Approved: April 26, 2001
Date

MINUTES OF THE HOUSE COMMITTEE ON ENVIRONMENT.

The meeting was called to order by Chairperson Joann Freeborn at 3:30 p.m. on March 13, 2001 in Room 231-N of the Capitol.

All members were present except: Representative Dan Thimesch - excused
Representative Clay Aurand - excused
Representative Vaughn Flora - excused
Representative Bill Light - excused

Committee staff present: Raney Gilliland, Kansas Legislative Research Department
Mary Ann Graham, Committee Secretary

Conferees appearing before the committee: Dr. Joe L. Ratigan, Sofregaz US, Inc., Huston, Texas
Dr. M. Lee Allison, State Geologist and Director, Kansas Geological Survey, University of Kansas, 1930 Constant Avenue, Lawrence, KS 66047-3726
Karl Mueldener, Director, Bureau of Water, Kansas Department of Health and Environment, Forbes 283, Topeka, KS 66620-0001
Steve Johnson, Executive Director, Corporate Relations, Kansas Gas Service Company, Overland Park, KS

Others attending: See Attached Sheet

Chairperson Joann Freeborn called the meeting to order at 3:30 p.m. in room 313-S. She reviewed the committee agenda for Thursday, March 15, which will be meeting in room 519-S. A group of about 30 members from the Kansas Environmental Leadership Program (KELP) will be visiting the committee that day. There will be possible action on **SB237** and discussion on Substitute for **SB204**.

The Chairperson welcomed the presenters addressing the committee today on the Natural Gas Storage near Hutchinson, Kansas:

Dr. Joe L. Ratigan, Sofregaz US, Inc. appeared on behalf of the city of Hutchinson. He began providing consulting services to that city on January 19, 2001. He addressed the current Kansas Department of Health and Environment rules for underground storage and whether these rules need revision. In his testimony he described the technology of storing liquid and gaseous hydrocarbons in solution mined salt caverns, the state regulation of such technology, and the Kansas regulations and how they compare to those in other states. (See attachment 1)

Dr. Lee Allison, State Geologist and Director, Kansas Geological Survey, University of Kansas. The Kansas Geological Survey is tasked under statute to investigate and report on the natural resources of the state. They are established as a research unit of the University of Kansas to bring unbiased and scientifically sound expertise to bear on resource issues. Their role in the Hutchinson situation began the day after the trailer park explosions when it became known that geological investigations were needed. They served initially as geologic advisors to Kansas Department of Health and Environment. When many of the early vent wells turned out to be dry holes, it became clear that complex geologic conditions were likely controlling the pathways and accumulations of the gas. (See attachment 2)

Karl Mueldener, Director, Bureau of Water, Kansas Department of Health and Environment, described the Kansas facilities; hydrocarbon storage, propane, butane, natural gas, and gasoline; Stored in salt formation, solution mined caverns, jugs; 10 active facilities, one natural gas, nine LPG; Companies: Kansas Gas Service, Koch, Ferrellgas, NCRA, Texaco, Williams, and Oneok; 623 active wells, 159 plugged wells, 80 million bbls total Kansas storage; and Seven inactive facilities. He reviewed the Regulatory Program History, History, State Regulatory Authority and Regulation Plans, along with maps and diagrams. (See attachment 3)

Steve Johnson, Executive Director, Corporate Relations, Kansas Gas Service Company, addressed the role that natural gas storage plays in the timely, cost effective distribution of natural gas to their customers. Underground natural gas storage is not a new industry practice, it dates back to 1915. In today's restructured, highly competitive natural gas market, storage has taken on a much higher profile. Significant expansions and new installations in storage capacity and deliver ability were made across the country in the 1990's. Today about 8.2 trillion cubic feet of natural gas is stored in the United States, of which about 300 billion cubic feet is stored in Kansas. (See attachment 4)

John Rose, Enron Transportation Services, Senior Reservoir Engineer for Northern Natural Gas, a subsidiary of Enron Corporation, submitted written only information on Natural Gas Storage Service. Northern operates in 23 Kansas counties and owns two natural gas underground storage facilities in Kansas located near Lyons and Cunningham. Underground natural gas storage facility sites may be depleted oil and gas fields, aquifer storage or salt cavern storage. The Lyons and Cunningham fields are representative of depleted gas fields that have been converted to provide underground storage service. (See attachment 5)

The Chairperson thanked the presenters for addressing the committee.

The meeting adjourned at 5:50 p.m. The next meeting is scheduled for Thursday, March 15, 2001.

HOUSE ENVIRONMENT COMMITTEE GUEST LIST

DATE: March 13, 2001

NAME	REPRESENTING
Jon Josserand	KU
Bob Krehbiel	KIOGA
Jim Kaup	
[illegible]	
John DeCoursey	Kansas Gas Service
Whitney Damron	KS Gas Service
Larry Fischer	Ks Gas Service
Mike Cochran	Kansas Dept. Health & Environment
Scott Schneider	GBBA

TESTIMONY
BEFORE THE KANSAS HOUSE ENVIRONMENT COMMITTEE
TOPEKA, KANSAS

By

Joe L. Ratigan, Ph.D.
Sofregaz US, Inc.
Houston, Texas

March 13, 2001

Good morning. I wish to thank you for the opportunity to provide this testimony.

My name is Joe Ratigan. I am a consulting Geologic Engineer, Senior Vice President, and Principal Consultant for Sofregaz US, a storage cavern engineering and construction firm in Houston, Texas. I hold bachelor and master degrees in mechanical engineering and a Ph.D. in geologic engineering. I am a Registered Professional Engineer in Texas and South Dakota. I provide consulting services to the underground solution-mining and hydrocarbon storage industry. The services include geomechanical studies and facility permitting.

I am also the Research Coordinator for the Solution Mining Research Institute, a professional organization of solution-mining and underground storage owners, service companies, and researchers. Additionally, I serve on a rules committee for the Louisiana Department of Natural Resources Injection & Mining Division, the organization responsible for developing revised salt cavern storage rules.

I am appearing today on behalf of the city of Hutchinson. I began providing consulting services to the city of Hutchinson on January 19, 2001.

My testimony today addresses the current Kansas Department of Health and Environment (KDHE) rules for underground storage and whether these rules need revision. In my testimony, I wish to describe the technology of storing liquid and gaseous hydrocarbons in solution-mined salt caverns, the state regulation of such technology, and the Kansas regulations and how they compare to those in other states.

This testimony is not intended to be a comprehensive review of the Kansas regulations nor is it a comprehensive review of the regulations of other states. It is, rather, a detailed introduction to the issues that need to be addressed as a result of the incidents in Hutchinson. It is my belief that Kansas needs to revise their rules for underground storage of hydrocarbons. I believe my testimony will convince the committee to adopt that same position.

House Environment
3-13-01
Attachment 1

My testimony today consists of a brief description of (1) North American salt formations, (2) salt as a construction material, (3) solution-mined caverns for hydrocarbon storage, and (4) the history of regulation and regulations in other states. I then conclude the testimony with a discussion of Kansas regulations.

NORTH AMERICAN SALT FORMATIONS

Salt formations are distributed throughout North America, as shown in Figure 1. There are two basic types of salt formations – salt domes and bedded salt.

Salt domes are very large bodies of salt (up to several miles in diameter and many miles "tall") consisting of nearly pure sodium chloride (usually >95 percent). Hundreds of salt domes in the United States are located along the Gulf Coast in the states of Alabama, Mississippi, Louisiana, and Texas. All of the salt domes in the Gulf Coast developed from a very deep (>30,000 feet) bedded salt called the Louann salt.

Bedded salt formations differ significantly from salt domes. Bedded salt formations consist of "layers" of salt interbedded with nonsalt rocks, such as shale, dolomite, and/or anhydrite. Bedded salt formations can vary considerably from one another. Additionally, a bedded salt formation within a specific basin can vary from one part of the basin to the other. For example, the Hutchinson bedded salt unit is only 40 to 50 percent salt in Oklahoma; whereas, in central Kansas, the Hutchinson salt unit can be as much as 80 percent sodium chloride. The principal "impurity" or nonsalt rock in the Hutchinson salt formation is shale. These impurities exist in small percentages within the salt beds, but primarily exist as distinct geologic units separating beds or layers of salt within the salt formation.

The only salt formations usable for storage caverns in Alabama, Mississippi, and Louisiana are salt domes. Texas is the only state that has both bedded salt and salt domes (at usable depths). The only salt formations in Kansas, Oklahoma, Ohio, Michigan, New York, and Pennsylvania are bedded salt formations.

SALT AS A CAVERN CONSTRUCTION MATERIAL

Salt is an excellent construction material for hydrocarbon storage caverns. It is easily, economically, and predictably mined (through solution mining) and is essentially impermeable at moderate pressures. The nonsalt interbeds that exist in bedded salts are, however, not impermeable and must be given consideration when developing storage caverns in bedded salt formations.

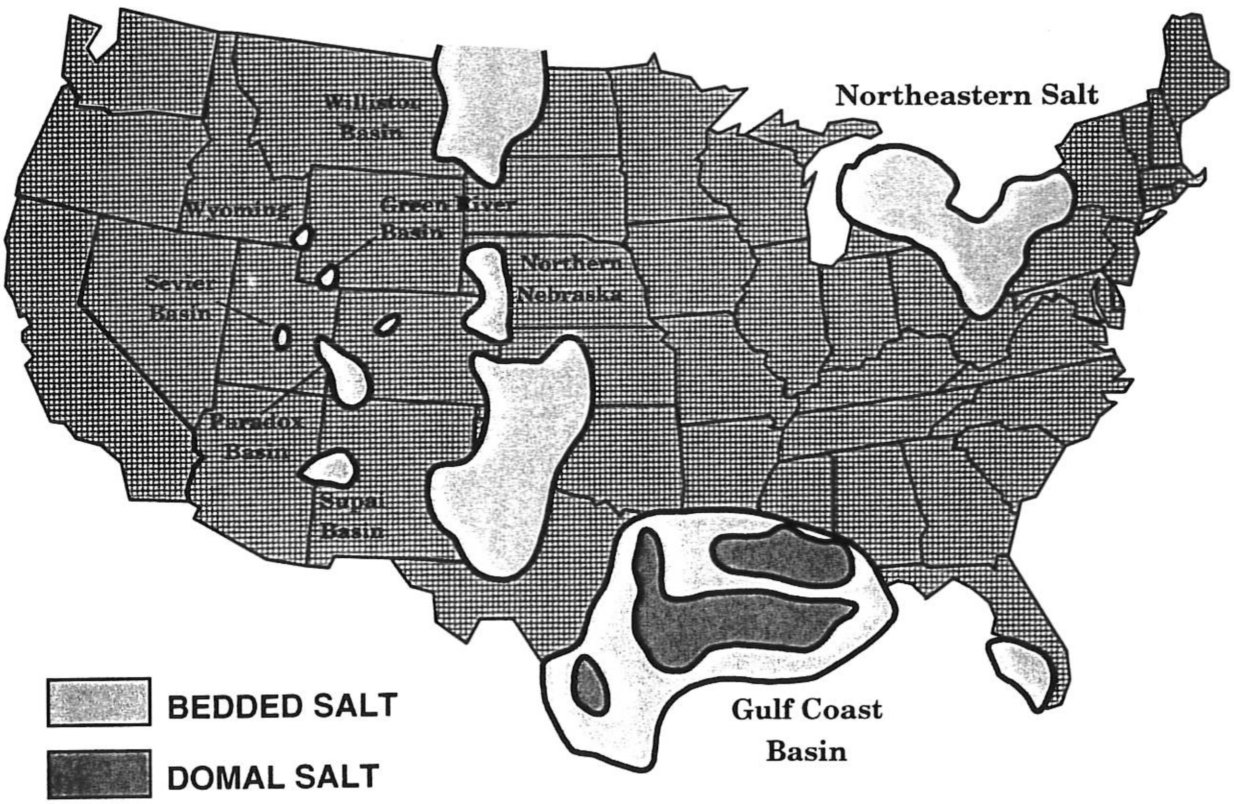


Figure 1. Salt Formations in North America.

