Kansas Field Conference
September 9–10, 2015

East-Central Kansas

Managing Resources for Economic Growth and the Environment

Field Guide

Compiled by Susan Stover and Catherine S. Evans

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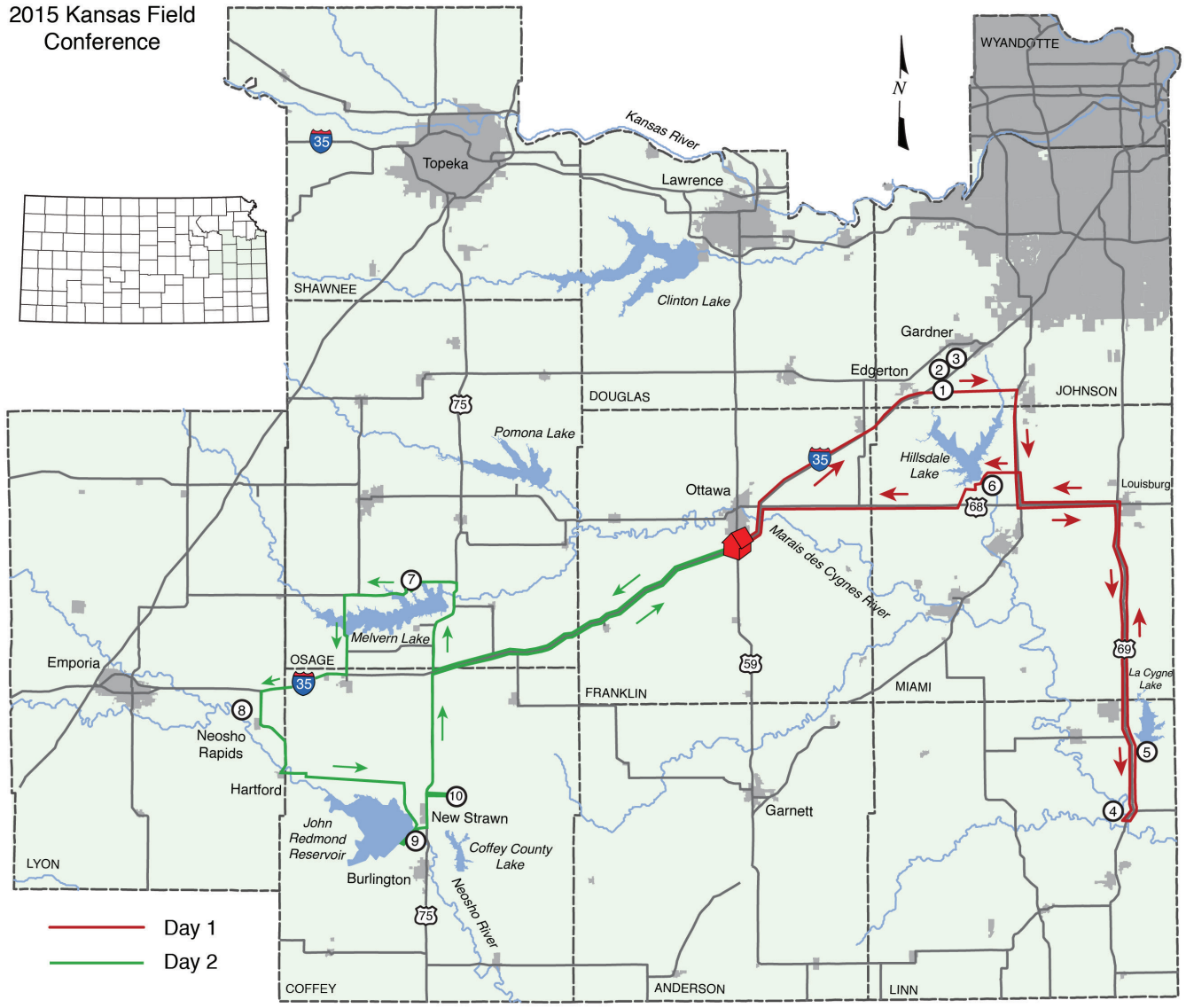
KGS Open-File Report 2015-4

Kansas Geological Survey
Geology Extension
The University of Kansas
1930 Constant Avenue
Lawrence, KS 66047-3724
785-864-3965
www.kgs.ku.edu

Cover photo: Marais des Cygnes Wildlife Area. Photo from the Kansas Department of Wildlife, Parks and Tourism.


2015 Kansas Field Conference
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Kansas River
Topeka
Lawrence
SHAWNEE
Clinton Lake
Gardner
Edgerton
JOHNSON
DOUGLAS
Pomona Lake
Hillsdale Lake
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Louisburg
Marais des Cygnes River
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La Cygne Lake
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Participants

Steve Adams, Chief of Planning, Kansas Department of Wildlife, Parks & Tourism

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John Bradford, Representative, Lansing

Scott Carlson, Assistant Director, Division of Conservation, Kansas Department of Agriculture

John Carmichael, Representative, Wichita

Willie Dove, Representative, Bonner Springs

Debra FitzGerald, Petroleum geologist & Kansas Geological Survey Advisory Council (GSAC) member

Steve Fitzgerald, Senator, Leavenworth

Dolores Furtado, Immediate past president, League of Women Voters of Kansas

Raney Gilliland, Director, Kansas Legislative Research Department

Tom Hawk, Senator, Manhattan

David Heinemann, Chair, Kansas Geological Survey Advisory Council (GSAC)

Bob Henthorne, Chief geologist, Kansas Department of Transportation

Larry Hibbard, Representative, Toronto

Kyle Hoffman, Representative, Coldwater

Mitch Holmes, Senator, St. John

Robin Jennison, Secretary, Kansas Department of Wildlife, Parks & Tourism

Laura Kelly, Senator, Topeka

Dan Kerschen, Senator, Garden Plain

Mike King, Secretary, Kansas Department of Transportation

Annie Kuether, Representative, Topeka

Tamera Lawrence, Assistant Revisor of Statutes, Kansas Office of Revisor of Statutes

Earl Lewis, Assistant Director, Kansas Water Office

Brad Loveless, Executive Director, Environmental Services, Westar Energy

Adam Lusker, Sr., Representative, Frontenac

Ed Martinko, Director, Kansas Biological Survey

Gary Mason, Deputy Secretary for Environment, Kansas Department of Health and Environment

Karma Mason, CEO/President, iSi Environmental & Kansas Water Authority member

Carolyn McGinn, Senator, Sedgwick

John Mitchell, Director, Division of Environment/ Kansas Department of Health and Environment

Ralph Ostmeyer, Senator, Grinnell

Tom Phillips, Representative, Manhattan

Larry Powell, Senator, Garden City

Josh Roe, Assistant Secretary, Kansas Department of Agriculture

Melissa Rooker, Representative, Fairway

Dennis Schwartz, Kansas Water Authority member

Sharon Schwartz, Representative, Washington

Paul Simpson, President, Trilobite Testing Inc. & Kansas Geological Survey Advisory Council (GSAC) member

Tracy Streeter, Director, Kansas Water Office

Susie Swanson, Representative, Clay Center

Marc Tanking, Middle school science teacher, Mater Dei Catholic School, Topeka

Caryn Tyson, Senator, Parker

Jim Ward, Representative, Wichita

Julie Westhoff, Senior project manager, Kennedy/ Jenks Consultants & Kansas Geological Survey Advisory Council (GSAC) member

Kansas Geological Survey Staff

Susan Stover
Rex Buchanan
Cathy Evans
Bob Sawin

Biographical Information

Steve Adams
Chief of Planning
Kansas Department of Wildlife, Parks and Tourism
1020 S. Kansas Avenue
Topeka KS 66612
785-296-2281 Business
steve.adams@ksoutdoors.com
Responsibilities and Experience: KDWPT, 1989–present. Education: Northeastern State University, BS; Oklahoma State University, MS

Bob Atchison
Rural Forestry Coordinator
Kansas Forest Service
2610 Claflin Rd
Manhattan KS 66502
785-532-3310 Business
Atchison@ksu.edu
Responsibilities and Experience: Responsible for statewide delivery of professional forestry—agroforestry technical services and the supervision of nine KFS foresters, GIS, and watershed specialists. Interests include geo-spatially identifying priority areas to address issues that are both threats and opportunities to Kansas forests, woodlands, and shelterbelts through the Kansas Forest Action Plan. Education: University of Missouri, BS, Forest Management

John Bradford
Kansas House of Representatives, District 40
125 Rock Creek Loop
Lansing KS 66043
785-296-7653 Business
913-683-0871 Home
jbrad125@gmail.com
Responsibilities and Experience: Member, Education, Federal and State Affairs, and Financial Institutions committees. Education: Chaminade University of Honolulu, BA, Political Science; U.S. Army Command and General Staff College, Diploma; Florida Institute of Technology, MS, Logistical Management

Scott Carlson
Assistant Director
Division of Conservation, Kansas Department of Agriculture
1320 Research Park Dr.
Manhattan KS 66502
785-564-6618 Business
scott.carlson@kda.ks.gov
Responsibilities and Experience: Assistant Director, Division of Conservation; Mined Land Reclamation Program manager. Education: Fort Hays State University, BS, Agriculture; University of Kansas, MPA

John Carmichael
Kansas House of Representatives, District 92
1475 Lieunett St
Wichita KS 67203
316-264-3300 Business
316-250-0969 Home
john.carmichael@house.ks.gov
Responsibilities and Experience: Member, House Energy and Environment, Local Government, and Elections committees; Attorney, Conlee, Schmidt & Emerson. Education: University of Kansas, BGS; Wichita State University, BS; University of Kansas, JD

Willie Dove
Kansas House of Representatives, District 38
14715 Timber Lane
Bonner Springs KS 66012
913-909-5866 Business
913-422-8317 Home
Williedove@sunflower.com
Responsibilities and Experience: House Majority Whip; Member, Insurance, and Education committees.

Debra FitzGerald
Petroleum Geologist
2343 N. Stoneybrook Ct.
Wichita KS 67226
316-619-7008 Business
debrafitz@yahoo.com
Responsibilities and Experience: Member, Kansas Geological Survey Advisory Council (GSAC); Consulting geologist; Past president and member, Kansas Geological Society; Past president and member, Kansas Geological Foundation; Member, American Association Petroleum Geologist; Licensed geologist, State of Kansas. Education: Wichita State University, geology.

Steve Fitzgerald
Kansas State Senate, District 5
3100 Tonganoxie Rd
Leavenworth KS 66048
913-306-1838 Home/Business
Fitz_Steve@hotmail.com
Responsibilities and Experience: Vice Chair, Local Government and Ethics and Education committees; Member, Transportation, Education, and Ways and Means committees; Retired military. Education: University of St. Martin, BA; Central Michigan University, MA; Command & General Staff College, MMAS

Dolores Furtado
Immediate Past President
League of Women Voters of Kansas
10104 Hemlock Dr.
Overland Park KS 66212
913-341-3072 Business/Home
dfurtado08@gmail.com
Responsibilities and Experience: Was involved in planning Intermodal in Gardner when on Johnson County Board of County Commissioners; Served in Kansas House of Representatives with interest in transportation and environmental impact; As a microbiologist, interests include the ecology of water and soil. Education: Cornell University, BS; University of Michigan, Ann Arbor, MS and PhD.

Raney Gilliland
Director
Kansas Legislative Research Department
300 SW 10th Ave, Rm 68–West
Topeka KS 66612-1504
785-296-3181 Business
Raney.Gilliland@klrd.ks.gov
Responsibilities and Experience: Director, KLRD; Staff for Agriculture and Natural Resources, Administrative Rules and Regulations, Energy and Environment Policy; 37 sessions in KLRD. Education: Kansas State University, BS, 1975, and MS, 1978

Tom Hawk
Kansas State Senate, District 22
2600 Woodhaven Ct
Manhattan KS 66502
785-341-4162 Business
tom@tomhawk.com
Responsibilities and Experience: Financial Institutions and Insurance (ranking democrat), Natural Resources, Agriculture, and Utilities committees. Education: Kansas State University, BS, MS, and PhD

Dave Heinemann
Chair, Kansas Geological Survey Advisory Council (GSAC)
3826 SW Cambridge Court
Topeka KS 66610
785–213–9895
daveh123@cox.net
Responsibilities and Experience: Legislative representative for American Heart Association, High Plains Public Radio, Schools for Quality Education, and Smoky Hills Public Television. Education: Augustana College, BA; University of Kansas; Washburn Law School, JD

Bob Henthorne
Chief Geologist
Kansas Department of Transportation
2300 Van Buren Street
Topeka KS 66611
785-291-3860
roberth@ksdot.org
Responsibilities and Experience: Chief geologist; Geologist member and elected secretary, Kansas State Board of Technical Professions; President-elect, Association of State Boards of Geology. Education: University of Kansas, BS, Geology

Larry Hibbard
Kansas House of Representatives, District 13
858 EE 75 Road
Toronto KS 66777
620-583-3334 Business
620-637-2454 Home
larryphibbard@gmail.com
Responsibilities and Experience: Ranching operation; Member, Agriculture and Natural Resources, Agriculture and Natural Resources Budget, Utilities and Telecommunications committees; Vice chairman, House Rural Caucus. Education: Kansas State University, 3 years, Animal Science

Kyle Hoffman
Kansas House of Representatives, District 116
1318 Avenue T
Coldwater KS 67029
620-635-5844 Business
620-582-2217 Home
kyle.hoffman@house.ks.gov
Responsibilities and Experience: Chair, Agriculture Budget Committee; Member,

Judiciary and Appropriations committees; Member, Comanche County Conservation District Board; Member, Pratt Community College Foundation Board. Education: Coldwater High School; Kansas State University, BS, Agriculture

Mitch Holmes
Kansas State Senate, District 33
211 SE 20th Ave.
St. John KS 67576
785-296-7667 Business
620-234-5834 Home
Mitch.Holmes@senate.ks.gov
Responsibilities and Experience: Chair, Ethics and Elections Committee; Member, Agriculture, Local Government, Public Health and Welfare, Federal and State Affairs committees; Select Committee on KPERS; Board member, Kansas Board of Emergency Medical Services; Small business owner. Education: Hutchison Community College, AA, Music; Friends University, Human Resource Management; DePaul University, Computer Programming

Robin Jennison
Secretary
Kansas Department of Wildlife, Parks and Tourism
1020 S. Kansas Avenue, Room 200
Topeka KS 66612
785-296-2282 Business
robin.jennison@ksoutdoors.com
Responsibilities and Experience: Secretary, Kansas Department of Wildlife, Parks and Tourism, 2011–present. Education: Healy USD 468; Fort Hays State University, Animal Science

Laura Kelly
Kansas State Senate, District 18
234 SW Greenwood Ave
Topeka KS 66606
758-296-7365 Business
785-357-5304 Home
laura@laurakelly.org
Responsibilities and Experience: Ranking Minority Member, Senate Ways & Means, Public Health & Welfare, and KanCare Oversight committees; Member, Financial Institution and Insurance, Legislative Post Audit, Healthcare Stabilization Oversight, KPERS Select, and Joint Building Construction committees. Education: Bradley University, BS; Indiana University, MS; New York University

Dan Kerschen
Kansas State Senate, District 26
645 S 263 W
Garden Plain KS 67050
316-535-2310 Business/Home
dnkerschen@gmail.com
Responsibilities and Experience: 3K Holstein Farm, Inc. and D&D Farms Partnership (owner-operator); Natural Resources, Agriculture committees. Education: Kansas State University, BS, Agriculture

Mike King
Secretary, Kansas Department of Transportation and Director, Kansas Turnpike Authority
700 SW Harrison Street
Topeka KS 66603-3745
785-296-3285 Business
peggyh@ksdot.org
Responsibilities and Experience: Secretary, Kansas Department of Transportation; Director, Kansas Turnpike Authority; Governor's Growth Team member; President, Mid America Association of State Transportation Officials. Education: John Brown University, BS, Building Construction

Annie Kuether
Kansas House of Representatives, District 55
1346 SW Wayne Ave
Topeka KS 66604
785-296-7669 Business
785-633-4555 Home
kuet@aol.com
Responsibilities and Experience: Ranking Member: Energy and Environment, Utilities and Telecommunications committees; Member: Judiciary Committee. Education: Webster Groves High School; Bowling Green State University, Ohio

Tamera Lawrence
Assistant Revisor of Statutes
Kansas Office of Revisor of Statutes
Statehouse
300 SW 10th, STE 24-E
Topeka KS 66612
785–296–5243 Business
tamera.lawrence@rs.ks.gov
Responsibilities and Experience: Staff, Natural Resources Committee, Kansas Electric Transmission Authority, House Education and House Veterans, Military and Homeland Security committees. Education: University of Kansas, BS, JD

Earl Lewis
Assistant Director
Kansas Water Office
900 SW Jackson, Suite 404
Topeka KS 66612
785-296-3185 Business
earl.lewis@kwo.ks.gov
Responsibilities and Experience: Day-to-day operations of KWO; Oversees budget development, water plan creation, and project implementation. Education: University of Kansas, BS, Engineering

Brad Loveless
Executive Director
Environmental Services
Westar Energy
818 S Kansas Avenue
Topeka KS 66601
785-575-8115 Business
brad.loveless@westarenergy.com
Responsibilities and Experience: Responsible for air, water, waste, environmental compliance as well as environmental protection, infrastructure siting, impact avoidance; Member, Kansas Forest Service Advisory Council, Kansas Water Authority; Chair, Kansas Alliance for Wetlands and Streams (KAWS). Education: Ohio State University, BS; University of Kansas

Adam Lusker, Sr.
Kansas House of Representatives, District 2
452 S 210th Street
Frontenac KS 66763
620-235-6685 Business
620-231-3754 Home
adam.lusker@house.ks.gov
Responsibilities and Experience: Member: Agriculture and Natural Resources, Veterans, Military and Homeland Security committees, Joint Committee on State Building Construction; Bricklayer. Education: Frontenac High School

Edward Martinko
Director
Kansas Biological Survey
Higuchi Hall
2101 Constant Avenue
University of Kansas
Lawrence KS 66047-3759
785-864-1505 Business
martinko@ku.edu
Responsibilities and Experience: State Biologist and Director, Kansas Biological Survey; Professor of Ecology and Evolutionary Biology; Ex-officio member, Kansas Water Authority. Education: College of Emporia, BS; University of Colorado, MA, 1970; University of Kansas, PhD

Gary Mason
Deputy Secretary for Environment
Kansas Department of Health and Environment
Curtis State Office Building
1000 SW Jackson St, Suite 540
Topeka KS 66612
785-296-1521 Business
gmason@kdheks.gov
Responsibilities and Experience: Provide support on policy for KDHE when dealing with environmental issues; Conduct outreach with regulated community, legislature, and other agencies; Work with KDHE Division of Environment to facilitate policy changes impacting operations. Interests: Staying informed on major environmental issues impacting state. Education: University of Missouri, BS, Chemical Engineering

Karma Mason
CEO/President, iSi Environmental
215 S. Laura
Wichita KS 67211
316-264-7050 Business
kmason@isienvironmental.com
Responsibilities and Experience: CEO/President of iSi Environmental, a full-service consulting and facility support firm with more than 150 employees; Serving fourth term on the Kansas Water Authority. Education: Wichita State University, MS, Geology

Carolyn McGinn
Kansas State Senate, District 31
PO Box A
Sedgwick KS 67135
316-655-3301 Business
316-772-0147 Home
mcginnfarm@gmail.com
Responsibilities and Experience: Senate Judiciary, Natural Resources, Agriculture, Corrections and Juvenile Justice committees; Joint Committee on Juvenile Justice Oversight; Agriculture producer; Interested in agritourism and fresh markets. Education: Wichita State University, BA, business administration; Friends University, MS, Environmental Studies

John Mitchell
Director, Division of Environment
Kansas Department of Health and Environment
1000 SW Jackson, Suite 400
Topeka KS 66612
785-296-1535 Business
jmitchell@kdheks.gov
Responsibilities and Experience: Day-to-day operations of all environmental programs within KDHE, Division of Environment—air, water, waste, remediation, district offices, and laboratories; Division staff is more than 400 employees statewide; At KDHE for more than 35 years. Education: University of Kansas, BA, Biology and Microbiology; University of Kansas, MS, Environmental Health Science

Ralph Ostmeyer
Kansas State Senate, District 40
P.O. Box 97
Grinnell KS 67738
785-673-9083 Business
785-824-3773 Home
rostmey@gmail.com
Responsibilities and Experience: Chair, Federal and State Affairs Committee; Member, Agriculture, Natural Resources, and Correction and Juvenile Justice, committees; Chair, Joint Committee on State-Tribal Relations; Member, Joint Committee on Administrative Rules and Regulations; Farmer and Rancher. Education: Fort Hays State University

Tom Phillips
Kansas House of Representatives, District 67
1530 Barrington Dr.
Manhattan KS 66503
785-770-2693 Business
785-537-2194 Home
tphillips3@cox.net
Responsibilities and Experience: Vice chair, Local Government Committee; Member, Children and Seniors, Energy and Environment, and Taxation committees; Community Development Consultant

