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Quantifying the Problem and Risks of Poorly Abandoned Oil and Gas Wells in Ventura County, California

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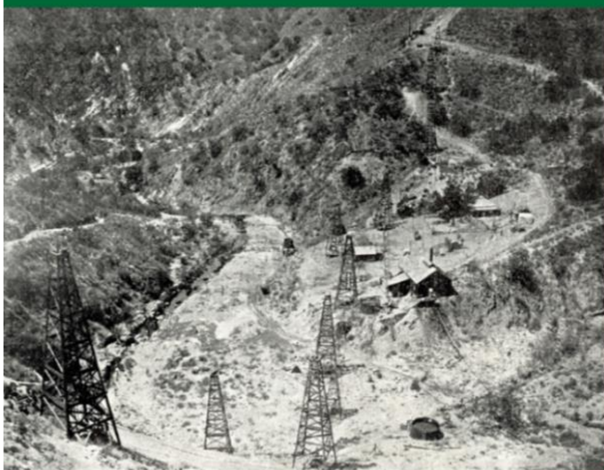

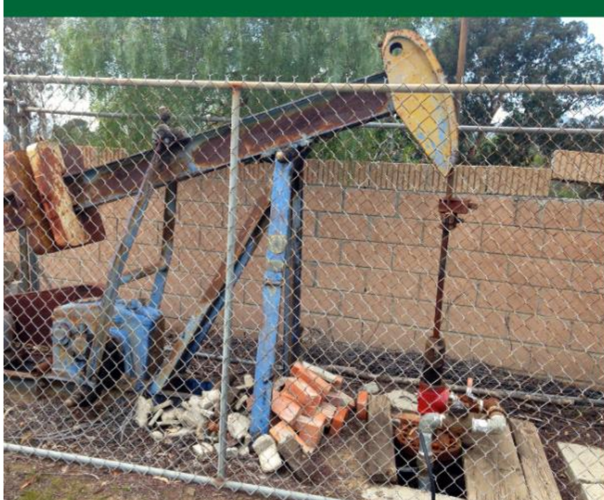

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May 2022

Climate First: Replacing Oil & Gas
Haley Ehlers

Abstract

Innovators around the world are frantically searching for new green technologies to make our lives more sustainable and combat the climate crisis we are experiencing. But as we move away from fossil fuels, we must address the threats present in this industry's legacy. The persistent extraction of oil and gas in Ventura County's history has left over 4,000 plugged and abandoned wells and over 2,000 idle wells. "Plugged and abandoned" is a term used the describe wells that have been safely and successfully closed – meaning that they should no longer pose any danger to the land, air, and water. Unfortunately, this study found this is not the case. After completing an analysis of historical well records, approximately 40 percent of abandoned wells cannot be confirmed as properly plugged. These wells were abandoned before modern plugging standards, utilized insufficient materials, and/or have missing or incomplete abandonment records. To assess the possible risks these poorly abandoned wells pose for Ventura County communities, their geographic location in relation to environmental and social factors – water, air, hazards, agriculture, wildlife spaces, and environmental justice areas – is analyzed. Lastly, a discussion of the costs and benefits of possible cleanup efforts and recommendations on the management of federal, state, and local funds and policies is offered.

About Climate First: Replacing Oil & Gas

Climate First: Replacing Oil & Gas (CFROG) is an independent, nonprofit watchdog dedicated to combating the climate crisis by working to shape the transition from fossil fuels to a carbon-free economy on California's Central Coast. Since its founding in 2014, CFROG has been committed to the establishment of a sustainable and inclusive economy that promotes renewable energy and good jobs. By working at the local level, CFROG has built awareness of how fossil fuels impact communities, and engaged area officials, government agencies, and other like-minded organizations and individuals to eliminate those impacts wherever possible. As a watchdog organization, CFROG is dedicated to ensuring that all existing oil and gas operations are properly reviewed, permitted, monitored, and compliant with relevant environmental and safety laws and regulations. Learn more about www.cfrog.org.

About the Author

Haley Ehlers is the Program Manager at CFROG where she works on a range of local advocacy issues, including sustainable planning, just transition, and oil and gas watchdogging, and manages programs like community air monitoring and a youth advocacy training program. From August 2021 to June 2022, Haley is serving at CFROG as a Peace Corps Fellow from the Stevenson Center at Illinois State University where she is completing a M.S. in Political Science, Applied Community and Economic Development Sequence. In addition to serving the interest of CFROG, this research was completed to meet academic requirements.

Acknowledgements

The author would like to thank CFROG board members and advisors, particularly Carol Holly, Dr. Steve Colomé, Sc.D, and Merrill Berge. Additionally, in the summer of 2021, Harriet Ferrer completed the majority of historical well record analysis and Cameron Robertson began the initial mapping of poorly abandoned wells in Ventura County – thank you for your work in kickstarting this project. Lastly, the author would like to thank Dr. Lori Riverstone-Newell and the Stevenson Center faculty and staff for their advising and support.

Executive Summary

The persistent extraction of oil and gas in Ventura County's history has left over 4,000 plugged and abandoned wells and over 2,000 idle wells. "Plugged and abandoned" is a term used to describe wells that have been safely and successfully closed – meaning that they should no longer pose any danger to the land, air, and water. Unfortunately, this study found this is not the case.

To quantify the problem of poorly abandoned wells and identify possible implications on the Ventura County environment, public, and economy, this research completes three analyses: (1) historical well record review and categorization, (2) geographic mapping and community risk assessment, and (3) cost and benefit estimation.

After completing an analysis of historical well records, approximately 40 percent of abandoned wells in the county (1,840) cannot be confirmed as properly plugged. The majority of these wells, 66 percent or 1,629 wells, were abandoned before 1953 when plugging standards were published nationally. An additional 372 wells were categorized as poorly abandoned due to method – including the use of insufficient plug materials, final abandonment responsibility transferred to the landowner, determined to be inadequate by agency review, or another noted major issue. Lastly, 211 wells had entirely missing records and 180 had incomplete abandonment documentation – despite being labeled as "plugged."

In place of much-needed field research and assessment of these leaky, old wells, this research considers their geographic location in relation to other environmental and social factors – water, air, hazards, agriculture, wildlife spaces, and environmental justice communities. After reviewing relevant scientific literature to gain context into how these factors can interact with aging oil and gas infrastructure, additional map layers were sourced and geographic analysis completed for all nine Ventura County communities. The communities of Santa Paula, Fillmore, and Ventura were found to have the most high-risk elements.

Lastly, the problem of poorly abandoned wells is analyzed in terms of cost, benefit, and next steps based on the polluter-pays principle which requires polluters to pay for the harm they have caused. Based on the only data available, cleanup cost estimates range from $7.4 million to $37.2 million and could offer over 400 well-paid job-years and greenhouse gas emission reductions in line with the county's goals. To ensure responsible management, the following recommendations are made:

- Require state plan for oil and gas industry fund reimbursement
- Include re-abandonment in criteria for orphan well cleanup

- Develop an abandoned well monitoring program
- Expand capacity and scope of methane aerial monitoring program
- Implement more strict timelines for well abandonment and close bankruptcy loopholes
- Increase transparency and community responsiveness
- Establish Oil & Gas Administrator in Ventura County
- Increase surety bond from $10,000
- Add abandoned wells to new or extended permits
- Create local restoration requirements

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Part 1 –
Discovery & Identification of Abandoned Wells in Ventura County

Electric cars, self-sufficient buildings, carbon capture – the list goes on. Innovators around the world are frantically searching for new green technologies to make our lives more sustainable and combat the climate crisis we are experiencing. But as we move away from fossil fuels, we must address the threats present in this industry's legacy.

The California Central Coast has a long history as an oil-producing region, which fracked its first wells in the 1950s using a mixture of sand and diesel fuel (Adamson, 2005). This history of extreme and persistent extraction has left Ventura County with over 4,000 plugged and abandoned wells and over 2,000 idle wells. "Plugged and abandoned" is a term used to describe wells that have been safely and successfully closed – meaning that they should no longer pose any danger to the land, air, and water. Unfortunately, this is often not the case. Many wells labeled as safely "plugged and abandoned" present significant environmental health risks – leaking volatile gasses and toxic fluids, including methane, a gas with an outsized warming impact on the climate (Saunois et al., 2016).

The question is – how prevalent is this problem? How many wells were poorly abandoned, and which should be cleaned up first? To answer these questions, this research investigates historical records for each of the 4,000+ abandoned wells in Ventura County to determine whether they were properly plugged, and which have gone years – or even decades – with a reported leak or containment issue that has gone unresolved. This section reviews relevant industry background and literature, frames the research methodology, and offers descriptive analysis and findings of poorly and properly abandoned oil and gas wells, ranked by cleanup priority, in Ventura County, California.

Background/Literature Review

Previous research has not specifically explored abandoned oil and gas wells in Ventura County, California, but there is literature that provides background on the industry of oil and gas in the county, and research done in other states confirming the importance and challenge of identifying and quantifying various types of oil and gas wells. Limited research on this topic has been done in California and presents a gap in the full understanding of the problem abandoned wells present.

History of Oil and Gas in Ventura County, California

Ventura County is located along California's Central Coast, between Santa Barbara and Los Angeles Counties. There are about 3,800 active wells in the county. In 2015, the economic presence of these wells was significant: according to the industry, oil and gas operations were responsible for $306.6 million in state and local taxes, $216.7 million in federal tax revenues, and nearly 6,000 jobs (LAEDC, 2017). Oil and gas production began in Ventura County in the late 1860s, with the first well drilled in the Ojai Oil Field in 1867. In the century that followed, other oil fields were discovered, and the county became one of the major producing areas in the state. Over 12,000 wells have been drilled in the Ventura Basin (VCRMA, 2021).

Throughout most of the twentieth century, "oil ruled Ventura County" (Watson, 1990). The industry's hand in local politics and socioeconomics began during this era and continued to influence local decisions for decades. The period before 1965 was a time of unprecedented national and cultural enthusiasm for modern technology and transformation (Hughes, 1989). During this time, there were very few restrictions on the development of oil and gas resources in California's coastal region, especially onshore development where most of the exploration and production was occurring (Adamson, 2005). In the 1920s, the oil industry shaped local growth outcomes by investing financial resources and aligning with key business leaders, elected officials, government offices, and other elites.

> [The oil and gas industry's] paramount interest lay in developing the extractive region that lay adjacent to the city without restriction. They were pleased to see Ventura grow quantitatively, but showed far less interest in the quality-of-life aspects of boosters' plans for the city. (Adamson, 2008, p. 151)

Oil companies recognized that an urban boom would threaten their interests by increasing the county's desire and ability to regulate areas where they operated. Of particular concern was the Ventura Avenue Oil Field, which the industry had defended against annexation for decades (Adamson, 2008). The industry's dominance over local decisions meant that Ventura failed to develop as a tourist and recreational destination and, by the 1950s, "more closely resembled inland California oil towns in terms of place than nearby Santa Barbara, which boosters had hoped to emulate" (Adamson, 2008, p. 150; Schmitt, Dugan, & Adamson, 2002).

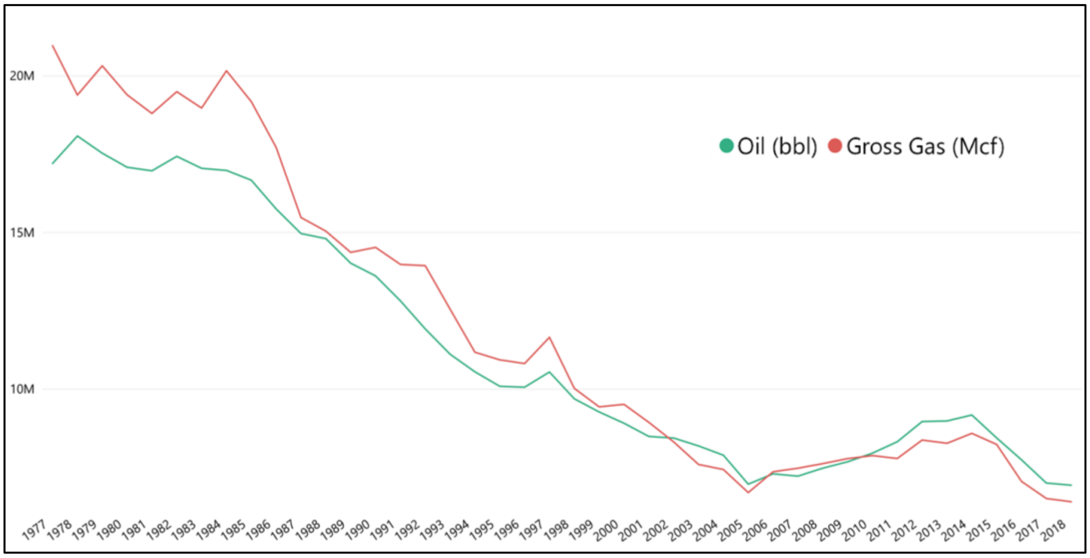
While Ventura experienced the social pressures of traditional oil booms – rapidly increasing real estate prices, overwhelmed public services, and increasing demand for utilities and housing – most residents were pleased with the spurred growth (Adamson, 2005). When the Great Depression halted the initial boom, Ventura had already solidified into an industrial city. A second wave of extraction sparked a second boom, but generally, the area did not experience the classic “boom and bust” of oil production. A 1954 survey, taken during the postwar oil boom, suggested that the city was not experiencing major economic oil boom problems. The study found that the “average” Ventura resident was hardworking, earned a relatively high income, was economically and emotionally secure, emphasized the lack of class distinctions among residents, and had high community spirit (Reith, 1963, p. 188). Many survey respondents also cited Ventura’s good schools and accessible parks and recreational opportunities – all supported by oil money – as key amenities of the city. An analysis of historical newspapers found evidence of short-term problems related to rapid urban expansion – largely in public health, housing, education, and government – but economic development was sustained by the oil industry’s activity (Adamson, 2005).

The local and regional cultural attitudes surrounding the oil industry began to shift in the mid-1960s, corresponding with the onset of the environmental era. People began challenging technological improvements and the values of a technological society, as well as nearly unregulated industrial production, resource extraction, and the corresponding impacts on the natural environment (Hughes, 1989). This movement gained significant political and social momentum, especially on the Central Coast, after the 1969 Santa Barbara oil spill[1] convinced residents that the “ocean, marine, and urban environments were particularly vulnerable to oil development along the California coast” (Adamson, 2005, p. 140). By 1965, as Ventura County was becoming increasingly professional and middle-class, economic diversification diminished the importance of oil activity. Residents support for environmentalism grew, resulting in the implementation of more regulations governing oil activity within the county (Paulsen et al., 1996).

By the 1990s, the oil and gas industry that built Ventura was said to be in its “last phases” (Watson, 1990). In 1958, the county’s wells produced 46.7 million barrels of crude oil. By 1988, production was down just below 15 million barrels (see Figure 1.1 for the production trend from 1977 to 2018). This decline in production resulted in fewer oil-related jobs and a shift from active drilling operations to the abandonment of oil fields (Watson, 1990).

[1] On January 28, 1969, an oil spill occurred off the coast of Santa Barbara, California. It was the largest oil spill in United States waters at that time and remains the largest oil spill to have occurred in the waters off California. An estimated 80,000 to 100,000 barrels of crude oil spilled into the Santa Barbara Channel and on to beaches across the Central Coast. This disaster inspired Earth Day – a national youth campaign and annual event on April 22 to demonstrate support for environmental protection. Read more about the spill and its impacts in *Slick Policy: Environmental and Science Policy in the Aftermath of the Santa Barbara Oil Spill* (Sabol Spezio, 2018).

Figure 1.1 – Oil and Natural Gas Production in Ventura County, California



Source: California Department of Conservation, Geologic Energy Management, WellSTAR

While the oil and gas industry's activity has gradually declined over the years, it continues to maintain permits and responsibility for current activities, as well as those of the past. Indeed, the oil and gas industry is fighting to maintain the relaxed regulations that benefited them at the turn of the century. In 2020, encouraged by the public, the Ventura County Board of Supervisors approved a regulation requiring standard environmental review for oil and gas projects on "antiquated permits" that were issued from the late 1940s to the mid-1960s. These old permits have no expiration date, no limit to the number of wells the permit holder is allowed to drill, and no restrictions on type of extraction method used. They were issued before the California Environmental Quality Act (CEQA)[2], which requires analysis of a project's impact on air, water, and other natural resources. The board's regulation established a consistent permitting and environmental review process for oil and gas projects, regardless of the original permit date. However, opponents, namely a political action committee (PAC) largely funded by an oil company, Aera Energy LLC, successfully moved the issue to a referendum vote. The PAC argued that this regulation would threaten jobs, tax revenues, and the income of royalty owners – a campaign that has been characterized by environmental groups as disingenuous (Gable, 2021). Voters will decide the outcome of this issue on the June 7, 2022, primary ballot.

[2] The California Environmental Quality Act (CEQA) is a statute passed in 1970 and signed into law by Governor Reagan to institute a statewide policy of environmental protection. According to the act (California Public Resources Code § 21000 et seq.), all state and local agencies must give major consideration to environmental protection in regulating public and private activities and should not approve projects for which there exist feasible and environmentally superior mitigation measures or alternatives.

Oil and Gas Well Plugging and Abandonment

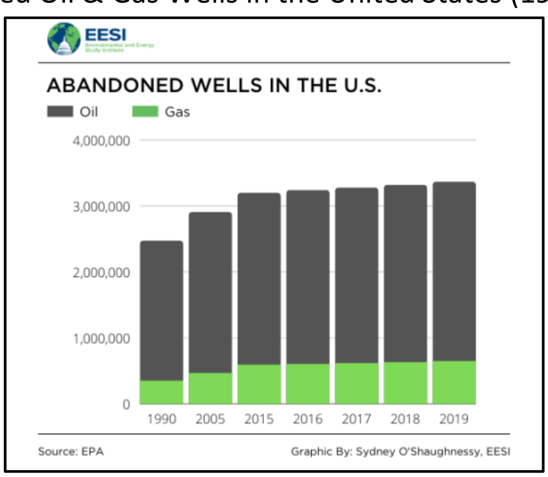
Abandonment History and Trends in the United States

According to the U.S. Environmental Protection Agency, there are 3.4 million abandoned oil and gas wells across the nation (EPA, 2021, see Figure 1.2). It is estimated that only one-third are plugged with cement, which is considered the proper way to prevent harmful chemical leaks and contamination, leaving about 60 percent poorly plugged (Bertrand, 2021). According to Natural Resources Defense Council:

> Orphaned and abandoned oil and gas wells are located everywhere. They can be in the middle of a forest, in backyards, in farm fields, even under sidewalks and houses. Basically, they are anywhere that oil and gas development has taken place – at sites of large-scale operation spread out over many acres as well as single-well outfits on tiny parcels of land. (Terrentine, 2021, para. 6)

Oil and gas wells are generally abandoned when they "go dry," meaning that they are no longer producing enough resources to be profitable. The prevalence of poorly abandoned wells is a result of the historic lack of permitting, plugging, and bonding requirements. The first American oil well was drilled in Titusville, Pennsylvania over 160 years ago – and for most of this history, it was "a largely unregulated industry with few well permitting or plugging requirements" (Boettner, 2021, p. 10). Before engineering standards were recognized and enforced within states, operators were essentially free to plug dry wells however most convenient and economical. This often meant that companies filled the hole with previously dug up ground, and used material other than cement, which is required nowadays, to secure sections of the wellbore (Plants, 2021).

Figure 1.2 – Abandoned Oil & Gas Wells in the United States (1990, 2005, 2015-2019)

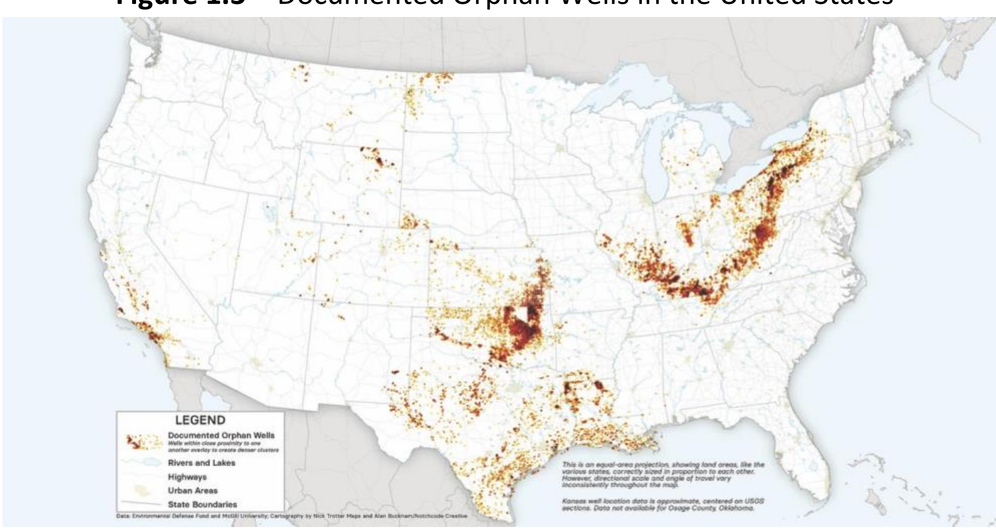


Source: Environmental and Energy Study Institute

This historic lack of regulations and flaws in record-keeping also means that the identification and tracking of wells is difficult and inconsistent. The Interstate Oil and Gas Compact Commission (IOGCC) reported 56,600 documented orphaned wells in 2018, but also estimated that there were an additional 211,000 to 746,000 undocumented orphan wells (IOGCC, 2018). One nonprofit watchdog organization argues that this report is "substantially underestimated" (Boettner, 2021, p. 11). In the last few years, new technological methods utilizing magnetic signaling have been developed to identify undocumented wells in the Eastern and Mid-West regions, helping to quantify the full inventory of these wells. A recent study utilizing aeromagnetic surveys found significantly more abandoned wells than those recorded by state databases in both Pennsylvania and Wyoming (Saint-Vincent et al., 2020).

Unplugged and poorly abandoned wells pose significant health, safety, and environmental problems. The EPA (2021) estimates that abandoned wells emitted 290 kilotons of methane in 2018, equivalent to burning over 16 million barrels of oil. Methane, a potent greenhouse gas, poses a significant threat to the climate because it is 25 times more effective than carbon dioxide in trapping heat in the atmosphere (EPA, 2021b). The most recent Intergovernmental Panel on Climate Change called for "strong, rapid, and sustained reductions" in methane emissions to avert significant impacts of climate change (IPCC, 2021, p. 27). In addition to methane, these wells can also leak other toxic chemicals into the air, soil, and groundwater – posing significant risks to human and environmental health (Kang et al., 2021). These risks are widespread. The Environmental Defense Fund (EDF) mapped all documented orphaned wells across the country (Figure 1.3) and found that approximately 9 million Americans live within a mile of a documented orphan well, which are inactive, unplugged, and have no solvent owner of record.

Figure 1.3 – Documented Orphan Wells in the United States



Source: Environmental Defense Fund (2021)

While this map shows orphaned wells rather than abandoned wells where past ownership is likely known, it illustrates the prevalence of harmful and aging oil and gas infrastructure and emphasizes the importance of holding companies responsible for properly plugging decommissioned wells. The map also highlights the regional nature of this problem. California has more than 81,000 documented orphan wells, 2,777 of which are categorized as deserted or potentially deserted (EDF, 2021).

Abandonment History and Trends in California and Ventura County

Consistent with other states across the country, oil and gas regulations in California were inconsistent until the mid-twentieth century. This was especially true for regulations related to plugging and abandoning wells. The California Mining Bureau was established in 1880, primarily to map and regulate the mining of precious metals. By the turn of the century, the bureau was attempting to regulate oil drilling, primarily to protect sources of fresh groundwater. Early Ventura County well records tell the story of an understaffed bureau that struggled with poor transportation and slow turnaround times for correspondence. Operators were often left to their own devices. These administrative deficiencies also resulted in poor record keeping. As explained below, this research found many records of oil wells that indicate no exact location. Inspections from the 1930s onward indicate that many of these wells could not be found. Often, another operator still producing oil in the same general area was the best source of information about these lost wells.

If a well was determined undesirable or unprofitable after drilling, the bureau required it to be abandoned. However, the rules for abandoning were mostly non-existent. Operators often attempted to retrieve the well's structural casing for reuse before filling the hole with mud and capping the top to finish the job. As time went by, the bureau required cement be used to fill the casing and prevent rusting and leakage. The cement had to be laid over something that would "bridge" the wellbore – CFROG researchers repeatedly found that operators used *paper sacks* for bridging materials. As time went by, abandoning wells became more and more regulated, but the process remained inconsistent and unpredictable through the 1960s (Benedictus, 2009).

Ventura County's history of persistent oil and gas extraction has resulted in over 4,000 documented plugged and abandoned wells and over 2,000 idle wells, currently inactive waiting for abandonment or reactivation. This research questions the validity of the notion that all wells labeled "plugged and abandoned" have been safely and successfully closed. Due to a historic lack of standardized plugging regulations, it is possible that many wells present significant environmental health risks and, thus, should be reassessed by regulators. By reviewing and analyzing well records, this research hopes to quantify the problem and provide some direction for remediation.

Research Design

To explore the prevalence and cleanup priority of abandoned oil and gas wells in Ventura County, this research will engage in descriptive and category analysis utilizing CalGEM administrative data and historical well records. The following discussion defines data sources, types of wells, variable measurements, and describes the data collection and analysis process.

CalGEM Administrative Data

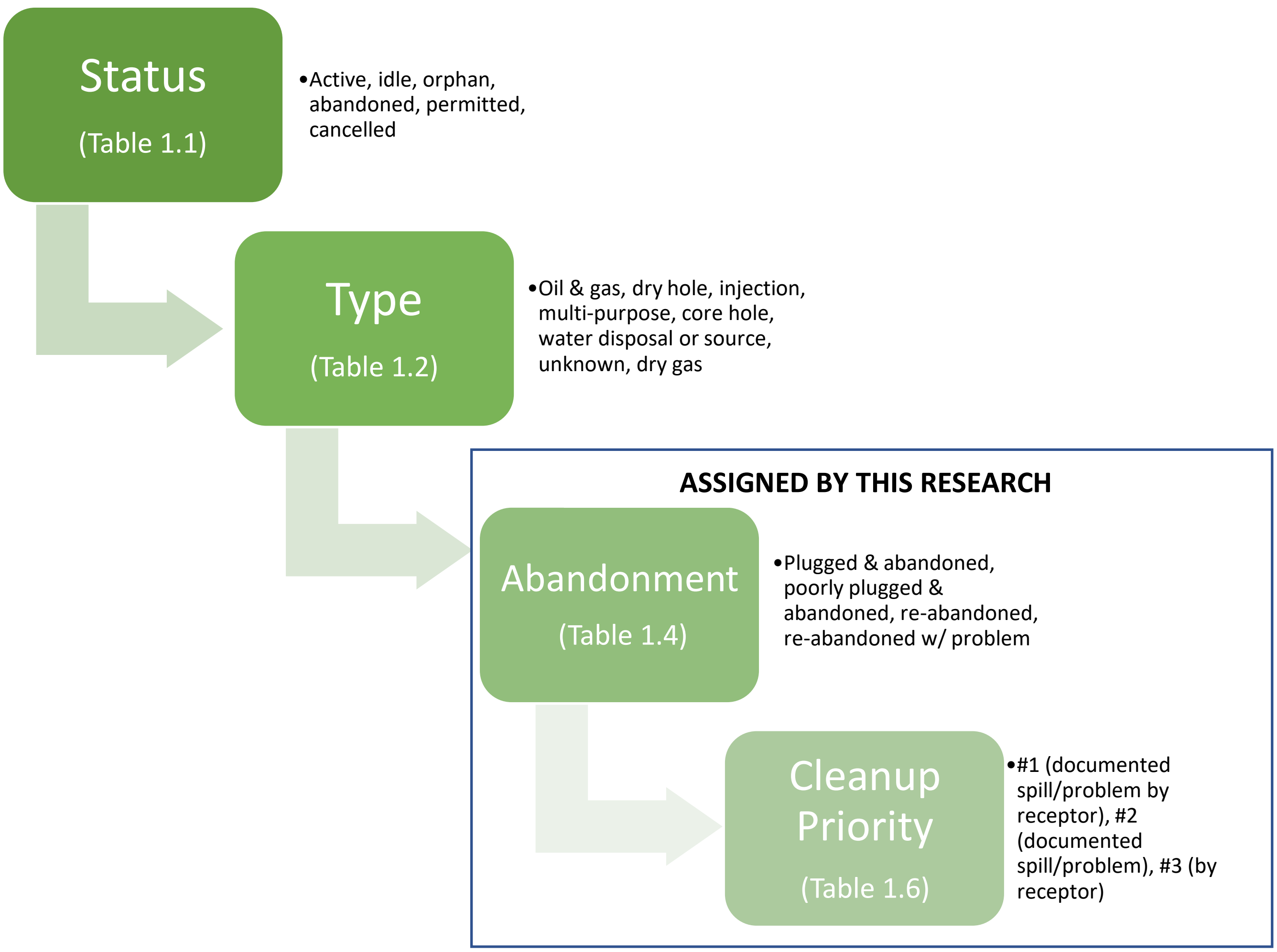
California Department of Conservation's Geologic Energy Management Division (CalGEM) is the regulatory agency for oil, natural gas, and geothermal industries in California. CalGEM manages a publicly available database called Well Statewide Tracking and Reporting System (WellSTAR), which is home to a variety of data on documented wells throughout the state, including geographic location, status, and histories. The use of state administrative data allows this research to examine the full population of abandoned wells within the county. Additionally, the use of this state agency data increases reputability of the findings within policy and regulatory decision-making processes.

This research began with a datasheet downloaded from WellSTAR which listed all individual wells located onshore within Ventura County by API number (American Petroleum Institute identification number). The data was then segmented by Well Status, and "Plugged" wells were analyzed by individual well records – see below for descriptions of all well status (Table 1.1) and types (Table 1.2).

Oil and Gas Well Status and Type Categories

State by state, report by report – there are no consistent definitions of oil and gas well statuses. In fact, the National Parks Conservation Association (2021) recently released an analysis with a map, "*Orphaned* Wells Near National Parks," where individual wells are named "*Abandoned* Well" but have the status of "*Idle*." This is likely for two reasons. First, and most important, differing documentation and reporting standards among states makes consistent national analysis difficult. Differing criteria means that a well considered "idle" in one state may be considered "orphan" in another. The second reason is semantical. The Oxford Dictionary definition of abandoned is "having been deserted or cast off." In terms of wells, this definition paints a different picture than what oil and gas regulators mean by abandoned: plugged in some form and no longer producing. But each of these status terms, idle, abandoned, and orphaned, are different, and it is important to clearly define them for the purposes of this research and generally within the literature. Figure 1.4 illustrates the four categories – status, type, abandonment status, and cleanup prioritization – utilized within this research.

Figure 1.4 – Four Categories for Oil and Gas Wells



This research adopts well status definitions used by CalGEM, which unfortunately also lack some clarity, as well statuses are often only defined in contrast to each other.[3] Utilizing

[3] CalGEM Code (Pub. Resources Code, § 3008, subd. (d).) defines a well no longer meeting the definition of idle well when: "[A]n idle well continues to be idle well until it has been properly abandoned in accordance with Section 3208 or it has been shown to the division's satisfaction that, since the well became an idle well, the well has for a continuous six-month period either maintained production of oil or natural gas, maintained production of water used in production stimulation, or been used for enhanced oil recovery, reservoir pressure management, or injection. An idle well does not include an active observation well."
CalGEM website explains "When a well is no longer needed, either because the oil or gas reservoir becomes depleted, or because no oil or gas was found (called a dry-hole), the well is permanently sealed and closed, aka

descriptions put forth by CalGEM in various web pages, reports, and datasets, Table 1.1 details the distinction between statuses: active, idle, abandoned, orphan, permitted, and canceled.

Table 1.1 – Well Statuses in Onshore Ventura County (VC)

Status	**Description**	**# in VC *(Mar. '22)***
Active	Represents wells currently in operation and producing oil, natural gas, or other resources	1,722
Idle	Represents any well that has not produced resources or been used in other industry processes in 24 consecutive months, but is still capable of being reactivated	2,313
Orphan	Represents idle wells for which there is no responsible operator *Note:* This term is not included in WellSTAR metadata and is therefore not a status delineated by CalGEM in publicly available data. This likely means that orphaned wells are present in idle and plugged & abandoned categories.	N/A
Plugged	**Represents wells that are no longer in use and have been sealed and plugged – to the standard of the abandonment date** *Note:* When referring to these types of wells, CalGEM often chooses to use "Plugged" as a noun and "Abandoned" as a verb. Additionally, in their metadata a distinction is made between "Plugged," representing "plugged and abandoned wells that are permanently sealed" and "Plugged Only," representing "plugged wells."	**4,376**
New	Represents new wells, including recently permitted wells or wells in the process of being drilled	7
Cancelled	Represents canceled well permits prior to drilling	98

Note: Table compiled using definitions put forth by CalGEM in various web pages, reports, and datasets (see Footnotes 3 & 4). Number of wells in Ventura County from CalGEM's "Oil and Gas Wells Table, Central Coast" dataset, view here.

plugged and abandoned in the oil and gas industry. A well is plugged by placing cement in the well-bore or casing at certain intervals as specified in California laws or regulations. The purpose of the cement is to seal the wellbore or casing and prevent fluid from migrating between underground rock layers. Cement plugs are required to be placed across the oil or gas reservoir (zone plug), across the base-of-fresh-water (BFW plug), and at the surface (surface plug). Other cement plugs may be required at the bottom of a string of open casing (shoe plug), on top of tools that may become stuck down hole (junk plug), on top of cut casing (stub plug), or anywhere else where a cement plug may be needed. Also, the hole is filled with drilling mud to help prevent the migration of fluids.

In addition to well status, CalGEM categorizes individual wells by type, or purpose. Table 1.2 details the well types associated with the plugged wells of Ventura County. As you can see, the majority produced oil and/or gas, but even those that did not could pose safety hazards and threats to groundwater and soil by creating pathways of contamination, if not properly abandoned.

Table 1.2 – Types of Plugged Wells in Ventura County (VC)

Type	**Description**	**# in VC (Mar. '22)**
Oil & gas	Drilled well that produced sufficient oil, natural gas, or other resources	2,770
Dry hole	Drilled well that did not produce enough oil or gas to be commercially viable	1,193
Injection, waterflood, or steamflood	Injection well in which pressurized water, steam, or other fluid was pushed deep into well to loosen hardened oil	260
Multi-purpose	Well that produced a combination of oil, natural gas, or other resources	60
Core hole	Well drilled for the purposes of extracting whole-rock samples (cores) from a well	39
Water disposal	Well injected with waste fluids from industrial activities	29
Water source	Well owned and operated by oil and gas companies for the collection of water resources to be used in industrial activities	15
Unknown	Records fail to indicate the type of well	8
Dry gas	Well that produces gas with little or no condensate or reservoir liquids	1

Note: In the absence of category definitions from CalGEM, table and definitions compiled by author utilizing Oilfield Glossary (Sclumberger, 2021) and conclusions made after viewing individual well records.

As explained above, this research is specifically interested in identifying and examining abandoned wells of any type. The last two category levels are abandonment and cleanup priority, which are variables uniquely defined and assigned by this research, further explained below.

Data Collection and Analysis of Abandonment and Cleanup Priority Variables
This research starts with a WellSTAR dataset of all individual wells located onshore within Ventura County by API (American Petroleum Institute) identification number. These data are then segmented by Well Status, and the complete sample of all 4,376 "Plugged" wells are analyzed.[4] In addition to the WellSTAR variables,[5] individual well records were examined to construct five additional variables – year abandoned, well depth, proximity to a sensitive receptor, plug method, incomplete records, and oil spill or gas leak and/or other problems. These variables are summarized in Table 1.3. Supplemental notes provide information indicating rarities, missing documents, and other specifics related to problems and spills/leaks. These six variables help to fill a major gap in CalGEM data pertaining to plugged and abandoned wells.

Table 1.3 - Variable Data Collected by CFROG Researcher from Individual Well Records

Variable	Descriptive Question
Year abandoned	If available, what year was the well abandoned?
Well depth (ft)	If available, how deep was the well originally drilled?
Sensitive receptor	Is the well located near or under a sensitive receptor - including housing, other social infrastructure (i.e., school), or natural resources (i.e., river)?
Plug methods	If available and other than cement, what was the well plugged and capped with?
Incomplete records	Does the well record have complete abandonment records, including the final abandonment approval by Department of Conservation?
Spills/leaks or problems	Does the well record confirm or indicate suspicion of oil spill/gas leak or other contamination problem(s)? Is the spill/leak current (i.e. happened after abandonment) or historic?