Like any other construction material, properties and in situ conditions[1] must be determined for the salt and nonsalt rocks in which a storage cavern is to be developed. These properties and conditions must be used in concert with the operating conditions of the intended storage cavern to ensure a successful storage project. For example, the fracture gradient[2] in the nonsalt units of the Hutchinson salt unit must be determined to establish a safe maximum gas storage pressure for a gas storage cavern developed in the Hutchinson unit.

SOLUTION-MINED CAVERNS FOR HYDROCARBON STORAGE

Salt has been mined by "solution-mining" since the late 1800s. The Hutchinson area was one of the first areas in the United States where solution mining of salt was practiced. In the late 1940s and early 1950s, the oil and gas industry realized that the cavities created during salt solution mining could be used to store natural gas liquids (NGLs) or liquefied petroleum gases (LPGs)[3]. The NGLs/LPGs could be injected into the solution-mined caverns and brine would be displaced as the NGLs/LPGs were injected. Similarly, when the cavern owner wanted to recover the NGLs/LPGs from the cavern, he could merely inject brine back into the cavern and NGLs/LPGs would be produced at the surface. Figure 2 provides a schematic illustration of a NGL/LPG storage cavern in a bedded salt formation.

Again, Hutchinson was on the leading edge of the hydrocarbon storage technology as Cities Service Oil Company developed propane storage caverns southwest of Hutchinson in the very early 1950s. Kansas currently has more NGL/LPG salt storage caverns (more than 600) than any other state in the Union. Texas ranks second in the number of NGL/LPG salt storage caverns.

About the same time that the oil and gas industry began exploiting solution-mined caverns for storing liquid hydrocarbons in bedded salt formations, the same development was going on in the salt domes along the Gulf Coast. Today, over 500 caverns in salt domes are used for storing NGLs/LPGs.

The solution-mined caverns in Kansas are very different from the solution-mined caverns used for LPG storage in the Gulf Coast. Specifically, the Kansas caverns are much smaller and are much shallower. A typical Kansas cavern has a volume of about 100,000 barrels (4.2 million gallons) and is located at a depth of about 600 to 800 feet. A typical Gulf Coast cavern is at least 10 to 20 times larger than a Kansas cavern and is usually located at a depth of more than 1,500 or 2,000 feet. Gulf Coast salt dome caverns used to store crude oil for the United States' Strategic Petroleum Reserve (SPR) are each 100 times the volume of a single typical Kansas cavern. One single SPR cavern has more volume than all of the Yaggy caverns combined.

[1] In situ conditions are conditions "in the ground," such as temperature and stress state.

[2] The fracture gradient for a formation is a common term in the oil and gas industry. It is the pressure (in pounds per square inch) required to "fracture" a formation at a certain depth divided by the depth (in feet).

[3] NGLs or LPGs are hydrocarbon compounds that can be stored as liquids if pressurized slightly.

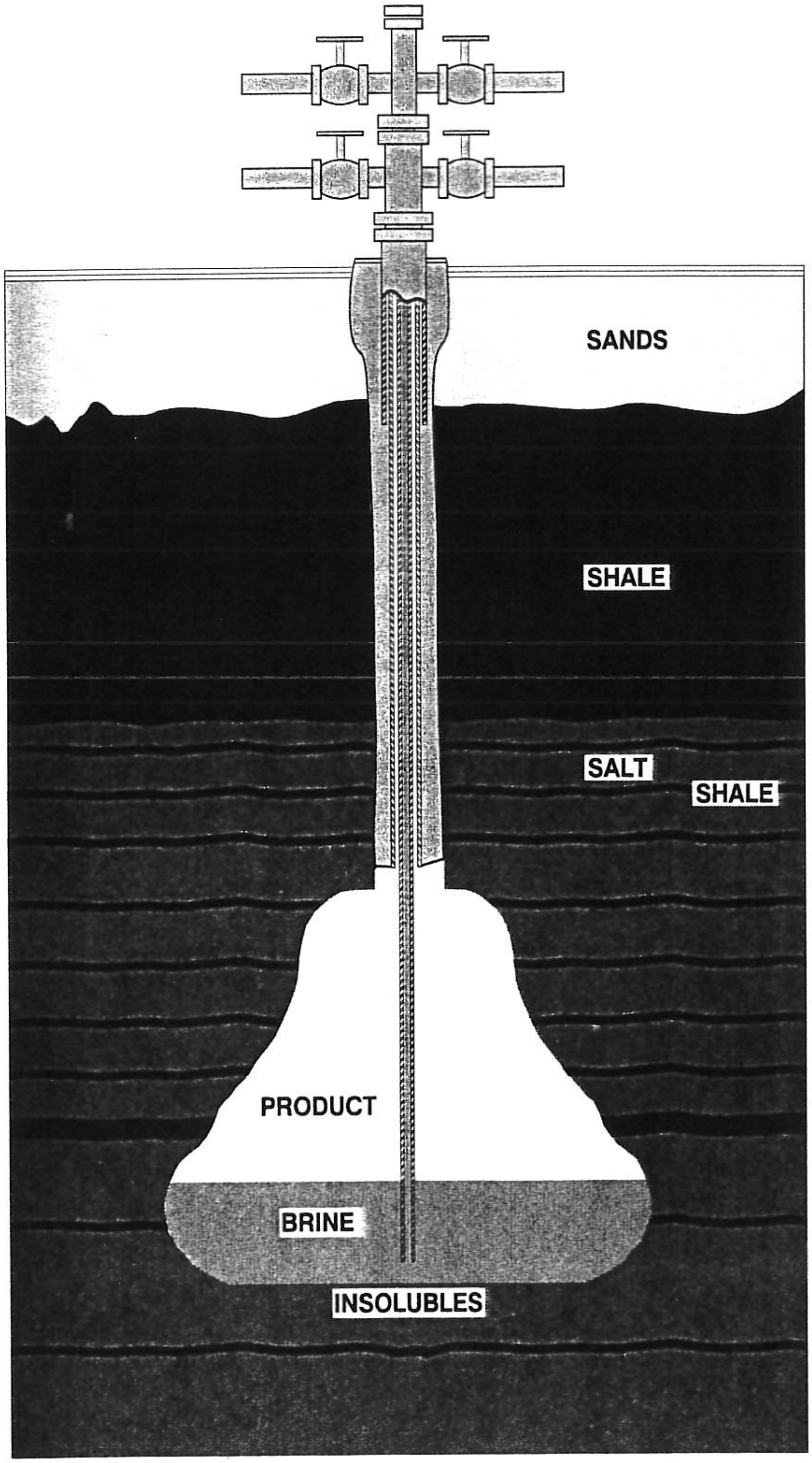


Figure 2. Schematic Illustration of a NGL/LPG Storage Cavern in a Bedded Salt Formation.

In the 1960s, the gas industry began to use solution-mined caverns in salt formations for storing compressed natural gas. Significant development of this technology for storing natural gas did not really take off until the deregulation of the natural gas industry in the early 1990s. Today, there are several hundred natural gas storage caverns in salt in the United States. Again, Kansas has more natural gas storage caverns than any other state in the Union. Gas stored in salt caverns can be delivered to the market place much faster than gas stored in depleted oil and gas reservoirs. Thus salt cavern storage is designed to respond to the peak demand market more so than to the seasonal demand market.

Natural gas is stored in solution-mined caverns in a much different way than LPG is stored (see Figure 3). In an LPG cavern, the cavern is always "full of liquids." The liquids are LPG and brine with the lighter LPG always on top of the heavier brine.

There is essentially no liquid in a natural gas storage cavern. Initially, the brine in a solution-mined cavern is removed by first installing tubing inside the casing. Gas is then injected down the annulus, forcing the brine up the tubing and out of the cavern. Thereafter, the cavern is operated "dry." The pressurized gas in the cavern is injected and removed by "free flowing" the gas through the well or by using compressors on the surface, as needed.

While the pressure in a LPG cavern is nearly always constant, the pressure in a compressed natural gas storage cavern can vary significantly. The pressure in the cavern is proportional to the amount of gas in the cavern. Some gas must always be left in the cavern "to hold up the cavern roof and walls." This amount of gas is called the "cushion gas" or the "base gas." The amount of gas that can be removed from the cavern and sold to the marketplace is called the "working gas." The sum of the *cushion gas* and the *working gas* is the total volume of gas that is injected into the cavern. The higher the maximum allowable pressure, the more gas that can be injected into a cavern. The lower the allowable minimum pressure, the less *cushion gas* in the cavern and thus, the greater the volume of *working gas*.

HISTORY OF REGULATION AND REGULATIONS IN OTHER STATES

Even though solution-mined caverns have been used for hydrocarbon storage for about 50 years, contemporary regulations are not nearly as mature. The first state regulation specifically dealing with solution-mined caverns for hydrocarbon storage was promulgated less than 25 years ago. Current rules in states with solution-mined storage caverns used for hydrocarbons are generally less than about 10 years old. Table 1 provides a list of many of the current state regulations and the dates the rule became effective.

The development of many state regulations for storing hydrocarbons in solution-mined storage caverns has generally occurred following an industrial accident at a storage facility. The current regulations in Louisiana (Statewide Order 29-M) followed a fire that occurred during the initial oil filling in a Strategic Petroleum Reserve cavern in the West Hackberry salt

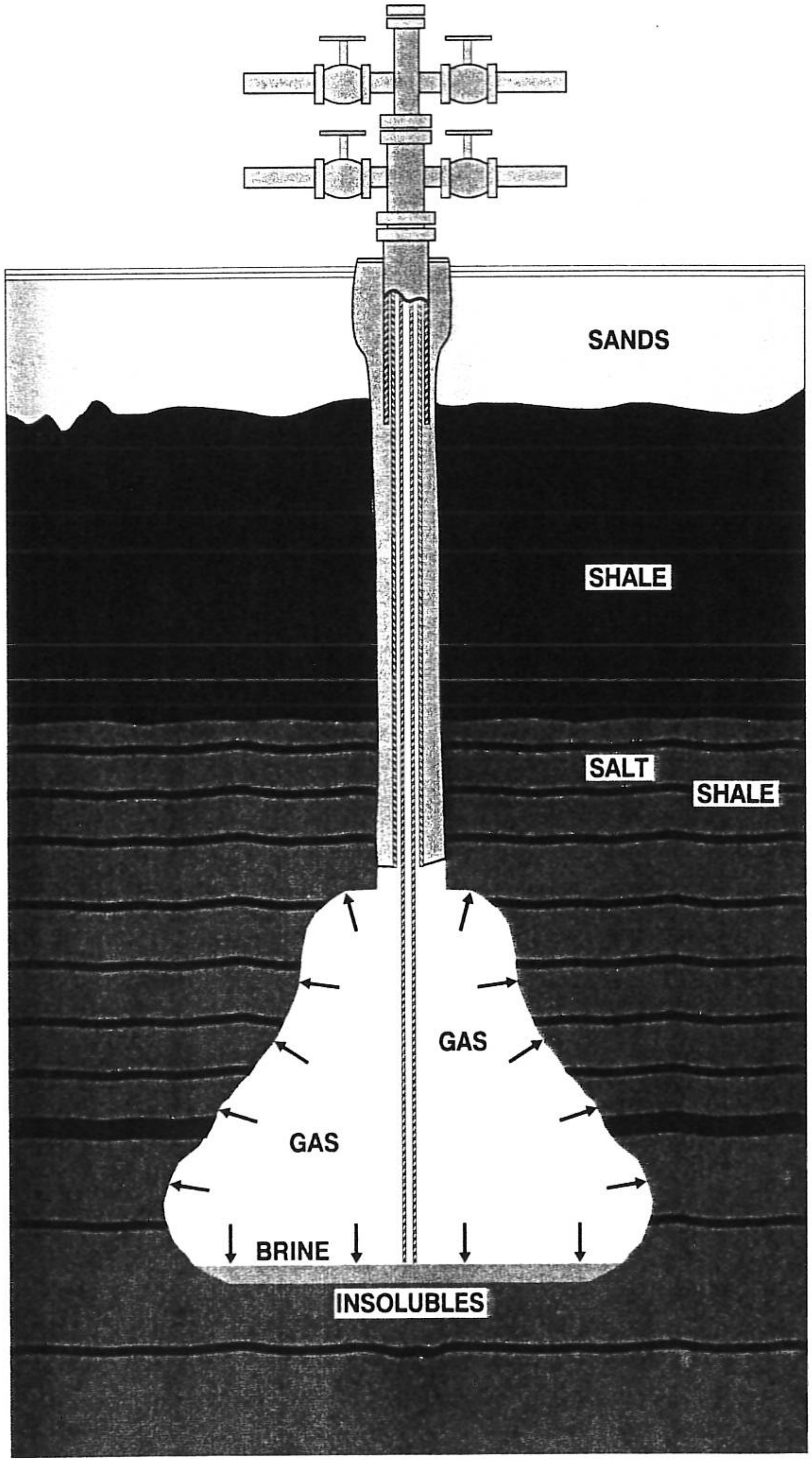


Figure 3. Schematic Illustration of a Compressed Natural Gas Storage Cavern in a Bedded Salt Formation.

dome. The current Texas Regulations (Railroad Commission Rules 95 and 97) were developed following the loss-of-product accident at the LPG storage facility in the Brenham salt dome. Development of the Kansas regulations followed the loss-of-product near Conway.

