Orphan Wells in California:

An Initial Assessment of the State's Potential Liabilities to Plug and Decommission Orphan Oil and Gas Wells

An Emerging Topic Report prepared by the California Council on Science and Technology

CCST
CALIFORNIA COUNCIL ON SCIENCE & TECHNOLOGY

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An Initial Assessment of the State's Potential Liabilities to Plug and Decommission Orphan Oil and Gas Wells

An Independent Review of Scientific & Technical Information

Judson Boomhower, PhD
University of California, San Diego
Lead Author

Mikel Shybut, PhD
California Council on Science and Technology
Author and Project Manager

M. Daniel DeCillis, PhD
California Council on Science and Technology
Author

Terence Thorn
JKM Consulting
Steering Committee Chair

Sarah E. Brady, PhD
California Council on Science and Technology
Project Director

Amber J. Mace, PhD
California Council on Science and Technology
Interim Executive Director

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About CCST

The California Council on Science and Technology is a nonpartisan, nonprofit organization established via the California State Legislature in 1988. CCST responds to the Governor, the Legislature, and other State entities who request independent assessment of public policy issues affecting the State of California relating to science and technology. CCST engages leading experts in science and technology to advise state policymakers — ensuring that California policy is strengthened and informed by scientific knowledge, research, and innovation.

Note

For questions or comments on this publication contact:
California Council on Science and Technology
1130 K Street, Suite 280 Sacramento, CA 95814
916-492-0996
ccst@ccst.us
www.ccst.us

Layout by A Graphic Advantage!
3901 Carter Street #2, Riverside, CA 92501
www.agraphicadvantage.com

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Acronyms and Abbreviations

AB	Assembly Bill
API	American Petroleum Institute (as in API number)
BOE	Barrel of Oil Equivalent
BLM	Bureau of Land Management
CCP	California Code of Civil Procedure
CCR	California Code of Regulations
CFR	Code of Federal Regulations
DOC	California Department of Conservation
Division	Division of Oil, Gas, and Geothermal Resources (the Division)
GAO	U.S. Government Accountability Office
HIDWAF	Hazardous and Idle-Deserted Well Abatement Fund
IQR	Interquartile Range
LMR	Liability Management Regime
PRC	California Public Resources Code
SB	Senate Bill
SLC	California State Lands Commission (the Commission)
Supervisor	State Oil and Gas Supervisor at the Division

Summary

In 2017, California was the fourth largest producer of crude oil and the fifteenth largest producer of natural gas among U.S. states (US EIA). There are about 107,000 active and idle oil and gas wells in California. At some point all of these wells will end their productive life and the operator/owner of the well will be required to carefully plug the well with cement and decommission the production facilities, restoring the well site to its prior condition. There is a large population of nonproductive wells in the state, known as idle wells, which have not produced oil and gas for at least two years and have not been plugged and decommissioned. Idle wells can become orphan wells if they are deserted by insolvent operators. When this happens, there is the risk of shifting responsibilities and costs for decommissioning the wells to the State.

There are policies in place to protect the State from the potential liabilities of orphan and idle wells. Operators are required to file indemnity bonds when drilling, reworking, or acquiring a well, to support the cost of plugging a well should it be deserted. However, the available bond funds are often not enough to fully cover the costs of plugging and decommissioning a well. In two recent insolvencies involving offshore facilities, Rincon Island and Platform Holly, the bonds recoverable by the State totaled about $32 million—well under the more than $100 million estimated cost to plug and decommission the wells at both facilities.

Issues with orphan wells are not limited to offshore wells. The vast majority of orphan wells in the state are located onshore. These wells represent potentially large liabilities for the State. In some cases, especially for older orphan wells, there may be no bond available. In an effort to prevent orphan wells, the operators of idle wells are required to pay fees or develop management plans to eliminate long-term idle wells. The Division of Oil, Gas, and Geothermal Resources (the Division) is in the process of updating these regulations and implementing new well testing requirements from recent legislation.

Concerned about the potential financial risks involved with idle and orphan wells and aware of similar problems in other parts of North America, the Division requested the California Council on Science and Technology (CCST) produce a study assessing the State's potential orphan well liabilities. Using existing data from the Division, we have conducted a rough estimate of potential future costs to the State for plugging and decommissioning orphan wells. We have also summarized recent studies that compare the policies and practices of California to other states and regions.

The preliminary analysis performed here finds that 5,540 wells in California may already have no viable operator or be at high risk of becoming orphaned in the near future. The likely plugging and abandonment costs for these wells, based on the State's historical experience with orphan wells, exceed the available bond funds by a factor of 10 or more. The State's potential net liability for these wells appears to be about $500 million. This

estimate ignores environmental or health damages that could be caused by orphan wells, which is a poorly understood category of potential impacts that is outside of the scope of this report and deserves greater study.