All 4,376 documented plugged and abandoned wells present in the county are included in the analysis. However, due to limitations in CalGEM data, some wells are missing variable information. The year of abandonment and well depth is missing for 531 wells and 407 wells, respectively. In those cases, abandonment status is determined based on original drilling dates

[4] The initial identification of properly and poorly abandoned wells was conducted in Spring 2021 by a CFROG subcontractor and University of California, Los Angeles graduate student, Herriet Ferrer. This data was then supplemented and edited by author, Haley Ehlers in Spring 2022.
[5] WellSTAR variables include: API, Lease Name, Well Number, Well Status, Welly Type, Operator Code, Operator Name, Field Name, Area Name, District, County Name, Section, Township, Range, Base Meridian, Latitude, Longitude, and GIS Source information.

and the presence or lack of abandonment documentation. Additionally, 211 wells have completely missing well records, despite being labeled as “plugged” by CalGEM.

Classification of Abandonment Variable

According to this analysis, the first documented plugging and abandonment of a well in Ventura County occurred in 1864. Since then, all wells that meet the abandonment criteria of the time have been labeled as “plugged” by CalGEM, effectively writing them off as safe and in need of no further assessment or monitoring. The American Petroleum Industry (API) did not publish standards on well cement and proper plugging processes until 1953 – as summarized in Table 1.4. Wells abandoned prior to this year are “often not considered to have effective cement plugs” (Benedictus, 2009, p. 8). As operators began abandoning wells in the late 1800s and early 1900s, cement was poured in from the surface without prior hole cleaning, leading to these early plugs not hardening as desired (NPC, 2011). This resulted in contamination within the wellbore of drilling mud, fluids, and plugging material. Additionally, before API standards, wells were commonly abandoned with “sundry materials:”

> In wells plugged prior to the more modern regulations and standards set in the 1950s and onward, many wells were abandoned with plugs consisting of brush, wood, paper sacks, linen or any other material that could be pushed into a well to form a basis for the dumping of one or two sacks of cement to “plug” the well. (NPC, 2011, p.10; Ide et al., 2006)

In contrast, wells abandoned today are generally plugged with cement with sealing additives, mud, bentonite, and mechanical plugs. The API cementing guidelines led to more standardized plugging programs, but it is important to note that even the 1953 distinction is conservative. As illustrated in Table 1.4, most states did not begin regulating the use of modern plugging methods until 1956 and modern *environmental* plugging requirements were not implemented until the 1970s and 80s. In 1974, Congress passed the Safe Drinking Water Act which increased the requirements for freshwater protection. This resulted in state regulation updates to include stricter requirements protecting freshwater aquifers and minimizing the flow of fluids between geologic formations (GWPC, 2009; NPC, 2011). To establish an acceptable baseline, this research uses the conservative parameter of wells abandoned during or prior to 1953 to determine wells “poorly abandoned due to age.”

Table 1.4 - Historical Developments in Oil and Gas Well Plugging

Year	Development
1878	Wells often plugged with wood and sediment
1881	Wells required to be filled with sand or rock sediment and wooden plugs above producing formation layers
1922	Patent on the two-plug wood method by Halliburton, limiting potential mud contamination
1928	Multiple cement types become available for plugging
~1930	Introduction of centralizers, enabling more uniform cement distribution in wells
1940	Introduction of two types of Portland cement and three types of additives
1940s	Invention and widespread use of caliper, enabling calculation of the exact quantity of cement
1953	Publication of American Petroleum Industry (API) standards on well cements
1956	Many states begin implementing and enforcing modern plugging requirements
1974	Congress passes the Safe Drinking Water Act, increasing requirements for freshwater protection, states update to stricter requirements
1975-85	Modern environmental plugging requirements developed and implemented

Note: Table compiled by author based on Benedictus (2009), NPC (2011), Pennsylvania Department of Environmental Protection (2018), and Ide et al. (2006).

CalGEM is aware of the dangers that an unsealed well poses and, because of this, revised its idle well regulations in April 2019 to "create far more stringent testing requirements that better protect public safety and the environment from the potential threats posed by idle wells" (CalGEM, 2019). In contrast, abandoned wells are only assessed during the plugging process or on a reactionary case-by-case basis, usually after a landowner or other stakeholder complains of a possible leak. Additionally, there are major gaps within publicly available CalGEM abandoned well data that this research aims to fill for Ventura County.

Utilizing the variables summarized in Table 1.3, this research develops four classifications for abandonment status. These classifications are listed in Table 1.5. A well is considered "poorly abandoned" if it was abandoned before 1953, if its plugging method is inconsistent with California's modern standards, and/or if its abandonment records are missing or incomplete.

Table 1.5 – Classification of Abandoned Wells in Ventura County (VC)	
Classification	**Description**
Plugged & abandoned	Well plugged and abandoned properly after 1953, consistent with regulations requiring cement plugs, plugged only once, and/or sufficient abandonment records available
Poorly plugged & abandoned	Well abandoned before 1953, plugged with poor quality materials (inconsistent with regulations requiring cement plugs), and/or incomplete or missing abandonment records
Re-abandoned	Well that was plugged and abandoned multiple times
Re-abandoned because of problem	Well that was plugged and abandoned multiple times due to confirmed or suspected spill, or other issue

Wells plugged after 1953 can also be categorized as "poorly abandoned" – based on the methods by which they were plugged. As explained above, the standardized plugging requirements were not implemented in full until the latter half of the twentieth century. California regulations[6] requires sufficient cement plugs and bridges to be placed in the well-bore or casing at specific intervals to protect aquifers, other natural resource reserves, and avoid the migration of fluids and gases. If a well's abandonment record details the use of insufficient plugging material, like paper sacks, rocks, or wood, it is also considered "poorly abandoned." Lastly, wells with incomplete or missing abandonment documentation cannot be confirmed as timely and properly plugged and are therefore labeled "poorly abandoned" as well.

The additional abandonment status categories consider re-abandonment. Records that indicate a well was abandoned a second or third time are classified as "Re-abandoned" and those re-abandoned because of confirmed or suspected leak, spill, or other problems are aptly classified as "Re-abandoned because of problem." The intention of noting the re-abandonment of wells is to better understand how and why previously plugged wells needed additional assessment and repair. This will likely inform the recommendations made to regulators to address the poorly plugged wells.

[6] A well is plugged by placing cement in the well-bore or casing at certain intervals as specified in California laws or regulations. The purpose of the cement is to seal the wellbore or casing and prevent fluid from migrating between underground rock layers. Cement plugs are required to be placed across the oil or gas reservoir (zone plug), across the base-of-fresh-water (BFW plug), and at the surface (surface plug). Other cement plugs may be required at the bottom of a string of open casing (shoe plug), on top of tools that may become stuck down hole (junk plug), on top of cut casing (stub plug), or anywhere else where a cement plug may be needed. Also, the hole is filled with drilling mud to help prevent the migration of fluids.

Classification of Cleanup Priority Variable

The second variable defined and assigned by this research is cleanup priority. With over 4,000 abandoned wells in Ventura County, the task of properly assessing and amending poorly abandoned wells is large. In hopes of providing direction to decision-makers and illustrating the immediate and serious nature of this problem, wells will be ranked by priority for cleanup, summarized in Table 1.6.

Table 1.6 – Classification of Cleanup Priority

Priority	Description
Priority 1	Documented oil spill, gas leak, or problem near a sensitive/environmental receptor(s)
Priority 2	Documented oil spill, gas leak, or problem
Priority 3	Near sensitive/environmental receptor(s)

Prioritization is determined based on two criteria – (1) documented or confirmed oil spills, gas leaks, or problems and (2) proximity to sensitive and/or environmental receptors. Priority 1 wells have documentation of any oil spill, gas leak, or problem and are located near at least one sensitive receptor. A confirmed oil spill, gas leak, or problem is any instance of rarity and cause for repair confirmed or indicated by state or local agencies, oil operators, and/or concerned neighbors. For example, a problem of note may be material left in the drilled hole or collapsed casing. These problems increase the risk of contamination and/or possible spills and leaks in the future (NPC, 2011). If a well record indicates that a spill or leak occurred, but was then remediated through repair or re-abandonment, this is noted as an "historic leak" but not ranked higher for current cleanup priority. This research utilizes CalGEM's (2021) definition of sensitive receptor:

> 'Sensitive receptor' means any residence including a private home, condominiums, apartments, and living quarters; education resources such as preschools and kindergarten through grade twelve (K-12) schools, daycare centers, any building housing a business that is open to the public; and health care facilities such as hospitals or retirement and nursing homes.

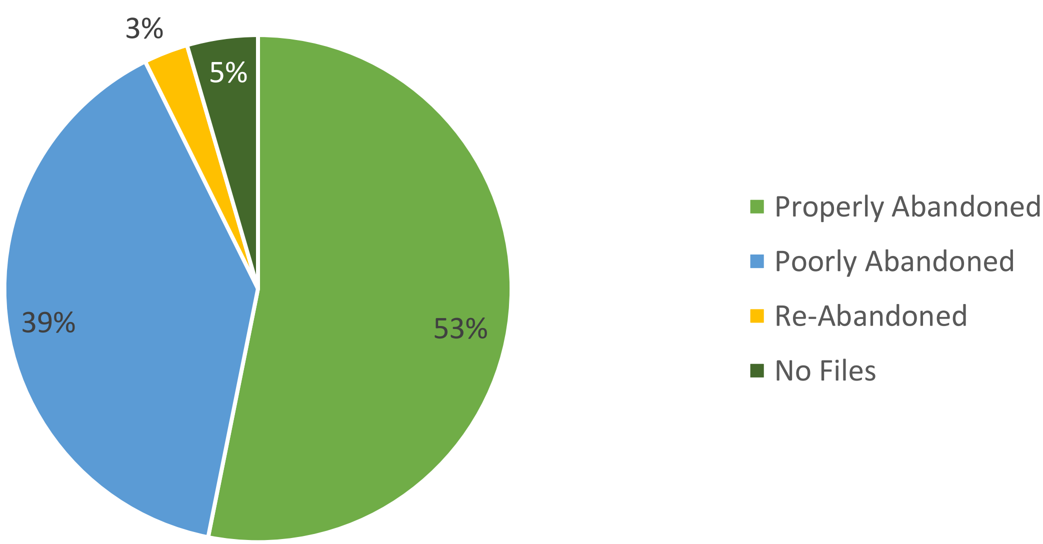
Environmental receptors are also considered and include natural areas, such as forests, watersheds, rivers, green spaces, and parks. Sensitive receptors are important to consider because they are locations where individuals and natural resources are more susceptible to the adverse effects of exposure to toxic chemicals and other pollutants. According to the EPA (2017), "extra care must be taken when dealing with contaminants and pollutants in close proximity to these areas" (p. 1). Priority 2 wells are those with an oil spill, gas leak, or other problem (like broken casing, material left in hole, etc.), but are not located near a receptor. Lastly, Priority 3 wells have no instances of rarity, as described above, except being poorly plugged and are located near sensitive and/or environmental receptors.

Findings

After reviewing the well records for all 4,376 documented plugged and abandoned wells in Ventura County, this research finds that a notable number of wells were not properly plugged and abandoned. As illustrated in Figure 1.5, 42 percent of abandoned wells cannot be confirmed as properly plugged, 37 percent are considered poorly abandoned (1,629), and 5 percent had no well record files (211 wells).[7]

Below is a discussion of additional findings, including those related to criteria for poorly abandoned wells (age, plugging methods, and incomplete records), clean-up priorities and sensitive and/or environmental receptors, and re-abandonment circumstances.

Figure 1.5 - Abandonment Status of Plugged Wells in Ventura County



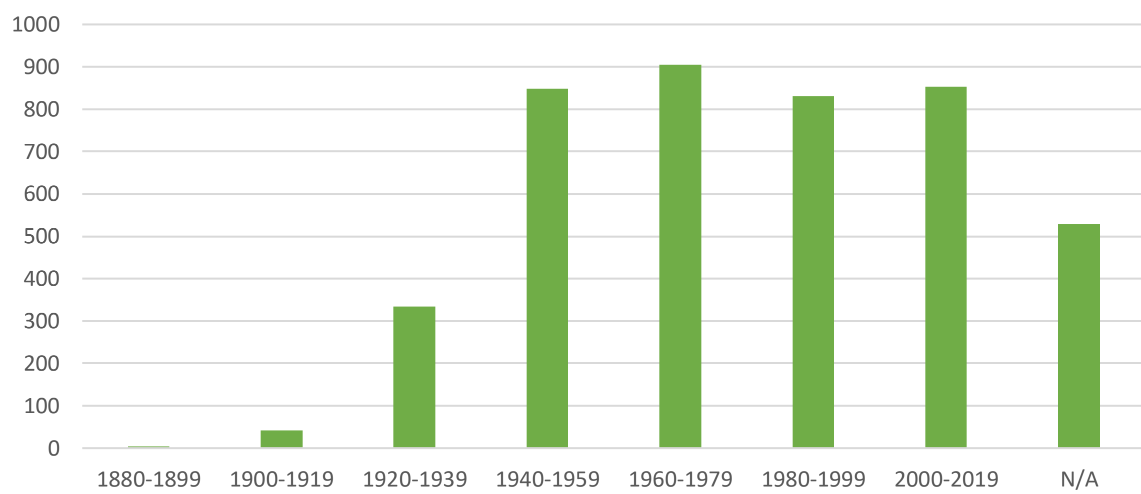
[7] The full dataset with findings can be found here.

Wells Poorly Abandoned Due to Age

Of the 1,629 poorly abandoned wells, 66 percent were plugged before or during 1953, when the American Petroleum Institute published plugging standards related to cement quality. The earliest recorded abandonment took place in 1864 on a well located near the San Antonio Creek in Ojai. The one-page, undated record (API 0411101386) mentions that it was abandoned on account of "lost tools and found no oil," so was likely abandoned soon after being drilled. The other 1,076 records tell of wells plugged with ropes, rocks, wood, and cement, broken casings, and Notice of Intention of Abandon Well submitted to state agencies, but final abandonment unconfirmed.

This research found that the rate of abandonment over the last eight decades has been relatively consistent among those for which year of abandonment could be confirmed, as illustrated in Figure 1.6. As explained above, CalGEM does include the date for which drilling began on a well, known as the "spud date," but does not list the abandonment date in searchable data. To determine when specific wells were abandoned, each record was reviewed to identify the date located on the Report of Well Abandonment or other documents, in the case of incomplete records.

Figure 1.6 - Number of Wells by Abandonment Date



Wells Poorly Abandoned Due to Method

It is clear, however, that the 1953 publication of plugging standards did not mean all wells were consequently properly abandoned. Analysis categorized 372 wells poorly plugged due to method – spanning abandonment years from 1954 to 2017. Documentation for these wells indicate a subpar abandonment process – insufficient materials used in plugging, responsibility transferred to the landowner, determination of inadequacy by agency review, and/or another major issue is noted (well/casing caving in, tools and material left in wellbore, etc.).

Insufficient plugging materials listed in well records include dirt, junk, paper sacks, rags, rock, and wood. These materials are often noted as being used as "bridges" or "plugs" to form a base upon which a few sacks of cement were then poured. The discovery of these insufficient bridge materials is consistent with the plugging and abandonment summary put together for the National Petroleum Council (NPC, 2011) referenced above. Two of the most common materials listed in these records are paper sacks (144 wells) and wood (116 wells). Until 1961, many records clearly denote the method of pushing paper sacks down the wellbore then pouring cement – likely originally transported in said sacks – on top. One example involves a well located in the Sespe Wilderness north of Fillmore (API 411102606) which was abandoned in 1960. The process was approved by the state despite using paper sacks to create a bridge 10 feet below the surface upon which the equivalent of five sacks of cement was dumped. See Figure 1.7 for excerpts from the original record.

Figure 1.7 – Excerpts from API 411102606 Record Detailing the Use of Paper Sacks as Bridge [Emphasis added]

The Engineer noted:
1. The bailer could not be spudded below 488' and brought up a sample of set cement.
2. The hole was bridged with paper sacks 10' below the surface.
3. A total of 5 sacks of cement was dumped on the bridge at 10', filling the 10" casing up to the surface of the ground.

THE PLUGGING OPERATIONS AS REPORTED AND WITNESSED ARE APPROVED.

The hole was entered and bailed to a depth of 520 ft. The bailer was spudded at 520 ft. and no headway could be made. Marks on the bailer indicated that iron junk was encountered. Upon permission of D. O. G., plugging operations were started at 520 ft. Ten sacks of cement were dumped in the hole beginning 520 ft. Top of the plug was located at 488 ft. at which depth the bailer could not be spudded and a sample of set cement was obtained. The top and hardness of the plug was witnessed and approved by the D. O. G. The hole was bridged 10 ft. below the surface. Five sacks of cement were dumped on the bridge at 10 ft. below the surface filling the 10" casing to the surface of the ground. The placing of this 10 ft. plug was witnessed and approved by the D. O. G. The well was abandoned April 21, 1960. The abandonment wa approved by the D. O. G.

Similarly, until 1971, many operators used wooden plugs at various depths within the wellbore, from as far down as 6,500 feet to just a few dozen feet below the surface. This is consistent with previous literature outlining the limitations of previous plugging methods (Calvert & Smith, 1994; Benedictus, 2009). These wooden plugs were often used in combination with cement plugs, likely following the two-plug method developed by Halliburton in 1922 (Benedictus, 2009). While this method did initially improve the potential mud contamination, by the 1970s more advanced and protective methods were available. For contextual comparison, mechanical plugs and cement retainers are used as bridges in today's abandonments. As featured in Figure 1.8, these are tools made of sturdy material, like cast iron, that provide a solid seal between sedimentary layers – freshwater aquifers, oil and gas formations, etc. – within a wellbore (Schlumberger, 2022; NPC, 2011). These bridge plugs can be permanent or retrievable, creating lasting or temporary isolation from production or an extraction treatment conducted on an upper well zone.

Figure 1.8 – Modern Mechanical Plugs

Cement Retainer

Cast Iron Bridge Plug

Source: NPC (2011)

In addition to the presence of insufficient materials, wells were categorized as "poorly abandoned" for other shortcomings in methodology. There are two rarities of note. First, in some cases, the final abandonment responsibility was transferred to the landowner based on their desire to convert it to a water well. The operators usually plugged the deep sections of these wells, leaving the cellar open with no surface plug. Successful conversion is noted in a few wells, but 21 wells have no further documentation on conversion or final proper abandonment. Second, 155 wells were inspected years after abandonment. The results of these inspections vary – evidence of some wells could not be found, and others concluded wells to be improperly abandoned, with inadequate freshwater plugs, inadequate prevention of leaks, and surrounding soil contamination. But after the inspection documents, the records run dry – no confirmation of re-abandonment, repair, or further assessment.

Wells Poorly Abandoned Due to Incomplete or Missing Abandonment Records
Findings related to the last criteria for "poorly abandoned" categorization are also considerable: 211 wells had entirely missing records and 180 had incomplete abandonment documentation, despite being labeled as "plugged." It is impossible to know how CalGEM determined these wells were plugged, their well histories, and exact locations. In the case of incomplete documentation, records often include Notices of Intention to Abandon Well but do not follow up with the final Report of Well Abandonment. Without approval from CalGEM, these wells cannot be determined as entirely and properly plugged – even to lax historic standards.

Re-Abandonment and Historic Spills/Leaks
A major motivation of this research is to encourage further assessment of wells that were abandoned decades ago. To better understand how and why CalGEM has previously been prompted to do this, this research identified 63 wells that had been re-abandoned. This is only 1.5 percent of all plugged wells in Ventura County. In some cases, re-abandonment took place because wells were brought back into production, new development projects were taking place nearby, or original abandonment was identified as insufficient. However, 12 wells were re-abandoned due to a documented problem, in most cases a spill, leak, or other contamination. For example, a well located in West Ventura (API 411104465) was re-abandoned three times – first in 1948, then again in 1972 after being reworked into production, and finally in 2005, after a decades-long gas leak. The record includes a 1984 letter claiming the well had not been properly abandoned and might be leaking gas to the surface. Shell, the operator at the time, replied that the gas was too minimal to be accurately measured and the well is not recorded as an active producer. Then 16 years later, in 2000, there is a note proposing to re-enter the well to stop the gas migration through the plug, which resulted in proper abandonment in 2005. At least 32 historic gas leaks or oil spills within Ventura County are documented in plugged well records.

Cleanup Priority
While all 1,838 wells not confirmed as properly plugged should be assessed and problems remediated, this analysis identified 21 Priority 1 wells, 28 wells as Priority 2, and 137 wells as Priority 3 (full list included in Appendix 1). These wells are located across Ventura County and were abandoned between 1864 and 2018. Identified sensitive receptors include beaches, creeks, golf courses, houses, housing tracts, rivers, schools, parks, shopping centers, and streams.

Limitations of this Study
This analysis is limited by two major factors: the restricted nature of WellSTAR data and the physically restrictive nature of underground oil and gas wells. First, this research depends solely

on the data and well record documents available in WellSTAR – of which there are many gaps. As detailed above, this research found 211 wells with no record documents available and an additional 180 that have some record but are missing any confirmation of final abandonment. Information about abandonment, including plugging date, materials, and well depth, has not been digitalized or transformed into electronic data – meaning that this research had to decipher many decades-old documents written by hand or unreliable typewriter. It is likely these limitations in WellSTAR data are a result of the lack of consistent historical records and low capacity and prioritization by CalGEM – as described in the background section above. Additionally, there are likely undocumented wells for which WellSTAR does not have information on or possibly knowledge of – a problem confirmed in other states (IOGCC, 2018; Boettner, 2021). Due to wells being hidden underground, identifying undocumented wells is difficult and requires advanced technology.

This is the second limiting factor – the majority of a well and where most problems can occur is underground. In addition to being unable to include undocumented wells, this analysis is unable to consider major variables like well barrier and integrity failure in prioritization. This is a major problem that CalGEM should consider by implementing monitoring of wells abandoned decades ago. Some studies find rates of some form of well barrier or integrity failure as high as 75 percent (Davies et al., 2014). This will be discussed further in Part 2, specifically as it relates to risks posed to groundwater and soil. It should be noted – even if CFROG had the capacity to physically examine the above or below ground pieces of a well to check the robustness of WellSTAR documentation, operators would need to provide access to the well site – permission not likely granted to a third-party watchdog.

Case Study of "Hotspot" Wells

While the number of poorly abandoned wells in Ventura County that pose threats of harm is unclear, case studies of individual problem wells can help us understand the historical, environmental, social, and economic issues these wells represent. Three "hotspot" wells stood out during this research, each of which is profiled below. This history was determined by examining the CalGEM records for each well.

API 411103114 – Priority 1 – Located in South Mountain Oil Field[8]

Originally drilled by Camden Oil Company in 1939, well 411103114 was 3,127 feet deep and plugged with cement after producing insufficient gas in 1940. After abandonment, multiple oil tanks were left on the property, and gas gradually forced small amounts of oil into the tank causing it to eventually overflow with water and oil. Just three years later, in July 1943, The

[8] To view historical documents and records related to this well, and referenced in this report, visit the CalGEM WellFinder website, search 0411103114, select the well, then "Well Record" and request files.

Texas Company complained that this well was leaking oil and contaminating their adjacent property. It is noted that this spill posed a fire hazard, and The Texas Company was not the only one impacted – the Fish & Game Commission also complained that oil had traveled down a neighboring ravine and into the Santa Clara River. Camden Oil Company refused to assume responsibility for the spill, but the well was finally re-abandoned and plugged with wood – a very porous material – in 1944.

An oil spill spreading into other areas and natural resources should have been a cause for concern and immediate action. However, according to the records, it took months for the situation to be resolved. This case highlights the sustained carelessness of oil companies and the potential hazards that poorly abandoned oil wells pose. The most recent document in the record is the final abandonment letter, dated June 7, 1944, nearly a decade before modern plugging standards were published.

API 411100863 – Re-Abandoned due to Problem – Located in Moorpark (ABD) Oil Field[9]
Drilled in 1954 to a depth of 8,500 feet, this well was plugged and abandoned in the same year. It was re-drilled in 1955, then left idle. An inspection in October 1983 found the area in poor condition with a broken fence, overgrown bushes, and two left oil tanks, one of which was unlocked and filled halfway with oil. The inspection found that the stuffing box, a device used to prevent the leaking of gases and liquids, was bubbling oil that flowed into a two-inch deep pool. This oil pool flowed into the access road down the hillside and into a ravine. This trail of oil was approaching a housing development, which had grown significantly since originally drilling in 1954, photographed in Figure 1.9. Despite pressure from the Department of Oil & Gas, the Fish & Game Commission, and the Resource Management Agency, it took five years – in 1988 – for the idle well and oil spill to be resolved. It was re-abandoned again in 2004 and once more in 2017.

Regardless of the urgency of the situation, the final abandonment of the well was prolonged due to the complex process of transferring ownership and operating oil companies refusing to take accountability. This introduces a common scenario found across Ventura County. In the 1980s, as crude oil production declined and this conventional oil became more difficult to extract, the large operators, like Shell and Exxon, moved out of the county and sold their inventory to smaller corporations. Abandoned wells are generally not included on new permit applications and extensions, even if they are located on the leased parcel. Additionally, smaller operators can more easily declare bankruptcy, leaving the decommissioning and abandonment of wells to the taxpayers (Rosenhall, 2018; Olade & Menezes, 2020).

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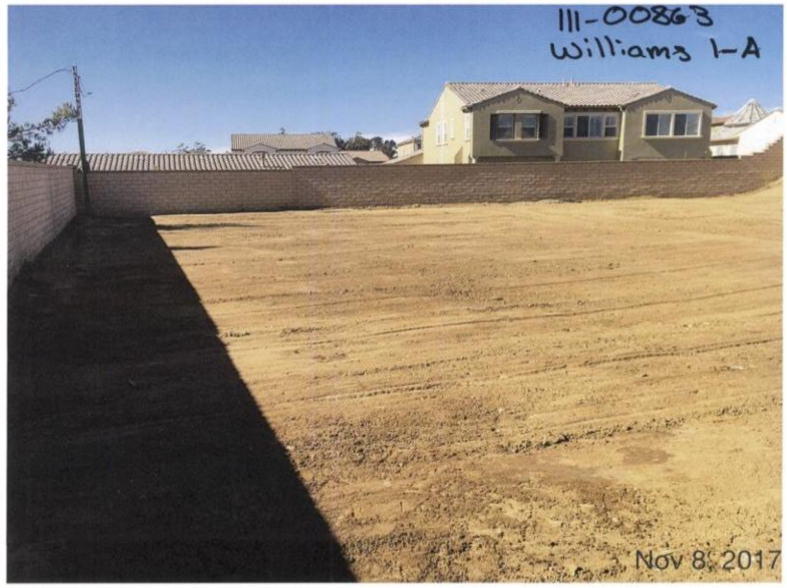
[9] To view historical documents and records related to this well, and referenced in this report, visit the CalGEM WellFinder website, search 0411100863, select the well, then "Well Record" and request files.

Figure 1.9 - Proximity of Well 411100863 to Neighboring Houses and Moorpark Community

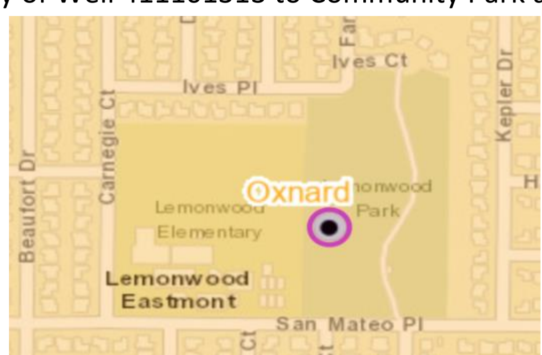


Source: WellSTAR Well Record 411100863

API 411101313 – Priority 1 – Located in Oxnard Oil Field[10]

Located in Lemonwood Park, neighboring Lemonwood Elementary School (see Figure 1.10), this well was drilled in 1959 to about 9,150 feet. It was plugged and abandoned in 1969, then re-drilled in 1970. It was left idle for years until 1988 when an environmental inspection of the property found that the well cellar was full of fluid and the fence around the area required repair. The owner, Duel Petroleum Company, was notified to correct these deficiencies and clear the spilled oil around the tank.

Figure 1.10 - Proximity of Well 411101313 to Community Park and Elementary School



Source: CalGEM WellFinder

[10] To view historical documents and records related to this well, and referenced in this report, visit the CalGEM WellFinder website, search 0411101313, select the well, then "Well Record" and request files.

After nearly three years and a quitclaim process, Chevron, the new owners, decided to finally abandon the well in 1991. In one document dated April 5, 1991, it was written that the area did not pass a surface inspection because the soil was still contaminated. Although there are no documents reporting that the soil contamination was resolved, the site passed a surface inspection years later in 1994.

This well shares ground with an elementary school that was established in 1981. According to the documents, children were around the seeping oil from this well, barely protected by a broken fence, for 13 years. In 2020, the student enrollment at Lemonwood Elementary was 98 percent minority (majority Hispanic) and ranked in the bottom 50 percent of all schools in California for overall test schools (Public School Review, 2021). The census tract in which it is located (6111004716) has a higher pollution burden than 81 percent of all California tracts (CalEnvironScreen, 2018). This case is a clear example of the often prolonged process of cleaning up poorly abandoned wells, and introduces the socioeconomic element of environmental justice communities – communities, often of color and low-income, that endure a disproportionate share of environmental pollution and degradation – which will be further explored in Part 2.

Discussion

California is moving to phase out oil extraction by 2045, and some local governments are moving even faster – both the City and County of Los Angeles have recently banned new oil and gas wells (Canon, 2022). These are major victories toward a fossil fuel-free future, but to fully rectify the century-long damage oil and gas extraction has had, California and Ventura County will have to also look to the past. This research suggests that the labeling of wells by CalGEM as "plugged and abandoned" does not necessarily mean these wells do not continue to pose a threat of spills, leaks, and contamination.

After creating a detailed category matrix based on American Petroleum Industry standards and reviewing thousands of individual well records, this research finds that 42 percent of these wells cannot be determined as properly plugged and abandoned. The majority of poorly abandoned wells were plugged before sufficient standards were adopted, while some were plugged with inadequate materials – including mud, paper sacks, and rags! Additionally, 186 wells are identified to need immediate and complete cleanup and remediation – including 21 with spills, leaks and/or problems, some in proximity to sensitive locations like schools (see Appendix 1 for full list).

These findings have major implications for the environment in Ventura County and if considered, have the potential to reshape the priorities of CalGEM and local agencies. Scientific studies confirm that abandoned oil and gas wells provide a potential pathway for subsurface migration and emissions of methane and other fluids to the atmosphere (Kang et al., 2014) – an element exacerbated by improperly plugged or deteriorating wells (Davies et al., 2014; Wright, 1986). Methane, a greenhouse gas, oxidizes to produce ozone that degrades air quality and adversely impacts human health, agricultural yields, and ecosystem productivity (Shindell et al., 2012). It also is more potent than carbon dioxide in terms of warming the climate (Garthwaite, 2021). The environmental implications of poorly abandoned wells will be further explored in Part 2 via risk assessment analyses for Ventura County communities.

The assessment and remediation of poorly abandoned wells also has major financial implications that should direct CalGEM and local agencies' priorities as it relates to their management. First, it may broaden the scope of CalGEM's Idle Well Program, which currently collects assessment fees from operators to plug idle wells, to also require funds for remediation of poorly plugged wells. At the very least, CalGEM should recognize the high complexity and costs associated with properly abandoning wells and utilize these findings to increase the bonding levels required of operators – which have already been found insufficient (Kretzmann, 2020). Local governments, like the County of Ventura, are responsible for land permits and could also use these findings to allocate funds to land restoration. Assessment and remediation of poorly abandoned wells, in Ventura County and across the state, will require a significant pool of labor from the oil and gas industry (Bolstad, 2020) – and could play a critical role in the just transition away from fossil fuels. Part 3 will provide cost and labor estimations and make policy and regulation recommendations at the federal, state, and local level.

Lastly, this research's category matrix design and findings should direct future research – completed by CalGEM or other organizations dedicated to the responsible transition away from oil and gas. For example, similar studies reviewing well records could be done in other oil-producing counties, like Los Angeles and Kern, or a sampling method could be developed to explore the issue at a state level. Additionally, scientific studies could be completed to specifically quantify the methane emissions and other environmental contamination from poorly abandoned wells in Ventura County.

Part 2 – Environmental Impacts of Poorly Abandoned Wells & Community Risk Assessments

Over the last few years, the harmful environmental impacts of poorly abandoned oil and gas wells have been gaining attention in the media. News stories often site antidotal experiences of harmful leaks and spills and the unfortunate consequences they have on humans and the larger environment. From seeping oil leaking into a ranch's water table to gas leaking into a septic system and exploding when someone tried to light a candle in a bathroom, killing a person and causing a house fire (Bussewitz & Irvine, 2021; Kusnetz, 2011). Instances like this are serious but are also difficult to predict, especially considering the little regulatory attention currently given to poorly abandoned wells – as described in Part 1.

In an attempt to assess the possible risks the poorly abandoned wells identified in Part 1 pose for Ventura County communities, Part 2 considers their geographic location in relation to other environmental and social factors.

First, a review of the scientific and investigative literature exploring the impact of poorly abandoned wells helps to identify the following at-risk factors – water, air quality, hazards (like earthquakes and landslides), agricultural resources, wildlife spaces, and environmental justice communities. Without direct field research completed in Ventura County, the negative impacts and interactions discovered by previous literature help to contextualize the geographic analysis. Then the additional data sources, risk assessment matrix design, and mapping analysis are discussed. Finally, map visualizations and risk assessment discussions are offered for each Ventura County community – Ventura, Oxnard, Camarillo, Moorpark, Simi Valley, Piru, Fillmore, Santa Paula, and Ojai Valley.

Literature Review

The environmental impacts of abandoned oil and gas wells have been studied for decades by a variety of scientific disciplines and regulatory bodies. Often these studies have similar limitations to this research itself – limited access to private land, incomplete administrative records, small sample sizes, and incomplete financing and capacity. Additionally, most studies have a small scope, exploring a very specific interaction between wells and, what this research calls, an at-risk factor. In this review, six major factors were identified – water, air quality, environmental hazards, agricultural resources, wildlife spaces, and environmental justice communities. There is currently no field research being completed by regulatory bodies to determine the exact impact poorly abandoned wells are having in Ventura County. In place of that necessary but missing monitoring, a review of previous studies completed in oil fields across the United States will help provide context to the geographic proximity these wells have to at-risk factors in Ventura County.

Water

In 1977, the U.S. Environmental Protection Agency (EPA) warned that abandoned wells can provide pathways for oil, gas, or brine waste to contaminate groundwater resources or travel up to the surface (Gass, Lehr, & Heiss, 1977). Since then, this warning has evolved into reality. Scientists at the United States Geological Survey (USGS) have found improperly abandoned wells polluting water wells and groundwater supplies in Kentucky, New York, Oklahoma, Illinois, and Colorado (Henderson et al., 2009; Keisig & Scott, 2013; Kharak et al., 2013; Gorczynska & Kay, 2016; McMahon et al., 2018). According to USGS (1995), improperly abandoned and orphaned wells:

> May act as conduits for the contamination of groundwater supplies by oil field brines and other pollutants. The casings of abandoned wells eventually develop leaks, which, if not properly plugged, can allow pollutants to reach freshwater aquifers that supply drinking water. Sources of pollutants include brine ponds, landfill sites, agricultural activities, industrial activities, illegal disposal sites, or accidental spills.

They note that this problem is particularly acute in regions with old petroleum fields and that urban areas can also contain wells that were abandoned and concealed during development.

This scientific research on groundwater contamination via leaky, old wells is often reactive, confirming a problem that people have already been made well aware of. In 1989, nine unique cases were identified where abandoned wells had contaminated groundwater, including one that rendered the water supply for nearly 40,000 people in Kentucky undrinkable (GAO, 1989). An assessment of 185 private water supply contamination incidents in Ohio from 1983 to 2007 found 41 incidents caused by orphaned well leakage (Kusnetz, 2011). Recently, after finding bubbling water at surface level, the Navajo Nation alerted the EPA, who found nearly 50 orphaned oil and gas wells between the borders of Utah and New Mexico with similar leaks. Tests found potentially dangerous levels of arsenic, sulfate, benzene, and chloride in the water from some of the wells (EPA, 2019).

Groundwater contamination from oil and gas operations has been documented in Ventura County as well. Groundwater is the largest single source of water in Ventura County, providing about 67 percent of the locally utilized water (VC Public Works, 2020). Three major groundwater basins in the county are designated as critically over-drafted; one of which is located underneath a large oil field, agricultural land, and was found to have traces of thermogenic gas mixed with microbial methane (VC Watersheds Coalition, 2017; Rosecrans et al., 2021). In 2010, farmworkers in the area noticed that irrigation water was oily and off-smelling. It was determined that pipes connecting diluent storage, a hydrocarbon fluid used to dilute heavy oil and reduce its viscosity for easier transportation, and tar sand extraction production had cracked and polluted the groundwater used for irrigation (Food & Water Watch, 2018). While the contaminated water was not used for drinking, an entire field of impacted broccoli had to be destroyed and hundreds of farmworkers were exposed to the toxic chemicals. As of early 2022, the Regional Water Board was in the process of finalizing a cleanup and abatement order to the oil and gas operator.[11] USGS scientists recently completed an analysis in the same area as this contamination and found

> The highest concentrations of thermogenic gas were observed in the proximity of relatively high density of oil wells, large injection volumes of water disposal and cyclic steam, shallow oil development, and hydrocarbon shows in sediments overlying the producing oil reservoir (Rosencrans et al., p. 1).