Table 1. Effective Dates for State Regulations for Hydrocarbons Storage Caverns

State	Rule	Effective Date
Alabama	Alabama State Oil and Gas Board 400-6 (Gas)	May 16, 2000
Kansas	Kansas Administrative Regulation 28-45 (Liquids and Gas (?))	1984
Louisiana	State Wide Order 29-M (Liquids and Gas)	July 20, 1977
Mississippi	Mississippi State Oil & Gas Board Rule 64 (Liquids and Gas)	February 19, 1992
New York	6 NYCRR, Part 559 (Liquids and Gas)	In Draft
Oklahoma	None	NA
Texas	Railroad Commission Rules No. 95 (Liquids) and No. 97 (Gas)	January 1, 1994

There are states that have promulgated rules that are not correlated to accidents within their state boundaries. For example, Mississippi, Alabama, and New York rule development did not follow a specific accident. The Louisiana rule is currently being revised by the Louisiana Department of Natural Resources. Oklahoma, despite having hydrocarbon storage caverns, has no rule specifically regulating this type of storage.

KANSAS REGULATIONS

The KDHE rules for underground storage wells and caverns are contained in Kansas Administrative Regulation 28-45. These rules have been around for some time, and KDHE recognized the need to revisit these rules some time ago. KDHE has been working with industry to revise the rules for several years.

It is important to recognize that these rules were promulgated at a time when there were no natural gas storage caverns in Kansas and thus, the rules can reasonably be expected to be deficient for gas storage caverns.

The significant weaknesses in the KDHE rules have been well documented in the press in recent weeks. For example, the rule does not require a Mechanical Integrity Test nor does it require any sort of casing inspection log. The rule does not address (nor perhaps contemplate) the reentry or drilling out of plugged and abandoned wells.

The Kansas rule does not address how close caverns can be to one another. This is perhaps not a major issue with liquid wells, but is important for gas storage caverns.

The Kansas rule does not require Emergency Shutdown Valves at the wellhead, which is a common requirement in other states. The Kansas rule requires minimal information to be reported to KDHE by operators compared to other states.

When discussing the Kansas rules, it is important to recognize that whereas Kansas has more liquid hydrocarbon wells and caverns and natural gas storage wells and caverns than any other state in the Union, they do not have the largest regulatory and enforcement staff or the largest budget. Clearly, that may be the biggest change required at KDHE.

It is difficult to make direct comparisons of manpower in one state versus manpower in another state merely because the areas of responsibility can be different from a state agency in one state to a seemingly similar state agency in another state. However, it is interesting to note that the Louisiana agency responsible for regulating underground storage wells employs nine professionals in Baton Rouge and regulates about 4,500 wells or about 500 wells per professional. The Texas agency responsible for regulating underground storage caverns employs two professionals in Austin who regulate about 950 wells or slightly less than 500 wells per professional. It is my understanding that KDHE employs two professionals in Topeka who are responsible for regulating more than 6,000 wells. *The number of "wells per professional" regulated in Kansas appears to be six times the number in the comparable Louisiana and Texas regulatory agencies.*

QUESTIONS

Are the Kansas regulations sufficient for regulating underground natural gas storage caverns and wells? When the current regulations were promulgated, natural gas was not stored in salt caverns in Kansas. Clearly, the Kansas regulations need revision. In that regard, the natural questions that arise are twofold:

1. What should be regulated?
2. How should the items in (1) above be regulated?

In response to the first question, at a minimum, the following should be regulated:

- Wells and wellheads
- Caverns

- Operations
- Testing and monitoring.

Wells and Wellheads

Kansas requires two casings in storage wells – one for groundwater protection and one casing at least 105 feet into the salt formation (50 feet in "existing" wells). Many states require one casing for groundwater protection and two casings in the salt, but these are states with caverns developed in salt domes. Salt domes are typically overlain with a "caprock" which is very porous and saturated with sodium chloride brine, which can be very corrosive. The same corrosive environment may or may not exist above or at the top of bedded salt formations. Texas, which has both bedded and domal formations, does not require two casings set into the salt for caverns developed in bedded salt formations.

Some states require pressure testing of the casing during the construction of the well (after cementing). Kansas does not. Some states require cathodic protection for some wells. Kansas does not require cathodic protection.

Questions that KDHE will need to address include:

1. Will Kansas require two cemented casings (or one casing and a protected annulus) into the salt in the future for wells?
2. Will storage wells in Kansas require cathodic protection?
3. Is corrosion a significant problem in well casings in storage wells in Kansas?
4. Will Kansas require pressure testing of cemented casings during construction of new wells in the future?
5. Will KDHE require Emergency Shutdown Valves?

Caverns

In many states, the location of the cavern (within the salt formation) is restricted and the size of the cavern must be periodically checked. In Kansas, performing a "gamma log" in the well periodically checks the "size" of the cavern. The gamma log is able to establish the location of the cavern roof and thus, the location of the cavern within the salt formation. Texas has rules similar to those in Kansas for monitoring the location of the cavern roof in bedded salt caverns. In Kansas, periodic sonar surveys are generally only required in caverns that have reached a volume of 120,000 petroleum barrels. There are, however, other situations for which KDHE may require a sonar survey.

Many other states regulate the distance between caverns (the "web thickness"). Kansas does not (except for brine production wells). It is not necessarily as important to regulate the distance between liquid storage caverns. However, since the pressure difference between adjacent natural gas storage caverns can be significant, the distance between caverns can be important.

Questions that KDHE will need to address include:

1. Has consideration been given to requiring a "minimum" web thickness between caverns?
2. Has consideration been given to requiring a "minimum" gas storage pressure? What does KDHE believe is important in establishing a minimum gas storage pressure?

Operations

All states have some level of regulation of cavern operations. Perhaps the most significant operational characteristic that is regulated is the maximum pressure allowed in a storage cavern. The maximum pressure in a storage cavern is stated as a pressure (in pounds per square inch) divided by a depth (in feet) at the depth of the casing shoe. The casing shoe is the deepest point of the "last" (most "inner") cemented casing. Maximum permissible pressures in many states range from 0.8 psi/foot to a high of 0.9 psi/foot. The higher maximum pressures are generally associated with caverns in salt domes rather than caverns in bedded formations.

Kansas does not specify a maximum pressure in terms of psi/foot. Rather, they ask for "a description of methods to be used to prevent overpressuring of wells to the point of lifting or fracturing overburden."

All states require reporting of maximum pressures and volumes of hydrocarbon injected and withdrawn over a period of time. Most states require reporting on a monthly or quarterly basis. Kansas requires reporting on an annual basis. The operator of a facility in Kansas need only report a maximum pressure for the entire year; whereas, operators in other states must report maximum pressures for every month or quarter of operation.

Most states besides Kansas require continuous monitoring of the pressure on every wellhead. Kansas only requires that the operator maintain records of product injections and withdrawals and maximum pressures during injections or withdrawals. These records need not be provided to the state, but must be available for inspection. Kansas also allows for recording of "each well or well system" pressures. Seemingly, if two or more wells are connected at a common manifold at the surface (as is the case at Yaggy), individual wellhead pressures need not be monitored or recorded. Rather, only the common manifold pressure need be recorded.

Questions that KDHE will need to address include:

1. What maximum pressure criterion will KDHE adopt?
2. Will KDHE have a different criterion for liquid storage than for gas storage?
3. What will KDHE require from an operator as proof that the maximum pressure is safe?

4. Does KDHE intend on increasing the requirements for reporting of wellhead pressures and product movements?

5. Will KDHE require continuous monitoring of wellhead pressures?

Testing and Monitoring

Most states require various types of testing and monitoring. Perhaps the most significant test required by most states (Kansas being an exception) is the Mechanical Integrity Test (MIT). Most states require this test of storage wells on a 5-year frequency. Kansas does not require an MIT for liquid or compressed natural gas wells, but does have an MIT requirement for brine mining wells.

Many states require MITs when the wellhead or cemented casings are modified. Kansas does not.

A few locations in some states require casing inspection logs on storage wells on a regular basis. For example, storage wells in salt domes with single cemented casings into the salt formation in Texas are required to have a casing inspection log on a regular basis. Texas wells in bedded salt formations are not required to have a casing inspection log. Kansas does not require casing inspection logs for any storage wells.

Many states are requiring (through permit conditions rather than rule) subsidence surveys on an annual basis. Kansas requires subsidence surveys every 2 years. Surveys in Kansas are required to be only third-order surveys. This may be inadequate for capturing any subsurface movement.

Questions that KDHE will need to address include:

1. Will KDHE require regular MITs?

2. Will KDHE allow alternative testing to substitute for MITs?

3. Will KDHE revisit their subsidence survey specifications?

4. Has KDHE considered requirements for casing inspection logs, particularly for "reentered" wells?

Again, I appreciate the opportunity to present these views on behalf of the city of Hutchinson. The city justifiably has very serious concerns regarding the aptness of the current Kansas regulations for underground hydrocarbon storage caverns. As a consultant that has committed his career to salt storage cavern technology, I have stated to the city that when properly designed, tested, monitored, operated, and regulated, salt caverns can be extraordinarily safe and effective facilities for storing hydrocarbons.

KANSAS GEOLOGICAL SURVEY
Office of the Director

The University of Kansas
1930 Constant Ave., Campus West
Lawrence, Kansas 66047-3726
phone 785-864-3965
fax 785-864-5317

GEOLOGY OF NATURAL GAS PATHWAYS AND ACCUMULATIONS UNDER HUTCHINSON, KANSAS

Presented to the House Environment Committee

March 13, 2001

M. Lee Allison, PhD, R.G.
State Geologist and Director
Kansas Geological Survey
University of Kansas

The Kansas Geological Survey is tasked under statute to investigate and report on the natural resources of the state. We are established as a research unit of the University of Kansas to bring unbiased and scientifically sound expertise to bear on resource issues.

Our role in the Hutchinson situation began the day after the trailer park explosions when it became known that geological investigations were needed. We served initially as geologic advisors to KDHE. When many of the early vent wells turned out to be dry holes, it became clear that complex geologic conditions were likely controlling the pathways and accumulations of the gas. Our work consisted of:

- Determining what layers might serve as geologic conduits for gas under the city;
- Compiling subsurface information on the shape and nature of the geologic layers;
- Compiling information on sinkholes and subsidence in the Hutchinson area;
- Examining rock cores from the Yaggy field and surrounding oil and gas fields;
- Examining geophysical wireline logs from wells to identify possible conduits;
- Producing subsurface geologic maps of relevant horizons;
- Developing a geologic model to guide drilling of vent wells and other remediation actions;
- Recommending additional investigative and exploratory steps.

