the blast will be measured.

j. The blasting affected zone will be cleared.

k. The warning signal will be given.

l. The blast signal will be given.

m. The blast will be detonated.

n. After the blaster has checked for misfires and gives the "ALL CLEAR" signal, inspectors will inspect any aboveground or below ground facilities for damage.

During the blasting operations, excessive vibration will be controlled by limiting the size of charges and by using charge delays which stagger or sequence the detonation times for each charge.

All blasting will be performed by registered licensed blasters and monitored by experienced blasting inspectors. Recording seismographs will be installed by the contractor at selected monitoring stations under the observation of Spire personnel. During construction, the contractor will submit blast reports for each blast and keep detailed records as described in Section 1.4.7.

Ground vibration and air overpressure effects of each blast will be monitored by seismographs. If a charge greater than eight lbs per delay is used, the distance of monitoring will be in accordance with the U.S. Bureau of Mines Report of Investigations 8507.

To maximize its responsiveness to the concerns of affected landowners, Spire will evaluate all complaints of well or structural damage associated with construction activities, including blasting. A toll-free landowner hotline will be established by Spire for landowners to use in reporting complaints or concerns. In the unlikely event that blasting activities temporarily impair well water, Spire will provide alternative sources of water or otherwise compensate the owner. If well or structural damage is substantiated, Spire will either compensate the owner for damages or arrange for a new well to be drilled.

Blasting operations, except by special permission of the authority having jurisdiction, shall be conducted during daylight hours.

When blasting is done, the blast shall be covered with blasting mats, constructed so that it is capable of preventing rock fragments (or flyrock) from being thrown. In addition, all other possible precautions shall be taken to prevent damage to livestock and other property and inconvenience to the property owner or tenant during blasting operations. In the event any rock is scattered outside the right-of-way by blasting operations, pending landowner permission, it shall immediately be retrieved or returned to the right-of-way.

Precautions shall be taken to prevent accidental discharge of electric blasting caps from currents induced by radar and radio transmitters, lightning, adjacent power lines, dust and snow storms, or other sources of extraneous electricity. Per 29 CFR 1926.900(k), these precautions shall include:

- Detonators shall be short-circuited in holes which have been primed and shunted until wired into the blasting circuit;
- Suspension of all blasting operations and removal of all personnel from the blasting area during the approach and progress of an electrical storm. Work will continue only after the nearest lightning activity is at least five miles beyond the blasting area. A approved lightning detector that is capable of measuring the degree of electrical activity associated with an approaching storm, and the distance to the storm front from the instrument located on the Construction right-of-way will be on-site;
- The posting of all signs warning against the use of mobile radio transmitters on all roads within 350 feet (107 m) of blasting operations;
- Ensuring that mobile radio transmitters which are less than 100 feet away from electric blasting caps, in other than original containers, shall be de-energized and effectively locked; and

- Observance of the latest recommendations with regard to blasting in the vicinity of radio transmitters or power lines, as set forth in the Institute of Makers of Explosives Safety Library Publication No. 20, *Safety Guide for the Prevention of Radio Frequency Radiation Hazards in the Use of Electric Blasting Caps*.

No blast shall be fired until the blaster-in-charge has made certain that all surplus explosive materials are in a safe place, all persons and equipment are at a safe distance or under sufficient cover, and that an adequate warning signal has been given.

Only the person making leading wire connections in electrical firing shall fire the shot. All connections should be made from the bore hole back to the source of firing current, and the leading wires shall remain shorted until the charge is to be fired. After firing an electric blast from a blasting machine, the leading wires shall be immediately disconnected from the machine and short-circuited. If there are any misfires while using cap and fuse, all persons shall remain away from the charge for at least one hour. If electrical blasting caps are used and a misfire occurs, this waiting period may be reduced to 30 minutes.

Misfires shall be handled under the direction of the person in charge of the blasting and all wires shall be carefully traced in search for the unexploded charges.

Explosives shall not be extracted from a hole that has once been charged or has misfired unless it is impossible to detonate the unexploded charge by insertion of a fresh additional primer.

