United States Government Accountability Office

Report to Congressional Requesters

October 2019

NATURAL GAS STORAGE

Actions Needed to Assess Inspection Workload and Progress toward Safety Outcomes

GAO-20-167

GAO Highlights

Highlights of GAO-20-167, a report to congressional requesters

October 2019

NATURAL GAS STORAGE

Actions Needed to Assess Inspection Workload and Progress toward Safety Outcomes

Why GAO Did This Study

About 400 natural gas storage sites are important to the U.S. natural gas system, providing about 30 percent of the nation's energy. During a 2015 leak at a storage site near Los Angeles, about 8,000 families were temporarily relocated due to symptoms such as migraines, nausea, and respiratory problems. The leak raised concerns about health and safety risks from other storage sites. In 2017, GAO recommended that PHMSA take actions, including using baseline data to develop performance goals for its natural gas storage program.

GAO was asked to review the health and environmental effects of activities at natural gas storage sites. This report, among other objectives, (1) assesses the extent to which PHMSA has developed its natural gas storage inspection program and (2) describes what is known about the potential health effects from chemicals in stored natural gas. GAO reviewed available documents about natural gas storage incidents from 2000 through 2018; compared PHMSA research, goals, and plans against leading planning practices; visited sites representing the three types of storage sites; and interviewed agency officials.

What GAO Recommends

GAO is making two recommendations, including that PHMSA should analyze factors affecting states' willingness to partner with PHMSA and analyze its workforce needs on an ongoing basis. The agency concurred with the recommendations.

View GAO-20-167. For more information, contact Alfredo Gómez at (202) 512-3841 or GomezJ@gao.gov

What GAO Found

In 2018, the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) set a goal for its natural gas storage inspection program to inspect all approximately 400 natural gas storage sites within 5 years, according to agency officials. PHMSA expected that all 25 eligible states would help inspect sites, but only 10 states agreed to partner with the agency. As a result, the agency's inspection workload increased by almost 60 percent from when it set its goal, according to PHMSA data. Because of the increase in its inspection workload over its preliminary estimate, PHMSA does not have assurance that it has enough resources to meet its inspection goal. Furthermore, PHMSA has not used a workforce analysis to inform its budget requests. PHMSA officials said that the agency does not expect to have enough data until 2022 or 2023 to further inform analysis of its workforce. By analyzing factors affecting states' willingness to partner with PHMSA and its workforce needs on an ongoing basis, the agency would have better assurance that it has the staff it needs to meet its inspection goal.

PHMSA Inspectors Conducting a Visual Inspection at a Natural Gas Storage Site

Source: GAO. | GAO-20-167

Health effects have been reported related to chemicals that may be found in stored natural gas. Several federal agencies—including the Environmental Protection Agency and the Agency for Toxic Substances and Disease Registry—have documented potential health effects of chemicals that may be found in stored natural gas. In addition, some chemicals may be added to natural gas, such as sulfur odorants that give natural gas a distinct smell in case of leaks. The combination of such chemicals varies from one natural gas storage site to another, based on the attributes of that site such as its geologic type and the extent to which sulfur odorants are added to the natural gas before storage. Many of these chemicals have been linked to adverse health effects. However, research is limited on the health effects of exposure to stored natural gas in general and on the effects in particular from exposure to chemicals that may occur in natural gas storage leaks or be present at the storage sites. Reports linking health effects are available on specific chemicals but not in the context of natural gas storage, based on GAO's literature review.

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Abbreviations

API	American Petroleum Institute
ATSDR	Agency for Toxic Substances and Disease Registry
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
CCST	California Council on Science and Technology
IRIS	Integrated Risk Information System
GPRA	Government Performance and Results Act of 1993
PIPES Act	Protecting Our Infrastructure of Pipelines and Enhancing Safety Act of 2016
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PHMSA	Pipeline and Hazardous Materials Safety Administration

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October 16, 2019

The Honorable Eddie Bernice Johnson
Chairwoman
Committee on Science, Space, and Technology
House of Representatives

The Honorable Suzanne Bonamici
House of Representatives

The Honorable Don Beyer
House of Representatives

Natural gas plays a vital role in the U.S. energy system. It provides about 30 percent of the nation's energy and is widely used to generate electricity, to heat and cool homes and businesses, and in a variety of industrial processes, according to the U.S. Energy Information Administration (EIA). As of July 2019, approximately 400 sites across the country store natural gas in underground geological formations and use wells at these sites to inject and withdraw natural gas, according to EIA. These sites typically are near or have convenient pipeline access to major metropolitan areas. This proximity helps to ensure that natural gas is available for times of peak energy use—such as in winter to heat homes—more quickly than would be possible if relying solely on pipelines that transport natural gas from distant production fields. However, these sites can pose risks.

In 2015, a natural gas leak from a well at the Aliso Canyon site near suburban Los Angeles, California—the fourth-largest storage site in the United States—raised concerns about the safety of the underground wells used at storage sites and about potential adverse health and environmental effects from natural gas releases. The leak released about 5.4 billion cubic feet of natural gas into the atmosphere, continued for almost 4 months, and eventually led to the temporary relocation of about 8,000 families in the nearby Porter Ranch neighborhood. California government officials identified two factors that contributed to the leak: (1)

the aging infrastructure of the well, which was drilled in 1953 as an oil production well, and (2) the lack of redundant safety valves at the well.[1]

After this emergency, the Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2016 was enacted.[2] The act, among other things, required the Secretary of Transportation to establish minimum safety standards for all underground natural gas storage sites by June 22, 2018.[3] The Department of Transportation's (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for setting and enforcing these standards for underground natural gas storage sites. In 2017, PHMSA established an oversight and enforcement program for natural gas storage sites. PHMSA's mission is to protect people and the environment by advancing the safe transport of natural gas, among other types of energy, and hazardous materials that are essential to our daily lives.

In 2018, PHMSA collected data that showed approximately 10,000 of the 17,000 (about 59 percent) underground natural gas storage wells across the country have design characteristics similar to the well at Aliso Canyon. This could increase the risk of more natural gas releases, according to a 2017 study by Harvard University researchers.[4] According to an analysis by the Department of Energy (DOE), more than 300 cities, towns, and other populated areas are located within about 3 miles of a natural gas storage site.[5]

In November 2017, we reported that PHMSA had taken steps in its recently established natural gas storage program, such as developing a

[1]To mitigate risk, multiple control points at a well add redundant layers of protection, according to the American Petroleum Institute. For example, according to California state officials, operators can install redundant valves that serve as barriers on underground wells that can help forestall or stop a natural gas storage leak if other systems fail.

[2]Pub. L. No. 114-183, 130 Stat. 514 (2016).

[3]For the purposes of this report, we refer to underground natural gas storage facilities as natural gas storage sites.

[4]Drew R. Michanowicz et al., "A National Assessment of Underground Natural Gas Storage: Identifying Wells with Designs Likely Vulnerable to a Single-Point-of-Failure," *Environmental Research Letters*, vol. 12, no. 6 (May 24, 2017).

[5]Department of Energy, National Energy Technology Laboratory, *Well Integrity for Natural Gas Storage in Depleted Reservoirs and Aquifers*, NETL-TRS-15-2016 (Washington, D.C.: Dec. 16, 2016).

training program for inspectors and setting a performance goal for its training program.[6] However, we found that PHMSA had not yet followed certain leading strategic planning practices for the program. For example, PHMSA had not yet defined the level of performance to be achieved, developed goals to address core program activities other than training, or used baseline data to develop goals. We recommended that PHMSA (1) define levels of performance and address all core program activities and (2) use budget data to refine its performance goals for its gas storage program. PHMSA officials concurred with these recommendations and implemented the first recommendation. PHMSA officials told us in July 2019 that to address our second recommendation, they would strive to add and refine performance goals as they continued to develop the program.

You asked us to review issues related to the safety of natural gas storage sites and potential environmental effects from site activities. This report (1) assesses the extent to which PHMSA has further developed its natural gas storage program since our November 2017 report, (2) describes what is known about the potential health effects from chemicals in stored natural gas, and (3) describes what is known about the potential environmental effects of releases at natural gas storage sites.

To address these objectives, we reviewed documents from PHMSA, the Environmental Protection Agency (EPA), DOE, the Agency for Toxic Substances and Disease Registry (ATSDR), the National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA), and met with officials from these agencies to determine the extent to which chemicals in stored natural gas have documented potential health effects. To identify releases of natural gas from storage sites, we conducted a literature search to identify releases such as leaks and explosions that occurred in the United States from 2000 through 2018 and reviewed PHMSA's list of natural gas storage sites from 2017, the first year PHMSA collected such information. We identified 93 releases of natural gas from storage sites; these 93

[6]GAO, *Natural Gas Storage: Department of Transportation Could Take Additional Steps to Improve Safety Enforcement Planning*, GAO-18-89 (Washington, D.C.: Nov. 22, 2017).

releases include incidents as defined by PHMSA regulations as well as releases of natural gas that may not meet that definition.[7]

We met with officials representing a nongeneralizable sample of seven states to understand their perspectives on the natural gas storage safety program and PHMSA's efforts to partner with states and conduct inspections. We selected four of the five states with the largest amount of working natural gas storage (Michigan, Texas, Louisiana, and California), one state in which PHMSA was conducting an inspection (Iowa), and two additional states that had considered partnering with PHMSA (Alaska and Colorado).[8] We visited sites representing each of the three types of natural gas storage sites—Moss Bluff in Texas (a salt cavern), Aliso Canyon in California (a depleted oil and gas field), and Redfield in Iowa (a depleted aquifer). We reviewed documentation from each site and interviewed officials representing these sites' operators. We selected these sites for specific reasons: Aliso Canyon because of the 2015 leak, Redfield because it was scheduled to undergo an inspection by PHMSA at the time of our visit, and Moss Bluff because it was readily accessible from a major urban area (Houston, Texas). Our findings from the sites we visited and officials we interviewed are not generalizable to sites and officials we did not include in our review but provide illustrative examples of such sites. We also met with officials from industry groups that represent companies that operate natural gas storage sites—the

[7]PHMSA regulations define an incident as: (1) an event that involves a release of gas from an underground natural gas storage facility that results in a death or personal injury necessitating in-patient hospitalization, estimated property damage of $50,000 or more, or unintentional estimated gas loss of 3 million cubic feet or more; (2) an event that results in an emergency shutdown of an underground natural gas storage facility; or (3) an event that is significant in the judgment of the operator. 49 C.F.R. § 191.3. This list of 93 releases includes three major incidents and other less significant incidents that released much smaller volumes of gas that may be related to maintenance work, valve leaks, and other activities, according to PHMSA. This list may not be comprehensive, as not all releases may have been documented, and no federal agency or independent source has cataloged all releases.

[8]This list is in order of capacity. We met with officials from the Michigan Department of Environmental Quality, Texas Railroad Commission, Louisiana Office of Conservation, public health and regulatory agencies in California, the Alaska Oil and Gas Conservation Commission, the Colorado Oil and Gas Conservation Commission, and the Iowa Department of Natural Resources. Our findings from the states we selected and officials we interviewed are not generalizable to states and officials we did not include in our review, but they provide illustrative examples of such states.

American Gas Association, the American Petroleum Institute (API),[9] and the Interstate Oil and Gas Compact Commission—to better understand these groups' perspectives on PHMSA's natural gas storage safety program.

