LOCATION RESTRICTIONS DEMONSTRATION REPORT NORTH ASH IMPOUNDMENT

Montrose Generating Station

Presented to:
Kansas City Power & Light Company
Montrose Generating Station
Henry County, Missouri

SCS ENGINEERS

27218131.01 | October 2018

8575 W 110th Street, Suite 100
Overland Park, Kansas 66210
913-681-0030

Table of Contents

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 North Ash Impoundment (Unit) at Kansas City Power & Light Company's (KCP&L) Montrose Generating Station (Montrose) 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 Montrose Generating Station in Henry 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 750 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. Clay unit
3. Basal clayey sand or gravel (uppermost aquifer)
4. Shale, siltstone, sandstone and coal (bedrock)

The site Investigation completed by AECOM confirmed that unconsolidated deposits consist of residual low to high plasticity clay, with a basal clayey sand or sandy clay unit. Borings drilled around the Unit encountered unconsolidated deposits ranging in thickness from 24 to 35 feet consisting of native material and up to 13 feet of locally sourced fill. The uppermost aquifer at the Unit was determined to be the basal unit present below the clay and immediately above the bedrock contact. The basal unit varied in thickness from 1 to 11 feet, with an average thickness of 4.5 feet.

The low permeability clay unit extends from a few feet below the ground surface to a clayey sand or gravel basal unit just above the top of bedrock. The basal clayey sand or gravel unit is the main water-bearing unit at the Unit and is identified as the uppermost aquifer beneath the North Ash Impoundment. The aquifer appears locally confined or semi-confined by low permeability clay and bedrock which act as upper and lower confining units, respectively, to the basal clayey sand or gravel unit (uppermost aquifer).

The base elevation of the Unit is estimated to be at 750 ft. MSL as noted in the Detailed Hydrogeologic Site Characterization Report (Section 1.4.1), as indicated in **Appendix A**. The report also identifies the uppermost aquifer as the basal unit immediately above the bedrock. A review of hydrostratigraphic cross sections in the report indicates a maximum uppermost aquifer elevation of approximately 740 ft. MSL. Based on this review, the base of the Unit is approximately 10 feet above the upper limit of the uppermost aquifer, therefore the base of the 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 May 1, 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 DSI prepared by AECOM in July 2017. The Montrose Generating Station is located within the Osage Plains physiographic section (MDNR, 2002). The physiographic section is defined by gently rolling hills, with typically residual fine grained soils overlying soft shale bedrock interbedded with sandstones and limestones of the Pennsylvanian Age. The 1987 hydrogeologic investigation (Terracon, 1987), and 2004 DSI investigation (URS, 2004) indicate that the stratigraphy at Montrose consists of approximately 23 to 33 feet of unconsolidated residual soils formed from the underlying bedrock consisting of varying types of sandstone, shale and sandstone with layers of coal, claystone and dolomite/limestone. The unconsolidated deposits consist of primarily high plasticity residual clay overlying lean clay with a thin, 2- to 6-foot, basal clayey sand or gravel zone above bedrock. The bedrock near the Unit consists of shale, siltstone, sandstone and coal (with underclays) with occasional resistant limestone beds, assigned to the Middle Pennsylvanian Age, Krebs and Cabaniss Subgroups of the Cherokee Group (USGS, 2015). These units are relatively typical of the cyclic sedimentary rock deposits present in the Midwest. Thickness of individual beds varies from thin coal “smuts” to beds as thick as twenty-five feet, with lateral variations occurring in many locations (Thompson, 1995).

Based on the geologic description above and a review of geotechnical data in the report(s), it is SCS’ professional opinion that the soils on site will not experience significant differential settlement. Pertinent sections of the 2017 AECOM report are provided in **Appendix B.1** describing the soils 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.

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 geologic structures and areas with potential caves were identified within the search area near the Unit. Neither the geologic structures nor the potential for caves in the area should 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. 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 – Henry County (https://dnr.mo.gov/geology/geosrv/geores/minemapshenry.htm)
- Oil and Gas in Missouri, Fact Sheet (https://dnr.mo.gov/pubs/pub652.pdf).
- Mineral Resources in Missouri (https://dnr.mo.gov/geology/adm/publications/docs/map-MinRes.pdf)
- Missouri Coal (https://dnr.mo.gov/geology/docs/BRO006MissouriCoal.pdf)
- Aerial photographs

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,
- Abandoned Mine Lands Projects,
- Industrial Mineral Mines,
- Metallic Mineral Waste Management Areas, and
- Oil and Gas Wells.

The Missouri Coal Report indicates a Major Coal Field (Tebo) is located in Henry County. The Missouri Mine Maps website includes two mine maps, located to the east and northeast of Montrose and the City of Clinton, Missouri; however, no mine maps were documented for the area including and around the Unit. The GeoSTRAT database showed the location of coal mines and oil/gas wells in Henry County, but no mines within 2 miles of the Unit and no oil/gas wells within 9 miles of the Unit.

SCS' review of the aerial photographs around the Unit showed indications of strip mining approximately 2.4 miles to the northeast of the Unit and 2.5 miles to the west of the Unit as well as several areas south of and across the lake. The aerial photographs confirm the presence of coal strip mining in the area; however none of the borings drilled for the ash impoundments or adjacent landfill reviewed by SCS indicated the presence of a heterogeneous backfill associated with coal strip mining.

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, North and South Ash Impoundments, Montrose Generating Station.

SCS Engineers (2017), Groundwater Monitoring System Certification Basis Report, North and South Ash Impoundments, Montrose Generation 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.

Terracon Consultants, EC, Inc. (1987), Geohydrologic and Groundwater Quality Assessment, Ash Disposal Site, Montrose Generating Facility.

URS (2004), Detailed Site Investigation, Geologic and Hydrologic Evaluation Report, Utility Waste Landfill Expansion, KCP&L Montrose Power Station.

USGS, (2015), Geologic Units in Henry County, Missouri, https://mrdata.usgs.gov/geology/state/fips-unit.php?code=f29083, accessed August 2018.

Thompson, (1995). The Stratigraphy Succession of Missouri, by Thomas L. Thompson, Missouri Department of Natural Resources, Volume 40, Second Series/Revised.

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 – Henry County, https://dnr.mo.gov/geology/geosrv/geores/minemapshenry.htm, accessed August 2018.

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

MDNR, Mineral Resources in Missouri, https://dnr.mo.gov/geology/adm/publications/docs/map-MinRes.pdf, accessed August 2018.

MDNR, Missouri Coal, https://dnr.mo.gov/geology/docs/BRO006MissouriCoal.pdf, accessed August 2018.

Google Earth (2017), Aerial photograph dated 9/15/2017, 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

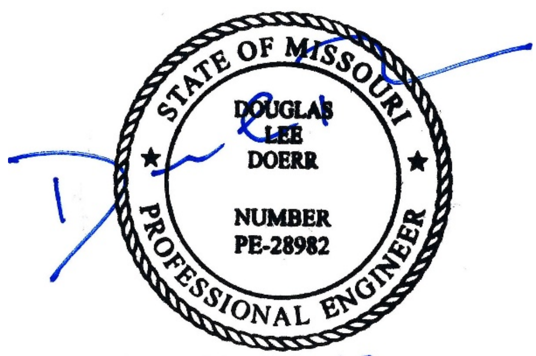
PE Registration State: PE Missouri

Registration Number: PE-28982

Professional Engineer Seal:

Douglas L. Doerr

Digitally signed by Douglas L. Doerr
Date: 2018.10.17 10:49:24 -05'00'



10-17-18

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.