1.4.5 Waterbody Crossing Blasting Procedures

To facilitate planning for blasting activities for waterbody crossings, rock drills or test excavations may be used in waterbodies to test the ditch-line during mainline blasting operations to evaluate the presence of rock in the trench-line. For testing and any subsequent blasting operations, stream flow will be maintained through the site. During blasting operations, the contractor shall comply with the waterbody crossing procedures specified in Spire’s documents, as well as any Project-specific permit conditions.

1.4.6 Disposal of Explosive Materials

All explosive materials that are obviously deteriorated or damaged shall not be used and shall be destroyed according to applicable local, state, and federal requirements.

Empty containers and packages, and paper or fiberboard packing materials that have previously contained explosive materials shall not be reused for any purpose. Such packaging materials shall be destroyed by burning at an approved outdoor location or by other approved method. All personnel shall remain at a safe distance from the disposal area.

All other explosive materials will be transported from the job site in approved magazines in compliance with all local, state, and federal regulations.

1.4.7 Blasting Records

A record of each blast shall be made and submitted, along with seismograph reports, to the Engineer. In accordance with Federal, State, and local requirements, the record shall contain the following minimum data for each blast:

a. name and address of company or contractor;

b. name, signature, and license number of contractor and of blaster in charge;

c. location, date, and time of blast;

d. a plan indicating blast hole layout and a cross-section of a blast hole showing the maximum lbs per delay, burden, spacing, depth of hole, subdrilling, stemming depth, decking location, and locations of detonators and explosives;

e. the horizontal distance and direction to the nearest construction from the blast site, that is neither owned nor leased by the person conducting or contracting for the blasting operation closest to the nearest loaded blast hole to be detonated;

f. identification number for each blast;

g. type of material blasted;

h. number of holes, burden, spacing, and depth of stemming;

i. diameter and depth of holes;

j. volume of rock in shot;

k. types of explosives used, specific gravity, energy release, lbs of explosive per delay, number of explosive cartridges (sticks) used and total lbs of explosive per shot;

l. number, brand name, and type of electric blasting caps used and the number of individual delay periods;

m. actual firing time where electric delay blasting caps do not fall within the manufacturer's sequence of delay time;

n. size and total length of detonating cord, when used, delay periods, and type of precaution to deaden sound effects;

o. delay type, interval, total number of delays, and holes per delay;

p. maximum amount of explosives per delay period of 17 ms or greater;

q. powder factor;

r. method of firing and type of circuit;

s. weather conditions, including wind speed direction, temperature, and cloud cover conditions;

t. type and height or length of stemming;

u. if mats or other protection were used; and

v. type of detonators and delay periods used.

The person taking the seismograph reading shall accurately indicate exact location of the seismograph, if used, and shall also show the distance of the seismograph from the blast.

Seismograph records, where required, should include:

a. identification of the instrument used;

b. the name of the observer;

c. the name of the interpreter;

d. the distance in feet and direction of the nearest construction from the blast site that is neither owned nor leased by the person conducting or contracting for the blasting operation closest to the nearest loaded blast hole to be detonated;

e. the distance in feet and direction of the instrument locations from the blast site;

f. the type of surface at the instrument location;

g. the maximum peak particle velocity of any one of the three mutually perpendicular components of the ground motion in the vertical and horizontal directions at the specific location in inches per second and the frequency range of the blast; and

h. the sound measurement in decibels measured on the linear frequency response or the overpressure in lbs per square inch.

1.5 Method to be Used to Minimize Hole-to-Hole Propagation

Hole-to-hole propagation problems are not anticipated with the proposed products and pattern for the following reasons:

- Only cartridge explosives will be used.
- The amount of explosives per borehole will be limited by the proximity of existing structures and utilities.

1.6 Types of Explosives/Initiation System to be Used

a. Dyno Nobel Unimax®: An extra gelatine dynamite with a specific gravity of 1.51 and a detonation rate of 19,600 feet per second (unconfined). The cartridge size will generally be two inches by eight inches (1.25 lbs/cartridge) or two inches by 16 inches (2.50 lbs/cartridge). 1055 cal/gram.

b. Dyno Nobel Unigel®: A semi-gelatine dynamite with a specific gravity of 1.30 and a detonation rate of 14,200 feet per second (unconfined). The cartridge size will generally be two inches by eight inches (1.15 lbs/cartridge) or two inches by 16 inches (2.30 lbs/cartridge). 955 cal/gram.