To assess the extent to which PHMSA has taken action to continue developing its program for natural gas storage since our November 2017 report, we reviewed documents related to the program, including strategic plans, DOT annual performance reports, and inspection-related documentation. We also met with PHMSA officials to discuss the program. We visited the Redfield gas storage facility in Iowa during a PHMSA storage safety inspection, and we met with officials from the Iowa Department of Natural Resources to discuss natural gas storage safety. We compared PHMSA efforts on its natural gas storage program's workforce planning against our prior work on best practices in workforce planning. We compared PHMSA's efforts on strategic planning against leading strategic planning practices we identified in our prior work. For example, we have previously reported that requirements of the Government Performance and Results Act of 1993, as amended (GPRA),[10] such as performance goals, that apply at the departmental or agency level can serve as leading practices for planning at lower levels, such as component agencies, offices, programs, and projects within federal agencies.[11]

To describe what is known about the potential health effects from chemicals in stored natural gas, we used literature search results that identified releases from 2000 through 2018 to determine whether there were any studies that empirically linked the releases of natural gas in

[9]API is a national trade association representing all facets of the natural gas and oil industry and has more than 600 members. Formed in 1919 as a standards-setting organization, in its first 100 years API has developed more than 700 standards to enhance operational and environmental safety, efficiency, and sustainability in oil and gas operations.

[10]Government Performance and Results Act of 1993, Pub. L. No. 103-62, 107 Stat. 285, *as amended by* GPRA Modernization Act of 2010, Pub. L. No. 111-352, 124 Stat. 3866 (2011).

[11]GAO, *Food Safety and Nutrition: FDA Can Build on Existing Efforts to Measure Progress and Implement Key Activities*, GAO-18-174 (Washington, D.C.: Jan. 31, 2018); *Coast Guard: Actions Needed to Enhance Performance Information Transparency and Monitoring*, GAO-18-13 (Washington, D.C: Oct. 27, 2017); and *Environmental Justice: EPA Needs to Take Additional Actions to Help Ensure Effective Implementation*, GAO-12-77 (Washington, D.C.: Oct. 6, 2011).

storage sites with health effects; we did not find any such studies. As a result, we reviewed chemicals known to be found in stored natural gas, some at trace levels.[12] As previously mentioned, we reviewed documents from and met with officials from EPA, ATSDR, OSHA, and NIOSH. We also identified chemicals that may be found in stored natural gas by reviewing the Safety Data Sheets from 12 operators with the largest storage capacity.[13] In addition, we reviewed documentation from California agencies on reported health symptoms and chemicals that were tested for during the Aliso Canyon incident. We also reviewed agency documents and spoke with agency officials about the natural gas storage program. Additionally, we reviewed reports from the Public Health and Environment Subgroup of an interagency task force that studied the Aliso Canyon incident and the California Council on Science and Technology (CCST).

To describe what is known about the environmental effects of releases from natural gas storage sites, we reviewed documentation from EPA on greenhouse gas emissions, in general and specifically for the Aliso Canyon natural gas leak in 2015. We also spoke with agency officials knowledgeable about EPA programs that track emissions of greenhouse gases.[14] We obtained data from EPA that estimated methane emissions from natural gas storage sites for 1995 through 2016, and we assessed the reliability of these data by reviewing information about the data and the methods EPA used to produce them.[15] We determined that these data were sufficiently reliable for our reporting objectives. We used our literature search results that identified 93 incidents in 2000 through 2018 to identify potential environmental effects associated with releases at natural gas storage sites. For the Aliso Canyon incident in 2015, we reviewed reports related to the release of methane during the leak. For more information about our scope and methodology, see appendix I.

[12]We include hazardous materials, such as hydrogen sulfide, in our review of chemicals.

[13]These 12 operators represented about 49 percent of natural gas storage sites' working capacity (volume) in the nation.

[14]These programs include the EPA Greenhouse Gas Inventory program, which produces an annual report. For the most recent of these annual reports as of October 2019, see Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*, EPA-430-P-19-001 (Washington, D.C.: Apr. 12, 2019).

[15]The largest component of natural gas is a hydrocarbon called methane. Natural gas also contains smaller amounts of other hydrocarbons called natural gas liquids and nonhydrocarbon gases such as carbon dioxide and water vapor.

We conducted this performance audit from December 2017 to October 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

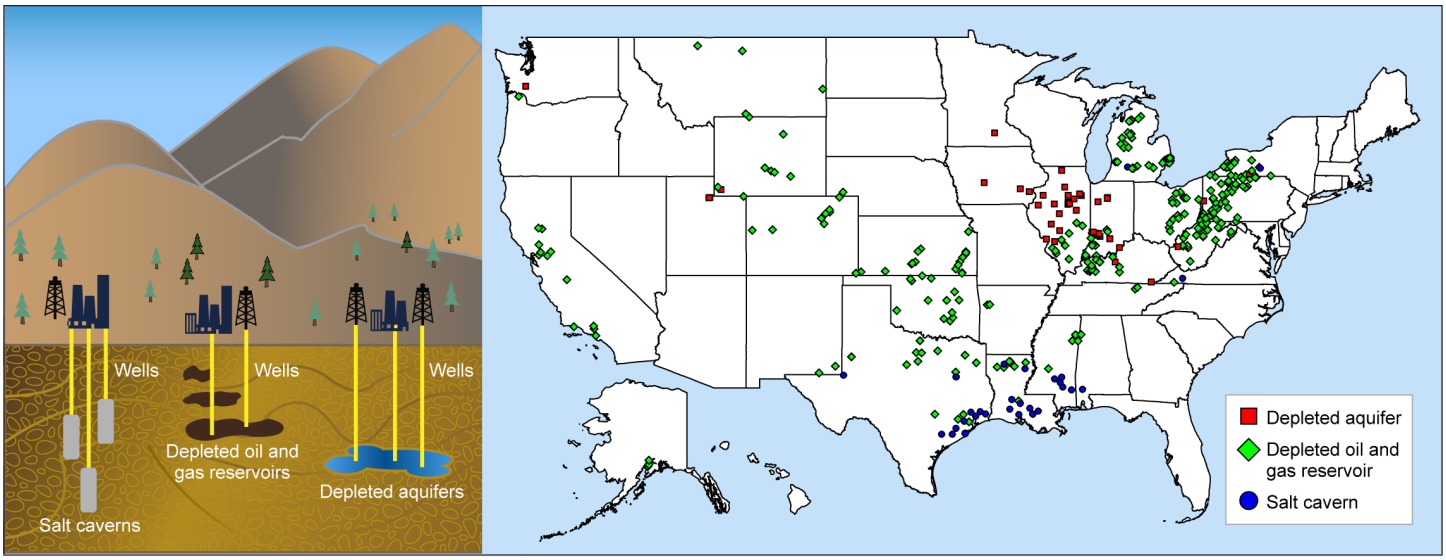
After it is extracted, natural gas—a colorless, odorless fossil energy source—is stored in three types of underground geologic formations: salt caverns, depleted aquifers, and depleted oil and gas reservoirs.[16] Two physical characteristics govern the suitability of each type of geologic formation for storage, including: (1) its capacity to hold natural gas for future use and (2) the rate at which natural gas can be withdrawn to meet demand. As of July 2019, about 80 percent of the approximately 400 natural gas storage sites in the United States are depleted natural gas or oil reservoirs because they are available in greater numbers than other types of formations, according to EIA. Underground salt caverns and depleted aquifers each account for about 10 percent of the sites.

Natural gas storage sites are located in 31 states. California, Louisiana, Michigan, Pennsylvania, and Texas together contain natural gas storage sites that provide more than half of the natural gas storage capacity in the United States.[17] Figure 1 illustrates the types of geologic formations used for natural gas storage and the locations of natural gas storage sites in the United States.

[16]Salt caverns are formed in salt domes or salt beds and are usually created by injecting fresh water, dissolving the salt, and producing saturated brine to enlarge the salt cavern. Depleted aquifers are geologic formations that are porous and permeable. According to DOE, depleted oil and gas reservoirs are geologic formations from which oil and gas were produced and that have proven ability to contain pressurized gas over geologic time.

[17]Natural gas storage sites are also located in Alabama, Alaska, Arkansas, Colorado, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Mexico, New York, Ohio, Oklahoma, Oregon, Tennessee, Utah, Virginia, Washington, West Virginia, and Wyoming.

Figure 1: Types of Geologic Formations Used for Natural Gas Storage and Locations of Storage Sites in the United States



Sources: GAO analysis of Pipeline and Hazardous Materials Safety Administration data and Energy Information Administration information; MapInfo (map). | GAO-20-167

The wells that inject natural gas into, or withdraw it from, the underground storage sites can extend thousands of feet underground. According to information from PHMSA, about 17,000 wells are used to inject and withdraw gas at approximately 400 natural gas storage sites, ranging from a few wells per site to more than a hundred wells at some larger sites. Wells are constructed with multiple layers of steel pipe, called casing, which are cemented in place. The layers of steel casing are intended to isolate the internal portion of the well from the outlying geological formations, which may include underground drinking water supplies. As a well is drilled deeper, progressively narrower casing is inserted further down the well and cemented in place. The wells at natural gas storage sites can be constructed to prevent leaks by installing multiple control points at each well, according to API.[18] If a well is not constructed with such multiple points of control, it could be subject to a single point of failure, in which the failure of a single component, such as a casing or a safety valve, can lead to a large release of natural gas—a

[18]Multiple control points add redundant layers of protection so that if one barrier decays or fails, a second barrier exists to prevent loss of containment, according to DOE. These barriers can take many forms, such as lowering a mechanical barrier called a “packer” into a well to separate two or more sections of a well with a liquid-tight seal.

factor that contributed to the Aliso Canyon incident, according to PHMSA officials.

Aliso Canyon Underground Storage Facility Leak

From October 23, 2015, through February 11, 2016, the Aliso Canyon Underground Storage Facility in Los Angeles County, California, experienced a large and uncontrolled natural gas leak. The Aliso Canyon natural gas storage site is a depleted oil field that was converted into a natural gas storage reservoir in the 1970s and that is near the Porter Ranch community, a residential community of about 30,000 people. It provides natural gas to the Los Angeles region for residential heating and cooling, commercial and industrial uses, and as fuel for electric power plants. According to the Energy Information Administration, the Aliso Canyon site has the fourth largest capacity among the approximately 400 underground natural gas storage sites in the United States. The leak reportedly was caused by damage to a well casing approximately 500 feet underground. California state government officials identified the damage as being caused by the aging infrastructure of that well, which had been drilled in 1953, and a lack of redundant safety valves at the well that prevented the leak from being stopped.[19]

Across a 4-month period, the site operator made multiple attempts to stop the leak. About 8,000 families near the Aliso Canyon leak were temporarily relocated in November 2015 due to ongoing odors and symptoms including headaches or migraines; nausea, vomiting, stomach aches, or diarrhea; nosebleeds; respiratory or breathing problems; chest tightness, coughing, or palpitations; and light-headedness and dizziness. Various agencies, including public health and regulatory agencies from state and local governments such as the Los Angeles County Public Health Department and California's Office of Environmental Health Hazard Assessment, responded to the leak.

