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Efforts to Plug ACSF SS-25 Destabilized Wellhead + Underground Natural Gas Storage Basics

A pair of recent articles, one from the Los Angeles Times and one from the Associated Press nationwide feed document how the efforts to plug Aliso Canyon Storage Field (ACSF) well "Standard Seson 25" (SS-25) destabilized the wellhead. I am quoted in both articles.

The gouges out of the earth surrounding SS-25 shown in the Earthworks overhead photographs on 17 December 2015 were mostly caused by the fluids that were injected down the wellhead to "kill" the well being pushed back up to the surface by the ACSF reservoir pressure, which measured as high as 2,680 PSI (Pounds per square inch on 11 06 1998, or 182.36 atmospheres) as measured in the well tubing.

Since there is strong media interest in this environmental disaster, the Wikipedia article about the ACSF natural gas leak is appended to provide context. In addition, a pair of articles about underground natural gas storage from the U.S. Energy Information Administration (EIA) are included with a graph from 13 January 2016 issue of EIA's Natural Gas Weekly Update showing nationwide seasonal natural gas storage trends. Nationwide natural gas storage peaks in late November most years. Historical ACSF trends suggest a peak field pressure near the end of October in most years. The geographical distribution of underground natural gas storage facilities and a schematic natural gas storage facility are also shown.

It is important to appreciate that the ACSF is the nation's 4th largest natural gas storage facility, per the EIA, with a working capacity of 86,000,000 Mcf. See: http://www.eia.gov/cfapps/ngqs/ngqs.cfm?f_report=RP7 While 86 billion cubic feet of natural gas seems like a large quantity, a 10 December 2015 SoCalGas news release noted this is about a six week or more supply for the Los Angeles area. This quantity of natural gas could become very important for the continued safety of the millions living in the greater Los Angeles area in the event of a large-scale natural disaster such as a major earthquake that disrupted the major natural gas supply lines feeding southern California, so suggestions to close ACSF are ill-advised.

In the same way that is it impractical to remove 100% of the contents of an aerosol can, local distribution companies (LDCs) cannot remove all of natural gas in an underground storage facility. In fact, about half of the gas in a facility such as ACSF must remain in the ground to maintain deliverability and allow the facility to be recharged. The half that remains in the ground is also known as "base gas." Thus, individuals calling for the complete drawdown of the ACSF fail to recognize the significance of base gas.

This information should serve as a counterbalance to the claims that exaggerate the risks of nuclear power during campaigns to either prevent startup or to shut down of nuclear power plants.

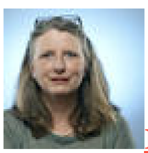
Additional submitted attachment is included below.

Los Angeles Times

CALIFORNIA
LOCAL CALIFORNIA

Efforts to plug Porter Ranch-area gas leak worsened blowout risk, regulators say

A view last month of Southern California Gas' leaking well near Porter Ranch, including the exposed wellhead. (Earthworks)



Paige St. John Contact Reporter

January 15, 2016 3:00 AM

http://www.latimes.com/local/california/la-me-aliso-well-hole-20160115-story.html

Southern California Gas Co.'s effort to plug its leaking natural gas well involves higher stakes than simply stopping the fumes that have sickened many residents of Porter Ranch.

The company also is trying to avoid a blowout, which state regulators said is now a significant concern after a seventh attempt to plug the well created more precarious conditions at the site.

If a blowout occurs, highly flammable gas would vent directly up through the well, known as SS25, rather than dissipating as it does now via the subsurface leak and underground channels.

State officials said a blowout would increase the amount of leaked gas, causing greater environmental damage. That natural gas also creates the risk of a massive fire if ignited by a spark. The risk of fire already is so high that cellphones and watches are banned from the site

California Department of Conservation spokesman Don Drysdale called the possibility of fire "a concern" even without a blowout. The department is the umbrella agency that oversees the oil and gas regulators responsible for well safety.

If the wellhead fails, the thing is just going to be full blast

.- Gene Nelson, physical sciences professor, Cuesta College.

The chief deputy director of the department, Jason Marshall, and a senior oil and gas field regulator assigned to daily watch at Aliso Canyon, Scott McGurk, told The Times the site and wellhead were made more unstable by the gas company's attempts to stop the leak by pumping a slurry directly into the well.

The last of those efforts, which stretched over several days beginning Dec. 22, expanded a crater around the wellhead, state and gas company officials said.

The crater is now 25 feet deep, 80 feet long and 30 feet wide, those officials said. The wellhead sits exposed within the cavernous space, held in place with cables attached after it wobbled during the plugging attempt, Marshall and McGurk said. The well pipe and its control valves are exposed and unsupported within that hole, atop a deep field of pressurized gas.

Southern California Gas is now attempting to stop the leak by drilling relief wells to intercept the damaged well. Workers are not expected to reach the base of the well, 1.6 miles below ground, for at least six weeks.

"If the wellhead fails, the thing is just going to be full blast," said Gene Nelson, a physical sciences professor at Cuesta College. "It will be a horrible, horrible problem. The leak rates would go way up."

Sempra Energy, which owns the gas company, declined repeated requests from The Times to discuss current conditions at SS25. A gas company spokeswoman said the utility "would not speculate" on those questions.

At a meeting with community representatives last week, the gas company's senior vice president for operations, Jimmie Cho, said attempts to plug the well from above were halted "for safety concerns."

"As much as what's going on is not a good thing, we don't want to take a risk of that wellhead being lost," Cho said.

State officials agreed.

"If one pushes too hard … and breaks the well in its entirety, we, the public residents, the operator, have a much bigger problem," Marshall said.

The gas company would not provide current photos of the site or allow media access. It did not provide a reason.

Aerial photographs obtained by The Times, taken by a pilot who slipped through no-fly zones imposed after the leak began, show the tension cables strung to hold the jeopardized well in place.

The photos, taken five days before the final plug attempt Dec. 22, show that the earth and the asphalt pad that directly surrounded the well are gone, scoured out by the backwash of mud repeatedly forced at high pressure into the leaky well in an attempt to plug it.

Statements by gas company officials and regulators, and descriptions found in internal records describe the conditions around the well. A bridge was cantilevered into place when the crater cut off access to the exposed "Christmas tree" of valves and ports that allow operators to control the well, those officials and documents show.

That wellhead is the only control operators currently have on a well that features a 2 7/8-inch pipe surrounded by a 7-inch casing. Engineering schematics show that the pipe and casing pierce an underground reservoir of gas and that both were used to insert and remove gas from the storage cavern. For all but the top 990 feet, there was no larger pipe to contain a leak if either pipe ruptured.

The two-mile long depleted oil reserve that houses the gas is the largest natural gas storage field west of the Mississippi River. **Each fall it is pumped with as much as 86 billion cubic feet of natural gas to run power plants and heat homes in Los Angeles during the winter.**

The gas company reported Oct. 23 that gas was escaping through small cracks in the rocky ground around well SS25, which is among 112 former oil extraction wells that have been converted for the natural gas storage operation.

In November, efforts to force heavy mud into the well resulted in blasting open a small vent in the ground from which gas could escape more readily.

By early January, state air quality regulators estimate, the leak had released more than 77 million kilograms of methane, the environmental equivalent of putting 1.9 million metric tons of carbon dioxide in the air.

Independent health impact studies are not yet complete. Mercaptan added to allow gas to be detected by smell has sickened residents more than a mile away, and Southern California Gas is paying to house more than 2,500 in temporary lodging and has installed air purifiers into the homes of a similar number who chose to stay.

Data captured by aerial surveys commissioned by the state Air Resources Board, which monitors pollution, show the amount of methane released increased over the first three weeks of November to 58,000 kilograms per hour from 44,000.

During that time, a Texas well control company was attempting to plug a suspected hole in the 7-inch well casing by pumping it with increasingly heavier slurries of mud. The mud was pushed against pressurized gas in the well, and the slurry began to find its own escape routes, gouging out a growing hole around the well, according to descriptions provided by Marshall, McGurk and by Cho.

During one of those attempts Nov. 13, a hole in the ground opened 20 feet north of the well, McGurk said last week. Gas that had seeped through diffuse rock fissures on the western side of the narrow ridge began streaming instead from the new vent, he said.

In one internal state report obtained by The Times, an agency official described that kill effort as a "blowout to surface."

"A large column of gas, aerated mud, and rock formed a geyser around the wellhead," the state observer wrote. "Mud brine also began to flow from around the wellhead fissures."

McGurk said the vent allowed a "serious amount of gas" to escape, at which point the state began requiring a state regulatory official to be at the site every day.

Three more efforts to plug the well were made in November, with increasing amounts of backwash and scouring along the wellhead itself that left the well jutting out of a deep hole, without surface support, according to interviews, descriptions contained in agency records and company statements.

During that time, a pilot taking weekly readings for the state Air Resources Board noted a spike in the rate of gas being released to the air from that location.