The study could not confirm whether the gasses in the groundwater were a result of a natural geological process or from oil operations. This area has 231 abandoned wells and 144 active/idle wells.

It is important to note that this spill was a result of tar sand extraction. Tar sand is the colloquial name for a thick, sticky petroleum deposit called bitumen, which is very difficult to extract and requires the injection of significant steam and chemical thinners (Tokar, 2014). This use of steam and chemicals is considered a type of "extreme extraction." These are techniques used to obtain unconventional resources like heavy crude, tar sands, and oil shale – i.e., dirtier, riskier, and harder to obtain petroleum materials (Walker, 2012). Another extreme extraction method is hydraulic fracturing, or "fracking," where massive amounts of water, sand, and chemicals are pumped into horizontal wells to fracture rock that holds oil and gas (Walker). While abandoned wells are no longer in operation, scientists are concerned about their proximity to wells utilizing extreme extraction.

The fracking boom started in 2008, and since then the number of documented abandoned wells nationwide has jumped by more than 12 percent (Groom, 2020). This is because fracking increases newer wells' capacity to produce, leaving older wells unattractive to operators. Investigative journalism found that EPA scientists mentioned concern that fracking near abandoned wells in Pennsylvania could threaten groundwater, saying the legacy wells "may

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[11] To view progress on this cleanup and abatement order from the Los Angeles Regional Water Quality Control Board to Peak Operators (former Vaca Energy, former Tri-Valley Oil), visit here.

present a risk unique to the hydrofrac process" (Kusnetz, 2011). Studies find support for the concern that injecting high-pressure water, sand, and chemicals into new wells will disrupt the earth, leading to gas and other contaminants being pushed into openings created by old, leaky wells (Brownlow, James, & Yelderman, 2016; Raimi et al., 2021). In one of the more extreme cases, an abandoned well in the Pinedale Gas Field in Wyoming produced a 30-food geyser of brine for more than a week because of hydraulic fracturing of a nearby well (Allison & Mandler, 2018). In addition to these fluids contaminating the surface environment, including soil and rivers or streams, and potentially groundwater, the unexpected pressure release caused by this fluid escape "reduces the effectiveness of the hydraulic fracturing operation, so there are both environmental and economic incentives to identify and plug wells near a planned hydraulic fracturing operation" (Allison & Mandler, 2018b). In other words, properly abandoning wells makes financial sense for oil companies by increasing the productivity of other wells.

Air Quality

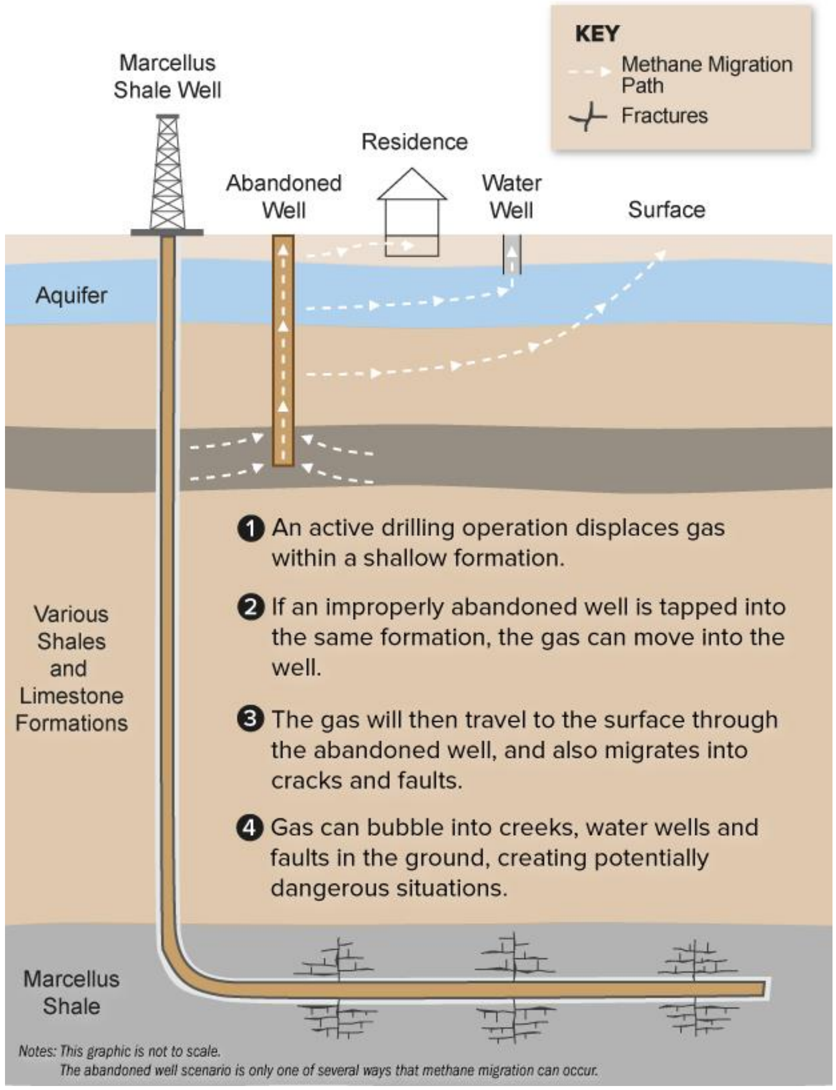
Air pollution from the oil and natural gas industry has been a major concern over the last decade, especially as it relates to wells in proximity to humans and the corresponding negative health impacts. In 2012, there remained "much uncertainty" about the actual amount and contents of air emissions released by the industry (Alvarez & Paranhos, p. 22). But over the last 10 years, public health and air quality scientists have confirmed that oil and gas wells – throughout their life from active to abandoned – emit greenhouse gases (GHG) and other harmful pollutants. According to the Environmental Integrity Project (2020), GHG emissions from petroleum and natural gas systems rose from 308 to 349 million tons between 2016 and 2018, a 13 percent increase over two years.[12] Additionally, based on the Energy Information Administration's annual projections for gas alone, GHG from drilling operations could reach 165 million tons in 2025, an increase of 27.4 percent above 2018 levels (EIP, 2020).

More specifically, the EPA (2021) estimates that in 2019, methane emissions from natural gas, petroleum systems, and abandoned oil and gas wells were the source of approximately 29 percent of total methane emissions in the U.S. and about 3 percent of total U.S. GHG emissions. As illustrated in Figure 2.1, methane gas can migrate from deep underground to the surface of a basement, water well, or the ground. Methane, the principal component of natural gas and a GHG, is a major air pollution concern due to its high warming potential: 28-34 times that of carbon dioxide over 100 years and 84-86 times over 20 years (EPA, 2021). In their latest report, the Intergovernmental Panel on Climate Change (2021) found methane levels in the air are higher now than at any point in the past 800,000 years and called for "strong, rapid and

[12] The data for earlier years are incomplete (most gathering and transmission systems did not report emissions until 2016), which makes longer-term comparisons impossible.

sustained reductions" in methane emissions to keep bold global warming limit goals within reach (under a 1.5°C average increase).

Figure 2.1 – Illustration Example of Methane Migration



Source: State Impact Pennsylvania (2012), graphic produced by Yan Lu

While the entire oil and gas industry emits GHGs, abandoned wells are a special case when it comes to methane. After a comprehensive review of all available data, Reuters concluded that orphaned and abandoned wells in the United States were collectively responsible for emitting 281,000 tons of methane into the atmosphere in 2018 (Groom, 2020). For context, the report explains the collective methane release as "the climate-damage equivalent of consuming about 16 million barrels of crude oil" (para. 8), which is about as much as the United States uses in a typical day. The report points out that the EPA believes most of the methane comes from the "more than 2 million abandoned wells it estimates were never properly plugged" (para. 9). But a recent study found that annual methane emission from abandoned wells is underestimated by 20 percent in the U.S. (and 150 percent in Canada) (Williams, Regehr, & Kand, 2021). This lower estimate is due to incomplete emission data from the oil and gas industry and state agencies (Lebel et al., 2020). This conclusion is supported by various studies finding evidence of methane emissions from abandoned oil and gas wells – in Pennsylvania and West Virginia (Kang et al., 2014; Kang et al., 2016; Riddick et al., 2019, Pekney et al., 2018), midwestern United States (Townsend-Small et al., 2016; Yin et al., 2020), United Kingdom (Boothroyd et al., 2016), Netherlands (Schout et al., 2019), and California (Lebel et al., 2020). Additionally, many of these studies found the majority of methane emissions from abandoned wells originated from thermogenic sources, suggesting a loss of well casing integrity (Kang et al., 2014; Kang we al., 2016; Townsend-Small et al., 2016; Davies et al., 2014).

A California study (Lebel et al., 2020, p. 14623) sampled 121 wells and suggests that surface methane emission levels from California's wells are similar to those in other United States regions. They found that emissions from plugged wells are low but detectable, and more substantial from idle wells. Their study also includes one unplugged well, not reported in the state agency database and with no production equipment on site. They found it was leaking at a rate consistent with the substantial emissions from idle wells (10.9 g CH_4 h^{-1}) (p. 14622). This finding supports the limitations outlined in Part 1: there may be a significant number of poorly plugged wells undocumented by state regulators, and therefore outside the scope of this research.

In addition to climate change concerns, leaking methane can cause other serious problems. When concentrated, methane can create a serious explosion and fire hazard. This is an especially dangerous situation for homes or commercial structures built directly over wells that have not been properly sealed (Chilingar & Endres, 2005). Leaking gas from abandoned wells caused explosions at a home in Pennsylvania in 2011 (Schellhammer, 2013) and a construction site in Colorado in 2007 (Quinton, 2018). Additionally, it can contaminate groundwater, as discussed above, worsen air quality by oxidizing to create ozone pollution (West & Fiore, 2005), and may also be accompanied by the release of other toxic chemicals, like volatile organic compounds (VOCs). Like so many aspects of poorly plugged wells, the exposure pathway of VOCs has not been specifically studied yet, but based on active and idle well findings, this is likely a risk (Raimi et al., 2021).

Chronic exposure to VOCs, like benzene and toluene, and other air pollutants from oil and gas wells can lead to upper respiratory tract irritation, dizziness, sore throat, headaches, asthma, cardiovascular effects, and cancer (Macey et al., 2014). There is a growing number of studies investigating the human health impacts of living near oil and gas wells. A 2017 study found that approximately 17.6 million people in the United States live within 1,600m (~1 mile) of at least one active well (Czolowski et al., 2017). A study out of Colorado found that mothers living near more intense oil and gas development activity have a 40 to 70 percent higher chance of having children with congenital heart defects compared to those living in areas of less intense activity (McKenzie, Allshouse, & Daniels, 2019). Similarly, a study found proximity to higher volume oil and gas production in California was associated with adverse birth outcomes among mothers living in rural areas (Tran et al., 2020).

Environmental Hazards

Ventura County is vulnerable to a variety of environmental hazards and climate disasters, including earthquakes, landslides, subsidence, wildfires, and coastal flooding. In some cases, the specific interaction between these events and abandoned oil and gas wells has not been studied, and even literature concerned with the interactions of general oil and gas development is sparse but does provide context for the possible risks.

Since the fracking boom in the late 2000s, there has been growing research done on earthquakes or seismic events *induced* by oil and gas development activities (Weingarten et al., 2015; Atkinson et al., 2016; Schultz et al., 2018). But there has been only one study quantifying the possible role seismicity can have on subsurface well leakage and other environmental problems. Kang et al. (2019) found, that of their three-region study, California has the most correlated clusters of oil and gas wells and earthquakes (magnitude (M) ≥ 1.0), with densities reaching ~60 wells per km^2 and ~40 earthquakes per km^2. Considering the interaction of these two factors helps to determine the potential for “earthquakes to create or enhance leakage pathways in and around wellbores” (p. 5). As illustrated in Figure 2.2, they found “hot spot” clusters, indicating high leakage potential, in the Central Valley and the southern coastal region (including Ventura). The study notes the “one well-documented catastrophic leakage” at the Aliso Canyon Natural Gas Storage Field, located near the Ventura and Los Angeles County border, but without more empirical field studies, the possible smaller leaks remain undetected. The study points out that the specific relationship between wellbore integrity and earthquakes has not been examined, but previous studies have linked the leakage pathways created by natural earthquakes with methane and other gas emissions (Giardini, Subbarayudu, & Melton, 1976), groundwater contamination (Shaw, 2007), and pipeline damage (O’Rourke & Ayala, 1993; Pineda-Porras & Najafi, 2010).

Figure 2.2 – Distribution of Well Densities, Earthquake Densities, and Leakage Potential

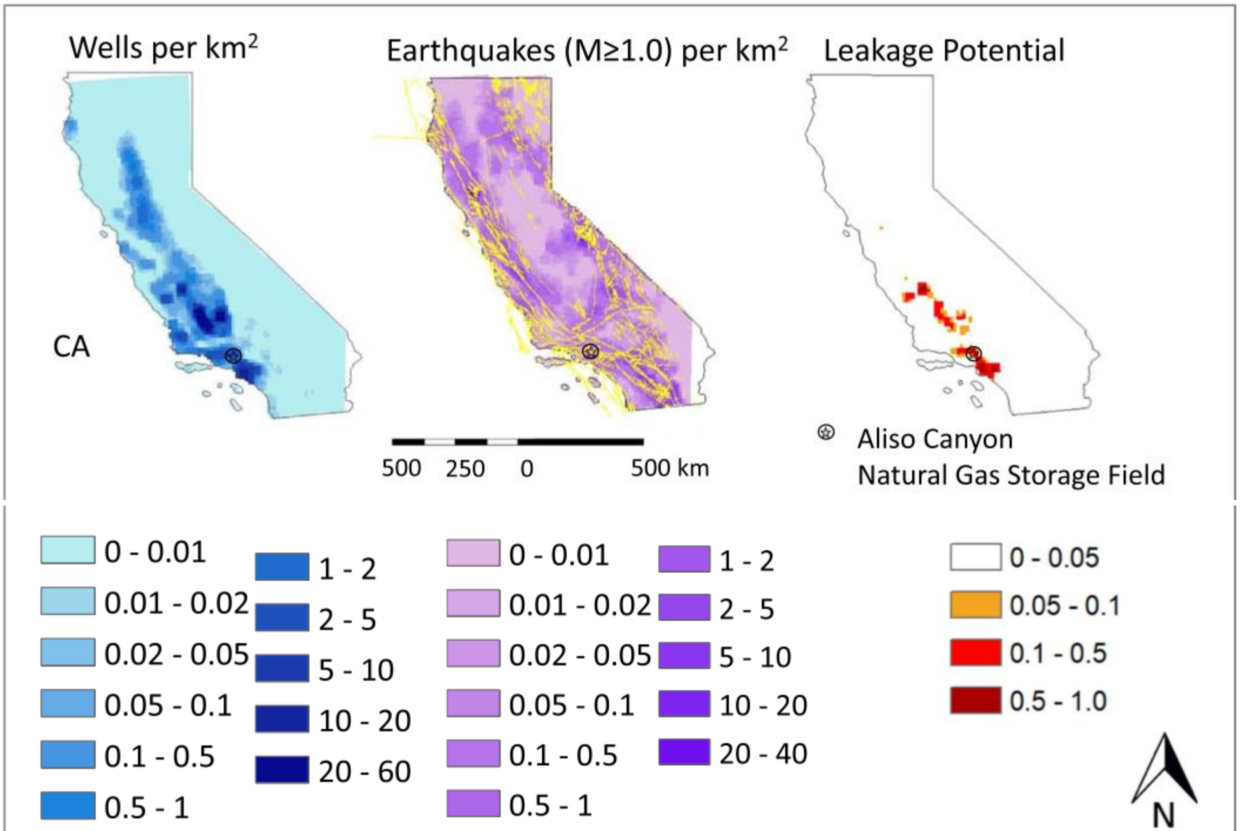


Figure 1. Distribution of earthquakes densities (M ⩾1.0) from 2009 to 2018, oil and gas well densities, and the enhanced wellbore leakage potential linked to earthquakes (L_i') in California (CA), Oklahoma (OK), and British Columbia (BC). The Aliso Canyon natural gas storage field, where a large gas leak occurred in 2015 [22], is identified in the California maps. For oil and gas wells, the units of the point density mapping are number of wells or earthquakes per square kilometer. The L_i' values ranges from 0 to 1.0, with 0 representing no leakage potential and 1.0 representing maximum leakage potential in region *i*. Hot spots ($L_i' > 0.1$) are shown in two shades of red and areas with $0.05 < L_i' < 0.1$ are shown in orange. The yellow lines in the middle column showing earthquake densities represent major faults in the USGS and BC Geological Survey's databases.

Source: Excerpt of figure from Kang et al. (2019)

Landslides, an additional hazard, are often triggered by earthquakes, storms, fires, extreme weather, erosion, or the steepening of slopes by human modification. Ventura County, like much of southern California, is susceptible to major and frequent landslides. La Conchita, a small town in northern Ventura County is a tragic case study. In 1995, after heavy winter rainfall, a major landslide damaged nine houses. Ten years later in 2005, after 15 days of near-record rainfall, a larger area failed and remobilized the original slide and damaged or destroyed 36 houses and killed 10 people (USGS, 2015). Landslides causing considerable damage to oil and gas infrastructure, including well pipe, pumps, pipelines, well machinery, and roads, within the region is well documented (Keefer & Wilson, 1995; Baum, Galloway, & Harp, 2008). In fact, in 1974, Getty Oil Company studied the challenges of locating and recovering 65 oil wells in the Ventura Avenue Field damaged by a landslide (Johnson). They found well damage ranging from slight bending to complete severing of all casing strings. Additionally, in 1998, a landslide ruptured a Ventura pipeline, resulting in thousands of gallons of crude oil spilling into the ocean and damaged a natural gas line that sparked a massive gas blast and fire, felt across the county (Bustillo, Gammon, & Heie, 1998).

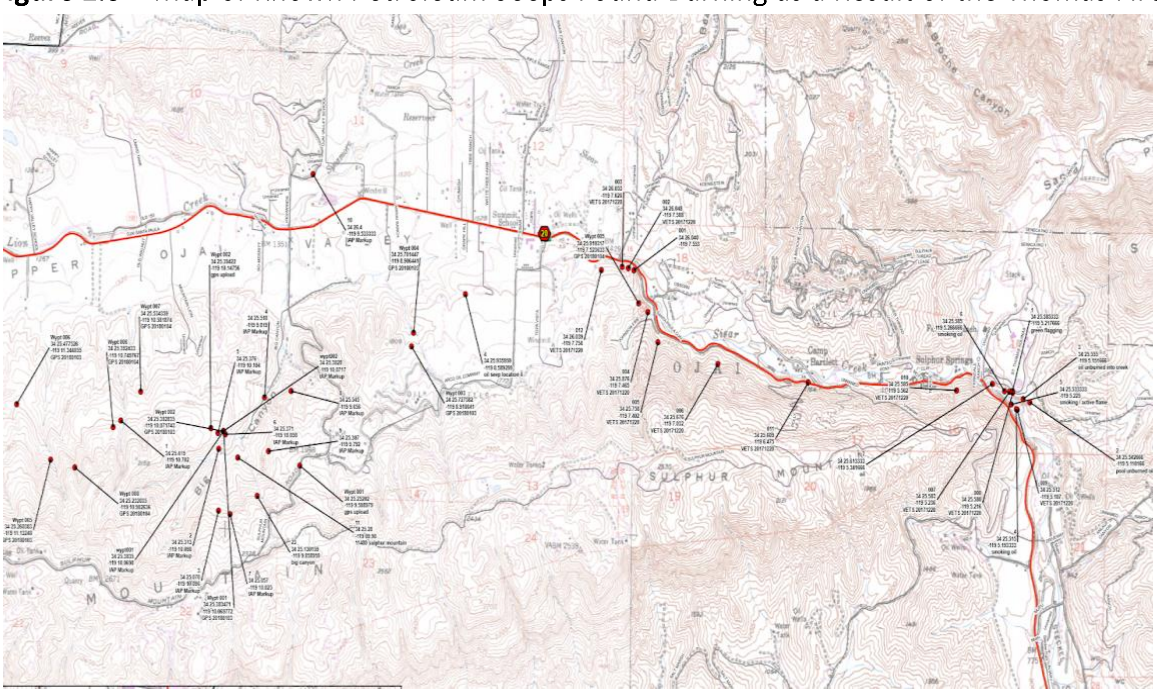
Land subsidence, or the sinking of land-surface elevation, is also an issue in California and Ventura County. This issue can be caused by natural processes but is exacerbated by human activities – largely the unsustainable extraction of groundwater (Borchers & Carpenter, 2014) and in some cases, oil and gas resources (Gurevich & Chilingarian, 1993). Abandoned wells have the potential to create increased ground instability. This, paired with aging casing and/or insufficient plugging material increases the possibility of environmental damage (Kim & Lu, 2020). Various geohazards, including subsidence due to sinkhole formation, ground deformation, and subsurface wastewater leakage, were found very close to aging abandoned oil wells in the Permian Basin (Kim & Lu) and northern Adriatic Coast in Italy (Baú, Gambolati, & Teatini, 2000). Similarly, a USGS study in Central Kansas found land subsidence near abandoned wells with failed well casings or plugs (Fader, 1975).

In coastal areas, like much of Ventura County, subsidence also worsens the impacts of sea-level rise (SLR) and flooding. Due to the warming of our atmosphere, because of fossil fuel burning, the sea level in California is expected to rise by at least half of one foot by 2030 and as much as seven feet by 2100 (Petek, 2020). A recent project called Toxic Tides (2021) identified 440 hazardous facilities, including power plants, oil and gas wells, refineries, and hazardous waste sites, within the areas projected to experience flooding events. SLR increases the risk of these facilities exposing the environment and nearby residents, the majority of whom live in disadvantaged communities, to hazardous pollutants. Oil and gas infrastructure located in low-lying coastal areas are more exposed to coastal flooding and storm surges, SLR, ground subsidence, and erosion (Paskal, 2009; Cruz & Krausmann, 2013). Previous literature has explored the impact SLR will have on active and abandoned offshore wells and platforms (Burkett, 2011; Cruz & Krausmann), but there has been no specific discussion of the impact it will have on onshore wells. Offshore wells are considerably more complex and expensive to abandon than onshore wells (Vrålstad et al., 2019). It is reasonable to expect that wells located near the coast, but onshore, were not abandoned with methods suitable for temporary or permanent inundation, especially in cases of wells plugged many decades ago.

Lastly, wildfires throughout California, including in Ventura County, have been growing at an exorbitant rate over the last decade, both in frequency and destructiveness. Like SLR, oil and gas extraction and consumption interact with the factor of wildfire in two ways. First, and more widely known, the burning of fossil fuels is a major contributor to climate change, the underlying reason for the more frequent and intense wildfires (IPCC, 2021). But in addition to contributing to more wildfires, oil fields and wells can help fuel fires. A 2018 study found that 31 percent of California's 517 oil fields have been burned by surrounding wildfires, affecting more than 10,000 oil and gas wells, and over half of these fields are located in Ventura and Los Angeles counties (Ferrar, 2018). The 2017 Thomas Fire, which burned throughout Ventura and Santa Barbara counties and was the largest wildfire in California's history at the time, is one example of this scenario. The Thomas Fire burned through nine oil fields where the "oil pumped to the surface for production and the stores of flammable chemicals provided explosive fuel to the wildfire" (Ferrar, para. 7). The oil fields were too dangerous for firefighters to access, so many oil fires remained burning for weeks before being extinguished.

The Ventura County Fire Department found approximately 40 oil seeps along the Ojai Valley still burning in the weeks after the fire, illustrated in Figure 2.3. Fire crews attempted to extinguish these seeps which were readily accessible from roadways, but no complete inventory of suppression efforts exists. While the seeps may have been fully extinguished, the possibility that some reignited, were never extinguished, or never identified motivated Climate First: Replacing Oil & Gas (CFROG) to research further.

Figure 2.3 – Map of Known Petroleum Seeps Found Burning as a Result of the Thomas Fire



Source: Ventura County Fire Department

In 2019, in partnership with California State University Channel Islands, CFROG used drone sensors to identify a still-burning seep on Sulfur Mountain in the Ojai Valley. They found a surface temperature of 150˚C, high methane concentrations, along with other petroleum hydrocarbons, and raw and combustion products. After mapping 73 percent of the originally identified seeps, this research was constrained by access denial to private land and the COVID-19 pandemic. While these seeps were not identified near particular wells, a poorly plugged well, as discussed above, can provide pathways for oil or gas to migrate to the surface – introducing the possible risk of fueling and prolonging future wildfires.

Agriculture

Across California and the United States, oil and gas wells are located alongside agricultural fields. A recent study of the contiguous United States identified more than 430,000 old wells eligible for restoration. These wells occupy more than 800,000 hectare of land and are concentrated mainly in forests, grassland, and cropland (Chomphosy et al., 2021). If the well sites and associated infrastructure (access roads, storage areas, fluid tanks, etc.) were restored, the study estimates over $14 billion in crops could be produced on these lands over the next 50 years. The study also estimates that restoring these lands could provide $7 billion in benefits from reducing greenhouse gas emissions, improved habitat for wildlife, increased timber production, and healthier ecosystems. Similarly, a smaller study done in north-central Arkansas found the reclamation of abandoned well infrastructure to be worth more than $2 million annually in agricultural, timber, and carbon sequestration (Nallur, McClung, & Moran, 2020).

While the reclamation of abandoned wells offers some positive opportunities for agriculture, without sufficient reclamation poorly abandoned wells pose significant risks. As the issue of orphaned and abandoned wells has gained media attention, many articles include antidotal stories from farmers. For example, a farmer in Montana discovered 16 open wells on his land (Levy-Uyeda, 2020); an oil leak from a legacy well in West Virginia made cattle sick (Stein, 2022); and a Californian farmer sued oil companies for their poorly abandoned wells contaminating his water supply (Ayers, 2017). In addition to the air quality issues discussed above, methane leaking from a well can have adverse impacts on agricultural yield and ecosystem productivity (Kang et al., 2014). Similarly, the threat of groundwater contamination discussed above (Kusnetz, 2011; McMahon, 2018) is relevant to agricultural production, which often uses groundwater for irrigation.

Agriculture is a major industry in Ventura County. In 2020, the county produced nearly $2 billion in crops, including strawberries, lemons, avocados, and tomatoes (VC Crop & Livestock Report, 2020). Amid the productive, green farmland, often used as a symbol for the area, the oil and gas industry has made its mark, particularly in the Oxnard Oil Field. The area has been described as

> [not fitting] the stereotypical image of an oil patch. […] Oxnard is better known as the "Strawberry Capital of the World," and the oil wells and storage tanks there are scattered among the berry fields and rows of broccoli, onions, and tomatoes. By day, farmworkers from Mexico and Central America harvest the crops. At night, oil workers come in and set up stadium lights to work by. The oil production is camouflaged by the farmland, making the tar sands extraction there one of California's best-kept hydrocarbon secrets. (Cherot, 2015b, para. 1)

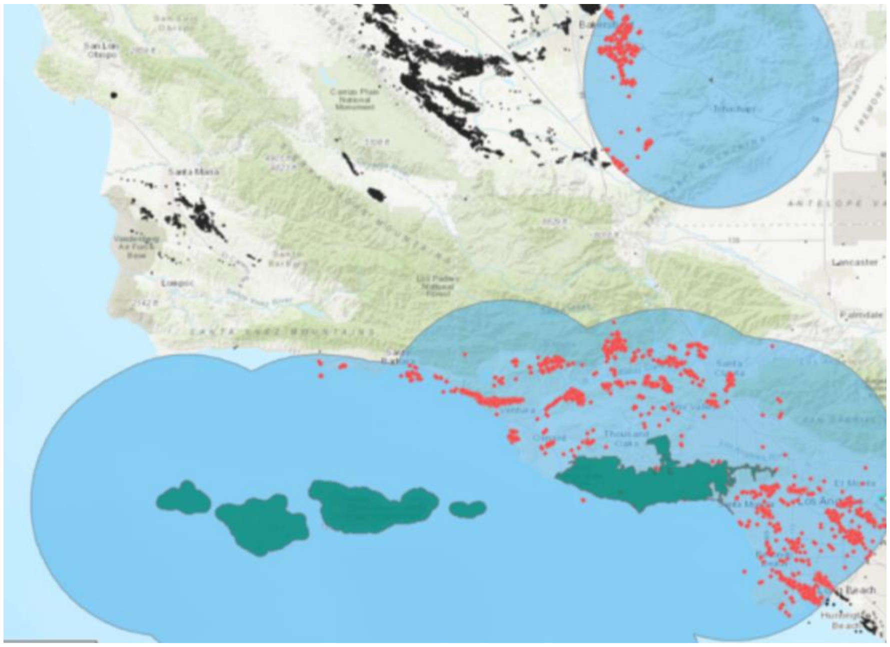
As described above in the discussion on water risk, there has been at least one case of active tar sands operation contaminating irrigation water supply and crops (Cherot, 2015). In Ventura County, nearly 85 percent of water used in farmlands is sourced from local groundwater aquifers (HydroMetrics, 2015). But active and idle wells may not be the only risk present. According to CalGEM records, there are wells in the Oxnard Oil Field that were abandoned as far back as 1930.

Wildlife Spaces

For over a century, oil and gas development, especially on public lands, has damaged ecosystems, displaced wildlife, destroyed habitat, led to damaging disasters, increased human activity in formerly undisturbed areas, and increased greenhouse gas emissions and global warming (Brittingham et al., 2014; Jones, Pejchar, & Kiesecker, 2015). As the United States transitions to more renewable energy development, like wind, solar, and geothermal, some of these ecosystem problems will continue but this development is necessary for avoiding further climate crises, which will cause the ultimate harm to wildlife (Trainor, McDonald, & Fargione, 2016; Agha et al., 2020).

The legacy of oil and gas extraction – in the form of abandoned and orphaned wells – has been identified to pose serious threats to wildlife and outdoor recreation. A recent report on federal lands across five states identified more than 5,000 at-risk wells in big game habitat, nearly 400 in sage grouse habitat, and in Montana, 67 wells within one mile of blue-ribbon trout streams (Gardner, 2021). Additionally, over 30,000 abandoned, orphaned, and idle wells were identified within a 30-mile radius of national park sites across the county (National Parks Conservation Association, 2021). This analysis found the Santa Monica Mountains National Recreation Area, located on the county line between Ventura and Los Angeles, to be the park with the most idle wells within 30 miles, and Channel Islands National Park, islands located 40 miles off the Ventura coast, to be the park with the fourth most, as seen in Figure 2.4 below.

Figure 2.4 – Idle Well Clusters by Santa Monica Mountains National Recreation Area and Channel Islands National Park



Source: National Parks Conservation Association (2021)

In addition to these national parks, Ventura County is home to critical coastal wetlands, the Santa Clara River, three critical wildlife passage corridors, and large parts of the Los Padres National Forest. These areas are home to approximately 100 federally endangered and threatened species, including the California condor (Ventura Fish and Wildlife, 2022). Over the last few decades, and thanks to millions in conservation funds, the California condors have made a slow comeback from near extinction. A 2015 environmental impact report by CalGEM[13] suggested that oil and gas production, specifically well-stimulation, could have significant and unavoidable impacts on endangered species (Guzik, 2015). The report cites the risk posed to birds in the Sespe Condor Sanctuary, a critical habitat for condors located near the Sespe Oil Field in central Ventura County.

Environmental Injustice

In the United States, communities of color, low-income communities, and generally marginalized communities experience disproportionate effects of environmental degradation. In the 1970s, studies using early EPA air quality data found that the poorer an area or neighborhood, the more polluted the air (Szasz & Meuser, 1997). Since then, research has continued to explore the intricacies of racial and economic environmental inequalities – from

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[13] In 2015, the state agency currently known as California Geologic Energy Management Division (CalGEM) was called California Division of Oil, Gas and Geothermal Resources (DOGGR).

air and water pollution, toxic waste, oil and gas production, and more. For example, a 20-year longitudinal study found that more than half of people who live within 1.86 miles of toxic waste sites in the United States are people of color (Bullard, Mohai, Saha, & Wright, 2007). More specific to oil and gas operations, studies done in South Texas found that Hispanic communities are disproportionately exposed the flaring, a process to dispose of excess gas through combustion, and wastewater disposal wells used in the fracking process are disproportionately permitted in areas with higher proportions of people of color and residents living in poverty (Johnston et al., 2020; Johnston, Werder, & Sebastian, 2016). A recent study has found that flaring can impact the health of people as far as 60 miles away (Blundell & Kokoza, 2022). While the listed disparities are not exhaustive, it is clear that marginalized communities are disproportionately impacted by a variety of factors including air and water pollution, toxic waste, climate change, and extreme weather, all of which are, in large part, caused by fossil fuel and non-renewable energy source industry production (Shahzad, 2012; Espinosa, 2013; Meinshausen et al., 2009). This disparity pattern is known as environmental injustice.

Environmental injustice related to oil and gas operations is widespread in California. Of the nearly five and a half million Californians who live within a mile of an oil and gas well, nearly four million are people of color (Srebotnjak & Rotkin-Ellman, 2014). Additionally, one-third of those living near wells live in communities with the highest levels of environmental pollution in the state. Residents living near wells suffer from the air pollution and water contamination risks discussed above. To better protect communities from these negative health and safety impacts, California is currently considering a 3,200-foot setback between new oil and gas wells and homes, schools, hospitals, and other sensitive locations (CalGEM, 2021). In Ventura County, more than 8,000 residents live within 2,500 feet of an oil well and 60 percent are Latinx/Hispanic (Brown, 2020). In the 2040 General Plan (2020), the county implemented similar setbacks: 2,500 feet between new oil and gas operations and schools, and 1,500 feet for homes. Both the state and county rules exclude existing wells and facilities and do not address orphaned or abandoned wells located within the setback area. Based on the geographic nature of oil fields, it is likely that residents who live near active and idle wells also live by abandoned wells.

This section aims to utilize previous research on oil and gas development, abandoned wells, and their interaction with environmental factors – water, air quality, hazards, agricultural resources, wildlife spaces, and environmental justice communities – to provide context for possible risks in Ventura County. By assessing the geographic proximity, quantity, and cleanup priority of wells and these environmental factors, this research will begin the exploration of the possible risks and implications Ventura County communities face from poorly abandoned wells.

Research Design

To assess the possible risks poorly abandoned wells pose for Ventura County, this research develops an interactive map and completes analysis based on the quantity and proximity of these wells to geographic elements representing the at-risk factors: water, air quality, hazards, agricultural resources, wildlife spaces, and environmental justice communities. A community risk assessment matrix will be developed and then applied to each community to highlight the possible problems they may face as these wells continue to deteriorate. The following discussion defines map layer data sources, geographic analysis type, and the risk assessment matrix.

Map Layer Data Sources

This geographic analysis and creation of an interactive map are done using ArcGIS Online, a web-based mapping software. The map features various layers representing abandoned wells and the environmental factors they may interact with. The first two, and most prominent, layers are wells featured by abandonment status and cleanup priority. These are the only layers created from unique data developed by this research, based on CalGEM records and the analysis completed in Part 1. These layers will be used as the basis of all geographic analyses on at-risk environmental and social factors.

The factor of water is represented by two map layers. The first features groundwater basins, including principal aquifers, created using U.S. Geological Survey Groundwater Atlas (2022) data. Groundwater basins are areas underground made up of permeable materials capable of storing and/or providing groundwater to wells. This layer includes principal and minor aquifers, as well as major alluvial aquifers that are not currently being withdrawn. The second layer shows rivers and streams with a 250-foot boundary, representing the U.S. EPA regulatory buffer. This surface-level data was sourced from the County of Ventura's Geographic Information Systems (2022a). Analysis of these factors will include counting the number of poorly abandoned wells located within the groundwater basin boundary and the 250-foot buffer for rivers and streams.

Representing continuous air quality is difficult, as it is changing daily, sometimes hourly, based on environmental factors and human activity. Without regular methane and other emission monitoring from CalGEM and other regulating bodies, it is impossible to know the exact air quality related to particular wells or oil and gas infrastructure in general. This map utilizes individual methane plume observations and their sources recorded by Carbon Mapper and NASA's Jet Propulsion Laboratory via Airborne Visible/Infrared Imaging Spectrometer (Duren et al., 2019). These point-source methane observations were located and quantified from air and space drone technology. But with only eight source sites identified throughout Ventura County, it is important to note this layer alone does not represent all emissions from abandoned wells or any oil and gas activity for that matter. Community risk for this factor will be assessed based on the presence of an emitting source, indicating an already high air pollution burden, and wells prioritizes for cleanup, particularly Priorities 1 and 2 which signifying possible leaks.