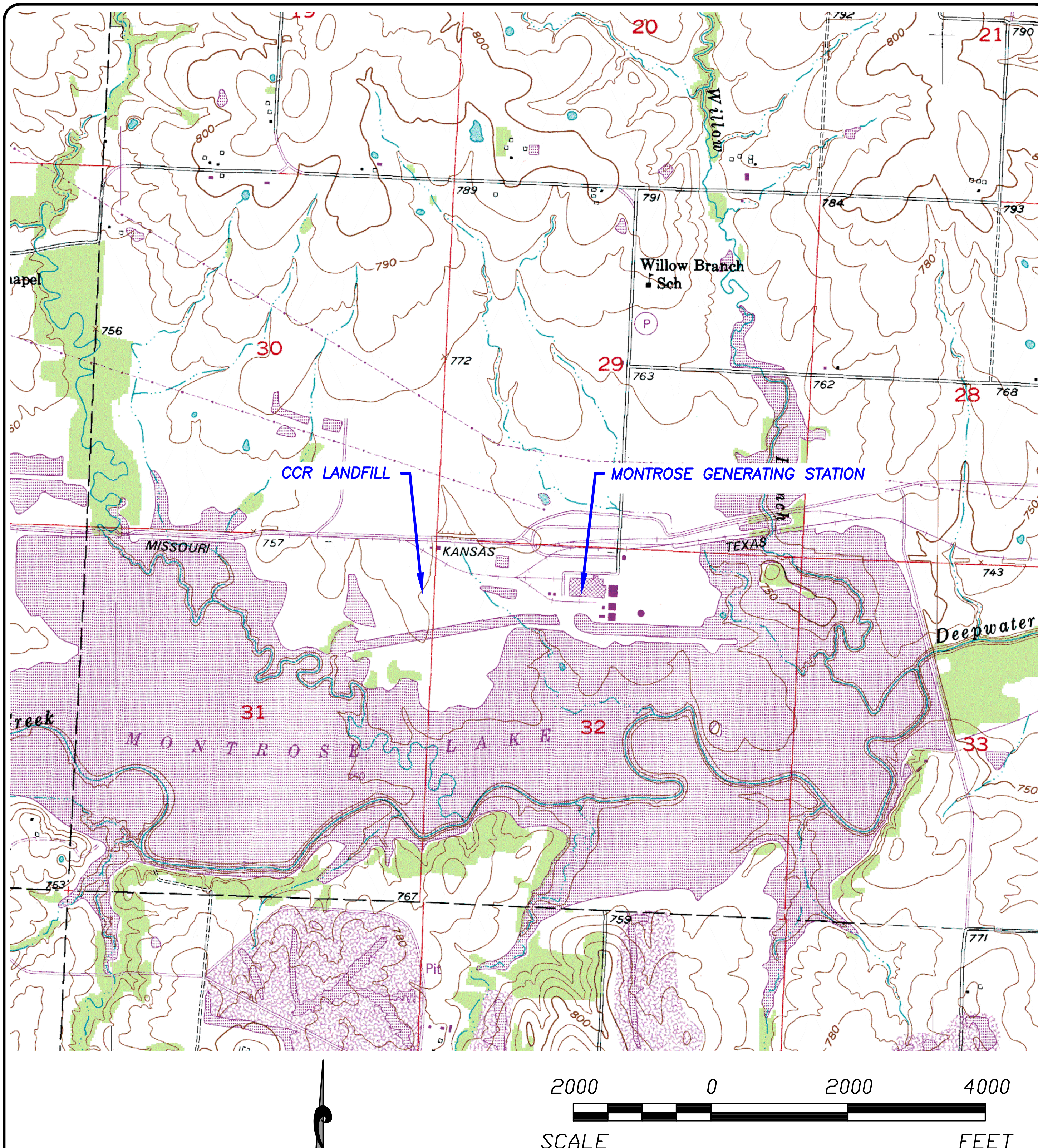
SCS Engineers

PG Registration State: PG Missouri

Registration Number: PG-0092

Professional Geologist Seal:

FIGURES



SOURCE:
1981 USGS MAP
MONTROSE QUADRANGLE
7.5 MINUTE SERIES (TOPOGRAPHIC)

SCS ENGINEERS
8575 W. 110th St, STE. 100
Overland Park, Kansas 66210
PH. (913) 681-0030 eFAX. (913) 681-0012

FIGURE 1
SITE LOCATION MAP
KCP&L MONTROSE GENERATING STATION - CCR LANDFILL
HENRY COUNTY, MISSOURI

CHK. BY: DLD	DWN. BY: TGW	DSN. BY: TGW	PROJ. NO. 27218131.01
PROJ. MGR: DLD	DATE: 10/2018	CADD FILE: FIGURE 1_SITE MAP.DWG	DRAWING NO. 1

T:\27218131.01\AUTOCAD\LANDFILL\FIGURE 1_SITE MAP.DWG

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 10/20/2014.

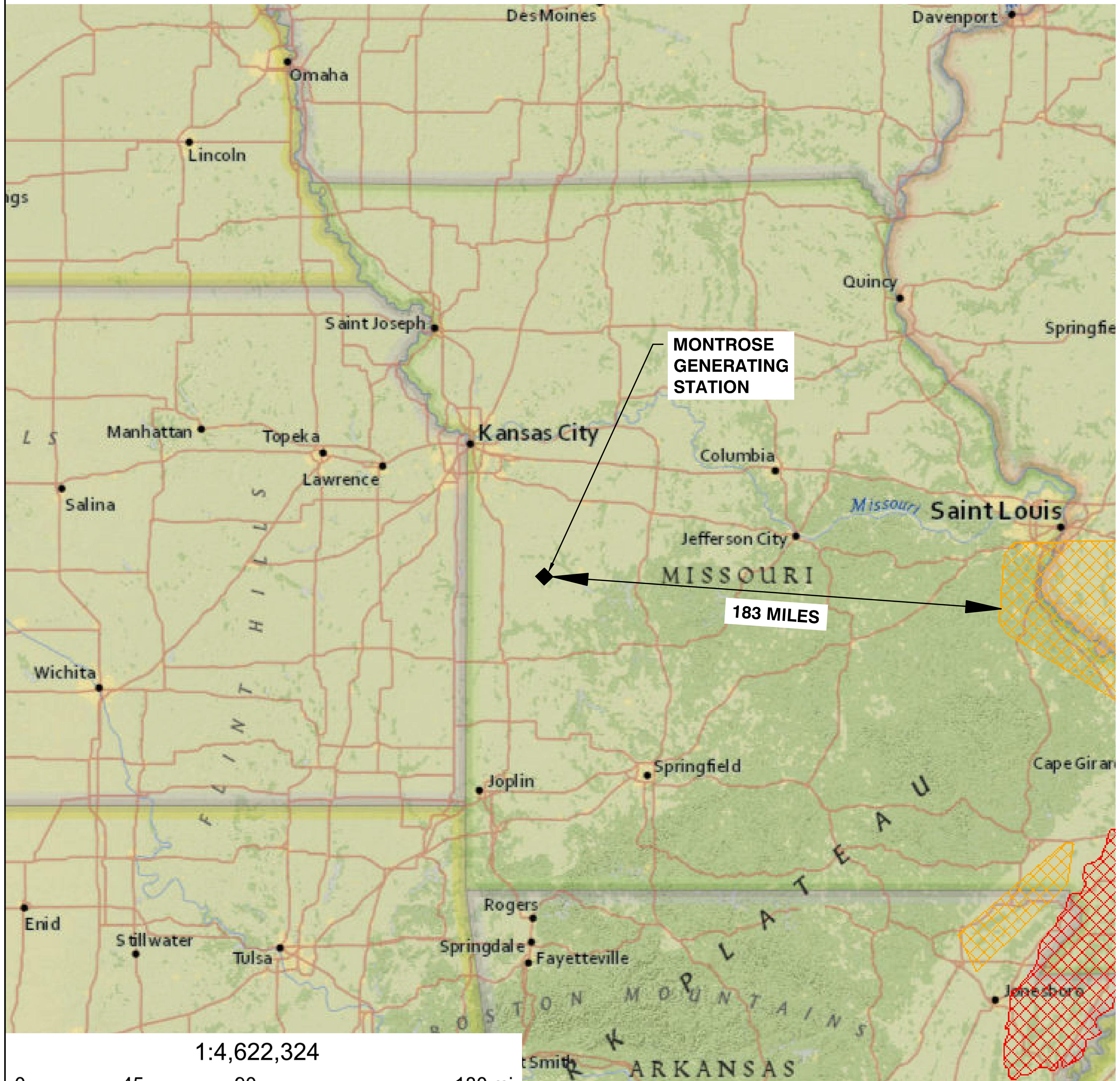
FIGURE 2
WETLANDS MAP

KCP&L MONTROSE GENERATING STATION - NORTH ASH IMPOUNDMENT
HENRY COUNTY, MISSOURI

SCS ENGINEERS
8575 W. 110th St. STE 100
Overland Park, Kansas 66210
PH. (913) 681-0030 eFAX. (913) 681-0012

CHK. BY: DLD	DWN. BY: TGW	DSN. BY: TGW	PROJ. NO. 27218131.01
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

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/

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

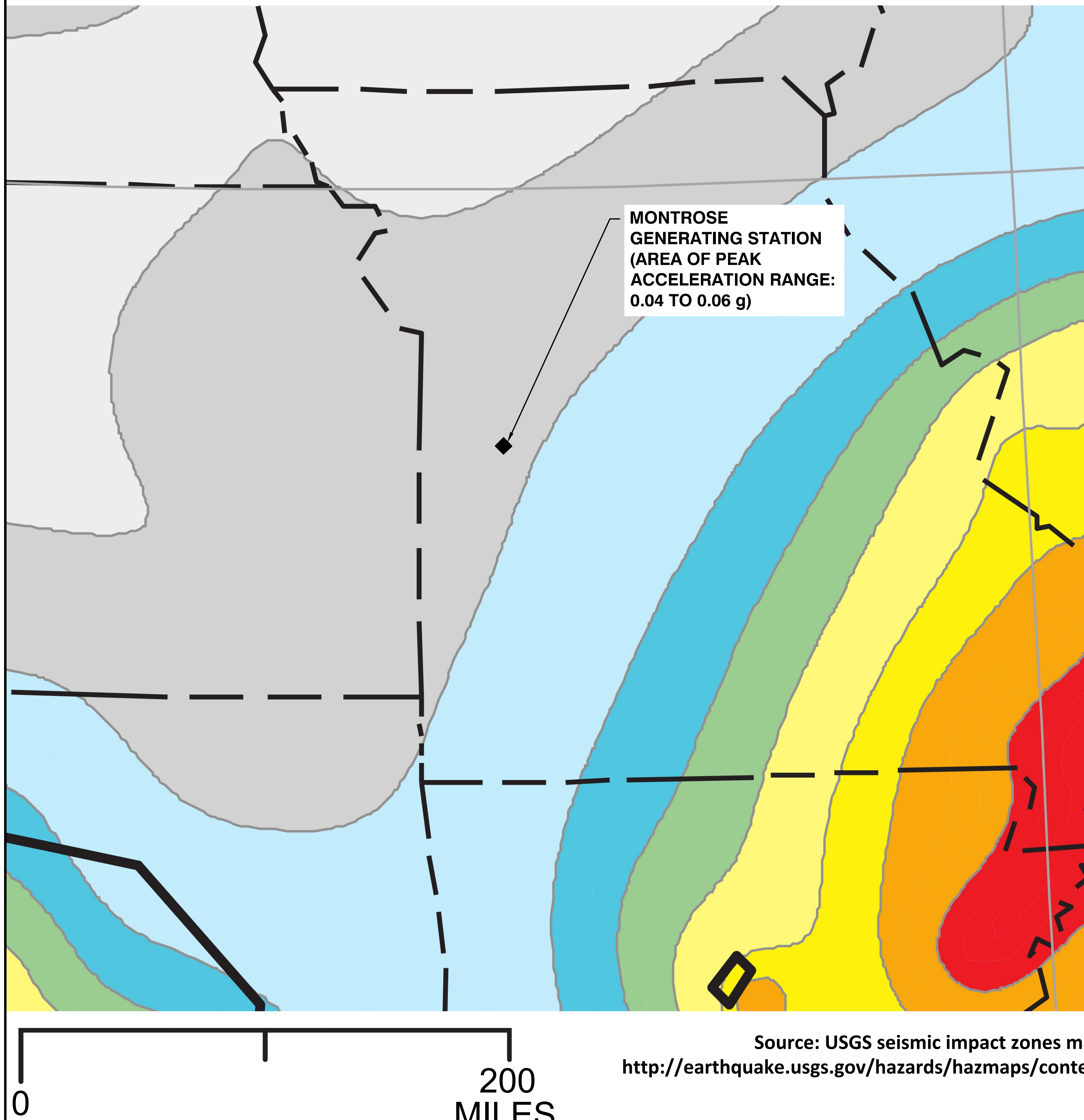
FIGURE 3
FAULT AREAS MAP
KCP&L MONTROSE GENERATING STATION - NORTH ASH IMPOUNDMENT
HENRY COUNTY, MISSOURI