An additional 69,425 economically marginal and idle wells are identified here that could become orphan wells in the future as their production declines and/or as they are acquired by financially weaker operators. Increasing the financial security for these wells while they are still profitable may avoid enforcement challenges in the future. Idle Well Fee and Management Plan requirements may also reduce the stock of idle wells, but operators have less incentive to comply with regulations after wells cease production.

The total costs of plugging and abandoning all of the state's 106,687 active and idle oil and gas wells are found to be about $9.1 billion. This gives an unlikely worst-case scenario for the state's total costs. The share of this cost that is ultimately borne by the State (as opposed to operators) will depend on policy choices, market dynamics, and other factors. In comparison, the bond amounts currently held by the state for these wells cover only about $110 million. This study recommends several specific areas where more in-depth research will better inform future policy approaches.

Findings, Conclusions, and Recommendations

Chapter 1: Background

Finding 1-1: California requires well operators to obtain an individual or blanket indemnity bond prior to drilling, reworking, or acquiring a well or wells, not to be released until the well is plugged and decommissioned. 1

Finding 1-2: The amount of the required indemnity bond depends on well depth for individual bonds, the number of wells in the state to be covered for blanket bonds, and whether the well is located onshore or offshore. Bond amounts range from $25,000 for a single well to $3 million for a blanket bond covering multiple wells. The amount on file may also depend on when the well was last drilled, reworked, or acquired, and the bonding requirements at that time. 2

Finding 1-3: The amount of an indemnity bond may not be adequate to cover the actual plugging and decommissioning costs. For example, bonds on file from the leases at Rincon Island and Platform Holly, $10 million and $22 million, respectively, were a fraction of the estimated total costs of over $100 million for both leases. 4

Finding 1-4: The vast majority (nearly 98%) of wells in the state are located onshore. The vast majority of idle wells in the state are also onshore. 6

Conclusion 1-1: Recent cases in California highlight the potentially expensive and complicated nature of plugging and decommissioning offshore wells and the difficulty of determining liabilities following bankruptcy. As most of California's wells are located onshore, it will be important to assess the potential liabilities for onshore wells in situations where idle wells may become orphan wells. 6

Chapter 2: Relevant Laws and Regulations Governing Oil and Gas Wells in California

Finding 2-1: Recent legislation revised California's indemnity bond requirements, requiring bonds for operators acquiring a well, increasing individual and blanket bond amounts, and requiring that a well be properly plugged and decommissioned before a bond is released. 8

Recommendations:

Using the data, results, and recommendations of this study as a framework, the Division should perform a more detailed analysis of orphan well liabilities guided by the following recommendations:

CCST Introduction

The California Council on Science and Technology (CCST) is a nonpartisan, nonprofit organization established via the Legislature in 1988 that is called upon by the State to conduct independent, scientifically rigorous studies to inform policy decisions. CCST studies are valued for their scientific and technical analysis, which undergoes a full peer review process to ensure that the information presented is accurate and technically sound.

This study was produced at the request of the Division of Oil, Gas, and Geothermal Resources (the Division) under the California Department of Conservation. It was researched and written by principal researchers and select CCST staff within a study team overseen by a Steering Committee Chair. The study team provides an appropriate range of expertise, a balance of perspectives, and no conflicts of interest.[1] This study was subject to a full and thorough peer review and the authors responded to all comments from reviewers.

CCST strives to produce reports through a transparent process to ensure that the final product is responsive to the questions of the sponsor, while maintaining full scientific independence. Transparency is achieved by engaging the sponsor in dialogue about the nature of the information needed and informing the sponsoring agency of study progress.

Language used in this study:
In oil and gas well terminology, there are many ways to say that a well has been properly plugged and/or that the remaining facilities have been removed and the site returned to its original condition: 'properly plug and abandon,' 'plugging and reclamation,' etc. In this study, we primarily use the term 'plug and decommission' to refer to the actual cementing or plugging of the well and restoration of the site.

1. See Appendix F for more information on the CCST study team selection and study process.

Chapter 1

Background

Among states in 2017, California was the fourth largest producer of crude oil (US EIA) and the fifteenth largest producer of natural gas (US EIA). The state's oil and gas fields are considered mature, and there is a growing population of nonproductive wells in the state.

The life cycle of oil and gas wells depends on a number of factors, the most important of which are production rates and energy market prices (Figure 1). A well can operate profitably for several years or decades depending on the rate of production and operating expenses. At low prices, or as production slows, operators may be inclined to shut down, idle, or hand off non-economic wells and leases. Once a well's productive life comes to an end, it must be carefully plugged with cement and its attendant production facilities decommissioned[1] to prevent any potential hazards. In California, this process is the operator's responsibility.