c. Dyno Nobel Dynomax Pro™: A propagation resistant dynamite, with a specific gravity of 1.45 and a detonation rate of 19,700 feet per second (unconfined). The cartridge size will generally be two inches by eight inches (1.225 lbs/cartridge) or two inches by 16 inches (2.45 lbs/cartridge). 1055 cal/gram.

d. Dyno TX or Blastex TX as a packaged emulsion product to use as a non-primed stick. 2.2 lb sticks. 808 cal/gram.

e. Dyno Nobel NONEL® 17 or 25 Millisecond Delay Connectors or Dyno Nobel NONEL EZ Det® (nonelectric) 25/350 or 25/500 or 25/700 millisecond delay.

f. A Dyno Nobel NONEL nonelectric shock tube system detonator will initiate all shots. This NONEL will be attached at one point only for initiation of the entire shot and will not be used for down hole priming.

1.7 Drill and Blast Pattern

The anticipated drilling program will be based on one or two rows of 2½-inch diameter holes drilled in a line two to four feet or with a grid spacing of approximately three to four feet wide by four to six feet along the ditch line. This shot pattern may be adjusted on a site-specific basis to compensate for different geology, nearby structures, utilities, or other sensitive areas. The drill pattern will be established using a powder factor of about 2.0 to 3.5 lbs per cubic yard to achieve the desired explosive energy ratio needed to break the rock and pull the ditch. Higher powder factors may be needed in extra deep ditch which will be addressed with a site-specific plan.

1.8 Charge Weight and Delays

Delays will be used accordingly to control the vibration as well as limiting the transmission of energy below the damaging levels at any existing structure. The delay pattern will be created to provide the energy relief immediately down the ditch in preference to a horizontal direction.

The main type of delays will be NONEL® MS-25, 17 ms or 42 ms, which are color-coded for easy identification of delay length. The amount of dynamite used in each hole will be limited to the manufacturer's recommendations and specifications. We will also use down hole delays where they are needed to meet specifications on maximum lbs per delay allowed.

When using Digishot® fully programmable electronic detonators a signature hole analysis will be performed to determine optimum timing for the specific geology. The signature hole data will be interpreted by Dyno Nobel Engineers who will specify timing to the blasters for in field detonator programming. Ongoing signature hole analysis will be necessary to adapt to the changing geology. How often this is completed will depend on the site-specific conditions. Digishot® detonators are not affected by radio frequency, static electricity from power lines, etc. The detonators can only be detonated by a proprietary device made specifically for this product.

1.9 Flyrock Control Plan

All shots will be carefully designed by the Licensed Blaster to control flyrock. All hole loading activity will be supervised by the Licensed Blaster. The Licensed Blaster will communicate with the drillers to obtain geological information for each shot.

Matting and or padding may be utilized at the discretion of the licensed blaster. A good quality, non-stemming material that completely fills any voids in the drill hole will also be used to reduce the amount of flyrock. A minus three-eighths-inch crushed rock will be used. This stemming size has been a standard for United States Army Corps of Engineers for decades.

1.10 Selection of Blasting Products and Methods

Spire anticipates the use of blasting products as manufactured by Dyno Nobel Inc. These blasting products have been chosen because of many years of dependable use and positive results which are demonstrated by the:

- quality, safety, and reliability of the product;
- support offered by the manufacturer;
- availability;
- price; and
- similar product was used to conduct the pre-construction ground vibration calibration tests.

A Dyno Nobel NONEL nonelectric detonator will initiate all shots. This completely nonelectric system (including initiation) has been selected for several important reasons:

a. Due to the proximity of the high voltage power lines, stray current may be an issue that could result in the premature firing of an electric detonator.

b. The numerous radio equipped trucks belonging to all personnel (surveyors, inspectors and other subcontractors) on the Project mandate that all shots be totally nonelectric to eliminate accidental detonation of electric caps. Furthermore, there may be other commercial and/or non-commercial radio users in the area not associated with the Project (logging operations, quarry sites, etc.) who could compromise the safety of the blasting operations.

c. The Dyno Nobel NONEL nonelectric detonator shock tube system works instantaneously (like electric blasting caps). This allows for precise and reliable initiation of shots in congested areas, adjacent to highways or in other locations where blast initiation control is an issue. Unlike electric blasting caps, the Dyno Nobel NONEL nonelectric detonator shock tube system is unaffected by extraneous electric currents from known and/or unknown sources.

