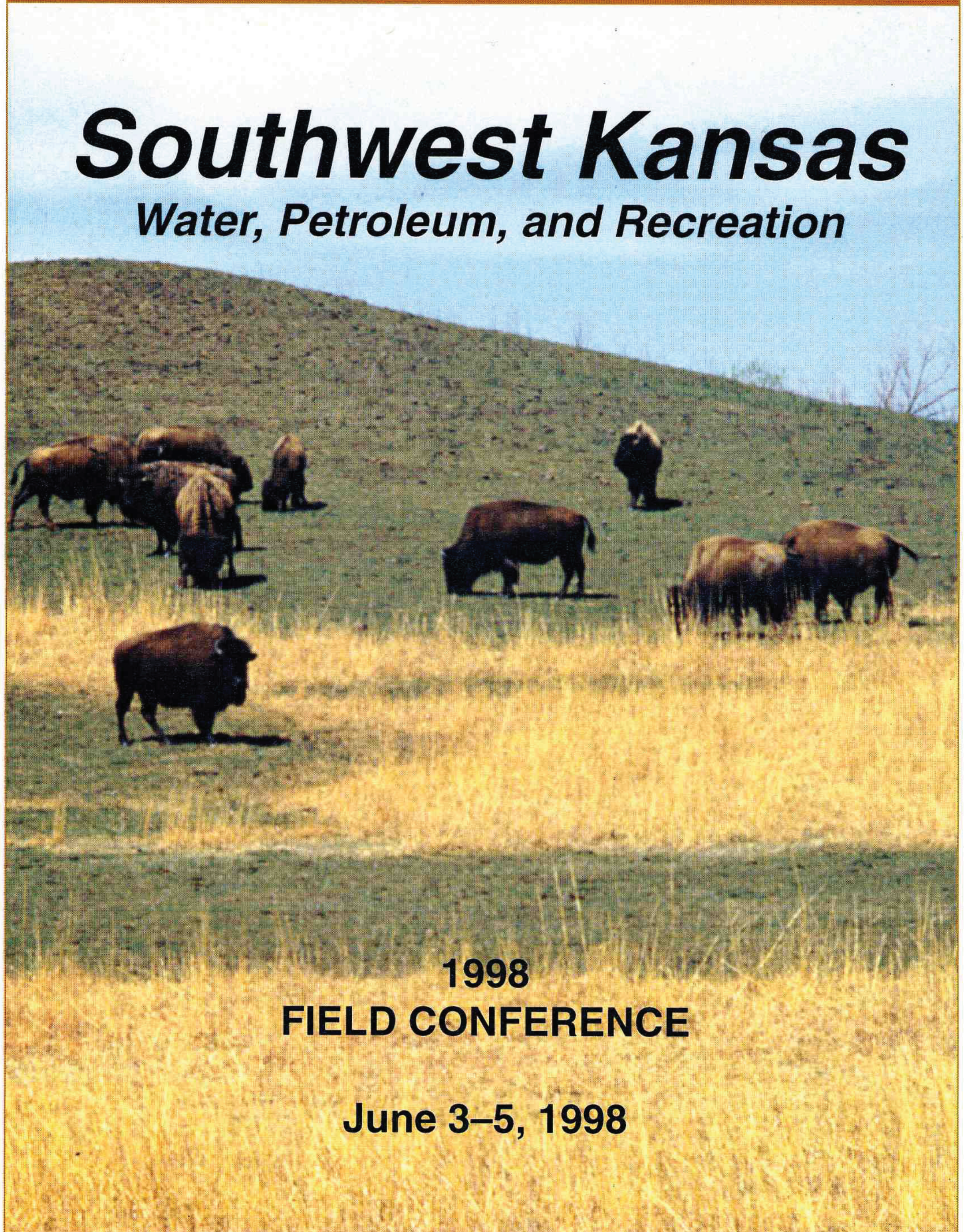
Kansas Earth Resources Field Project

Southwest Kansas

Water, Petroleum, and Recreation



1998
FIELD CONFERENCE

June 3–5, 1998

Sponsored by Kansas Geological Survey
Kansas Corporation Commission, Kansas Department of Agriculture,
and Kansas Department of Wildlife and Parks

KANSAS EARTH RESOURCES FIELD PROJECT

FIELD GUIDE

1998 FIELD CONFERENCE

Southwest Kansas

Water, Petroleum, and Recreation

June 3-5, 1998

Edited by

Robert S. Sawin
and
Rex C. Buchanan

This project is operated by the Kansas Geological Survey and funded, in part, by the Kansas Department of Agriculture, Kansas Corporation Commission, and Kansas Department of Wildlife and Parks.

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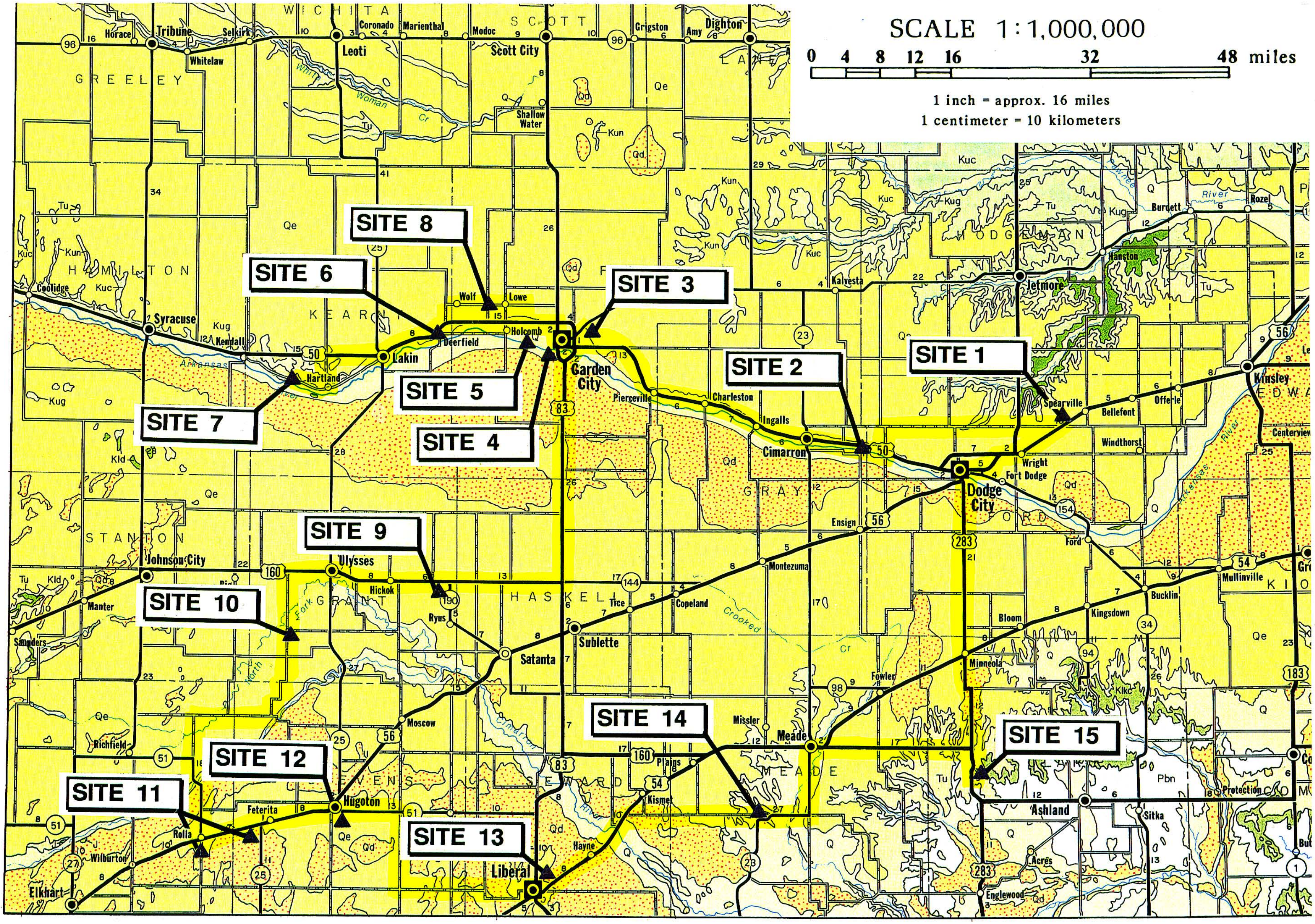
1998 Field Conference ***SOUTHWEST KANSAS - Water, Petroleum, and Recreation***



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KANSAS EARTH RESOURCES FIELD PROJECT

Southwest Kansas

Water, Petroleum, and Recreation

1998 FIELD CONFERENCE

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PARTICIPANTS LIST

Name	Title	Affiliation	Business Address
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BIOGRAPHICAL INFORMATION

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Senator, 3rd District
Affiliation
Kansas Senate
Address and Telephone
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Current Responsibilities
State Senate.
Experience
Mutual Savings Association.
Education
Kansas State University - BS, 1952

Christine Downey
Title
Senator, 31st District
Affiliation
Kansas Senate
Address and Telephone
10320 N. Wheat State Rd.
Inman, KS 67546
316/543-2628
Current Responsibilities
Agriculture Committee; Adjunct Professor, Bethel College; Agribusiness Partner.
Experience
Public School Teacher, 20 years.
Education
Wichita State University - BA 1980
Wichita State University - MEd 1986

Vaughn L. Flora
Title
Representative, 57th District
Affiliation
Kansas House of Representatives
Address and Telephone
431 Woodland Ave.
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785/232-5147
Current Responsibilities
House Environment Committee.
Experience
President, Non-profit Affordable Housing Corp.; CEO Topeka City Homes; Farmer.
Education
Kansas State University - BS, 1968

Joann Flower
Title
Representative, 47th District
Affiliation
Kansas House of Representatives
Address and Telephone
P.O. Box 97
Oskaloosa, KS 66066
785/863-2918
Current Responsibilities
Chair, House Agriculture Committee.
Experience
Legislature, 10 years.
Education
Johns Hopkins University - BS, 1958

Steve Frost
Title
Executive Director
Affiliation
Southwest Kansas Groundwater Management District
Address and Telephone
409 Campus Dr., Suite 106
Garden City, KS 67846
316/275-7147
Current Responsibilities
Manager, Groundwater Management District No. 3.
Experience
District No. 3, 13 years; Division of Water Resources, 5 years.
Education
University of Colorado - BA, 1979

Raney Gilliland
Title
Principal Analyst
Affiliation
Kansas Legislative Research Department
Address and Telephone
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785/296-3181
Current Responsibilities
Staff - House and Senate Agriculture Committees; House Environment Committee; and Senate Energy and Natural Resources for the Kansas Legislature.
Experience
Legislative Research, 18 years.

Education
Kansas State University - BS, 1975
Kansas State University - MS, 1979

Dave Heinemann
Title
Executive Director
Affiliation
Kansas Corporation Commission
Address and Telephone
1500 SW Arrowhead Rd.
Topeka, KS 66604
785/271-3162
Current Responsibilities
Executive Director, KCC.
Experience
State Representative, 27 years; General Counsel, KCC, 2 years.
Education
Augustana College - BA, 1967
University of Kansas - 1967-68
Washburn Law School - JD, 1973

Blake Henning
Title
Resource Administrator
Affiliation
State Conservation Commission
Address and Telephone
109 SW 9th St., Suite 500
Topeka, KS 66612
785/296-3600
Current Responsibilities
Assistant to the Director; Manage costshare programs and policies; Assist Conservation and Watershed Districts.
Experience
Kansas Water Office, 1.5 years; State Conservation Commission, 5 years; State of Nebraska; State of Wyoming.
Education
University of Nebraska - BS, 1987
Kansas State University - MS, 1991

Carl Holmes
Title
Representative, 125th District
Affiliation
Kansas House of Representatives
Address and Telephone
P.O. Box 2288
Liberal, KS 67905
316/624-7361
Current Responsibilities
Chairman, Appropriations Subcommittee.
Experience
Chairman, House Energy & Natural Resources Committee.
Education
Colorado State University - BS, 1962

Becky Hutchins
Title
Representative, 50th District
Affiliation
Kansas House of Representatives
Address and Telephone
700 Wyoming
Holton, KS 66436
913/364-2612
Current Responsibilities
House Agriculture Committee; Environment Committee.
Experience
Second term in Kansas House of Representatives, 50th District.
Education
Washburn University - BA, 1985

Dick Koerth
Title
Assistant Secretary for Administration
Affiliation
Kansas Department of Wildlife and Parks
Address and Telephone
Room 502 N. Landon
State Office Building
900 SW Jackson
Topeka, KS 66612
785/296-2281
Current Responsibilities
Administrative affairs of KDWP include accounting, budgeting, personnel, engineering, and licensing.
Experience
Kansas Division of the Budget, 1972-1989.
Education
University of Kansas - BA, 1971
University of Kansas - MPA, 1973

Wayne Lebsack
Title
President
Affiliation
Lebsack Oil Production Inc.
Address and Telephone
P.O. Box 489
Hays, KS 67601
316/938-2396

Current Responsibilities
Direct and manage oil and gas exploration and development.
Experience
Oil and gas exploration; Ground-water exploration and pollution research.
Education
Colorado School of Mines - Geol. Eng., 1949
Colorado School of Mines - Geol. Eng., 1951
Colorado School of Mines - 2 years grad. studies

Al LeDoux
Title
Director
Affiliation
Kansas Water Office
Address and Telephone
109 SW 9th, Suite 300
Topeka, KS 66612-1249
913/296-3185
Current Responsibilities
Plan, market, develop, implement, and evaluate policies/programs for current and future water needs.
Experience
Sr. Govt. Affairs Liaison, Gov. Graves; Adm. Assist. to Maj. Leader, KS. Sen., Lt. Gov. Frahm; Legis. Liaison and Ag. Advisor, Gov. Hayden; Admin. Assist. to the Maj. Leader, KS. House; Farmer and Stockman.
Education
Baker University - BA, 1969
University of Kansas - Graduate School

Rob Manes
Title
Assistant Secretary for Operations
Affiliation
Kansas Department of Wildlife and Parks
Address and Telephone
512 SE 25th Ave.
Pratt, KS 67124
316/672-5911
Current Responsibilities
Oversee field operations: 24 parks, 86 public wildlife areas and state fishing lakes; law enforcement activities.
Experience
Department of Wildlife and Parks, 12 years (Wildlife Education Coordinator, Environmental Education Project Leader, Parks and Public Land Assistant Director, Special Assistant.
Education
Kansas State University - BS, 1982
Friends University - MS, 1993

Laura McClure
Title
Representative, 119th District
Affiliation
House Environment Committee
Address and Telephone
202 South 4th
Osborne, KS 67473
785/296-7680
Current Responsibilities
State Representative, 119th District.
Experience
Owner/operator flower and antiques shop; Nutrition site manager, Beloit Senior Center; Grassroots Lobbyist.
Education
Mankato High School - 1968

Gary Mitchell
Title
Secretary
Affiliation
Kansas Department of Health and Environment
Address and Telephone
900 SW Jackson, Suite 620
Topeka, KS 66612-1290
785/296-0461
Current Responsibilities
Governor appointee to Cabinet Agency with responsibility for protection of public health and the environment.
Experience
Chief of Staff, Committee on Agriculture, U.S. House of Representatives; State Director for Congressman Pat Roberts; Assistant to Congressman Pat Roberts in Washington, D.C.
Education
Kansas State University - BS, 1978

Steve Morris
Title
Senator, 39th District
Affiliation
Kansas Senate
Address and Telephone
600 Trindle
Hugoton, KS 67951
316/544-2084
Current Responsibilities
Kansas Senate; Energy and Natural Resources Committee, Vice Chair; Agriculture Committee, Chair.
Experience
Kansas State Senate, 5 years; Farming operation.
Education
Kansas State University - BS, 1969

Matt Scherer
Title
Program Manager
Affiliation
Division of Water Resources, Kansas Department of Agriculture
Address and Telephone
901 S. Kansas Ave.
Topeka, KS 66612
785/296-3705
Current Responsibilities
Manager, Water Management Services Program, Division of Water Resources, dealing with long-term water-management issues, interstate-water issues, and support.
Experience
10 years with DWR, past 3 as Basin Team leader; 2 years as Water Resource planner in KWO; several years with SCS (now NRCS).
Education
Kansas State University - BS, 1979
Kansas State University - MS, 1983

Eugene Shore
Title
Representative, 124th District
Affiliation
Kansas House of Representatives
Address and Telephone
6788 E Rd 24
Johnson, KS 67855
316/492-2449
Current Responsibilities
Farm Owner/Operator, State Representative.
Experience
Farm Owner/Operator; Groundwater Management District #3; Kansas Water Authority; SW Natural Gas Consumers.
Education
Panhandle State University - BS, 1958

Mary Jane Stattelman
Title
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Affiliation
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Current Responsibilities
Executive Director, KACEE.
Experience
Special Assistant for Environment and Natural Resources to Governor Mike Hayden, 2 years; Acting Secretary, Kansas Department of Wildlife and Parks, 1987 and 1995; Kansas State and Extension Forestry, Kansas State University, 33 years; U.S. Forest Service, 4 years.
Education
University of Missouri - BS, 1957
Kansas State University - MS, 1968

Mary Torrence
Title
Assistant Revisor of Statutes
Affiliation
Revisor of Statutes Office
Address and Telephone
300 SW 10th, Suite 322S
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Current Responsibilities
Legislative staff; drafting legislation; and legal advisor.
Experience
Revisor of Statutes Office, 22 years.
Education
University of Kansas - BA, 1971
University of Kansas - JD, 1974

Jack Walker
Title
Northwest Kansas Regional Representative
Affiliation
Kansas Earth Science Teachers Association
Address and Telephone
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Goodland, KS 67735
785/899-5656
Current Responsibilities
Farmer, Cattleman, Science Teacher.
Experience
Science teacher, 30 years; Farmer.
Education
Hutchinson Community College - AA, 1961
Fort Hays State University - BS, 1966
Emporia State University - MS, 1975

Sid Warner

Title

Managing General Partner

Affiliation

Warner Ranches, L.P.; Kansas Board of Regents

Address and Telephone

P.O. Box 309
Cimarron, KS 67835
316/855-2282

Current Responsibilities

Managing General Partner of Warner Ranches, L.P.

Experience

Farming, Ranching, Insurance, Commercial cattle feeding.

Education

Kansas State University - BS, 1956

David Williams

Title

Supervisor of Production/Geologist

Affiliation

Kansas Corporation Commission

Address and Telephone

130 S. Market #2078
Wichita, KS 67202
316/337-6218

Current Responsibilities

Production supervisor for regulation - permits, completions, prorations, plugging, etc.

Experience

KCC, 1989-present; Consulting Petroleum Geologist/Operator, 10 years; Adjunct Instructor; Exploration/Exploitation Geologist.

Education

Fort Hays State University - BS, 1974

Mike Zamrzla

Title

Staff member

Affiliation

Office of Congressman Jerry Moran

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203 Davis Hall
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Fort Hays State University
Hays, KS 67601-0249
785/628-6247

Current Responsibilities

Assist Congressman Moran, constituent services.

Experience

Campaign Manager for Rep. Jeff Peterson; Assistant Residence Life Coordinator, K-State.

Education

Kansas State University - BS, 1995
Kansas State University - MS, 1997

KANSAS GEOLOGICAL SURVEY STAFF

Lee Gerhard
Title
Director and State Geologist
Affiliation
Kansas Geological Survey
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Current Responsibilities
Director of administration and geologic research at the Kansas Geological Survey.
Experience
Kansas Geological Survey, 9 years; Colorado School of Mines, 5 years; North Dakota Geological Survey, 6 years; W. Indies Lab., Fairleigh Dickinson Univ., 3 years; Univ. of Southern Colorado, 6 years; Sinclair, 2 years; Consultant and Independent Petroleum Geologist.
Education
Syracuse University - BS, 1958
University of Kansas - MS, 1961
University of Kansas - PhD, 1964

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Title
Associate Director
Affiliation
Public Outreach, Kansas Geological Survey
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Current Responsibilities
Supervise publication and public outreach activities, media relations, and non-technical communications.
Experience
Kansas Geological Survey, 17 years; University-Industry Research, University of Wisconsin, 3 years; Salina Journal, 4 years.
Education
Kansas Wesleyan University - BA, 1975
University of Wisconsin-Madison - MA, 1978
University of Wisconsin-Madison - MS, 1982

Tim Carr
Title
Senior Scientist
Affiliation
Chief, Petroleum Research Section, Kansas Geological Survey
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1930 Constant Ave.
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Current Responsibilities
Chief, Petroleum Research Section; Co-Director, Energy Research Center; Adjunct Professor of Geology.
Experience
Kansas Geological Survey, 6 years; ARCO Oil and Gas Company, 12 years; Petroleum research, exploration, and operations.
Education
University of Wisconsin - BS, 1973
Texas Tech University - MS, 1977
University of Wisconsin - PhD, 1980

Bill Harrison
Title
Deputy Director
Affiliation
Kansas Geological Survey
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Current Responsibilities
Plan and initiate major research programs; Assess scientific quality of current programs; Secretary/Treasurer of the Division of Environmental Geosciences of AAPG.
Experience
Lockheed Martin Idaho Technologies; EG&G Idaho, Inc.; ARCO Exploration & Technology; University of Oklahoma/Oklahoma Geological Survey, Faculty/Staff Geologist
Education
Lamar State College of Technology - BS, 1966
University of Oklahoma - MS, 1968
Louisiana State University - PhD, 1976

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Title
Student Assistant
Affiliation
Kansas Geological Survey
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Current Responsibilities
Student library assistant; Student assistant for Geology Extension.
Experience
Kansas Geological Survey, 3 years.
Education
University of Kansas - BS, 1997
University of Kansas - BA, 1998
University of Cincinnati - MS, Candidate

Jim McCauley
Title
Assistant Scientist
Affiliation
Geologic Investigations Section, Kansas Geological Survey
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Current Responsibilities
Geologic mapping, remote sensing, and public inquiries.
Experience
Kansas Geological Survey, 19 years; KU Remote Sensing Laboratory, 6 years.
Education
University of Kansas - BS, 1970
University of Kansas - MS, 1973
University of Kansas - PhD, 1977

Bob Sawin
Title
Research Assistant
Affiliation
Geology Extension, Publications and Public Affairs Section, Kansas Geological Survey
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Current Responsibilities
Public outreach activities, Kansas Earth Resources Field Project, and public inquiries.
Experience
Kansas Geological Survey, 6 years; Petroleum Geology, 15 years; Engineering Geology, 6 years.
Education
Kansas State University - BS, 1972
Kansas State University - MS, 1977

Don Whittemore
Title
Senior Scientist
Affiliation
Chief, Geohydrology Section, Kansas Geological Survey
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Current Responsibilities
Chief, Geohydrology Section; environmental geochemistry; geochemistry of ground- and surface-water resources.
Experience
Kansas Geological Survey, 8 years; Assistant Professor, Kansas State University, 6 years.
Education
University of New Hampshire - BS, 1966
Pennsylvania State University - PhD, 1973

Southwest Kansas

Water, Petroleum, and Recreation

1998 FIELD CONFERENCE

June 3-5, 1998

Welcome to the 1998 Field Conference, co-sponsored by the Kansas Geological Survey, the Kansas Corporation Commission, the Kansas Department of Wildlife and Parks, and the Kansas Department of Agriculture. Past field conferences have focused on specific natural-resource issues, such as water or energy. Because of the number and magnitude of the issues facing southwestern Kansas, the theme of this year's Field Conference is *Southwest Kansas--Water, Petroleum, and Recreation.*

From the giant Hugoton Natural Gas Area to the water supplies from the Ogallala aquifer, the natural resources of southwestern Kansas make a monumental contribution to the state's economy. At the same time, this area faces concerns about diminishing resources--declining water levels in the Ogallala and dropping gas pressures in the Hugoton. There are concerns about environmental degradation--saline water in the Arkansas River, for example, or the impact of confined livestock feeding operations. Like all of Kansas, this corner of the state faces issues related to outdoor recreation, including access to hunting and fishing, the protection of rare plants and animals, and the preservation and management of state lands.

These issues do not exist in isolation, but rather are related to each other. Declining gas pressures in the Hugoton, for example, have a direct impact on the availability of natural gas to operate irrigation pumps. Drawdowns in the Ogallala aquifer have meant that less surface water is available to sustain the area's streams and lakes, which has a direct impact on the region's flora and fauna. To understand any of these issues, it is necessary to consider them all.

That is why, for the next two-and-a-half days, we will look at the area as an entity, rather than focus on any single concern. We will visit sites that will provide first-hand knowledge of resource production and transportation, such as a oil and gas drilling rig, three-dimensional seismic, and natural gas processing plant. We will see the range of water issues by examining an outcrop of the water-producing Ogallala Formation, following the flow of the troubled Arkansas River, and discussing public water supplies (ranging from a rural water district to Garden City). Throughout the trip we will talk about and visit locations that exemplify recreation and wildlife issues, such as a playa lake, walk-in hunting areas, and a state park.