Under current rules (which have recently been revised), prior to drilling, reworking, or acquiring a well, an operator must file a security with the State in the form of an indemnity bond or other deposit. As of January 1, 2018, this bond cannot be released until the well is properly plugged and decommissioned. Indemnity bonds are an agreement between a principal (the operator), an obligee (the State), and a surety bond company (the surety) that protects the State in cases where operators do not fulfill their obligations to decommission a well—providing payment of the bond amount to the State. These bonds range in amount depending on the depth of the well and the number of wells to be covered. Current requirements for onshore wells range from $25,000 for a single well to $3 million for a blanket bond to cover all of an operator's wells. For offshore leases, there is a blanket $1 million bond required for drilling or modifying one or more wells. The historic and existing bond requirements as well as the availability and adequacy of bonds on file to cover the plugging and decommissioning of potential orphan wells are discussed in Chapters 2 and 3.

Finding 1-1: California requires well operators to obtain an individual or blanket indemnity bond prior to drilling, reworking, or acquiring a well or wells, not to be released until the well is plugged and decommissioned.

1. 14 CCR § 1760 "Decommission" means to safely dismantle and remove a production facility and to restore the site where it was located.

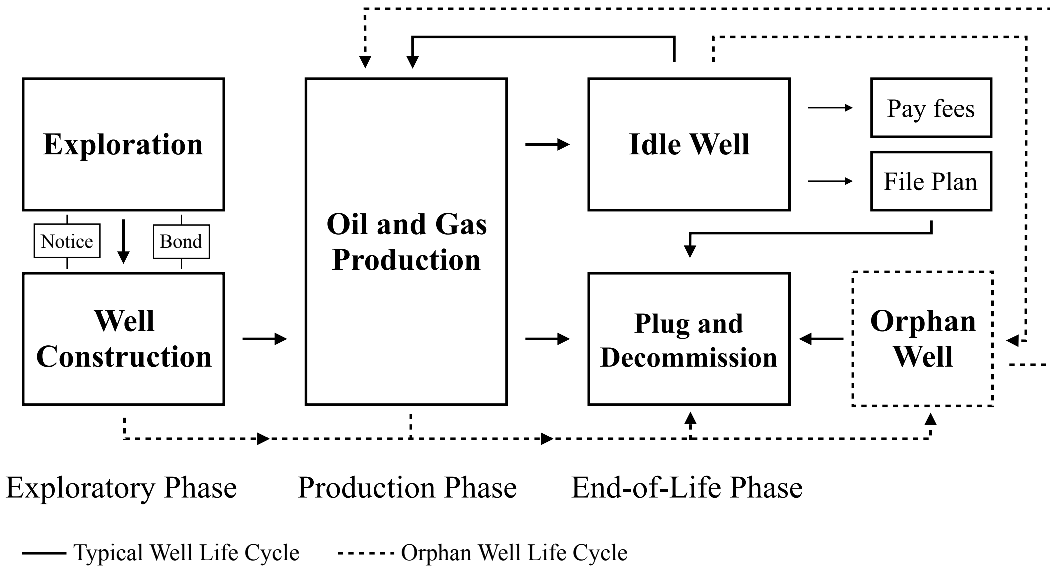

Figure 1. Typical well life cycle in California compared with the orphan well cycle. The initial exploratory phase encompasses the discovery and evaluation of reserves, drilling and completion of the exploratory well, and the determination that the well (field) can economically produce oil or gas. Prior to drilling, a notice of drilling along with an indemnity bond must be filed and approved. Production can last several years or decades depending on the size of the field and operating expenses. When the rate of production and sales fails to cover the expenses associated with maintenance and production, it has reached its economic limit. At that limit, the well may be considered a liability by the owner and may be plugged and abandoned, the production facilities decommissioned, and the indemnity bond recovered. Production can also be idled. A well is classified as idle when there is zero production, or other defined uses, for at least 24 consecutive months. Operators may eventually return idle wells to production, but while idle they may need to either pay annual idle well fees or file an Idle Well Management Plan. Finally, if a well is orphaned prior to plugging, the responsibilities of plugging and decommissioning the well may ultimately fall upon the State.

Finding 1-2: The amount of the required indemnity bond depends on well depth for individual bonds, the number of wells in the state to be covered for blanket bonds, and whether the well is located onshore or offshore. Bond amounts range from $25,000 for a single well to $3 million for a blanket bond covering multiple wells. The amount on file may also depend on when the well was last drilled, reworked, or acquired, and the bonding requirements at that time.

