Kansas Field Conference
September 11–13, 2017

Northeast Kansas

Shaped by Glaciation and the Missouri River

Field Guide

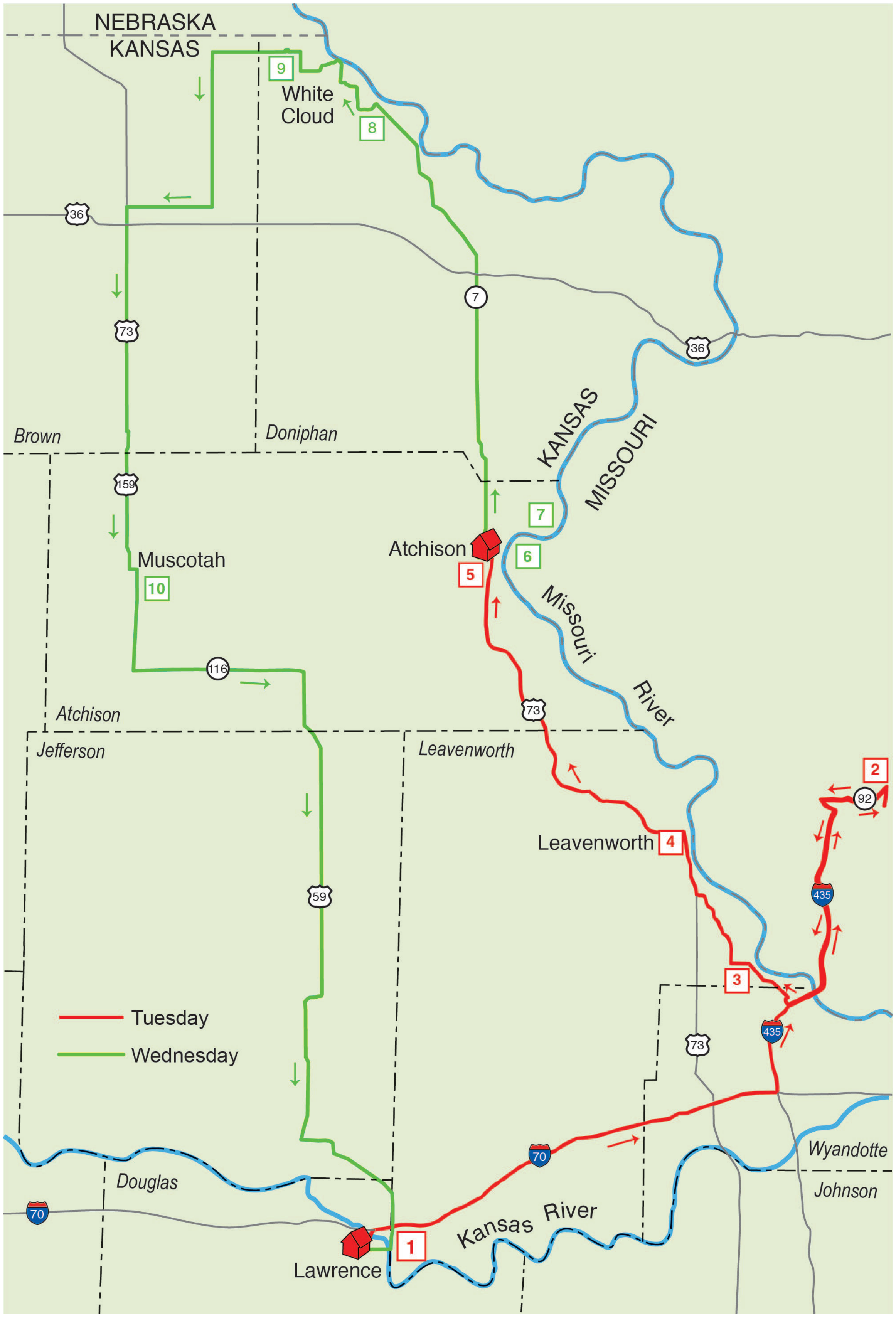
Susan Stover and Catherine S. Evans

This project is operated by the Kansas Geological Survey and funded, in part, by the Kansas Water Office, the Kansas Department of Transportation, and the Kansas Department of Wildlife, Parks and Tourism.

KGS Open-File Report 2017-47

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: Missouri River in Leavenworth County (Kansas Geological Survey)



Route map. Site stops numbered on Tuesday (Day 2) and Wednesday (Day 3) agendas.

Contents

Participants

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

Mike Armstrong, General Manager, WaterOne

Bob Atchison, Rural Forestry Coordinator, Kansas Forest Service

Dave Baker, Representative, Council Grove

Richard Billinger, Senator, Goodland

Hugh Bogle, District 1 Engineer, Kansas Department of Transportation

Sydney Carlin, Representative, Manhattan

John Carmichael, Representative, Wichita

Steve Crum, Representative, Haysville

John Eplee, Representative, Atchison

Marci Francisco, Senator, Lawrence

Jaime Gaggero, Director, Bureau of Water, Kansas Department of Health and Environment

Raney Gilliland, Director, Kansas Legislative Research Department

Dan Goddard, Senator, Parsons

Robert Goldstein, Provost's Special Advisor on Campus Development and Distinguished Professor of Geology, University of Kansas

Kyle Halverson, Chief Geologist, Kansas Department of Transportation

Kyle Hamilton, Assistant Revisor of Statutes, Kansas Office of Revisor of Statutes

Randall Hardy, Senator, Salina

Tom Hawk, Senator, Manhattan

Dave Heinemann, KGS Advisory Council (GSAC)

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

Laura Kelly, Senator, Topeka

Dan Kerschen, Senator, Garden Plain

Annie Kuether, Representative, Topeka

Lane Letourneau, Water Appropriation Program Manager, Division of Water Resources, Kansas Department of Agriculture

Earl Lewis, Assistant Director, Kansas Water Office

Greg Lewis, Representative, St. John

Brad Loveless, Executive Director, Environmental Services, Westar Energy

Rob Manes, State Director, The Nature Conservancy in Kansas

Ed Martinko, Director and Professor, Kansas Biological Survey

Carolyn McGinn, Senator, Sedgwick

Cindy Neighbor, Representative, Shawnee

Pat Pettey, Senator, Kansas City

Ken Rahjes, Representative, Agra

Lynn Rogers, Senator, Wichita

Melissa Rooker, Representative, Fairway

Mark Schreiber, Representative, Emporia

Diane Silver, GHawker Editor, University of Kansas Department of Geology

Tracy Streeter, Director, Kansas Water Office

Susie Swanson, Representative, Clay Center

Ed Trimmer, Representative, Winfield

Ponka-We Victors, Representative, Wichita

Jim Ward, Representative, Wichita

Julie WestHoff, Chair, KGS Advisory Council (GSAC)

Kansas Geological Survey Staff

Susan Stover
Rolfe Mandel
Cathy Evans
Tony Layzell

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@ks.gov
Responsibilities and Experience: KDWPT, 1989–present. Education: Northeastern State University, BS; Oklahoma State University, MS

Mike Armstrong
General Manager
WaterOne
10747 Renner Blvd
Lenexa KS 66219
913-895-5517 Business
Responsibilities and Experience: General manager of Water District No. 1, Johnson County (WaterOne), a public water supplier for most of Johnson County; Member, Kansas Water Authority and American Water Works Association (AWWA); Chair, Water Utility Council of the Kansas AWWA; Represents water supply stakeholders on the Missouri River Recovery Implementation Committee (MRRIC); Former member, Overland Park Chamber of Commerce Board of Directors. Education: Kansas State University, BA, Political Science; University of Kansas, JD

Bob Atchison
Rural Forestry Coordinator
Kansas Forest Service
2610 Claflin Road
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 through the Kansas Forest Action Plan to address issues that are both opportunities and threats to Kansas forests, woodlands, and shelterbelts. Education: University of Missouri, BS, Forest Management

Dave Baker
Kansas House of Representatives, District 68
278 Lake Road
Council Grove KS 66846
620-767-2528 Business
620-767-6403 Home
davebaker@house.ks.gov
Responsibilities and Experience: Member, Government, Technology & Security, Children & Seniors, Agriculture, and Commerce, Labor & Economic Development committees. Sells real estate.

Richard Billinger
Senator, District 40
Box 594
Goodland KS 67735
785-899-4700 Business
RB_Rick@Hotmail.com
Responsibilities and Experience: Vice chair, Ways & Means and Financial Institutions & Insurance committees and Joint Committee on State Building Construction; Member, Agriculture & Natural Resources Committee. Farmer and retired businessman; Former Goodland mayor and city council member. Interests: Kansas politics, farming, golfing, and travel. Education: Fort Hays State University

Hugh Bogle
District 1 Engineer
Kansas Department of Transportation
121 SW 21st St
Topeka KS 66612
785-296-3881 Business
hugh.bogle@ks.gov
Responsibilities and Experience: Northeast Kansas district engineer, KDOT; Licensed professional engineer (PE). Education: University of Kansas, BSCE

Sydney Carlin
Kansas House of Representatives, District 66
1650 Sunny Slope
Manhattan KS 66502
785-341-7455 Cell
sydcar44@gmail.com
Responsibilities and Experience: Ranking minority member, Agriculture and Agriculture & Natural Resources Budget committees; Member, Appropriations Committee and Joint Committee on Corrections & Juvenile Justice Oversight; First elected 2002. Education: Kansas State University, BS

John Carmichael
Kansas House of Representatives, District 92
1475 N Lieunett St
Wichita KS 67203
785-296-7650 Business
316-250-0969 Cell
john.carmichael@house.ks.gov
Responsibilities and Experience: Ranking minority member, Judiciary Committee; Member, Commerce, Labor & Economic Development and Energy, Utilities & Telecommunications committees; Member, Joint Committee on Administrative Rules & Regulations; Attorney, Conlee, Schmidt & Emerson, LLP. Interests: Hunting, fishing, flying, and Kansas history. Education: University of Kansas, BGS; Wichita State University, BS; University of Kansas, JD

Steve Crum
Kansas House of Representatives, District 98
315 Linden Ln
Haysville KS 67060
316-491-1977 Home
crumforkansas@gmail.com
Responsibilities and Experience: Member, Water & Environment, Education, and Health & Human Services committees; City council member, teacher and coach; Self-proclaimed science geek. Education: Newman University, BS, Elementary Education

John Eplee
Kansas House of Representatives, District 63
820 Raven Hill Drive
Atchison KS 66002
913-367-6672 Business
913-367-5910 Cell
jeplee@atchhosp.org
Responsibilities and Experience: Member, Health & Human Services, Taxation, Insurance, & Financial Institutions, and Pensions committees; Family physician; Fellow in American Academy of Family Medicine. Education: Kansas State University, BS, Psychology and Pre-Med; University of Kansas, MD

Marci Francisco
Kansas State Senate, District 2
1101 Ohio Street
Lawrence KS 66044
785-766-1473 Cell
785-842-6402 Home
maf@sunflower.com
Responsibilities and Experience: Ranking minority member, Agriculture & Natural Resources Committee; Member, Utilities and Assessment & Tax committees. Education: University of Kansas, Bachelor's of Architecture

Jaime Gaggero
Director
Bureau of Water, Kansas Department of Health and Environment
1000 SW Jackson
Topeka KS 66612
785-296-5504 Business
jaime.gaggero@ks.gov
Responsibilities and Experience: Oversees multiple regulatory and non-regulatory programs, including the KDHE monitoring and assessment program, water quality standards and total maximum daily loads, municipal and industrial wastewater systems, public drinking water systems, confined animal feeding operations, underground injection control program and hydrocarbon storage, the water well license program, non-point source abatement, including the Kansas Watershed Restoration and Protection Strategy (WRAPS), and the Local Environmental Protection Program. Education: University of Kansas, Bachelor's in Environmental Studies and Master's in Public Administration

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 Senate Agriculture & Natural Resources Committee and Joint Committee on Administrative Rules and Regulations. Education: Kansas State University, BS, Political Science; Kansas State University, MS, Agricultural Economics

Dan Goddard
Kansas State Senate, District 15
3420 Mosher Rd
Parsons KS 67357
620-423-0407
dwgoddard@cableone.net
Responsibilities and Experience: Member, Transportation, Ways & Means, and Assessment & Taxation committees and Select Committee on Education Finance; Parsons City Commissioner; Retired Air Force Colonel. Education: University of Wisconsin, BA, Geology; Troy State University, MS, Personnel Management

Robert Goldstein
Provost's Special Advisor on Campus Development and Distinguished Professor or Geology
Office of the Provost
1450 Jayhawk Blvd, Rm 250
Lawrence KS 66045
785-864-4904 Business
gold@ku.edu
Responsibilities and Experience: As the Provost's Special Advisor on Campus Development, focused on campus development, including the Earth, Energy, and Environment Center and KU's Central District. As Haas Distinguished Professor, teaches introductory geology courses and advanced lab and field classes; conducts research related to availability of fossil fuel energy and location and generation of oil and natural gas resources. His research integrates regional-scale geology and microscopic-scale chemistry to reconstruct geologic history and identify rock pores that might hold significant oil and gas accumulations, and he is author of book on fluid inclusions that serves as the standard text for this technique. Former associate dean for natural sciences and mathematics, KU College of Liberal Arts and Sciences. Education: Juniata College, BS; University of Wisconsin, MS and PhD

Kyle Halverson
Chief Geologist
Kansas Department of Transportation
700 SW Harrison St
Topeka KS 66603
785-291-3860 Business
kyle.halverson@ks.gov
Responsibilities and Experience: Responsible for KDOT's geology functions in the Bureau of Structures and Geotechnical Services, which provides critical information to road, bridge, and construction activities. Manages work program of five regional offices that provide geotechnical data used in design, construction, and maintenance of bridges, highways, and facilities. Provides oversight on numerous high-profile projects. Responsible for geologic inspection of aggregate sources to comply with KDOT specifications. Interests: Hunting, fishing, sports, and spending time with family.

Kyle Hamilton
Assistant Revisor of Statutes
Kansas Office of Revisor of Statutes
1610 W 1st Ave
Topeka KS 66606
785–296–5247 Business
kyle.hamilton@rs.ks.gov
Responsibilities and Experience: Drafts and briefs bills for the House Standing Committee on Agriculture. Formerly a legal intern for the Kansas Department of Agriculture. Education: Washburn University, JD

Randall Hardy
Kansas State Senate, District 24
816 Highland Ave
Salina KS 67401
785-296-7369 Business
785-823-7968 Home
randall.hardy@senate.ks.gov
Responsibilities and Experience: Member, Ethics, Elections & Local Government, Transportation, Judiciary, and Utilities committees; Salina City Commissioner, 2013–2017. Interests: Travel, nature, photography, hiking, family, volunteering, church. Education: Oral Roberts University, BA, Psychology, University of Kansas, MBA, General Management

Tom Hawk
Kansas State Senate, District 22
2600 Woodhaven Ct
Manhattan KS 66502
785-537-8000 Business
785-341-4162 Cell
tom@tomhawk.com
Responsibilities and Experience: Ranking minority member, Utilities Committee; Member, Transportation and Ways & Means committees and Joint Committee on Administrative Rules & Regulations. Education: Kansas State University, BS, MS, and PhD

Dave Heinemann
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

Robin Jennison
Secretary
Kansas Department of Wildlife, Parks and Tourism
1020 S. Kansas Avenue, Room 200
Topeka KS 66612
785-296-2281 Business
robin.jennison@ksoutdoors.com
Responsibilities and Experience: Secretary, Kansas Department of Wildlife, Parks and Tourism, 2011–present. Education: Fort Hays State University, Animal Science

Laura Kelly
Kansas State Senate, District 18
234 SW Greenwood Ave
Topeka KS 66606
785-296-7365 Business
785-357-5304 Home
laura.kelly@senate.ks.gov
Responsibilities and Experience: Assistant Minority Leader; Ranking minority member, Senate Ways & Means, Public Health & Welfare, and KanCare Oversight committees. Serves, or has served, on the Board of Directors for the Greater Topeka Chamber of Commerce, the United Way of Greater Topeka, Kansas Leadership Center, Sunflower State Games, Kansas Children's Discovery Center, and Family Service and Guidance Center; Member, North Topeka Business Alliance, Heartland Visioning Steering Committee, CASA Advisory Board, and Topeka City of Character Advisory Board. Education: Bradley University, BS, Psychology; Indiana University, MS, Park and Recreation Administration

Dan Kerschen
Kansas State Senate, District 26
645 S 263 W
Garden Plain KS 67050
254-813-9313 Business
316-535-2310 Home
dnkerschen@gmail.com
Responsibilities and Experience: Chair, Agriculture & Natural Resources Committee; Vice chair, Taxation Committee; Member, Ways & Means Committee; Chair, Claims against the State Advisory Board; Member Kansas Geological Survey Advisory Council; Member, Kansas Farm Bureau of Sedgwick County, Kansas Livestock Association, Cheney Lake Association. Education: Kansas State University, BS, Agriculture

Annie Kuether
Kansas House of Representatives, District 55
1346 SW Wayne Ave
Topeka KS 66604
785-296-7669 Business
785-633-4555 Cell
kuet@aol.com
Responsibilities and Experience: Ranking minority member, Energy, Utilities & Telecommunication Committee; Member, Water & Environment, Corrections & Juvenile Justice, and Judiciary committees. Education: Bowling Green State University

Lane Letourneau
Water Appropriation Program Manager
Kansas Department of Agriculture, Division of Water Resources
1320 Research Park Dr.
Manhattan KS 66502
785-564-6636 Business
lane.letourneau@kda.ks.gov
Responsibilities and Experience: Manager, Water Appropriation Program, which administers the Kansas Water Appropriation Act (provides a framework for water allocation to ensure full beneficial use of water resources while protecting private property rights). Education: Fort Hays State University, BS, Geology

Earl Lewis
Assistant Director
Kansas Water Office
900 SW Jackson, Suite 404
Topeka KS 66612
785-296-0867 Business
earl.lewis@kwo.ks.gov
Responsibilities and Experience: Oversees operations of KWO, including water planning, technical work, and reservoir operations. Education: University of Kansas, BS, Mechanical Engineering

Greg Lewis
Kansas House of Representatives, District 113
910 NE 30th Ave.
St. John KS 67576
620-546-4177 Cell
620-458-3541 Home
greg.lewis@house.ks.gov
Responsibilities and Experience: Vice chair, Government Technology & Security Committee; Member, Agriculture, Local Government, and Water & Environment committees. Fourth generation farmer/rancher. Education: Kansas State University, BA, Landscape Architecture

Brad Loveless
Executive Director
Environmental Services
Westar Energy
818 S Kansas Avenue
Topeka KS 66612
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, MS

Rob Manes
State Director
The Nature Conservancy in Kansas
2420 NW Button Rd
Topeka KS 66618
785-233-4400 Business
kansas@tnc.org
Responsibilities and Experience: 35-year conservation professional. Under Manes' leadership, the Conservancy has expanded outreach and protected critical lands and habitat in Kansas and raised million of dollars in private money. Brings together various interests and is a leader on guiding wind energy development and species protection. National Advisor, Wildlife and Hunting Heritage Conservation Council, which advises the U.S. secretaries of the Interior and Agriculture. Member, Board of Directors for U.S. Roundtable for Sustainable Beef, a multi-stakeholder initiative. Education: Kansas State University, bachelor's; Friends University, MS, environmental science

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

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: Chair, Ways & Means committee; Vice chair, Legislative Budget Committee and Senate Select Committee on Education Finance; Member, Confirmation Oversight and Agriculture & Natural Resources committees; Member, Administrative Rules & Regulations and State Building Construction joint committees; Agriculture producer; Interested in agritourism and fresh markets. Education: Wichita State University, BA, business administration; Friends University, MS, Environmental Studies

Cindy Neighbor
Kansas House of Representatives, District 18
10405 West 52nd Terr
Shawnee KS 66203
816-225-0580 Cell
913-268-9061 Home
cindyneighbor@aol.com
Responsibilities and Experience: Ranking minority member, Insurance Committee; Member, Agriculture and General Government Budget committees; From family that was "Illinois Farm Family of the Year" for many years because of its conservation practices; Background in medicine and dentistry. Education: Johnson County Community College; Kansas City, Kansas, Community College; UMKC School of Dentistry, Sedation Specialist

