LOCATION RESTRICTIONS DEMONSTRATION REPORT SLAG SETTLING IMPOUNDMENT

Sibley Generating Station

Presented to:
KCP&L Greater Missouri Operations Company
Sibley Generating Station
Sibley, Missouri

SCS ENGINEERS

27218131.03 | October 2018

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1 INTRODUCTION AND PURPOSE

The Disposal of Coal Combustion Residuals (CCR) from Electric Utilities Final Rule (CCR Rule) 40 CFR 257.60 through 257.64 requires owner/operators of existing CCR units to make demonstrations in the event a unit is located in certain areas. The purpose of this report is to demonstrate whether the Slag Settling Impoundment (Unit) at KCP&L Greater Missouri Operations Company (KCP&L GMO) Sibley Generating Station (Sibley) is located in any of those areas; and, if so, to make certain demonstrations per the CCR Rule that will permit continued CCR disposal/management operations.

The Unit, which is an existing CCR surface impoundment, is located at the Sibley Generating Station in Jackson County, Missouri, as indicated in Figure 1.

SCS Engineers (SCS) has reviewed the documents provided in Section 7 and completed site visit(s) to develop this report. This document provides demonstrations that documents if the Unit is located:

- with a base that is constructed no less than 5 feet above the upper limit of the uppermost aquifer (40 CFR §257.60);
- in wetlands (40 CFR §257.61);
- within 200 feet of the outermost damage zone of a fault which has been displaced in Holocene time (40 CFR §257.62);
- within a seismic impact zone (40 CFR §257.63); and
- in an unstable area (40 CFR §257.64).

The applicable CCR Rule requirement for each of the above is listed in the respective section in italics followed by an explanation of the review and determinations completed by SCS.

2 PLACEMENT ABOVE THE UPPERMOST AQUIFER (§257.60)

§257.60 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must be constructed with a base that is located no less than 1.52 meters (five feet) above the upper limit of the uppermost aquifer, or must demonstrate that there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations (including the seasonal high water table). The owner or operator must demonstrate by the dates specified in paragraph (c) of this section that the CCR unit meets the minimum requirements for placement above the uppermost aquifer.

SCS compared the location and elevation of the base of the Unit (approximately 713 feet MSL [mean sea level]) to the elevation of the upper limit of the uppermost aquifer by reviewing the site geology as characterized by AECOM in the Detailed Hydrogeologic Site Characterization Report (DSI) prepared in October 2017 (AECOM, 2017). Pertinent sections of this report have been provided in **Appendix A** summarizing and showing the location of the base of the Unit and the uppermost aquifer. As described in the investigation, the generalized geology underlying the Unit includes the following, from the surface down:

1. Surficial fill material
2. Native alluvial clay and silt unit
3. Basal silty sand (uppermost aquifer)
4. Shale and limestone (bedrock)

The site Investigation completed by AECOM confirmed that unconsolidated deposits consist of fill from ground surface to approximately 15 to 17 feet below ground surface (bgs). The fill overlies native alluvium consisting of clay and silt, with a basal silty sand unit above bedrock. The transition from the native alluvium clay and silt was marked by an increase in sand content. Borings drilled around the Unit encountered these unconsolidated deposits up to approximately 55 feet where bedrock was encountered. The uppermost aquifer at the site was determined to be the basal sand unit present below the native clay and silt and immediately above the bedrock contact. The basal unit varied in thickness from 19 to 24 feet, with an average thickness of 22 feet.

The lower permeability clay and silt unit extends from 26.5 to 32 feet bgs to the basal silty sand unit just above the top of bedrock. The basal silty sand unit is the main water-bearing unit at the site and is identified as the uppermost aquifer beneath the Slag Settling Impoundment. The aquifer appears locally confined or semi-confined by low permeability clay and silt and bedrock which act as upper and lower confining units, respectively, to the basal silty sand unit (uppermost aquifer). Although groundwater levels measured in the wells may occasionally extend up and into the clay and silt unit, the level is believed to be representative of the potentiometric head and not the water table elevation.

The Slag Settling Impoundment is an incised, concrete-lined impoundment approximately 11 feet deep with a top elevation of approximately 724 feet MSL and a bottom elevation of approximately 713 feet MSL. as noted in the Detailed Hydrogeologic Site Characterization Report (Section 1.2) in **Appendix A**. The report also identifies the uppermost aquifer as the basal unit immediately above the bedrock. A review of hydrostratigraphic cross sections and boring logs in the report indicate the maximum uppermost aquifer elevation of approximately 697 ft. MSL based on the boring log for MW-702. Based on this review, the base of the Unit is approximately 16 feet above the upper limit of the uppermost aquifer, therefore the base of the concrete liner was constructed no less than five feet above the upper limit of the uppermost aquifer. Consequently, no additional demonstration is necessary.

3 WETLANDS (§257.61)

§257.61 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in wetlands, as defined in §232.2 of this chapter, unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that the CCR unit meets the requirements of paragraphs (a)(1) through (5) of this section."

A figure developed for this analysis is provided as **Figure 2**. A Certified Wetland Delineator with SCS visited the Unit on April 30, 2018 to determine if any areas within the boundaries of the Unit are potentially located in existing wetland areas as defined in 40 CFR §232.2. The areas reviewed are indicated on **Figure 2**. Based on this review, SCS determined the Unit is not located within a wetland area, as defined in 40 CFR §232.2. Consequently, no additional demonstration is necessary.

4 FAULT AREAS (§257.62)

§257.62 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located within 60 meters (200 feet) of the outermost damage zone of a fault that has had displacement in Holocene time unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that an alternative setback distance of less than 60 meters (200 feet) will prevent damage to the structural integrity of the CCR unit.

SCS compared the location of the Unit to the location of faults as shown in the United States Geologic Survey (USGS) Quaternary Faults and Folds Database for the United States. The nearest fault area is indicated on Figure 3. Based on this review, SCS determined the Unit is not located within 200 feet of the outermost damage zone of a fault that has had displacement in the Holocene time, the most recent portion of the Quaternary Age. Consequently, no additional demonstration is necessary.

5 SEISMIC IMPACT ZONES (§257.63)

§257.63 (a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in seismic impact zones unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that all structural components including liners, leachate collection and removal systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

SCS compared the location of the Unit to the location of seismic impact zones as defined in §257.53, as shown in the USGS map "Two Percent Probability of Exceedance in 50 Years Map of Peak Ground Acceleration". The location of the Unit in relation to the nearest seismic impact zones (i.e., in areas of at least 0.1 g as shown on the map in dark blue) are indicated on **Figure 4**. The Unit falls within the 0.04 g to 0.06g range of the map. Based on this review, SCS determined the Unit is not located within a seismic impact zone. Consequently, no additional demonstration is necessary.

6 UNSTABLE AREAS (§257.64)

§257.64 (a) An existing or new CCR landfill, existing or new CCR surface impoundment, or any lateral expansion of a CCR unit must not be located in an unstable area unless the owner or operator demonstrates by the dates specified in paragraph (d) of this section that recognized and generally accepted good engineering practices have been incorporated into the design of the CCR unit to ensure that the integrity of the structural components of the CCR unit will not be disrupted.

SCS evaluated the location of the Unit for the presence of on-site or local unstable areas as defined in §257.53. Evaluations of the conditions listed in §257.64 (b)(1) through (3) were evaluated and are discussed below. Based on this review, SCS determined the Unit is not located within an unstable area as defined in §257.53. Consequently, no additional demonstration is necessary.

257.64 (b) The owner or operator must consider all of the following factors, at a minimum, when determining whether an area is unstable:

6.1 UNSTABLE FACTORS CONSIDERED: DIFFERENTIAL SETTLING (§257.64(b)(1))

On-site or local soil conditions that may result in significant differential settling;

SCS has visited the Unit and evaluated site-specific reports detailing the conditions of the on-site and local soils for conditions that could result in significant differential settling. The site was characterized in the "Detailed Hydrogeologic Site Characterization Report, Slag Settling Impoundment" (DSI) prepared by AECOM in October 2017. The Sibley Generating Station is located along within the Missouri River within the Osage Plains physiographic section (MDNR, 2002). The geomorphology is defined by gently rolling hills, with typically soft shale bedrock interbedded with sandstones and limestones characterized by a series of east-facing escarpments that indicate the presence of more resistant bedrock units (typically limestone) in the surficial rocks.

A series of Pleistocene ice sheets extended into the northern portion of Jackson County, leaving glacial till deposited predominantly along the Missouri River valley and in the Buckner-Sibley area. A large portion of northern Jackson County along the Missouri River is covered in a deep deposit of wind-deposited silt associated with the Pleistocene glaciation. The thickest deposits are observed along the bluffs of the Missouri River.

Generally, the alluvial deposits on the south side of the Missouri River are thin, between 25-50 feet thick, and somewhat fine grained with a coarsening sequence of primarily clay, with silt, sand, and some gravel. Alluvial deposits on the north side of the Missouri River are estimated to be approximately 100 feet deep, and have a more pronounced transition from overlying clay to sand to boulders with depth (Gentile, 2014).

The 2017 DSI (AECOM, 2017) investigation indicated that the soil stratigraphy at the Slag Settling Impoundment consists of fill over naturally occurring unconsolidated alluvial clays and silts, which transitioned into silty sands and then limestone bedrock at a depth of approximately 55 feet. Four borings were drilled in the area of the slag settling basin to depths of 50 to 55 feet during the DSI. Each boring encountered 15 to 17 feet of fill. Bedrock was encountered in one boring at a depth of 55 feet and not encountered in the three borings drilled to depths of 50 feet.

Based on the geologic description above and a review of geotechnical data in the report(s), it is SCS' professional opinion that the soils under the Unit will not experience significant differential settlement. Pertinent sections of the 2017 AECOM report are provided in **Appendix B.1** summarizing the soil properties at and near the Unit. Based on this review, SCS determined the Unit is not located within an area with on-site or local soil conditions that may result in significant differential settling. Additional demonstration(s) are not required.

6.2 UNSTABLE FACTORS CONSIDERED: GEOLOGIC/GEOMORPHOLOGIC FEATURES (§257.64(b)(2))

On-site or local geologic or geomorphologic features; and

SCS has visited the Unit and evaluated published data and site-specific reports for the presence of on-site or local geologic and geomorphologic features, to include karst terrain, steep slopes, and sinkholes. Documents and websites reviewed include:

- MDNR Geologic and Related Hazards in Missouri (https://dnr.mo.gov/geology/geosrv/geores/geohazhp.htm)
- Sinkholes in Missouri (https://dnr.mo.gov/geology/geosrv/envgeo/sinkholes.htm)
- Map of Sinkholes in Missouri (https://dnr.mo.gov/geology/geosrv/envgeo/images/sinkholesinmissouri.jpg)

SCS also used the Missouri Geologic Survey Geosciences Technical Resource Assessment Tool (GeoSTRAT) (http://dnr.mo.gov/geostrat/) database to identify geologic and geomorphologic features that may have an impact on the Unit. Data layers examined by SCS included the following:

- Geologic Structures,
- Earthquake Collapse Potential,
- Earthquake Liquefaction Potential,
- Mines,
- Springs,
- Cave Density,
- Sinkhole Areas, and
- Sinkhole Points.

As shown on the GeoSTRAT map in Appendix A.2, only a geologic structure was identified within the search area near the Unit. The geologic structure should not have an impact on the Unit.

Neither the GeoSTRAT database nor published data indicate the presence of karst terrain, sinkholes, caves, or ground conditions that could cause a structural failure in the area of the Unit or region around the Unit. Locally, three structural features are noted in the bedrock geology near the Unit (Gentile, 2014). They include a west-southeast trending anticline (Hayes Park dome), a complimentary west-southeast trending syncline, and several buried bedrock incised paleovalleys south of the Missouri river (AECOM, 2017). A map showing the general structural features near the Unit is included in **Appendix B.2**. SCS' visits to the Unit and a review of terrain at and near the Unit indicated no steep slopes, terrain features, or other local geologic or geomorphologic features that could feasibly result in an unstable condition. Pertinent documents and sections of documents reviewed are provided in **Appendix B.2**, and indicate the location of the Unit in relation to the known geologic or geomorphologic features nearest the Unit.

Based on this review, SCS determined the Unit is not located within an area with on-site or local geologic or geomorphologic features that would result in an unstable environment for the Unit.

6.3 UNSTABLE FACTORS CONSIDERED: HUMAN-MADE FEATURES OR EVENTS (§257.64(b)(3))

On-site or local human-made features or events (both surface and subsurface).

SCS has visited the Unit and evaluated published data and site-specific reports for the presence of on-site or local human-made features or events (both surface and subsurface), to include surface and subsurface mining, extensive withdrawal of oil and gas, steep slopes, and sources of rapid groundwater drawdown, in strata that could feasibly impact the Unit. Documents and websites reviewed include:

- Missouri Mine Maps (https://dnr.mo.gov/geology/geosrv/geores/mine-maps/)
- Mine Maps – Jackson County (https://dnr.mo.gov/geology/geosrv/geores/minemapsjackson.htm)
- Oil and Gas in Missouri, Fact Sheet (https://dnr.mo.gov/pubs/pub652.pdf)
- Oil and Gas in the Show-Me State, The Geologic Column of Missouri, published by the MDNR Division of Geology and Land Survey, Volume 2, Issue 1, Summer 2007

SCS used the Missouri GeoSTRAT database to identify man-made features or events that may have an impact on the Unit. Data layers examined by SCS included the following:

- Inventory of Mines, Occurrences and Prospects,
- Industrial Mineral Mines, and
- Oil and Gas Wells.

The GeoSTRAT maps indicated the presence of mines and oil and gas production in Jackson County. The mining in the area of the City of Sibley, Missouri consists of mining to the west of Township 50 North, Range 30 West where numerous underground limestone mines exist. Underground mining is ongoing approximately 10 miles west of the Unit, as well as north of Missouri River in Clay County.

The GeoSTRAT database showed the location of oil/gas wells in Jackson County, but no oil/gas wells within 4 miles of the Unit.

No evidence of steep slopes in the vicinity of the unit nor areas of rapid groundwater drawdown were identified.

Selected pertinent documents and sections of documents are provided in **Appendix B.3** to indicate the types and locations of human-made features in this area of Missouri and their locations relative to the Unit.

Based on this review, SCS determined the Unit is not located within an area with on-site or local human-made features or events (both surface and subsurface) that could feasibly result in an unstable condition at the Unit.

7 REFERENCES

AECOM (2017), Detailed Hydrogeologic Site Characterization Report, Slag Settling Impoundment, Sibley Generating Station.

SCS Engineers (2017), Groundwater Monitoring System Certification Basis Report, Slag Settling Impoundment, Sibley Generating Station.

USGS (2017), Two Percent Probability of Exceedance in 50 Years Map of Peak Ground Acceleration.

MDNR (2002), Physiographic Regions of Missouri, Division of Geology and Land Survey, Missouri Department of Natural Resources.

USGS (2015), Geologic Units in Jackson County, Missouri, https://mrdata.usgs.gov/geology/state/fips-unit.php?code=f29095, accessed August 2018.

MDNR, MDNR Geologic and Related Hazards in Missouri, https://dnr.mo.gov/geology/geosrv/geores/geohazhp.htm, accessed August 2018.

MDNR (2015), Geologic Hazards in Missouri, https://dnr.mo.gov/pubs/pub2467.pdf, accessed August 2018.

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MDNR, Missouri Geologic Survey Geosciences Technical Resource Assessment Tool (GeoSTRAT), https://dnr.mo.gov/geology/geostrat.htm, accessed August 2018.

MDNR, Missouri Mine Maps, https://dnr.mo.gov/geology/geosrv/geores/mine-maps/, accessed August 2018.