1.11 Monitoring, Reporting, and Controlling Ground Cracking and Displacement

It is not expected that this type of rock will fracture in such a way as to cause any type of ground displacement outside the temporary construction easement. Following each blast, the area will be examined for signs of ground cracking. Any indication of overbreak (cracks greater than half the distance to nearby adjacent structures) will be brought to the attention of the blaster and noted on the blast report. The shot pattern and/or loading will be adjusted to minimize or eliminate overbreak.

1.12 Explosives Storage and Transportation Procedures

Explosives storage and transportation shall follow the guidelines contained within the Federal guidelines as defined by Title 27 CFR 181, Title 49 CFR 177, Title 29 CFR 1926.900 et seq. Subpart U, and 29 CFR 1910.109, as well as "The Illinois Explosives Act" found under Title 62: Part 200 and Missouri's Department of Public Safety found under Title 11 CSR 40-7.

1.13 Peak Particle Velocity Monitoring, Air Blast Effects, and Control

Each blast will be monitored by an independent third-party firm experienced in monitoring blasts using a seismograph machine. Seismographs shall be Instantel Blastmate III GeoSconics 3000-LCP unit, or an instrument capable of monitoring trial-axial ground particle velocity, frequency response range, and continuous data recording. The seismograph shall have a seismic range from 0.005 to 10 inches per second and have a frequency response range from 2 to 300 hertz. The equipment's transducers shall be firmly coupled to the ground in accordance with manufacturer's recommendations.

Seismographs shall be placed at the "point of interest" which, in most cases, will be next to the foundation of the closest building, power line foundation, utility, or well. In all cases, both the sensor and seismograph will be protected from flyrock. Multiple seismographs may be needed if several sensitive receptors are located within proximity of the blasting area.

During the blasting activities, the seismograph shall be set to continuously record direct peak particle velocity ("PPV") readings as well as decibel readings to capture sound levels. After each blast, a blast report will be compiled and the PPV at the point of interest shall be submitted to the Engineer within three days of the blasting activities.

The industry standard for many years has been 12 inches per second maximum PPV on any underground structures. Based on US Bureau of Mines Report of Investigations 8507, the PPVs expected for this Project are below a threshold of four inches per second or lower on underground structures and two inches per second or lower on wells and above ground structures.

An approved instrument shall be utilized to measure air blast during blasting activities. The maximum allowable air blast at any building resulting from blasting operations shall not exceed 130 decibels peak when accurately measured by an instrument having a flat frequency response (plus or minus three decibels) over the range of at least 6 to 200 Hertz of following local authority's regulations, whichever is more stringent.

1.14 Fire Prevention

Following the required waiting period after each shot, the blast area will be inspected for any indication of fire or fire hazard. Particular attention will be paid to the vegetated areas outside of the right-of-way. Normally, the explosives vaporize at the instant of detonation and there is no fiber or other material left to smolder or be a source of concern. Any plastic shock tube from the initiation system that remains after the blast will be picked up for proper disposal immediately after the blast.

a. The blasting operation will generally take place after the grading operation has graded the right-of-way to bare mineral soil. The blaster shall ensure that the initiating detonator is placed on bare mineral soil and that there is no vegetation within a 20-foot radius.

b. The initiating detonator will be a minimum of 650 feet from the nearest loaded hole.

c. When fire danger is high due to forest conditions, a two-person fire watch team may patrol.

d. Each blast area for a period of one hour after the required waiting period.

1.15 Environmental Concerns

All residents within 300 feet of the blast will be notified one day before the blast day. All residents within 100 feet of the blasting operation shall be notified in accordance with the local land agent's site-specific procedure.

All necessary measures will be taken to exclude livestock from the blasting area. During the normal safety check prior to blasting, the area will be checked for both livestock and wildlife. The blast will not be initiated until the area is clear.

For major stream crossings, the Blasting Contractor shall comply with applicable Stream and Wildlife Construction and Mitigation Procedures and site-specific requirements.