Of the approximately 229,000 oil and gas wells in California, about 122,000 have already been plugged. The remaining 107,000 of them are classified as either active or idle wells. California regulators consider a well to be an idle well if it has not produced oil or gas for

24 consecutive months.[2] Many of California's idle wells are long-term idle wells—wells that have been idle wells for eight or more years.[3] These idle wells are potentially at risk of becoming orphan wells. If not properly maintained or plugged, idle and orphan wells can present a potential environmental hazard. In some cases, these wells may provide a source for fluid and gas migration to unwanted zones. For example, they may leak oil, injected fluids, or formation water into nearby underground drinking water or surface water reservoirs, or release methane or other gases into groundwater or the atmosphere.

From idle to orphan

Wells are not always plugged and decommissioned immediately after production ceases. Operators often maintain wells in a nonproductive, idle state—either to preserve the option of resuming production in the future, or simply to defer the expense of permanently plugging the well.

It costs much less in the short term for operators to maintain a well in an idle state than to properly plug and decommission a well. In California, the required fees to maintain an idle well range from $150 per year to $1,500 per year. This approach also maintains the potential to return the well to production if energy prices increase. Although this "option value" from the ability to resume production can in principle be quite important, research in Alberta, Canada, has shown the decision to leave a well idle is more often driven by a desire to defer decommissioning costs on wells with little likelihood of resuming production (Muehlenbachs, 2015). Ultimately, some operators may declare bankruptcy in order to relinquish their leases and forfeit any requirement to plug and decommission the well, potentially leaving the costs to the governmental regulator.

Wells deserted by insolvent operators become orphan wells. Since orphan wells have no financially viable operator, the State may become responsible for plugging and decommissioning costs. At this point, the State may use the available indemnity bond funds on file, if any, to contribute toward the cost of plugging and decommissioning the well.

Orphan wells are a concern in every state and region that produces oil and gas. At the federal level, a recent study by the U.S. Government Accountability Office (GAO) made several recommendations to the U.S. Department of Interior in order to better protect against billions of dollars of potential decommissioning liabilities for offshore wells in the Gulf of Mexico (GAO, 2016). In Alberta, Canada, potential liabilities were estimated at between $129 million and $257 million for known orphan wells, with the total costs of well liabilities (when considering potential future insolvencies) estimated at up to $8.6 billion (Dachis et al., 2017).

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2. PRC §3008(d) Wells that for 24 consecutive months have not produced oil or gas, or have not produced water used to stimulate production, for enhanced oil recovery, reservoir pressure management, or injection.

3. PRC §3008(e).

Recent offshore cases in California: Rincon Island and Platform Holly

In California, there have been several prominent cases where the State has had to take responsibility for an oil or gas field. Two offshore facilities in southern California and their associated wells recently became the responsibility of the State: Rincon Island in Ventura County and Platform Holly in Santa Barbara County. Offshore wells are much more expensive to plug and decommission than their onshore counterparts—often amounting to millions of dollars rather than thousands—and have a high priority to plug due to their environmental risk. For these reasons, operators of offshore wells are required to file higher amounts of security than what is required for onshore wells, either as part of their lease with the State or under Division regulations. This security, typically in the form of a surety bond, is intended to protect the State against losses in the event that the operator cannot afford the cost of plugging and decommissioning their wells. However, at Rincon Island and Platform Holly, the security amounts available were not enough for either facility. The State Lands Commission (the Commission) is responsible for managing leases on submerged lands in the state, including the three miles off the Pacific coast. The Commission requested $108.5 million over three years from the state's General Fund to plug and decommission the wells (California State Lands Commission, 2018a), in addition to millions already appropriated to maintain and monitor the wells.

Finding 1-3: The amount of an indemnity bond may not be adequate to cover the actual plugging and decommissioning costs. For example, bonds on file from the leases at Rincon Island and Platform Holly, $10 million and $22 million, respectively, were a fraction of the estimated costs of over $100 million for both leases.

In the case of Rincon Island, operated by Rincon Island Limited Partnership, the lease had not produced oil or gas since 2008. According to a staff report, Commission staff were prepared to recommend termination of the lease in August 2016 over regulatory violations (potentially risking environmental contamination) and other lease requirements. However, Rincon Island Limited Partnership filed for chapter 11 bankruptcy before the lease was terminated (Fabel & Blackmon 2018). After bankruptcy and eventual relinquishment of the leases, the Commission—with no responsible operator available to take over—entered into an emergency contract with a company to oversee the wells. The Commission also obtained $8 million in a settlement agreement with prior lessee ARCO and worked to secure a combined $10 million surety bond that was held by Rincon Island Limited Partnership.[4] The cost to plug the 49 wells and decommission the facilities at Rincon Island was estimated to be around $50 million over three years (California State Lands Commission 2018a).

