

LOCATION RESTRICTIONS DEMONSTRATION REPORT CCR LANDFILL

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 CCR Landfill (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 landfill, 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 3 and completed site visit(s) to develop this report. This document provides demonstrations that documents if the Unit is located:

- in an unstable area (40 CFR §257.64).

The applicable CCR Rule requirement for the above is listed in Section 2 in italics followed by an explanation of the review and determinations completed by SCS.

2 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:*

2.1 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, CCR Landfill” (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 Permit Application (Burns & McDonnell, 1987) and DSI (AECOM, 2017) investigation indicate that the landfill is located in an area where the bedrock has been overlain by thick overburden deposits of loess and glacial till. The soil stratigraphy at the Sibley Ash Landfill area consists of topsoil and loess to depths of 17 to 36 feet, glacial till with a thickness of up to 30 feet, and sandstones and shales of the Pennsylvanian-aged Pleasanton Group as well as the Holdenville and Appanoose Subgroups of the Marmaton Group.

The loess thickness ranges from 15 to 34 feet, but is generally 20 to 25 feet. The loess consists of a reddish-brown to gray silty clay or clayey silt, generally classified as a CL, mottled with rust coloring and some organics. The loess is underlain by glacial till consisting of low to medium plastic silty clay, classified as a CL or CH, at depths ranging from 15 to 34 feet. Bedrock at the site was encountered at depths ranging from 24 to 48 feet and consists of alternating layers of sandstones and shales of the Pleasanton group. The permit application shows the landfill was constructed in the loess layer, above the till layer.

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 Permit Application (Burns & McDonnell, 1987) and the DSI (AECOM, 2017) report are provided in Appendix A.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.

2.2 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, 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 A.2**. SCS' visits to the site 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 A.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.

2.3 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.

Location Restrictions Demonstration Report

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 A.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.

3 REFERENCES

AECOM (2017), Detailed Hydrogeologic Site Characterization Report, CCR Landfill, Sibley Generating Station.

Burns & McDonnell (1987 – Revised 1988), Permit Application and Operating Plan for Solid Waste Disposal Area, Fly Ash Landfill, Sibley Generating Station.

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.

MDNR, Sinkholes in Missouri, <https://dnr.mo.gov/geology/geosrv/envgeo/sinkholes.htm>, accessed August 2018.

MDNR, Map of Sinkholes in Missouri, <https://dnr.mo.gov/geology/geosrv/envgeo/images/sinkholesinmissouri.jpg>, accessed August 2018

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.

4 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION (§§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 paragraph §§257.64(a).

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

_____ SCS Engineers _____

PE Registration State: _____ Missouri _____

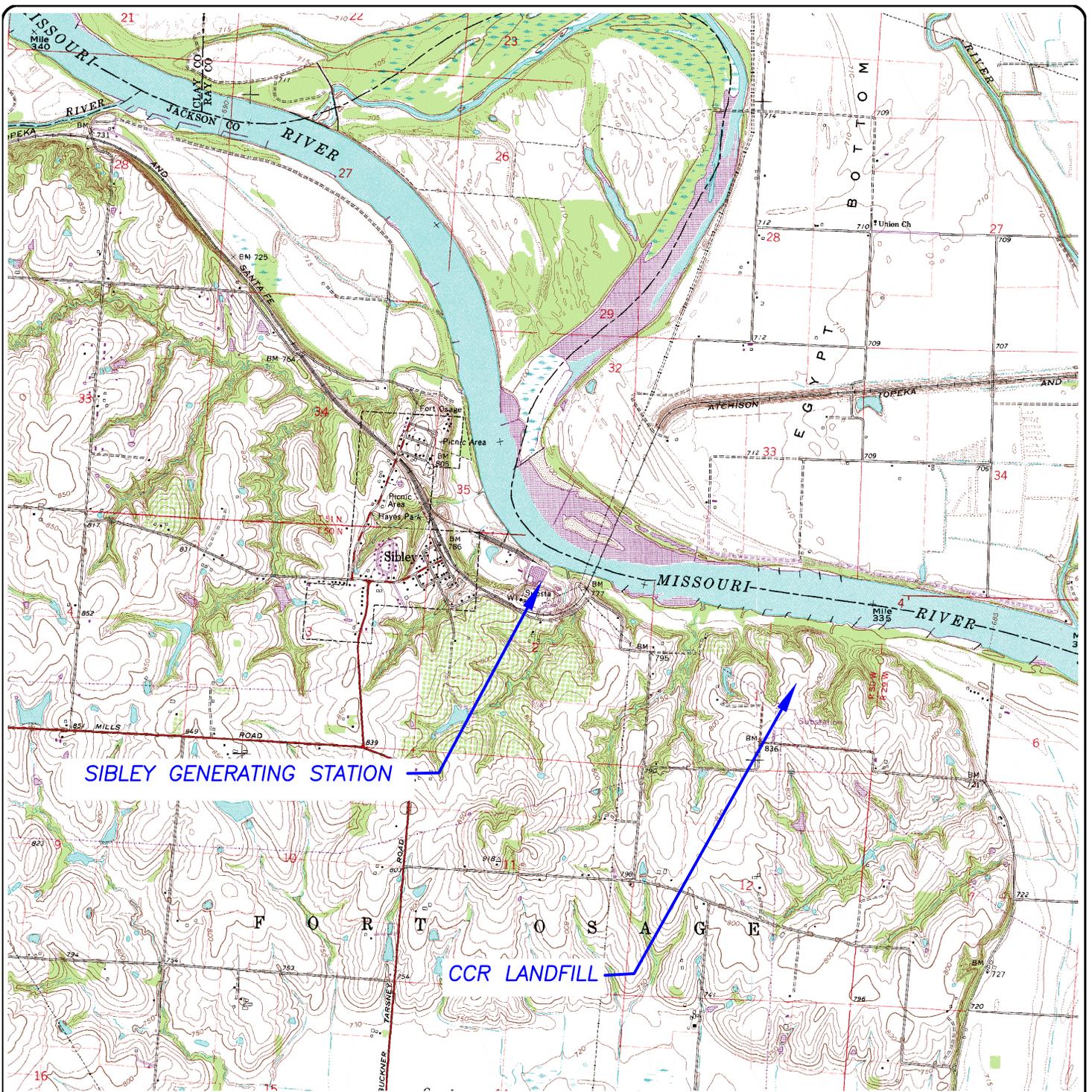
Registration Number: _____ PE-28982 _____