1.16 Post-Blast Inspections

Once blasting operations are completed, Spire will then document the post-blasting conditions by repeating a similar inspection as the pre-blasting condition survey described in Section 1.3. The results of the pre-blasting condition survey will be compared against the post-blasting condition survey. Should any damage or change occur during the blasting operations, Spire's blasting Contractor will perform remedial measures to restore the feature to pre-blasting condition. In the unlikely event that blasting activities temporarily impair well water, Spire will provide alternative sources of water or otherwise compensate the owner. If well or structural damage is substantiated, Spire will either compensate the owner for damages or arrange for a new well to be drilled.

1.17 Blasting Damage

Blasting will create air and ground vibration that may damage adjacent structures. Adjustments to the blasting plan will be made based on the assessments of damage potential. Should the blasting operations or accidental detonations cause any damages to structures, property, wells, or other facilities, immediate action will be undertaken to repair the property, structure, or facility back to safe and usable conditions. Thereafter and without delay, all permanent repairs, reconstruction, and other work necessary to restore the property, structure, or facility to at least as good of condition as that preceding the event causing the damage shall be completed.

1.18 References

Church, Horace K. 1981. *Excavation Handbook*. New York: McGraw-Hill.

Natural Resources Conservation Service. 2015. Web Soil Survey.

Occupational Safety and Health Administration. *Blasting Requirements, 29 CFR 1926.900(k)*.

United States Code of Federal Regulations. *27 CFR Part 55, Commerce in Explosives; 49 CFR Parts 171 through 178, Hazardous Materials Regulations; and 49 CFR Parts 390 through 397, Federal Motor Carrier Safety Regulations*.

ATTACHMENT A

Spire Blasting Specifications

Attachment A Spire Blasting Specifications

1 Pre-Requisites for Use of Explosives

Prior to the use of any explosives, the Contractor shall:

a. Submit a blasting procedure/plan a minimum of two weeks prior to any blasting activities and receive Company approval. The blasting procedure shall take into account adjacent pipelines, power lines and specific requirements outlined in the Contract Documents and shall include as a minimum:

   i. storage of explosives;

   ii. transportation of explosives;

   iii. inspection of drilling areas;

   iv. loading of explosives;

   v. non-electric detonation methods - electric detonation methods are not acceptable;

   vi. control of flyrock during blasting, including mat placement if used;

   vii. security procedures;

   viii. sequence of events leading up the detonation of explosives;

   ix. proposed hours of blasting;

   x. true distances to buildings or operating pipelines;

   xi. maximum charge mass per delay interval;

   xii. borehole diameter;

   xiii. hole pattern, burden, and spacing;

   xiv. borehole depth, subgrade depth, and unloaded collar length;

   xv. sketch showing borehole loading details;

   xvi. explosive names, properties, and delay sequences;

   xvii. calculated powder factor (weight per volume of rock), based on explosive energy of 1000 calories per gram;

   xviii. geology description;

   xix. borehole stemming depth;

xx. special conditions or variations for grade rock, trench rock, underwater blasting, and blasting at undercrossings of existing utilities; and

xxi. blast to open face.

b. Obtain Company approval and provide a notice of 72 hours prior to detonation of any explosives.

c. Obtain approval from the Company if the blasting parameters vary from the requirements set out in this specification or the Contract Documents.

2 Use of Explosives

a. The Contractor shall secure and comply with all the applicable permits required for the handling, transportation, storage, and use of explosives.

b. The Contractor shall not endanger life, livestock, or adjacent properties.

c. The Contractor shall minimize inconveniences to the property owners or tenants during all phases of blasting.

d. The Contractor shall provide physical protection to any above-grade utilities and equipment in the area of the blast.

e. The Company is to be given the opportunity to set up any required monitoring equipment.

f. The Contractor shall provide monitoring equipment to ensure vibrations are limited to two inches per second [50 millimetres per second (mm/s)] PPV, when measured at dwellings, buildings, structures, and power line towers. For power line towers, this limit applies to the greatest of the three vectors; otherwise this limit is the vector sum of the three planes. The Contractor limits vibrations to one-inch per second (25 mm/s) PPV for vibration-sensitive structures specified by the Company. In no case shall vibration amplitude exceed 0.004-inch (0.15 mm).

