SOIL GAS INVESTIGATION OF PORTER RANCH, CALIFORNIA RELATED TO ALISO CANYON GAS STORAGE FIELD

A Thesis

Presented to the

Faculty of

California State Polytechnic University, Pomona

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

In

Geological Sciences

By

Kenneth S. Craig

2017

SIGNATURE PAGE

THESIS:	SOIL GAS INVESTIGATION OF PORTER RANCH, CALIFORNIA RELATED TO ALISO CANYON GAS STORAGE FIELD
AUTHOR:	Kenneth S. Craig
DATE SUBMITTED:	Summer 2017
	Geological Sciences Department

Dr. Stephen G. Osborn, Ph.D.
Thesis Committee Chair
Geological Sciences
____

Dr. Jon Nourse, Ph.D.
Geological Sciences
____

Dr. Nick Van Buer, Ph.D.
Geological Sciences
____

ACKNOWLEDGEMENTS

This study was funded by a grant provided by Association of American Petroleum Geologists (AAPG) awarded to Kenneth Craig.

ABSTRACT

Aliso Canyon gas storage facility is located in the Santa Susana Mountains, California. The facility is depleted oil field, repurposed for gas storage in 1973. Porter Ranch is a residential community, adjacently located to the south of the facility. On October 23, 2015, a blowout was discovered at well SS-25. Several residential families have been relocated due to concerns of health risk due to poor air quality. On February 18, 2016, California state officials announced the leak was sealed. There is a significant public interest concerning the safety of this facility. Our investigation is to measure soil gasses in Porter Ranch, determine if stored gasses have migrated out of the storage field, and released through the soil into the atmosphere. Detected gasses will be characterized to determine biogenic, native thermogenic, or non-native thermogenic source. Our methods to survey soil gasses are the installation of soil gas wells, and testing of soil gasses. These wells will be located in Porter Ranch. Wells will be monitored weekly or as needed and methane values tested with a photoionization detector (PID).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Natural gas is a commodity that is currently necessary and has had significant production growth in the U.S in recent years due to the hydraulic fracturing boom (after ~2007). Concern for the potential contamination of shallow aquifers, soils, and the atmosphere has grown in parallel due to the increased proximity of production and storage operations with the public. Yet there still is little publicly available research addressing concerns and understanding the mechanisms of contamination. Natural gas is a combination of flammable gasses such as methane, ethane, propane, and butane. Small amounts of other higher chain hydrocarbons may be found as well. Natural gas is used for electrical power generation, heating application, and transportation. It is an essential constituent to our infrastructure. Most of this natural gas is produced from petroleum extraction operations, and shipped globally by railcar, trucks, ships, and pipeline. Natural gas is stored, often in depleted gas fields, which have been repurposed for storage operations. Some of these storage facilities can be large and in close proximity to residential areas, such as with the Aliso Canyon facility. The proximity may represent a safety concern. When there is a failure, the results can be potentially dangerous.

Aliso Canyon Gas Storage field is the largest gas storage field in California, and is directly adjacent to the community at Porter Ranch California. This facility experienced a significant natural gas leak from late 2015 through early 2016, which resulted in the declaration of a state of emergency by the state of California [1]. This thesis presents results from a soil gas survey (March 2016 through March 2017) in public areas directly adjacent and overlying the storage facility, testing for potential subsurface gas migration.

1.1 History of Aliso Canyon Gas Storage Field and surrounding community

Aliso Canyon Oil Field, also known as Aliso Canyon Gas Storage Field, is an oil and natural gas storage facility in the transverse Santa Susana Mountains, on the northern boundary of Los Angeles County, California. Getty Tidewater Oil Company first discovered the field in 1938. After the gas and oil was depleted, the field was repurposed into a gas storage field in 1973. Today, the field is the second largest such gas storage facilities in the United States, with a capacity of 86 billion cubic feet of natural gas storage capacity. The field is one of four such natural gas storage fields in southern California. [2]

Porter Ranch is a residential neighborhood that is directly south of Aliso Canyon. The community is immediately south of the Santa Susana Mountains, and north of the 118 freeway, in the San Fernando Valley of California. There are an estimated 30,571 residents in Porter Ranch [20].

1.2 Current Use of Field

There are 115 active wells in Aliso Canyon, with 32 producing wells. The oil and gas field continues to produce both oil, and natural gas, in addition to gas storage operations. There are three operators of the field, The Termo Company, Crimson Resource Management Corp, and Southern California Gas Company, (SOCAL Gas). SOCAL Gas is responsible for gas storage operations [2].

In 2009 SOCAL gas proposed an expansion of it’s storage field, with an upgrade of some of the equipment. The expansion project involved replacing two obsolete gas injection turbines, which resulted in an increased injection rate from 300 million to 450 million cubic feet per day. Many of the active wells had been installed more than fifty years previously. There have been concerns over safety that had been brought to the attention of the State Public Utility Commission in 2014 [21].

Aliso Canyon Gas Storage facility is part of a network of pipelines, and other gas storage fields that provide service to southern California. Aliso Canyon Gas Storage Field is the largest of four storage fields in southern California. Aliso Canyon Gas Storage field accounts for approximately 71% of the natural gas storage capacity for Southern California [2].

1.3 Timeline of the Gas Leak

On October 23, 2015, a gas storage well, Standard Sesnon 25 (SS-25) failed, and a rupture along the casing caused a blowout. Approximately 50 – 60 million cubic feet of natural gas per day was released [2]. The well had been originally installed in 1953, and been repurposed into a gas injection well in 1973. A blowout preventer had not been installed on the well, and a malfunctioning safety valve was removed, but not replaced. [2]

The well was finally sealed and shut down as of February 18, 2016, after several months of failed attempts. There have been several estimates of the total volume of natural gas released from this event. Table 1 includes the estimated methane release from different agencies.

Table 1: Methane Release from Aliso Canyon [Natural Gas Storage Safety Task Force (NGSS) US Energy Dept.]

Source	Method	Metric Tons Methane Released, estimated
Scientific Aviation	Aircraft	97,100
SoCalGas	Stored Gas Inventory	84,200
SoCalGas	Aerodyne tracer flux	86,000
State California, preliminary	Aircraft	94,500
State of California, updated estimate	Multiple sources	99,650

The volume of methane release is the largest single event methane release in US history [1]. The estimated emission from this event accounts for nearly one quarter of the polluting emission for the state of California for the year.

The residents of Porter Ranch may have been directly affected by the release of natural gas. 6,800 families were evacuated during this time, and 10,000 homes received air purification systems. Hundreds of complaints of health effects were made by the residents to state and local officials, and remains a concern today.

1.4 Geologic Background:

The Aliso Canyon oil field is located in the Eastern Santa Susana Mountains near Oat Mountain. The Geological USGS 7.5 min map [9] shows the geological structures of the region. The cross section from this map is referenced throughout this paper to indicate faults, and geological formations, and is seen in Figure 1. Major structures in the region are the Oat Mountain syncline to the north (Figure 1). Aliso Canyon gas field is in a half anticline. The Santa Susana Mountains are comprised of Miocene age shallow marine sediments. The surface geology at the Aliso Canyon field consists of Miocene and Pliocene age marine and non-marine Quaternary units. The Santa Susana fault is comprised of two sections, a northern strand, and a southern strand [7]. Both strands are near vertical at depth, and bend to a near horizontal to the south, at the surface. They are exposed along the topographical break at along Sesnon Blvd in Porter Ranch and may be conduits for natural gas migration from depth.

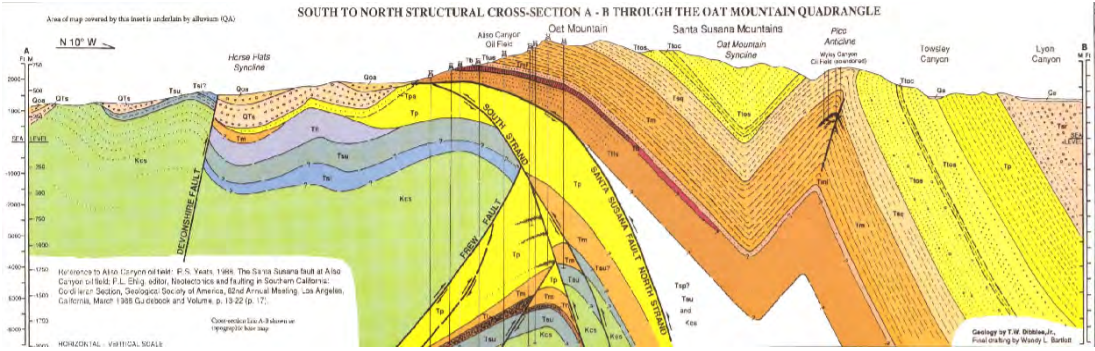


Figure 1: Oat Mountain Cross-Section

The reservoir rock of the Aliso Canyon Gas Storage Field is comprised of the Sesnon and Frew zones. These are the gas storage reservoirs for the Aliso Canyon field. The Sesnon zone is within the Modelo Formation, and is mid Miocene. The Sesnon zone is approximately 200 ft to 400 ft thick. The Sesnon Zone and is gray, medium to coarse-grained, well-sorted sandstone with interbedded limey siltstone and occasional pebbles [2]. The Sesnon zone is normally found at about 350 ft below the top of Modelo Formation [2].

The Frew zone is comprised of Eocene age marine deposits. The Frew zone is the upper member within the Llajas Formation, deposited on top of undifferentiated Cretaceous marine sediments. The Frew zone consists of coarse-grained, friable sandstone with occasional igneous pebbles and interbedded silty shale. The reported porosity is between 17 to 30 %. A Stratigraphic Column can be seen in Figure 2. Figure 3 shows the Aliso Canyon Structural Map. Figure 4 shows the A to A’ cross section. Figure 5 shows the D to D’ cross section [2]. Figure 3 indicates the location of wells in Aliso Canyon Gas Storage field [5].

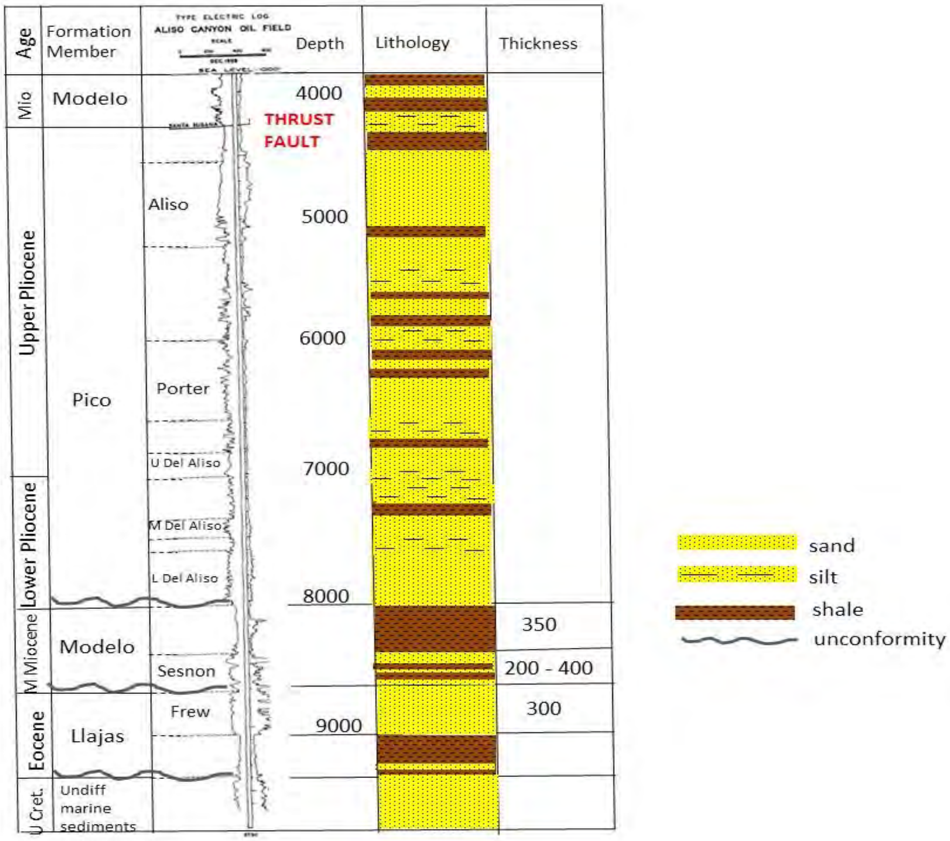


Figure 2: Aliso Canyon Stratigraphy [California Dept. Oil Gas and Geothermal Resources]