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A version of this article appeared in print on January 15, 2016, in the News section of the Los Angeles Times with the headline "ALISO CANYON GAS LEAK - Blowout fears rise with weakened wellhead - Regulators say efforts to plug gas leak have made site more unstable"

AP THE BIG STORY

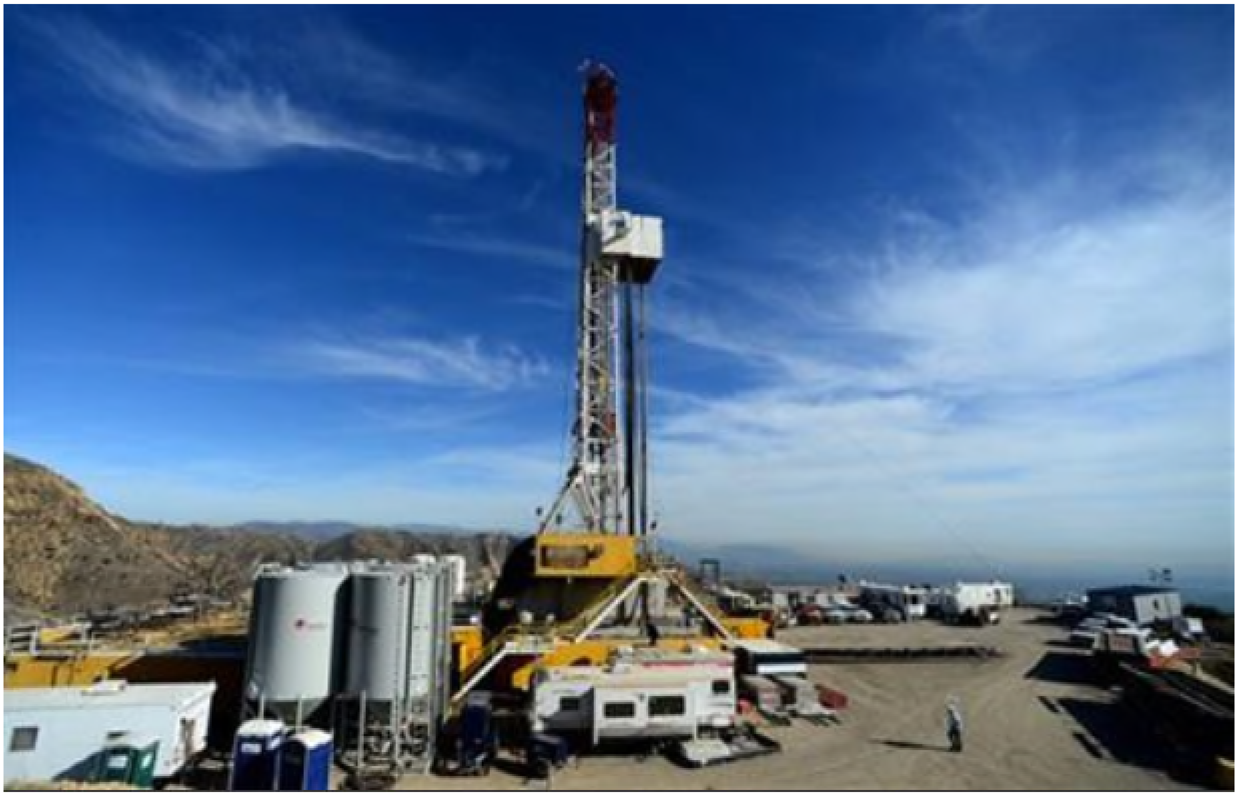
http://bigstory.ap.org/article/0b2ba21df2634c1abcc13e7d426de049/things-know-about-12-week-old-los-angeles-gas-leak

Things to know about 12-week-old Los Angeles gas leak

By BRIAN MELLEY
Jan. 15, 2016 10:52 PM EST

3 photos

FILE - In this Jan. 6, 2016, file photo, a truck leaves the Southern California Gas Co. facility where a natural gas well has been leaking uncontrollably for weeks in the Porter Ranch section of Los Angeles. In trying to reassure the public there's no long-term health risk from the leak, Southern California Gas Co. has said in news releases and FAQs on its website that since the crisis began, just two air samples briefly showed elevated concentrations of the substance. But a closer look at the online data by The Associated Press and outside experts actually shows that a dozen samples from the Porter Ranch community contained at least twice the amount of benzene that Southern California air regulators consider the normal background level. (AP Photo/Brian Melley, File)



FILE - In this Dec. 9, 2015, file pool photo, crews work on a relief well at the Aliso Canyon facility above the Porter Ranch area of Los Angeles. In trying to reassure the public there's no long-term health risk from the leak, Southern California Gas Co. has said in news releases and FAQs on its website that since the crisis began, just two air samples briefly showed elevated concentrations of the substance. But a closer look at the online data by The Associated Press and outside experts actually shows that a dozen samples from the Porter Ranch community contained at least twice the amount of benzene that Southern California air regulators consider the normal background level. (Dean Musgrove/Los Angeles Daily News via AP, Pool, File)

FILE - This Jan. 6, 2016, file photo shows a neighborhood in the upscale community of Porter Ranch a section of Los Angeles where residents have moved out because of a natural gas leak from a Southern California Gas Co. storage facility located nearby. California Gov. Jerry Brown has declared a state of emergency over the massive natural-gas leak that has been spewing methane and other gases into the neighborhood, sickening residents and forcing thousands to evacuate. (AP Photo/Brian Melley, File)

LOS ANGELES (AP) **— A leak from an underground natural gas storage facility that has sickened Los Angeles residents and sent thousands from their homes has been out of control for 12 weeks and a possible fix is expected no sooner than March**. Here are some things to know about it:

SCOPE OF THE PROBLEM

Gov. Jerry Brown declared an emergency for the Southern California Gas Co. leak that some environmentalists are calling the worst disaster since the BP oil spill in the Gulf of Mexico in 2010.

The leak first reported Oct. 23 has foiled efforts to contain it, and **some attempts may have made the problem worse.**

In addition to bathing the Porter Ranch community in a foul smell that is blamed for nausea, nosebleeds, headaches and other symptoms, **it has also released an immense amount of climate-changing methane equivalent at one point to about a quarter of the state's total output of the gas.**

A SoCalGas executive has said the leak is unprecedented. Financial filings show the company anticipates spending $50 million a month for the complex effort to cap the leak and up to $7,500 a month for each of the 4,500 families being relocated through as late as April.

It also faces more than two dozen lawsuits, some of which are seeking class-action status.

POSSIBLE DANGER

The company has said the leak, which is located about a mile from the nearest homes, does not pose an imminent threat to public safety. But crews are working under safety restrictions around the flammable gas, **and efforts to stop the leak may have weakened the well and created a greater problem**.

The Los Angeles Times reported Friday that a "blowout" is a concern after seven attempts to plug the leak by pouring a muddy mix into it.

A blowout would send a large amount of gas directly up the well instead of dissipating through the ground and could cause a massive fire if sparked. Workers cannot use cellphones and wear watches at the site because of fire danger.

"**If the wellhead fails, the thing is just going to be full blast," said Gene Nelson, a physical sciences professor at Cuesta College. "It will be a horrible, horrible problem. The leak rates would go way up."**

Attempts to stop the high-pressure leak with a briny solution have created a crater around the wellhead and opened up a vent in the ground about 20 feet from the well.

Sempra Energy, which owns the gas company, would not comment on the blowout danger.

The company is drilling a relief well to intercept the well and plug it about a mile-and-a-half underground where it taps into a vacant oil field storing natural gas.

Regulators have also expressed fears that the attempts to burn off escaping natural gas will lead to an explosion.

The state Public Utility Commission has asked the company in a letter to address its concerns by Tuesday.

The letter says the burn-off system as currently devised "is NOT fully designed and needs further work and analysis," according to the Los Angeles Times.

THE GAS COMPANY'S RESPONSE

SoCalGas initially acted slowly to publicly acknowledge the leak and notify residents about what happened.

It eventually apologized for its response, and it has posted on a website daily updates and results from twice-daily air quality tests as part of efforts to be more open with the public about what's going on.

In summarizing air quality reports**, the company understated levels of the cancer-causing chemical benzene found in the community. After inquiries from The Associated Press, SoCalGas acknowledged Thursday that higher-than-normal readings had been found in at least 14 samples**. It previously stated that just two air samples over the past three months showed elevated concentrations of the compound.

A spokeswoman said the error was an oversight that would be corrected. The incorrect information was still on the website Friday.

WHERE IS THE GOVERNMENT?

An alphabet soup of state and local government agencies are overseeing work at the site of the leak and issuing a variety of orders to fix the problem.

The Los Angeles County Department of Public Health ordered the company to relocate anyone seeking to move while the leak continues. The South Coast Air Quality Management District issued a notice of violation for the leak and can assess penalties ranging from $1,000 to $1 million a day for each day of the nuisance.

The state Division of Oil, Gas, and Geothermal Resources is overseeing efforts to stop the leak and will investigate the cause once it's plugged.

California lawmakers proposed bills this week that will carry stronger regulations to prevent future incidents like the one at the Aliso Canyon facility. One proposed bill would require safety valves on such wells. The leaking well previously had a safety valve, but it was removed in 1979 after it leaked. A replacement wasn't required.