Additionally, several studies about the leak have been conducted or are planned. CCST, a nonpartisan, nonprofit organization established in

[19]In May 2019, an energy consulting firm selected by California regulatory agencies and PHMSA completed a root cause analysis of the Aliso Canyon incident. The firm found that the direct cause of the leak was that a portion of the leaking well's casing had been corroded by groundwater. The firm also identified root causes of the incident, such as that the operator had not assessed the risks to the integrity of its wells and that the leaking well lacked multiple points of control. See Blade Energy Consultants, *Root Cause Analysis of the Uncontrolled Hydrocarbon Release from Aliso Canyon SS-25, Main Report* (Frisco, Texas: May 16, 2019).

response to a California state legislative resolution, published an independent review of the viability of underground natural gas in California, including an analysis of the health effects from stored natural gas releases.[20] An interagency task force established pursuant to federal law, led by DOE and PHMSA, studied the Aliso Canyon incident and in 2016 provided a report to relevant congressional committees with recommendations to enhance safety.[21] According to the 2016 interagency task force report, natural gas stored in geologic formations is under high pressure, which can force the gas through underground fissures or unplugged oil and gas wells and allow the gas to find its way to the surface.[22] Leaks can also occur if the wells lose integrity because of cracking of the cement used to seal them, among other factors. Older wells used for natural gas storage were often drilled for other reasons, such as oil and gas production, and are more likely to have age-related degradation. As part of its work, the interagency task force chartered a Public Health and Environment Subgroup, led by EPA, to summarize the actions taken by local, state, and federal agencies to monitor and mitigate impacts to public health and the environment. The subgroup was to also recommend actions to prepare local, state, and federal agencies if a release from a natural gas storage facility should occur in the future.

Safety Regulations and Enforcement for Underground Natural Gas Storage Sites

When the Aliso Canyon leak occurred in 2015, federal safety regulations applied to conventional surface pipelines and above-ground equipment at all natural gas storage sites. Only state safety regulations applied to underground natural gas storage sites at that time.[23] The PIPES Act of 2016 significantly changed the regulation of natural gas storage. It requires, among other things, that DOT establish minimum safety standards for all natural gas storage sites. Within DOT, PHMSA's mission is to protect people and the environment by advancing the safe

[20]California Council on Science and Technology, *Long-Term Viability of Underground Natural Gas Storage In California: An Independent Review Of Scientific And Technical Information (Full Report)* (Sacramento, CA: Jan. 18, 2018).

[21]Department of Energy, *Ensuring Safe and Reliable Underground Natural Gas Storage: Final Report of the Interagency Task Force on Natural Gas Storage Safety* (Washington, D.C.: Oct. 24, 2016). Section 31 of the PIPES Act required the Secretary of Energy to establish and lead the task force. Pub. L. No. 114-183, § 31(a), 130 Stat. 514, 533 (2016).

[22]Department of Energy, *Ensuring Safe and Reliable Underground Natural Gas Storage*.

[23]Prior to 2017, many state governments had applied various safety standards that addressed underground conditions at natural gas storage sites, according to the interagency task force.

transportation of energy and other hazardous materials, and because natural gas storage is a part of this mission, PHMSA is responsible for natural gas storage safety. In response to the act's requirement, PHMSA issued an interim final rule in December 2016 that took effect in January 2017.[24] The rule included minimum safety standards based largely on recommended practices from API and generally required compliance by natural gas storage sites by January 2018. PHMSA provided for a public comment period, and after reviewing the public comments received on the interim final rule, PHMSA may modify aspects of the interim final rule by issuing a final rule. In August 2019, PHMSA officials told us they planned to issue a final rule in October 2019.[25]

PHMSA's interim final rule contains four different reporting requirements for operators of all natural gas storage sites, including an annual report with gas storage volumes, gas storage pressures, well depths, gas injection and withdrawal rates, and maintenance information that is conducted to ensure the safety of a facility.[26] The interim final rule also requires operators to develop emergency response plans, but the required elements for such plans vary depending on the type of natural gas storage site.[27]

[24]81 Fed. Reg. 91,860 (Dec. 19, 2016) (*codified at* 49 C.F.R. pt. 191, 192). The standards are minimum standards and state regulators can require additional or more stringent requirements at intrastate sites if such standards are compatible with PHMSA's minimum standards.

[25]On August 12, 2019, PHMSA submitted the final rule to the Office of Management and Budget for its review.

[26]In addition to requiring operators to submit an annual report, the interim final rule also requires operators to provide PHMSA with reports on incidents at storage sites as defined by the rule; safety-related condition reports that identify findings that compromise the safety of the well or reservoir or the structural integrity or reliability of an underground natural gas storage facility; and national registry information to identify the facility operator that has primary responsibility for operations through an assigned Operator Identification Number.

[27]Separately, for its pipeline safety program, PHMSA has developed guidance for those responding to pipeline emergencies that provides suggestions for organizing necessary communications. PHMSA's "Guide for Communicating Emergency Response Information for Natural Gas and Hazardous Liquids Pipelines" addresses topics such as assessing health effects, but there is no similar guide for storage sites. See National Academy of Sciences Transportation Research Board, *Hazardous Materials Cooperative Research Program: Guide for Communicating Emergency Response Information for Natural Gas and Hazardous Liquids Pipelines* (Washington, D.C.: 2014).

While PHMSA has authority for oversight of underground natural gas storage facilities, the PIPES Act also authorizes states to participate in such oversight by annually obtaining certification from or entering into an agreement with PHMSA (which we refer to as partnering with PHMSA).[28] Authorized states are responsible for inspecting intrastate underground natural gas storage facilities on sites fully within their borders. According to PHMSA officials, 25 of the 31 states where underground natural gas storage sites are located have such intrastate sites, and PHMSA expected to partner with these 25 states by granting them oversight authorization, according to PHMSA officials.[29]

In addition, the PIPES Act requires PHMSA to set and charge user fees for operators of underground natural gas storage sites. The act restricts the use of these fees to activities related to natural gas storage site safety. The act also prohibits PHMSA from collecting fees unless the expenditure of these fees is provided in advance in an appropriations act; as a result, PHMSA can only collect fees up to the amount provided in advance in an appropriations act.

Public Health and Environmental Effects from Hazardous Chemicals

Human health can be affected by breathing hazardous chemicals in the air; drinking water contaminated by such chemicals; or making skin contact with contaminated soil, dust, or water. Chemicals that can affect human health include several types of hazardous materials that pose a risk to human health and safety. Environmental effects of chemicals can include greenhouse gas emissions and groundwater contamination.

Several federal agencies have a role in assessing the public health and environmental effects from exposure to hazardous chemicals, although these efforts may not be specifically related to underground natural gas storage as described in this report. For example, the Toxic Substances Control Act authorizes EPA to review the environmental and health effects of certain chemicals and regulate those that pose unreasonable risks to human health or the environment. According to EPA's July 2018 *Report on the Environment*, relationships between environmental

[28]49 U.S.C. § 60141(c). Certification allows states to assume responsibility for enforcing the federal minimum safety standards for intrastate underground natural gas storage facilities, and agreements allow states to establish programs to implement the federal minimum safety standards but not to take enforcement actions.

[29]The other six states only have interstate underground natural gas storage sites, according to PHMSA.

exposures and health outcomes can only be established through well-designed epidemiological, toxicological, and clinical studies.[30] Developing evidence that environmental contaminants cause or contribute to the incidence of adverse health effects can be challenging, particularly for effects that occur in a relatively small proportion of the population or effects with multiple causes. For example, there may be factors related to both the exposure and the health effect—confounding factors—that can make it difficult to detect a relationship between exposure to environmental contaminants and disease.

In its 2018 report, EPA stated that it uses the results of scientific research to help identify linkages between exposure to environmental contaminants and diseases, conditions, or other health outcomes. These linkages, in turn, identify environmental contaminants and health outcomes of potential agency interest. Research has established a relationship between exposure and disease for some environmental contaminants, including

- radon and lung cancer,
- arsenic and cancer in several organs, and
- lead and nervous system disorders.

OSHA established the Air Contaminants Standard to limit employees' occupational exposure to more than 400 chemicals.[31] It also established the Hazard Communication Standard, which requires employers to provide information to their employees about the hazardous chemicals to which they are exposed by means of Safety Data Sheets, among other things.[32] Other federal agencies have responsibilities related to the human health effects of chemicals, including ATSDR and NIOSH.[33]

[30]Environmental Protection Agency, National Center for Environmental Assessment, *EPA's 2018 Report on the Environment* (July 2018), Available at https://www.epa.gov/report-environment.

[31]29 C.F.R. § 1910.1000.

[32]29 C.F.R. § 1910.1200.

[33]ATSDR, a public health agency within the U.S. Department of Health and Human Services, prepares toxicological profiles of certain hazardous substances. These profiles provide interpretations of data that can be useful for officials evaluating the chemical hazards at sites with a release or threatened releases of hazardous substances. Also, NIOSH, an institute of the Centers for Disease Control and Prevention, conducts occupational safety and health research and workplace evaluations and makes recommendations to prevent worker injuries and illnesses.

ATSDR has authority to, among other things, perform health assessments for releases or facilities where information was provided that individuals were exposed to a hazardous substance for which the probable source of such exposure is a release. NIOSH researches the safe use of chemicals in the workplace and provides information on how to measure chemicals in the work environment, among other things, for understanding and managing chemicals safely at work.

2017 GAO Report Findings and Recommendations

In November 2017, we reported on PHMSA's natural gas storage program.[34] At the time of our 2017 review, PHMSA was still establishing its program, and we reviewed its planning efforts for developing the program. We found that although PHMSA had established a strategic goal for its natural gas storage program and set a performance goal for training inspectors, it had not yet followed other leading practices for strategic planning. PHMSA officials told us that the program would be guided by one of PHMSA's existing strategic goals: to promote continuous improvement in safety performance. We found that PHMSA had not defined the level of performance to be achieved and did not have performance goals that addressed other core program activities, such as conducting inspections. We recommended that PHMSA define levels of performance, address core program activities, and use baseline data to develop performance goals for its natural gas storage program. At that time, we also found that PHMSA had not yet used initial baseline data it gathered early in the program to inform the development of its performance goal. We recommended that PHMSA use other data and information about budgetary resources as they become available to inform and refine its performance goals. PHMSA agreed with these recommendations and in May 2018 established a performance goal for inspections of natural gas storage sites. PHMSA officials told us in July 2019 that they were continuing to inform and refine agency performance goals based on budgetary information.

[34]GAO-18-89.

Since November 2017, PHMSA Has Not Fully Evaluated Its Workforce Needs for the Program or Established Performance Goals That Reflect Efforts to Improve Safety

After our report in November 2017, PHMSA began inspecting natural gas storage sites but has not fully assessed resource needs for its changing workload or established a performance goal that measures PHMSA's progress toward its relevant strategic goal to improve safety.[35] First, because PHMSA has not used an analysis of its workforce needs to inform its budget requests, the agency may not have assurance that it has enough resources to meet its performance goal of inspecting all of the approximately 400 natural gas storage sites within 5 years (from early 2018 through early 2023). Second, although PHMSA has established a performance goal that focused on the number of inspections completed, the goal does not reflect the agency's contributions toward its strategic goal to promote continuous improvement in safety.

Since 2017, PHMSA Has Established and Worked toward an Inspection Performance Goal but Has Not Used a Workforce Analysis to Guide Its Resource Decisions

In November 2017, we reported that PHMSA had established a strategic goal for its natural gas storage program but had not yet set performance goals that define the level of performance officials hope to achieve or that address all core program activities, such as conducting effective inspections. PHMSA's inspections of natural gas storage sites are designed to determine the extent to which these sites meet PHMSA's 2016 minimum safety standards for natural gas storage sites, according to PHMSA officials and documents. In our November 2017 report, we stated that our prior work had identified several leading practices for strategic planning that PHMSA had not yet followed, such as setting goals that define a certain level of performance and address all core program activities. We recommended that PHMSA develop such goals, and the agency concurred.[36]

In 2018, PHMSA officials told us that the agency had established a performance goal to inspect all of the approximately 400 natural gas storage sites over 5 years (from early 2018 through early 2023), with the expectation that state partners would help PHMSA inspect the sites. The

[35]PHMSA's strategic goal is to promote continuous improvement in safety performance, which supports PHMSA's mission to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. See Pipeline and Hazardous Materials Safety Administration, *PHMSA 2021 Business Plan-2017* (Washington, D.C.: Dec. 16, 2016).