Professional Engineer Seal:



FIGURES

Figure 1 - Site Location Map



SIBLEY GENERATING STATION

CCR LANDFILL



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 - CCR LANDFILL 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

APPENDIX A

Unstable Areas Supporting Information

APPENDIX A.1

Portions of Previous Reports

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

Portions of Permit Application and Operating Plan for Solid Waste Disposal Area (Burns & McDonnell, 1987)

with 10 CSR 80-2.015 (MDNR, 2007A) for an expansion of the CCR Landfill to the current permitted area. KCP&L GMO received the landfill construction permit for the Sibley Utility Waste Landfill Expansion Stage A (Permit Number 0909502) from the MDNR on September 10, 2009, as documented in the Sibley Utility Waste Landfill Stage A Operating Permit Application (URS, 2010A). The 25-acre expansion increased the total permitted waste footprint of the CCR Landfill to approximately 46.5 acres. Stage A was completed in 2010 (URS, 2010A). Approximately 22.2 acres has been constructed as of 2017.

According to engineering drawings (Burns and McDonnell, 1988 and AECOM, 2010), the base grade of the CCR Landfill ranged from approximately 800 ft. to 760 ft. (unless otherwise noted, all elevations in this report are in a plant datum as defined in "URS Plans For Construction, KCP&L Sibley Generating Station, Design File 16530511.00001, Dated January 2010"), with the lowest elevation in the northwest corner and the highest along the southern extent. Design drawings include a two feet thick compacted soil liner under the entire footprint of the landfill, and a geomembrane liner under the initial 5-acre (approximate) northern expansion area. A sedimentation pond, originally located in the existing northwest corner of the landfill, was closed prior to the initial expansion.

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. The largest of these ravines is located along the east side of the CCR Landfill, extending from Twiehaus Road northward to the Missouri River. A second ravine is located northwest

PART I
SITE GEOLOGY

The site for the proposed fly ash landfill is located approximately 1.5 miles east of Sibley, Missouri, along the Missouri River. The landfill is to be located on the loess bluffs which form the southern boundary of the Missouri River floodplain. The elevations of the bluffs range from approximately 750 feet to 820 feet above Mean Sea Level.

In order to obtain subsurface information, 20 soil borings were drilled at the site. The glacial till strata was fully penetrated in only six of the 20 borings. The till was encountered to a maximum depth of 48 feet in Borings B-14 and B-17. The glacial till is composed of a reddish-brown to tan clay which is generally very stiff. There are traces of fine sand present throughout the glacial till matrix. The amount of sand generally appears to increase with depth in the till stratum.

The proposed site occurs in an area where the bedrock has been blanketed by thick soil overburden deposits. These deposits consists of, from the ground surface downward, (1) silty topsoil approximately 0.4-1.5 feet thick; (2) loess (wind deposited silt, in some places redeposited by erosion) 15 to 34 feet thick, (3) glacial till, thickness ranges up to as much as approximately 30 feet, directly overlying the bedrock.

The loess, which forms a thick blanket over much of the site, is on the average of 20-25 feet thick but may be thinner or thicker in some areas. The loess consists of silty clay varying in color from reddish-brown to gray with rust colored mottling and some organics. The moisture content varies from moist to wet and a plasticity varying from low to medium plastic.

Two reports on the soil properties of the region provide pertinent information on suitability of the soil materials found at the site for construction of a facility of this type. Both reports indicate that the site is well suited for landfill construction, if consideration is given to particular soil engineering properties which require special design features, handling procedures, and seeding.

The first report is the U.S. Soil Conservation Survey report on the Soil Survey of Jackson County, Missouri. That report indicates that most of the soils in the active landfill area belong to the Knox silt loam, 5 to 9 percent slopes. A large area on the top of the hill is assigned to the Sibley silt loam, 2 to 5 percent slopes. The wooded side slopes around the edge of the site (outside the active fill area) have soils assigned to the Knox silty clay loam, 5 to 14 percent slopes, severely eroded, and Knox silt loam, 14 to 20 percent slopes. Thus, the active area of the fill is predominantly in Knox silt loam, with some Sibley silt loam.

The Knox silt loam, 5 to 9 percent slopes, which comprises the bulk of the active landfill area is reported to have good properties for daily landfill

PART III
SUBSURFACE CONDITIONS

A. SUBSURFACE MATERIALS ENCOUNTERED

The locations of two geologic profiles which illustrate the generalized subsurface conditions at the site are shown on Figure III-1. The geologic profiles are shown on Figures III-2 and III-3. The site is generally covered by approximately 0.4 to 1.5 feet of topsoil classified as silty clay with some roots. The topsoil is underlain by a layer of loess consisting of low to medium plastic silty clay to approximate depths ranging from 15 feet in Boring B-7 to 34 feet in Boring B-17. The loess is underlain by glacial till consisting of medium to highly plastic silty clay and clay. The till was encountered to a maximum depth of 48 feet in Boring B-17. Individual samples from several borings in the till layer were classified to be sandy silt, sandy clayey silt, sandy clay, and clayey sand, however, these appear to be laterally discontinuous materials which vary in thickness.

Bedrock was encountered in six of the borings drilled for this investigation at depths ranging from 24 feet in Borings B-5 and B-7 to 48 feet in Borings B-14 and B-17. The bedrock materials which are described in Part I, Site Geology, of this report are all located below the proposed bottom elevation of the landfill and will not conflict with the landfill design or construction.