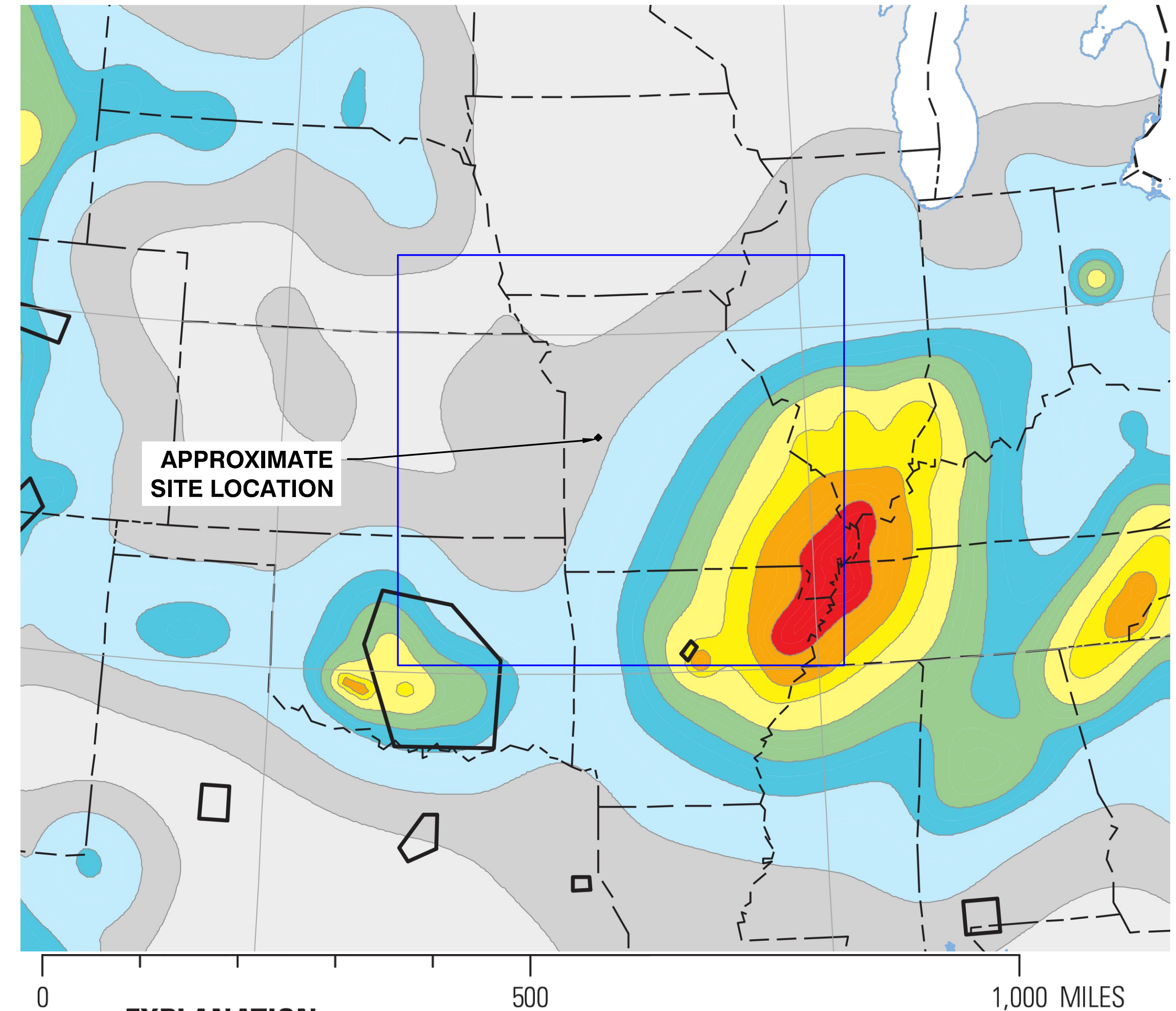
SCS ENGINEERS

8575 W. 110th St. STE 100
Overland Park, Kansas 66210
PH. (913) 681-0030 eFAX. (913) 681-0012

CHK. BY: DLD	DWN. BY: TGW	DSN. BY: TGW	PROJ. NO. 27218131.01
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





EXPLANATION

Peak acceleration, expressed as a fraction of standard gravity (g)

- 0.8
- 0.4
- 0.3
- 0.2
- 0.14
- 0.1
- 0.06
- 0.04
- 0.02
- 0

Areas with suspected nontectonic earthquakes are not included.

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

FIGURE 4
HORIZONTAL ACCELERATION MAP

KCP&L MONTROSE GENERATING STATION - NORTH ASH IMPOUNDMENT
HENRY COUNTY, MISSOURI

SCS ENGINEERS

8575 W. 110th St. STE 100
Overland Park, Kansas 66210
PH. (913) 681-0030 eFAX. (913) 681-0012

CHK. BY: DLD	DWN. BY: TGW	DSN. BY: TGW	PROJ. NO. 27218131.01
PROJ. MGR: DLD	DATE: 10/2018	CADD FILE: FIGURE 4_SEISMIC.DWG	

APPENDIX A

Placement Above the Uppermost Aquifer Supporting Information

- Portions of Detailed Hydrogeologic Site Characterization Report (AECOM 2017) deposits that tend to restrict flow to the deeper, regional Ozark Plateaus Aquifer System (Imes and Emmett, 1994, Jorgenson, et al, 1993). The Site is located near the northwestern edge of the Ozark Plateaus Aquifer system where total dissolved solids concentrations are typically between approximately 500 and 1,000 mg/L and indicate where saline water mixes with freshwater in Bates and Henry Counties (Imes and Emmett, 1994)

A search of MDNR well records (MDNR, 2007B and MDNR, 2017) including public and private water supply wells within a ¼ mile radius of the Site returned no wells, as indicated in **Appendix F**, **Figure F.1**. Regional drinking water is typically obtained from groundwater production wells reportedly screened at depths from 275 ft. to greater than 1,000 ft. below ground surface (bgs) (URS, 2004). As examples, static water levels in regional wells are approximately 60 to 180 ft. bgs (MDNR, 2007B); however, drinking water walls are typically installed between 435-460 ft. bgs, within dolomite of the Jefferson City Formation (MDNR, 2007B). Public data of groundwater quality suggests water is typically high in chlorides, sulfates and total dissolved solids and is typically treated (Shepard, 1907).

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

1.4 Land Use

1.4.1 Historic Land Use

Prior to construction of the Montrose Station, the land within ¼ mile radius of the North and South Ash Impoundments was used for agricultural purposes including cultivated crops and grazing. As described in Section 1.2, KCP&L began plant operation starting in 1958. The area of the surface impoundments was included as part of the solid waste permit issued in 1987. The original permit for the existing landfill was issued on July 16, 1987 (No. 708305). Terracon Consultants performed a hydrogeologic evaluation of the area in 1987. Part of the investigation included drilling borings to evaluate the base elevation of the ash. Based on the Terracon borings, the base grade of the existing landfill is estimated to be 757 ft. and the base grade of the ash impoundments is estimated to be 750 ft. The permit also identifies the location of the Western Flyash bagging facility located within the proposed expansion area. The facility included three 1,000-ton silos, one 50-ton silo, office and maintenance buildings, and one bag loading plant. In addition, the facility included a 160-foot deep water well (Walter Handy Well). The approximate locations of this facility and the Terracon borings are shown on **Figure B.6** of **Appendix B**. Above grade demolition of the Western Flyash facility was accomplished in 1992, and the well was decommissioned on November 14, 2003. An expanded 15-acre landfill area northwest of the impoundments was constructed in 2011 with a compacted soil liner and leachate collection system. A sanitary lagoon system with three ponds and a leach field exist just to the north of the impoundments, and a neutralization basin and the generating plant exists to the east, as shown on **Figure A.4** of **Appendix A**.

1.4.2 Current Land Use

As indicated previously, the current land use for the Site is surface impoundments to collect CCR landfill runoff/leachate. See **Appendix A**, **Figure A.4** showing the existing features of the area within ¼ mile of the Site, as well as current property ownership. Within ¼ mile of the Site, predominant land use to the north is agricultural and pastureland; to the east is Montrose Station-related uses (power generation, and waste management); to the west is the CCR Landfill, a stormwater pond, and forested and conservation area land; and to the south is forested land, water (discharge canal and Montrose Lake) and open green space. No residences, mines, sinkholes, springs, or other significant geologic features are known to be located within ¼ mile of the Site.

The permitted solid waste facility includes a stormwater pond, the CCR Landfill and North and South Ash Impoundments that discharge to a cooling water discharge canal (**Figure A.1** in **Appendix A**). The preconstruction surface elevation ranges from approximately 770 ft. to 760 ft. from north to south. The

APPENDIX B

Unstable Areas Supporting Information

APPENDIX B.1

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

beneficially is managed in the North and South Ash Impoundments and the CCR Landfill, situated within the permitted solid waste facility located on the western portion of the property.