[36]GAO-18-89.

officials also told us the agency has started inspecting sites to meet that goal. Currently, 10 states have agreed to partner with PHMSA to help inspect natural gas storage sites, according to agency officials.

Natural Gas Storage Site Inspections Conducted by the Pipeline and Hazardous Materials Safety Administration (PHMSA)

At a PHMSA inspection of a natural gas storage site in rural Iowa, we observed PHMSA inspectors conducting visual inspections of natural gas storage wells in the field to ensure that the site operator's wells matched the operator's documentation and that the wells were operating within safe limits.

During the inspection, PHMSA's inspectors also conducted a review of the storage site operator's safety procedures, such as the operator's schedule for inspecting its wells for potential leaks or pressure changes, its emergency contact protocols, and its procedures for ensuring the integrity of wells. As part of the review, PHMSA inspectors reviewed the site operator's documentation to evaluate the operator's efforts to implement the agency's 2016 minimum safety standards for natural gas storage sites.

Source: GAO. | GAO-20-167

To meet its performance goal, PHMSA set targets for each of the 5 years (see app. II for details about PHMSA's annual targets for this performance goal). For example, PHMSA set a target that its inspectors and state partners would inspect a total of 41 sites in 2018. According to PHMSA officials, the agency completed 35 inspections, and its state partners inspected an additional 30 sites, for a total of 65 inspections in 2018.[37] In future years, according to PHMSA planning documents, PHMSA's annual site inspection targets will almost double from 41 total site inspections in 2018 to 80 total site inspections in 2019.

However, PHMSA's inspection workload for its natural gas storage program has increased since November 2017, which may affect its ability to meet its inspection performance goal. We reported in November 2017 that PHMSA had developed a preliminary estimate of the workforce it would need to inspect half of the approximately 400 natural gas storage sites. That estimate was based on the agency's experience from its pipeline safety program. Specifically, in 2017, agency officials said that they expected 25 state governments would partner with PHMSA to inspect about 200 of the sites and that six agency employees would inspect the remaining approximately 200 sites.[38] Specifically, in 2017 PHMSA estimated the inspections would require about 203 work weeks of inspectors' time. However, in October 2018, PHMSA officials told us that their inspectors would need more time than previously estimated to complete each natural gas storage site inspection, due to requirements for operators in the 2016 minimum safety standards.

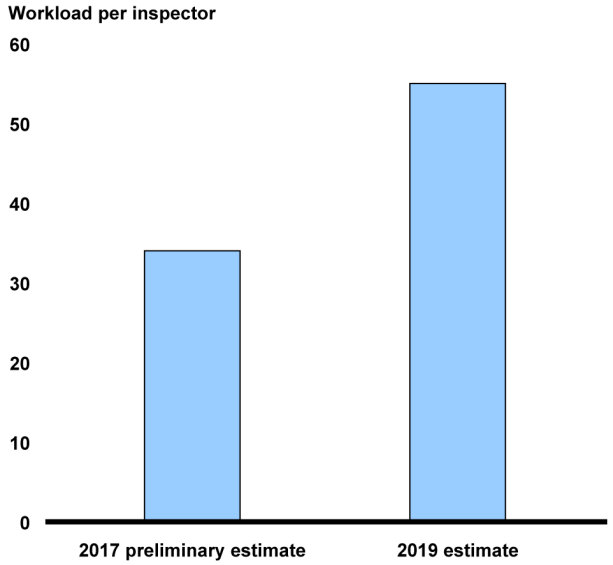
[37]For purposes of tracking progress toward its goal, PHMSA uses different annual timeframes to count inspections toward its goal between sites inspected by PHMSA and sites inspected by its state partners. PHMSA counts federal inspections on a fiscal year cycle (ending September 30). During fiscal year 2018, PHMSA inspected 35 sites, and by the end of calendar year 2018, PHMSA inspected an additional 8 sites, according to agency officials. PHMSA counts state inspections on a calendar year cycle (ending December 31).

[38]PHMSA has staffed seven full-time employees to the natural gas storage program, consisting of the equivalent of six inspectors and one additional employee to coordinate the program. PHMSA placed the natural gas storage program within its pipeline safety program, which employs the equivalent of about 130 inspectors, according to agency officials. In 2017, prior to adding natural gas storage inspections, PHMSA's pipeline safety program planned to complete 1,439 inspection activities, calculating about 1 work week per activity.

Furthermore, in its 2017 estimate, PHMSA assumed that all 25 state governments eligible to partner with PHMSA on inspections would agree to do so. However, as of June 2019, only 10 of the 25 eligible states had agreed to partner with PHMSA, according to agency officials.[39] PHMSA officials told us that more states may decide to participate in the future. However, there are a variety of reasons why states may be reluctant to partner with PHMSA. For example, officials from two states told us that PHMSA had not offered enough funding to cover the cost of partnering with the agency. Officials from two states told us that partnering with PHMSA required some lead time to obtain funds through their states' legislative processes for such inspections. In addition, PHMSA officials told us that some states are waiting until the interim final rule is issued as a final rule before determining whether to partner. As a result, according to PHMSA data, unless additional states partner with the agency, PHMSA will need to increase the number of sites it inspects from about 200 to 322 in order for the agency to meet its performance goal of inspecting all of the approximately 400 sites by 2023. This would increase PHMSA's inspection workload by about 60 percent, as shown in figure 2.

[39]The 10 states that have agreed to partner with PHMSA are Arkansas, California, Illinois, Indiana, Kansas, Louisiana, Minnesota, Oklahoma, Oregon, and Pennsylvania.

Figure 2: Comparison of the Pipeline and Hazardous Materials Safety Administration's (PHMSA) 2017 Preliminary Workload Estimate and 2019 Workload Estimate for Natural Gas Storage Site Inspections



Source: GAO analysis of PHMSA data. | GAO-20-167

Note: The workload illustrated in this figure reflects PHMSA's estimate of the number of "inspection units," which PHMSA defines as collections of assets (e.g., wells, pipeline segments, or storage facilities) that an inspector could inspect in 1 week.

Because of the increase in its inspection workload over its preliminary estimate, PHMSA does not have assurance that it has enough resources to meet its inspection goal. Specifically, PHMSA has requested and received the same budget authority for its natural gas storage safety activities—$8 million—for each fiscal year from 2017 through 2019.[40] Of the $8 million, PHMSA requested $2 million for federal employees to inspect about 200 of about 400 natural gas storage sites. PHMSA requested the remaining $6 million for grants to authorized states to conduct inspections of the remaining sites. However, of the 25 states PHMSA expected to request such authority, only 10 did so and are partnering with PHMSA to conduct inspections, according to PHMSA officials. This means that the number of sites that states could inspect is about 90 rather than about 200, as PHMSA had initially estimated. In comparison, PHMSA's workload for its natural gas storage inspection

[40]Additional details about PHMSA's annual budget requests, budget authority, obligations, and expenditures are provided in appendix III.

program is more than three times higher than the workload for PHMSA's pipeline inspection program.[41]

We also recommended in November 2017 that PHMSA use other data and information about budgetary resources to inform and revise its performance goals. PHMSA concurred with our recommendation. However, officials told us that as of July 2019, the agency had not yet fully addressed this recommendation to use workforce data to inform and revise its goals. In December 2018, PHMSA issued a strategic workforce plan that indicates it represents a thorough analysis of the agency's current workforce composition as of 2018 and the collective viewpoints of employees and senior leadership regarding the future.[42] PHMSA stated in this plan that workforce planning will allow the agency to respond to emerging challenges and responsibilities and improve overall mission effectiveness and efficiency. Specifically, the plan states that PHMSA leadership recognizes that while the agency has implemented some foundational elements of workforce management and the overall workforce is staffed with skilled professionals, the agency's workforce planning has tended to be more reactive than proactive. The plan cites as evidence underdeveloped succession plans, inconsistent hiring results, increased turnover, and limited workforce analysis and forecasting. To address these gaps, the plan identifies the following three high-level strategies to supplement and expand agency capabilities:

- expand and enhance PHMSA's recruitment and hiring plans,
- conduct operational workforce planning and workload analysis by program office, and
- implement succession planning and develop leadership and staff.

[41]According to PHMSA officials, the agency's natural gas storage program is modeled on its pipeline inspection program, and some of the inspections are comparable in scope and duration. PHMSA's natural gas storage program workload is currently 3.5 times greater per inspector than its pipeline safety program. The workload for PHMSA's natural gas storage program is about 55 inspection units per inspector; PHMSA defines one inspection unit as the equivalent of about 1 week of inspection work by an inspector. In contrast, the pipeline safety program assigns about 16 inspection units per inspector, according to PHMSA data we reviewed.

[42]Pipeline and Hazardous Materials Safety Administration, *Strategic Workforce Plan FY19* (Washington, D.C.: Dec. 13, 2018). PHMSA officials stated that this document was written in response to a recommendation by the DOT Inspector General that found PHMSA had not updated its workforce plan since 2005. See U.S. Department of Transportation, Office of Inspector General, *PHMSA Has Improved Its Workforce Management but Planning, Hiring, and Retention Challenges Remain*, ST2018010 (Washington, D.C.: Nov. 21, 2017).

PHMSA officials said that the agency has been assessing its workforce, but they told us this assessment will not guide the agency's budget requests for its natural gas storage program.[43] PHMSA officials told us they did not plan to change the workforce levels reflected in the agency's budget requests until 2022 or 2023. This is because although PHMSA has been collecting and assessing workforce data since March 2018, the agency does not expect to have the workforce data it needs to further inform workforce analysis until 2022 or 2023, according to PHMSA officials. The officials indicated that the additional data they have begun gathering may include variables such as the number of additional states that may partner with PHMSA in the future; resources used, by region; and the capacity of inspection teams of different sizes. In technical comments PHMSA provided on a draft of this report, PHMSA officials stated that the agency recently concluded a workforce assessment of its pipeline inspection program—including its natural gas storage program—covering the 5 years from 2020 through 2024.[44] PHMSA's workforce assessment indicated that the state of Texas is likely to partner with PHMSA beginning in 2020, which would reduce the number of natural gas storage sites PHMSA would need to inspect.[45] Based on our preliminary review of the information PHMSA officials provided, however, PHMSA's assessment does not address the reasons its inspectors' workload increased by about 60 percent, such as the factors affecting states' participation in inspections. Moreover, PHMSA officials did not indicate whether PHMSA would use this workforce information to guide its workforce planning or budget requests.

We have reported that strategic workforce planning is an essential tool to help agencies align their workforces with their current and emerging missions and develop long-term strategies for acquiring, developing, and

[43]PHMSA officials told us that this workforce assessment is focused on the pipeline safety program, which includes its natural gas storage program.

[44]Cycla Corporation for PHMSA Office of Pipeline Safety, *PHMSA—Office of Pipeline Safety Inspection Workforce Assessment* (Alexandria, Virginia: August 2019).