There are five layers representing the environmental hazards present in Ventura County. First, from the County of Ventura's mapping database (2022b), the location of earthquake fault hazard zones is illustrated. These are areas near seismic zones with a high level of potential hazards caused by earthquakes. Also accessed from this database are the landslide and subsidence layers (County of Ventura, 2022c, 2022d). The first shows the location of prior and potential landslides. Metadata mentions that the north half of the county, in the Los Padres National Forest, is incomplete. The second shows the boundary of subsidence or the settling or sinking of the ground surface. The metadata mentions that a significant area in the county, the Oxnard Plain, is experiencing subsidence. Sea-level rise (SLR) is represented with a layer created by the Pacific Institute using data from the Federal Emergency Management Agency (FEMA) to illustrate the 100-year flood elevations based the year 2100, with an SLR of 1.4 meters (55 inches). These projections were developed from sound estimates but are rather conservative and do not reflect the worst-case SLR that could occur (Gordon et al., 2014). To be consistent with other local research on this topic (Toxic Tides, 2021), this analysis utilizes the 2014 FEMA estimates. The last environmental hazard is wildfire which is represented by data from FEMA's (2021) National Risk Index Annualized Frequency Wildfire index. This wildfire data is organized by census tract and filtered to only feature tracts with a risk of 0.0136-0.07 events per year, the top two levels of intensity. All environmental hazard factors will be analyzed considering the relationship between their degree of intensity and proximity to poorly abandoned wells.

Important farmlands inventory data is featured for the agriculture factor. This data was also sourced from the County of Ventura (2022e) and provided by the Department of Conservation's Farmland Mapping and Monitoring Program. Four types of farmland inventory are featured: prime farmland, farmland of statewide importance, farmland of local importance, and unique farmland. Definitions for each type are provided in Table 2.1, based on metadata. The analysis will be done on the complete important farmlands inventory found in a community, rather than for each type. This factor will be analyzed on farmland presence and the number of poorly abandoned wells in proximity.

Table 2.1 – Types of Farmland Inventory

Type of Farmland	Definition
Prime	The best combination of physical and chemical features to sustain long-term agricultural production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields.
Of Statewide Importance	Similar to prime farmland but with minor shortcomings, such as greater slopes or less ability to store soil moisture.
Unique	Consists of less quality soils used for the production of the state's leading agricultural crops. This land is usually irrigated but may include non-irrigated orchards or vineyards as found in some climatic zones in California.
Of Local Importance	Soils that are listed as Prime or Statewide that are not irrigated, and soils growing dryland crops – beans, grain, dryland walnuts, or dryland apricots.

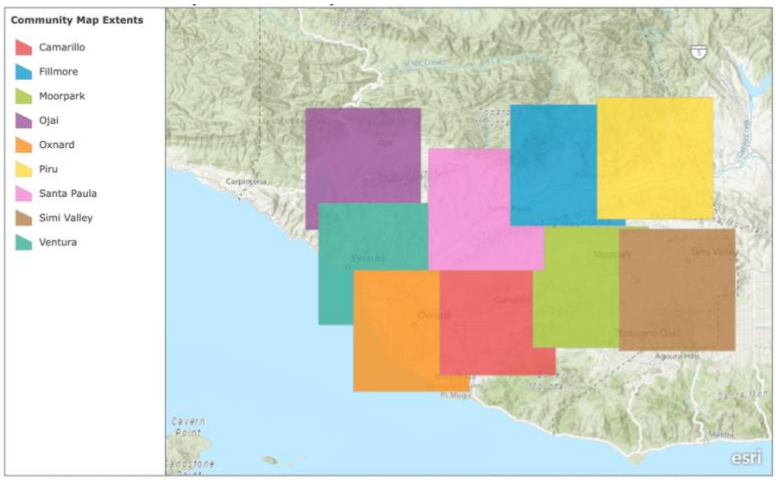
Source: Metadata Ventura County Important Farmland

The various wildlife spaces in Ventura County are represented in three layers. First, the National Wetlands Inventory shows large wetlands and deep-water habitats identified in 2007, based on U.S. Fish & Wildlife Service (2022) data. Second, the Habitat Connectivity and Wildlife Corridors layer, sourced from the County of Ventura (2019), illustrates natural habitat areas or largely underdeveloped lands of sufficient width to facilitate the movement, migration, foraging, breeding, and dispersal of multiple animal or plant species. Lastly, the outer boundary of the Los Padres National Forest is demarcated, sourced from the County of Ventura (2022f). Due to the boundaryless nature of wildlife and recreation, the analysis will consider the number of poorly abandoned wells within a buffer zone around these map items.

Environmental justice is represented by the CalEnvironScreen 4.0 results. This tool was created by the Office of Environmental Health Hazard Assessment (2021) and identifies California communities that are disproportionately burdened by multiple sources of pollution. The assessment uses various indicators, including exposure levels to pollution (ozone, particulate matter, diesel particulate matter, etc.), environmental effects (nearby cleanup sites, groundwater threats, hazardous waste, etc.), sensitive populations (rates of asthma, low birth weight, and cardiovascular disease), and socioeconomic factors (education, linguistic isolation, poverty, etc.). The results for each indicator range from 0 to 100 and represent the percentile ranking of individual census tracts relative to other tracts across California. Ventura County tracts range from the 94th percentile (central Oxnard) to the 8th (Point Mugu State Park, on Ventura and Los Angeles County line). Before analysis, this data is filtered to only include census tracts with a ranking between 70 and 100, generally representing disadvantaged communities with high pollution burdens. Within the risk assessment, the overall CalEnviroScreen status of the community will be considered, in addition to the number of poorly abandoned and cleanup priority wells within already-pollution burdened areas.

Finally, there are nine Ventura County communities being assessed for risk in this analysis: Ventura, Oxnard, Camarillo, Moorpark, Simi Valley, Piru, Fillmore, Santa Paula, and Ojai Valley. Rather than use the city boundaries, which exclude unincorporated areas, the geographic extent used in the analysis for each community is 130 square miles situated around the central metropolitan areas, as illustrated in Figure 2.5.

Figure 2.5 – Ventura County Community Map Extents (130 sq. miles each)



A map featuring poorly abandoned oil and gas wells, with cleanup priorities, in Ventura County - as well as other layers used in community risk assessment analysis created for Climate First: Replacing Oil & Gas (CFROG).

It is important to note that these community extents do not include the entire county or all abandoned wells and are not mutually exclusive. The overlap of, for example, Ventura, Oxnard, and Camarillo account for the unbound nature of environmental and social factors.

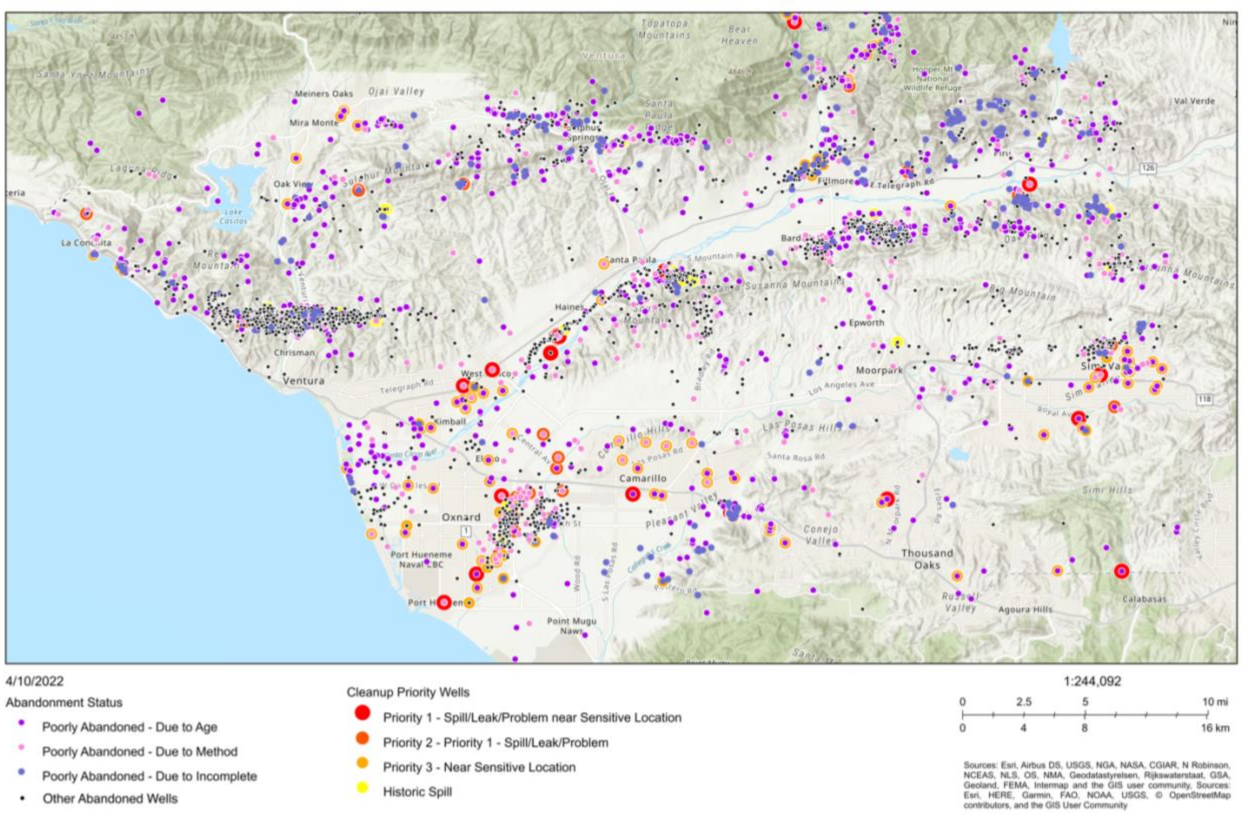
Geographic Analysis and Community Risk Assessment Matrix

A risk assessment matrix is completed for each Ventura County community based on geographic analysis completed in ArcGIS. The risk level for each factor – cleanup priority, water, air, hazards, agriculture, wildlife spaces, and environmental justice communities – will be ranked low, medium, or high based on the percentile of poorly abandoned wells in proximity. First, the presence of each risk factor is quantified in square miles or number of locations and percentage of total land within each community extent. Then, the number of poorly abandoned wells located within particular buffer zones. For example, the number of poorly abandoned wells located within 250 feet of rivers and streams or one mile of an earthquake hazard zone. These buffer zones were determined based on the previous studies reviewed above. In the case of risk factors represented by multiple map layers, the number of abandoned wells within proximity for each layer are added together before communities are compared. After the geographic analysis is complete for each community, risk assessment ranking is assigned to each community's factors based on percentile groups – high risk for those 75th percentiles or higher, medium risk for those between 50th and 75th, and low for those between 25th and 50th.

Community Risk Assessment Analyses

To further localize the large issue of poorly abandoned oil and gas wells in Ventura County, the proximity of these wells and various at-risk factors were analyzed by community and then ranked by risk: low, medium, and high. Below is a brief discussion, risk assessment matrix, and select maps for each community. Only the primary at-risk factors for each community are featured on maps. All abandoned wells are included, with poorly abandoned and those prioritized for cleanup highlighted, as illustrated in the county map in Figure 2.6. For the full interactive map visit https://bit.ly/VCPlugged.

Figure 2.6 – Abandoned Wells in Ventura County



Ventura

There are 298 wells that cannot be confirmed as properly plugged in the Ventura community, which includes the West Ventura, Downtown, Midtown, East End, and South Bank neighborhoods. The majority are clustered in the Ventura Oil Field, one of the major producing fields in the county. Many of these poorly abandoned wells have the potential to interact with environmental and social factors. The community ranks high for potential risks to water, air, and environmental justice communities and medium for environmental hazards and wildlife spaces, as summarized in Table 2.2. As illustrated in Figure 2.7, there are two large groundwater basins in the area: the Ventura River Valley and Santa Clara River Valley. Neither are critically over-drafted, but the Santa Clara River Valley is classified as a high priority for efforts to return to a sustainable yield. There are two methane super emitter sources, both oil and natural gas infrastructure, in the area. Like much of the pollution in the area, these are located on the Westside near an environmental justice neighborhood flagged by CalEnviroScreen known as "The Avenue," represented in Figure 2.8. This area has a higher pollution burden than 87 percent of other California census tracts and 71 percent of residents are Hispanic/Latinx. There are 27 square miles of actual and potential landslide spots in the area, mainly clustered around the oil field (see Figure 2.9). This is in alignment with the previous literature outlining the historic impact landslides have had (Bustillo, Gammon, & Heie, 1998; Johnson, 1974). Lastly, Ventura has a high number of wells prioritized for cleanup (see Figure 2.10), historic spills and leaks, and re-abandonments – all indicative of a long and persistent history of extraction.

Table 2.2 – Ventura Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	259		Priority 1	3	HIGH
No Files	9		Priority 2	3	
Properly Plugged & Abandoned	595		Priority 3	22	
Re-Abandoned	18				
Re-Abandoned due to Problem	7		Historic Spill/Leak	10	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	HIGH
Groundwater Basins	62.04	48%	Located on/through	155	
River/Stream Watersheds	12.34	9%	Within 250 ft of	56	
Air Quality	*Amount*				HIGH
Methane Super Emitter Sources	2		Within 1 mile of	33	
Methane Plumes	2				
Enviro. Hazards	*Sq.Miles*	*% of Land*			MED
Earthquake Hazard Zones	1.45	1%	Within 1 mile of	8	
Landslides	27.96	22%	Located on	43	
Subsidence	37.94	29%	Located on	80	
Sea-level Rise (55" 2100)	2.34	2%	Within 250 ft of	15	
Wildfire (.036-.07/year)	36.76	28%	Located on	88	
Agriculture					LOW
Important Farmland Inventory	18.84	14%	Within 250 ft of	76	
Wildlife Spaces					MED
Regional Wildlife Corridors	4.25	3%	Within 1 mile of	188	
National Wetlands Inventory	11.42	9%	Within 250 ft of	164	
National Forest	0	0	Within 1 mile of		
EJ Communities					HIGH
CalEnviroScreen (70-100)	5.58	4%	Within 2,500 ft of	135	

Figure 2.7 – Ventura Water Resources

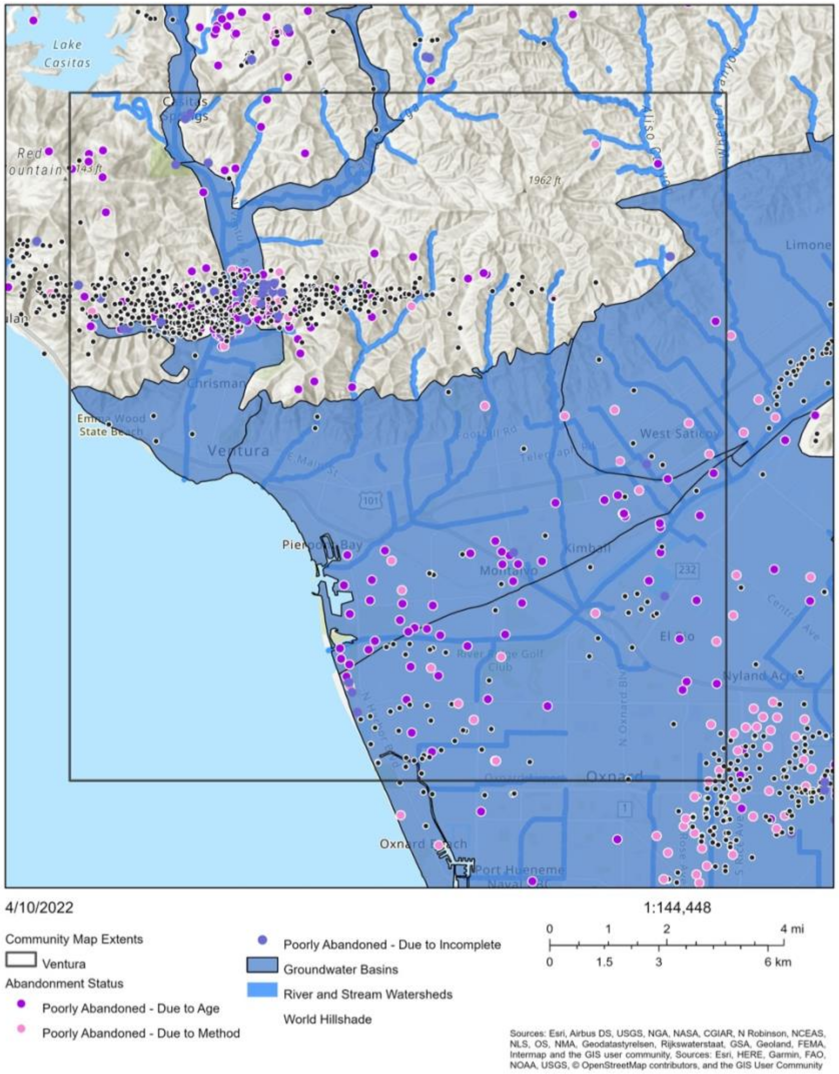


Figure 2.8 – Ventura Environmental Justice Communities

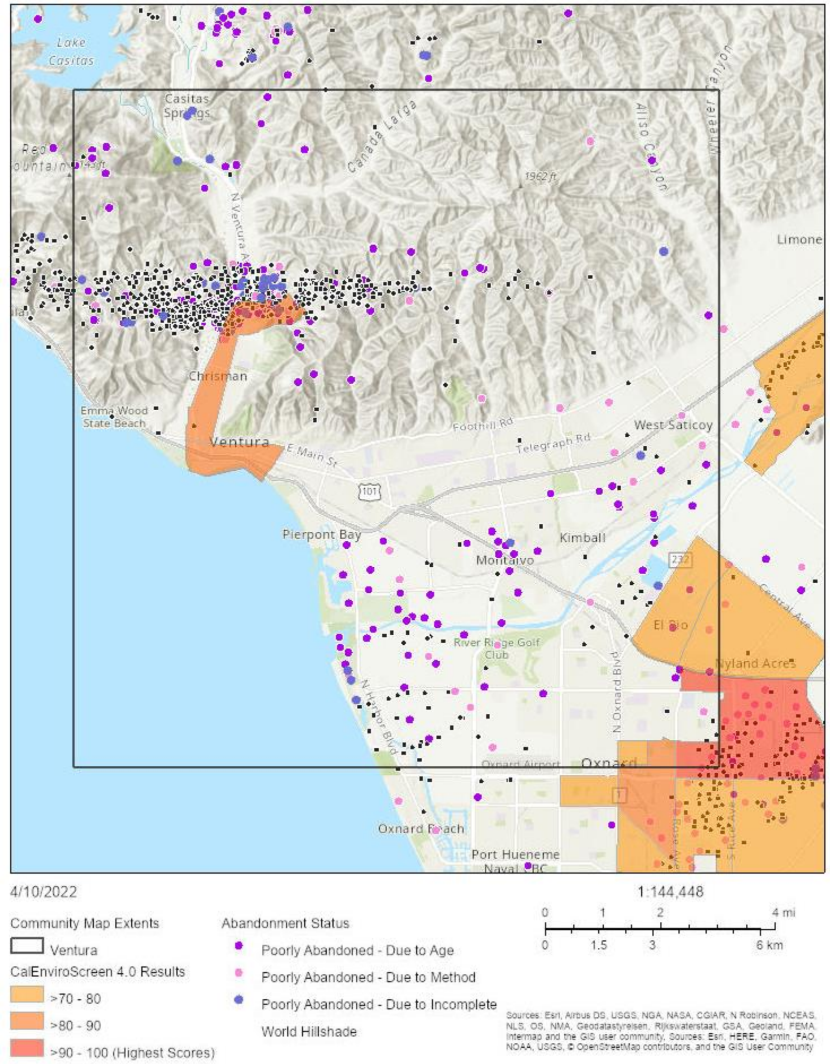


Figure 2.9 – Ventura Landslides

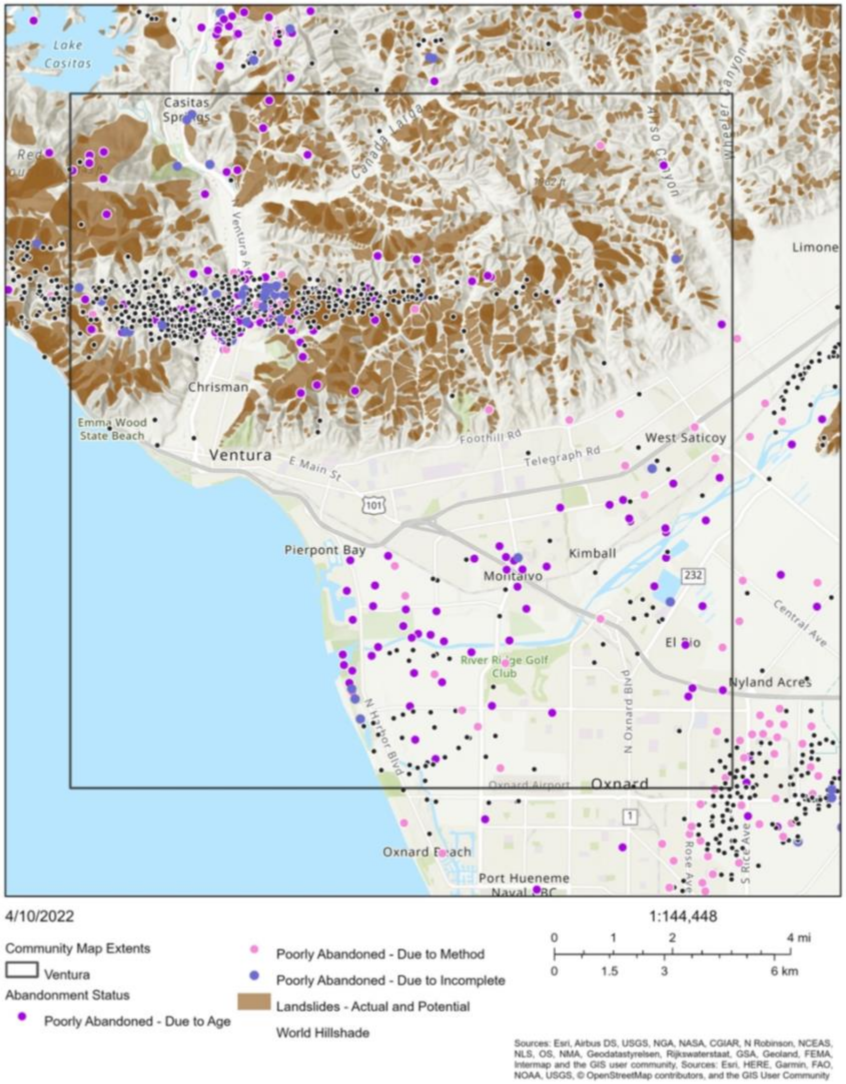
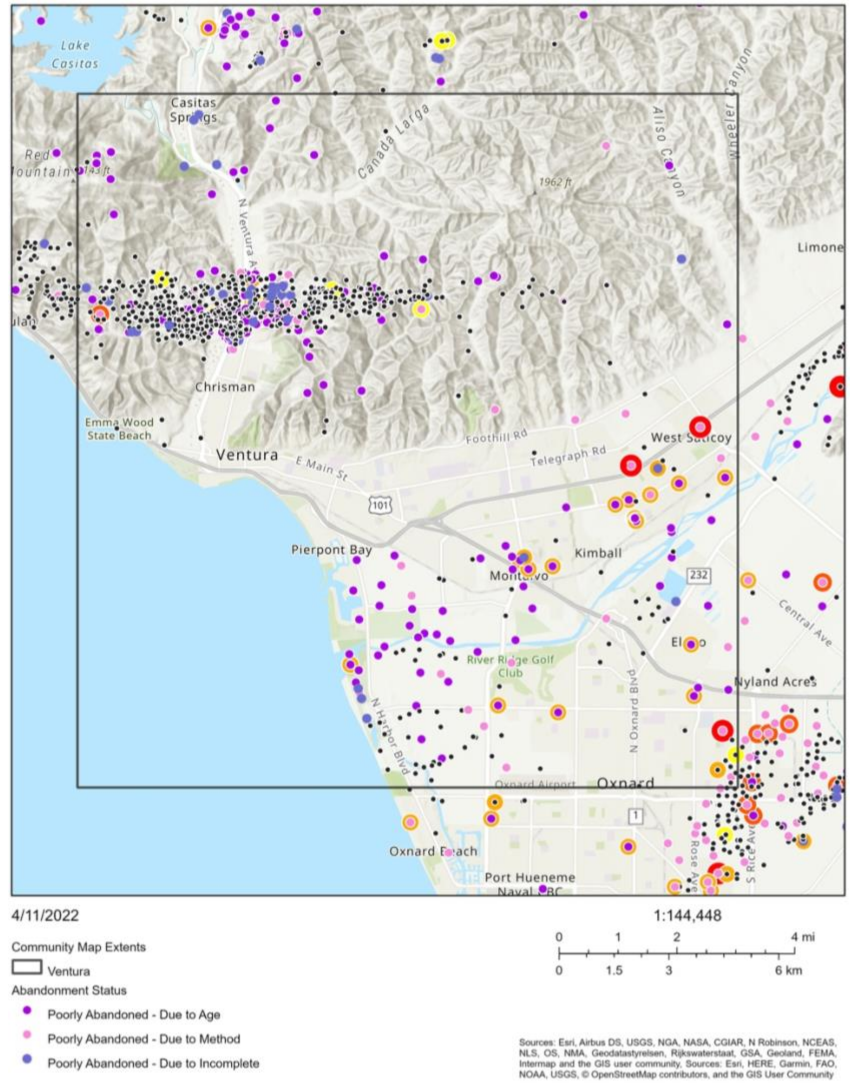


Figure 2.10 – Ventura Cleanup Priority Wells



Oxnard

The Oxnard community extent spans from Pierpont Bay to the Point Mugu Naval Base and includes 157 wells that cannot be confirmed as properly abandoned, summarized in Table 2.3. Based on their proximity to various map layers, the community ranks high for risks to water, environmental justice communities, and the number of wells prioritized for cleanup. Large swaths of the area cover the Santa Clara River Valley Oxnard groundwater basin (see Figure 2.11), which is critically over-drafted, has high levels of salt intrusion from seawater, and is making subsidence in the area worse, as illustrated in Figure 2.12. Additionally, the Santa Clara River, which is the largest river system in southern California that remains in a relatively natural state, runs through the community and drains into the Pacific Ocean. A large cluster of abandoned wells, with many poorly plugged due to insufficient method, are in the Oxnard Oil Field which lies underneath large agricultural fields with farmland of prime and statewide Importance, as shown in Figure 2.13, and neighboring environmental justice communities. As illustrated in Figure 2.14, the communities in this area have high levels of pollution burden and experience other socioeconomic disparities. These census tracts rank the highest in California for pesticide exposure and rank near the top for impaired or polluted groundwater, indicating the area is being impacted by pollution from multiple sources.

Table 2.3 – Oxnard Risk Assessment of Poorly Abandoned Wells

					Rank
Poorly Plugged & Abandoned	154		Priority 1	4	HIGH
No Files	3		Priority 2	11	
Properly Plugged & Abandoned	230		Priority 3	32	
Re-Abandoned	25				
Re-Abandoned due to Problem	3		Historic Spill/Leak	2	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	HIGH
Groundwater Basins	97.66	75%	Located on/through	157	
River/Stream Watersheds	11.09	9%	Within 250 ft of	41	
Air Quality	*Amount*				
Methane Super Emitter Sources	0		Within 1 mile of	0	
Methane Plumes	0				
Enviro. Hazards	*Sq.Miles*	*% of Land*			MED
Earthquake Hazard Zones	0.75	1%	Within 1 mile of	15	
Landslides	0.15	0	Located on	0	
Subsidence	90.77	70%	Located on	152	
Sea-level Rise (55" 2100)	19.18	15%	Within 250 ft of	23	
Wildfire (.036-.07/year)	8.70	7%	Located on	8	
Agriculture					MED
Important Farmland Inventory	41.86	32%	Within 250 ft of	107	
Wildlife Spaces					
Regional Wildlife Corridors	3.29	3%	Within 1 mile of	49	
National Wetlands Inventory	3.91	3%	Within 250 ft of	16	
National Forest	0	0	Within 1 mile of	0	
EJ Communities					HIGH
CalEnviroScreen (70-100)	31.32	24%	Within 2,500 ft of	147	

Figure 2.11 – Oxnard Water Resources

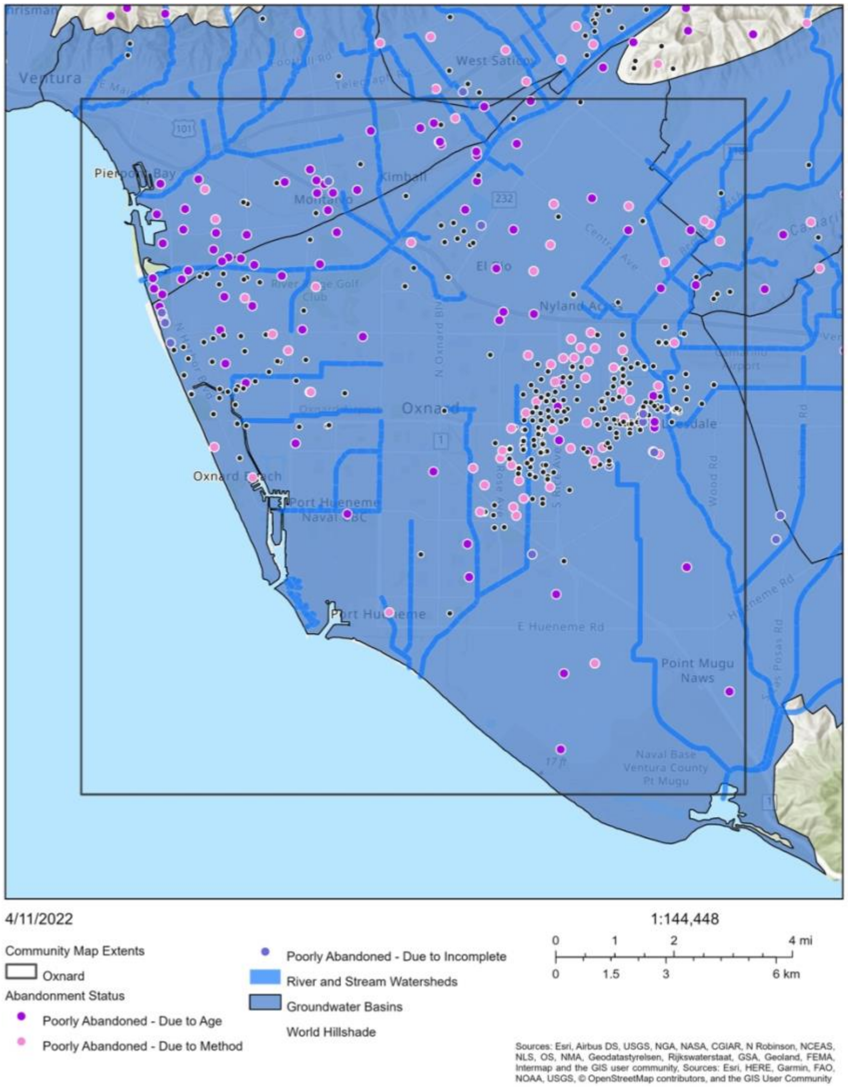


Figure 2.12 – Oxnard Subsidence & Sea-level Rise

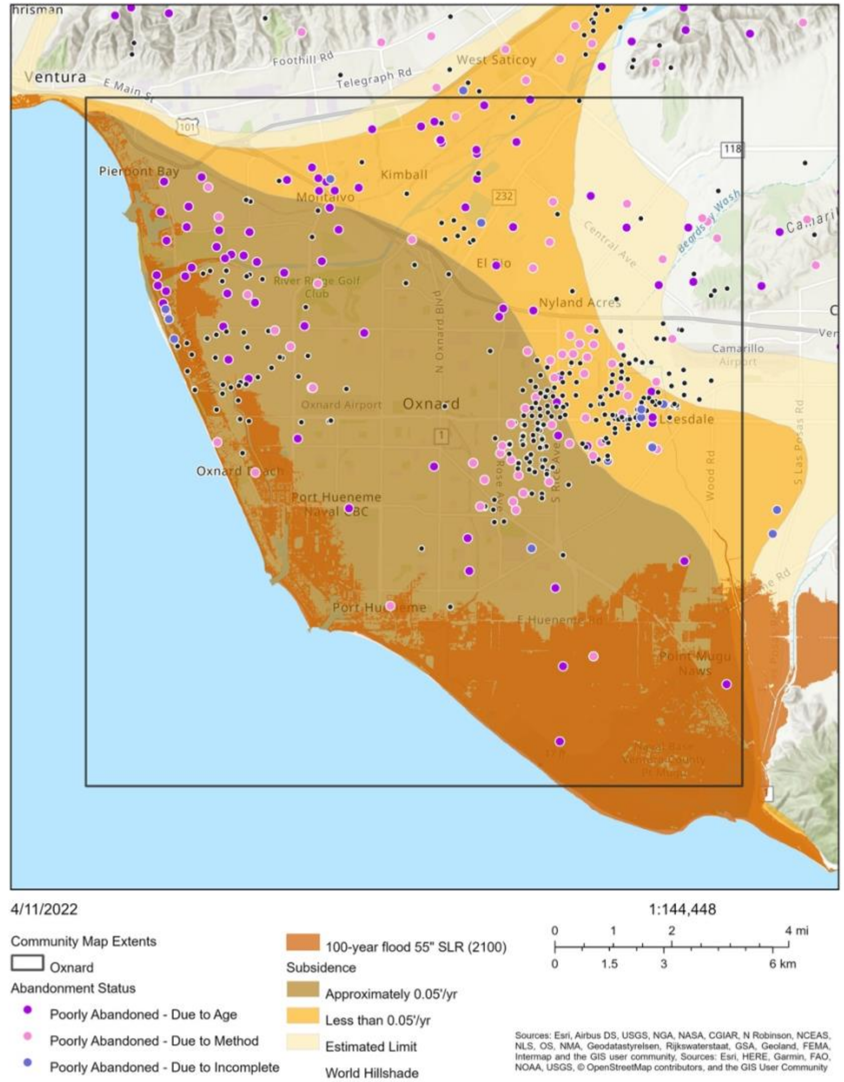


Figure 2.13 – Oxnard Important Farmland

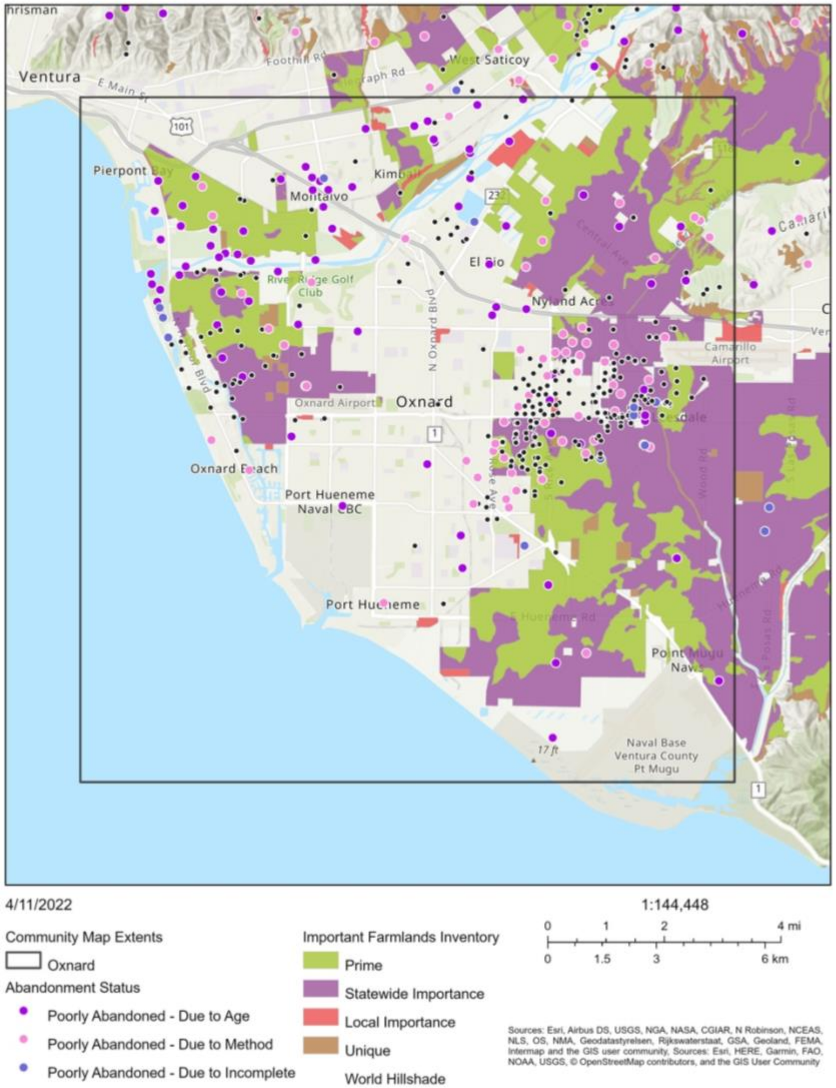
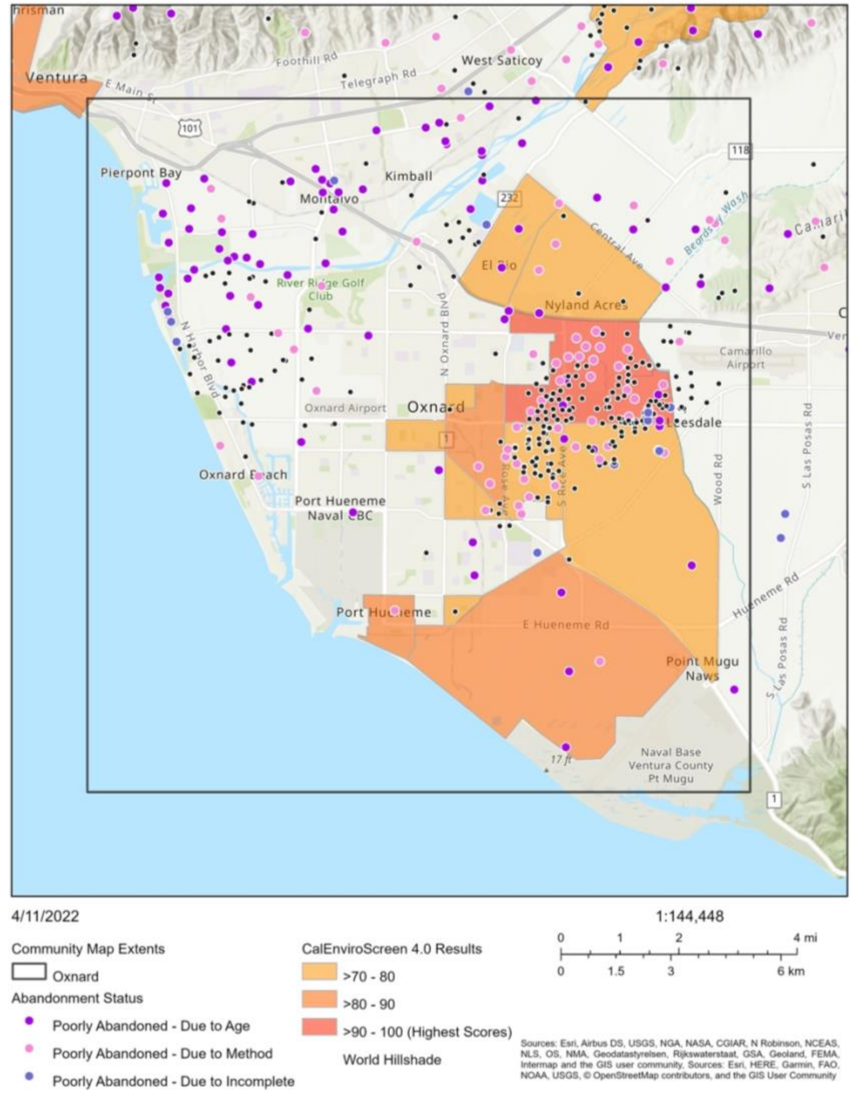


Figure 2.14 – Oxnard Environmental Justice Communities



Camarillo

The Camarillo community intersects with the Oxnard community extents and extends from south Santa Paula to the Conejo Valley. This area has over 300 wells that cannot be confirmed as properly plugged (see Table 2.4), which include those clustered in the Oxnard Oil Field and a significant cluster in the Conejo Oil Field, located on and near what is now the Camarillo Springs Golf Course. Most of these wells were drilled in the 1920s, have no abandonment records, and could not be identified by a 1971 inspection of the area. Many of the wells in this area are categorized as Priority 3 because they are in house tracts, by streams, commercial buildings, and said golf course, as shown in Figure 2.15. Additionally, the area ranks at high risk for water and agriculture. The Santa Clara River Valley Oxnard and Pleasant Valley groundwater basins cover 83 percent of the 130 square acre community boundary, both of which are critically over-drafted and prioritized as high by the Sustainable Groundwater Management Act (Figure 2.16). The area also boasts prime, statewide important, and unique farmland, as seen in Figure 2.17, where about half of the poorly abandoned wells are located within 250 feet of. Camarillo is also home to a few important wetlands, including Calleguas Creek, and part of the Santa Monica Sierra Madre wildlife corridor, featured in Figure 2.18.