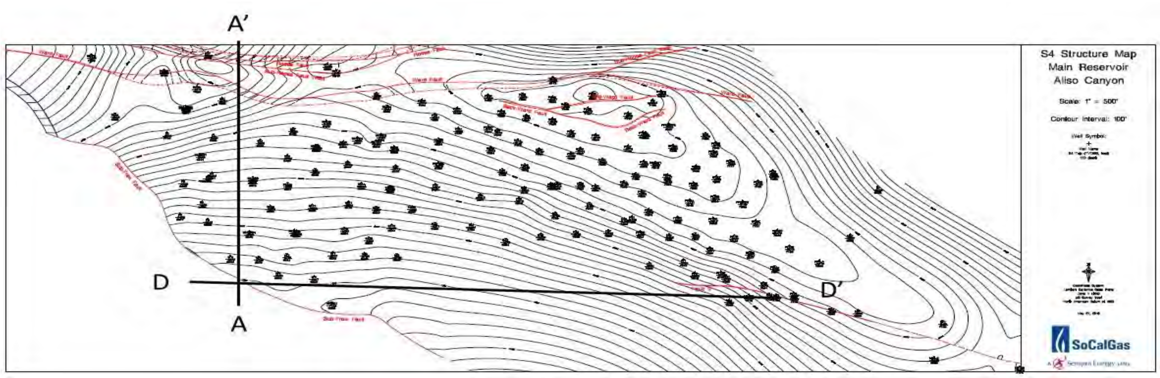


Figure 3: Aliso Canyon Gas Storage Geological Structure Map [DOGGR]

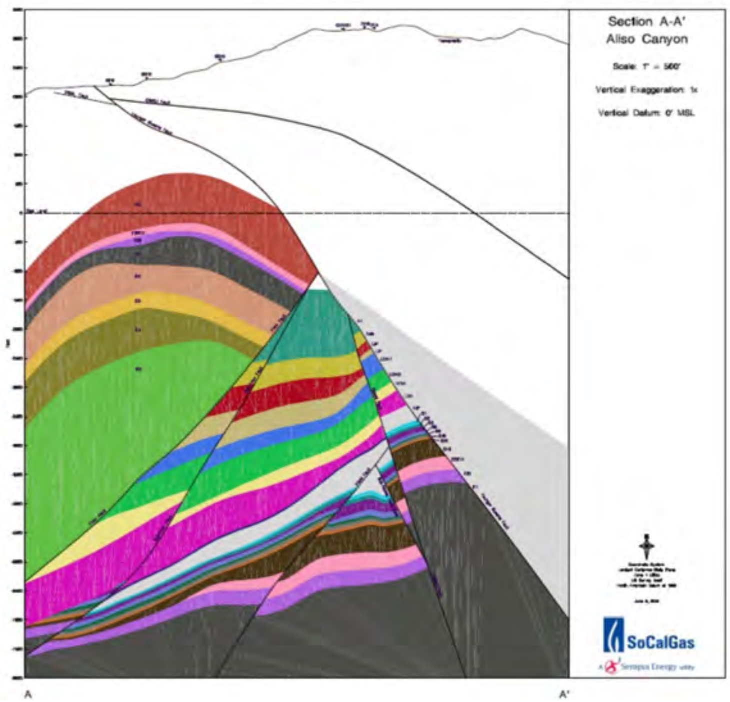


Figure 4: Aliso Canyon Gas Storage Field – A-A' Cross Section [DOGGR]

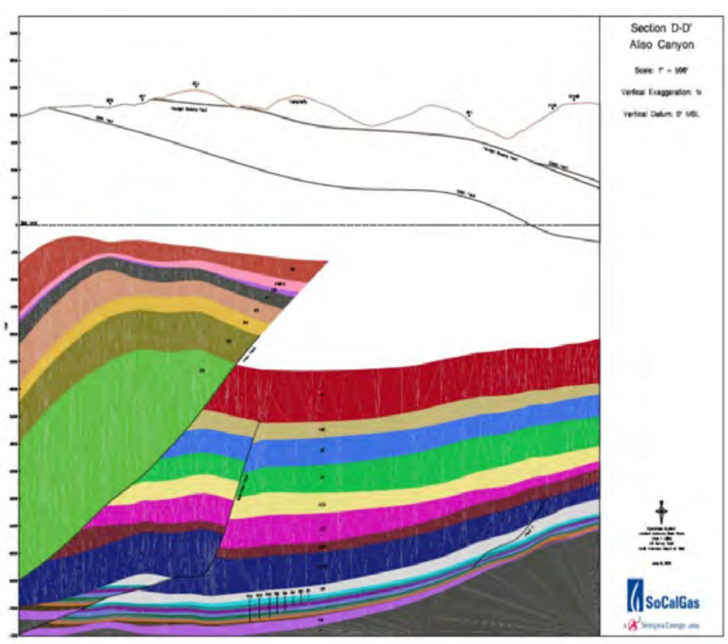


Figure 5: Aliso Canyon Gas Storage Field –D-D' Cross Section [DOGGR]

These figures demonstrated that Aliso Canyon Gas Storage field is an ideal location for gas storage. There is concern however that if containment is compromised however, there is a potential gas migration pathway through the subsurface, namely the permeable Modelo Formation, and the Santa Susana fault system.

1.5 Pre- and Post-Blowout Air Sampling (CARB, SCAQMD)

Due to odor complaints made by the residents of Porter Ranch and the surrounding communities, both the California Air Resource Board (CARB), and Southern California Air Quality Management District (SCAQMD) were called to action in Porter Ranch. The combined agencies developed a sampling plan to measure gasses in Porter Ranch, and the surrounding communities. The complaint map is seen in Figure 6 [1].

A 24-hour continuous monitoring of methane was set up at 8 locations in Porter Ranch. A map of the 8, continuous monitoring sites can be seen in Figure 7. The results from the continuous monitoring of methane are seen in Figure 8, and 9. From the results in Figure 8, there is a significant drop in atmospheric methane in February. This drop precisely coincides with the sealing of well SS-25. After this event, the results of atmospheric methane are near, or below a 4 parts per million (ppm) level. This data strongly supports that the methane in the atmosphere at Porter Ranch is a result of the well failure, and surface gas leak at well SS-25 [1].

When the results of figure 9 are examined however, there is evidence that there is some persistent methane that remains, and site 1 shows an increase in June and July 2016. The sites maintained by the CARB were removed as of July 26, 2016.

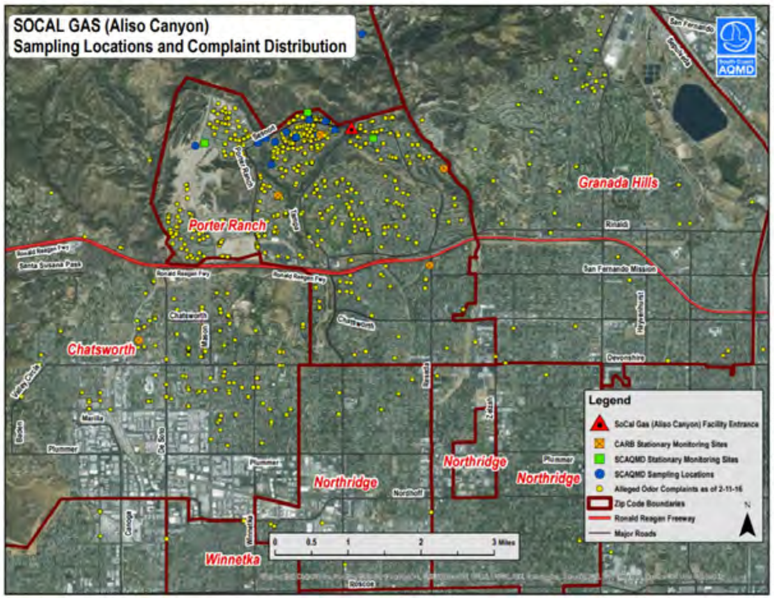


Figure 6: Air Complaint Map (AQMD)

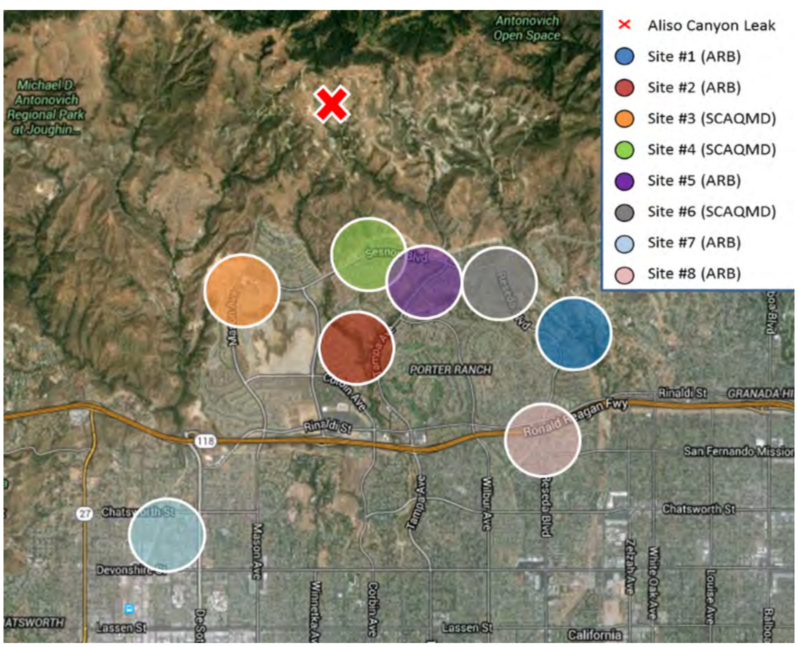


Figure 7: Continuous Monitoring Locations (AQMD, CARB)

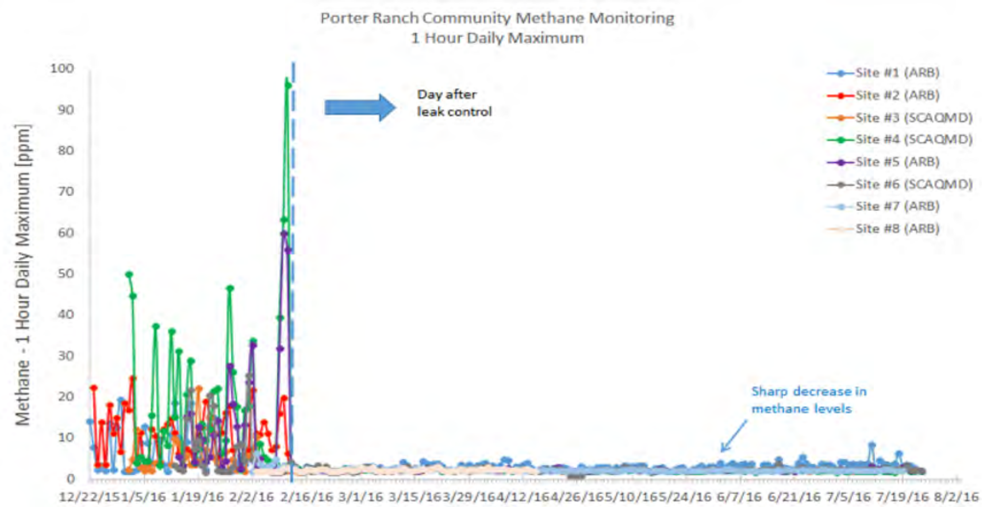


Figure 8: Methane Results From Continuous Monitoring Sites (AQMD)

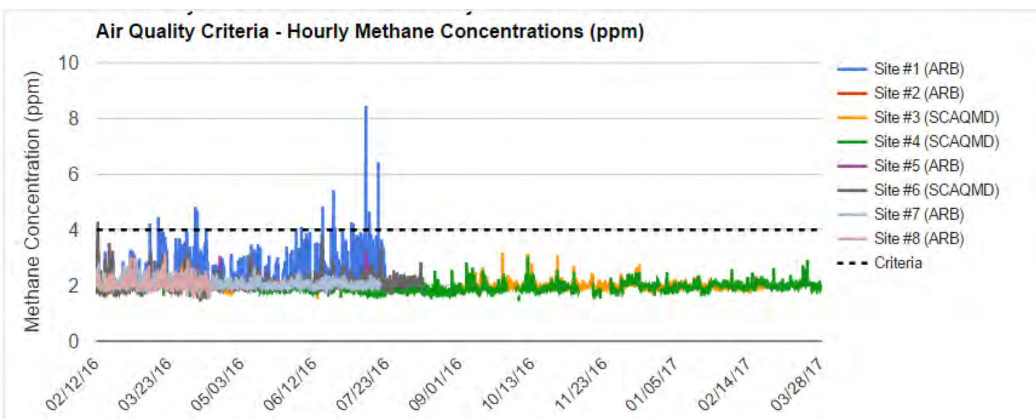
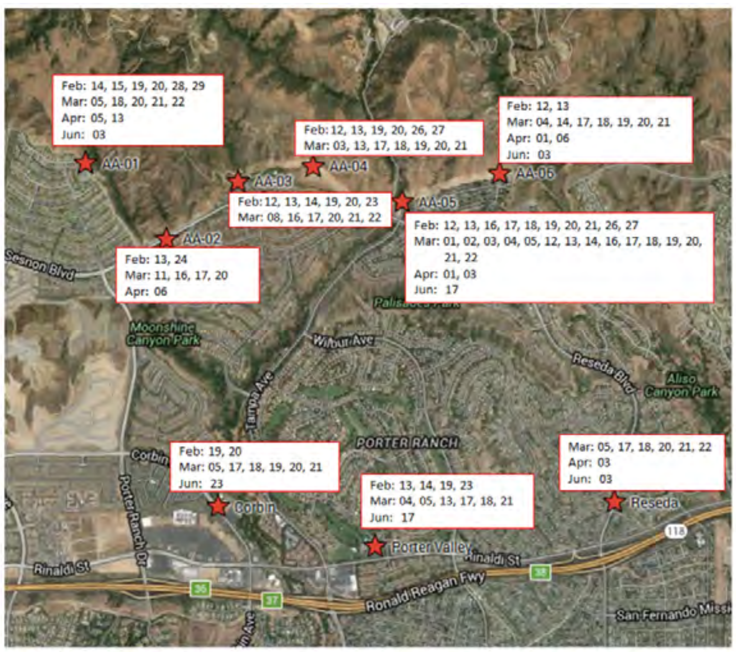


Figure 9: Methane Results From Continuous Monitoring Sites, 2016-2017 (AQMD)

In addition to continuous monitoring, 12-hour samples were collected throughout Porter Ranch by means of a 6-liter vacuum canister. These samples had been contracted to be tested for methane, and other volatile organic carbon compounds (VOCs'). Methane results indicate several dates where methane concentrations exceed the limit of 3 ppm as seen in Figure 10. What is of particular interest is that in the month of March, several samples indicate values that exceed 3 ppm. This is one month after SS-25 was sealed. It is difficult explain why methane would linger in this manner since methane is lighter than air. This data strongly supports the possibility of subsurface gas migration. What is of added interest, is that in addition to higher than 3 ppm methane results after February, but that there are instances where there are higher values further away from Aliso Canyon than closer, also suggesting the possibility of subsurface methane migration.