The Kansas Geological Survey has done the following so far:

- Collected, processed, and interpreted a 3.5-mile long seismic reflection line along Wilson Road between Yaggy and Hutchinson, and a 1/4 mile long line at Rice Park;
- Completed specialized computer processing on the seismic data to identify two possible gas-bearing amplitude anomalies (both were drilled and produced gas);
- Created structure contour maps on a variety of geologic horizons using 3700 oil and gas wells;
- Created a detailed structure contour map on the gas-bearing layer using water well & vent well data;
- Identified and correlated the gas-bearing layer on geophysical logs from oil and gas wells and vent wells in the area;
- Compiled reports on the history of subsidence in the Hutchinson area;
- Examined well cores to determine the geologic origin of the gas-bearing layers in order to predict possible pathways, including the Atomic Energy Commission core in Rice County;
- Acquired, digitized, and processed sonic well logs to create a synthetic seismogram to correlate the

House Environment
3-13-01
Attachment 2

- Acquired, digitized, and processed sonic well logs to create a synthetic seismogram to correlate the seismic lines to the wells;
- Calculated that there are geologically feasible conditions under which high-pressure gas could have traveled 7 miles underground in a few days;
- Examined outcrops in the region that might be equivalent to the gas-bearing layer;
- Advised the Groundwater Management District on a groundwater-monitoring program;
- Analyzed brine samples from the geysers for inorganic materials for source studies;
- Considered the potential for subsidence due to collapse of brine well caverns;
- Produced digital orthophoto quadrangle air photos for plotting data;
- Briefed federal, state, and local officials on the geology;
- Briefed U.S. Department of Energy and NASA; discussed cooperative efforts;
- Organized a one-day technical meeting for involved parties to plan further geologic investigations;
- Worked with KDHE, Kansas Gas Service, and the City of Hutchinson to recommend drilling locations, core locations, and types of logs to run; and
- Responded to scores of inquiries from citizens, consultants, attorneys, and the news media.

We have found that:

- The gas is confined to a relatively thin geologic layer at the top of the Permian-aged (approximately 250 million years old) Wellington Shale, about 200 feet above the Hutchinson Salt Member;
- The regional dip of the deeper rock layers is to the west, meaning that, all other factors being equal, gas would move in general to the east (because methane is lighter than water, it will tend to move updip - from lower to higher areas - through rock);
- The large number of vent wells that are dry holes suggests that the gas pathways are discrete and cover a relatively small area under the city;
- The seismic amplitude anomalies were drilled and found to contain gas; each is about 150-200 ft. across;
- The gas-bearing layer may contain narrow belts of a particular type of rock that is preferentially fractured;
- There are anticlines present (rocks folded into an arch) that could serve to direct gas along their crests; and
- There are deep faults or fractures (many thousands of feet deep) that appear to control the orientation of the Arkansas River channel and may have controlled the location and orientation of geologic deposition during the Permian period as well.

What investigations need to be done to return confidence to Hutchinson and ensure that this cannot happen again?

- Determine which of these factors or combination of factors is responsible for the gas moving under Hutchinson: pathways along buried channels or similar sedimentary features; along structural dip or anticlines; along fractures and faults; or along some combination of these features;
- Verify that the vent wells have adequately drained all the pockets of gas;
- Monitor water wells for contamination;
- Locate abandoned brine wells drilled from the late 1800s onward;
- Evaluate gas accumulations in the surrounding areas;
- Establish base line studies in the event of subsidence;
- Identify other potential gas pathways.

Types of Natural Gas Storage Facilities

The three principal types of underground storage sites used in the United States today are: (1) depleted reservoirs in oil and/or gas fields, (2) aquifers, and (3) salt cavern formations. (Several reconditioned **mines** are also in use as gas storage facilities). Each type has its own physical characteristics (porosity, permeability, retention capability) and economics (site preparation costs, deliverability rates, cycling capability), which govern its suitability to particular applications. Two of the most important characteristics of an underground storage reservoir are its capability to hold natural gas for future use and the rate at which gas inventory can be withdrawn, its deliverability rate.

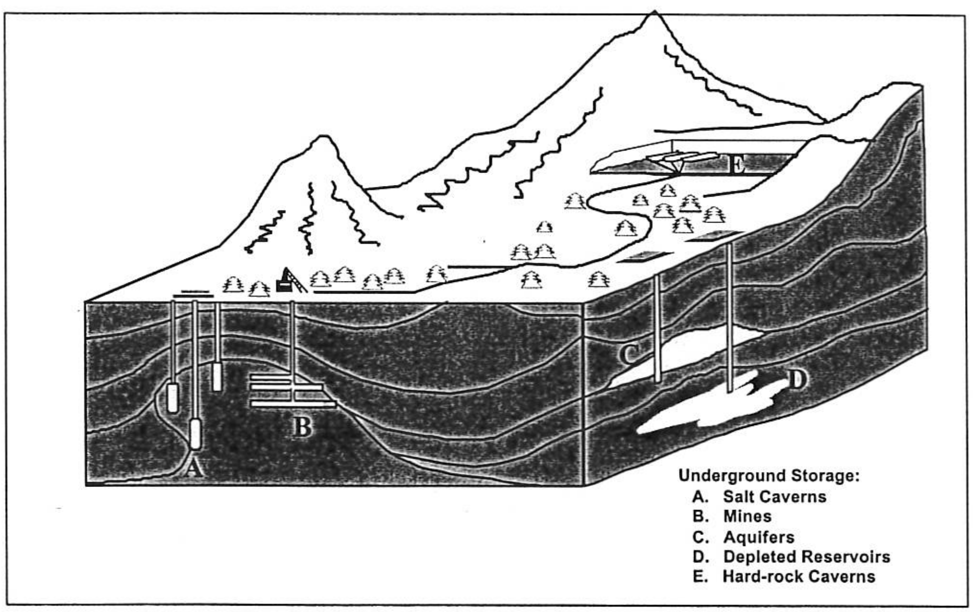
Most existing gas storage in the United States is in **depleted natural gas or oil fields** that are close to consumption centers. Conversion of a field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections. Depleted oil and gas reservoirs are the most commonly used underground storage sites because of their wide availability.

In some areas, most notably the Midwestern United States, natural **aquifers** have been converted to gas storage reservoirs. An aquifer is suitable for gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to depleted production fields, their use in gas storage usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance. Deliverability rates may be enhanced by the presence of an active water drive.

Salt caverns provide very high withdrawal and injection rates compared with their working gas capacity. Base gas requirements are relatively low. The large majority of salt cavern storage facilities have been developed in salt dome formations located in the Gulf Coast States. Salt caverns leached from bedded salt formations in Northeastern, Midwestern, and Western States are also being developed to take advantage of the high volume and flexible operations possible with a cavern facility. Cavern construction is more costly than depleted field conversions when measured on the basis of dollars per thousand cubic feet of working gas capacity, but the ability to perform several withdrawal and injection cycles each year reduces the per-unit cost of each thousand cubic feet of gas injected and withdrawn.

The potential use of **Hard-rock cavern** storage is currently undergoing testing in the United States. None are operational as natural gas storage sites at the present time.

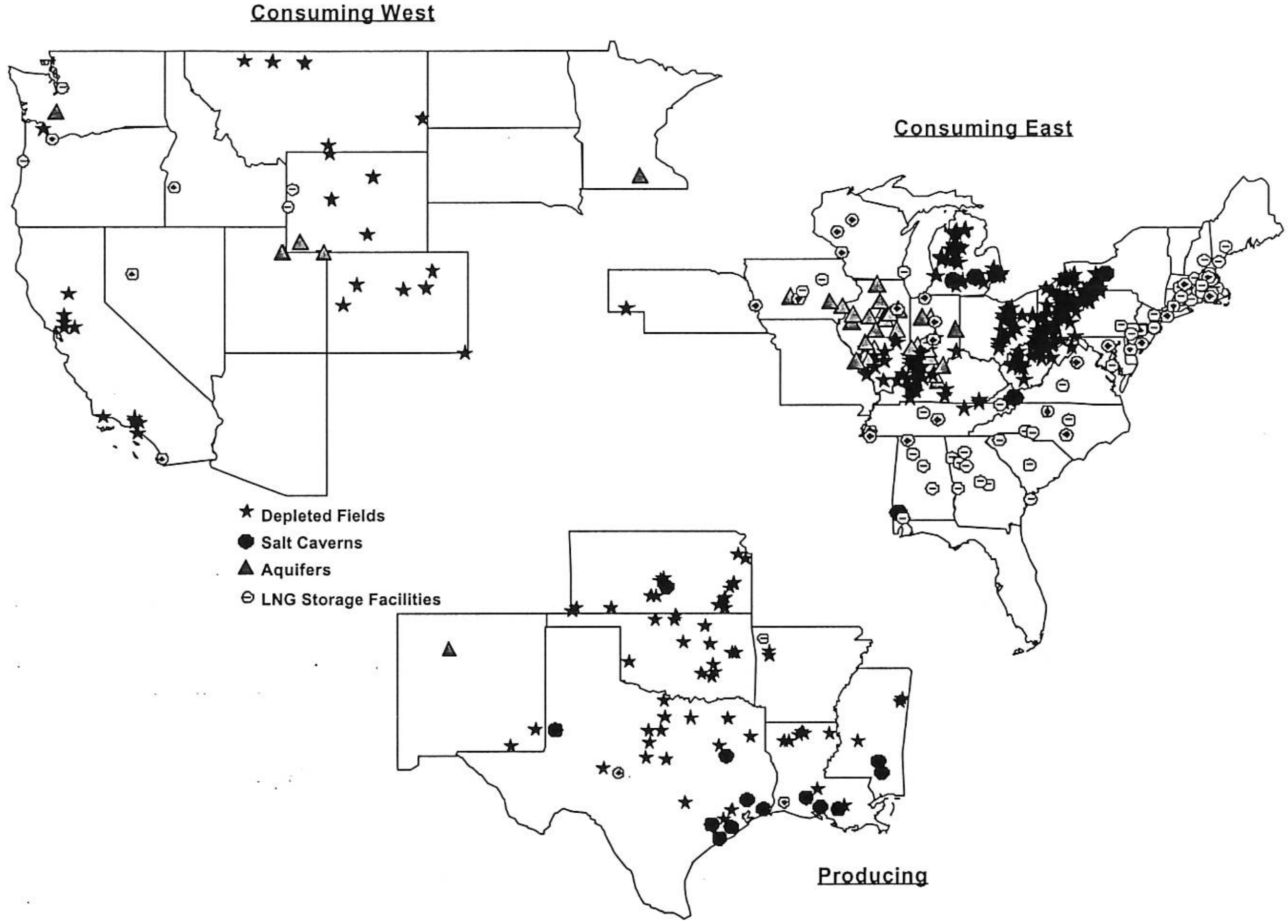
Types of Underground Storage



Source: PB-KBB Inc. Recreated by Energy Information Administration, Office of Oil and Gas.

2-3

Figure 1. The Largest Number of Underground and LNG Storage Sites Are Located in the Consuming East Region



Summary of Underground and LNG Storage, by AGA Region and Reservoir Type, 2000

Region	Depleted Gas/Oil			Aquifer Storage			Salt Cavern Storage			Total			LNG Facilities		
	Sites	Working Gas Capacity (Bcf)	Daily Deliver-ability (MMcf/d)	Sites	Working Gas Capacity (Bcf)	Daily Deliver-ability (MMcf/d)	Sites	Working Gas Capacity (Bcf)	Daily Deliver-ability (MMcf/d)	Sites	Working Gas Capacity (Bcf)	Daily Deliver-ability (MMcf/d)	Sites	Site Capacity (Bcf)	Daily Deliver-ability (MMcf/d)
East	243	1,690	31,888	33	351	7,457	4	4	298	280	2,045	39,643	83	73	10,135
West	31	590	8,620	6	39	1,175	0	0	0	37	628	9,795	13	12	1,186
Producing	74	1,089	17,166	1	1	12	23	135	11,118	98	1,226	28,296	3	7	312
Total	**348**	**3,368**	**57,674**	**40**	**392**	**8,644**	**27**	**139**	**11,416**	**415**	**3,899**	**77,734**	**99**	**92**	**11,633**

Bcf = Billion cubic feet. MMcf/d = Million cubic feet per day. LNG = Liquefied natural gas.
Note: Regions are those established by the American Gas Association.
Source: Energy Information Administration, Form EIA-191, "Underground Gas Storage Report."