MDNR, Mine Maps – Jackson County, https://dnr.mo.gov/geology/geosrv/geores/minemapsjackson.htm, accessed August 2018.

MDNR, Oil and Gas in Missouri, Fact Sheet, https://dnr.mo.gov/pubs/pub652.pdf, accessed August 2018.

8 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION (§§257.60(B), 257.61(B), 257.62(B), 257.63(B), 257.64(C))

The undersigned registered professional engineer is familiar with the requirements of the CCR Rule and has visited and examined the Unit and/or has supervised examination of the Unit and development of this report by appropriately qualified personnel. I hereby certify based on a review of available information and observations, that this report meets the requirements of paragraphs §§257.60(a), 257.61(a), 257.62(a), 257.63(a) and 257.64(a).

Professional Engineer: Company: Douglas L. Doerr, P.E.

SCS Engineers

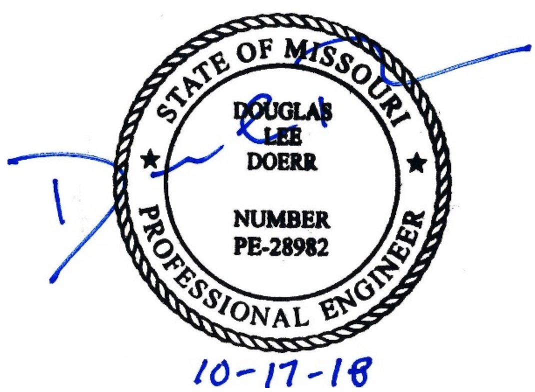
PE Registration State: Missouri

Registration Number: PE-28982

Professional Engineer Seal:

Douglas L. Doerr

Digitally signed by Douglas L. Doerr
Date: 2018.10.17 10:51:10 -05'00'



The undersigned registered professional geologist is familiar with the requirements of the CCR Rule and has visited and examined the Unit and/or has supervised examination of the Unit and development of this report by appropriately qualified personnel. I hereby certify based on a review of available information and observations, that this report meets the requirements of paragraphs §§257.60(a).

Professional Geologist: Company: John R. Rockhold, P.G.

SCS Engineers

PG Registration State: Missouri

Registration Number: PG 0092

Professional Geologist Seal:

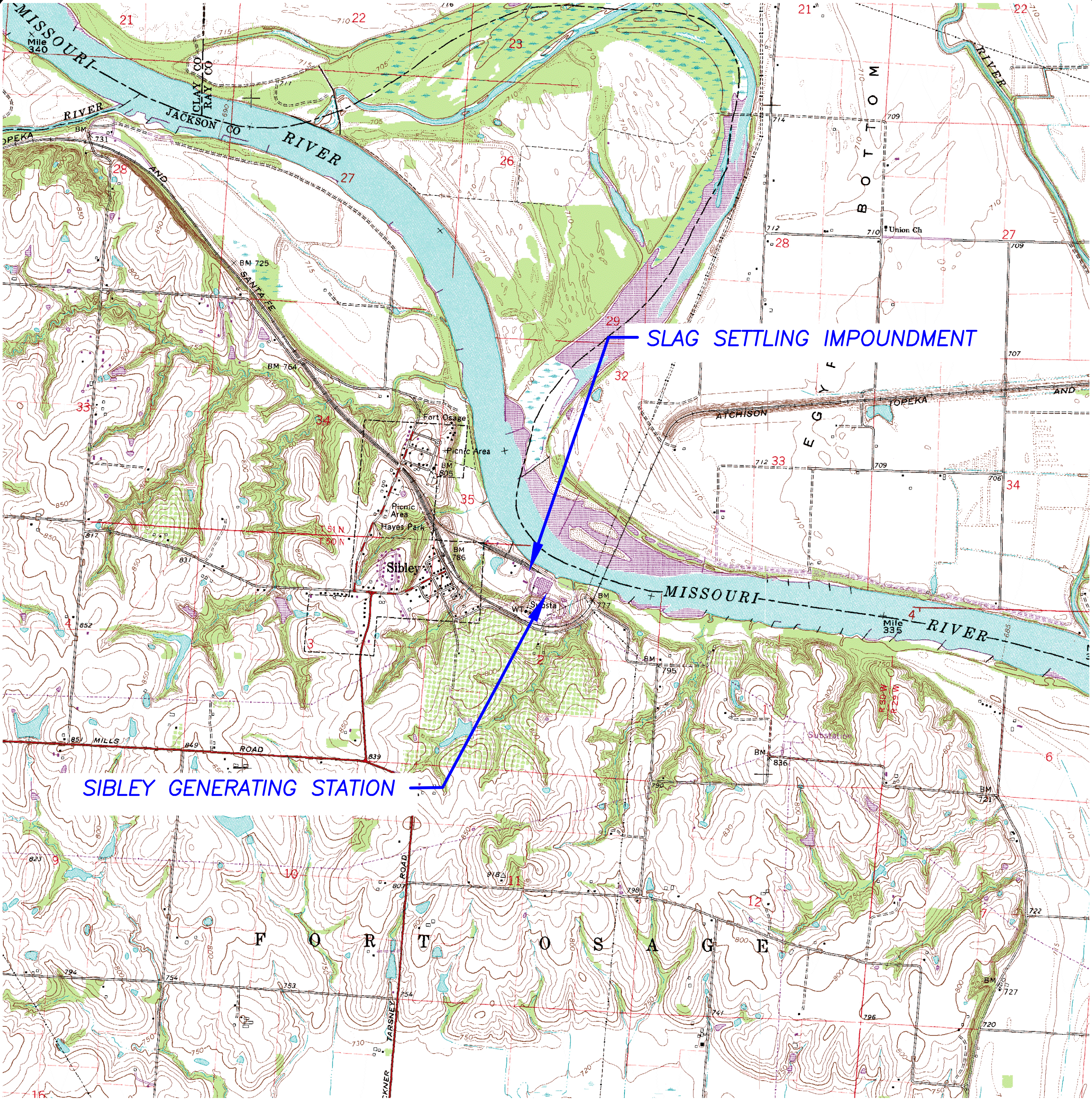
FIGURES

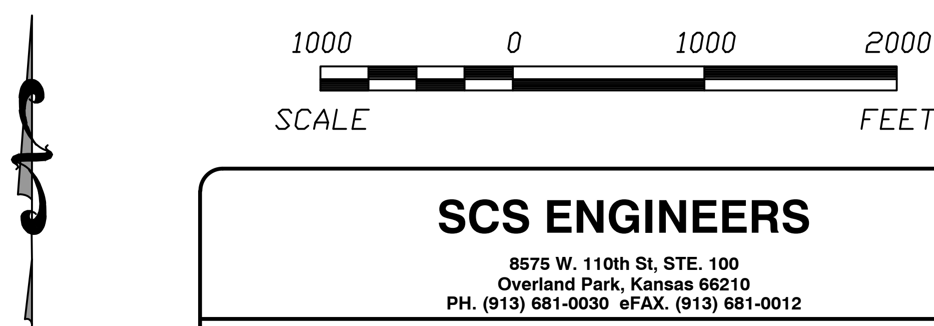
Figure 1 - Site Location Map

Figure 2 - Wetlands Map

Figure 3 - Fault Areas Map

Figure 4 - Horizontal Acceleration Map





SOURCE:
1975 USGS MAP
BUCKNER QUADRANGLE
7.5 MINUTE SERIES (TOPOGRAPHIC)

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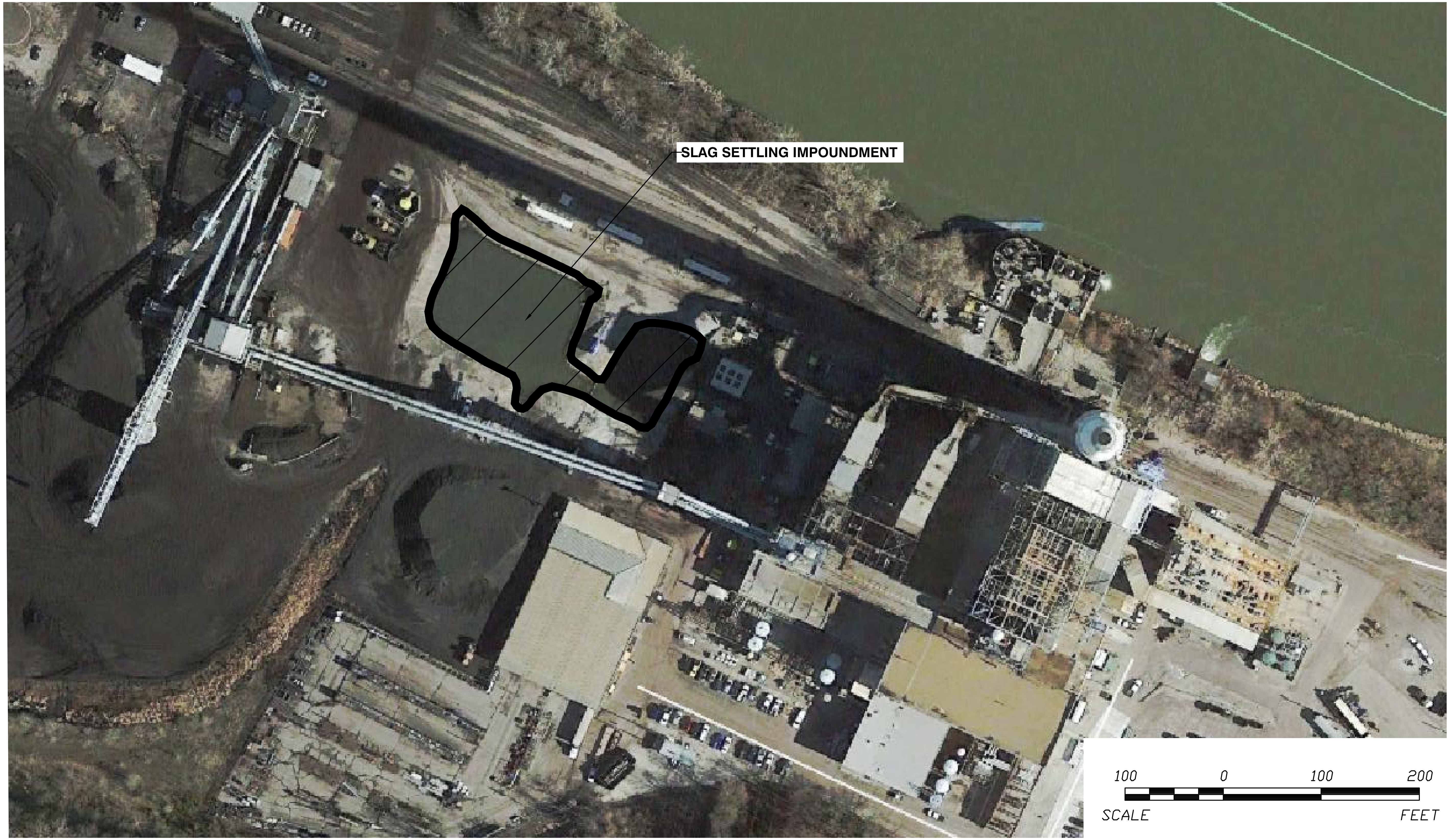
FIGURE 1
SITE LOCATION MAP
KCP&L GMO SIBLEY GENERATING STATION - SLAG SETTLING IMPOUNDMENT
SIBLEY, MISSOURI

CHK. BY: DLD	DWN. BY: TGW	DSN. BY: TGW	PROJ. NO. 27218131.03
PROJ. MGR: DLD	DATE: 10/2018	CADD FILE: FIGURE 1_SITE MAP.DWG	DRAWING NO. 1



LEGEND:

AREAS THAT WERE FOUND NOT TO INCLUDE WETLANDS BASED ON REVIEW OF VEGETATION, SOIL TYPE, AND HYDROLOGIC CHARACTERISTICS.

NOTES:

1. GOOGLE EARTH IMAGE DATED MARCH 2015.

FIGURE 2
WETLANDS MAP
KCP&L GMO SIBLEY GENERATING STATION - SLAG SETTLING IMPOUNDMENT
SIBLEY, MISSOURI

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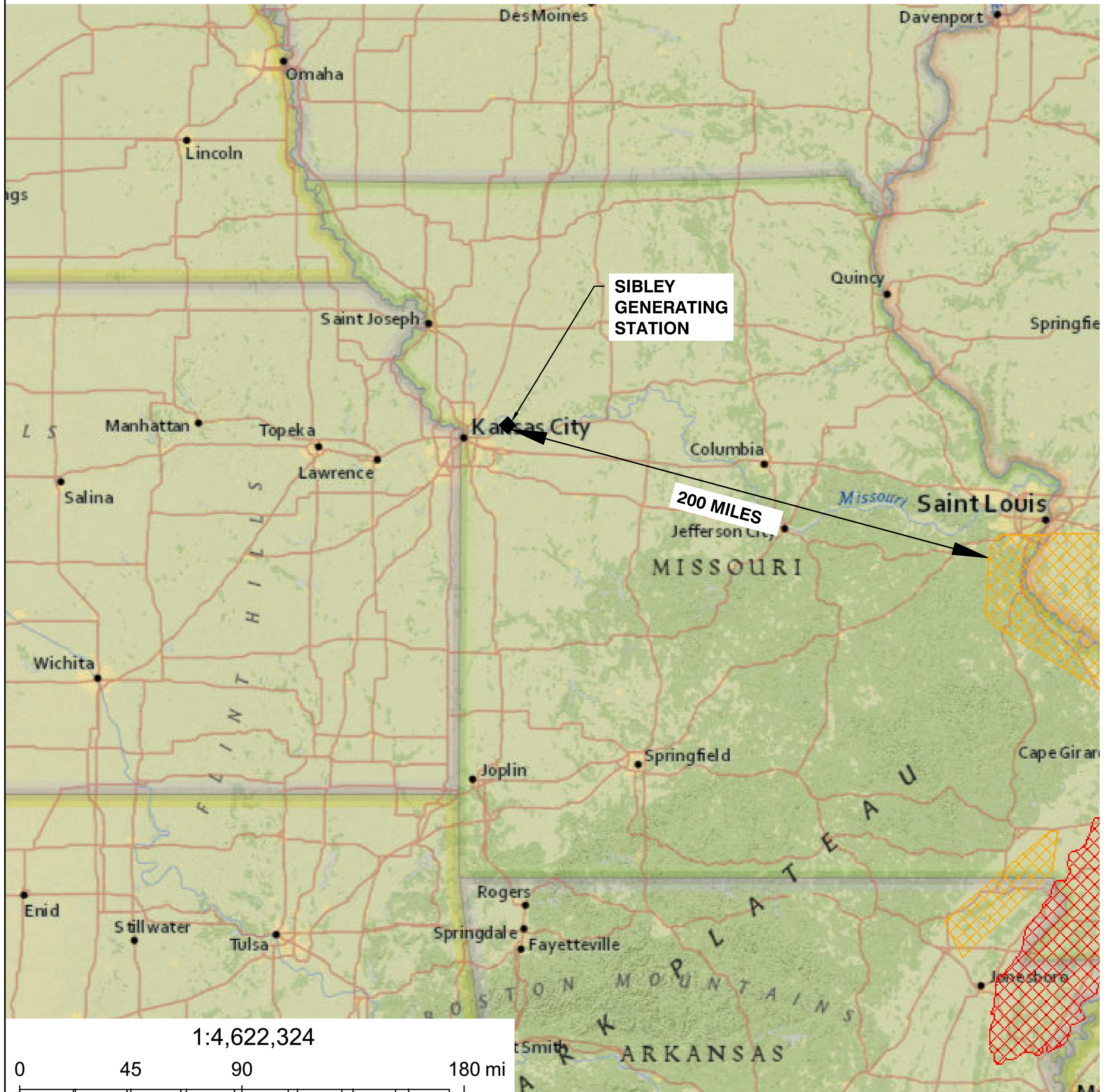
PROJ. MGR: DLD	DATE: 10/2018	CADD FILE: FIGURE 2_WETLANDS.DWG	