The North and South Ash Impoundments were permitted on July 16, 1987 by the MDNR within an 85-acre area consisting of “approximately 39 acres designated for solid waste disposal and approximately 46 acres designated for special waste landfill related design features such as sediment ponds, monitoring wells, and access roads.” The permit was modified in 2010, adding approximately 15 acres to the north end of the CCR Landfill. The water surface area for the North Ash Impoundment (one cell) is approximately 1.6 acres at an elevation of 756.5 feet (ft.) (unless otherwise noted, all elevations in this report are in the NAVD88 datum). The combined water surface area for the South Ash Impoundment (two cells) is approximately 2.3 acres at an elevation of 751.4 ft.

Both of the impoundments accept sluiced economizer ash from the plant and provide stormwater and leachate control for the eastern portion of the CCR Landfill. The Initial Inflow Design Flood Control System Plans for the North and South Ash Impoundments (AECOM, 2016A and AECOM, 2016B) concluded the impoundments managed the combined inflow of plant flows and the 25-year, 24-hour inflow design flood. Impoundment discharges are monitored and reported in accordance with the facility’s National Pollutant Discharge Elimination System (NPDES) permit.

Periodic maintenance of the impoundments includes the removal and dewatering of the economizer ash to maintain an approximate open water operating depth of six feet. The dewatered economizer ash is transported by truck to the CCR Landfill for final disposal.

1.3 Regional Geology and Hydrogeology

1.3.1 Geomorphology

The Montrose Station is located within the Osage Plains physiographic section, which is included within the larger Central Lowland province of the Interior Plains physiographic division (MDNR, 2002). The area 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. Local surface topographic relief is typically less than 250 ft. with greatest relief occurring where major streams incise the underlying rocks (Fenneman, 1938, Imes and Emmett, 1994).

The regional drainage pattern is generally semi-rectangular to dendritic (United States Geological Survey (USGS), 2014). The area is part of the larger South Grand Watershed (EPA, 2017), and the major stream in this area is Deepwater Creek. Deepwater Creek flows in an easterly direction, south of the Montrose Station, and is dammed about one mile east of the Montrose Station, forming Montrose Lake (South Grand River Watershed Alliance, 2012).

1.3.2 Geology

1.3.2.1 Surficial Soils

The United States Department of Agriculture, (USDA) Soil Conservation Service has produced soil maps of this area (USDA, 1976), which are provided as **Figures B.1** and **B.2** in **Appendix B**. The near surface soils include the Hartwell-Deepwater Association and Verdigris-Osage Association. The Hartwell-Deepwater Association soils are described as “deep, nearly level to moderately sloping, somewhat poorly drained and moderately well drained soils that formed in thin loess and the underlying residuum derived from shale.” The representative soil profile of the Hartwell Series is described as “the surface layer is very dark grayish brown silt loam about 10 inches thick. The subsurface layer is grayish brown silt loam about 5 inches thick. The subsoil is about 27 inches thick. The upper part of the subsoil is very dark grayish brown and grayish brown, very firm clay, and the lower part is grayish brown and pale brown, firm and very firm silty clay loam. The underlying material is very pale brown, brownish-yellow, and light brownish gray silt loam." The permeability is described as slow, and the runoff is slow to medium. A perched water table is sometimes present on top of the very firm clay subsoil in wet seasons (USDA, 1976).

The Verdigris-Osage Association soils are mapped as thin, narrow deposits in the stream valleys, located east, west, and south of the Site. These soils are described as "deep, nearly level, moderately well drained and poorly drained soils that formed in alluvium" (USDA, 1976).

1.3.2.2 Stratigraphy

The bedrock near the Site consists of shale, siltstone, sandstone and coal (with underclays) with occasional resistant limestone beds, assigned to the Middle Pennsylvanian Age, Krebs and Cabaniss Subgroups of the Cherokee Group (USGS, 2015). These units are relatively typical of the cyclic sedimentary rock deposits present in the Midwest. Thickness of individual beds varies from thin coal "smuts" to beds as thick as twenty-five ft., with lateral variations occurring in many locations (Thompson, 1995). The specific formations present at the Site have not been identified. A geologic column of the Krebs and Cabaniss Subgroups is presented on **Figures B.3** and **B.4** in **Appendix B**.

Stratigraphy is generally correlated from nearby rock outcrops. An outcrop, located about one mile southwest of the Montrose Station, exposed the lower 5 1/2 ft. of the Bluejacket Formation, about 19 ft. of the Drywood Formation and possibly about one foot of the Rowe Formation at the bottom of the exposure. Another outcrop, located slightly farther southwest of the Montrose Station, had about 2 ½ ft. of the Weir Formation exposed. One additional rock exposure, located about 2 miles east northeast of the Montrose Station, encountered about 1 foot of the Seville Formation overlying about 10 ft. of the Bluejacket Formation (Henderson, 1958). Although exact elevations of these exposed rock units were not documented, the approximate elevations in the area appear to be about the same as those at the Site.

1.3.2.3 Structural Features

The La Due – Freeman Anticline is the closest major structure, mapped approximately 5 miles to the northeast of the Montrose Station. This structure is described as "the largest anticline in Pennsylvanian rocks in western Missouri. It has a broad anticlinal axis with gentle dips that are not apparent in the study of local areas" (McCracken, 1971). **Appendix B**, **Figure B.5** presents the major geologic structures in Henry County.

Local geologic structures in the form of small folds and troughs are observed in several of the coal mine pits in Henry County. Most of these minor structures show dips of the bedrock units of up to 20 degrees and are very small in lateral extent (McCracken, 1971).

In general, bedrock units in this area of Missouri are dipping downward to the northwest on the order of about 6 ½ ft. per mile. The strike of the bedrock units is about 20 – 30 degrees east of north. Local variations are known to occur (McCracken, 1971).

The bedrock units, especially the limestone units, have been subjected to stress in the geologic past, and therefore exhibit a series of near-vertical fractures, termed joints. Joints are also noted in the sandstone and shale units but are more difficult to identify and map. In general, the joints appear to be oriented in two general directions, or sets. The principal joint set has a strike of North 40 – 50 degrees East, with the secondary joint set oriented about 60 – 80 degrees from the primary set. Typically, these joint sets are tight, but may have been subjected to erosion along the fractures (McCracken, 1971).

1.3.3 Hydrogeologic Setting

The Middle Pennsylvanian Age bedrock units beneath the Site are included in the regional hydrogeologic Western Interior Plains Confining System, a thick sequence of mostly layered shale, limestone, sandstone, and evaporate constructed top of the CCR Landfill is currently at approximately 810 ft. A drainage swale around the CCR Landfill directs runoff southward into the stormwater pond or impoundments that eventually discharge to Montrose Lake.

1.5 Site Setting Per Previous Studies

Various hydrogeologic studies have been conducted at the Montrose Station. Terracon Consultants performed a hydrogeologic investigation for the ash disposal area in 1987 (Terracon, 1987), in advance of the facility's operating permit approval dated July 16, 1987. This study included both the original CCR Landfill area and surface impoundment area. The 1987 study included drilling and installation of piezometers to collect groundwater samples and monitor groundwater elevations. AECOM (formerly URS and Woodward-Clyde) completed an investigation titled "Detailed Site Investigation, Geologic and Hydrologic Evaluation Report, Utility Waste Landfill Expansion, KCP&L Montrose Power Station" (URS, 2004), in accordance with 10 CSR 80-2.015 (MDNR, 2007A) for the adjacent 15-acre (approximate) expansion of the CCR Landfill. This document was approved in advance of the facility's construction permit approval dated June 21, 2010, as documented in the Montrose Utility Waste Landfill Expansion Operating Permit Application (URS, 2011). URS installed six groundwater monitoring wells in 2010 in support of the construction permit, as documented in a letter addressed to KCP&L dated November 1, 2010 (URS, 2010).

The locations of the historic borings and monitoring wells from the previous investigations are shown in **Appendix A, Figure A.5**. Historic boring logs and well construction logs are included in **Appendices D.2** and **J.1**, respectively. All the historic wells were re-surveyed by Whitehead Consultants, Inc. in July 2017. The boring logs and well construction logs, provided in **Appendices D.2** and **J.1,** have been marked to reflect the updated survey data. The stratigraphy and hydrogeologic setting encountered during the previous investigations are described below.

1.5.1 Stratigraphy

The 1987 hydrogeologic investigation and 2004 DSI investigation indicate that the stratigraphy at the Montrose Station consists of approximately 23 to 33 ft. of unconsolidated sediments overlying varying types of sandstone, shale and sandstone with layers of coal, claystone and dolomite/limestone. The unconsolidated deposits consist of primarily high plasticity clay overlying lean clay with a thin, 2 to 6 ft., basal clayey sand or gravel zone above bedrock. A thin layer of surface fill material overlies the native soils in some areas.

A series of soil borings were advanced under the direction of Terracon west of the impoundments as part of the 1987 hydrogeologic investigation (Terracon, 1987). In general, the subsurface materials described included unconsolidated clay and silt, averaging 29-ft. in thickness, overlying sandstone bedrock. The unconsolidated deposits varied in constituent content, but generally were relatively plastic near the surface and progressively became silty and sandy with depth towards the parent material, sandstone.

Fourteen soil borings (9 in the landfill expansion area and 5 in the borrow area) were completed for the 2004 DSI investigation. The borrow area borings were shallow (10 ft. bgs). The expansion area borings were deeper (27.5 ft. to 62 ft. bgs) and were completed at or into bedrock. Soil thickness varied from approximately 23.5 to 33 ft. and typically consisted of low to high plasticity clay, probably residual in origin, overlying a sandy or gravely zone immediately above bedrock. In a few areas, a thin layer of fill material was encountered above the native soils.