At Platform Holly, which had been non-operational since the Refugio Oil Spill in May 2015, the operator Venoco relinquished its leases of the South Ellwood Field in April 2017 and filed

4. According to a February 2018 SLC staff report (Fabel & Blackmon), the Division requested their combined $350,000 bond be released to the Commission, which holds a $9.65 million bond.

a petition for relief under chapter 11 bankruptcy, returning the lease and the platform's 32 wells to the Commission. The Division subsequently ordered that the Venoco wells be plugged and abandoned. When Venoco was unable to do so, the Commission called on and received Venoco's $22 million bond. This bond amount was intended to be larger. In August 2013, an amendment to the lease included provisions for increasing the bond amount incrementally by $4 million per year to eventually reach $30 million in September 2018. This amount was intended to be adjusted in 2025 and every 10 years to accurately reflect the full cost of Venoco's liabilities (California State Lands Commission, 2013).

In 1997, Venoco became the third operator assigned to the lease, following approximately 28 years by ARCO and 4 years by Mobil Oil Company. Under California law, the Division can pursue previous operators as far back as January 1, 1996, for plugging and decommissioning responsibilities. After calling on Venoco's bond, the Commission sought an agreement with the prior lessee, now ExxonMobil, to plug and abandon the wells. In August 2017, the Commission and ExxonMobil filed a letter of intent to discuss the plugging and abandonment of the Venoco wells and collaborated to assess needed repairs that would ease the plugging process. Meanwhile, the Commission hired a contractor to take over daily operations of Platform Holly. Anticipating a potentially lengthy process to reach a final agreement on the extent of liability and funding amount with ExxonMobil—and recognizing the urgency of the situation—the Commission requested $58.04 million from the General Fund to manage the platform and plug and abandon the wells (California State Lands Commission 2018a). In June 2018, the Commission and ExxonMobil entered into a Phase 1 agreement for plugging and abandoning the 32 wells on site, with provisions addressing contested wells modified by Venoco (California State Lands Commission and Exxon Mobil 2018).

In response to these recent offshore bankruptcies, the Governor signed legislation in September 2018 to specifically address any inadequate financial security of offshore oil and gas wells in California (SB 1147, Hertzberg).

The decommissioning of onshore wells

Though these recent cases highlight the more expensive and complicated nature of the offshore plugging and decommissioning process, most wells in California are located onshore. In fact, offshore wells account for just over 2% of all wells in California and, as of January 2018, there were only 19 offshore leases remaining in the state (California State Lands Commission, 2018b). No new offshore lease has been approved by the Commission since 1968.

Like their offshore counterparts in California, onshore wells can also be hazardous and expensive to decommission, especially in dense urban areas. In 2004, an orphan well leaked in a neighborhood in the city of Huntington Beach for several hours. An emergency rig was called in to plug the well (Division of Oil, Gas, and Geothermal Resources, 2011). In 2016, two buried orphan wells were discovered on Firmin Street in the residential Echo

Park neighborhood of downtown Los Angeles after reports of an odor coming from one of the wells. Drilled before 1903, these wells were deserted by their operators. The Division utilized industry funds from their orphan wells program to properly plug the wells. It cost the Division more than $1 million to plug the wells, according to its own estimates. The expense of such onshore projects, along with the sheer number of onshore wells and their location throughout the state, makes them a major point of concern for the State in terms of potential liabilities.

Finding 1-4: The vast majority (nearly 98%) of wells in the state are located onshore. The vast majority of idle wells in the state are also onshore.

Conclusion 1-1: Recent cases in California highlight the potentially expensive and complicated nature of plugging and decommissioning offshore wells and the difficulty of determining liabilities following bankruptcy. As most of California's wells are located onshore, it will be important to assess the potential liabilities for onshore wells in situations where idle wells may become orphan wells.

Considering these recent experiences and concerned about the potential cost and liabilities associated with plugging and decommissioning both existing orphan wells and wells that may become orphaned—which may include some of the thousands of idle and long-term idle wells—the Division asked CCST to assess these potential costs. CCST was also asked to look at the policies of other states and regions regarding orphan well management and cost recovery for how they could inform California policy. To accomplish these tasks, the CCST study team undertook a literature review and examined available datasets from the Division and elsewhere. Through meetings, investigations, and literature and data review, the CCST study team has drafted this report to address the questions and concerns of the Division.