USGS Quaternary Faults and Folds Database



1:4,622,324

0 45 90 180 mi

0 70 140 280 km

7/5/2018, 9:50:24 AM

1:18,489,298

0 185 370 740 mi

0 287.5 575 1,150 km

Site Investigations

Quaternary Faults

historical (<150 years), well constrained location

historical (<150 years), moderately constrained location

historical (<150 years), inferred location

latest Quaternary (<15,000 years), well constrained location

Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Source: USGS fault map - https://earthquake.usgs.gov/hazards/qfaults/

FIGURE 3
FAULT AREAS MAP
KCP&L GMO SIBLEY GENERATING STATION - SLAG SETTLING IMPOUNDMENT
SIBLEY, MISSOURI

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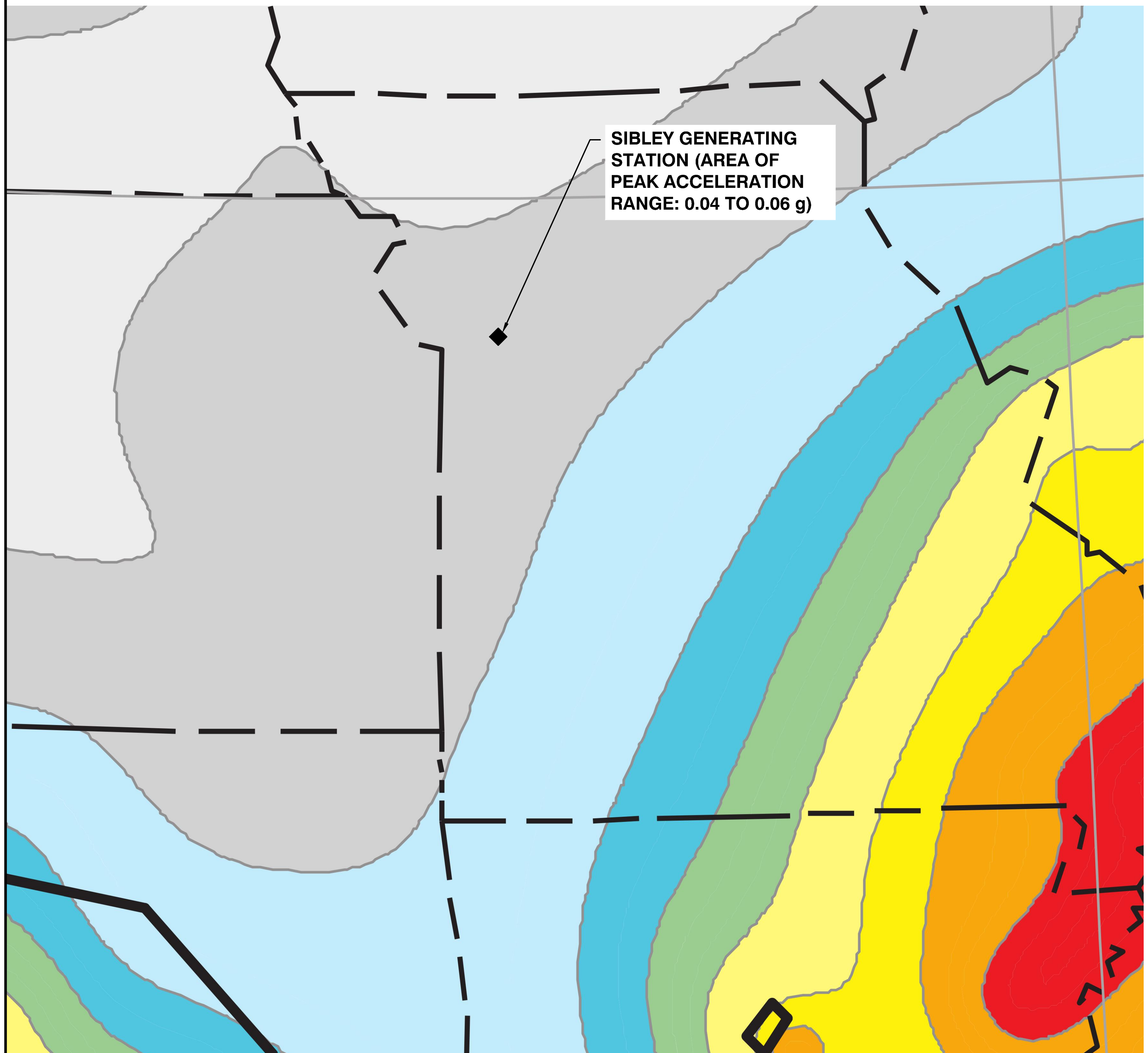
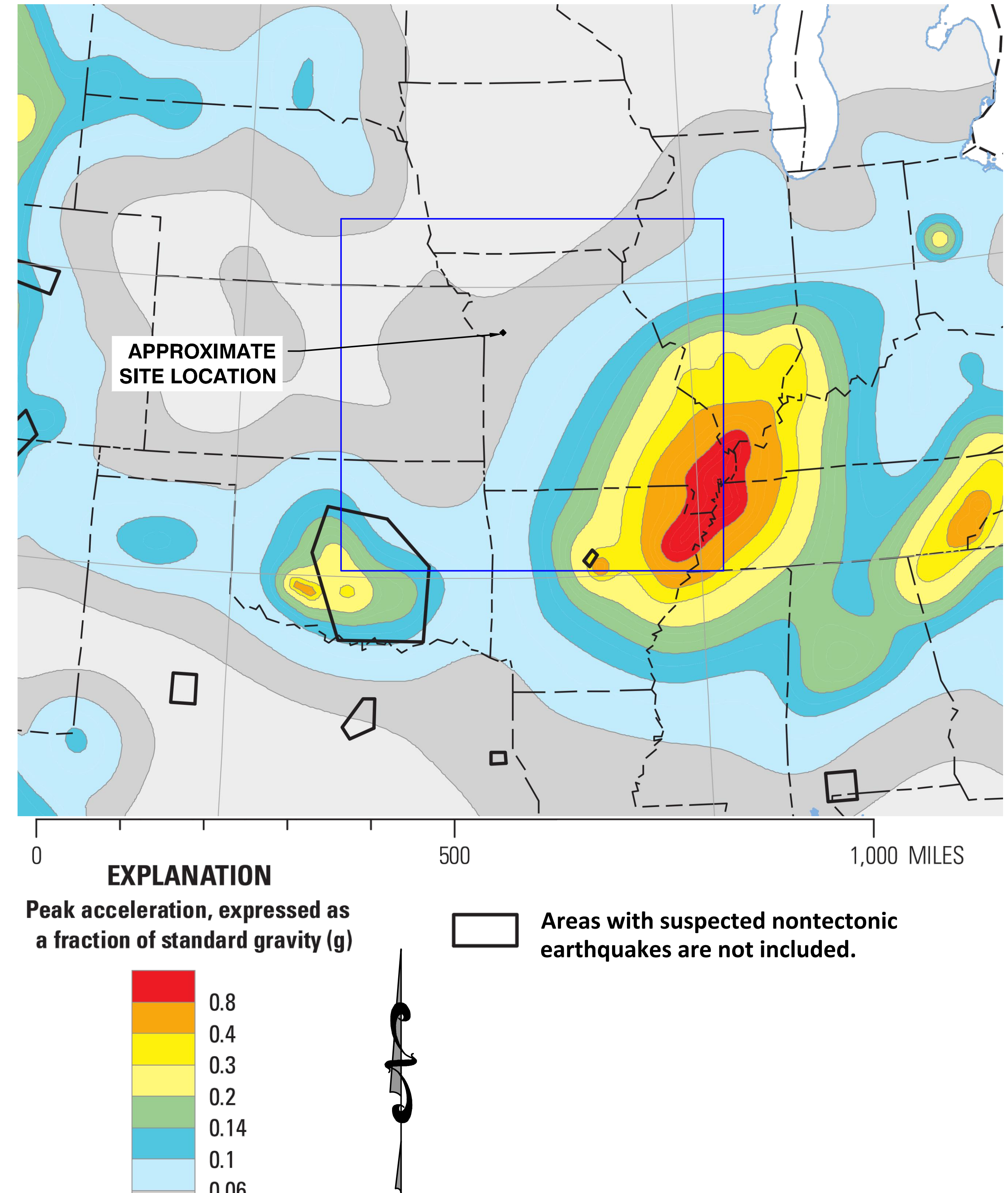
PROJ. MGR: DLD	DATE: 10/2018	CADD FILE: FIGURE 3_FAULT AREAS.DWG	

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





Source: USGS seismic impact zones map (2014) - http://earthquake.usgs.gov/hazards/hazmaps/conterminous/index.php#2014

FIGURE 4
HORIZONTAL ACCELERATION MAP
KCP&L GMO SIBLEY GENERATING STATION - SLAG SETTLING IMPOUNDMENT
SIBLEY, MISSOURI

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APPENDIX A

Placement Above the Uppermost Aquifer Supporting Information

- Portions of Detailed Hydrogeologic Site Characterization Report (AECOM 2017)

1 Introduction

1.1 Background

KCP&L Greater Missouri Operations Company (KCP&L GMO) owns and operates the Sibley Generating Station near Sibley, Missouri (Sibley Station). The Sibley Station includes the Slag Settling Impoundment (Site) which is classified as a coal combustion residual (CCR) unit under the Coal Combustion Residuals Rule (CCR Rule) published by the United States Environmental Protection Agency (US EPA) on April 17, 2015 (US EPA, 2015, 40 CFR §257 Subpart D). 40 CFR 257.91 requires that CCR units have a groundwater monitoring system that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that accurately represents the quality of background groundwater that has not been affected by leakage from a CCR unit; and that accurately represents the quality of groundwater passing the waste boundary of the CCR unit.

KCP&L GMO retained AECOM to review and collect site-specific technical information to be used to install new monitoring wells to assess the Site in accordance with the CCR Rule. AECOM first conducted a desktop hydrogeologic analysis of previous investigations. The desktop review was followed by site-specific field investigations consisting of investigation borings and monitoring well installations, and a hydraulic characterization of the aquifer. The investigation procedures generally followed the Missouri Department of Natural Resources (MDNR) *Guidance for Conducting a Detailed Hydrogeologic Site Characterization and Designing a Groundwater Monitoring Program* (MDNR, 2010). The investigation included a thorough characterization of aquifer thickness, groundwater flow rate, groundwater flow direction and saturated and unsaturated geologic units and fill materials overlying the uppermost aquifer, materials comprising the uppermost aquifer, and materials comprising the lower boundary of the uppermost aquifer.

This report includes a summary of local and regional geologic and hydrogeologic conditions, the method of conducting this study, the results of this investigation, and the conclusions reached from the data. As the Slag Settling Impoundment is an existing unit with no proposed changes, locational documentation such as wetland locations, floodplains, and seismic impact zones are not provided, but may be referred to in existing documentation from a previous Detailed Site Investigation (DSI) of the nearby CCR Landfill conducted by Shaw Environmental, Inc. (Shaw, 2008).

1.2 Location and History

The Slag Settling Impoundment at the Sibley Station is located in the north ½ of Section 2, Township 50 North, Range 30 West, in Jackson County, Missouri. In addition to the Slag Settling Impoundment, the Sibley Station also includes, from west to east, the power plant, Fly Ash Impoundment, Leachate Pond, and CCR Landfill, as presented in **Figure A.1** in **Appendix A**. A Site Map is provided in **Figure A.2** in **Appendix A**. The power plant consists of three coal-fired units and is situated on the west side of the property.

The Slag Settling Impoundment at the Sibley Station is an onsite surface impoundment commissioned in 1986. The incised, concrete-lined impoundment is approximately 11 ft. deep with a top elevation of 724.0 ft. [NGVD29] (Black & Veatch, 1986), a bottom elevation of 713.0 ft. [NGVD29] and has 3 to 1 (horizontal to vertical) side slopes. The incised impoundment has a surface area of approximately 1.1 acres at the zero freeboard elevation

3.2.2 Groundwater Conditions

The primary receiving water body for groundwater discharge in the area of the impoundment is the Missouri River north of the Site. Five sets of water levels from monitoring wells MW-701 through MW-704 from May 2016 through May 2017 were provided by SCS Engineers, and are summarized in **Table 2** and **Chart 1** in **Appendix C**. These data were used to assess the magnitude and direction of the hydraulic gradient at the Site, and are presented on the potentiometric surface maps in **Appendix A.6**. The potentiometric contours indicate that groundwater in the area generally flows north towards the Missouri River. The calculations for hydraulic gradient for the water level readings are included in **Appendix C**. The hydraulic gradient is approximately -0.030 from southwest to northeast.

3.3 Site-Specific Technical Information (40 CFR 257.91(b))

The site-specific technical information required by 40 CFR 257.91(b) is summarized in the sections below. The information has been divided into sections based on the requirements of the CCR Rule in order to characterize the overlying geologic units, the uppermost aquifer, and the confining unit defining the lower boundary of the uppermost aquifer. The data presented is based on the 2015 Site Investigation at the Slag Settling Impoundment, and is supplemented with applicable data from the nearby Fly Ash Impoundment.

3.3.1 Overlying Geologic Units

The material overlying the aquifer at the Slag Settling Impoundment is generally fill overlying low plasticity clay, which transitions to silt and then sand with depth. All of the 2015 Site Investigation borings were drilled through fill around the impoundment. Boring logs indicate that fill extends to elevations between 706 and 710 ft. before reaching alluvial clay and silt. The clay and silt beneath the fill and over the basal sand unit is about 10 to 16 ft. thick. Water was encountered perched on the clay/silt within the fill in three borings at about 7 and 8 ft. bgs. Stabilized water levels from monitoring wells completed in the basal sand unit are below the contact between the fill and native alluvium, indicating that the silt and clay overlying the aquifer acts as a locally confining or semi-confining unit, similar to the conditions encountered at the Fly Ash Impoundment. Although moisture was encountered within the clay or silt, for the purposes of the CCR Rule, the water-bearing unit that has been defined as the aquifer is the basal sand unit below the clay and silt, as described in Section 3.3.2.

At the nearby Fly Ash Impoundment, the vertical hydraulic conductivity of the embankment fill (clay) and native alluvium (silt) was measured by conducting falling head permeability laboratory tests from representative samples collected within the clay fill and silt. The hydraulic conductivity ranged from 2.9×10^{-09} to 2.6×10^{-06} cm/sec for the clay fill and 2.7×10^{-06} to 5.7×10^{-06} cm/sec for the silt, as presented in **Appendix C**, **Table 4**. The silt at the Fly Ash Impoundment is lithologically similar to the silt at the Slag Settling Impoundment. Therefore, the hydraulic conductivity of the silt at the Slag Settling Impoundment was assumed to be between 2.7×10^{-06} to 5.7×10^{-06} cm/sec. The falling head permeability laboratory tests at the Fly Ash Impoundment were conducted on embankment fill material. This material had been brought in from a borrow area near the CCR Landfill and recompacted during construction of the Fly Ash Impoundment to achieve a lower hydraulic conductivity. For this reason, it was considered to be dissimilar to the native clay material at the Slag Settling Impoundment. The hydraulic conductivity of the clay at the Site was therefore selected based on literature values for clay after Domenico and Schwartz, 1990, resulting in a hydraulic conductivity of 9×10^{-07} to 4×10^{-04} cm/sec. The porosity of clay is 34 - 60%, and the effective porosity of clay is 1 - 20%, based on literature values after Walton, 1988 and Domenico and Schwartz, 1990. The porosity of silt is 34 - 61%, and the effective porosity of silt is 1 - 30%, based on literature values after Walton, 1988 and Domenico and Schwartz, 1990.