Lawmakers want the company to cover the costs of the leak, **pay for greenhouse gas emissions and not pass them on to customers through higher rates.**

Coordinates: 34°18′54″N 118°33′51″W

Aliso Canyon gas leak

From Wikipedia, the free encyclopedia

The **Aliso Canyon gas leak** (also called **Porter Ranch gas leak**[1]) is a massive, uncontrolled, ongoing leak from a natural gas well connected to the Aliso Canyon underground storage facility near Porter Ranch, Los Angeles, California since October 23, 2015.[2] The second largest gas storage facility of its kind in the United States belongs to the Southern California Gas Company, a subsidiary of Sempra Energy. On January 6, 2016, Governor Jerry Brown issued a state of emergency.[3]

Aliso Canyon gas leak

Aliso Canyon leak site on December 14, 2015

Duration	October 23, 2015 – present
Location	Porter Ranch, Los Angeles, California
Coordinates	34°18′54″N 118°33′51″W
Also known as	Porter Ranch gas leak
Type	Gas leak

Gas leak site shown within the Los Angeles metropolitan area

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Source and causes

After oil had been discovered at Aliso Canyon in 1938, J. Paul Getty's Tidewater Associated Oil Company produced oil and gas until it was depleted in the early 1970s. Getty sold the field to Pacific Lighting Company, a gas company from when gas was used to light homes converted the depleted oil field to storage in 1972. Older wells were not sealed to surrounding rock formation, including more than one mile of steel pipe. Today, "cement from the surface of the ground to the bottom of the well [...] makes the casings stronger and protects them from water."[4]

The source of the leak is a metal pipe in a breached 7-inch casing of injection well SS 25 that is 8,750 feet deep. The field can hold 86 billion cubic feet of natural gas[2] and is the second largest storage facility of its kind in the United States.[2] Well SS 25 had been drilled in 1953 and was initially provided with a safety valve. The safety valve was removed in 1979 as it was old and leaking.[4] Because the well was not considered "critical, that is, one within 100 feet of a road or a park, or within 300 feet of a home", the valve was only removed and not replaced.[4][5] The atmospheric scientist Steve Conley said the wellhead in Aliso Canyon was 61 years old and implied it was no "shock that it failed".[6]

On December 7th, 2015, a video emerged depicting a cloud of methane gas hovering over the community of Porter Ranch[7]. The video was shot with an infrared camera, which captures the true extent of the Aliso Canyon damage.

Emissions

Natural gas consists largely of methane, an invisible and odorless greenhouse gas with a global warming potential 86 times greater than carbon dioxide in a 20-year time frame, tailing off to about 29 times the effect of carbon dioxide in a 100 year time frame.[8] The leak initially released about 44,000 kilograms (kg) of methane per hour or 1,200 tons of methane every day, which in terms of greenhouse gas output per month was compared to the equivalent of what 200,000 cars would emit in a year,[2] On 14 January 2016, Time magazine compared the 1.6 million lbs. of methane each day to 6 coal fired powerplants or 2.2 million cows in one day, or driving 4.5 million cars.[9] As of January 2016, the latest methane measurement per the California Air Resources Board (Carb) was from 22 December 2015 and had decreased to 30,300 kg/h,[6] the equivalent of "more than 1,411,851 cars" by a different calculation using EPA estimates.[10] The Aliso gas leak carbon footprint is referred to as "larger than the Deepwater Horizon leak in the Gulf of Mexico".[11]

Steve Conley, an atmospheric scientist at UC Davis is the person single-handedly measuring the gas emissions. He samples the air by flying over the site in his single-engine airplane, modified and equipped with an analyzer, which is one of only 3 or 4 of such planes in the country. He said the Aliso Canyon flights were "the hardest [...] I've ever done" because of the headache-inducing smell and sickening turbulence. He doubted the readings initially, "thought [the instruments] had stopped working because I'd never seen measurement that large before." He had coincidentally been contracted by the California Energy Commission prior to the gas leak, and said that if he hadn't been contracted and ready to go, "no one would have known how big [the leak] was."[6]

Besides methane, the gas leak also contains tert-butyl mercaptan, tetrahydrothiophene.[12] and methyl mercaptan that give the gas a rotten-egg smell. In addition, the gas contains some volatile organic compounds such as benzene.[13] Benzene is a carcinogen.[14] The pollutants may have long-term consequences far beyond the region.[15]

Effect on local community

Local residents have reported headaches, nausea, and severe nosebleeds.[2] About 50 children per day saw schoolnurses for severe nosebleeding.[11] There have been more eye, ear and throat infections.[5] By December 25, 2015 more than 2,200 families from the "affluent Porter Ranch neighborhood in northern Los Angeles"[6] had been temporarily relocated, and more than 2,500 households were still being processed.[14] As of January 7, 2016, 2,824 households or about 11,296 people had been temporarily relocated by SoCal Gas.[10] while more than 6,500 families have filed for help.[16] Two schools were to be relocated in January.[4]

Regulatory reactions

The Federal Aviation Administration established a temporary flight restriction over the leak site until March 2016. On December 15, 2015 the county of Los Angeles declared a state of emergency.[1]

Local residents called upon Governor Jerry Brown to intercede. Kathleen Brown, his sister, is on the board of Sempra Energy, which owns Southern California Gas. The Governor visited the site and the neighborhood on January 4, 2016.[17] and declared a state of emergency on 6 January 2016. He issued stepped-up inspections and safety measures for all natural gas storage facilities in California, while further injections of gas at Aliso Canyon had already been prohibited.[3]

Local health officials indicated that long-term exposure to certain trace chemicals could lead to health problems.[2]

Closure of well

By the end of November SoCalGas had attempted six well kill procedures to stop the gas flow by pouring a mixture of mud and brine down the well, the last being on 25 November.[4] These failures were because of ice and a high upward pressure averaging 2,700 pounds per square inch.[16]

On 4 December 2015 SoCalGas started to drill a relief well with the help of Boots & Coots, a subsidiary of Halliburton. The plan is to pour liquid and cement into the well once the relief well is 8,000 feet deep.[4][18] A first relief well is estimated to be completed by February 24, 2016.[18] SoCalGas, plans to drill a secondary relief well, estimating the leak repair to take up until the end of March 2016.[18]

After the seventh effort to to plug the leaking well with slurry that started on December 22, state regulators became more concerned about the stability of the wellhead.[19] The plugging efforts created a 25 feet deep crater around the wellhead that needed to be stabilized with tension cables. As a failure of the wellhead may lead to a blowout, further attempts to plug the well from above have been halted.[19]

Criticism

Residents of the nearby Porter Ranch neighborhood reported what they thought was a home with a major leak on October 23. SoCalgas "went from home to home to home, giving everybody the A-OK and [..] didn't admit to having a gas leak until ... probably around the 28th of October".[20]

Steve Conley, the atmospheric scientist that has been measuring the leak's gas emissions has stated that there was no Rapid Response plan for this kind of event: "We do not have anything in place to measure giant leaks like this, or to watch them to solve issues." He suggested that contracts needed to be ready so that, "as soon as a leak is spotted you are given a go order and two hours later you're measuring a leak."[6]

The Center for Biological Diversity has criticized Governor Brown's slow response "because state regulators' hands-off approach to underground injection helped set the stage for this catastrophe" and that "The state has known for years that aging natural gas infrastructure was a disaster waiting to happen, but officials mostly ignored those risks."[21]

Experts in petroleum engineering have criticized the delay in drilling a relief well 6 weeks after knowing about the leak and to drill only one relief well so far instead of two.[4]

In January, 2016 the Associated Press reported that SoCalGas had been under reporting the levels of benzene in the air surrounding the well.[22]

See also

- Four Corners Methane Hot Spot

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External links

Wikimedia Commons has media related to ***Aliso Canyon gas leak***.

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Categories: 2015 in California | 2015 in the environment | 2015 disasters in the United States | 2016 disasters in the United States | Ongoing events | Air pollution in California | Environment of Los Angeles, California | Environmental disasters in the United States | Pipeline accidents

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U.S. Energy Information Administration

Natural Gas

The Basics of Underground Natural Gas Storage

Release Date: November 16, 2015

Natural gas–a colorless, odorless, gaseous hydrocarbon–may be stored in a number of different ways. It is most commonly held in inventory underground under pressure in three types of facilities. These underground facilities are depleted reservoirs in oil and/or natural gas fields, aquifers, and salt cavern formations. Natural gas is also stored in liquid or gaseous form in above–ground tanks.

Each storage type has its own physical characteristics (porosity, permeability, retention capability) and economics (site preparation and maintenance costs, deliverability rates, and cycling capability), which govern its suitability for particular applications. Two important characteristics of an underground storage reservoir are its capacity to hold natural gas for future use and the rate at which gas inventory can be withdrawn–called its its deliverability rate (see *Storage Measures*, below, for definitions).