Chapter 2

Relevant Laws and Regulations Governing Oil and Gas Wells in California

The statutory requirements and definitions relating to the operation of oil and gas wells in California are provided in Division 3 of the Public Resources Code (PRC) and Title 14, Chapter 4 of the California Code of Regulations (CCR), with primary responsibilities given to the Division of Oil, Gas, and Geothermal Resources (the Division), led by the state oil and gas supervisor (the Supervisor), under the California Department of Conservation (DOC).

The operation of oil and gas wells

There are numerous laws affecting the operation of oil and gas wells in California. The operator of a well is the entity who has the right to drill or operate a well.[1] Drilling new wells or the deepening or redrilling of existing wells requires a notice of intention, to be approved by the Supervisor or district deputy.[2] Alongside the notice of intention, operators must provide an indemnity bond, or a deposit in lieu of a bond,[3] for any well drilled or reworked, intended to protect the State against losses in case the operator cannot afford to plug the well. The bond can be released once the well is properly plugged and decommissioned. Operators must notify the Supervisor or district deputy when selling or transferring their wells or production facilities[4] and are similarly required to do so when they acquire a well or production facility. [5]

Bonding requirements

Bonding requirements for wells have changed over the years (Table 9). Initially set at $5,000 per well (Ch. 93, 1939), they have since increased in cost and been modified to account for well depth, idle status, location onshore or offshore, and number, allowing the use of blanket bonds for operators with many wells. Most recently refined by AB 2729 (Williams et al., 2016), operators are now required to obtain individual indemnity bonds when they drill, redrill, deepen, or permanently alter any well. Beginning January 1, 2018, these

1. PRC §3009 Person who either by ownership or lease has the right to drill, operate, maintain, or control a well.
2. PRC §3203.
3. CCP §995.710.
4. PRC §3201 When selling, exchanging, transferring, or otherwise disposing of their wells or production facilities.
5. PRC §3202.

requirements were also applied to any operator who acquires a well. As increased by SB 665 (Wolk, 2013), operators must file indemnity bonds with the Supervisor for either $25,000 for each well that is less than 10,000 feet deep, or $40,000 for each well that is 10,000 or more feet deep (Table 1).[6] A bond of $100,000 is also required for each Class II commercial wastewater disposal well.[7] The bond is specified to protect the state against all losses, charges, and expenses incurred in obtaining operator compliance with the provisions.

Table 1: Individual bonds

Well Depth	Amount
10,000 ft or more	$40,000
Less than 10,000 ft	$25,000
Class II disposal well	$100,000

Blanket indemnity bonds cover the drilling or modification of 20 or more wells at a time.[8] The blanket bond covers all of the operator's other onshore wells in the state. If the operator has 50 or fewer wells in the state, they must provide a bond of $200,000 to cover them all, or $400,000 for more than 50 wells. New upper level categories of $2 million for more than 500 wells, and $3 million for more than 10,000 wells, were added by AB 2729 (Table 2). These well numbers do not include any wells that the operator has already plugged. Another notable change resulting from AB 2729 is that, as of January 1, 2018, state law only allows indemnity bonds to be released upon proper plugging and decommissioning of wells rather than at the time of completion of the well.[9] This requires all necessary steps to ensure proper separation from underground or surface water.[10] For safety purposes, the Supervisor or district deputy may also order or permit the reabandonment of any well they suspect was not properly plugged or any well that is not visible or accessible.[11] Reabandonment is an operator's responsibility, except for a few scenarios in which the operator did plug and decommission the well in conformity with the requirements at the time.

Finding 2-1: Recent legislation revised California's indemnity bond requirements, requiring bonds for operators acquiring a well, increasing individual and blanket bond amounts, and requiring that a well be properly plugged and decommissioned before a bond is released.

6. PRC §3204.
7. PRC §3205.2.
8. PRC §3205.
9. PRC §3207.
10. PRC §3208.
11. PRC §3208.1.

Table 2: Blanket bonds

# Wells in State	Amount
More than 10,000	$3,000,000
501 - 10,000	$2,000,000
51 - 500	$400,000
50 or fewer	$200,000
Offshore	$1,000,000

Offshore wells

For offshore wells, there is a blanket $1 million bond required for drilling or modifying one or more wells located in submerged, ocean waters within the state's jurisdiction.[12] In addition, the entity who operates one or more of these offshore wells is required by the Supervisor to provide security to cover the full cost of plugging and decommissioning of the wells. However, there is an exception to this additional security in cases where a similar bonding agreement is part of the lease with the State, usually with the State Lands Commission, for offshore wells. The Commission tracks bonds for each of the 19 remaining offshore leases, which are as high as $30 million for a single lease (California State Lands Commission, 2018c). In September 2018, the Governor signed SB 1147 (Hertzberg), seeking to more adequately cover the cost of plugging and decommissioning offshore oil and gas wells.