2-4

Definitions

- **Hydrocarbon**: Any organic compound, gaseous, liquid, or solid, consisting solely of carbon and hydrogen. They are divided into groups of which those of especial interest to geologists are the paraffin, cycloparaffin, olefin, and aromatic groups. Crude oil is essentially a complex mixture of hydrocarbons.

- **Natural gas**: a) Hydrocarbons that exist as a gas or vapor at ordinary pressures and temperatures. Methane (CH_4) is the most important, but ethane (C_2H_6), propane (C_3H_8), and others may be present. Common impurities include nitrogen, carbon dioxide, and hydrogen sulfide. Natural gas may occur alone or associated with oil. Syn: *gas*. b) Gaseous hydrocarbons trapped in the zone of ground-water saturation, under pressure from, and partially dissolved in, underlying water or petroleum.

- **Natural-gas liquids**: Hydrocarbons that occur naturally in gaseous form or in solution with oil in the reservoir, and that are recoverable as liquids by condensation or absorption; e.g. *condensate* and *liquefied petroleum gas.*

- **Coal**: A readily combustible rock containing more than 50% by weight and more than 70% by volume of carbonaceous material including inherent moisture, formed from compaction and induration of variously altered plant remains similar to those in peat. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and in the range of impurity (grade) are characteristic of coal and are used in classification.

These definitions are from The Glossary of Geology, 4th edition, Julia A. Jackson (ed.), American Geological Institute, 1997.

House Environment
3-13-01
Attachment 3

Information on
Hutchinson Gas Incident
to
the House Environment Committee

Presented by
Karl Mueldener
Kansas Department of Health & Environment
Bureau of Water

March 13, 2001

Describe Kansas Facilities

- Hydrocarbon storage
  - propane,butane,natural gas, gasoline
- Stored in salt formation
  - solution mined caverns, jugs
- 10 active facilities
  - 1 natural gas, 9 LPG
- Companies: Kansas Gas Service, Koch, Ferrellgas, NCRA, Texaco, Williams, Oneok
- 624 active wells, 159 plugged wells, 80 million bbls total Kansas storage
- 7 inactive facilities

KDHE/Bureau of Water
March 2001

Regulatory Program History

- Natural gas storage and LPG storage from 1950's
- Federal Safe Drinking Water Act, 1974 (UIC)
- KDHE regulations from 1981
- 1986, injection programs divided between KCC and KDHE
- KCC has oil field related waste brine disposal
- KDHE has industrial waste disposal, federal underground injection control, including salt solution mining wells (without oil field)
- Related program is Underground Injection Control (UIC), from Federal Safe Drinking Water Act

KDHE/Bureau of Water
March 2001

History

- 5 types of injection wells addressed by UIC
  - Class 1, hazardous and non-hazardous waste injection (KDHE)
  - Class 2, oil field brine injection (KCC)
  - Class 3, salt solution mining (KDHE)
  - Class 4, hazardous waste into and above aquifers (illegal)
  - Class 5, others not covered above
- Hydrocarbon storage wells not covered by UIC, but are a state program

KDHE/Bureau of Water
March 2001

3-3

State Regulatory Authority

- KSA 65-171d(a), "protect the soil and waters of the state from pollution resulting from under ground storage reservoirs of hydrocarbons and liquid petroleum gas"
- KAR 28-45-1 through 11

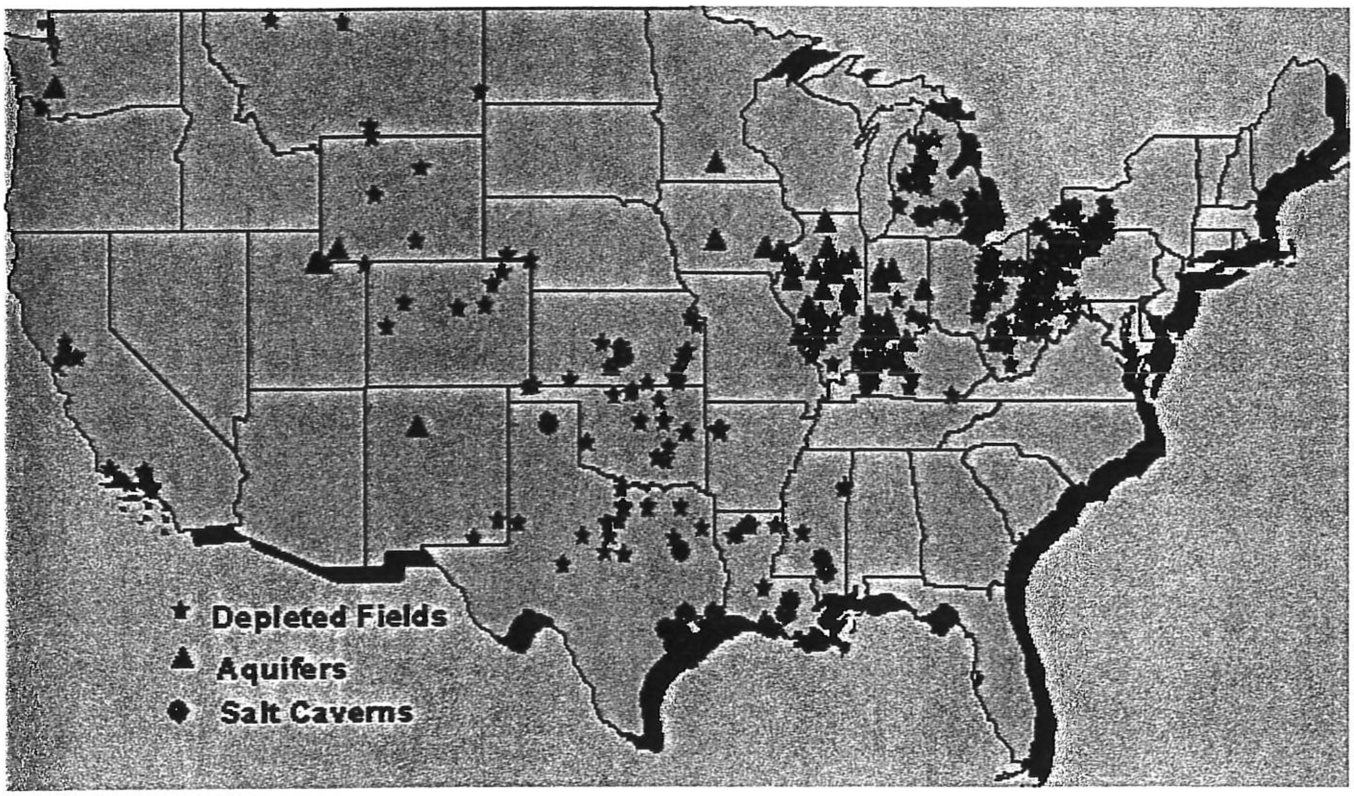
KDHE/Bureau of Water
March 2001

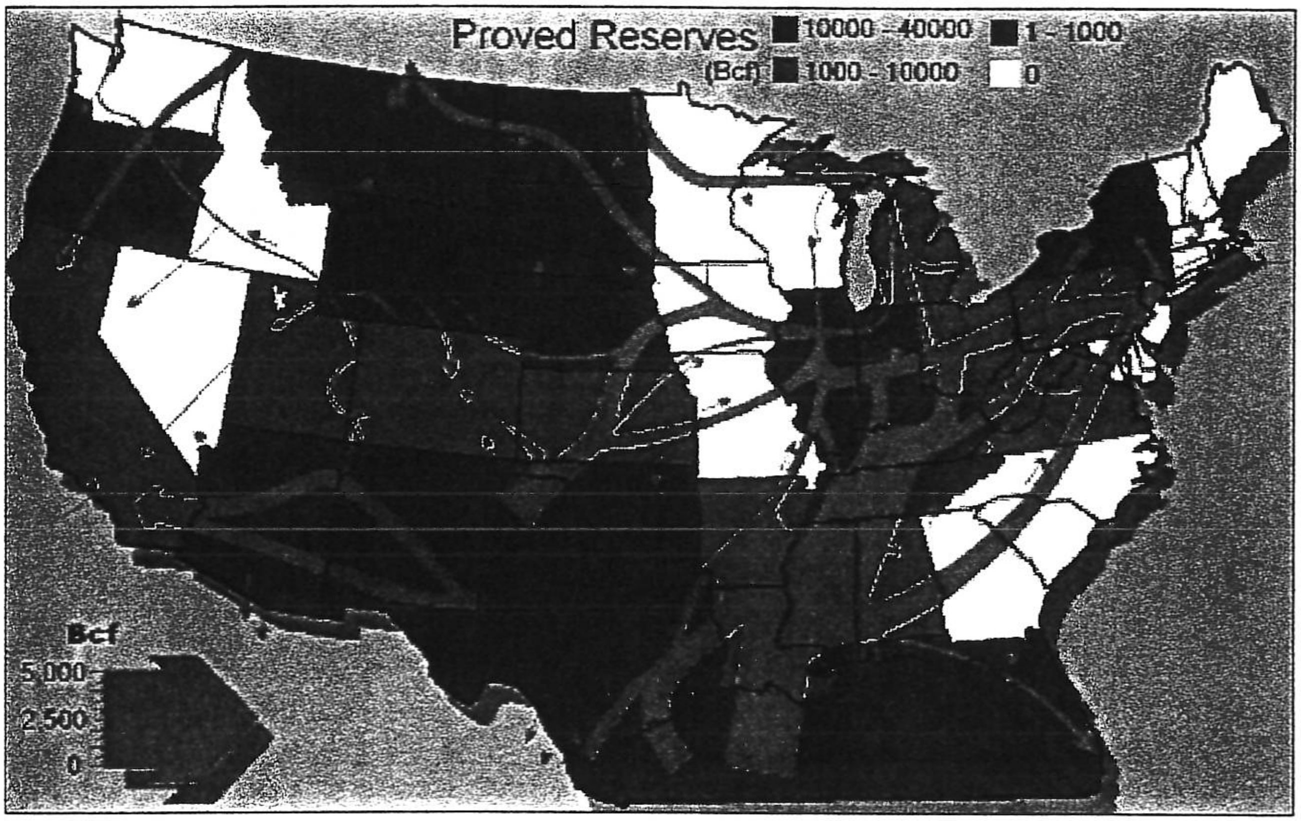
Regulation Plans

- Update started in 1996
- Meetings with industry
- Hutchinson incident gives new priority to regulation update
- Staff temporarily assigned to regulation process