Larry Powell
Kansas State Senate, District 39
2209 Grandview Dr E
Garden City KS 67846
785-380-1262 Business
620-275-6789 Home
lpowell18@cox.net
Responsibilities and Experience: Chair, Senate Natural Resources Committee; Member, Ways and Means, Tax, Agriculture, and Utilities committees. Education: Garden City Community College, Associate's Degree, Agriculture

Josh Roe
Assistant Secretary
Kansas Department of Agriculture
1320 Research Park Dr.
Manhattan KS 66502
785-564-6700 Business
josh.roe@kda.ks.gov
Responsibilities and Experience: Water policy; Tax policy; Interaction of agriculture, environment, and the economy. Education: Kansas State University, BS, Agricultural Economics; Iowa State University, MS, Agricultural Economics

Melissa Rooker
Kansas House of Representatives, District 25
4124 Brookridge Dr
Fairway KS 66205
913-961-1555 Business
913-384-7371 Home
melissa@melissarooker.com
Responsibilities and Experience: Member, Transportation, Transportation and Public Budget, Vision 2020, Children and Seniors committees. Fifteen years as VP of Development for Clint Eastwood at Malpaso Productions; Community volunteer. Education: University of Kansas, BFA, Art History

Dennis Schwartz
Kansas Water Authority
6314 SW Monarch Ct.
Topeka KS 66610
785-215-8688 Home
nrwadennis@aol.com
Responsibilities and Experience: Protecting, preserving, and managing the water resources of the state of Kansas; As a director of the National Rural Water Association, working for the interest of public water supply systems

Sharon Schwartz
Kansas House of Representatives, District 106
2051 20th Rd
Washington KS 66968
785-296-7637 Business
785-325-2568 Home
Sharon.schwartz@house.ks.gov
Responsibilities and Experience: Chair, Agriculture and Natural Resources committee;

Vice chair, Appropriations and Legislative Budget committees; Farms with family in Washington County

Paul Simpson
Kansas Geological Survey Advisory Council (GSAC)
President, Trilobite Testing, Inc.
1515 Commerce Parkway
Hays KS 67601
785-625-4778 Business
paul@trilobitetesting.net
Responsibilities and Experience: President, Trilobite Testing, Inc.; President, Monster Pump Operations, Inc. Education: Fort Hays State University, BS, Geology

Tracy Streeter
Director
Kansas Water Office
900 SW Jackson, Suite 404
Topeka KS 66612
785-296-3185 Business
tracy.streeter@kwo.ks.gov
Responsibilities and Experience: Agency head since 2004; 30 years state service; Western States Water Council; MoRAST; Chair, Governor's Drought Response Team; Chair, Kansas GIS Policy Board; Private pilot. Education: Highland Community College, AA; Missouri Western State University, BS, Agricultural Economics; University of Kansas, MPA

Susie Swanson
Kansas House of Representatives, District 64
1422 5th Street
Clay Center KS 67432
785-296-7642 Business
785-587-7483 Cell
svswan@twinvalley.net
Responsibilities and Experience: Member, Vision 20/20, Children & Seniors, Corrections & Juvenile Justice, and Agriculture and Natural Resources committees. Education: Emporia State University, BA, Sociology; University of Kansas, MSW, Social Work

Marc Tanking
Middle School Science Teacher
Mater Dei Catholic School
704 SW Grand Ct.
Topeka KS 66606
785-233-1727 Business
Responsibilities and Experience: Teaches earth, life, and physical science; Interested in learning about issues within the state to benefit students and help guide them to a future career in science. Education: Kansas State University, BS, Agriculture

Caryn Tyson
Kansas State Senate, District 12
P.O. Box 191
Parker KS 66072
913-898-2366 Home
Caryn.Tyson@senate.ks.gov
Responsibilities and Experience: Vice chair, Assessment and Taxation Committee; Member, Natural Resources, Education, Ways and Means committees

Jim Ward
Kansas State House of Representatives, District 86
3100 E Clark
Wichita KS 67211
316-210-3609 Business/Home
repwardks86@gmail.com
Responsibilities and Experience: Attorney; Member, Judiciary and Pensions & Benefits committees. Education: Creighton University, BA; Washburn School of Law, JD

Julie Westhoff
Senior Project Manager
Kennedy/Jenks Consultants
5800 Foxridge Drive
Mission KS 66202
913–643-4951 Business
juliewesthoff@kennedyjenks.com
Responsibilities and Experience: Manages environmental projects for clients with emphasis on site investigations and remediation; Member, KGS Advisory Council (GSAC), KDHE Bureau of Environmental Remediation Advisory Board, and KU Geology Associates Advisory Board; Member, Association of Environmental and Engineering Geologists. Education: University of Kansas, BS, Geology and Biology

Kansas Geological Survey Staff

Rex Buchanan
Interim Director
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2106
rex@kgs.ku.edu
Responsibilities and Experience:
Responsible for operations and direction of the Kansas Geological Survey; Previous: University-Industry Research, University of Wisconsin; Salina Journal. Education: Kansas Wesleyan University, BA, Biology and History; University of Wisconsin–Madison, MA, History of Science; University of Wisconsin–Madison, MS, Agricultural Journalism

Cathy Evans
Writer/Communications Coordinator
Outreach and Public Service
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2195
cevans@kgs.ku.edu
Responsibilities and Experience: Writes news releases and educational materials; oversees writing and editing aspects of KGS Outreach and Public Service; assists with Kansas Field Conference and guidebook. Previous: University Press of Kansas; Spencer Museum of Art. Education: University of Kansas, BA, Art History; University of Kansas, MS, Journalism

Bob Sawin
Geologist/Stratigraphic Research
Stratigraphic Research/Outreach and Public Service
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2099
bsawin@kgs.ku.edu
Responsibilities and Experience:
Stratigraphic research, geologic mapping, stratigraphic nomenclature committee chair; Kansas Geological Survey. Previous: Petroleum geology; engineering geology. Education: Kansas State University, BS, Geology; Kansas State University, MS, Geology

Susan Stover
Geologist/Outreach Manager
Outreach and Public Service
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2063
sstover@kgs.ku.edu
Responsibilities and Experience: Outreach Manager; Kansas Field Conference. Previous: Kansas Water Office; Kansas Department of Health and Environment; Cleveland Museum of Natural History. Education: University of Nebraska, BA, Geology and Anthropology; University of Kansas, MS, Geology

East-Central Kansas

Managing Resources for Economic Growth and the Environment

September 9–10, 2015

This 21st annual Kansas Field Conference offers decision-makers who influence policy on Kansas natural resources the opportunity to learn more about how some of those resources are used and conserved in east-central Kansas, from suburban Kansas City south to the Marais des Cygnes wildlife areas and west to John Redmond Reservoir. The Kansas Geological Survey (KGS) and this year's other sponsors—the Kansas Water Office, Kansas Department of Transportation, and Kansas Department of Wildlife, Parks and Tourism—have arranged a variety of stops where experts from private companies, agencies, and organizations will provide background on topics ranging from cutting-edge transportation and shipping systems to power plant environmental upgrades to stream-bank erosion, wetland management, and reservoir restoration. There will be plenty of opportunities for discussions and questions.

On Wednesday, September 9, the Field Conference first heads to the BNSF Intermodal and Logistics Park Kansas City near Edgerton. First stop is at the diverging-diamond interchange on I-35 built to handle the increasing traffic to the intermodal and southwestern Johnson County. A variation of the traditional diamond interchange, the I-35 interchange was the first of its kind in Kansas upon opening in October 2013. Next we'll visit the BNSF Intermodal, a highly efficient hub for rail and truck shipping, then two businesses in the adjacent Logistics Park distribution and warehouse complex. The visit will conclude with a panel discussion by state and local officials involved in the development process about the resources and conditions necessary for this type of economic growth.

After lunch, the drive south will include a bus session about the effect of the Kansas-Missouri Border War that took place along the corridor we'll travel. The fourth stop is the Marais des Cygnes Wildlife Area, managed by the Kansas Department of Wildlife, Parks and Tourism (KDWPT), which provides both valuable wildlife habitat and recreational opportunities. There we'll discuss the ecology and management of the hardwood forest, wetland, and native grassland ecosystems in the area. Next on the agenda is the La Cygne Generating Station, a coal-powered electrical power plant co-owned by Kansas City Power & Light (KCP&L) and Westar Energy. The facility has recently undergone upgrades to comply with federal and state emission-control rules and regulations. La Cygne lake is used for the plant's cooling water. KCP&L also leases use of the lake and some surrounding land to KDWPT and Linn County for recreation and wildlife habitat. Day 1 ends at Hillsdale State Park and Reservoir. This is an area where KDWPT must manage recreational use of the park with competing interests from homeowners in new development on the edges of the park. Fisheries management will be demonstrated at Hillsdale Reservoir with hoop nets and fish shocking, methods to inventory the variety and sizes of fish. Finally the need, timeline, and estimated costs for securing state-owned storage in federal reservoirs will be discussed. Dinner will be served at the lake.

Thursday, September 10, begins with a bus session update on the earthquake activity in south-central Kansas. The potentially induced seismicity occurs near saltwater disposal wells that inject large volumes of wastewater from oil and gas wells, particularly the long horizontal, hydraulically fractured wells. The first stop of Day 2 provides a geologic perspective of time at a fossil site

north of Melvern Lake where a variety of marine shells are weathering out of shale. A bus session on the Kansas Water Vision is followed by a stop to discuss stream-bank stabilization on the Cottonwood River to help reduce downstream infill and loss of storage in reservoirs. Passing through the Flint Hills Wildlife Refuge, the refuge manager will talk on the bus about the area, which is overseen by the U.S. Fish and Wildlife Service. The next stop is John Redmond Reservoir, the resting place for much of the sediment eroded upstream. Sedimentation there has filled more than 40% of the storage pool space at an infill rate nearly 80% faster than projected. The discussion will focus on the hydraulic dredging planned at John Redmond, the first federal reservoir slated for dredging to regain state-owned water storage space. The last stop will be at the Dwight D. Eisenhower Education Center at Wolf Creek Generating Station for lunch followed by a discussion with panelists from the KGS and energy companies about projections and trends in the Kansas oil and gas industry in a time of volatile energy prices and technological advances.

A detailed itinerary for the tour—from the morning of Wednesday, September 9, through the afternoon of Thursday, September 10—can be found in this guidebook at the front of each daily section. For those who arrive Tuesday evening, an informal social will be held from 7 to 8:30 p.m. at the hotel, co-sponsored by iSi Environmental.

About the Kansas Field Conference

The Field Conference is designed to give a diverse group of policymakers with a range of legislative, government, education, and private-business expertise the opportunity to explore and discuss natural-resource issues. The objective is to give participants the opportunity to see what effects government and business decisions can have on natural resources and communities and to talk with local, state, and federal officials, environmental groups, business people, and citizens' organizations. The co-sponsors aim to provide a broad, informed perspective that will be useful in formulating policies. In addition, the annual field guides furnish background on sites and issues and can serve as handy references long after the Field Conference is over.

At each stop and on the bus, we want you to contribute to the discussion, to ask questions, and to otherwise join in on deliberations. **The bus microphone is open to everyone, and we encourage everyone to participate.** Please remember that in the course of the Field Conference, we do not seek to resolve policy or regulatory conflicts. By bringing together experts on energy, water, and other resources, we hope to go beyond merely identifying issues. We want this combination of first-hand experience and interaction among participants to result in a new level of understanding of and discussions about the state's natural-resource issues.

As often as possible, we attempt to provide a forum for all sides of contentious issues. The opinions presented during the Field Conference are not necessarily those of the KGS or Field Conference co-sponsors. Nonetheless, we believe it is important for participants to hear various viewpoints on complex issues.

The co-sponsors appreciate your attendance at this year's Field Conference. Participant input over the past 20 years has helped make the Field Conference a model that has been adopted by other state geological surveys, and we look forward to receiving any insights you may have about ways to improve it and locations to visit in the future.

Sponsors

Kansas Geological Survey

The KGS is a research and service division of the University of Kansas. Its mission is to study and report on the state's geologic resources and hazards. The KGS is headquartered on west campus at KU and has a branch office in Wichita, the Wichita Well Sample Library. Much of the KGS focus is on

energy, water, and a better understanding of the state's surface and subsurface geology. By statutory charge, the KGS role is strictly one of research and reporting. The KGS has no regulatory functions.

The following KGS staff are participating in the 2015 Field Conference:

Susan Stover, Geologist/Outreach Manager
Cathy Evans, Writer/Communications Coordinator
Rex Buchanan, Interim Director
Bob Sawin, Geologist/Stratigraphic Research

Kansas Geological Survey
1930 Constant Avenue
Lawrence, KS 66047-3724
785-864-3965
www.kgs.ku.edu

Kansas Department of Transportation

The Kansas Department of Transportation (KDOT) is charged with providing a statewide transportation system to meet the needs of Kansans. Its primary activities are road and bridge maintenance; transportation planning, data collection, and evaluation; project scoping, designing, and letting; contract compliance inspection of material and labor; federal program funding administration; and administrative support. In addition to dealing with roadways for automobile traffic, KDOT is responsible for other modes of transportation, including aviation, rail, and bicycles/pedestrians. Mike King is Secretary of Transportation and Bob Henthorne is KDOT's chief geologist.

Kansas Department of Transportation
Dwight D. Eisenhower State Office Building
700 SW Harrison Street
Topeka, KS 66603-3754
785-296-3566
www.ksdot.org

Kansas Department of Wildlife, Parks and Tourism

The Kansas Department of Wildlife, Parks and Tourism (KDWPT) is responsible for managing the state's living natural resources. Its mission is to conserve and enhance Kansas' natural heritage, wildlife, and wildlife habitats. KDWPT works to assure future generations the benefits of the state's diverse living resources; to provide public use of the natural resources of Kansas, consistent with the conservation of those resources; and to inform the public of the status of the natural resources of Kansas to promote understanding and gain assistance in achieving this mission. Its responsibilities include protecting and conserving fish and wildlife and their habitats while providing for the wise use of these resources and associated recreational opportunities and providing public outdoor-recreation opportunities through the system of state parks, state fishing lakes, wildlife-management areas, and recreational boating on the state's public waters. Robin Jennison is Secretary of Wildlife, Parks and Tourism and Steve Adams is Chief of Planning. A seven-member Wildlife and Parks Commission advises KDWPT.

Kansas Department of Wildlife, Parks and Tourism
Secretary
1020 S. Kansas Avenue, Rm 200
Topeka, KS 66612-1327
785-296-2281
www.kdwp.state.ks.us

Kansas Department of Wildlife, Parks and Tourism
Operations Office
512 SE 25th Avenue
Pratt, KS 67124-8174
620-672-5911

Kansas Water Office

The Kansas Water Office (KWO) is the water planning, policy, coordination, and marketing agency for the state. The KWO evaluates and develops public policies, coordinating the water-resource operations of agencies at all levels of government; administers the Kansas Water Plan Storage Act, the Kansas Weather Modification Act, and the Water Assurance Act; advises the governor on drought conditions and coordinates the governor's drought-response team; and develops the Kansas Water Plan, which addresses the management, conservation, and development of water resources in the state. The Kansas Water Authority, a 13-member appointed board, along with 11 nonvoting *ex officio* members who represent various state water-related agencies, is statutorily within and a part of the KWO. The Authority advises the governor, legislature and director of the KWO. Tracy Streeter is Director of the KWO, and Earl Lewis is Assistant Director.

Kansas Water Office
900 SW Jackson, Suite 404
Topeka, KS 66612-1249
785-296-3185
www.kwo.org

Supporting Organizations and KGS Staff

The KGS would like to acknowledge the help of other companies, organizations, and agencies that have contributed to the 2015 Field Conference. Our thanks to Secretary Mike King and Bob Henthorne with Kansas Department of Transportation, Secretary Robin Jennison and Steve Adams with Kansas Department of Wildlife, Parks and Tourism, Director Tracy Streeter and Earl Lewis at the Kansas Water Office, and Raney Gilliland, Director of Kansas Legislative Research, for their advice about topics, speakers, and locations. Alan Pollam with The Nature Conservancy and Karl Karrow at Kansas Department of Wildlife, Parks and Tourism provided useful background information on the Marais des Cygnes wildlife areas. Julie Tollefson, KGS editor, edited and laid out the field guide. Mark Schoneweis, KGS graphic designer, prepared the route map. Our appreciation to BNSF Railway, Westar Energy, and iSi Environmental for their sponsorship of meals and the social.

WEDNESDAY, SEPTEMBER 9, 2015

6:00 a.m. Breakfast—Ottawa Comfort Inn
Catered by Smokies BBQ
(starting time is informal)

7:15 a.m. Welcome, Introductions, and Conference Overview
Susan Stover, Outreach Manager, Kansas Geological Survey
Rex Buchanan, Interim Director, Kansas Geological Survey

8:00 a.m. **Bus Leaves Ottawa Comfort Inn for Site 1**

8:30 a.m. **SITE 1—**Diverging Diamond Interchange
Steve King, Road Design Leader, Kansas Department of Transportation

9:00 a.m. **SITE 2**—BNSF Intermodal
Joseph Lumbert, Senior Manager Hub Operations, BNSF

10:00 a.m. **SITE 3**—Logistics Park Kansas City
1) Smart Warehouse, *Carl Wasinger*, Founder and CEO
2) DEMDACO Warehouse, *Jeff Baker*, Manager

11:00 a.m. **Panel:** Planning for Economic Development
Moderator: *Rex Buchanan*
Steve King, Road Design Leader, Kansas Department of Transportation
Beth Linn, City Administrator, City of Edgerton
Allan Soetaert, Manager, Water District 7, Gardner; President, Hillsdale Area Water Cooperative (HAWC)
Greg Martinette, President, Southwest Johnson County Economic Development Council

11:50 a.m. Lunch at DEMDACO
Meal provided courtesy of BNSF

12:30 p.m. Bus to Site 4

Bus Session—The Border War's Impact on the Area's Settlement and Environment
Arnold Schofield, National Park Service (retired), Freedom Frontiers

1:40 p.m. **SITE 4**—Marais des Cygnes Wildlife Area's Ecology and Management
Jacob Coulter, Assistant Area Manager, Kansas Department of Wildlife, Parks and Tourism
Jason Deal, Region 5, Public Lands Supervisor, KDWP&T

2:30 p.m. Restroom Break, Trading Post

2:50 p.m. Bus to Site 5

3:10 p.m. **SITE 5—**La Cygne Generating Station: Meeting Environmental Standards
Paul Ling, Director of Compliance, Kansas City Power & Light

3:30 p.m. Bus to Site 6

Bus Session—Managing Wildlife, Recreation, and Housing Expansion at Hillsdale Reservoir
Steve Adams, Chief of Planning, Kansas Department of Wildlife, Parks and Tourism

4:20 p.m. **SITE 6**—Hillsdale Reservoir Park and Fisheries Management
Gary Lucas, Park Manager, Hillsdale State Park, KDWP&T
Luke Kowalewski, Fisheries Biologist, Hillsdale Reservoir, KDWP&T

5:30 p.m. Return to Shelter House 1

5:40 p.m. Discussion at Shelter House 1
Plans to Call Federal Reservoir Storage into State Service
Earl Lewis, Assistant Director, Kansas Water Office

6:00 p.m. Social

6:30 p.m. Dinner at Shelter House
Catered by Beethoven's 9th Restaurant, Paola

8:30 p.m. Return to Ottawa Comfort Inn

Diverging Diamond Interchange at I-35 and Homestead Lane

As businesses expanded into southwestern Johnson County and the population grew, better access to I-35 was needed to handle increased traffic and support economic development in the area. The Kansas Department of Transportation (KDOT) determined that a new interchange at I-35 and Homestead Lane would provide the best spacing between the existing Gardner Road and Sunflower Road interchanges; create the least impact to air quality, farmland, rights-of-way, and the surrounding environment; and be the least expensive option.

Traffic on I-35 was expected to jump from 25,000 vehicles per day upon the opening of the interchange in October 2013 to 91,925 by 2040. The new BNSF Railways Intermodal and Logistics Park Kansas City, when they reach full capacity, are expected to bring in 17,000 vehicles per day, including 7,000 commercial trucks. KDOT estimated the $33 million project would provide more than $600 million in economic benefits to the region (KDOT, 2012).

To manage current and future traffic, KDOT constructed a diverging diamond interchange (DDI) at the I-35 and Homestead Lane interchange (fig. 1). Unlike at a traditional diamond interchange, lanes on the non-interstate roadway at a DDI cross over each other at both ends of an overpass or underpass so that traffic briefly travels on the opposite side of the road from what is normal. That is, traffic crosses from the right side to the left at the first traffic light then crosses back at the second light (fig. 2).

The directional crossover of the DDI, also known as a double crossover diamond, eliminates cross-traffic left turns for vehicles entering or exiting an expressway. All left

Figure 1—Aerial view of the diverging diamond interchange at I-35 and Homestead Lane. Photo courtesy Burns & McDonnell.