For the sake of this conference, southwestern Kansas is defined as the 14 counties in the southwestern corner of the state, starting with Hamilton, Kearny, Finney, and Hodgeman in the north; Stanton, Grant, Haskell, Gray, and Ford in the center; and Morton, Stevens, Seward, Meade, and Clark along the southern edge. These counties are tied together by geology, physiography, climate, vegetation, and natural resources. Most of the region is part of the High Plains physiographic province. Much of it is geologically young, covered with sediments washed out onto the High Plains (except for outcrops of much older Permian rocks in Meade and Clark counties, and Cretaceous rocks in parts of Hodgeman, Finney, and Ford counties). This is an arid region; precipitation averages less than 25 inches per year in virtually all of the area, and less than 20 inches per year in much of it. The natural vegetation is mostly short-grass prairie. The region is underlain by the Hugoton Natural Gas Area and the Ogallala aquifer.

About the Kansas Field Conference

The 1998 Field Conference is the fourth of the Survey's annual field conferences. These conferences are designed to serve as more than guided tours. Rather, the sites are selected to demonstrate particular perspectives on an issue, and the program is designed to provide first-hand experience. Local and regional experts in resource development will describe each site and the resource issues related to it. In addition, this comprehensive Field Guide will provide background on the sites and the issues, serving as a handy reference long after the Field Conference is over.

When possible, participants will interact with county, state, and regional officials, environmental groups, and citizens' organizations. This information base will provide participants with new and broader perspectives useful in formulating policies. During the Field Conference, participants are expected to be just that--participants. You are encouraged to make contributions to the discussions, ask questions, and otherwise participate in deliberations. The bus microphone is open to everyone, and everyone is encouraged to contribute.

In the course of this Field Conference, we do not seek to resolve policy or regulatory conflicts. Instead, we are trying to provide opportunities to acquaint decision-makers and policy-makers with resource problems and issues. We want to go beyond merely identifying issues; we want to bring together experts who examine the unique technical, geographical, geological, environmental, social, and economic realities of the region. We want this combination of first-hand experience and interaction among participants to result in a new level of understanding of the state's natural resource issues.

The Kansas Field Conference is an education outreach program of the Kansas Geological Survey, administered through its Geology Extension program. The mission of the Field Conference is to provide educational opportunities to individuals who make and influence policy about earth resources and related social, economic, and environmental issues in Kansas. Earth resources are defined as the mineral, energy, water, and oil resources of the earth. The industries that deal with earth resources include energy, mining, quarrying, and agriculture. The Survey's Geology Extension program is designed to develop materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.

The Kansas Field Conference is modeled after a similar program of national scope, the Energy and Minerals Field Institute, operated by the Colorado School of Mines. The Kansas Geological Survey appreciates the support of Dr. Erling Brostuen, Director of the Energy and Minerals Field Institute, in helping develop the Kansas project.

Kansas Geological Survey

Since 1889, the Kansas Geological Survey has studied and reported on the state's geologic resources and hazards. Today the Survey's mission is to study and provide information about the state's geologic resources and hazards, particularly ground water, oil, natural gas, and other minerals. In many cases, the Survey's work coincides with the state's most pressing natural-resource issues.

The KGS has no regulatory function. By statutory charge, the Survey's role is strictly one of research and reporting. It is a division of the University of Kansas, part of the University's Research and Public Service division. The KGS employs about 70 full-time staff members and about 80 students and grant-funded staff. It is administratively divided into four research sections--geohydrology, mathematical geology, petroleum research, and geologic investigations--and several other sections that provide research support or deal directly with the public. Survey programs can be divided by subject: water, energy, geology, and information dissemination.

Water issues directly affect the life of every Kansan. Water supplies are crucial for domestic and municipal use, and in much of the state's economic activity. Western Kansas agriculture and industry relies heavily on ground water; in eastern Kansas, growing populations and industry use surface water. The Survey's water research and service includes an annual water-level measurement program (in cooperation with the Kansas Department of Agriculture), studies of mineral intrusion in the Big Bend and Equus Beds areas, nitrates in the Solomon River basin and in central Kansas, and studies of water resources in the Dakota aquifer, the Quivira National Wildlife Refuge, Rattlesnake Creek, the Republican River, and the Arkansas River.

Kansas energy production generates more than $2 billion worth of income each year. Because much of the state has long been explored for oil and gas, maintaining that production takes research and information. The Survey studies the state's coal resources, its Mississippian-age petroleum reservoirs, techniques such as high-frequency ground-penetrating radar, and new methods of providing information, such as a digital petroleum atlas. The Survey has recently begun a multi-year study of the resources of the Hugoton Natural Gas Area.

Much of the Survey's work is aimed at producing basic geologic information, which can be applied to a variety of resource and environmental issues. The Survey develops and applies methods to study the subsurface, such as high-resolution seismic reflection, undertakes mapping of the surficial geology of the state's counties, applies statistical analyses to geologic problems and issues, and studies specific resources, such as road and highway materials.

To be useful, geologic information must be disseminated in a form that is most appropriate to the people who need it. The Survey provides information to the general public, to policy makers, to oil and gas explorationists, water specialists, other governmental agencies, and academic specialists. Information is disseminated through a publication sales office, automated mapping, the state's Data Access and Support Center (located at the Survey), a data library, electronic publication, geology extension, and the Survey's Wichita Well Sample Library.

Kansas Geological Survey Staff participating in the 1998 Field Conference:

Lee C. Gerhard, Director and State Geologist

William Harrison, Deputy Director
Rex C. Buchanan, Associate Director, Public Outreach
Tim Carr, Chief, Petroleum Research Section
James R. McCauley, Assistant Scientist, Geologic Investigations Section
Robert S. Sawin, Research Assistant, Geology Extension
Donald O. Whittemore, Chief, Geohydrology Section
Melanie M. Hathaway, Student Assistant, Geology Extension

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Lawrence, KS 66047
785-864-3965
785-864-5317 (fax)

http://www.kgs.ukans.edu

Kansas Department Of Wildlife And Parks

The Kansas Department of Wildlife and Parks is responsible for management of the state's living natural resources. Its mission is to conserve and enhance Kansas' natural heritage, its wildlife, and its habitats. The Department works to assure future generations the benefits of the state's diverse, living resources; provide the public with opportunities for the use and appreciation of the natural resources of Kansas, consistent with the conservation of those resources; inform the public of the status of the natural resources of Kansas to promote understanding and gain assistance in achieving this mission.

The Department's responsibility includes protecting and conserving fish and wildlife and their associated habitats while providing for the wise use of these resources, and providing associated recreational opportunities. The Department is also responsible for providing public outdoor recreation opportunities through the system of state parks, state fishing lakes, wildlife management areas, and recreational boating on all public waters of the state.

In 1987, two state agencies, the Kansas Fish and Game Commission and the Kansas Park and Resources Authority, were combined into a single, cabinet-level agency operated under separate comprehensive planning systems. The Department operates from offices in Pratt, Topeka, five regional offices, and a number of state park and wildlife area offices.

Kansas Dept. of Wildlife and Parks
Operations Office
512 SE 25th Ave.
Pratt, KS 67124-8174
316-672-5911
316-672-6020 (fax)

Secretary's Office
Landon State Office Building
900 SW Jackson, Suite 502
Topeka, KS 66612-1220
785-2962281
785-296-6953 (fax)

http://www.ink.org/public/kdwp/

Kansas Corporation Commission

The mission of the Kansas Corporation Commission (KCC) is to protect the public interest through impartial and efficient resolution of all jurisdictional issues. The agency regulates rates, service, and safety of public utilities, common carriers, motor carriers, and regulates oil and gas production by protecting correlative rights and environmental resources. The KCC's responsibility is to ensure that the public interest is served by customers receiving adequate, reliable service at fair and reasonable rates which will allow the utilities' investors the opportunity to earn an adequate return to ensure the viability and health of the company. This same standard applies to the regulation of common carriers and motor carriers and falls under the KCC Transportation Division.

The KCC consists of three Commissioners appointed by the Governor with the consent of the Senate. By law, no more than two commissioners may be of the same political party. The Chairman of the Commission is elected by the Commission.

The Conservation Division is one of the major divisions of the Kansas Corporation Commission. The oil and gas regulatory activities of the Conservation Division were first enacted by the Kansas Legislature in 1931. In 1935, the Commission was given responsibility for the salt water injection program. The KCC Conservation Division was given sole authority for the regulation of oil and gas activities in 1986, including responsibility for the water and environmental protection aspects.

The Conservation Division's rules and regulations are basically tailored toward protection of fresh and usable water and soil; prevention of waste of oil and gas resources; and protection of correlative rights. The goal of the KCC Conservation Division is to set practical and effective standards that protect the environment without unduly restricting drilling and production of oil and gas.

Organization - In order to enforce rules and regulations, the Conservation Division consists of six operating divisions that are administered from the Conservation Division Office in Wichita, Kansas. The Conservation Division also has district offices in Dodge City, Wichita, Chanute, and Hays.

Commission Information
1500 SW Arrowhead
Topeka, KS 66604-4027
785-271-3100
785-271-3354 (fax)

Conservation Division
Kansas Corporation Commission
130 S. Market, Suite 2078
Wichita, Kansas 67202-3758
316/337-6200

http://www.kcc.state.ks.us/

Kansas Department Of Agriculture

The mission of the Kansas Department of Agriculture is to administer the laws and programs assigned to the Department for the benefit of the people of Kansas. Areas of Department jurisdiction include pesticides; weeds and insect crop pests; meat, poultry, dairy products, eggs, fertilizers, seeds, chemicals, and feeding stuffs; commercial weighing and measuring devices; water resources; and marketing and promotion of Kansas corn, grain sorghum, and soybeans.

The department is organized into divisions of work: administrative and commodity commissions; inspections; agricultural laboratories; plant health; statistics; weights and measures; and water resources.

- Administrative services provides policy, coordination, and management functions for the department. Administrative services consists of the fiscal, personnel, legal, research, information, and telecommunication systems, and includes the office of the Secretary. Also administered are the three Kansas Commodity Commissions for the marketing, promotion, and improvement of corn, soybean, and grain sorghum crops.
- Statistical services collects, analyzes, and disseminates information about Kansas agriculture that is used by other arms of government, producers, agribusiness, consumers, and the general public.
- The plant health division ensures the safe usage of pesticides and protects the agricultural industry by barring the introduction of foreign plant pests and weeds and helping to eradicate noxious weeds already found in the state of Kansas. It provides licensing, certification, and services.
- The division of inspections provides public safety and consumer protection through the regulation of meat, poultry, dairy products, eggs, fertilizers, agricultural seeds, chemicals, and feeding stuffs. A goal is to protect both consumers and the agricultural industry by maintaining a climate of consistency and confidence in the marketplace.
- The weights and measures division inspects large and small scales, scanners, and fuel quality and quantity. Private scale companies and their technicians are trained, certified, and monitored to perform tests of measuring devices. The state maintains a nationally certified laboratory to calibrate weights and measures.
- The division of laboratories provides necessary support to the inspections and plant health divisions by analyzing and testing regulatory samples collected by inspectors. The division also operates a seed laboratory that performs various service analyses on seed samples submitted by farmers, seedsmen, and the agricultural industry.
- The water resources division manages water resources and water structures. The water appropriation segment of the program manages and allocates limited supplies of ground and surface water through a system of permits, reviews, and inspections. The water structures subprogram inspects and regulates dams and stream obstructions. Also administered is the state's participation in four interstate river compacts and the sub-basin resource management plan, which is developed in conjunction with local agencies to create a long-term statewide water usage plan.

Kansas Department of Agriculture
901 S. Kansas Avenue
Topeka, Kansas. 66612-1280
Telephone: 785-296-3558
Fax: 785-296-8389

http://www.ink.org/public/kda/

SCHEDULE & ITINERARY

Wednesday June 3, 1998

7:00 am	Breakfast
7:20 am	Conference Overview *Lee Gerhard*, Director, Kansas Geological Survey
7:45 am	Bus to Site 1
8:10 am	**SITE 1** - Stein Playa - Playa Lakes Joint Venture *Scotty Baugh*, Regional Supervisor, Kansas Dept. of Wildlife and Parks
8:45 am	Bus to Site 2
9:30 ~~9:15~~ am	**SITE 2** - Ogallala Formation *Jim McCauley*, Geologist, Kansas Geological Survey
9:45 ~~9:30~~ am	Bus to Site 3
10:15 am	**SITE 3** - Southwest Research Extension Center - Center Pivot Irrigation *Todd Trooien*, Irrigation Engineer, Kansas State University
11:15 am	Bus to Site 4
11:30 am	**SITE 4** - City of Garden City, Kansas *Bob Halloran*, City Manager, Garden City
12:15 pm	Lunch at the Finnup Center
1:15 pm	Bus to Site 5
1:30 pm	**SITE 5** - Finney County Rural Water District No. 1 *Doyle Koehn*, Chairman of the Board, Finney County Rural Water District No. 1
1:45 pm	Bus to Site 6
2:00 pm	**SITE 6** - City of Deerfield, Kansas *Wayne West*, City Administrator, Deerfield
2:30 pm	Bus to Site 7
3:00 pm	**SITE 7** - Arkansas River and the Amazon Ditch Diversion *Mark Rude*, Water Commissioner, Kansas Dept. of Agriculture, Division of Water Resources *Don Whittemore*, Chief, Geohydrology Section, Kansas Geological Survey
4:00 pm	**SITE 8** - The Garden City Company - Flood Irrigation *David Brenn*, Vice President/General Manager, The Garden City Company
5:30 pm	Bus to Garden City
5:45 pm	Arrive Plaza Inn, Garden City
6:15 pm	Cash Bar
7:00 pm	Dinner at the Plaza Inn
7:30 pm	Evening Session - The Hugoton Natural Gas Area *Tim Carr*, Chief, Petroleum Research Section, Kansas Geological Survey

Stein Playa

The Stein Playa is located three miles southwest of Spearville, Kansas, on Highway 50-56 and one-half mile north, in Ford County. Stein Playa is a shallow, closed basin that naturally collects and holds water during wet periods. The area managed by the Department of Wildlife and Parks totals 117 acres, with around 80 acres of seasonal wetland.

An 80-acre tract on this site was purchased in 1995, and the remaining 36.97 acres were purchased in 1996. Sites are purchased from willing sellers through the Kansas Playa Lakes Plan, which is a portion of the Playa Lakes Joint Venture Plan. This, in turn, is a component of the North American Waterfowl Management Plan. The goal of the Playa Lakes Joint Venture is to provide quality habitat for waterfowl and other wildlife over-wintering in, migrating through, and breeding in the five-state Playa Lakes Region, which includes parts of Texas, New Mexico, Colorado, Oklahoma, and Kansas. The Kansas Playa Lakes Management Plan is a three-part program that utilizes acquisition, leasing, and wetland restoration and enhancement to meet the objectives of the Playa Lakes Joint Venture. The Kansas program is funded by partners as shown in Table 1.

The primary purpose for acquiring this playa is to protect the basin from future habitat loss and to manage it for waterfowl use as a feeding and nesting area, primarily during migration periods. A secondary purpose is for public hunting and wildlife observation.

The area will be managed as a natural playa, meaning water will be present only as weather patterns permit. It is anticipated the playa will be dry around 50 percent of the time. Even when dry, it will provide important habitat for wildlife. During the 1997 waterfowl season, hunters were allowed to utilize the area for half-day hunts early and late in the season. During the rest of the year, the area was managed as a wildlife refuge.

The Stein Playa provides important habitat for ducks, geese, coot, grebes, pelicans, sandhill cranes, shorebirds, pheasants, songbirds, and many other wildlife species.

Resource Contact

Scotty Baugh
Fisheries/Wildlife Supervisor
Kansas Dept. of Wildlife and Parks
1001 McArtor Road
Dodge City, KS 67801-6024
316/227-8609
FAX 316/227-8600

Table 1. Playa Lakes Joint Venture Partnership

$100,000	North American Wetlands Conservation Council	50%
50,000	Kansas Department of Wildlife and Parks	25%
25,000	Phillips Petroleum	12.5%
25,000	Ducks Unlimited	12.5%
$200,000		100%

Ogallala Formation

The most important source of ground water in western Kansas is, without question, the Ogallala Formation. Water from the Ogallala is used for domestic and industrial purposes, and is the primary source of water for the irrigation that has changed the face of the western part of the state. Water from the Ogallala is the basis for the corn, livestock, and meat-packing industries that now dominant this part of Kansas.

The Ogallala Formation underlies all or parts of eight western states: South Dakota, Nebraska, Wyoming, Colorado, Oklahoma, Texas, New Mexico, and Kansas (see Fig. 1). The formation is named for outcrops near the former cowtown of Ogallala in western Nebraska, and was deposited during the Pliocene Epoch of geologic history, about 2-5 million years ago. The Ogallala is a thick blanket of a variety of rock types that were washed onto the High Plains after the Rocky Mountains to the west were uplifted. Streams flowing eastward quickly lost their energy as they reached the flatter topography and drier climate of the plains. As a result, the streams became less able to carry the heavy sediment load they brought out of the mountains, and began to drop this sediment in the valleys. They became aggrading streams--streams that tend to build up their river beds rather than dig them deeper. These early valleys were filled with sediment and the streams spilled out of their divides, eventually joining other streams that were also filling up their valleys. In time, these streams coalesced and completely filled in the earlier landscape, creating a vast alluvial plain stretching to the east from the Rockies for hundreds of miles.

The Ogallala is mostly composed of the rock fragments weathered from the Rocky Mountains, including igneous and metamorphic rocks that have been rounded and smoothed during their trip across the plains. The size of these fragments ranges from clays to boulders. Some layers of the Ogallala are naturally cemented with calcareous cement and are referred to as "mortar beds." Where one of these mortar beds forms a prominent escarpment it is often called the "caprock." An especially good place to see these mortar beds is at Point of Rocks in the Cimarron National Grasslands or at Lake Scott State Park, where they form the rim of the canyon above Lake Scott. Much of the Ogallala Formation, however, is poorly cemented sand and gravel, which makes it an excellent aquifer where it is saturated by groundwater.

During much of its history, the Ogallala has soaked up the small amounts of precipitation that have fallen and percolated down into it. Recharge rates here are low--one-quarter to one-half inch per year, on average--but with enough time, water can accumulate to saturate several hundred feet of sand and gravel (the thickness of an aquifer that contains water is referred to as its "saturated thickness"). It has also soaked up many of the streams that have flowed across it. In this way, it has become an important water resource and the principal geologic unit in what geologists call the High Plains aquifer.

The Ogallala is found throughout much of the western third of Kansas with outliers occurring as far east as Marion County. In Kansas, it is thickest in the southwestern part of the state, where it reaches 600 feet in thickness. The upper boundary of the Ogallala is often difficult to determine because younger Pleistocene and Recent sediments, with very similar characteristics, overlie the Ogallala. Water does not differentiate between these two ages of sediment either, and moves freely across this time boundary. Thus, these two ages of rocks are said to be in hydrologic connection. The same can be said of the valley fill deposits of modern streams that have cut down into older deposits. All these sediments--Recent, Quaternary, Ogallala, and even some older rocks that underlie the Ogallala--constitute one large hydrologically connected ground-water resource known as the High Plains aquifer (see Fig. 2).

For the most part, water quality in the Ogallala Formation is good. That's because the sands and gravels of the formation have a low solubility and act as a filter to help purify the water. Water quantity, however, is a much larger issue. The bulk of the water pumped from the Ogallala in Kansas is for irrigation. Flood irrigation, or flooding fields through pipes, began in the early 1900s, was common through the 1950s, and is still used today where the ground is flat and particularly conducive to this form of irrigation. In the late 1940s, however, center-pivot systems were developed. These are systems in which large sprinklers move around a field, usually a quarter-section, allowing irrigation in areas of slightly hilly terrain that were not suitable for flood irrigation. Based on these center-pivot systems, irrigation expanded rapidly in the 1950s, 1960s, and 1970s. These irrigation systems require high capacity wells that take several hundred gallons of water per minute from the aquifer.

A 1953 Kansas Geological Survey report on water use from the Ogallala in Sherman County said, "Ground water is being used to some extent for irrigation, and that this use will increase in the future is probable. At the present rate of withdrawal, the danger of seriously depleting the water supply is slight . . ." The report correctly predicted increased development, but misjudged depletion. Rates of withdrawal increased dramatically, and declines in water levels soon became apparent throughout western Kansas. The Division of Water Resources (DWR) of the Kansas Department of Agriculture is the state agency with the primary responsibility for regulating water use within the state, and each year the DWR and the Kansas Geological Survey measure ground-water levels in the High Plains aquifer, measuring approximately 1,500 water wells in western and central Kansas in January. The Survey publishes these water-level change data annually and makes the information available, for each well it measures, over the Survey's home page at (http://magellan.kgs.ukans.edu/WaterLevels/index.html).

These measurements show that declines in the High Plains aquifer in southwestern Kansas have been pronounced. From pre-development to 1997, the total decline has averaged 52.2 feet across the 14 counties of southwestern Kansas. These declines are especially great in parts of Stanton, Grant, Haskell, Stevens, and Finney counties. In areas west of Ulysses, for example, declines of more than 150 feet are fairly common. There are also areas in Grant, Stanton, Morton, Hamilton, and Finney counties where saturated thickness has decreased by more than 50 percent. Because the aquifer originally contained such large amounts of water, substantial reserves of groundwater still remain in places, in spite of the heavy pumping.

References

Buchanan, R., and Buddemeier, R., comp., 1993, Kansas ground water: an introduction to the state's water quantity, quality, and management issues: Kansas Geological Survey, Educational Series 10, 44 p.

Gutentag, E.D., and Weeks, J.B., 1980, Water table in the High Plains aquifer in 1978 in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey, Hydrologic Investigations Atlas HA 642, 1 sheet, scale 1:2,500,000.

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Opie, J., 1993, Ogallala: Water for a dry land: University of Nebraska Press, 412 p.

Woods, J.J., Schloss, J.A., and Macfarlane, P.A., 1997, January 1997 Kansas water levels and data related to water-level changes: Kansas Geological Survey, Technical Series 11, 90 p.

Yoder, S., Buddemeier, R.W., Jayatilake, H., Frost, S., and Coe, D., 1995, Saturated thickness at section centers in the High Plains aquifer: Kansas Geological Survey, Open-file Report 95-18, 8 sheets, scale 1:175,000.

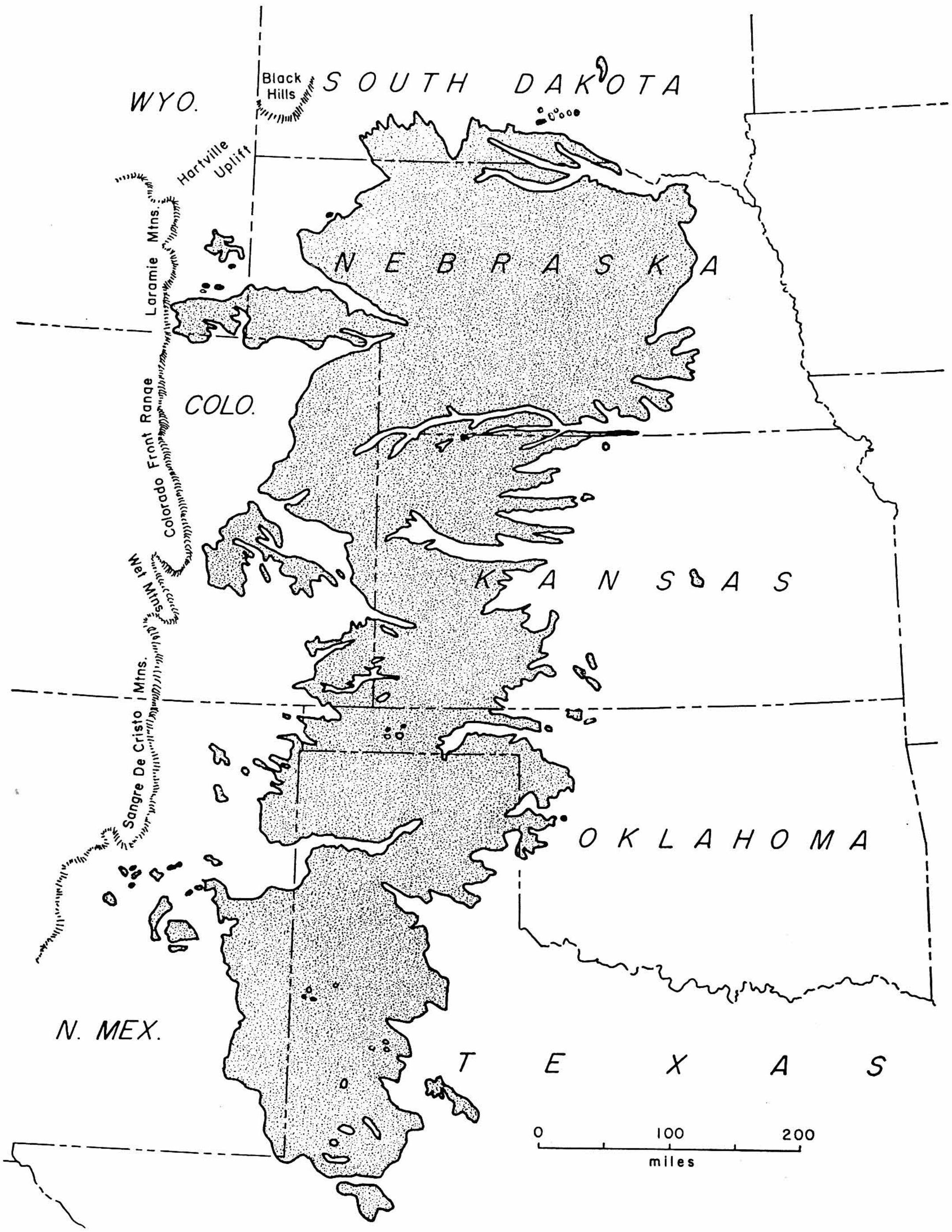

Figure 1. Distribution of the Ogallala Formation in the Great Plains (from Merriam, 1963).