APPENDIX A.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

At the Sibley Station, the CCR Landfill is underlain by unconsolidated loess and glacial drift and then undifferentiated bedrock assigned to the Pleasanton Group as well as the Holdenville and Appanoose Subgroups which outcrop in the ravines below the landfill. The nearby Fly Ash Impoundment lies on the Missouri River floodplain and is underlain by unconsolidated floodplain alluvium and undifferentiated bedrock assigned to the Appanoose Subgroup. The nearby Slag Settling Impoundment is underlain by unconsolidated floodplain alluvium and undifferentiated bedrock assigned to the Fort Scott Subgroup. The Site stratigraphy is illustrated in a regional stratigraphic column provided in **Figure B.2** in **Appendix B**. The general surficial geologic map of the Site is 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, 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

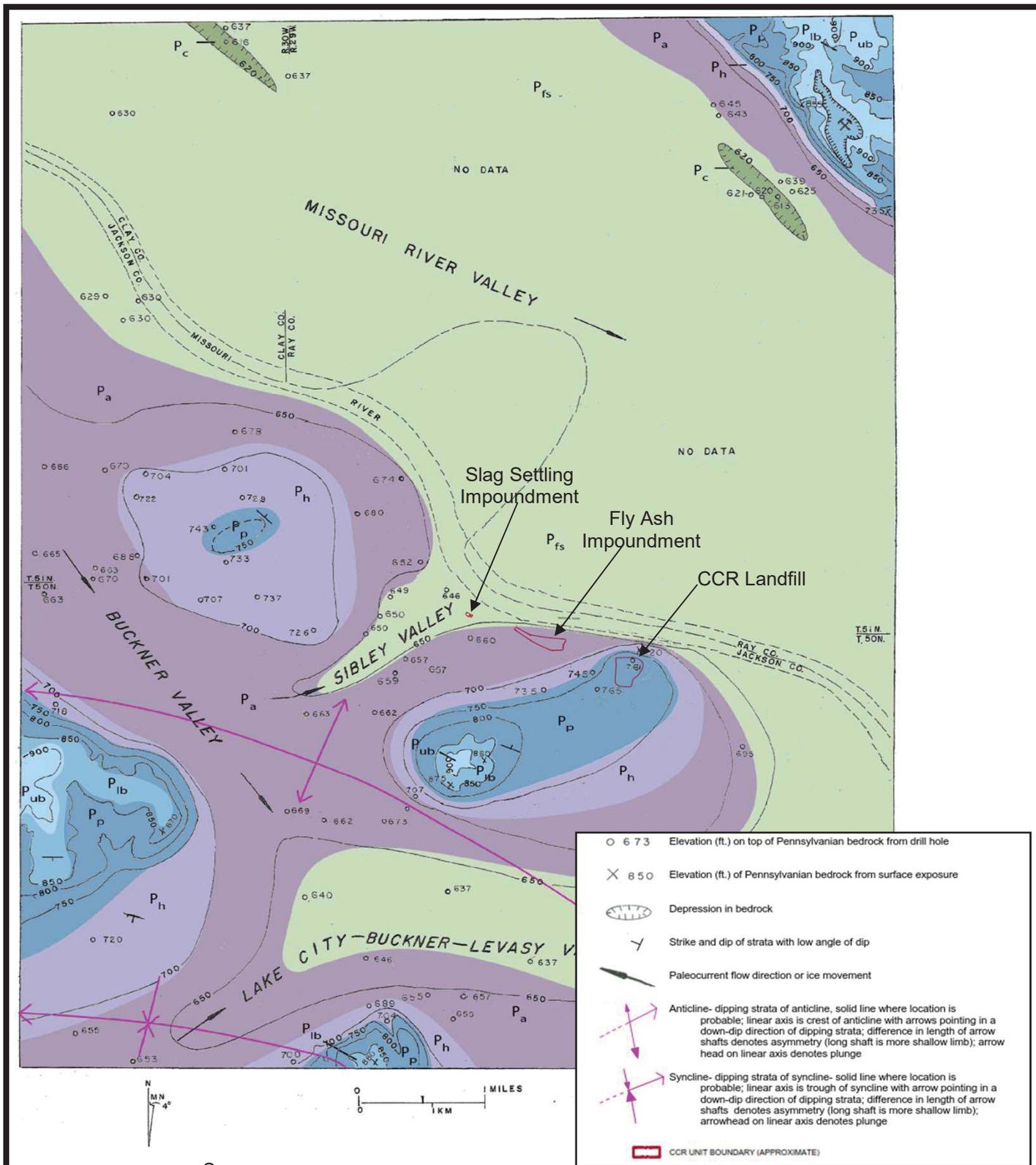
The CCR Landfill is located on a topographic high which drops off dramatically to the north down to the Missouri River floodplain. Twiehaus Road is the approximate southern divide for the watershed. In general, the surface water runoff drains north to the Missouri River. The primary surface drainage features which receive surface water runoff from the landfill area are two deeply incised ravines, as shown in **Figure A.3** in **Appendix A**.

Most of the surface runoff to the east of the Site, including the east portion of the existing landfill, is captured by the east ravine. The watershed for the area west of the landfill extends to the south to Twiehaus Road, west to approximately 900 ft. west of the farm pond, and east to the landfill. Most of the surface water runoff west of the Site appears to be captured by the southwest branch of the west ravine and is retained in the farm pond. A portion of the runoff currently flows through the center of the area west of the landfill via the southeast branch of the west ravine (Shaw, 2008).