g. Any blasting in close proximity to existing in-service piping is to be in accordance with the Contract Documents.

h. Charge loading is to be spread in order to obtain the optimum breakage of rock. The Contractor shall attempt to achieve a fragmentation rate of at least 75 percent of the trench rock to less than six inches (150 mm) in diameter.

i. All delay connectors used shall have a delay interval of at least 17 milliseconds.

j. There are to be no loaded holes left overnight, and the site is inspected after each blast for any un-detonated charges.

k. The Contractor shall discuss the blasting plan with the Company prior to each blast, including the maximum charge weight per delay, hole sizes, spacing, depths and layout. Upon completion of blasting each day, the Contractor shall provide the Company with the following data for each blast:

i. blasting contractor license number;

ii. date, time, and location of blast;

iii. hole sizes, spacing, depths, layout, and volume of rock in blast;

iv. delay type, interval, total number of delays, and holes per delay;

v. explosive type, specific gravity, energy release, weight of explosive per delay, and total weight of explosive per shot;

vi. powder factor; and

vii. copies of any draft seismographic data.

3 Evaluation of Close-In Blasts

The following additional limitations apply for blasting at distances of less than 25 feet from the pipeline. These criteria were extrapolated from a 1970 US Bureau of Mines Study on cratering in granite and refined based on a 2004 failure investigation by others.

a. Blasting on Pipeline Right-of-Way: Blasting should not be allowed on the pipeline right-of-way except when conducted for the benefit of the Company and under the supervision of a Company representative or qualified Blasting Inspector familiar with the Company's blasting requirements.

b. Minimum Offset from Blast Holes to Pipeline:

   i. No blast holes should be loaded at an offset of less than 25 feet from the centerline of an in-service pipeline except in cases where precise measurements are taken to ensure that the pipeline will have at least one-foot of Clearance (C) from the theoretical area surrounding the blast hole in which the ground could be permanently deformed by the blast under worst case conditions.

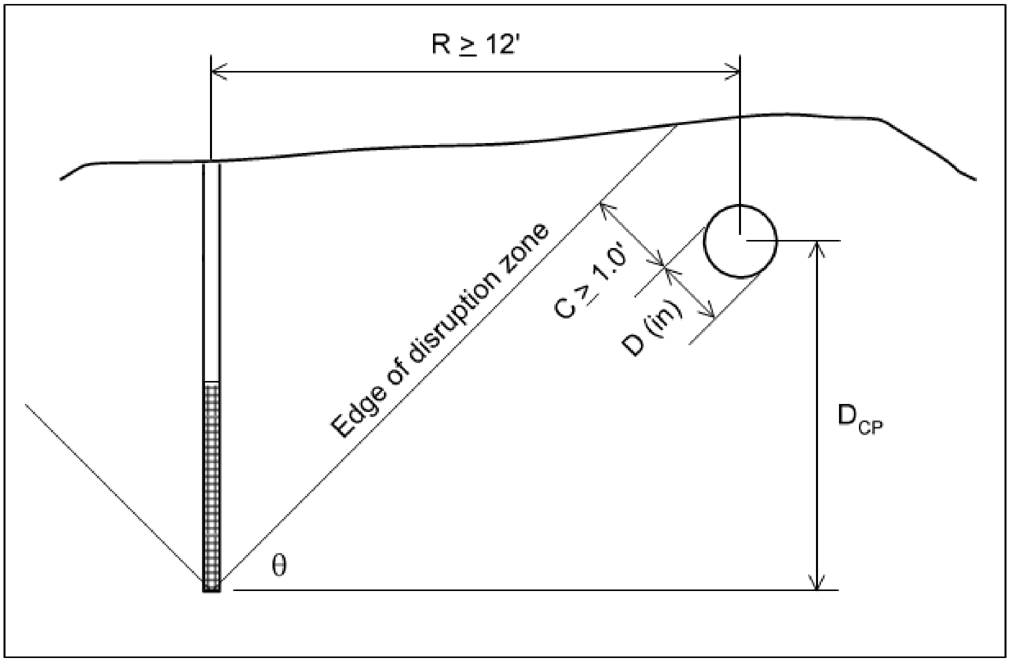
   ii. This theoretical area is a conical shape originating at the bottom of the blast hole and extending out at an angle up to the ground surface as depicted on Figure 1.

   iii. The clearance value C can be calculated by:

$$C = R \times \sin\theta - D_{CP} \times \cos\theta - \frac{D}{24}$$

   with D in inches and the other dimensions in feet, and where θ is the angle from the horizontal of the theoretical zone of permanent disruption.