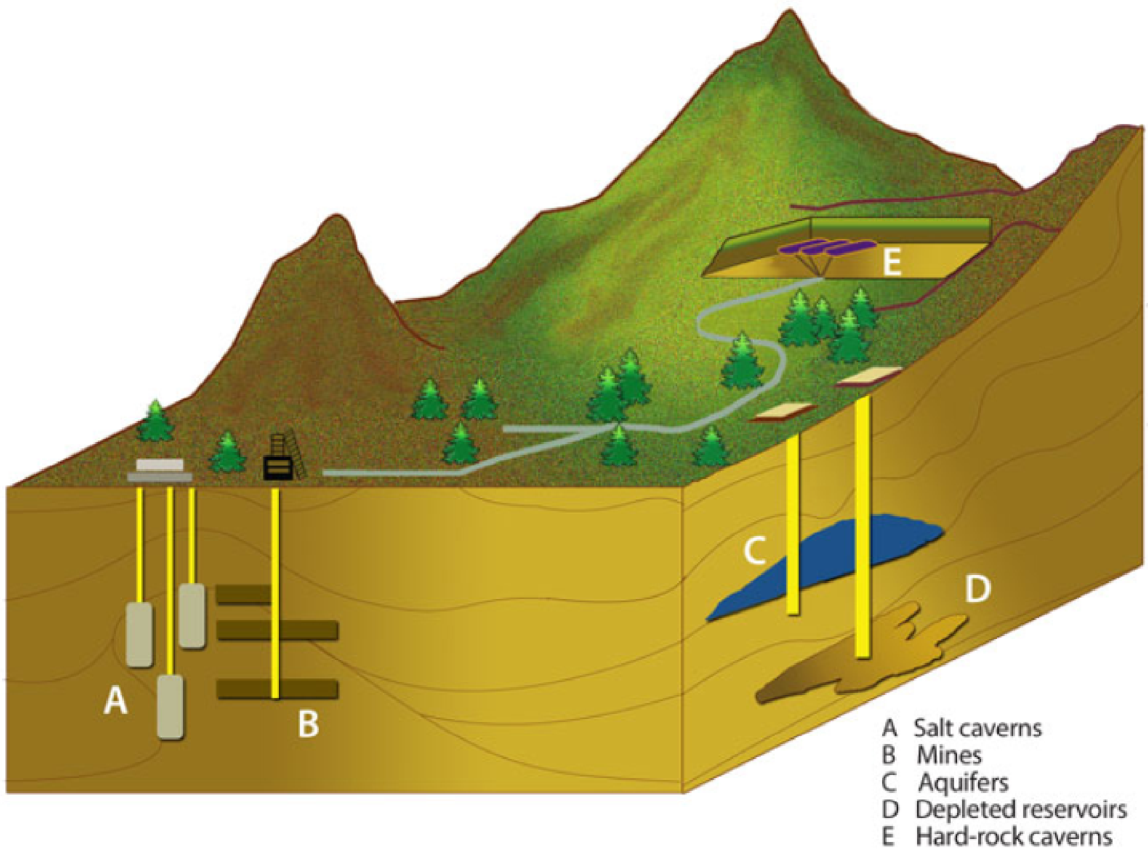
Most existing natural gas storage in the United States is in **depleted natural gas or oil fields** that are close to consumption centers. Conversion of a field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections. Depleted oil and natural gas 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 natural gas storage reservoirs. An aquifer is suitable for gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. Although the geology of aquifers is similar to depleted production fields, their use for natural gas storage usually requires more base (cushion) gas and allows less flexibility in injecting and withdrawing. Deliverability rates may be enhanced by the presence of an active water drive, which supports the reservoir pressure through the injection and production cycles.

Salt caverns provide very high withdrawal and injection rates relative to their working gas capacity. Base gas requirements are relatively low. Most salt cavern storage facilities have been developed in salt dome formations located in the Gulf Coast states. Salt caverns have also been made (by a process called leaching) in bedded salt formations in Northeastern, Midwestern, and Southwestern states. 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.

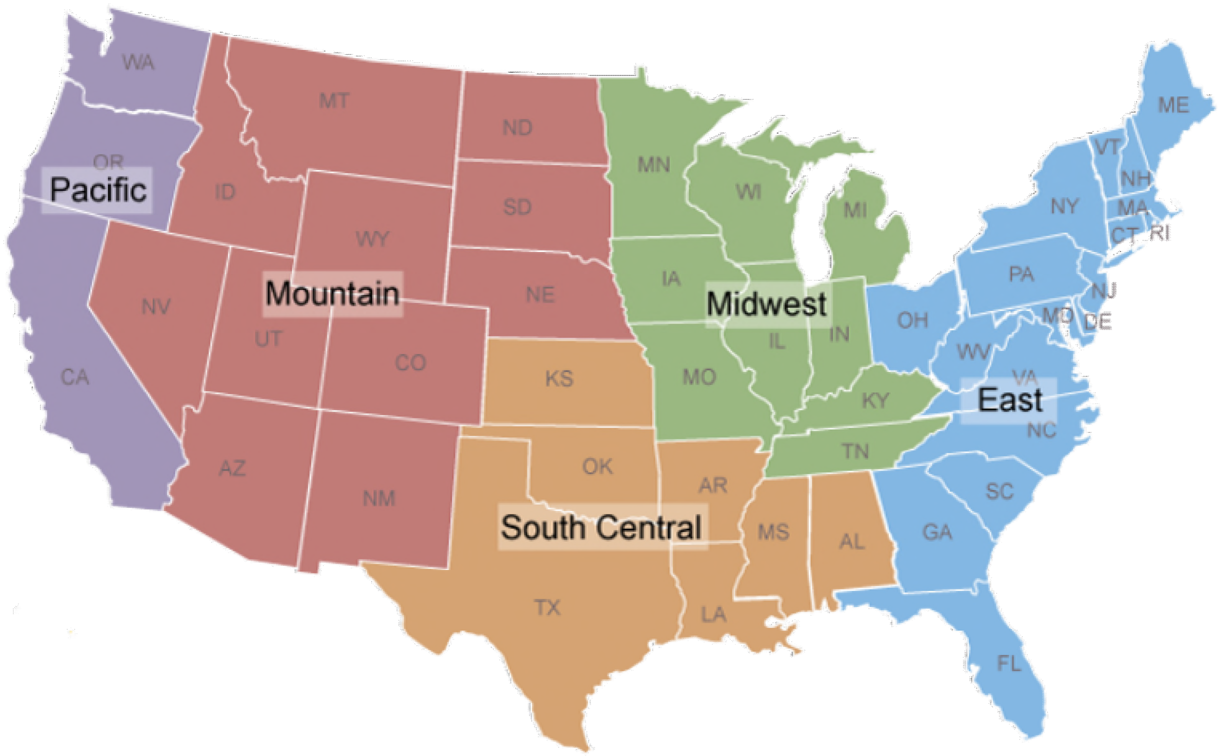
Figure 1 is a stylized representation of the various types of underground storage facilities. Figure 2 shows the U.S. natural gas storage regions.

Figure 1. Types of underground natural gas storage facilities



Source: PB-KBB, inc., enhanced by EIA.

Figure 2. Underground natural gas storage regions



Owners and Operators of Storage Facilities

The principal owners/operators of underground storage facilities are interstate pipeline companies, intrastate pipeline companies, local distribution companies (LDCs), and independent storage service providers. About 120 entities currently operate the nearly 400 active underground storage facilities in the Lower 48 states. If a storage facility serves interstate commerce, it is subject to the jurisdiction of the Federal Energy Regulatory Commission (FERC); otherwise, it is state-regulated.

Owners/operators of storage facilities are not necessarily the owners of the natural gas held in storage. In fact, most working gas held in storage facilities is held under lease with shippers, LDCs, or end users who own the gas. The type of entity that owns/operates the facility will determine to some extent how that facility's storage capacity is utilized.

For example, **interstate pipeline companies** rely heavily on underground storage to facilitate load balancing and system supply management on their long-haul transmission lines. FERC regulations allow interstate pipeline companies to reserve some portion of their storage capacity for this purpose. Nonetheless, the bulk of their storage capacity is leased to other industry participants. **Intrastate pipeline companies** also use storage capacity and inventories for similar purposes, in addition to serving customers.

In the past, **LDCs** have generally used underground storage exclusively to serve customer needs directly. However, some LDCs have recognized and have been able to pursue the opportunities for additional revenues available with the deregulation of underground storage (see **"Open Access" to Storage Capacity**, below). These LDCs, which tend to be the ones with large distribution systems and a number of storage facilities, have been able to manage their facilities so they can lease a portion of their storage capacity to third parties (often marketers) while still fully meeting their obligations to serve core customers. (Of course, these arrangements are subject to approval by the respective state-level regulators.)

The deregulation of underground storage combined with other factors such as the growth in the number of natural gas-fired electricity generating plants has placed a premium on high-deliverability storage facilities. Many salt formation and other high-deliverability sites, both existing and under development, have been initiated by **independent storage service providers**, often smaller, more focused companies started by entrepreneurs who recognized the potential profitability of these specialized facilities. These facilities are used almost exclusively to serve third-party customers who can most benefit from the characteristics of these facilities, such as marketers and electricity generators.

History of "Open Access" to Storage Capacity

Prior to 1994, interstate pipeline companies, which are subject to the jurisdiction of FERC, owned all of the natural gas flowing through their systems, including gas held in storage, and these companies had exclusive control over the capacity and utilization of their storage facilities. With the implementation of FERC Order 636, interstate pipeline companies were required to operate their storage facilities on an open-access basis. That is, the major portion of working gas capacity (beyond what may be reserved by the pipeline/operator to maintain system integrity and for load balancing) at each site must be made available for lease to third parties on a nondiscriminatory basis.

Today, in addition to the interstate storage sites, many storage facilities owned/operated by large LDCs, intrastate pipelines, and independent operators also operate on an open-access basis, especially those sites affiliated with natural gas market centers. Open access has allowed storage to be used other than simply as backup inventory or as a supplemental seasonal supply source. For example, marketers and other third parties may move natural gas into and out of storage (subject to the operational capabilities of the site or the tariff limitations) as changes in price levels present opportunities to buy and store natural gas when demand is relatively low, and sell during periods of peak-demand when the price is elevated. Further, storage is used in conjunction with various financial instruments (e.g., futures and options contracts, swaps, etc.) in creative and complex ways in an attempt to profit from market conditions.