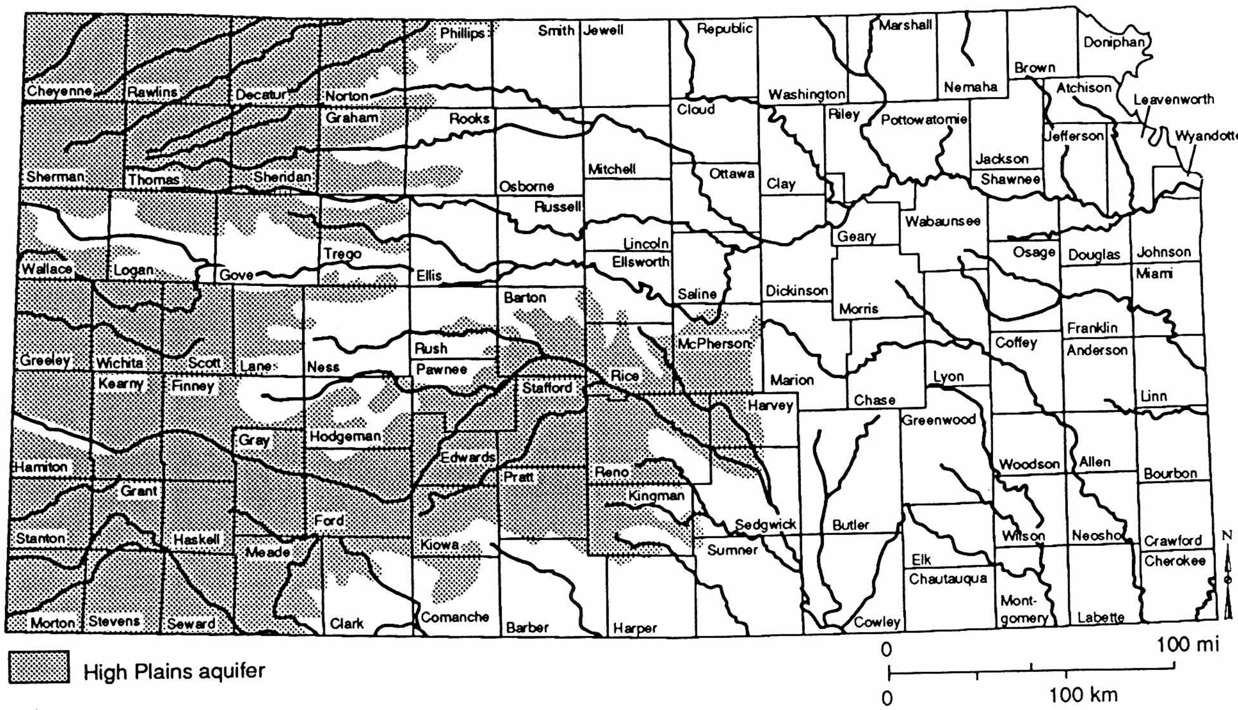

Figure 2. The portion of Kansas underlain by the High Plains aquifer (from Buchanan and Buddemeier, 1993).

Southwest Kansas Groundwater Management District

Groundwater Management Districts (GMDs) are locally managed political subdivisions in Kansas that have been formed to manage ground-water resources. GMD's cooperate with other water-related agencies and are bound by the state's ground-water laws and regulations. The Legislature authorized formation of GMD's by the Groundwater Management District Act of 1972. There are five GMD's in Kansas (Fig. 1): Southwest Kansas Groundwater Management District No. 3, Northwest Kansas Groundwater Management District No. 4, Big Bend Groundwater Management District No. 5, Western Kansas Groundwater Management District No. 1, and Equus Beds Groundwater Management District No. 2.

The Southwest Kansas Groundwater Management District No. 3 is located in the heart of the agri-business/industrial area overlying the High Plains aquifer. Originally incorporated in 1976, the District was organized to conserve ground water resources, prevent economic deterioration, and provide for the stabilization of agriculture by establishing the right of the local users to determine their own destiny with respect to the use of ground water.

The District is legally described as a political subdivision of the State of Kansas. It is politically organized to address water management problems and requirements in conjunction with Federal, State, and Local governments as may be necessary and appropriate for the area. The District maintains a formal statement of Management Programs, which has been approved by the Chief Engineer, Division of Water Resources, Kansas Department of Agriculture. Although a majority of the District's efforts are integrated with the Division of Water Resources, the District has a very distinct function and purpose apart from the Division and other State agencies.

Today more than 11,000 large-capacity wells within the District extract ground water for many purposes, including domestic, irrigation, municipal, industrial, and stockwatering uses. Of the 5.3 million total acres within the District, 1.9 million acres are irrigated. Although the rate of new development has been severely restricted, the extent of aquifer depletion has not. Southwest Kansas now leads the eight-state High Plains aquifer region in the overall rate of depletion. Maps showing the saturated thickness of the High Plains aquifer (1993, 1994, 1995 average), depletion of the aquifer from predevelopment to 1995, and projected depletion of the aquifer at the end of the 21st century follow figure 1.

The High Plains aquifer underlies the entire District. The most important ground water source in the High Plains aquifer is the Ogallala Formation. The overlying undifferentiated Pleistocene (Quaternary) and alluvial (Recent) deposits are very similar in composition to the Ogallala and are also a source of ground water. Locally, the mixture of fine-grained and course-grained beds can create confined conditions with wells completed in separate zones, but overall, the High Plains aquifer responds as a single unconfined aquifer. The High Plains aquifer ranges in saturated thickness from zero to 600 feet. The Dakota aquifer also supplies ground water within the District and is hydraulically connected to the High Plains aquifer in some locations.

General flow within the High Plains aquifer is eastward, although streams and rivers may affect local flow patterns as they become discharge or recharge points for the aquifer. Prior to heavy development, streams were recharged by the aquifer and the connected alluvial deposits. Under these conditions, ground water naturally flowed toward the rivers. Water table declines have reduced water levels so that the flowing river may now act as a recharge point for the underlying sediments. Depth to water in the High Plains aquifer may be less than 50 feet where it is connected to major stream valleys. Away from stream valleys the depth to water increases and may be more than 300 feet.

References

The Groundwater Resources of Southwest Kansas. Southwest Kansas Groundwater Management District brochure.

Water for the 21st Century. Southwest Kansas Groundwater Management District brochure.

Yoder, S., Buddemeier, R.W., Jayatilake, H., Frost, S., and Coe, D., 1995, Saturated thickness at section centers in the High Plains aquifer: Kansas Geological Survey Open-file Report 95-18 (prepared in cooperation with the Southwest Kansas Groundwater Management District), 8 sheets.

Resource Contact

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Groundwater Management Districts of Kansas

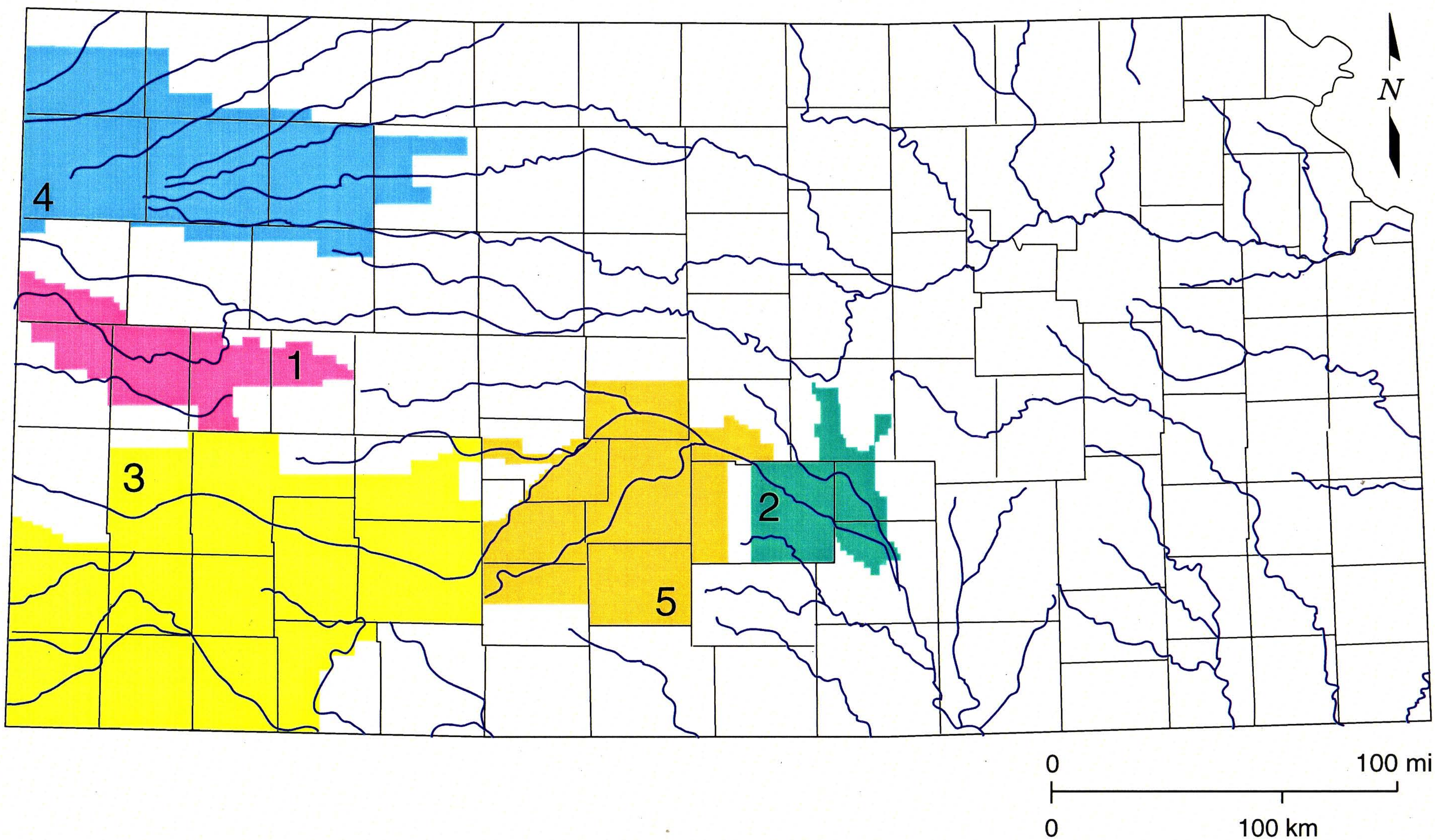
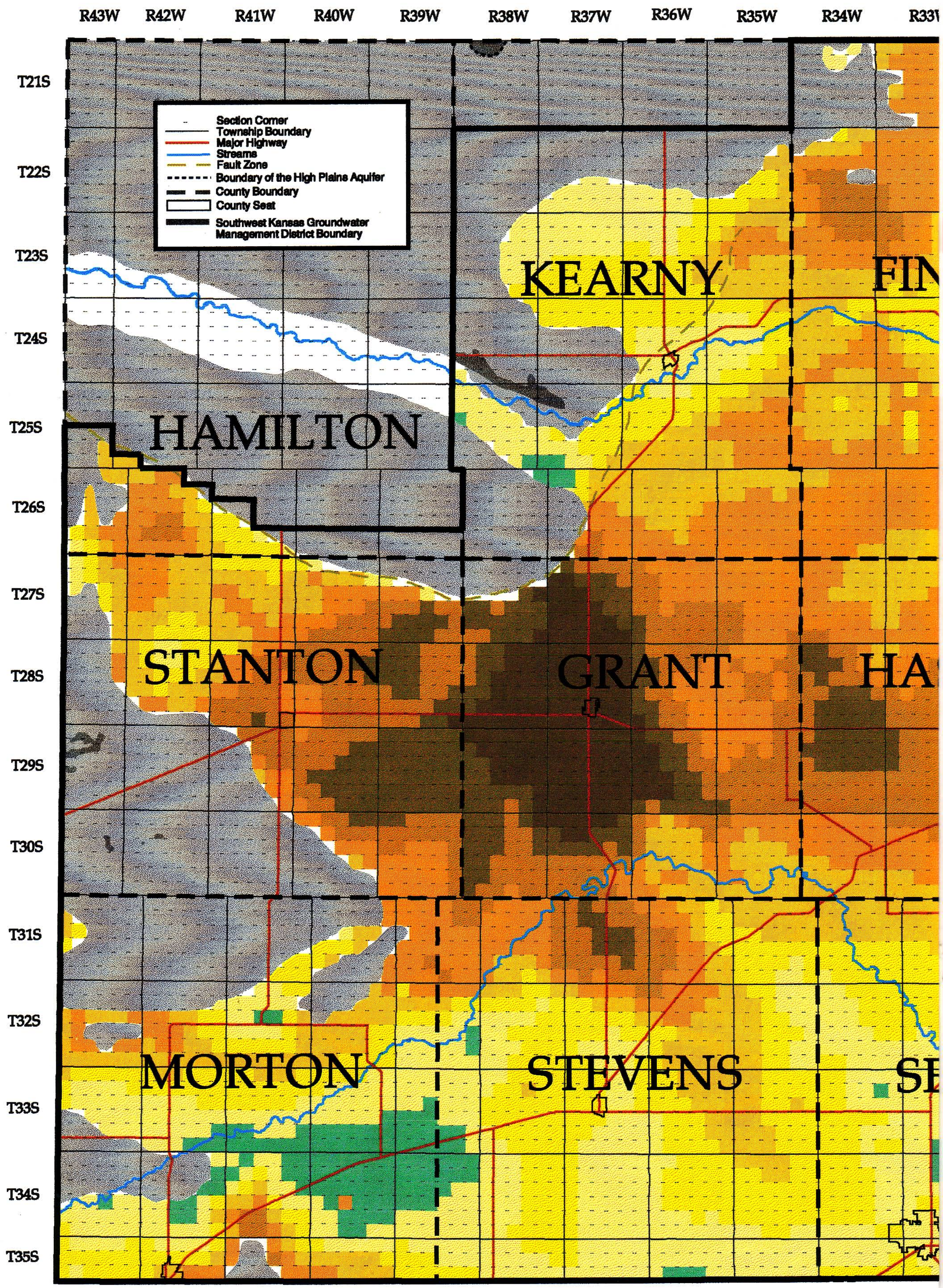


Figure 1. Groundwater Management Districts in Kansas. Southwest Kansas Groundwater Management District No. 3 is shown in yellow.



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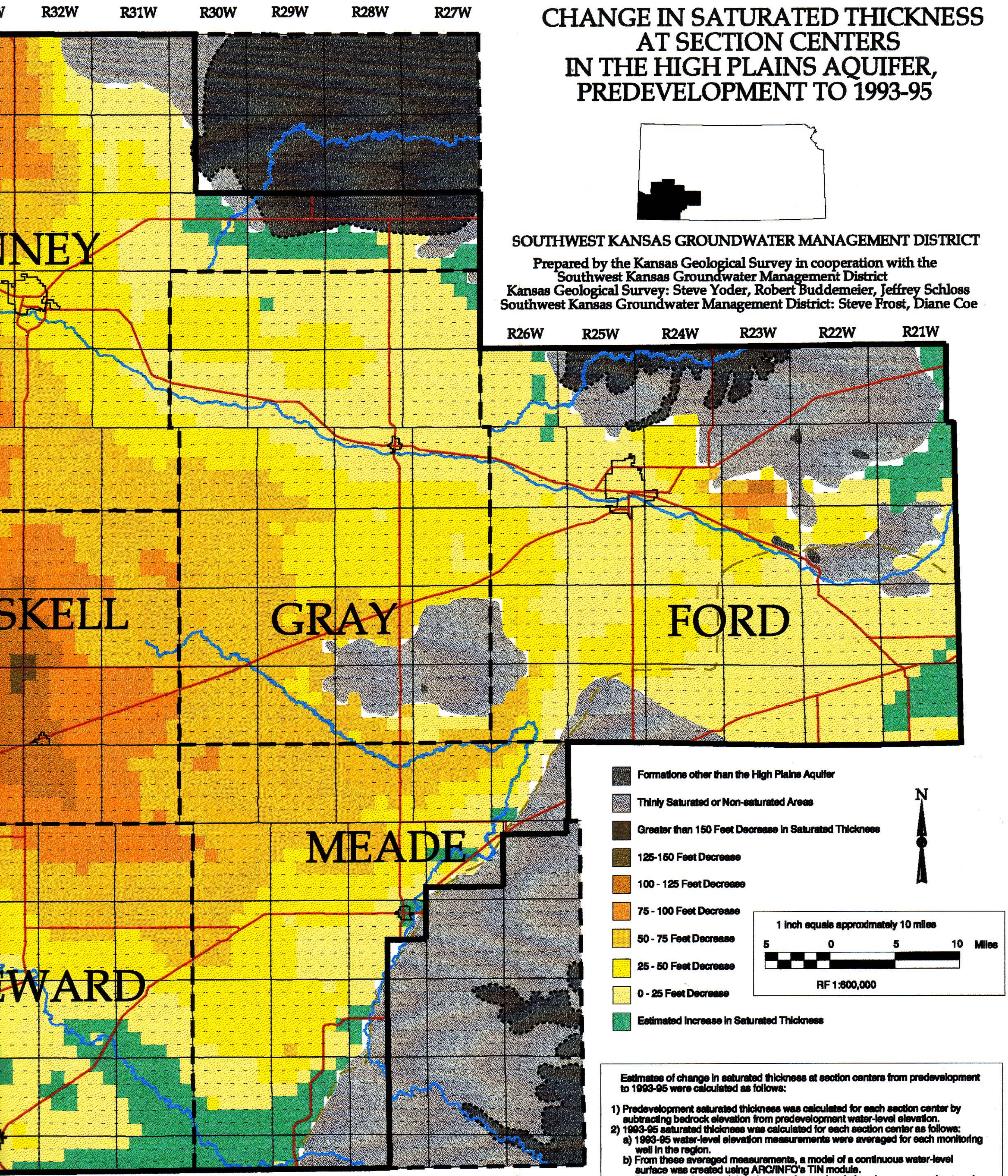
Township Boundary
Major Highway
Streams
Fault Zone
Boundary of the High Plains Aquifer
County Boundary
County Seat
Southwest Kansas Groundwater Management District Boundary
KEARNY
HAMILTON
STANTON
GRANT
MORTON
STEVENS

CHANGE IN SATURATED THICKNESS AT SECTION CENTERS IN THE HIGH PLAINS AQUIFER, PREDEVELOPMENT TO 1993-95

SOUTHWEST KANSAS GROUNDWATER MANAGEMENT DISTRICT

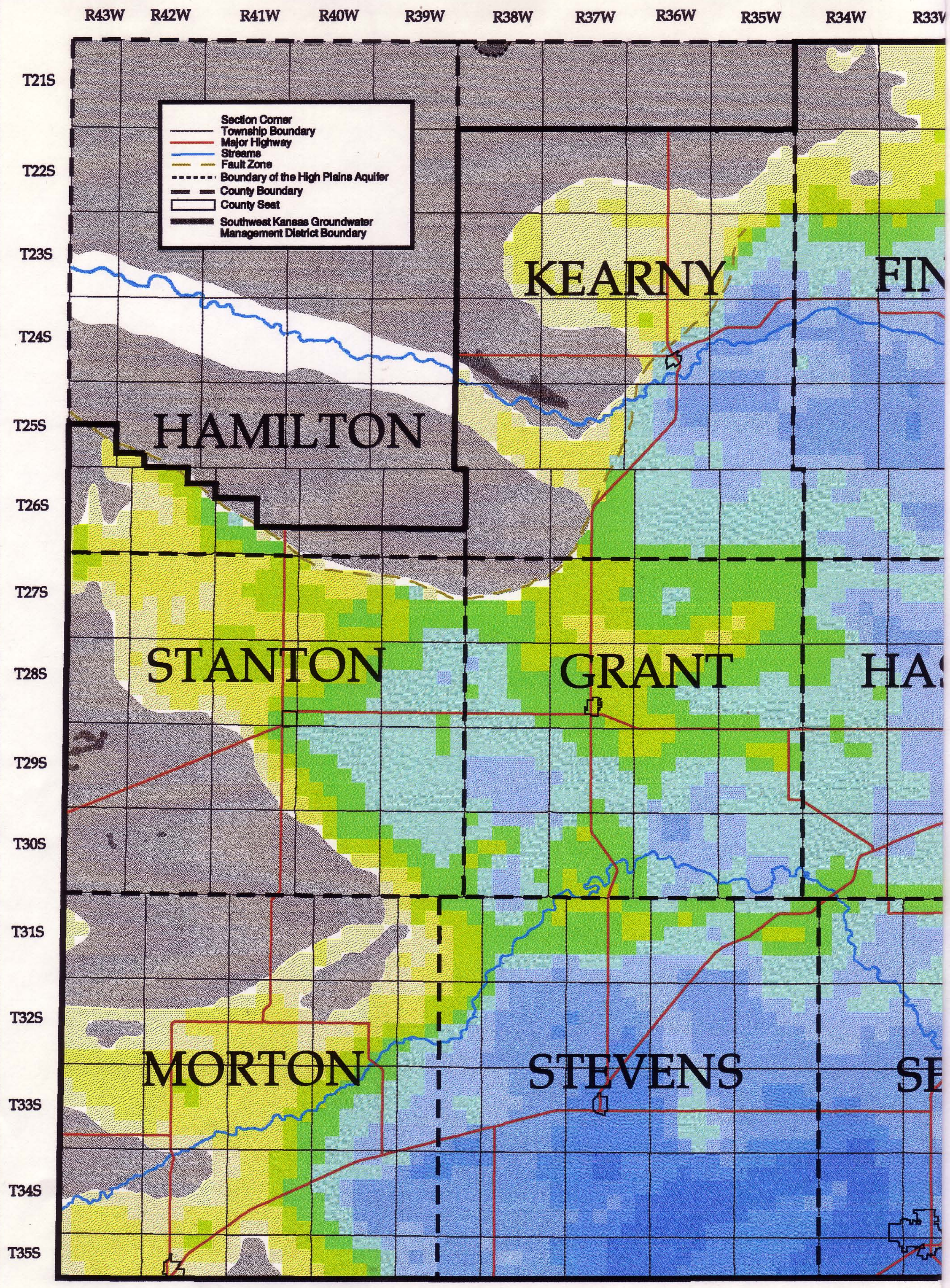
Prepared by the Kansas Geological Survey in cooperation with the Southwest Kansas Groundwater Management District
Kansas Geological Survey: Steve Yoder, Robert Buddemeier, Jeffrey Schloss
Southwest Kansas Groundwater Management District: Steve Frost, Diane Coe



Estimates of change in saturated thickness at section centers from predevelopment to 1993-95 were calculated as follows:

1) Predevelopment saturated thickness was calculated for each section center by subtracting bedrock elevation from predevelopment water-level elevation.
2) 1993-95 saturated thickness was calculated for each section center as follows:
   a) 1993-95 water-level elevation measurements were averaged for each monitoring well in the region.
   b) From these averaged measurements, a model of a continuous water-level surface was created using ARC/INFO's TIN module.
   c) From this surface model, estimates of water-level elevations were made at each section center.
   d) For each section center, bedrock elevation was subtracted from estimated water-level elevation.
3) For each section center, 1993-95 saturated thickness was subtracted from predevelopment saturated thickness.