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

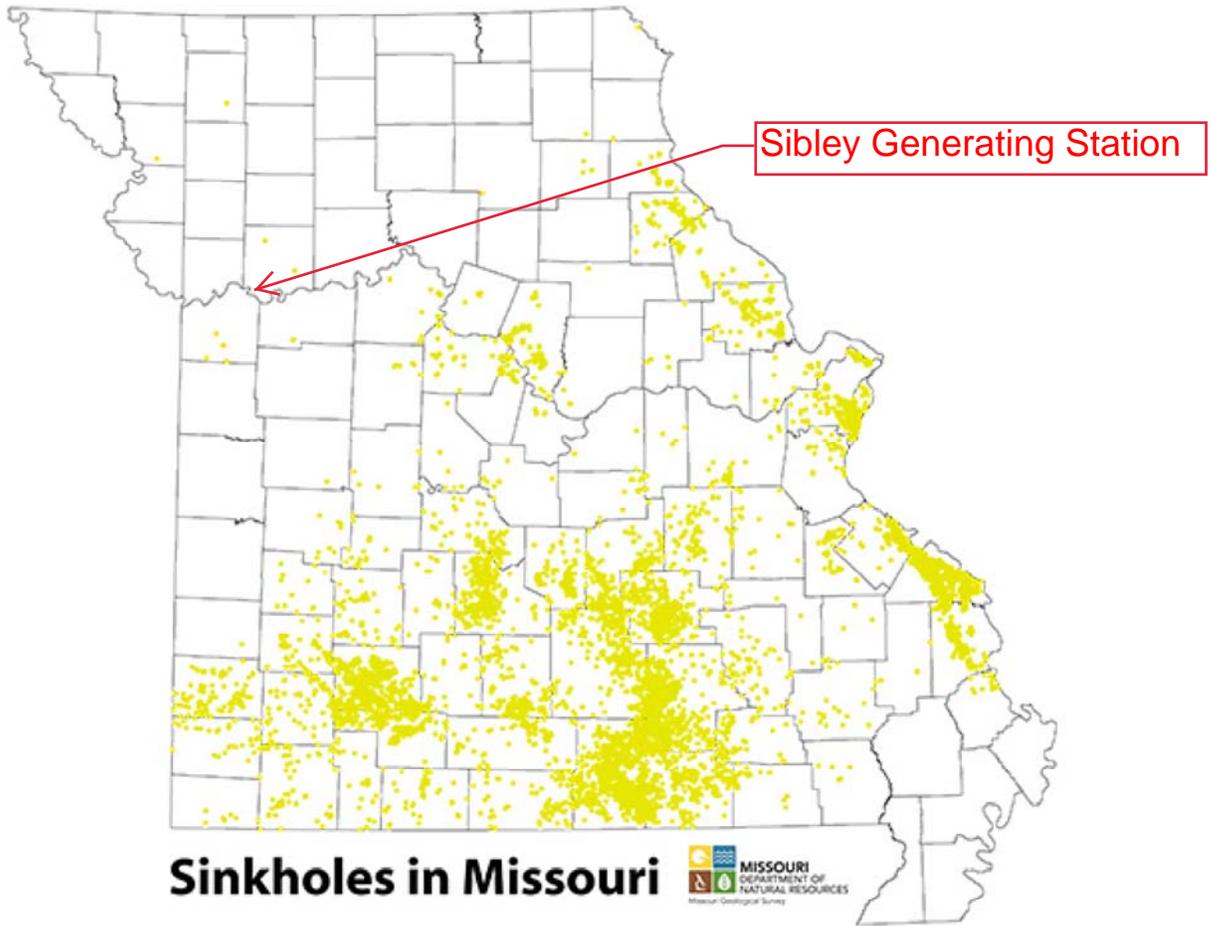
1.3.3.2 Subsurface Hydrology

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



Source
Geologic Map of the Buckner Quadrangle, Gentile, 2014

	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



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



PUB2467 9/15

GEOLOGIC HAZARDS

in Missouri



Earthquakes
Sinkholes
Landslides
Abandoned Mines



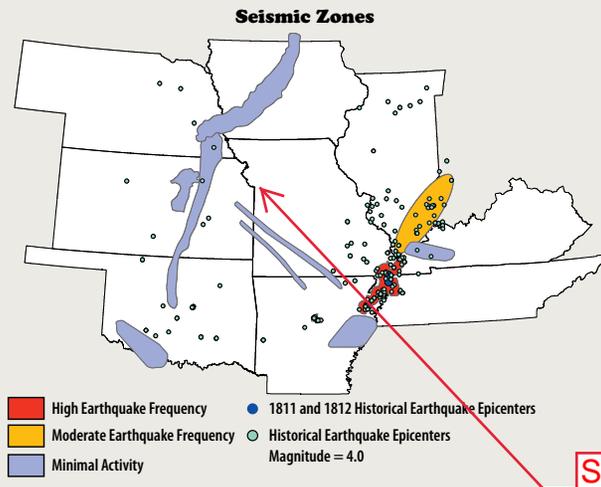
Earthquakes

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.

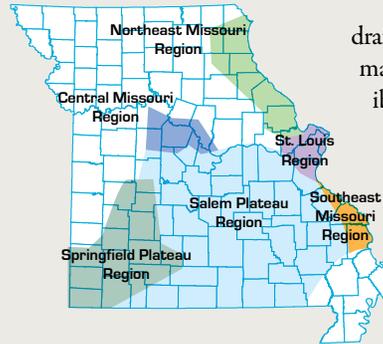
Knowledge and preparation are crucial to earthquake preparedness. Information related to earthquakes and disaster preparedness is available at dnr.mo.gov/geology/geosrv/earthquakes.htm.



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

Primary Sinkhole Regions of Missouri



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.

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/geoes/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



— Geologic Structures

Sibley Generating Station

CCR Landfill



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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

APPENDIX A.3

Human-made Features or Events Documentation

Mine Maps – Jackson County (MDNR)

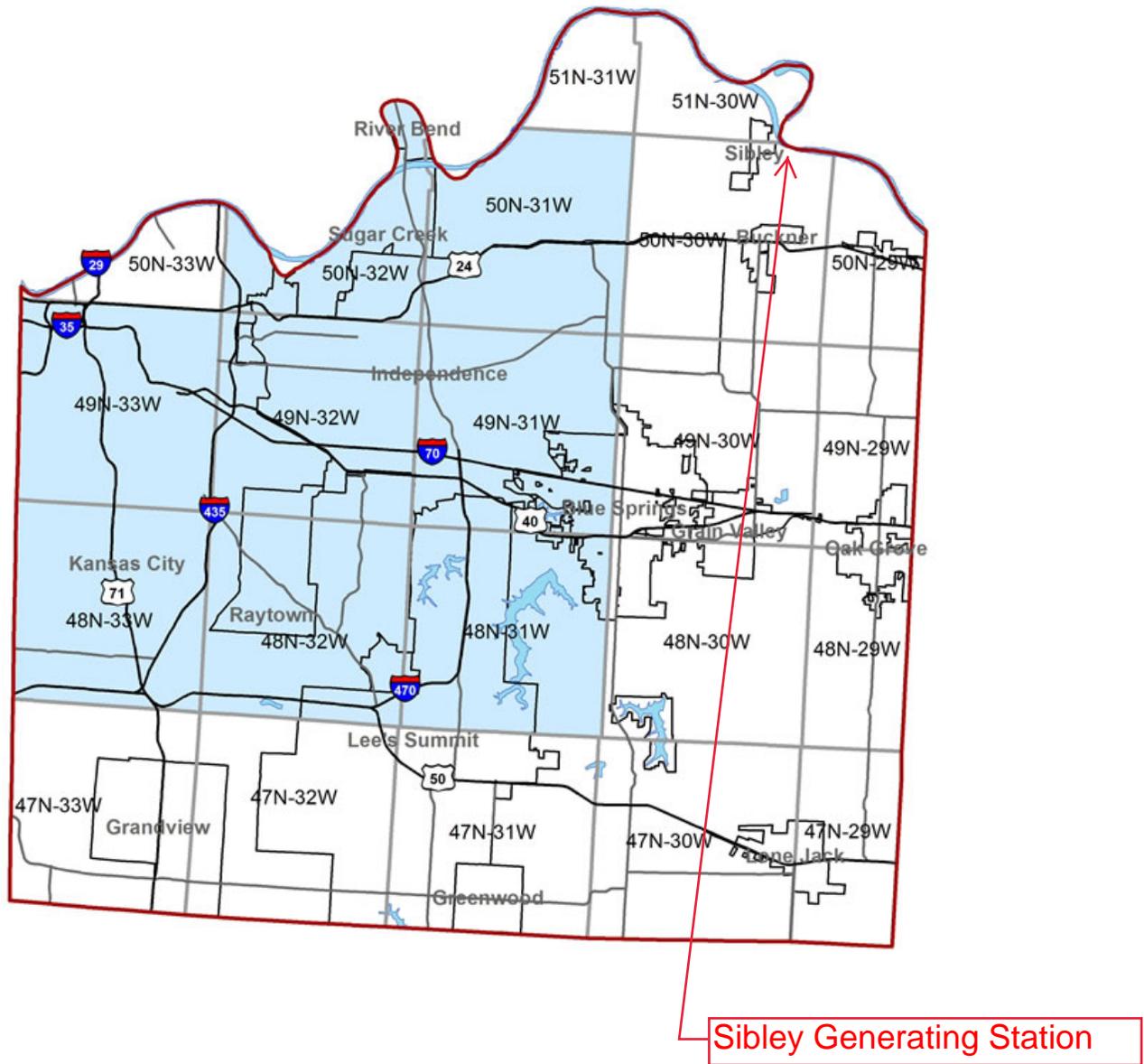
Oil and Gas in Missouri Fact Sheet (MDNR)