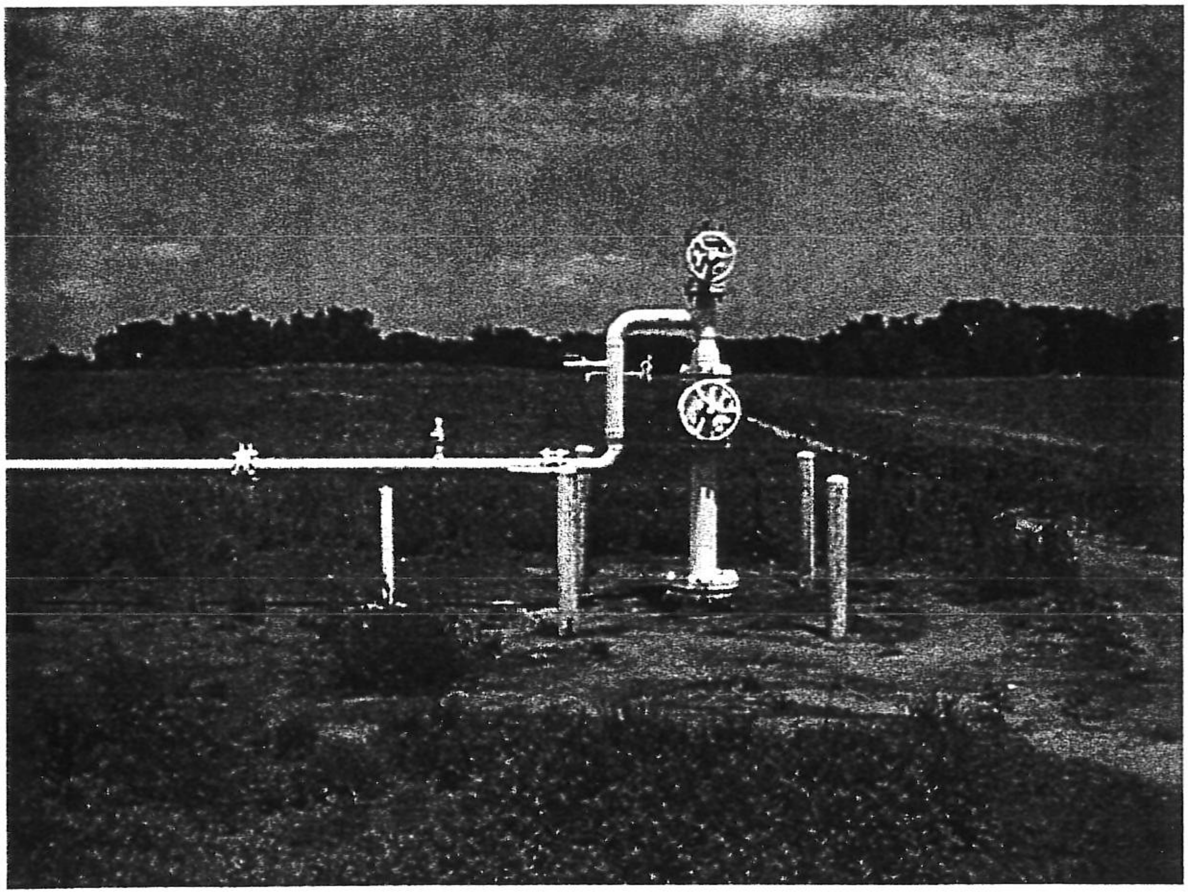
KDHE/Bureau of Water
March 2001

Natural Gas Storage Facilities in the United States

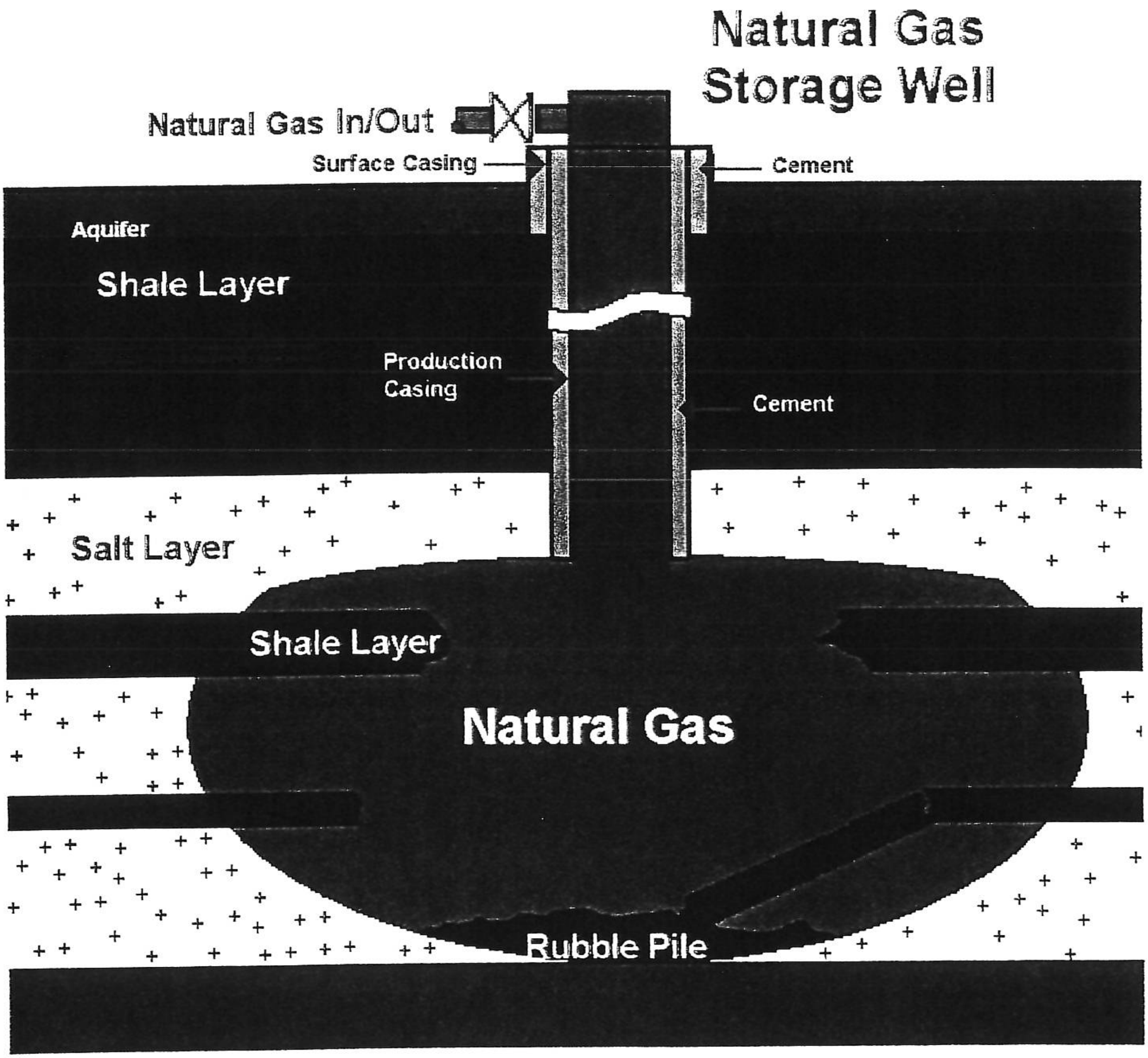




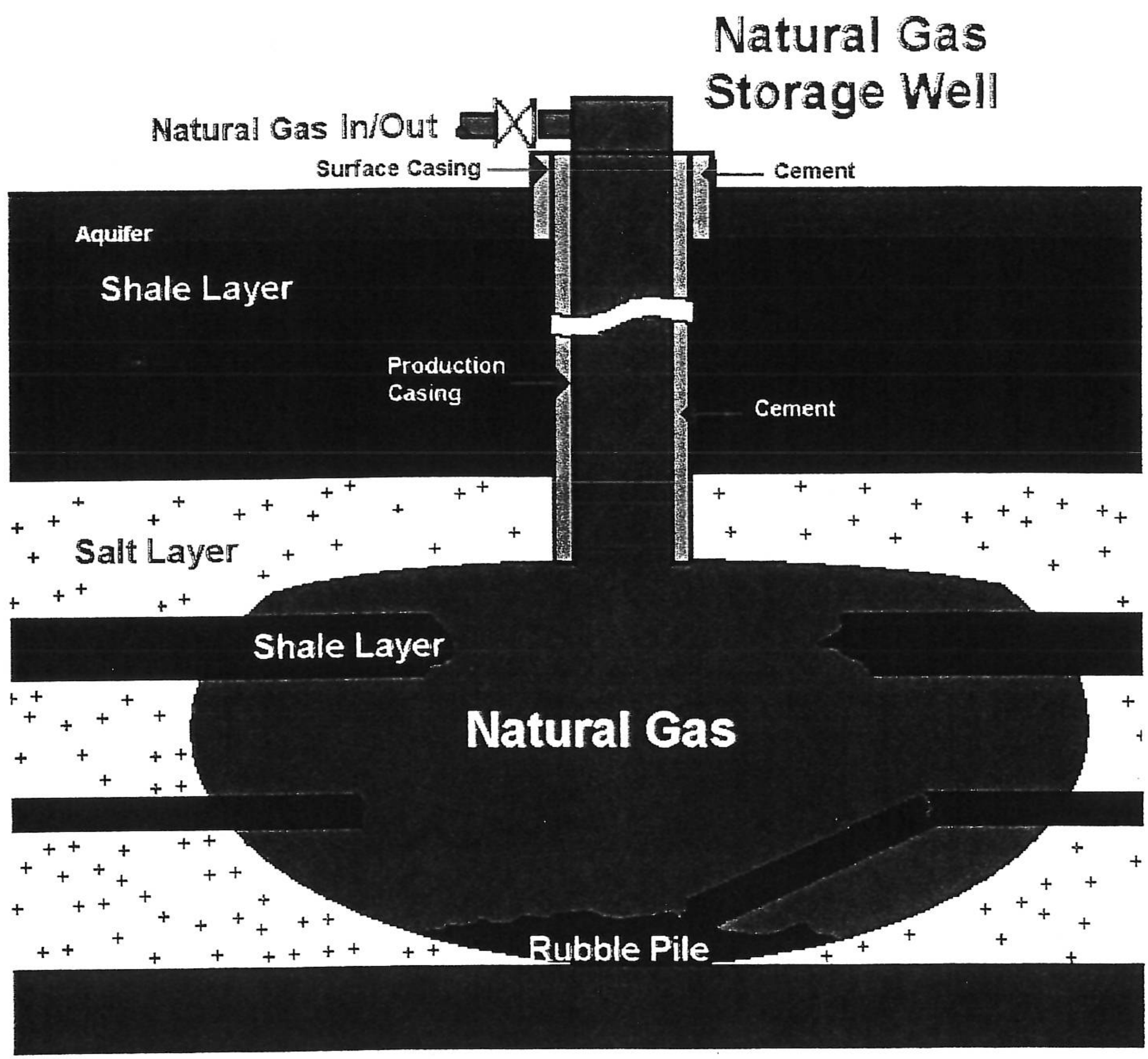
This map shows the principal flow of natural gas in the lower 48 states. It also shows the areas that hold most of the nation's proved reserves. The flow of natural gas from the Gulf region is nearly 5,000 Bcf annually.