3.3.2 Aquifer Characterization

The 2015 Site Investigation indicated that the basal sand unit acts as the uppermost aquifer at the Slag Settling Impoundment. This unit was typically composed of fine- to medium-grained silty sand to sand, with silt content decreasing with depth. The aquifer is locally semi-confined to confined by the overlying low permeability clay/silt acting as an upper confining unit and confined by the thicker limestone and shale bedrock of the Fort Scott Subgroup acting as a lower confining unit. The thickness of the aquifer ranged from 19 to 24 ft., with an average thickness of approximately 22 ft. Based on the water level measurements in the monitoring wells, the groundwater flow direction is from southwest to northeast across the impoundment. The calculated seepage velocity (flow rate) of the aquifer ranges from about 7.7 x 10^{-04} to 9.3 x 10^{-03} cm/sec. Calculations of the seepage velocity are included in **Appendix C**.

There was sometimes a gradational change as grain size increased with depth in the overlying clay/silt to the basal sand unit, as noted in the boring logs. The gradational change was not pronounced or sufficiently contiguous to map as a separate unit on the hydrostratigraphic cross section. In some of these locations, the well screen was set higher in the clay/silt to monitor possible local variations in the contact with the basal sand unit.

The horizontal hydraulic conductivity of the aquifer was characterized using published correlations from a Mansur-Kaufman field study to relate grain-size and hydraulic conductivity (USACE, 2000). Grain size data from the Slag Settling Impoundment borings were used along with grain size data from the nearby Fly Ash Impoundment (AECOM, 2017). Materials classified as fine grained or with considerable fines were not considered for the grain size-hydraulic conductivity correlation. These correlations are included in the calculations in **Appendix C**, and indicated a hydraulic conductivity range of 6.0 x 10^{-03} to 7.2 x 10^{-02} cm/sec. A comparison of grain size and hydraulic conductivity to elevation is also included in the Calculations in **Appendix C**. This comparison showed a layer of high hydraulic conductivity from approximately 690 to 700 ft., and then a slight increase in grain size/hydraulic conductivity with decreasing elevation. The porosity of the aquifer is 26 – 53% and the effective porosity is 10 - 35%, based on literature values for the types of materials after Walton, 1988 and Domenico and Schwartz, 1990.

3.3.3 Lower Boundary Confining Geologic Unit

The lower boundary confining geologic unit was bedrock. Limestone bedrock was encountered in one of the borings directly beneath the basal sand unit. The remaining three borings were terminated within the basal sand unit.

The hydraulic conductivity, porosity, and effective porosity ranges of the limestone are 1 x 10^{-07} to 6 x 10^{-04} cm/sec, 0 - 40%, and 0.1 - 5%, respectively, based on literature values for limestone after Walton, 1988 and Domenico and Schwartz, 1990. The limestone unit is included with other underlying shale units in the Fort Scott Subgroup of the Marmaton Group that further act as a confining unit. The hydraulic conductivity, porosity, and effective porosity ranges of the shale are 1 x 10^{-11} to 2 x 10^{-07} cm/sec, 1 - 10%, and 0.5 - 5%, respectively, based on literature values for the shale after Walton, 1988, and Domenico and Schwartz, 1990.

3.3.4 Characteristics of Geologic Units

A summary table including the hydraulic conductivities, porosities, and effective porosities of each geologic unit encountered during the field investigation activities at the Slag Settling Impoundment is included in **Table 3-1**. The data presented in **Table 3-1** was obtained using the following methods:

- Hydraulic Conductivities:
  - The hydraulic conductivity of the clay was based on literature values for hydraulic conductivity after Domenico and Schwartz, 1990.
  - The hydraulic conductivities of the silt were obtained by conducting falling head permeability tests in accordance with ASTM D5084. The silt at the Slag Settling Impoundment was lithologically

APPENDIX B

Unstable Areas Supporting Information

APPENDIX B.1

Portions of Detailed Hydrogeologic Site Characterization Report (AECOM, 2017)

of 724.0 ft. [NGVD29]. The unit has a surface water area of approximately 0.6 acres at the normal operating level of 717.0 ft. [NGVD29].

Generally, Bottom Ash (slag) is currently sluiced from the power plant into the eastern side of the Slag Settling Impoundment at an approximate rate of 959,000 gallons per day (gpd) or 1.5 cubic ft. per second (cfs) (US EPA, 2010). The water mixed with the ash flows from the eastern side of the impoundment over an in-line weir structure to a ponding area on the west side of the impoundment. Currently, an excavator removes the ash onto the concrete slopes to allow water to drain. After dewatering is complete, ash material is moved by an excavator to a concrete slab where it is loaded into trucks for beneficial use or transported to the CCR Landfill for disposal. Therefore, the storage capacity of the impoundment does not significantly change from year to year (AECOM, 2016). Water discharges to the National Pollutant Discharge Elimination System (NPDES) permitted Outfall 002 on the south bank of the Missouri River (AECOM, 2016).

1.3 Regional Geology and Hydrogeology

1.3.1 Geomorphology

The Sibley Station is located along the Missouri River and is situated within the Osage Plains physiographic section of the larger Central Lowland province, which is in turn part of the larger Interior Plains physiographic division (MDNR, 2002). The geomorphology is defined by gently rolling hills, with typically soft shale bedrock interbedded with sandstones and limestones characterized by a series of east-facing escarpments that indicate the presence of more resistant bedrock units (typically limestone) in the surficial rocks. The Dissected Till Plains physiographic section, also included in the Central Lowlands province, begins just north of the Missouri River, and is characterized by former plains that have been covered by glacial drift, with subsequent development of well-defined drainage systems (Fenneman, 1928). Local surface topographic relief is typically less than 250 ft. with greatest relief occurring where major streams incise the underlying rocks (Fenneman, 1928, Imes and Emmett, 1994).

A series of Pleistocene ice sheets extended into the northern portion of Jackson County, leaving glacial till deposited predominantly along the Missouri River valley and in the Buckner-Sibley area.

A large portion of northern Jackson County along the Missouri River is covered in a deep deposit of loess (wind-deposited silt) associated with the Pleistocene glaciation. The thickest deposits are observed along the bluffs of the Missouri River.

Generally, the alluvial deposits on the south side of the Missouri River are thin, between 25-50 ft. thick, and somewhat fine grained with a coarsening sequence of primarily clay, with silt, sand, and some gravel. Alluvial deposits on the north side of the Missouri River are estimated to be approximately 100 ft. deep, and have a more pronounced transition from overlying clay to sand to boulders with depth (Gentile, 2014).

The regional drainage pattern is generally dendritic (United States Department of Agriculture (USDA), 2007). The area is part of the larger Lower-Missouri-Crooked River Watershed (EPA, 2017), and the major stream in this area is the Missouri River. The Site is located on the southern banks of the Missouri River, which flows east-southeasterly past the Site.

The area surrounding the Sibley Station consists of undulating hills that form a series of ridges overlooking the south side of the Missouri River floodplain. The landscape is cut by a series of deeply incised ravines that flow to the north toward the Missouri River. Two ravines drain to the floodplain east and west of the Slag Settling Impoundment. Both ravines begin approximately 4,000 ft. southwest of the Slag Settling Impoundment and extend northeastward to the Missouri River. The ravines start at a surface elevation of approximately 800 ft. [NAVD88] to a base elevation of approximately 720 ft. [NAVD88] at the Missouri River floodplain (USGS, 2014).

APPENDIX B.2

Geologic/Geomorphologic Features Documentation

Portions of Detailed Hydrogeologic Site Characterization Report (AECOM 2017)

Sinkholes in Missouri (MDNR)

Geologic Hazards in Missouri (MDNR, 2015)

GeoSTRAT Database Review

provided in **Figure B.3** in **Appendix B**. The general geologic map of Pennsylvanian bedrock units is provided in Figure **B.4** in **Appendix B**.

A few small faults have been identified in Jackson County (McCourt, 1917). The most noticeable is located in a creek 2.5 miles west of Lee's Summit (approximately 20 miles south of the Site) where the creek crosses between Sections 2 and 11 of Township 47 North, Range 32 West. Just south of this point, the Hertha Limestone member is sharply folded and fractured. The fold axis strikes at north 25° west. A short distance to the north along the Rock Island Railroad, the Bethany Falls and Winterset Limestones are faulted. The fault in this area has a throw of 7 ft., a strike of north 23° west, and a dip of 47° south 67° west. Seismic risk in the area is considered to be low, additional hazard assessment may be referred to in existing DSI documentation for the Site (Shaw, 2008).

Structural contours of the Raytown Limestone identified a syncline in northwest Kansas City with a northwest to southeast orientation (McCourt, 1917). The greatest deformation is 50 ft. with the width ranging from 1 to 2 miles. A series of minor folds near normal to the axis have a deformation of less than 35 ft. and a general strike of north 70° east. Dome-like structures occur where anticlinal axes cross.

Locally, three structural features are noted in the bedrock geology near the Site (Gentile, 2014). They include a west-southeast trending anticline, a complimentary west-southeast trending syncline, and several buried bedrock incised paleovalleys south of the Missouri river. A map showing the general structural features near the Site is included as **Figure B.4** in **Appendix B**.

1.3.3 Hydrogeologic Setting

1.3.3.1 Surface Hydrology

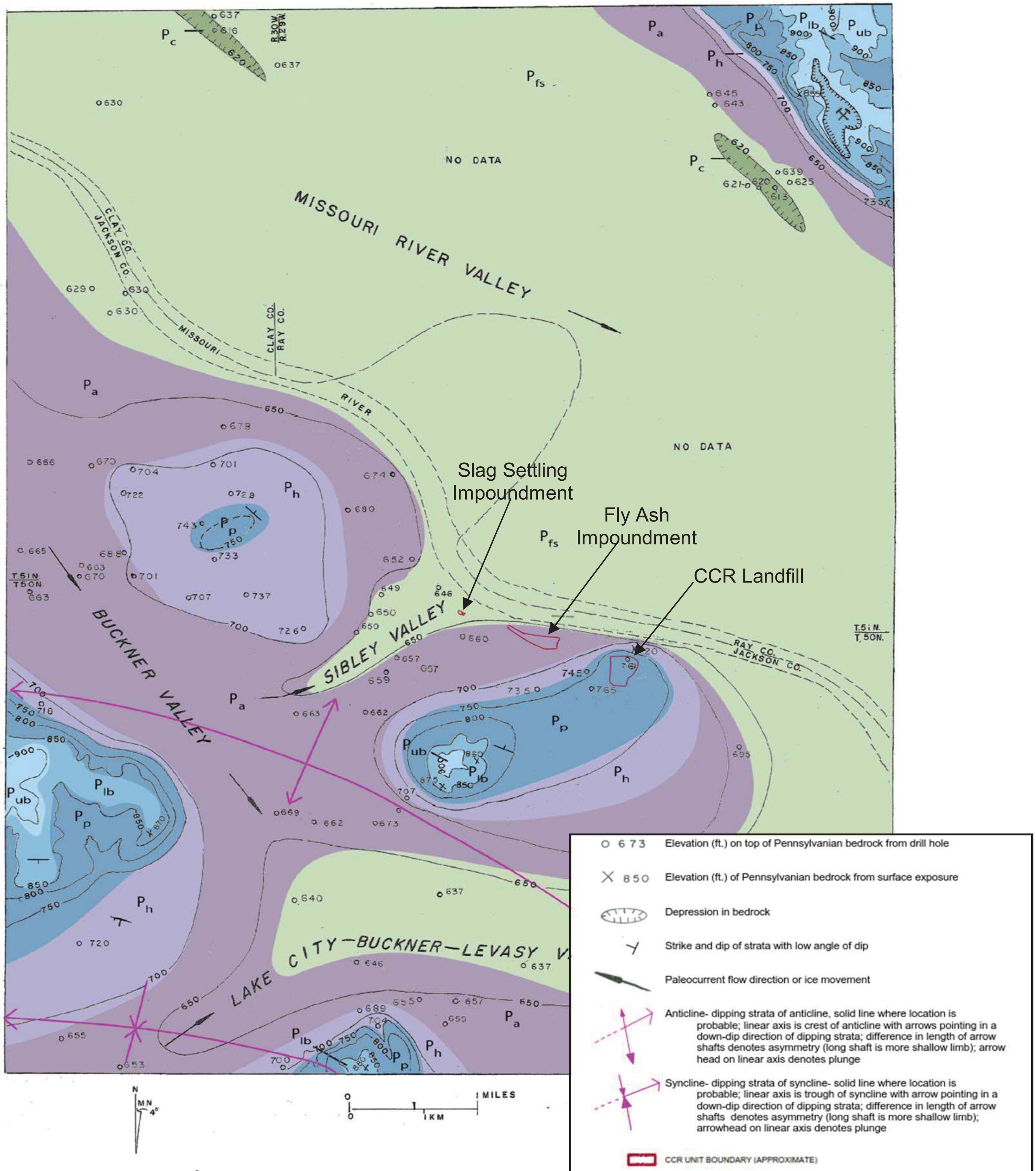
The Slag Settling Impoundment is located near the south bank of the Missouri River. The surface topography around the Slag Settling Impoundment increases to the south. The natural topographic relief is approximately 100 ft. from Walnut Street (800 ft. [NAVD88]) to the southern edge of the Missouri River (700 ft. NAVD88]). In general, the surface water runoff drains north to the Missouri River (USGS, 2014). The primary surface drainage features which receive surface water runoff from the area are the Missouri River to the north or two small intermittent stream valleys mapped east and west of the Sibley Station that drain to the Missouri River, as shown in **Figure A.3** in **Appendix A**. The watershed for the area of the impoundment extends to the southwest to a local high point to the northwest of the intersection of N Buckner Tarsney and E Blue Mills Roads (USGS, 2014).

Appendix A, **Figure A.3** presents a hydrologic map of the area. Major bodies of water, streams, and drainage courses are shown.