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.

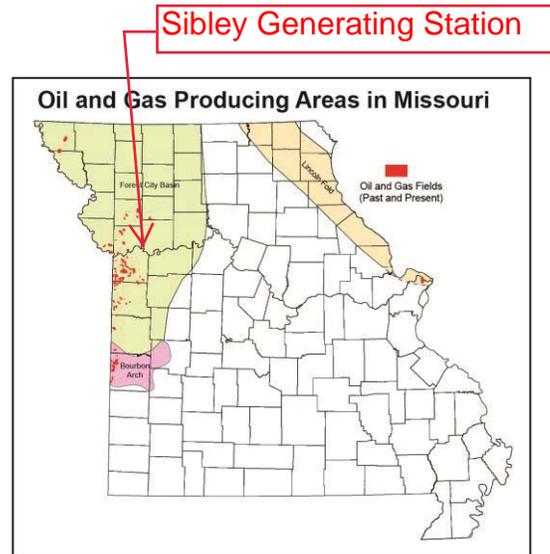
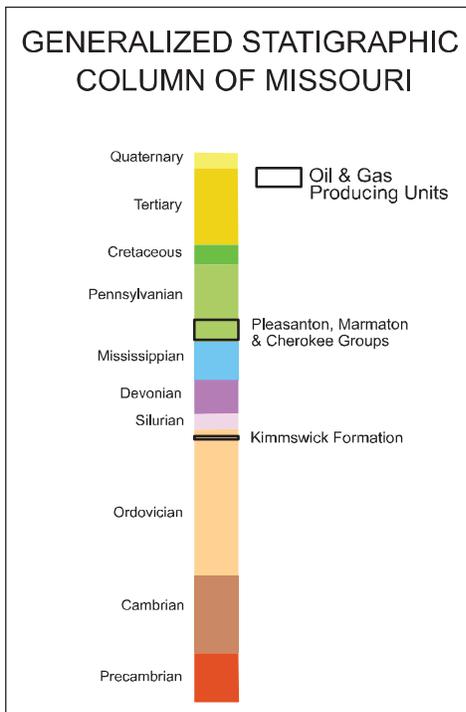


Oil and Gas in Missouri

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.

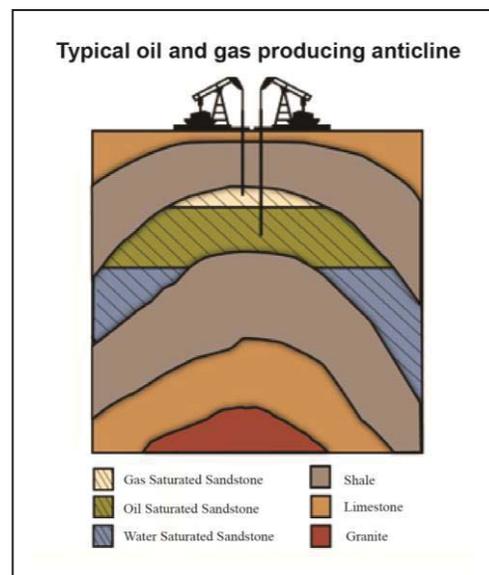
In Missouri, the first oil and gas wells were drilled in the Kansas City area shortly after the Civil War in the 1860s. Hundreds of shallow wells were drilled in western Missouri along the Kansas border during the late 1800s and early 1900s. Many of these wells produced gas used in private homes, farmsteads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

Nothing in this document may be used to implement any enforcement action or levy any penalty unless promulgated or authorized by statute.