Table 2.4 – Camarillo Risk Assessment of Poorly Abandoned Wells

					Rank
Poorly Plugged & Abandoned	295		Priority 1	4	HIGH
No Files	30		Priority 2	7	
Properly Plugged & Abandoned	155		Priority 3	55	
Re-Abandoned	7				
Re-Abandoned due to Problem	0		Historic Spill/Leak	0	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	HIGH
Groundwater Basins	107.66	83%	Located on/through	183	
River/Stream Watersheds	16.48	13%	Within 250 ft of	74	
Air Quality	*Amount*				
Methane Super Emitter Sources	0		Within 1 mile of	0	
Methane Plumes	0				
Enviro. Hazards	*Sq.Miles*	*% of Land*			LOW
Earthquake Hazard Zones	4.58	4%	Within 1 mile of	89	
Landslides	5.20	4%	Located on	2	
Subsidence	34.66	27%	Located on	43	
Sea-level Rise (55" 2100)	7.06	5%	Within 250 ft of	3	
Wildfire (.036-.07/year)	32.68	25%	Located on	27	
Agriculture					HIGH
Important Farmland Inventory	68.25	52%	Within 250 ft of	166	
Wildlife Spaces					MED
Regional Wildlife Corridors	16.36	13%	Within 1 mile of	242	
National Wetlands Inventory	4.24	3%	Within 250 ft of	54	
National Forest	0	0%	Within 1 mile of	0	
EJ Communities					MED
CalEnviroScreen (70-100)	15.74	12%	Within 2,500 ft of	59	

Figure 2.15 – Camarillo Cleanup Priority Wells

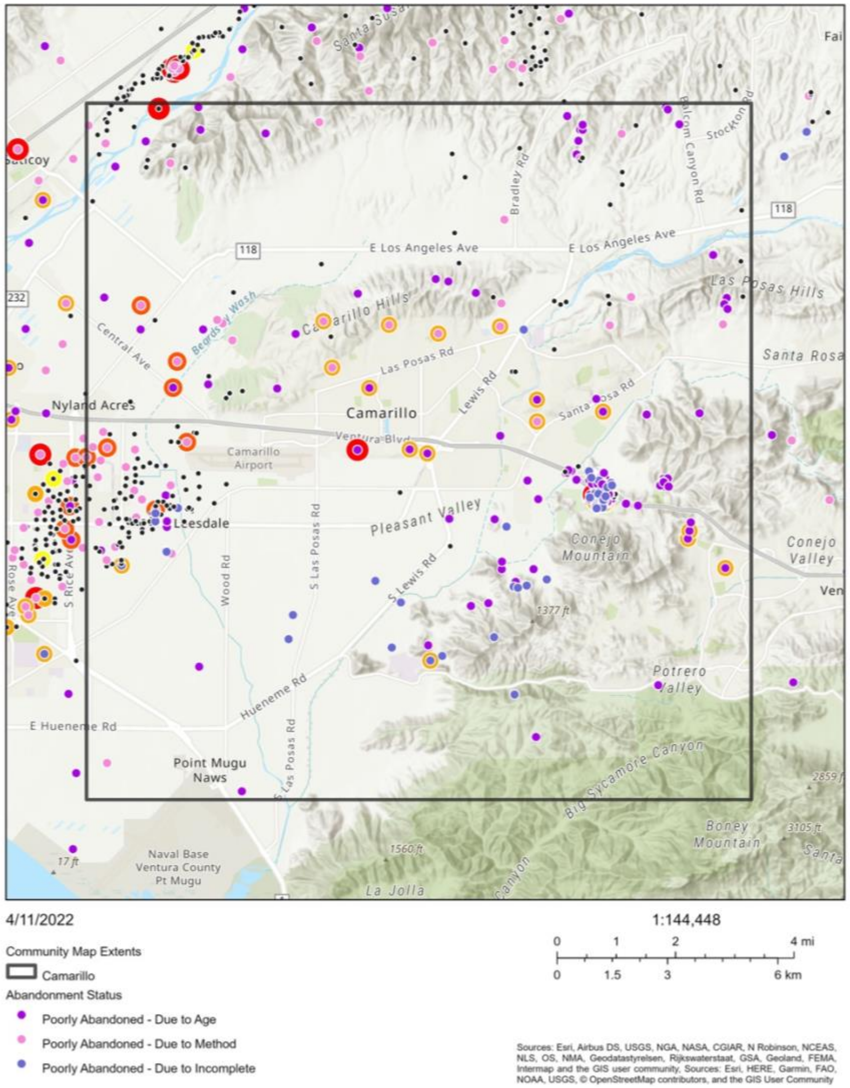


Figure 2.16 – Camarillo Water Resources

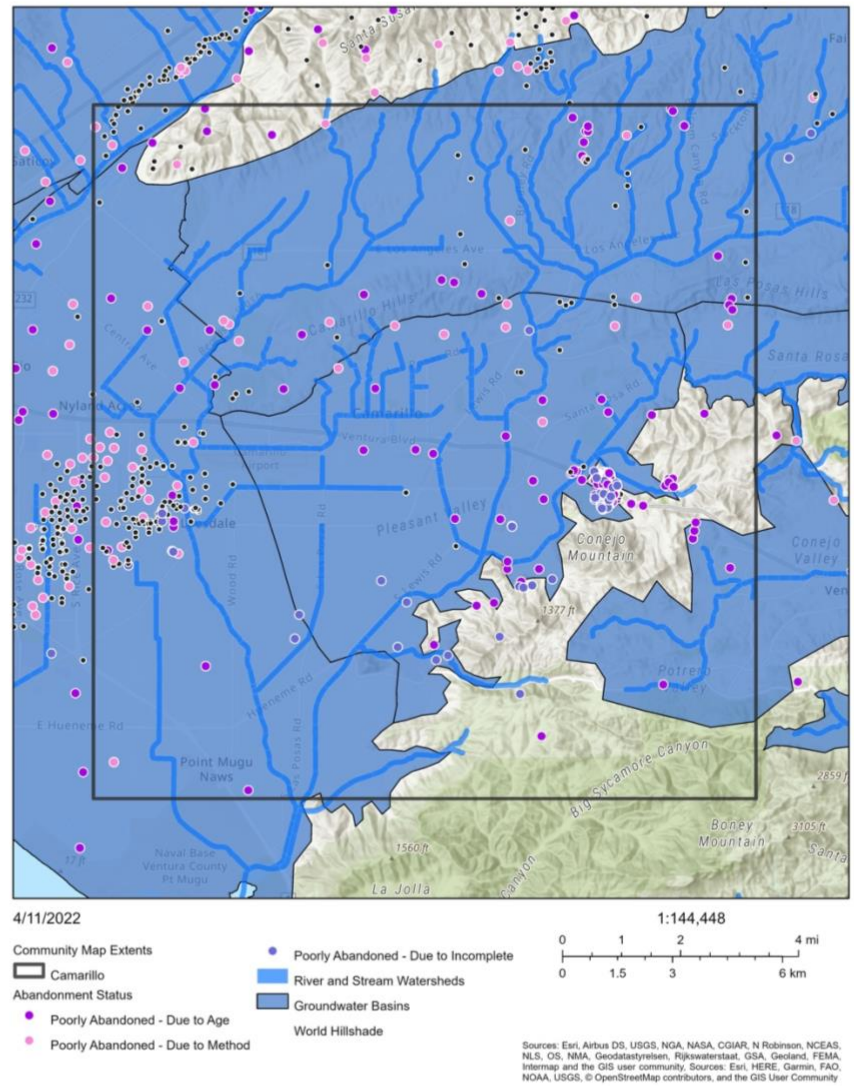


Figure 2.17 – Camarillo Important Farmland

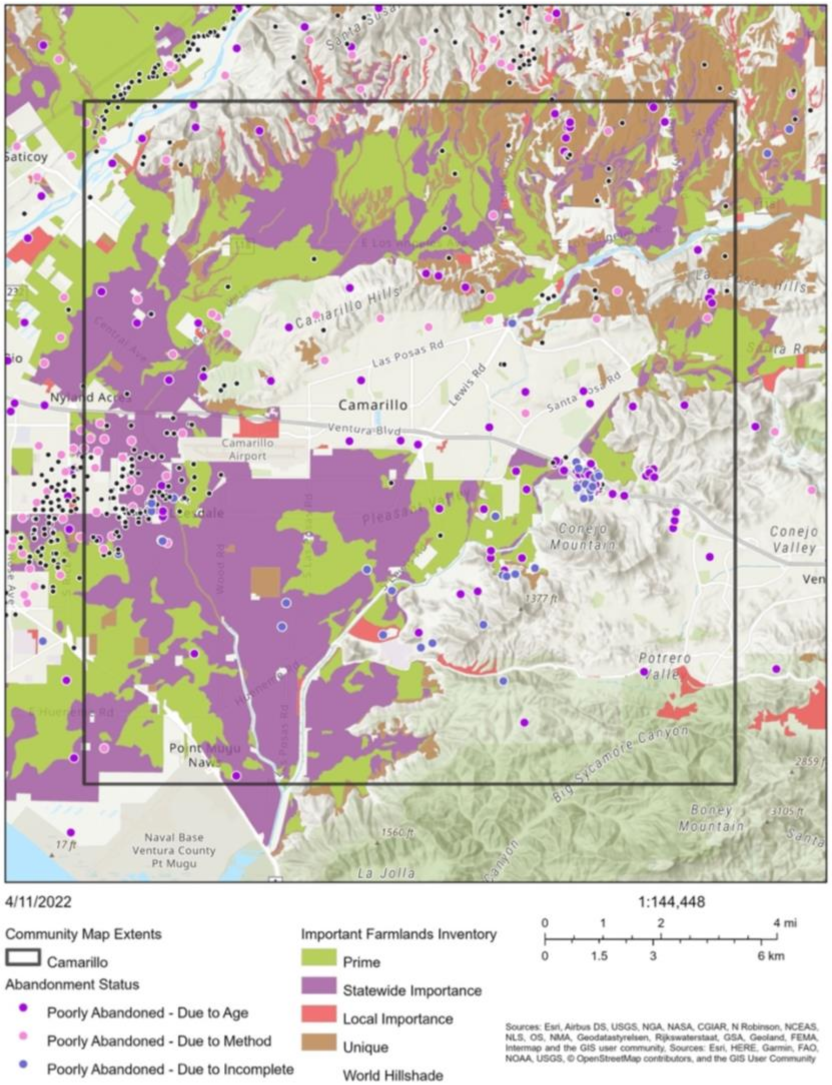
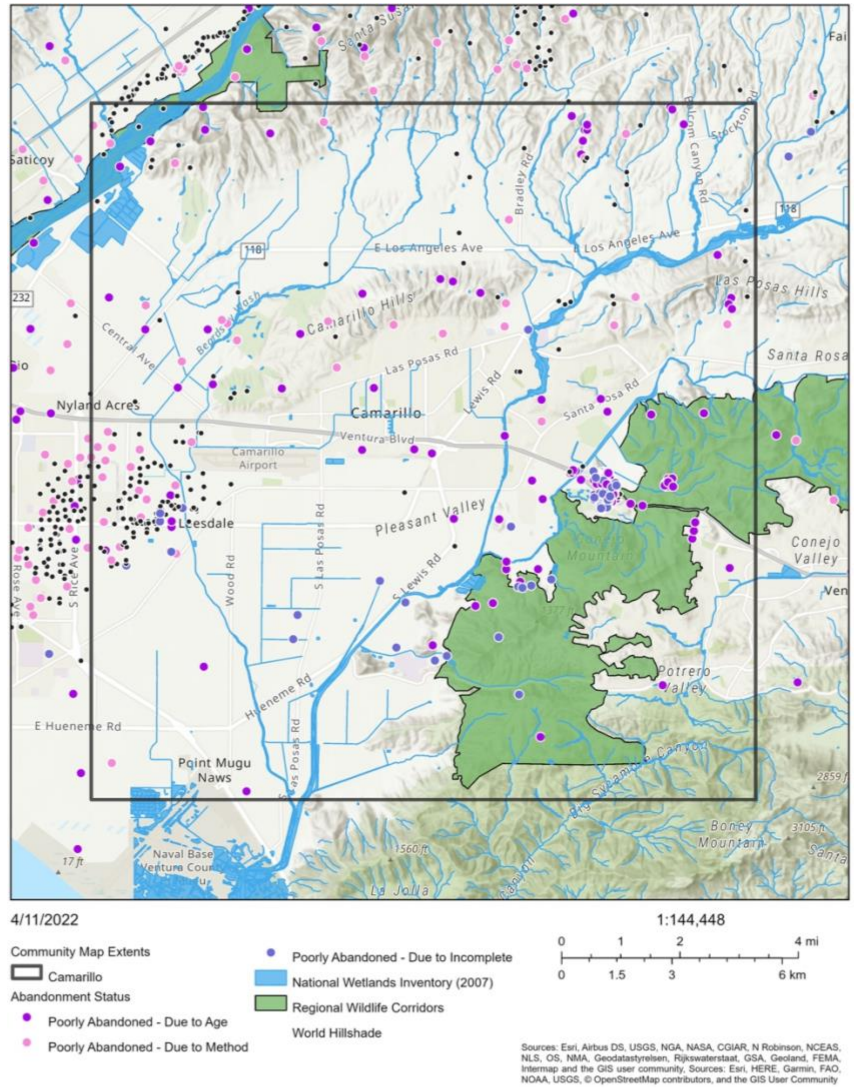


Figure 2.18 – Camarillo Wetlands & Wildlife Corridors



Moorpark

The Moorpark community does not have any major abandoned well clusters or oil fields but is still home to nearly 100 poorly plugged wells, as stated in Table 2.5. The community also does not have a large presence of many of the at-risk factors. This in combination with having a relatively small number of wells means it only ranks in the low percentile for water, agriculture, and environmental justice communities. The major groundwater basin here is Las Posas Valley, as seen in Figure 2.19, which is not critically over-drafted but is prioritized as high by the Sustainable Groundwater Management Act due to other factors. Additionally, this area has some important farmland inventory, particularly of local importance and unique, as illustrated in Figure. 2.20.

Table 2.5 – Moorpark Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	97		Priority 1	1	
No Files	2		Priority 2	1	
Properly Plugged & Abandoned	79		Priority 3	4	
Re-Abandoned	6				
Re-Abandoned due to Problem	1		Historic Spill/Leak	0	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	
Groundwater Basins	85.10	65%	Located on/through	49	LOW
River/Stream Watersheds	17.56	14%	Within 250 ft of	48	
Air Quality	*Amount*				
Methane Super Emitter Sources	0		Within 1 mile of	0	
Methane Plumes	0				
Enviro. Hazards	*Sq.Miles*	*% of Land*			
Earthquake Hazard Zones	3.99	3%	Within 1 mile of	56	
Landslides	4.55	3%	Located on	4	
Subsidence	0	0	Located on	0	
Sea-level Rise (55” 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	43.02	33%	Located on	26	
Agriculture					
Important Farmland Inventory	26.39	20%	Within 250 ft of	38	LOW
Wildlife Spaces					
Regional Wildlife Corridors	39.97	31%	Within 1 mile of	74	
National Wetlands Inventory	3.53	3%	Within 250 ft of	46	
National Forest	0	0	Within 1 mile of	0	
EJ Communities					
CalEnviroScreen (70-100)	0.97	1%	Within 2,500 ft of	1	LOW

Figure 2.19 – Moorpark Water Resources

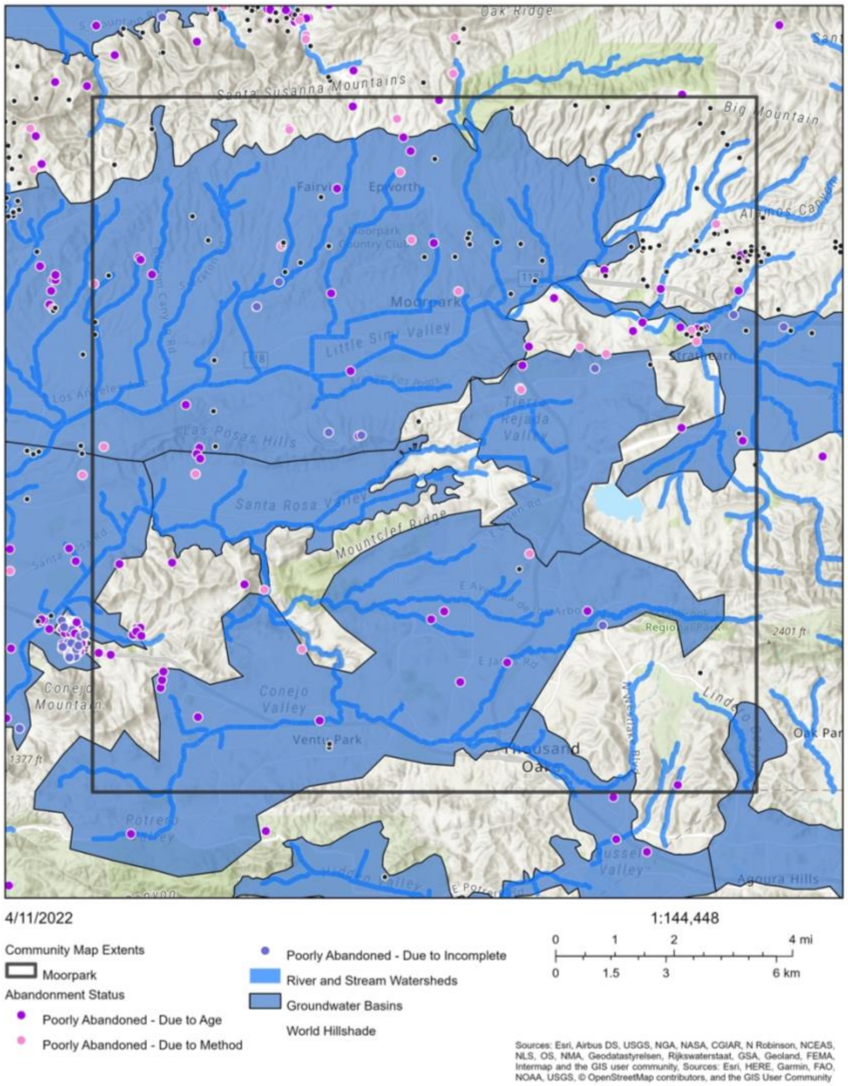
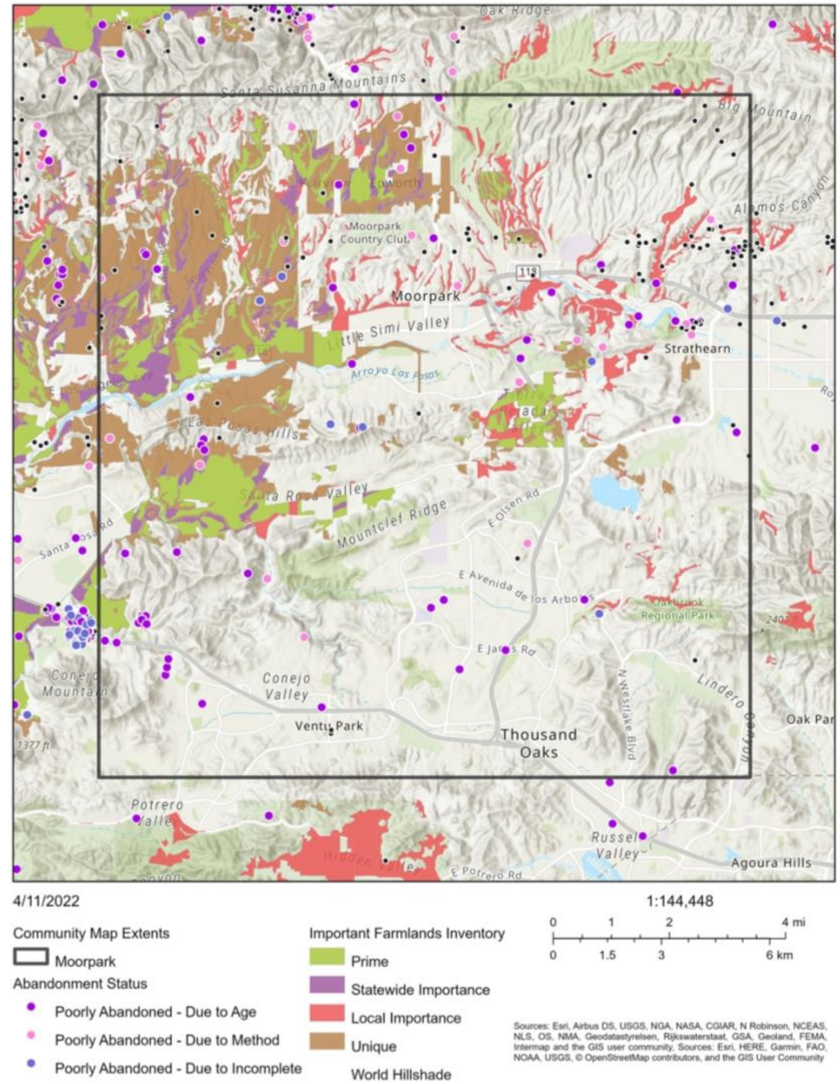


Figure 2.20 – Moorpark Important Farmland



Simi Valley

Simi Valley has 88 wells that cannot be confirmed as properly plugged and a few small clusters of abandoned wells in the hills above the developed areas. Despite having a small number of wells overall, the area ranks medium risk for wells prioritized for clean-up, as detailed in Table 2.6. This is because, as seen in Figure 2.21, there are many individual wells located underneath or near housing tracts. In a few cases, the records for these wells include analysis from CalGEM recommending that no structure be built over or in the proximity of these wells, or at the very least, a vent system should be installed, but the construction of which is not mentioned. Additionally, the area ranks low in risk for water and wildlife space, as illustrated in Figure 2.22.

Table 2.6 – Simi Valley Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	79		Priority 1	3	MED
No Files	9		Priority 2	2	
Properly Plugged & Abandoned	145		Priority 3	22	
Re-Abandoned	7				
Re-Abandoned due to Problem	0		Historic Spill/Leak	0	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	LOW
Groundwater Basins	25.82	20%	Located on/through	42	
River/Stream Watersheds	15.50	12%	Within 250 ft of	50	
Air Quality	*Amount*				
Methane Super Emitter Sources	0		Within 1 mile of	0	
Methane Plumes	0				
Enviro. Hazards	*Sq.Miles*	*% of Land*			
Earthquake Hazard Zones	1.96	2%	Within 1 mile of	77	
Landslides	4.88	4%	Located on	2	
Subsidence	0	0	Located on	0	
Sea-level Rise (55" 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	37.33	29%	Located on	47	
Agriculture					
Important Farmland Inventory	3.55	3%	Within 250 ft of	17	
Wildlife Spaces					
Regional Wildlife Corridors	64.76	50%	Within 1 mile of	74	LOW
National Wetlands Inventory	3.22	2%	Within 250 ft of	56	
National Forest	0	0	Within 1 mile of	0	
EJ Communities					
CalEnviroScreen (70-100)	0	0	Within 2,500 ft of	0	

Figure 2.21 – Simi Valley Cleanup Priority

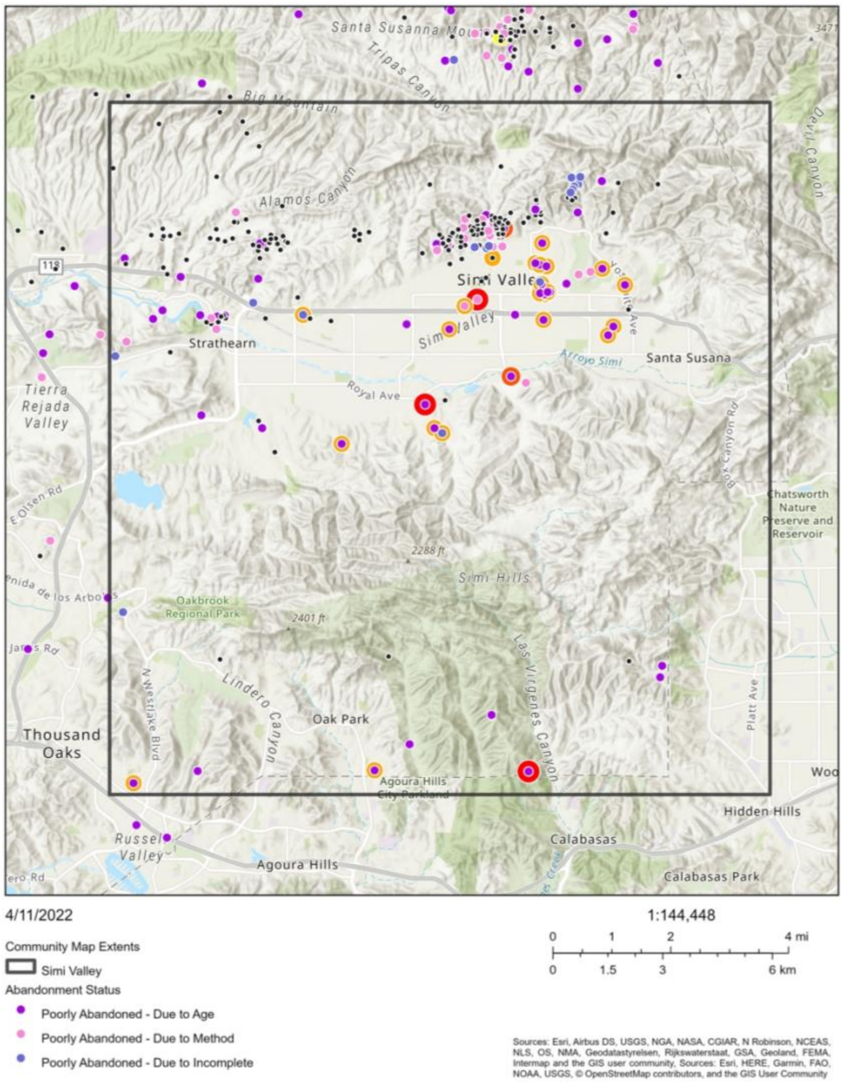
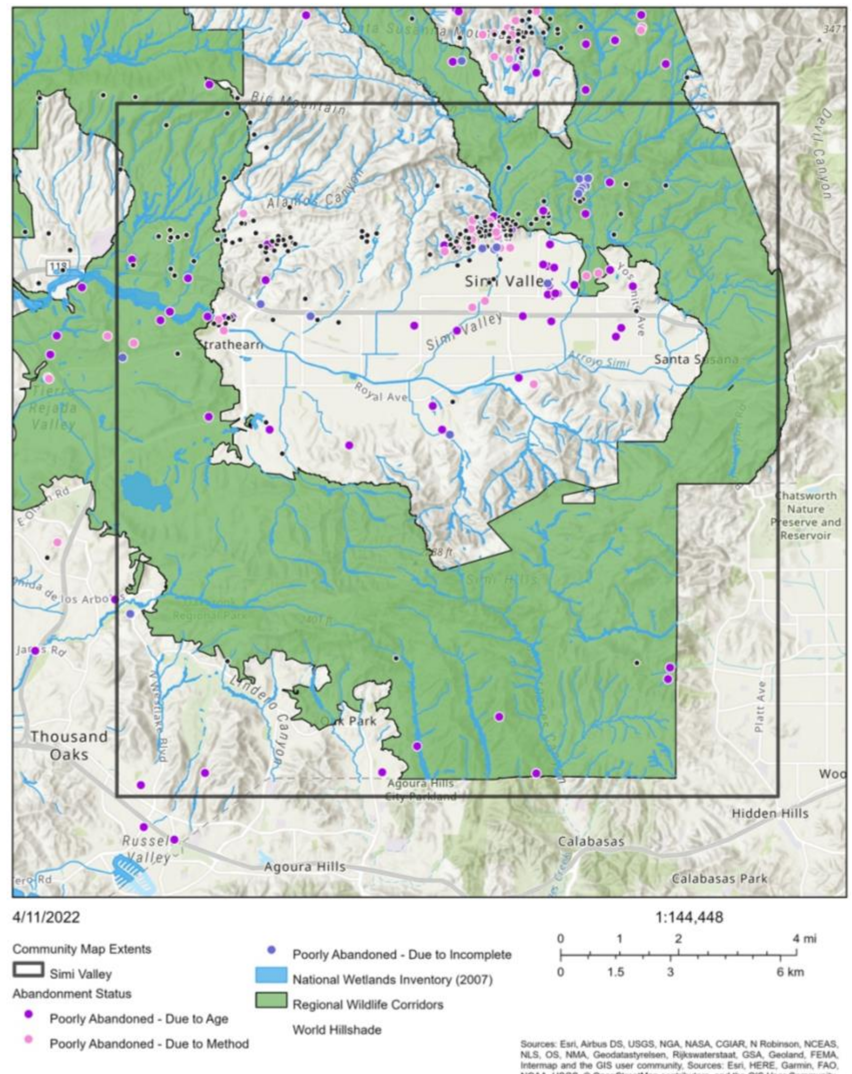


Figure 2.22 – Simi Valley Wetlands & Wildlife Corridors



Piru

Piru, located in east Ventura County, has over 300 wells that cannot be confirmed as properly plugged and abandoned. This area includes many small oil fields, including Torrey Canyon, Tapo North, Ramona, and Piru. These fields are in the hills north and south of the developed community and are near many environmental hazards, as summarized in Table 2.7. There are 69 poorly plugged wells located on possible landslide zones, as shown in Figure 2.23. More alarming is the high-risk wildfires pose, which cover the entire community extent boundary, and could impact all wells (Figure 2.24). Additionally, the area includes major wetland space, including the Santa Clara River and Lake Piru, and wildlife corridors, connecting the Santa Monica Sierra Madre with the Los Padres National Forest, located in the northern area of the community, as illustrated in Figure 2.25.