Map of 12 hour samples with methane concentrations >3ppm

Figure 10: Air Samples from 12-hour canister results Exceeding 3ppm Methane (AQMD)

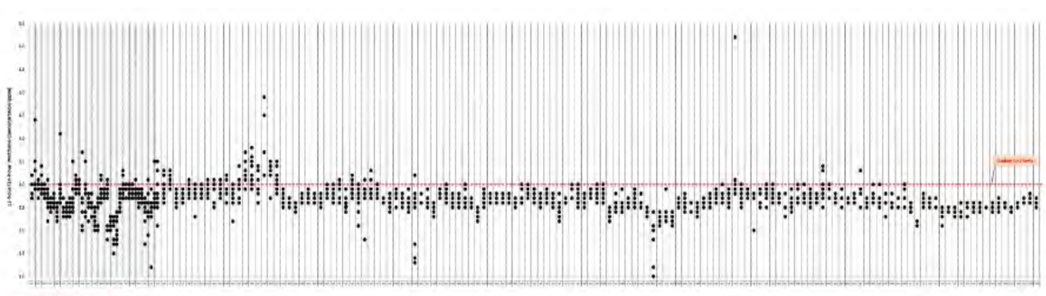


Figure 11: Air Samples from 12-hour canister results (AQMD)

A special purpose vehicle that has been outfitted with a Li-Cor methane monitoring system was used for air sampling on a mobile platform, a car. Weekly monitoring had been done by Li-Cor during the course of this investigation. The results can be found on AQMD website. Figure 11 indicates a hotspot of 45 ppm methane on January 11, 2016. On February 10, 2016, a hotspot of 58 ppm methane was shown in the same location. Considering the distance from well SS-25 being almost 2km, it would seem unlikely for methane to stay in a concentrated plume in the air moving down gradient. Results nearby the high methane hotspot should be rapidly diffused. A hotspot of 9.4 ppm was detected by Li Cor in a different location on July 8, 2016. This data suggests that a subsurface pathway may indeed contribute to methane in Porter Ranch.

A vehicle was outfitted with a LI-COR methane detector, and driven around Porter Ranch to collect mobile methane data. Results are made available to the public. Some of the maps are presented in FIGURES 11-14. These figures were obtained from AQMD [16].

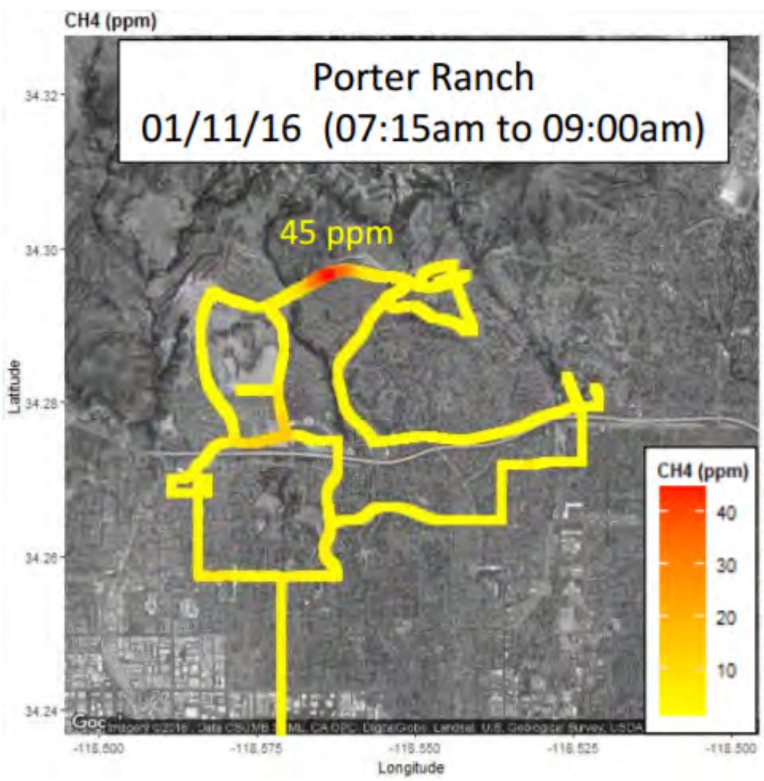


Figure 12: Li-Cor results, 01/11/16 [16].

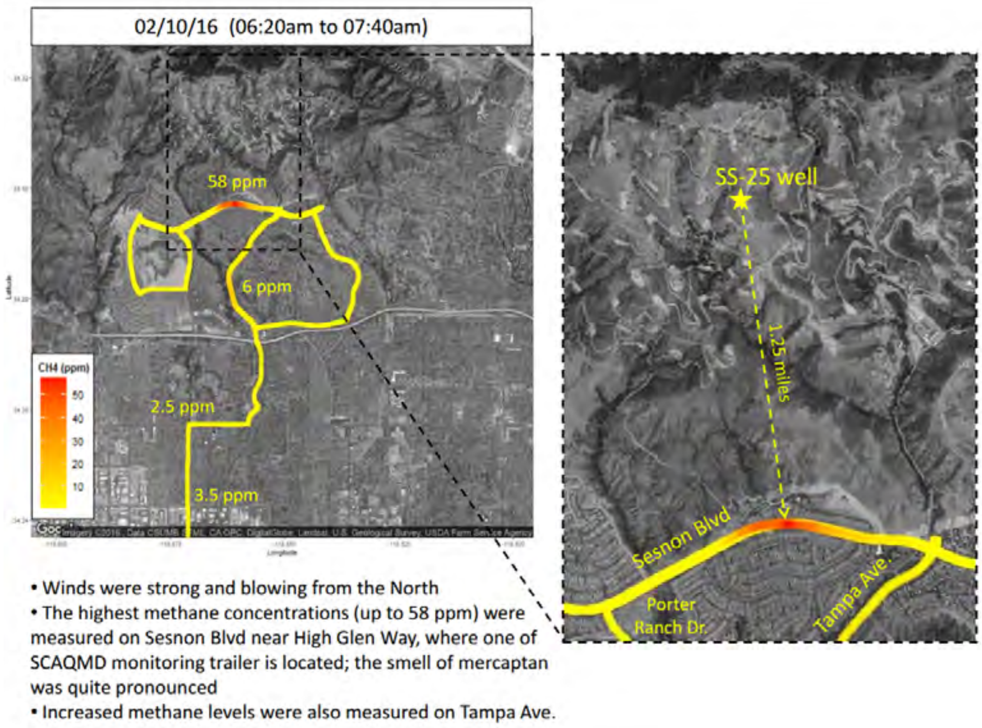


Figure 13: Li-Cor results 02/10/16 [16].

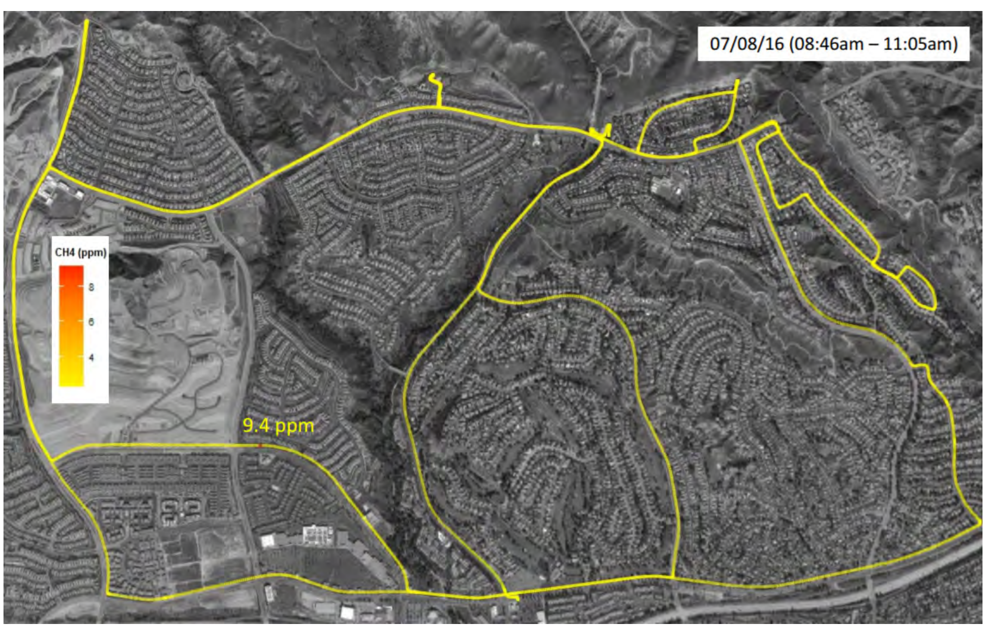


Figure 14: Li-Cor Results 07/08/16 [16].

12/07/16 (11:20am – 12:20pm)

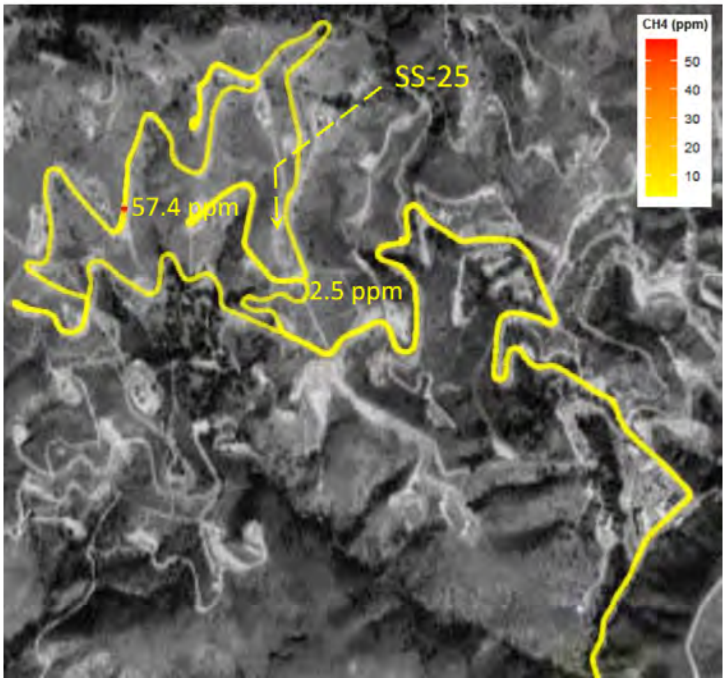


Figure 15: Li-Cor Results 12/07/16 [16].

From the figures 11-14, sporadically high methane results are measures, which appear to be highly localized.

1.6 Pre- and Post Blowout SOCAL Gas, Well Testing

SOCAL Gas, with Department of Conservation, and Department of Oil, Gas and Geothermal Resources conducted an extensive well safety program. This is in response is California Senate Bill 380. A total of eight tests were to be performed, in two stages. The first stage included a temperature and noise log to detect leaks. The temperature log will show a decompression cooling anomaly if there is a leak. A drop in temperature can also be caused by cooling water at a certain depth. In this case, a noise log must be included. A pressurized gas leak will have a noise, taken with the temperature log, is a good indication that a leak is present. All 114 wells have passed, or been repaired to pass in the first stage of testing [15].

The second stage of testing requires a work-over rig, to pull out the tubing, and test the casing. Additional testing includes a Casing Wall Thickness Inspection, a Cement Bond Log, a Multi-Arm Caliper Inspection, and a Pressure Test. All of these tests must be completed in order for the well to pass inspection [15].

The results of these tests are to be made available to the public as part of California Senate Bill 380. The nature of these tests requires specialized knowledge, which is largely beyond the scope of this investigation. The most useful information for this investigation is field pressure, obtained from the temperature logs [23]. The field pressure is a critical condition to subsurface gas flow. If the pressure is low, the gas may not be able to overcome the overburden, which can have the effect of a seal. When a fluid such as a gas is moving through a permeable solid medium such as sandstone, pressure is also important in overcoming surface resistance. Pressure gradient is a dominant variable in Darcy's Law: $Q = -KA\,(h_1-h_2)/L$, where Q is total volume discharge, K is permeability, A is the area, L is the distance measured, and h_1-h_2 is the difference in head, or pressure between two point along a flow path. When the field pressure decreases, the total volume discharge decreases, as well as the linear velocity.