[45]Texas state officials told us they had not partnered with PHMSA because of uncertainty about what the final rule would require and concerns that the final rule would disrupt the state's current regulatory scheme for underground natural gas storage sites, which is not based on the API recommended practices. Texas sued PHMSA over its interim final rule but the litigation was stayed until issuance of the final rule. *State of Texas et. al v. United States Dep't of Transportation*, No. 17-60189 (5th Cir.).

retaining staff.[46] Furthermore, we have reported that existing strategic workforce planning tools and models and our own work suggest that there are certain principles that such a process should address. These principles include developing strategies tailored to address gaps in number, deployment, and alignment of human capital to enable and sustain the contributions of all critical skills and competencies. We also have reported that workforce planning should include (1) identification of the knowledge, skills, and abilities and other characteristics (i.e., competencies) needed by the future workforce; the competencies of the current workforce; and gaps between the two; (2) development of a workforce action plan designed to address these gaps; and (3) monitoring and evaluation of the workforce planning actions taken.[47] Furthermore, we have found in our prior work that completing and regularly updating staffing models in a timely manner can help support agencies' activities and decision-making.[48] By analyzing the factors affecting states' participation in inspections and analyzing the agency's workforce needs on an ongoing basis and using this information to guide its budget requests, PHMSA would have more reasonable assurance that it has the necessary staff to meet its inspection goal.

Since 2017, PHMSA Has Established a Performance Goal, but the Goal Does Not Reflect the Agency's Contributions to Its Strategic Goal of Promoting Continuous Safety Performance

PHMSA has established a strategic goal for its natural gas storage program to promote continuous safety performance but as of April 2019 had not established performance goals that reflect the agency's contributions to protecting human health and the environment. According to PHMSA officials, PHMSA's natural gas storage program is guided by the agency's strategic goal to promote continuous improvement in safety performance. PHMSA officials acknowledged that the agency's inspection performance goal provides information about activities or outputs—specifically, the number of inspections. However, this goal does not provide information on the outcomes or results of PHMSA's contributions toward its strategic goal of improving safety at natural gas storage sites,

[46]GAO, *Human Capital: Key Principles for Effective Strategic Workforce Planning*, GAO-04-39 (Washington, D.C.: Dec. 11, 2003).

[47]GAO, *Small Business Administration: Steps Taken to Better Manage Its Human Capital, but More Needs to Be Done*, GAO/T-GGD/AIMD-00-256 (Washington, D.C.: July 20, 2000).

[48]GAO, *Federal Protective Service: Enhancements to Performance Measures and Data Quality Processes Could Improve Human Capital Planning*, GAO-16-384 (Washington, D.C.: Mar. 24, 2016).

consistent with leading practices under GPRA.[49] An example of an outcome-oriented performance goal could be to measure reductions in the volume of gas released from natural gas storage wells, which could indicate that operators of natural gas storage sites are reducing safety risks through improved maintenance.

Based on our previous work, measuring performance outcomes is an important management tool for agencies, and leading practices indicate that results-oriented performance goals focus on expected results to show progress toward, or contributions to, intended results.[50] By establishing performance goals that demonstrate improvements to safety outcomes, PHMSA would have better assurance that it can show its progress toward meeting the agency's strategic goal of continuously improving safety performance.

In addition to the performance goal PHMSA established, agency officials told us that DOT applied an outcome-oriented, department-wide performance goal to its natural gas storage program. Based on our review of DOT's *2018-19 Annual Performance Plan—2017 Annual Performance Report*, PHMSA is responsible for meeting the department-wide performance goal of reducing incidents involving death or major injury resulting from the transport of hazardous materials by all modes, including pipelines.[51] While PHMSA officials told us this was an outcome-

[49]GPRA, as amended, defines a performance goal as the target level of performance expressed as a tangible, measurable objective against which actual achievement is to be compared, including a goal expressed as a quantitative standard, value, or rate. 31 U.S.C. § 1115(h)(9).

[50]For example, see GAO, *Government Reform: Goal-Setting and Performance*, GAO/AIMD/GGD-95-130R (Washington, D.C.: Mar. 27, 1995). Some of this prior work examined requirements under GPRA as amended by the GPRA Modernization Act of 2010. GPRA, which was significantly updated and enhanced by the GPRA Modernization Act of 2010, requires agencies to develop annual performance plans that, among other things, establish performance goals to define the level of performance to be achieved. We have previously reported that requirements under these acts can serve as leading practices for planning at lower levels of the agency.

[51]This goal is based on a combined measure of both pipeline-related and hazardous materials-related incidents involving reports of death or major injury. Each component of the goal is further defined as follows: (1) hazardous materials incidents include those involving a fatality or a major injury requiring admittance to the hospital and/or loss of 3 days or more from work due to the extent of injury; and (2) pipeline incidents include those involving a fatality or injury requiring in-patient hospitalization, but excludes gas distribution incidents with a cause of other outside force damage or nearby fire or explosion as the primary cause of the incident. See U.S. Department of Transportation, *2018-19 Annual Performance Plan—2017 Annual Performance Report* (August 2018).

oriented goal, we believe it would not provide a meaningful measure of safety improvements at natural gas storage sites because, according to PHMSA data, there have been zero incidents involving death or major injuries at natural gas storage sites since 2017, when PHMSA started tracking incidents. While no deaths or major injuries have been reported at natural gas storage sites since 2017, PHMSA reported seven incidents—four in fiscal year 2017 and three in fiscal year 2018—that did not result in death or major injury. These seven incidents resulted in natural gas releases of 3 million cubic feet or more or caused estimated property damage of $50,000 or more. By tracking reductions to these incidents, PHMSA may have additional opportunities to measure outcomes in safety improvements.

Federal Agencies Have Documented Potential Health Effects from Chemicals that May Be Found in Stored Natural Gas

Several federal agencies—including EPA, ATSDR, OSHA and NIOSH—have documented potential health effects of chemicals that may be found in stored natural gas. These chemicals—some at trace amounts—are known to cause health effects at specific levels of exposure.[52] Stored natural gas primarily consists of methane, and during large releases at natural gas storage sites, downwind methane concentrations can be higher than flammability or explosion limits, creating health and safety concerns, according to CCST.[53] In addition, other chemicals occur naturally in natural gas or are residues from the storage site's previous use. For example, hydrogen sulfide, a flammable, colorless gas that smells like rotten eggs, can occur in depleted oil and gas reservoirs. Figure 3 shows a building containing a well at a natural gas storage site with a notice that warns of hydrogen sulfide, which may collect in confined spaces in amounts that are acutely toxic. Hydrogen sulfide can cause a

[52]Health effects from exposure to hazardous chemicals depend on a range of factors such as the concentration of the exposure, the duration of exposure, and the individual's susceptibility.

[53]California Council on Science and Technology, *Long-Term Viability of Underground Natural Gas Storage In California*, 326.

range of human health effects, from eye irritation to serious lung injury, according to ATSDR.[54]

Figure 3: Hydrogen Sulfide Warning at a Natural Gas Storage Site

Source: GAO. | GAO-20-167

In addition, some chemicals may be added to natural gas, such as sulfur odorants that are added to give natural gas a distinct smell in case of leaks.[55] The combination of such chemicals varies from one storage site to another based on the attributes of that site, such as its geologic type and the extent to which sulfur odorants are added to the natural gas before storage. Many of these chemicals have been linked to adverse

[54]According to an ATSDR fact sheet on hydrogen sulfide, studies in humans suggest that the respiratory tract and nervous system are the most sensitive targets of hydrogen sulfide toxicity. Exposure to low concentrations of hydrogen sulfide may cause irritation to the eyes, nose, or throat and may cause difficulty in breathing for some asthmatics. Respiratory distress or arrest has been observed in people exposed to very high concentrations of hydrogen sulfide. Exposure to low concentrations of hydrogen sulfide may cause headaches, poor memory, tiredness, and balance problems. Brief exposures to high concentrations of hydrogen sulfide can cause loss of consciousness. In most cases, the person appears to regain consciousness without any other effects. However, in some individuals, there may be permanent or long-term effects such as headaches, poor attention span, poor memory, and poor motor function.

[55]For example, operators often add sulfur odorants to natural gas to help detect leaks, and in high concentrations these odorants can affect health, according to to PHMSA officials. In addition, some chemicals can be used to clean and treat the natural gas or maintain the well.

health effects.[56] However, research is limited on the health effects of exposure to stored natural gas in general and on the effects in particular from exposure to chemicals that may occur in natural gas storage leaks or be present at the storage sites. Reports linking health effects are available on specific chemicals but not in the context of natural gas storage, based on our literature review. Scientific studies are important for establishing the association between chemicals in stored natural gas and symptoms community members may experience during leaks to determine health effects.

EPA, through its Integrated Risk Information System (IRIS) Program, identifies and characterizes the health hazards of chemicals found in the environment and has produced assessments on several chemicals that may be present in natural gas. EPA established the IRIS Program in 1985 to help develop consensus opinions within the agency about the health effects from lifetime exposure to chemicals. The IRIS database of chemical assessments contains EPA's scientific positions on the potential human health effects that may result from exposure to various chemicals in the environment. As of November 2018, the database included information on 510 chemicals.[57] To conduct an assessment of a chemical, the agency follows a multi-step process that includes identifying credible health hazards associated with exposures to a chemical and characterizing the quantitative relationship between chemical exposure and each credible health hazard. The program derives toxicity values through this quantitative relationship. EPA has completed assessments on several chemicals that may be in stored natural gas, including hydrogen sulfide, benzene, toluene, ethylbenzene, and xylene. In its IRIS assessment on benzene, EPA found that, as is the case with many other organic solvents, benzene has been shown to produce neurotoxic effects in test animals and humans after short-term exposures to relatively high concentrations.

ATSDR develops toxicological profiles—summaries of its evaluations concerning whether, and at what levels of exposure, adverse health effects occur and levels at which no adverse effects occur—for several chemicals that may be present in natural gas, including hydrogen sulfide,

[56]Benzene, for example, is a known carcinogen, according to EPA. Other hazardous chemicals can also be found in stored natural gas.

[57]GAO, *Chemical Assessments: Status of EPA's Efforts to Produce Assessments and Implement the Toxic Substances Control Act*, GAO-19-270 (Washington, D.C.: Mar. 4, 2019).

benzene, toluene, ethylbenzene, and xylene. For example, ATSDR has found that inhaling benzene can cause drowsiness, dizziness, and unconsciousness and that long-term benzene exposure affects the bone marrow and can cause anemia and leukemia. Also, ATSDR found that toluene may affect the nervous system and at low to moderate levels can cause tiredness, confusion, weakness, memory loss, nausea, and loss of appetite.[58] However, these symptoms usually disappear when the exposure stops.

NIOSH researches the safe use of chemicals in the workplace and provides information on how to measure chemicals in the work environment, engineering controls and personal protective equipment, risk assessments, and communication tools for understanding and safely managing chemicals at work. NIOSH publishes information on chemical hazards in the workplace to inform workers, employers, and occupational health professionals. For example, NIOSH reports on occupational exposure limits for ethylbenzene. NIOSH's Pocket Guide to Chemical Hazards provides key facts on the health effects from exposures to chemicals and recommends occupational exposure limits to chemicals that can affect human health. In addition, NIOSH helped initiate the International Chemical Safety Cards, a joint international agency effort. The cards, which provide essential safety and health information in a clear and concise way, are drafted and peer-reviewed by an international group of scientists from institutions concerned with occupational safety and health.[59] The cards provide information about some chemicals that can occur in natural gas storage sites, including hydrogen sulfide, benzene, toluene, ethylbenzene, and xylene.

OSHA collects information on chemicals and occupational health effects for workers and compiles that information into a database. OSHA

[58]In addition to toluene, ethylbenzene inhaled in low levels has resulted in hearing effects and kidney damage in animals, and at very high levels it can cause dizziness and throat and eye irritation, according to an ATSDR factsheet. Xylene, according to another ATSDR factsheet, has no noted health effects at the background levels that people are exposed to on a daily basis, but exposure to high levels of xylene for short periods can cause irritation of the skin, eyes, nose, and throat; delayed reaction time; memory difficulties; and stomach discomfort.