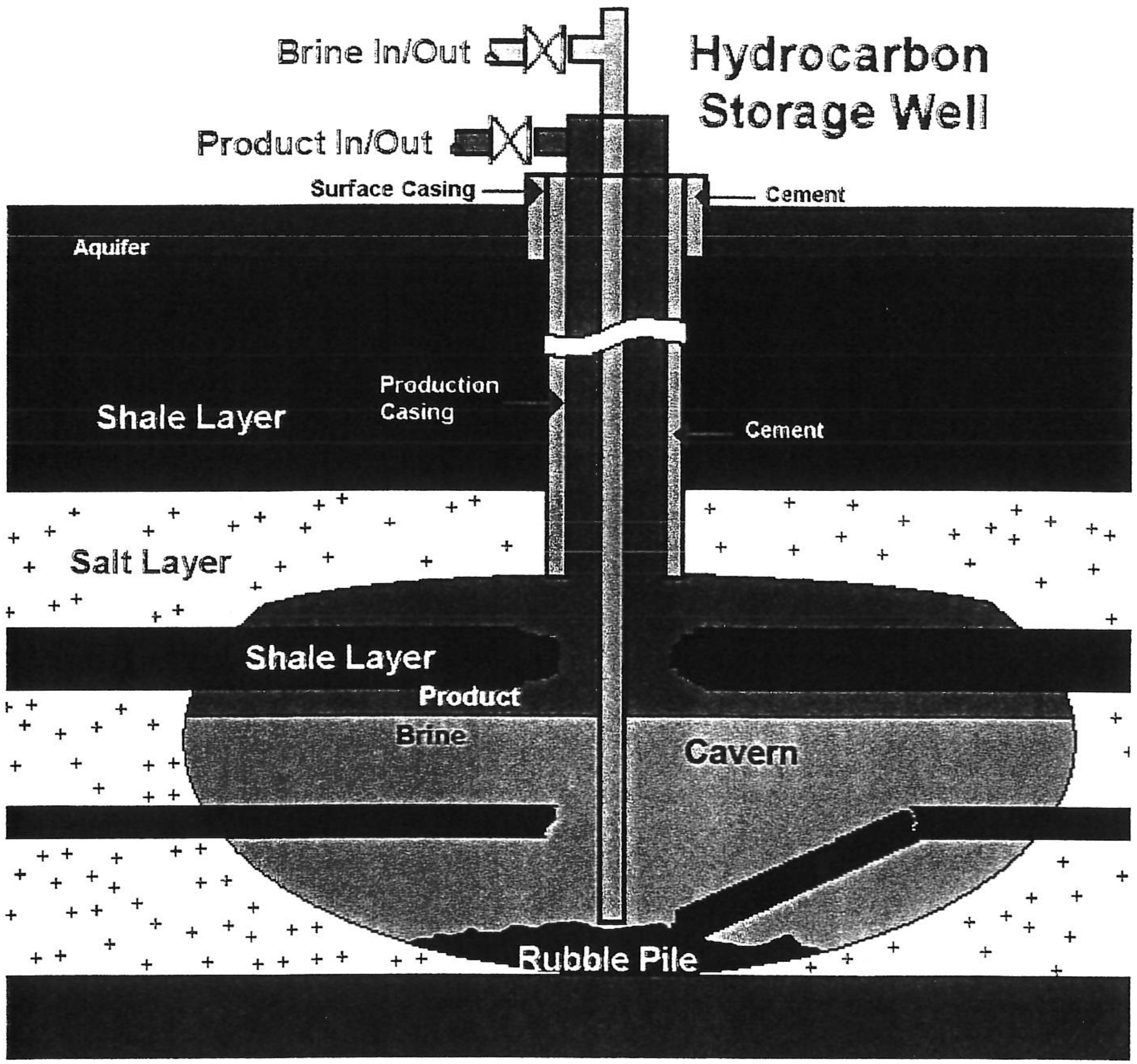
Kansas Gas Service
Yaggy Facility
Storage Well S-1



Natural Gas
Storage Well
Natural Gas In/Out
Surface Casing
Cement
Aquifer
Shale Layer
Production
Casing
Cement
Salt Layer
Shale Layer
Natural Gas
Rubble Pile



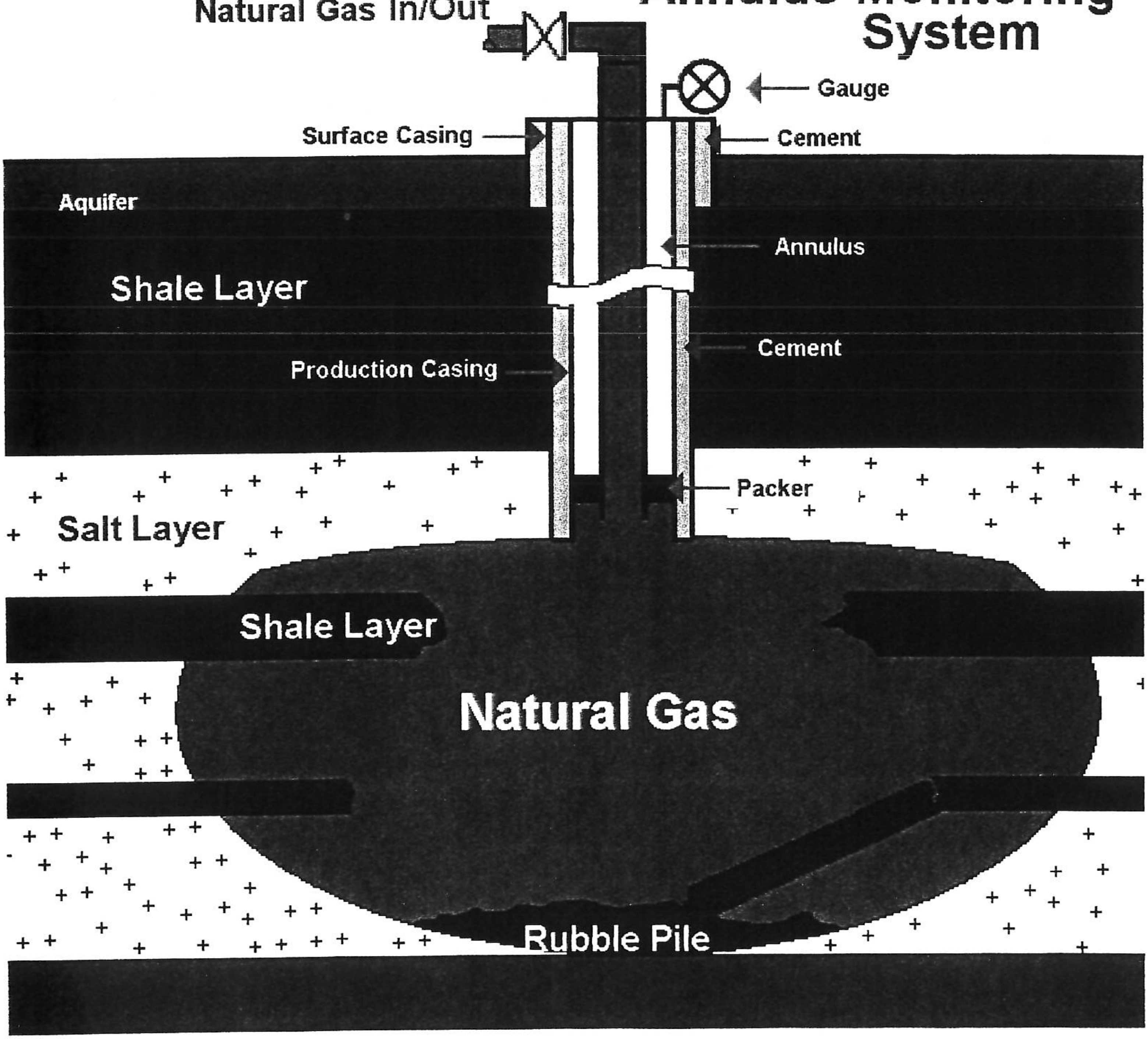
Natural Gas
Storage Well
Natural Gas In/Out
Surface Casing
Cement
Aquifer
Shale Layer
Production
Casing
Cement
Salt Layer
Shale Layer
Natural Gas
Rubble Pile

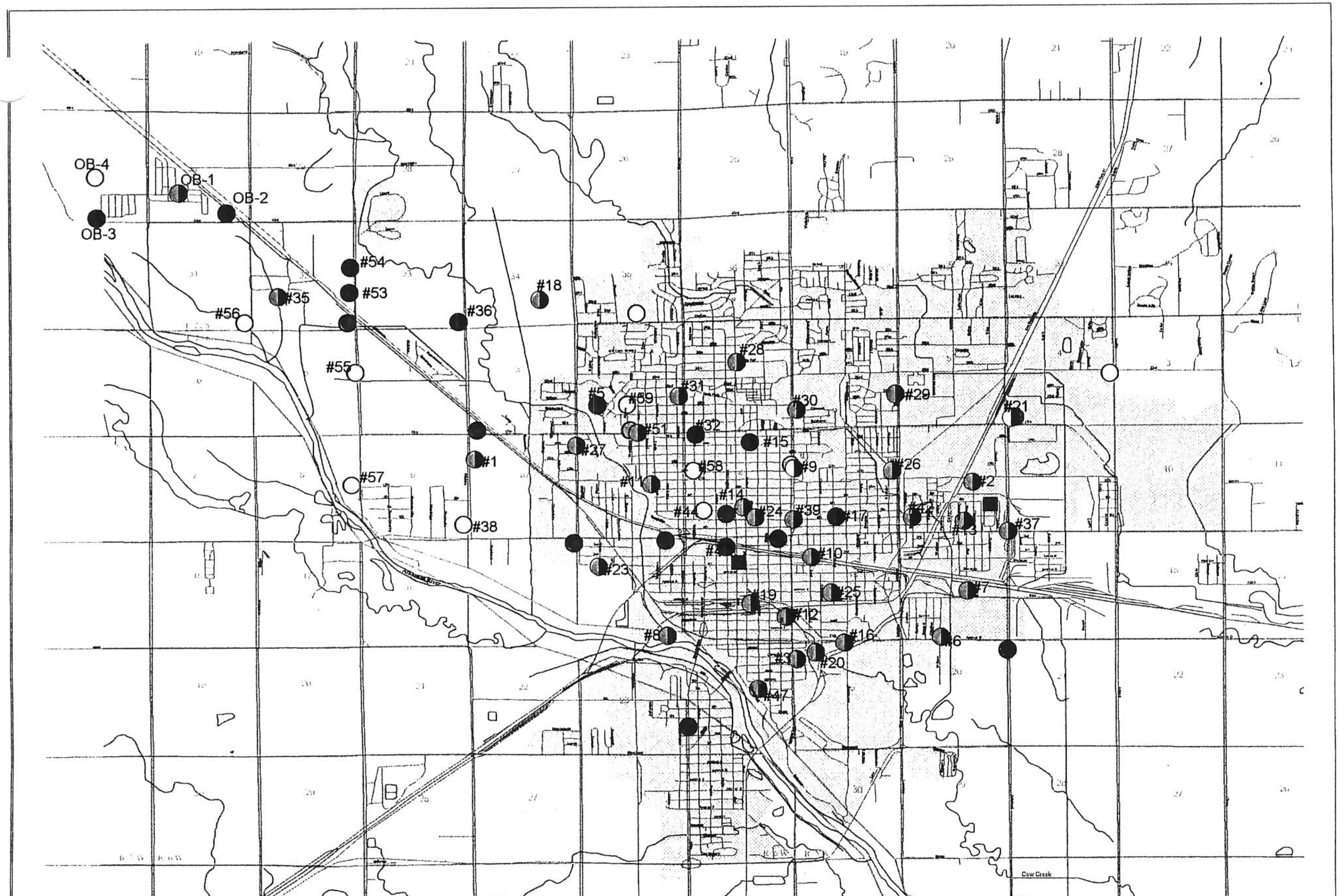


Hydrocarbon Storage Well
Brine In/Out
Product In/Out
Surface Casing
Cement
Aquifer
Production Casing
Shale Layer
Cement
Salt Layer
Shale Layer
Product
Brine
Cavern
Rubble Pile

concept

Annulus Monitoring System





LEGEND

- Deep Drilled Vent Well - No Methane Gas Detected
- Deep Drilled Vent Well - Methane Gas Venting
- Deep Drilled Vent Well - Methane Gas No Longer Venting
- Deep Drilled Vent Well - Current/Proposed Drilling
- Cathodic Protection Well - Venting Gas or No Longer Venting Gas
- Cathodic Protection Well
- Explosion Site
- Railroad
- Incorporated Areas

N

LOCATIONS OF METHANE GAS INCIDENTS AND INVESTIGATION AREAS - HUTCHINSON

Printed 2/23/01

3-11

Testimony to Kansas State House
Environment Committee Hearing
March 13, 2001
By
Steve Johnson, Executive Director
Corporate Relations
Kansas Gas Service Company

Madam Chair Freeborn, members of the committee and guests, thank you for this opportunity to talk to you about the role that natural gas storage plays in the timely, cost-effective distribution of natural gas to our customers

KGS is a division of Tulsa-based ONEOK, Inc. and distributes natural gas to more than 625,000 Kansas residential, commercial and industrial customers, more than two-thirds of the end-users in the state. While KGS owns no storage facilities, we purchase storage services from two sources, which I'll explain in a moment.