The 2004 DSI investigation borings encountered bedrock at seven (7) locations at depth of about 23.5 to 33 ft. NX-sized rock core was drilled and collected at some locations to a maximum depth of approximately 43 to 62 ft. bgs. The bedrock varied considerably and consisted of alternating layers of shale and sandstone with occasional layers of claystone and dolomite/limestone. Several coal beds were encountered during the drilling. Surface mining activities were reportedly conducted west of the landfill expansion area. However, voids and cavities were

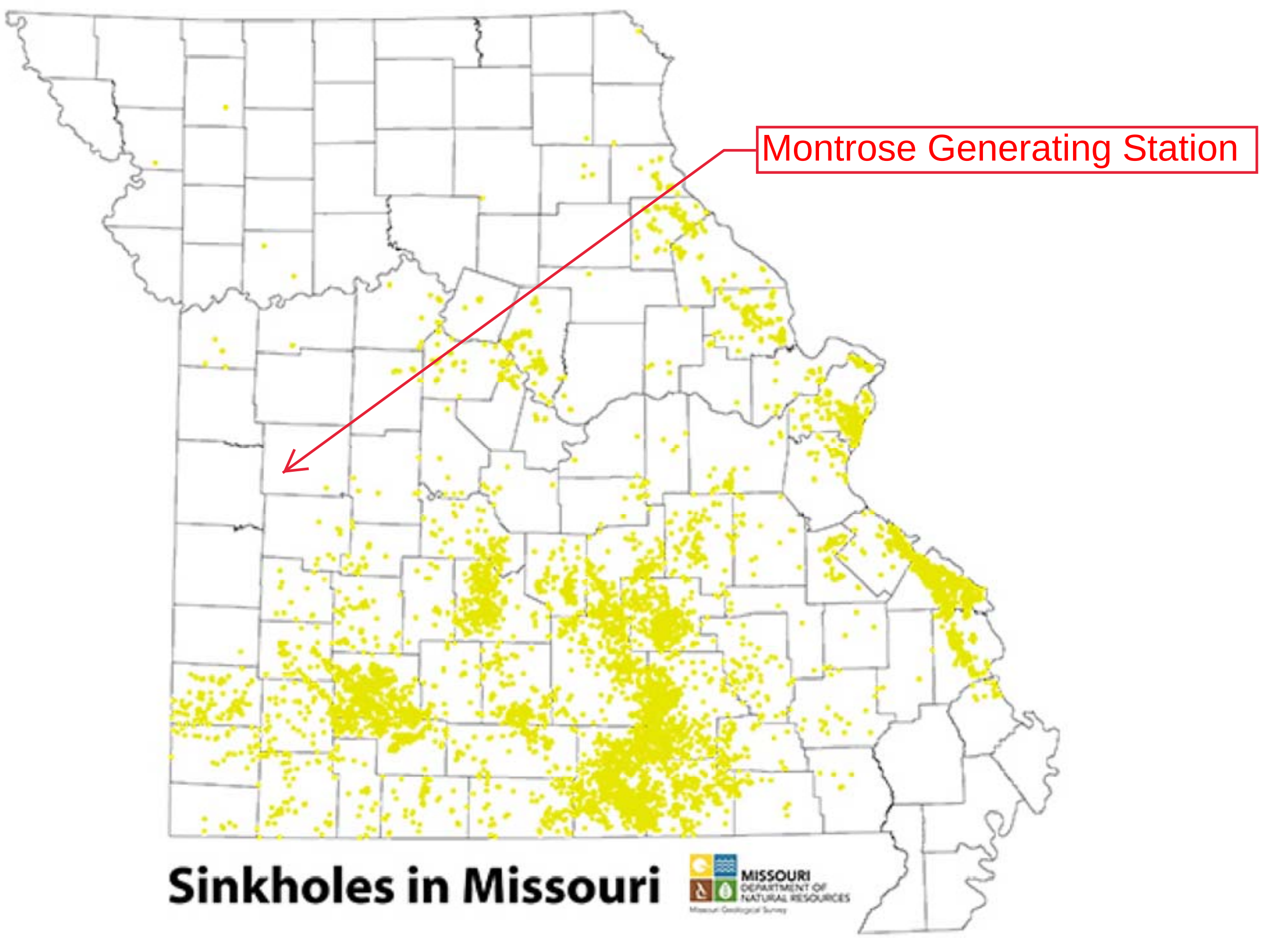
APPENDIX B.2

Geologic/Geomorphologic Features Documentation

Sinkholes in Missouri (MDNR)

Geologic Hazards in Missouri (MDNR, 2015)

GeoSTRAT Database Review


Montrose 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

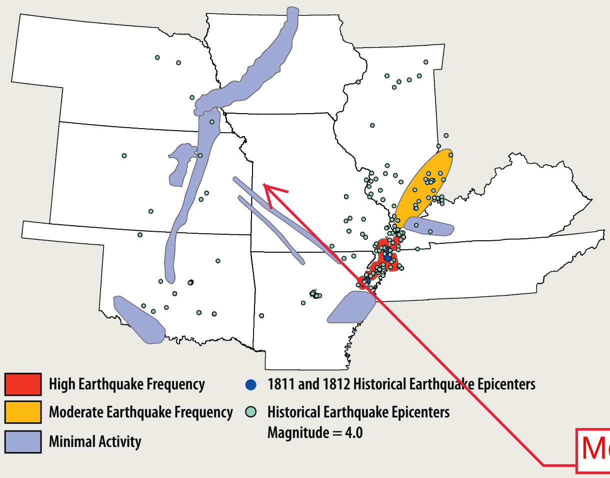
Most Missourians are familiar with the large 1811-1812 earthquakes that occurred in the New Madrid Seismic Zone (NMSZ) in southeast Missouri. However, Missouri experiences small earthquakes nearly every day. These earthquakes typically are too small to be felt but are recorded on seismographs, devices 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.

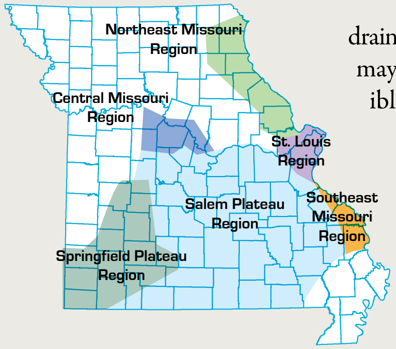
Seismic Zones



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

Geologic Structures

Cave Density

1 cave

2 - 10 caves

11 - 50 caves

N

Printed: 9/17/2018, 4:49:07 PM

APPENDIX B.3

Human-made Features or Events Documentation

Mine Maps – Henry County (MDNR)

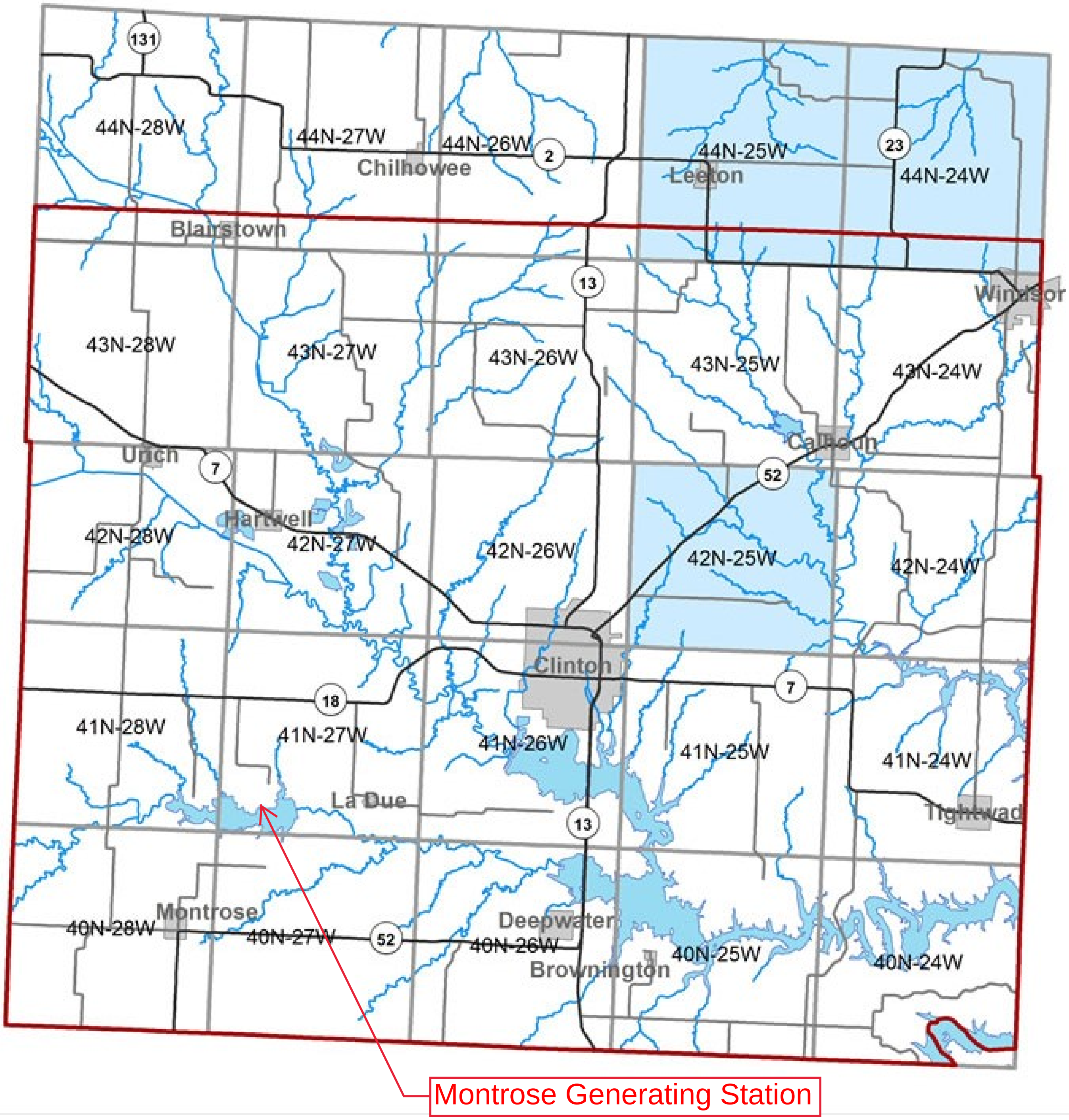
Oil and Gas in Missouri Fact Sheet (MDNR)

Mineral Resources in Missouri (MDNR)

Missouri Coal (MDNR)

Mine Maps -- Henry 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.