1.3.3.2 Subsurface Hydrology

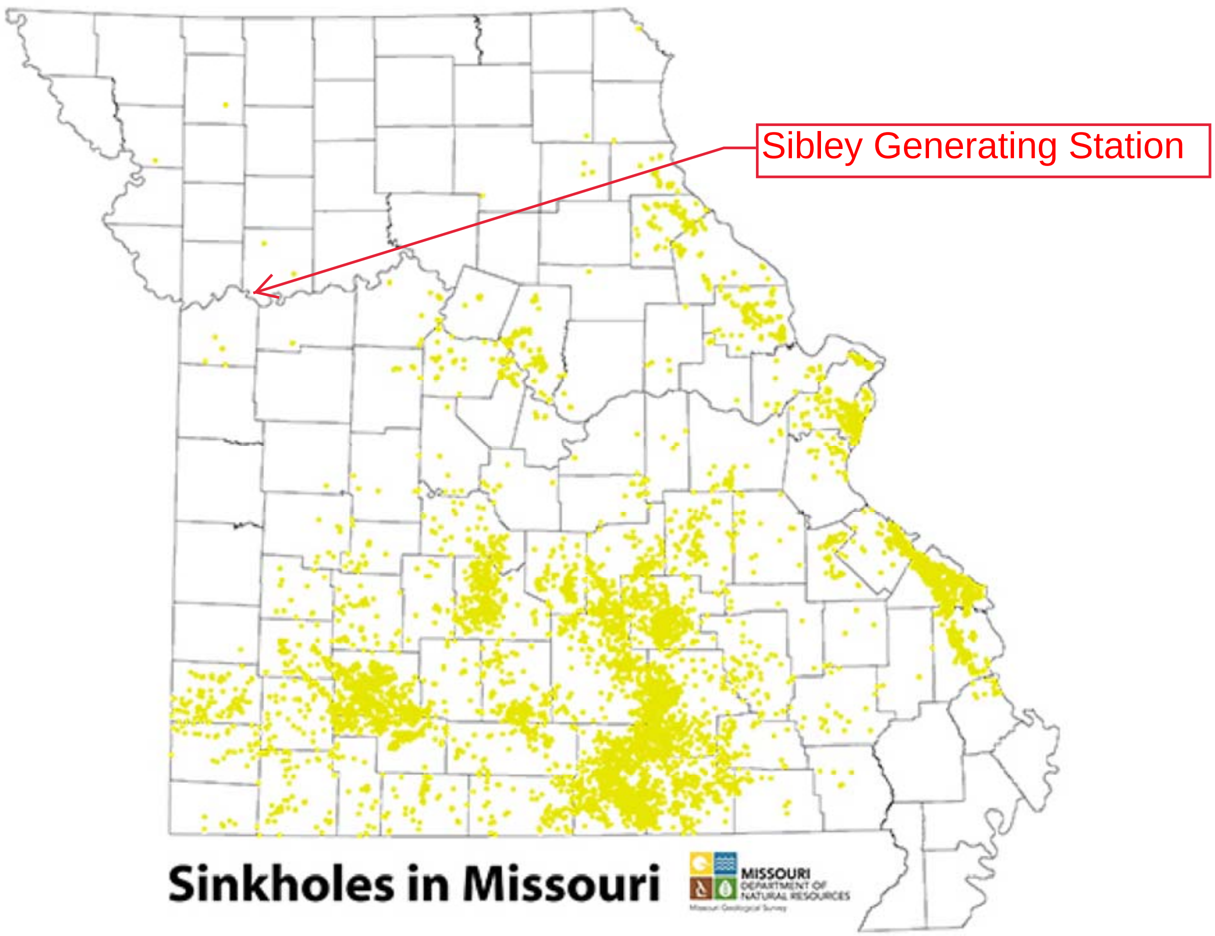
The primary unconsolidated aquifers in northern Jackson County are associated with alluvial and terrace deposits found along the Missouri River, and secondary aquifers are associated with nearby loess and shale residuum. The Missouri River Aquifer consists of alluvial deposits and channel fill varying in size from clay to boulders (USGS, 2003). Small yields may be produced from the loess deposits found along the Missouri River. Most of the remaining portions of the county are covered by low transmissivity residuum derived from weathered shale (Miller, 1997). The unconsolidated material overlying the bedrock in the impoundment area consists of floodplain alluvium, as shown in **Figure B.3** in **Appendix B**.

The bedrock aquifers underlying Jackson County consist of the shales, limestones, and sandstones of Pennsylvanian and older ages. The Pennsylvanian age shales, sandstones, and limestone that underlie the overburden generally have low hydraulic conductivities (Miller, 1997). The groundwater in these beds is typically highly mineralized in much of the area adjacent to the Missouri River. Most of the shales in Jackson County have such low hydraulic conductivities that they do not transmit any significant quantities of groundwater. Typically, the limestones in Jackson County are relatively impermeable and do not transmit any significant quantities of



Source
Geologic Map of the Buckner Quadrangle, Gentile, 2014

AECOM	2380 McGee Street, Suite 200 Kansas City, Missouri 64108	KCP&L Greater Missouri Operations Company DETAILED HYDROGEOLOGIC SITE CHARACTERIZATION	PROJECT NO: **60428461**	DATE: **9/20/2017**
		GEOLOGIC STRUCTURE MAP OF JACKSON COUNTY	CHECKED BY: **BEH**	FIGURE NO. **B.4**


Sibley Generating Station
Sinkholes in Missouri
MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Abandoned Mines

Abandoned mines are found throughout Missouri. They include both surface pits and underground mines. These mines produced a variety of economic, industrial and energy minerals and provided raw materials that helped build Missouri and the nation. Some abandoned mines date back to the original French settlers in the 1700s and are a major part of Missouri's history.

Older mines typically were abandoned and seldom reclaimed or closed. These mines operated long before permitting laws established requirements for reclamation and closure. Today, these pits, voids, open adits and shafts can pose a public safety hazard.

Abandoned mine sites appear attractive to explore, but are unsafe to walk, climb or ride in. What appears to be solid ground may only have a thin veneer of cover hiding an abandoned shaft, which could collapse under the weight of a person walking. Embankments or high walls may be unstable or not visible behind piled material. High walls that appear to be stable can collapse. Piles of waste material called "tailings" or "slime" may be unstable and can slide and bury someone climbing on them. Abandoned quarries or other surface mines often are appealing swimming holes. However, from the surface it is impossible to tell how deep the mine is or if shallow ledges left from mining remain but cannot be seen.

Abandoned underground mines can have poor air quality. Active underground mines are ventilated to bring fresh air to miners. Abandoned mines, however, may have dangerous levels of carbon monoxide or methane.

The Missouri Geological Survey maintains the official Missouri Mine Map Repository and the Inventory of Mines, Occurrences and Prospects (IMOP). The Repository houses more than 2,000 maps of underground mines while the IMOP database contains locations of more than 27,000 surface and underground mines. Learn more at dnr.mo.gov/geology/geosrv/geores/minemaps.htm.

Publications

Geologic maps and other geologic and hydrologic publications are available from the Missouri Geology Store by visiting this website missourigeologystore.com.

Abandoned mine shaft in southwest Missouri.

Geological Survey Program
111 Fairgrounds Road • Rolla, MO 65401
Phone: 573-368-2143 • Fax: 573-368-2111
gspgeol@dnr.mo.gov
dnr.mo.gov/geology/geosrv

MISSOURI DEPARTMENT OF NATURAL RESOURCES
Missouri Geological Survey
PUB2467 9/15

GEOLOGIC HAZARDS in Missouri

Earthquakes
Sinkholes
Landslides
Abandoned Mines

MISSOURI DEPARTMENT OF NATURAL RESOURCES
Missouri Geological Survey

Earthquakes

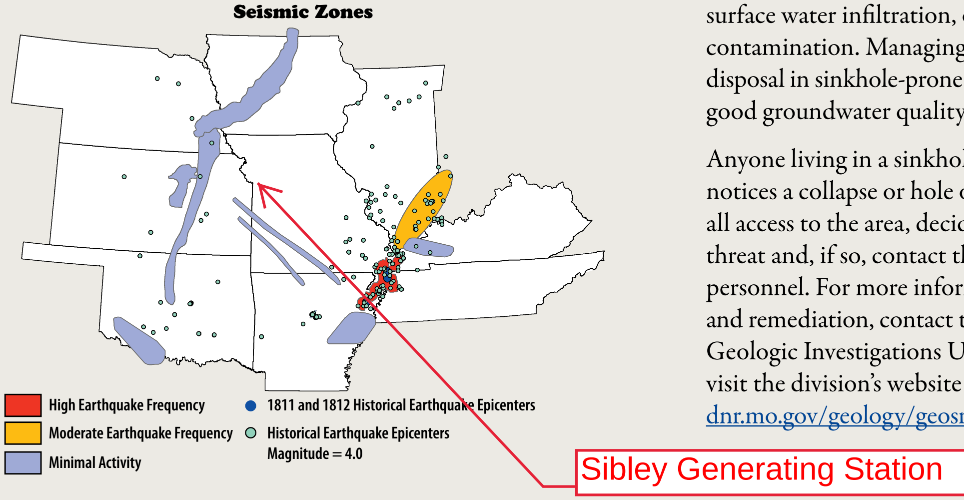
Most Missourians are familiar with the large 1811-1812 earthquakes that occurred in the New Madrid Seismic Zone (NMSZ) in southeast Missouri. However, Missouri experiences small earthquakes nearly every day. These earthquakes typically are too small to be felt but are recorded on seismographs, devices that measure the earth's movement. While these earthquakes are more frequent in the NMSZ in southeast Missouri, they also occur on other faults located in Missouri and surrounding states.

Earthquakes occur when pressure builds up on two sides of a fault. The fault sides slip against one another, shifting the rock and sending waves of motion through the earth. Movement along a fault can occur thousands of feet below ground surface, often with no visible signs of the fault at the surface.

It is impossible to predict when or where an earthquake might occur in Missouri or elsewhere. Based on the history of past earthquakes, U.S. Geological Survey seismologists (earthquake researchers) suggested in 2009 the chance of having a magnitude 7.0 - 8.0 earthquake in the NMSZ in the next 50 years is about 7 to 10 percent. Smaller earthquakes have a greater chance of occurring.

Knowledge and preparation are crucial to earthquake preparedness. Information related to earthquakes and disaster preparedness is available at dnr.mo.gov/geology/geosrv/earthquakes.htm.

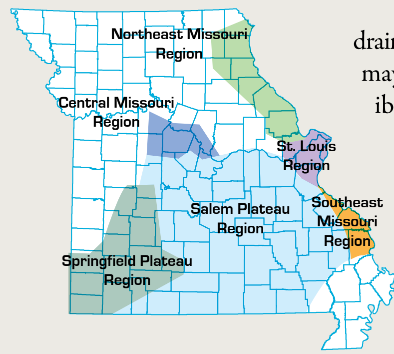
Seismic Zones



Sinkholes

Sinkholes are collapsed areas formed by the dissolution of carbonate bedrock or collapse of underlying caves. They range in size from several square yards to hundreds of acres and may be very shallow or hundreds of feet deep. Often, sinkholes are visible from the ground surface as circular depressions or areas of internal drainage. Other sinkholes may not be readily visible from the ground surface because they are plugged or capped with soil or thin layers of rock.

Primary Sinkhole Regions of Missouri



Development in areas prone to sinkhole formation can be very dangerous. Collapse of the plug or cap can open the underground void to the surface. Sinkholes may start as a small hole in the ground that slowly grows to full size or may form in a sudden catastrophic collapse that occurs with no warning. Collapsed sinkholes generally are steep-sided and very unstable. They often experience continued slumping and collapse along their edges; therefore, activities near sinkholes should be undertaken with great caution.

When sinkholes form, they can act as conduits for rapid surface water infiltration, often resulting in groundwater contamination. Managing storm water runoff and waste disposal in sinkhole-prone areas is important to maintaining good groundwater quality.

Anyone living in a sinkhole-prone area of the state who notices a collapse or hole opening should first block off all access to the area, decide if there is an immediate safety threat and, if so, contact their local emergency management personnel. For more information about sinkhole collapse and remediation, contact the Missouri Geological Survey's Geologic Investigations Unit by calling 573-368-2100 or visit the division's website at dnr.mo.gov/geology/geosrv/geores/geohazhp.htm.

Landslides

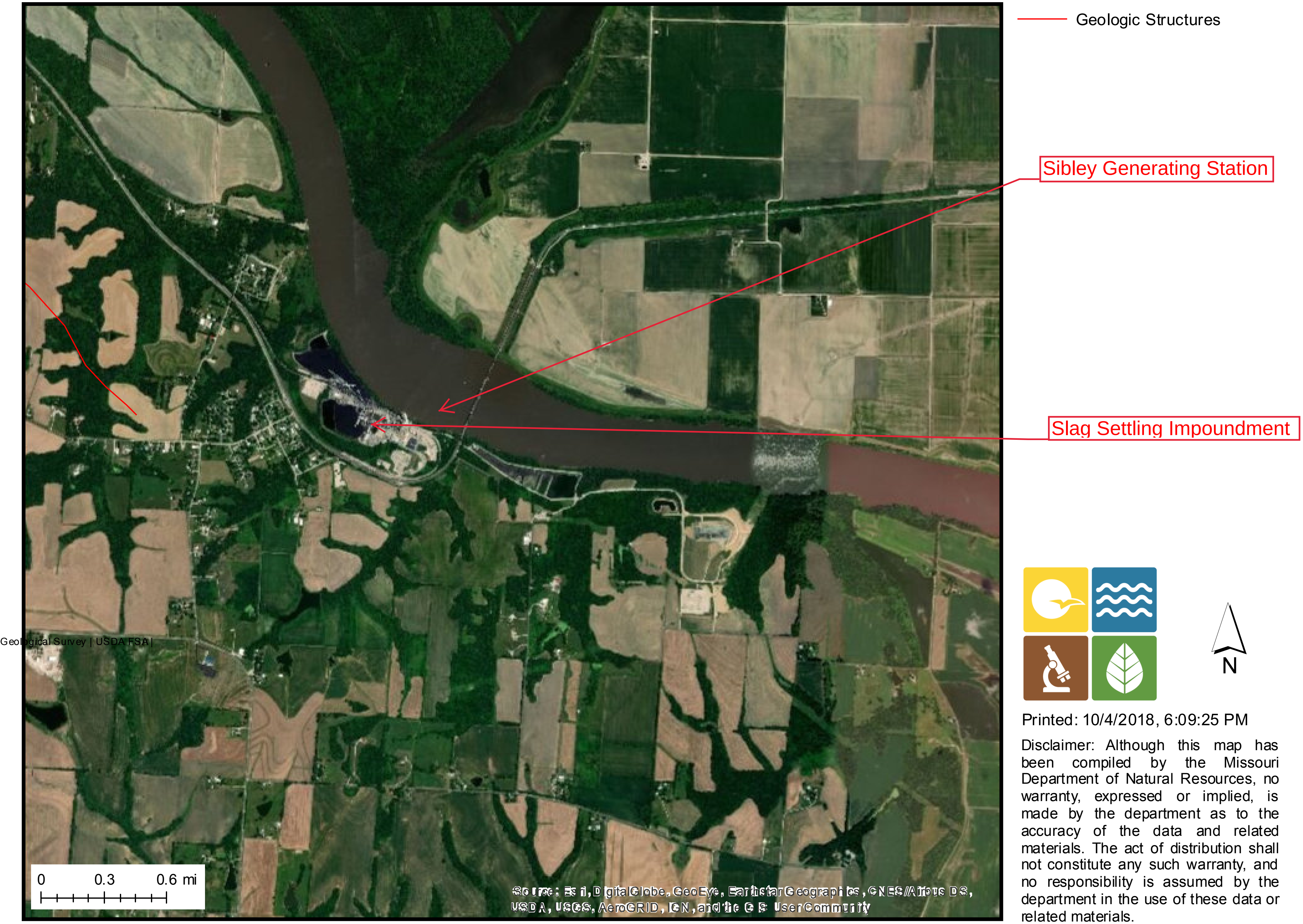
Landslides, slumps and rockfalls are potential geologic hazards throughout Missouri and can occur where there are bluffs or steep slopes. They often can be triggered when surficial materials are moved or modified by man. In general, the higher and steeper the slope, the farther and faster the slide will travel.

Landslides and slumps generally occur where there are steep slopes of unconsolidated material or thick soils. Slopes with shale are also susceptible to landslides. Slumps appear as curved scars along the slope and an uneven or unusually flat surface at the base of slopes. Slope stability often is reduced by change in water tables or when heavy rains oversaturate soils, by the removal of vegetation or by increased human activity. Modification of a slope, such as cutting a road in a hillside, can cause problems, even on slopes that appear stable. Care should be taken when modifying slopes or changing water's natural drainage course.

Rockfalls are common hazards in areas that have bluffs or extremely steep hillsides. The most hazardous are bluffs that contain thick beds of sandstone or carbonate rock underlain by shale. The shale will often become soft and weather out, leaving large pieces of balanced rock. Bluffs of highly fractured rock are also at great risk for rockfalls. As with landslides and slumps, rockfalls are also more likely to occur during times of heavy rains.