Pat Pettey
Kansas State Senate, District 6
5316 Lakewood St
Kansas City KS 66106
913-579-3741 Cell
jmphp42@yahoo.com
Responsibilities and Experience: Member, Education, Transportation, Health, Judiciary, and Juvenile Justice Oversight committees; Interested in education, health, and environmental issues. Education: University of Kansas, BS and MS, Education

Ken Rahjes
Kansas House of Representatives, District 110
1798 E 900 Rd
Agra KS 67621
785-302-8416 Cell
kenrahjes@gmail.com
Responsibilities and Experience: Vice chair, Water & Environment Committee; Editor of AgView.net, a multi-media agriculture communication company. Education: Colby Community College and Kansas State University

Lynn Rogers
Kansas State Senate, District 25
912 Spaulding
Wichita KS 67203
316-640-1390 Cell
lynnwrogers@sbcglobal.net
Responsibilities and Experience: Member, Agriculture & Natural Resources, Financial Institutions & Insurance, and Federal & State Affairs committees

Melissa Rooker
Kansas House of Representatives, District 25
4124 Brookridge Dr
Fairway KS 66205
913-961-1555 Cell
melissa@melissarooker.com
Responsibilities and Experience: Member, Federal & State Affairs, K–12 Budget, and Education committees; Member, Kansas Forestry Advisory Council and Johnson County Education Research Triangle Authority; Retired film executive (VP of development for Clint Eastwood's Malpaso Productions). Education: University of Kansas, BFA, Art History

Mark Schreiber
Kansas House of Representatives, District 60
1722 Yucca Lane
Emporia KS 66801
785-296-2721 Business
785-230-0897 Cell
mschreiber82@gmail.com
Responsibilities and Experience: Member, Water & Environment, Education, Transportation, and Energy, Utilities & Telecommunications committees; Retired from Westar Energy (served as a biologist at Wolf Creek Generating Station then in emergency planning and government affairs). Education: Emporia State University, BS and MS, Aquatic Biology

Diane Silver
Editor of GHawker
KU Department of Geology
3101 W 27th St
Lawrence KS 66047
785-766-2187 Cell
dsswriter94@gmail.com
Responsibilities and Experience: Produced the KU Department of Geology GHawker publication for last decade; grant writer for nonprofits; teaches and writes magazine articles, essays, and books. Education: Michigan State University, BA and MA, Journalism

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; Served as executive director of State Conservation Commission and on USD 338 Board of Education. Private pilot. Interests include hunting, golf, fishing, camping, and flying. Education: Highland Community College, AS; 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
785-587-7483 Business
svswan@twinvalley.net
Responsibilities and Experience: Vice chair, Higher Education Budget committee; Member, Water & Environment and Corrections & Juvenile Justice committees; Member, EMS Board, Community Corrections Advisory Board, Head Start Board, and Clay County Arts Council Board. Employed part-time at Presbyterian Manor. Education: Emporia State University, BA, Sociology; University of Kansas, MSW, Social Work

Ed Trimmer
Kansas House of Representatives, District 79
1402 E 9th Ave
Winfield KS 67156
620-262-6812 Business
620-221-7146 Home
etrimmer@cox.net
Responsibilities and Experience: Ranking minority member, K–12 Education Budget committee; Member, Legislative Post Audit, Education, Rules & Journal, and Financial Institutions & Pensions committees; Member, Kansas Geological Survey Advisory Board (GSAC): Education: Emporia State University, BSE

Ponka-We Victors
Kansas House of Representatives, District 103
PO Box 48081
Wichita KS 67201
316-708-9020 Cell
ponka-we.victors@house.ks.gov
Responsibilities and Experience: Ranking minority member, Water & Environment Committee; Member: Transportation and State-Tribal Relations committees. Member of the Tohono O'odham Nation and Ponca Tribe. Education: Newman University, BA, Biology; Wichita State University, MS, Public Administration

Jim Ward
Kansas State House of Representatives, District 86
3100 E Clark
Wichita KS 67211
785-296-7630 Business
316-210-3609 Cell
repwardks86@gmail.com
Responsibilities and Experience: House Minority Leader; Member, State Finance Council, Legislative Budget and Interstate Cooperation committees, and Joint Committee on Administrative Rules & Regulations; Previously served on Wichita City Council, as a board member for USD 259, and in Kansas Senate; Practicing attorney. Education: Creighton University, BA; Washburn School of Law, JD

Julie WestHoff
KGS Advisory Council
5800 Foxridge Drive, Suite 304
Mission KS 66202
913-643-4951 Business
juliewesthoff@kennedyjenks.com
Responsibilities and Experience: Principal at Kennedy/Jenks Consultants; Senior Project Manager of environmental projects for clients in Kansas and Missouri; Chair, Kansas Geological Survey Advisory Council (GSAC). Education: University of Kansas, BS, Biology, and BS, Geology

Kansas Geological Survey Staff

Susan Stover
Geologist/Outreach Manager
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 coordinator; Professional licensed geologist. Education: University of Nebraska, BA, Geology; Louisiana State University, graduate work, Geology; University of Arizona, graduate work, Hydrology; University of Kansas, MS, Geology

Rolfe Mandel
Director
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2171
mandel@kgs.ku.edu
Responsibilities and Experience: Responsible for operations and direction of the KGS; Executive Director, Odyssey Research Program; KGS Senior Scientist; Distinguished Professor, KU Department of Anthropology. Education: University of Texas, BA, Geography; University of Kansas, MA, Geography, and PhD, Special Studies Quaternary Research Program

Cathy Evans
Writer/Communications Coordinator
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-2195
cevans@kgs.ku.edu
Responsibilities and Experience: Write news releases and educational materials; oversee writing and editing aspects of KGS Outreach and Public Service. Education: University of Kansas, BA, Art History, and MS, Journalism

Tony Layzell
Assistant Research Professor/Stratigraphic Research
Kansas Geological Survey
1930 Constant Avenue
Lawrence KS 66047-3724
785-864-7767
alayzell@kgs.ku.edu
Responsibilities and Experience: Quaternary geology, fluvial geomorphology, stratigraphic research, geologic mapping. Education: University of Nottingham, BSc, Geography; University of North Carolina-Charlotte, MS, Geology; University of Kansas, PhD, Geography

Northeast Kansas

Shaped by Glaciation and the Missouri River

September 11–13, 2017

Welcome to the 2017 Kansas Field Conference. Geology and hydrology in northeast Kansas have significantly influenced the region's land use, economy, and culture. During the Pleistocene, glacial advances stretched across nearly a third of North America and twice reached into northeast Kansas. Ice sheets reshaped the land, buried old river systems, and created new ones, including the modern day Missouri River. Glacial ice left a mix of cobbles, sand, silt, and mud. Boulders of pink Sioux quartzite carried in by glaciers can be seen scattered in fields. Thick deposits of a windblown silty sediment called loess (commonly pronounced "luss") underlie the glacial hills and contribute to the rich, productive soils. The Missouri River has a large influence on the state as a navigation route, a source of sand and gravel, and an abundant source of water for municipalities, electrical generation, industry, and irrigation. Major flooding in the past has led to extensive engineering to control the river.

During the conference, participants will visit diverse sites—many not accessible without special permission—and interact with a variety of experts from private industries, government agencies, and other organizations about issues important to the future of the state's economy and preservation of natural resources. The Kansas Geological Survey, Kansas Water Office, Kansas Department of Transportation, and Kansas Department of Wildlife, Parks and Tourism are sponsors of the 2017 field conference and provided ideas for issues, sites, and speakers to include in the trip.

Day 1. The conference begins Monday, September 11, at 5:30 p.m. with a tour of the newly constructed Earth, Energy and Environment Center (EEEC) at the University of Kansas. Scheduled to open in December 2017, the EEEC encompasses Ritchie Hall and Slawson Hall and will accommodate the geology department and chemical and petroleum engineering. It will house faculty, staff, and students from multiple disciplines and have state-of-the-art classrooms; the Beren Petroleum Center as a crossroad for students, researchers, industry and public engagement; and new and expanded research labs. A social at the adjoining Eaton Hall Atrium, will follow the tour, from 6:15 to 7:30 p.m. We spend the first night in Lawrence.

Day 2. On Tuesday, September 12, our first stop is at the Kansas River to discuss its growing importance as a water source for the region as well as a source of aggregate (sand and gravel). We then head to Missouri to visit Martin Marietta's Stamper Mine, an active, underground mine for bedrock aggregate (crushed rock). The quality and the proximity of aggregate sources are a key factor in the cost of buildings, roads, and other infrastructure.

We head back to Kansas for a catered lunch at Johnson County WaterOne's Wolcott Treatment Center followed by a tour of the facility. WaterOne, a public utility, is adjusting its intake wells and installing collector wells to deal with a highly fluctuating Missouri River elevation, exacerbated by past bed degradation. At one of the collector wells, participants can choose to climb the stairs for a look at the well controls and an elevated view of the Missouri River.

Next, we travel to Fort Leavenworth to tour the Frontier Army Museum and the base to learn more about its historic and current missions. *(**Note:** To be allowed on base,* *everyone will need a valid State of Kansas driver's license or other official identification.)* The day's final destination is Atchison, where we will spend the night. There, we will view the Missouri River bluffs and discuss their formation. At Elizabeth's (above Jerry's Again), the venue for the evening social and dinner, representatives from Midwest Grain Products (MGP) Ingredients, Inc. will give an overview of their business operations. MGP is a major industry for the region.

Day 3. The tour begins early on Wednesday, September 13, with the bus leaving at 7:30 a.m. to meet U.S. Army Corps of Engineers and Kansas Department of Wildlife, Parks and Tourism folks at the Missouri River dock. By boat, we'll view the river's engineering and work done on the river to meet navigation requirements and aquatic habitat goals. By land, we'll visit Benedictine Bottoms to see how reclaimed land is being managed to restore wetland and wildlife habitat.

On route north toward White Cloud, we will discuss inter-basin water transfers. In Sparks, two members of the Iowa Tribe of Kansas & Nebraska will join us for a bus talk on American Indian water rights and cultural sites. These two issues would need to be addressed if the much-debated proposal to transfer Missouri River water westward through an aqueduct were to move forward. We will tour the area that would be inundated by an upstream reservoir for the aqueduct, as conceived in a 1982 Corps of Engineer's study. A local farmer who is also an Iowa Township trustee will join us at the conceptual reservoir site to share his thoughts about the aqueduct concept and what it could mean for area communities.

Lunch at the Iowa Tribe's community center will be followed by a panel discussion on groundwater quality in the region. High nitrate levels in groundwater are a widespread and growing problem and are costly to treat. The last stop on our return to Lawrence is Muscotah Marsh, a naturally occurring fen that has both scientific value and an important ecological role.

Detailed itineraries can be found in this guidebook at the beginning of each daily section.

About the Kansas Field Conference

The Kansas 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. Participants can see, first hand, the effects government and business decisions have on natural resources and communities by visiting sites and talking with local, state, and federal officials, environmental groups, business people, and citizens' organizations. The field conference co-sponsors aim to provide a broad, informed perspective that will be useful in formulating policies. In addition, the annual field conference guidebooks 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 encourage participants to contribute to the discussion, ask questions, and otherwise join in on deliberations. The bus microphone is open to everyone, and we encourage everyone to participate.

We want the 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. By bringing together experts on energy, water, and other resources, we hope to go beyond merely identifying issues. As often as possible, we provide a forum for all sides of contentious issues, but please remember that, in the course of the field conference, we do not seek to resolve policy or regulatory conflicts.

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 in the past has helped make the field conference a model that has been adopted by other state geological surveys. We look forward to receiving any insights you may have about ways to improve it and locations to visit in the future.

Sponsors

The Kansas Field Conference is made possible and kept affordable through the generous support of many groups. In addition to the co-sponsors listed below, the 2017 field conference received support for socials and meals from the Iowa Tribe of Kansas & Nebraska, Johnson County WaterOne, Kennedy-Jenks Consultants, Kansas University Department of Geology, and MGP Ingredients, Inc. We thank them for their support.

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. 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. Headquartered on KU's west campus, the KGS also has a Well Sample Library in Wichita.

The following KGS staff are participating in the 2017 field conference:
Susan Stover, Geologist/Outreach Manager
Cathy Evans, Writer/Communications Coordinator
Rolfe Mandel, Director
Tony Layzell, Assistant Research Professor/ Stratigraphic Research
Jim Butler, Geohydrology Section Chief
Don Whittemore, Senior Scientific Fellow Emeritus

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

Wichita Well Sample Library
4150 W. Monroe Street
Wichita, Kansas 67209-2640
316-943-2343

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.

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. 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 state parks, state fishing lakes, wildlife-management areas, and recreational boating on the state's public waters.

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

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

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. The KWO administers the Kansas Water Plan Storage Act and the Water Assurance Act and advises the governor on drought conditions. The KWO develops the Kansas Water Plan, which addresses the management, conservation, and development of water resources in the state. The Kansas Water Authority, statutorily within and a part of the KWO, advises the governor, legislature and director of the KWO.

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

Acknowledgments

The following people helped make this an informative and successful field conference: Director Tracy Streeter and Assistant Director Earl Lewis, Kansas Water Office; Secretary Robin Jennison and Chief of Planning Steve Adams, Kansas Department of Wildlife, Parks and Tourism; and Secretary Richard Carlson and Chief Geologist Kyle Halverson, Kansas Department of Transportation. Mark Schoneweis, KGS, graphic designer, prepared the route map. Special appreciation goes to Julie Tollefson, KGS editor, for her extensive help editing and laying out the field guide.

The KGS also extends our appreciation to the following people, without whom this conference would not have been possible: Bob Goldstein and Jen Roberts, University of Kansas; Jerry Younger, Kansas Association of Aggregate Producers; Rob Manes, The Nature Conservancy; Chris Bollinger and Bill Beggs, Martin-Marietta Mines; Mike Armstrong and Tom Schrempp, Johnson County WaterOne; Greg Hoffman and George Moore, Fort Leavenworth; Steve Glaser and Steve Pickman, MGP Ingredients, Inc.; Todd Gemeinhardt, Dave Hoover, Christi Ostrander, and Jennifer Switzer, U.S. Army Corps of Engineers; Kirk Thompson, Kansas Department of Wildlife, Parks and Tourism; Alan Kelly and Lance Foster, Iowa Tribe of Kansas & Nebraska; Ken McCauley, Iowa Township trustee; Mike Nichols, City of Hiawatha; Jaime Gaggero, Kansas Department of Health and Environment; and Frank Norman, Kansas Association of Wetlands and Streams. We also thank Dean and Angie Banks for generously allowing us onto their property to view the Muscotah Marsh.

Monday, September 11, 2017

5:00 p.m.	Meet in Hampton Inn Lobby for shuttle to Earth, Energy and Environment Center (EEEC) or drive on own to University of Kansas campus
	Hampton Inn 2300 W. 6th Street, Lawrence, Kansas
5:30 p.m.	Meet at security gate to enter EEEC Crescent Road near intersection with Naismith Drive *Bring a signed EEEC Visitor's Form**
	Tour EEEC
6:15 p.m.	Social in Eaton Hall Atrium, KU School of Engineering Across the street from EEEC; enter on 15th Street
7:30 p.m.	Shuttle back to Hampton Inn. Dinner on your own.

* An EEEC Visitor's Form was sent to you with your guidebook. For another copy, email sstover@kgs.ku.edu.

Tuesday, September 12, 2017

6 a.m.	Breakfast opens at Hampton Inn
7:15 a.m.	Welcome, introductions and conference overview Hampton Inn lobby/breakfast area *Susan Stover,* Kansas Geological Survey *Rolfe Mandel,* Kansas Geological Survey
7:45 a.m.	Turn in room keys, move cars to back of lot, and load luggage into bus
8 a.m.	**Bus leaves Lawrence**
8:10 a.m.	**Site 1**: Kansas River—Aggregate Source and Groundwater/Surface Water Interaction *Jerry Younger*, Kansas Aggregate Producers' Association *Jim Butler,* Kansas Geological Survey
8:45 a.m.	Bus to Site 2
	Bus Session—The Importance of the Kansas River *Tracy Streeter*, Kansas Water Office *Rob Manes*, The Nature Conservancy in Kansas
	Bus Session—Video: Mine Safety (required viewing for mine entrance)
	Discussion: Mined Land Reclamation *Bill Beggs*, Martin Marietta
9:50 a.m.	**Site 2**: Martin Marietta Stamper Mine *Chris Bollinger*, Martin Marietta *Bill Beggs*, Martin Marietta
	Restroom and coffee break
	Tour mine
11:20 a.m.	Bus to Site 3
	Bus Session—Introduction to Johnson County WaterOne *Mike Armstrong*, Johnson County WaterOne
11:50 a.m.	**Site 3**: Wolcott Treatment Center, Johnson County WaterOne Restroom Break Lunch

12:30 p.m.	Tour Wolcott Center *Mike Armstrong*, Johnson County WaterOne *Tom Schrempp*, Johnson County WaterOne
1:20 p.m.	Bus to and tour of WaterOne's collector well
2:10 p.m.	Bus to Site 4
2:45 p.m.	**Site 4**: Fort Leavenworth *(Note: Must have a Kansas drivers' license or other valid ID to enter)* *Greg Hoffman*, Master Planner, Fort Leavenworth *George Moore*, Frontier Army Museum, Fort Leavenworth
	Restroom Break
	Tour museum
3:30 p.m.	Bus tour of fort
4:10 p.m.	Bus to Site 5
4:40 p.m.	**Site 5**: Lewis & Clark Pavilion, Atchison–Glacial Hills and the Missouri River *Tony Layzell*, Kansas Geological Survey
5 p.m.	Bus to Holiday Inn Express Hotel, Atchison
5:50 p.m.	Bus or walk two blocks to dinner site
6 p.m.	Social at Elizabeth's 121 N. 5th Street (upstairs)
6:20 p.m.	MGP Ingredients—Short overview of MGP business *Steve Pickman,* MGP Products *Steve Glaser,* MGP Products
6:45 p.m.	Dinner
7:45 p.m.	Bus returns to hotel

Kansas River Alluvial Aquifer Monitoring Network

On the surface, a flowing river appears to be a self-contained unit within its channel. However, what you see is, in reality, just the visible portion of a much broader riverine system. Underground and adjacent to the stream is a parallel alluvial aquifer—buried sand, gravel, silt, and clay deposits (known as alluvium) saturated with water. Depth to water tends to be shallow in an alluvial aquifer, which usually has a direct hydraulic connection to the river. That is, water flows between the two, as groundwater becomes surface water and vice versa. Even when a river is dry, which is often the case with the Arkansas River in western Kansas, the aquifer is still there, although at a level too low to feed the stream.

The Kansas river extends from the confluence of the Smoky Hill and Republican rivers at Junction City to the Missouri River at Kansas City. It is one of only three rivers in the state still open to new, year-round water-right appropriations. Eight of the state's ten largest cities and two of the three fastest growing counties—Johnson and Wyandotte—lie totally or partially within the Kansas River basin.

The Kansas River alluvial aquifer is an important source of stored water. In 2012, 61% of the reported water use in the lower Kansas River system (downstream of Topeka) was from surface water and 39% from groundwater (Whittemore and Wilson, 2014). Demographic growth and increasing demand on the Kansas River made monitoring the alluvial aquifer–surface water interaction a priority in the Long-Term Vision for the Future of Water Supply in Kansas (KWO and KDA, 2015). Water trend data for the Kansas River system, including the alluvial aquifer, are needed to inform future development and management decisions to meet growth demands and ecological requirements in the corridor.