This map is based upon data from the Ogallala and undifferentiated Quaternary units and, as such, does not represent conditions in other aquifer units (e.g., Dakota, alluvial systems).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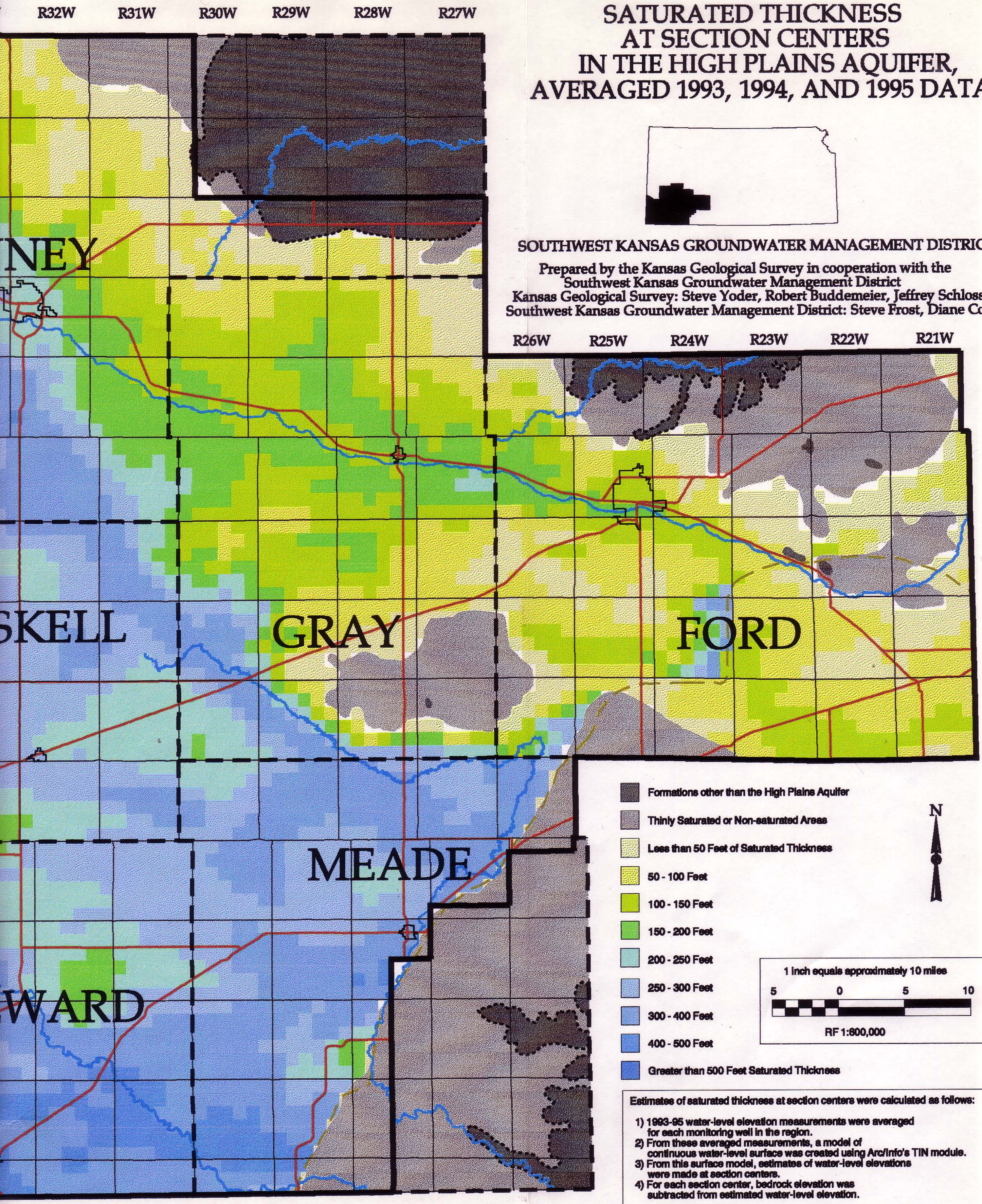
Boundary of the High Plains Aquifer
County Boundary
County Seat
Southwest Kansas Groundwater Management District Boundary
KEARNY
HAMILTON
STANTON
GRANT
MORTON
STEVENS

SATURATED THICKNESS AT SECTION CENTERS IN THE HIGH PLAINS AQUIFER, AVERAGED 1993, 1994, AND 1995 DATA

SOUTHWEST KANSAS GROUNDWATER MANAGEMENT DISTRICT

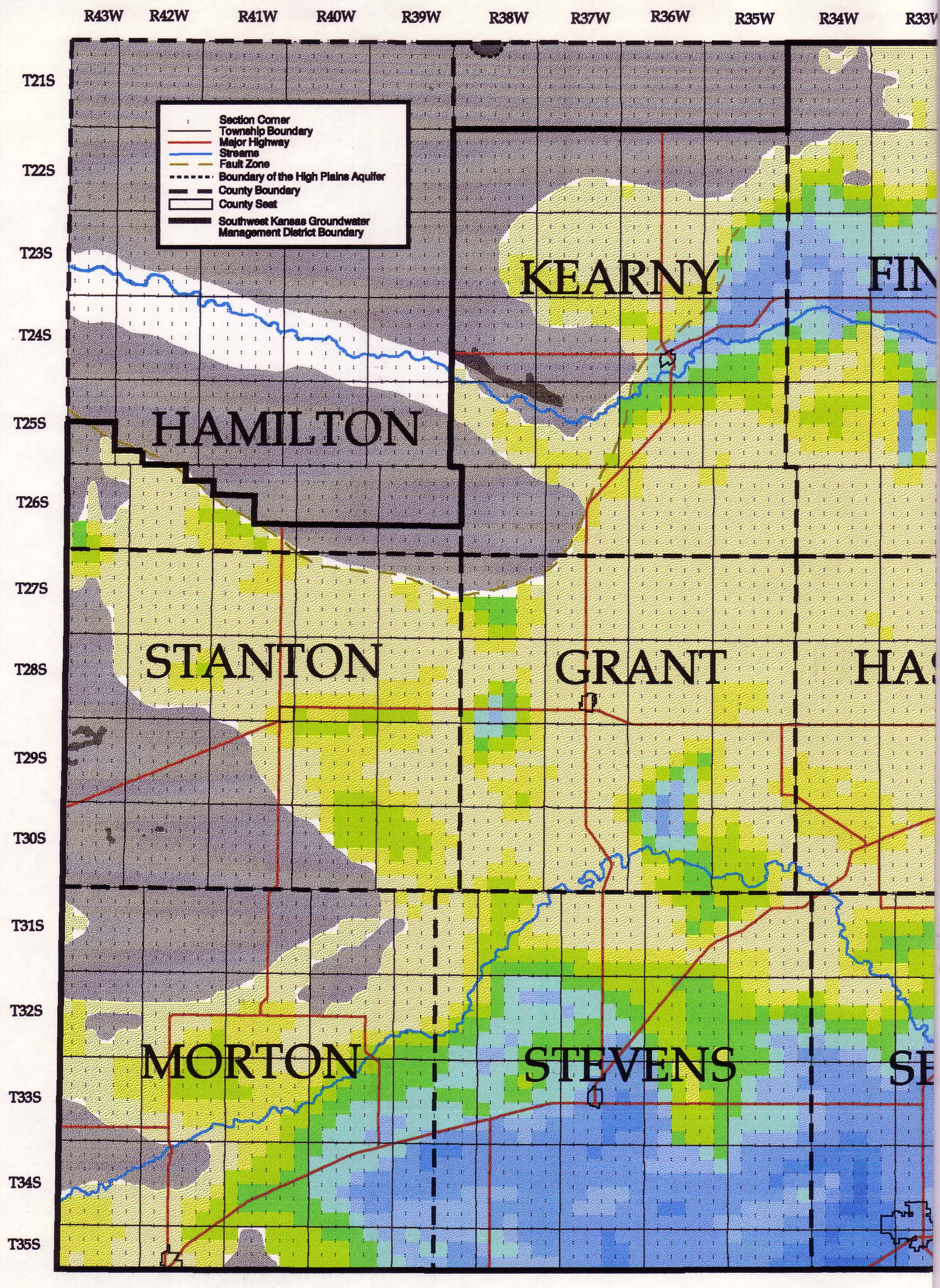
Prepared by the Kansas Geological Survey in cooperation with the Southwest Kansas Groundwater Management District
Kansas Geological Survey: Steve Yoder, Robert Buddemeier, Jeffrey Schloss
Southwest Kansas Groundwater Management District: Steve Frost, Diane Coe



Estimates of saturated thickness at section centers were calculated as follows:

1) 1993-95 water-level elevation measurements were averaged for each monitoring well in the region.
2) From these averaged measurements, a model of continuous water-level surface was created using Arc/Info's TIN module.
3) From this surface model, estimates of water-level elevations were made at section centers.
4) For each section center, bedrock elevation was subtracted from estimated water-level elevation.

This map is based upon data from the Ogallala and undifferentiated Quaternary units and, as such, does not represent conditions in other aquifer units (e.g., Dakota, alluvial systems).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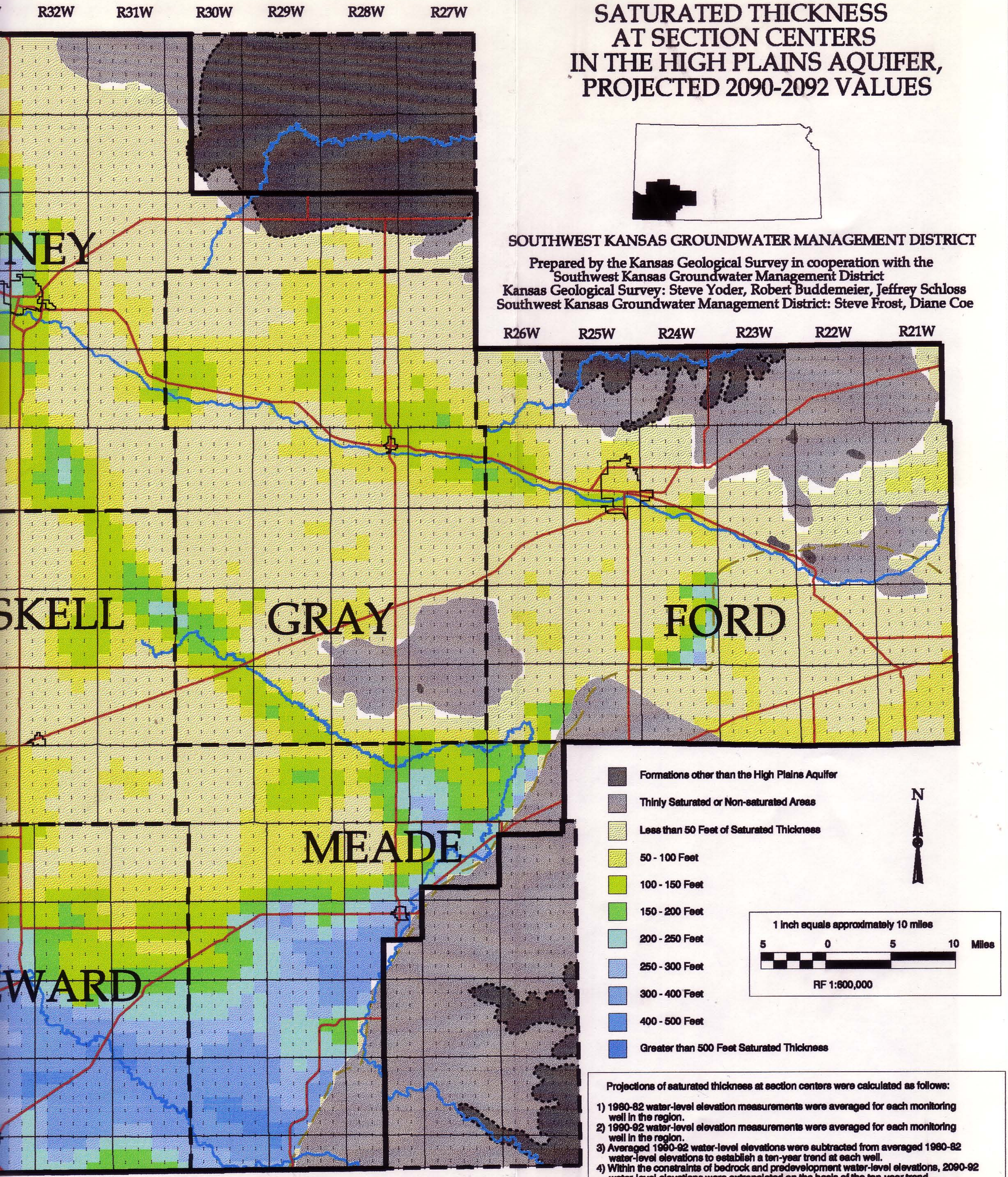
Boundary of the High Plains Aquifer
County Boundary
County Seat
Southwest Kansas Groundwater Management District Boundary
KEARNY
HAMILTON
STANTON
GRANT
MORTON
STEVENS

SATURATED THICKNESS AT SECTION CENTERS IN THE HIGH PLAINS AQUIFER, PROJECTED 2090-2092 VALUES

SOUTHWEST KANSAS GROUNDWATER MANAGEMENT DISTRICT

Prepared by the Kansas Geological Survey in cooperation with the Southwest Kansas Groundwater Management District
Kansas Geological Survey: Steve Yoder, Robert Buddemeier, Jeffrey Schloss
Southwest Kansas Groundwater Management District: Steve Frost, Diane Coe



This map is based upon data from the Ogallala and undifferentiated Quaternary units and, as such, does not represent conditions in other aquifer units (e.g., Dakota, alluvial systems).

Projections of saturated thickness at section centers were calculated as follows:

1) 1980-82 water-level elevation measurements were averaged for each monitoring well in the region.
2) 1990-92 water-level elevation measurements were averaged for each monitoring well in the region.
3) Averaged 1990-92 water-level elevations were subtracted from averaged 1980-82 water-level elevations to establish a ten-year trend at each well.
4) Within the constraints of bedrock and predevelopment water-level elevations, 2090-92 water-level elevations were extrapolated on the basis of the ten-year trend.
5) From these projected water-level elevations, a model of a continuous water-level surface was created using Arc/Info's TIN module.
6) From this surface model, estimates of water-level elevations were made at each section center (within the constraints of bedrock and predevelopment water-level elevations).
7) For each section center, bedrock elevation was subtracted from estimated water-level elevation.

Center Pivot and Subsurface Drip Irrigation

Center Pivot Irrigation

Surface irrigation used to be the most common method of irrigation in Kansas, but now approximately one-half of the State's irrigated acreage is watered by center pivot systems. Center pivots reduce the amount of labor associated with irrigation and usually supply water to a crop more efficiently and uniformly than flood irrigation. Because of declining aquifer levels, different types of sprinkler systems have been developed to improve efficiency and to more effectively distribute a limited water supply over a large area (Rogers and Sothers, 1994).

Water loss from sprinkler and surface irrigation includes air losses, canopy losses, soil and water surface evaporation, runoff, and deep percolation (Rogers et al., 1997). Figure 1 illustrates how irrigation water loss occurs from three sprinkler types and from surface irrigation.

Sprinkler systems have changed over time. A popular trend has been to lower spray nozzle pressures and to position the nozzles closer to the ground. LEPA, which stands for Low Energy Precision Application, is a method of delivering water to crops from center pivot irrigation systems. LEPA is a combination sprinkler package and management concept. The goal of the LEPA management system is to maximize use of the total water resources available to a crop, including maintaining high irrigation efficiency and utilizing captured rainfall, resulting in reduced energy and water usage (Rogers et al., 1994).

LEPA nozzles are positioned close to the ground, usually no more than 18 inches above the furrow. The LEPA nozzle minimizes wind drift loss and evaporation from soil and crop canopy. Practical requirements for using LEPA as an irrigation-tillage management system include field slope of less than 1 percent, fields farmed in circular rows parallel to the wheel track, and some method of furrow diking. New center pivot systems with LEPA may be somewhat more expensive than a conventionally equipped center pivot system, but the advantages seem to make the investment worthwhile.

Advantages of LEPA Systems

- High Irrigation application efficiency (95-98 percent).
- High uniformity.
- Reduced wetting of foliage, lower evaporation losses, and reduced disease problems.
- Potential reduction in energy costs for pumping because of high application efficiency and low operating pressures.
- Minimal soil evaporation losses.

Disadvantages of LEPA Systems

- Higher material and installation costs.
- Runoff must be controlled by furrow diking and planting in a circle.
- Pressure regulators are generally required for proper nozzle flow.

Subsurface Drip Irrigation

As irrigation sustainability becomes an increasing concern, irrigation improvements, such as high efficiency subsurface drip irrigation (SDI), are playing an increasing role. SDI is likely to become more popular as producers become more familiar with SDI technology and as aging irrigation systems are replaced (Lamm and Trooien, 1998). SDI systems use plastic pipe with small drip emitters buried a few inches below the surface of the field.

Many producers can increase irrigation efficiency by moving from surface irrigation to center pivot sprinkler irrigation. However, irregular field shapes and sizes are not conducive to center pivot irrigation. SDI is easily sized to fit any field configuration.

A number of studies have indicated that subsurface drip irrigation has the potential to increase water use efficiency. Kansas State University has been actively involved in evaluating SDI for corn production since 1989. Lamm et al. (1995) concluded that SDI could reduce net irrigation water requirements by 25% while still maintaining corn yields greater than 200 bushels/acre. Since the application efficiencies of other irrigation systems are typically 15 to 35% lower than SDI, the 25% reduction in net irrigation water use can actually be a 35-55% reduction in the gross irrigation water amount.

Installation costs for SDI are about $540 per acre compared to $340 per acre for a center pivot system. The SDI system life is estimated to be 10-20 years.

Subsurface drip irrigation is just one of many irrigation options, but as irrigation efficiency becomes more important, it has many benefits. SDI does not require a change in occupation, it can reduce water waste to a negligible amount, and it is environmentally friendly. The SDI system can be economically sized to the available water source. It has low operational energy costs and is well suited for off-peak electrical load management strategies. Irrigation events can be fine-tuned to avoid water stress. SDI can efficiently augment the summer precipitation pattern of the region more than any other irrigation method.

Chemigation

Chemigation is the application of agricultural chemicals (fertilizers, micronutrients, fungicides, herbicides, insecticides, nematicides, soil conditioners, growth regulators, biological agents, and gray water and animal wastes) into water flowing through an irrigation system. Chemigation is an efficient and economical means of applying agricultural chemicals necessary for crops (Anderson, 1997).

Chemigation can be conducted using drip/trickle, flood, furrow, and sprinkler irrigation systems. Drip/trickle and subsurface systems can only be used for chemigation of soil-applied agricultural chemicals. Flood and furrow irrigation systems can, at times, present problems with chemical application uniformity and may limit some chemical applications. Sprinkler irrigation systems can accommodate both soil and foliage applied chemicals and are the primary method of choice in Kansas.

Just as there are benefits and risks associated with applying agricultural chemicals using conventional (ground and aerial) methods, there are benefits and risks associated with chemigation. In some cases, with proper management, better application efficiencies offer a reduction in the amount of agricultural chemical used, timely application, and less impact on the environment.

The most significant risk when utilizing chemigation is for water source contamination due to backsiphonage, backpressure, or over irrigation. To minimize risks related to chemigation, an irrigation system must be properly designed, equipped, and operated. Proper management and maintenance of the recommended safety equipment is essential for successful chemigation. Mandatory safety equipment, record keeping, permitting, certification, and management requirements are outlined by the Kansas Chemigation Safety Law.

<u>Advantages of Chemigation</u>

- Properly designed and operated irrigation systems may apply chemicals more uniformly than aircraft or ground sprayers.
- Chemigation allows timely application of chemicals even when fields are too wet for tractors or conditions are unsuitable for aircraft.
- Water applied through irrigation can incorporate chemicals to the desired depth and, at the same time, and provide moisture for activation.
- Chemigation allows for the application of chemicals under various tillage situations, making it compatible with reduced or no-till farming.
- Applying chemicals through irrigation can reduce compaction caused by tractors and other tillage implements.
- Damage to the crop by sprayers is reduced.
- Chemigation reduces operator exposure to chemicals. It is essentially a closed transfer system and an operator is not required in the field during the application.
- Chemigation may reduce environmental hazards associated with spray drift.
- Applying chemicals through an irrigation system can save 40% or more in chemical application costs. Greater savings can be obtained when two chemicals are applied simultaneously (co-chemigation).
- Chemigation can reduce energy used for chemical application by 90% and, and in some cases, eliminate the need for soil incorporation.

<u>Disadvantages of Chemigation</u>

- Chemigation requires considerable management input and personnel training.
- Chemigation requires a change in management techniques.
- Some chemicals may be corrosive to irrigation equipment.
- Using an irrigation system to apply chemicals to the crop may apply moisture at a time when it is not required or when the soil is already too wet.
- Additional equipment and capital outlay may be required for chemigation.
- Chemigation increases application time compared to aerial spraying, so climatic factors may interfere or delay application.
- Some chemicals may not be suited for chemigation.
- Environmental concerns include the possibility of backsiphon or direct contamination of the water source.

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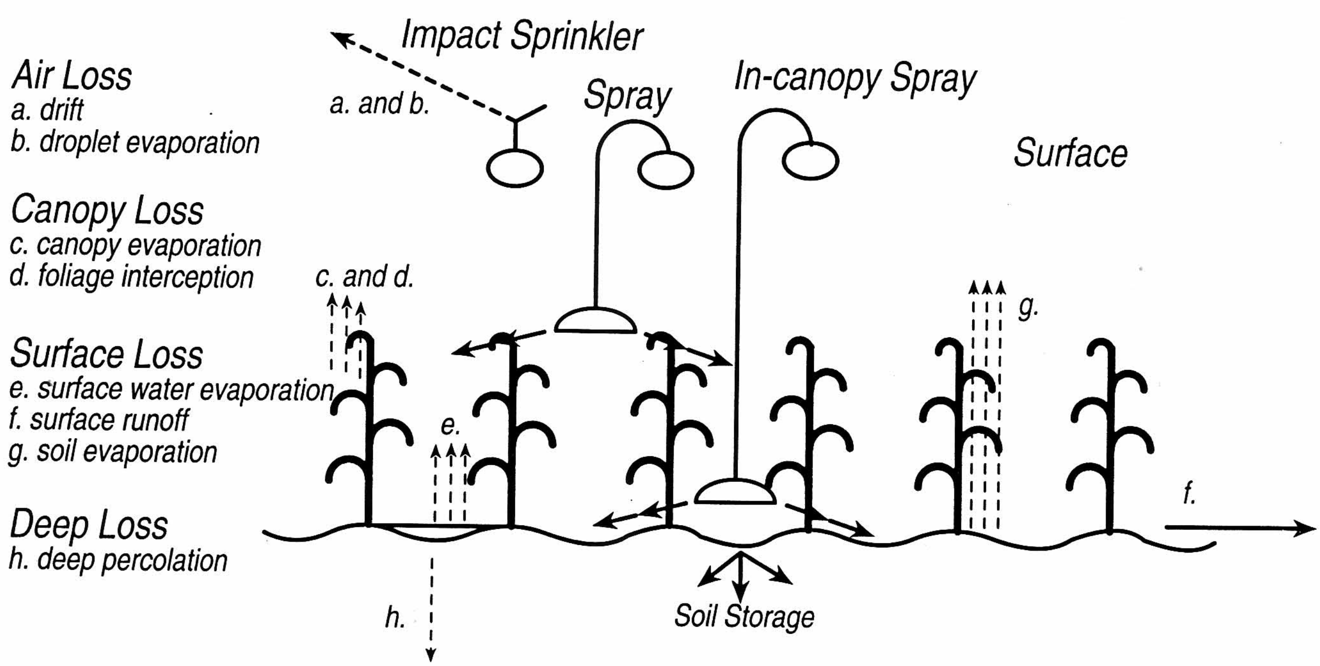

Figure 1. Irrigation water loss and storage locations (from Rogers et al., 1997).

Natural Resources Issues - Garden City, Kansas

Garden City, the seat of Finney County, is in the heart of southwestern Kansas. Garden City is closer to Denver, Colorado (325 miles northwest) than Topeka (330 miles northeast). Garden City, founded in 1878 and incorporated in 1883, was named for the garden grown by Mrs. William D. Fulton, wife of one of the town's founders. Finney County, named after David Wesley Finney, lieutenant governor of Kansas from 1881 to 1885, originally covered a much larger portion of southwestern Kansas, but was reduced to its present size in 1887 after a boom in the 1880's increased population and necessitated the creation of additional counties.

Finney County and Garden City have long been an area of ethnically diverse populations. The construction and maintenance of the Santa Fe Railroad, followed by the sugar beet industry in the early 1900's, created a demand for labor. Many Mexican-born immigrants moved to the area in the 1910's and 1920's (Shortridge, 1995).

After suffering through the Dust Bowl era, Garden City's population began to grow again. In 1960, it was 11,000; by 1974, it was 18,000; and by 1994, it was 24,900. The population increased by 37 percent during the period of from 1980 to 1994, based largely on the demand for labor in the cattle feeding and packing industries. A number of meat-packing plants operate in Garden City, Liberal, and Dodge City. The largest is Iowa Beef Processor's (IBP) plant in nearby Holcomb; this is one of the largest in the world, with the capacity to handle up to 5,000 head of cattle per day. IBP employs the largest number of people in the area, nearly 2,800. In the 1980s, between 2,000 and 3,000 Southeast Asians moved to the region, many of them to work in the meat-packing business (Stull, 1990).

Today, the population of Garden City is 68 percent white, one percent black, three percent Asian, and 28 percent Hispanic. Thus, the region is among the most ethnically diverse in Kansas, and much of that diversity can be traced back to the natural resource of the High Plains aquifer, which produces water, which irrigates corn to feed livestock, which support a meat-packing industry that employs the local population.

The High Plains aquifer not only supports the economy of Garden City, it also provides the town with its municipal water supply. Many of the same water quality and quantity issues that affect agriculture and smaller communities in south-western Kansas are also concerns for Garden City.

Water Quality Issues - Garden City Wellhead Protection Program

Garden City is developing a wellhead protection program to protect its municipal water supplies. The purpose of the program is to identify and abate water development and production practices that threaten the viability of potable water supplies.

Other water quality concerns include increasing salinities in the shallow alluvial aquifer because of increased river flow, and the potential impact of storm water treatment requirements on municipalities.

Potable Water Identification and Production - The Swap

Garden City recently started discussions with adjacent landowners about the possibility of providing treated effluent from the City's sewage treatment plant to agricultural landowners for irrigation purposes. In exchange, that quantity of water (viewed by the City as an asset) would be swapped for existing irrigation appropriations that would be diverted for municipal use.

This capital intensive program could provide the City with a readily available supply of potable water if the economics can be developed through a more equitable determination in the appropriation process from irrigation to municipal designation.