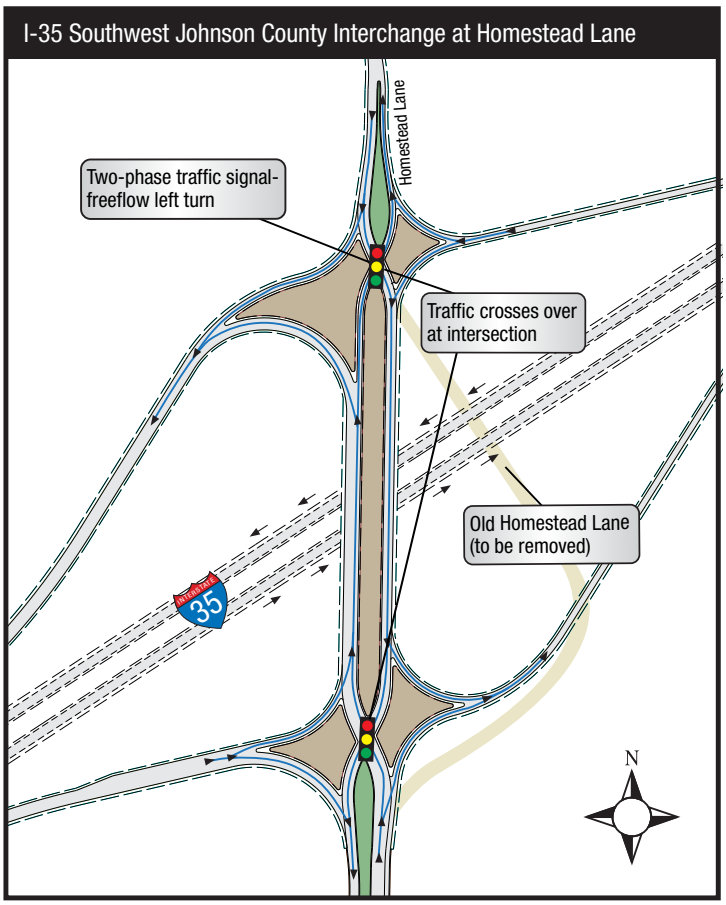

Figure 2—Diagram of the diverging diamond interchange at I-35 and Homestead Lane (KDOT, 2012).

Figure 3—Street view of I-44 and Missouri Route 13 (Kansas Expressway) interchange in Springfield, Missouri. Photo courtesy User:Brandonrush/Wikimedia Commons/Public Domain.

turns are made using on and off ramps while the vehicle is on the left side of the road. Because DDIs generally have fewer signal phases than other intersections and left-turning vehicles do not have to wait for traffic to clear, the potential for long queues is decreased. That improves traffic flow and can also minimize construction costs if the width of the underpass or overpass is reduced due to the elimination of turn lanes. Field studies in the United States have shown that the geometric design of the DDI keeps traffic flowing more efficiently. Further studies are being conducted to evaluate DDI traffic patterns (FHWA, 2014).

The first DDI in the United States was built in 2009 at the intersection of I-44 and Missouri Route 13 (Kansas Expressway) in Springfield, Missouri (fig. 3). Before that, the only ones were in France (MDOT, 2010). The interchange at I-35 and Homestead Lane, which opened in the fall of 2013, is the first of several completed, under construction, or planned in Kansas In October 2014, a second one opened in Johnson County at I-35 and Roe Avenue. That $9.5 million interchange replaced the Roe Avenue Bridge built in 1970 and is nearly identical to the Homestead Lane interchange (KDOT, 2014). The ongoing Johnson County Gateway Project includes two more. One at K-10 and Ridgeview Road opened in July 2015, and construction on the other is planned for 2016 at I-35 and 95th Street (Johnson County Gateway, 2015).

Construction should begin in late June for a DDI at the I-70 and US-77 interchange in Junction City, and others are being planned or considered for the intersections at K-7 and 130th Street in Bonner Springs, K-18 and K-113 in Manhattan, and US-40 and K-10 near Lawrence (Steve King, personal correspondence, 2015).

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Contact

Steve King
Kansas Department of Transportation
700 SW Harrison St
Topeka KS 66603-3745
785-296-0255
StevenK@ksdot.org

BNSF Intermodal and LPKC Warehouse Park: An Inland Port

Intermodal transport involves moving freight containers by two or more modes of transportation (ship, rail, truck, or air). Once containers are loaded, just the containers are handled and not the cargo itself. That greatly increases efficiencies, reduces loss, saves on labor and packing costs, and allows goods to be transported faster. The intermodal system began as a method to improve shipping productivity and evolved into an integrated logistically linked system.

Shipping in standardized containers is a major shift in transportation. Pallets used to be the common cargo unit, but they are relatively small and prone to damage or theft. The standardization of containers originated with maritime shipping; before standardized containers and the equipment to move them, ships could spend as much time in port unloading and reloading cargo as they did at sea. Intermodal containers, known as ISO containers, are standardized in size and designed to be moved in high-speed intermodal transfers using a minimum of labor. The universal size used to describe shipping capacity of ships and containers is a 20-foot box (20 feet in length, 8 feet 6 inches high, and 8 feet wide) known as a Twenty-foot Equivalent Unit (TEU). The majority of containers now used are 40-feet long, or two TEUs. ISOs have led to the globalization of intermodal transport.

Although ISO containers allow faster, more cost-effective, and secure transport, the data handling, processing, and distribution systems that ensure safe, reliable, and efficient transportation are the keys to the intermodal's ultimate success. An Electronic Data Interchange (EDI) used to share documents in a standard electronic format helps companies and government agencies manage an increasingly active, complex global transport system (Rodrigue, 2011).

Another factor influencing the growth in intermodalism was the change to public policies in the United States and Europe that had restricted or barred companies from owning more than one mode of transport. Without being able to have a business interest in various modes of transport, each company sought to maximize its business by keeping the freight on a single mode. One important policy change was the Staggers Rail Act of 1980, which granted railroads greater freedom in pricing and allowed multi-mode ownership (Rodrigue, 2011).

The BNSF Intermodal and Logistics Park Kansas City (LPKC) grand opening was in October 2013. This added to the expanding railway network across North America (fig. 1). Near Edgerton, Kansas, the intermodal has six tracks, 8,000-feet each, for loading and unloading containers on rail (fig 2). Security features at the intermodal yard include fencing, lighting, and full gate inspections, as well as bio-identification of truck drivers picking up freight. The BNSF intermodal park covers 433 acres, with an annual lift capacity of 500,000 ISO containers. Expansion plans include increasing the capacity to 1.5 million lifts annually. In 2015, BNSF plans to add crossovers at the end of the intermodal facility to make it easier for trains to move between tracks (Kansas City Star, 2015).

The LPKC (fig. 3) is an essential partner in the intermodal complex. It is a 1,500-acre distribution and warehouse development located by the BNSF railway's intermodal hub. The central location and multi-modal infrastructure attracts industry to locate production facilities, warehouses, and distribution centers nearby. In addition to the BNSF rail and the heavy-haul corridor for truck traffic, other regional transport modes are the navigable Missouri/Mississippi inland waterway and Kansas City International

Figure 1—BNSF intermodal routes, April 2015. Prepared by Bartlett & West.

Figure 2—BNSF intermodal facility near Edgerton, Kansas, June 2014. Photo: LPKC

Figure 3—Schematic map of intermodal, LPKC business parks and new Homestead Lane interchange. Source: www.logisticsparkkc.com

Airport, which moves the most air cargo in a six-state region.

In May 2015, Northpoint Development announced the construction of Inland Port XIV, an 822,104-square-foot speculative building at the LPKC. The building will feature a 36-foot clear height. It is scheduled to be completed by December 2015.

The field conference will visit two warehouses. The first is Smart Warehouse, which provides third-party logistics. It offers supply-chain and fulfillment services—storing, picking, packing, and shipping products—for its clients so clients can focus on their core business. The second warehouse is DEMDACO, a Leawood-based importer that specializes in home décor and artistic gifts. DEMDACO has a long-term lease at LPKC for a 326,650-square-foot distribution center.

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Contacts

Patrick Robinson, Vice President
North Point Development
816-888-7872
patrick@northpointkc.com

Jeff Davis
Government Affairs
BNSF Railway
913-551-4202
Jeffrey.Davis@BNSF.com

Marais des Cygnes Wildlife Area and National Wildlife Refuge

The adjoining Marais des Cygnes Wildlife Area (managed by the Kansas Department of Wildlife, Parks and Tourism) (fig. 1) and Marais des Cygnes National Wildlife Refuge (under the U.S. Fish and Wildlife Service) represent effective state-federal cooperative land management. The wildlife areas lie in the floodplain of the Marais des Cygnes River (fig. 2). French trappers named the area wetlands "Marais des Cygnes," or "marsh of swans." Trumpeter swans, historically common in the Midwest, likely used the wetlands adjacent to the river during the spring and fall migrations. Our site visit begins at the Marais des Cygnes Wildlife Area headquarters due west of Trading Post, possibly the oldest European settlement in Kansas. Records for the post on the river date back to 1825, pre-dating the military trail along what is now Highway 69.

In Kansas, the Marais des Cygnes main stem stretches about 177 river miles from southeastern Wabaunsee County to central Linn County before flowing into Missouri. The Kansas watershed for this river is about 3,300 square miles. The river flows are affected by Hillsdale, Pomona, Melvern, and La Cygne reservoirs, which control roughly 23 percent of the watershed. Additionally, seasonal flows are retained at the Marais des Cygnes Wildlife Area marshes, which can hold about 5,500 acre feet.

The wildlife area managed by the Kansas Department of Wildlife, Parks and Tourism (KDWPT) encompasses more than 7,650 acres. Recreational activities include hunting, fishing (April 15 through September 15), birding (especially good during spring migration, April through mid-June), and seasonal pecan picking and mushroom hunting. The U.S. Fish and Wildlife Service (FWS) manages 7,500 acres, of which 5,000 acres are available for recreation.

The Marais des Cygnes wildlife area is known for its hunting. On average, waterfowl hunters harvest 5,000 ducks in a season. The majority of these hunters travel 50 miles or

Figure 1—Marais des Cygnes Wildlife Area. Photo: Tom Loats.

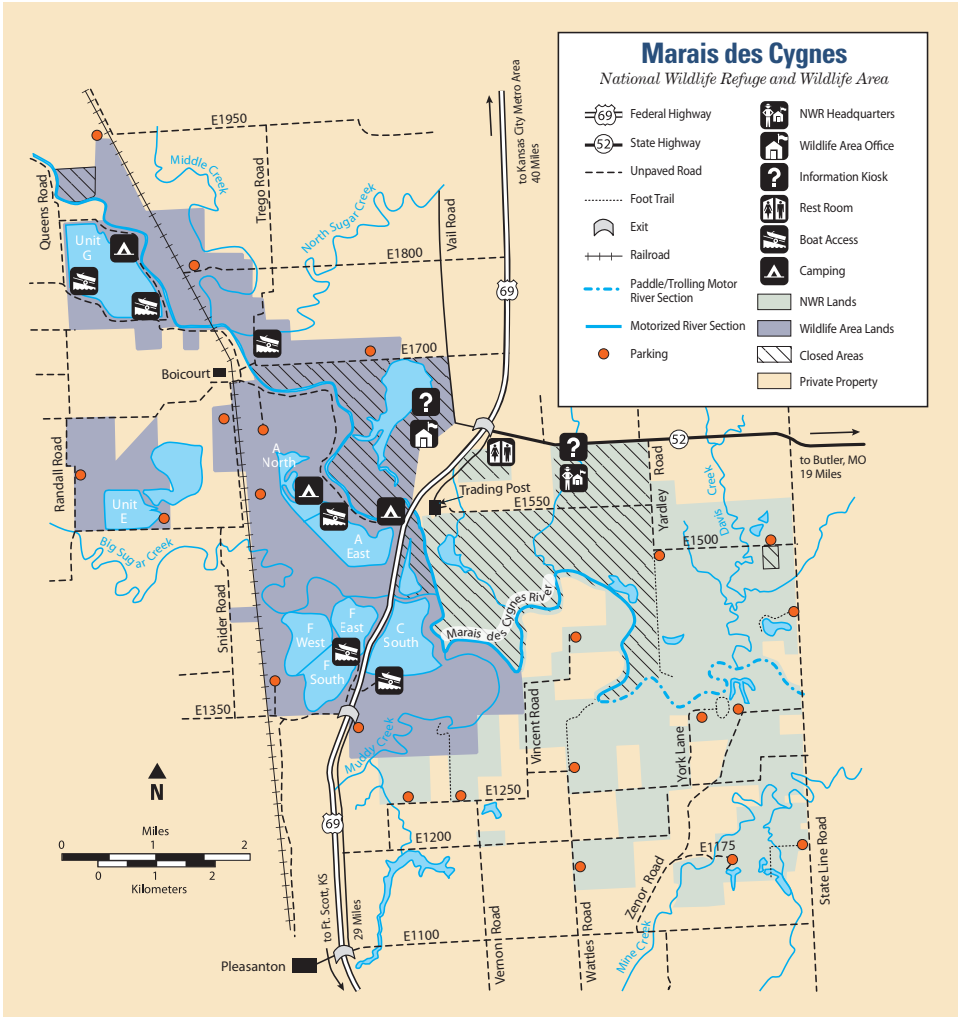

Figure 2—Marais des Cygnes Refuge and Wildlife Area map. Source: FWS.

more to hunt here. Hunting is also good on adjacent private land. More than 40 duck clubs benefit from waterfowl using the public areas. Deer hunting is also a popular activity. Archery hunters across the country come to the wildlife area for a chance to harvest a mature Kansas whitetail deer.

The wildlife areas encompass three ecosystems: 1) bottomland (floodplain) hardwood forest, 2) wetlands, and 3) native prairie. Upland forest, restored native grassland, and cropland are also present and managed for wildlife benefits. The quality, quantity, and diversity of managed wetlands and bottomland hardwood forests make these areas unique to Kansas. Frequent flooding and wet conditions discouraged many from farming the acres, although much of the native habitat was eventually converted to pasture, cropland, and other uses.

Composed largely of pecan, pin oak, shellbark hickory, green ash, and American elm, the bottomland hardwood forest provides valuable habitat for migrating waterfowl, deer, turkey, amphibians, and songbirds. In addition to resident songbirds, the hardwood forest provides an important stopover location for songbirds to feast and prepare for their migration across the prairie to the north. The forest provides habitat for about 300 species of birds, including about 100 species that nest in the refuge. The forest also reduces sedimentation into the river, with the canopy reducing the erosive effects of rain and wind and the deep woody roots strengthening the stream banks.

Figure 3—Mallards and pintails on ice near a muskrat house, Marais des Cygnes Wildlife Area. Photo: Tom Loats.

Figure 4—Split tail flycatcher with a meal. Photo: Sarah Ellis, USFWS.

Managed for diversity of habitats, the wetlands provide food and cover for migratory waterfowl and other wetland species. Wetlands serve a valuable role in filtering pollution and as water storage during floods. Typically, some wetland units are de-watered in the spring and re-flooded in the fall with water pumped from the river. The region also includes natural sloughs and oxbows. These habitats are extremely important to local and migratory waterfowl and other wetland birds, including wood ducks, hooded merganser, mallard, bald eagle, heron, and egrets. During peak fall migration, more than 50,000 ducks and geese can be found using the wildlife area. The wetlands are also home to a variety of mussels, fish, amphibians and reptiles, and mammals such as otters.

The native prairie contains big and little bluestem, switch grass, Indian grass, sideoats, grama, and native forbs. It also includes savannah and grove habitat of post oak, blackjack oak, and pin oak with an understory of native grass as well as an upland shrub area outside of the bottomland forest. The prairie provides important habitat for grassland birds, including meadowlark, grasshopper sparrow, northern bobwhite, dickcissal, and raptors, such as the American kestrel and red-tailed hawk.

History of the state wildlife area and federal wildlife refuge

The bulk of the Marais des Cygnes Wildlife Area managed by KDWPT was acquired in three major purchases from 1954 to 1956. Smaller purchases were made through 2008. This wildlife area has preserved a native habitat legacy for Kansans.

Figure 5—Rough-legged hawk. Photo: KDWPT.

When the FWS acquired the Marais des Cygnes National Wildlife Refuge in 1992, the agency was authorized to acquire land in a 9,300-acre area. However, about 1,800 acres dispersed throughout the area remained in private ownership, mostly the property of duck clubs, and the FWS ended up acquiring 7,500 acres. Nearly 800 acres of historically hardwood forests had become infested with weeds or converted to other uses and required restoration (FWS, 1992). Today, evidence of former homesteads on 40-acre tracts of farmland can still be found within what is now the managed national refuge.

The FWS's core of roughly 2,000 acres of hardwood forest and wetlands became available when Pittsburg & Midland coal decided to sell its land holdings along the floodplain after Kansas City Power & Light discontinued the company's contract to supply coal for the La Cygne generating plant. Using the low-quality eastern Kansas coal made it difficult for the plant to meet air emission standards. State, federal, and private partners cooperated to purchase the land. After more than two years of complex negotiations, the Nature Conservancy Kansas Chapter took temporary ownership until the FWS could acquire it. Senators Bob Dole and Nancy Kassebaum and Representative Jan Meyers were instrumental in getting a timely federal appropriation to fund the bulk of the purchase. Initially, the Nature Conservancy kept title to 726 acres of the property, but the FWS also acquired that parcel later.

Figure 6—Broadhead skink. Photo: Amy Coffman, USFWS.

The Nature Conservancy has identified the Marais des Cygnes River as a high-quality

river system and an ecologically functioning landscape of significance. The National Wildlife Refuge provides habitat for several federally listed threatened and endangered species, including the bald eagle, peregrine falcon, least tern, piping plover, and Mead's milkweed.

Figure 7—Bumblebee on liatris. Photo: KDWPT.

Sources

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Contact

Karl Karrow, Manager
16382 Vail Road
Pleasanton, KS 66075
913-352-8941

La Cygne Generating Station and La Cygne Lake

The La Cygne Generating Station in Linn County (fig. 1) is operated by Kansas City Power & Light (KCP&L), a subsidiary of Great Plains Energy Inc., and is co-owned 50/50 by KCP&L and Westar Energy. The first unit of the power plant went online in 1973 followed by the second unit in 1977. Unit 1 was originally designed to burn local coal mined near the facility but today uses mainly low-sulfur coal from the southern Powder River Basin (PRB) in Wyoming blended with a small amount of locally mined coal. Unit 2 burns only PRB coal (KCC, 2011c). Together, the two coal-fired units have a generating capacity of 1,450 megawatts (MW) (KCP&L, 2015a).

Regulations and plant upgrades

To comply with federal and state laws and regulations enacted to improve air quality and reduce emissions, KCP&L recently completed installation of upgraded emission control technologies at La Cygne (fig. 1). Under the 1999 federal Regional Haze Rule, states were required to develop plans to reduce pollution and improve visibility in 156 designated national parks and wilderness areas in the United States. The Kansas Department of Health and Environment (KDHE), the agency responsible for air quality, determined which facilities would have to reduce emissions and set emission limits for those facilities.

KDHE negotiated Regional Haze Agreements with KCP&L and Westar—which owned or operated the designated facilities, including the La Cygne Generating Station—and incorporated the agreements into the Kansas Regional Haze State Implementation Plan (SIP). The Environmental Protection Agency (EPA) approved the Kansas SIP in December 2011. In its agreement with KDHE, KCP&L was required to retrofit the La Cygne Generating Station by June 2015.

In addition to meeting Regional Haze Rule requirements, installation of the equipment addressed provisions of the National Ambient Air Quality Standards (NAAQS) established by the EPA as required in the Clean Air Act, the Acid Rain Program, the Mercury and Air Toxics Rule, the Cross-State Air Pollution Rule, and other federal environmental rules and regulations. The new equipment may also help the plant keep pace with continuously changing standards, such as the Effluent Limitation Guidelines, and meet new or upcoming rules, including the coal combustion residuals rule. Besides providing compliance with government regulations, the upgrades satisfied a 2007 agreement between KCP&L,

Figure 1—Illustration of the La Cygne Generating Station showing all of the proposed upgrades (from KCP&L).

the Sierra Club, and the Concerned Citizens of Platte County to limit stack particulate matter and other emissions from the La Cygne plant (KCC, 2011b; Missouri PSC, 2014).

Upgrades to Unit 1 include a wet scrubber to reduce sulfur dioxide emissions and a baghouse (fabric filter) to control particle matter. Upgrades to Unit 2 also include a wet scrubber and baghouse as well as low NO_x (nitrogen oxides) burners, an overfire air system, and a selective catalytic reduction system to reduce NO_x emissions. A new chimney was built to serve both units (KCP&L, 2014; KCP&L, 2015a).

KCC approval and rate requests

KCP&L, as operator of the La Cygne Generating Station, petitioned the Kansas Corporation Commission (KCC) in 2011 requesting that the KCC approve the retrofit and allow KCP&L and Westar to recover costs. KCP&L presented testimony as to why its decision to retrofit the coal-powered plant was more economical than switching to other sources of energy, such as natural gas. The KCC determined that the decision to make the upgrades and the cost, estimated at $1.23 billion, were reasonable. The KCC denied KCP&L's request to recover costs through an environmental cost recovery rider (ECRR), which would have been added as a separate billing item on customers' statements and would have allowed the companies to start recovering costs immediately. Instead, the companies were only allowed to recover costs through traditional rate-hike requests filed with the KCC (KCC, 2011a).