Alluvial aquifer managed as stored water

The difference in altitude between two points is a strong influence on the direction water flows. When groundwater elevation is higher than stream level, water seeps into the stream and provides base flow, creating a "gaining" stream (fig. 1a). When the stream level is above the water table, water percolating down from the stream recharges the aquifer. This is known as a "losing" stream (fig. 1b). If the water table drops below the stream channel bottom, the groundwater can no longer provide a base flow. Where groundwater no longer provides base flow, stream flow typically becomes ephemeral or intermittent. This has occurred along portions of the Pawnee, Walnut, Smoky Hill, Arkansas, and Solomon rivers (KWO, 2009). The Kansas River alluvial aquifer typically provides base flow to the river. Close responses between precipitation, surface water flow, and groundwater level are seen in the Kansas River system (fig 2).

To track water-level changes and observe the hydraulic connection between the Kansas

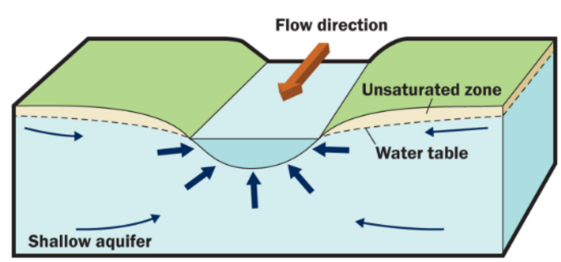


Figure 1a. Schematic of a gaining stream

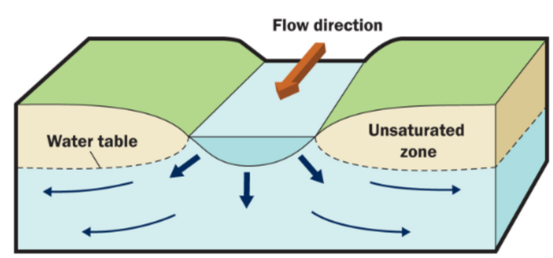


Figure 1b. Schematic of a losing stream. Source: Winter et al., 1998.

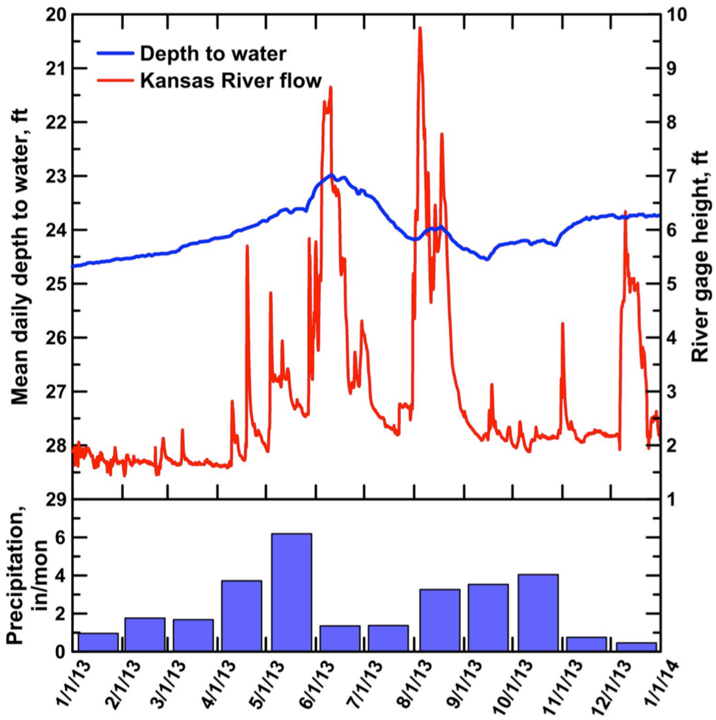


Figure 2. Depth to groundwater at a U.S. Geological Survey observation well southwest of Lawrence Airport, Kansas river height at Lecompton gage, and monthly precipitation in northeast Lawrence. Source: Whittemore and Wilson, 2014.

River and its alluvial aquifer, the Kansas Geological Survey (KGS) is installing a monitoring well network between Junction City and Kansas City. The collected data can be used to help manage the groundwater to maintain the hydraulic connection between the aquifer and river and ensure a continuous base flow for the stream during dry periods. The data also can provide information about changing contributions from tributary streams and the influence of upstream impoundments (reservoirs).

Although there are already monitoring wells in the river valley near the Kansas City metropolitan region, most are owned by municipalities and industries and not all of the acquired data are made public. Additionally, many of those wells do not reflect a true static water level because they are influenced by nearby pumping wells, and they do not provide information about the condition of the Kansas River alluvial aquifer farther upstream. Several upstream wells were hand measured regularly by the Kansas Department of Agriculture, Division of Water Resources, but most of those measurements were discontinued in 2000. The few isolated upstream monitoring wells that are still in service show signs of degradation due to clogged screens and other issues (Wilson, 2016).

In support of the new Kansas River groundwater monitoring network, the KGS received funding from the U.S. Geological Survey to install five 2-inch diameter wells in the Kansas River valley. In addition, the Kansas Water Office received state funding in FY2018 to partner with the KGS to expand the monitoring program and gather data on the Kansas River hydrologic system.

To provide a true record of static water levels, the new observation wells will be located away from the direct influence of existing pumping wells (fig. 3). Where possible, they will be placed near wells that were hand measured before 2000. Before drilling, KGS researchers will identify general physical characteristics of the subsurface sediments to help determine optimum construction of the wells. The new wells will be drilled in the summer or fall of 2017. Once the monitoring equipment is installed and running, transducer and data telemetry units in the wells will record and transmit hourly water levels. This information will be available in near real time on the KGS web site.

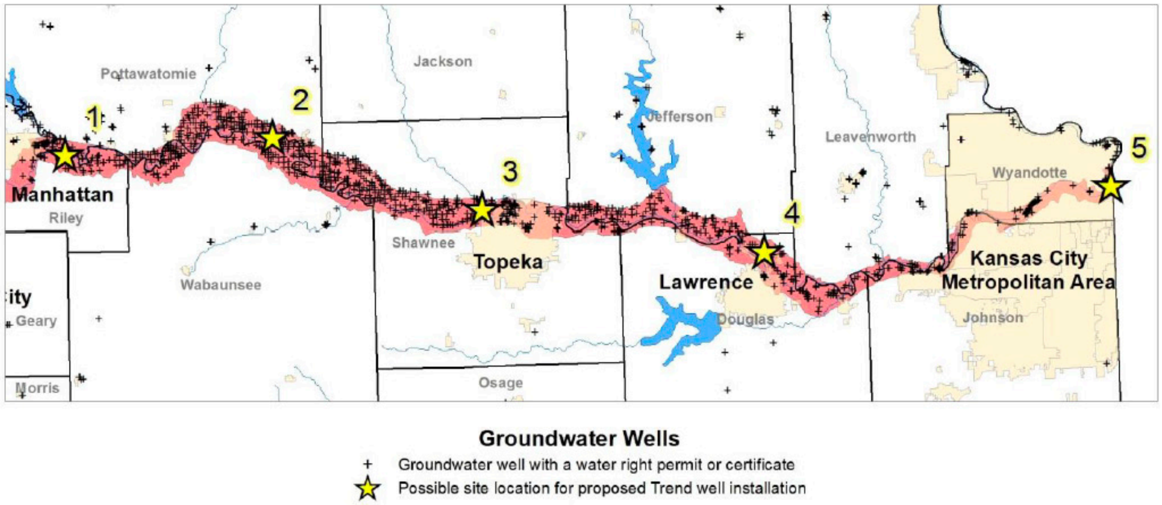


Figure 3. Proposed locations for the five KGS monitoring wells for determining water-level trends in the Kansas River alluvial aquifer (Wilson, 2016).

Sources

Kansas Water Office, 2009, Kansas Water Plan. http://www.kwo.org/water-vision-water-plan/water-plan

KWO and KDA (Kansas Water Office and Kansas Department of Agriculture), 2015, A long-term vision for the future of water supply in Kansas—Developed based upon input from the citizens of Kansas. 171p. http://bit.ly/2xiMUUl

Whittemore, D., and Wilson, B., 2014, The Kansas River alluvial aquifer as a managed reservoir system: 23rd Annual Kansas Hydrology Seminar, Topeka, Kansas.

Wilson, B. B., 2016, Establishing Kansas as a data provider to the national ground-water monitoring network: Kansas Geological Survey, Open-File Report 2016-28, 12 p.

Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998, Ground water and surface water: A single resource: U.S. Geological Survey, Circular 1139, 79 p. https://pubs.usgs.gov/circ/circ1139/

Contact

Brownie Wilson
Manager of Geohydrology Support Services
Kansas Geological Survey
785-864-2118
bwilson@kgs.ku.edu

Sand, Gravel, and Crushed Stone: Aggregate Dredging, Quarrying, and Mining in Kansas

Production of sand, gravel, and crushed stone, collectively called aggregate, is not highly visible but is very common in Kansas. Vast quantities of aggregate mined, quarried, or dredged in the state are used in concrete, asphalt, brick mortar, tile grout, and fiberglass or alone as railroad bedding, road covering, and construction fill. Unpaved roads throughout Kansas are covered with sand and gravel.

Of the estimated 945 million metric tons of construction sand and gravel produced and shipped for consumption in the United States in 2016, 8.9 million metric tons valued at $55.4 million were produced in Kansas (fig. 1). Of the estimated 1.36 billion metric tons of crushed stone produced in the United States in 2016, 16.4 million metric tons valued at $158 million were produced in Kansas (fig. 2; USGS, 2017b). In 2013, Kansas had 119 construction sand and gravel operations (including 29 dredging operations), 77 active crushed stone operations, 84 active quarries, and 72 processing plants (USGS, 2016).

Sand and gravel

Sand and gravel is extracted from riverbeds and sandpits (fig. 3), which may be dry or filled with groundwater. During a river dredging operation, a moored hydraulic dredge is used to suction a slurry of sand, gravel, and water then pump it through a pipeline to a land-based processing plant (U.S. Army Corps of Engineers, 2016). In Kansas, river dredging occurs mainly on the Kansas River. Dredging is also permitted on the Missouri River, and most of the sand and gravel extracted from the river near Kansas City is used by local construction and manufacturing industries. However, sand

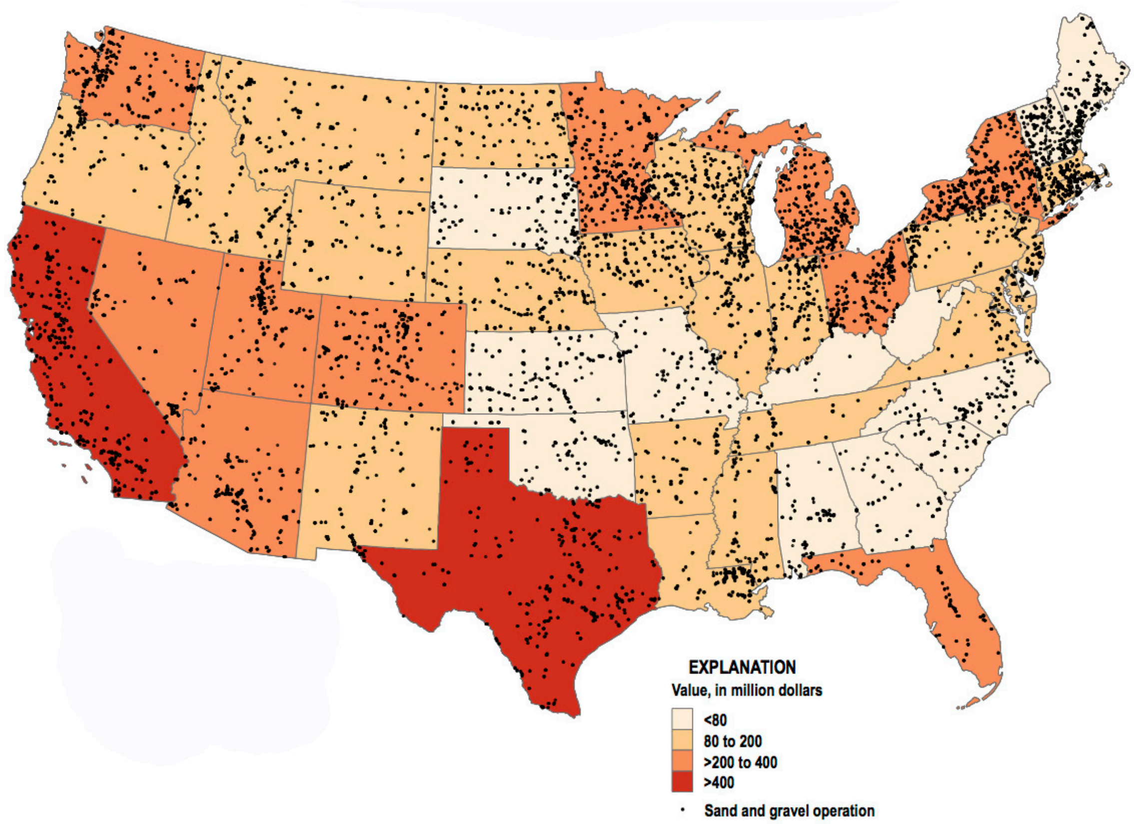


Figure 1. Location and value, by state, of sand and gravel produced in 2016 (modified from USGS, 2017a, p. 19).

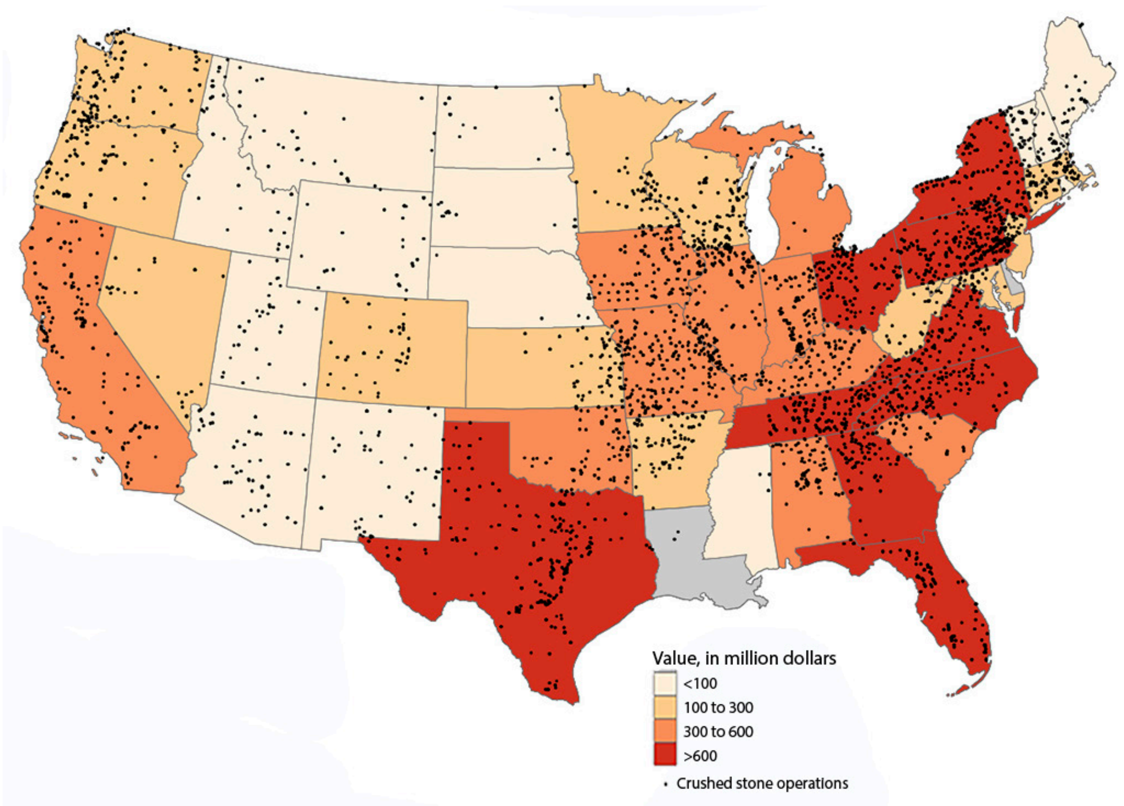


Figure 2. Location and value, by state, of crushed stone produced in 2016 (modified from USGS, 2017a, p. 18).

and gravel from the Missouri River is generally considered to be of lower quality than that from the Kansas River because it contains small amounts of lignite, a form of brown coal (U.S. Army Corps of Engineers, 2016).

Producers access subsurface sand and gravel deposits in floodplains adjacent to rivers, particularly along the Arkansas and Kansas rivers and their tributaries, by digging pits to the water table, which causes the pits to fill with groundwater. Dredges are floated on the water to extract sediment from the bottom of sandpits. In some areas of western Kansas, sand and gravel also are removed from small, dry pits using front-end loaders (Grisafe, 1997).

Dredging riverbeds is cheaper than digging and dredging water-filled sandpits. Sandpit producers have the added expenses of purchasing or leasing land, removing as much as 20 feet of overburden, potentially needing a water right or term permit for evaporative losses, and reclaiming the land once a pit is abandoned because it is no long economically viable, which is required by law (Barfield, 2017). Numerous housing developments and parks have been developed around lakes created by sand and gravel companies.

Crushed stone

Crushed stone is mainly quarried from limestone deposits in the eastern third of the state. Smaller amounts of limestone and other rocks, including crushed sandstone and quartzite, have been produced in north-central and northwest Kansas (USGS, 2016). To produce crushed stone, workers blast rocks from quarry or mine walls then crush it and screen it to sort out sizes for different uses. Often blended into cement and asphalt, crushed stone is also used as construction base material, rip rap to protect shorelines, a replacement for mulch, and landscaping. Farmers use the leftover fine, dust-like material as agricultural lime to reduce soil acidity (Grisafe, 1997).

Figure 3. Sandpit near Nickerson in Reno County (photo by Bill Johnson).

Martin Marietta Stamper Mine

The underground Martin Marietta Stamper Mine (fig. 4) is just across the state line near Platte City, Missouri, and is a main supplier of crushed stone in the Kansas City area. Aggregate from the mine is shipped as far as Westar's Jeffrey Energy Center in Pottawatomie County, Kansas. Limestone at the facility is mined about 350 feet underground using the room-and-pillar method, with 40 foot by 40 foot rooms and 30 foot by 30 foot pillars left standing to support the roof. At the request of county officials, some locations on the property are not mined to preserve routes for future roads. Displacement that occurs when the surface subsides or collapses into an abandoned underground mine can severely damage overlying roadways.

The Stamper Mine has 58 employees and is estimated to have more than 40 years of limestone reserves. It currently produces more than a million tons of limestone construction aggregate annually from the Pennsylvanian-age Bethany Falls member of the Swope formation.

Regulations, environmental concerns, and industry challenges

Before the early 1990s, individual counties regulated aggregate operations in Kansas. In 1994, the State Conservation Commission (now the Kansas Department of Agriculture Division of Conservation, or KDA-DOC) became responsible for setting uniform rules for all non-fuel mining operations except river dredging, which remains under the authority of the U.S. Army Corps of Engineers. In the mid-1960s, concerns about river channel degradation led various state and federal agencies to focus on the declining riverbed elevations, which could negatively affect bridges, buried gas pipelines, and other structures. In 1990, the Corps completed the Kansas River Dredging Environmental Impact Statement, which included restrictions to minimize dredging-related problems (U.S. Army Corps of Engineers, 2017).

With tighter restrictions on the Kansas River, production from the Missouri River increased significantly in the early 1990s.

Subsequent decreases in extraction from the Missouri, beginning in 2007, have been attributed to the national economic downturn and reductions in permitting beginning in 2011. At that time, a correlation between commercial sand and gravel mining and degradation in areas of the Missouri River, similar to that in the Kansas River, was identified (U.S. Army Corps of Engineers, 2017). Although dredged areas may be refurbished with material carried from upstream, natural processes cannot always keep up with removal rates. Besides channel degradation, other environmental concerns include bank erosion, deteriorating water quality due to stirred up pesticides and other contaminants, and adverse effects on wildlife (Grisafe, 1997).

Sand and gravel operations fall under the purview of the KDA-DOC, which administers the Surface-Mining Land Conservation and Reclamation Act of 1994. Producers must register their mining sites, file a reclamation plan for each site, and reclaim mining sites upon completion of mining operations.