MINERAL INDUSTRIES IN MISSOURI

MISSOURI DEPARTMENT OF
NATURAL RESOURCES
Division of Geology and Land Survey
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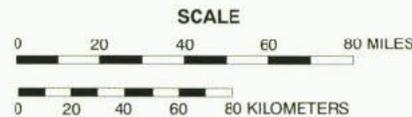
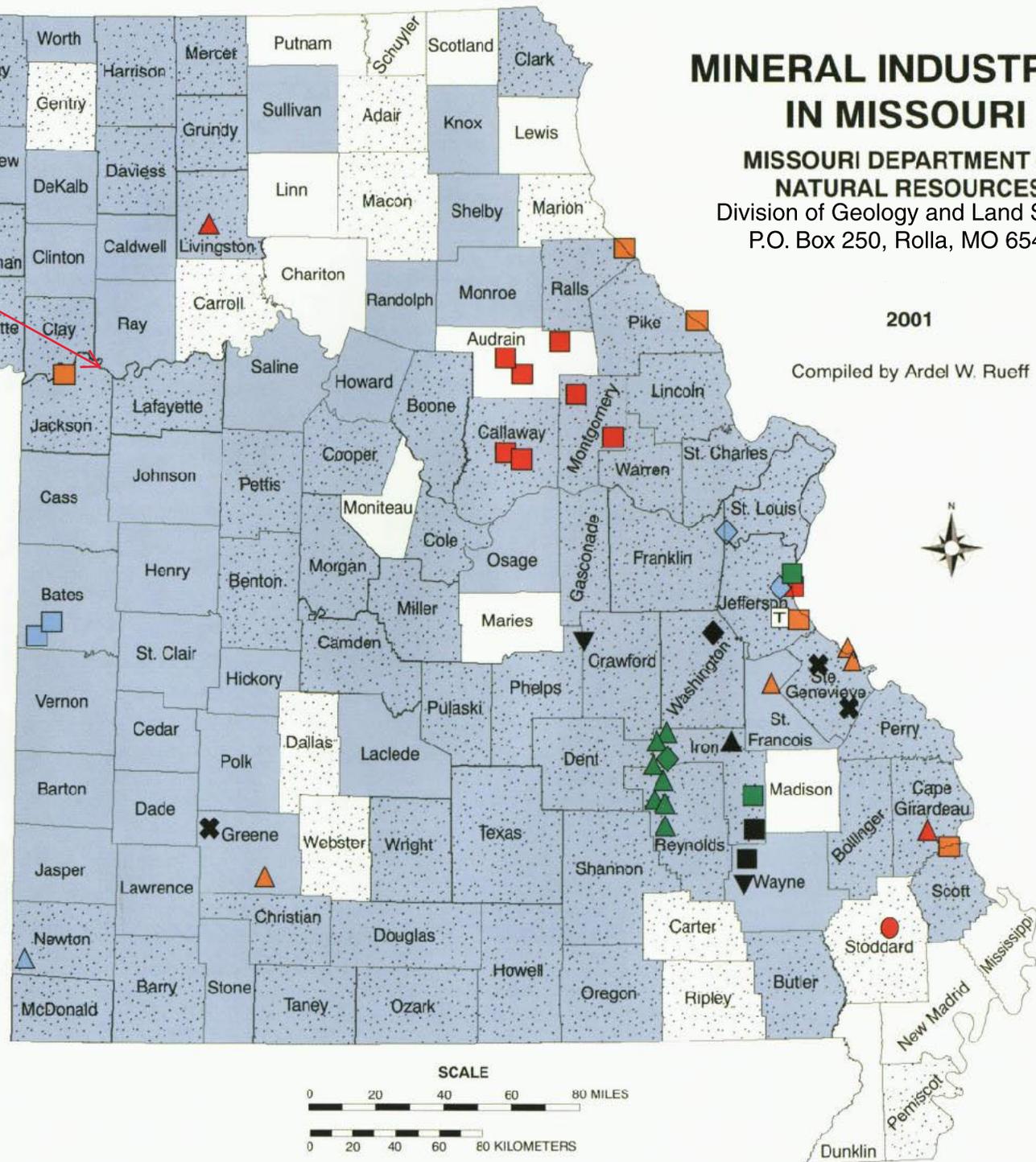
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Compiled by Ardel W. Rueff

LEGEND

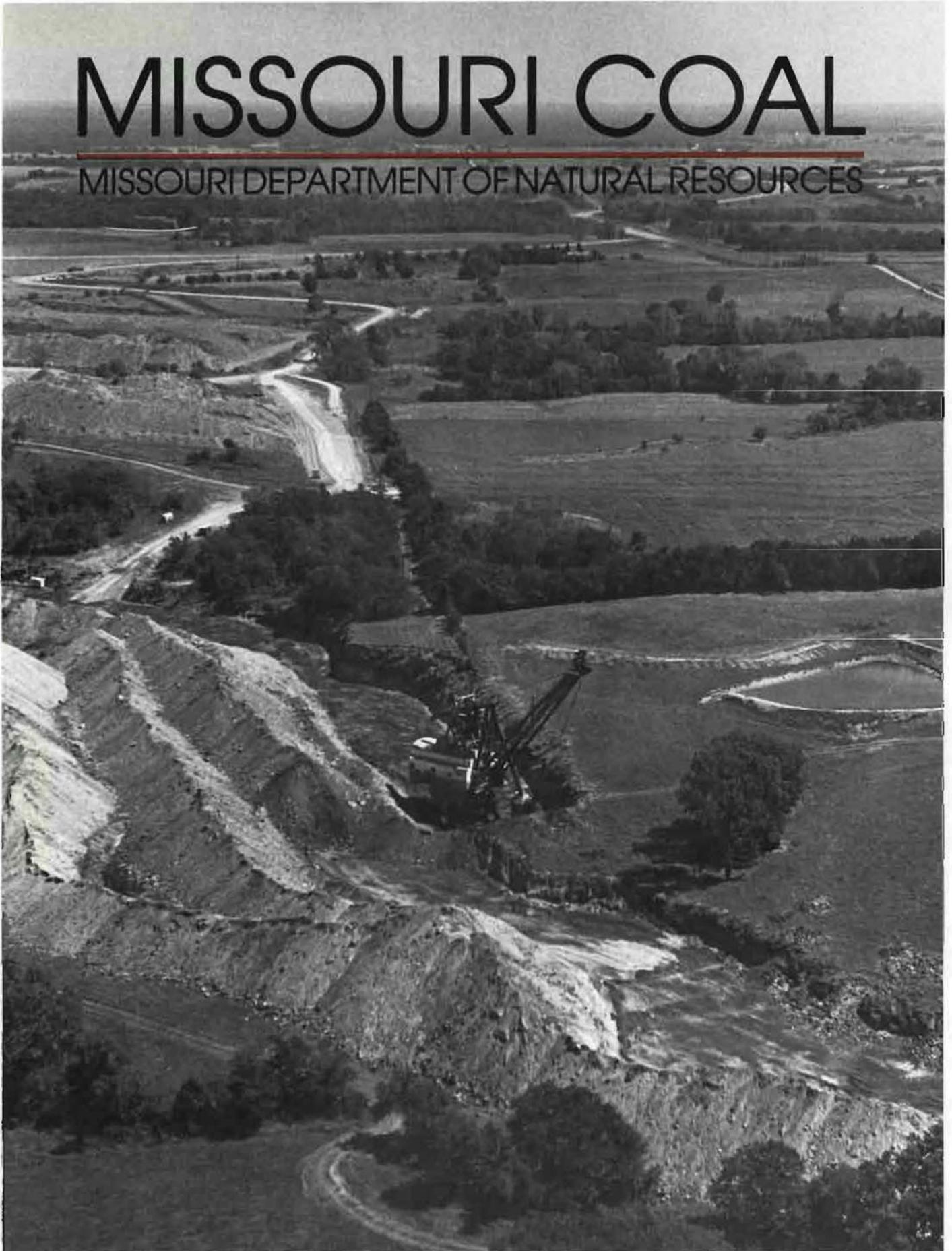
- Absorbent Clay Products Plants
- ◆ Barite Grinding Plant
- ▲ Brick & Tile Plant
- Cement Plant
- Coal Mine
- ▲ Dimension Granite Quarry
- ▼ Dimension Sandstone Quarry
- ✕ Dimension Limestone/Dolomite Quarry
- T Terrazzo Quarry
- ◆ Industrial Sand Quarry
- Iron Mine
- ▲ Lead Mine & Mill
- Lead Smelter
- ◆ 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)