Sand and Gravel Mining and Reclamation

Nearly every river basin in Kansas has lands adjacent to rivers that have been leased for sand and gravel extraction. Of particular concern to the City are abandoned sand pits and adjacent lands that retain scars and hazards years after the mining has ceased. Current reclamation regulations prevent such problems from occurring today, but the City is concerned about removing floodway obstacle hazards and opportunities for additional uses of these river areas.

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Finney County Rural Water District No. 1

Finney County Rural Water District No. 1 was formed in April 1995 through Resolution by the Finney County Commissioners. The original District was bounded by the City of Holcomb to the west, the City of Garden City to the east, the railroad tracks to the south, and U.S. Highway 50 Bypass to the north (see Fig. 1). This portion of the District has a residential, commercial, and agricultural makeup, with a large percentage (80%) of the residential property consisting of mobile home parks. In July 1996 the District was increased by the addition of 7.5 square miles north of U.S. Highway 50 Bypass. This area is mostly rural, but includes the lightly developed Northwest Industrial District, and some residential development in and adjacent to the Highland Addition.

Water Sources

Domestic water wells serve businesses, permanent residences, and mobile homes. Larger mobile home parks have developed single water wells capable of serving up to 60 mobile homes. New-construction residential homeowners frequently drill individual water wells. No bulk water distribution system exists within the District.

The City of Holcomb, immediately west of the District, serves its residents and a few homeowners and businesses located immediately adjacent to its city limits. Holcomb does not have the capacity to extend service beyond its present users. The City of Garden City, immediately east of the District, is not able to provide service to the District. The west side of Garden City is generally the oldest part of town, and bulk distribution piping and water-well supply in that part of the city are both limited.

Potential ground water sources for domestic potable water within the District include the Ogallala and the Dakota aquifers. While replacement water wells within the Ogallala can be constructed, new large-capacity wells sufficient to serve the District are precluded because the Ogallala rights are over-appropriated in this area. The District was granted appropriation rights for 750 acre-feet/year from the Dakota aquifer in March 1997.

Water Quality

Many of the existing water wells that serve the residents and businesses within the District were developed prior to modern well design, construction, and spacing standards that provide protection against overuse or contamination of the ground-water supply. The first wells were developed in the Arkansas River alluvium. These wells, usually less than 80 feet in deep, are prone to contamination from agricultural sources and domestic sewage discharges, and are no longer suitable for domestic purposes.

Later, water wells were developed in the Ogallala aquifer. The Ogallala is deeper (about 250 feet) and separated from the alluvium by clay layers, and is therefore less prone to contamination from the surface. However, over the last 20 years, there has been a gradual deterioration in the water quality of the Ogallala aquifer. Today, many of the domestic wells in the Ogallala barely meet the water quality standards established by the Kansas Department of Health and Environment.

The Dakota aquifer, from which the District will produce water, is about 750 to 800 feet deep. The water quality in the Dakota meets the requirements of the District for the foreseeable future. Well-spacing restrictions for the Dakota, and new-well construction requirements, will help protect this important water source.

The Water System

Construction of the water system is scheduled in June 1998. The water system includes two Dakota water wells, a water column-style storage tank (standpipe), approximately six miles of primary water distribution piping, and two miles of local service distribution piping. The system will include individual metered service connections.

A two-mile interconnection with the City of Holcomb is also planned. This interconnection will provide redundancy in water storage capacity, and make possible emergency inter-system transfers of water between the two entities. In addition, the sale of surplus water to Holcomb will relieve some of the Districts operating costs, and provide Holcomb with additional water for peak demand periods.

The District has contracted with the City of Holcomb for operation and maintenance, billing, and other services necessary to operate the system. The District does not anticipate employing any personnel in the foreseeable future.

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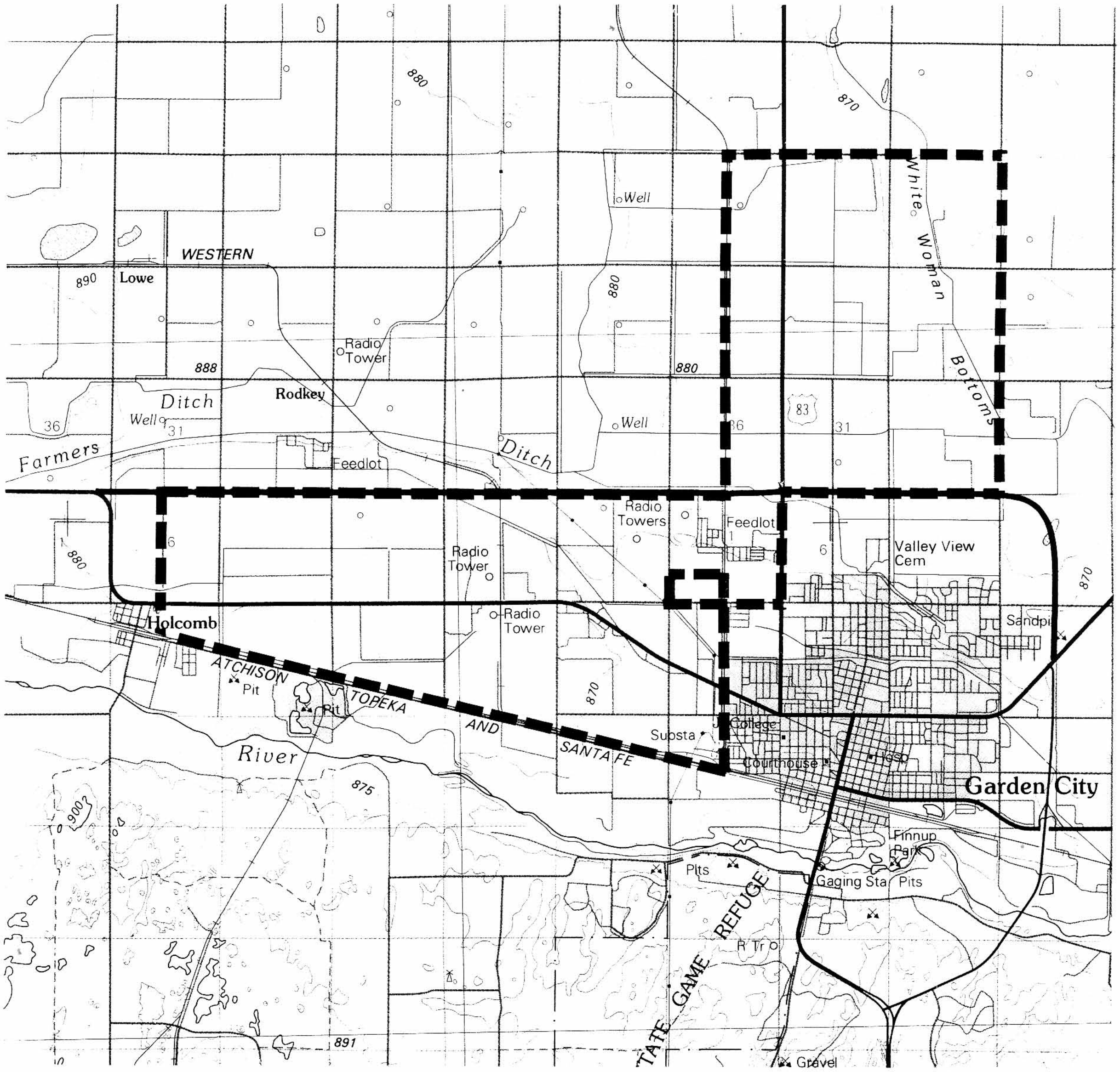

Figure 1. Finney County Rural Water District No. 1.

Public Water Supply - Deerfield, Kansas

The city of Deerfield in eastern Kearny County is located on the north side of the Arkansas River valley. Three municipal wells supply water to the city. All are within the city limits and were installed at different times (the Park well about 1950, the 10th Street well in 1958, and the Big well in 1978). The wells are completed in the High Plains aquifer. The water pumped from the aquifer from 1950 to the early 1980's was very fresh and contained sulfate concentrations that were nearly always between 100 and 150 mg/L (milligrams per liter) (Fig. 1). During the early 1980's the salinity in the well water started to increase rapidly; by 1990 the average sulfate concentration in the well waters rose above 250 mg/L, the maximum recommended for public drinking supplies (500 mg/L has been proposed as a maximum contaminant limit by the U.S. EPA). Chloride contents have remained below 70 mg/L.

Kansas Department of Health and Environment (KDHE) data for the quality of municipal ground-water supplies generally reflect samples from individual wells for the period up to the mid-1970's. Based on new federal requirements in the mid-1970's, KDHE had municipalities submit samples from the distribution system, instead of individual wells, for analysis. The regulations reverted back to sampling individual wells several years ago, again allowing determination of differences in the quality of individual water sources. Recent cooperative sampling by the City Administrator and the KGS shows that the quality of the well waters shows no definite upward or downward trend but varies appreciably from well to well and with time (Fig. 1). During the last two years, the Park well has produced the freshest water (sulfate concentration 207-276 mg/L), the 10th Street well has yielded the most saline water (sulfate 338-495 mg/L), and the Big well, with the largest capacity, pumps water with an intermediate quality (sulfate 294-414 mg/L).

A multi-level well site for observation of water levels and quality was recently installed southwest of the Deerfield High School, less than a half mile south and southwest of the municipal wells. The water levels from these and irrigation wells in the region indicate that ground water is flowing downward and also in a generally west-northwest to east-southeast direction in the Deerfield area. The five observation wells at the school site show that the salinity of the water steadily decreases with depth; the sulfate concentration at 37-45 feet is 1,680 mg/L whereas the sulfate content at 330-340 feet (the bottom of the aquifer at this location) is 160 mg/L (Fig. 2). The interval of the deepest observation well is within the elevation range of the screened interval of Deerfield's Big well.

The Upper Arkansas River Corridor Study of the KGS has determined a plausible mechanism for contamination of the water supply. Starting in the 1880's, saline Arkansas River and ditch irrigation water (mainly containing sodium, calcium, and sulfate) slowly seeped into the shallow portion of the High Plains aquifer. When ground-water levels began to drop substantially in the High Plains aquifer during the 1970's, the water levels fell below the bottom of the upper aquifer zone, thereby allowing shallow saline water to enter the lower aquifer. This saline water moved laterally through the sand and gravel layers of the lower aquifer to Deerfield's water-supply wells and caused the pronounced increase in salinity during the 1980's. Although the rapid increase in salinity of the 1980's is no longer occurring, continued seepage of ditch irrigation water into the aquifer west of Deerfield could be expected to slowly increase the salinity of the lower aquifer. Thus, although the water pumped by the municipal wells may vary in quality as recently observed, the long-range forecast is a general increase in the average salinity.

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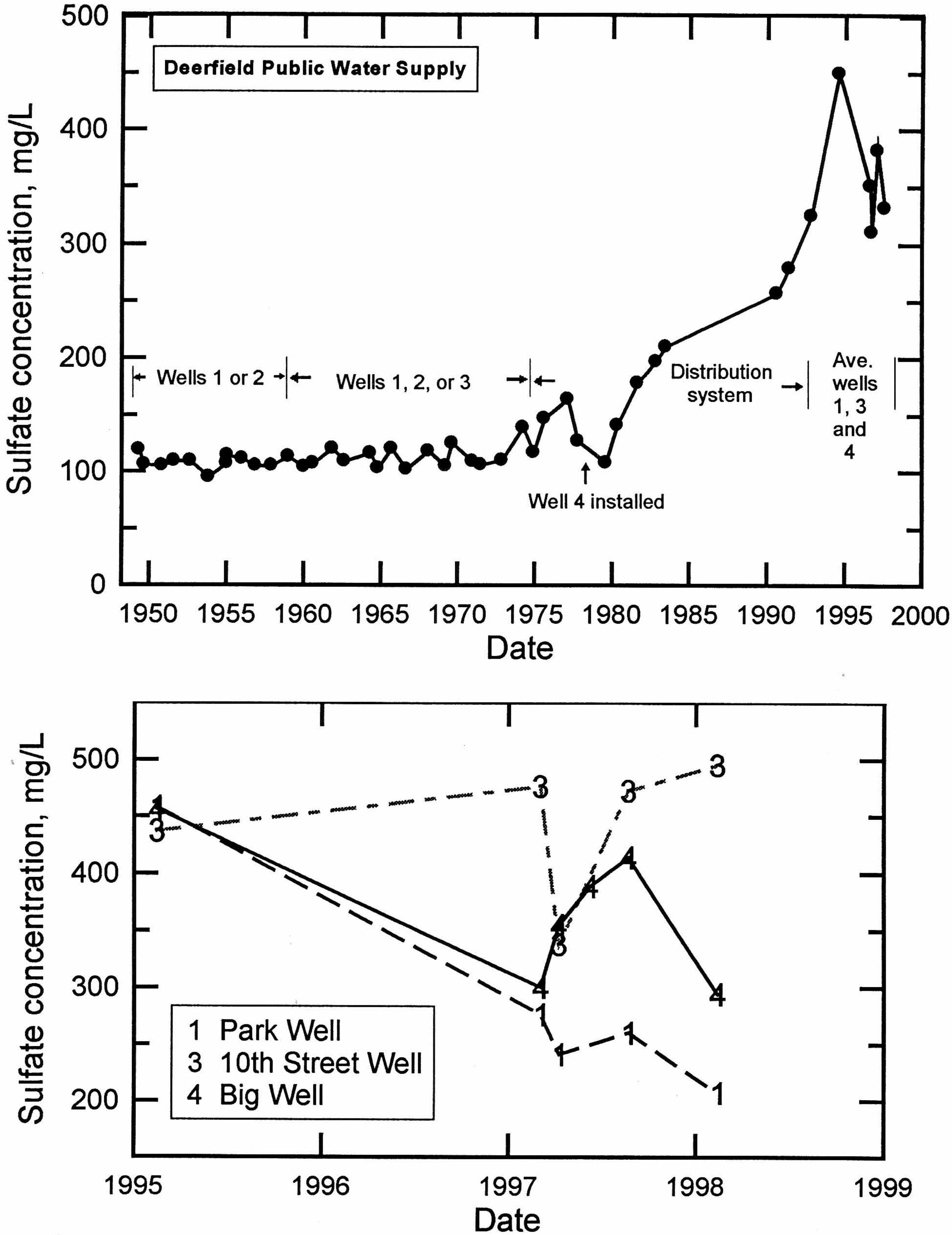

Figure 1. Quality of the Deerfield public water supply from 1950 to 1998 (top) and for individual wells from 1995 to 1998 (bottom).

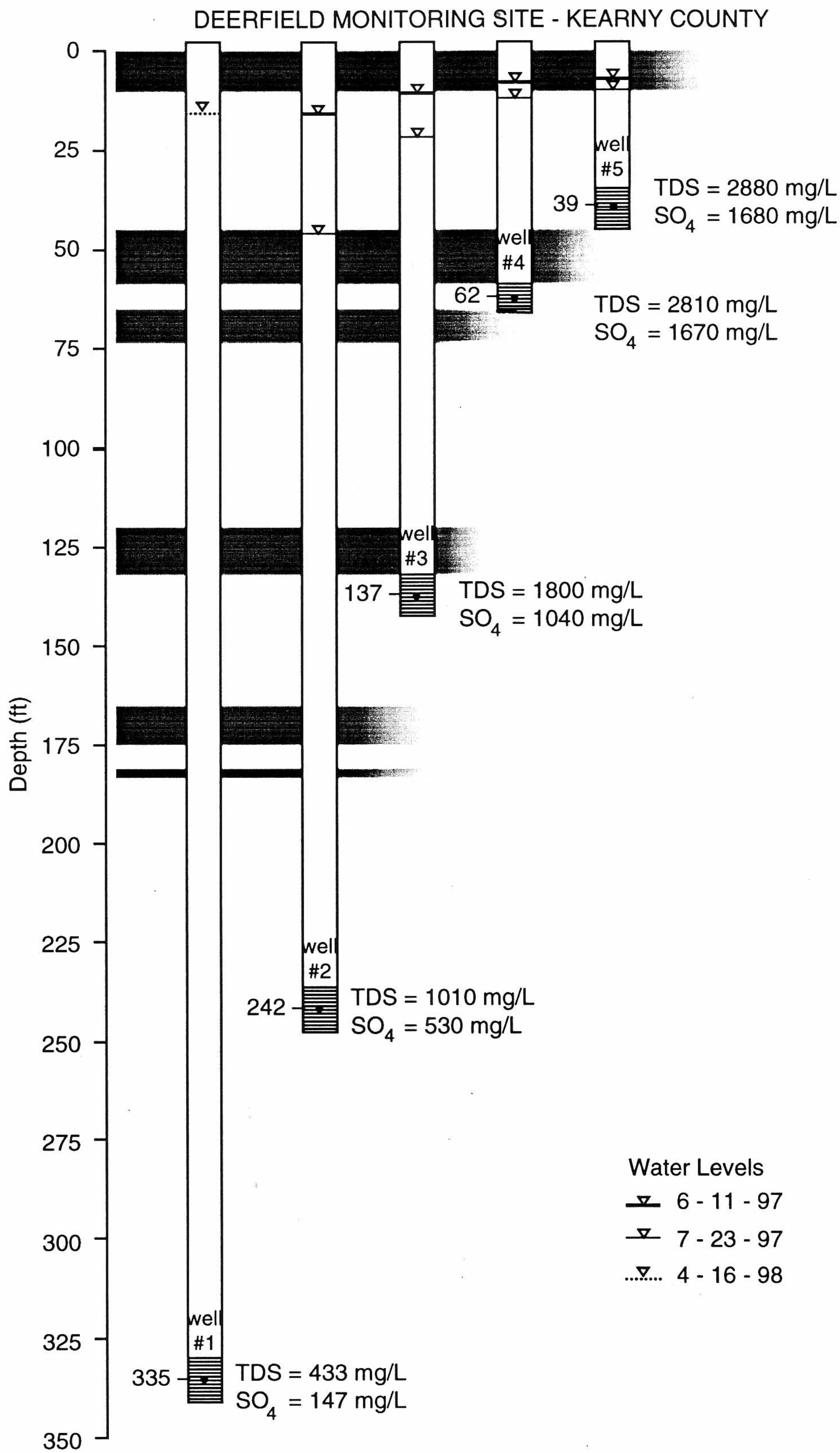

Figure 2. Well depths and water quality for multi-level well site near the Deerfield High School.

The Arkansas River

The Arkansas River drains much of the southern half of the state and, together with the Kansas River watershed to the north, forms one of the two major drainages in the state. Unlike the Kansas, which drains into the Missouri River, the Arkansas flows to the south and joins the Mississippi River in southeastern Arkansas. At 1,459 miles, the Arkansas is the third longest river in the continental U.S.; it drains more than 160,000 square miles. The river gets its start in Lake County, Colorado, near the town of Leadville, and passes through the Royal Gorge at Canon City. It enters Kansas near Coolidge in Hamilton County and drains generally southeast.

The elevation at the river's edge at Garden City is 2,830 feet, or about 200 feet higher than the Smoky Hill River to the north, or the Cimarron River, to the south, in spite of the fact that the Arkansas enters Kansas at a lower elevation than the other two rivers. In Kansas, no tributaries of any significance flow into the Ark until the Pawnee River joins it near Larned. That makes streamflow in the river particularly dependent on snowmelt from the mountains and on local rainfall. Because the Ark receives little additional flow, it drops the load of sediment that it carried out of the mountains, becoming an aggrading stream, building up its stream bed.

Though the Arkansas River occasionally dried up during historic times, its flow became increasingly unreliable in the late 1960's and early 1970's, until it ceased flowing completely through the state. Except for extremely wet years, the river was often dry from about western Finney County until Great Bend during the late 1970's, 1980's, and early 1990's. The lack of streamflow was caused by lower water tables due to irrigation from alluvial wells and evaporation from large reservoirs in eastern Colorado.

The lack of water in the Arkansas led to a celebrated court case that began in 1985 when Kansas filed suit against Colorado for failing to live up to terms of an interstate compact between the two states concerning water in the river. In May 1995, the U.S. Supreme Court ruled in Kansas' favor when it determined that wells in eastern Colorado were pumping too much water from the alluvial aquifer and causing the lessened streamflows. The case is now in the penalty phase, as the court determines how Kansas is to be repaid for the lost water.

Water Quality

Within the past few years, the Arkansas River has recovered somewhat and regularly flows entirely through the state. However, recent research has shown that Arkansas River water quality is also a problem. With funding from the Kansas Water Plan, and the cooperation of state and local agencies, the Kansas Geological Survey is documenting the fate and effects of contaminated Arkansas River flows on the alluvial and High Plains aquifers in the river corridor in southwest Kansas. That study is clearly establishing the links between decreased flow in the river, lower ground-water tables, and the increased levels of aquifer contamination.

In southwestern Kansas, the Arkansas is one of the most saline rivers in the U.S. The dissolved constituents (mainly sodium, calcium, and sulfate) are naturally derived from the flow of rain and ground water through soils and bedrock in Colorado. The great increase in dissolved salt concentration occurs as water is evaporated from reservoirs, ditches, and fields and is transpired into the atmosphere by plants, while the dissolved salts remain behind in the residual water. The flow across the Kansas border is saline during both high and low flow periods, although the salinity decreases with greater flow (Fig. 1 and 2). Sulfate concentrations can reach 2,400 milligrams per liter (mg/L) in water flowing across the state line. This compares with a maximum of 250 mg/L recommended for public drinking supplies and 500 mg/L proposed as a maximum contaminant limit by the Environmental Protection Agency. The salinity of the river water is usually great enough to cause substantial declines in crop yields when used for irrigation in comparison with fresh water.

Water levels have declined in the High Plains aquifer in southwestern Kansas because of pumping and because of decreased recharge from the river. As a result, when flow from the Arkansas enters Kansas, it seeps into the subsurface in the stretch of the river from the state line to Dodge City. Some water also seeps into the subsurface from ditches diverting river water and from fields irrigated with the ditch water. In addition, water is lost by evaportranspiration during irrigation.

The infiltration of water into the subsurface appears to have affected mainly shallow ground water from the beginning of ditch irrigation in Colorado and Kansas in the late 1800's to the 1970's. During the 1970's, the rate of water-level declines in the High Plains aquifer in the river corridor increased. The water levels then dropped below the shallow zone of the aquifer and allowed the saline water to move down into the main aquifer (Fig. 3).

Lower permeability silt and clay layers in the High Plains aquifer retard the rate of downward movement of the saline water. However, flow down the space between the borehole and the casing (the annulus) of a water well appears to be an avenue for appreciably increasing the rate of movement of saline water into the lower aquifer.

The annulus is usually sealed with cement through the upper aquifer in municipal and newer domestic wells. In irrigation wells, the annulus is typically filled with gravel to near the surface or within the shallow part of the aquifer, thereby allowing perched saline water to flow down the gravel pack and into the aquifer. This could also explain why old domestic and municipal wells without a good seal have allowed saline water and other contaminants to enter the zone of the aquifer pumped by the wells.

The Survey study is determining the areal and vertical distribution and temporal variation of the saline waters, the future movement of these contaminated waters into freshwater areas, and the implications of these results to possible management and protection strategies.

The Survey's Upper Arkansas River Corridor Study is a Kansas Water Plan project conducted in cooperation with other state and local agencies and associations, especially the Subbasin Water Resources Management program of the Division of Water Resources, Kansas Department of Agriculture.

Water Rights

Some of the earliest, large-scale irrigation was by ditches from the Arkansas River. The companies that operate these ditches have some of the oldest water rights in the region. Kansas originally operated under riparian water law, which meant that the owners of land along a stream also owned the right to the water. Riparian water law worked well in eastern Kansas, where surface water is plentiful, but was less effective in western Kansas, where ground water is the primary water source.

In 1945, the Legislature passed the Water Appropriation Act, creating a new mode of water regulation in the state. The act viewed water as a resource held in common by the state's citizens; water belonged to the people of the state of Kansas, but the state could grant the right to use water for beneficial purposes. Those rights would be based on the time of application. This doctrine is usually summarized as "first in time, first in right." That is, the older rights are more senior, and therefore have priority, over more recent rights. Individuals who use water in the state must have a vested right or permit, except in the case of water used solely for domestic purposes--household use, water livestock on pasture, or watering up to two acres of lawn and gardens.

In 1917, the Legislature charged the Kansas State Board of Agriculture with the regulation of water rights under the old riparian doctrine. In 1927, it created the Division of Water Resources within the Board of Agriculture; the Division was headed by a chief engineer. Today, the chief engineer and the Division of Water Resources of the Kansas Department of Agriculture are still responsible for issuing permits to appropriate water, regulate usage, and keep records of all water rights in the state.

Amazon Ditch Diversion

This diversion on the Arkansas River was built to take water from the river for irrigation of fields to the northeast of here. Ditch irrigation in southwestern Kansas began in the 1880's, but was long hampered by engineering problems, low flows in the river, and rivalries between the various associations formed to build ditches. Still, a drought in 1887 encouraged rapid construction, and Charles J. "Buffalo" Jones filed a claim for water from the river and organized the Amazon Irrigating Company. The company planned for 75 miles of main ditch and another 100 miles of lateral ditches; these ditches would take water from near Hartland in Kearny County and move it to the north and east into Finney, Gray, and Scott counties. A crew of about 15 men and 30 horses operated graders and earth-moving equipment, and in 1890, the first water began moving down the canal.