Reflecting this change in focus within the natural gas storage industry during recent years, the largest growth in daily withdrawal capability has been from high-deliverability storage sites, which include salt cavern storage reservoirs as well as some depleted oil or natural gas reservoirs. These facilities can cycle their inventories–i.e., completely withdraw and refill working gas (or vice versa)–more rapidly than can other types of storage, a feature more suitable to the flexible operational needs of today's storage users. Since 1993, daily withdrawal capability from high-deliverability salt cavern storage facilities has grown significantly. Nevertheless, conventional storage facilities continue to be very important to the industry.

Underground Natural Gas Storage Data

The U.S. Energy Information Administration (EIA) collects a variety of data on the storage measures discussed above, and EIA publishes selected data on a weekly, monthly, and annual basis. EIA uses Form EIA-912, *Weekly Natural Gas Storage Report*, to collect data on end-of-week working gas in storage at the company and regional level from a sample of all underground natural gas storage operators. The regions used for weekly reporting were formally the East, West and Producing regions. In October 2015, EIA increased the number of regions (Figure 2) and changed their names to better align the storage locations with the markets they serve and to provide more information to market observers and participants. Data from the EIA-912 survey are tabulated and published weekly at regional and national levels. The EIA-191, *Monthly Underground Gas Storage Report,*, collects data on total capacity, base gas, working gas, injections, and withdrawals, by reservoir and by storage facility, from all underground natural gas storage operators. Data derived from the EIA-191 survey are published at a state level on a monthly basis in the *Natural Gas Monthly*, with select data available at the field level in the Natural Gas Respondent Query System. The data shown in the *Natural Gas Monthly* include tabulations of base gas, total inventories, total storage capacity, injections, and withdrawals at state and regional levels.

Storage Measures

Several volumetric measures are used to quantify the fundamental characteristics of an underground storage facility and the gas contained within it. For some of these measures, it is important to distinguish between the characteristic of a facility, such as its *capacity*, and the characteristic of the natural gas within the facility such as the actual *inventory level*. These measures are as follows:

Total natural gas storage capacity is the maximum volume of natural gas that can be stored in an underground storage facility in accordance with its design, which comprises the physical characteristics of the reservoir, installed equipment, and operating procedures particular to the site.

Total gas in storage is the volume of natural gas in the underground facility at a particular time.

Base gas (or cushion gas) is the volume of natural gas intended as permanent inventory in a storage reservoir to maintain adequate pressure and deliverability rates throughout the withdrawal season.

Working gas capacity refers to total gas storage capacity minus base gas.

Working gas is the volume of gas in the reservoir above the level of base gas. Working gas is available to the marketplace.

Deliverability is most often expressed as a measure of the amount of gas that can be delivered (withdrawn) from a storage facility on a daily basis. Also referred to as the deliverability rate, withdrawal rate, or withdrawal capacity, deliverability is usually expressed in terms of million cubic feet per day (MMcf/d). Occasionally, deliverability is expressed in terms of equivalent heat content of the gas withdrawn from the facility, most often in dekatherms per day (a therm is 100,000 Btu, which is roughly equivalent to 100 cubic feet of natural gas; a dekatherm is the equivalent of about one thousand cubic feet (Mcf)). The deliverability of a given storage facility is variable, and it depends on factors such as the amount of natural gas in the reservoir at any particular time, the pressure within the reservoir, the compression capability available to the reservoir, the configuration and capabilities of surface facilities associated with the reservoir, and other factors. In general, a facility's deliverability rate varies directly with the total amount of natural gas in the reservoir: it is at its highest when the reservoir is most full and declines as working gas is withdrawn.

Injection capacity (or rate) is the complement of the deliverability or withdrawal rate–it is the amount of natural gas that can be injected into a storage facility on a daily basis. As with deliverability, injection capacity is usually expressed in MMcf/d, although dekatherms/day is also used. The injection capacity of a storage facility is also variable, and it is dependent on factors comparable to those that determine deliverability. By contrast, the injection rate varies inversely with the total amount of gas in storage: it is at its lowest when the reservoir is most full and increases as working gas is withdrawn.

None of these measures for any given storage facility are fixed or absolute. The rates of injection and withdrawal change as the level of natural gas varies within the facility. In practice, a storage facility may be able to exceed certificated total capacity in some circumstances by exceeding certain operational parameters. The facility's total capacity can also vary, temporarily or permanently, as its defining parameters vary. Measures of base gas, working gas, and working gas capacity also can also change from time to time. These changes occur, for example, when a storage operator reclassifies one category of natural gas to the other, often as a result of new wells, equipment, or operating practices (such a change generally requires approval by the appropriate regulatory authority). Finally, storage facilities can withdraw base gas for supply to market during times of particularly heavy demand, although by definition, this gas is not intended for that use.

U.S. Energy Information Administration

NATURAL GAS

About U.S. Natural Gas Pipelines - Transporting Natural Gas

based on data through 2007/2008 with selected updates

Underground Natural Gas Storage

Overview | Regional Breakdowns

Overview

Underground natural gas storage provides pipelines, local distribution companies, producers, and pipeline shippers with an inventory management tool, seasonal supply backup, and access to natural gas needed to avoid imbalances between receipts and deliveries on a pipeline network.

There are three principal types of underground storage sites used in the United States today. They are:

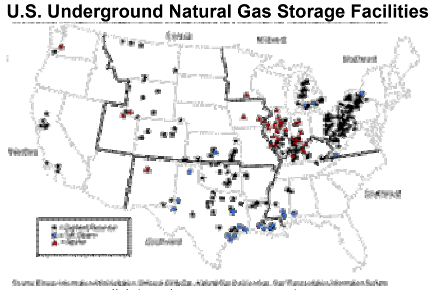
- depleted natural gas or oil fields (326),
- aquifers (43), or
- salt caverns (31).

In a few cases mine caverns have been used. Most underground storage facilities, 82 percent at the beginning of 2008, were created from reservoirs located in depleted natural gas production fields that were relatively easy to convert to storage service, and that were often close to consumption centers and existing natural gas pipeline systems.

In some regions, such as the Midwestern United States, suitable natural aquifers have also been converted for use as natural gas storage facilities. An aquifer is usable for natural gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to that of depleted production fields, their use in gas storage usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance.

Since the 1980s, the number of salt cavern storage sites developed in the United States has grown steadily, principally because of its unique capabilities and high cycling rate (inventory turnover). 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 have also been developed but the number has been limited due to a lack of suitable geology. Cavern construction is more costly than depleted field conversion 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.

U.S. Underground Natural Gas Storage Facilities



click to enlarge   more recent map

More information related to underground storage…

Depleted Reservoir Storage Well - illustration
Aquifers - illustration
Salt Caverns - illustration

Underground Storage Capabilities by State - table

Field Level Annual Storage Capacity Data

Peak Underground Working Natural Gas Storage Capacity

Other Natural Gas Transportation Topics:

Interstate - Pipeline systems that cross one or more States
Intrastate - Pipeline systems that operate only within State boundaries
Network Design - Basic concepts and parameters
Pipeline Capacity & Usage
Regulatory Authorities
Transportation, Processing, & Gathering
Transportation Corridors - Major interstate routes
Pipeline Development & Expansion
U.S./Canada/Mexico Import & Export Locations

Underground Storage by U.S. Region

At the close of 2007, 400 underground natural gas storage sites were operational in the United States. During the year, four new storage sites were added, one in Michigan, Mississippi, Pennsylvania, and West Virginia, while 18 existing storage fields underwent expansions, and two storage fields were abandoned (ceased operations). Consequently, working gas capacity in the U.S. increased by 32 Bcf, to 4,091 Bcf (4,059 Bcf in 2006) while deliverability rates rose to 88.2 Bcf/d (85.1 Bcf/d in 2006). The largest expansion of working gas capacity (9.3Bcf) occurred at the Midland natural gas storage site in Kentucky, a depleted-reservoir facility. Depleted-reservoir storage accounted for about 89 percent of the 41 Bcf of new working gas capacity added in 2007.

The number, type, and profile of underground natural gas storage varies by region. Below is a brief overview for each of the six regions in the lower-48 States.

Central (49) | Midwest (121) | Northeast (110) | Southeast (34) | Southwest (66) | Western (20) | Overall (400)

Central Region

Underground natural gas storage in the Central Region is notable for several reasons. First, many of the 49 storage facilities located in the region are used to store excess production rather than to serve as a supply source for local markets. Production is stored to allow a stable flow rate despite temporary demand fluctuations.

Second, the region has the Nation's largest storage site, the Baker/Cedar Creek Field in Montana, with a total capacity of 287 billion cubic feet (Bcf) and a working gas capacity of 164 Bcf. The total regional working gas storage capacity (approximately 557 billion cubic feet) is 14 percent of the U.S. total, while daily deliverability from storage is only 6.2 billion cubic feet per day, or 7 percent of the U.S. total.