The most frequent objections to land-based aggregate sites are related to traffic, noise, and dust and come from neighbors in residential areas, particularly in high-density regions (Grisafe, 1997). Other challenges facing producers include finding aggregate that meets the users' standards; meeting regulations associated with river dredging, zoning, and water evaporation from sandpits; downturns in infrastructure spending; maintaining qualified workforces; and a need for more geologic data. Charged with producing geological information and data about the state's natural resources, the Kansas Geological Survey continually generates new county geologic maps and data resources that producers can use to help determine source locations as well as the type, quality, and quantity of aggregates at potential quarry and mine sites.

To help alleviate the need for new sources of aggregate, companies that recycle concrete, asphalt, and other materials have stepped up their efforts, although still not at a pace to meet growing demands without further increases in aggregate extraction.

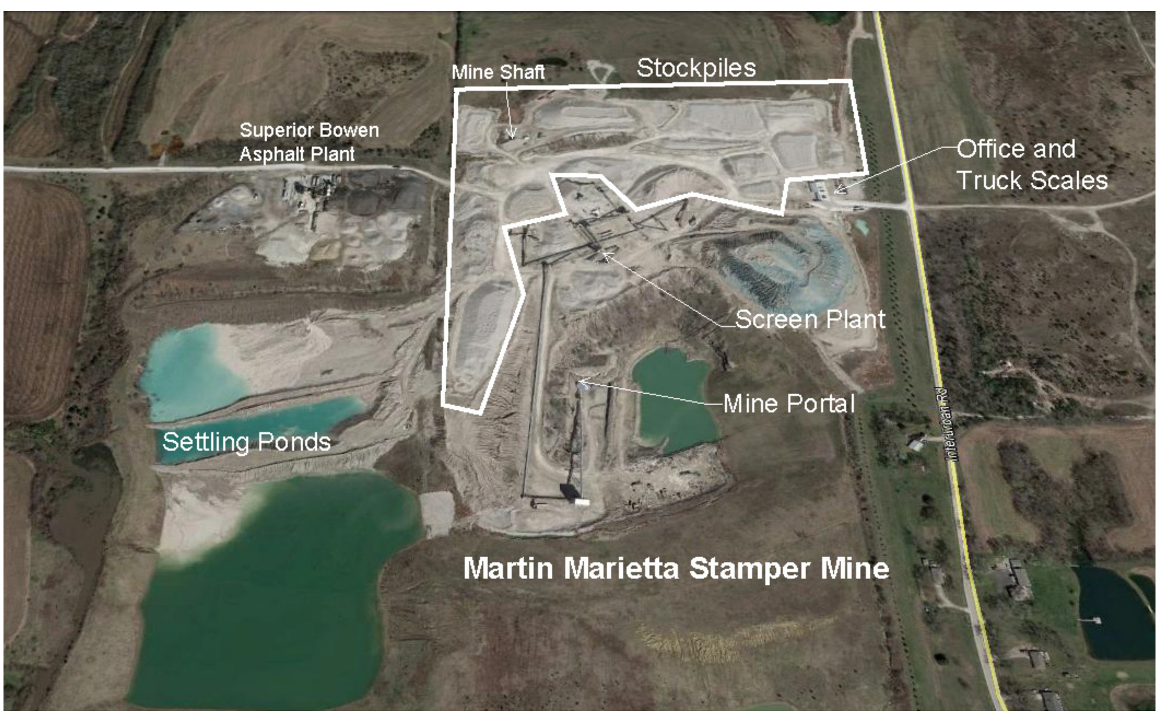


Figure 4. Martin Marietta Stamper Mine near Parkville, Missouri.

Aggregate quality and cost concerns

Not all aggregate resources are of equal quality and some do not meet all customers' standards. Aggregate purchase by the Kansas Department of Transportation, for example, must meet freeze-thaw and other performance standards set by KDOT to minimize road repairs. Although buying from a nearby quarry has the advantages of reduced upfront transportation costs and time savings, KDOT may have to ship materials from out of state if local materials do not meet its standards.

Sources

Barfield, D., 2017, Rules and regulations—Kansas Water Appropriation Act: Kansas Department of Agriculture, Division of Water Resources, 188 p., http://bit.ly/2wLMJzJ.

Grisafe, D.A., 1997, Sand, gravel, and crushed stone—Their production and use in Kansas: Kansas Geological Survey, Public Information Circular 6, 4 p., http://bit.ly/2vmHpVL.

KDA, 2017, Surface mining reclamation: Kansas Department of Agriculture, http://bit.ly/2uKdoM9.

U.S. Army Corps of Engineers, 2016, Kansas River commercial sand and gravel dredging—Draft environmental impact statement: U.S. Army Corps of Engineers, 391 p., http://bit.ly/2vmNG41.

U.S. Army Corps of Engineers, 2017, Missouri River bed degradation feasibility study—Technical report: U.S. Army Corps of Engineers, 94 p., http://bit.ly/2vSLYrt.

USGS, 2016, 2012–2013 Minerals yearbook—Kansas: U.S. Geological Survey, 9 p., https://on.doi.gov/2utRuNK.

USGS, 2017a, Mineral commodity summary: U.S. Geological Survey, 208 p., https://on.doi.gov/2siRsvg.

USGS 2017b, Mineral industry surveys: Crushed stone and sand and gravel in the first quarter 2017: U.S. Geological Survey, 8 p., https://on.doi.gov/2usHKaw.

Contacts

Jerry Younger
Managing Director
Kansas Aggregate Producers Association
785-235-1188
jyounger@kapa-krmca.org

Kyle Halverson
Chief Geologist
Kansas Department of Transportation
785-291-3860
kyle.halverson@ks.gov

WaterOne and Missouri River Water Use in Kansas

Most Kansas public water suppliers that draw water from the Missouri River Basin—from the river, its tributaries, and wells drilled into aquifers and glacial deposits—are in the seven counties at least partially within the basin's borders (fig. 1). The largest Kansas supplier drawing from the river, though, is WaterOne in Johnson County, which the Missouri River does not touch. One tributary, the Blue River, does flow a short distance through Johnson County, but it is not a source of public water.

WaterOne (Johnson County Water District No. 1)

As the largest water supplier in the state, WaterOne, short for Johnson County Water District No. 1, services most of the county, including 17 communities and some unincorporated areas (fig. 2). That area encompasses nearly 15% of the population of Kansas. WaterOne is a non-profit, quasi-municipal-government public water utility that, like city and county governments, can issue bonds and has the power of eminent domain. WaterOne, which is not affiliated with Johnson County government, has an elected seven-member board that has full jurisdiction to set water rates but no taxing authority (Wirth, 2016).

Anticipating in the early 2000s that water demands in the county eventually would exceed its capacity, WaterOne continued expansion of its infrastructure. It now includes two treatment plants—one near the Kansas River and one near the Missouri River—wells in the alluvial aquifers of both rivers, and 16 miles of pipeline (fig. 3; Black & Veatch, 2017).

When Johnson County Water District No. 1 was formed in 1957 after disgruntled customers in the Mission area bought out the Kansas City Suburban Water Company, it supplied up to 5 million gallons of water per day. By 1970 when the county's population topped 220,000, the district supplied 140,000 residents an average of 12 million gallons per day from the Kansas River and wells drilled into the Kansas River valley alluvium (O'Connor, 1971). Today WaterOne provides water to nearly 425,000 of the county's 580,000-plus residents. Its two treatment facilities are capable of providing up to 200 million gallons per day (WaterOne, 2017).

About 60% of WaterOne's water supply comes from

Figure 1. Portion of the Missouri River Basin that falls within Kansas borders. Includes part or all of seven Kansas counties: Marshall, Nemaha, Brown, Doniphan, Atchison, Leavenworth, and Wyandotte (KWO, 2009).

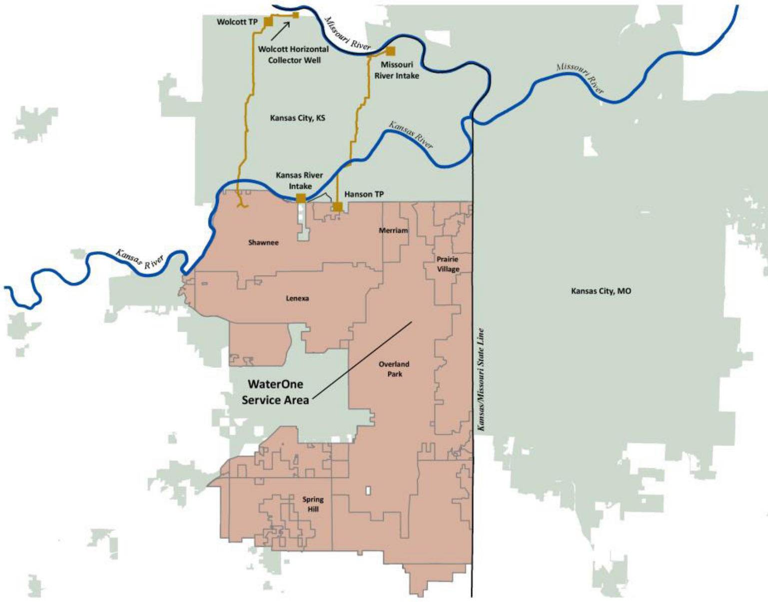


Figure 2. WaterOne service area in Johnson County (WaterOne, 2017).

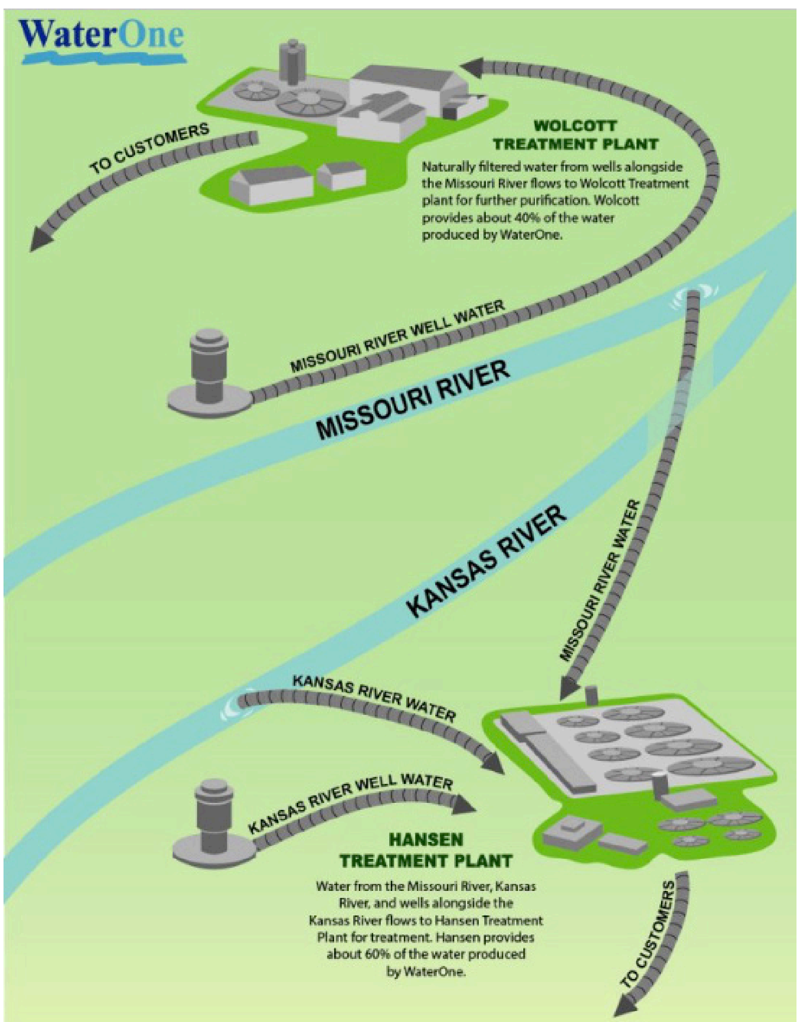


Figure 3. WaterOne plants and wells schematic (WaterOne, 2017).

its Hansen Treatment Plant, just outside Johnson County in Kansas City, Kansas. A tunnel under the Kansas River is used to transport surface water to the plant from the Missouri River intake, which has a capacity of 125 million gallons per day. The rest of the water treated at the plant comes from the Kansas River intake and a nearby well field (WaterOne, 2017).

WaterOne's newest facility, the Wolcott Treatment Plant, near the Missouri River in Wyandotte County, is on the field conference agenda. The plant produces the remaining 40% of WaterOne's water supply, drawn from a horizontal collector well, rather than through a traditional river intake, to avoid having to contend with low surface-water quality and other hazards caused by flooding and drought conditions. To access a large quantity of water per day, the well has 10 laterals, each 200 feet long (fig. 4). As part of the water treatment process, the plant uses microfiltration membranes, which provide a physical barrier to contaminants, in place of conventional sand and anthracite filters (Schrempp, 2013).

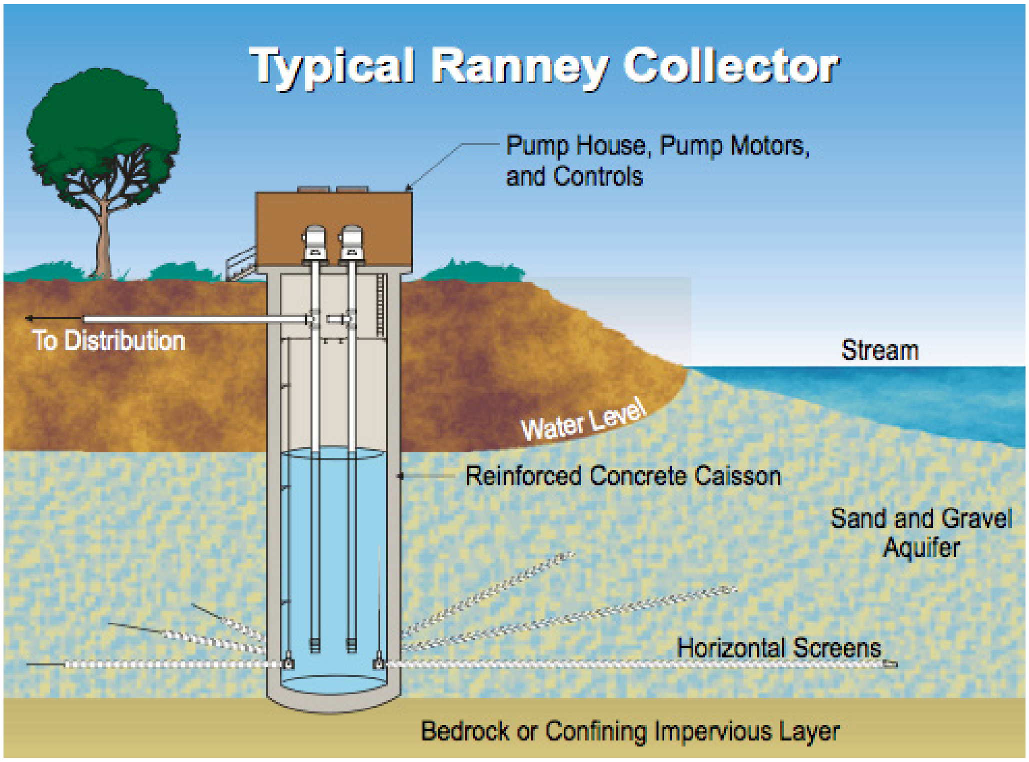


Figure 4. Type of collector well used at the Wolcott Treatment Plant (Wirth, 2016).

Equipment for the collector well, which is designed to withstand a 500-year flood, normally stands on dry land away from the river and about 20 feet above the riverbank level (fig. 5). When the levee on the north side of the river failed during the 2011 flood, the river encircled the collector well (fig. 6), but the equipment survived. Because the river was closed to navigation during high flood stage, WaterOne had to get special permission from the U.S. Army Corps of Engineers to launch boats and access the well (Schrempp, 2013).

The Wolcott plant, which can be operated remotely to lower costs, was built to accommodate future expansion. Its operation building was designed to look like a horse barn to blend in with its rural Wyandotte County neighborhood (fig. 7; Black & Veatch, 2017).

Also in anticipation of growing water demands, WaterOne joined Kansas River Water Assurance District No. 1, which is made up of more than a dozen municipal and industrial water users that, as a group, purchase water stored in upstream Milford, Tuttle Creek, and Perry reservoirs. Members are eligible to use enhanced stream flow released into the Kansas River by the state during periods of drought (WaterOne, 2017). Flows in the Kansas and Missouri rivers are managed by the Corps through storage and release of water from upstream reservoirs. In Kansas, storage in federal reservoirs is owned, in part, by water assurance districts and the state and federal governments.

Beyond Johnson County

An estimated 143,000 residents lived in the Missouri River Basin in Kansas in 2000, and the seven counties that fall at least partially within its boundaries (Marshall, Nemaha, Brown, Doniphan, Atchison, Leavenworth, and Wyandotte) had a population of 284,000. The northern, rural counties in the basin are projected to lose population (KWO, 2009). The urbanized southern portion of the basin is projected to have population gains, particularly in Leavenworth County where the growth is projected to rise about 30% by 2040. At the

Figure 5. Wolcott collector well (photo courtesy of Mike Armstrong).

Figure 6. Wolcott collector well surrounded by Missouri River water during 2011 flood (Wirth, 2016).

same time, Johnson County is projected to grow by more than 40% (MARC, 2017). Future increased Missouri River water use, then, will be concentrated in the Kansas City area.

Of the water withdrawn in Kansas from the Missouri River Basin in 2016, 80% went to municipal water supplies, less than 1% to industries not using municipal water, 9% for irrigation, and 11% for stock and other purposes. About 88% was surface water and 12% was groundwater.

In Kansas City, Kansas, water for residents and businesses is provided by the Kansas City Board of Public Utilities (BPU), which services

Figure 7. WaterOne's Wolcott treatment facility (photo courtesy of Black and Veatch).

51,000 water customers (or 161,000 people). Some of those are in suburban Wyandotte, Leavenworth, and Johnson counties. BPU is a publicly owned administrative agency of the Unified Government of Wyandotte County/Kansas City, Kansas (UG) and is governed by an elected six-member board (BPU, 2016). After flooding along the Missouri River in 1993, BPU updated its antiquated river intake systems and treatment plants. In 1997 and 2004, new high capacity horizontal collector wells were built, each with a capacity in excess of 40 million gallons per day (Layne, 2013).

In Leavenworth, city-owned Leavenworth Waterworks has two water plants, each with a capacity of 6 million gallons per day. Current average output from both together is about 5 million gallons. The north plant draws directly from the river and the south plant from nine water wells on the riverbank. Both pump water to the Pilot Knob Reservoir. The Leavenworth Waterworks service area includes about 50,000 residents in Leavenworth, Lansing, and six rural water districts (Leavenworth Waterworks, 2017).

On the Missouri side of the river, treatment plants operated by Kansas City Water Services, a department of the city of Kansas City, Missouri, produce up to 240 million gallons of water per day from the Missouri River for more than 170,000 residential and business customers (as opposed to the number of individual residents cited by WaterOne) and 32 wholesale customers in the region (KCWater, 2017).

Sources

Black & Veatch, 2017, WaterOne secures reliable water supply while protecting the natural setting: Black & Veatch Holding Company, http://bit.ly/2uIOKAv.

BPU, 2016, PBPU fast facts: General utility information: Kansas City Board of Public Utilities, http://bit.ly/2uIOQrR.

KCWater, 2017, Water: Kansas City Water Services, http://bit.ly/2fLDgFA.

KWO, 2009, Kansas-Lower Republican River Basin; *in,* 2009 Kansas Water Plan: Kansas Water Office, http://bit.ly/2vvroJT.

Layne, 2013, Technical summary—Ranney collector wells, Layne, http://www.layne.com/user_area/content_media/ts_ranneycollectorwellandanglewelldesign-v-1.pdf.

Leavenworth Waterworks, 2017, History and overview: Leavenworth Waterworks, www.lvnwater.com/history.html.