The Amazon ditch still operates today. It has a right to divert 31,000 acre feet of water per year from the river (an acre foot is the amount of water necessary to cover one acre with 12 inches of water; an acre-foot equals 325,851 gallons). The water can be taken out at the rate of 200 cubic feet per second (or cfs) on a rotating schedule that is shared between several ditch companies. By way of comparison, the flow of the river at Syracuse, upstream and to the west of here, varied from around 200 cfs to as much as 2,750 cfs from June 1995 to August 1996. High flow periods were in early summer, usually June and July; from August 1995 to April 1996, flow was generally around 250 cfs.

This diversion is also the location where the Great Eastern canal takes water from the river. Water for both canals travels down the Amazon ditch until a point just west of Lake McKinney, where water from the Amazon is diverted into the lake, then water is taken from lake for the Great Eastern ditch. The water right for the Great Eastern canal at this diversion is 60,000 acre feet per year, and can be diverted at the rate of 354 cfs on a rotating schedule.

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Diversion Canals

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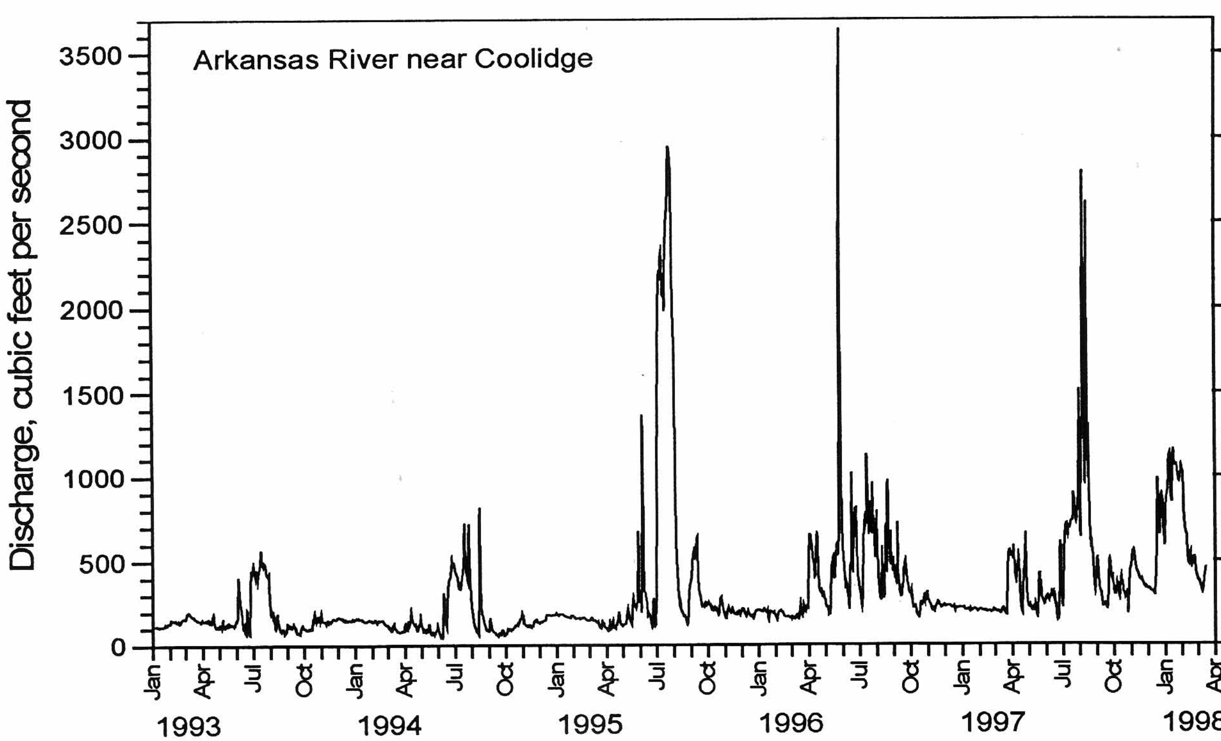

Figure 1. Flow of the Arkansas River near Coolidge, Kansas for 1993 through early 1998.

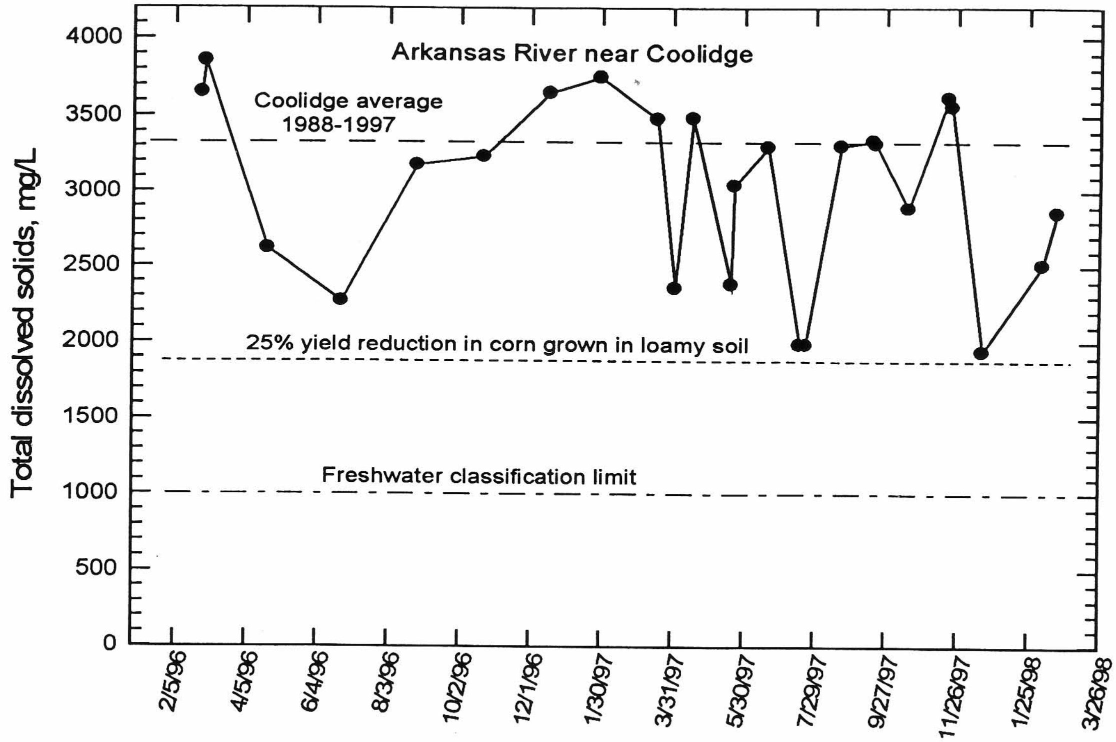

Figure 2. Salinity of the Arkansas River near Coolidge, Kansas for 1996 through early 1998.

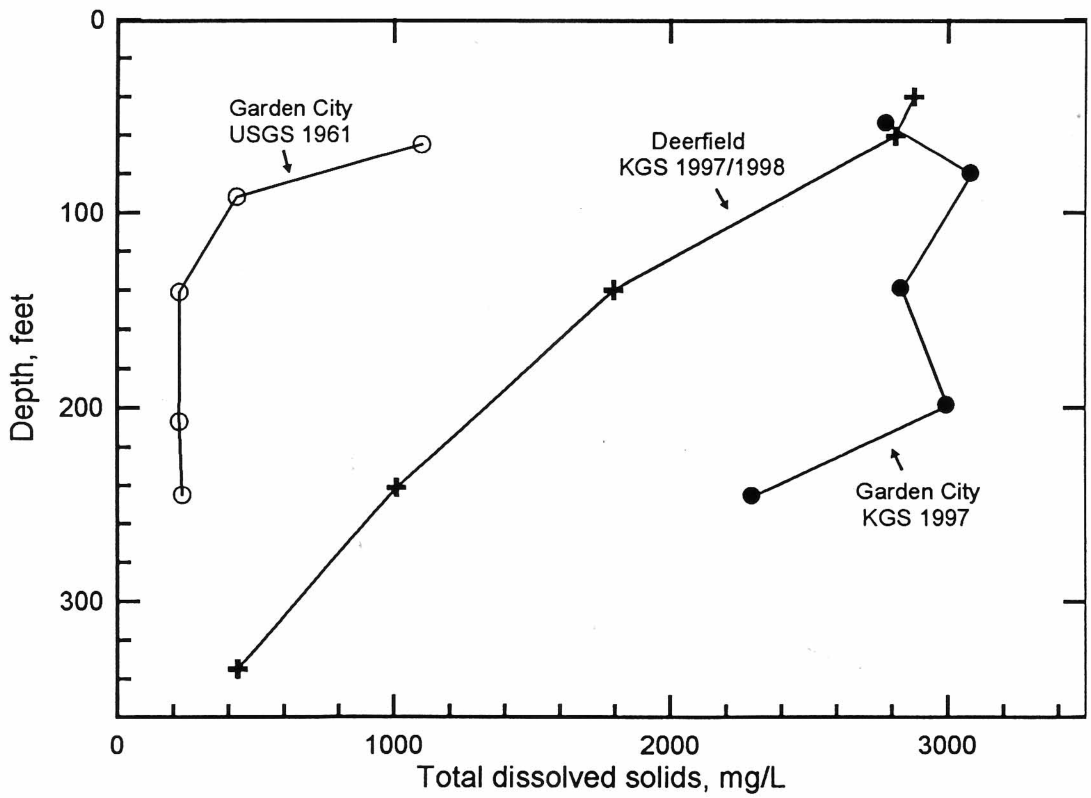

Figure 3. Multi-level observation well and test hole sites in the Arkansas River valley. Depth for the observation well points are at the middle of a 10 feet screened interval. The two Garden City sites are within 400 yards of each other. Note the large increase in salinity of the High Plains aquifer at the same depths from 1961 to 1997.

The Garden City Company and Flood Irrigation

The Garden City Company had its beginnings in the early 1900's with the formation of the United States Sugar and Land Company. This early venture was entrepreneurial in nature and consisted of land acquisition, surface irrigation canals and reservoirs, and construction and development of the sugar factory.

The primary crop produced was sugar beets. The acreage owned and controlled by the United States Sugar and Land Company grew to nearly 52,000 acres in Finney, Kearny, and Scott counties. The company farmed its own land until 1920, and then in 1921, leased the land to tenants. These original farms consisted of approximately 80 acres, with a house, barn, and mule team provided for each farm. Sugar beets were produced on the farms and delivered to the sugar factory for processing. The sugar factory, built in 1906, employed nearly 400 at its peak.

In 1916, the Garden City Western Railway was developed for transportation of sugar beets from the fields to the factory. That same year, the company built a power plant that supplied power to the sugar factory and the local area.

The sugar factory closed in 1955, and the power plant and railroad were subsequently sold. Since the sale of the sugar plant, the company has concentrated on its farm operations.

The Garden City Company today is a land holding company, leasing its ground to 22 farmers, many of whom are second and third generation farmers. Today, The Garden City Company owns approximately 28,000 acres of mostly irrigated land. The land is flood irrigated by two systems: deep wells in the Ogallala and Dakota formations, and surface water diverted from the Arkansas River.

Sugar beets required large amounts of water. As part of the original purchase, the U.S. Sugar and Land Company secured the Great Eastern Ditch (Fig. 1). This ditch ran from Hartland, Kansas (now a ghost town), through the company's land northwest of Garden City. The ditch stretched 100 miles from the intake at the Arkansas River to its termination northwest of Garden City. As plans were being made to build the sugar beet plant, early developers realized the water supply from the Arkansas River was increasingly being absorbed in Colorado. As a way to assure a steady supply of water for the crops, the company built small reservoirs to store water when there was a surplus in the river.

The largest of these reservoirs was a 3,000 acre reservoir near Deerfield called Lake McKinney. Lake McKinney was constructed in 1906 and 1907 and was the largest man-made lake in Kansas at the time. The Great Eastern Canal filled the lake from the head gates at Hartland until 1952. Lawsuits against the ditch company, and flood damage, forced the company to abandon the western section of the ditch. The Garden City Company, owner of the ditch, then negotiated with the Amazon River Canal to deliver water to Lake McKinney. In 1976, the lake was reduced in size to approximately 1,000 acres because of the shortage of water from Colorado. The remaining 2,000 acres that were formerly part of Lake McKinney were converted to farmland.

Ditch water is not the only source of water for irrigation. Water wells became popular during the twenties. F.A. Gillespie became interested in irrigation after serving as general manager of the company, and became one of the developers and pioneers of irrigation in southwest Kansas. The Garden City Company today owns several ground-water wells. During the 1980's, there were 86 deep wells in operation.

The primary crops now grown on the company's land include wheat, corn, milo, and soybeans. Rent is paid by the tenants in 1/3 crop shares and is delivered to The Garden City Company's farm headquarters at Lowe, Kansas, commercial elevators, or feedlots. The Garden City Company's grain storage capacity at Lowe consists of 180,000 bushels of Harvestore storage and dry grain storage of 325,000 bushels.

In addition to farming operations, a major part of the land owned by The Garden City Company is involved in mineral development.

References

Sherow, J.E., 1990, Watering the valley: development along the High Plains Arkansas River, 1870-1950: University Press of Kansas, Lawrence, Kansas, 222 p.

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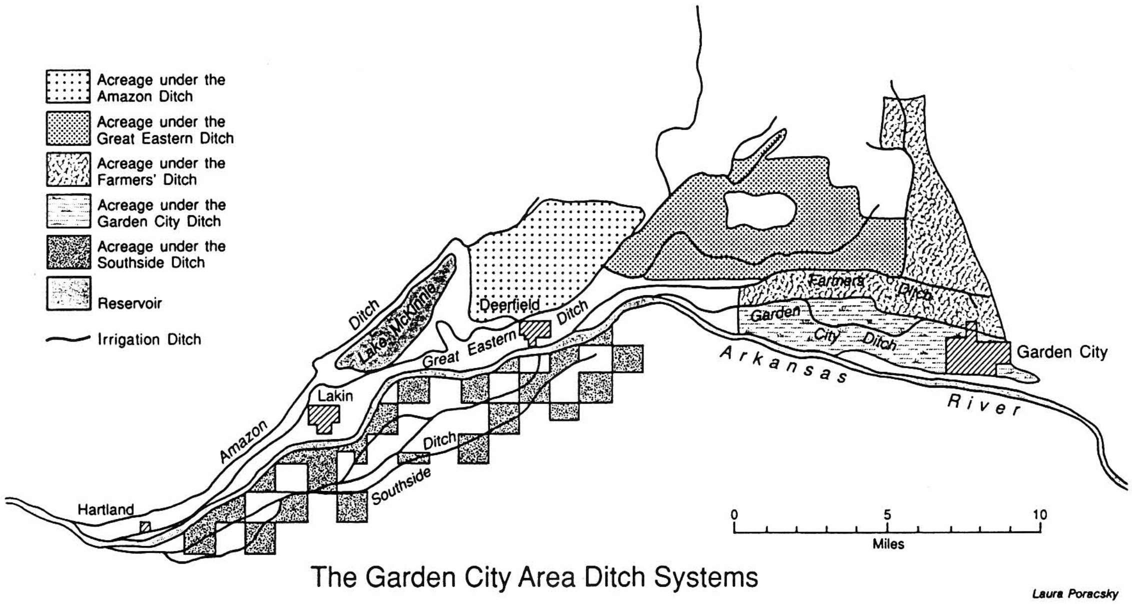

Figure 1. Historic map of the irrigation ditch systems in the Garden City area (from Sherow, 1990).

SCHEDULE & ITINERARY

Thursday June 4, 1998

7:00 am	Breakfast
8:00 am	Bus to Site 9
9:00 am	**SITE 9** - Hugoton Jayhawk Gas Plant *Bob Henderson*, Plant Manager, Amoco Production Company
10:15 am	Bus to Site 10
10:45 am	**SITE 10** - Irrigation Gas *Larry Kepley*, Southwest Kansas Irrigators Association
11:15 am	Bus to Site 11
12:00 noon	**SITE 11** - Seaboard Farms, Rolla Office / Lunch / Feterita Swine Feeding Sites *Jerry Frizzell,* Director of Safety and Environmental Affairs, Seaboard Corp. *Keith Siemsen,* Environmental Engineering Manager, Seaboard Farms, Inc. *Al Guernsey*, District Engineer, Kansas Dept. of Health and Environment
1:45 pm	Bus to Site 12
2:00 pm	**SITE 12** - Anadarko Petroleum Corp. - Oil and Gas Drilling in the Hugoton Field *Jerry Smith,* Division Operations Manager, Anadarko Petroleum Corp. *M.L. Korphage*, Kansas Corporation Commission
5:30 pm	Arrive Sleep Inn, Liberal
6:30 pm	Bus to Dinner
7:00 pm	Dinner - Liberal Petroleum Club
7:45 pm	Evening Session - Southwest Kansas *Senator Stephen Morris,* Hugoton

Hugoton Jayhawk Gas Plant

The Hugoton Jayhawk Gas Plant is a cryogenic (low temperature) natural gas liquids (NGL) recovery plant with both helium recovery and nitrogen rejection capabilities. The facility is in Grant County, about 13 miles east of Ulysses, Kansas, on U.S. Highway 160. The plant uses technology that does not require water in processing natural gas. All of the plant's compressors are driven by electric motors, essentially eliminating air emissions from the plant.

The Hugoton Jayhawk Gas Plant is designed to process 450 million standard cubic feet per day (MMSCF/D) of natural gas at approximately 300 pounds per square inch gas (psig). The plant receives gas from Amoco's gas gathering facilities and from other producers.

Processing the natural gas as it comes into the plant (inlet gas) involves compression, dehydration, recovery of natural gas liquids, recovery of nitrogen and helium, and propane fractionation (Fig. 1). Propane storage, truck loading facilities, and residue gas pipeline compressors are also located at the plant.

The Hugoton Jayhawk Gas Plant's inlet gas compressors and residue gas compressors share a single drive shaft, operating in tandem and powered by 16,500 horse power electric motors that use 13.8KV of power.

The inlet gas compressors, each rated at 160 MMSCF/D, boost the inlet gas pressure from approximately 300 psig to 850 psig for downstream processing. The residue gas compressors, each rated for 37.5 MMSCF/D, boost the residue gas pressure from approximately 92 psig to 335 psig for flow to the residue gas pipeline. Each compressor is equipped with an individual surge control system to protect it from power overloads.

Recovery of natural gas liquids from the inlet gas, and the relatively high concentration of inert gases (nitrogen and helium), reduces the heating value of the residue gas delivered from the plant. The high concentration of inert gas in the inlet gas limits the amount of NGL recovery because of the low heating value of the inlet gas. By removing the inert gases from the natural gas streams in the nitrogen recovery unit (cold box), a higher level of NGL recovery is achieved. Following the processing in the nitrogen recovery unit, the remaining residue gas is delivered to Williams Natural Gas Company's metering station and the residue gas pipeline.

The natural gas liquids are a Y-Grade mix that can be delivered to Koch or MAPCO's liquid pipelines. The nitrogen and helium are further separated into liquefied nitrogen and crude helium. The helium is delivered to the Praxair system, and the nitrogen is vented.

The propane fractionation unit is designed to produce 3,000 barrels per day of propane during the winter and 2,000 barrels per day during the summer.

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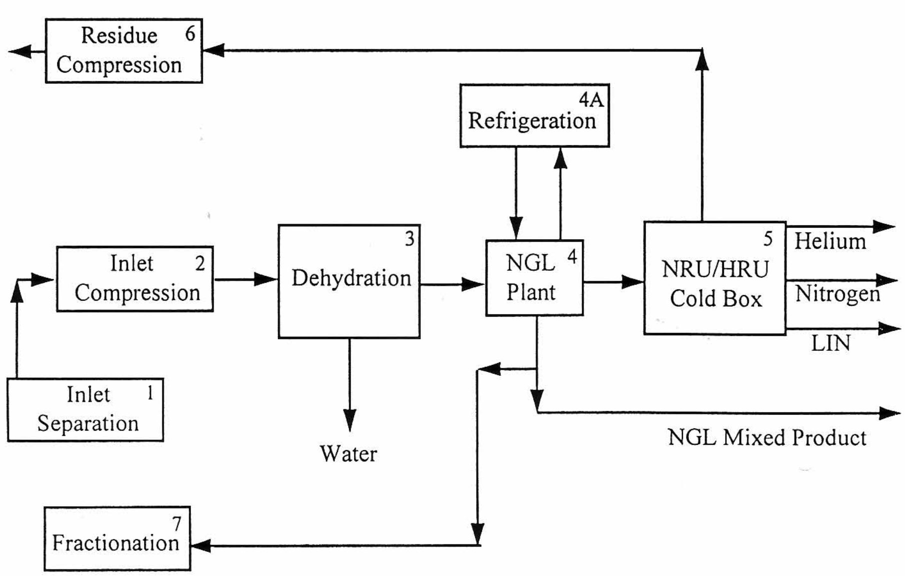

Figure 1. Block flow diagram of the Hugoton Jayhawk Gas Plant.

Irrigation Gas

The Hugoton Natural Gas Area may be one of the largest gas fields in the world, but it is not infinite. Eight decades of production have lowered reservoir pressure within the field from about 400 pounds per square inch (psi) to around 85 psi today. As long as the reservoir pressure (the natural pressure in the subsurface rock formations that hold the gas) is greater than surface pressure (14.7 psi), gas flows naturally to the surface. Reservoir pressures of around 90 psi are reduced to about 20 psi by the time the gas reaches the surface, which is barely sufficient for the gas to flow.

In parts of the reservoir where the pressure is even lower, companies are installing compressors to increase pressure in the pipelines that move the gas away from the wellhead. In effect, those compressors produce a vacuum that suctions the gas out of the well.

Declining pressures have an even greater impact on small users. For years, irrigators have used natural gas from the Hugoton to operate their irrigation wells. Today, about 85 percent of the pumps on irrigation wells in southwestern Kansas are powered by Hugoton gas. Many irrigators installed lines from the wellhead to their pumps in the days when Hugoton pressures were much higher. These small-diameter pipes (1-1/4 to 2 inches in diameter) take gas as much as a mile or two, from the wellhead to the irrigation pump. According to irrigators, pumps require about 8-10 psi. With reservoir pressures below 90, and wellhead pressures below 20, by the time the gas reaches the irrigation pump, the pressure may be too low to operate the pump.

Irrigators are taking various steps to deal with the problem. In some cases, they are adding their own compressors, an expense that farmers had not previously encountered. They are also forming non-profit utility companies to acquire gas from high pressure lines and distribute it to irrigators. The economic feasibility of these measures depends in part on commodity prices. The situation is exacerbated by dropping water levels in the High Plains aquifer, which mean that additional energy is necessary to move the water to the surface.

References

Kansas Geological Survey, 1997, Hugoton pressure declines concern irrigators: Kansas Geological Survey, The Geologic Record, v. 3.2, p. 1, 4.

Unruh, T., 13 March 1997, SW Kansas has gas pains, Garden City Telegram, p. 1-2.

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Seaboard Farms - Confined Swine Feeding Operations

Confined livestock feeding operations have become one of the most contentious issues in western Kansas. In 1994, the Kansas Legislature voted to give counties the option to decide whether to exempt themselves from a state law that bans most corporate ownership of swine production. Corporations have been a major player in hog production in Oklahoma for some time; the combination of arid climate, feed availability, and sparse human population has made the Oklahoma panhandle a center for hog production and packing. As of November 1997, 16 Kansas counties had approved corporate livestock facilities, either by public vote or by vote of county commissioners.

The movement of large hog feeding operations into southwestern Kansas raised a number of issues, among them environmental issues of air quality and ground-water contamination. During the 1998 legislative session, the Kansas legislature worked to address these concerns by passing a bill that sets a variety of new standards for confined feeding operations. Many of those standards are based on the size of the operation; the larger the number of hogs, the more stringent the regulations. Among the features of the bill are new requirements for

- setbacks--that is, the distance that hog facilities must be located from residences, public buildings, wildlife refuges, water wells, or surface water,
- different types of liners of the lagoons that operators use to dispose of waste; larger operations will be required to use synthetic liners, depending on depth to ground water,
- monitoring wells to measure the movement of waste-water from the lagoons,
- the application of manure from the feeding operations,
- inspection of confined feed operations, and
- the training of operators.

The legislature increased the number of inspectors from the Kansas Department of Health and Environment who are responsible for monitoring compliance with these regulations.

Kansas State University agronomists are currently studying many of the environmental issues related to confined feeding operations. In late April 1998 they presented a report to the Legislature on the operation of lagoons, and they will continue to study the issue for at least two more years (Ham et al., 1998). An executive summary of that report begins on page 4-5.

According to the Kansas Pork Producers Council, Kansas ranked 9th in the nation in hog production in 1996. State pork producers marketed 2.1 million head of hogs from 4,100 operations. Among the largest of those producers is Seaboard Farms Inc., which operates farm throughout western Kansas and Oklahoma.

References

Ham, J.M., Reddi, L., Rice, C.W., and Murphy, J.P., 1998, Evaluation of lagoons for the containment of animal waste: Kansas State University, research report submitted to the Kansas Dept. of Health and Environment, 28 April 1998.

House Bill 2950, Kansas Legislature, Session of 1998.