On January 2, 2015, KCP&L filed a rate increase request of 12.5% with the KCC. The $67.3 million revenue increase would, in part, be used to cover environmental upgrades at the La Cygne power plant. KCP&L had been allowed to recover some of the cost through rate hikes during the construction phase, and some of the 2015 rate increase would be used to fund other projects. The company also filed a 15.8% rate increase request with the Missouri Public Service Commission on October 30, 2014 (KCP&L, 2015c). On March 2, 2015, Westar filed a request with the KCC to raise its prices by 7.9%, or $152 million. The revenue would be used for the La Cygne upgrades and other projects (Westar Energy, 2015b). The KCC was expected to rule on KCP&L's and Westar's rate requests within eight months of submission. The Missouri Public Service Commission was expected to rule within 11 months of KCP&L's request.

EPA Clean Power Plan

In August 2015, the EPA released the Clean Power Plan (CPP) , which includes cuts in carbon pollution from existing power plants. Limits were already in place on the level of arsenic, mercury, sulfur dioxide, nitrogen oxides, and particle pollution emission from power plants but none for carbon. About one-third of greenhouse emissions in the United States are produced by power plants. Under the CPP, CO_2 emissions from power plants nationwide are to be lowered 32% by 2030, with reductions based on 2005 levels. States are to develop their own plans to meet that goal (EPA, 2015).

West Virginia and 11 other states, including Kansas, sued the EPA in 2014 to block the proposed CPP (Zajac and Drajem, 2014). Kansas also enacted legislation in 2014 authorizing the Secretary of KDHE to establish separate standards of performance for carbon dioxide emissions that would provide flexibility in meeting federal greenhouse gas standards (Condon and Durkay, 2015).

KCP&L and Westar Energy

KCP&L is an investor-owned, regulated electric utility that serves more than 800,000 customers in 47 northwest Missouri and eastern Kansas counties. With a service area of about 18,000 square miles, KCP&L uses more than 3,000 miles of transmission lines, 24,000 miles of distribution lines, and 400 substations to deliver power to KCP&L customers (KCP&L, 2015b). Westar Energy, headquartered in Topeka, serves nearly 700,000 customers in 55 counties in the eastern half of Kansas. The company has

a generation capacity of 7,000 megawatts and owns more than 35,000 miles of transmission and distribution lines (Westar Energy, 2015a).

La Cygne Lake

North Sugar Creek, a tributary of the Marais des Cygnes River, was dammed to create La Cygne Lake (fig. 2), which is owned by KCP&L. The 2,600-acre lake has a maximum depth of 35 feet, an average depth of about 15 feet, and a storage capacity of 40,000 acre feet. The Kansas Department of Wildlife, Parks, and Tourism (KDWPT) and Linn County lease the lake and surrounding land for public recreation. KDWPT manages 2,000 acres of the watershed as a wildlife area, which is mainly wooded uplands with some meadows and croplands. On the west side of the lake, Linn County maintains Linn County Park, including docks, a marina, campsites, cabins, horse trails, and a swimming pool. Boating on the lake is limited to fishing and hunting, and swimming is not allowed (Linn County Economic Development, 2012; KDWPT, 2004).

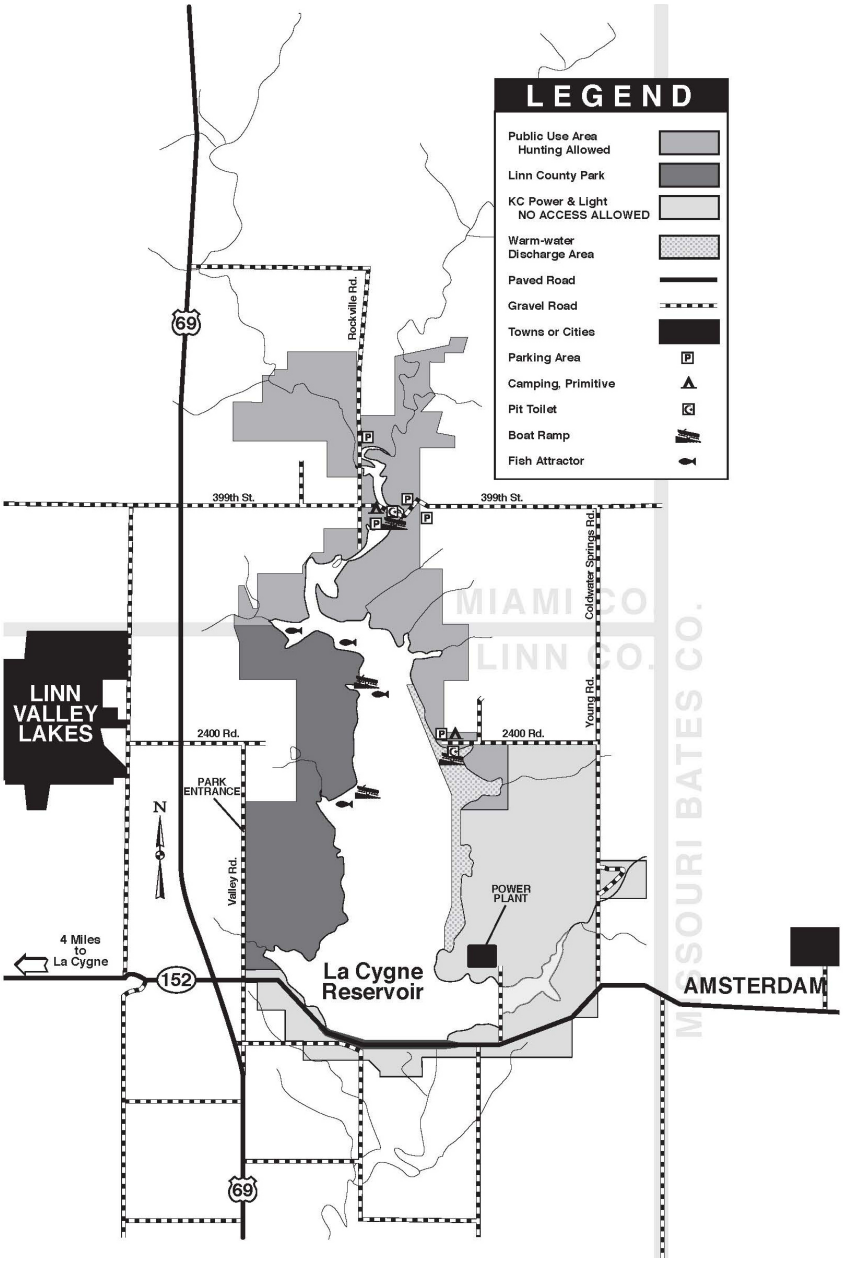

Figure 2—La Cygne Lake and Wildlife Area (from Kansas Department of Wildlife, Parks and Tourism).

Water rights and the Marais des Cygnes River Water Assurance District

The La Cygne Generating Station has water rights for the damming of Sugar Creek and for the creek's natural flow. It also has rights to pump water from the Marais des Cygnes River to maintain the lake at an operating level of 840 feet above mean sea level (msl). The power plant must be shut down if the lake drops too far below that level (Paul Ling, personal communication, 2015).

KCP&L and municipalities along the Marais des Cygnes River formed one of three water assurance districts in Kansas to help ensure their water needs would be met when river flow was insufficient. The assurance districts buy storage space in upstream reservoirs from the state, which acquired water reservation rights to store water in the reservoirs built and managed by the U.S. Army Corps of Engineers. Participants in the Marais des Cygnes assurance district, which includes KCP&L and the cities of Melvern, Ottawa, Paola, Osawatomie, and La Cygne, purchase storage space in Melvern and Pomona reservoirs (KDA, 2009).

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Contact

Paul Ling, P.E., JD
Director of Compliance
Kansas City Power & Light Company
Paul.Ling@KCPL.com
816-556-2899

Hillsdale State Park and Lake

Congress authorized the construction of Hillsdale Lake in 1954 for flood control along Bull Creek, a tributary of the Marais des Cygnes River within the Osage River and Missouri River basins. The U.S. Army Corps of Engineers built the 4,580-acre lake (fig. 1) in Miami County between 1976 and 1982. In 1989, the Corps leased 12,880 acres of land and water to the Kansas Department of Wildlife and Parks—now Kansas Department of Wildlife, Parks and Tourism (KDWPT)—and Hillsdale State Park officially opened in 1994 (U.S. Army Corps of Engineers, 2015; KDWPT, 2015).

In a transition zone between mixed hardwood forests to the east and prairie grasslands to the west, Hillsdale State Park has oak-hickory woodland, native prairie, cropland, and wetland habitats that support a diverse plant and wildlife community. Woodland species include oak, sycamore, cottonwood, walnut, hackberry, ash, elm, hickory, and eastern red cedar. When the lake was filled, more than 70% of the standing timber was left in the reservoir to provide habitat for walleye, catfish, largemouth bass, crappie, bluegill, and other fish. Other wildlife includes whitetail deer, bobwhite quail, bald eagles, shorebirds, beaver, and muskrat (KDWPT, 2015).

KDWPT and the Corps of Engineers manage and maintain the lake facilities. KDWPT oversees the recreational facilities for swimming, boating, modern and primitive camping, hunting, fishing, and other activities as well as the nearly 5,000-acre wildlife area. The park has multi-use trails for hiking, mountain biking, and horseback riding (fig. 2), including an equestrian area with 32 miles of marked trails; an aerial remote control field; an archery range; and a shooting range (KDWPT, 2012).

The Corps manages the natural resources in cooperation with KDWPT. Projects include wetland development, native grassland

Figure 1—Hillsdale Lake Marina. Photo: U.S. Army Corps of Engineers.

planting, agricultural crop production, cedar and invasive species control, fisheries habitat development, improvement of timber stands, and prescribed burning. Wetlands constructed around the lake provide habitat for many species, and the waterfowl refuge on the north end is a feeding and resting area for migratory birds. Other operations managed by the Corps include dam and outlet maintenance, visitor services, lake patrol, and weather data collection. Through its Water Quality Program, the Corps collects monthly water samples from April through September to measure 34 chemical, physical, and biological parameters. The data are used to monitor nutrients, sediment, herbicides, metals, and contaminants (U.S. Army Corps of Engineers, 2014). Hillsdale Lake is a leading water supplier for the local area, providing millions of gallons of water each day to residential and municipal users (U.S. Army Corps of Engineers, 2015).

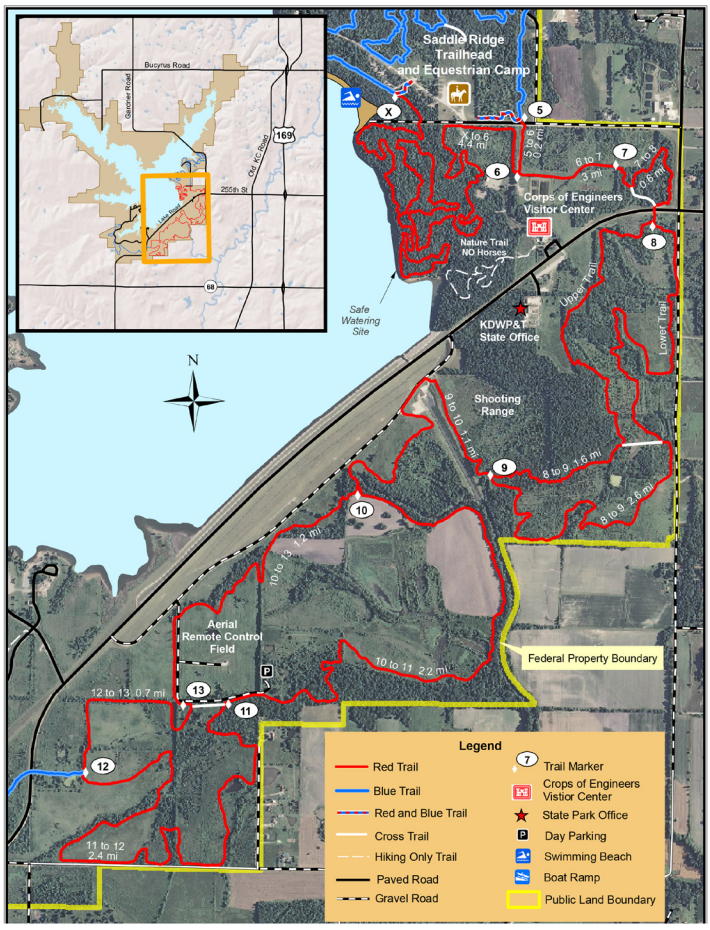

Figure 2—Portion of the trails at Hillsdale Lake State Park (U.S. Army Corps of Engineers, 2015).

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Contact

U.S. Army Corps of Engineers
Hillsdale Reservoir
26000 W. 255th Paola, KS 66071
913-783-4366

Gary Lucas, Manager
Hillsdale State Park
26001 W. 255 St.
Paola, KS 66071
913-783-4507

Kansas Water Storage in Federal Reservoirs

Water storage in reservoirs is an essential part of water management in Kansas. Reservoirs provide protection against floods, a source of water during droughts, recreation, and wildlife habitat. Roughly two-thirds of the state's residents rely on reservoirs for at least a portion of their public water supply. Energy is another big user; about 60% of Kansas power plants use reservoir water for their operations.

The State of Kansas owns storage in 13 federal reservoirs (fig. 1) and sells the stored water to municipal and industrial users through the state's Water Marketing and Water Assurance programs. Eleven reservoirs are used in the Water Marketing Program, and eight of the reservoirs have storage for the state's three water assurance districts.

The state has contracts with the Corps of Engineers for storage in five reservoirs (Big Hill, Clinton, Hillsdale, Milford, and Perry) with a clause that allows the state to defer calling that storage into service until it is needed. This storage is known as future use storage. The cost of purchase and the operation and maintenance costs are also deferred until it is called into use; however, interest continues to accrue, which creates an unfunded liability. If the storage is called into service at the latest possible date, the balance due would be $180.4 million dollars (Lewis, 2011). The contract expiration dates for the reservoirs vary from 2027 for Clinton Reservoir to 2041 for Perry Reservoirs.

The Kansas Water Office (KWO) is preparing a plan for Kansas Water Authority approval on when to convert future use to present use, as authorized in the Water Resources Reform and Development Act of 2014 (H.R. 3080). The federal requirements are for the plan to have a 10-year timeline. The report is due January 1, 2016, to the Secretary of the Army.

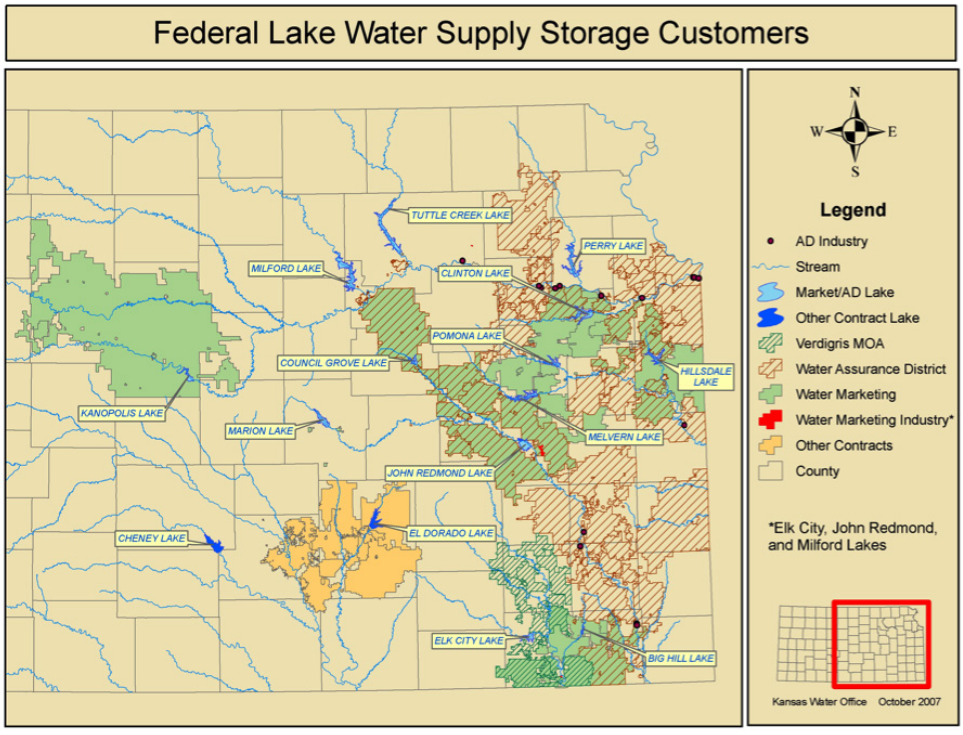

Figure 1—The state owns storage in all of the reservoirs on the map except Cheney and El Dorado lakes, where storage is city owned (from Kansas Water Office).

Water Marketing Program

The Water Marketing Program provides water supply to municipal and industrial customers from state-owned water storage in reservoirs built by the U.S. Army Corps of Engineers. Customers enter into long-term contracts with the KWO, which administers the program. Negotiated contracts indicate the length of time the contract will be in effect, the amount of water to be withdrawn, place of use, billing and payment procedures, metering, and conservation measures. All contracts since 1983 include a price for water, which is set annually by the Kansas Water Authority. The rate is set to ensure adequate revenue is recovered to meet expected expenses of the program. Customers pay for half of the contracted amount of water if half or less is withdrawn and for the actual quantity if more than half is used. The KWO sells surplus water in the program on a short-term basis when and where it is available. All water-marketing contracts negotiated must be reviewed by the Kansas Water Authority, which approves those contracts determined to be in the best interest of the state.

Water Assurance Program

Municipal and industrial water-right holders below federal reservoirs may only need to use stored water during extended dry periods. During times of drought, members in a water assurance district can receive enhanced stream flows with releases of water in storage purchased by the assurance district and managed by the state for their benefit. Releases increase the water-delivery efficiencies and improve the water-right holders' abilities to satisfy their water rights. The KWO asks the Division of Water Resources, Kansas Department of Agriculture, to protect the releases to meet the needs of the assurance districts, in accordance with the operating agreement. This protection includes preventing unauthorized diversions of that released water.

Three water assurance districts have formed and are operational: Kansas River Water Assurance District No. 1, Marais des Cygnes River Water Assurance District No. 2 (fig. 2), and Cottonwood and Neosho River Basins Assurance District No. 3 (fig. 3). Upon organization and formation of a district, participation is mandatory for all eligible water-right holders. Assurance districts have the authority to levy an annual charge to district members to cover the costs for acquiring, operating, and maintaining water-supply storage to meet the district's needs.

Marais des Cygnes River Water Assurance District No. 2

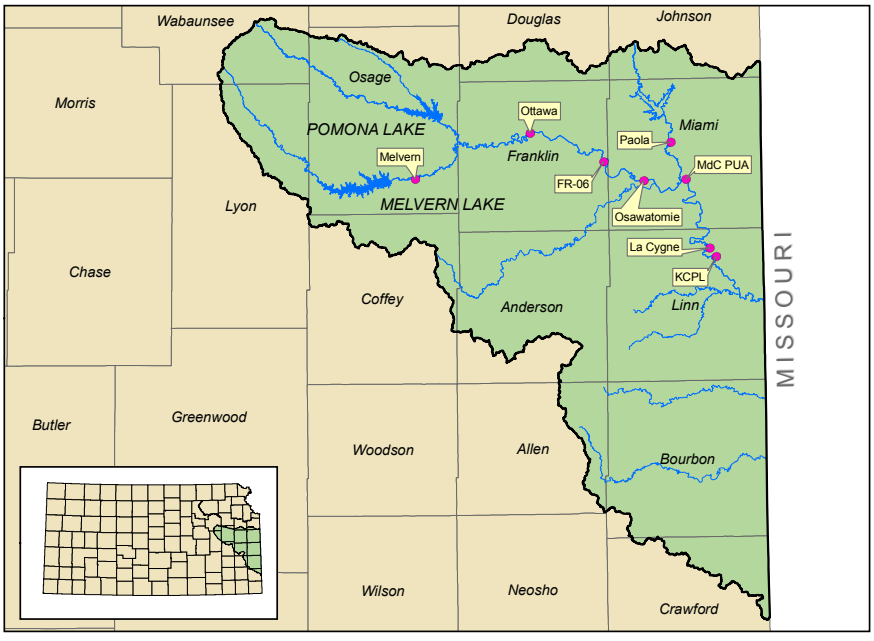

Figure 2—The Marais des Cygnes River Water Assurance District, with seven municipal and one industrial user, relies on storage in Melvern and Pomona lakes.