Central Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Central Region												
Colorado	8	42	1,088	0	0	0	0	0	0	8	42	1,088
Iowa	0	0	0	4	77	1,060	0	0	0	4	77	1,060
Kansas	18	116	2,418	0	0	0	1	1	0	19	117	2,418
Missouri	0	0	0	1	11	350	0	0	0	1	11	350
Montana	5	196	310	0	0	0	0	0	0	5	196	310
Nebraska	1	16	169	0	0	0	0	0	0	1	16	169
North Dakota	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
South Dakota	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Utah	1	51	427	2	1	100	0	0	0	3	52	527
Wyoming	7	45	227	1	1	75	0	0	0	8	46	302
Total Sites	40	466	4,639	8	90	1,585	1	1	0	49	557	6,224
(Marginal Sites)[1]	(5)	(2)	(186)	(0)	(0)	(0)	(1)	(1)	(0)	(6)	(3)	(186)
Percent of U.S.	12	13	7	19	23	19	3	1	0	12	14	7

[1] **Marginal sites: very little or no activity reported during the 2007 calendar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet. States with no underground storage facilities are shown in *Italics*.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

The Baker/Cedar Creek Field, owned and operated by the Williston Basin Interstate Pipeline Company, serves as support infrastructure for the natural gas that is produced in association with oil production in the area. With an estimated peak-day withdrawal rate of about 134 million cubic feet per day, the flow from this storage field is directed primarily to interconnections with the Northern Border Pipeline Company system between North and South Dakota. In recent years, however, the Baker field has not been heavily utilized due to a decrease in production from nearby associated-gas fields.

Storage facilities in Kansas, specifically in the southeastern portion of the region, provide service to the interstate pipeline systems that move natural gas to the Midwest Region, but they are also integral to regional requirements. For instance, about 35 percent of the State's working gas storage capacity of approximately 118 billion cubic feet is owned and operated by Southern Star Central Gas Pipeline Company, which is primarily a regional interstate pipeline.

About 96 percent of the storage capacity in Kansas is available to customers and shippers on other interstate trunklines, while the remaining 4 percent is devoted to local distribution and production field service. About 40 percent of the daily peak-day storage deliverability in the State, or 967 million cubic feet per day, is available to the two interstate pipeline companies traversing the region, Northern Natural Gas Company and Panhandle Eastern Pipe Line Company.

Storage facilities in the rest of the region serve primarily as seasonal supply sources for local markets. Storage fields in Utah provide service to shippers on the Questar Pipeline Company system as well as to customers within the Salt Lake City area. The storage fields in Colorado and portions of Wyoming service the Denver area through the Colorado Interstate Gas Company system. The local distribution companies serving these markets account for about 16 percent of the total storage deliverability in the region.

Midwest Region

Many of the pipelines serving the region also provide their shipper/customers with access to a large amount of underground storage capacity located in Illinois, Indiana, Michigan, and Ohio. The Midwest Region has 121 sites, the largest number in the country.

Of all six regions, this region has the largest volume of underground (working gas) storage capacity (almost 1.2 trillion cubic feet (Tcf)) and daily deliverability (28.5Bcf/d) from storage. These levels account for about 30 percent of the U.S. total in each category. Regional intrastate pipelines and/or local distribution companies, such as Northern Illinois Gas Company (NICOR), control about 61 percent of daily deliverability from storage in this region.

Midwest Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Midwest Region												
Illinois	11	52	832	18	249	5,304	0	0	0	29	301	6,136
Indiana	10	14	261	12	20	526	0	0	0	22	34	787
Michigan	43	641	16,786	0	0	0	2	2	85	45	643	16,871
Minnesota	0	0	0	1	2	60	0	0	0	1	2	60
Ohio	24	220	4,670	0	0	0	0	0	0	24	220	4,670
Wisconsin	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total Sites	88	927	22,549	31	271	5,890	2	2	85	121	1,200	28,524
(Marginal Sites)[1]	(10)	(8)	(258)	(2)	(4)	(108)	(0)	(0)	(0)	(12)	(12)	(366)
Percent of U.S.	27	26	34	72	69	70	6	1	1	30	29	32

[1] **Marginal sites: very little or no activity reported during the 2007 calendar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet. States with no underground storage facilities are shown in *Italics*.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

In Illinois, 50 percent of the daily deliverability from storage is integrated into three pipeline or distribution systems: Northern Illinois Gas Company, Illinois Power Company, and Central Illinois Public Service Company. Northern Illinois Gas Company also provides access to part of its working gas storage to support shippers using the regional Chicago natural gas market center.

The Great Lakes Gas Transmission Company and the ANR Pipeline Company systems both use Michigan storage facilities extensively to support their shippers' needs. In the first case, the Great Lakes Transmission Company system transports most of its volume eventually to markets in Ontario, Canada, but it uses storage sites located in Michigan to store supplies shipped for Canadian customers during the summer, providing withdrawal and delivery services during winter peak periods. ANR Pipeline Company and its affiliate ANR Storage Company together operate 15 sites in the State, while other storage operators in the State include the MichCon Gas Company (four sites), the Michigan Gas Storage Company (three sites), and its parent Consumers Energy Company (14 sites).

Elsewhere in the Midwest Region, Consumers Energy Company, with 14 sites in Michigan, is the single largest LDC operator of underground storage fields in the lower 48 States. Its sites have an overall deliverability of more than 4.0 Bcf/d and working capacity of 140 Bcf. Trailing closely is the Northern Illinois Gas Company, which operates eight natural gas storage facilities in Illinois with a total daily deliverability level of 3.1 Bcf/d but with a total working gas capacity level of more than 152 Bcf.

Northeast Region

The States of Pennsylvania and New York are the key transit areas for gas deliveries within the region and include the major service territories of Dominion Transmission Company and Columbia Gas Transmission Company systems. These States, along with West Virginia, also have the largest underground storage capacity in the region. Storage is essential as a supply backup and for balancing gas supplies on the pipelines operating in the region. More pipeline capacity exits these States than enters, reflecting their storage capability as a seasonal supply source for the States to the north and east.

Northeast Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Northeast Region												
Connecticut	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Delaware	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Maine	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Maryland	1	17	400	0	0	0	0	0	0	1	17	400
Massachusetts	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
New Hampshire	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
New Jersey	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
New York	23	116	1,696	0	0	0	1	1	145	24	117	1,841
Pennsylvania	50	406	8,615	0	0	0	0	0	0	50	406	8,615
Rhode Island	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Vermont	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Virginia	1	1	20	0	0	0	2	4	325	3	5	345
West Virginia	32	251	4,002	0	0	0	0	0	0	32	251	4,002
Total Sites	107	791	14,733	0	0	0	3	5	470	110	796	15,203
(Marginal Sites)[1]	(7)	(31)	(43)	(0)	(0)	(0)	(0)	(0)	(0)	(7)	(31)	(43)
Percent of U.S.	33	22	22	0	0	0	10	3	3	28	19	17

[1] **Marginal sites: very little or no activity reported during the 2007 calandar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet. States with no underground storage facilities are shown in *Italics*.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

The largest storage operators in the Northeast are also three of the largest pipeline companies in the region. Columbia Gas Transmission Company operates 22 storage facilities (out of 110 within the region), with a working gas storage capacity of 138 Bcf (out of a total 796 Bcf). Although Dominion Transmission Company operates only 15, its facilities have the largest amount of working gas capacity in the region, 413Bcf. National Fuel Gas Supply Company operates the largest number of storage facilities in the region, 31, but its storage fields are only capable of storing up to 106 Bcf of working gas.

(Note: The peak-day deliverability from LNG in the region, 5.1 Bcf per day, is 33 percent as large as the total daily deliverability from underground storage facilities. This backup capability is incorporated into the operations of the regional network and is used to meet the rapid increases in demand that can occur because of sudden temperature changes in the region. Three of the eight currently active LNG importing facilities in the U.S. are located in the Northeast Region, the Cove Point LNG Company facility, located on the eastern shore of Maryland, the Northeast Gateway LNG Terminal located 16 miles offshore of Massachusetts,and the DistriGas Company's Everett LNG facility located outside of Boston, Massachusetts.)

Southeast Region

The Texas Gas Transmission Company is the only long-haul natural gas pipeline system that retains a large portion of its deliverability for regional service, primarily in Kentucky. Slightly over 50 percent of its deliverability is within the region. This pipeline company also provides its shippers access to five company-owned underground storage facilities with a working gas capacity of more than 80 Bcf, or about 66 percent of the total working gas capacity in the State of Kentucky (and 45 percent of the regional total).

Southeast Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Southeast Region												
Alabama	1	8	300	0	0	0	1	7	600	2	15	900
Florida	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0
Georgia	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0
Kentucky	20	89	1,792	3	7	68	0	0	0	23	96	1,860
Mississippi	5	51	1,048	0	0	0	3	32	3,022	8	83	4,070
North Carolina	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0
South Carolina	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	0	0	0
Tennessee	1	1	20	0	0	0	0	0	0	1	1	20
Total Sites	27	149	3,160	3	7	68	4	39	3,622	34	195	6,850
(Marginal Sites)[1]	(4)	(2)	(24)	(0)	(0)	(0)	(0)	(0)	(0)	(4)	(2)	(24)
Percent of U.S.	8	4	5	7	2	1	13	23	26	9	5	8

[1] **Marginal sites: very little or no activity reported during the 2007 calendar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet. States with no underground storage facilities are shown in *Italics*.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

That level of storage service is equivalent to about 80 percent of the total daily capacity of Texas Gas Transmission Company's lines moving north into Indiana. These storage facilities are also in close proximity to the ANR Pipeline Company system, which traverses the State of Kentucky to Indiana and Michigan. Combined, Texas Gas Transmission Company and ANR Pipeline Company have the capacity to move 3.0 Bcf per day north into Indiana.