Figure 1. Separation from Blast Hole



iv. The disruption zone angle θ shall be taken to be 32°, except when both of the following special circumstances hold. If both of these conditions hold, the disruption zone angle θ may be taken to be 45°.

v. Charge weight per delay does not exceed 0.9 times the ordinary maximum allowable charge weight and

vi. Charge weight per delay in lbs must not be greater than effective hole depth in feet, divided by 2.5 lb/foot. (Example: for 15-foot hole depth, maximum charge no greater than 15 feet/2.5 lb/foot. = 6 lb).

c. If the calculated clearance C would be less than one-foot, the minimum offset distance must be increased accordingly. The minimum offset R to achieve one-foot clearance is:

$$R = \frac{1\,ft}{\sin\theta} + \frac{D}{24 \times \sin\theta} + \frac{D_{cp}}{\tan\theta} \quad \text{, or:}$$

- $\theta = 32°$: $R = 1.887\,ft + \frac{D}{12.718} + 1.6 \times D_{cp}$
- $\theta = 45°$: $R = 1.414\,ft + \frac{D}{16.971} + D_{cp}$

d. When blast holes are angled from the vertical, this can have the effect of directing the disruption from the blast in one direction (the surface acts as a free face, allowing movement in that direction). For this reason, blast holes within 25 feet of an existing pipeline must be drilled vertically or angled away from the pipeline as the hole gets deeper.

e. In all cases, the absolute minimum offset R is 12 feet.

4 Mechanical Rock Removal

a. Mechanical rock removal shall occur between the hours of 7:00 am and 7:00 pm, unless otherwise specified by the Company.

b. The Contractor shall achieve a fragmentation rate of at least 75 percent of the trench rock to less than six inches (150 mm) in diameter.

ATTACHMENT B

Explosives Safety Program

Attachment B Explosives Safety Program

1 Federal and State Regulations

The Blasting Contractor will follow all Federal and State regulations:

a. Bureau of Alcohol, Tobacco and Firearms - 27 CFR 181 (Commerce in Explosives).

b. Occupational Safety and Health Administration (OSHA) - 29 CFR 1926.90 (Safety and Health Regulations for Construction Blasting and Use of Explosives).

c. Carriage by Public Highway peak particle velocity 49 CFR 177 (self-explanatory).

d. Explosives and Blasting Agents - OSHA, 29 CFR 1910.109 (Safety in the Workplace When Using Explosives).

e. Guidelines to be Followed by Natural Gas Pipeline Companies in the Planning, Locating, Clearing and Maintenance of Right-of-Way and the Construction of Above Ground Facilities - 18 CFR 2.69.

2 General Regulations

a. Only authorized and qualified personnel shall handle explosives and shall always be under the direct supervision of a blaster licensed, if required, by the States of Missouri and Illinois.

b. No flame, heat, radio transmitter, or spark-producing device shall be permitted in or near explosives during handling, transport, or use.

c. No person shall be allowed to handle, use or work in the area while under the influence of liquor, narcotics, or dangerous drugs.

d. Explosives shall be accounted for at all times. Explosives not in use shall be kept in locked, approved storage magazines. A running inventory shall be maintained at all times. Appropriate authorities shall be notified of any loss, theft or unauthorized entry into a magazine.

e. No explosives shall be abandoned.

f. No fires shall be fought where contact with explosives is imminent. All personnel shall be cleared and area guarded against other intruders.

g. Separate Class I and II magazines shall be used for transport of detonators and explosives from magazine storage area to blast site. Magazines shall be kept locked except for removal of material for use. In addition, explosives will be loaded directly to each shot point from the magazines on approved ground transportation equipment.

h. When blasting in areas of congestion or in close proximity of other structures or services, special precaution will be taken to avoid damage or personal injury.

i. Every reasonable precaution shall be used to notify others of use of explosives (visual, audible, flags, barricades, etc.). No onlookers or unauthorized personnel will be permitted within 1,000 feet during loading or blasting. Flaggers shall be stationed on roadways that pass through the danger zone to stop traffic during blasting operations.

j. All necessary precautions shall be taken to prevent accidental current discharge from any possible source. The exclusive use of a nonelectric initiation system will eliminate this possibility in nearly every situation with the possible exception of lightning strikes. Lightning detectors will be used in all loading and shooting operations.