Sibley Generating Station



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.

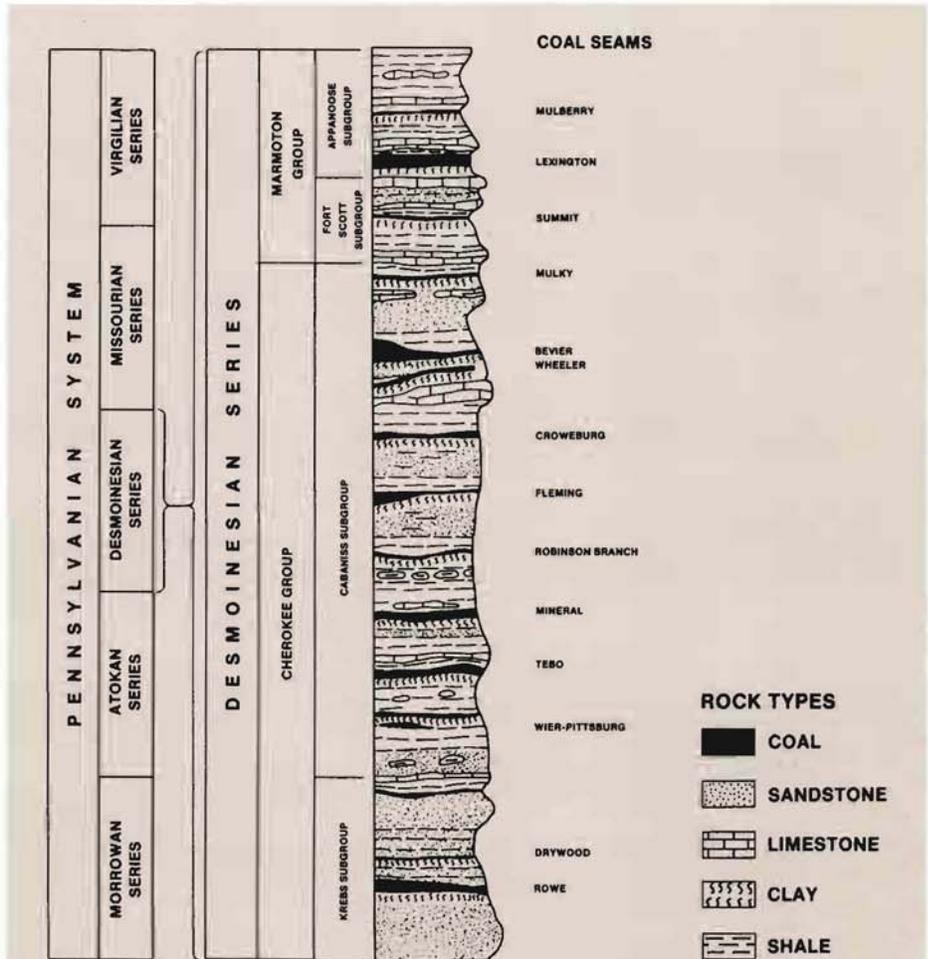
Peat continues to form in places like the Dismal Swamp in North Carolina and Virginia. However, it takes 36 feet of peat to form three feet of bituminous coal, in a process much slower than the rate at which we use it.

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.

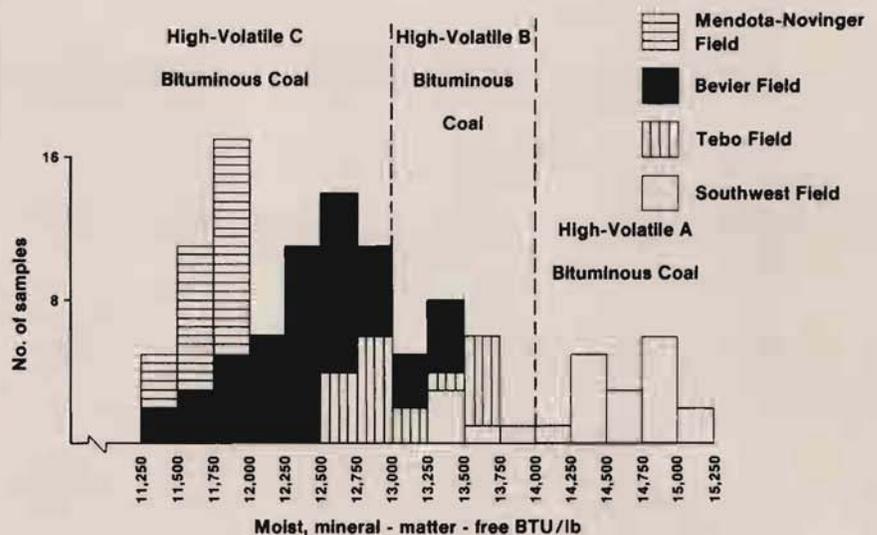
Coal quality includes such factors as ash content, sulfur content, and heat value. In fact, the principal value of coal is in the amount of heat it can generate, a factor directly related to stage of development. Heat value is measured in British Thermal Units, or BTUs. One BTU is the energy necessary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



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.