In addition to the conventional underground storage facilities located in the northern portion of the region, a number of high-deliverability (salt cavern) storage sites have been built during the past decade in the southern portion to better serve a restructured U.S. natural gas pipeline industry. Four such sites are now located in Mississippi (three) and Alabama (one), with several more planned. The availability of these sites has made these two States a prime market for the type of storage services needed by shippers with high upstream demand swings and local load balancing requirements. These sites are used by customers and shippers doing business on Florida Gas Transmission Company, Gulf South Pipeline Company, Tennessee Gas Pipeline Company, Transcontinental Gas Pipeline Company, and Southern Natural Pipeline Company systems.

Southwest

Underground natural gas storage plays a vital role in the efficient export and transmission of natural gas from the Southwest to other regions, as well as in supplementing regional needs. Its 66 underground storage facilities represent 1,030 Bcf of working gas capacity and an estimated daily deliverability level of 23.2 million cubic feet.

Only the Midwest Region has more working gas capacity and daily deliverability from storage. A large portion of regional storage is near production fields and is used to balance production flows with fluctuating market demand.

In recent years, however, an increasing amount of the area's storage capacity is being developed and used to support regional natural gas market center/hub operations. It is also being used as high-deliverability storage (from salt-caverns) to serve the growing number of variable-load customers, such as gas-fired power plants, that are emerging in the region and which have a need for rapid access to stored natural gas working gas.

Southwest Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Southwest Region												
Arkansas	2	15	231	0	0	0	0	0	0	2	15	231
Louisiana	8	286	3,965	0	0	0	7	48	3,165	15	334	7,130
New Mexico	2	54	375	0	0	0	0	0	0	2	54	375
Oklahoma	13	194	3,772	0	0	0	0	0	0	13	194	3,772
Texas	20	365	5,334	0	0	0	14	78	6,361	34	443	11,695
Total Sites	45	914	13,677	0	0	0	21	126	9,526	66	1,040	23,203
(Marginal Sites)[1]	(8)	(30)	(184)	(0)	(0)	(0)	(1)	(4)	(0)	(9)	(34)	(184)
Percent of U.S.	14	26	21	0	0	0	68	73	70	17	25	26

[1] **Marginal sites: very little or no activity reported during the 2007 calendar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

The States of Louisiana and Texas have more salt-cavern natural gas storage facilities (21) than anywhere else in the United States, of which almost half are owned/operated by independent storage operators. In fact, one-fifth of the working gas capacity and one-third of the daily deliverability available in the region is operated by independents.

About 35 percent of the region's daily storage deliverability remains with interstate pipeline companies, while the rest is operated by LDCs (33 percent) or intrastate pipeline companies (32 percent).

All of the interstate pipeline-owned storage and most of the independently-owned storage is open access, that is, working gas storage capacity that is available to shippers/customers on a first-come, first-served basis at nondiscriminatory rates. The remainder is reserved for system or pipeline use, such as load balancing operations.

While only about a third of the region's storage capacity is owned by LDCs and used exclusively for local service, regional distributors also have access to and use interstate and independent storage facilities. Most of the LDC-owned storage is near major industrial and population centers and has little impact upon the interstate pipeline network in the area. In Texas and Oklahoma, approximately 40 percent of underground storage capacity is at facilities operated by LDCs or intrastate pipeline companies, whereas in Arkansas all of the storage capacity is controlled by local operators.

Western Region

Underground natural gas storage facilities are found in only half of the states in the region, California, Oregon, and Washington. Moreover, approximately 88 percent of the region's working gas capacity is located in California's 12 underground natural gas storage sites, seven of which are owned by the two principal gas distributors in the State, Southern California Gas Company (SoCal) and Pacific Gas and Electric Company (PG&E). Most of their storage capacity is used for system balancing and as a way of maintaining a steady and high-utilization of pipeline capacity directed from Canada and the Southwest.

The five independent storage facilities in California are used primarily as depositories for gas produced within the State that is not immediately marketable. In addition, these sites are connected to, and deliver their withdrawals to, the Southern California Gas Company and/or Pacific Gas and Electric Company systems.

Western Region -- Underground Natural Gas Storage, by State and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region/ State	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)	Sites	Working Gas Capacity (Bcf)	Daily Withdrawal Capability (MMcf)
Western Region												
Arizona	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
California	12	266	6,875	0	0	0	0	0	0	12	266	6,875
Idaho	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Nevada	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Oregon	7	15	497	0	0	0	0	0	0	7	15	497
Washington	0	0	0	1	22	850	0	0	0	1	22	850
Total Sites	19	281	7372	1	22	850	0	0	0	20	303	8,222
(Marginal Sites)[1]	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Percent of U.S.	6	8	11	2	6	10	0	0	0	5	7	9

[1] **Marginal sites: very little or no activity reported during the 2007 calandar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet.

Source: Energy Information Administration, Gas Transportation Information System, December 2008.

Storage facilities in Washington and Oregon are used primarily to provide seasonal backup to several LDCs located in the northwest and are crucial in maintaining their operational flexibility and system integrity. These storage facilities are also used by some Canadian shipper/customers to support their marketing and operational needs. The import/export facilities of the Northwest Pipeline Company at Sumas, Washington, are used to move natural gas in either direction to storage, depending on marketing conditions.

Overall

Total U.S. working gas capacity and daily deliverability at the beginning of 2008 reached 4.1 Tcf and 88.2 Bcf per day, respectively. Four hundred underground natural gas storage facilities were operational in the lower 48 States although 38 were marginal operations that reported little or no activity during 2007. The number of operational underground natural gas storage facilities peaked in 2001 at 418.

In almost all operational aspects, the underground natural gas storage profile of the Midwest Region is larger than that of any of the other five regions. The prevailing cold winters, large population centers, large natural gas pipeline systems, and available geology, have all contributed to major storage development in the region over the past century. The Southwest Region, on the other hand, with its large natural gas production levels and the presence of many large salt-formations, is the second largest source of working gas capacity and daily deliverability in the lower 48 States.

Summary of Underground Natural Gas Storage, by Region and Reservoir Type, Close of 2007

	Depleted Gas/Oil Fields			Aquifer Storage			Salt Cavern Storage			Total		
Region	Sites	Working Gas Capacity (Bcf)	**Daily Withdrawal Capability (MMcf)**	Sites	Working Gas Capacity (Bcf)	**Daily Withdrawal Capability (MMcf)**	Sites	Working Gas Capacity (Bcf)	**Daily Withdrawal Capability (MMcf)**	Sites	Working Gas Capacity (Bcf)	**Daily Withdrawal Capability (MMcf)**
Central	40	466	4,639	8	90	1,585	1	1	0	49	557	6,224
Midwest	88	927	22,549	31	271	5,890	2	2	85	121	1,200	28,524
Northeast	107	791	14,733	0	0	0	3	5	470	110	796	15,203
Southeast	27	149	3,160	3	7	68	4	39	3,622	34	195	6,850
Southwest	45	914	13,677	0	0	0	21	126	9,526	66	1,040	23,203
Western	19	281	7372	1	22	850	0	0	0	20	303	8,222
Total U.S.	326	3,528	66,130	43	390	8,393	31	173	13,703	400	4,091	88,226
(Marginal Sites)[1]	**(34)**	**(73)**	**(695)**	**(2)**	**(4)**	**(108)**	**(2)**	**(5)**	**(0)**	**(38)**	**(82)**	**(803)**

[1] **Marginal sites: very little or no activity reported during the 2007 calandar year. Marginal sites included in State/Regional total.**

Note: Bcf = Billion cubic feet. MMcf = Million cubic feet.

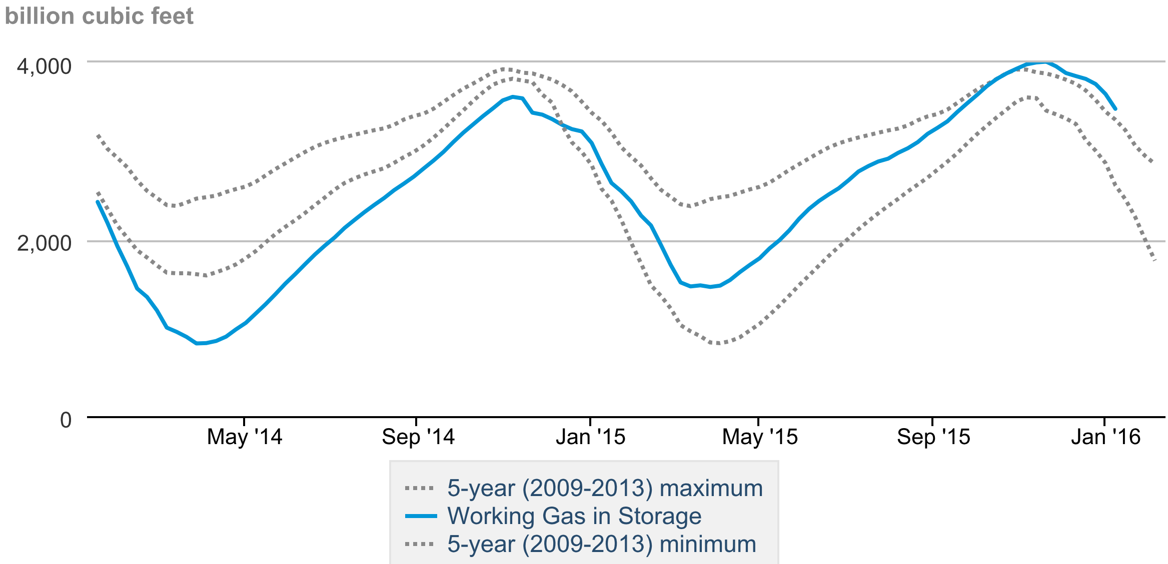
Source: Energy Information Administration, Gas Transportation Information System, December 2008.