  1) Electrical Storms:

    a) All blasting operations shall be suspended and all persons shall be removed from the blasting areas during the approach and progress of an electrical storm. The following rules must be followed:

    b) A lightning detector will be used to monitor the proximity of lightning to the shot. When the storm is 10 miles distant as identified by the lightning detector, notify all persons in the blasting crew of approaching storm. Stop all loading of holes and evacuate all personnel, except blaster and assistant, to a safe distance (1,000 feet) from the blast area.

    c) If the blast cannot be initiated before the storm arrives (within 10 miles as indicated by the lightning detector), the blaster and assistant shall evacuate the site to a safe distance.

    d) Personnel may return to worksite when the storm has passed and is 10 miles distant as determined by the lightning detector or after the completion of blast which allows for inspection of site and/or misfire.

k. Empty packing material shall not be used again for any purpose. It shall be burned at an approved location. Typically, this will be in the excavated trench or other designated area.

l. Damaged or deteriorated blasting supplies shall not be used.

m. Delivery and issue of explosives shall only be under, by and to authorized persons and into authorized magazine or temporary storage handling areas.

n. Blasting operations shall not be carried out in the proximity of other utilities or property owners without prior approval. “ONE CALL” notification requirements shall be followed.

o. All loading and firing shall be directed and supervised by a competent and experienced licensed blaster.

p. No loaded holes shall be left unattended or unprotected. No explosives or blasting agents shall be abandoned on the right-of-way. Explosives shall not be primed until immediately before use and shall not be allowed to lay overnight in drilled holes.

q. All jurisdictional authorities shall be granted unrestricted access to all explosive records as well as site access for procedural inspections. All personnel not involved with the current blasting operation must check in with the blaster before entering the blasting zone.

r. Warning signs, indicating the blast area, shall be erected and maintained at all approaches to the blast area. Warning sign lettering shall be a minimum of four inches in height on a contrasting background. Warning signs shall comply with the requirements of the jurisdictional authorities.

s. The warning signs (four-inch lettering) will be erected and maintained at all approaches to the blast area. Flaggers will be stationed on all roadways passing within 1,000 feet of the blast area and be responsible to stop all traffic during blasting operations. All personnel not involved in the actual blast shall stand back at least 1,000 feet and workers involved in the actual blast shall stand back 650 feet from the time the blast signal is given until the "All Clear" has been sounded. An audible blasting signal (air horn or siren) shall be used. The following blast signals will be used during blasting:

   1) Warning Signal: A one minute series of long horn or siren sounds will be made five minutes prior to the blast.

   2) Blast Signal: A series of short horn or siren sounds will be made one minute prior to the blast.

   3) All Clear Signal: A prolonged horn or siren sound following the inspection of the blast area.

t. Blaster qualifications shall meet all federal, state and local standards.

u. Misfires:

   1) If there are any misfires, all employees shall remain away from the suspected misfire area for at least 15 minutes. Misfires shall be handled under the direction of the person in charge of the blasting. All leads shall be carefully traced and a search made for unexploded charges.

   2) If a misfire is found, the blaster shall provide proper safeguards for excluding all employees from the danger zone.

   3) No other work shall be done except that necessary to remove the hazard of the misfire and only those employees necessary to do the work shall remain in the danger zone.

   4) A new primer shall be inserted into the hole and the hole shall be reshot. If re-firing of the misfired hole presents a hazard, the explosives may be removed by hand, vacuum, washing out with water or, where the misfire is underwater, blown out with air.

   5) No drilling, shall be permitted until all missed holes have been located, detonated or the authorized representative has approved that work can proceed.

   6) It may be recommended that the excavator digging on the suspect misfire, be shielded with Plexiglas or equivalent.

v. Initiation will be accomplished using a NONEL (nonelectric) shock tube detonator, electronic, detonating cord or comparable product.