[59]The International Chemical Safety Card project is a joint effort of the World Health Organization and the International Labour Organization, with the cooperation of the European Commission. More than 1,700 cards are available in English, Chinese, Finnish, French, Hungarian, Italian, Japanese, Polish, and Spanish. Translated cards are also under development in German, Hebrew, Russian, and other languages.

accumulates information from several government agencies, including EPA, ATSDR, and NIOSH. This information includes chemical identification and physical properties, occupational exposure limits, and sampling information. OSHA's Occupational Chemical Database provides information on chemicals, including those that can be present in stored natural gas, such as hydrogen sulfide, benzene, toluene, ethylbenzene, and xylene. In addition, among other general information, OSHA regulations require employers to maintain and make available to employees Safety Data Sheets in the workplace for each hazardous chemical they use.[60]

Potential Environmental Effects of Releases at Natural Gas Storage Sites Include Greenhouse Gas Emissions and Some Risks to Groundwater

Releases at natural gas storage sites are known to emit greenhouse gases—mainly carbon dioxide and methane—into the atmosphere, according to EPA and CCST reports. In addition, we identified two natural gas storage site releases from 2000 through 2018 that potentially impacted groundwater, but information about such releases is limited.

Reports Reviewed Indicate that Natural Gas Storage Sites Emit Greenhouse Gases

Releases at natural gas storage sites emit greenhouse gases into the atmosphere, according to data from EPA's program on greenhouse gas emissions. These can be major releases, such as the Aliso Canyon leak, or other emissions, such as leaking pipes and valves. According to the 2019 EPA annual report *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, the main greenhouse gases released from natural gas storage sites are methane, the largest component of natural gas, and carbon

[60]Safety Data Sheets (SDS), formerly called "Material Safety Data Sheets," are required by OSHA's Hazard Communication Standard (29 C.F.R. § 1910.1200(g)). This standard requires that the chemical manufacturer, distributor, or importer provide an SDS for each hazardous chemical and that employers maintain and make available to employees an SDS for each hazardous chemical in the workplace. The SDS is to include information such as the physical and chemical properties, accidental release measures, toxicological and ecological information, and handling and storage information.

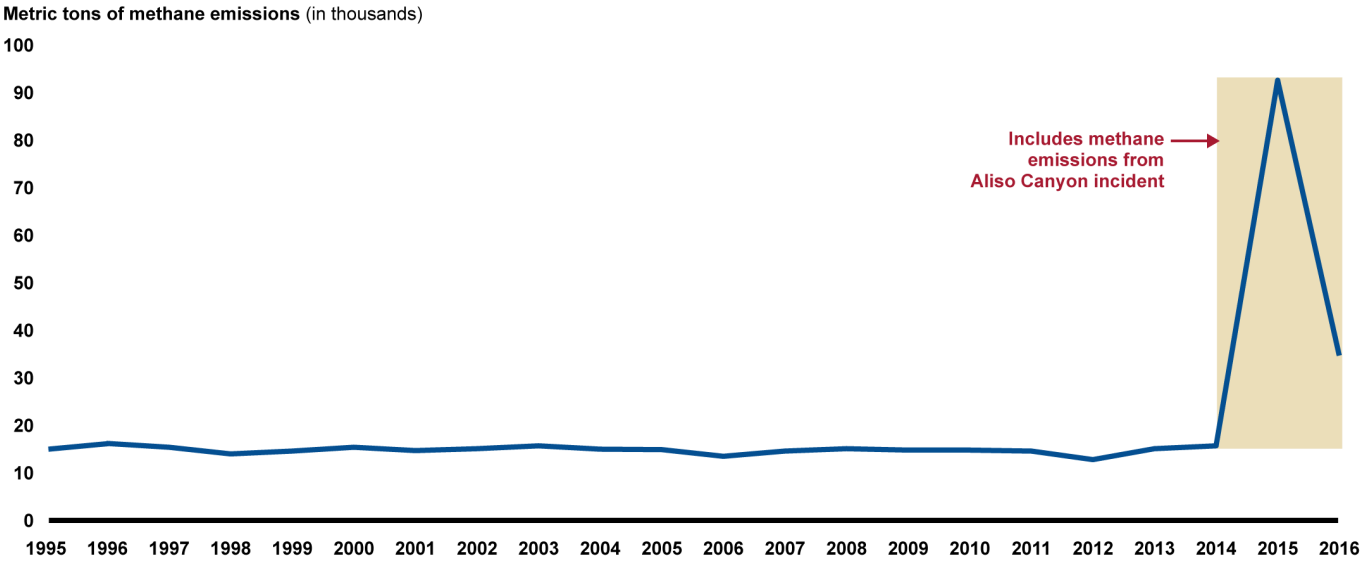
dioxide, the main greenhouse gas produced by natural gas combustion.[61] Of the two, methane makes a greater pound-for-pound contribution to climate change—the comparative impact of methane is more than 28 to 36 times greater than carbon dioxide over a 100-year period, according to EPA officials who cited the Intergovernmental Panel on Climate Change. As a result, leaks such as the Aliso Canyon incident contribute to climate change, according to EPA. For example, the Aliso Canyon leak resulted in the single largest release of methane in U.S. history, with a release of 78,000 metric tons of methane in 2015 and an additional 22,000 metric tons in the first 2 months of 2016.[62] The Aliso Canyon leak equaled the greenhouse gas emissions from approximately 529,000 passenger vehicles driven for 1 year, according to EPA data.

In most years since 1995, an annual average of 15,000 metric tons of methane were released from natural gas storage, according to EPA data on greenhouse gases. In 2015, however, due to the Aliso Canyon leak, greenhouse gas emissions from all natural gas storage wells increased to more than 92,000 metric tons of methane—about 6 times greater than the release for an average year—according to EPA estimates. Figure 4 shows EPA's estimates of annual methane emissions from natural gas storage sites from 1995 through 2016, including the estimated emissions from the Aliso Canyon leak in 2015 and 2016.

[61]EPA has published an annual report, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, since the early 1990s. EPA updated this report to reflect 2017 data in Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*.

[62]Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Update to Storage Segment Emissions: Incorporating an Estimate for the Aliso Canyon Leak* (Washington, D.C.: April 2017).

Figure 4: The Environmental Protection Agency's (EPA) Estimated Methane Emissions from All U.S. Natural Gas Storage Sites, 1995-2016



Sources: Environmental Protection Agency (EPA) inventory of greenhouse gas emissions and sinks. Estimates from the California Air Resources Board specific to the Aliso Canyon incident were included as part of EPA's analysis. | GAO-20-167

Note: According to EPA officials, these estimates have an uncertainty range of about plus or minus 15 to 20 percent.

Chronic releases during routine operations at natural gas storage sites, such as small leaks from valves or from equipment exhaust, also emit greenhouse gases into the atmosphere and may persist for long periods of time. These chronic releases tend to be slow leaks from natural gas wells, such as releases from seals and valves. Slow leaks can persist for long periods because, unlike major leaks, they are less likely to be detected, according to a CCST report.[63] Moreover, slow leaks, if identified, may not be prioritized due to a perception that they present few implications for worker safety and public health, according to CCST's report. However, the CCST report also stated that chronic releases may routinely occur, although the amount of the release is difficult to measure since it may not be known when the release started, and these chronic releases may lead to a significant release of greenhouse gas.

[63]California Council on Science and Technology, *Long-Term Viability of Underground Natural Gas Storage in California*.

In 2016, California conducted an assessment of all its natural gas storage wells across its 11 natural gas storage sites and found 229 chronic leaks. Methane releases from these slow, chronic leaks generally represent a small share of the statewide reported methane releases in California. However, over a 10-year period, the cumulative impact of these releases from routine operations in California can equal the amount of methane released in the Aliso Canyon leak, according to CCST, using estimates from the California Air Resources Board.[64]

Evidence from Releases Indicates Some Risk to Groundwater from Natural Gas Storage, but Data Are Limited

In some instances, groundwater has been contaminated by the release of natural gas from storage sites, but the extent of the risk to groundwater is not known because data are limited. We identified two examples of releases from 2000 through 2018 that potentially affected groundwater: a 2003 release at the Playa Del Rey storage site in California and a 2006 release at a storage site near Fort Morgan in Colorado.[65]

Natural gas storage site releases can impact groundwater sources in different ways. For example, these releases can impact groundwater sources above the storage site when they involve the upward migration of gas and other fluids mixed with the gas. According to CCST, this occurred at the Playa Del Rey site, where stored natural gas has leaked into a freshwater aquifer for a number of years. In other cases, faulty natural gas well design and construction, such as inadequate cementing, can allow natural gas to migrate through fractures and infiltrate overlying groundwater sources or enter drinking water wells. For example, gas infiltrated an aquifer that served drinking water wells in Fort Morgan, Colorado, which led to an evacuation of about a dozen families until the release was stopped. Subsurface leaks can also result from abandoned wells in which the casings or cement have degraded over time or from improperly plugged wells.[66]

[64]The board is charged with protecting the public from the harmful effects of air pollution and developing programs and actions to fight climate change.

[65]We conducted a literature search to identify natural gas storage site releases from 2000 through 2018 within the United States.

[66]Plugged wells, according to the interagency task force report, are wells that operators have closed permanently using a procedure called plugging and abandonment. According to the interagency task force report, regulatory requirements vary for plugging and abandonment procedures, but most require that cement plugs be placed across certain areas. These areas may be hydrocarbon-bearing formations, freshwater aquifers, and other surface areas near the top of the well.

In January 2017, PHMSA started collecting data from operators on incidents, including releases of natural gas from underground storage sites that cause more than $50,000 of property damage; these incidents could include leaks that harm groundwater resources, according to PHMSA officials. Based on our review of PHMSA incident information, no reported incidents have included groundwater contamination. Moreover, PHMSA officials told us they are not aware of any incidents involving groundwater contamination that meet reporting thresholds. PHMSA does not require operators to submit information about groundwater contamination unless that contamination meets the regulatory definition of an incident.[67]

Conclusions

Natural gas storage is an integral part of the nation's energy system, ensuring that energy is available to meet peak demands across the nation. PHMSA's safety program for natural gas storage fills a gap that existed in the regulation of underground storage prior to 2017. PHMSA met its inspection targets in the first year of its program, but it faces challenges in meeting its performance goal to inspect 400 storage sites by 2023 because fewer states agreed to partner with the agency on inspections than PHMSA originally envisioned. Because of the increase in its inspection workload from its preliminary estimate, PHMSA does not have assurance that it has enough resources to meet its inspection goal. PHMSA officials told us that while the agency has conducted a workforce assessment, it will not have the data to complete a workforce analysis it can use to guide its workforce allocations and budget requests until 2022 or 2023. The officials also told us that more states may decide to participate in the future. By analyzing the factors affecting states' willingness to participate in inspections and analyzing its workforce needs on an ongoing basis, PHMSA would have more reasonable assurance that it has the necessary staff to meet its inspection goal.

In addition, while PHMSA addressed one of the two recommendations in our November 2017 report and has established a performance goal that provides information about the number of completed inspections, this

[67]PHMSA defines an incident as (1) an event that involves a release of gas from an underground natural gas storage facility, that results in a death or personal injury necessitating in-patient hospitalization, estimated property damage of $50,000 or more, or unintentional estimated gas loss of three million cubic feet or more; (2) an event that results in an emergency shutdown of an underground natural gas storage facility; or (3) an event that is significant in the judgment of the operator. 49 C.F.R. § 191.3.

performance goal does not provide information on the outcome of PHMSA's efforts to improve safety at natural gas storage sites, consistent with leading practices under GPRA. By establishing performance goals that demonstrate improvements to safety outcomes, such as tracking reductions in incidents ranging from releases of natural gas to death or major injury, PHMSA would have better assurance that it can measure its progress toward meeting its strategic goal to improve safety.