Disclaimer – This information is inclusive of maps archived in or scanned by the Missouri Mine Map Repository. It does not contain maps for all underground mines in the state of Missouri.

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

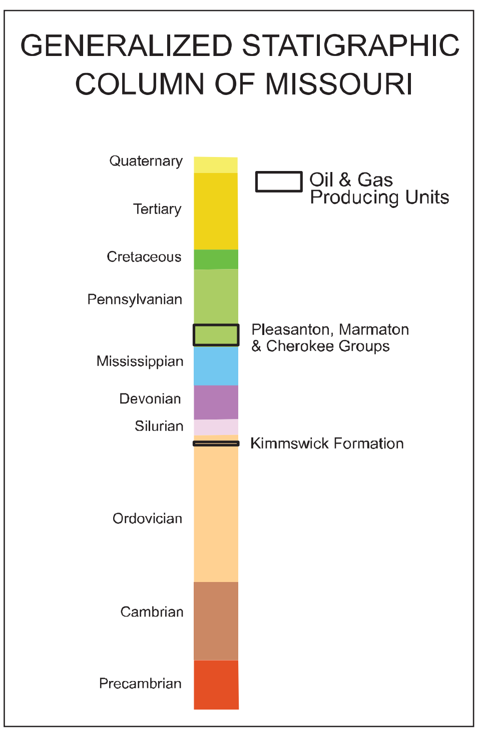
Oil and Gas in Missouri

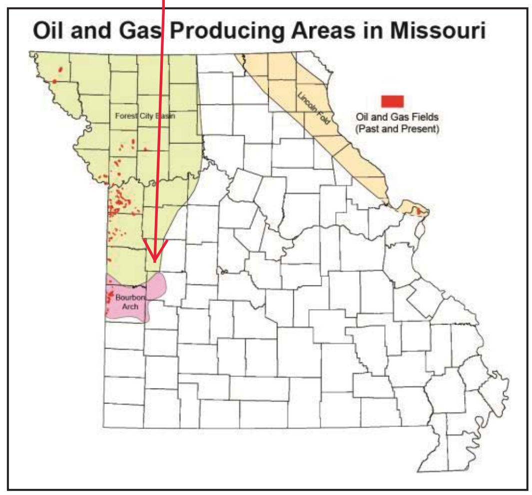
Missouri Geological Survey fact sheet number 19
Missouri Geological Survey Director: Joe Gillman

11/2016

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.

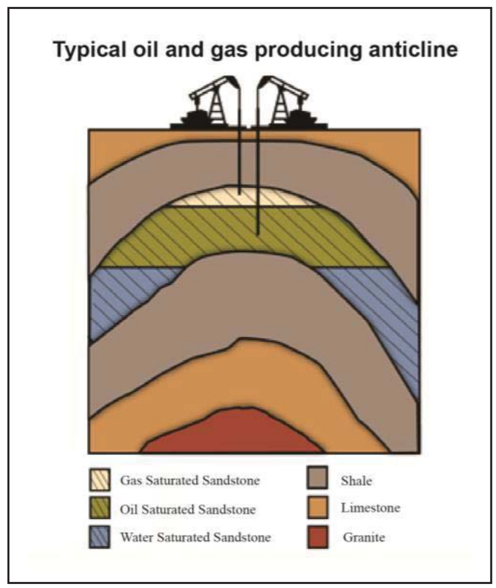
Oil and gas forms from the burial and thermal alteration of shale or mudstone containing abundant organic material from dead marine organisms. Tiny amounts of oil and gas are produced in the shale or mudstone. Under certain geologic conditions, oil and gas migrate and accumulate into pools. The pools 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.

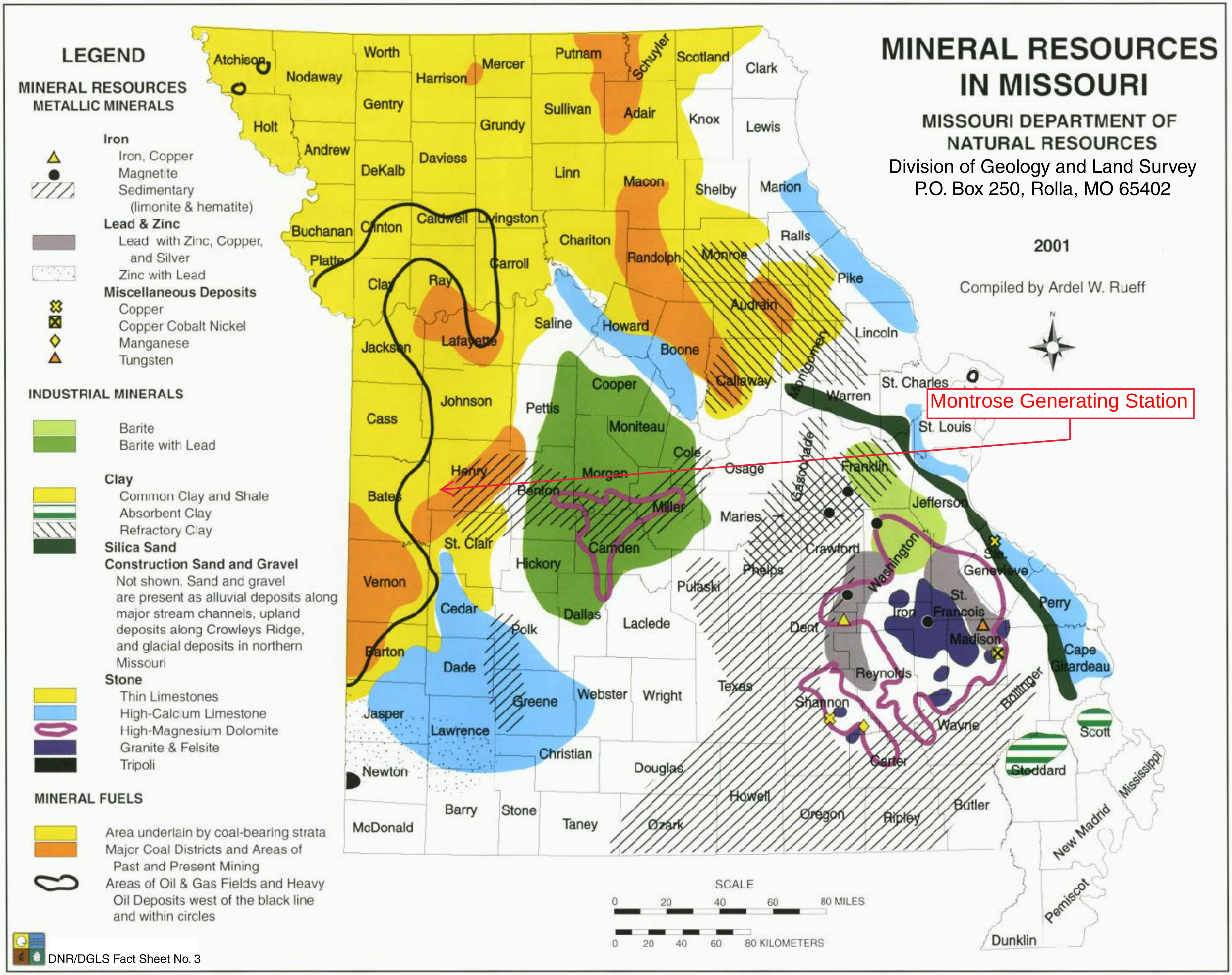
Due to the success of these wells, additional sites were explored in central and eastern Missouri. By the early 1930s, more than 2,500 wells had been drilled in search of oil and gas resources. Additional pools were discovered in Vernon County in the 1920s, Caldwell County in 1940, Atchison County in 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.