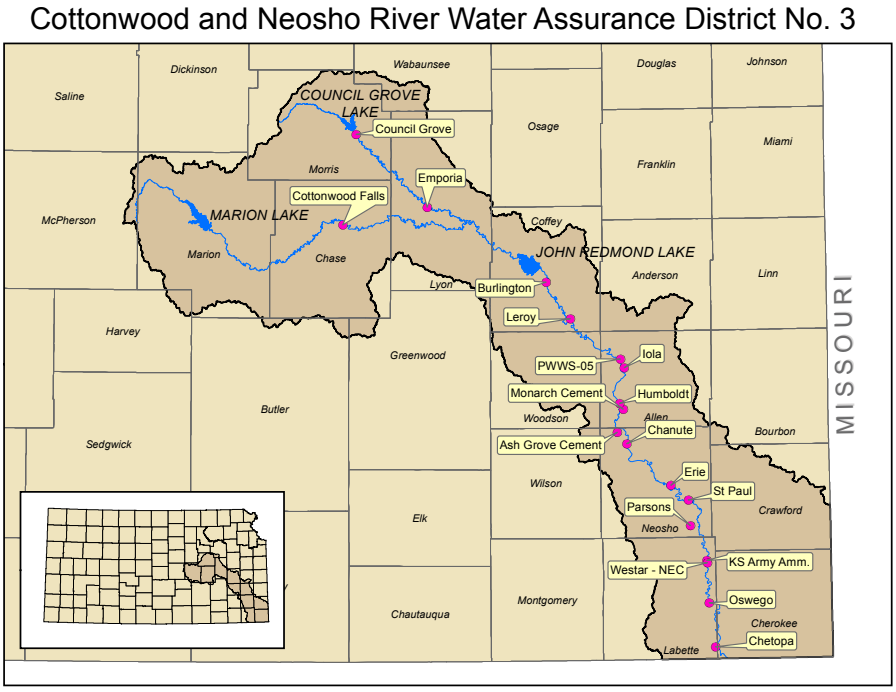

Figure 3—The Cottonwood and Neosho River Water Assurance District, with 18 members, relies on storage in John Redmond, Marion, and Council Grove reservoirs.

State-Owned Storage and Contracts with Deferred Implementation Dates

The state began purchasing storage in 1974, with its most recent purchase at Kanopolis Reservoir in 2002. The water-marketing and water-assurance customers pay for the costs associated with the purchases, operation and maintenance, and administration of the programs. Between 1985 and 1995, the state was given the opportunity to purchase additional storage in federal reservoirs at the original construction cost if it paid for it up front and agreed to protect releases made for in-stream purposes. The state acquired storage in seven reservoirs at that time. Six of those seven reservoirs—Council Grove, Elk City, Marion, Melvern, Pomona, and Tuttle Creek—have storage as reserve capacity, space that is not yet committed to customers through the Water Marketing or Water Assurance programs. The state controls that storage and pays annual operation and maintenance costs. John Redmond was the seventh reservoir in that purchase.

Future use storage is space in federal reservoirs that the state has contracted to buy. However, because the state has deferred purchase of the space, it has no control over the storage. Figures 4 through 7 show 2015 water-storage allocations for Hillsdale, Milford, John Redmond, and Pomona reservoirs, which are examples of lakes with and without reserve capacity and future use storage.

At Hillsdale (fig. 4), future use capacity (45,111 AF) must be called into service by 2030. The Hillsdale Area Water Cooperative (HAWC) negotiated a graduated-use schedule with the KWO for bringing that storage water into use through the Water Marketing Program. The nine HAWC members are the cities of Edgerton, Gardner, Spring Hill, and Wellsville and the rural water districts of Franklin County No.1, Johnson County No. 7, Miami County No. 1, Miami County No. 2, and Miami County No. 4.

At Milford (fig. 5), future use capacity (243,498 AF) must be called into service by 2040. The water-marketing contract with the customer, Jeffries Energy, was established in the 1970s. No new water-marketing customers have been added since the Kansas River Water Assurance District was established, as an assurance district membership provides a

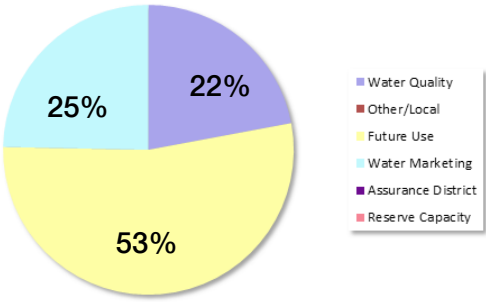

Figure 4—Hillsdale Reservoir 2015 water-storage allocations (Kansas Water Office, 2014).

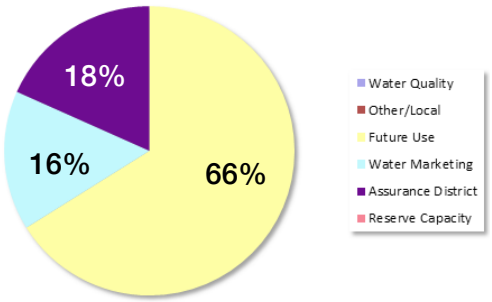

Figure 5—Milford Reservoir 2015 water-storage allocations (Kansas Water Office, 2014).

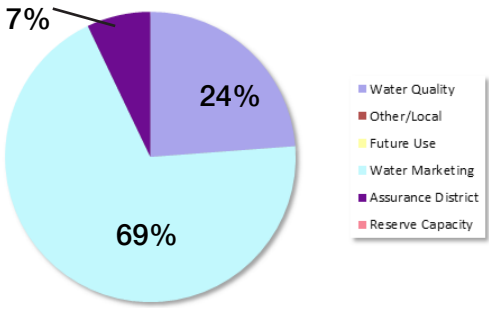

Figure 6—John Redmond Reservoir 2015 water-storage allocations (Kansas Water Office, 2014).

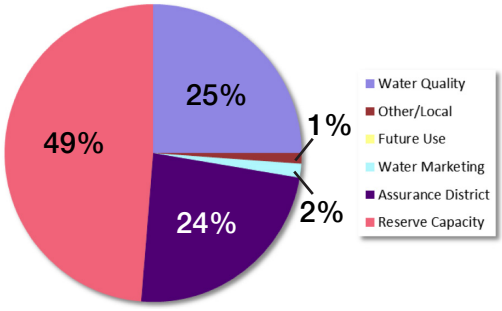

Figure 7—Pomona Reservoir CY 2015 water storage allocations (Kansas Water Office, 2014).

lower-cost alternative to a water-marketing contract with equal reliability. The Kansas River Water Assurance District has storage in Milford, Perry, and Tuttle Creek reservoirs. The Kansas River Water Assurance District may want to purchase the future use storage in Milford for use by its members.

John Redmond Reservoir water storage is fully committed (fig. 6). Sixty-nine percent is reserved for the Water Marketing Program, whose customer, Wolf Creek Generating Station, is contracting for a maximum of 29,682 AF in 2015.

State contracted storage in Pomona Reservoir has been purchased, and operation and maintenance costs are paid annually. Pomona Lake has reserve capacity for additional customers. Some reserve capacity water storage can be contracted as surplus water under short-term contracts. There are no 2015 surplus water customers for Pomona Lake water.

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Contact

Earl Lewis, Assistant Director
Kansas Water Office
900 SW Jackson, Suite 404
Topeka, KS 66612-1249
785-296-3185
Earl.Lewis@kwo.ks.gov

THURSDAY, SEPTEMBER 10, 2015

6:00 a.m. Breakfast—Ottawa Comfort Inn
Catered by Smokey's BBQ
(starting time is informal)

7:30 a.m. **Bus leaves Ottawa Comfort Inn for Site 7**

Bus Session: Induced Seismicity in Kansas
Rex Buchanan, Interim Director, Kansas Geological Survey

8:15 a.m. **SITE 7—**Fossils at Turkey Point Locality, Melvern Lake
Bob Henthorne, Chief Geologist, Kansas Department of Transportation

8:40 a.m. Travel to Site 8

Bus Session: Kansas Water Vision SMART Goals
Tracy Streeter, Director, Kansas Water Office

9:15 a.m. **SITE 8**—Cottonwood Stream Bank Stabilization Projects
Earl Lewis, P.E., Assistant Director, Kansas Water Office

9:35 a.m. Bus to Hartford

10:00 a.m. Restroom Break, U.S. Fish & Wildlife Flint Hills Wildlife Refuge Headquarters

10:25 a.m. Bus to Site 9

Bus Session: Flint Hills Wildlife Refuge
Jack Bohannan, Refuge Manager, U.S. Fish and Wildlife Service

11:00 a.m. **SITE 9**—John Redmond Reservoir

Dam Crest Road view
John Redmond Reservoir Restoration and Protection
Tracy Streeter, Director, Kansas Water Office

Mitigation of Pool Rise with Storage Reallocation
Eugene Goff, Operations Project Manager Kansas Area, Tulsa District U.S. Army Corps of Engineers

John Redmond dredging staging area
Core of Sediments in John Redmond Reservoir
Jerry deNoyelles, Deputy Director and Senior Scientist, Kansas Biological Survey

Dredging John Redmond Process
Ken Kemner, General Superintendent, Rivers and Lakes Division, Great Lakes Dredge and Dock Company, LLC

Potential Confined Disposal Facility—Site B
Ken Kemner, Great Lakes Dredge and Dock

12:45 p.m. Bus to Site 10

1:00 p.m. **SITE 10**—Dwight D. Eisenhower Education Center, Wolf Creek Generating Station

1:00 p.m. Lunch, provided courtesy of Westar Energy

1:45 p.m. Panel: Kansas Oil and Gas Industry Economics and Trends
Moderator: *Rex Buchanan*
Dave Newell, Senior Scientist, Kansas Geological Survey
Nick Powell, President, Colt Energy
David Doyel, Executive Vice President, Murfin Drilling, Co. Inc.

4:00 p.m. Arrive back at Ottawa Comfort Inn

The Potential for Induced Seismicity in Kansas

Induced seismicity is earthquake activity linked to such human activities as mining, underground nuclear testing, and oil and gas operations. Recent public debate has focused on horizontal drilling in conjunction with hydraulic fracturing, popularly called "fracking," as the potential cause of earthquakes. In actuality, only a few confirmed cases of felt seismic activity caused by hydraulic fracturing have been documented—in a remote area of British Columbia between 2009 and 2011, in England in 2011, in Ohio in March 2014, and, highly likely, in Oklahoma in 2013.

More often, scientists think induced seismicity near oil and gas operations is related to wastewater disposal. (In the disposal process, saltwater and recovered hydraulic fracturing fluids are injected into deep and confined porous rock, usually using only the force of gravity.) Even when the association between an earthquake and a wastewater disposal well, or even a group of wells, appears likely, it is difficult to prove a connection. Complex subsurface geology and limited data about that geology make it hard to pinpoint the specific cause of many seismic events, particularly in regions prone to naturally occurring earthquakes.

The Kansas Geological Survey (KGS) has been studying unprecedented earthquake activity in south-central Kansas, where horizontal drilling in the Mississippian limestone play—a complex group of oil and gas reservoirs—and associated wastewater disposal have increased since 2010. Seismic activity there started to increase in September 2013 (fig. 1). During 2014, more than 100 earthquakes of magnitude (M) 2 or greater were recorded, mainly in Harper and Sumner counties (fig. 2). (Earthquakes under magnitude 2.5 are seldom felt.) Figure 3 shows historic and recorded earthquakes in Kansas through 2014.

Monitoring Earthquakes in Kansas

In late 2014 and early 2015, the KGS installed a temporary seven-station network to more accurately pinpoint earthquake depths and epicenters; define zones of increased risk; guide installation methods in anticipation of a KGS-

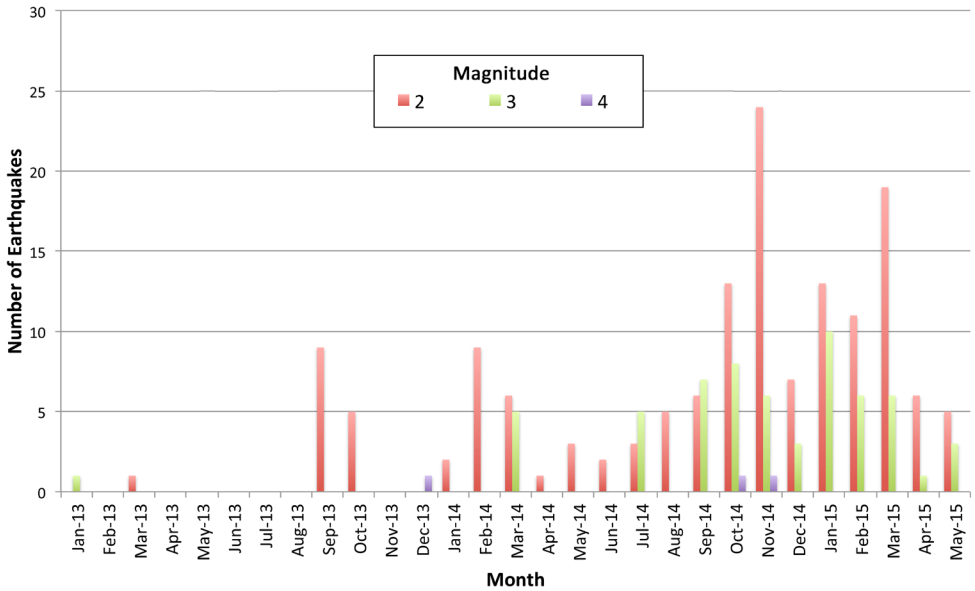

Figure 1—Earthquakes recorded in Kansas, 2013 to mid-May 2015, based on data from the USGS (KGS, 2015).

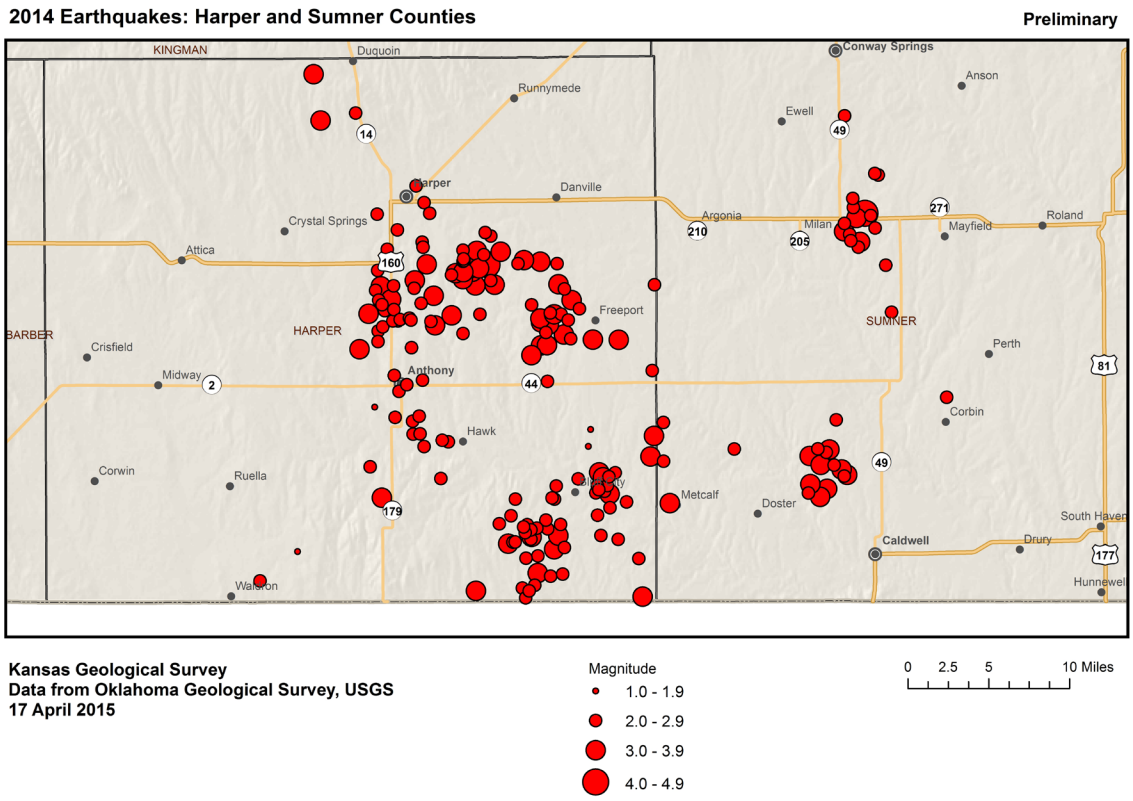

Figure 2—Earthquakes in Harper and Sumner counties in 2014.

proposed permanent statewide network; help guide future scientific and regulatory responses to the seismic activity; and gather background geologic data in areas with potential earthquake activity. Kansas earthquakes have been recorded for decades. At least 25 felt earthquakes were documented in written accounts in Kansas between 1867 and 1976 and more than 200 were recorded in Kansas and Nebraska by a KGS temporary network of seismometers between 1977 and 1989.

The U.S. Geological Survey (USGS) operates two permanent seismic monitoring stations in the state—one at Cedar Bluff Reservoir in western Kansas and the other at the Konza Prairie Biological Station south of Manhattan in northeastern Kansas. In 2014, the USGS also installed several temporary stations in Harper and Sumner counties. Larger Kansas seismic events and smaller ones close to the Oklahoma state line are also picked up by the Oklahoma Geological Survey.

Before 2013, the only recorded instance of possible induced seismicity in Kansas occurred in 1989 when small earthquakes were recorded near Palco in Rooks County, about 30 miles northwest of Hays near injection wells associated with conventional vertical oil well operations. The largest, at M 4.0, caused minor damage (Steeples and Brosius, 1996).

Further understanding of the complex subsurface geology in the region is needed to estimate what impact wastewater disposal in the area has on local seismic activity. Through the KGS's temporary monitoring network, seismologists are collecting data to further our understanding of the geology and the earthquakes. A permanent statewide KGS network is being installed.

Wastewater Injection and Class II Disposal Wells

There are approximately 172,000 fluid-injection wells in the United States used to dispose of wastewater or to extract additional oil out of fields nearly depleted by traditional production methods. Of those wells, designated Underground Injection Control (UIC) Class

II wells by the U.S. Environmental Protection Agency (EPA), about 20% are used for the disposal of saltwater produced along with oil and natural gas and most of the rest are used during enhanced oil recovery operations to squeeze additional oil out of underground rocks (EPA, 2012). In the disposal process, saltwater is injected into a deep formation selected for wastewater disposal and not into the formation from which it was originally produced. Non-potable water and chemicals used in the hydraulic fracturing process, which must be disposed of under State of Kansas requirements, are also injected into these wells.

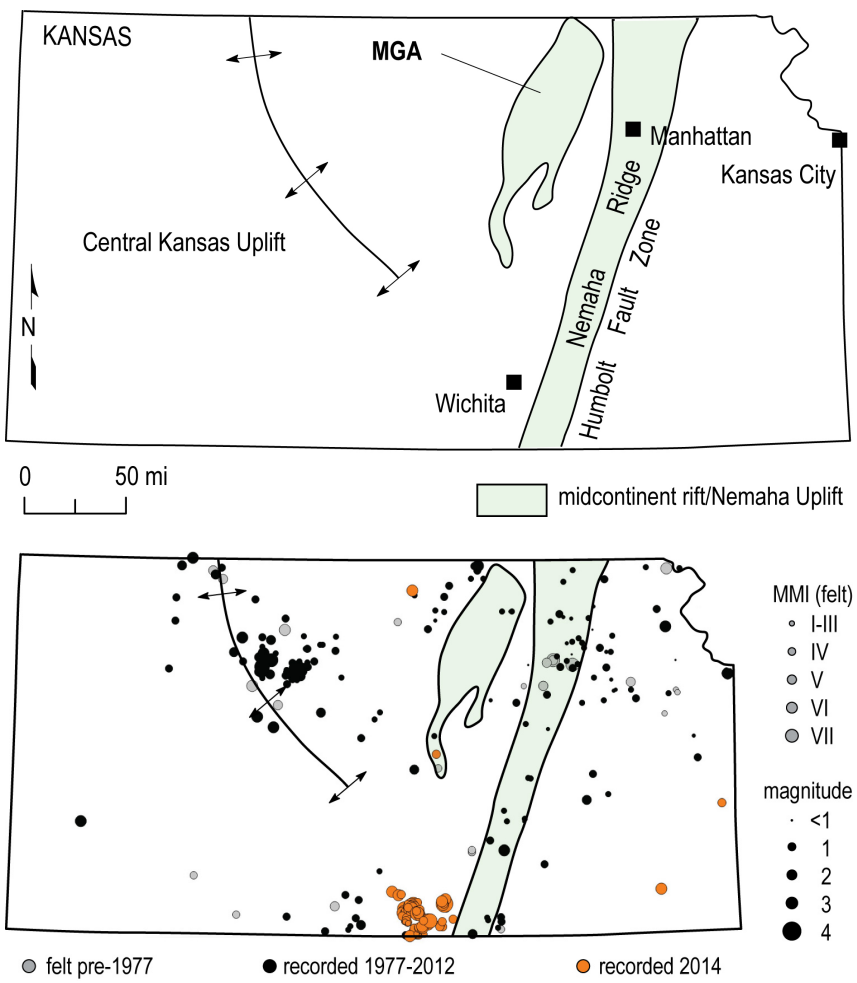

Figure 3—Prominent subsurface geologic structures in the granite basement rock (top) and recorded earthquake activity in relation to those structures (bottom) (modified from Hildebrand et al., 1988). MGA is Midcontinent Geophysical Anomaly.