Finding 2-2: In addition to the required offshore indemnity bond of $1 million, offshore wells require a supplemental form of security to cover the full costs of plugging all of the operator's offshore wells. However, these bonds may be filed as part of the operator's lease with the State Lands Commission, rather than as additional security with the Division.

Idle well fees and management

Recently, requirements from AB 2729 (Williams et al., 2016) increased annual idle well fees, based on the amount of time each well has been idle. The law also requires the operator of any idle well, even if that idle well is already bonded, to either pay the annual fee or file an Idle Well Management Plan to manage or eliminate their long-term idle wells. Prior to January 1, 2018, operators who already had an indemnity bond on an idle well or held a $2,000,000 all-inclusive blanket bond were exempt from these fees. Now, on an annual basis on or before January 31, operators must file a fee of $150 for each well that has been an idle well for 3 years or longer,[13] $300 for each well that has been an idle well for 8 years or longer, $750 for each well that has been an idle well for 15 years or longer, or $1,500 for

12. PRC §3205.1.

13. Since idle wells are wells that have not produced for 24 consecutive months, if a well is classified as an idle well for three years, it means the well has not been productive for five total years.

each well that has been an idle well for 20 years or longer (Table 3).[14] These fees go into the Hazardous and Idle-Deserted Well Abatement Fund (HIDWAF), which is continuously appropriated without regard to fiscal year for the plugging and/or decommissioning of wells or production facilities at hazardous or potentially hazardous sites. Hazardous wells and facilities are those that have been determined to be a potential danger to life, health, or natural resources and have no known operator responsible for plugging or decommissioning. If an operator fails to pay idle well fees for any of their idle wells, that failure may serve as conclusive evidence of desertion, for which the Supervisor can order the current operator to plug and decommission the well. Additionally, since the implementation of AB 1960 (Nava, 2008), if an operator has a history of violating the Division's regulations, they may be ordered to keep a life-of-well bond, covering the full estimated lifetime costs of their wells.[15]

Table 3: Idle well fees

Years Classified as an Idle Well	Annual Fee
20 or more	$1,500
15 to 19	$750
8 to 14	$300
3 to 7	$150

Finding 2-3: Recent legislation in California has increased idle well fee requirements and revised the requirements for the idle well management program.

Finding 2-4: Fees from the idle well program go into the Hazardous and Idle-Deserted Well Abatement Fund (HIDWAF), which is continuously appropriated without regard to fiscal year to support the plugging and decommissioning of hazardous or potentially hazardous wells and facilities.

Finding 2-5: Wells may be considered deserted and ordered plugged if the operator fails to comply with certain well regulations, including payment of idle well fees.

Finding 2-6: Since 2008, operators with a history of violating well regulations may be required to hold a life-of-well bond, covering the full estimated lifetime costs of the well and/or production facility, including plugging, decommissioning, and spill response, rather than a categorical indemnity bond based on well depth, or a blanket bond. According to the Division, no operator currently holds such a life-of-well bond.

14. PRC §3206.

15. PRC §3270.4: A life-of-well bond includes an amount adequate to plug each well and decommission each production facility and to finance a spill response and incident cleanup.

As an alternative to paying idle well fees, operators may file a plan with the Supervisor to manage or eliminate their long-term idle wells: operators with 250 or fewer idle wells must plug and decommission 4% of their long-term idle wells each year, operators with 251 to 1,250 idle wells must get rid of 5% of their long-term stock, and operators with more than 1,250 idle wells must get rid of 6% of their long-term idle wells each year (Table 4).[16] In each case, operators must eliminate at least one long-term idle well per year.

Table 4: Idle Well Management Plans

# Idle Wells	Annual Reduction of Long-Term Idle Wells*
1,250 or more	6%
251 to 1,249	5%
250 or fewer	4%

*In each case, operators must eliminate at least one long-term idle well per year

Idle well testing and management requirements

The passage of AB 2729 (Williams et al., 2016) required the Division to update its regulations relating to idle wells by June 1, 2018. It is in the process of doing so. The bill included idle well testing and management requirements to determine separation from drinking water sources; well mechanical integrity or appropriate remediation; and an engineering analysis for wells that are idle 15 years or more to see if they could return to production. If an operator does not remediate a well or fails to show that it could return to operation, then the operator must plug and decommission the well. If an operator fails to comply with these well testing requirements, it can be considered conclusive evidence of desertion.[17] The Supervisor is also required to present an annual report to the Legislature commencing on or before July 1, 2019, including the following:

1. A list of all idle and long-term idle wells and any status changes
2. A list of remaining orphan wells including identified idle/long-term idle wells that have become orphan wells and the costs and timeline for abandoning those wells
3. A list of all operators who have filed their long-term idle well plans.[18]

The Division is in the process of preparing this information.