Landslide along a Missouri roadway.

Geo STRAT



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APPENDIX B.3

Human-made Features or Events Documentation

Mine Maps – Jackson County (MDNR)

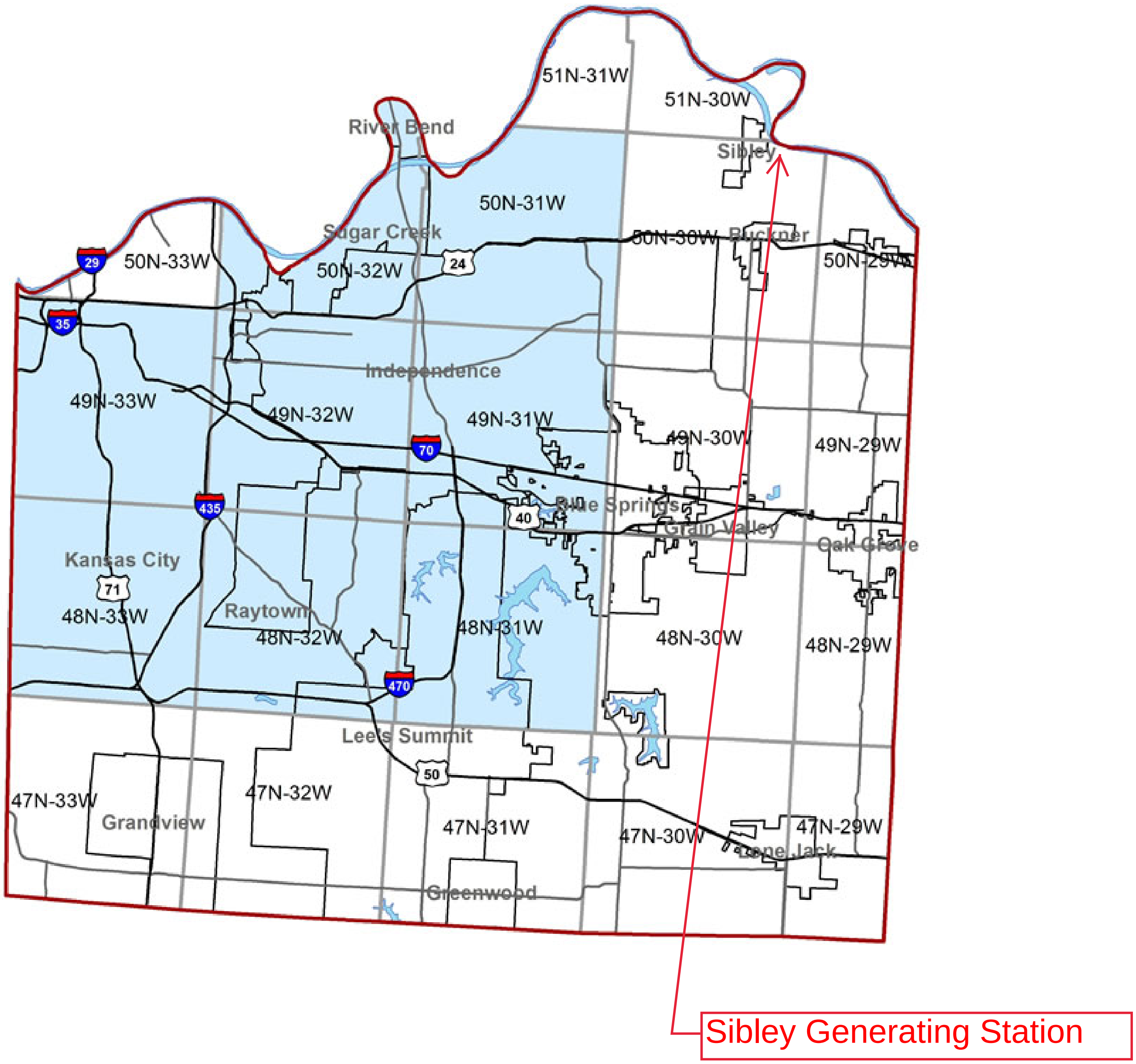
Oil and Gas in Missouri Fact Sheet (MDNR)

Mineral Resources in Missouri (MDNR)

Missouri Coal (MDNR)

Mine Maps -- Jackson County

Blue tint indicates areas where mine maps are presently available. Click on a highlighted area to see a list of maps that are available.

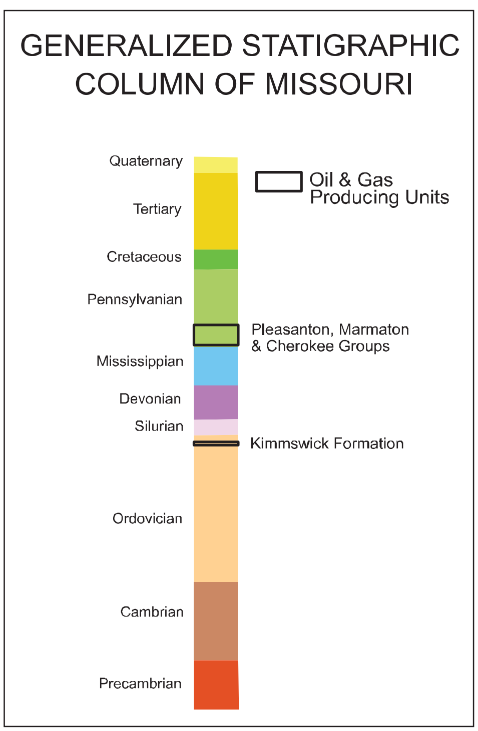


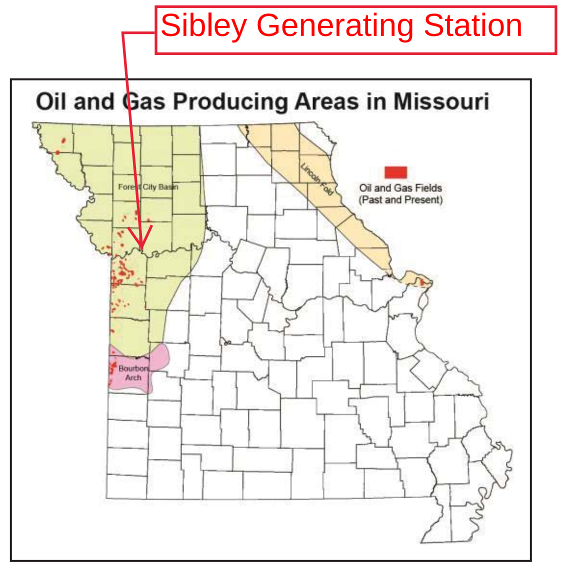
Oil and Gas in Missouri

Missouri Geological Survey fact sheet number 19
Missouri Geological Survey Director: Joe Gillman

Oil and gas are naturally occurring, combustible hydrocarbon substances. Oil is also called petroleum or crude oil. Gas is also known as natural gas. Oil is a very complex mixture of hydrocarbon liquids, whereas gas is simply methane gas that contains small to trace amounts of other gasses, including: ethane, propane, butane, nitrogen, carbon dioxide and helium. Varying amounts of gas are dissolved in most oils.

Oils are classified as light, intermediate and heavy based on their consistency at room temperature. Light oils are thin and flow readily like water or paint thinner. Their color ranges from pale yellow to nearly colorless. Intermediate oils have a syrupy consistency, with colors ranging from green to black. Heavy oils are thick and flow like molasses or not at all. Their color usually is black. The majority of Missouri's oil is in the intermediate to heavy range.





Oil and gas are both classified as sweet or sour, based on the amount of sulfur content. Sweet oil and gas have little or no sulfur and are considered high quality. Sour oil and gas contain undesirable amounts of sulfur, usually in the form of hydrogen sulfide, which smells like rotten eggs. Missouri's oil and gas deposits are considered to be sweet.

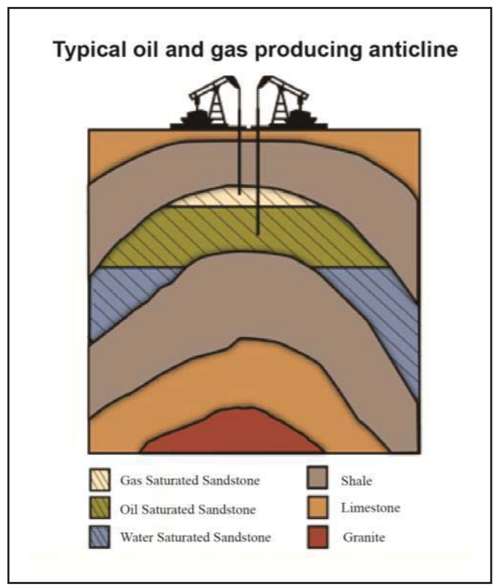
Oil and gas forms from the burial and thermal alteration of shale or mudstone containing abundant organic material from dead marine organisms. Tiny amounts of oil and gas are produced in the shale or mudstone. Under certain geologic conditions, oil and gas migrate and accumulate into pools. The pools typically are located in porous strata such as sandstones, conglomerates or fractured limestones and dolomites. These pools are trapped in the reservoir strata by impervious layers of shale within a geologic structure such as an anticline.

In Missouri, the first oil and gas wells were drilled in the Kansas City area shortly after the Civil War in the 1860s. Hundreds of shallow wells were drilled in western Missouri along the Kansas border during the late 1800s and early 1900s. Many of these wells produced gas used in private homes, farmsteads and small towns.

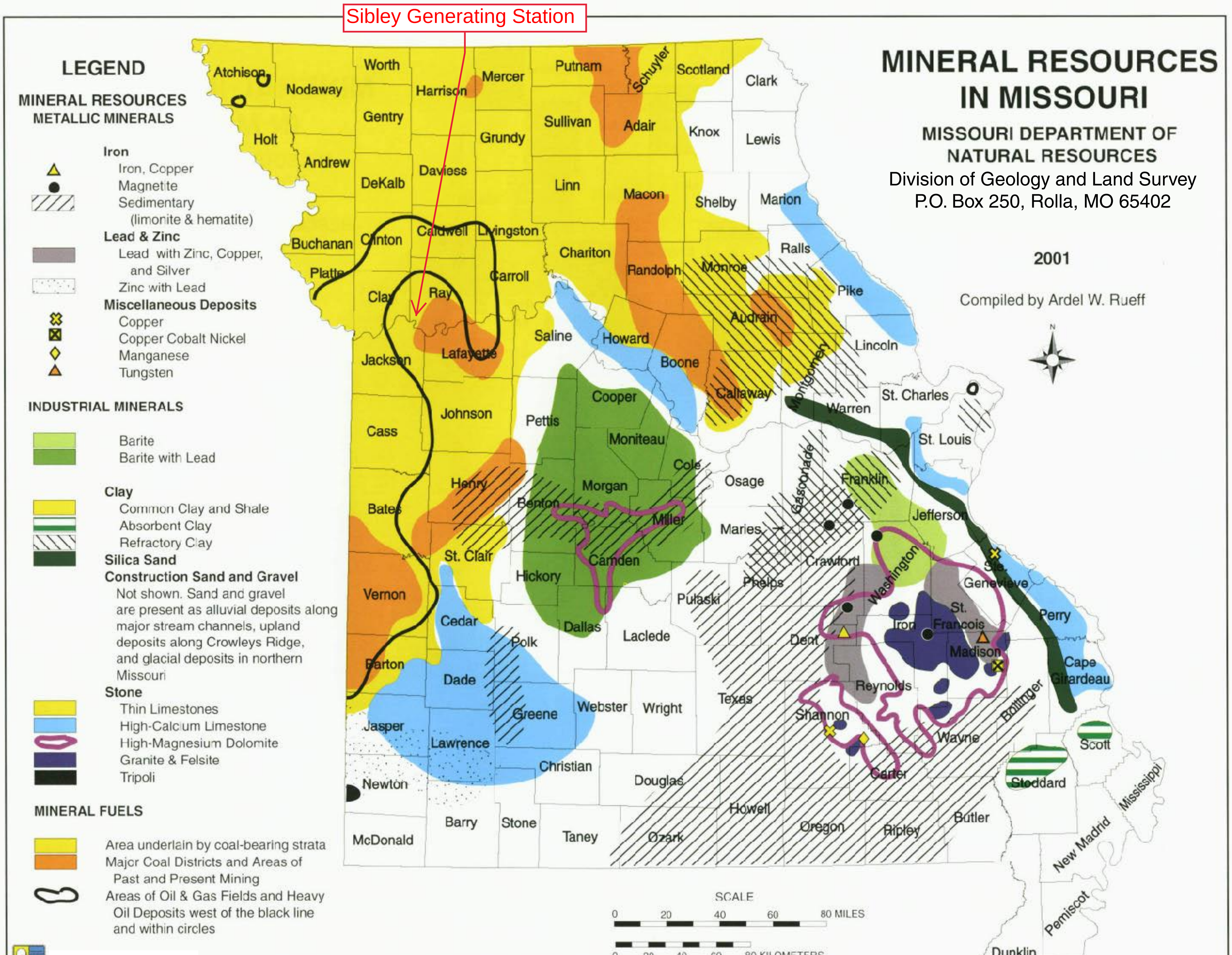
Due to the success of these wells, additional sites were explored in central and eastern Missouri. By the early 1930s, more than 2,500 wells had been drilled in search of oil and gas resources. Additional pools were discovered in Vernon County in the 1920s, Caldwell County in 1940, Atchison County in 1942, Clinton County in 1952 and St. Louis County in 1953. Missouri's newest field along the Holt and Atchison county border was discovered in 1987.

There are three areas of current oil and gas production in the state: the Forest City Basin in northwestern Missouri, the Bourbon Arch in western Missouri and the Lincoln Fold in northeastern Missouri. Within these fields, oil and gas production comes from two producing zones: the Pennsylvanian-age Pleasanton, Marmaton and Cherokee groups and the Ordovician-age Kimmswick Formation. The depth of production in the Cherokee Group ranges from less than 200 feet in the Eastern field of Vernon County to more than 1,500 feet in the Tarkio Field in Atchison County. Production in the Kimmswick Formation ranges from 1,200 feet in the Florissant Dome in St. Louis County to more than 2,800 feet in the Runamuck Field in Atchison County.