MARC, 2017, 2040 Forecast: Mid-America Regional Council, http://bit.ly/2waPMpb.

O'Connor, H.G., 1971, Geology and ground-water resources of Johnson County—Northeastern Kansas: Kansas Geological Survey, Bulletin 203, 72 p., http://bit.ly/2uIlkCm.

Schrempp, T., 2013, WaterOne: Big Muddy Speakers Series, Missouri River Relief and Friends of Big Muddy, http://bit.ly/2x4Aui2.

WaterOne, 2017, About Us: WaterOne, www.waterone.org/about-us.

Wirth, M.A., 2016, Missouri River water quality and water treatment impacts: WaterOne PowerPoint presentation at Missouri Regional Advisory Committee meeting, June 2, 2016.

Contacts

Mike Armstrong
General Manager
WaterOne
913-895-5500

Tom Schrempp
Director of Production
WaterOne
913-895-5500

Fort Leavenworth

Over nearly two centuries, Fort Leavenworth has transformed from a primary supply depot, arsenal, and troop post on the western frontier to a major military educational facility. In 1827, it was established to protect travel and trade on the Santa Fe Trail and maintain peace between travelers, settlers, and Native Americans (KSHS, 2017). Henry Leavenworth and battalions from the 3rd Infantry Regiment were sent to the young state of Missouri with instructions to build a fort on the Missouri River near its confluence with the Little Platte River. Having seen that river bottoms like the one he encountered were prone to flooding and associated with malaria, Leavenworth instead picked a spot high on a bluff across the river (Bernstein et al., 2008).

Throughout its history, Fort Leavenworth (fig. 1) has served many purposes. The Army of the West was organized there at the beginning of the U.S.–Mexican War in 1846. After the war, the fort became a main supply and command link for military installations in the Southwest, and the Army authorized an ordnance depot in 1858. To make room for permanent quarters for the arsenal commander, bodies were exhumed from the fort's burial ground and moved to the site of present-day Fort Leavenworth National Cemetery. During the Civil War, the fort was an enrollment and training center for Kansas volunteers (Bernstein et al., 2008).

As Leavenworth's importance as a troop post diminished in the late 19th century, its educational role expanded. When the Army began putting greater emphasis on leadership education, General William T. Sherman established the School of Application for Cavalry and Infantry at Fort Leavenworth in 1881. Over the years, the school went through several mission tweaks and name changes before becoming the U.S. Army Command and General Staff College (CGSC) in 1947 (Bernstein et al., 2008). Graduates include Dwight D. Eisenhower, Omar N. Bradley, and George S. Patton, Jr. (KSHS, 2017).

After the Vietnam War in 1973, the Army reorganized and created two new commands, including the Training and Doctrine Command (TRADOC). Under TRADOC, Fort Leavenworth was designated as the headquarters for the new Combined Arms Center (CAC). The center provides doctrine, combat, and leadership development and is the home of the CGSC (Bernstein et al., 2008). CAC has more than 32,000 military and civilian employees stationed in the United States, Europe, Korea, and Southwest Asia. It oversees 37 U.S. Army schools serving more than 350,000 students annually, including nearly 10,000 from 86 different nations and more than 10,000 sailors, airmen, and Marines from the Joint Force (USACAC, 2017). The CGSC, housed in the state-of-the-art Lewis and Clark Center, provides intermediate-level education for U.S. Army field commanders, sister service officers, interagency representatives, and international military officers (Bernstein et al., 2008).

Fort Leavenworth's garrison side includes military and civilian personnel who maintain and guard the fort and provide many of the same services a city would. Services include soldier and family support, public affairs, stewardship functions, community relations, building operations, health care, housing assistance, a substance-abuse program, childcare, public works, emergency services, human resources, historic preservation, and military history (U.S. Army Fort Leavenworth, 2017). Fort Leavenworth has its own Kansas public school district, which includes three grade schools and a junior high.

Figure 1. Fort Leavenworth's central historic area (U.S. Army Fort Leavenworth, 2017).

Architecture and history

The third-oldest active Army post in the United States, Fort Leavenworth has an extensive inventory of historic architecture, including 266 still-occupied houses and 231 other buildings, mostly repurposed for modern uses. The fort's history also has been preserved through memorials such as the Buffalo Soldier Monument; non-architectural sites, including wagon wheel ruts; and historic collections, such as those displayed at the Frontier Army Museum.

Buffalo Soldier Monument

Regiments of black soldiers led by white officers during the Civil War were known as the United States Colored Troops. After the Army was reorganized in 1866, two black regiments were designated the 9th and 10th U.S. Cavalry. Four infantry regiments were also designated. Men in these regiments, nicknamed Buffalo Soldiers, were the first African Americans to serve during peacetime. They often received secondhand uniforms and the poorest horses and equipment. The Buffalo Soldier Monument (fig. 2) commemorates all the regiments and particularly the 10th Cavalry, which was organized in 1866 at Fort Leavenworth, mainly with recruits from Philadelphia, Boston, and Pittsburgh. In 1867, the 10th Cavalry moved west and served more than 20 years in the Great Plains, New Mexico, and Arizona. During the Spanish-American War, it was instrumental in the famous charge up San Juan Hill. Colin L. Powell, the first African American to serve as chairman of the Joint Chiefs of Staff, originated the idea of the monument. He dedicated it on July 25, 1992 (Bernstein et al., 2008; U.S. Army Fort Leavenworth, 2017).

Grant, Sheridan, and Sherman halls (Building 52)

Building 52, which encompasses Sheridan, Sherman, and Grant halls (fig. 3), serves as CAC headquarters. The side wings, Sheridan and Sherman halls, were built in 1859 as architecturally simple arsenal storehouses. The more elegant center Grant Hall, with its clock tower and architectural embellishments, was added between 1904 and 1907 to connect Sheridan and Sherman into one building. To align with Grant Hall, Sheridan Hall had to be raised 10 feet. The new design included the clock tower with a 2,000-pound bell, a segmental dome, pediments, cornices, moldings, and porches to create a more stylish façade for the entire set of buildings. Upon completion, the renovated halls became home to the Army Services Schools (National Archives, 2017).

Figure 2. Buffalo Soldier Monument (photo courtesy of Greg Hoffman).

The Rookery

Built between 1828 and 1834, the Rookery is the oldest building on the post and is likely the oldest continuously occupied building in Kansas. It is constructed of masonry and timber and has a brick extension. The floor joists and some of the partitions are hewn logs. Divided into two

Figure 3. Grant, Sheridan, and Sherman halls, collectively known as Building 52.

apartments, the Rookery was the temporary home of Kansas territorial governor Andrew J. Reeder in 1854 and reportedly was occupied by First Lieutenant Douglas MacArthur when he was an Army Engineer School instructor from 1907 to 1912. The origin of the name is not known but explanations include 1) it was usually occupied by full "bird" colonels, 2) rowdy young officers who lived there in the 19th century were as noisy as birds, and 3) cheaply built buildings in the early 19th century were called rookeries (Schillare, 2015). The Rookery has been called the most haunted building on the post, which is known for its apparitions. The Rookery's angst-ridden lady in white is one of the most infamous (Hames, 2012).

The Beehive (aka the National Simulation Center)

One of the most unique renovation projects at the fort is a modern computer-based war-gaming facility concealed behind a 19th-century façade. Built in 1882–1883, the building that would be dubbed the Beehive in later years started off as a two-story barracks for infantry and post headquarters. It was repurposed several times, with a third story added in 1902 and a rear wing in 1910, and served as Bell Apartments from 1927 to 1978. The apartment building eventually became known as the Beehive because the largest families, often with five or more children, were placed there. Today it is the National Simulation Center (the NSC), a 19th-century building equipped with 21st-century technology and totally blacked-out windows (Schillare, 2015).

The Old United States Disciplinary Barracks (The Castle) site

Fort Leavenworth has had a military prison since 1875. The prison grew into a complex of buildings, including a massive structure with wings that surrounded a central rotunda. Built between 1908 and 1915, this core building was known as the Castle. Upon its completion, the prison name was changed to the United States

Disciplinary Barracks (USDB) (Schillare, 2015). After the old prison was replaced by a new USDB facility on the north edge of the fort in 2002, the Castle was demolished. Other buildings within the old prison complex have been converted into office space. The current 515-bed USDB is the only U.S. Department of Defense maximum-security correctional facility. In 2010, the lower-security, 512-bed Midwest Joint Regional Correctional Facility opened adjacent to USDB. Together, the two facilities are known as the Military Correctional Complex (MilitaryBases.US, 2017). Two civilian prisons—the United States Penitentiary in Leavenworth and the state's Lansing Correctional Facility—are nearby (U.S. Army, 2011).

Trail swale

A distinct rut cuts into a slope where wagons—some headed for the Santa Fe, Oregon, and California trails—were pulled up after being ferried across the Missouri River (fig. 4). A trail leading westward from Leavenworth was a feeder route for the three main trails. The swales are at a natural break in the bluff, where the slope was not too steep for wagon traffic (Schillare, 2015).

Frontier Army Museum

The Frontier Army Museum galleries highlight Fort Leavenworth's role in the exploration and expansion of the United States during the 19th century and its continuing contribution to military leadership and education. The collection includes military tools used throughout the 19th and early 20th centuries and emphasizes the Frontier Army's efforts, from Lewis and Clark's expedition in 1804 to General John Pershing's pursuit of Pancho Villa in 1916 (Army University Press, 2017).

Figure 4. Swale created by wagons coming up from the river landing in the 19th century.

Lewis and Clark Center

One of the newest additions to Fort Leavenworth, the Lewis and Clark Center, was dedicated in 2007 and is the fourth home of the Command and General Staff College. It was designed to incorporate the latest in education technology and adapt to future technological changes (Bernstein et al., 2008).

Sources

Army University Press, 2017, Educational services—Frontier Army Museum: Army University Press, http://bit.ly/2vgqxNS.

Bernstein, L., Robertson, W. G., and Crow, K. D., 2008, The house on the bluff: Leavenworth, Kansas, Combat Studies Institute Press, 73 p.

Hames, J. M., 2012, Fort Leavenworth—The most haunted base in the army?: Soldiers—The Official U.S. Army Magazine, http://bit.ly/1HEAHc4.

KSHS, 2017, Fort Leavenworth: Kansas State Historical Society, Kansaspedia, http://bit.ly/2xdXHPU.

MilitaryBases.US, 2017 U.S. Army Disciplinary Barracks: MilitaryBases.US, http://bit.ly/2w4Sda1.

National Archives, 2017, Tentative sketch of the clock tower complex, including Grant, Sherman, and Sheridan halls, Fort Leavenworth, Kansas: National Archives, Designs for Democracy—200 Years of Drawings, http://bit.ly/2vpDvZ5.

Schillare, Q. W., 2015, Fort Leavenworth—The people behind the names: Leavenworth, Kansas, Combat Studies Institute Press, 233 p.

U.S. Army, 2011, Joint Regional Correctional Facility, www.army.mil/article/55146.

U.S. Army Fort Leavenworth, 2017, http://garrison.leavenworth.army.mil.

USACAC, 2017, What is CAC?: United States Army Combined Arms Center, http://usacac.army.mil.

Contacts

George Moore
Director, Frontier Army Museum
913-684-3189
George.r.moore.civ@mail.mil

Greg Hoffman
Directorate of Public Works, Master Planning Division
913-684-8915
gregory.j.hoffman.civ@mail.mil

Glacial Hills and the Missouri River

Glaciers descending into northeast Kansas hundreds of thousands of years ago were a major force in shaping the region's physical geography, from its rolling hills covered with rich, fertile soils to the route of the Missouri River. In many ways, this geography is key to the region's "personality," with crops and grasslands on the glacial hills and cities bordering a major river for trade and travel.

During the last Ice Age (the Pleistocene Epoch), about 2.6 million to 11,700 years before present (BP), massive continental ice sheets spread across many parts of the world, including North America. Smaller regional ice lobes advanced during multiple cold glacial periods throughout the Pleistocene in North America, interspersed with warmer interglacial periods when ice disappeared long enough for soils to form. At least two of the glacial advances reached into northeast Kansas (Aber, 1991; Lyle, 2009), extending as far as present-day Topeka and Kansas City (fig. 1). Glacial "erratics," rocks that are not native to the region and could only have been carried by ice, particularly the often boulder-sized pink Sioux quartzite (fig. 2), are evidence of how far south and west the ice moved into Kansas. Advancing ice sheets buried ancestral drainages and dammed the ancestral Kansas River in several locations (Dort, 2004). As the ice sheet retreated, it left behind thick deposits of glacial drift, including till (an unsorted mix of clay, sand, gravel, and boulders) and glacial outwash (sediments "washed out" and separated into deposits of similarly sized materials by flowing water). Today, these outwash deposits provide an important groundwater resource in the region (Denne et al., 1998). During interglacial periods, melting ice sheets resulted in torrential flows of water that formed new drainages, two of which are now the Kansas River and the Missouri River.

Figure 1. Extent of glaciation in North America (Lyle, 2009).

The last major advance of an ice sheet in North America was during the Wisconsinan glaciation, which lasted from about 122,000 to 10,000 years BP (Richmond and Fullerton, 1986). Although ice did not extend into Kansas at this time, the effects of glaciation can still be seen in the rerouting of rivers and the type of sediments that were deposited. The Missouri River was a major drainage for the southern edge of the ice sheet and carried

Figure 2. Sioux quartzite boulder 2 miles northwest of Dover, Kansas (Dort, 2004).

much of the meltwater during ice retreat, particularly from about 20,000 to 10,000 years ago. Sediment that had been ground as fine as flour by glaciers was deposited on the floodplain, creating vast mud flats. As the mud flats dried, the fine-grained sediment was picked up by strong winds and carried in huge dust storms. The wind-carried silt, known as loess (pronounced "luss"), accumulated along the margins of the Missouri River valley and the adjacent uplands. Repeated over thousands of years, this process added layer upon layer, resulting in loess deposits that can exceed 50 feet in thickness.

Glacial Hills

Loess has distinctive properties. In northeast Kansas, it has a yellow-tan color and is composed of angular silt-sized grains of mostly quartz, often partially cemented with calcium carbonate (Lyle, 2009). Loess deposits can be quite cohesive when dry, forming sheer, nearly vertical faces, such as the bluffs that front the Missouri River. When wet, however, loess loses much of its cohesive properties and is easily eroded. Erosion has been a major factor in creating the rolling topography of the region and especially in reshaping the loess deposits. Erosion is particularly pronounced in the deep, narrow, steep-sided gullies in the region. These gullies lengthen headward quickly after rainstorms, cutting into cropland and transporting large quantities of fine-grained material into streams and reservoirs. Although gully erosion has been intensified by human activity, such as stream channelization, episodes of gully cutting and filling have occurred repeatedly over the last 20,000 years, significantly rearranging loess deposits.

Loess soils are among the most fertile in the world and in the Midwest sustain the productivity of the "corn belt." The fertility of loess soils stems principally from the abundance of silt particles that provide a ready supply of moisture, good aeration, widespread penetration by plant roots, and easy cultivation (Catt, 2001). Also, loess soils have been shown to require less potassium additions to obtain maximum crop yields than those soils developed in other materials, such as till (Sander et al., 1991).

The Missouri River

The geology along the Missouri River valley is a combination of alluvial river deposits, glacial drift, and loess along with much older Paleozoic bedrock (fig. 3). Historically, the Missouri River was dynamic, frequently

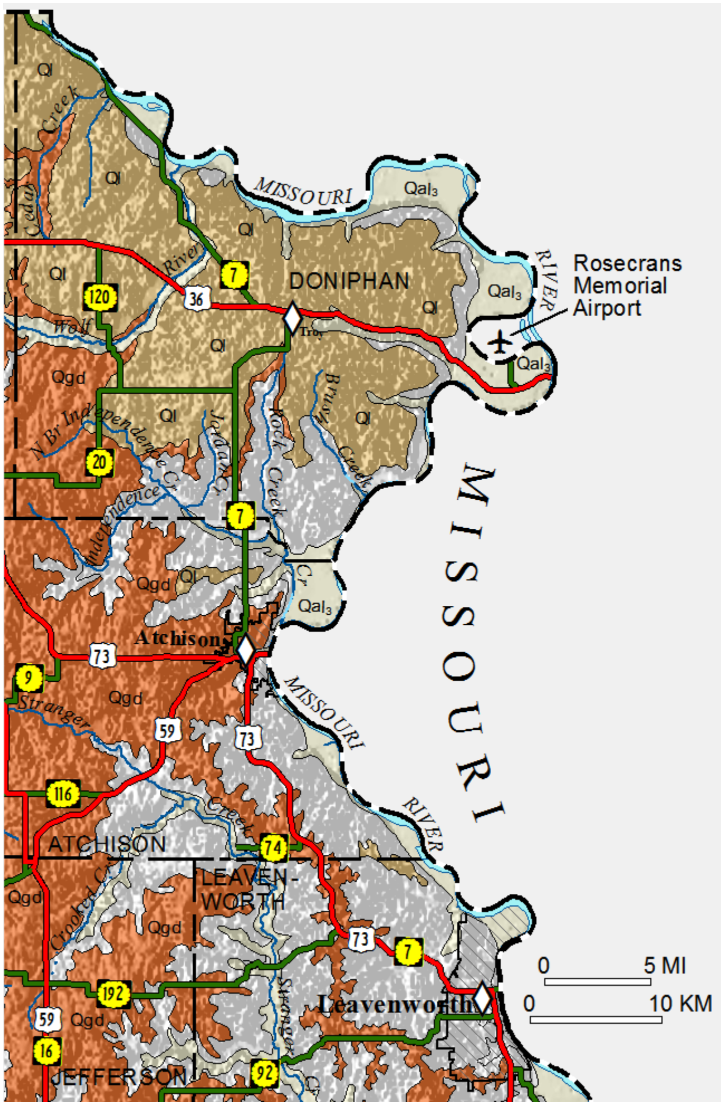
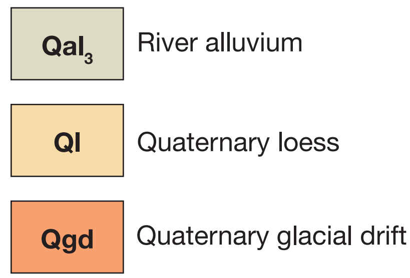


Figure 3. Geologic map of northeast Kansas indicating deposits of glacial drift, loess, and river alluvium. Unlabeled gray areas are Paleozoic bedrock. Note the Kansas-Missouri state border is along the river, except where the flood of 1952 cut off a meander loop of land that houses Rosencrans Airport (Kansas Geological Survey).



changing course as it meandered across the floodplain (fig. 4). Old meander scars can be seen on the land surface, some having formed oxbow lakes. Engineering has transformed the river into a regulated navigation system through a series of upstream reservoirs, flood control structures such as levees, and bank stabilization projects. Flood flows do still occur, however, and the flood of 1952 cut off a meander loop and stranded Missouri's Rosencrans Memorial Airport on the west side of the river (fig. 3).

The Missouri River has been a navigation route for trade and migrants long before engineering controlled its flow. Native American archaeologic sites are common in the Missouri River valley, and the river served as a trade route for furs and other goods, prompting the establishment of the French Fort de Cavagnial around 1744 near what is now Leavenworth. Lewis and Clark followed the Missouri River to find a water route to the Pacific Ocean. And by the mid-1800s, startup towns on both sides of the river were vying to be the regional trade and transportation hub. Kansas City, our region's largest metropolis, became the clear-cut winner when the Hannibal and St. Joseph Railroad completed the first bridge across the Missouri River there in 1869 (Shortridge, 1988).