The EPA regulates the licensing and operation of Class II disposal wells under the Safe Drinking Water Act or delegates authority to state agencies. The act is primarily designed to protect aquifers and other drinking water sources from contamination by injected fluids. Class II well operators submit a form annually indicating total monthly injected volumes and the maximum monthly recorded surface injection pressure.

The Kansas Corporation Commission (KCC) regulates the approximately 16,600 Class II wells in Kansas. About 5,000 of those wells are for wastewater disposal and 11,600 for secondary and enhanced oil recovery (KCC, 2014). Class II wells are used only for the injection of fluids associated with oil and gas production. Hazardous and non-hazardous industrial waste, regulated by the Kansas Department of Health and Environment (KDHE), is disposed of in UIC Class I wells. There are 47 Class I wells in Kansas (KDHE, 2012).

Preventive and Remedial Measures

In response to the increased earthquake activity in south-central Kansas, Governor Brownback established the State Task Force on Induced Seismicity in January 2014. With one representative each from the KGS, KCC, and KDHE, the task force focused on the possible link between wastewater disposal wells and seismic activity. The resulting "Kansas Seismic Action Plan" recommended installation of

a six-station, statewide seismic monitoring network and outlined a response plan for seismic events (KDHE et al., 2015).

Under the proposed response plan, a recorded seismic event of M 2 or greater would trigger a response. The KGS would determine the magnitude, location, and depth of the event and assign it a seismic action score based on magnitude, location, risk, clustering and timing, and other variables. A low SAS would require no further action. If the SAS were above a set threshold, the KGS would notify the KCC and KDHE, which would determine the location of any disposal wells within about a 6-mile radius of the epicenter. The KGS would study existing data to determine whether any known faults were in the area. For any wells suspected of inducing seismicity, the KCC and KDHE would check the injection history of the wells and pass on all information about the wells to the KGS. Based on injection well data, the KGS might recommend deploying a portable seismic array in the area, and the KCC and KDHE might request more frequent reporting on fluid disposal volume from the well operators. After considering available data and seismic conditions, the three agencies would determine whether regulatory remedies allowed by statute were warranted (KDHE et al., 2015).

In March 2015, the KCC issued an order requiring operators to reduce the rate of injection into the deep Arbuckle aquifer in five areas of Harper and Sumner counties that the KGS had identified as having high seismic action scores. The operators are required to regularly report data showing compliance with the order, and the KGS continues to measure seismic activity in the area. The order also set a maximum daily injection limit for all injection wells in Harper and Sumner counties not in the five areas of concern. The wells affected by this order are a small fraction of the 4,300 Arbuckle injection wells operating statewide (KCC, 2015).

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Contact

Rex Buchanan
Kansas Geological Survey
1930 Constant Ave.
Lawrence KS 66047-3724
785-864-2106
rex@kgs.ku.edu

Fossils at Turkey Point Locality, Melvern Lake

Century after century. Rain, wind, cubic miles of ice. Bedrock becomes boulders, boulders become stones; the ice retreats, a lake forms, and galaxies of freshwater clams flap their million shells at the sun and close and die and the lake seeps away.

All the Light We Cannot See,
Anthony Doerr, 2014

Kansas has much of its deep history preserved in the fossil record. It is rich in fossils. Most of the state is covered with sedimentary rocks, which are rocks that formed at the earth's surface, including underwater. For evidence of past life to be preserved, it needs to be buried quickly in an environment likely to preserve it, such as silts and clays. Fossils and the rocks they occur in provide a record of past life, environments, and climates. The road cut at Turkey Point exposes rocks from the Upper Pennsylvanian Series. During the Pennsylvanian, which spanned about 318 to 299 million years before present, Kansas was part of the supercontinent Pangea and the paleo-equator passed diagonally through the central midcontinent, including near present-day Kansas City (Gentile, 2011).

The alternating layers of mostly limestone and shale represent cycles (called cyclothems) of numerous transgressions and regressions of shallow inland seas. Sediments deposited reflect whether they formed in deep water, a near-shore marine environment, estuaries, or upland swamps and streams. Although rock layers may only be a few feet thick, they stretch across large areas. The Pennsylvanian had abundant sea life of mollusks, corals, bryozoan, arthropods, echinoids, sharks, and primitive bony fish. Ferns, rushes, large amphibians, and primitive reptiles were on land (Gentile, 2011).

The fossils at the Turkey Point road cut are weathering out of the Severy Shale, a formation in the Wabaunsee Group. Named for rocks exposed near Severy, in Greenwood County, the Severy Shale was deposited during a period of sea level regression and an increased influx of sediments into the inland sea (White, 1986). The sediments and fossils in the Severy at the Turkey Point locality were deposited in a near-shore marine environment.

Fossils found at this locality include foraminifera (fusilinids), corals, bryozoa, mollusks (snails, bivalves), brachiopods, trilobites, crinoids, and a crushing toothed shark (Moore and Morales, unpublished manuscript).

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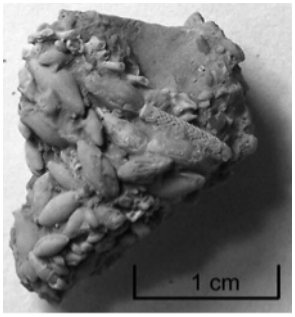
Contact

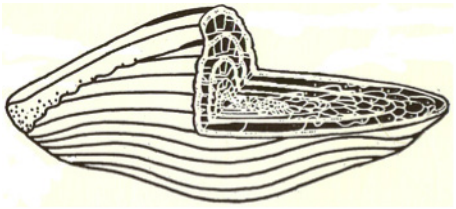
Mike Morales, Ph.D.
Geology Museum Director and Associate Professor
Emporia State University
620-341-5978
mmorales@emporia.edu

Fossil Key

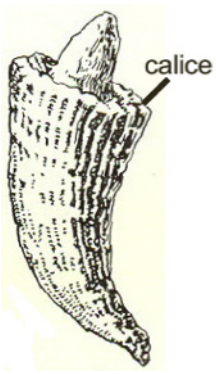
Adapted from Moore and Morales, unpublished manuscript; photos and descriptions from Kallie Moore; drawings from R. C. Moore, et al., 1952.

Common Name: fusulinids (Genus: *Triticites*)
Size Range: Height = 2mm–5mm
Abundance: Rare (clusters, not individuals)
Keys to Identification: Small, single-celled organisms, about the size and shape of a wheat grain. Occur in clusters in the limestone beds.

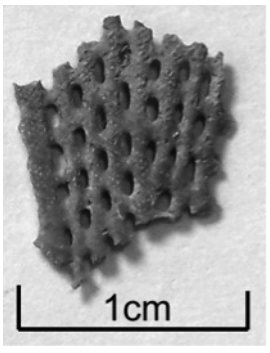


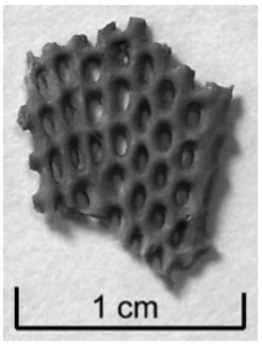


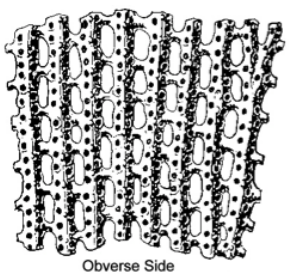
Common Name: Horn Coral (**Genus:** *Lophophyllidium*)
Size Range: Height = 2.2 cm or less
Abundance: Rare
Keys to Identification: Cone-shaped coral with a protruding conical area that is higher than the surrounding calice. The exterior of this coral has grooves that run anterior to posterior. Usually found as an individual, not in a colony.

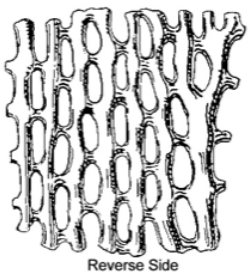


Common Name: fenestral bryozoa or moss animal
Size Range: Height ≈ 0.4cm–3.5cm+
Abundance: Abundant
Keys to Identification: Colonies of bryozoans that secreted a lace or window shaped carbonate framework that grew in a fan-shape.

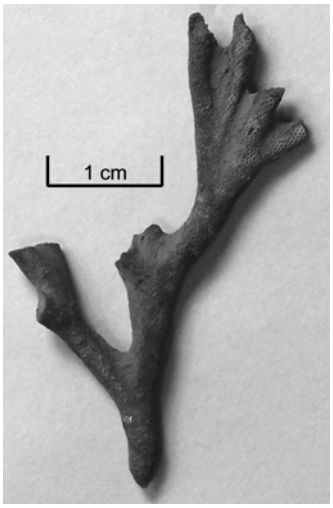




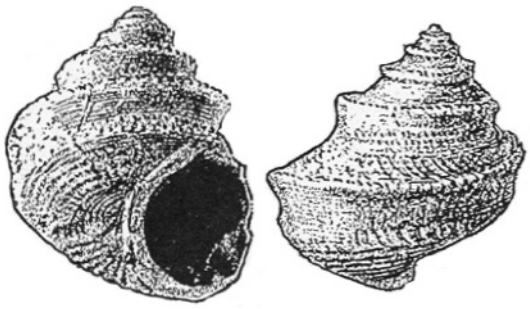




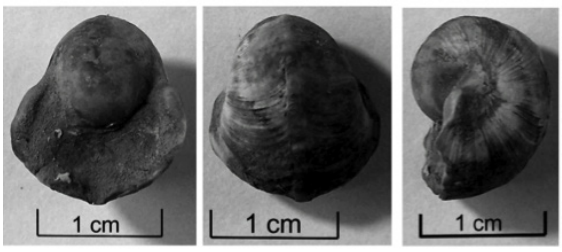
Common Name: Stick Bryozoan (Genus: *Rhombopora*)
Size Range: Height ≈ 1.0cm–4.2cm
Abundance: Abundant
Keys to Identification: Bryozoans that have a slender and a branching form.

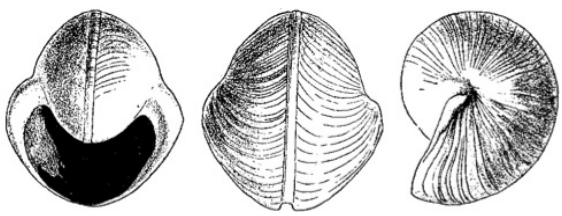


Common name: Gastropod or snail **(**Genus: *Worthenia)*
Size Range: Height = 1.4cm–4.7cm, Width = 1.1cm–3.7cm
Abundance: Moderate
Keys to Identification: Fairly large gastropod, with an average size of 3.1cm in height. Genus has a high spire with large whorls.

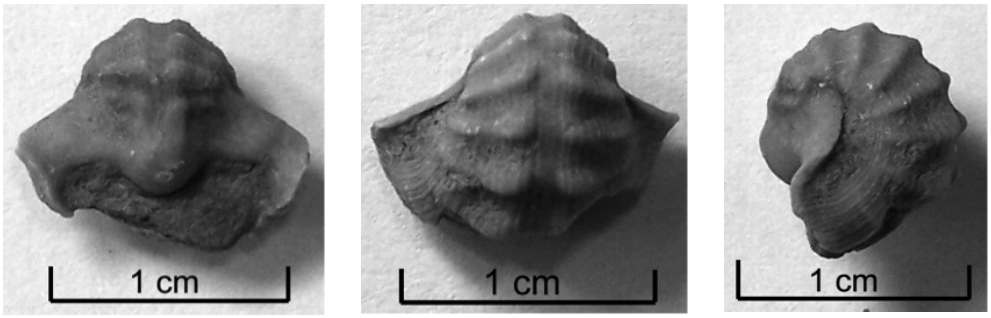


Common Name: Gastropod or snail (Genus: *Bellerophon)*
Size Range: Height = 0.5cm–4.6cm, Width = 0.6cm–4.2cm, Thickness = 0.4cm–2.6cm
Abundance: Abundant
Key to Identification: This gastropod has a large size range, with the smaller forms more common. *Bellerophon* has a round, globular appearance where only the outer coil is visible.

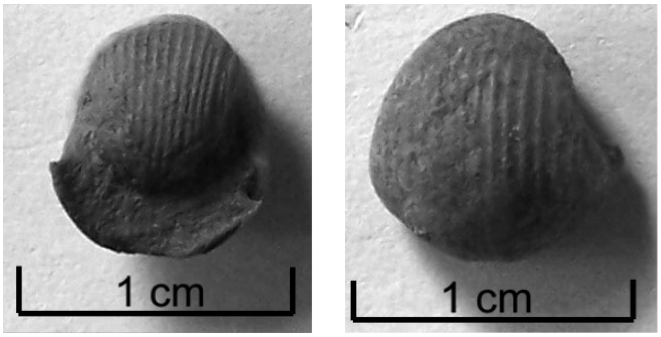




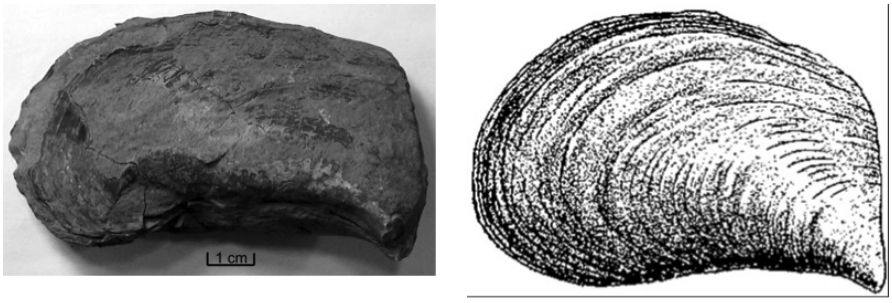
Common Name: Gastropod or snail **(Genus:** *Knightes)*
Size Range: Height = 0.6cm–2.3cm, Width = 0.7cm–2.8cm
Abundance: Abundant
Keys to Identification: This genus is similar in size and shape to *Bellerophon* except that the ornamentation is much different; it has raised horizontal growth lines.



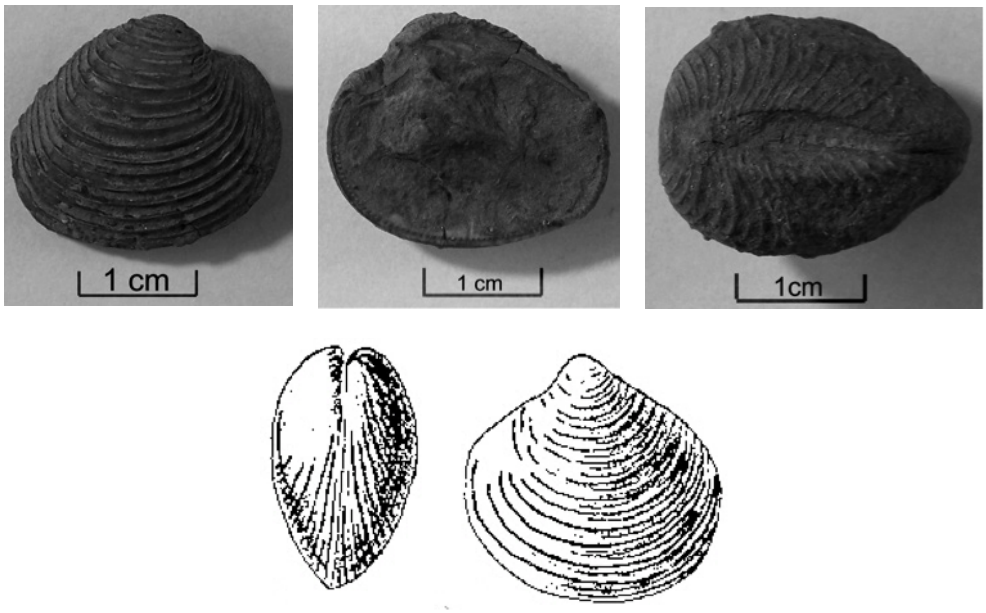
Common Name: Gastropod or snail **(Genus:** *Euphemites)*
Size Range: Height = 0.6cm–1.5cm, Width = 0.6cm–1.4cm, Thickness = 0.5cm–1.2cm
Abundance: Abundant
Keys to Identification: *Euphemites* is most similar to *Bellerophon*. The only difference between these two specimens is the direction of the growth/ornamentation lines. Instead of being horizontal, *Euphemites* has vertical growth lines with no obvious raised growth line.



Common Name: Bivalve or clam; (Genus: *Orthomyalina)*
Size Range: Height = 6.1cm–8.2cm, Width = 3.2cm–4.1cm, Thickness = 0.8cm–2.1cm (both shells)
Abundance: Abundant
Keys to Identification: This is one of the larger shells that can be found. One specimen has been found with both shells still together and unbroken. Although this is rare, many larger specimens have been found with the posterior end broken off. These were not added into the size range. Usually only the beak (most anterior portion) of the shell is preserved.

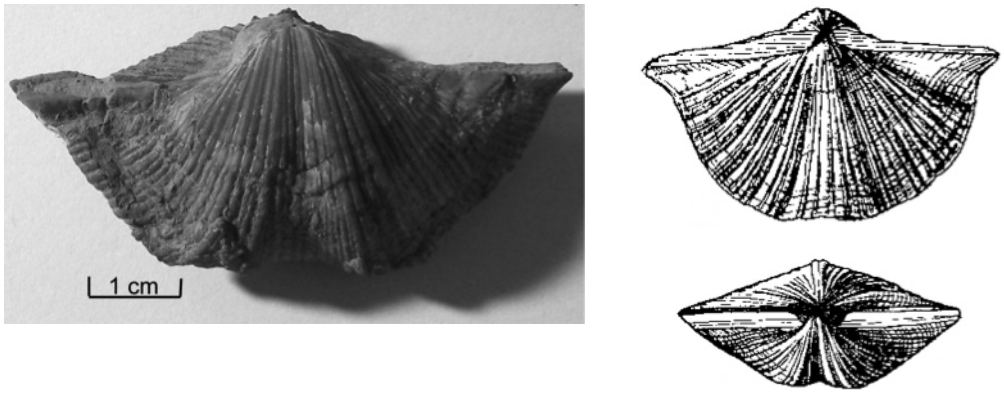


Common Name: Bivalve or clam (Genus: *Astartella)*
Size Range: Height = 0.8cm–2.5cm, Width = 1.0cm–3.0cm
Abundance: Abundant
Keys to Identification: The most noticeable feature of this genus is the deep, ornamental growth lines that follow the curvature of the shell. The shells are usually found separated from each other. They also do not deform during the fossilization process. Around the hinge line, there is a row of teeth that helped hold the shell halves together.

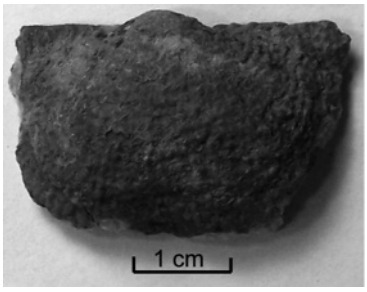


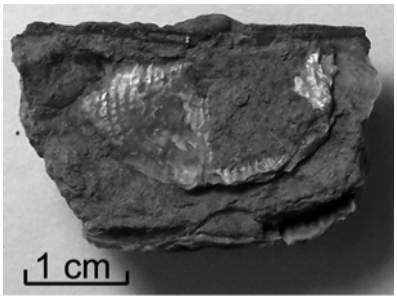
(Note: All bivalves and brachiopods have two valves or shells, but their plane of symmetry is different. On a bivalve, the two shells match; the plane of symmetry parallels the hinge line. On a brachiopod, the two valves are quite different, but the left side of a valve mirrors its right side; its plane of symmetry is perpendicular to the hinge line.)

Common Name: Brachiopod (Genus: *Neospirifer*)
Size Range: Height = 23mm–27mm, Width = 38mm–61mm,
Abundance: moderate
Keys to Identification: *Neospirifer* has extended hinge line, "wings," and deep grooves that radiate with respect to the beak. These grooves form the texture on the shell. There is also a major rounded elevation along the longitudinal mid-line.

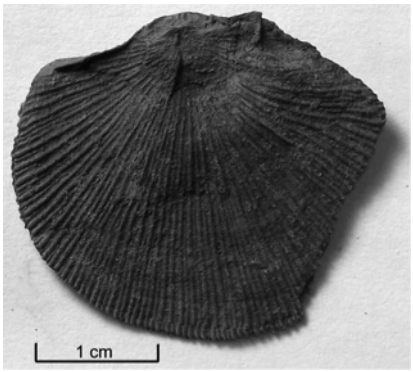


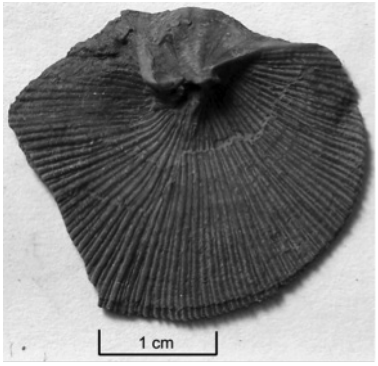
Common Name: Brachiopod (Genus: *Juresania)*
Size Range: Height ≈ 2.3cm, Width ≈ 3.4cm, Thickness ≈ 1.1cm
Abundance: Moderate
Keys to Identification: This genus has a convex ventral shell and a concave dorsal shell and both can be covered with spines. These spines are typically removed by the fossilization process and small bumps are left in their place.