Recommendations for Executive Action

We are making the following two recommendations to PHMSA:

The PHMSA Administrator should analyze the factors affecting states' participation in underground natural gas storage inspections and analyze its workforce needs on an ongoing basis to guide its budget requests. (Recommendation 1)

The PHMSA Administrator should establish performance goals that demonstrate improvements to safety outcomes for the natural gas storage program, such as tracking reductions to incidents. (Recommendation 2)

Agency Comments

We provided a draft of this report to DOT for review and comment. In written comments, DOT concurred with the report's recommendations and provided additional information on steps it is taking or plans to take as part of its implementation of the underground natural gas storage program. In addition, DOT stated that it would provide a detailed response to each recommendation within 180 days of our final report's issuance. The complete comment letter is reproduced in appendix IV.

If you or members of your staff have any questions about this report, please contact me at (202) 512-3841, or gomezj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix V.

J. Alfredo Gómez
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

This report (1) assesses the extent to which the Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) has further developed its natural gas storage program since our November 2017 report, (2) describes what is known about the potential health effects from chemicals in stored natural gas, and (3) describes what is known about the potential environmental effects of releases at natural gas storage sites.

To address these objectives, we reviewed documents from PHMSA, the Department of Energy, and the Environmental Protection Agency (EPA) and met with officials from these agencies to understand their roles in natural gas storage safety. Since there was no comprehensive list of natural gas storage releases, we conducted a literature search for reports of incidents that occurred in the United States from 2000 through 2018. Later, we expanded our search to include reports of incidents related to mercaptan, an odorant added to natural gas, regardless of whether these incidents occurred at a natural gas storage site. We sought reports and studies from news reports and trade and peer-reviewed journals. We conducted searches in research databases such as Nexis' All English Language News, Elsevier's Scopus, Ei EnCompassLIT, and Chemical Safety Newsbase. We further expanded our search to include state or county reports that had conducted studies or released reports on these issues.

We also reviewed three reports referred to us by agency officials we interviewed that compiled lists of natural gas storage releases to identify those releases that occurred from 2000 through 2018 at underground natural gas storage sites in the United States.[1] The specific reports we reviewed were: *An Appraisal of Underground Gas Storage Technologies and Incidents, for the Development of Risk Assessment Methodology*;[2] "Analysis of Occurrences at Underground Fuel Storage Facilities and Assessment of the Main Mechanisms Leading to Loss of Storage

[1]The search employed phrases such as "natural gas storage," "underground gas storage," and "leak" to find relevant articles.

[2]Evans, David J., and J. M. West, *An Appraisal of Underground Gas Storage Technologies and Incidents, for the Development of Risk Assessment Methodology*, Report by the British Geological Survey to the Health & Safety Executive (HSE), HSE Research Report Series Number RR605 (2008).

Integrity";[3] and *U.S. Natural Gas Storage Risk-Based Ranking Methodology and Results*.[4] We also included a list of incidents at natural gas storage sites in 2017, the first year for which PHMSA collected and compiled these data for underground natural gas storage.

From these sources, we identified 93 releases of natural gas from storage sites; these 93 releases include incidents as defined by PHMSA regulations as well as releases of natural gas that may not meet that definition.[5] The releases we identified could include releases, leaks, explosions, or fires that occurred at natural gas storage sites, and we included these releases regardless of the severity of their impacts, such as injury, death, cost associated with release, or volume of gas released in the incident. We excluded releases at other types of storage, such as aboveground storage or oil storage. This list may not represent the complete universe of releases because not all releases may have been documented, and no federal agency or independent source cataloged all releases for this time period. We reviewed the list of releases to identify any documented examples of health or environmental effects associated with a release. We identified one example of reported health symptoms associated with a natural gas storage release at the Aliso Canyon Storage Site in 2015; the studies we identified did not empirically link the release of natural gas at Aliso Canyon to health effects. The studies also

[3]Evans, David J., and Richard A. Schultz, "Analysis of Occurrences at Underground Fuel Storage Facilities and Assessment of the Main Mechanisms Leading to Loss of Storage Integrity," In *51st US Rock Mechanics/Geomechanics Symposium*, American Rock Mechanics Association (2017).

[4]Department of Energy, Argonne National Laboratory, *US Natural Gas Storage Risk-Based Ranking Methodology and Results*, ANL-16/19 (Argonne, IL: December 2016).

[5]PHMSA regulations define an incident as: (1) an event that involves a release of gas from an underground natural gas storage facility that results in a death or personal injury necessitating in-patient hospitalization, estimated property damage of $50,000 or more, or unintentional estimated gas loss of three million cubic feet or more; (2) an event that results in an emergency shutdown of an underground natural gas storage facility; or (3) an event that is significant in the judgment of the operator. 49 C.F.R. § 191.3.

identified two examples of potential groundwater impacts from two other natural gas storage leaks.[6]

We visited natural gas storage facilities selected to represent each of the three types of underground storage—for depleted fields, Aliso Canyon in California; for salt caverns, Moss Bluff in Texas; and for aquifers, Redfield in Iowa. We reviewed documentation from each site and interviewed these sites' operators. We selected these sites for specific reasons: Aliso Canyon because of the 2015 leak, Redfield because it was scheduled to undergo an inspection by PHMSA at the time of our visit, and Moss Bluff because it was readily accessible from a major urban area (Houston, Texas). Our findings from the sites we visited and officials we interviewed are not generalizable to sites and officials we did not include in our review but provide illustrative examples of such sites. We also met with officials from industry groups that represent companies that operate natural gas storage sites—the American Gas Association, American Petroleum Institute, and Interstate Oil and Gas Compact Commission—to better understand these groups' perspectives on the natural gas storage safety program. We also met with the Environmental Defense Fund to understand its perspective on natural gas storage.

To examine the extent to which PHMSA has taken action since our 2017 report to continue developing its program for natural gas storage, we reviewed documents related to the program, including strategic plans, business plans, guidance and plans related to inspections, data on the number of trained inspectors and completed inspection counts, and workforce planning. We also met with PHMSA officials to discuss the program. We selected a nongeneralizable sample of seven states: four of the five states with the largest amount of working natural gas storage (Michigan, Texas, Louisiana, and California), one state in which PHMSA was conducting an inspection (Iowa), and two additional states that had

[6]We identified one incident, Aliso Canyon, in which nearby residents reported health symptoms associated with a natural gas leak. The reports we reviewed included Office of Environmental Health Hazard Assessment, *Summary of Expert Advisor Input Regarding Public Health Measures Taken for The Aliso Canyon Gas Leak,* Memorandum (Feb. 12, 2016); and Los Angeles County Department of Public Health, *Aliso Canyon Gas Leak Community Assessment for Public Health Emergency Response (CASPER)* (Los Angeles, CA: May 13, 2016).

considered partnering with PHMSA (Alaska and Colorado).[7] We met with officials representing these seven states to understand their perspectives on PHMSA's natural gas storage safety program and their efforts to partner with PHMSA and conduct inspections.

We compared PHMSA efforts on its natural gas storage program's workforce planning with our prior work on best practices in workforce planning. We also compared PHMSA's efforts on strategic planning with leading strategic planning practices that our past work has identified. For example, we have previously reported that requirements of the Government Performance and Results Act of 1993, as amended[8]—such as performance goals—that apply at the departmental or agency level can serve as leading practices for planning at lower levels, such as component agencies, offices, programs, and projects, within federal agencies.[9]

To describe what is known about the potential health effects from chemicals in stored natural gas, we used our literature search results that identified releases from 2000 through 2018 to determine whether there were any studies that empirically linked the releases of natural gas in storage sites with health effects; we did not find any such studies. Since no list of natural gas storage site composition exists, we took steps to identify the components and chemicals that may be present in stored

[7]This list is in order of capacity. We met with officials from the Michigan Department of Environmental Quality, Texas Railroad Commission, Louisiana Department of Natural Resources Office of Conservation, public health and regulatory agencies in California (the Department of Conservation's Division of Oil, Gas, and Geothermal Resources; the South Coast Air Quality Management District; and the Los Angeles County Department of Public Health), the Iowa Department of Natural Resources, the Alaska Oil and Gas Conservation Commission, and the Colorado Oil and Gas Conservation Commission. To better understand inspections, we accompanied PHMSA officials while they conducted an inspection at Redfield Storage Field in Iowa and met with officials from the Iowa Department of Natural Resources in conjunction with the visit. Our findings from the states we selected and officials we interviewed are not generalizable to states and officials we did not include in our review but provide illustrative examples of such states.

[8]Government Performance and Results Act of 1993 (GPRA), Pub. L. No. 103-62, 107 Stat. 285, *as amended by* GPRA Modernization Act of 2010, Pub. L. No. 111-352, 124 Stat. 3866 (2011).

[9]GAO, *Food Safety and Nutrition: FDA Can Build on Existing Efforts to Measure Progress and Implement Key Activities*, GAO-18-174 (Washington, D.C.: Jan. 31, 2018); *Coast Guard: Actions Needed to Enhance Performance Information Transparency and Monitoring*, GAO-18-13 (Washington, D.C: Oct. 27, 2017); and *Environmental Justice: EPA Needs to Take Additional Actions to Help Ensure Effective Implementation*, GAO-12-77 (Washington, D.C.: Oct. 6, 2011).

natural gas.[10] First, we identified operators of natural gas storage sites that represented 49 percent of the total storage capacity of all natural gas storage sites within the United States. We identified these operators by reviewing Energy Information Administration data on natural gas storage working capacity from 2016. Next, we obtained and analyzed each operator's Safety Data Sheet for natural gas and identified the components of natural gas.[11] Also, we reviewed the interagency task force report to identify any additional chemicals that may be present in natural gas, and we reviewed reports to identify chemicals that had been identified as present in the Aliso Canyon storage site release in 2015.[12]

We then met with and obtained documents from federal agencies that focused on public health and occupational health to determine the extent to which chemicals within natural gas storage had documented potential health effects. We reviewed databases from EPA and the Agency for Toxic Substances and Disease Registry to identify the health effects that may be caused by exposure to chemicals. We also reviewed documents from and met with officials from the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). To examine the health symptoms associated with the Aliso Canyon storage site leak, we (1) visited the storage facility; (2) met with officials from California state agencies, including the Los Angeles Department of Public Health, Division of Gas and Geothermal Resources, and South Coast Air Quality Management District to discuss the Aliso Canyon natural gas leak; and (3) reviewed reports related to potential health effects during and after the Aliso Canyon leak, including results on community health (2016);[13] indoor dust samples (2016);[14] and

[10]We include hazardous materials, such as hydrogen sulfide, in our review of chemicals.

[11]The Occupational Safety and Health Administration's Hazard Communication Standard (29 C.F.R. § 1910.1200) requires that employers maintain and make available to employees an SDS for each hazardous chemical in the workplace. The SDS is to include information such as the physical and chemical properties, accidental release measures, toxicological and ecological information, and handling and storage information.

[12]Los Angeles County Department of Public Health, *Aliso Canyon Gas Leak Community Assessment*; and South Coast Air Quality Management District, *Aliso Canyon Natural Gas Leak: Air Monitoring Results: Final Report* (Diamond Bar, Calif.: January 2018).

[13]Los Angeles County Department of Public Health, *Aliso Canyon Gas Leak Community Assessment*.

[14]Leighton Consulting, Inc., *Summary Report: Time Critical Residential Indoor Environmental Sampling: Aliso Canyon Natural Gas Incident, Porter Ranch Community, Los Angeles, California* (report prepared for the Los Angeles County Department of Public Health) (Irvine, CA: May 13, 2016).

air monitoring for methane, benzene, volatile organic compounds, and sulfur odorants.[15] Additionally, we reviewed reports from the Public Health and Environment Subgroup of an interagency task force that studied the Aliso Canyon incident and from the California Council on Science and Technology (CCST).