Table 2.7 – Piru Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	230		Priority 1	1	
No Files	97		Priority 2	4	
Properly Plugged & Abandoned	370		Priority 3	1	
Re-Abandoned	0				
Re-Abandoned due to Problem	1		Historic Spill/Leak	8	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	
Groundwater Basins	85.67	14%	Located on/through	31	
River/Stream Watersheds	6.04	5%	Within 250 ft of	56	
Air Quality	*Amount*				
Methane Super Emitter Sources	1		Within 1 mile of	1	
Methane Plumes	1				
Enviro. Hazards	*Sq.Miles*	*% of Land*			
Earthquake Hazard Zones	1.32	1%	Within 1 mile of	41	HIGH
Landslides	28.03	22%	Located on	69	
Subsidence	5.42	4%	Located on	4	
Sea-level Rise (55” 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	130.00	100%	Located on	328	
Agriculture					
Important Farmland Inventory	12.57	10%	Within 250 ft of	101	MED
Wildlife Spaces					
Regional Wildlife Corridors	65.23	50%	Within 1 mile of	388	HIGH
National Wetlands Inventory	7.34	6%	Within 250 ft of	175	
National Forest	22.80	18%	Within 1 mile of	34	
EJ Communities					
CalEnviroScreen (70-100)	0	0	Within 2,500 ft of	0	

Figure 2.23 – Piru Landslides & Earthquake Hazard Zones

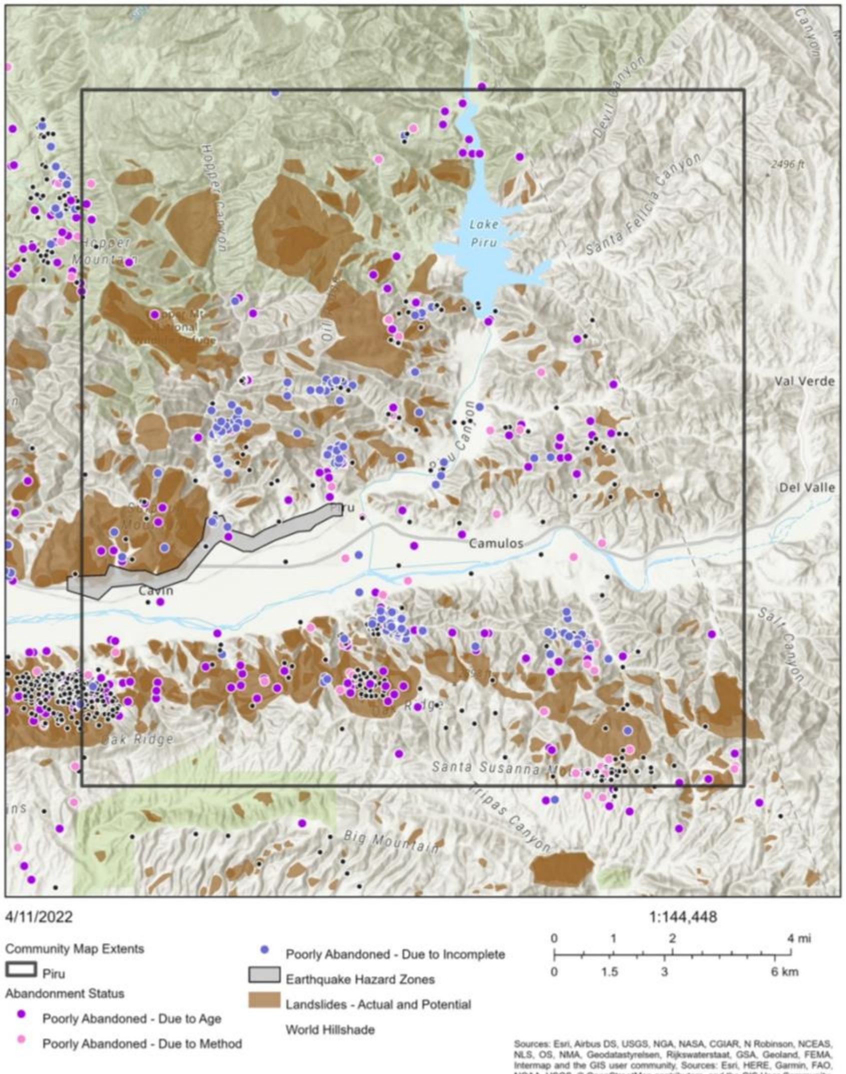


Figure 2.24 – Piru Wildfire Risk

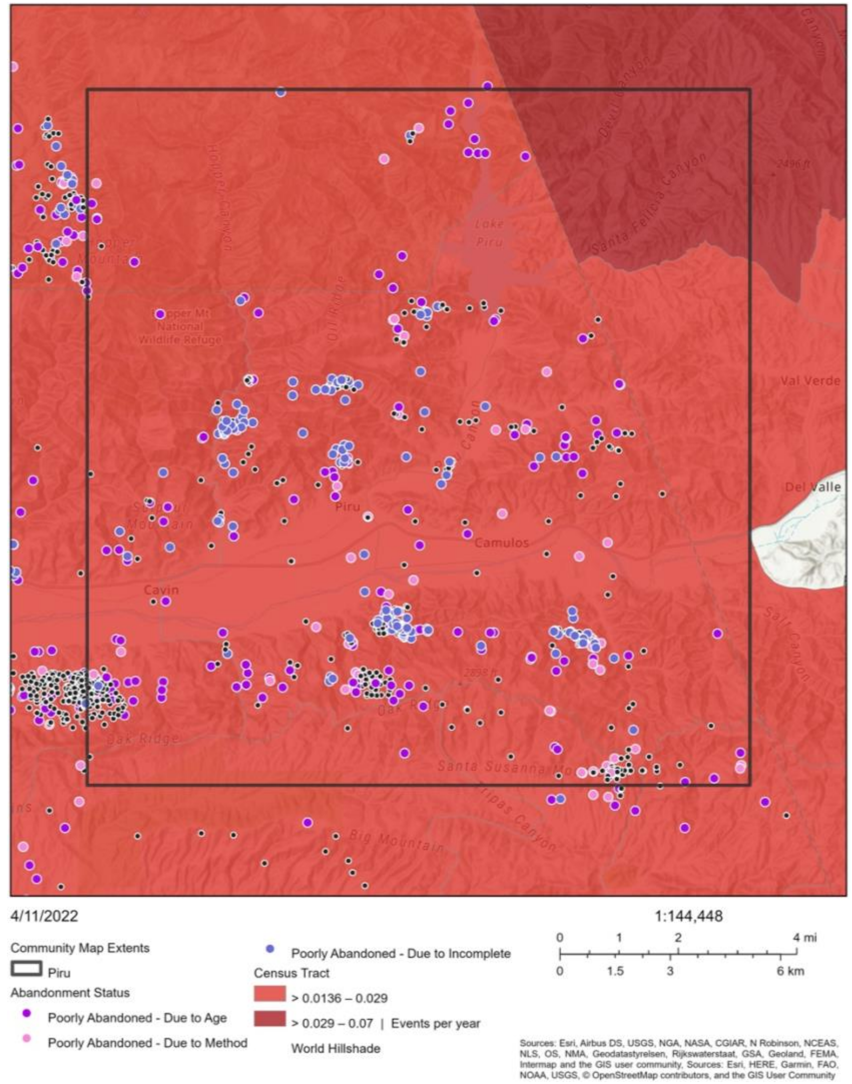
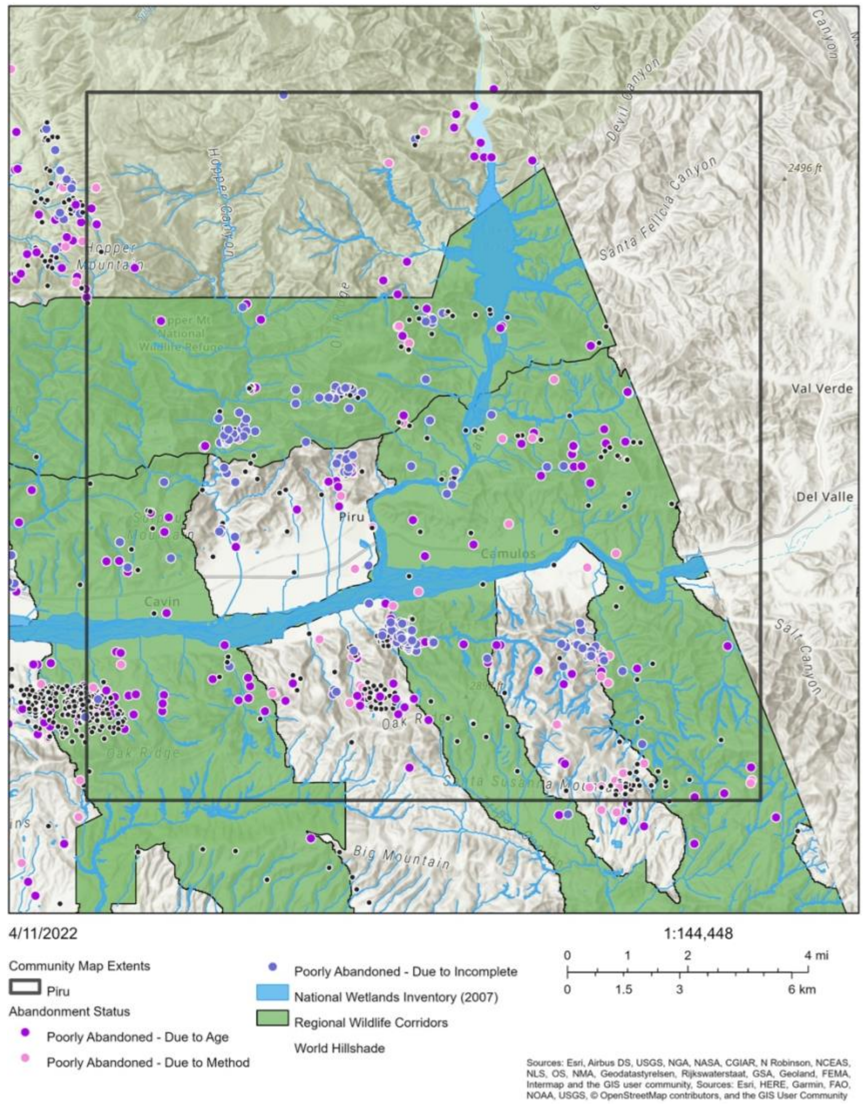


Figure 2.25 – Piru Wetlands & Wildlife Corridors



Fillmore

The Fillmore community, which spans from Sespe to Santa Susana Mountains, has been extensively drilled and extracted for oil and gas. The area has over 350 wells that cannot be confirmed as properly plugged based on their records and as shown in Table 2.8, ranks high or medium risk for all factors. First, the area ranks as a medium risk to water, but it is important to note that groundwater and soil contamination of petroleum-related chemicals benzene and toluene because of oil operations has been documented in the area (EPA, 2011). Second, the area has two methane super emitter sources, one of which is an oil and gas facility and is surrounded by 44 poorly abandoned wells. Third, due to having many earthquake, landslide, and wildfire hazard zones, as illustrated in Figures 2.26-27, the area ranks high for environmental hazards, with close to 200 wells within one mile of an earthquake zone. The area also boasts important farmland inventory, covering 19 percent of the total area, with 185 poorly abandoned wells nearby (Figure 2.28). Lastly, due to its proximity to the Los Padres National Forest and Santa Clara River, per Figure 2.29, the high number of poorly abandoned wells in the area puts these factors at high risk as well.

Table 2.8 – Fillmore Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned		293	Priority 1	1	MED
No Files		61	Priority 2	4	
Properly Plugged & Abandoned		605	Priority 3	11	
Re-Abandoned		2			
Re-Abandoned due to Problem		0	Historic Spill/Leak	2	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	MED
Groundwater Basins	35.95	28%	Located on/through	65	
River/Stream Watersheds	10.44	8%	Within 250 ft of	82	
Air Quality	*Amount*				HIGH
Methane Super Emitter Sources	2		Within 1 mile of	44	
Methane Plumes	12				
Enviro. Hazards	*Sq.Miles*	*% of Land*			HIGH
Earthquake Hazard Zones	3.89	3%	Within 1 mile of	194	
Landslides	38.47	30%	Located on	140	
Subsidence	17.21	13%	Located on	21	
Sea-level Rise (55" 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	130.00	100%	Located on	354	
Agriculture					HIGH
Important Farmland Inventory	25.34	19%	Within 250 ft of	185	
Wildlife Spaces					HIGH
Regional Wildlife Corridors	44.50	34%	Within 1 mile of	331	
National Wetlands Inventory	7.97	6%	Within 250 ft of	141	
National Forest	43.46	33%	Within 1 mile of	115	
EJ Communities					MED
CalEnviroScreen (70-100)	4.70	4%	Within 2,500 ft of	9	

Figure 2.26 – Fillmore Landslides & Earthquake Hazard Zones

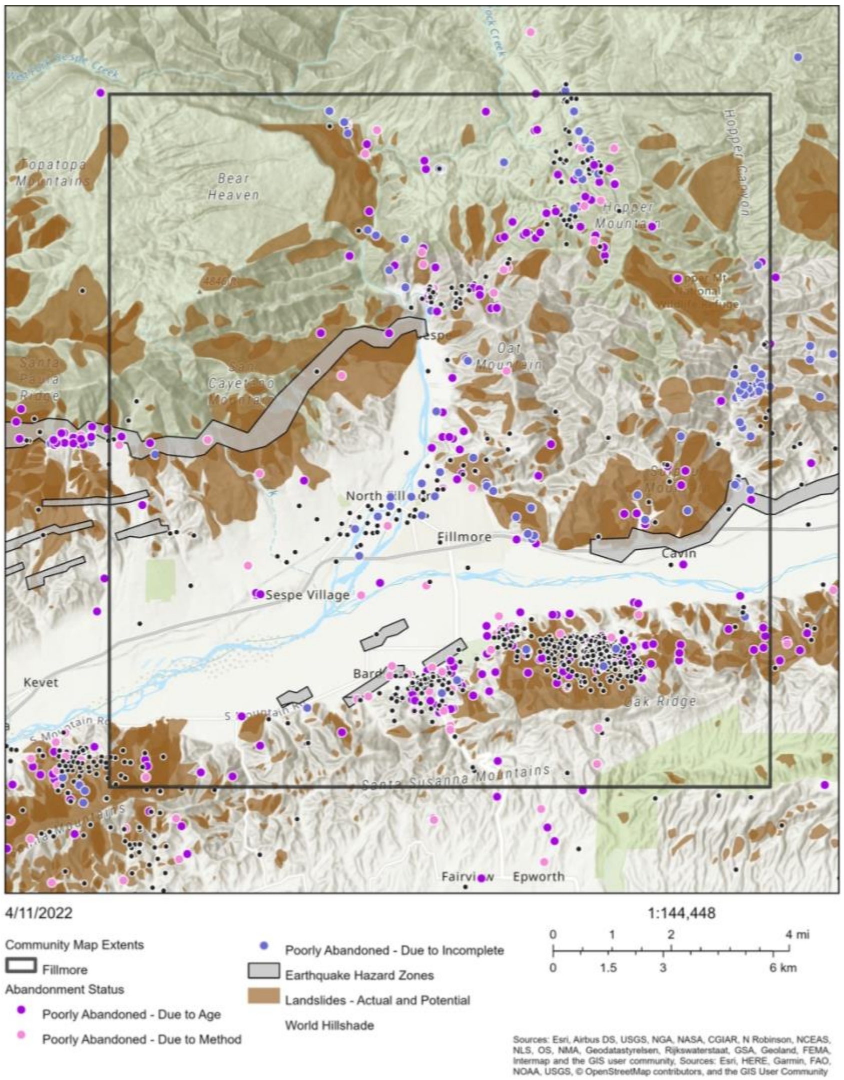


Figure 2.27 – Fillmore Wildfire Risk

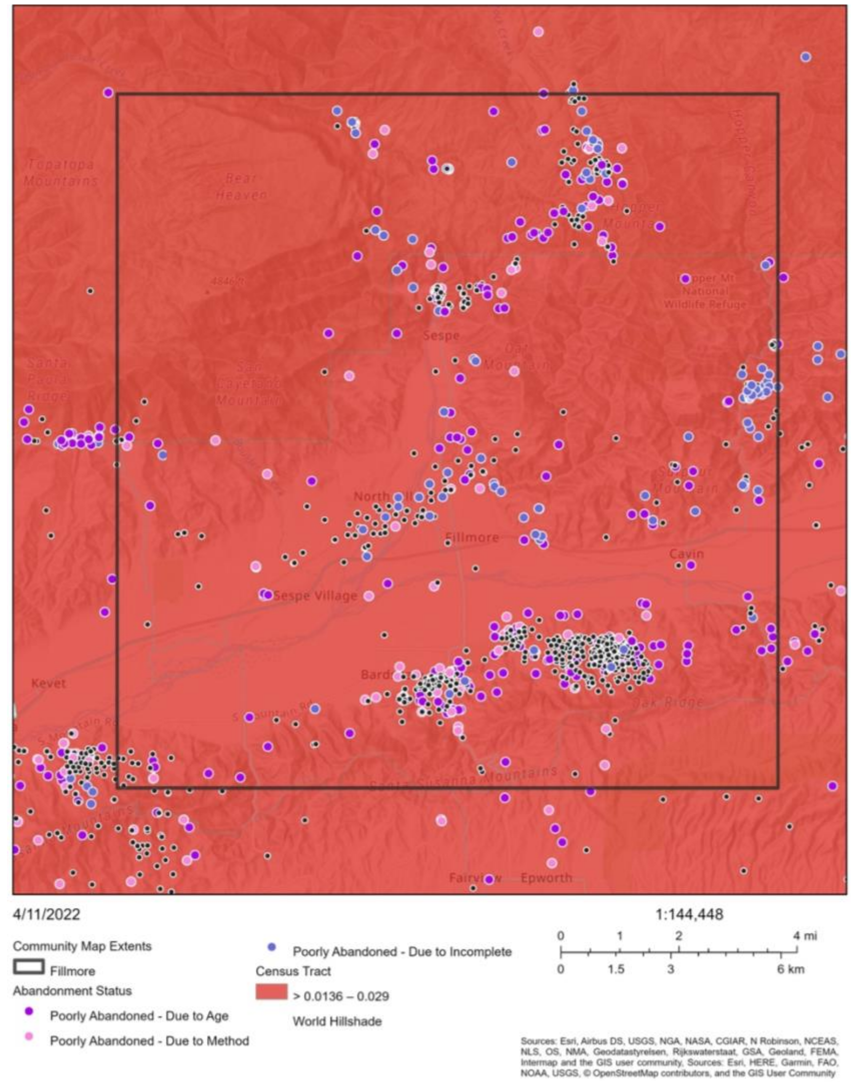
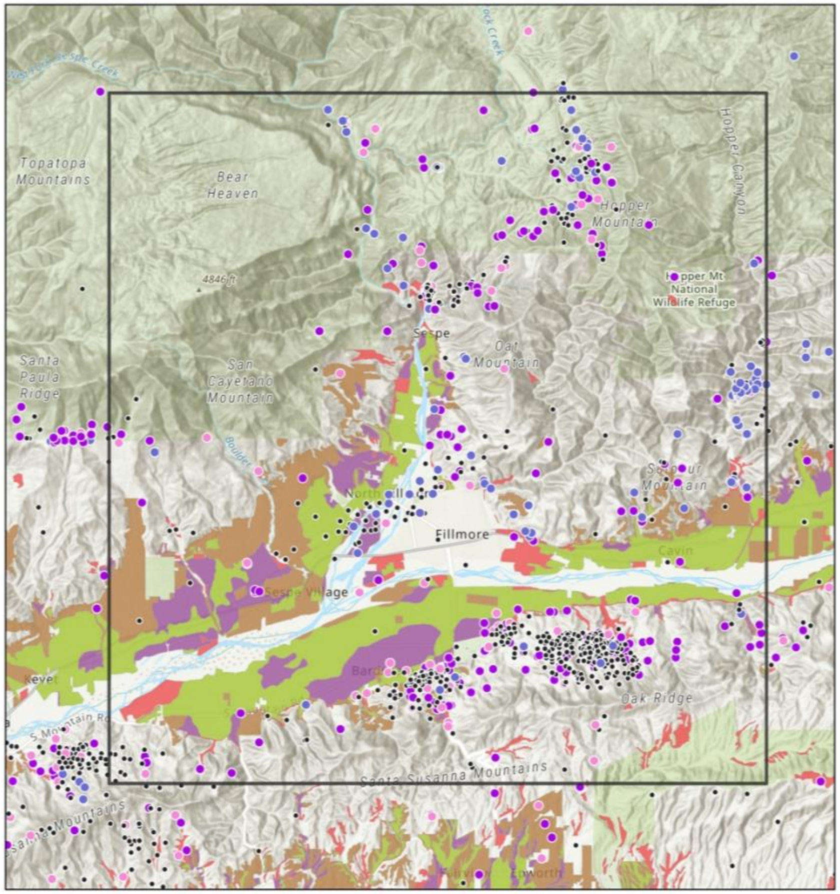


Figure 2.28 – Fillmore Important Farmland



4/11/2022

1:144,448

0 1 2 4 mi

0 1.5 3 6 km

Community Map Extents

Fillmore

Abandonment Status

Poorly Abandoned - Due to Age

Poorly Abandoned - Due to Method

Poorly Abandoned - Due to Incomplete

Important Farmlands Inventory

Prime

Statewide Importance

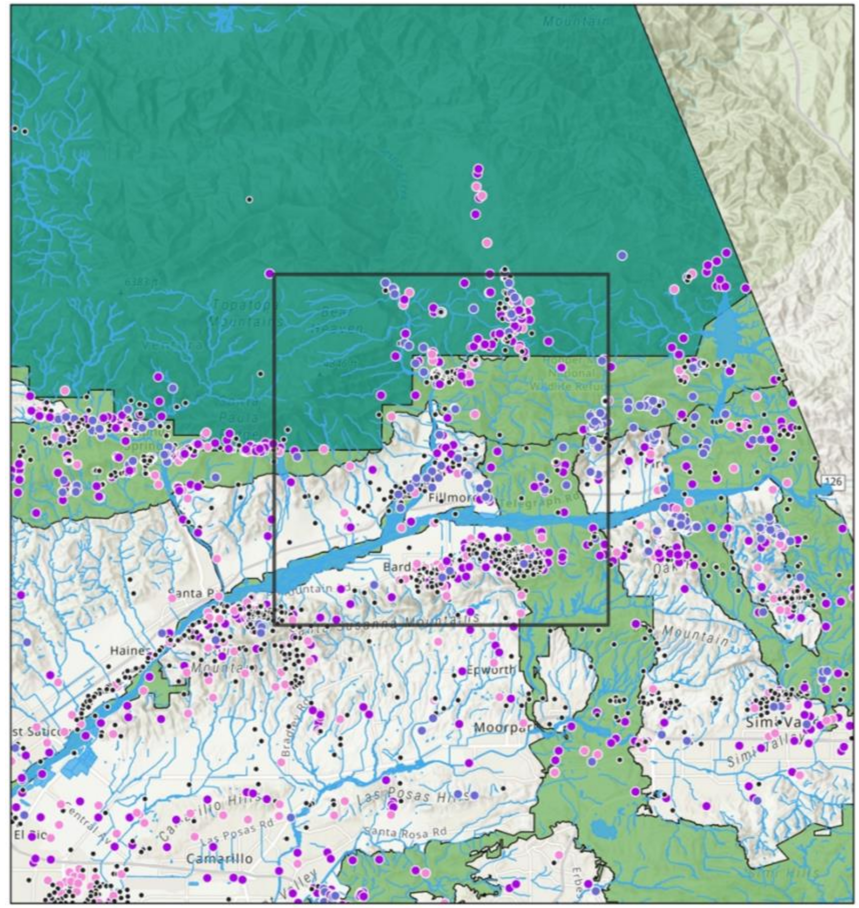
Local Importance

Unique

World Hillshade

Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Figure 2.29 – Fillmore Wetlands, Wildlife Corridors & National Forest



4/11/2022

1:288,895

0 2 4 8 mi

0 3.25 6.5 13 km

Community Map Extents

Fillmore

Abandonment Status

Poorly Abandoned - Due to Age

Poorly Abandoned - Due to Method

Poorly Abandoned - Due to Incomplete

National Wetlands Inventory (2007)

Regional Wildlife Corridors

National Forest Boundary

World Hillshade

Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Santa Paula

The Santa Paula community, which includes parts of Sulfur Springs and West Saticoy areas, has 278 wells that cannot be confirmed as properly abandoned. Like Fillmore, this high number and the geography of the area means it ranks medium or high risk for all factors, except cleanup priority wells, as summarized in Table 2.9. There is one methane super emitter source, which is classified as oil and natural gas infrastructure and is near 15 other poorly abandoned wells. As illustrated in Figure 2.30, this area has a significant earthquake hazard zone, where 157 wells are located within one mile, along with 45 square miles of landslide risk. Like other central Ventura County communities, this area is also at very high risk for wildfire, per Figure 2.31. The community is home to important farmland inventory (Figure 2.32) and the Santa Clara River, a major wetland (Figure 2.33), both of which are in proximity to at least 100 poorly abandoned wells. Lastly, as illustrated in Figure 2.34, 16 percent of the area is made up of an environmental justice community with a pollution burden higher than 81 percent of other Californian communities. This community is impacted by very high pesticide exposure, impaired or polluted groundwater, and hazardous waste.

Table 2.9 – Santa Paula Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	262		Priority 1	6	LOW
No Files	16		Priority 2	1	
Properly Plugged & Abandoned	455		Priority 3	2	
Re-Abandoned	5				
Re-Abandoned due to Problem	1		Historic Spill/Leak	8	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	MED
Groundwater Basins	65.50	50%	Located on/through	99	
River/Stream Watersheds	15.14	12%	Within 250 ft of	61	
Air Quality	*Amount*				HIGH
Methane Super Emitter Sources	1		Within 1 mile of	15	
Methane Plumes	10				
Enviro. Hazards	*Sq.Miles*	*% of Land*			HIGH
Earthquake Hazard Zones	5.18	4%	Within 1 mile of	157	
Landslides	45.63	35%	Located on	113	
Subsidence	16.94	13%	Located on	18	
Sea-level Rise (55" 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	126.66	97%	Located on	272	
Agriculture					HIGH
Important Farmland Inventory	42.56	33%	Within 250 ft of	171	
Wildlife Spaces					HIGH
Regional Wildlife Corridors	28.62	22%	Within 1 mile of	249	
National Wetlands Inventory	7.08	5%	Within 250 ft of	117	
National Forest	11.91	9%	Within 1 mile of	117	
EJ Communities					HIGH
CalEnviroScreen (70-100)	21.36	16%	Within 2,500 ft of	85	

Figure 2.30 – Santa Paula Landslides & Earthquake Hazard Zones

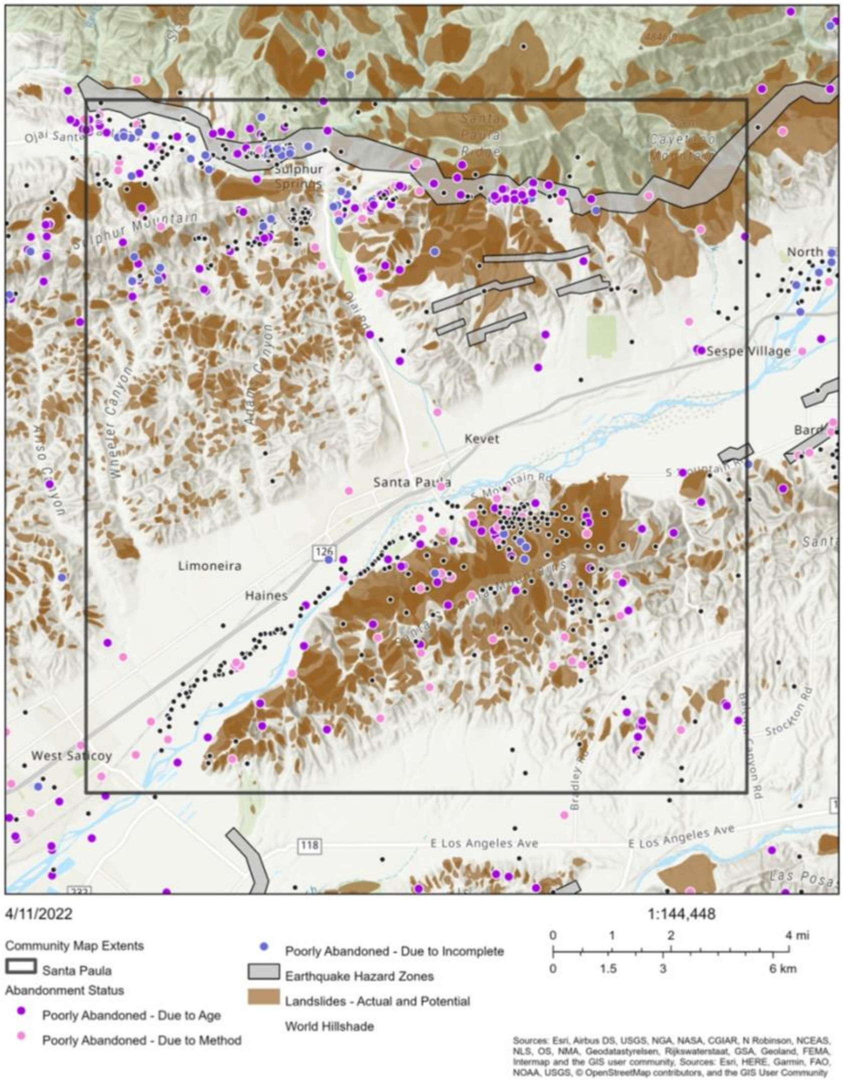


Figure 2.31 – Santa Paula Wildfire Risk

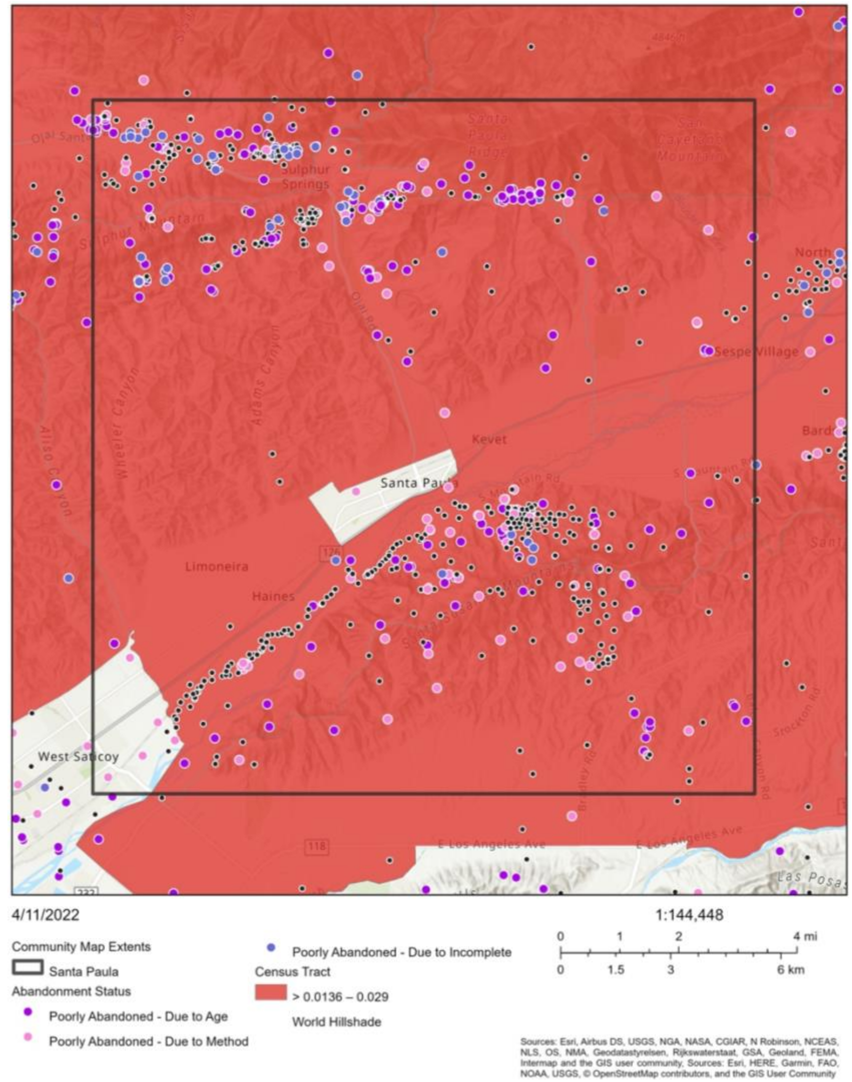


Figure 2.32 – Santa Paula Important Farmland Inventory

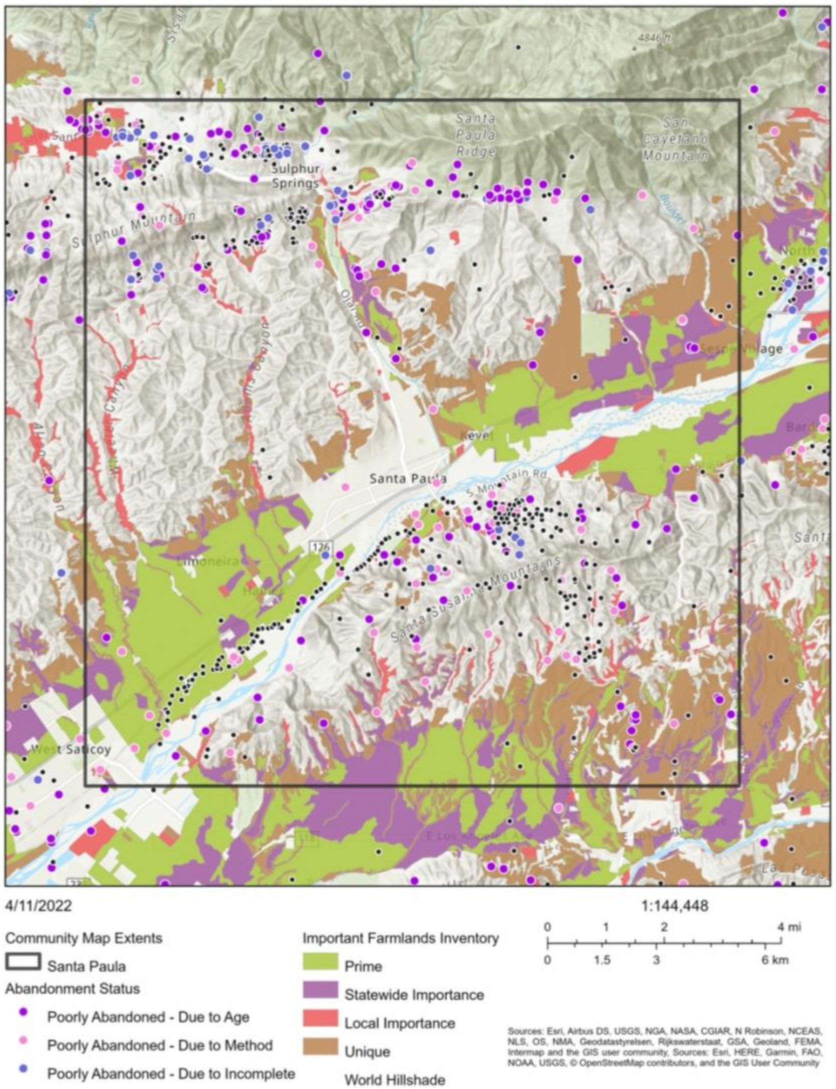


Figure 2.33 – Santa Paula Wetlands & Wildlife Corridors

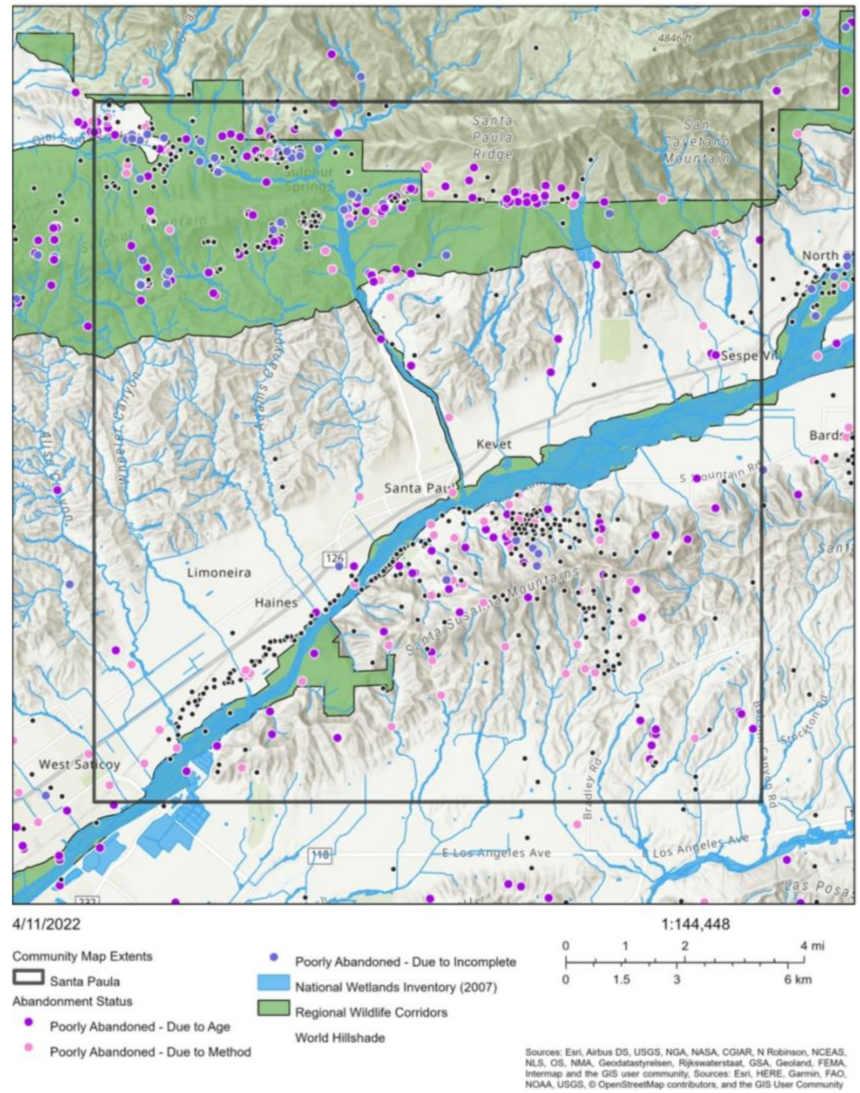
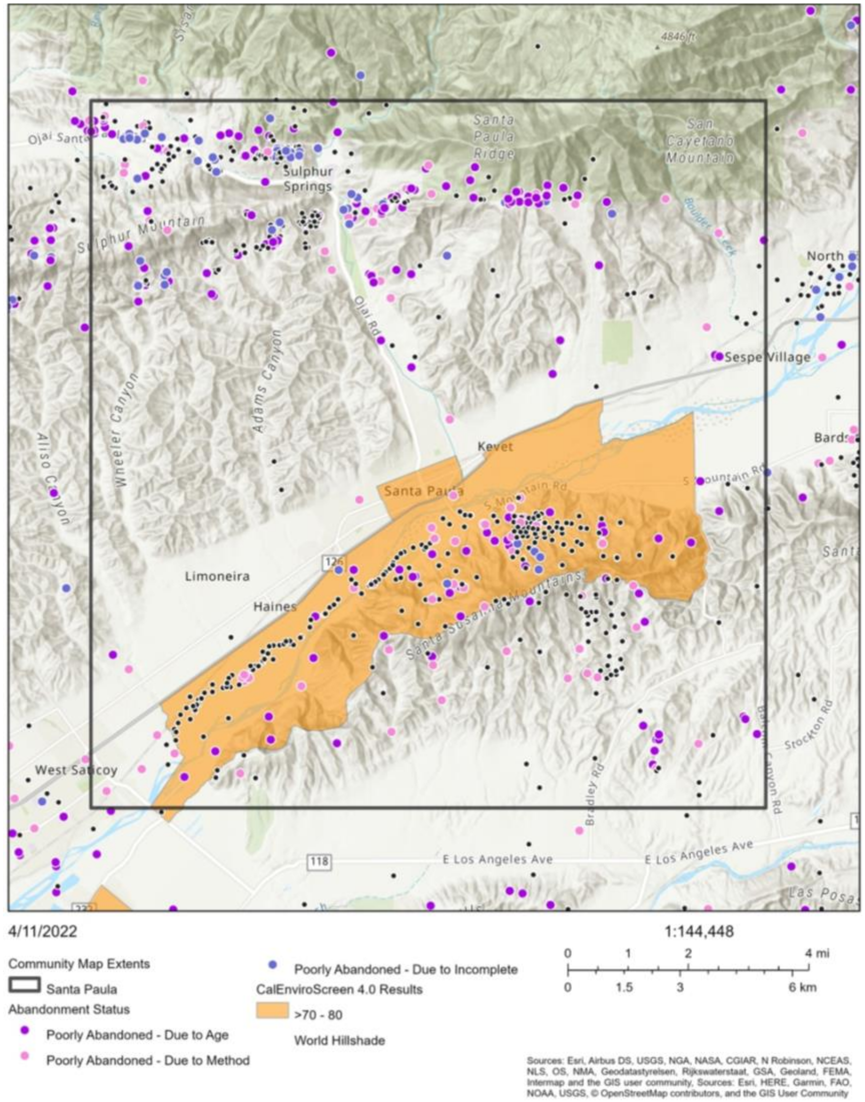


Figure 2.34 – Santa Paula Environmental Justice Communities



Ojai Valley

Almost 60 percent of all abandoned wells in the Ojai Valley area cannot be confirmed as properly plugged and abandoned. Despite this high ratio, the area ranks low in risk for cleanup priority wells, environmental hazards, and wildlife spaces, as summarized in Table 2.10. Close to 90 percent of the area is at high risk for wildfire, as seen in Figure 2.35, and the Ventura River and Lake Casitas offer significant wetland areas, as seen in Figure 2.36.