SOCAL Gas is the operator of Aliso Canyon Gas Storage Field, and regularly conducts

Mobile methane detection by Li-Cor was also conducted in Aliso Canyon Gas Storage Field. Since access to this area is strictly prohibited, information is difficult to obtain. Since there are 114 wells in Aliso Canyon, and they have been in a state of testing, and repair since October 2015, it is difficult to determine a subsurface leak, from a wellhead surface leak. Figure 15 indicates a high concentrating of 57.4 ppm methane on December 7, 2016 [1]. This is of interest, because it indicates that while there may be a high concentration in Aliso Canyon Gas Storage Field, that methane plume does not seem to migrate through the atmosphere. This data supports potential subsurface gas migration into Porter Ranch.

The data from the several hundred of test documents is beyond the scope of this investigation. From the temperature survey logs however, field pressure data was recorded. SOCAL Gas was directed to reduce the working gas level to 15 billion cubic feet on January 21, 2016. The field was reduced, and a 2-day shut-in occurred as of March 11, 2016. This indicates a drop from 2460 pounds per square inch (psi) on December 9, 2016, to 1072 psi on March 11, 2016 [24]. There is no data available for field pressure for January and February of 2016. Since the inventory had not been authorized to be lowered until January 21, 2016, an extra value is used as a place mark in the data set, with the same value as the value for December. There is no data for February; however, two values for March 2016 have been included. There is no data for May, or June of 2016. There is a value for July however. Since the field inventory is typically not publicly disclosed, it is impossible to have an accurate field inventory graph. An estimated field pressure graph has been generated from data collected from well test reports seen in Figures 17, and 21.

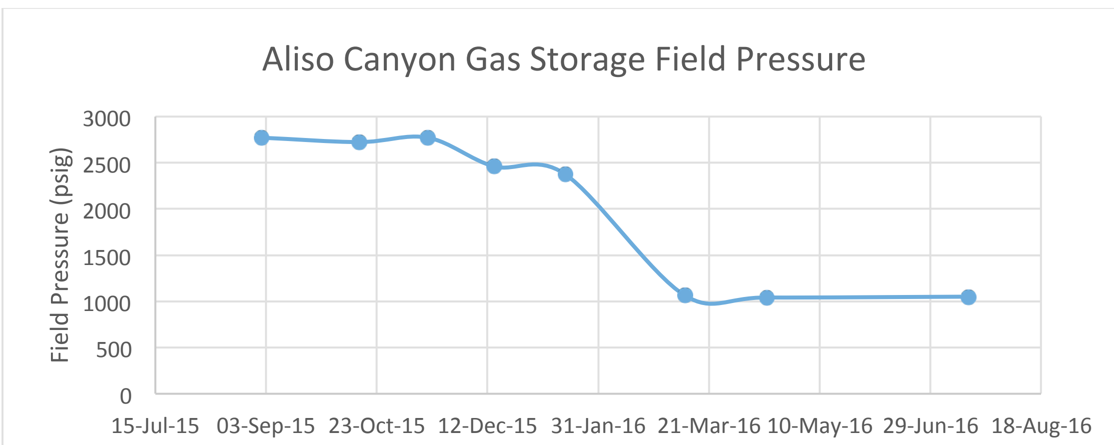


Figure 16: Aliso Canyon Field Pressure in PSI, [15]

The most significant of the results is that of the 45 wells that have passed complete safety inspection, 14 had required repair in order to pass. This indicates that not including SS-25, 14 out of 45 wells, or about one third fail a safety inspection [15]. This presents the potential that any one of these failed well may have contributed to a subsurface fugitive natural gas that had gone unnoticed.

1.7 Purpose of this Investigation

While several agencies have put forth significant effort in measuring surface gases associated with the gas leak at well SS-25, there has been surprisingly little discussion, or effort to measure subsurface gasses associated with the Porter Ranch community that is publicly available. The purpose of this investigation is to survey Porter Ranch, measure and record subsurface soil gasses, namely, methane.

This study addresses the following research questions:

- Are there elevated soil methane values found in the residential areas of Porter Ranch?
- Do the soil gasses found present a safety risk for the residents of Porter Ranch?
- Do the soil gasses found at Porter Ranch a result from natural occurrence, or as a result of activities associated with Aliso Canyon Gas Storage Field?

There is evidence of atmospheric gasses at Porter Ranch. This is supported by the data obtained by AQMD and California ARB by several methods. 8 stations in Porter Ranch were set up as 24-hour monitoring stations. Air grab samples were taken at several sites, and tested daily for VOCs, (Volatile Organic Compounds), and a methane monitoring system was placed on a vehicle that could be driven on the street, and measure methane levels in Porter Ranch. All of these methods measure atmospheric methane, and do not address soil gases, or a soil gas migration. Considering that Aliso Canyon Gas Storage Field is at an elevation of approximately 1,000 feet higher than Porter Ranch, and the fact that methane density is lower than that of both oxygen, and nitrogen, the occurrence of methane sinking from Aliso Canyon gas Storage Field into Porter

Ranch would seem unlikely. An investigation of soil gas migration from regulating agencies would seem reasonable, however I find no evidence that an investigation of this nature had been discussed, nor implemented publicly. For this reason, an investigation of soil gasses that may have originated from Aliso Canyon seems well justified.

Public safety is of the highest concern. There is the question as to what levels of methane are considered to be a public safety concern. At this time, the federal EPA has no limit of action with respect to methane. The state of California however has set state limits. California Air Resource Board establishes a limit of 4 ppm of methane of concern, 3 ppm is considered to be an actionable level [1].

On March 24, 1985, in the Fairfax district of Los Angeles, a methane gas seep from an underground source seeped into a Ross Department Store basement. When an employee punched his timesheet, the spark ignited the flammable gas, causing an explosion that blew out the windows, blew off the roof, and injured 23 people. Investigators at the time could not agree on the gas's origin. Possible origins include an old improperly capped well from the Salt Lake Oil field, methane producing bacteria called methanogens, or gas migration through a fractured fault system [11]. Gas seeps are still of great concern today in Los Angeles County, and present a fire hazard, which must be addressed in the interest of public health.

Concerning the origin of soil gas methane at Porter Ranch, there are three likely sources. The first is poorly capped wells in the Horse Flat Oil Field [7]. This is directly under Porter ranch. There is a possible source of methane if there are wells that have been improperly sealed, and allow methane to seep to the surface. The second would be methane producing microorganisms such as methanogens that produce methane as part of their metabolic function. The third source would be from gas migration from Aliso Canyon Gas Storage field, which is 2 kilometers to the north, and is communicated by the Santa Susana fault.

CHAPTER 2

METHODS

To address the research questions above (Section 1.7), the following methods are detailed here. Careful consideration was given to determine what testing methods would be need, and what could be done in order to support this investigation. The methods had to be within the capabilities of the participants of this investigation. It is also essential to gather relevant data, which is not being carried out or made publicly available by other agencies such as the AQMD, CARB, or DOGGR. It was determined that a series of shallow soil gas wells could be installed, and monitored on a regular basis, and the soil gases could be measured by means of a Photo Ion Detector, also known as a PID. The wells locations would have to be determined, as well as the number of wells.

2.1 Soil Gas Wells

The soil gas data portion of this investigation was collected over a period of 12 months. The design of the project was according to guidelines of the USGS, soil gas survey [24]. Well installation, and measurement was done with the assistance of Tyler Vale, an undergraduate student in the Geological Sciences Department at Cal Poly Pomona.

Well site locations were chosen based on a several factors. The first, consideration, is that the location must be in a public place, not private property. This prohibits entering into Aliso Canyon administrative boundary. The sites must be readily accessible, but also not readily visible to prevent tampering. This means that a no more than a 45 minute to go from station to station. The sites must be numerous enough to be representative at the scale of the Porter Ranch community. The number of eight sites was based on the number of 24-hour methane monitoring location by ARB, and SCAQMD. The site distribution of soil gas wells resembles that of the 24-

hour monitoring, and the 12-hour air lab samples. For the purpose of this investigation, the sample size and distribution is comparable to regulating agencies. Soil gas wells were monitored and recorded with weekly frequency for 6 months, and monthly, or bimonthly toward the end of the investigation. When the relative soil gas values were all less than 1 ppm, monthly monitoring was sufficient for the purpose of this investigation. The exact locations of the sites were largely based on the geology of the region. Sites near the Santa Susana faults and Devonshire fault was given priority. Proximity to abandoned wells was given a second tier priority. Locations where there is significant water from washes and streams was given third tier priority. This was done for the greatest likelihood of biogenic methane. In total, it would take about 4 -5 hours to collect samples from all eight locations, plus 3 hours of transportation, makes each day about 8 hours of time. I included a control well In Azusa. The purpose of this is to be used as a negative control. Since the well construction was with the same materials as the wells installed in Porter Ranch, and emplaced at the same time, if the PID was measuring any outgasses from the well material itself, it would be seen in the control results. The location of Azusa was chosen because of the lack of methane, natural gas, or petroleum activity in the area. Soil Gas well locations are recorded in Table2. The location of these wells is mapped, and can be seen on Figure 17. The Geological map indicated the location of the Santa Susana Fault, and the proximity to well sites, 1, 4, and 8. Figure 18 shows soil gas well in relationship to 24 hour monitoring sites maintained by AQMD and ARB.

Table 2: Soil Gas Well History

Well History				
Well Name	**Latitude**	**Longitude**	**Installation Date**	**Well #**
Aliso Park	34.27943	-118.52539	11-Mar-16	1
Receda	34.28696	-118.53842	11-Mar-16	2
Porter Ridge	34.29762	-118.54033	11-Mar-16	3
Guard Station	34.29529	-118.54033	11-Mar-16	4
Palisade Park	34.28987	-118.55708	18-Mar-16	5
Limekiln Park	34.27495	-118.56039	18-Mar-16	6
Sesnon Park	34.29001	-118.56962	18-Mar-16	7
Mason	34.30149	-118.57957	18-Mar-16	8
Azusa (control)	34.13971	-117.91434	11-Mar-16	0

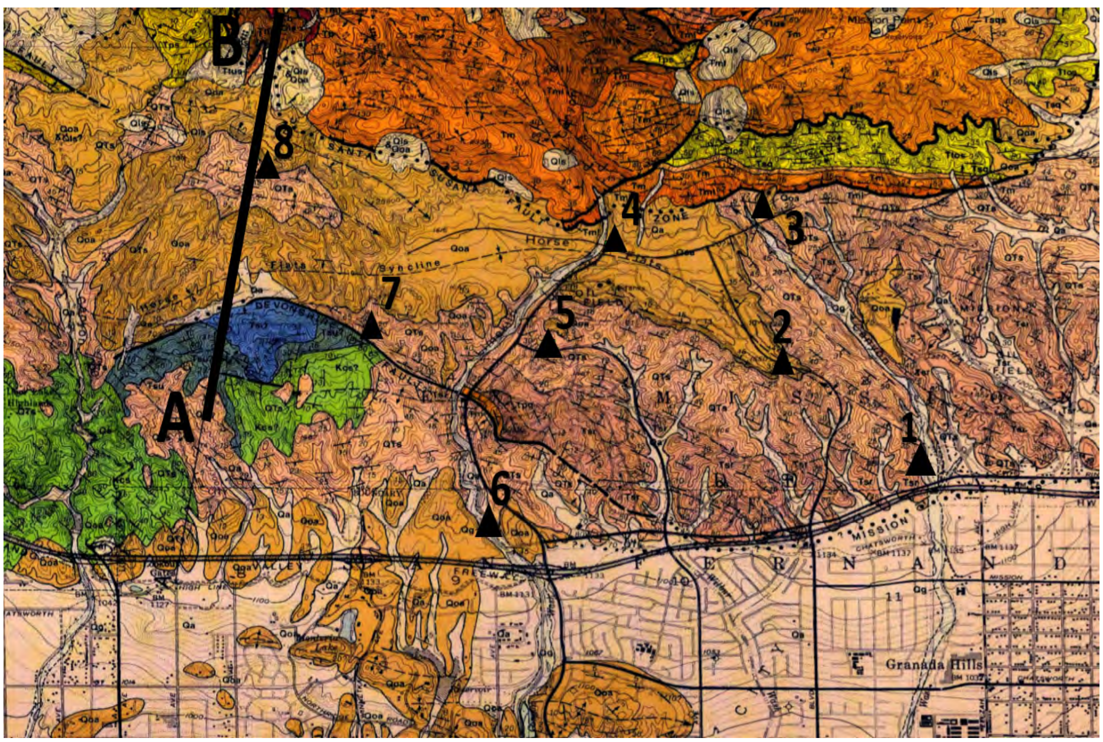


Figure 17: Soil Gas Well Locations (Base Map USGS 7.5 Oat Mountain, Dibblee).