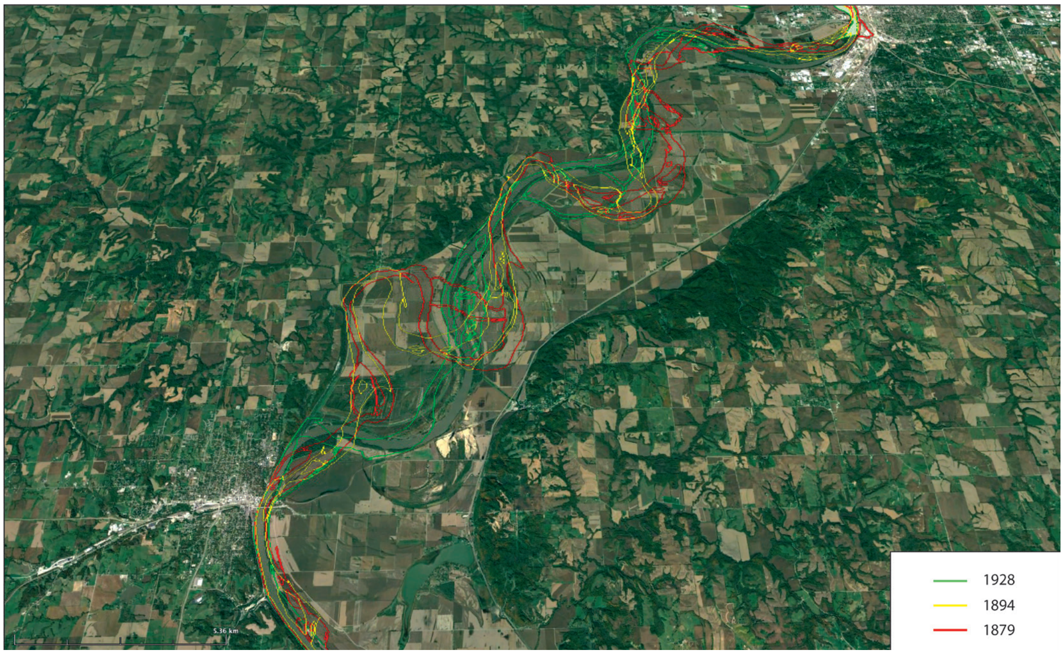


Figure 4. Meanders of Missouri River between Atchison, Kansas, and St. Joseph Missouri, with past years overlain on current conditions (Kansas Geological Survey).

Sources

Aber, J. S., 1991, The glaciation of northeastern Kansas: Boreas, v. 20, no. 4, p. 297–314.

Catt, J. A., 2001, The agricultural importance of loess: Earth-Science Reviews, v. 54, p. 213–229.

Denne, J. E., Miller, R. E., Hathaway, L. R., O'Connor, H. G., and Johnson, W. C., 1998, Hydrogeology and geochemistry of glacial deposits in northeastern Kansas: Kansas Geological Survey, Bulletin 229, 127 p. http://bit.ly/2xsXCHm.

Dort, W., 2004, Multiple pre-Illinoian tills and associated sediments and paleosols, Northeastern Kansas and Central Missouri; *in,* Guidebook of the 18th Biennial Meeting of the American Quaternary Association, R. Mandel, ed.: Kansas Geological Survey, Technical Series 21, 146 p. http://bit.ly/2xt4rsk.

Lyle, S., 2009, Glaciers in Kansas: Kansas Geological Survey, Public Information Circular 28, 6 p., http://bit.ly/2ezjesR.

Richmond , G. M., and Fullerton, D. S., 1986, Summation of Quaternary glaciations in the United States of America—Quaternary glaciations in the Northern Hemisphere: Quaternary Science Reviews, v. 5, p. 183–196.

Sander, D. H., Penas, E. J., and Walters, D. T., 1991, Winter wheat phosphorous fertilization as influenced by glacial till and loess soils: Soil Science Society of America Journal, v. 55, p. 1,474–1,479.

Shortridge, J. R., 1977, updated 1988, Kaw valley landscapes, A traveler's guide to northeastern Kansas: Lawrence, Kansas, University of Kansas Press, 240 p.

Contacts

Tony Layzell
Assistant Research Professor
Kansas Geological Survey
785-864-7767
alayzell@kgs.ku.edu

Rolfe Mandel
Director
Kansas Geological Survey
785-864-2171
mandel@kgs.ku.edu

Wednesday, September 13, 2017

6 a.m.	Breakfast opens at hotel
7:15 a.m.	Load suitcases, turn in room keys
7:30 a.m.	**Bus leaves hotel** Bus to Site 6
7:40 a.m.	**Sites 6 and 7:** Missouri River and Benedictine Bottoms *Colonel Douglas Guttormsen,* U.S. Army Corps of Engineers *Todd Gemeinhardt*, U.S. Army Corps of Engineers *Pete Hentschel,* U.S. Army Corps of Engineers *Dave Hoover*, U.S. Army Corps of Engineers *Rex Ostrander,* U.S. Army Corps of Engineers *Kirk Thompson*, Kansas Department of Wildlife and Parks *Steve Adams*, Kansas Department of Wildlife and Parks Participants divide into two groups: One group boards boats for river tour, and the other stays on bus for Benedictine Bottoms tour
9 a.m.	Groups exchange tours Restroom break at Missouri River dock site
10:30 a.m.	Bus to Site 8 Bus Session—Interbasin Water Transfer Projects Outside of Kansas *Earl Lewis*, Kansas Water Office Bus Session—Aqueduct Considerations: Federal Reserve Water Rights and Protection of American Indian Historic and Cultural Resources *Alan Kelley*, Iowa Tribe of Kansas & Nebraska *Lance Foster*, Iowa Tribe of Kansas & Nebraska
11:30 a.m.	**Site 8**: Conceptual Kansas Aqueduct Upstream Reservoir Site *Ken McCauley*, Landowner and Iowa Township Trustee
Noon	Bus to Site 9

12:10 p.m.	**Site 9:** George Ogden Jr. Community Building Restroom Break Lunch
	Panel: Groundwater Quality in Northeast Kansas *Don Whittemore*, Kansas Geological Survey *Mike Nichols*, City of Hiawatha *Alan Kelley*, Iowa Tribe of Kansas & Nebraska *Jaime Gaggero*, Bureau of Water, Kansas Department of Health and Environment Moderator: *Susan Stover*, Kansas Geological Survey
1:45 p.m.	Bus to Site 10
	Bus Session—Bioremediation of Nitrate in Groundwater *Julie WestHoff*, Kennedy & Jenks
	Bus Session—Scientific Findings at Muscotah Marsh *Rolfe Mandel,* Kansas Geological Survey
2:45 p.m.	**Site 10:** Muscotah Marsh *Frank Norman,* Norman Ecological Consulting and Kansas Association of Wetlands and Streams
3:20 p.m.	Bus to Lawrence
	Restroom Break in Nortonville
5 p.m.	Return to Hampton Inn, Lawrence

Managing the Lower Missouri River System

The Missouri River, which forms Kansas' only natural border, is a highly valuable water resource for the state. The river carries an enormous amount of water, draining a watershed that exceeds 500,000 square miles, or nearly one-sixth of the United States. The Missouri River basin includes 10 states and a portion of Canada, all of whom have an interest in the river, and is a source of municipal, industrial, and irrigation waters; food; and navigation. The river, which supports a diverse ecological environment, is more than 2,200 miles long, stretching from Three Forks, Montana, to its confluence with the Mississippi River near St. Louis. During the 20th century, the Missouri River was significantly altered to provide economic benefits associated with navigation, hydropower, water supply, and flood protection. Though the upper third of the river's length is largely natural, a series of very large reservoirs have been constructed on the middle third and the lower third (735 miles) was channelized to support navigation from near Sioux City, Iowa, to St. Louis. In addition to the economic benefits of these projects, the alterations have also led to riverbed degradation, a decrease in sediment load, loss of native habitat, and a reduction in abundance of native species.

The U.S. Army Corps of Engineers (Corps) manages and maintains the mainstem reservoirs, the channelized portion of the river, and many of the federal reservoirs on tributaries in the basin. During stops 6 and 7, we will explore current and past engineering efforts to manage the river and examples of habitat restoration projects on mitigation land that have been undertaken to offset the losses associated with past river management.

Channel and flow management

Historically, the Missouri River was a sinuous, meandering river, often with extensive stretches of braided channel. Two major modifications have greatly affected the river's long-term flows and habitat: 1) the Missouri River Mainstem Reservoir System and 2) The Missouri River Bank Stabilization and Navigation Project (BSNP).

The Missouri River Mainstem Reservoir System, authorized by the 1944 Flood Control Act, consists of six large dams: Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and

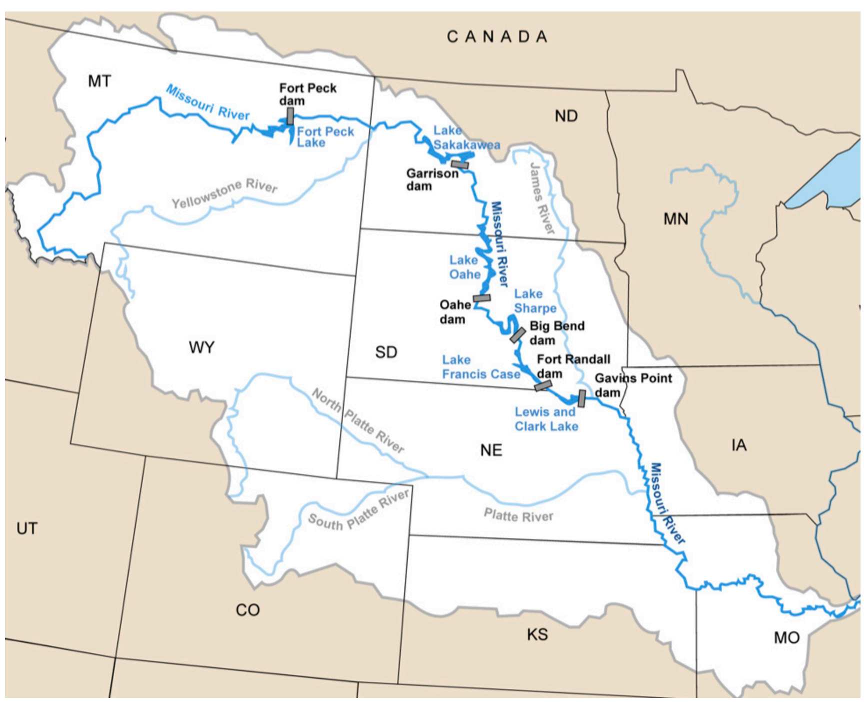


Figure 1. Dams on Missouri River mainstem (GAO, 2014).

Gavins Point (fig. 1). In addition, roughly 75 dams and impoundments have been developed in tributaries to the Missouri River. The Corps manages the river and reservoir system for the congressionally authorized purposes of flood control, irrigation, navigation, hydropower, water supply, water quality, recreation, and fish and wildlife enhancement. Although flood control is a major purpose of the reservoir system, the reservoirs can only mitigate, not eliminate, flooding. The largest volume of flood water recorded in the Missouri River system occurred in 2011, although the severity and damage were likely reduced due to the reservoirs' operations (Haj et al., 2014).

The BSNP, authorized by the 1945 River and Harbors Act, requires that the Corps maintain a 9-foot deep, 300-foot wide navigation channel downstream of Sioux City, Iowa, to the confluence with the Mississippi River, a distance of 735 miles. The primary way to achieve the minimum navigation depth is through channel constriction. The width of the original channel was reduced with wing dikes that extend perpendicular from the bank to trap sediment and confine water flow to a much narrower area. The photographs in fig. 2a–e, all taken from the same location near Indian Cave State Park in Nebraska, not far from the Kansas border, show the progression of the channel confinement over time.

The full service flow target during navigation season is 41,000 cubic feet per second (cfs) at Kansas City (minimum service is 35,000 cfs). Why is this important to Kansas? In the event of insufficient natural flows, water is released from upstream reservoirs to achieve minimum flow rates. The majority of that released water comes from the mainstem reservoirs in Montana, North Dakota, and South Dakota. However, at times when the Kansas City flow target hasn't been met, water has been released from federally controlled storage at Milford, Tuttle Creek, and Perry reservoirs in Kansas to increase the flow rate in the Missouri River.

Because these navigation releases are made during abnormally dry times, they present an increased risk for water supply and economic stability for the two-thirds of the state's population that live in the corridor along the Kansas River. These reservoirs hold the majority of the available water supply storage in the Kansas River basin for municipal and industrial water supply. In addition, water-based recreation and associated expenditures by visitors is a significant economic engine for local economies. The amount of federally controlled water released during low flow times can be up to 6 feet below conservation pool from these reservoirs, which constitutes a significant impairment to recreational access to the lakes. The conservation pool is the storage space between the base of the flood pool, an area normally free of water, and the top of the dead pool, which is too low to drain through the dam's outlet; the conservation pool is used for normal reservoir operations. The state has contracts to purchase, if funds are secured, additional conservation pool storage in Milford and Perry, which have 242,260 acre feet and 160,113 acre feet available, respectively (KWO, 2016).

Missouri River sediment

Historically, the Missouri River was turbid, carrying a large volume of sediment that earned it the nickname "Big Muddy." Dams and channel controls have resulted in a decrease in the lower Missouri River sediment load. Sediment gets trapped in the reservoirs and behind bank revetments and dikes designed to stabilize and narrow the channel. Levees further reduce river sediment by capturing sediment from overland flows. Sand and gravel dredging removes sediment entirely from the river system and was a contributing cause of channel degradation in the Kansas City region (Corps, 2017).

Clear water releases below major dams scour from the bed until the sediment load returns to equilibrium with the ability of the water to pick up and transport it. Other sediment removals can also create a more

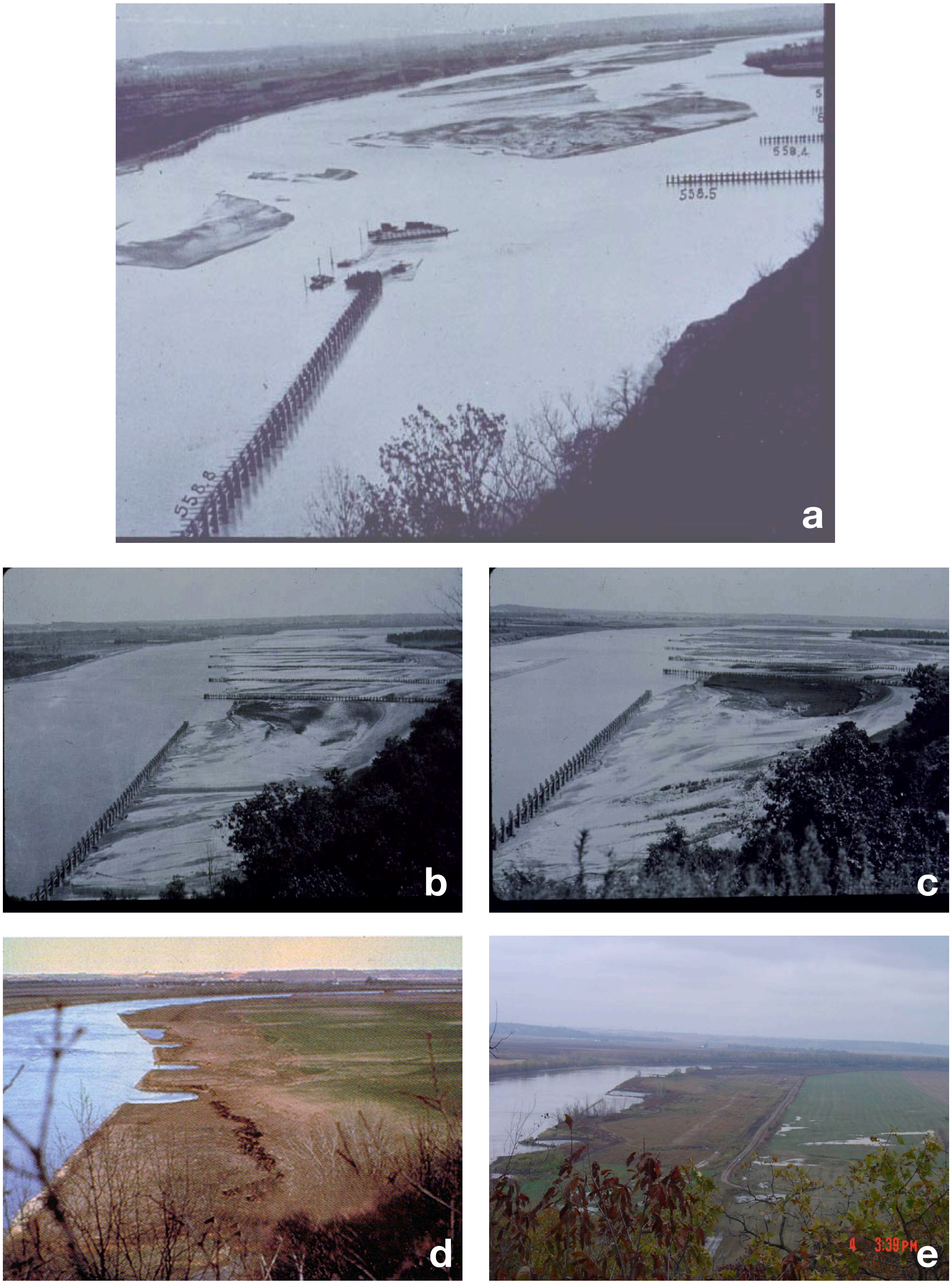


Figure 2a-e. Missouri River near Indian Cave State Park, Nebraska, looking downstream. a) 1934: Note sand bars in center of channel. b) 1935: After one spring rise, sand bars migrated from mid-channel to behind the wing dikes. c) 1936: Two spring rises after construction, more sediment has accumulated, small trees are taking hold, and the channel is significantly narrowed. d) 1977: Dikes added to restrict the river and improve the navigation channel, and the floodplain now put into crop production. e) 2003: Note levee on the right bank, put in by agricultural interests to protect the cropland from flooding (photos from Corps, 2017).

erosive flow ("hungry water") until the water velocity and sediment load balance is re-established.

Bed degradation concerns

Bed degradation, the lowering of the stream bed or floodplain, causes considerable problems on portions of the lower Missouri River. It leads to bank instability (fig. 3), erodes foundations of infrastructure (fig. 4), and disables water intakes. Repairs or modifications to water supply intakes, bridges, levees, and channel stabilizing structures are expensive. Historical expenses due to bed degradation are estimated at $45 million in infrastructure construction costs and $55 million in increased operating costs (Corps, 2017).

Changes in river bed elevations are connected to the amount of sediment carried in its waters. If more sediment leaves than enters a reach, or segment of the river, the elevation is lowered. Sediment held or removed in one stretch of river can affect downstream segments (fig. 5). The streambed can degrade significantly to cause an abrupt change in slope of the stream channel, called a "knickpoint." An increase in the slope of the river will increase its erosive power, and the erosive head may continue to migrate upstream. This has occurred on the Missouri mainstem and some tributaries. Before 2011, the critical and severe bed degradation in the Missouri River had been concentrated in reaches near the Kansas City area. However, the 2011 flood resulted in an upstream migration of the most critical bed degradation by about 30 miles (Corps, 2017).

In May 2017, the Corps released a feasibility study that evaluated potential measures to reduce bed degradation, including ways to either increase sediment in or decrease the amount of sediment removed from the river system. Proposals evaluated included increasing sediment into the system, such as partial flow bypass around Gavins Point dam when high flows are carrying large sediment loads, or physically re-introducing gravel into the river from the floodplain. Structural changes were evaluated that might reduce flow velocities so less sediment can be transported, such as widening the channel or placing a

Figure 3. Bank collapse due to bed degradation from the Missouri River that moved up a small tributary in Wyandotte County, Kansas (Corps, 2017).

Figure 4. Damaged bridge piers along a Missouri River tributary that was affected by bed degradation in Platte County, Missouri (Corps, 2017).

series of underwater grade control structures to slow the flow. At this time, it is not clear these measures are feasible. Reducing sediment loss could be achieved by further restricting in-channel sand and gravel mining. These activities are permitted under the purview of the Environmental Protection Agency (Section 404 of the Clean Water Act) and Corps (Section 408, U.S. Code 33). Although no recommendations were made as a result of the study, a technical report presents its findings (Corps, 2017).