Table 2.10 – Ojai Valley Risk Assessment of Poorly Abandoned Wells					
					Rank
Poorly Plugged & Abandoned	108		Priority 1	0	LOW
No Files	8		Priority 2	3	
Properly Plugged & Abandoned	66		Priority 3	6	
Re-Abandoned	0				
Re-Abandoned due to Problem	0		Historic Spill/Leak	3	
			Proximity to Poorly Abandoned Wells		**Rank**
Water	*Sq.Miles*	*% of Land*	*Level of Analysis*	# of Wells	
Groundwater Basins	21.31	16%	Located on/through	7	
River/Stream Watersheds	13.50	10%	Within 250 ft of	40	
Air Quality	*Amount*				
Methane Super Emitter Sources	0		Within 1 mile of	0	
Methane Plumes	0				
Enviro. Hazards	*Sq.Miles*	*% of Land*			LOW
Earthquake Hazard Zones	1.32	1%	Within 1 mile of	41	
Landslides	31.54	24%	Located on	25	
Subsidence	0	0	Located on	0	
Sea-level Rise (55” 2100)	0	0	Within 250 ft of	0	
Wildfire (.036-.07/year)	112.97	87%	Located on	116	
Agriculture					
Important Farmland Inventory	10.65	8%	Within 250 ft of	3	
Wildlife Spaces					LOW
Regional Wildlife Corridors	33.90	26%	Within 1 mile of	106	
National Wetlands Inventory	9.28	7%	Within 250 ft of	84	
National Forest	35.53	27%	Within 1 mile of	2	
EJ Communities					
CalEnviroScreen (70-100)	0	0	Within 2,500 ft of	0	

Figure 2.35 – Ojai Valley Wildfire Risk

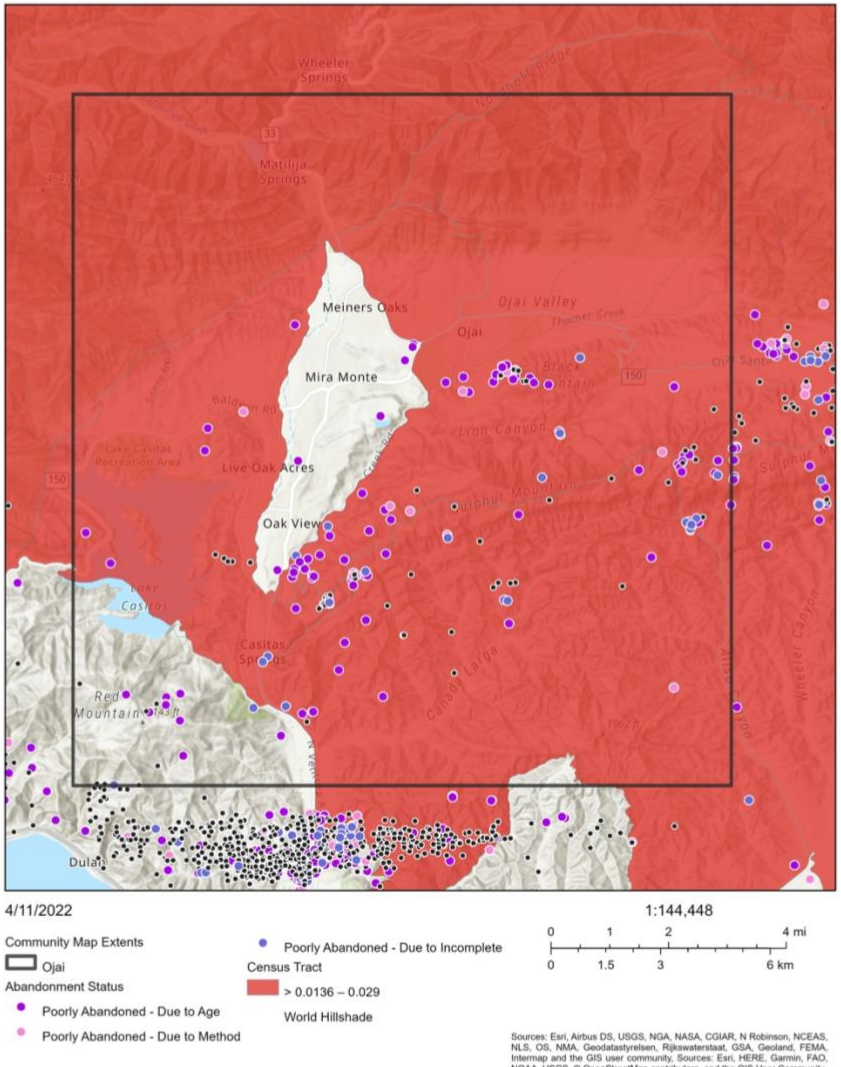
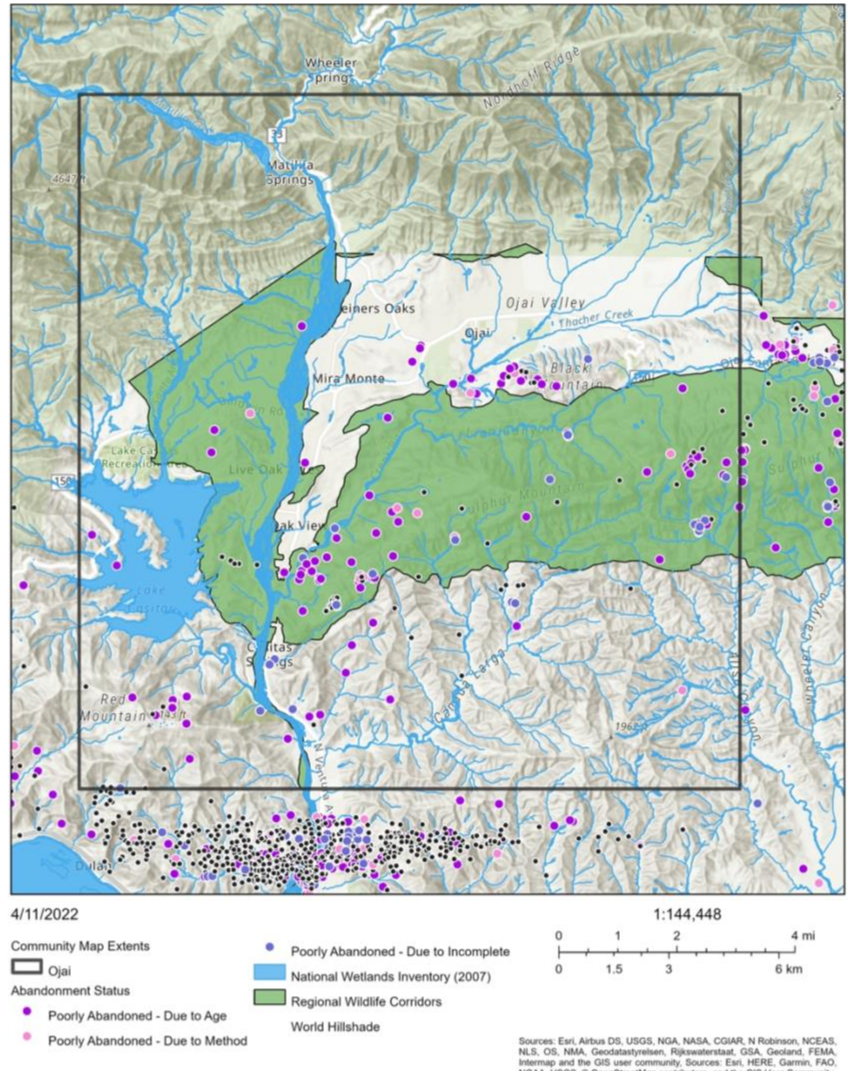


Figure 2.36 – Ojai Valley Wetlands & Wildlife Corridors



Discussion

Once a well is labeled "plugged and abandoned" by the California Department of Conservation's Geologic Energy Management Division (CalGEM), it ceases to be monitored or further assessed.[14] Despite the fact that leaky, old, abandoned wells have been confirmed by various agencies and investigations to pose serious risks for groundwater contamination, methane emission levels, and the safety and health of people and the environment, California is not checking up on them. In place of much-needed field research on these wells, and inspired by the findings of previous literature, this analysis considers their proximity to at-risk factors for each Ventura County community. While the risks and factors vary for each area, all nine communities are host to poorly abandoned wells.

After analyzing the proximity of poorly abandoned wells and map layers representative of at-risk factors, this research ranked each element from no to high risk for each community. Findings are summarized in Table 2.11. Santa Paula has five high-risk elements, the most of all Ventura County communities, and Fillmore and Ventura have the second most. In contrast, Moorpark and the Ojai Valley only rank low risk for three elements.

Table 2.11 – Risk Assessment Results by Community for Poorly Abandoned Well Proximity

	Priority	Water	Air	Hazards	Agriculture	Wildlife	Enviro. Justice
Ventura	HIGH	HIGH	HIGH	MED	LOW	MED	HIGH
Oxnard	HIGH	HIGH		MED	MED		HIGH
Camarillo	HIGH	HIGH		LOW	HIGH	MED	MED
Moorpark		LOW			LOW		LOW
Simi Valley	MED	LOW				LOW	
Piru				HIGH	MED	HIGH	
Fillmore	MED	MED	HIGH	HIGH	HIGH	HIGH	MED
Santa Paula	LOW	MED	HIGH	HIGH	HIGH	HIGH	HIGH
Ojai Valley	LOW			LOW		LOW	

This geographic analysis intends to provide information to the local governments and residents of the nine Ventura County communities and to identify possible disparities. But due to the interconnectedness of the factors, problems caused by poorly abandoned wells are likely to

[14] CalGEM representative confirmed this at a Virtual Briefings on State Abandonments and Orphan Wells for Central Valley/Kern/Coastal District on Wednesday, April 6th, 2022

have impacts far beyond each community's extent. Below are the geographic analysis findings at a county level:

Water

- 34 percent of poorly abandoned wells in Ventura County (636 wells) are located within groundwater basin boundaries
- 413 poorly abandoned wells are located within 250 feet of river and stream watersheds throughout Ventura County

Air

- 95 poorly abandoned wells within one mile of a methane super emitter source

Environmental Hazards

- 38 percent of poorly abandoned wells (712 wells) are located within one mile of the 36 earthquake hazard zones in Ventura County
- 373 poorly abandoned wells are located on areas with potential or actual landslide risk
- 196 poorly abandoned wells are located on areas experiencing subsidence, including the Oxnard coast, and spanning up the Santa Clara River
- 30 poorly abandoned wells are located within 250 feet of expected sea level rise based on the conservative 55-inch estimate of 100-year flood data
- 63 percent of poorly abandoned wells (1,161 wells) are in areas of Ventura County with an annualized high frequency of wildfire (0.0136 to 0.07)

Agriculture

- 752 poorly abandoned wells are located within 250 feet of important farmland inventory in Ventura County

Wildlife Spaces

- Nearly 80 percent of poorly abandoned wells (1,470 wells) are located within one mile of the three regional wildlife corridors in Ventura County
- 830 poorly abandoned wells are located within 250 feet of National Wetlands Inventory in Ventura County
- 390 poorly abandoned wells are located within one mile of the Los Padres National Forest

Environmental Justice Communities

- Nearly 20 percent of poorly abandoned wells are located within 2,500 feet of environmental justice communities, as defined by census tracts flagged by

CalEnviroScreen with overall percentile score from 70 to 100 (including pollution burden and population characteristic percentiles)

If considered, these findings can have two major implications. First, local Ventura County agencies and residents can use the map to identify possible problem areas. By including abandonment status categorization and notes taken during historical record analysis, individuals can learn more about the wells near their neighborhoods, parks, and outdoor recreation areas. By increasing the availability of information, individuals or groups may consider nearby poorly abandoned wells if there is an instance of a suspicious smell in the air or substance on the ground. Additionally, local agencies should consider the location of these wells in their planning and management, particularly those located in communities with identified high risk. For example, this information is pertinent to the various groundwater sustainability agencies, Ventura County Air Pollution Control District, parks and recreation departments, Ventura County Agricultural Commissioner, fire departments, and more. Second, these findings should help direct CalGEM's cleanup efforts in Ventura County. The agency has stated plans to recognize and value public concern and recommendations when identifying wells in need of plugging or repair.[15]

Like the historical record analysis done in Part 1, this geographic risk assessment is limited due to the lack of necessary comparable data. First, the largest gap in this analysis is the lack of regular and comprehensive methane emission detection and recording. Based on the determination of previous studies that poorly abandoned wells leak high levels of methane, these risk assessment findings are likely drastically underestimated. The only available data for methane pollution in Ventura County is records taken from two to 21 jet flyovers, measuring emissions at a large scale, missing smaller, but still harmful leaks (Duren et al., 2019). This gap should further strengthen the case for more methane detection monitoring at the local or state level. Second, without similar assessments done in other counties or regions, the Ventura County communities can only be compared to each other in terms of low, medium, or high risk. If other states or California counties with a history of oil and gas production completed risk assessments, or at the very least categorized poorly abandoned wells, the level of risk assigned to each community could be based on a larger sample of this common problem.

[15] CalGEM representative confirmed this at a Virtual Briefings on State Abandonments and Orphan Wells for Central Valley/Kern/Coastal District on Wednesday, April 6th, 2022

Part 3 – Costs, Benefits and Recommendations: Financial and Job Implications for Ventura County

Poorly abandoned, idle, and orphaned wells can pose serious threats to the surrounding environment and communities. But the threat does not stop there – the cleanup costs are substantial, and if not seriously considered and planned for, the bill will end up in the wrong place: addressed to the taxpayer. On the other hand, with enough forethought, the remediation and re-abandonment of these wells can offer exciting and significant benefits to Ventura County's greenhouse gas emission reduction goals and oil and gas industry jobs, which have stagnated in the last decade.

Based on the previous quantification of poorly abandoned wells and geographic proximity to environmental factors, Part 3 utilizes the limited cost and benefit estimates of previous studies to paint a picture of the economic implications these wells may pose for Ventura County.

Elements of cost are discussed first, including a summary of the legal requirements for well plugging, abandonment, and re-abandonment in California, determining cost factors, and then the estimates for the cleanup of poorly abandoned wells in Ventura County – based on first-time abandonment of orphan wells, the only available data currently. Second, a summary of the current Ventura County jobs within the oil and gas sector is provided, then similar estimates for job creation and methane emission reduction based on previous studies is offered. The section ends with a supportive discussion of the polluter-pays principle, a common sustainable development practice that requires the entity responsible for environmental damages to pay the expenses of preventing, controlling, and cleaning up pollution (Grossman, 2006; Luppi et al., 2012), and federal, state, and local recommendations are offered.

Cleanup Requirements and Costs

As discussed in Part 1, when an oil and gas well is determined to no longer be producing enough resources to be profitable, operators typically begin the "plugging and abandonment" process. In current times, this is a thoughtfully planned and regulated process of plugging the well, restoring or reclaiming the surface well site, and remediation of contaminated areas (Boettner, 2021). But as investigated in Part 1, this process has not always been regulated and has resulted in over 1,800 poorly plugged wells in Ventura County. Below is a review of current-day requirements for abandonment and re-abandonment in California, factors that determine plugging costs, and cleanup cost estimates for poorly abandoned wells in Ventura County.

California Requirements for Abandonment and Re-Abandonment

Federal regulations on well plugging and site reclamation do not include technical requirements and are concerned with only federal and non-federal oil and gas wells located in National Parks (Boettner, 2021). This leaves the states to create and implement laws and regulations governing the standards of well plugging and abandonment. The California Geologic Energy Management Division (CalGEM) is the governing agency of well abandonment in California and the primary sources of plugging requirements can be found in Division 3, Chapter 1 of California's Public Resources Code, and Title 14 of its Code of Regulations (Reitman, Reitman & Bourdon, 2020).

First, a summary of rules related to the initial plugging of a well: In addition to following the technical plugging rules outlined in each well permit, operators must observe other duties. For example, an operator must maintain financial securities for the wells, communicate with and obtain the Oil and Gas Supervisor's approval to enter different phases of operations, prevent waste, keep and submit accurate records, file an intention of a notice to abandon, and more. There are additional requirements for the plugging method, planning, and execution as well.[16] Before plugging a well, the operator must notify the Supervisor, coordinate plugging operations with CalGEM because some operations must be observed by agency employees, identify water, oil-bearing, and gas-bearing strata encountered in the well, ensure proper materials are used, clean the well, and make plans to recover casing and surface remediation.[17] Once these plans are approved, operators cannot deviate from them except in emergency situations.[18] There are a variety of specific rules governing plugging methods, processes, and well types, on topics of surface cement pours, open holes, surface plugging, removing the casing, and remediation.[19] Regulation managing restoration requires well sites to be "returned to as near a natural state as practicable" within 60 days of plugging and abandoning a well.[20]

Operators are responsible for the cost and operations of plugging a well. According to California rules, a non-compliant party may be forced to re-plug an improperly plugged well.[21] Additionally, the Supervisor or California's attorney general could choose to foreclose on the real or personal property of the operator, levy a life-of-well bond that must be repaid within 30

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[16] 14 Cal. Code Regs., §§ 1722.8, 1714, 1722.1.1(a), 1723(e), 1772(a), 1772.1.4, 1772.1.2; Cal. Pub. Rec. Code §§ 3501, 3210, 3213, 3215(a), 3227, 3230, 3206(a)(2)(v)

[17] 14 Cal. Code Regs., §§ 1714, 1776, 1723.7, 1723.1, 1723.2, 1723, 1723.2, 1723.6, 1776; Cal. Pub. Rec. Code §§ 3229, 3230, 3232, 3228

[18] 14 Cal. Code Regs., § 1722(g)

[19] 14 Cal. Code Regs., §§ 1723(d), 1723.1(a), 1723.2(a), 1723.2, 1723.5, 1723.6, 1776, 1723.1(c), (d), Cal. Pub. Rec. Code §§ 3208, 3237

[20] 14 Cal. Code Regs., § 1776

[21] Cal. Pub. Rec. Code § 3208.1

days, require additional financial securities, deny other proposed operations, etc.[22] But these regulations holding operators accountable for cleanup are significantly more limited in the case of re-abandonment, which is likely to be the needed remediation for many of the poorly abandoned wells.

In efforts to prevent "damage to life, health, and property" CalGEM may order the re-abandonment of any previously abandoned well if there is reason to question the integrity of the previous abandonment, or if the well is not accessible or visible.[23] But the criteria requiring operators to be responsible for re-abandonment is diminished if the Supervisor finds the initial abandonment in conformity with the requirements in effect *at the time of plugging*.[24] The majority of poorly abandoned wells in Ventura County were categorized based on age – being abandoned to the standards of 1953 or before. This regulation means that for many, the cost of re-abandonment will likely fall to state regulators. While California's legal requirements for plugging and abandonment have developed in recent decades, there are still many areas of uncertainty and lack of financial forethought.

Factors Determining Well Abandonment Costs

One major area of uncertainty is the exact cost of plugging, abandonment, and well site restoration – not to mention re-abandonment, which has not been the priority of any reports or investigations yet. Many reports estimate the average plugging cost per well for a region or state based on a relatively small sample. But the reality is that these costs can drastically differ from one well to the next, depending on several factors.

First, the physical status and history of a well is a major factor in the cost and length of time needed to properly plug. For example, if the integrity of the well casing is poor or the wellbore has collapsed, even partially, it will need to be redrilled, cleaned out, and then plugged again (Boettner, 2021). In the review of Ventura County well records, this was a common problem cited but not always mitigated. Individual well depths also make an impact: the deeper the well, the more expensive to plug. A recent study of 19,500 wells across the United States found that each additional 1,000 feet of well depth increase cost by 20 percent (Raimi et al., 2021). Poorly abandoned wells in Ventura County reach depths up to 18,000 feet. This study also found that older wells are more costly than newer ones, natural gas wells are 9 percent more expensive than oil wells, and costs vary widely by state. Other factors to consider include the need to remove material from inside the wellbore or surface and the level of surface contamination needed to be remediated (Boettner, 2021; Boomhower et al., 2018).

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[22] Cal. Pub. Rec. Code §§ 3226, 3205.3, 3203, 3236.5; 14 Cal. Code Regs., §§ 1722.8(f), 1722.8

[23] Cal. Pub. Rec. Code §§ 3208.1(a)

[24] Cal. Pub. Rec. Code §§ 3208.1(b)

The geology surrounding a well can also impact the cost. If the well is difficult to access, roads and changes to the land may be necessary to make way for the required drilling equipment and rigs. If the well is near contaminated groundwater or sensitive receptors, like homes, creeks, or schools, the cost can dramatically increase and warrant the increased oversight of other agencies (Boettner, 2021). Boomhower et al. (2018) also found that each additional 10 feet of elevation change in the five-acre area surrounding a well raise costs by three percent. Last to consider is the availability of labor contractors and the number of wells included in a contract. Each additional well included in a contract can reduce decommissioning labor costs by three percent per well. A study completed in Pennsylvania found that the average well plugging costs per foot for larger contracts is one-third the cost of small contracts (Weber, 2018).

California is beginning to recognize the vast cost variation in well plugging and the importance of considering multiple factors in estimating cleanup costs. In early 2022, CalGEM drafted new regulation requiring operators to calculate and provide cost estimates for abandonment, production facility decommissioning, and site remediation for all wells.[25] The estimates must consider characteristics like well depth, number of casing strings, age of well, well location and surrounding environment, current condition, and additional risk factors including history of spills or leaks and emission production. While this new rule will not immediately change any other financial requirements, it has the potential to encourage regulators to adjust bonding obligations to better match the characteristics of individual wells.

Plugging Estimates of Poorly Abandoned Wells in Ventura County

Much like the varied terminology for legacy wells, a review of average well plugging costs demonstrates that costs can vary dramatically by state, contract, and well. In an attempt to provide rough reclamation cost estimates for poorly abandoned wells at the county level, which has not been done before, this research begins with estimates for orphan well plugging and calculates the cost for different cleanup extents. Table 3.1 offers possible, and likely conservative, costs based on five estimates from previous literature, ranging from $103 million to $3.7 million.

[25] Cost estimate regulations for oil and gas operations. California Code of Regulations, Title 14, Division 2. Department of Conservation, Chapter 4. Development, regulation, and conservation of oil and gas resources.

Table 3.1 – Cost Estimates Based on Initial Plugging Average Estimates

Source	CalGEM (2021)	Raimi et al. (2021)	CCST (2018)	**CCST (2018)**	Raimi et al. (2021)
Estimate	Average	Median	Average	**Average**	Median
Context	Remediation of Deserted Well	Plugging & Surface Reclamation	Plugging	**Plugging**	Plugging Only
Sample Size & Location		19,500 (US)	86 (CA)	**20 (Coastal District)**	19,500 (US)
Per Well	$ 111,000	$ 76,000	$ 68,000	**$ 40,000**	$ 20,000
Priority Cleanup Wells (186)	$ 20,646,000	$ 14,136,000	$ 12,648,000	**$ 7,440,000**	$ 3,720,000
25% of Poorly Abandoned Wells (460)	$ 51,060,000	$ 34,960,000	$ 31,280,000	**$ 18,400,000**	$ 9,200,000
50% of Poorly Abandoned Wells (920)	$ 103,230,000	$ 70,680,000	$ 63,240,000	**$ 37,200,000**	$ 18,600,000

A major limitation of this cost analysis is the absence of available estimates for re-abandonment and reclamation of poorly abandoned wells.[26] The five sources featured above are based on the initial, first-time plugging of an idle, orphaned, or deserted well. Re-abandonment is often more technical and complicated (Plants, 2021), and therefore likely more expensive than initial abandonment, so the estimates in Table 3.1 are conservative. Additionally, to reflect the reality of potential cleanup, estimates are provided at three different extent levels. First, if only the 186 wells prioritized for cleanup were remediated. Then if only 25 percent and 50 percent of all wells identified as poorly abandoned were remediated. While the over 1,800 Ventura County wells that cannot be confirmed as properly plugged should be assessed and monitored, full remediation and cleanup is likely unnecessary, and frankly, unrealistic given the current limited capacity of CalGEM and other agencies. Based on the emphasis placed on regionality by previous literature, the Coastal District cost estimates

[26] The author reached out to CalGEM multiple times for cost estimates on re-abandonment and did not receive a response. Private contractors working in re-abandonment in Southern California were also reached out to with no success.

calculated by the California Council of Science & Technology (CCST, Boomhower et al., 2018) may be the best place to start: ranging from $7.4 million for cleanup priority wells to $37 million for half of all poorly abandoned wells in the county. But further investigation at the local and state level should be completed to fortify this estimate because, while it was calculated based on the trends and geology of the Coastal District, where Ventura County is located, it was found with a very small sample of only 20 wells, representing less than one percent of all abandoned wells in the county. To gain a more comprehensive view of the possible financial expenses of this major problem, all estimates provided in Table 3.1 should be considered in planning.

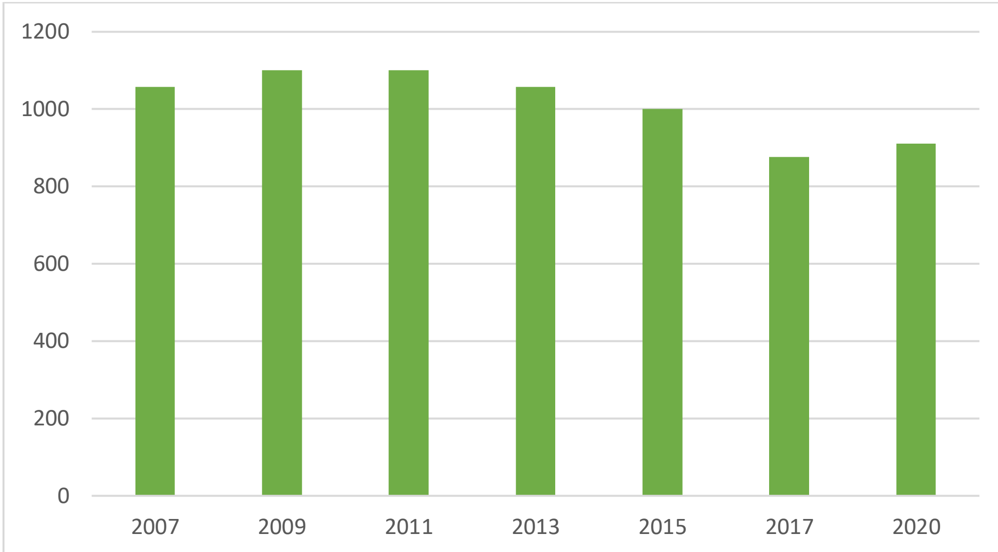
Benefits: Opportunity for Jobs and Greenhouse Gas Emission Reduction

The assessment and remediation of poorly abandoned wells in Ventura County also offer large-scale benefits. First, it has the potential to create thousands of jobs in the oil and gas industry, which has stagnated in growth in recent years. As fossil fuel production continues to decline in the county, this could be an opportunity to utilize and protract the oil and gas workforce. Second, repairing and re-abandoning these wells can reduce air pollution leaks that contribute to greenhouse gas emissions and harm the surrounding environment. Addressing leaks of methane and volatile organic compounds will help Ventura County meet its climate goals and enhance public safety.

Current and Potential Oil and Gas Industry Jobs in Ventura County

As discussed in Part 1, oil and natural gas production in Ventura County has been steadily decreasing over the last few decades. This decline in production is concurring with a slowing rate in oil extraction industry jobs. Figure 3.1 illustrates the number of jobs within the industry from 2007 to 2020. In 2020, the 910 jobs represented just over one percent of all goods-producing jobs, which does not include the much larger number of service-providing jobs in the county. Additionally, these estimates do not yet reflect the likely decrease in oil and gas jobs as a result of the COVID-19 pandemic. Across the United States, 107,000 jobs were lost in this industry between March and August 2020, 70 percent of which were unlikely to return by the end of 2021 (Dickson et al., 2020).

Figure 3.1 – Mining and Oil Extraction Employment in Ventura County (2007-2020)



Source: Ventura County Civic Alliance, State of the Region Report (2017, 2019, 2021)

Recent research completed by Food & Water Watch (2022) found job creation claims made by the fossil fuel industry across the country are false. In California, the Western States Petroleum Association claimed that the oil industry supports almost 668,000 jobs, whereases the Bureau of Labor Statistics lists only 22,000 jobs involved in oil production in 2020. The research finds that oil and gas production accounts for only one-tenth of one percent of all employment in the state. The remediation and re-abandonment of poorly abandoned wells have the potential to create a significant number of jobs in Ventura County, filling the gap left by a decline in production, the pandemic, and false industry claims. According to industry experts: "there is a clear match between the skills of unemployed oil and gas workers and the requirements needed to plug orphaned and other abandoned wells properly" (Raimi, Nerurkar, & Bordoff, 2020, p. 16). Unfortunately, estimating the number of jobs this opportunity could offer Ventura County is difficult. California-specific estimates are unavailable and the estimates available from other states only consider first-time abandonment. These two factors mean the following job creation estimates are likely significantly underestimated for the Ventura County context.

After analyzing available data from four states,[27] Raimi, Nerurkar, and Bordoff (2020) found that it takes an average of 13,445 job-years and costs between $101,112 and $202,224 per job-year to plug 56,600 wells. Based on this estimation, the remediation of all 1,840 poorly abandoned wells in Ventura County may require 423 job-years. Based on the average salary in the mining and oil extraction sector in Ventura County in 2020, these job-years would cost almost $44 million in total. These estimates are limited in nature but provide some

[27] States include Alberta (Canada), Colorado, North Dakota, and Pennsylvania

encouragement in the economic potential addressing poorly abandoned wells has for stimulating the Ventura County economy and satisfying labor gaps.

Greenhouse Gas Emission Reduction

In addition to stimulating jobs in the oil and gas sector, the remediation and re-abandonment of poorly plugged wells offer additional benefits in decreasing methane, a potent greenhouse gas (GHG), emissions. While unplugged idle and orphaned wells have been found to leak methane at higher rates than plugged wells (Lebel et al., 2020; Boettner, 2021), literature investigating point source pollution from wells is limited in geographic and sample scope (Pekney, 2021), and does not yet include a focus on poorly plugged wells. Without more specific field research and methane detection in the region, it is impossible to quantify the estimated GHG reduction that would result from cleaning up the 1,840 wells that could not be confirmed as properly plugged in Ventura County. But as a climate action described as "low-hanging fruit," (Clark, Malik & Rathi, 2021; Lynch, 2020) the cleaning up of leaky fossil fuel infrastructure should be discussed within the context of Ventura County's bold climate goals.

In 2020, Ventura County adopted a General Plan with ambitious and necessary GHG emission reduction targets – most imminent, to reduce emissions by 41 percent below 2015 levels by 2030. This plan commits the county to "improv[ing] the long-term sustainability of the community through local efforts" to reduce GHG emissions (p. 6-17). A recent emissions inventory found that 15 percent of total GHG emissions in unincorporated Ventura County come from oil and gas production alone (275,096 MTCO2e) (p. B-8). Addressing possible leaks from old, inactive wells is an easy and uncontroversial opportunity to reduce these emissions without impacting current production. The Ventura County Climate Emergency Council, an appointed council responsible for advising the Board of Supervisors on climate action planning, recognized this opportunity by recommending a resolution supporting CalGEM's efforts to cap methane leaks from oil and gas wells and pipelines in the county.[28] Resolutions like this, which call for localized support from regulating agencies, are one way for local jurisdictions to overcome their limited ability to address this problem.

Recommendations

Poorly abandoned oil and gas wells are a national problem playing out locally in Ventura County. Addressing the problem with monitoring, remediation, and re-abandonment will cost a significant amount of money but does offer benefits in oil and gas sector job stimulation and greenhouse gas emission reduction. To ensure the costs are not left to the taxpayer and future

[28] View resolution approved by Ventura County Climate Emergency Council on March 15, 2022 (p. 151).

generations, all cleanup plans should be based on the polluter-pays principle which requires the party responsible for producing pollution to be responsible for paying for the damage to the surrounding environment. Below is a discussion of the polluter-pays principle and recommendations at the federal, state, and local level to facilitate the cleanup of poorly abandoned wells based on this principle.

Polluter-Pays Principle

In the mid-1970s, the Organization for Economic Co-operation and Development (OECD) defined the polluter-pays (PP) principle as “the polluter should bear the costs of pollution prevention and control measures, the latter being measures decided by public authorities to ensure that the environment is in an acceptable state” (OECD, 1992, p. 5). In other words, “a polluter has to bear all the costs of preventing and controlling any pollution that he originates” and should not receive assistance, such as grants, subsidies, tax allowances, or below-cost charges for public services. This practice is well-rooted in Western legal history and for the last five decades has stood as an international guideline for judicial, legislative, and constitutional reforms throughout the world for mitigating harm (Luppi et al., 2012).

In the context of pollution caused by oil and gas extraction in the United States, the PP principle has only been limitedly followed. After the Exxon Valdez spill in Alaska, the Oil Pollution Act of 1990 was enacted and made oil companies responsible for the cleanup of oil spills, but limited liability for damages to $75 million (West Coast Environmental Law, 2010). An Oil Spill Liability Trust Fund was also created with $1 billion in public money. In 2010, after the major BP Gulf of Mexico spill, the Obama administration raised the liability cap to approximately $134 million for offshore oil and gas facilities (Pfeiffer, 2010; Gillette, 2014). Onshore wells and facilities, the vast majority regulated by states, have not received the same comprehensive PP principle attention. The recent funds authorized under the Infrastructure Investment and Jobs Act for states to clean up orphan wells fail to consider the principle at all, passing the funds through as a grant.

Federal Recommendations

The recently enacted Infrastructure Investment and Jobs Act includes $1.15 billion in funding available to states for the cleanup of orphaned oil and gas wells. As of April 2022, the U.S. Interior Department is preparing to grant up to $165 million to California with no PP principle requirements. To ensure this funding is not an industry handout, polluters are held financially responsible, and all legacy wells are accounted for, this research recommends:

Require State Plan for Oil and Gas Industry Fund Reimbursement

As part of demonstrating "the readiness of the State to carry out proposed activities using the grant," the U.S. Interior Department should require CalGEM to set a plan to identify and procure funds from the oil and gas industry to reimburse all public funds expended on well remediation. CalGEM has the legal authority to recoup costs from operators, including prior operators when the current operator is unable to pay or be identified.[29] In the case of wells where no past or present solvent operator can be identified, the industry-wide assessment fee[30] should be increased to account for the reimbursement of these remediation costs.[31]

Include Re-Abandonment in Criteria for Orphan Well Cleanup

As of right now, these funds can only be used for the first-time abandonment of unplugged orphan wells. As made clear by this research, this omits the significant number of poorly abandoned wells that require repair or re-abandonment. In future releases of the funds, the U.S. Interior Department should expand the criteria for well remediation to include all types of legacy wells with no solvent owner of record.