To describe what is known about the potential environmental effects of releases at natural gas storage sites, we reviewed documentation and data from EPA on greenhouse gas emissions in general and specifically for the Aliso Canyon natural gas leak in 2015, and we spoke with officials from EPA knowledgeable about the agency's greenhouse gas reporting program and inventory program. In addition, we obtained data from EPA estimating methane emissions from natural gas storage sites from 1995 through 2016. We assessed the reliability of these data by (1) corroborating these data with other published sources, (2) reviewing existing information about the data and the methods that produced them, and (3) interviewing agency officials knowledgeable about the data. We determined that these data were sufficiently reliable for the purposes of our reporting objectives, specifically to illustrate the relative size of the Aliso Canyon leak relative to estimated releases from natural gas sites. We identified an EPA report summarizing the amount of air emissions at the Aliso Canyon leak.[16]

For the Aliso Canyon incident in 2015, we reviewed reports that we identified through officials related to the release of methane, including results from air samples for methane taken by California agencies. We visited the Aliso Canyon storage facility and met with relevant California state agency officials. Also, through our literature search, we identified two examples of natural gas storage releases of chemicals into groundwater: the Playa Del Rey storage site in California and a storage site near Fort Morgan, Colorado. Additionally, we met with California Council on Science and Technology officials and reviewed the council's report, *Long-Term Viability of Natural Gas Storage in California*, to better

[15]South Coast Air Quality Management District, *Aliso Canyon Natural Gas Leak: Air Monitoring Results*.

[16]These programs include the EPA Greenhouse Gas Inventory program, which produces an annual report. *Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017*, EPA-430-P-19-001 (Washington, D.C.: Apr. 12, 2019). Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2015: Update to Storage Segment Emissions: Incorporating an Estimate for the Aliso Canyon Leak* (Washington, D.C.: April 2017).

understand how a natural gas storage incident could impact groundwater. We also reviewed recommendations made in an October 2016 report by the Interagency Task Force on Natural Gas Storage Safety.[17]

We conducted this performance audit from December 2017 to October 2019 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[17]U.S. Department of Energy, *Ensuring Safe and Reliable Underground Natural Gas Storage: Final Report of the Interagency Task Force on Natural Gas Storage Safety* (Washington, D.C.: Oct. 24, 2016).

Appendix II: Annual Inspection Targets Set to Complete the 5-Year Goal Set by the Pipeline and Hazardous Materials Safety Administration

The Pipeline and Hazardous Materials Safety Administration (PHMSA) has set a goal to inspect all of the approximately 400 storage sites over 5 years, from early 2018 to early 2023, according to PHMSA officials. To meet this five-year goal, PHMSA divided its workload of approximately 400 inspections over the 5 years it planned to meet its goal. PHMSA planned that its state partners would complete about one-quarter of the inspections while its federal inspectors would complete the remaining three-quarters of inspections. PHMSA's targets for inspections, and its actual inspections according to PHMSA officials, are illustrated in table 1 below.

Table 1: Annual Targets for Natural Gas Storage Sites Inspections Set by the Pipeline and Hazardous Materials Safety Administration (PHMSA)

Year	2018	2019	2020	2021	2022	2023	Total
Number of sites to be inspected by PHMSA inspectors	29	63	63	63	63	30	**311**
Actual inspections	35[a]						
Number of sites to be inspected jointly by state programs and PHMSA	12	17	17	17	17	9	**89**
Actual inspections	30[a]						
Total number of sites to be inspected (approximate)	**41**	**80**	**80**	**80**	**80**	**39**	**400**
Actual inspections	**65**						

Source: GAO analysis of PHMSA data. | GAO-20-167.

[a]For purposes of tracking progress toward its goal, PHMSA uses different annual timeframes to count inspections toward its goal between sites inspected by PHMSA and sites inspected by its state partners. PHMSA counts federal inspections on a fiscal year cycle (ending September 30). Specifically during fiscal year 2018, PHMSA inspected 35 sites; by the end of calendar year 2018, PHMSA inspected an additional 8 sites, according to PHMSA officials. In 2008, PHMSA officials counted 30 state inspections on a calendar year cycle (ending December 31).

Appendix III: Budget Request, Budget Authority, User Fee, and Obligation Information for the Underground Natural Gas Storage Program as of June 2019

The Pipeline and Hazardous Materials Safety Administration (PHMSA) funds its enforcement activities, such as inspections by PHMSA employees and grants to states, partially through user fees paid by operators of natural gas storage sites. However, PHMSA cannot collect user fees from operators unless expenditure of the fees is provided in advance in an appropriations act. Annually, prior to the start of the fiscal year, PHMSA submits a budget request to Congress that identifies the amount of budget authority it needs for the underground natural gas storage program. The annual appropriations act then provides for expenditure of a certain amount of fees and PHMSA is authorized to collect that amount in fees. PHMSA then obligates the fees it receives either (1) for federal activities, such as inspections by PHMSA employees, or (2) for grants to state governments, which carry out inspections at some natural gas storage sites. Table 2 provides details about the PHMSA's budget request, budget authority, user fees, and obligations.

Table 2: The Pipeline and Hazardous Materials Safety Administration's (PHMSA) Underground Natural Gas Storage Safety Program Budget Request, Budget Authority, User Fees, and Obligations as of June 2019

All figures in dollars

Fiscal Year	2017	2018	2019	2020
Requested	8,000,000	8,000,000	8,000,000	8,000,000
Appropriated	8,000,000	8,000,000	8,000,000	[a]
Fees collected from natural gas storage operators[b]	7,691,237	7,901,279	6,820,496	-
Obligations for PHMSA federal underground natural gas storage enforcement activities	2,498,273	1,237,996	[c]	-
Obligations for grants to state governments for state underground natural gas storage enforcement activities (total)	3,707,056	5,662,659[d]	-	-
Grant awarded to Pennsylvania	18,751	25,760[d]	-	-
Grant awarded to Minnesota	22,000	21,817[d]	-	-
Grant awarded to Illinois	422,350	685,022[d]	-	-
Grant awarded to California	3,243,955	4,090,919[d]	-	-
Grant awarded to Indiana	-	643,408[d]	-	-
Grant awarded to Louisiana	-	66,307[d]	-	-
Grant awarded to Oklahoma	-	79,858[d]	-	-
Grant awarded to Oregon	-	49,568[d]	-	-
Total obligations	**7,691,237**	**6,900,655**[d]	-	-
Budget authority remaining (fees PHMSA collected minus obligations)	**0**	**1,000,624**[d]	**6,820,496**	-

Source: GAO presentation of budget information reported by PHMSA. | GAO-20-167.

Note: All figures are as of June 2019. These figures have been rounded up to the nearest dollar.

[a]As of August 2019, PHMSA had not yet received an appropriation for fiscal year 2020.

[b]The Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2016 (Pub. L. No. 114-183, § 12(c), 130 Stat. 514, 523 (2016)) requires PHMSA to impose user fees on operators of underground natural gas storage facilities. PHMSA cannot collect user fees from operators unless expenditure of the fees is provided in advance in an appropriations act. According to PHMSA officials, these reported amounts do not include certain fees that are not available for use.

[c]As of June 2019, PHMSA had not yet made any obligations (such as awarding grants) using its fiscal year 2019 budget authority.

[d]As of June 2019, PHMSA had notified states of their grant award amounts and was issuing awards.

Appendix IV: Comments from the Department of Transportation

U.S. Department of Transportation
Office of the Secretary of Transportation

AUG 2 9 2019

1200 New Jersey Avenue, SE
Washington, DC 20590

J. Alfredo Gomez
Director, Natural Resources and Environment
U.S. Government Accountability Office (GAO)
441 G Street NW
Washington, DC 20548

Dear Mr. Gomez:

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is committed to protecting people and the environment by advancing the safe transportation of energy products and other hazardous materials that are essential to our daily lives. With the passage of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2016, PHMSA oversees the safety of facilities that store natural gas underground in depleted hydrocarbon reservoirs, aquifer reservoirs, and salt caverns—commonly known as underground natural gas storage facilities (UNGSFs). As of August 2019, there are approximately 400 active UNGSFs scattered across 31 States. In 2018, PHMSA established the performance goal to inspect all sites over 5 years—2018 through 2023—with assistance from its state pipeline safety agency partners. PHMSA's inspection program is designed to prioritize site inspections using a risk-based ranking methodology, and to determine operator compliance with PHMSA's minimum safety standards for natural gas storage sites.

PHMSA is pursuing its planned implementation of its new underground natural gas storage program, and has begun efforts to refine existing performance metrics to improve how PHMSA measures the efficacy of the program. Specific actions PHMSA has taken include the following:

- Published an Interim Final Rule (IFR) entitled "Pipeline Safety: Safety of Underground Natural Gas Storage Facilities" on December 19, 2016. The IFR revises the Federal pipeline safety regulations to address critical safety issues related to downhole facilities, including wells, wellbore tubing, and casing, at UNGSFs. PHMSA is currently addressing comments on the IFR and plans to issue a Final Rule in October 2019;
- Assessed industry alignment with the new regulations by reviewing a cross-section of facilities;
- Implemented a Fiscal Year 2018 GAO recommendation[1] on natural gas storage by defining levels of performance addressing core program activities. Also, instituted a process to refine performance goals each year using available data and budgetary resources to provide information on the outcome of our efforts to improve safety;

[1] *Natural Gas Storage: Department of Transportation Could Take Additional Steps to Improve Safety Enforcement Planning*, GAO-18-89

- Conducted a workforce assessment of the pipeline safety inspection program for interstate pipeline facilities covering a 5-year period—2020 through 2024—and determined that sufficient resources are available to inspect underground gas storage facilities without additional state program participation;
- Developed a curriculum and performance goal for training Federal and state partner inspectors to inspect underground storage facilities;
- Established inspection criteria for policies, procedures, and records, for operating, maintenance, and emergency preparedness practices;
- Encouraged all states who have not partnered with PHMSA to participate in the UNGS program for Calendar Year 2020; and
- Conducted a risk-ranking of the nearly 400 interstate and intrastate underground natural gas storage facilities currently in operation throughout the United States.

Upon review of the draft report, we concur with both recommendations to (1) analyze the factors affecting states' participation in inspections and its workforce needs on an ongoing basis to guide its budget requests; and (2) establish performance goals that demonstrate improvements to safety outcomes for the natural gas storage program, such as tracking reductions to incidents. The Department will provide a detailed response to each recommendation within 180 days of the final report's issuance.

We appreciate the opportunity to respond to the GAO draft report. Please contact Madeline M. Chulumovich, Director of Audit Relations and Program Improvement, at (202) 366-6512, with any questions or if GAO would like to obtain additional details.

Sincerely,

Keith Washington
Deputy Assistant Secretary for Administration

Appendix V: GAO Contacts and Staff Acknowledgments

GAO Contacts

J. Alfredo Gómez at (202) 512-3841 or gomezj@gao.gov

Staff Acknowledgments

In addition to the contact named above, Diane Raynes and Janet Frisch (Assistant Directors), Lee Carroll (Analyst in Charge), Ellen Fried, Cindy Gilbert, Jennifer Gould, Rich Johnson, Jessica Lemke, John Mingus, Katrina Pekar-Carpenter, Rebecca Parkhurst, Jeanette Soares, Sheryl Stein, Sara Vermillion, and Kiki Theodoropoulos made important contributions to this report.