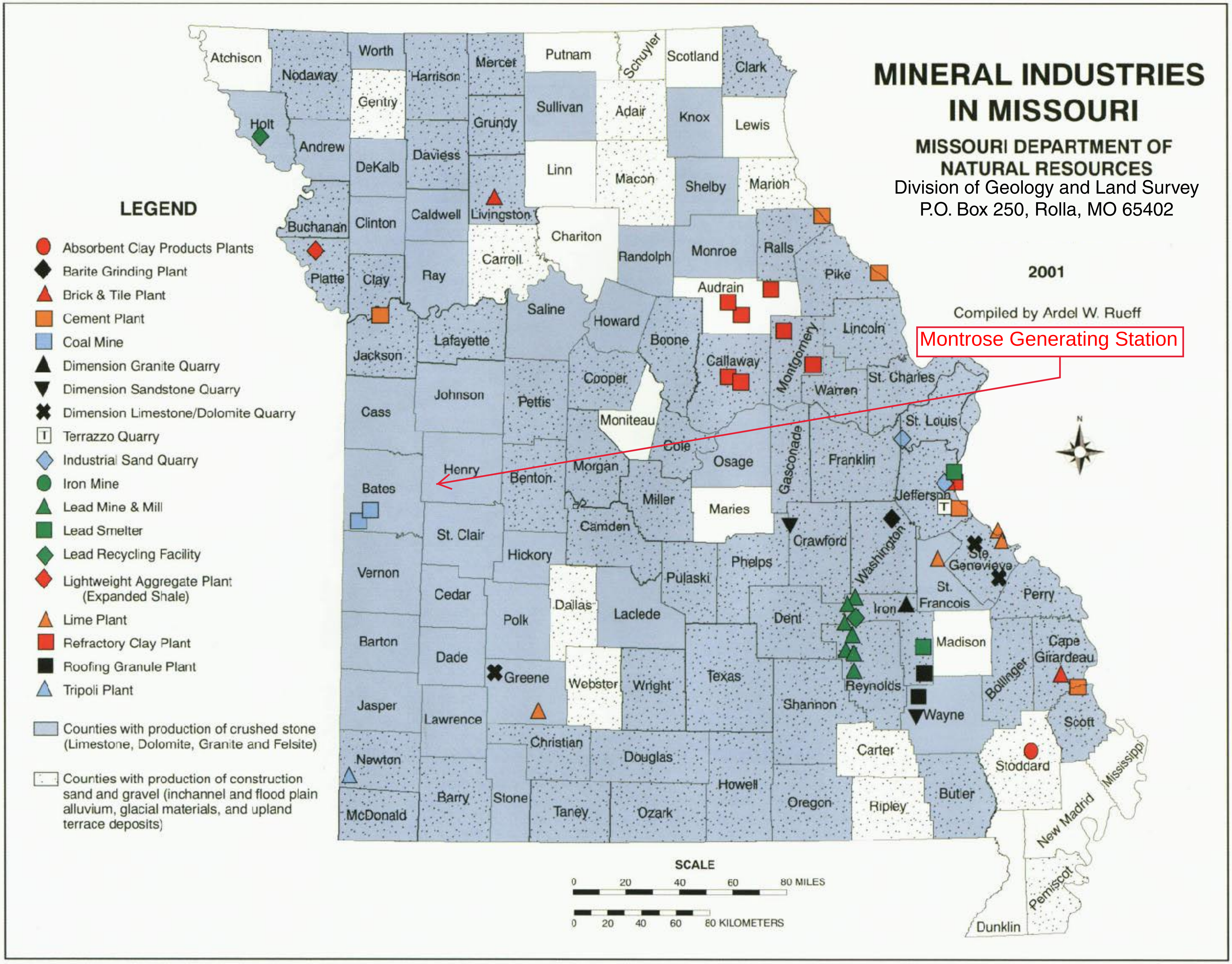
There are three areas of current oil and gas production in the state: the Forest City Basin in northwestern Missouri, the Bourbon Arch in western Missouri and the Lincoln Fold in northeastern Missouri. Within these fields, oil and gas production comes from two producing zones: the Pennsylvanian-age Pleasanton, 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.



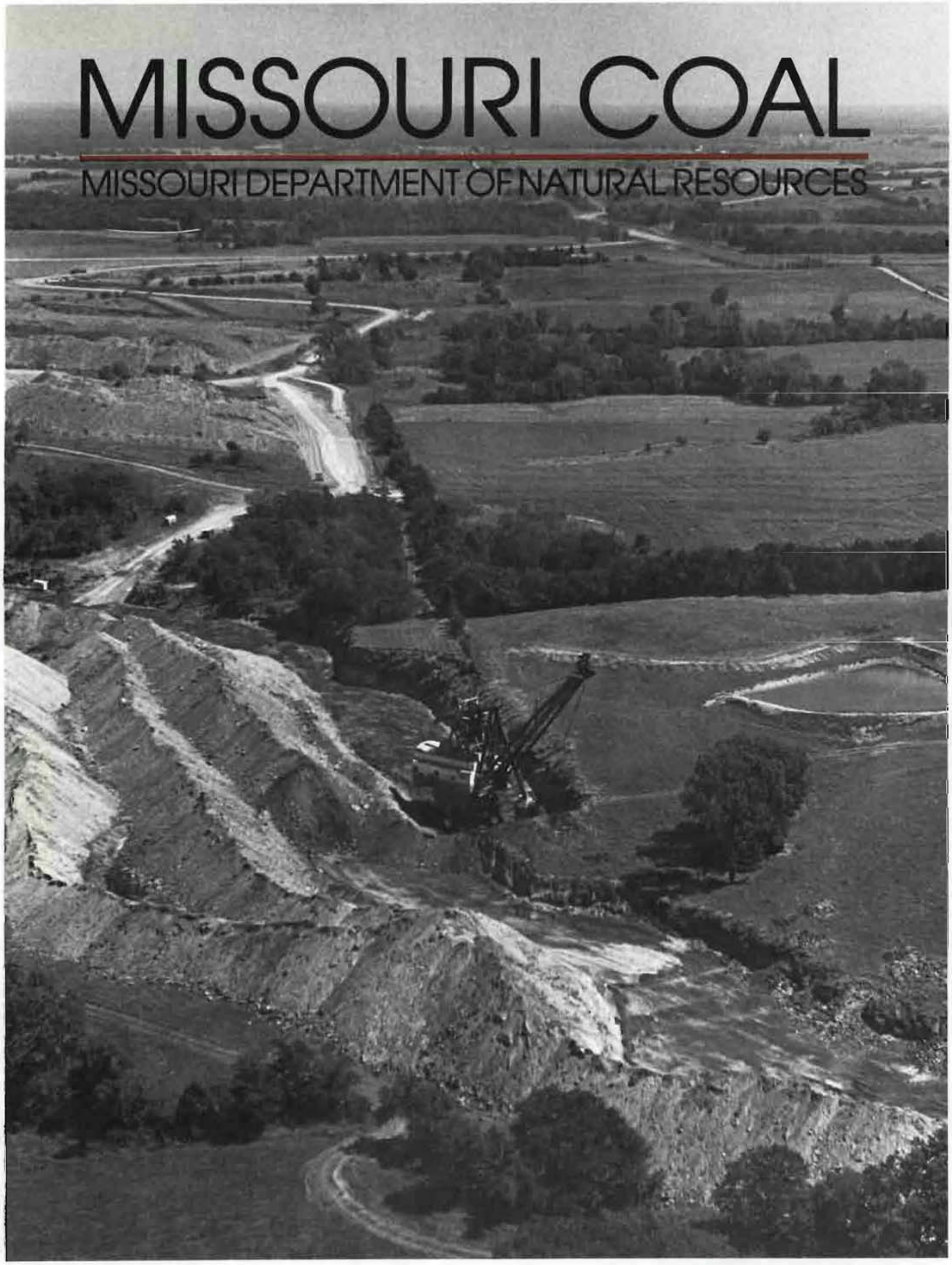
The Missouri Geological Survey has a number of publications about petroleum production and exploration including: OFR-90-80-OG, *Heavy-Oil Resource Potential of Southwest Missouri*; RI-1, *Recent Drilling in Northwestern Missouri*; V-27, *The Oil and Gas Resources of Cass and Jackson Counties Missouri*; 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.


MINERAL RESOURCES IN MISSOURI
MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey
P.O. Box 250, Rolla, MO 65402
2001
Compiled by Ardel W. Rueff
N
Montrose Generating Station
LEGEND
MINERAL RESOURCES
METALLIC MINERALS
Iron
Iron, Copper
Magnetite
Sedimentary (limonite & hematite)
Lead & Zinc
Lead with Zinc, Copper, and Silver
Zinc with Lead
Miscellaneous Deposits
Copper
Copper Cobalt Nickel
Manganese
Tungsten
INDUSTRIAL MINERALS
Barite
Barite with Lead
Clay
Common Clay and Shale
Absorbent Clay
Refractory Clay
Silica Sand
Construction Sand and Gravel
Not shown. Sand and gravel are present as alluvial deposits along major stream channels, upland deposits along Crowleys Ridge, and glacial deposits in northern Missouri
Stone
Thin Limestones
High-Calcium Limestone
High-Magnesium Dolomite
Granite & Felsite
Tripoli
MINERAL FUELS
Area underlain by coal-bearing strata
Major Coal Districts and Areas of Past and Present Mining
Areas of Oil & Gas Fields and Heavy Oil Deposits west of the black line and within circles
Atchison
Nodaway
Worth
Harrison
Mercer
Putnam
Schuyler
Scotland
Clark
Holt
Andrew
Gentry
Grundy
Sullivan
Adair
Knox
Lewis
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
Montgomery
Callaway
Cooper
St. Charles
Warren
Johnson
Pettis
Moniteau
Cass
St. Louis
Cole
Osage
Gasconade
Franklin
Henry
Benton
Morgan
Miller
Bates
Maries
Jefferson
St. Clair
Camden
Crawford
Hickory
Washington
Ste. Genevieve
Phelps
Pulaski
Vernon
St. Francois
Perry
Cedar
Dallas
Laclede
Iron
Polk
Dent
Madison
Barton
Cape Girardeau
Dade
Reynolds
Bollinger
Greene
Webster
Wright
Texas
Shannon
Jasper
Wayne
Lawrence
Scott
Christian
Douglas
Carter
Stoddard
Newton
Howell
Butler
Mississippi
Barry
Stone
Taney
Ozark
Oregon
Ripley
New Madrid
McDonald
Pemiscot
Dunklin
SCALE
0 20 40 60 80 MILES
0 20 40 60 80 KILOMETERS
DNR/DGLS Fact Sheet No. 3


MINERAL INDUSTRIES IN MISSOURI
MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey
P.O. Box 250, Rolla, MO 65402
2001
Compiled by Ardel W. Rueff
Montrose 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
Cooper
Warren
Cass
Johnson
Pettis
Moniteau
St. Louis
Cole
Osage
Gasconade
Franklin
Henry
Benton
Morgan
Bates
Miller
Maries
Jefferson
Camden
Crawford
St. Clair
Hickory
Washington
Ste. Genevieve
Phelps
Pulaski
Vernon
Cedar
Dallas
St. Francois
Perry
Laclede
Iron
Dent
Polk
Barton
Madison
Cape Girardeau
Dade
Greene
Webster
Wright
Texas
Reynolds
Bollinger
Shannon
Jasper
Lawrence
Wayne
Scott
Christian
Carter
Douglas
Stoddard
Mississippi
Newton
Howell
Barry
Stone
Oregon
Ripley
Butler
Taney
Ozark
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.