State Recommendations

As the major state regulators of well abandonment, changes in CalGEM processes, funding structure, and programs offer significant potential in addressing the problem of poorly abandoned wells by upholding PP principles. The following recommendations may need to be directed by the California legislature and modifications to the state budget.

Develop an Abandoned Well Monitoring Program

Consistent with the idle and orphan well programs already established, CalGEM should develop a monitoring program to systematically evaluate and remediate abandoned wells. The findings of this research make clear that wells labeled as "plugged and abandoned" may not be permanently sealed and could harm surrounding water, land, and air. The problem of idle and orphan wells is large and should be addressed promptly, but CalGEM and California decision-makers need to recognize well remediation needs do not stop there.

In prioritizing which wells to assess or remediate first, CalGEM should utilize and expand upon the categorization matrix put forward by this research. Additions and adaptations should be made based on public comments and recommendations, expert consultation, and regional differences. A high consideration should be given to wells located in environmental justice

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[29] Cal. Pub. Rec. Code § 3237(c)

[30] 14 Cal. Code Regs. § 1776

[31] This recommendation was included in a letter drafted by Center for Biological Diversity, signed by CFROG and other orgs, sent to the U.S. Department of the Interior on March 30, 2022.

communities and sensitive environmental habitats. Wells identified with suspected leaks or spills should be remediated immediately.

Expand Capacity and Scope of Methane Aerial Monitoring Program

In addition to utilizing available well record data to assess abandoned wells, CalGEM should use this recently identified problem to expand the capacity and geographic scope of its aerial monitoring for methane emissions. In 2021, the agency expanded its drone operations to include the aerial surveillance of methane. As of early 2022, the program was only being executed in the Southern District, with 297 sites prioritized and an average of 4-5 sites flown over each week.[32] At this rate, it will take CalGEM over a year to assess just those already identified, which do not include any abandoned wells. Expanding the methane monitoring program can help California meet its greenhouse gas emission reduction goals (40 percent below 1990 levels by 2030) and fill the gap identified by this research for field and sensor study of poorly abandoned wells.

Implement More Strict Timelines for Well Abandonment and Close Bankruptcy Loopholes

Despite having a reputation for strict and protective environmental regulation, California has fallen behind other states in managing idle and potentially orphaned wells. To ensure poorly abandoned wells are a thing of the past, CalGEM should implement more strict timelines for the abandonment of idle wells to ensure operators are paying for and completing proper plugging. A 2016 study found that California had no specific limit on how long a well could sit idle, whereas 19 of the other 21 states surveyed had a maximum limit of two years (Ho et al., 2016). Additionally, the likelihood of an idle well being reactivated decreases the longer it remains idle (Boomhower et al., 2018). As oil and gas production continues to decrease, California should be more vigilant in the abandonment of idle wells.

This increased attention on idle wells is especially important given the recent trends in well ownership transfer and operators filing for bankruptcy and therefore avoiding cleanup costs. Since 2015, more than 39 oil and gas producers filed for Chapter 11 bankruptcy each year in the United States and Canada, including a total of seven in California (Haynes Boone, 2022). Operators can escape liability through bankruptcy loopholes and restructuring schemes. A case of this is currently playing out in Ventura County where California Resources Corporation filed for Chapter 11 bankruptcy in 2020, divested local assets – including over 100 idle wells – a year later, and is unlikely to pay the current $4.9 billion they own in debt, including decommissioning costs (Williams-Derry, 2020).

[32] Presentation given to the Ventura County Climate Emergency Council by Michel Vasconcellos, Senior Oil and Gas Engineer, Supervisor at CalGEM on Aerial Methane Surveillance Program.

Increase Transparency and Community Responsiveness

This investigation into poorly abandoned wells in Ventura County relied heavily on publicly available data from CalGEM but identified many shortcomings. First, five percent of plugged wells in the county had no historical records, and even more had incomplete records. Without this documentation, it is impossible to know how CalGEM determined them to be plugged. CalGEM should work to improve data transparency, completeness, and ease of access to well records and other relevant oil and gas data. Additionally, the author reached out to CalGEM's Office of Transparency multiple times with inquiries and never received a response. A better process for tracking and following through on comments, concerns, and questions from the public is recommended. A possible vehicle for these improvements is the implementation of a public oversight board. In 2021, groups successfully advocated for the creation of an environmental safety and oversight board and environmental justice advisory body at the Department of Toxic Substances Control, which had "remained a black box to residents and advocates for too long" (Mason, 2021, para. 2). A similar structure could be built at CalGEM to increase transparency and accountability to California communities.

Local Recommendations

The ability of county and city jurisdictions to address this problem is limited but there are a few opportunities to enhance adherence to the PP principle. In California, local regulation of oil and gas is generally limited to land use and zoning ordinances related to the permitting of onshore proposed operations. Within this realm, Ventura County should consider and establish the following recommendations:

Establish Oil & Gas Administrator in Ventura County

To increase county oversight, an Oil and Gas Administrator or oversight department should be established. Oil and gas have been extracted and produced in Ventura County for over a century – without any real oversight or direction at the county level. Land use authority in permitting falls under the Commercial/Industrial Permits team in the Planning Division of the Resource Management Agency. This is a team of just six planners with one manager, responsible for all commercial and industrial permits, from a new apartment building to oil lease extensions. Over the last few years, it has become clear that any oil and gas issue that falls outside of permitting is neglected.[33] Ventura County can look to its neighbors, Los Angeles and Santa Barbara Counties, which both have county-level oversight entities for a framework. In addition to tracking the development and completion of county-level oil and gas reports, this oversight would allow the county entrance to oil and gas leases or facilities without the pre-

[33] In 2016, the Ventura County Grand Jury recommended the need for an annual report on crude oil pipelines. This was tasked by the Board of Supervisors to County staff but there was no follow up to date.

approval of oil companies. This ability would greatly increase the ability and legitimacy of regulatory checks and emergency response.

Increase Surety Bond from $10,000

Currently, Ventura County is enacting bare minimum surety bond requirements: $10,000 for one well or a blanket of $10,000 for all wells operated by a particular company in the county. These are funds oil operators are required to pay in anticipation of accidents, capping and remediation, bankruptcy, compliance, or other expenses – and are woefully insufficient and outdated. As discussed above, the remediation of wells is costly, and to ensure all wells are properly plugged and abandoned in the future, the county should immediately raise this bond to reflect the high costs. As the entity responsible for land permits, the County of Ventura must take ultimate responsibility for ensuring the land is restored to its natural state after fossil fuel extraction and should be actively planning for the financial consequences.

Add Abandoned Wells to New or Extended Permits

As described in Part 2, poorly abandoned wells can negatively interact with a variety of factors, including new and active wells. To ensure possible damages caused by this interaction are the financial responsibility of current operators, Ventura County should require abandoned wells, no matter their status, be included in newly granted or extended oil and gas permits. The inclusion of the full inventory of wells within a permit parcel is a simple way to guarantee the financial responsibility of any future problem is that of the current operator. For example, a leak or issue in a plugged well caused by nearby extraction. If all abandoned wells are properly plugged and sealed, as claimed by CalGEM, the inclusion of them in modern permits does not elicit a higher risk for the operators of nearby active wells.

Create Local Restoration Requirements

Once a well is plugged, California law requires the land to be returned to its natural state as part of the restoration process. Ventura County is lacking in necessary specifics and parameters in the enforcement of this rule. To better facilitate accurate revegetation and restoration of these spaces, the county should consult local ecology and indigenous experts to clearly define requirements per native plants, contouring of terrain, placement of topsoil, irrigation, erosion control, and monitoring and reporting.

After quantifying the little-known but big problem of poorly abandoned wells in Ventura County, and analyzing their geographic proximity to at-risk factors, this section offers a discussion on costs, benefits, and next steps. First, the state requirements for abandonment and re-abandonment are reviewed. Then, based on the only data available, cleanup cost estimations are provided, with the most realistic costs ranging from $7.4 million to $37.2

million. If planned for sustainably, the cleanup of these wells offers major benefits to Ventura County: over 400 well-paid job-years and greenhouse gas emission reductions. Lastly, recommendations based on the polluter-pays principle are offered at the federal, state, and local levels.

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Appendix 1 – Plugged & Abandoned Wells Prioritized 1-3 for Cleanup and Historic Spills in Ventura County						
Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
1	411105547		Due to Age	1932	5936'	letter from 1973 saying that the Dept of fish and game identified a leaking well and suggested abd for the well but there are no records of such work; turned over to landowner for use as a water well in 1932 - leaking water?
1	411105742	Housing tract	Due to Age	1940	4706'	located in a residential neighborhood; 1940 letters that stated they could not reach the owner to get him to take action to abd the well; letter also mentioned the possibility of contamination of surface fresh water w/ deep salt water -means the well is not in satisfactory condition
1	411103114	River	Due to Age	1944	3127'	originally abd in 1940 but complaints of oil leak starting july 1943; operator ceased production since there was insufficient oil to cont. production but tank was left on the property and sufficient gas forced a small amount of oil into the tank to eventually fill the tank w/ water and oil. the tank overflowed down the ravine and into the Santa Clara river. fish and game commission complained "from time to time"; Texas company also complained that oil was running down to their property, causing a fire hazard; Camden Oil company refused to assume responsibility for abd
1	411105657	Housing tract	Due to Age	1951	2303'	boulders were dropped into the hole to form a bridge at 1115'; turned into water well; in housing tract
1	411105671	Housing tract	Due to Age	1952	7247'	wooden bridge plug set at 1585' and 269'; in housing tract
1	411105739	Shopping center	Due to Age	1954	2110'	tried to re-abd in 1995 but reqs were not fulfilled bc unable to clean out to at least 900', plug cement from 900'-800', unable to fill unplugged portions with cement, and unable to fill the well w/ cement from 250'-151'; the Division recommends that no structure be built over or near the well unless they install a vent system; well is under Camarillo outlets parking lot
1	411105762	Housing tract	Due to Method	1955	10,122'	left full of heavy drilling fluid; in housing tract; missing surface cement plug to be converted to water well
1	411105763	Housing tract	Due to Method	1955	2452'	as part of a development project, this well was concluded in 2018 to not be abd to current standards as surface plug and freshwater plug do not meet current standards
1	411102588	River	Due to method	1959	1647'	wooden plug, bridge of paper sacks, cement casing not tested; near Santa Clara River
1	411101136	Housing tract	Due to Method	1959	7416'	in housing tract; bridged w/ sacks 16' below; was suppose to be re-abd if a structure were to be built on or near the well but looks like re-abd never happened and they continued to built housing tract over the well
1	411105641	Housing tract	Due to Method	1959	771'	in housing tract; note says that well was abd to standards of 1959 but it no longer meets the standards of 1993 - could be the sack bridge at 100' ; in housing tract
1	411105982	River	Due to Method	1961	17,440'	near the Santa Clara River; bridged w/ sacks 25' below surface
1	411104014	House	Due to Method	1966	7357'	drill collars lost inside; house built on top
1	411102585	Jail	Due to Method	1968	7500'	wooden plug 35' below surface; 1990 letter from DOG suggested what work would need to be done to this well if something were to be built nearby; Ventura County Jail nearby
1	411102586	Jail	Due to Method	1968	7600'	wooden plug 35' below surface; 1990 letter from DOG suggested what work would need to be done to this well if something were to be built nearby; Ventura County Jail nearby
1	411102584	Jail	Due to Method	1968	7634'	ran wooden plug in casing to 35'; 1990 letter from DOG suggested what work would need to be done to this well if something were to be built nearby; Ventura County Jail nearby
1	411102583	Jail	Due to Method	1968	7900'	wooden plug at 30'; 1990 letter from DOG suggested what work would need to be done to this well if something were to be built nearby; Ventura County Jail nearby
1	411100539	Golf course	Due to Method	1971	43'	possible cause of leak in Camarillo springs golf course
1	411100538	Golf course	Due to Method	1971	65'	possible cause of leak in Camarillo springs golf course
1	411102777	Stream	Due to Method	1973	600'	the storage tank, which was located 500 ft from a stream, was filled w/ water w/ slight scum of oil on top; oil was running down the road and into Sespe Creek and small animals and birds were trapped in the oil ; other wells in

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						this area were found to be open at the surface; although there are no abd records, a letter lists out the remedial work that was done
1	411101313	School, Park	Due to Method	1994	7410'	oil found on the ground around the well head, fluid in the cellar, hole in the fence first reported in 1988; surface inspection (4/5/91)- not ok, soil contamination; Chevron agrees to abandon but not responsible for soil clean up; located in a park next to a school
2	411100651		Due to Age	1917	1157'	1985 memo says damage of fresh water might occur since there are no cement plugs above 650' and no casing to surface from 480'; could not find well using a metal detector
2	411101159		Due to Age	1930	1712'	according to a recent re-assesment of the well for property development, this well is not abd to current division standards as of 3/12/18; no details on surface plug and freshwater plug does not meet current reqs
2	411103103		Due to Age	1935	1034'	no records of abd, though many letters exchanged in 1935 urging the abd of the well; in 1937, the well was inspected and they found that the hole appeared to have filled up w/ fluid and the cellar contained oil; no further records of work being done
2	411106249		Due to Age	1937	2800'	originally abd in 1937 and was going to be abd in 1976 but it was canceled; oil seepage has been around the well site for years
2	411105658		Due to Age	1938	2812'	tried to re-p&a in 1990 but was unable to clean out the hole below 30', mud below 30', and plug the hole w/ cement from 900'-800'; DOG recommended that no structure be built over or in proximity of this well, but if so, a vent system should be installed
2	411106109		Due to Age	1941	2863'	reported as a possible hazard in 1991 when an inspection found a heavy sulphur smell in the well and a reservoir w/ mucky water near the well - water flowed of 1,700 ppm at a steady rate ; no further updates
2	411105741		Due to Age	1946	3553'	as part of a development project, this well was concluded in 2018 to not be abd to current standards as surface plug and freshwater plug do not meet current standards
2	411101133		Due to Age	1947	4937'	this property is being developed so DOG is re-assessing the abd status of the wells in the area (2018); abd status of well is not abd to current division standards as of 3/12/18; no details of surface plug and freshwater plug does not meet current standards
2	411104008		Due to Age	1947	6381'	note from 1996 stating that this well was not abd to current standards and it outlined action required for abd but no further documents of suggested abd
2	411106010		Due to Age	1949	1633'	bridged w/ paper sacks; on Aug. 1987, oil and gas was found seeping to the surface of this area that is now an orchard - this area correlated w/ this well but it is only an assumption that it is this well since they have not excavated the area and there are no further documents on this situation
2	411102767		Due to Age	1949	2160'	wooden plug(found floating on the water) was driven to 550'
2	411100342		Due to Method	1954	6672'	Property owner complained about well in disrepair; water leaking; "plug supported a part of the weight of tubing. Samples of semi-set sement were brought up by the tubing when it was pulled"
2	411101265		Due to Method	1957	7300'	according to a 2018 re-assesment of the well, it's not abd to current standards; freshwater plug and oil and gas zone plug doesn't meet current standards
2	411101289		Due to Method	1959	6730'	this area is subject to possible property development - 2020 inspection concluded that this well does not have an adequate freshwater plug
2	411105731		Due to Method	1960	10,080'	as part of a development project, this well was concluded in 2018 to not be abd to current standards as surface plug and freshwater plug do not meet current standards
2	411102461		Due to Method	1967	7350'	this area is subject to possible property development - a 2020 inspection found oily dirt, oily rags, and wood debris in the excavated dirt as well as a hydrocarbon odor; hydrocarbons were present in the soil at this wellsite
2	411102460		Due to Method	1967	7500'	this area is subject to possible property development - a 2020 inspection concluded that this well does not have an adequate freshwater plug
2	411120957		Due to Method	1983	9450'	letter from 2018 states that this well is not abd to current standards as surface plug and freshwater plug does not meet current standards

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Priority	API	Sensitive Location	Poorly Abandoned	Year ABD	Well Depth	Well Record Notes
2	411105117		Due to Method	1985	8125'	missing final letter; it was noted that surface inspection was not approved since the well was still leaking in 1986; it was noted that well was still leaking in january 1986, july 1986, june 1987, and january 1990; no further records of that situation
2	411102785		Due to Method	1986	1467'	the files don't have much info on the oil spill but according to the files on well 411102777, this well was the source of an oil spill; discovered to have a pool of oil on the ground where the casing had been graded over; uncovered evidence of old oil leakage on the road from this well;
2	411101131		Due to Method	1989	10,643'	a 1985 letter mentions that there was a spill from the well but no further details; letter says "due to the nature of the spill of your well.."
2	411120993		Due to Method	2010	2427'	note from 1/2010 said that they could not clean out to below base of fresh water and this well is a problem in the future and there should be no injection operations within1/4 mile of this well - but final letter was issued dated 6/2010
2	411102093		Due to Method	2013	7248'	identified as leaking a small amount of oil from the well head and was ordered to be re-abd in april 2020; letter from Jan 2021 says surface condition and casing pressure are now being monitored on a weekly basis for the next two months
2	411102125		Due to Method	2013	8240'	letter from March 2020 stating that this well was identified as leaking oil; identified as leaking a small amount of oil from the well head and was ordered to be re-abd in april 2020; letter from Jan 2021 says surface condition and casing pressure are now being monitored on a weekly basis for the next two months
2	411120506		Due to Method	2014	3974'	abd in 2014 but a 2017 inspection found that the abd was not done properly so they need to rework the well - unsure if the work was finished since no docs of the work besides the permit
2	411101592		Due to Method		1450'	missing abd records; drilled in 1921; casing was taken out; drilled within 100' of another well that has sulphur water flowing to the top of the hole
2	411100226		Incomplete			according to a DOG letter on file for the wells nearby, this well is a hazard w/ the surface leaking oil and gas; TD unknown; refer to files for well 411106319
2	411101591		Incomplete			missing abd and other records; drilled within 100' of another well; apparently has sulphure water flowing to the top of the hole according to the nearby well's records
3	411101386	Creek	Due to Age	1864	843'	abandoned on account of lost tools; located near San Antonio Creek; still visible
3	411106081	Housing tract	Due to Age	1921	1246'	bridged w/ rock and dirt to 737'; missing final letter of abd ; in housing tract
3	411102277	Housing tract	Due to Age	1921	155'	plugged at bottom w/ rock and cement; abd operations were not witnessed and no reports of such operations; in housing tract
3	411105771	Housing tract	Due to Age	1921	2597'	in housing tract; plugged w/ old wire cable and formation from 150' to surface
3	411106087	House	Due to Age	1921	336'	no final letter of abd; house built on top
3	411102255	Housing tract	Due to Age	1921	500'	missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411105723	Housing tract	Due to Age	1921	538'	in housing tract
3	411105576	Housing tract	Due to Age	1921	860'	missing final abd letter; in housing tract
3	411105635	Housing tract	Due to Age	1922	1000'	missing final letter of abd; in housing tract
3	411105632	Housing tract	Due to Age	1922	545'	missing final letter of abd; in housing tract

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3	411105636	Housing tract	Due to Age	1923	1155'	casing left in hole; used for water well; missing abd final letter; in housing tract
3	411105718	Housing tract	Due to Age	1926	5720'	filled w/ mud; wooden plug at 2977'; in housing tract
3	411105726	Housing tract	Due to Age	1927	2470'	in housing tract
3	411105786	Housing tract	Due to Age	1927	6791'	in housing tract; filled w/ heavy mud and wooden plug at 1800'
3	411105775	Shopping center	Due to Age	1928	1166'	in parking lot of shopping center; filled w/ heavy mud; no casing in well
3	411105790	Housing tract	Due to Age	1928	1314'	filled w/ heavy mud and bridged w/ old ropes; from 5' to surface filled w/ soil; in housing tract
3	411105788	Housing tract	Due to Age	1928	1400'	filled w/ heavy mud; plugged from 20' to surface w/ wooden plug, boulders, gravel, and dirt; in housing tract
3	411105778	Housing tract	Due to Age	1928	1527'	in housing tract; filled w/ heavy mud and missing final letter
3	411105796	Housing tract	Due to Age	1928	1935'	left full of mud; wooden plug; in housing tract
3	411105787	Housing tract	Due to Age	1929	1245'	filled w/ heavy mud; wooden plug at 35' and filled w/ dirt to the top; in housing tract
3	411105789	Housing tract	Due to Age	1929	1313'	filled w/ heavy mud; wooden plug 20' from surface; filled to surface w/ broken cement, rock, and dirt; in housing tract
3	411105618	Housing tract	Due to Age	1929	1724'	filled w/ rock and dirt; missing final letter of abd; in housing tract
3	411102010	Beach	Due to Age	1929	3200'	filled w/ heavy mud; photos from 2019 and 2020 showing an exposed well cellar on the shore that is being filled w ocean waves
3	411105611	Housing tract	Due to Age	1930	3172'	missing final abd letter; in housing tract
3	411101190	House	Due to Age	1932	2215'	with rock, dirt, brick; house built on top
3	411101108	House	Due to Age	1932	2950'	junk drill pipe left in the hole; suggested that ABD should be done again but no proper docs on re-abd; house on top;
3	411104267	Housing tract	Due to Age	1932	650'	in housing tract
3	411105452	Housing tract	Due to Age	1932	785'	in housing tract; bridge of wood, rope, and piece of drill pipe at 413'
3	411105630	School	Due to Age	1934	565'	filled to the surface w/ shale mud; no casing in hole; under a school
3	411105620	School	Due to Age	1935	1950'	under a school
3	411105619	Housing tract	Due to Age	1935	898'	in housing tract
3	411103001	Housing tract	Due to Age	1936	534'	filled w/ soil from 150' to surface; in housing tract

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
3	411100746	Beach	Due to Age	1937	7625'	well was under inspection in 1970 after a water leak was reported - unsure if that issue was ever resolved; in 2004, recent rains, tidal action, wave action, and river erosion has exposed the footings of the standard derrick and well cellar - no further records of that issue
3	411105637	Housing tract	Due to Age	1938	1000'	filled w/ rock and dirt; in housing tract
3	411105746	Housing tract	Due to Age	1938	3086'	surface was not plugged in case the landowner wanted to use it as a water well; filled w/ mud; in housing tract
3	411105610	Housing tract	Due to Age	1939	6302'	in housing tract; wooden plug driven to 965'
3	411105669	Housing tract	Due to Age	1941	1268'	filled w/ heavy mud to within 4' of surface; in housing tract
3	411121714	Housing tract	Due to Age	1942	~65'	filled w/ surface dirt; in housing tract
3	411121715	Housing tract	Due to Age	1942	~65'	filled w/ surface dirt; in housing tract
3	411121716	Housing tract	Due to Age	1942	~65'	filled w/ surface dirt; in housing tract
3	411121718	Housing tract	Due to Age	1942	~65'	filled w/ surface dirt; in housing tract
3	411121719	Housing tract	Due to Age	1942	~65'	filled w/ surface dirt; in housing tract
3	411100749	Housing tract	Due to Age	1942	3600'	in housing tract
3	411121720	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract
3	411121722	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract
3	411121723	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract
3	411121726	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract
3	411121727	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area
3	411121729	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411121732	Housing tract	Due to Age	1942	40'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area
3	411121721	Housing tract	Due to Age	1942	60'	filled w/ surface dirt; in housing tract
3	411121725	Housing tract	Due to Age	1942	60'	filled w/ surface dirt; in housing tract
3	411121728	Housing tract	Due to Age	1942	60'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
3	411121730	Housing tract	Due to Age	1942	60'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area
3	411121731	Housing tract	Due to Age	1942	60'	filled w/ surface dirt; in housing tract; a 1971 inspection found no evidence of this well in the area
3	411100519	Housing tract	Due to Age	1943	123'	filled w/ dirt; in housing tract
3	411105655	Housing tract	Due to Age	1944	4000'	in housing tract
3	411105800	Housing tract	Due to Age	1946	11,027'	in housing tract
3	411102713	Creek	Due to Age	1946	1100'	near Sespe Creek
3	411105713	Housing tract	Due to Age	1947	1073'	left full of heavy mud or surface material; no final letter of abd; in housing tract
3	411105562	Housing tract	Due to Age	1947	1300'	bridged hole w/ rock at 138'; in housing tract
3	411105799	Housing tract	Due to Age	1949	15,581'	in housing tract
3	411105793	Housing tract	Due to Age	1949	9806'	in housing tract
3	411103082	Housing tract	Due to Age	1950	1219'	in housing tract
3	411103081	Housing tract	Due to Age	1950	3048'	in housing tract
3	411105664	Housing tract	Due to Age	1951	1178'	in housing tract
3	411105609	Housing tract	Due to Age	1951	3106'	in housing tract
3	411105645	Housing tract	Due to Age	1952	3789'	in housing tract
3	411101075	Housing tract	Due to Age	1952	4423'	located in housing tract
3	411105633	Housing tract	Due to Age	1952	870'	produced more water than oil so was abd to use as water well; in housing tract
3	411105760	Housing tract	Due to Age	1954	1800'	in housing tract; filled w/ heavy mud
3	411106030	River	Due to Age	1954	2279'	near Santa Clara River
3	411105553	Housing tract	Due to Age	1954	4872'	in housing tract
3	411105727	Housing tract	Due to Method	1954	6471'	Plug at 2010' was not tested; landowner to convert to water well
3	411105612	Housing tract	Due to method	1955	10056'	in housing tract

Appendix 1 – Plugged & Abandoned Wells Prioritized 1-3 for Cleanup and Historic Spills in Ventura County						
Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
3	411100553	Housing tract	Due to Method	1955	121'	filled w/ dirt to 10' from top
3	411105766	Housing tract	Due to Method	1955	1400'	bridged w/ paper sacks 10' below surface; in housing tract
3	411105757	Housing tract	Due to Method	1955	8182'	bridge of paper sacks formed 10' below casing head; in housing tract
3	411105708	Hospital	Due to Method	1955	9900'	bridge of paper sacks at 25' below ground level
3	411105725	Housing tract	Due to Method	1957	6993'	in housing tract; cement plug at 1493' but then abandonment responsibility transferred to landowner for water well
3	411105910	Housing tract	Due to Method	1957	9924'	in housing tract; bridge of paper sacks formed 10' below cellar
3	411105614	Housing tract; school	Incomplete	1958	10167'	Incomplete abandonment recrods
3	411102671	Creek	Due to Method	1958	1220'	filled w/ rocks and surface material 866' - 1085' and a 286' - to create bridge; near a creek
3	411105613	Housing tract	Due to method	1958	14,351'	wood plug 25' below cellar floor; in housing tract
3	411101149	Commercial	Due to Method	1958	7300'	sack bridge hung 10' below cellar floor
3	411100657	Housing tract	Due to method	1959	14,026'	in housing tract; converted to water well, landowner "agress to assume responsibility for final abandonment when necessary"
3	411105640	Housing tract	Due to Method	1959	600'	bridged w/ paper sacks and dirt at 150' - in housing tract
3	411105542	School	Due to method	1959	8700'	next to a high school; bridged with paper sacks 10' below the cellar floor
3	411103003	Housing tract		1959	888'	abd as is for the landowner to turn as a water well; in housing tract
3	411105751	Housing tract	Due to Method	1960	8537'	bridged w/ a wooden plug at 14' below surface; in housing tract
3	411101287	Housing tract	Due to method	1961	6900'	wooden plug at 25' below cellar; in housing tract
3	411101299	Housing tract; School	Due to method	1961	8889'	wooden plug casing at 24' from surface and filled with cement to the surface; cement not tested and top plugs not located; in housing tract;
3	411105764		Due to Method	1962	10,979'	as part of a development project, this well was concluded in 2018 to not be abd to current standards as surface plug and freshwater plug do not meet current standards
3	411100261	Housing Tract	Due to Method	1967	11,221'	wooden plug at 43'
3	411101312	Housing tract	Due to Method	1970	9150'	wooden plug; in a housing tract; note says no irregularities
3	411101311	Housing tract	Due to Method	1970	9520'	wooden plug; in a housing tract
3	411120666	Lemon Trees	Incomplete	1976	2650'	missing final letter
3	411102560	River	Due to Method	1978	11,509'	docs to re-abd in 1993 but was canceled; near Santa Clara River

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
3	411106286	Housing tract	Incomplete	1986	unknown	missing final letter; in housing tract
3	411105667	Housing tract	Incomplete	1997	3247'	missing final letter of abd; in housing tract
3	411102857	Creek	Incomplete	2007	2018'	near a creek; missing final letter of abd
3	411104338	Housing tract	Incomplete	2007	6013'	missing final letter
3	411121487	Ocean	Incomplete	2018	12632'	abandonded by State Lands Commission; still in abd process??, intention to abd files in 2018, no final documentation;
3	411101888	Ocean	Incomplete	2018	3854'	still in abandonment process?; intention of abandonment from 2018 but no final abandonment documentation; drilled in 1945
3	411101887	Ocean	Incomplete	2018	4205'	abandonded by State Lands Commission; still in abd process??, intention to abd files in 2018, no final documentation; a 1976 doc notes that the bridge plug at 3710' does not fulfill requirements; drilled 1945
3	411101897	Ocean	Incomplete	2018	4694'	abandonded by State Lands Commission; still in abd process??, intention to abd files in 2018, no final documentation; 1984 doc explains that operations were done without required approval prior
3	411102254	Housing tract	Due to Age		105'	drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; no casing; in housing tract
3	411100562	Housing tract	Due to Age		111'	drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411100560	Housing tract	Due to Age		138'	drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411102741	Creek	Due to Age		1519'	missing abd and other records; drilled before 1899; near a creek
3	411100561	Housing tract	Due to Age		177'	drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411121657	Housing tract	Due to Method		40'	drilled in 1946; missing abd records; landowner said the well was deserted and filled w/ surface material; in housing tract
3	411105622	Housing tract	Due to Age		440'	missing abd records; in housing tract; drilled in 1929
3	411105597	Housing tract	Incomplete		72'	missing abd records; in housing tract
3	411100563	Housing tract	Due to Age			drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411100565	Housing tract	Due to Age			drilled in 1921; missing abd records; a 1971 inspection found no evidence of this well in the area; in housing tract
3	411120637	Housing tract	Incomplete			in housing tract
3	411106381	Housing tract	Incomplete			in housing tract
3	411106383	Housing tract	Incomplete			in housing tract
3	411106388	Housing tract	Incomplete			in housing tract

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
3	411106389	Housing tract	Incomplete			in housing tract
3	411106390	Housing tract	Incomplete			in housing tract
3	411106391	Housing tract	Incomplete			in housing tract
3	411106396	Housing tract	Incomplete			in housing tract
3	411106397	Housing tract	Incomplete			in housing tract
3	411106400	Housing tract	Incomplete			in housing tract
3	411106402	Housing tract	Incomplete			in housing tract
3	411109393	Housing tract	Incomplete			in housing tract
3	411109397	Housing tract	Incomplete			in housing tract
3	411121782	Housing tract	Incomplete			in housing tract
3	411100015	Housing tract	Incomplete			near two other wells and three wells are under the same housing unit
3	411100050	Housing tract	Incomplete			in housing tract
3	411106333	Creek	Incomplete			on documents from the other Nathan wells it says that this well cannot be located; located very close to Sespe creek
3	411105770	Housing tract	Incomplete			in housing tract; missing abd records
3	411106401	Housing tract	Incomplete			missing abd and other records; in housing tract
3	411106288	Creek	Due to Age			near a creek; drilled in 1904' missing abd and other records
3	411100022	Agriculture	Incomplete			no abandonment records; only electric & radioactive logs
Historic Spill	411106025		Due to Age	1942	1306'	salt water was seen flowing over the top prior to abd
Historic Spill	411103424			1971	3380'	pinhole gas leak developed in the annulus between the 10" and 12 1/2" casings but was fixed 1970
Historic Spill	411106239			1975	1500'	was an unidentified abandoned well that was leaking to surface
Historic Spill	411104436			1981	7155'	multiple casing leaks led to this well being abd
Historic Spill	411105511			1986	2941'	originally abd in 1980, but it leaked oil, gas, water, and rotary mud from well head in 1986; re-abd in 1986 but no final letter

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
Historic Spill	411102482		Due to Method	1987	616'	drilled in 1917, left idle since 1974 then was discovered to be flowing oil and water to the surface so had to abd
Historic Spill	411104060			1989	2396'	well was abd bc of surface leaks and it was not economical to repair
Historic Spill	411101285	Housing tract		1989	6800'	in housing tract; prior to the 1989 abd, Chevron tried to abd in 1987 but canceled it, but they left the well in such a state that hydrocarbons accumulated in the cellar, which was not fenced/protected and it was open to the atmosphere
Historic Spill	411103390			1990	3124'	abd bc of surface leak around the casing
Historic Spill	411103425			1990	3549'	in 1946, the well was being worked on when oil and gas started flowing through the kelly bushing and slipe and caught on fire. two workers were burned and died
Historic Spill	411101251			1990	6508'	water broke in and caused severe sand problems in 1961 so the well was re-drilled
Historic Spill	411106314		Due to Method	1991	~700'?	DOG letter from May 1991 concluding this well as hazardous leaking oil and gas at the surface so they had to abd; TD is unknown; no other files besides the letter and abd reports
Historic Spill	411106319		Due to Method	1991	~700'?	DOG letter from May 1991 concluding this well as hazardous leaking oil and gas at the surface so they had to abd; TD is unknown; no other files besides the letter and abd reports
Historic Spill	411106355		Due to Method	1991	~700'?	DOG letter from May 1991 concluding this well as hazardous leaking oil and gas at the surface so they had to abd; TD is unknown; no other files besides the letter and abd reports
Historic Spill	411104634			1991	10,435'	re-abd due to gas leaking to the surface through the surface plug
Historic Spill	411102335			1995	2066'	tank was damaged by rockslide and had excess fluid on ground
Historic Spill	411104465			2005	4742'	abd in 1948, then reworked and abd in 1972; letter from 1984 says that the well was never abd properly and may be leaking gas to the surface but Shell's reply was that the gas was too minimal to be accurately measured and the well is not recorded as a producer; then a note from 2000 that wishes to re-enter the well to stop the gas migration up through the plug - finally abd properly in 2005
Historic Spill	411104029		Due to Method	2006	2441'	in 1987 inspection - discharge valve on one of the tanks was seeping oil and water
Historic Spill	411104021			2006	2505'	1987 inspection found crude oil in the depression at the site
Historic Spill	411104273			2007	6068'	report on operations from 2005 says that plugging operations were not approved due to gas leak in the well; no further information on that gas leak but well was finally abd in 2007
Historic Spill	411101116		Due to Method	2010	1223'	in 1986, workers discovered oil seeping through a road and determined this well to be the source - no further documents of work on this well until 2008 when abd began
Historic Spill	411100941		Due to Method	2012	1439'	oil leak of 5-9 barrels but the source was undetermined - contaminated oil, well pad, and cellar concrete and junk piping were removed
Historic Spill	411104435			2017	11,415'	re-abd bc of minor leak up the annulus
Historic Spill	411105032		Due to Method	2017	13,497'	oil leak from a pipeline on july 13, 2016 and was cleaned up on july 18
Historic Spill	411100863	Housing tract		2017	4381'	well was left idle for two years until in 1983, an inspection found oil leaking from the casing onto the ground and downhill into a ravine and towards a housing development; abd in 88', 92', 05', and 17'; in housing tract

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Priority	**API**	**Sensitive Location**	**Poorly Abandoned**	**Year ABD**	**Well Depth**	**Well Record Notes**
Historic Spill	411104279		Due to Method	2017	6101'	on 11/2/16, a gas leak was discovered and it was caused by a damaged casing valve while the well was being prepped for abd
Historic Spill	411102533			2018	8143'	Aug 17'- incident occurred during the pressure test for idle well testing where the casing parted and the wellhead flew into the air. proper cleanup has been done including removal of contaminated soil and free liquid
Historic Spill	411104177			2019	1550'	drilled in 1900; identified as "offset well" in 2019; in abandonment process had issue with small surface leak after bring cement to surface
Historic Spill	411100513	Stream		2019	2685'	in March 2018, approx. 20 barrels of oil overflowed the Hammond Canyon tanks that were connected to the Hammond wells and some part of the oil flowed into a nearby stream
Historic Spill	411100511	Stream		2019	5770'	in March 2018, approx. 20 barrels of oil overflowed the Hammond Canyon tanks that were connected to the Hammond wells and some part of the oil flowed into a nearby stream
Historic Spill	411105396			2021	10280'	1984 document refers to casing leak; was "plugback and suspended" in 2006 but did not pass pressure test; currently in abandonment process(?); no final abandonment documents; DOC approved forgoing permit requirements for "squeezing cement" at the deep depths of the well
Historic Spill	411104880			2021	10935'	drilled in 1938; DOC make requests that "sufficient" cement be used on secondary water string, there were not carried out (1938); 1966 suspected hole in casing; still in abandonment process(?); no abandonment final documents; Difficulties faced in cleaning past 10142' and suspect they encountered liner damage; Aera request to plug at 9,192' was not approved by DOC; discovered bubbling in cellar due to flow path created during failed pressure tests; back and forth emails Aera-DOC asking to "reconsider" requirements;