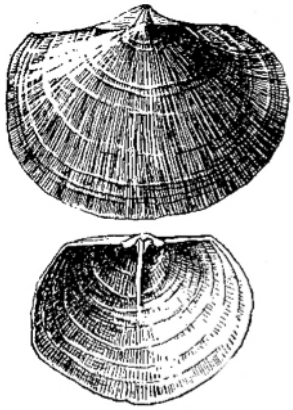




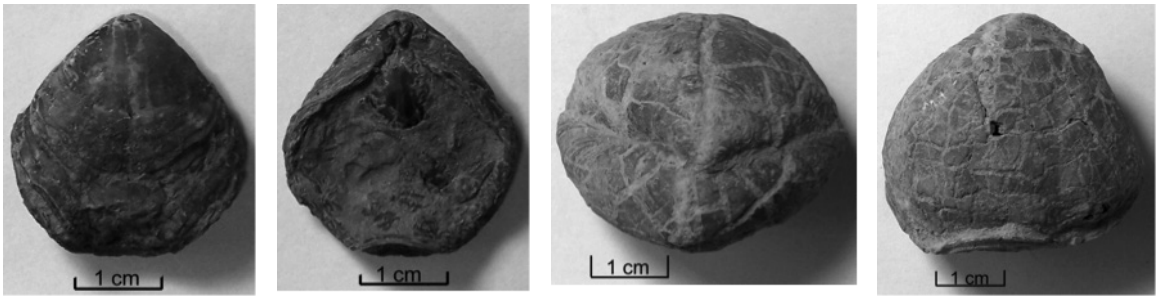
Common Name: Brachiopod (Genus: *Derbyia)*
Size Range: Height = 1.1cm–2.5cm, Width = 2.0cm–3.0cm
Abundance: Abundant (fragments)
Keys to Identification: During the fossilization process, *Derbyia* is frequently flattened. Slightly compressed specimens can be found in the limestone beds. These specimens still retain their original shape, which is fairly circular. There are thin ribs that radiate from the beak region.

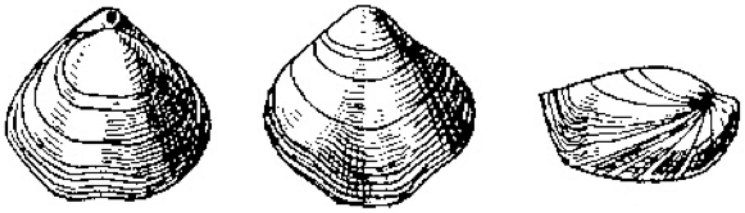




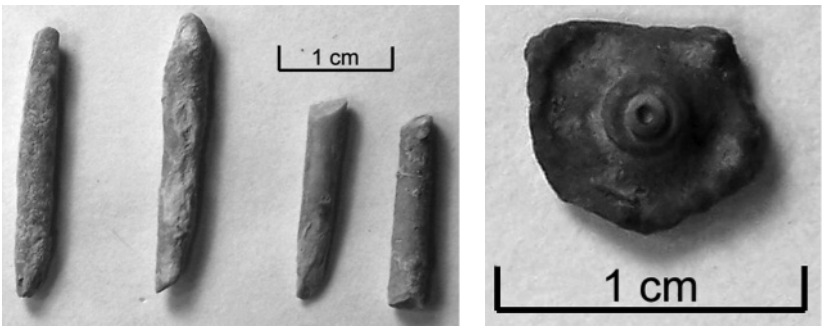


Common Name: Brachiopod (Genus: *Composita)*
Size Range: Height = 0.6cm–3.0cm, Width = 0.6cm–2.8cm
Abundance: Abundant
Keys to Identification: This genus has a pronounced ventral groove and a dorsal fold at the posterior end. Both shells are convex. Typically these shells stay together during the fossilization.

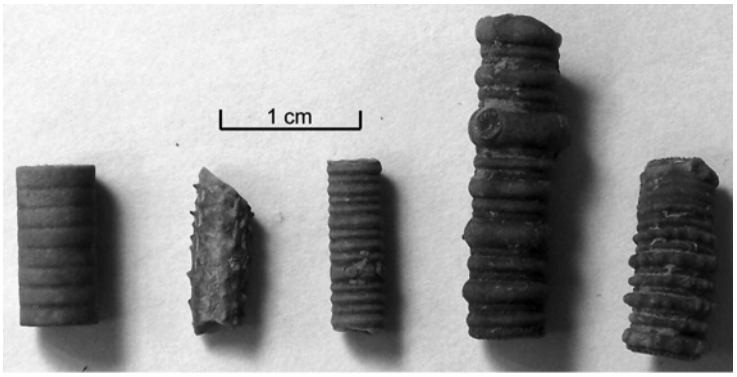


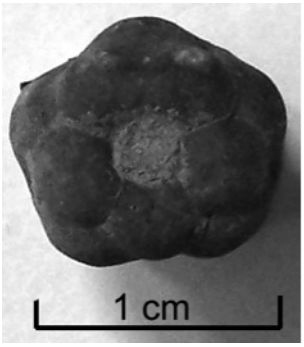


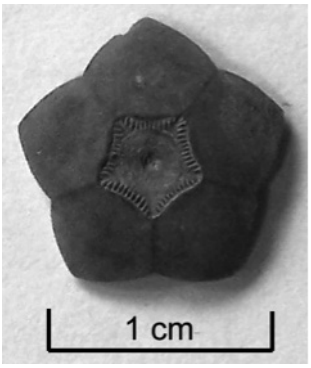
Common name: Echinoid or sea urchin
Size Range: Height ≈ 2.5cm (spine)
Abundance: Moderate
Keys to Identification: Sea urchin spines are relatively monotonous. A fragmentary spine can be 2.5cm long and has a highly weathered exterior. Can be confused with Crinoidea stems, but the spines are not segmented. This plate can be confused with a crinoid calyx plate; however the crinoid plate does not have this area of attachment for a spine.

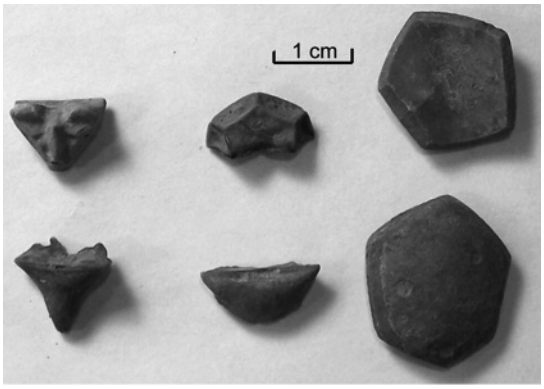


Common name: Crinoid or sea lily (Genus: *Delocrinus* , Class Crinoidea)
Size Range: Height = 9.5cm, Width = 11 cm
Abundance: Rare–Abundant
Keys to Identification: Crinoids are identified by their complete to partially preserved calyx; unfortunately these are rare.









John Redmond Reservoir: Storage Recovery and Protection

Reservoir Data

Located on the Neosho River in Coffey County, John Redmond Reservoir was built by the U.S. Army Corps of Engineers primarily for flood control and low-flow regulation. The reservoir also provides industrial and municipal water supply, recreation, and wildlife habitat. Completed in 1964 at a cost of $29.3 million, it covered 9,800 acres and had a water storage capacity of 82,200 acre-feet (AF—an acre foot is 325,850 gallons). (The town of Strawn, located in the lake's flood area, was relocated eastward to higher ground.) Outflow is controlled by 14 tainter gates and three gate valves.

There are two types of water-storage zones or "pools" in John Redmond: flood-control storage and water conservation. At design, the flood-control storage provided 562,500 AF of space reserved for floodwaters. This space remains empty except during flood-control operations. The conservation pool provided 82,200 AF of storage for water supply and water quality as well as space for sediment. The state owns more than 76% of the conservation storage in John Redmond Reservoir for municipal and industrial use. The Corps retains ownership of the water-quality storage in this pool. When stream flow gets low, the Corps, in consultation with the Kansas Water Office, will release water to meet minimum flows (~20 cubic feet per second at the Parsons gage) for water-quality purposes.

The Kansas Water Office manages the state-owned storage and makes it available through its Water Marketing and Water Assurance programs. Wolf Creek Nuclear Power Plant holds the only water-marketing contract, obtaining water for its cooling lake (Coffey County State Lake). Water is also provided for the Cottonwood-Neosho Water Assurance District, which has 19 municipal and industrial members. In 2015, 46,534 AF of state-controlled storage in this reservoir is committed to meet these customer contracts.

All built reservoirs have an original design

Figure 1—John Redmond Dam and Tainter Gates. Photo credit: Kansas Water Office.

life; John Redmond's was 50 years. The design life reflects the anticipated ratio of storage to the mean annual sediment yield trapped in the reservoir, which is based on the upstream sediment supply and the reservoir trapping efficiency. In 2007, the Kansas Biological Survey completed a bathymetric survey of John Redmond reservoir and determined that the lake's surface area was reduced to about 8,800 acres from the original 9,800 acres and its water-storage capacity was reduced to 50,200 AF from the initial 82,200 AF. The loss of surface acres and storage capacity is due to sedimentation. By 2010, there was roughly a 42% loss of water pool storage capacity. The actual sedimentation rate was about 80% more than the original projected rate.

Actions to Protect and Restore Storage

The Kansas Water Office and other agencies took action to address the loss of water conservation storage capacity at John Redmond Reservoir on several fronts: 1) a 2-foot reallocation of storage capacity from the flood pool to the conservation pool for a more equitable accounting of the higher than anticipated sedimentation rate; 2) reduction of incoming sediment through stream-bank stabilization projects; and 3) dredging of the reservoir.

Pool Rise

In 2013, the U.S. Army Corps of Engineers approved the Kansas Water Office's request for a more equitable distribution of sediment accounting between the flood control pool and the water conservation pool. The resulting permanent 2-foot conservation pool rise from 1,039 feet to 1,041 feet increased the state's water supply storage capacity by a little more than 17,000 AF. Areas potentially affected by this pool rise are the John Redmond Reservoir and Dam, the Flint Hills National Wildlife Refuge, and the Otter Creek Wildlife area, as well as 190 Neosho River miles downstream of the dam. Actions have been taken to compensate for loss of areas inundated.

Sediment Reduction

John Redmond Reservoir lies within a basin that drains 3,000 square miles of mostly grass and cultivated land. The U.S. Geological Survey estimates sedimentation into John Redmond Reservoir is about 620,000 tons annually (Juracek, 2010). Stream-bank stabilization projects upstream from John Redmond Reservoir were implemented along 8.3 miles of the Neosho River and are currently underway on the Cottonwood River. The approach has been to target entire reaches of highly erodible stream bank to more effectively reduce sedimentation rates and to extend the storage capacity of reservoirs.

The Watershed Institute (TWI), a non-profit corporation, assessed the riparian areas and stability of stream banks upstream from John Redmond Reservoir. Using aerial photos, 15 hot spots of stream-bank erosion along the Neosho and Cottonwood rivers were identified; TWI estimates these areas contributed 21,712 tons of sediment per year.

The Cottonwood River stream-bank stabilization projects are being implemented in two phases. Phase I is funded through the Kansas Water Pollution Control Revolving Fund (KWPCRF) received by the Flint Hills Resource Conservation and Development Council (RC&D). (KWPCRF is administered through the Kansas Department of Health and Environment, and RC&Ds are unique non-profit organizations made up of local volunteers.) Working with the Kansas Water Office and TWI, the RC&D identified a 9,625-foot reach of the Cottonwood River as a high priority for bank stabilization and riparian buffer restoration. This reach was divided into 14 sites, and the RC&D sought bids for projects at each site. Based on these bids, funding was sufficient for nine site projects. These sites were completed in early spring 2015.

Phase II of the Cottonwood stream bank and riparian restoration is being implemented through the Kansas Water Office, also using KWPCRF. A high priority 9,781-foot reach was identified for stabilization and riparian

Figure 2—Neosho stream bank, pre-stabilization. Photo: Kansas Water Office and The Watershed Institute.

Figure 3—Neosho River stream bank after reshaping for stability. Photo: Kansas Water Office and The Watershed Institute.

buffer remediation. The reach was divided into 11 projects; based on bids, funding was sufficient for eight projects, which are being implemented.

Dredging to Regain Storage

Dredging to remove accumulated lake-bottom sediment out of John Redmond Reservoir will benefit regional water users as well as restore

lost wildlife habitat. The intent of the dredging is to restore the conservation pool to ensure that 55,000 AF of storage is available to meet authorized project purposes. The conservation pool provides 67,302 AF of water when the lake is at elevation 1,041 feet. This project will remove roughly 3 million cubic yards of sediment. The Kansas Water Office received approval for, and in 2015 signed onto, a $20 million bond to cover the cost of dredging and disposal over a five-year period. Repayment will be through the Kansas Water Plan (75%) and the Water Marketing Program (25%).

Figure 4—Hydraulic dredging with slurry pipeline. Photo: Great Lakes Dredge and Dock Company.

Figure 5—Cutter head on sediment dredge. Photo: Great Lakes Dredge and Dock Company.

The first five-year project includes deployment of dredging equipment, placement of slurry pipelines, laying of electrical lines, and construction of four Confinement Disposal Facilities (CDF) that will receive the slurry. CDF "B" is on federal land (fig. 6).

Hydraulic dredging, which allows for sediment removal without lake draw down, will be used at John Redmond. During this process, the dredging equipment is on a floating platform. The cutter head dislodges the sediments and a centrifugal pump sucks up the slurry, a mixture of sediments and water. The slurry is piped to a disposal basin on land where the water is drained off and the sediments are left to dry. Hydraulically dredged slurries are commonly 80% to 90% water.

The slurry from John Redmond will be pumped to a CDF. The proposed final design will use a four-CDF approach with the initial slurry going to the farthest CDF (Matt Unruh, Kansas Water Office, personal communication). This allows a longer drainage distance, as water travels through multiple CDFs before its discharge into the Neosho River. Internal baffling will slow the drainage of water and help settle out suspended fine sediments (fig. 7). Before any slurry removal, the slurry is analyzed for how quickly the fine sediments settle out. If needed, a polymer can be added to increase the settling out of fine

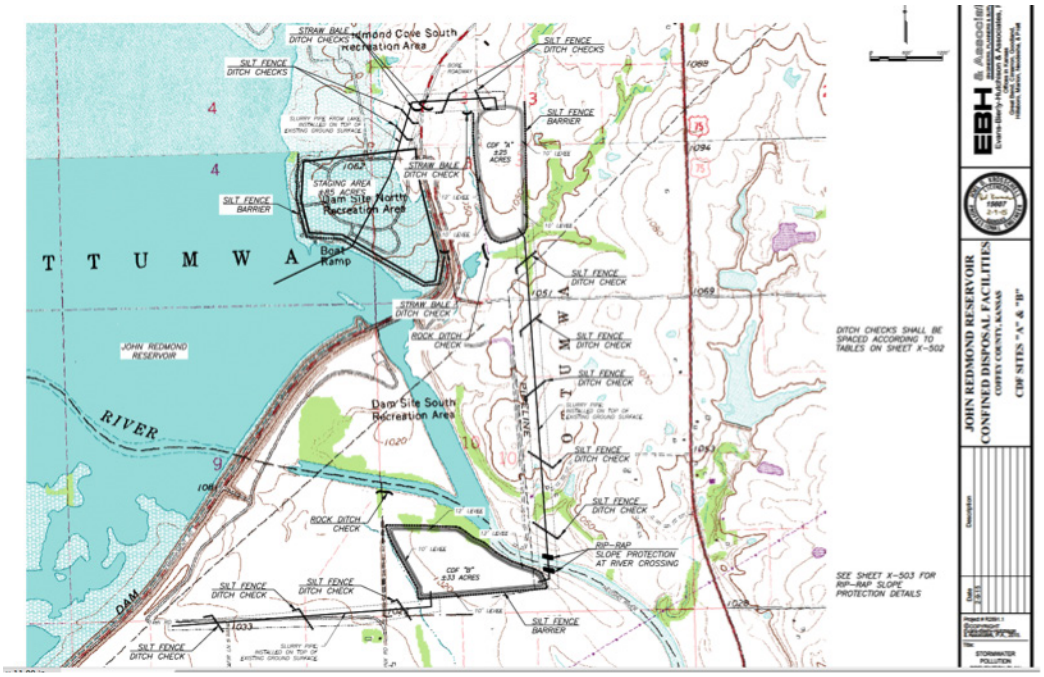


Figure 6—Schematic of staging area, slurry pipeline, and proposed CDFs. Source: Kansas Water Office.

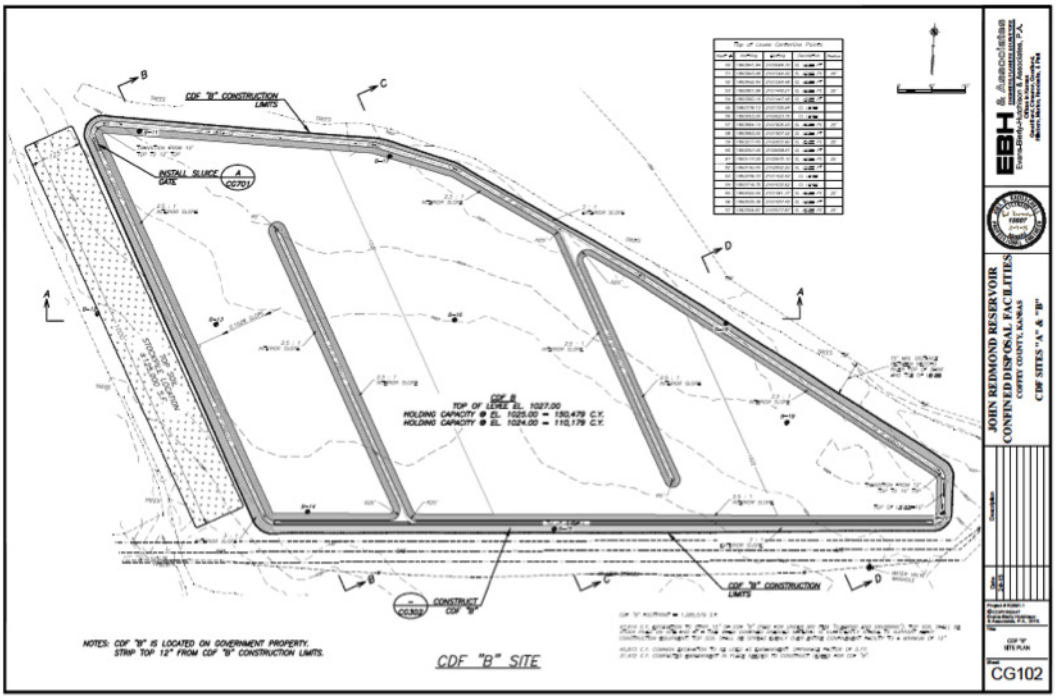


Figure 7—Schematic of CDF B. Source: Kansas Water Office.

sediments. Total suspended sediments and total phosphorous are the primary parameters evaluated and monitored to assure waters drained from the slurry do not degrade the Neosho River water quality.

Federal and state permits and environmental reports have been extensive and taken more time than originally planned. Once dredging begins, it will take 10 to 12 months to remove the 3 million cubic yards of sediment. Once the CDF is filled and the sediments dried, the site will be remediated and incorporated into the landscape.

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Contacts

Tracy Streeter, Director
Kansas Water Office
900 SW Jackson, Suite 404
Topeka KS 66612
785-296-3185
tracy.streeter@kwo.ks.gov

Eugene Goff
Operations Project Manager, Kansas Area
U.S. Army Corps of Engineers, Tulsa District
1565 Embankment Rd SW
Burlington KS 66839
620-364-8614
eugene.goff@usace.army.mil

Kansas Oil and Gas Industry Economics and Trends

In 2014, oil was produced in 91 of the 105 counties in Kansas (fig. 1), and natural gas was produced in 54 (fig. 2).

Oil production increased in 2014 (figs. 3 and 4), boosted mainly by activity in a few south-central and northwestern counties, but drilling started to slow toward the end of the year and into 2015 as oil prices fell. For the Mississippian limestone play in south-central Kansas, for example, 38 intents to drill horizontal wells were issued in October 2014 while only 7 were issued in February 2015.

The play, colloquially known as the "Mississippi Lime," has been a hot spot for drilling in the state since 2010, especially in Barber and Harper counties. Most of the activity over the last five years has been horizontal drilling with multistage hydraulic fracturing, popularly known as fracking. Although production rose significantly in Harper County in 2014, new drilling was down in the Mississippian play in proportion to the decline in intents.

Six of the top-ten oil-producing counties, including Barber County, showed losses in production volumes in 2014 (table 1). Harper County and Rawlins County in northwestern Kansas were notable exceptions. In Rawlins County, oil production from vertical wells drawing from the Pennsylvanian-age Lansing–Kansas City Group increased significantly in 2014, moving the county from the 22nd highest producer in the state in 2013 to 10th in 2014. Logan and Scott counties, although not among the top-ten producing counties, also showed significant increased production from vertical wells.