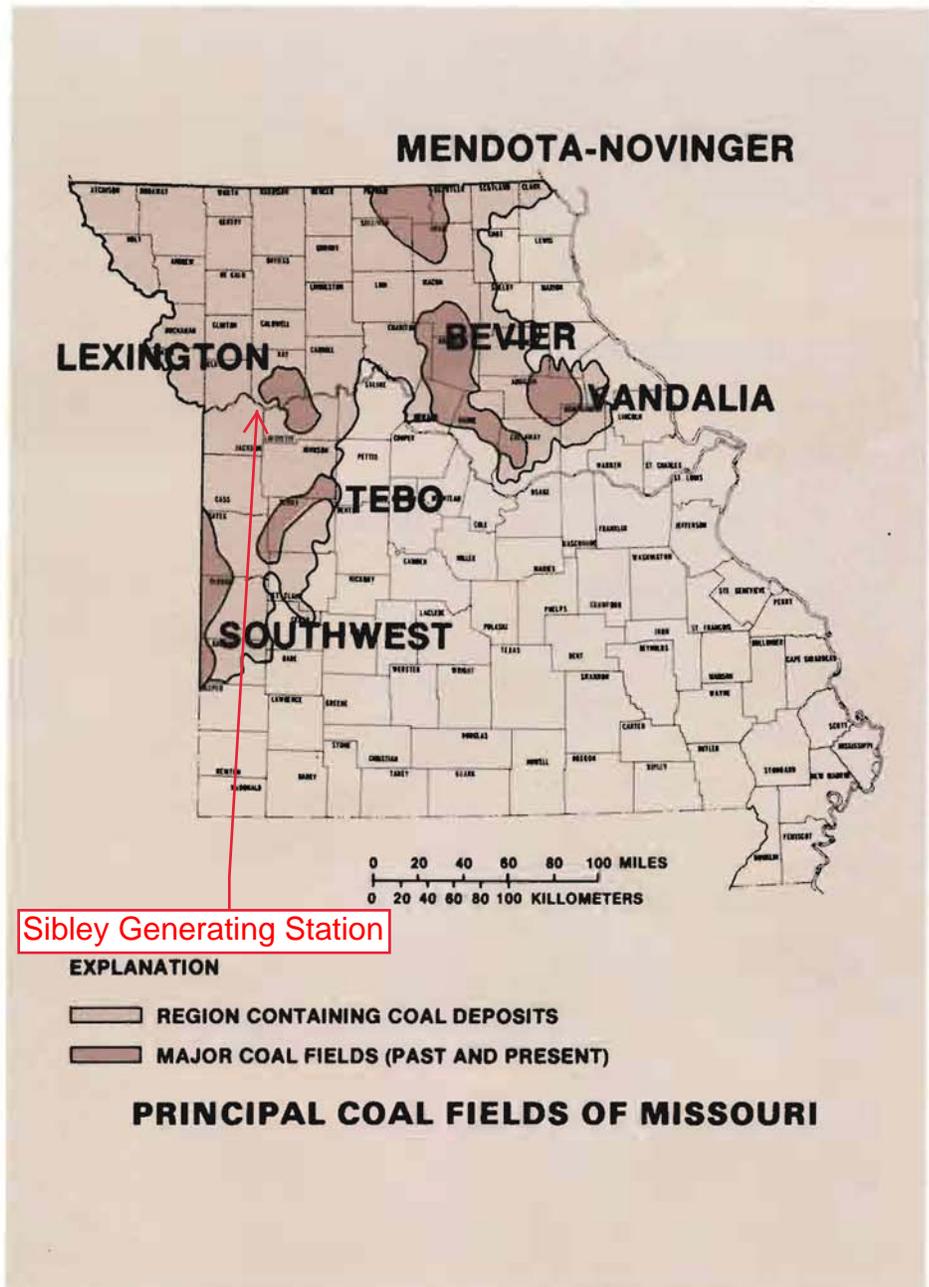
The Tebo field was the largest producing area in the state before mining activity increased in the Bevier field in the late 1970s. Current production from the Tebo field constitutes 10 percent of the state's annual coal production. Most of the coal produced in the region is mined from the Tebo seam.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



Sibley Generating Station

EXPLANATION

-  REGION CONTAINING COAL DEPOSITS
-  MAJOR COAL FIELDS (PAST AND PRESENT)

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.

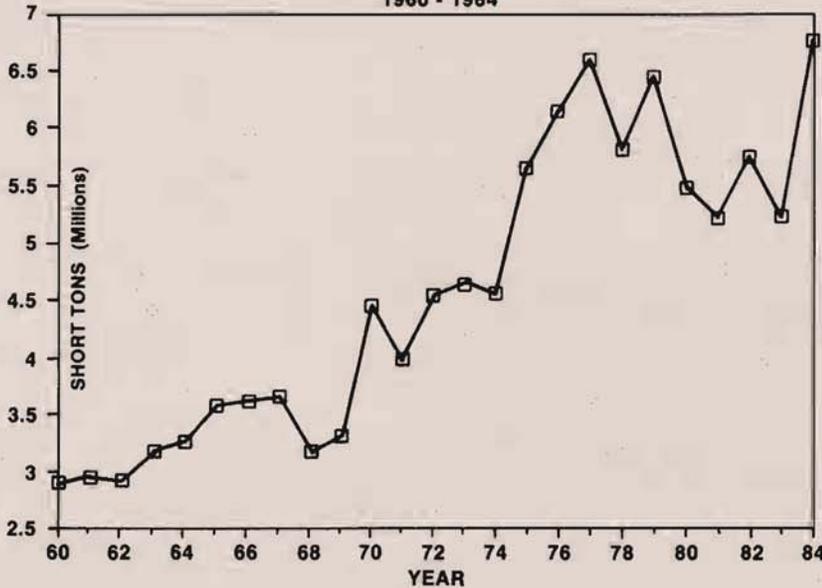
The coal industry is subject to the same laws of supply and demand as are other industries. For example, when cheap natural gas and petroleum began flooding the market in the mid-1940s, demand for coal as locomotive and heating fuel declined until production reached a low of 2.5 million tons in 1958.

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,

MISSOURI COAL PRODUCTION

1960 - 1984



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 unremediated 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

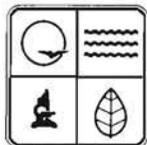
Missouri has sufficient proven coal reserves to support a potential annual production of 28 million tons for 30 years.

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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