Kansas Farm Bureau, April 20, 1998, Bill Regulating Swine Facilities Sent to Governor: Legislative News, p. 1.

McNamar, Jerry, November 1997, Hog Issue More than Just Smell, Kansas Lifeline, p. 6.

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Evaluation of Lagoons for the Containment of Animal Waste
Executive Summary

J.M. Ham, L. Reddi, C.W. Rice, and J.P. Murphy
Kansas State University

Earthen storage lagoons are an integral part of the waste management and treatment system at many concentrated animal operations (CAOs) in Kansas. Lagoon waste contains significant concentrations of nitrogen, phosphorous, and other nutrients that are eventually applied to nearby farmland as liquid fertilizer. However, concerns have arisen that subsurface seepage losses from earthen lagoons could affect water quality in underlying aquifers. Therefore, research was initiated with the short–term objective of determining if lagoons built in accordance with Kansas regulations will keep seepage losses to less than 0.25 in./day, the recommended design standard. The long–term objectives of the project are to determine the relationship between seepage losses and groundwater quality. The initial research plan had four components: (1) a laboratory assessment of hydraulic conductivity (permeability) of several Kansas soils and the movement of water and animal wastes through those soils; (2) water balance studies of whole–lagoon seepage rates and waste chemistry at existing cattle feedlots and swine operations; (3) a preliminary survey of well–water quality in the vicinity of CAOs; and (4) a detailed review and summary of previous research conducted on seepage losses from earthen lagoons for animal waste. Research in these areas is ongoing and results presented here represent results to date, not final conclusions.

1. The laboratory study evaluated 22 soil samples covering a wide range of textures and physical properties. Permeability was measured using standard laboratory methods after unconsolidated soil samples were compacted at near–optimum water contents in 5–cm tall cores. The coefficient of permeability ranged from 4.95×10^{-7} to 4.8×10^{-9} cm/sec. If the soils analyzed were used to construct compacted liners 3 feet thick and subjected to a hydraulic head of 20 feet, the calculated seepage rates would lie between 0.13 to 0.0013 in./day. These data suggest that the existing standard of 0.25 in./day can be achieved with these soils provided field compaction is adequate and liner thickness is greater than 12 inches. When waste was used as the test fluid, the permeability of the soil cores tended to decrease with time but the effect was not pronounced or consistent. The waste used for the analysis was the liquid effluent, not the sludge that normally accumulates on the bottom of lagoons. Chemical and microbial analysis of leachate from the waste–permeated cores was highly variable. This will require additional study. Compaction characteristics of the samples showed that construction practices may strongly influence liner permeability.

2. Whole–lagoon seepage rates of three swine–waste lagoons and one cattle–feedlot runoff lagoon were measured using the water balance method. Seepage was calculated as the difference between evaporation and the change in water depth from data collected during periods when waste additions to the lagoons were precluded. Evaporation and depth changes were measured with automated floating lysimeters and water–level recorders developed specifically for the experiments. The swine lagoons tested were built in the mid 1990s, ranged in size from 2 to 6 acres, and contained 16.5 to 19 feet of waste. Seepage rates from the three swine lagoons were 0.05, 0.08, and 0.02 in./day. Seepage from an older cattle–feedlot lagoon was 0.09 in./day when waste depth was 4 to 5 feet. Losses were below the recommended standard of 0.25 in./day, and evaluation of soil hydraulic properties indicated that some degree of sealing resulted from organic sludge on the bottom of the lagoons.

Analysis of waste from the field experiments showed that ammonium was the primary form of nitrogen in the effluent, averaging 684 mg/L in swine–waste lagoons and 140 mg/L in cattle–feedlot runoff lagoons. Data on waste chemistry were used in combination with measurements of whole–lagoon seepage to estimate the mass of nitrogen being lost through the soil liners.

3. Although the well–water analysis is limited and ongoing, the current sampling scheme indicates no widespread nitrate contamination of

groundwater in the vicinity of CAOs. However, a more comprehensive sampling approach is needed to draw definite conclusions about spatial patterns of nitrate movement near lagoons and other sources of nitrogen.

4. A review of over 200 scientific papers shows that seepage losses from lagoons typically decrease rapidly during the first six months following the application of manure. The mat of organic sludge that accumulates on the bottom of the lagoon reduces liner permeability by the physical clogging of soil pores, with biological factors playing a minor role in the sealing process. Although measurements of whole–lagoon seepage rates are rare, available data show that seepage is typically less than 0.2 in./day in almost all cases after sufficient time for sealing has elapsed. However, there is evidence that most of the seepage is from the sides of the lagoon where the liquid surface meets the side–embankment. Lack of a sludge layer, coupled with erosion, pediogenesis, freezing–thawing, wetting–drying, and biological processes (roots, arthropods, etc.) can increase the permeability in this zone. It is likely that overall lagoon performance is the net result of extremely low permeability on the sludge–laden bottom zone coupled with an offsetting higher permeability of the side embankments. In the review of literature, measurements of water quality near waste lagoons were highly variable. However, the majority of studies in medium to finer–textured soils found no appreciable nitrogen contamination in the groundwater within about 100 feet of the lagoons. Several studies conducted outside Kansas in coarse–textured soils with high water tables, however, found appreciable contamination and seepage. Regional and statewide studies of well–water samples found that nitrate concentrations in the groundwater were negligible, regardless of proximity to CAOs, when the depth to the water table was greater than 100 to 130 feet. Analysis of lagoon waste shows that 95% of the nitrogen is in the form of ammonium, and a large fraction of the leachate is absorbed in soil directly under the lagoon. A significant and potentially hazardous quantity of this stored nitrogen could be converted to the mobile nitrate form when the lagoons are dried or abandoned. This finding points to the importance of developing a plan to reclaim the nitrogen beneath the lagoon after a facility is emptied or closed.

In summary, results provided in this report, coupled with a review of the literature, suggest that lagoons built in accordance with Kansas guidelines should have average seepage rates less than 0.25 in./day. Very low seepage rates (<0.1 in./day) can easily be achieved using 12– to 18–inch compacted soil liners built from appropriate soils. Questions remain concerning the relationships between seepage rates and groundwater quality. However, no widespread evidence of contamination in the vicinity of livestock operations is evident at this time. Locations with coarse–textured soils, low soil cation exchange capacities, and shallow water tables may require low–permeability soil liners or synthetic liners to protect local groundwater supplies. Given the variation in geology, soils, and types of animal operations in Kansas, decisions regarding lagoon permitting, construction, and management should consider both nitrogen input loading (e.g., nitrogen concentrations in the waste, liner performance, and seepage rates) and aquifer vulnerability (e.g., depth to groundwater, underlying soil hydraulic and chemical properties). Additional research on the fate and transport of chemicals beneath lagoons, coupled with risk analyses, will be required to tailor this approach for Kansas and surrounding states.

Reference

Ham, J.M., Reddi, L., Rice, C.W., and Murphy, J.P., 1998, Evaluation of lagoons for the containment of animal waste: Kansas State University, research report submitted to the Kansas Dept. of Health and Environment, 28 April 1998.

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Anadarko Petroleum Corporation

Anadarko Petroleum Corporation is one of the world's largest independent exploration and production companies, with proved reserves equivalent to more than 700 million barrels (MMBbls) of oil or over 4 trillion cubic feet (Tcf) of gas.

The reserve mix of the Company has shifted significantly in recent years, due to large oil discoveries in the U.S. and overseas. Oil now accounts for 59 percent of the Company's proved reserves compared to just six percent 10 years ago. At year-end 1997, Anadarko's proved energy reserves were 1,74 Tcf of natural gas and 420 MMBbls of crude oil, condensate, and natural gas liquids (NGLs). About 74 percent of the Company's reserves are located in the U.S. and 26 percent are located in Algeria.

Anadarko's core domestic drilling and production operations are located primarily in Kansas, Oklahoma, Texas, and the Gulf of Mexico. Anadarko and partners are developing a major oil field on Alaska's North Slope and exploring in southern Alaska's Cook Inlet Basin. Overseas, the Company has projects in Algeria, Eritrea, Jordan, Peru, the North Atlantic Margin, and Tunisia.

At year-end 1997, Anadarko had 1,386 employees. The Company's corporate office is located at 17001 Northchase Drive, Houston, Texas 77060-2141.

Hugoton Embayment

Anadarko's largest asset is reserves in the Hugoton Embayment, located in southwest Kansas and the Oklahoma and Texas panhandles. The Company controls about 1,000,000 lease acres in these areas and operates about 2,750 wells. Anadarko's net production from the Hugoton Embayment in 1997 was 99.2 billion cubic feet (Bcf) of gas and 1.53 MMBbls of oil and condensate. This represents about 40 percent of Anadarko's total production. During 1997, Anadarko drilled 177 conventional wells, 49 horizontal wells, and recompleted 55 wells in the area. The Company plans to drill more than 200 wells in the area in 1998.

Anadarko's activities in the Hugoton Embayment are concentrated on three areas: the shallow gas fields in southwest Kansas and the Oklahoma Panhandle, the deeper oil and gas zones below shallow production, and horizontal drilling in the shallow West Panhandle Field of Texas.

Shallow Production. Anadarko's oldest and largest field is the Kansas Hugoton Field. With about 10 percent of the wells in the Field, Anadarko controls nearly 14 percent of the Field's total production. Anadarko has a continuing program of drilling infill and replacement wells in the Field. During 1997, the Company drilled about 50 shallow gas wells (2,000-3,000 feet) in the Hugoton Embayment.

Deep Exploitation. The largest area of spending in the Hugoton Embayment is in the deep drilling program, with multiple productive zones from 4,000-6,000 feet. Anadarko doubled its spending level in the deep play during 1997.

Beneath the shallow gas fields is an extensive network of deeper oil and gas fields. Three dimensional (3-D) seismic has proved successful in exploiting these deeper pay zones. As of year-end 1997, Anadarko had acquired 480 square miles of 3-D seismic in the Hugoton Embayment. During 1997, the Company drilled about 120 wells. Production from the deeper horizons averaged nearly 4,000 BOPD and 60 MMcf/d of gas during 1997. Anadarko is now the largest oil producer in the region.

Over the last five years, Anadarko has invested about $93 million on its deep program. The Company drilled and completed more than 550 wells and added reserves of 38 million energy equivalent barrels (EEBs), representing a cost of finding of $2.44 per EEB.

Anadarko increased its drilling opportunities in the deep Hugoton play through a strategic alliance with Mobil signed in late 1997. In this Anadarko-operated venture, Mobil contributes 484,000 net undeveloped acres. In return, Anadarko contributes about 150,000 acres that revert to the Company from another operator in April 1999. Both parties own a 50-percent interest and Anadarko is committed to spend at least $24 million over the next four years. The venture can be extended indefinitely. Over the next decade, Anadarko may drill up to 700 wells on the alliance's deep acreage. About 40 wells are planned for 1998.

Anadarko has a vast gas gathering system in the Hugoton Embayment, with about 2,300 miles of pipe connecting more than 1,300 Company-operated wells. Combined, these systems move about 300 MMcf/d of gas, of which 250 MMcf/d is gas from Anadarko's wells. Pipeline pressures have been lowered, allowing lower pressure wells to produce more gas into the system. Anadarko has invested more than $120 million on gathering in the Hugoton Embayment since 1990.

The Company has 270 employees working the Hugoton Embayment and is a dominant player in the area. In an area where hydrocarbons have been produced for more than 75 years and production has long been on a natural decline, Anadarko continues to increase production and add reserves.

Reference

Anadarko Petroleum Corporation, 1997 Annual Report.

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Oil and Gas Drilling

Once the decision has been made to drill an exploration or development well for oil and gas, the process of actually drilling the well begins. The selection of the drill site is based on geological and geophysical evidence indicating the possible accumulation of petroleum. Once the drill site has been selected, an area is prepared to erect the drilling rig, excavate reserve pits, and provide storage for the materials and equipment that will be required for the drilling program. The drilling rig and all necessary equipment are moved onto the location with large, specially equipped trucks.

The first step in the drilling operation is to drill a surface hole and line it with steel casing. The surface casing protects aquifers that may contain freshwater. The surface hole may be several hundred or several thousand feet deep. Cement is pumped between the outside of the casing and the well bore all the way to the surface.

Modern rotary drilling rigs use a drill bit on the end of a string of drill pipe to drill the hole (Fig. 1). The entire string of pipe is rotated at the surface by a turntable causing the bit to chew up bits of rock at the bottom of the hole. The drill string, consisting of a drill bit, drill collars, drill pipe, and kelly, is assembled at the surface and lowered into the hole. Drilling fluid, better known as drilling mud, is circulated through the center of the drill string by pumps connected to the swivel, which is connected to the upper end of the kelly. The swivel enables drilling mud to be circulated while the kelly and drill string are rotated. The drilling mud passes through the swivel, kelly, drill pipe, drill collars, and drill bit, and then is returned to the surface through the space between the drill pipe and the walls of the hole (this space is called the annulus). At the surface, the drilling mud, which contains the rock cut up by the drill bit, is directed over the shale shaker, a device that separates the cuttings from the drilling mud. The drilling mud is returned to the mud tanks, where it is recirculated.

As drilling progresses, a geologist examines drill cuttings for signs of oil and gas. Sometimes special equipment, known a as mud logging equipment, is used to detect the presence of oil or gas in the drill cuttings or drilling fluid. By examining the drill cuttings, the geologist determines the type of rock that the bit is penetrating and the geologic formation from which the cuttings are originating.

Usually, the only interruptions to the drilling operation will be to removal the drill string (a procedure known as tripping) to replace the drill bit, conduct formation tests (called drill stem testing), or to cut a core.

When drilling has reached a predetermined total depth, the well is tested, if warranted, and logged with geophysical logging tools. By analyzing these logs, geologists and engineers can determine the depth from the surface to various formations, formation characteristics such as rock type and porosity, and indications of the presence of oil or gas.

If evidence indicates that no oil or gas are present, the well will be plugged and abandoned as a dry hole. If oil or gas are found in economic quantities, the well will be completed as a producer.

Reference

Baars, D.L., Watney, W.L., Steeples, D., and Brostuen, E.A., 1989, Petroleum: a primer for Kansas: Kansas Geological Survey, Educational Series 7, 40 p.

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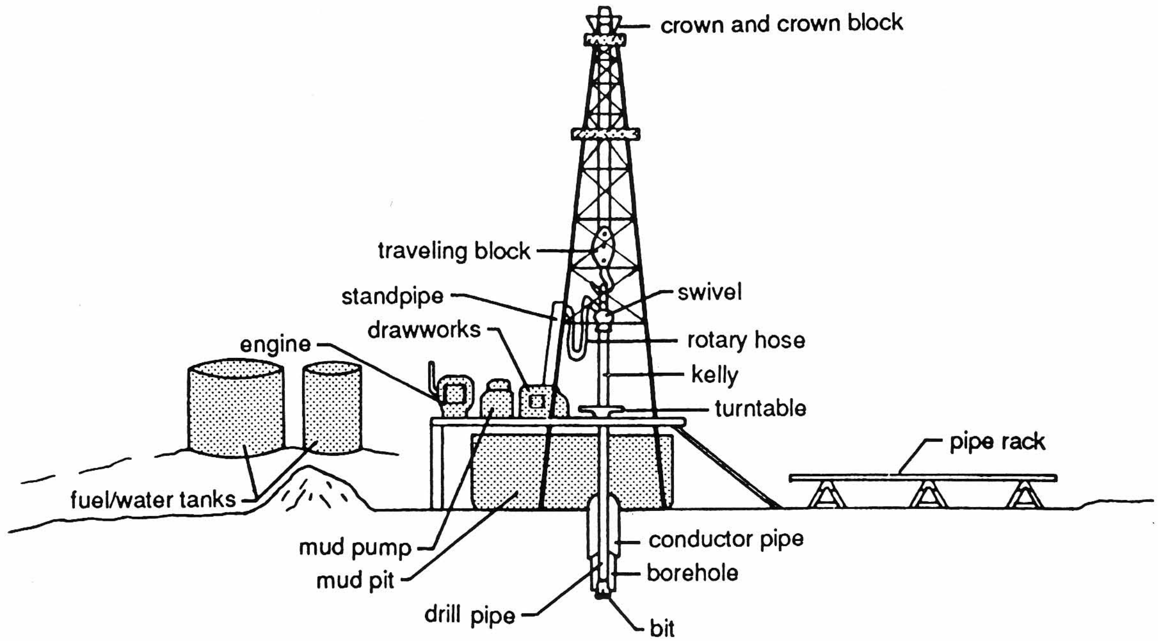

Figure 1. Drilling rig with its major components and related equipment (from Baars et al., 1989).

Kansas Geological Survey
Public Information Circular 5 January 1997

Hugoton Natural Gas Area of Kansas

Timothy Carr
Petroleum Research Section, Kansas Geological Survey
Robert S. Sawin
Geology Extension, Kansas Geological Survey

Introduction

The Hugoton field is the largest natural gas field in North America and the second largest in the world. The Hugoton is only one of many gas fields in southwest Kansas (fig. 1) that have been important to Kansas since their development in the 1930's. The major gas fields of this area—Hugoton, Panoma, Bradshaw, Greenwood, and Byerly—have produced almost 27 trillion cubic feet of gas (enough gas to supply every household in Kansas for 364 years, based on 1994 gas consumption rates). The Hugoton and associated gas fields are part of a large, bowl-shaped structure that underlies most of southwest Kansas. This region is referred to as the Hugoton natural gas area.

The Hugoton natural gas area provides gas and oil to Kansas and the nation, generating significant revenues and providing jobs and income in at least 13 counties in southwest Kansas. Economically, the Hugoton area is Kansas's most important natural resource. It will continue to be an important resource for Kansas in the future, but it must be understood, managed, and developed in a way that will maximize its benefit to Kansans. This circular explains the history and geology of the Hugoton gas area, its importance to the state, and how foresight and stewardship will affect its future.

Economically, the Hugoton area is Kansas's most important natural resource.

Geology

Geologists refer to southwest Kansas as the Hugoton basin or Hugoton embayment, a northern shelf-like extension of a larger and deeper subsurface feature in Oklahoma and Texas known as the Anadarko basin. The Hugoton embayment is a large (about 12,000 square miles; 31,080 square kilometers), southward-plunging trough bounded by uplifted areas on the west, north, and east.

In the ancient past, the Hugoton natural gas area was low and often covered by seas that repeatedly inundated and retreated from the shallow arm (or embayment) of the deeper Anadarko basin, leaving interbedded deposits of carbonate (limestone and dolomite) and shale. Thousands of feet of sediment accumulated over millions of years of geologic time. Sedimentary rocks thicken toward the middle of the basin and southward to about 9,000 feet (2,740 meters) near the Kansas-Oklahoma border. Oil and gas wells drilled in the deepest part of the Hugoton in Kansas are over 5,000 feet

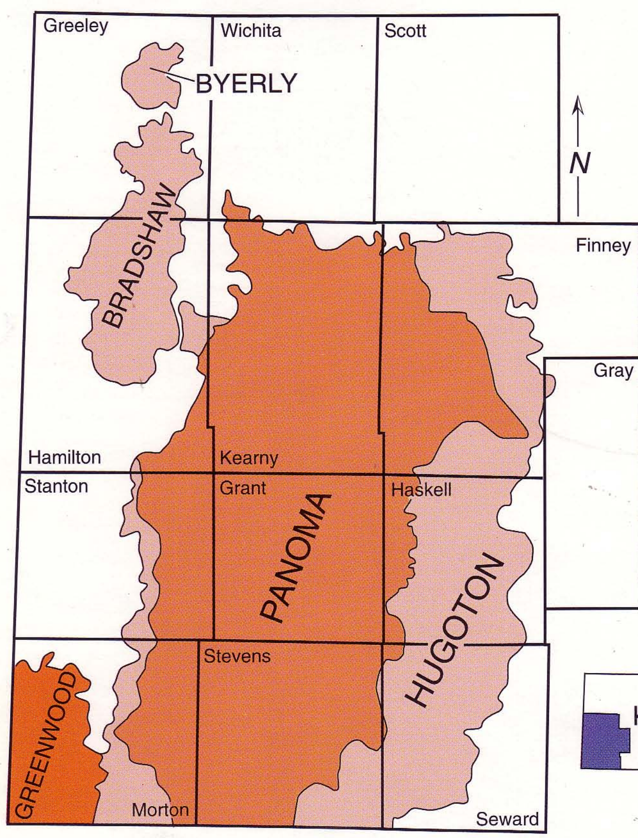

Figure 1—*The Hugoton natural gas area in Kansas.*

The potential for finding significant quantities of oil and gas is good, especially in the older Pennsylvanian and Mississippian rocks.

(1,520 meters) deep, deeper than wells drilled in other parts of the state. As the Anadarko basin deepens into Texas and Oklahoma, some wells are over 20,000 feet (6,090 meters) deep.

Natural gas and oil are produced from several different rock layers (fig. 2) and many individual fields. Most of the gas is produced from two rock units, the Chase and Council Grove Groups, that were deposited during the Permian Period, about 280 million years ago. These same units crop out in the Flint Hills of eastern Kansas. The Hugoton, Byerly, and Bradshaw fields produce gas from the Chase Group. Council Grove Group production is restricted to the Panoma field that is underneath and geographically overlapped by the Hugoton field (fig. 3). Rocks that are deeper and older than these units also produce significant amounts of oil and some gas in the Hugoton area, but many of these deeper zones have not been thoroughly tested. The potential for finding significant quantities of oil and gas is good, especially in the older Pennsylvanian and Mississippian rocks.

Period	Group	Field
Permian	Sumner	
	Chase	Hugoton Byerly Bradshaw
	Council Grove	Panoma
Pennsylvanian	Admire	
	Wabaunsee	Greenwood
	Shawnee	

Figure 2—*Geologic units that produce gas in the Hugoton area.*

Gas has accumulated in porous reservoir rocks, mostly Permian limestone and dolomite. Figure 3 illustrates a west-east cross section through the Hugoton field. The rocks of the Chase and Council Grove Groups are tilted slightly downward toward the east (and southeast) because of the uplift of the Rocky Mountains to the west. Gas moving from the deeper Anadarko Basin through porous rocks always seeks a higher level (geologists say it moves updip) until it is stopped or trapped. The updip trap on the west and north sides of the field is a stratigraphic-type trap—that is, a trap created by a change in the type of rock. Porous limestones and dolomites interfinger into red shales and siltstones (which were washed eastward from the Rocky Mountain uplift); these shales and siltstones form a barrier that effectively stops the migration of gas. The field is pinched off to the east where the impermeable rocks of the Sumner Group meet the underlying ground water (fig. 3). The top seal is provided by the overlying Sumner Group, a very tight barrier of anhydrite and shale.

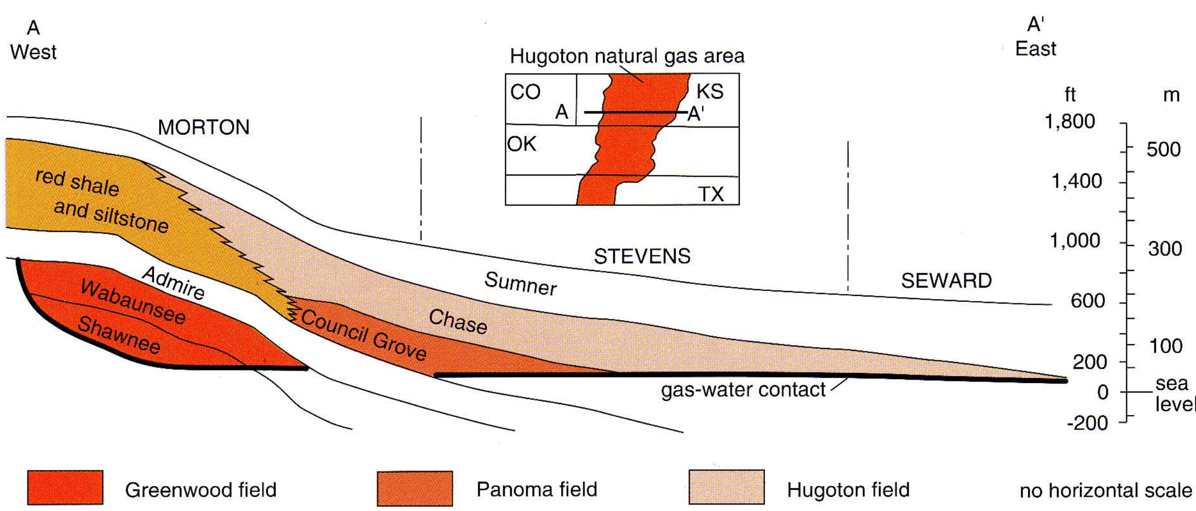

Figure 3—*Schematic west-east cross section through the Hugoton natural gas area (modified from Parham and Campbell, 1993).*

History

Gas in the Hugoton embayment was discovered in 1922 in Seward County, three miles west of Liberal. Because this well did not produce oil, it was considered to have little value and remained unused for several years. In 1927, gas was discovered at the Independent Oil and Gas Company's Crawford No. 1, about 2,600 feet (790 meters) below the surface southwest of Hugoton, Kansas, in Stevens County (Furbush, 1959). This is now considered the center of the Hugoton producing area. By the end of 1928, five wells had been drilled in the field and the first pipeline was transporting gas to local markets. In 1929, Argus Pipe Line Company started construction of a pipeline to furnish gas to Dodge City, Kansas (Hinton, 1952). Construction of major pipelines in the 1930's encouraged further drilling in the area. Today, approximately 11,000 wells produce gas and oil in the Kansas portion of the Hugoton area, and thousands of miles of pipeline carry Hugoton gas to many parts of the U.S.