Underground natural gas storage is not a new industry practice – it dates back to 1915. But in today's restructured, highly competitive natural gas market, storage has taken on a much higher profile. Significant expansions and new installations in storage capacity and deliverability were made across the country in the 1990s. Today about 8.2 trillion cubic feet of natural gas is stored in the United States, of which about 300 billion cubic feet is stored in Kansas.

House Environment
3-13-01
Attachment 4

KGS gets two-thirds of its natural gas for peak-day delivery from storage. Its main suppliers of storage services are:

- Williams Gas Pipeline Central for 13.4 billion cubic feet (bcf)
- Mid Continent Market Center (MCMC) for 2.1 bcf.

Mid Continent Market Center (MCMC) is ONEOK's Kansas gas transmission and storage company. The majority of KGS' purchased storage is at the Brehm Storage Field, a depleted gas reservoir in Pratt County, and at the Yaggy Storage Field, a group of interconnected salt caverns in Reno County. Brehm has a total capacity of about 1.6 bcf, all of which is dedicated to KGS. Yaggy has a total capacity of 3.5 bcf. KGS uses about one bcf of that capacity.

Storage facilities offer various advantages to local distribution companies (LDCs) and consumers:

- LDCs, such as KGS, can provide customers with more reliable service, especially during peak periods such as winter months.
- When production or transportation services are interrupted, supply demands can still be met through storage gas.
- Stored gas offers flexibility. We can buy gas under long-term contracts to secure a reliable supply, and commit to short-term purchases when it's most cost-effective. For example, at the end of December when it appeared that Kansas would continue to experience severe winter weather, we determined that the supplies available to meet customer needs might be insufficient and we purchased additional flowing gas. Some of these incremental purchases were injected into storage when

cold weather did not materialize in early January in order to ensure reliability for the remainder of the winter.

- Storage facilities are especially useful in highly volatile markets, like Kansas, where we have peak winter days and high summer loads due to electric generation needs. We have seen times when our storage is empty at the end of July, yet it usually is full in time for winter needs.

As you are well aware, release of natural gas through abandoned, uncapped and unplugged salt solution wells caused two explosions in Hutchinson on Jan. 17 and 18, resulting in the loss of two lives, the destruction of two businesses and the evacuation of more than 200 homes and businesses in and around the Big Chief mobile home park.

Throughout this crisis, Kansas Gas Service has been committed to three objectives:

- To ensure the community's safety by investigating any potential natural gas leaks and drilling vent wells in the area
- To return the evacuees to their homes as soon as safely possible
- And to determine what caused natural gas to be present in the ground below Hutchinson and to fully understand the chain of events that led to the two explosions.

We brought in up to 180 employees from around the state and experts from our offices in Oklahoma and the Midwest to help us bring the situation under control. As we conducted leak surveys along 23,000 service lines and 252 miles of distribution main, and drilled numerous vent wells, we were able to identify problems unrelated to the underground gas, as well as finding leaks from the surface distribution system.

To date, we have drilled more than 49 deep vent wells including re-entering one abandoned salt solution well. Eleven of those wells found gas, were flared, and five continue to flare. Thirty-eight wells produced no gas. At Yaggy Field itself, we have drilled three monitoring wells, two of which found gas and were flared. The third was also dry.

To identify and plug all abandoned salt solution wells in the area and close off potential avenues for natural gas, the Kansas Geological Survey, KDHE and the City of Hutchinson are mapping the locations of these wells. KGS is helping to identify such wells in the Big Chief Mobile Home Park area.

With the leak surveying, the vent well drilling program and identification of abandoned salt solution wells to be plugged, Hutchinson is much safer than it was when this crisis began.

Because KGS is anticipating that it may not be able to inject gas into Yaggy this summer for next winter's heating season, we are reviewing several options to meet this seasonal need. KGS currently plans to issue a request for proposal to replace approximately 55,000 mmbtu per day of the Yaggy storage for the upcoming year in order to meet peak day requirements.

Salt-dome storage facilities in Kansas are monitored and regulated by the Kansas Department of Health and Environment. ONEOK has always endeavored to meet or exceed all storage safety requirements. The rates charged by Williams for interstate storage services are regulated by the Federal Energy Regulatory Commission and MCMC's intrastate rates are approved by the KCC.

Again, thank you for this opportunity to discuss storage and its role in our industry. We'll now be happy to answer any questions.

###

Presentation by John Rose
Enron Transportation Services

Submitted to
House Environment Committee

Tuesday, March 13, 2001
Natural Gas Storage Service

House Environment
3-13-01
Attachment 5

Introduction

Chairman and members of the committee, for the record my name is John Rose. I have 23 years of gas storage experience in Kansas as a Senior Reservoir Engineer for Northern Natural Gas (Northern), a subsidiary of Enron Corp. Northern is Enron's largest interstate pipeline system with approximately 17,000 miles of pipeline and an Upper Midwest market area capacity of 4.2 billion cubic feet per day. Northern operates in 23 Kansas counties and owns two natural gas underground storage facilities in Kansas located near Lyons and Cunningham. My remarks will address the development and operation of these two storage facilities.

Types of Storage

Underground natural gas storage facility sites may be depleted oil and gas fields, aquifer storage or salt cavern storage. The Lyons and Cunningham fields are representative of depleted gas fields that have been converted to provide underground storage service. To be considered for gas storage service, a field must have sufficient volumetric capacity, have sufficient daily deliverability and have an impermeable caprock to hold the gas in place. A very detailed application is then made to the Federal Energy Regulatory Commission and to the Kansas Corporation Commission. This process usually takes one to two years. Upon approval, the old wells are plugged, new wells drilled, pipelines are laid, and separation, dehydration and compression facilities are set. This process takes several years and is very capital intensive. The Cunningham project cost over $100 million to develop, including gas costs.

Lyons

The Lyons gas field was discovered in 1936 and produced 9 billion cubic feet during the period of 1937-48. The field was then plugged and abandoned. Northern began coverting the field to gas storage service in 1973 and the first natural gas injections were in 1975. There are currently 34 injection/withdrawal wells, 22 observation wells and 2 water disposal wells. A typical well completion schematic is attached on the back sheet. The Arbuckle dolomite serves as the storage formation and the Simpson shale is the caprock at a depth of 3300 feet. The reservoir is about about a half a mile wide and three miles long. Approximately 5.3 billion cubic feet of gas is injected in the summer and withdrawn in the winter. The peak withdrawal rate is 80 million cubic feet per day. The Lyons field could on an equivalent basis, provide heat for approximately 80,000 homes on a peak day.

Cunningham

The Cunningham storage field is one of the largest in the state of Kansas. It was discovered in 1932 and produced 71 billion cubic feet through 1970. Northern began converting Cunningham to gas storage service in 1974 and the first gas injections were in 1978. There are currently 53 injection/withdrawal wells, 18 observation wells and 1 water disposal well. The Viola dolomite and Simpson sand formations serve as storage reservoirs and the Kinderhook and Simpson shales serve as caprocks, at depths of 4000 and 4100 feet, respectively. The reservoir is approximately 4 miles wide and 9 miles long. As much as 30 billion cubic feet is injected and withdrawn from the field on an annual basis and the peak withdrawal rate is 650 million cubic feet per day. The Cunningham field could on an equivalent basis provide heat for approximately 650,000 homes on a peak day.

Value of Storage Facilities

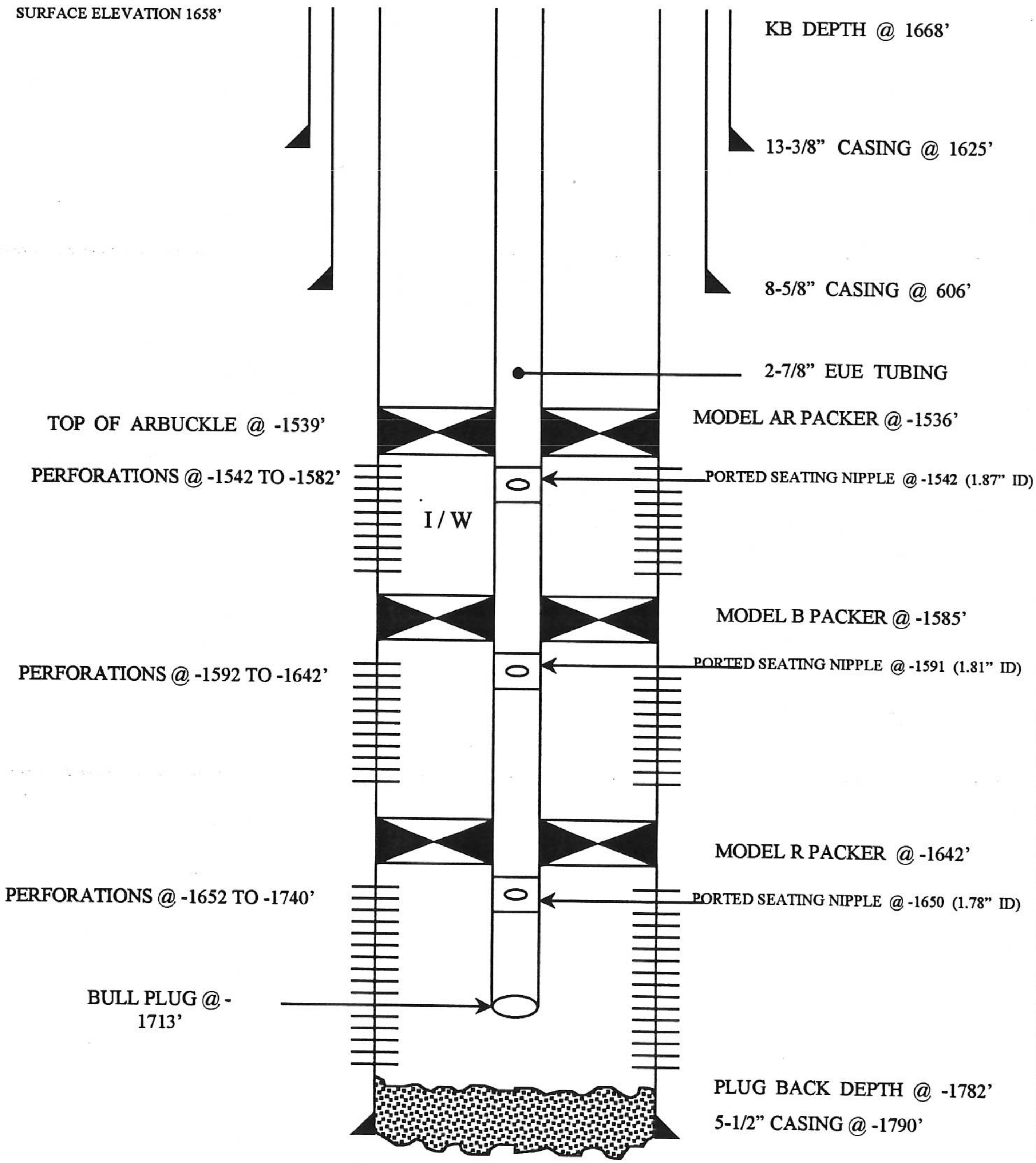
Underground storage facilities allow Northern's customers, local distribution companies and marketers to store natural gas and allows Northern to balance its pipeline system and meet operational swings throughout the year. The customer may use storage services to meet demand changes based on unexpected changes in the weather. Storage management is an important piece of a customer's purchasing strategy, along with its supply portfolio and financial management tools. Most importantly, gas storage allows gas to be purchased in the summer rather than in the winter which typically saves consumers money. The Cunningham and Lyons underground storage facilities are very valuable assets for our customers.

This concludes my remarks. I welcome any questions you may have at the conclusion of all of the presentations.

7/17/96

Well 11-01

WELL COMPLETION SCHEMATIC
LYONS GAS STORAGE FIELD



5-5