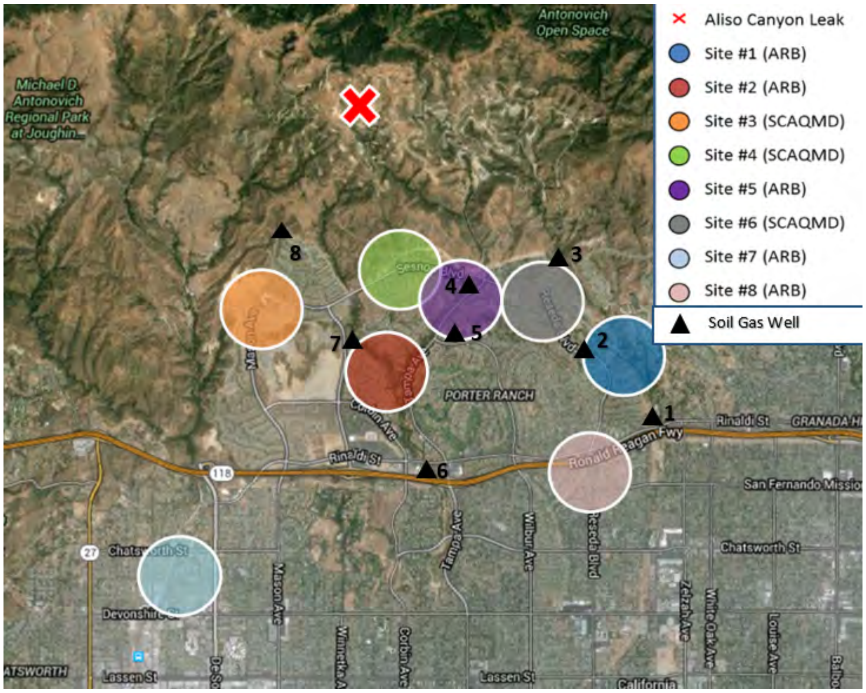


Figure 18: Soil Gas Well Locations and 24 hour Air Monitoring

Well design was based on soil gas wells from the USGS [25]. Each well consisted of a 36-inch hole dug with the use of a hand auger. In all wells, the depth was in the C-horizon of the soil. A 2.5-inch diameter 36-inch long ABS pipe with a threaded cleanout endcap was placed in each well as a sort of temporary casing. The bottom 6 inches had holes perforated for enhanced gas flow. Each well was cased in bentonite clay, to make an airtight seal, preventing surface air exchange. Each well was then covered with natural debris in order to prevent tampering. Well design can be seen in Figure 19.

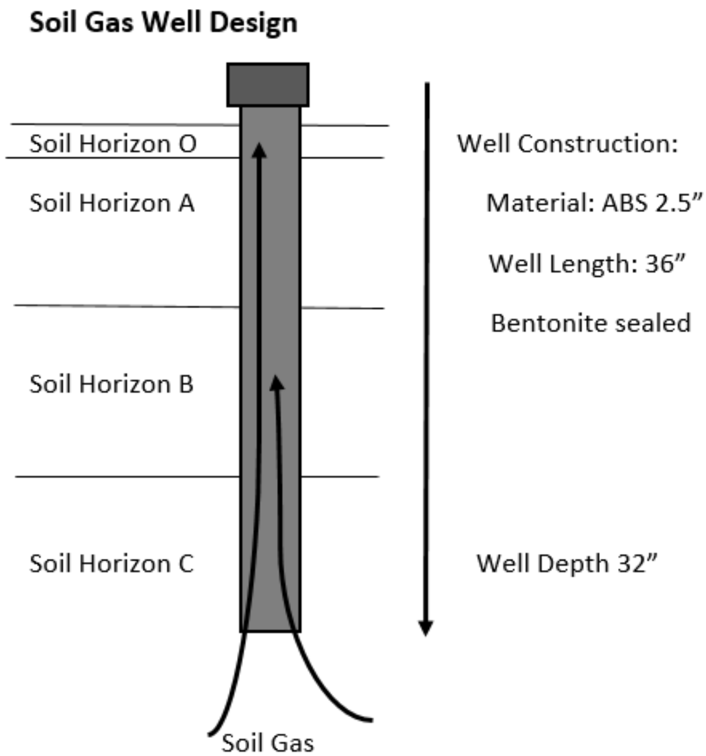


Figure 19: Soil Gas Well Design

Soil gases were measured by means of a Photo Ion Detector (PID). In this case, an ION tiger multi gas meter. The meter was calibrated according to manufacturing specifications, and set for measurement as methane, specifically. A 10-ppm methane standard from Airgas specialty gasses was used as a control to verify low ppm methane. An additional well was emplaced in Azusa Ca, and was used as a zero control.

Measurement of soil gasses included a 4 foot vacuum hose, with a threaded fitting to connect to a sampling well. Each time a soil gas well was measured, the PID was zeroed to surface air. This is to measure the soil gas as a function of the difference of the surface air compared to the soil gas. On reason for this is the limited battery life of the PID. If the PID meter was kept on from a zero ppm in Azusa, the transport to Porter Ranch, the battery would fail. It was determined that a relative soil gas measurement is not only sufficient, but even preferred.

It should be noted that at two locations, there was some tampering with the soil gas wells. There is no data for these dates, and the wells had to be repaired. It should also be noted that Starting in November 2016, private security namely the Pinkertons, began to take an interest into activities associated with this investigation.

CHAPTER 3

RESULTS

The results presented here are recorded from field data collected of the period of 12 months. The results are from 8 monitoring well site in Porter Ranch. An additional well was installed in Azusa, and used as a negative control (see also Table two). This is to verify that the PID was functioning correctly, and no instrument error high results would be recorded.

3.1 Soil Gas Results

The results of measured soil gasses as methane are recorded in Table 3.

Table 3: Soil Gas Methane Results (Note: numbered column headers are sample locations).

Soil Well Gas Data									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Control**
3/25/2016	4.5	3.4	6.2	3.4	2.4	2.4	2.1	1.6	0.1
4/8/2016	4	2.3	6.1	3.3	2.6	2.1	2	1.2	0
4/29/2016	3.5	2.1	5.7	3	2	1.4	2.5	1.8	0
5/6/2016	4.2	1.7	5.7	3.3	1.3	1.6	2	1.6	0.1
5/13/2016	4.3	1.4	6.3	3.6	1.5	1.7	1.9	1.5	0
5/20/2016	4.3	1.1	5.8	3.5	1.5	2	2.4	1.3	0.1
5/27/2016	3.9	1.2	4.6	3.3	1	1.8	2.1	1.6	0.1
6/3/2016	3.2	2.2	4.1	2.8	1.8	1.5	2.5	1.8	0.1
6/10/2016	3.5	1.8	5.2	2.9	1.9	1.7	2.1	1.6	0.1
6/17/2016	3.3	1.6	3.9	3.1	2	1.9	2.2	1.9	0
6/24/2016	3.1	1.1	3.5	2.8	2.2	2.4	2.3	1.9	0.1
7/7/2016	2.8	0.8	2.9	2.2	1.1	1.8	2.2	1.3	0
7/14/2016	2.7	1.1	2.7	2.1	0.8	1.9	na	1.5	0.1
7/21/2016	2.9	0.9	2.7	2.3	1.1	1.6	2.4	1.6	0
7/28/2016	3.1	0.9	2.5	2.1	0.9	1.6	1.9	1.5	0.1
8/4/2016	3.1	1.1	2.7	2.3	0.9	1.8	2.2	2.1	0
8/10/2016	2.5	0.9	2.4	2.1	0.9	1.7	na	1.8	0.1
8/18/2016	2.8	1.2	2.8	2.3	1.1	1.5	2.1	1.6	0
8/25/2016	2.7	1.4	3.8	2.2	1.3	1.6	2	1.9	0
9/2/2016	0.6	1	1.3	0.8	0.6	0.9	0.7	0.6	0
9/8/2016	0.7	0.7	0.9	0.8	0.6	0.8	0.6	0.4	0
9/15/2016	0.4	0.7	0.6	0.6	0.5	0.4	0.7	0.2	0
9/21/2016	0.2	0.8	0.4	0.9	0.8	0.8	0.8	0.6	0
10/4/2016	0.4	0.6	0.5	0.6	0.5	0.5	0.5	0.6	0
10/11/2016	0	0.5	0.3	0.5	0.2	0.1	0.4	0.3	0
10/19/2016	0.1	0.4	0.3	0.4	0.4	0.2	0.3	0.3	0.1
10/26/2016	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.1
11/3/2016	0.4	0.3	0.5	0.4	0.3	0.3	0.3	0.2	0
12/29/2016	0.1	0.4	0	0.1	0	0.1	0	0.1	0
1/26/2017	0.1	0	0	0.2	0.1	0.2	0.1	na	0
2/23/2017	0.1	0.1	0	0.2	0.1	0	0	na	0

The data is plotted into a scatter plot, with a trend line for each sample site. The soil gas results are measured with the surface air at each location as zero (relative methane concentration). It is important to remember that the values therefore obtained are not absolute methane concentrations, but in fact methane values in the soil higher that than that of the local air. The plot of these results can be seen in Figure 20. The results of the measured soil gasses are recorded for a period of one year, from March 2016 to February 2017. The importance of this time period is to record any seasonal trending. The fixed location of the sampling sites is measure local seasonal trending, if present.

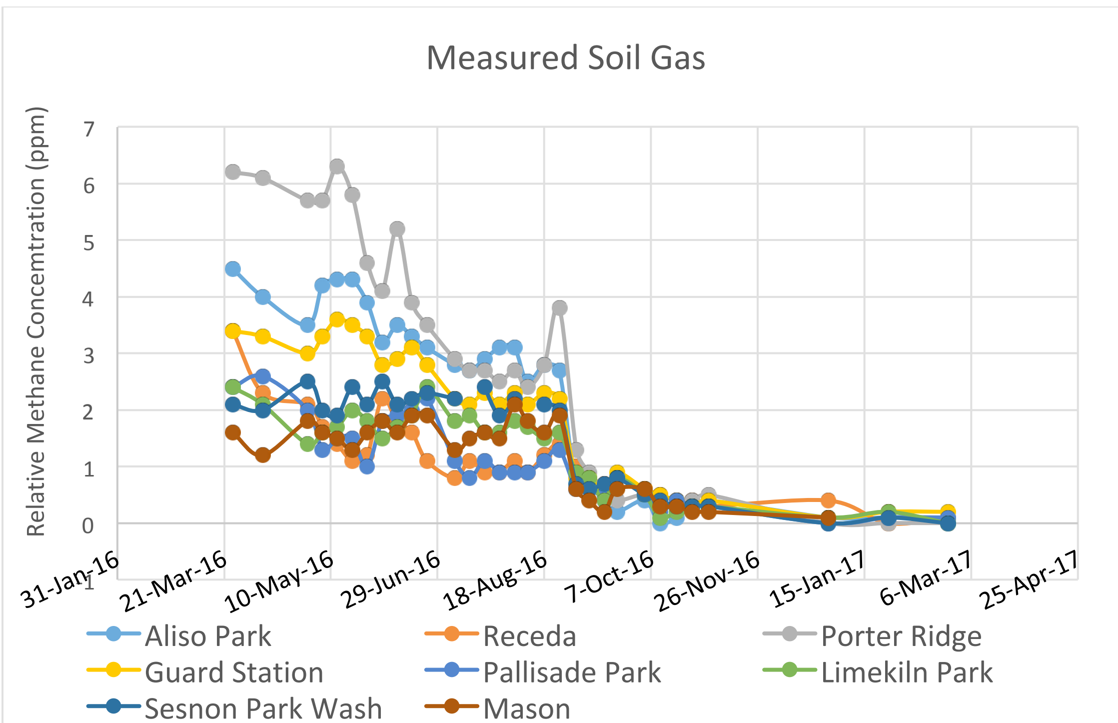


Figure 20: Measured Soil Gas

3.2 Comparison Results

Publicly available results from California Dept. Conservation, Dept. Oil Gas and Geothermal resources were used to obtain the data for Aliso Canyon field pressure. Of the 114 wells, there are hundreds of reports to be reviewed. The reports that were used for field pressure were from the temperature survey logs. A temperature survey log measures the temperature of the well with depth. Typically, the temperature will gradually increase with depth due to geothermal gradient. When there is a sudden drop in temperature however, this can be the result of a leak. The leak causes decompression cooling of the natural gas. The natural gas is the well is typically at a higher pressure that outside the well. When the well casing has a leak, it can be seen in the temperature log. A drop in temperature can also be caused by cool injected water or fluid in contact with the well casing. Therefore, temperature logs alone are not enough to determine a leak. In the report of the Temperature log, sometimes the field pressure is recorded in the report.

Air Quality Management District (AQMD), working with California Air Resource Board (CARB), was responsible for monitoring air quality in Porter Ranch. The reports from these agencies were used to obtain the information presented in this investigation.

CHAPTER 4

DISCUSSION

4.1 Gas Migration: Fairfax, Belridge, Hutchinson

A petroleum system is comprised of three primary components. First is the source rock. This is where kerogen deposits are heated, and oil and natural gas is produced. The second component is a migration pathway. The third component is an accumulation are, or a trap. This is defined by a seal rock with low permeability. A petroleum pathway is critical in migration of oil and gas from the source rock to the trap rock. We know that there are two migration pathways, the first being the primary permeability of the rock. The second is the fracture patterns of the rock (secondary porosity). Due the low density of gas and oil, migration must be up-dip, or have a vertical component.