In the interest of conservation, efficiency, and fairness, Kansas oil and gas production has been regulated since the 1930's. Regulations governing well spacing and rates of production continue to change as new technology and more information become available.

In 1983, the Deep Horizons Bill, which encouraged deeper exploration below the shallower gas-producing zones in the Hugoton area, was passed by the Kansas Legislature. For many years, wells were drilled on 640-acre (2.59-square kilometers) spacing units, or approximately one well per square mile. In 1986, the Kansas Corporation Commission (KCC) ruled that the Chase Group rocks in the Hugoton field were not being efficiently drained of gas and that more wells were needed to improve production. At that time, the Commission estimated that an additional 3.5 to 5 trillion cubic feet of gas, or roughly 10 to 15 years of additional production (at 1985 rates), could be recovered from the Chase Group in the Hugoton field. The Deep Horizons Bill, in conjunction with the KCC ruling, encouraged drilling and has led to increased gas production and the doubling of oil production from southwest Kansas (figs. 4 and 5).

Today, approximately 11,000 wells produce gas and oil in the Kansas portion of the Hugoton area, and thousands of miles of pipeline carry Hugoton gas to many parts of the U.S.

Importance to the State

The Hugoton gas area contributes significantly to the Kansas economy, both in terms of revenue and jobs. Since its discovery, the Kansas portion of the Hugoton gas area has produced almost 27 trillion cubic feet of gas. In 1995 alone, southwest Kansas fields produced 639 billion cubic feet (BCF) of natural gas, or 90% of the total gas produced in Kansas (fig. 4). In the same year, these fields produced 10 million barrels of oil (MBO), about 23% of the state's annual oil production (fig. 5). The combined worth of this gas and oil is estimated at $1.3 billion. During that same year, the Hugoton area provided about $80 million in severance taxes to the State and probably an equal or greater amount from *ad valorum*, sales, and income taxes on royalty owners, companies, and employees. The State also receives other taxes that result from the activities of the oil and gas industry. These include indirect taxes on the goods and services purchased by the oil and gas industry and the taxes paid by downstream industries, those involved in refining, distribution, and manufacturing of hydrocarbon-based commodities, such as plastic and fertilizer. The oil and gas industry also pays property taxes to the counties.

Gas and oil production in the Hugoton area has been increasing, and the long-term producibility is the best in the state. Hugoton gas and oil production have both doubled in the last decade, resulting in

In 1995 alone, southwest Kansas fields produced 639 billion cubic feet (BCF) of natural gas, or 90% of the total gas produced in Kansas.

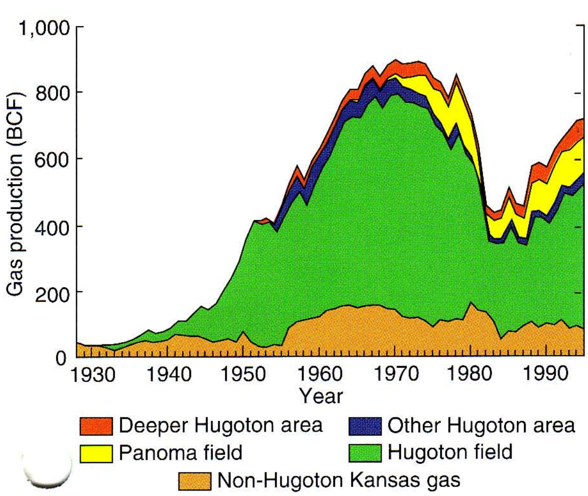

Figure 4—*Gas production in Kansas (BCF = billion cubic feet of gas).*

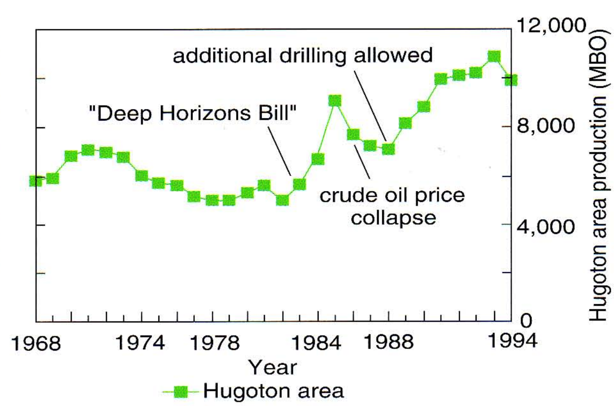

Figure 5—*Hugoton oil production (MBO = million barrels of oil).*

production valued at $1.5 billion, which translates into $90 million in additional severance tax money to the State. This production increase is in sharp contrast to the steady production declines in the rest of the state and nation. Gas and oil production from the Hugoton area of southwest Kansas is important, if not critical, to the economic health of the region and the state.

Future of the Hugoton Gas Area

Published information on the Hugoton area is rare considering its geographic size, the amounts of gas and oil produced, and the revenues generated. Despite the Hugoton's long history of production, no comprehensive study has guided how best to explore, produce, and regulate gas and oil in the Hugoton area. Relatively little is known of the basic architecture of the reservoirs or the fundamental geologic controls on the migration, trapping, and production of gas and oil.

For years, geologists thought the reservoirs that produced gas from the giant fields were relatively continuous, or homogeneous. Modern studies now show the rocks can contain barriers restricting the flow of gas both vertically and horizontally, causing many of the reservoirs to be isolated into individual compartments. Understanding how the reservoir is divided is important for efficient recovery of gas and oil. The ultimate goal is to drill the minimum number of wells that will recover the maximum amount of available gas or oil.

The urgency for policy based on strong scientific knowledge is highlighted by declining trends in reservoir pressure. Reservoir pressures that are higher than the surface pressure force gas to the surface, much like letting air out of a balloon. Because of development, the average reservoir pressure in the Hugoton area has declined from over 400 pounds per square inch (psi) to under 100 psi today. At the current rate of decline (fig. 6), pressures will soon approach their economic limit—that is, the cost of bringing the gas to the surface will exceed the value of the gas. As reservoir pressures continue to decline, intelligent energy policies and new technologies must be developed to assure continued production.

Knowledge and a technical base are required for intelligent stewardship, generation of new opportunities, and continued improvement in recovery strategies. A better understanding of the Hugoton area would allow more efficient exploitation of this resource. State policy-makers, operators, regulators, and mineral owners need accurate information to make informed decisions about regulations, drilling and production programs (for example, infill drilling and drilling of deeper horizons), and how to recover the most gas and oil from the Hugoton area. The Kansas Geological Survey is proposing a comprehensive study that will provide the geological information that is needed for intelligent decision-making.

The Hugoton area in Kansas contains an estimated 10 to 15 trillion cubic feet of natural gas. Even a small increase in annual and ultimate production of gas and oil from the Kansas portion of the Hugoton area will result in many millions of dollars of economic activity and tax revenues. Savings from more efficient production practices and access to smaller, currently unknown reservoirs could extend the field's life. Both the public and private sectors will benefit from efficient and increased production of oil and gas from the Hugoton area.

Kansans should be aware that the oil and gas resources of the state require continuous stewardship. Just as we manage our valuable ground-water resources, we must protect and manage the Hugoton natural gas area. Periodic review of energy policies and development of new technologies must continue in order to maintain the environment for conscientious and beneficial exploration, development, and production.

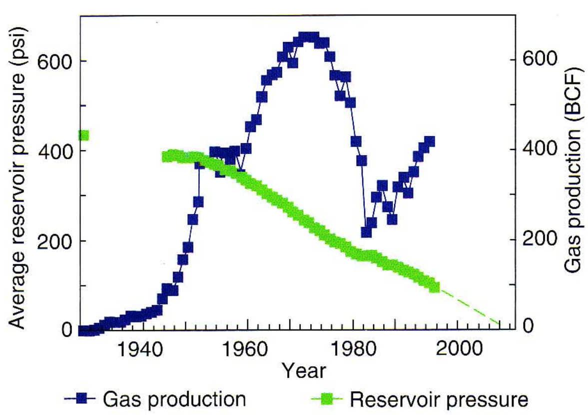

Figure 6—*Declines in reservoir pressure in the Hugoton natural gas area (BCF = billion cubic feet of gas) (modified from David Williams, Kansas Corporation Commission).*

Despite the Hugoton's long history of production, no comprehensive study has guided how best to explore, produce, and regulate gas and oil in the Hugoton area.

The mission of the Kansas Geological Survey, operated by The University of Kansas in connection with its research and service program, is to conduct geological studies and research and to collect, correlate, preserve, and disseminate information leading to a better understanding of the geology of Kansas, with special emphasis on natural resources of economic value, water quality and quantity, and geologic hazards.

The Geology Extension program furthers the mission of the KGS by developing materials, projects, and services that communicate information about the geology of Kansas, the state's earth resources, and the products of the Kansas Geological Survey to the people of the state.

Public Information Circular 5
January 1997

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References

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Parham, K. D., and Campbell, J. A., 1993, PM-8. Wolfcampian shallow-shelf carbonate—Hugoton embayment, Kansas and Oklahoma; *in*, Atlas of Major Midcontinent Gas Reservoirs, D. G. Bebout, W. A. White, T. F. Hentz, and M. K. Grasmick, eds.: Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas, 85 p.

SCHEDULE & ITINERARY

Friday June 5, 1998

7:00 am	Breakfast
7:50 am	Bus to Site 13
8:00 am	**SITE 13** - OXY USA Inc. - Electronic Metering and Well Control *Bob Summers,* Senior Production Technician, OXY USA Inc. *Lisa Sellmyer*, Operations Leader, OXY USA Inc. *M.L. Korphage*, Kansas Corporation Commission
9:00 am	Bus to Site 14
9:30 am	**SITE 14** - Lake Meade State Park *Mark Goldsberry*, Park Manager, Kansas Dept. of Wildlife and Parks
10:15 am	Bus to Site 15
11:00 am	**SITE 15** - Big Basin Prairie Preserve *Rob Manes*, Asst. Secretary for Operations, Kansas Dept. of Wildlife and Parks *Alan Pollom,* State Director, The Nature Conservancy
11:45 am	Bus to Dodge City
12:30 pm	**Arrive Holiday Inn Express, Dodge City**

Electronic Gas Measurement and Well Control

OXY USA Inc. operates over 1,000 oil and gas wells in southwest Kansas. In 1991, OXY installed Totalflow electronic meters (fig. 1) on each gas well. Electronic meters greatly increase the accuracy of measurements and provide "real time" flow status for each well.

The electronic meters communicate with the office computers with 900 megahertz radio systems. Each morning, the computer system "polls" each meter for current readings on pressure, temperature, flow-rate, and the previous day's gas volume. This data is supplied to field personnel, giving them information they need to make decisions about where to spend their time in the field. This information is also sent electronically to the region office and then forwarded to other pipeline companies, allowing OXY to conduct business on a daily basis instead of waiting until the end of the month.

Another benefit of electronic metering and well control is state testing. Prior to the installation of electronic meters, OXY personnel and Kansas Corporation Commission representatives had to visit each location to conduct tests. With electronic metering, wells can be tested from one central location, thus saving time for OXY and KCC employees. Also, each well can be programmed to produce gas according to State of Kansas allowables.

With the advent of Wide Area Networks, all OXY wells in southwest Kansas can be controlled from one central location. OXY is in the process of expanding the role of electronic meters, using them to monitor tank levels and look for leaks, thus providing additional safeguards against environmental accidents.

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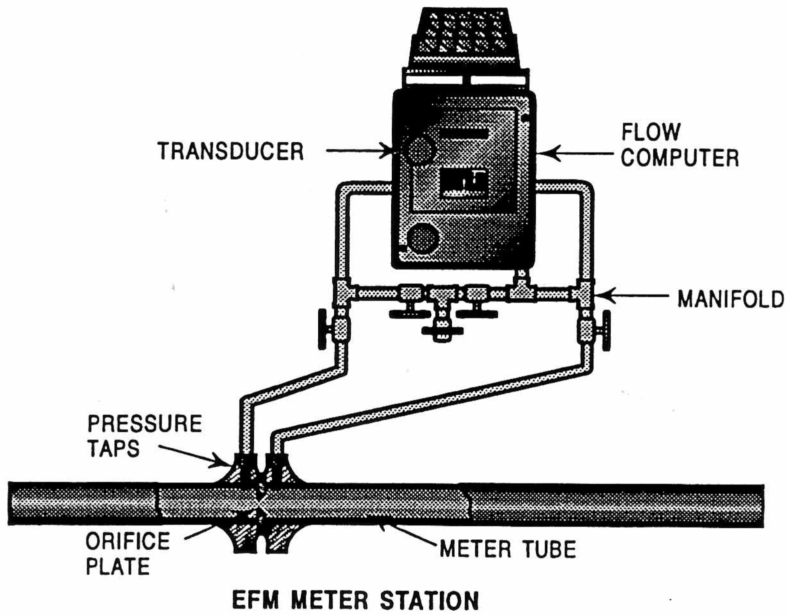

Figure 1. Electronic flow measurement (EFM) is an electronic means of gathering flow data and converting it into gas flow rates and total volumes. The transducer converts mechanical measurements into electrical signals.

Lake Meade State Park

Originally carved out of the Turkey Track Ranch in 1927, Lake Meade State Park rests in the High Plains of southwest Kansas, just west of the Red Hills. Located eight miles south and five miles west of Meade on Kansas Highway 23, the state park and wildlife area comprise 803 acres of land and water.

Meade Lake dam was built in the 1930's by the Civilian Conservation Corps (CCC). This site was chosen for the lake because of numerous springs in the area. A fault east of the lake has created artesian conditions in this part of Meade County. A test well drilled near the lake in 1939 had an artesian head of 17.4 feet (Frye, 1942), that is, water rose under its own pressure in a pipe that far above the land surface. Today, because irrigation has lowered the water table, flow from the springs and artesian wells has deminished or stopped all together. A flowing artesian well in the park just west of the lake flows at a rate of about 5 gallon per minute.

Originally called Lake Larrabee, the 80-acre lake was turned over to the Kansas Park and Resources Authority in the 1960's to be developed as a park. The lake itself is considered a state fishing lake, and the 443 acres surrounding it is a state park. About 35 to 40 acres near the lake have been developed with shower buildings, toilets, blacktop roads, tables, grills, campgrounds, and utility camp sites. The rest is managed for wildlife habitat and public use.

The average annual visitation at Lake Meade State Park (1993 to 1997) was 82,715. Low visitation in 1994 and 1995 was caused by major fires that closed part of the park until staff could remove damaged and dangerous trees. Last year, visitation was 130,694.

People who use the area camp, fish, picnic, swim, and view native wildlife and plants. Lake Meade State Park is the only water-based recreation area for miles in any direction. The closest lake is Clark State Fishing Lake, 60 miles to the east. The nearest state park is Scott State Park, about 110 miles northwest.

Issues at Lake Meade State Park

- Springs that historically kept the lake charged with water have dried up as artesian pressures continue to decrease. As irrigation and water use increase, water in the lake will continue to diminish. After the lake went dry in 1983, the Department obtained a water right to pump 500 acre-feet of water from a well near the fish hatchery.
- Most of the trees on the property were planted in the 1930's and 1940's. The older cottonwoods are in their advanced years, and young trees need to be planted.
- The population in southwest Kansas is increasing, and the need for water-based recreation has intensified. Meade Lake is an important resource for the people in western Kansas, Oklahoma, and the Texas panhandle. The lake provides an oasis where they can relax and enjoy the outdoors.

References

Lake Meade State Park, Kansas Dept. of Wildlife and Parks, brochure.

Frye, J.C., 1942, Geology and ground-water resources of Meade County, Kansas: Kansas Geological Survey Bulletin 45, 152 p.

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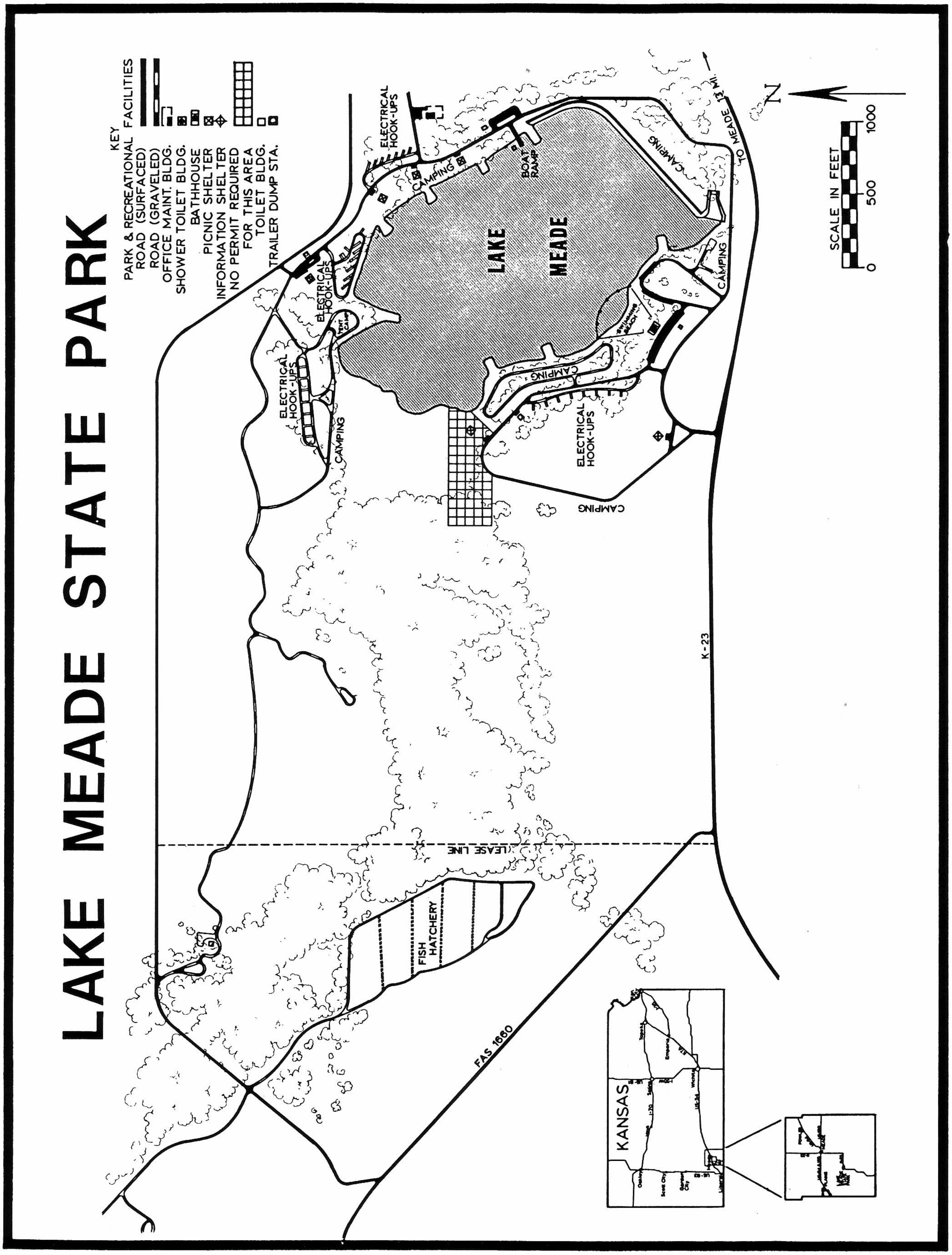

LAKE MEADE STATE PARK
KEY
PARK & RECREATIONAL FACILITIES
ROAD (SURFACED)
ROAD (GRAVELED)
OFFICE MAINT. BLDG.
SHOWER TOILET BLDG.
BATHHOUSE
PICNIC SHELTER
INFORMATION SHELTER
NO PERMIT REQUIRED FOR THIS AREA
TOILET BLDG.
TRAILER DUMP STA.
LAKE
MEADE
ELECTRICAL HOOK-UPS
CAMPING
BOAT RAMP
ELECTRICAL HOOK-UPS
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KANSAS

Walk-In Hunting Areas

The WIHA (short for Walk-In Hunting Area) program is opening unprecedented hunting opportunities in Kansas. Likely one of the most popular projects initiated by the Kansas Department of Wildlife and Parks in recent years, the WIHA program leases private land and opens it to public hunting. Because of the relative paucity of public hunting areas in Kansas, this program provides alternative locations for hunters. It was fashioned after a program in South Dakota. Payments to landowners are based on acreage enrolled and length of the contract. The average of the 1997-1998 season is $1.23 per acre.

Initiated as a pilot project during the 1995-1996 hunting season, the WIHA program had a modest beginning in southcentral Kansas. Forty-six landowners in seven counties enrolled 10,400 acres in that first year. Due to overwhelming positive response from both landowners and sportsmen, the program was expanded statewide prior to the 1996-1997 hunting seasons. That year 380 landowners enrolled 181,000 acres in 84 counties. And this year the program's growth has continued with 330,000 acres enrolled by 725 landowners in 89 counties.

Much of the land involved in the program is CRP (Conservation Reserve Program which returns highly erodible land to native grass). However, other habitat types including wetlands, riparian, and crop areas are also included in the current program. The minimum amount of land that can be enrolled is 80 contiguous acres, and there are several landowners who have enrolled more than 1,000 acres.

Hunters can locate enrolled tracts of land by picking up a WIHA atlas from any regional, state park, or department office. In addition to the index, listing each tract's size and hunting opportunities, the atlas includes a full county map for each county with WIHA tracts. Each tract is marked and numbered on the map. Access is by foot traffic only. Each of the areas enrolled are patrolled by conservation officers similar to activity seen on public hunting areas.

References

Murrell, M., 1997, WIHA opportunities to hunt: Kansas Wildlife and Parks, vol. 54, no. 6, p. 31-32.

Kansas Department of Wildlife and Parks, 1997, Kansas Walk-In Hunting Area Atlas, 104 p.

Resource Contact

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Big Basin Prairie Preserve

The Big Basin Prairie Preserve is 1,818 acres of native short-grass to midgrass prairie in an area of steepsided sink holes that is managed by the Kansas Department of Wildlife and Parks. This area is in the Red Hills physiographic region of Kansas, located in Clark County about 14 miles west of Ashland on U.S. Highways 160 and 283. The landscape can generally be described as rolling hills with level uplands and small canyons. The preserve also includes an intermittent stream, Keiger Creek, which flows through the northeast corner of the preserve, and two undrained basins that make the preserve topographically and geologically unique.

The Nature Conservancy acquired Big Basin Prairie Preserve in 1972 and sold it to the Kansas Department of Wildlife and Parks in 1974 with the stipulation that it be managed as a nature preserve. In December of 1978, the preserve was designated as a National Natural Landmark and was added to the National Registry of Natural Landmarks.

Historically, St. Jacob's Well and Big Basin were used as landmarks and watering sites on trail drives that were bringing cattle from Texas. A Living Water Monument commemorates the area's importance to early settlers.

Rocks at the surface are Permian, Cretaceous, and Tertiary in age. Permian rocks contain gypsum layers in the subsurface. Big Basin, Little Basin, and St. Jacob's Well were formed in the recent geological past by a process known as solution-subsidence. This process occurs when surface water gains access and dissolves underground deposits of salt, gypsum, or limestone. The overlaying layers of rock and minerals subside to fill the volume vacated by the water soluble deposits. Small depressions forming within Little Basin are evidence that the process of solution-subsidence is still occurring. A small sink dropped about 200 yards east of St. Jacob's well in 1944.

Big Basin is a large circular depression that is one mile in diameter and about 100 feet deep. Scattered across the floor of Big Basin are small ephemeral ponds that catch and temporarily hold water that falls into the basin. U.S. Highway 283 bisects Big Basin, with approximately two-thirds of the basin lying east of the road and within the confines of the preserve. The remaining western third of the basin is privately owned.

Little Basin is about 280 yards in diameter and 35 feet from rim to floor. Within Little Basin is a small permanent pond (sink hole) known as St. Jacob's Well. St. Jacob's Well is a pool of water about 84 feet in diameter that has never been known to go dry. The well has been the subject of many local legends, most associated with the idea that the well was bottomless or connected to an underground stream that was capable of washing away anything that fell in the well. The well was also reportedly inhabited by blind fish. Research has shown the well to be roughly funnel shaped and 58 feet deep. No evidence of an underground stream or blind fish has been found.

The primary objective in managing the preserve is to maintain the site in its natural state and thus preserve a unique ecological and geological area. Grazing is a natural and healthy activity in the prairie ecosystem, and herds of bison are maintained at the preserve to continue this natural process. The preserve is also utilized as an education center, providing opportunities for conservation education and research. Those visiting the preserve will develop a greater appreciation of the natural resources of Kansas and more concern for the conservation of all natural resources.

Vehicles are restricted to the improved trails. Maintenance of these trails is minimal so visitors should drive slowly and with caution. Foot traffic on the remainder of the area is allowed and encouraged. However, persons on foot should stay clear of the bison area. No hunting is allowed in the area.

References

Big Basin Prairie Preserve, Kansas Dept. of Wildlife and Parks, brochure.

Resource Contacts

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BIG BASIN PRAIRIE PRESERVE (1818 Acres)