Natural gas production in Kansas continued to decline in 2014 (figs. 5 and 6), with eight of the top ten gas-producing counties experiencing losses in production volumes (table 2). Production from the

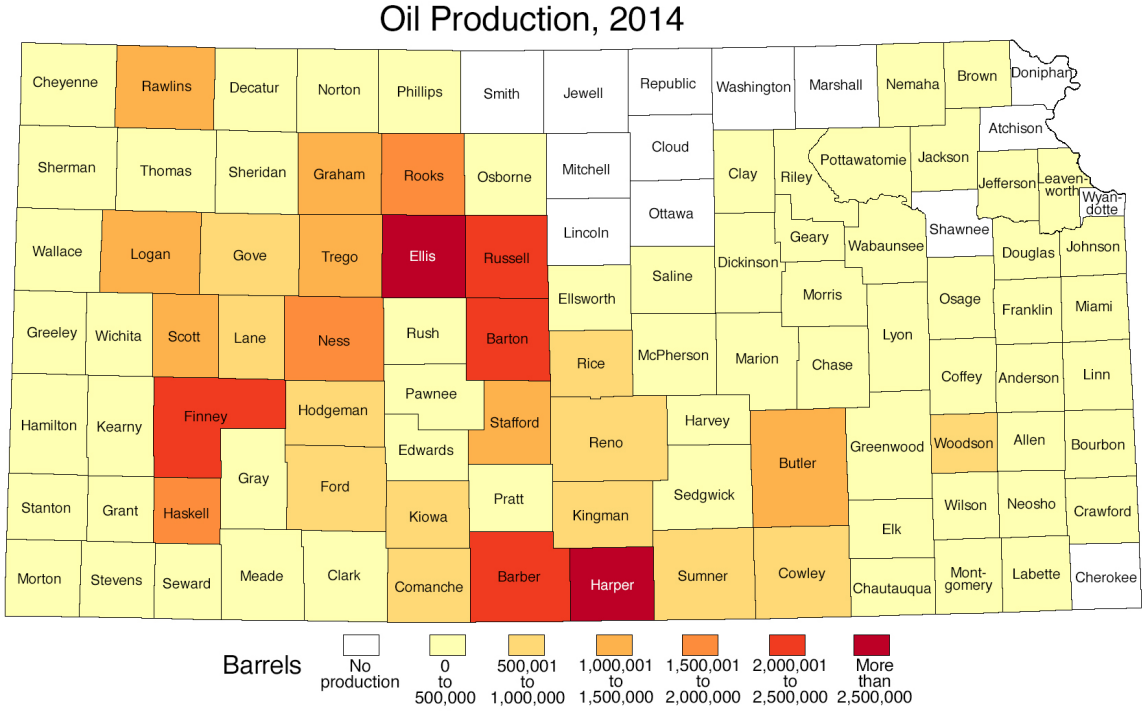

Figure 1—Kansas oil production by county in 2014 (KGS, 2015).

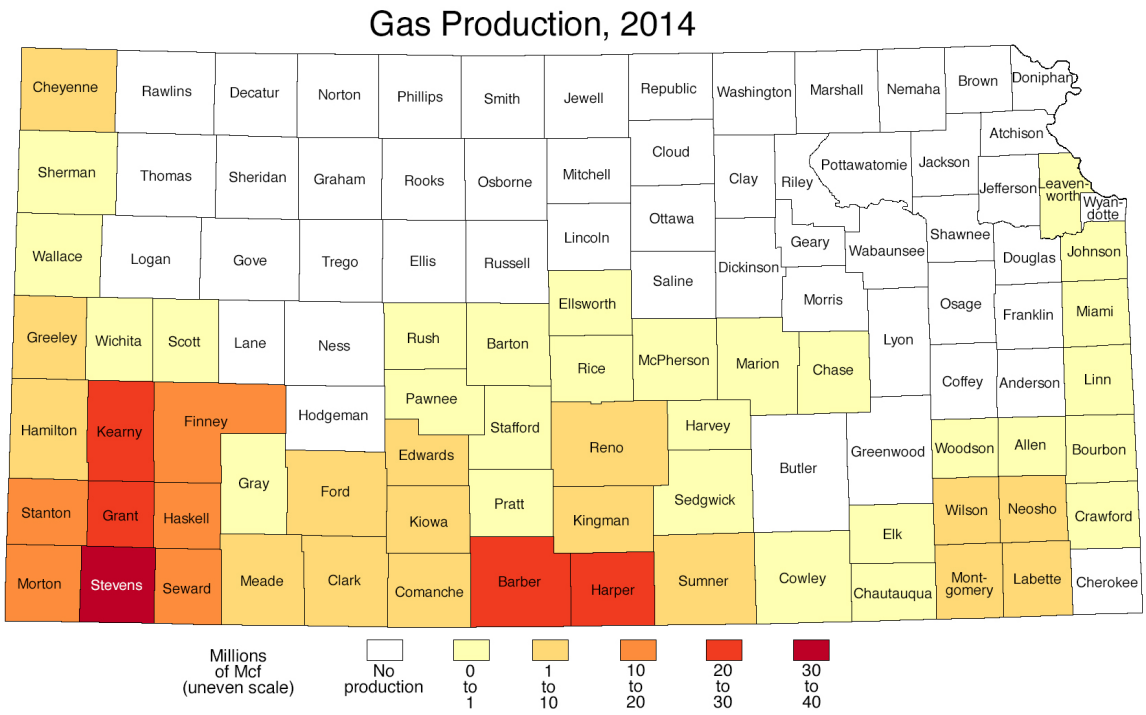

Figure 2—Kansas natural gas production by county in 2014 (KGS, 2015).

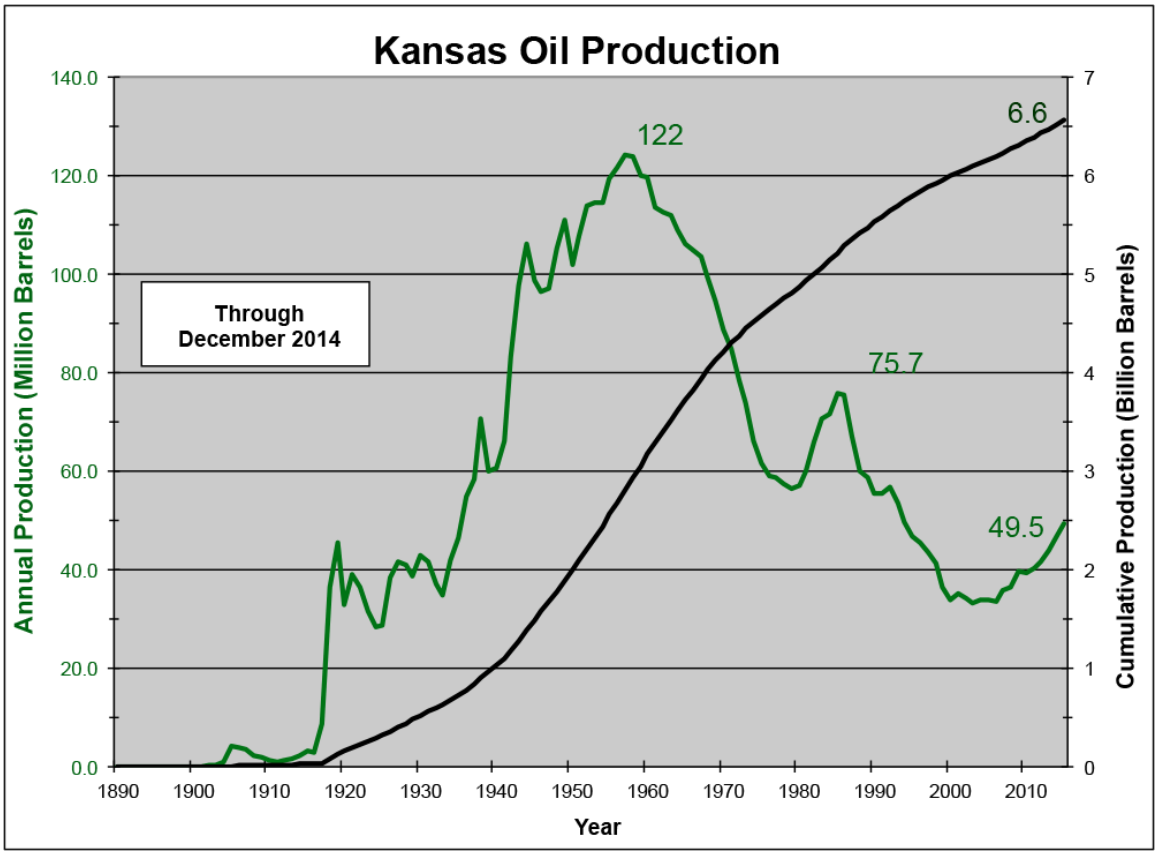

Figure 3—Historical oil production in Kansas through January 2015 (KGS, 2015).

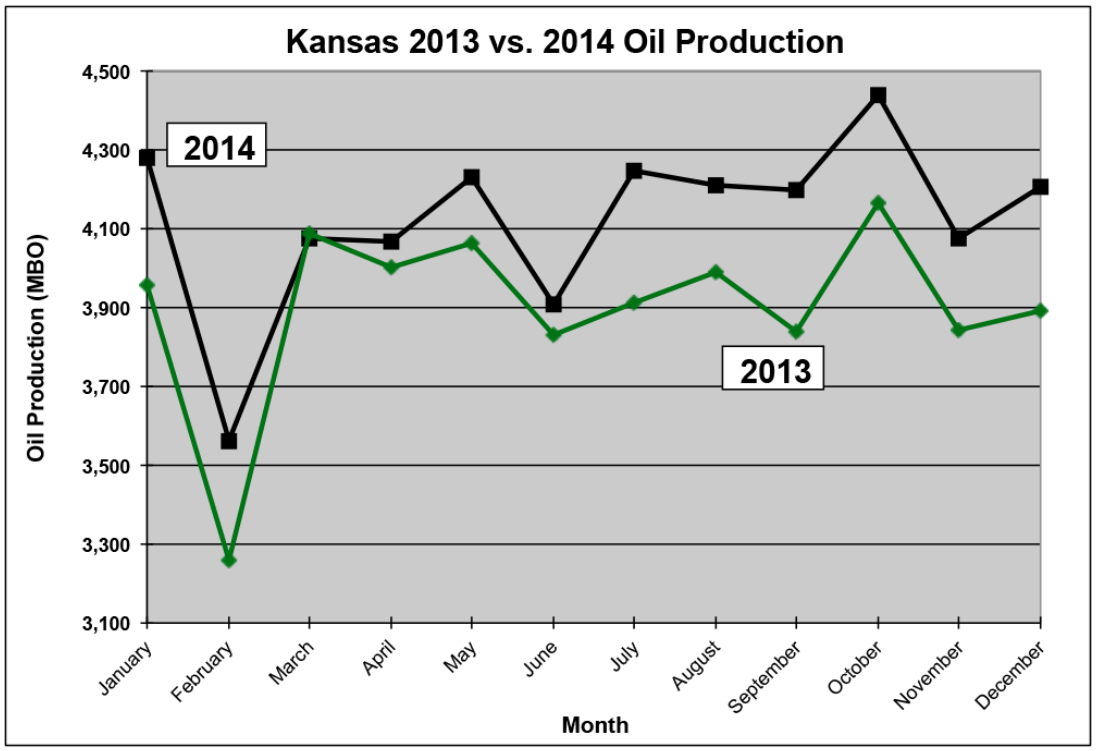

Figure 4—Volume of oil produced in Kansas in 2013 and 2014 (KGS, 2015). MBO=million barrels of oil.

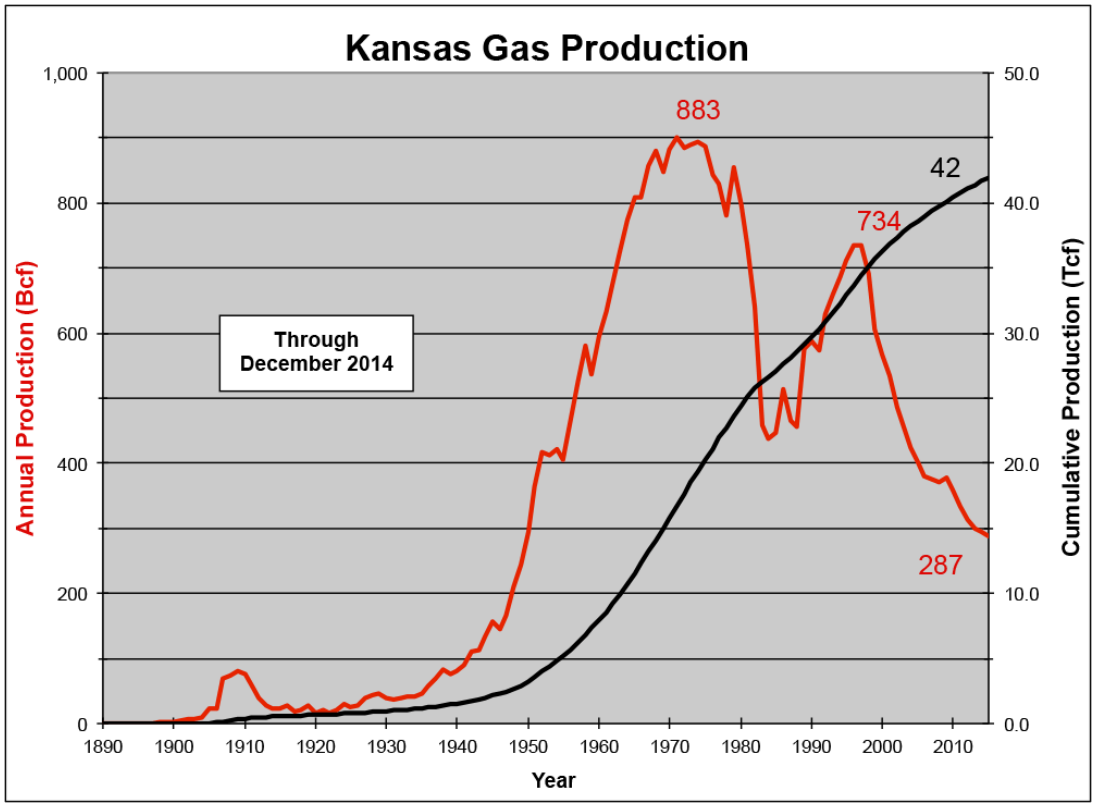

Figure 5—Historical natural gas production in Kansas through January 2015 (KGS, 2015). Bcf=billion cubic feet. Tcf=trillion cubic feet.

Table 1—Top ten oil producing counties in Kansas in 2014.

County	bbl (barrels of oil)	% of state total	2013 Rank	% Change from 2013 volume
1. Ellis	3,251,336	6.6	1	-8.1
2. Harper	2,936,587	5.9	9	+69.4
3. Barton	2,190,862	4.4	3	-.6
4. Barber	2,059,774	4.2	2	-12.6
5. Russell	2,055,084	4.2	5	+0.5
6. Finney	2,027,040	4.1	8	+15.2
7. Ness	1,996,876	4.0	4	-5.7
8. Rooks	1,967,091	4.0	7	-0.2
9. Haskell	1,921,203	3.9	6	-3.7
10. Rawlins	1,455,445	2.9	new	+97.3
State Total	**49,499,845 bbl**			**+5.7**

Table 2—Top ten natural gas producing counties in Kansas in 2014.

County	mcf (thousand cubic feet)	% of state total	2013 Rank	% Change from 2013 volume
1. Stevens	33,813,228	11.8	1	-11.2
2. Grant	28,685,777	10.0	2	-2.2
3. Barber	27,762,756	9.7	3	-2.5
4. Kearny	24,906,706	8.7	4	-3.5
5. Harper	24,312,982	8.5	8	+80.1
6. Haskell	17,126,352	6.0	5	-6.1
7. Finney	15,592,991	5.4	6	-7.0
8. Morton	14,846,521	5.2	7	-7.3
9. Stanton	11,969,363	4.2	new	+5.8
10. Seward	11,864,000	4.1	9	-9.8
State Total	**287,473,278 mcf**			**-2.6**

expansive Hugoton Gas Area in southwestern Kansas dropped as depletion of the field by conventional methods continued and sluggish gas prices made enhanced production—used to recover gas from tight rocks—economically untenable.

Production of natural gas from the Mississippian play was mixed, declining slightly in Barber County but rising significantly in Harper County. Lower natural gas prices also led to the continued decline of drilling and production in southeastern Kansas, where gas is produced mainly from shallow coal beds. Production there has dropped more than 40% since its peak in 2008.

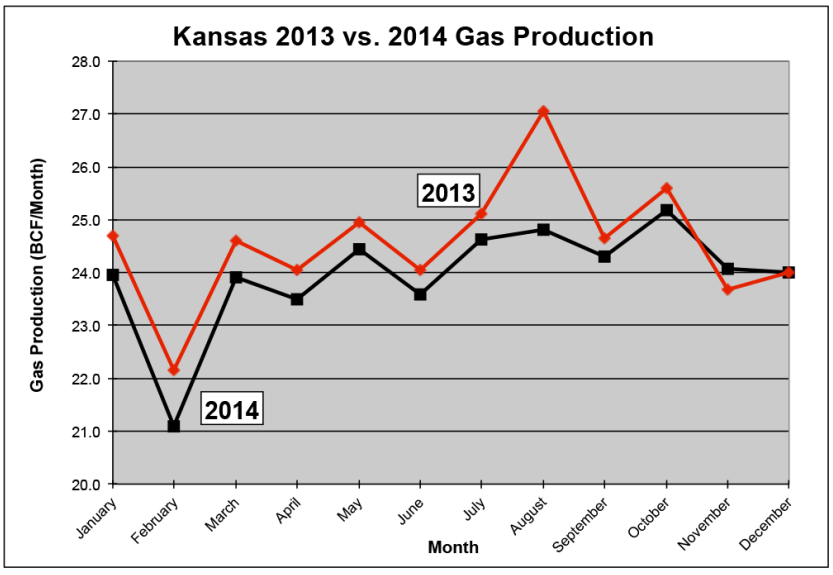

Figure 6—Volume of natural gas produced in Kansas in 2013 and 2014 (KGS, 2015). Bcf=billion cubic feet.

Oil and Gas Prices, Values, and Revenue

Even though oil production was up in Kansas in 2014, the cumulative value of the state's production decreased slightly due to price declines in the latter half of the year. Prices fell from a high around $100 per barrel in June 2014 to a low just under $60 in December, fluctuated throughout the spring, and remained below $50 in July 2015. Although natural gas production in the state declined in 2014, the cumulative value rose a little after the price peaked at $5.36 per thousand cubic feet (mcf) in February 2014 and averaged about $3.92 per mcf for the year, up slightly over 2013. In December, the price of natural gas was down to about $3 per mcf and remained down in early 2015 due to the large natural gas supply in the United States.

In April 2015, the Kansas Division of the Budget and Kansas

Legislative Research Department (KLRD) forecast that lower relative oil and gas prices would continue in the foreseeable future. They estimated 2015 oil and gas severance tax receipts for the state general fund would be about 23% lower than in 2014 (Kansas Division of the Budget and KLRD, 2015). The Kansas mineral severance tax is an excise tax on oil, natural gas, and coal extracted from the ground and produced for sale, transport, storage, profit, or commercial use. The tax rate is 8% of the gross value of oil and gas and $1 per ton of coal (Kansas Department of Revenue, 2014).

Local governments also are affected by the variable oil and gas prices. Counties are required by the state to appraise oil and gas property based on prices at a set time each year. They then receive property-tax revenue based on that set price even when prices fluctuate. If, for example, the valuation were set at $50 per barrel but the price rose to $100 per barrel later in the year, annual revenues for each oil and gas producing county, school district, and other local taxing entity would be based on $50 per barrel for the whole year. According to state statute, a portion of the Kansas severance tax is to go into an oil and gas depletion fund used to help local governments during times of low oil and gas property tax revenues. However, in recent years the state has transferred some of the revenues out of this fund and allocated them for other purposes (Shale Public Finance Project, 2015).

Based on the number of intents to drill filed, drilling is down by about a third in 2015. That translates into layoffs and less spending on motels, food, equipment, and other expenditures by the energy sector and a subsequent reduction in sales and income tax receipts. As companies' revenues drop due to falling prices, producing wells that become unprofitable, especially marginal ones, may be abandoned. Investor royalties also fall in proportion to oil and gas prices.

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Contacts

K. David Newell
Kansas Geological Survey
1930 Constant Ave.
Lawrence KS 66047
785-864-2183
dnewell@kgs.ku.edu

Nick Powell, President
Colt Energy
1112 Rhode Island Road
P.O. Box 388
Iola, KS 66749
Nickpowell@msn.com

David Doyel, Executive Vice President, Geologist
Murfin Drilling Company, Inc.
250 N. Water, Suite 300
Wichita, KS 67202
ddoyel@murfininc.com