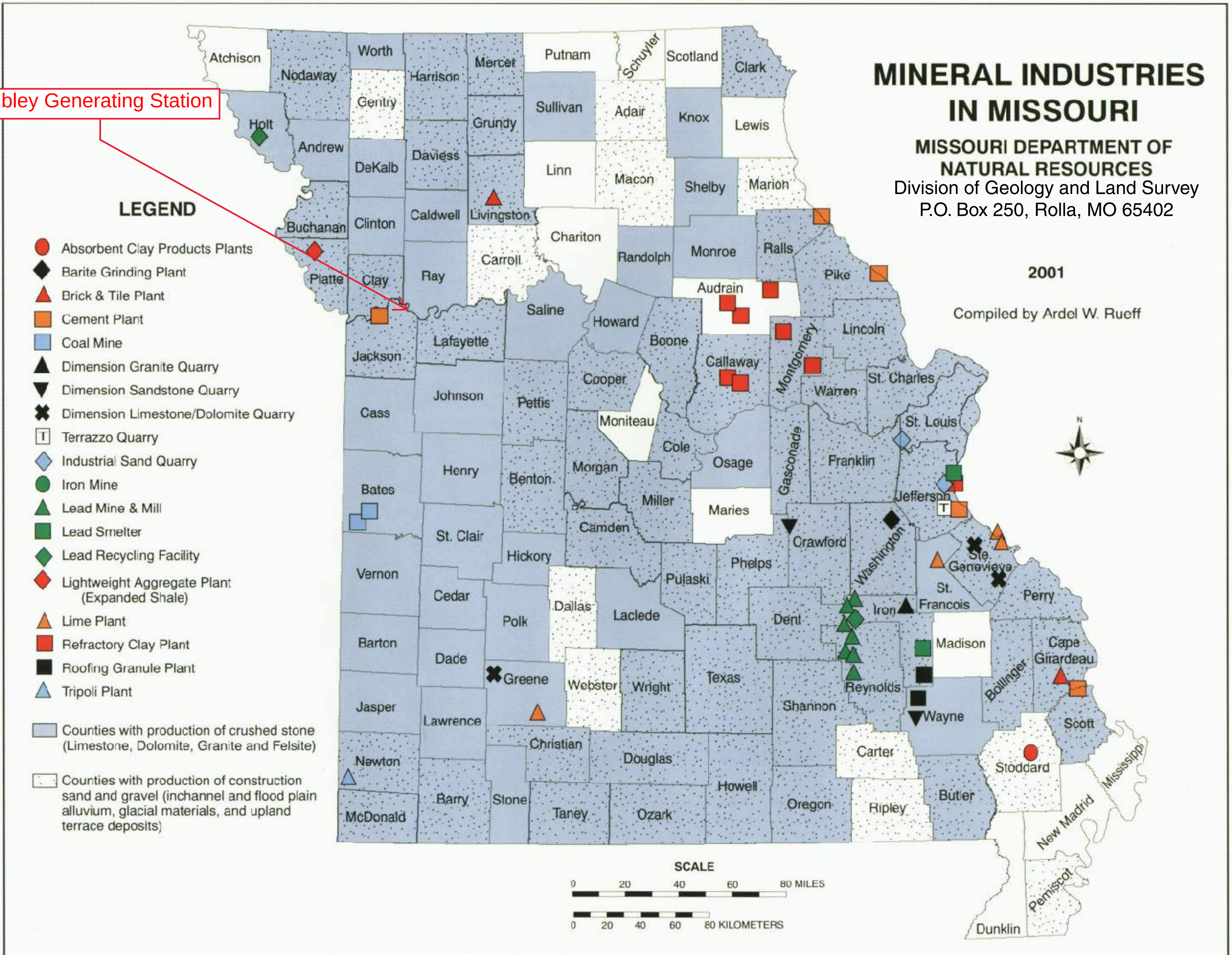
Producing intervals in the Pennsylvanian come from sandstones and black shales. The Ordovician Kimmswick is a fractured limestone. The structures most commonly associated with oil and gas production are anticlines (or elongated domes) and typically do not extend for more than one-quarter mile. In 2006, Missouri produced nearly 90,000 barrels of oil from 323 wells in five counties (Atchison, Cass, Jackson, St. Louis and Vernon). This oil was worth approximately $4.87 million. While there is currently no gas pro-duced for commercial sale in the state, gas was produced for private use from 45 registered wells. Additionally, two large wells produced gas for a private company.



The Missouri Geological Survey has a number of publications about petroleum production and exploration including: OFR-90-80-OG, *Heavy-Oil Resource Potential of Southwest Missouri*; RI-1, *Recent Drilling in Northwestern Missouri*; V-27, *The Oil and Gas Resources of Cass and Jackson Counties Missouri*; OFM-81-54-OG, *Oil and Gas Fields of Missouri*, as well as maps and other publications. Some are historical documents written in the early 1900s.



DNR/DGLS Fact Sheet No. 3


MINERAL INDUSTRIES IN MISSOURI
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Division of Geology and Land Survey
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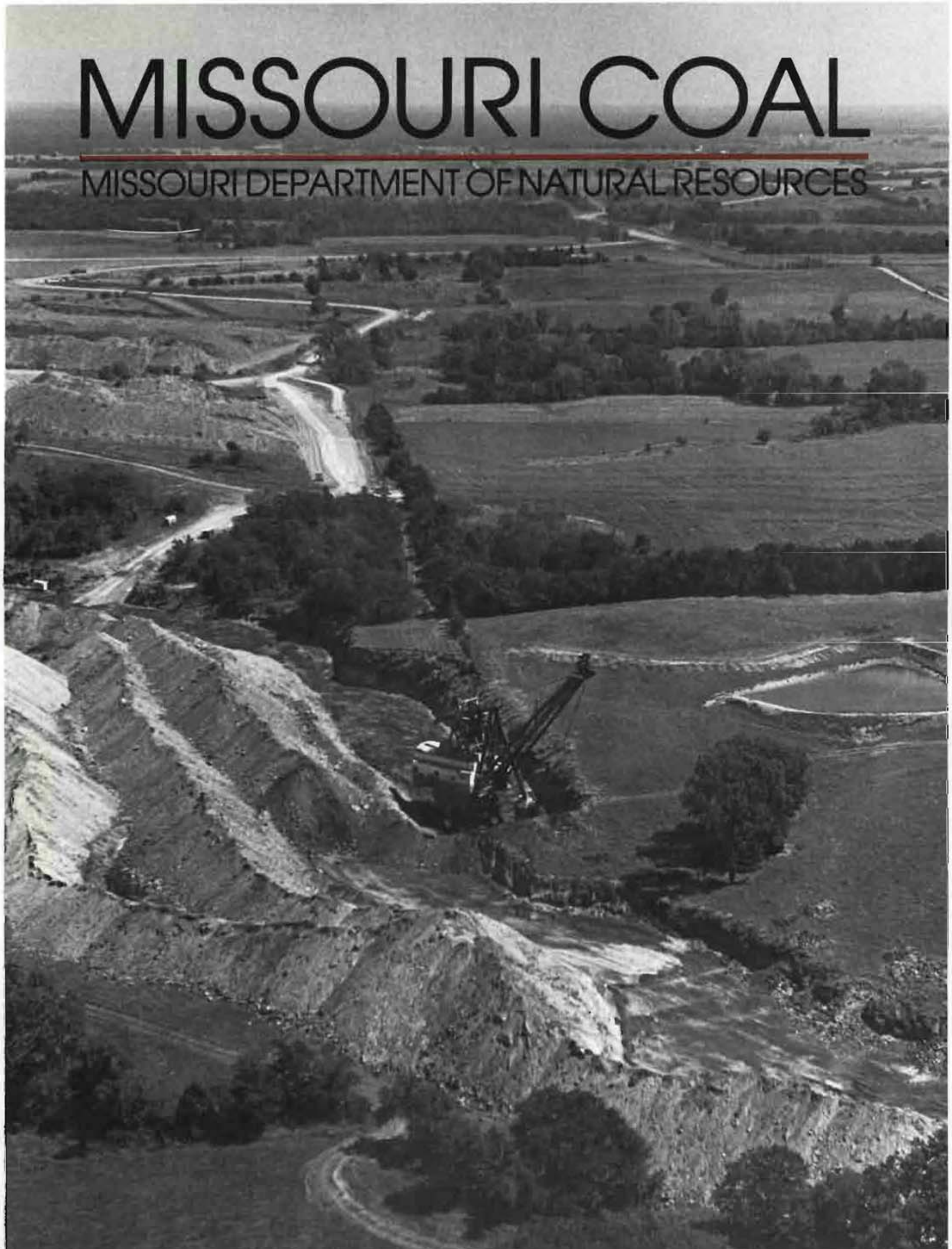
Sibley Generating Station
LEGEND
Absorbent Clay Products Plants
Barite Grinding Plant
Brick & Tile Plant
Cement Plant
Coal Mine
Dimension Granite Quarry
Dimension Sandstone Quarry
Dimension Limestone/Dolomite Quarry
Terrazzo Quarry
Industrial Sand Quarry
Iron Mine
Lead Mine & Mill
Lead Smelter
Lead Recycling Facility
Lightweight Aggregate Plant (Expanded Shale)
Lime Plant
Refractory Clay Plant
Roofing Granule Plant
Tripoli Plant
Counties with production of crushed stone (Limestone, Dolomite, Granite and Felsite)
Counties with production of construction sand and gravel (inchannel and flood plain alluvium, glacial materials, and upland terrace deposits)
SCALE
0 20 40 60 80 MILES
0 20 40 60 80 KILOMETERS
N
Atchison
Nodaway
Worth
Harrison
Mercer
Putnam
Schuyler
Scotland
Clark
Holt
Gentry
Grundy
Sullivan
Adair
Knox
Lewis
Andrew
DeKalb
Daviess
Linn
Macon
Shelby
Marion
Buchanan
Clinton
Caldwell
Livingston
Chariton
Randolph
Monroe
Ralls
Platte
Clay
Ray
Carroll
Audrain
Pike
Saline
Howard
Boone
Lincoln
Jackson
Lafayette
Callaway
Montgomery
St. Charles
Warren
Cooper
Johnson
Pettis
Moniteau
Cass
St. Louis
Cole
Osage
Gasconade
Franklin
Henry
Benton
Morgan
Bates
Miller
Maries
Jefferson
Camden
Crawford
St. Clair
Hickory
Washington
Ste. Genevieve
Vernon
Pulaski
Phelps
Cedar
Dallas
Laclede
St. Francois
Perry
Polk
Dent
Iron
Madison
Barton
Dade
Cape Girardeau
Greene
Webster
Wright
Texas
Bollinger
Reynolds
Shannon
Jasper
Lawrence
Wayne
Scott
Christian
Carter
Douglas
Newton
Howell
Stoddard
Mississippi
Barry
Stone
Taney
Ozark
Oregon
Ripley
Butler
McDonald
New Madrid
Pemiscot
Dunklin

MISSOURI COAL

MISSOURI DEPARTMENT OF NATURAL RESOURCES



INTRODUCTION

Coal, sometimes nicknamed "the rock that burns," is a product of nature's continual growth and decay.

Although not a true coal, peat is considered to be its first stage of development. Further stages of development are the soft coals lignite, or brown coal; subbituminous coal; bituminous coal; and finally, anthracite, or hard coal.

The coal we use now is as much as 300 million years old, formed in an era when lush vegetation and steamy, tropical conditions existed over much of the world. As plants and animals died, the biomass accumulated in layers, eventually forming beds of peat.

Through the centuries, prehistoric seas alternately advanced and receded, depositing layers of sediment on the peat. The sediment accumulated and the earth's crust shifted, compressing the peat, squeezing out its moisture, and burying it deeper and deeper.

Heat generated by the tremendous pressure on the buried beds drove out most of the oxygen and hydrogen, leaving a residue of impure carbon — coal.

Peat continues to form in places like the Dismal Swamp in North Carolina and Virginia. However, it takes 36 feet of peat to form three feet of bituminous coal, in a process much slower than the rate at which we use it.

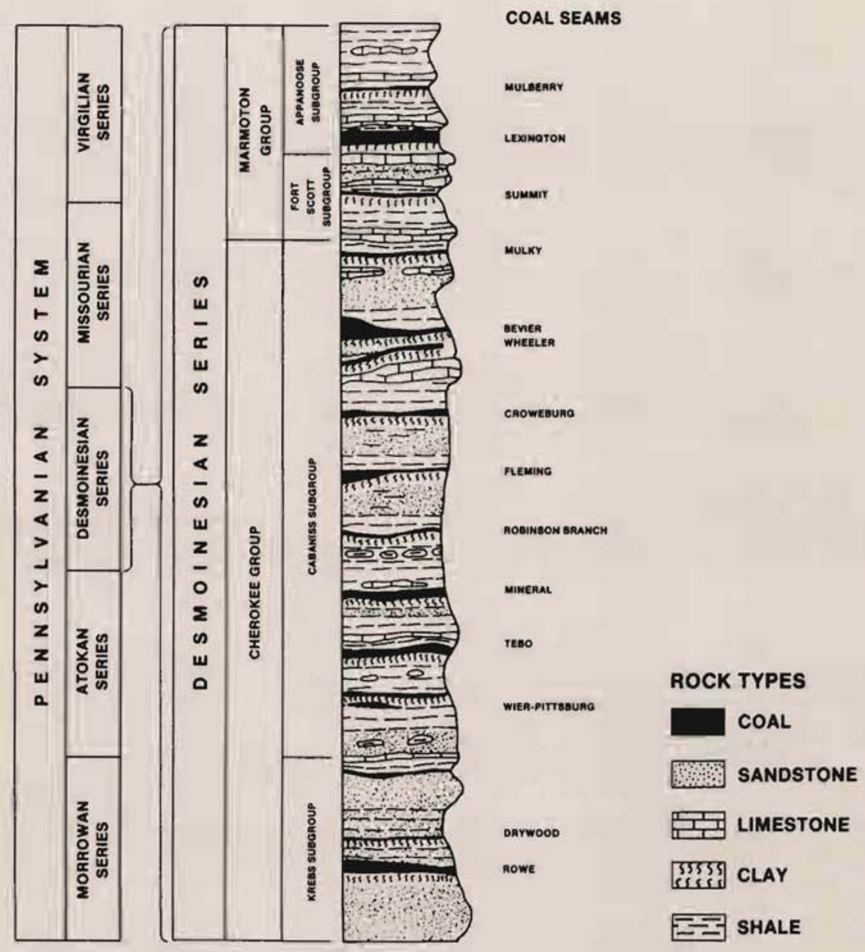
COAL QUALITY

The description of coal includes its stage of development and its quality. Quality refers to the desirability of coal for use as a fuel or for producing other commodities.

Coal quality includes such factors as ash content, sulfur content, and heat value. In fact, the principal value of coal is in the amount of heat it can generate, a factor directly related to stage of development. Heat value is measured in British Thermal Units, or BTUs. One BTU is the energy necessary to raise the temperature of one pound (one pint) of water one degree Fahrenheit.

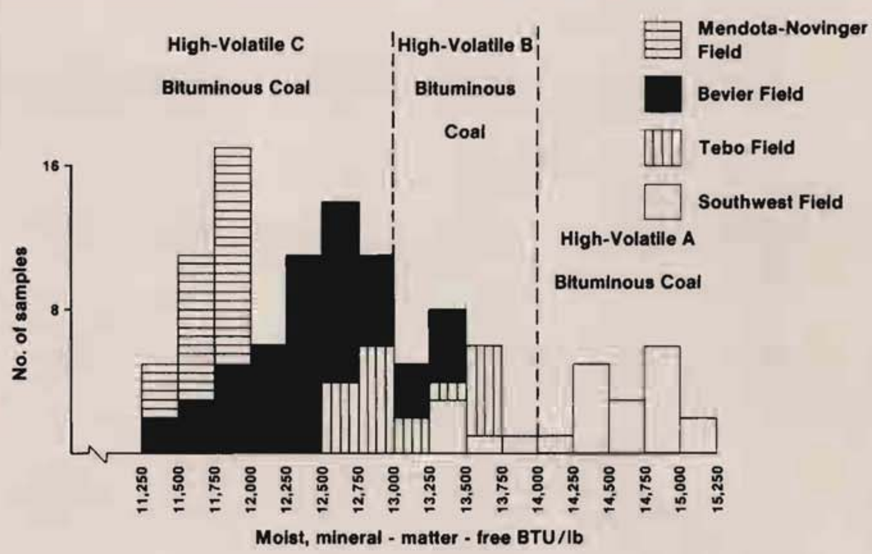
The stage of development, or rank, of coal is partly determined by the heat value of moist, mineral-matter-free coal samples. Heat values of Missouri coal

Cover: Coal mining in western Missouri



PRINCIPAL COAL SEAMS OF MISSOURI AND THEIR ASSOCIATED ROCK STRATA

The coal seams are shown in an idealized column in order of age, from the oldest at the bottom to the youngest at the top.