Addenum

Preliminary data for 2008 indicates that at least 7 new underground storage facilities, 4 salt cavern facilities and 3 depleted reservoir fields, were completed during the year. An additional 5 underground storage sites, 3 of which were salt cavern facilities, underwent expansion. The new facilities added 34 Bcf of working gas capacity and 5.1 Bcf/d of withdrawal capability, while the expansions added an estimated 15 Bcf of working gas capacity and 1.1 Bcf/d of withdrawal capability. If verified, these activities during 2008 will have raised total U.S. working gas capacity to 4,140 Bcf and total withdrawal capability to 94 Bcf/d.

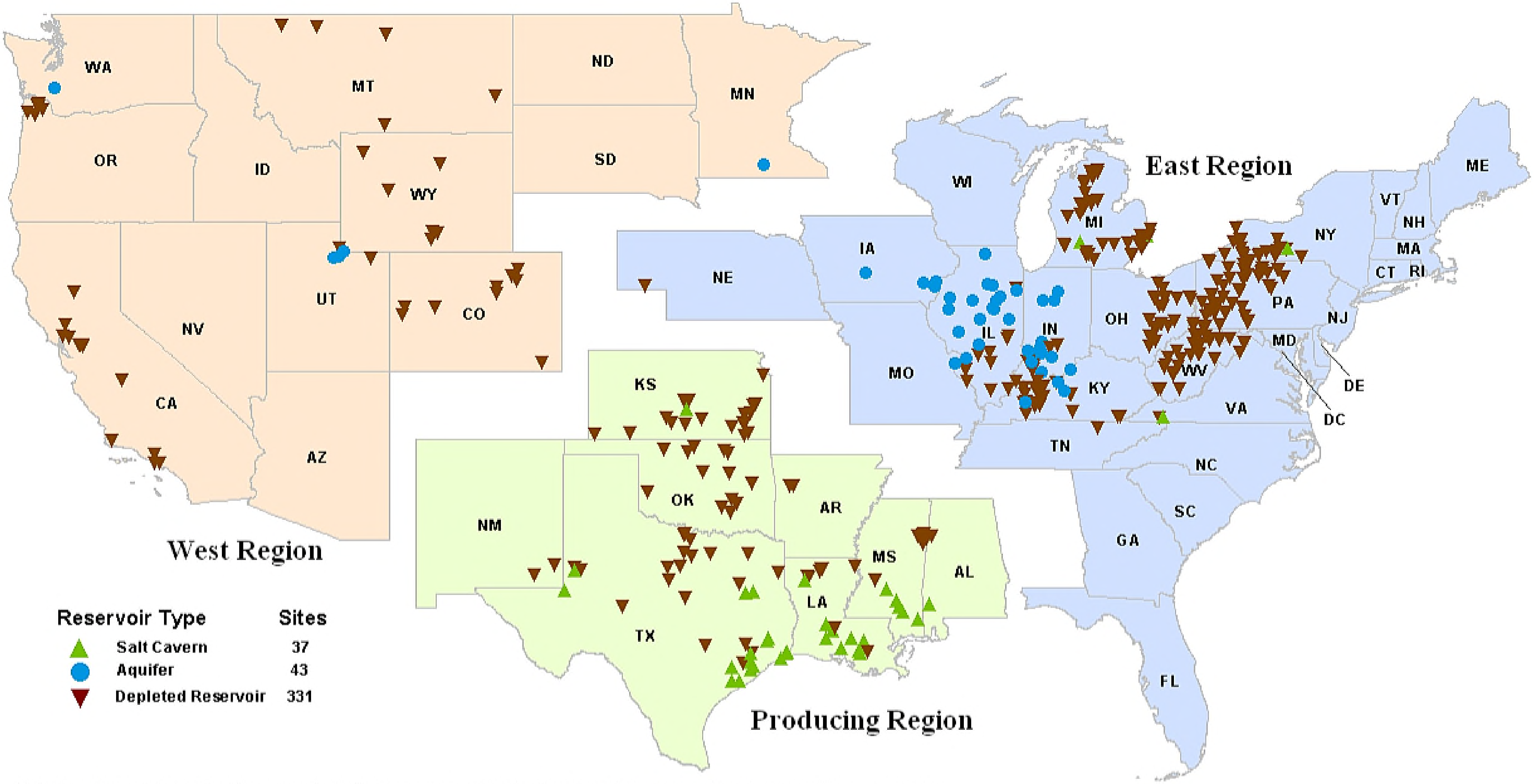
While it is unknown if any maginal existing underground storage sites were formally abandoned in 2008, several were known to be undergoing the process.

Working natural gas in underground storage

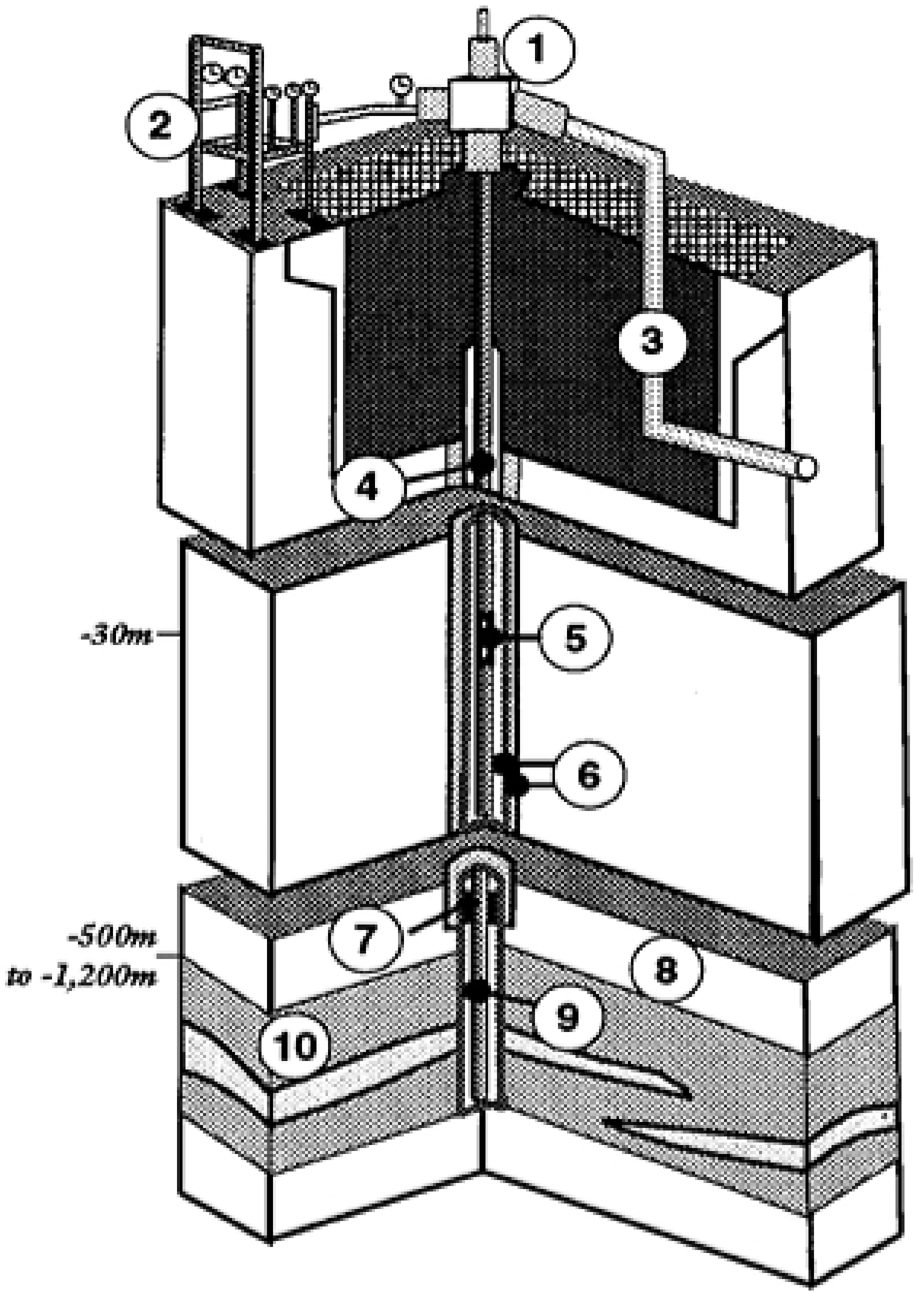


Source: Form EIA-912, "Weekly Underground Natural Gas Storage Report"

U.S. Lower 48 Underground Natural Gas Storage Facilities, by Type (December 31, 2010)



Note: Locations of storage facilities presented in the map are approximate. Some symbols representing storage facilities may overlap.
Source: U.S. Energy Information Administration, Form EIA-191A, "Annual Underground Gas Storage Report"



Cross Section of a Storage Well:

1. Wellhead.
2. Safety Valve Control.
3. Connection Pipe.
4. Flow Tubing String.
5. Automatic Safety Valve.
6. Cemented Casing.
7. Packer.
8. Caprock.
9. Strainers(-500 to -1,200m).
10. Reservoir.

Source: Gaz de France, "Underground Storages Facilities" (June 1992): Recreated by Energy Information Administration, Office of Planning, Management, and Information Services.