In the case of Fairfax district, Los Angeles, the source and cause are still debated. The source at the time of the investigation was never determined. Potential gas sources could have been biogenic methane, natural seepage from a natural condition, or gas seepage related to petroleum drilling operations [11]. In order for the explosion that occurred, a lower explosive limit (LEL) of 5% must have been reached. The Upper Explosive Limit (UEL) is 15%. This is equivalent to 50,000 ppm (LEL). There is no data reported from Porter Ranch from 2016 that comes close to this value. In the case of the Fairfax incident however, that value must have been obtained. To this day, the Fairfax incident has several unanswered questions. A source was not identified, nor a migration pathway [11]. Wastewater injections are likely to have contributed to the methane gas leak however. See Figure 21.

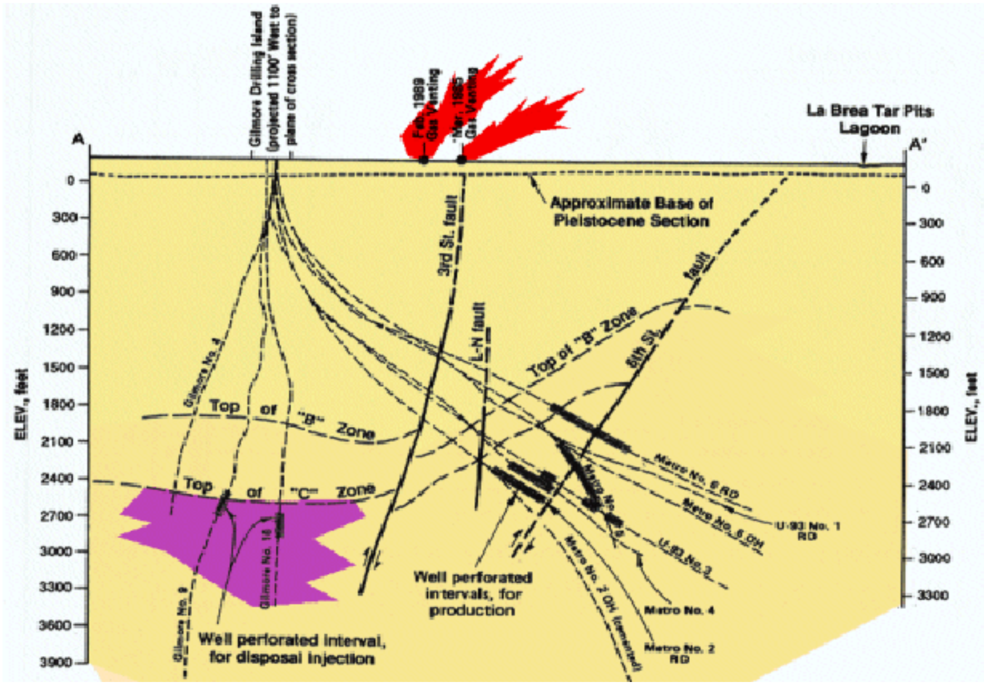


Figure 21: Fairfax district cross section [Stanford]

In the case of Aliso Canyon, all 115 wells are intersected by the Santa Susana fault. The Santa Susana fault has actually two faults, one being the northern strand, the other being the southern strand. Together they are referred to as the Santa Susana fault system. The fault is near vertical to the north, with a bend that is near horizontal to the south. This can be seen in cross section see Figure 22.

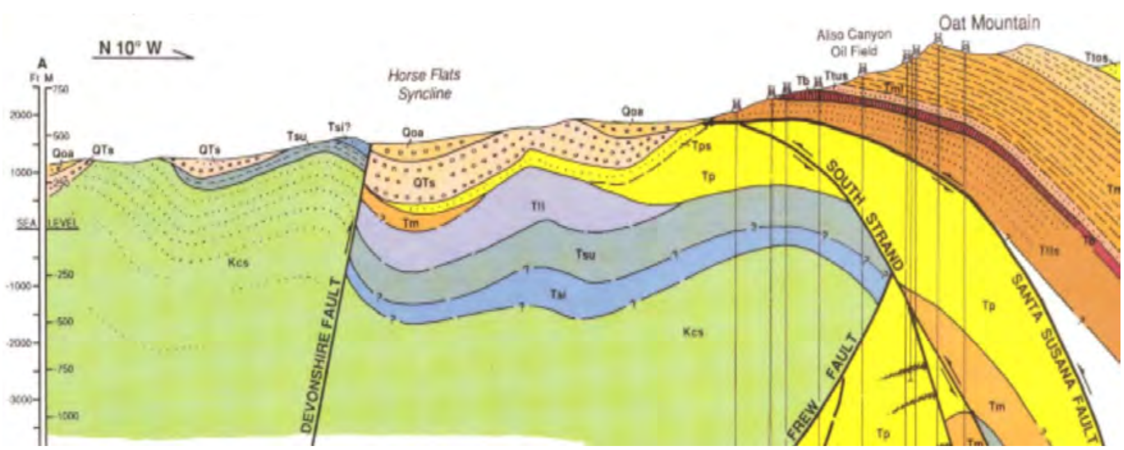


Figure 22: Aliso Canyon Cross Section

The fault system is a thrust fault, with an estimated slip rate of 5 – 7 mm/year, [8] and considering the proximity to the Pico thrust, and the Elysian Park fault, there is concern that the Santa Susana fault can have a shear stress on all of the wells. An example of this is the Belridge oil field. In this case, the wells intersected by a fault have undergone a dogleg [13] deformation strain in the casing, due to the combination of stress of the local fault system, and land subsidence [14]. An extensive safety inspection of the wells at Aliso Canyon, however, does not show this type of strain in the casing. Repair logs for the 14 repaired wells at Aliso Canyon are likely due to corrosion. If there was ground activity in the Santa Susana fault system, wells would likely have been sheared in the Northridge quake 1994, of the Sylmar quake in 1971 [8]. Neither of these events had catastrophic failures at the time. The potential for a catastrophic failure still may exist,

The Santa Susana faults do provide a potential gas migration pathway for fugitive gasses from Aliso Canyon to Porter Ranch, if the casing, is ruptured. The faults provide a highly permeable fault breccia that may be a migration pathway. If this is the case, this can support the occasionally high methane results encountered by ARB, and SCAQMD near this fault and perhaps explain results presented here in. The Surface exposure of the Santa Susana fault is very close to the sampling sites. If the methane was migrating through the Santa Susana fault system, some of the methane may be measured by these monitoring sites.

Upon initial review of Figure 8, results within one-day drop from values, which exceed 40 ppm methane, to values, that are less than 4 ppm. It would be reasonable to attribute this to methane movement in the air from Aliso Canyon to Porter Ranch down gradient. Methane has a density of 0.656 kg/m^3 STP [CRC, 2015]. Air has a density of 1.23 kg/m^3 STP [CRC, 2015]. This density difference indicates that methane tends to rise in air, with the exception of turbulent wind conditions. The local wind conditions, with close proximity to the Santa Susana Mountains may have a turbulent flow pattern which accounts for the atmospheric methane transport from Aliso Canyon to Porter Ranch.

Consider Hutchinson Kansas, January 17, 2001. A Yaggy gas storage facility reported a loss of pressure in one of the wells on site. Hours later, there were gas explosions at Hutchison Kansas. The distance travelled for the gas was about 8 miles in a time of 2 hours. The pressure of the gas wells at Yaggy was about 600 psi. There is a shallow up-dip of 3 to 4 degrees. The migration at Yaggy occurred at a rate of nearly 4 miles per hour (6 km/h). Considering that there is about 2km on the surface from Porter Ranch to Aliso Canyon, and 3 km if the Santa Susana fault is traced, Yaggy gives an indication that the results reported by SCAQMD, and ARB of methane concentrations dropping within a day, the methane migration may have traveled along a subsurface route in that time [12]. The example of Yaggy is an example of how little we know about the rate subsurface gas migration. See Figure 23.

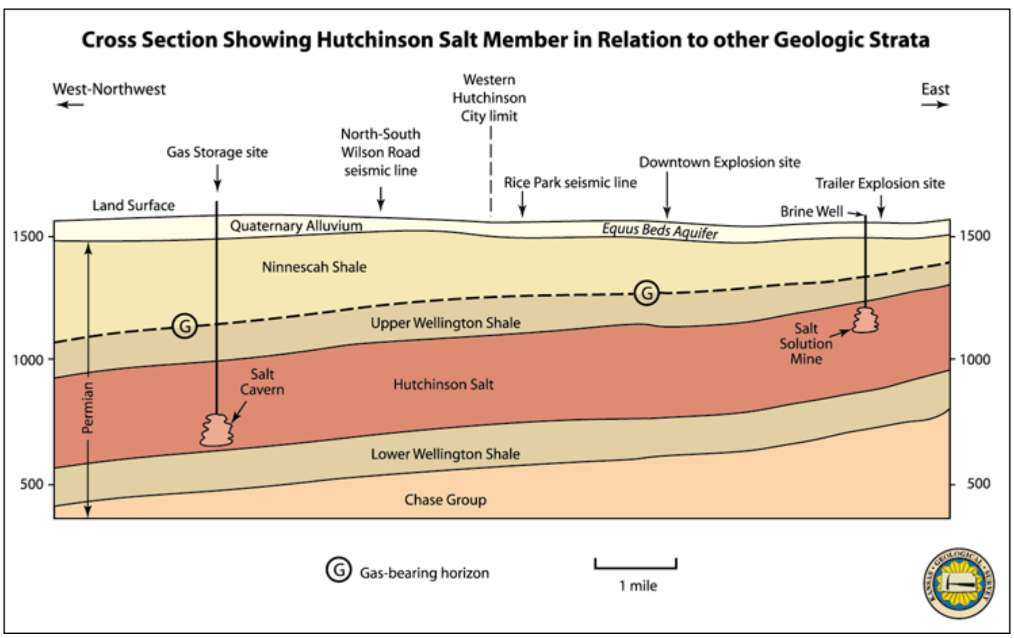


Figure 23: Hutchinson Kansas Cross Section

4.2 Soil Gas Origin

A significant purpose of this investigation is to determine the origin of soil gasses detected. Initially, this investigation was to determine if soil gasses found were a natural occurrence, or a result of activities associated with Aliso Canyon Gas Storage Facility.

Naturally occurring methane can come from one of two primary sources. The first are the natural seeps of natural gas that are from petroleum deposits at depth (~1000's m). The second main source of methane is produced by microbes at shallow depths (less than ~400 m) [18]. Naturally occurring petroleum gas formations are found in the Modelo formation, which is precisely why there is a gas and oil field in Aliso Canyon.

Methane is produced by certain types of microorganisms, namely methanogens. These microorganisms are a type of bacteria that produce methane as part of their metabolic function. This type of methane production is common in landfills, and waste treatment facilities. These methanogens tend to be sensitive to temperature and available water. In a naturally occurring system, these methanogens are subject to seasonal effects.

A conventional oil and gas field has effectively three primary components. The first component is the source rock for the hydrocarbons. This is where carbon containing kerogen deposits are heated by burial and liberated from the rock. In the case of the Modelo formation, this is an organic-rich shale rock. The second principle component to a petroleum system is a gas and oil migration pathway. This is typically a highly permeable rock, which allow oil and gas fluids to migrate. The third component is a trap. This is a structure, which allows the petroleum products oil and gas to be stored. There are several types of structural traps. Fault traps and Anticline traps are some of the most common. The trap usually is comprised of a high porosity rock such as sandstone, which acts as a medium to hold (reservoir) and transmit the oil and gas. The trap must also consist of a low permeable rock, such as shale, or an evaporate, which prevents the low-density oil and gas from escaping to shallow zones and into the atmosphere. Under this low permeable rock, also called a cap rock is where the naturally occurring petroleum is stored. Aliso Canyon gas storage field is essentially a half anticline, fault trap conventional petroleum system. To the north, there is a large syncline that has no cap rock. In this area, natural gas seeps out of the ground forming tar deposits on the surface and natural gas can be seen bubbling in the streams of Towsley Canyon.

To the south is Porter Ranch. There is an old oil field just under Porter Ranch. This field is known as the Horse Meadow oilfield, which gets its name from the horse flats. There is a small anticline in the area that extends to the Santa Susana fault to the north, and Devonshire fault to the South. The anticline is comprised of Eocene Llajas formation, and Paleocene Santa Susana formation. This oil field is abandoned. There is the possibility however that methane could seep from either the formation, or from abandoned wells.

Another naturally occurring source of methane is from Aliso Canyon gas and oil field. Since there are known petroleum seeps to the north in Towsely, there is a possibility of naturally occurring seeps in the south, along the Pico formation, into Porter Ranch. The gas migration pathway would likely be the Santa Susana fault. Both of these represent potential natural occurring methane sources.