DISTRIBUTION OF MOIST, MINERAL-MATTER-FREE BTU/LB IN COAL SAMPLES FROM THE MENDOTA-NOVINGER, BEVIER, TEBO, AND SOUTHWEST FIELDS, MISSOURI

range from 11,250 BTUs per pound to 15,250 BTUs per pound. Missouri coal is classified by rank as high-volatile A, B, and C bituminous.

All but a small fraction of Missouri coal has a high sulfur content. More than one-half of the state's coal reserves contain 4 percent to 5 percent sulfur; one-fourth contains 3 percent to 4 percent; a small fraction contains less than 3 percent; and the remainder contains more than 5 percent sulfur.

The heat value of Missouri coal on an as-received basis ranges from just over 10,000 BTUs per pound to 12,500 BTUs per pound, with an average of 11,016 BTUs per pound. The moisture content averages 11.1 percent; the ash content, 11.5 percent. These qualities make Missouri coal a good fuel for heating boilers in steam electric-generating plants.

COAL IN MISSOURI

Coal-bearing strata underlie an estimated 24,000 square miles of northern and western Missouri, about 35 percent of the state's surface area. It occurs in seams or beds over large areas called coal fields. Coal seams currently mined are 12 to 42 inches thick. They are named for geographic features at or near where they typically occur. For example, the Drywood seam is named for Drywood Creek in Barton County, where the seam is exposed along its banks. Broader classifications of seams are based on world-wide standards derived from such factors as how readily identifiable the seams are and how long ago they were deposited. Fields usually are named for a principal coal seam mined in the area or for a nearby mining town. The Bevier field, for example, was named for a town of the same name in Macon County.

The Bevier field currently is the most productive in Missouri. It underlies several counties, but about 60 percent of the state's total annual production is mined in Howard and Randolph counties. The Bevier-Wheeler is the principal seam mined; the Summit, Mulky and Croweburg seams are lesser producers. At present, the second-largest producing coal field in the state is the Southwest field, which yields 24 percent of the state's annual coal production. Seams currently mined are the Mulberry in Bates County; the Mineral and Croweburg seams in Vernon County; and the Rowe and Drywood seams in Barton County.

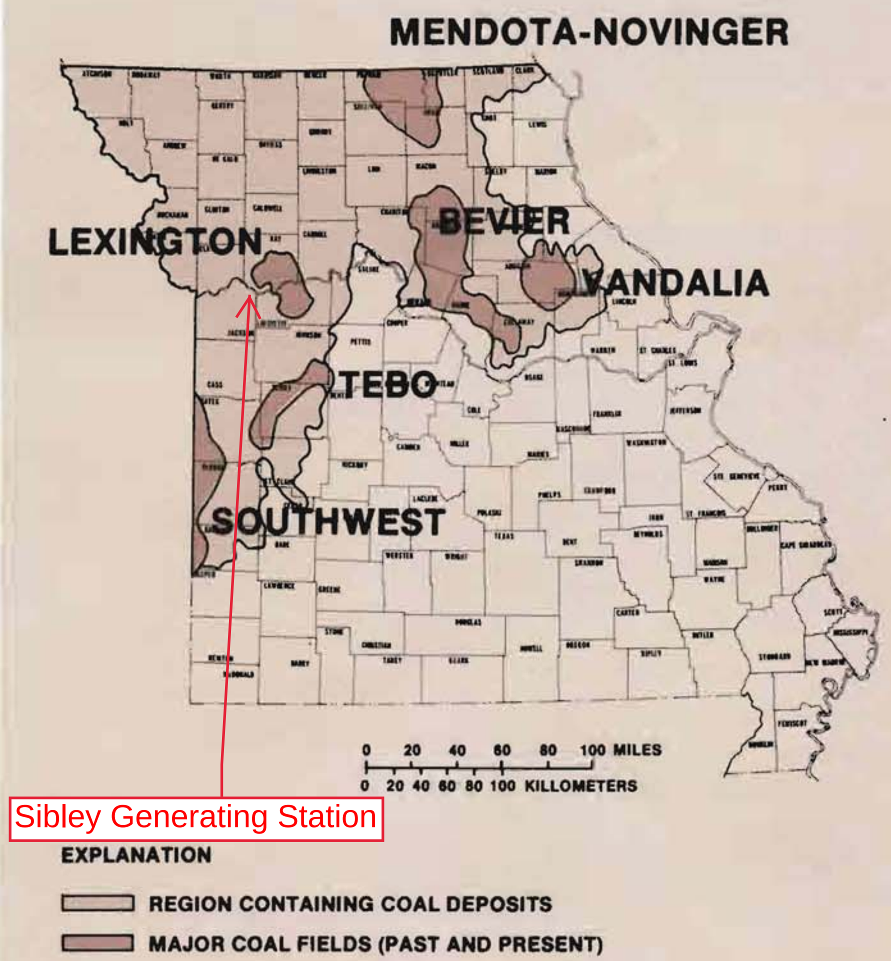
The Tebo field was the largest producing area in the state before mining activity increased in the Bevier field in the late 1970s. Current production from the Tebo field constitutes 10 percent of the state's annual coal production. Most of the coal produced in the region is mined from the Tebo seam. Small amounts are recovered from the Weir-Pittsburg seam.

The Mendota-Novinger and Vandalia coal fields yield less than 3 percent of the state's annual coal production. The Lexington and Mulky seams are the only seams currently being mined in those two fields.

The Lexington coal field is inactive at present, although it was an important producer in the past. The Lexington was the only seam mined, and recovery was primarily by underground methods.

COAL MINING IN MISSOURI

Missouri was the first state west of the Mississippi River to produce coal commercially. In 1806, Captain Zebulon Pike observed coal in bluffs along the Osage River, south of the present site of Prairie City in Bates County. "Black diamond" was mined from such outcrops by digging



PRINCIPAL COAL FIELDS OF MISSOURI

James Brothers Mine at Bevier, Missouri (circa 1911). The horse hoisted coal and supplies up the mine shaft, which is covered by the sheds. The mine car in the right foreground was used underground to haul coal from the working face to the main shaft.

drift mines as far into the hillside as good ventilation would allow, usually only a few hundred feet. Despite difficulties, coal mining had become a thriving enterprise by 1880.

Most early coal mines in Missouri were underground. Interest in strip mining developed in the mid-1930s, and by the late 1960s, it was the only method used. It is a simpler process and is cheaper in lives and dollars.

In early strip mining, horse-drawn scrapers moved the soil and shale, or overburden, covering the coal, beyond the outcropping. Only a few tons of coal could be mined, because the coal seams extended under thicker and thicker overburden that eventually was impossible to remove.

Today, mines use enormous electric shovels and draglines that can remove more than 100 feet of overburden. After topsoil removal, overburden is taken up in strips that may be more than a mile long, and the coal is mined by scrapers and dozers.The overburden is then removed from a second parallel strip and dumped into the first mined area. The process is continued as the machine moves slowly across the terrain, alternately removing overburden and mining coal. At the same time, reclamation begins on land already mined.

Missouri ranks 19th among the 27 states that produce bituminous coal. Currently, 14 surface mines in the state produce coal. In 1984, they produced almost seven million tons of it — a new state record and a dramatic increase from the mere 9,972 tons of coal mined in 1840.

ECONOMICS OF MINING COAL

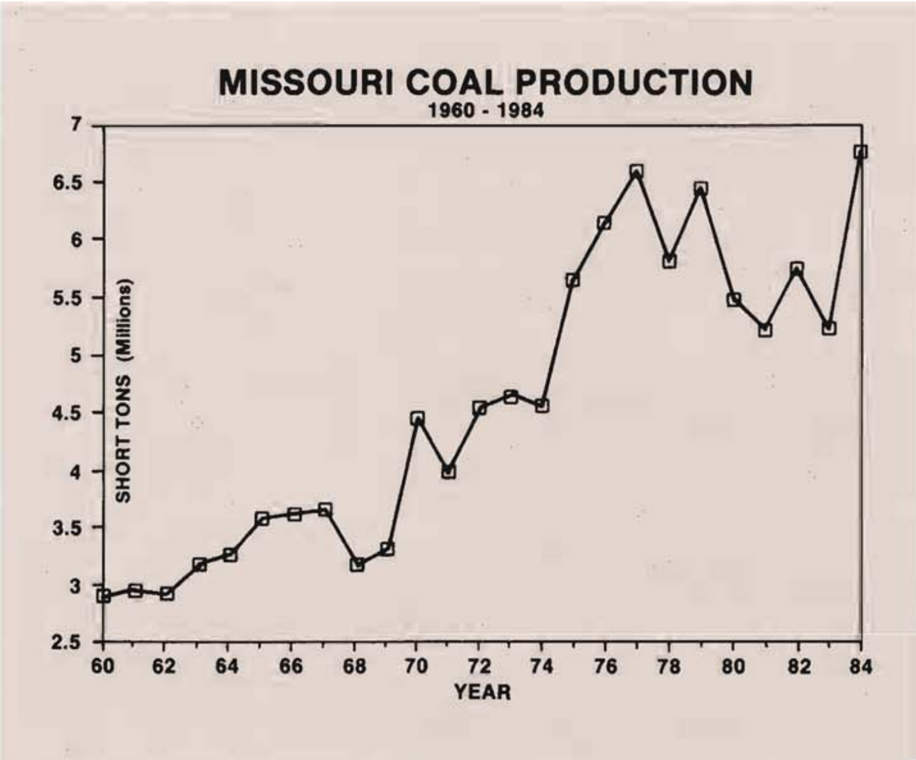
The 6,810,336 tons of coal mined in 1984 was valued at more than $170 million. That was an average price of $25 per ton received at the mine, a price that had changed little from the previous three years.

In 1984, Missouri's coal industry employed 1,217 miners, who earned about $35 million. These salaries generated additional revenue of more than $64 million in business, industry, and taxes. For every two miners employed, another job was created in support services.

The coal industry is subject to the same laws of supply and demand as are other industries. For example, when cheap natural gas and petroleum began flooding the market in the mid-1940s, demand for coal as locomotive and heating fuel declined until production reached a low of 2.5 million tons in 1958.

Energy-tax credits for coal users and the oil price hikes of 1979-80 also encouraged increased interest in coal, as did the realization that dependence on foreign oil supplies provides a shaky foundation for the American economy.

At present, coal is significantly cheaper than crude oil and natural gas. In 1983,



for example, $1.17 bought one million BTUs of coal, but we paid $4.51 for crude oil and $2.32 for natural gas having an equivalent heat value.

The cost of mining coal is about 30 percent of the total cost of using it. Prospecting, acquiring coal-bearing land, mining and processing equipment, mine development, and production are all factors that determine the initial price.

The ultimate cost of coal to users involves many other factors. Land reclamation expenses, for example, also must be considered; they depend on such factors as the thickness of the coal seam mined and the quality of the land disturbed.

Because transportation expenses add as much as 25 percent to the price of coal in Missouri, power plants located at the mine (mine-mouth plants) are significantly more economical to operate. In 1970, for example, the price of coal at the three mine-mouth plants in Missouri averaged $4.07 per ton, $1.27 less per ton than the average price statewide.

Cost of coal-burning equipment and of power-plant operation and maintenance, including pollution control and waste disposal, also affect the cost of coal to users, as does the quality of coal — high sulfur content, for example, means extra expenses for emissions-control equipment.

All these factors must be weighed in deciding the coal source to use. Missouri's coal must compete with coal from other areas. For example, power plants in the St. Louis metropolitan area use Illinois coal because the Missouri coal fields are farther away, in the northern and western parts of the state.

HOW MISSOURI COAL IS USED

During the 1800s, coal was used to fuel steam locomotives. It also heated homes and commercial buildings, gradually replacing wood as the primary heat source.

In the 1940s, petroleum and natural gas usurped coal as a fuel, but with construction of electric-generating utility plants in the 1950s came the increased need for coal to fire them. That need encouraged development of strip mining as a quick method of coal recovery.

Almost all Missouri coal is used by electric utilities in Missouri, Kansas, and Iowa. A small amount, about 3 percent, is used for manufacturing and for direct space heating.

In 1983, the coal that Missouri produced and used accounted for about 40 percent of the state's fuel needs. Missouri's reliance on coal was almost 18 percent higher than the national average. Natural gas supplied 19.3 percent of Missouri's energy, petroleum 41.2 percent, and hydroelectric power 1.2 percent.

Almost half the coal produced in the state is used by four electric utilities at mine-mouth sites: Thomas Hill Power Plant near Moberly, Asbury Power Plant north of Joplin, Montrose Power Plant near Clinton, and LaCygne Power Plant at LaCygne, Kan.

EFFECTS OF MINING AND USING COAL

Missouri's coal mining industry contributes substantially to the state's economy, particularly to that of the mining areas. In fact, many such areas are economically dependent on mining.

Reclamation of previously mined lands can improve recreation potential by creating lakes or improving wildlife habitats. It also can increase farming potential by recontouring the land, making it more accessible to farming equipment, or less subject to erosion caused by improper farming methods on steep, hilly land.

Uncontrolled mining damages the environment, and uncontrolled burning of coal produces serious side effects, notably air pollution from sulfur dioxide, nitrous oxide, and other contaminants. In the past, such side effects were taken for granted as the price of using coal.

During the 1960s, however, the nation became aware of the deterioration of our environment, resulting from misuse of our resources, including coal. Several remedial federal and state laws were enacted.

The federal Clean Air Act of 1965 and its amendments in 1970 and 1977 established the foundation for our air pollution control program. Federal and state regulations now limit the amount of sulfur and other pollutants that may be emitted during coal burning.

The 1965 Water Quality Act and the 1972 Water Pollution Control Act provided a means to restore the nation's lakes and rivers to good condition, and to protect them from further dumping or leaching of wastes.

Missouri has always had good water, but in 1973 the state enacted the Missouri Clean Water Law "to conserve the waters of the state and to protect, maintain, and improve the quality thereof."

The Missouri Land Reclamation Law of 1972 and amendments of 1978 require surface-mining companies in the state to return land disturbed by their activities to pre-mining stability. They must post a performance bond pledging to return the land to productive use.

The laws limit the amount of sediment and other substances allowed in drainage from mined lands. They also establish procedures for monitoring the quality of all water, including runoff, that mining may affect. Mining companies also must remove and save topsoil so that it can be replaced during reclamation, before new vegetation is planted.

About 67,000 acres in the state were mined before 1971 and are therefore unaffected by these regulations.

Much of the land has recovered through natural processes to become valuable fish and wildlife habitat. About 14,000 barren acres, however, continue to cause environmental problems; such areas left unmended leach acids into nearby streams, polluting the water and killing aquatic wildlife. The terrain of these abandoned mines is often ugly and unusable.

The federal Surface Mining Control and Reclamation Act, enacted in 1977, provides not only nationwide regulation of companies currently mining coal but also a means of restoring the productivity of abandoned, unrestored areas. This legislation requires mining companies to pay 35 cents per ton on all surface-mined coal, a fee that is used to fund reclamation of abandoned mined areas.

FUTURE OF COAL IN MISSOURI

Missouri has sufficient proven coal reserves to support a potential annual production of 28 million tons for 30 years. To realize this level of production, it would be necessary to secure new markets for Missouri coal and to expand existing markets.

Technologies being developed to reduce the sulfur content of coal hold promise for increased use of Missouri coal. They include advanced chemical cleaning of coal before combustion, and coal gasification, the conversion of coal to low- and medium-BTU gas.

Development of fluidized-bed combustion units for boilers in industry and for small electric power plants also may be a solution. These units remove sulfur during combustion.

Advanced levels of coal production will depend on the ultimate cost of large-scale operation of these new technologies. Meanwhile, current markets for Missouri coal will continue to exist. Demand for Missouri coal is influenced most strongly by the demand for electricity in Missouri, Kansas, and Iowa a demand that is slowly but steadily increasing.

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