Missouri River recovery for ecological concerns

Construction of the mainstem reservoir system and management of the river for navigation resulted in unintended ecological consequences, including physical alteration of nearly 3 million acres of riverine and floodplain habitat, dampening the spring and summer high (and low) flows, and dramatically reducing sediment, much of which once reached coastal Louisiana (NRC, 2011). These, along with other factors, led to a decline in the native fish population (NRC, 2002). Of the 67 native fish species that live along the mainstem, the majority are decreasing in number throughout the Missouri River. The Missouri River ecosystem is also home to hundreds of native birds and other wildlife that have been affected by loss of habitat on an unprecedented scale.

Three species that rely on the Missouri River system are on the federal threatened and endangered species list: the pallid sturgeon, the piping plover, and the least tern. The pallid sturgeon, a long-lived, bottom-dwelling fish that adapted to turbid, high-sediment conditions of the pre-regulated river, is found only in the Missouri River (and tributaries) and the lower Mississippi River. Its riverine habitat has been fragmented and reduced. The least tern and piping plover are migratory birds that nest in shallow depressions on sparsely vegetated sandbars of the Missouri River. Suitable sandbar nesting sites became less common after reservoirs were built and flows regulated. Fortunately, populations of the least tern have improved and the species is currently proposed for de-listing.

The Corps has undertaken engineering and operational changes along the Missouri River system to improve habitat for these three species. For example, the least tern and piping plover both nest on sparsely vegetated sandbars that emerge above the water line. These sandbars are created naturally when the river runs high. The modification of flows in the system has resulted in conditions where these sandbars with little vegetation are formed

Figure 5. Schematic on bed channel as a function of the sediment moving into and out of the river reach from upstream (US) to downstream (DS) and active aggregate mining (Corps, 2017).

less often. In addition, these species prefer to nest on the sandbars very near the waters edge, making the nests vulnerable to water level increases for hydropower, navigation, or other water releases. The Corps has tried to encourage the birds to nest at slightly higher elevations with short pulses (releases) of water downstream of Gavins Point dam during the pre-nesting period. Emergent sandbars also can be constructed from dredged river sediment. To reduce risk of flooding the sandbars during active nesting, the Corps reduces water released when no navigation traffic is scheduled. Protection against predators is also part of the management efforts.

Actions to improve the pallid sturgeon's survival have included a variety of efforts, including in-channel habitat efforts, creation of side channels and chutes, and other efforts to restore habitat diversity. In addition, populations have been augmented with pallid sturgeon that are raised at several federal- and state-operated hatcheries in the basin.

Some scientists, though, are concerned that management changes specifically designed to improve habitat for the three currently listed species cannot reproduce the variety of habitats needed for other species that were more abundant in the pre-regulated river system (NRC, 2002). The Kansas Department of Wildlife, Parks and Tourism (KDWPT) is among the entities that advocate looking beyond the species currently listed as threatened or endangered to consider the many other species associated with the Missouri River system that are known to be in decline. If the actions designed to help currently threatened species do not also stabilize other declining species, agencies may be caught in a "chase" cycle of constant changes targeting species after species as populations decline. Such a pattern would likely result in a much reduced chance of success and much higher cost.

Benedictine Bottoms

Benedictine Bottoms, the Corps' first major acquisition of land for the Missouri River Recovery Program to reestablish wetlands and riparian habitat, is home to a great variety of wildlife, including songbirds, waterfowl, shorebirds, and wading birds. The 2,100 acres, purchased from willing landowners, has been restored from what had been primarily row crops to three types of habitat: timber, native grass, and wetlands. The timber provides fruits, nuts, and seeds as well as cover for wildlife. The grasslands provide nesting sites, food, and cover for escape. A few crops are also grown to serve as food plots for wildlife. Through a cooperative agreement, the KDWPT is the on-site management agency. The 450 acres of wetlands are managed with low-head berms and water control structures, such as the modified river dikes and two side-channel chutes, that increase habitat diversity (fig. 6).

Figure 6. Chutes similar to these at Dalby Bottoms wetlands downstream of Benedictine Bottoms have been constructed at Benedictine Bottoms to increase habitat diversity (Corps, 2017).

Sources

Corps (U.S. Army Corps of Engineers), 2016, Draft Missouri River recovery management plan and environmental impact statement: U.S. Army Corps of Engineers Kansas City District. http://bit.ly/2vp3ika

Corps (U.S. Army Corps of Engineers), 2017, Missouri River bed degradation feasibility study: U.S. Army Corps of Engineers Kansas City District, Technical Report, 127 p. http://bit.ly/2vSLYrt.

Corps (U.S. Army Corps of Engineers), 2011, Missouri River commercial dredging final environmental impact statement: U.S. Army Corps of Engineers Kansas City District.

GAO, 2014, Missouri River flood and drought—Experts agree the Corps took appropriate action, given the circumstances, but should examine new forecasting: United States Government Accountability Office, 50 p., http://www.gao.gov/assets/670/665763.pdf.

Haj, A., Christiansen, D., and Viger, R., 2014, Effects of Missouri River mainstem reservoir system operations on 2011 flooding using a precipitation-runoff modeling system model: U.S. Geological Survey and U.S. Department of Interior, Professional Paper 1798-K, 33 p. https://on.doi.gov/2w3StWF.

Kansas Water Office, 2016, Surplus Water Available in Water Marketing Program Lakes Calendar Year 2017, December 2017, 35 p. http://bit.ly/2vsrGS1.

NRC (National Research Council), 2002, The Missouri River ecosystem: Exploring the prospects for recovery: Washington D.C., National Academies Press, 176 p. http://bit.ly/2w4n6eo.

NRC (National Research Council), 2011, Missouri River planning: Recognizing and incorporating sediment management: Washington D.C., National Academies Press, 152 p. http://bit.ly/2vZiSqk.

Contacts

Todd Gemeinhardt
Habitat Assessment and Monitoring Program Manager
U.S. Army Corps of Engineers, Kansas City Office
816-389-2268
Todd.R.Gemeinhardt@usace.army.mil

Kirk Thompson
Manager
Benedictine Bottoms
Kansas Department of Wildlife, Parks and Tourism
913-367-7811
Kirk.Thompson@KS.Gov

Steve Adams
Chief of Planning
Kansas Department of Wildlife, Parks and Tourism
785-296-0019
Steve.Adams@ks.gov

Upstream Considerations of the Kansas Aqueduct Concept

By the 1970s, it was clear that the High Plains aquifer was undergoing severe declines and that these declines posed serious agricultural, economic, and social problems for the regions that relied heavily on the aquifer. The federal Water Resources Development Act of 1976 authorized the Six-State High Plains-Ogallala Aquifer Area Regional Resources Study. This study included Appendix B, "Water Transfer from the Missouri River to Western Kansas," one of several interbasin transfers evaluated (1982, Corps). This route would divert high flows from the Missouri River in northeast Kansas to western Kansas. Because the Missouri River has the capacity to provide a greater quantity of water than any other surface-water source in Kansas, it potentially could be tapped for uses beyond the northeast corner of the state.

The plan was never pursued, but interest was revived in 2011 when much of western Kansas was experiencing severe drought conditions and the Missouri River was flooding in eastern Kansas. A Kansas Aqueduct Coalition formed to support the concept.

The Kansas Water Office and the U.S. Army Corps of Engineers (Corps) updated the 1982 study, not as an endorsement but to explore the possibilities based on current technologies, legal considerations, and costs. Their 2015 study addressed engineering of the water transfer system, potential water demands, and preliminary cost estimates. The 1982 plan evaluated an aqueduct diversion of high flows from the Missouri River into an interbasin transfer reservoir near White Cloud in far northeastern Kansas, then to a proposed reservoir near Utica (fig. 1), with possible water diversions along the way. Irrigators were projected to be the largest users of the diverted water (KWO and Corps, 2015).

In reaction to the proposed White Cloud reservoir, people whose crops and businesses would be inundated or cut off have expressed

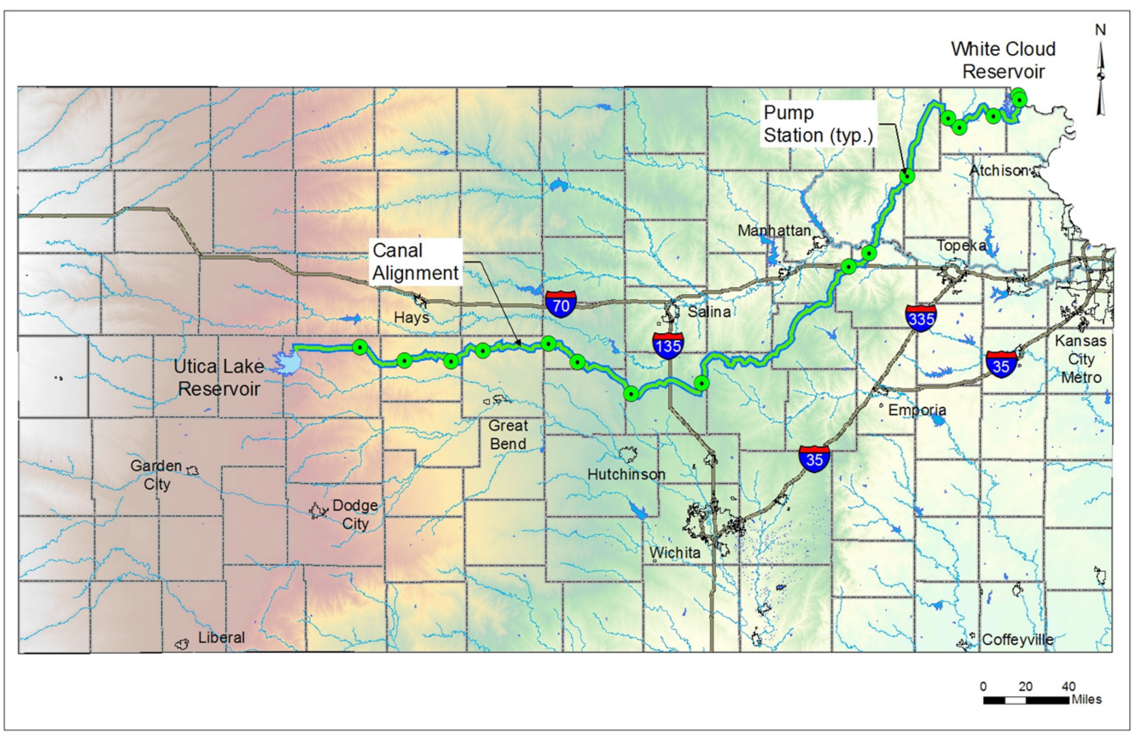


Figure 1. Route of a conceptualized Kansas Aqueduct (KWO and Corps, 2015).

concerns that negative economic and social effects would occur if the aqueduct and reservoir were built (Unruh, 2015; McCauley, 2017, personal communication). The conceptual White Cloud reservoir would cover roughly 20 square miles.

The Missouri River basin

The Missouri River Basin encompasses all or a portion of 10 states, including 28 tribal lands, and a small portion of Canada. The Missouri River passes through or borders Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri and enters the Mississippi River near St. Louis.

The flows of the Missouri River are highly variable, with the basin experiencing periods of floods and droughts. Six mainstem reservoirs were built in the 1940s and 1960s, in large part to provide flood protection. These impoundments have a storage capacity of 74 million acre feet (KWO and Corps, 2015). Although the upstream reservoirs and tributary reservoirs reduce the severity of floods, flooding still occurs—most recently in 1993 and 2011. The reservoirs also provide relief during droughts through the release of stored water. In addition to managing the river for flood protection, the Corps also manages for several other congressionally authorized uses, including navigation.

Interbasin transfer concept

As visualized, the aqueduct would move water 360 miles through a combination of pipes and concrete-lined canals. The conceptual White Cloud reservoir would hold 700,000 acre feet of water, with the entire site—including embankments, buffers, and facilities—requiring 19,000 acres. The terminal aquifer near Utica, Kansas, would be sized to receive water at a constant rate, yet meet demands that vary by season. The authors of the 2015 updated study determined how much high-flow water would generally be available for the aqueduct based on the historical frequency of flows in the Missouri River. Flows that exceeded navigation requirements and water supply intake targets were evaluated for potential diversion (KWO and Corps, 2015). Additionally, if diversions do not exceed 6,000 cubic feet per second (cfs), a lock and dam structure on the Missouri River could be avoided (KWO and Corps, 2015).

Although the evaluated aqueduct route runs along a ridgeline, 15 pump stations (fig. 1) would be needed to lift water 1,745 feet uphill. That would require approximately 8.78 million megawatt hours of electricity to divert roughly 1.2 million acre feet of water annually. Based on the most efficient flow rate of water in the aqueduct— 6,000 cfs—a very preliminary cost estimate for the project is $450 per acre foot. The total estimated cost of $18 billion assumes a 3.5% borrowing rate and includes construction over a 20-year period as well as annual energy, operation, and maintenance costs. The estimate does not include costs for environmental conservation, legal issues, or the additional infrastructure and pumping needed

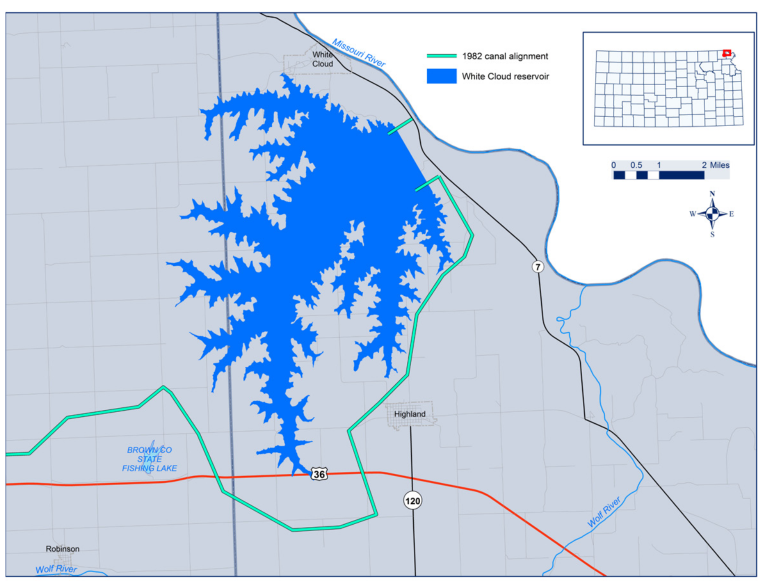


Figure 2. Extent of conceptual White Cloud Reservoir as part of Kansas aqueduct (map by Erika Stanley, KWO, based on 1982 study).

to deliver water from the Utica reservoir to eventual users.

Another non-trivial cost not included in the estimate is the filing fee that must accompany the state's application for a water-right permit. A water-right permit is required for all new diversions of water, other than for domestic wells. The filing fee is about $20 per 100 acre feet (KWO and Corps, 2015). For a project of this magnitude, the filing fee would cost nearly a million dollars. The 2016 legislative session introduced bills to amend certain procedures to appropriate surface water that otherwise would leave the state (SB 322; S Sub for HB2059), but died in conference committee. The Kansas Water Authority proposed to study the policy implications of large-scale transfers of interstate water.

Native American issues

Water rights

Before a Kansas aqueduct could move forward, its potential impact on the water rights of the 28 American Indian tribes in the Missouri basin would need to be addressed. American Indian tribes on reservations have federal reserved water rights. When the federal government established reservations, the right to sufficient water to satisfy the purpose of the reservation was implicit, according to the 1908 Winters Doctrine (Pope and Rolfs, 2014). The Supreme Court ruled in 1963 that the quantity of water reserved should be based on the amount necessary to practicably irrigate the reservation's acreage (Pope and Rolfs, 2014).

The priority of American Indian tribes' federal reserved water rights is based on the date each reservation was established. The four tribes in Kansas have very senior priority because the Prairie Band Potawatomi Nation reservation dates to 1846, the Kickapoo Tribe in Kansas reservation to 1832, and the reservations of the Sac and Fox Nation of Missouri in Kansas & Nebraska and the Iowa Tribe of Kansas & Nebraska to 1854 (Sheets, 2016). In water rights discussions, the Iowa Tribe of Kansas & Nebraska refers to the Treaty of 1836, the "Platte Purchase," under which it relinquished Missouri and moved to its reservation in Kansas and Nebraska (Kelley, 2017). Federal reserved water rights are not subject to abandonment as long as they are held by the tribe or tribal members (Pope and Rolfs, 2014). In Kansas, only the Kickapoo Tribe has sought to have its water right quantified. Through an agreement with the State of Kansas, the tribe can divert 4,700 acre-feet of water annually, and the Kansas Division of Water Resources is required to protect the tribe's water rights during times of shortage (Kickapoo Tribe in Kansas and the State of Kansas, 2017).

Historic and cultural resources

Several federal and state laws protect the historic and cultural resources of American Indian tribes, including the National Historic Preservation Act, Native American Graves Protection and Repatriation Act, Archaeological Resources Protection Act, and Kansas Historic Preservation Act (Pope and Rolfs, 2014). The conceptual aqueduct reservoirs and route are in the vicinity of many known and potentially unknown Native American cultural resources that would need protection and preservation.

Economic

Large mainstem reservoirs developed under the authority of the 1944 Flood Control Act (FCA) for flood control, hydropower, water supply, and irrigation have provided huge, although uneven, benefits to residents in the Missouri River basin. Recreation at the lakes has been more important than anticipated. However, a navigation system that was constructed and maintained for the river has resulted in less cargo shipping than anticipated in the FCA, and fewer irrigation projects were completed than originally planned (Pope and Rolfs, 2014). According to a 2014 report for the Kansas Water Office, the mainstem and tributary reservoirs resulted in unforeseen and substantial negative effects on the economies and resources of American Indian Tribes after tribal lands were inundated by reservoirs. The tribes did not receive much economic benefit from the mainstem reservoirs or many tributary projects (Pope and Rolfs, 2014).

Basin and statewide regulations

Unlike many interstate rivers, there is no compact that allocates potential diversion of Missouri River water between states. Additionally, the State of Kansas has not specified how much of the river water can be used (Pope and Rolfs, 2014). Estimates of high-flow waters can be made from historical flow records, but those evaluations are based on physically available quantities above target flows for navigation and existing surface water intakes, and not on an authorized quantity for Kansas. The available water quantities could be defined by an apportionment of the Missouri River by the Supreme Court, Congress, or an interstate river compact (Pope and Rolfs, 2014).

Every diversion of water, other than for domestic use, must have a state approved permit under the Kansas Water Appropriation Act. The chief engineer at the Kansas Department of Agriculture's Division of Water Resources determines whether applications meet the statutory requirements for approval. Among the requirements are that the proposed use cannot a) impair a use under an existing water right and b) unreasonably affect the public interest.

A Kansas aqueduct project would trigger the Kansas Water Transfer Act (WTA). The WTA, enacted in 1983, regulates the amount and length of a water diversion. The act is triggered when an application is made to divert and transport 2,000 acre feet or more of water farther than 35 miles. The WTA has a review process and a panel that consists of the chief engineer, the director of the Kansas Water Office, and the secretary of the Kansas Department of Health and Environment (or director of KDHE's Division of Environment, if designated by the secretary).

Sources

Corps (U.S. Army Corps of Engineers), 1982, Water transfer from Missouri River to western Kansas, reconnaissance study alternate route B, water transfer element; *in,* Six-State High Plains Ogallala Aquifer Regional Resources Study: U.S. Army Corps of Engineers Kansas City District, 39 p.

Kelley, A., vice chairman of Iowa Tribe of Kansas & Nebraska. Personal communication, September 18, 2017.

Kickapoo Tribe in Kansas and the State of Kansas, 2016, Kickapoo Tribe water rights settlement agreement between the Kickapoo Tribe in Kansas and the State of Kansas. http://bit.ly/2vSEFjQ

KWO and Corps (Kansas Water Office and the U.S. Army Corps of Engineers), 2015, Update of 1982 six state High Plains aquifer study, alternate route B.