Methane in the soil can also be the result of activities associated with Aliso Canyon Gas Storage Field by methane migration from depth or production by soil microorganisms. The Most obvious example of possible gas migration is when there is a well failure such as SS-25. In this case, there is a subsurface rupture, which results in a quantity of natural gas being vented into the atmosphere. There is however the likelihood of a subsurface leaks as well. When a casing is ruptured, as in the case of SS-25, the annulus becomes pressurized, and the casing no longer contains gas, or the cap rock for that matter. The gas can freely migrate through permeable rock, such as fault breccia, and follow a low-pressure path, typically up. This gas is called fugitive gas. When this occurs, the different components in the natural gas, such as methane, ethane, propane, and mercaptans, do not travel through the rock medium at the same rate. The smaller molecule, such as methane will travel fastest. This is a similar principle to Gas Chromatography. In Gas Chromatography, a mixture of gasses are injected into a capillary column, called a solid phase, typically 30m long, with an inner diameter of about 0.25μm (about the diameter of a human hair), with a polymer coating such as a polyethylene glycol 3350 which retards the linear velocity of larger, and more polar molecules. There is a gas phase, which is called a carrier gas that helps move molecules through this solid phase. When the molecules exit the solid phase, there is a detector, which responds to the presence of the molecules. In Gas Chromatography, the first molecules detected typically are small, non-polar molecules such as methane, and larger molecules become detected later. Some molecules, which are larger such as C20 oils, or strongly polar molecules such as sugars may remain in the column, and never become detected. In the case of fugitive gas, the earth is the solid phase, and the gas is well, the gas phase. The different minerals in the earth will carry a charge, such as clay and act as a polar retardant. If this gas seeps to the surface, often the ratio of ethane, propane, and methane is not the same as the initial natural gas. This type of fugitive gas does not need a blowout in order for this to occur. Any leak in the casing can allow gas to become fugitive. Considering that 14 out of 45 wells at Aliso Canyon required repair after safety inspections, any one or all of these could have been allowing natural gas to become fugitive. There are an additional 69 wells that are still in the process of being tested, and one well permanently shut down as of May 2017.

Another potential source of methane is in the groundwater. Aliso Canyon, like most petroleum operations, uses high-pressure injection wells to stimulate gas and oil recovery. This water can become saturated with methane, and become mixed with groundwater. The saturation point of water at 20 ^oC and 1 atm is 29ppm. This value can be higher with higher pressure, and lower temperature. Water at a temperature <20 ^oC will have a higher methane saturation value (>29 ppm) at 1atm. Water at 20 ^oC at a higher pressure (>1atm) likewise has a higher saturation point (>29 ppm). Therefore if 20 ^oC water at 1atm is at 29 ppm methane, and the water is heated, the methane saturation point is decreased, and methane will become released. A similar phenomenon can be witnessed by bringing carbonated water to a boil. Much of the carbon dioxide in the carbonated water will become driven off due to the change in saturation point of the water at boil. If saturated cold, high-pressure water is saturated with methane, and moves to a higher temperature, lower pressure condition, methane can outgas from this system. This is a potential pathway that should be considered. An investigation of this type is beyond the scope of this investigation, as water samples from monitoring wells from Aliso Canyon would be required. However, degassing of migrating waters may be an important reservoir of methane in shallow aquifers and soils

In the course of this investigation, another potential source of atmospheric methane became apparent. In the case of high results from SCAQMD mobile methane detection, it was observed that several of the vehicles used in operations Aliso Canyon use CNG as a fuel. There is a security gate on Tampa and Sesnon Blvd where vehicles are idled before security clearance is given. CNG or Compressed Natural Gas vehicles us compressed natural gas as a fuel. There have been cases where this CNG has been found to be leaking due to poor connecting fuel lines. If “the car” was near a CNG vehicle that had a leaking fuel tank, this may have a very high anomalous methane value. The likelihood of this type of methane origin may seem remote, however, it should remain as a possibility.

There is the possibility that propane, butane, and other greater than air density hydrocarbons had infiltrated the soil from the air during the period of October 2015 to February 2016. This scenario is unlikely due to the low propane and butane results presented by SCAQMD. Values for propane and butane were measured in tens of parts per billion by volume and are unlikely to permeate though soil horizons O, A, and B.

The soil methane data obtained in this investigation indicates a decreasing trend from March 2016 to August 2016. A sharp decrease in methane values occurs from August 2016 to September 2016, with very low values until February 2017. See Figure 24.

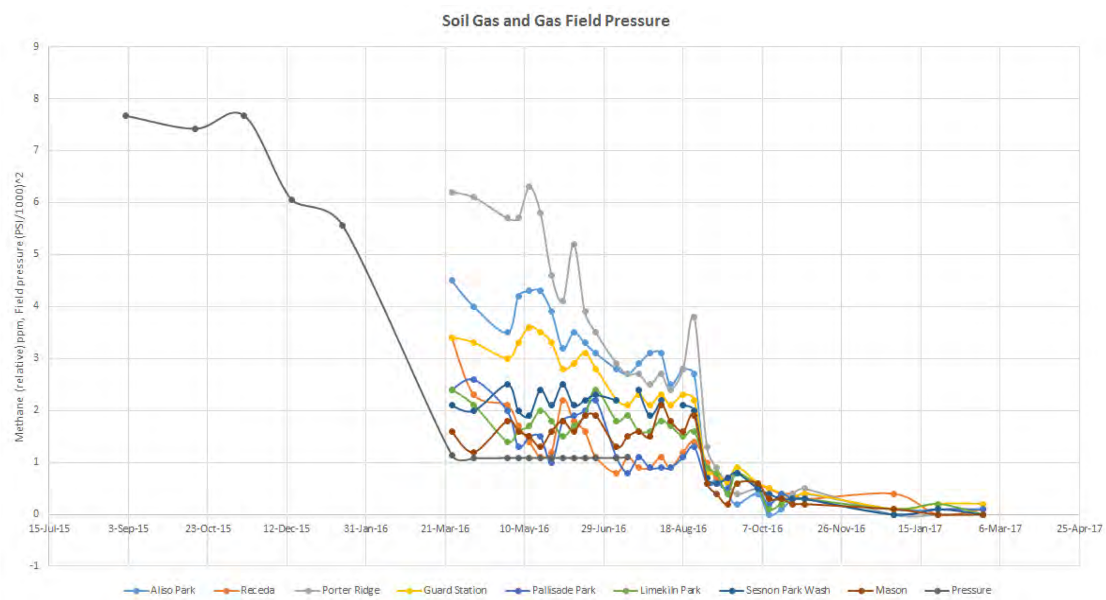


Figure 24: Soil Gas and Field Pressure

The first to note is that none of the values exceed 1ppm after September 2016. From a safety point of view, with respect to these locations, there is not a high enough of a methane concentration to be considered a safety risk during the sampling period.

The second point to take from the data is that the measured methane concentrations in the soil do not appear to have been affected to seasonal changes. If seasonal effects were to have been producing the measured methane, a sigmoidal plot would have been expected. In other words, if seasonal were responsible for the methane, values obtained, then there would be an expected return to measured values. If, for example, biogenic methane was produced in the soil, retained in the water, and released in the summer, which is plausible, then low methane values would be expected in the spring, high values in the summer, and a return to low values in the fall. This is not what is observed. What are observed are high values in the spring, with a decrease in the summer, near zero values in the fall, and winter, and near zero levels in the following spring. Seasonal effects would most likely have been supporting biogenic methane production. Biogenic methane production is sensitive to temperature, and water, and oxidized carbon availability. Although the data does not support a biogenic origin of measured methane beyond trace/background levels, it is assumed that some of the measured methane is biogenic, yet the data presented here indicates that biogenic methane is not the primary source of high methane concentrations.

The third point to consider is that the methane values are not constant over the course of a year. If natural petroleum seepage from abandoned leaking gas wells were to be the source of the methane, the values would be expected to remain relatively constant throughout the year. For example, if an abandoned well was leaking, it would likely be at a constant rate, such as a leaking water hose. If such methane was detected, the rate would appear to be consistent throughout the year. This is typical of soil methane measurements from other gas storage fields, which are typically 2-3 ppm methane.   The data in Figure 24 does not support leaking abandoned well from Horse Flat oil field, despite that the field is directly under Porter Ranch. The data does support that some sort of change has occurred in the subsurface methane from March 2016 to September 2016. The most likely source of this change is with operations related to Aliso Canyon Gas

Storage Facility. The measured soil gas values do correlate to changes in Aliso Canyon Gas Storage Field Pressure.

A critical point to consider is the steep drop in methane values in September. The steep drop has several potential explanations.   There is a possibility that temperature changes had an effect on this drop. The temperatures from August to September however did not change significantly enough to account for this. Another potential is that the methane had been released from groundwater. If this would have been the case, a more gradual decline would have been expected. There is the possibility of operator error in the data. This is unlikely since there had been no change in equipment, sampling technique, or operator in the timeframe. The most likely cause in the decrease in values therefore has something to do with operations at Aliso Canyon. T

Field pressure for a gas storage field is typically not available to the public. Gas field pressure is measured during what is called a "shut-in". A shut-in is scheduled to occur, and the gas storage field temporality stops all gas injection, and gas deliveries. Typically, this occurs for two or three days, for the field pressure to balance throughout the field. One or two wells are selected for which the pressure is measured, and reported. Shut in values are critical in determining the total amount of gas stored. Field pressure is also recorded during maintenance and well safety testing operations.   Well testing reports were made available to the public for the Aliso Canyon Gas Storage Field. From these well reports, which are thousands of reports, field pressure data was obtained and used for this investigation. The gas field was ordered by Sacramento to deplete the field in February 2016 due to safety concerns.

The question presented here is that if measured atmospheric methane is caused by surface rupture leaks, and the field was depleted by March 2016, why then are there higher than 3 ppm measured methane in April, May and June 2016? Soil gas methane would be expected to be of a higher value than air samples collected at four feet of the ground due to air dilution of the methane. The

12-hour air samples strongly support the soil gas data, which was collected, not only in timing, but also in concentration. In other words, two independent investigations both presented a similar data set. The 12-hour air sample data validates the accuracy of the soil gas data collected. Both data sets support the soil gas migration scenario.

The measured soil gas data does suggest a trend that is related to the operations at Aliso Canyon. There are three considerations as far as point of origin. The first and most obvious is the well failure at SS-25. With a failure and blowout in October 2015, and a well kill in February 2016, there is good reason to suspect that in addition to a surface methane expulsion of natural gas, that there was a subsurface migration as well. A possible scenario is that a ruptured casing may have pressurized the annulus of SS-25 with natural gas. The annulus is the space between the rock and the casing. In the case of SS-25, the annulus had a drill bit of 11.75” with a 7” OD casing. Since this would be no longer contained in the cap rock of the gas field, fugitive natural gas may have migrated along the fractured fault brechia along the Santa Susana fault system. Another migration pathway may have been in the permeable sedimentary rock in the Modelo Formation, or any other permeable formation. A third migration pathway may have been in the groundwater as dissolved phase transport. If natural gas was to saturate the groundwater, and this groundwater was to flow from Aliso Canyon to Porter Ranch, and the groundwater temperature pressure conditions changed, outgassing of methane from groundwater may have occurred.

Another interpretation of the data may suggest that the measured soil gas has less to do with an isolated well failure of SS-25, but one or more of several of the 115 wells at Aliso Canyon. Well inspections are conducted on a regular basis, as required by DOGGR. The testing however has not historically included pressure testing. Any number of wells may have contributed to a gas migration scenario as previously mentioned with SS-25, only that a surface rupture had not occurred.

It is also possible that the integrity the entire Aliso Canyon Gas Storage field has been comprised. The discovery pressure Sesnon zone discovery well, Porter 12, had an initial pressure of 3,595 psi at a depth of 5,150' vertical sub-sea (base of Sesnon zone). Porter 12 has a surface elevation of 1,971'; the vertical depth to point of discovery pressure measured is 7,121'. This corresponds to 0.505 psi/ft discovery pressure gradient. Aliso Canyon has maintained a pressure of about 2,700 psi. This is about 75% of the original discovery pressure, and has been determined to be within safety limits.

Of particular interest is that of the decreasing soil gas trend in Figure 21. A sharp decrease is seen in both figures, with Soil Gas measurements lagging by about six months. In order for natural gas to migrate in the subsurface, two conditions must be present. First, the medium must be permeable. Second, the direction of the permeability must have a vertical direction. In addition, a driving mechanism must be present. This can either be a difference in density, or a pressurized system. In the case of SS-25, the entire annulus from the surface to depth of 8,000 feet was under pressure, and gas would have been allowed to be present anywhere along this column. Since both the Northern and Southern Strand of the Santa Susana fault intersect this well, either fault could be considered to be a potential migration pathway. Since both faults gradually change their direction, steeper dip at depth, and bending to near horizontal at the surface, the conditions of gas migration have been met. If the Santa Susana North strand is considered a migration pathway, then the total distance from Porter Ranch to Aliso Canyon is about 2000 meters, if the Southern Strand of the Santa Susana Fault is followed, about 3000 meters. If the lag time seen in these figures is about 6 months, then a linear velocity of about 10 -15 meters per day could be estimated. It is unlikely that gas migration remains a constant rate however. This value is only an estimate, and a more thorough examination of gas permeability in the Pico formation, and the Santa Susana fault would have to be made. The delay of six months is therefore only an estimate. Determining the specific migration pathway, and driving mechanism is beyond the scope of this investigation. The importance is to recognize that a potential migration pathway does exist, and further investigation is required.

There may be a critical pressure value where a minimum pressure is required to stored gas to become fugitive and become measurable in Porter Ranch. If field pressure is below this critical pressure, then the stored gasses cannot overcome the opposing forces that allow the stored gasses to remain stored. To calculate this critical pressure is beyond the scope of this investigation, and more research would be required.