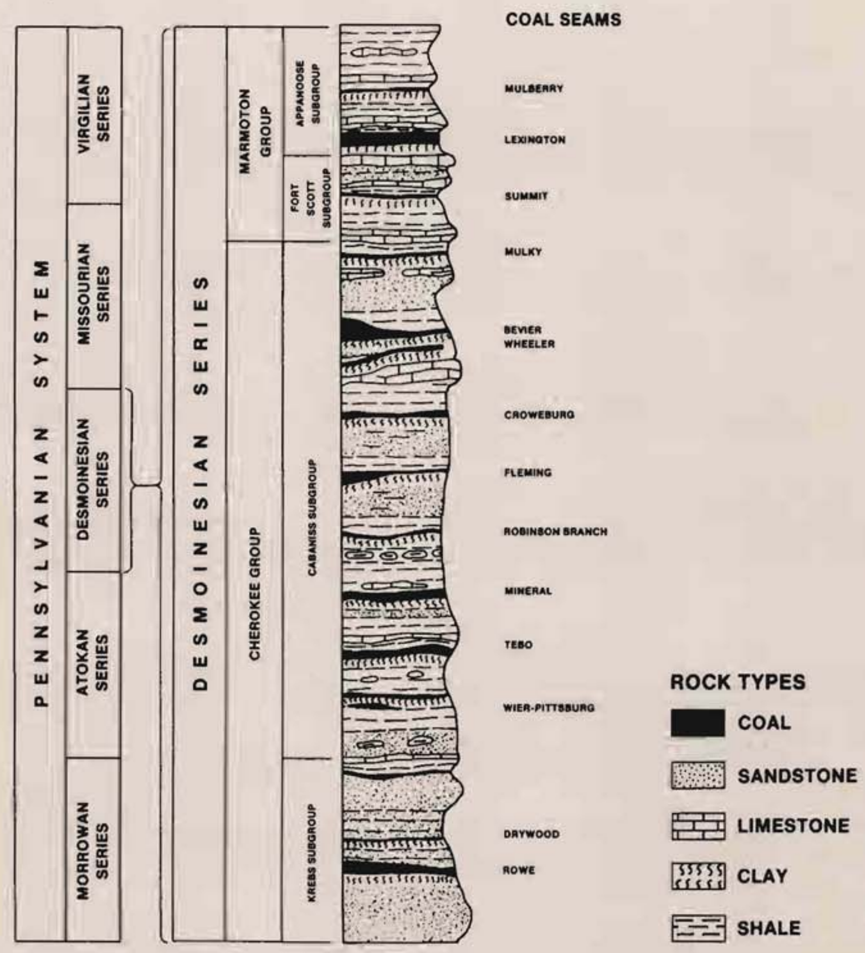
COAL QUALITY

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.

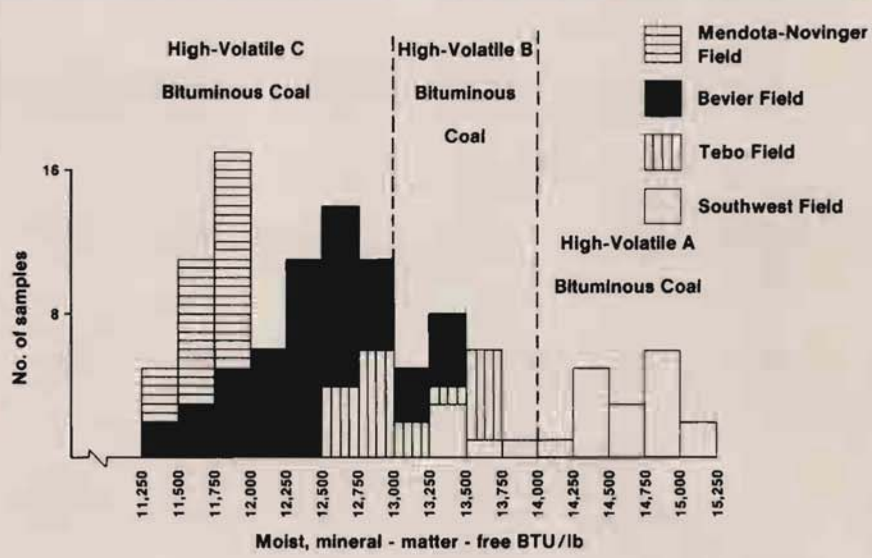
The stage of development, or rank, of coal is partly determined by the heat value of moist, mineral-matter-free coal samples. Heat values of Missouri coal

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.

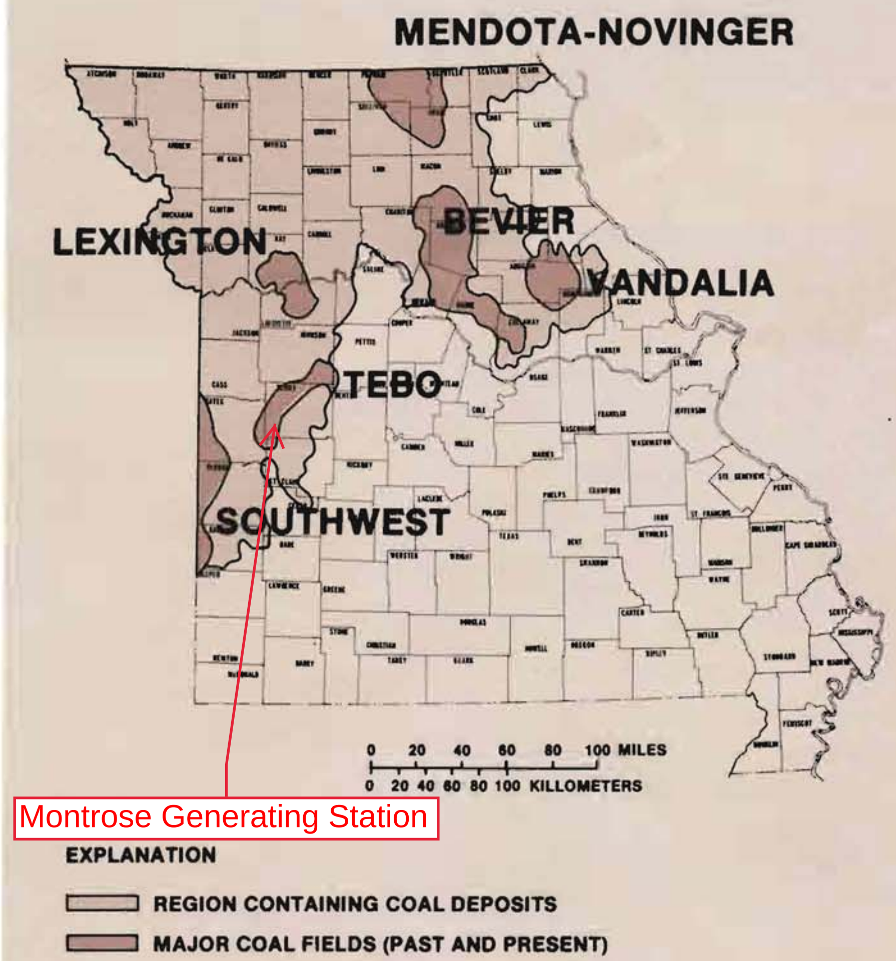
The Tebo field was the largest producing area in the state before mining activity increased in the Bevier field in the late 1970s. Current production from the Tebo field constitutes 10 percent of the state's annual coal production. Most of the coal produced in the region is mined from the Tebo seam.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

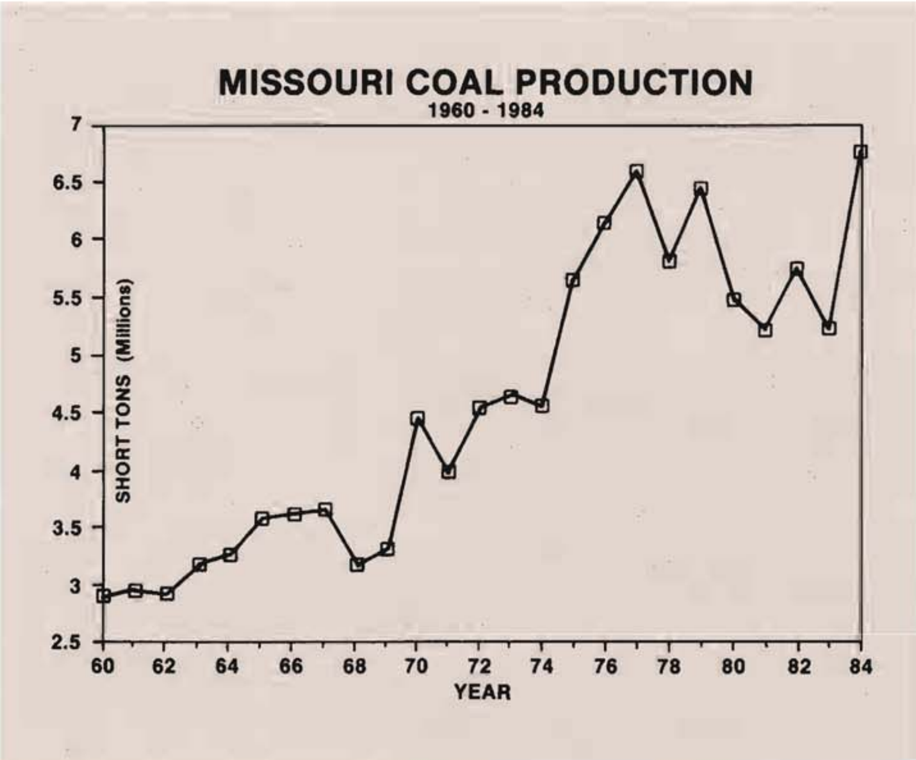
The 6,810,336 tons of coal mined in 1984 was valued at more than $170 million. That was an average price of $25 per ton received at the mine, a price that had changed little from the previous three years.

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.

MISSOURI DEPARTMENT OF NATURAL RESOURCES
Division of Geology and Land Survey
P.O. Box 250
Rolla, MO 65401