Pope, D. L., and Rolfs, L. E., 2014, Issue evaluation for the Kansas Aqueduct study, review of legal, legislative and political issues: report for the Kansas Water Office, December 5, 2014, 42 p.

Sheets, E. S., 2016, Tribal water sovereignty, 101: Governor's Conference on the Future of Water in Kansas, November 14–15, 2016, Manhattan, Kansas.

Unruh, T., 2015, Testy exchange occurs during aqueduct meeting in Salina: Salina Journal, January 22, 2015.

Contacts

Earl Lewis, Assistant Director
Kansas Water Office
785-296-0867
Earl.Lewis@kwo.ks.gov

Alan Kelly, Vice Chairman
Iowa Tribe of Kansas & Nebraska
785-595-3258
akelley@iowas.org

Ken McCauley
Farmer and Iowa Township Trustee
785-741-1729
Mccauley3318@gmail.com

Groundwater Quality in Northeast Kansas

The Missouri Regional Advisory Committee, a local advisory committee to the Kansas Water Authority (fig. 1), has set goals to improve the understanding of groundwater quality and quantity in the region. Such an understanding will help define efforts to achieve "adequate, sustainable and affordable quality water supply in the Missouri region, while protecting Tribal water rights and sacred and cultural sites" (Missouri Regional Advisory Committee, 2016).

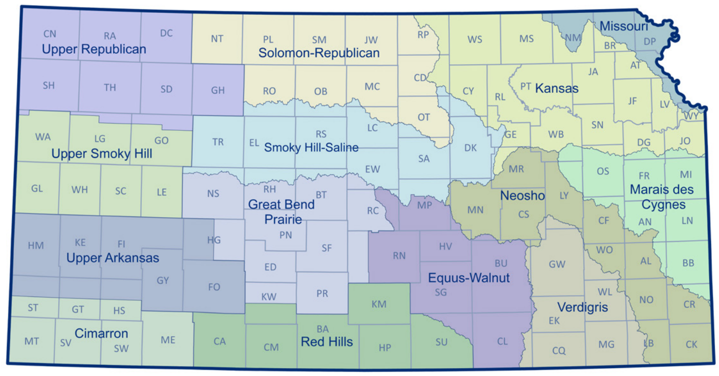


Figure 1. Regional planning areas, each with a regional advisory committee. Source: Kansas Water Office, 2014.

Surface water is the dominant source in northeast Kansas, with groundwater accounting for just 12 percent of water use in the Missouri regional planning area and about 7 percent in the Kansas regional planning area in 2016. There are significant surface water sources in the two planning areas, with more than 6,400 miles of perennial streams, including the Missouri River (KWO, 2009). Municipalities are the primary users, with irrigation a distant second, in terms of quantity (fig. 2). With the exception of the more populous Wyandotte

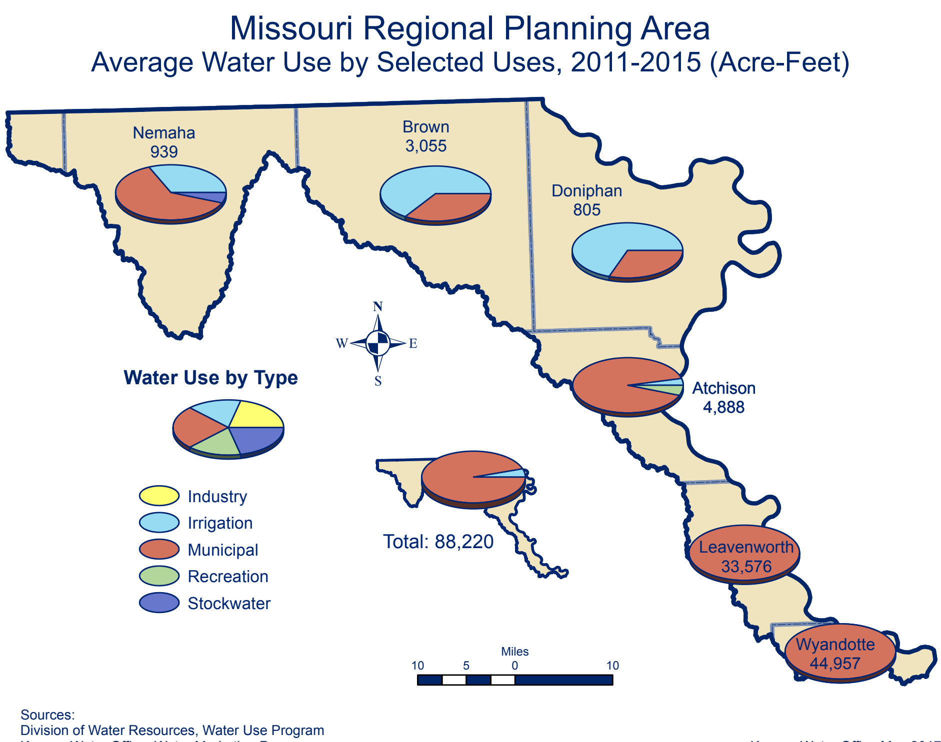


Figure 2. Average annual water use by type in the Missouri Regional Planning Area. Provided by Tina Rajala, Kansas Water Office.

and Leavenworth counties, the total water use in the Missouri regional planning area is comparatively light. This reflects in large part the wet climate in the northeast; less irrigation is necessary.

Groundwater sources

Groundwater in northeast Kansas occurs primarily in glacial drift aquifers and alluvial aquifers that parallel rivers and streams. The hills of northeast Kansas are underlain by glacial drift, a mix of boulders, pebbles, silt, and clay left behind when the ice sheets melted. Windblown, fine-grained loess (pronounced "luss") deposits cover much of the glacial hills, more than 50 feet thick in some areas. These deposits are typically porous. Very rich soils have developed on the loess, especially in Brown and Doniphan counties. Aquifers in the glacial drift tend to be fairly localized in lateral extent with highly variable characteristics for holding and moving water. For example, there is a wide range in the rate water will flow in the glacial aquifers from 115 gallons per day/feet^2 to 5,000 gallons per day/ft^2 (Denne et al., 1998).

The Flint Hills and Osage aquifers in northeast Kansas tend to occur in limestone fracture zones and are low yielding but appropriate for stock water and domestic wells (Macfarlane et al., 2000). The Kansas Geological Survey is further defining the availability of groundwater in the Missouri Regional Planning Area.

Nitrate in groundwater

Nitrate in groundwater can be a health concern at high levels. The U.S. Environmental Protection Agency set the safe drinking water maximum contaminant level (MCL) for nitrate at 10 mg/L. Although public water supplies monitor water quality for nitrate as part of a suite of constituents, many private well owners do not. Without testing, nitrate is undetectable—it is colorless, odorless, and tasteless. Groundwater is the source for nearly all private domestic wells in Kansas. At high levels, nitrate ingestion can lead to methemoglobinemia in infants, or blue baby syndrome, a condition that inhibits their immature bodies' ability to use oxygen effectively.

Nitrate occurs naturally in groundwater at levels up to 2 or 3 mg/L. Higher levels of nitrate in groundwater typically reflect contamination by human activities. Common sources are leaking septic systems, animal manure, and inorganic fertilizers. The vulnerability of an aquifer to nitrate contamination depends on both the amount and length of time nitrogen is on the land or water surface and the ability of the soils and sediments to transmit the water and chemicals.

Several public water suppliers have had elevated nitrate or nitrite levels (fig. 3). If a point source for the contamination is found, removal of the source and treatment of the plume is in order. If nitrate levels exceed the MCL for drinking water, non-treatment

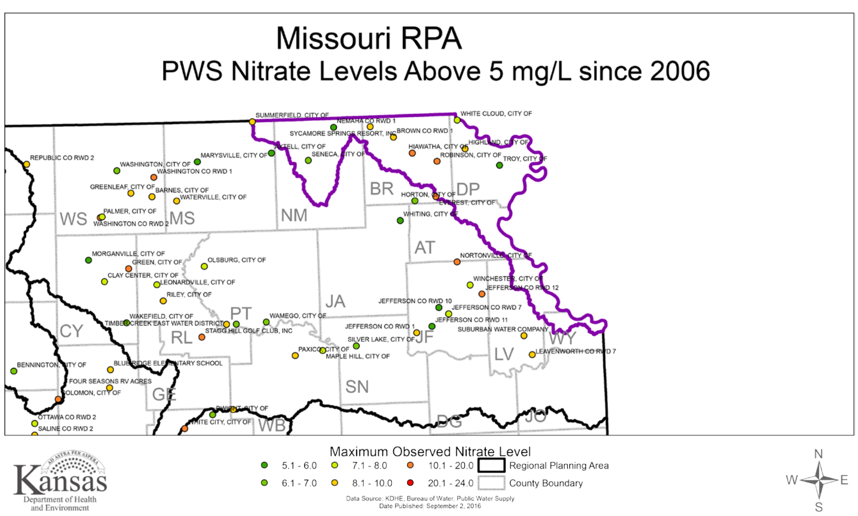


Figure 3. Nitrate levels above 5 mg/L in public water supplies since 2006 (source: KDHE).

options include blending with other wells to get the overall level below 10 mg/L or abandoning the well and finding a new source. Common treatment options are ion exchange or reverse osmosis. Electrodialysis, biological denitrification, and chemical denitrification are also treatment options. Treatment systems are costly (table 1) and can pose a significant financial obligation for smaller, aging communities.

Table 1. Nitrate treatment costs for Kansas municipalities, as of January 2016. Data from the Kansas Department of Health and Environment.

Municipality	Estimated Cost (project not bid)	Actual Cost	Population Served	Project Notes
Hiawatha		$4,900,000	5,079	Ion exchange system
Norwich	$2,260,209.00		487	
Conway Springs	$2,324,310.00		2,831	
Argonia	$2,576,718.00		814	Treatment is for nitrates and arsenic
Beverly		$243,000.00	161	Project was for new wells not treatment
Harper		$1,470,000.00	1,800	Project amount based on population served
St. John		$2,744,597.90	1,295	Project included treatment, wells, and transmission main
Goodland		$5,711,606.85	4,361	Project included transmission mains to facilitate centralized treatment
Kirwin		$218,966.43	211	Point of use project
Anthony		$2,339,433.00	2,254*	
Green		$270,000.00	130*	Pre-manufactured treatment facility (40 GPM)
Lewis	$713,000.00		434*	Pre-manufactured treatment facility (510 GPM)
Everest		$825,000.00	282*	
Sumner Co RWD 5		$3,400,000.00		
Haven	$2,000,000.00		1,233*	

** Population from Kansas Secretary of State, July 2014.*

The Kansas Department of Health and Environment (KDHE) developed a Drinking Water Protection Program to help public water suppliers assess potential and current threats to their source water and develop action plans as needed. Public water suppliers are encouraged to evaluate their source water risks and develop a comprehensive plan to protect their well fields.

Communities with nitrate contamination at levels below the MCL, but with increasing trends, are a priority for KDHE. Under the

Drinking Water Protection Program, KDHE will work with public water suppliers to mitigate growing contamination and avoid building a costly treatment plant. As a municipal well field begins to have elevated nitrate levels, an in-depth investigation would determine likely sources of the nitrate, identify potential pathways, and consider what steps could mitigate further contamination. For example, if a primary source is from fertilization of row crops, best management practices could improve when and how nitrogen-rich fertilizer is applied to fields so that crops take up more of the fertilizer and less leeches into groundwater. KDHE plans to pilot this program in 2018.

Sources

Denne, J. E., Miller, R E., Hathaway, L. R., O'Connor, H., and Johnson, W., 1998, Hydrogeology and geochemistry of glacial deposits in northeast Kansas: Kansas Geological Survey, Bulletin 229, 127 p.

Kansas Water Office, 2014, Regional Planning Areas established by Kansas Water Authority, http://www.kwo.org/about-the-kwo/regional-advisory-committees.

KWO (Kansas Water Office), 2009, Kansas water plan, volume III, http://bit.ly/2vvroJT.

Macfarlane, P.A., Misgna, G.M, and Buddemeier, R.W., 2000, Preliminary analysis of potential ground-water supplies; in, An Atlas of the Kansas High Plains Aquifer: Kansas Geological Survey, Open-File Report 2000-29.

Missouri Regional Advisory Committee, 2016, Missouri regional goals action plan: Kansas Water Authority. http://bit.ly/2utDYK4

Contacts

Cathy Tucker Vogel
Public Water Supply Section Chief
Kansas Department of Health and Environment.
785.368.7130
cathy.tucker-vogel@ks.gov

Don Whittemore
Emeritus Senior Scientific Fellow
Kansas Geological Survey
785.864.2118
donwhitt@kgs.ku.edu

Muscotah Marsh

Despite Kansas' reputation as a dry expanse of prairie and agricultural fields, naturally occurring wetlands play an important role in the function of the state's watersheds. These areas where water covers the soil or is near the surface for all or much of the year, including during the growing season, filter out sediment, supply fresh water, slow flood waters, recharge groundwater, and host a high level of biodiversity, both aquatic and terrestrial. Two Kansas wetlands—Cheyenne Bottoms and Quivira National Wildlife Refuge—are listed as wetlands of international importance.

Kansas has lost nearly 50% of pre-settlement wetlands. Scientists estimate 435,000 natural wetland acres remain in the state (Kenny, 1996). The Muscotah Marsh, on the Delaware River floodplain about 1.5 miles south of Muscotah, Kansas, (fig. 1) represents a rare type of wetland in Kansas. It is one of only several fens, a wetland generally fed by groundwater that, despite peat deposits, supports more plant life than related but nutrient-poor bogs. A marsh is a wetland that is nutrient rich and supports a variety of reeds and grasses.

A few acres in size and located on privately owned land, the Muscotah Marsh was described as "totally different from any other area in the state" (Horr and McGregor, 1948, p. 197). The raised marsh, up to 7 feet above adjacent land, measures 15 to 54 yards in width and 274 yards in length. At the time of Horr and McGregor's study, a semi-permanent swampy region surrounded the marsh, which owed its existence to an artesian spring (groundwater that flows to the surface under its own pressure). The marsh contains small pools of water (fig. 2) and consists of mounds of very black soil rich in organic material that extends down 25 feet or more. Walking on it is springy. "Upon jumping up and down it is observed that an area extending several feet in every direction is made to shake and quiver; water spurts out of crayfish holes…There is little doubt that water is constantly moving slowly upward through the mounds…" (Horr

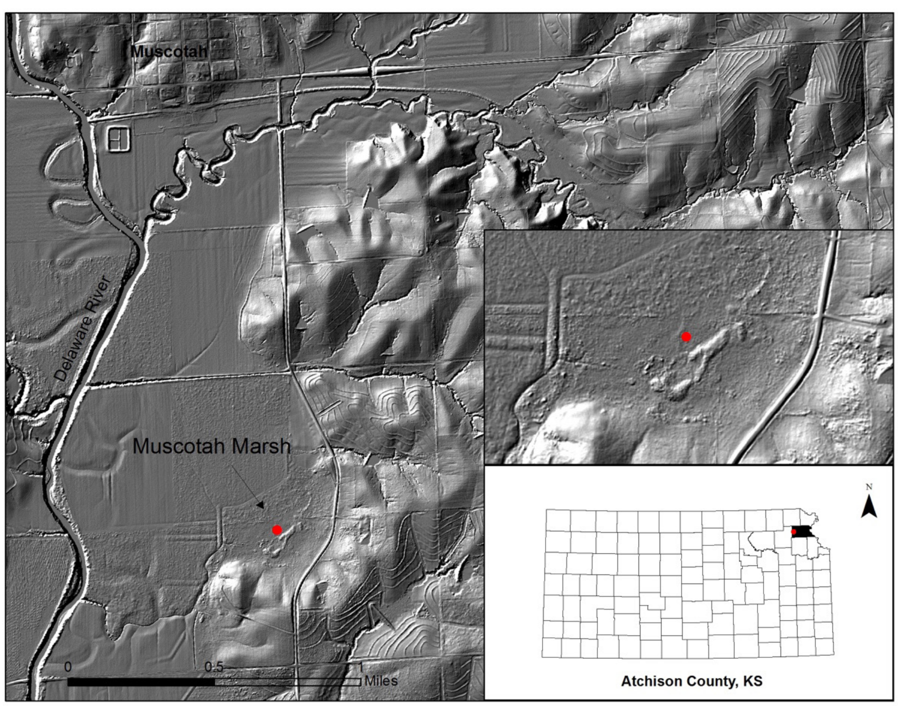


Figure 1. Muscotah Marsh seen from LiDAR (source: Frank Norman).

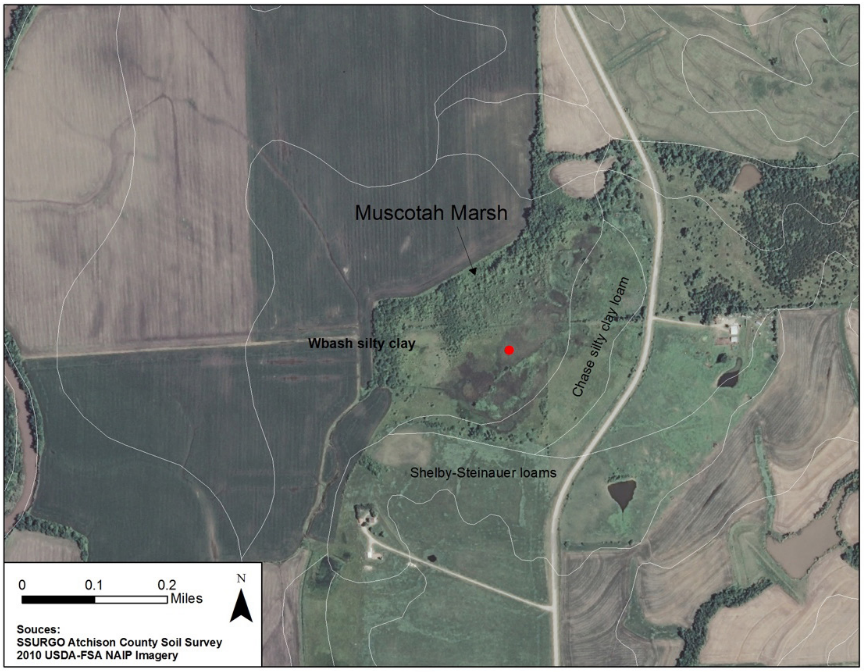


Figure 2. Muscotah Marsh with soils classification (source: Frank Norman).

and McGregor, 1948, p. 198). Sedges dominate the vegetation on the marsh, with grasses bordering the wetter areas.

The Muscotah Marsh is scientifically valuable in that it provides a continuous Holocene pollen record of the eastern Great Plains. Pollen from a core collected in 2000 at the marsh confirmed that before European settlement, the Great Plains was a tallgrass prairie (Baker at al., 2006). Unfortunately, water continually moves through the marsh system, so the pollen was mixed throughout the core and not stratigraphically sequenced, or layered. However, conditions in the marsh have resulted in excellent preservation of plant fossils (Mandel, personal communication, 2017).

Sources

Baker, R. G., Fredlund, G. G., Mandel, R., Bettis, E. A., III, and Moss, P., 2006, Late Quaternary paleoecology of the eastern Great Plains; in, Guidebook of the 18th Biennial Meeting of the American Quaternary Association, R. Mandel, Ed.: Kansas Geological Survey, Technical Series 21, 146 p.

Horr, W. H., and McGregor, R. L., 1948, A raised marsh near Muscotah, Kansas: Transactions of Kansas Academy of Science, v. 51, no. 2, p. 197–200.

Kenny, J., 1996, Kansas wetland resources; in, National Water Summary On Wetland Resources, compiled by J. Fretwell, J. Williams, and P. Redman: U.S. Geological Survey, Water Supply Paper 2425, 431 p. http://bit.ly/2vn2fV8

Contacts

Rolfe Mandel
Director
Kansas Geological Survey
785-864-2171
mandel@kgs.ku.edu

Frank J. Norman
Senior Ecologist, Professional Wetland Scientist
Norman Ecological Consulting, LLC
785-691-9748
Fjnorman52@gmail.com
www.normanecological.com