With consideration to the local geology, and the results obtained from this investigation, as well as AQMD data, a proposed potential gas migration from Aliso Canyon Gas Storage Field is suggested, and can be seen in Figure 25.

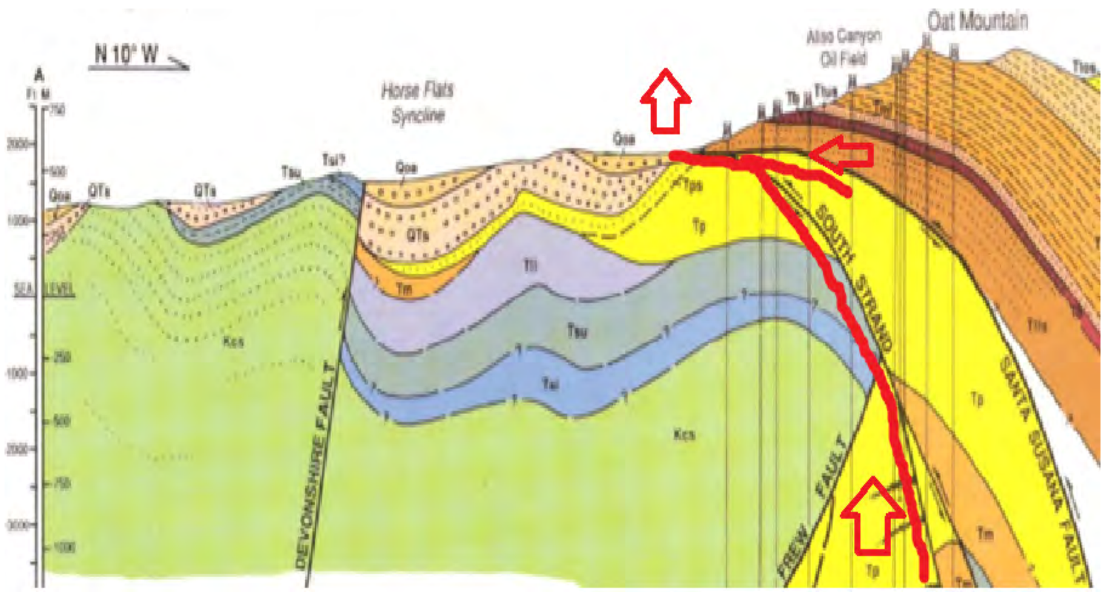


Figure 25: Proposed Methane Gas Migration

4.3 Regulation

Large-scale public works projects such as Aliso Canyon often present a safety concern for the public. Such large-scale projects require a multi-disciplinary approach to regulation. When a failure such as well SS-25 occurs, several regulating agencies become involved to investigate cause, and mitigate damage. At this time, Aliso Canyon is one of four gas storage facilities in southern California, and the largest. There is limited Federal oversight, and no EPA methane regulatory limits. At the state level, California regulates petroleum activities under the Department of Conservation, Division of Oil Gas and Geothermal Resources (DOGGR). When the well SS-25 failed in Aliso Canyon, and the residents of Porter Ranch and the surrounding communities made odor complaints, additional agencies, namely California Air Resource Board (ARB), and Southern California Air Quality Management District (SCAQMD) became involved. There are other state agencies that are involved with the incident of SS-25, however these are the California agencies most directly involved with sample data collection. These agencies work with several organizations including the California Council of Science, as well state, and national laboratories. When more specialized experience is required, industry consultants are contracted for services.

One of the most significant responses to the well failure of SS-25 was to shut down all of the wells at Aliso Canyon, and for each well to undergo a rigorous, two phase safety inspection. The results of these inspections are publicly available, and maintained through a Dept. Conservation website.

Without publicly available testing results from DOGGR, ARB, and SCAQMD, this investigation would not have been possible. It is the findings of this investigation that these agencies have provided useful information to the public, and no shortcoming has been found.

CHAPTER 5

CONCLUSIONS

5.0 Conclusions

In the course of this investigation, is has been observed that there are indeed elevated levels of methane relative to average atmospheric levels in some of the soils present in Porter Ranch. Though, soil concentrations are not at explosion levels based on this data set. The data presented in this investigation supports the position of correlating this methane with fugitive natural gas migrated from Aliso Canyon, through subsurface pathways. This investigation does not identify a single subsurface migration pathway, but suggests that there are indeed several potential pathways. The conclusion of this investigation suggests that such subsurface gas migration has contributed to the elevated methane concentration during the events related to the gas leak of well SS-25.

The data collected from this investigation supplements the data collected by several agencies. The data presented in this investigation contributes to the body of scientific knowledge of this not only this gas storage field, but can provide insights to other such facilities.

5.1 Future Direction

There are several unanswered questions, which remain concerning activities at Aliso Canyon Gas Storage Field. The future direction of this investigation would be to continue monitoring soil gasses at Porter Ranch. A continuation of soil gas measurements if and when Aliso Canyon begins to use the facility for gas storage would be of value

As of 31JUL2017, California regulators have allowed Aliso Canyon, Gas Storage injection operations to resume, on a limited basis. If soil gas monitoring is continued after this time, there are two likely expectations either soil methane will be detected, or it will not be detected. If soil methane is detected after 6 months, then there are likely continued safety concerns at Aliso Canyon, and this risk must be assessed. If soil methane is detected, a more thorough investigation should be conducted to determine if the source of the methane. The methane may be the result of water injection, or of natural gas injection. If no methane is detected in the soil, then leaking wells from Aliso Canyon have likely been repaired, and there is no apparent fugitive gas from Aliso Canyon. If no soil gas is detected in Porter Ranch after Aliso Canyon resumes using the facility for gas storage, then this is strong evidence for fugitive gas migration from damaged wells that have been repaired. If soil gasses are detected in Porter Ranch without change in activities from Aliso Canyon, then more questions must be investigated. Another approach is to expand the number of wells, and target locations where air samples from mobile testing have indicated hot spots. This approach would not require significantly more resources than this investigation. By targeting specific hot spot location, this will examine the possibility that methane may be seeping through subsurface conduits, and instead of diffusing through the soil, may indeed be migrating in a fracture system.

Continued research would require administrative permission to access prohibited areas, namely the Aliso Canyon administrative boundary. If permission was granted, a fence line of soil gas monitoring could be emplaced east to west along the northern border of Porter Ranch. This approach is similar to the method used by landfills to detect fugitive in the soil. Another approach is to collect water samples from groundwater in Porter Ranch, and measure the methane concentration. Since injection wells for well stimulation are being used at Aliso Canyon, these waters will likely be saturated with methane, and these operations of injection wells may be a significant contributor to the soil gasses detected in this investigation. It is unlikely to gain permission to sample these wells.

5.2 Public Safety

In the interest of public safety, the operations at Aliso Canyon must be well regulated, and monitored my knowledgeable and skilled professionals. Residents of Porter Ranch and the surrounding communities are entitled to clean air, not contaminated from operations at Porter Ranch. In the course of this investigation it should be noted that no soil gas samples taken after September 2016 had any methane results exceeding 1ppm greater than that of the surface air. The data collected from this investing does not support an additional public safety risk that is not already known. California Air Resource Board has continued monitoring air quality, specifically chemical agents that likely are to have a negative impact on health at low concentrations. Monitoring programs for methane, hydrogen sulfide, benzene, and mercaptans have been implemented, and results are public record.

Of the 115 wells pertaining to Aliso Canyon, well SS-25 has been permanently sealed, 70 have been temporarily sealed, waiting complete safety inspection, and 45 have passed all safety inspections and requirements. Of the 45 that have passed all safety inspections and requirements, 14 have had to undergo repair. There is significant political interest in the operations at Aliso Canyon. Whether the site will ever resume gas operation activities will the decision of Public officials, and industry professionals.

On 29 July 2017, California State officials, have determined that Aliso Canyon Gas Storage Field has been sufficiently tested for safety, and will be allowed to resume gas injection storage, despite the requests from the local residents to halt gas storage activities. As of Aug 012, 2017, Aliso Canyon Gas Storage Field started to resume gas injection operations.

REFERENCES

1 Ensuring Safe and Reliable Underground Natural Gas Storage: Public Health and Environment Subgroup Report Appendix to the Final Report of the Interagency Task Force on Natural Gas Storage Safety, https://energy.gov/sites/prod/files/2016/12/f34/Appendix%20II%20-%20Public%20Health%20and%20Environment%20Working%20Group%20Report.pdf

2 Ensuring Safe and Reliable Underground Natural Gas Storage Final Report of the Interagency Task Force on Natural Gas Storage Safety, https://www.energy.gov/sites/prod/files/2016/10/f33/Ensuring%20Safe%20and%20Reliable%20Underground%20Natural%20Gas%20Storage%20-%20Final%20Report.pdf

3 Estimated Geomechanical Properties for the Aliso Canyon Gas Storage Fieldhttp://www.conservation.ca.gov/dog/Documents/Aliso/Att_1_Estimated_GeoMechanics_Properties_for_the_Aliso_Canyon_Gas_Storage_Field_7_18_16.pdf

4 Ventura Basin Oil Fields: Structural Setting and Petroleum System, http://www.thomasldavisgeologist.com/resources/Ventura-Basin-PS-AAPG-GdBk-May-2015.pdf

5 Geology, Soils, and Seismicity, https://www.socalgas.com/regulatory/documents/a-09-09-020/4-6_Geology-Soils.pdf

6 Geology of Southeastern Ventura Basin Los Angeles County California By E. L. WINTERER and D. L. DURHAM, https://pubs.usgs.gov/pp/0334h/report.pdf

7 The Santa Susana fault, Aliso Canyon gas storage field, southern California-possible fault rupture hazard, gas well integrity, and regulatory implications Thomas L. Davis, Geologist, Ventura, CA, http://geologicmapsfoundation.org/resources/Davis_2016b_abstract.pdf

8 SEISMIC HAZARD ZONE REPORT FOR THE OAT MOUNTAIN 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA, http://gmw.consrv.ca.gov/shmp/download/quad/OAT_MOUNTAIN/reports/oatm_eval.pdf

9 Geological Map of the Oat Mountain and Canoga Park, Thomas Dibblee, Jr, http://www.dtsc-ssfl.com/files/maps/Geologic%20Map%20of%20Oat%20Mountain%20and%20Canoga%20Park%20-%20North%20Half.pdf

10 An Independent Scientic Assessment of Well Stimulation in California, https://ccst.us/publications/2015/2015SB4-v1.pdf

11 Cause of the 1985 Ross store explosion and other gas ventings, Fairfax district, Los Angeles, Ca, https://web.stanford.edu/~meehan/la/pubs/pubross.pdf

12 THE HUTCHINSON GAS EXPLOSIONS: UNRAVELING A GEOLOGIC MYSTERY, http://www.kgs.ku.edu/Hydro/Hutch/Refs/Hutch_KBA_final.pdf

13 Casing Shear: Causes, Cases, Cures, http://www.geomechtech.com/article/spe72060.pdf

14 Land subsidence and well failure in the Belridge diatomite oil field, Kern county, California, http://hydrologie.org/redbooks/a234/iahs_234_0069.pdf

15 Doggr, Test Results of Aliso Canyon Wells, http://www.conservation.ca.gov/dog/AlisoCanyon/Pages/Well-Detail.aspx

16 Aliso Canyon Updades, http://www.aqmd.gov/home/regulations/compliance/aliso-canyon-update

17 Gas Well Blowout – Relocation and Safe Return SoCal Gas – Aliso Canyon Storage Facility, http://www.porterranchlawsuit.com/wp-content/uploads/2016/02/Letter-to-SoCalGas-Regarding-48-Hour-Relocation-Notice.pdf

18 Origin: Biogenic vs. Thermogenic, https://pubs.usgs.gov/of/1996/of96-272/ch03s07.html

19 Recommendations on Model Criteria for Groundwater Sampling, Testing, and Monitoring of Oil and Gas Development in California http://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/llnl_recommendations_report.pdf

20 CITY of LOS ANGELES: 2008 POPULATION ESTIMATE, http://planning.lacity.org/dru/Locl/LocFrame.cfm?geo=cp&loc=Cht&sgo=CT&rpt=HOc&yrx=Y08

21 SOUTHERN CALIFORNIA GAS COMPANY STORAGE EXPANSION STUDY, https://www.socalgas.com/regulatory/documents/StorageExpansionStudy2011.pdf

22 Geology of the Aliso and Browns Canyon area, Santa Susana Mountains, California, http://thesis.library.caltech.edu/3145/

23 Summary of Senate Bill 380 (Chapter 14,statutes of 2016), http://www.conservation.ca.gov/dog/Documents/Aliso/Summary_of_Senate_Bill_380.pdf

24 Aliso Canyon Working Gas Inventory, Production Capacity, Injection Capacity, and Well Availability for Reliability Revised Report – Public Utilities Code Section 715 Energy Division 7/19/2017, http://www.cpuc.ca.gov/uploadedfiles/cpuc_public_website/content/news_room/news_and_updates/reportreliability.pdf

25 Simple techniques for assessing impacts of oil and gas operations on public lands: a field evaluation of a photoionization detector (PID) at a condensate release site, Padre Island National Seashore, Texas Online edition by James K. Otton1 and Robert A. Zielinski1 Open-File Report 01-183, https://pubs.usgs.gov/of/2001/ofr-01-183/OFR01-183.pdf