District discretionary authority

The Supervisor and district deputy are also granted the authority to order the plugging and decommissioning of a well or the decommissioning of production facilities that are determined to be deserted. Credible evidence for desertion includes the operational

16. PRC §3206.
17. PRC §3206.1.
18. PRC §3206.3.

history, operator response, operator compliance with existing law, and other criteria[19] and are presumed to be deserted under a number of scenarios.[20] An operator can counter a presumption of desertion with credible evidence. If a well is deserted but the operator cannot pay for the costs of plugging and decommissioning the well, the Division can pursue previous operators as far back as January 1, 1996, as stipulated by SB 2007 (Costa, 1996).[21] If no responsible operator is identified, the Supervisor can plug and decommission the well, in line with their policies for plugging hazardous wells and facilities.[22]

As of July 1, 2018, the Division's expenditure authority for plugging and decommissioning hazardous or orphan wells and facilities was increased to up to $3 million per fiscal year (from $1 million) from the annually-assessed industry fees on production that fund the Division's operations (Lara 2017). [23] Beginning with the 2022-23 fiscal year, that amount will decrease to the previous amount of $1 million. Funds from idle well fees in HIDWAF (which are continuously appropriated without regard to fiscal year) are available for additional support. Alongside the increased expenditure authority, the Division is required to develop criteria for plugging and decommissioning hazardous or orphan (idle-deserted) wells and facilities. On October 1, 2020, the DOC is required to report to the Legislature the number of hazardous and orphan wells and facilities remaining and the estimated costs and timeline for plugging and decommissioning them. On October 1, 2023, the DOC must provide an update on actual costs, average costs per well and facility, the number of wells plugged and abandoned, the number of facilities decommissioned, the total projects completed, and any additional wells identified for plugging and decommissioning.[24]

Finding 2-7: The Division's expenditure authority for plugging and decommissioning orphan or hazardous wells and facilities was recently increased to up to $3 million per fiscal year until 2022, when it will decrease back to $1 million per year. With this expenditure authority, there are numerous reporting requirements to the Legislature regarding orphan and hazardous wells and facilities.

Conclusion 2-1: With the recent updates to idle well management and testing requirements, and the numerous reporting requirements, the State will gain a more comprehensive list of remaining hazardous and orphan wells and a better sense of responsible operators based on compliance with the updated idle well requirements.

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19. PRC §3237(a)(2).

20. PRC §3237(a)(3).

21. PRC §3237.

22. PRC §3250 - 3258.

23. See PRC §3258 for expenditure authority. Changes in expenditure authority may result in an adjustment to the rate that determines annual charges on oil and gas production as described beginning with PRC §3400.

24. PRC §3258.

Chapter 3

Quantifying Potential Oil and Gas Well Liabilities in California

This chapter uses administrative data from the Division to roughly estimate the potential future costs to the State to plug and decommission orphan wells. To do this, a simple screen was developed to identify wells that may already be orphaned or be at high risk of becoming orphaned in the future. The likely plugging and abandonment costs for these wells were benchmarked using historical costs for other wells plugged by the State. Finally, the available bond funds from each well's operator were considered to generate an estimated net cost to the State.

This chapter begins by describing the data provided by the Division and how this raw data was merged and cleaned to create the analysis dataset. Results are presented in three subsections focused on identifying orphan wells, understanding likely plugging costs, and calculating available bond funds. The final section of this chapter combines these pieces into an overall estimate of the State's potential net liabilities for orphan wells.

Data and descriptive statistics

Our analysis is based on administrative data on oil and gas wells provided by the Division, which provided information on 240,741 wells. We remove 12,093 well records with a status of "Canceled", which indicates permits that were never drilled, leaving 228,648 wells. This dataset includes plugged, active, and idle wells. The well types in the dataset include both oil and gas production wells and other related well types, such as injection wells. The data appendix provides more detail on the input datasets and how those raw data were used to build the final dataset.

Table 5 presents summary statistics for the analysis dataset. The median production rate across active and idle wells is just 2.7 barrel-of-oil-equivalents (BOE) per day.[1] The median year of first production is 1989 and 28% of the unplugged wells in the dataset are officially classified as "idle" by the Division.[2] These production statistics underscore the mature status of oil and gas fields in California. With few major discoveries in recent decades, producers are now focused on efficiently extracting remaining oil and gas from partially-depleted fields. Most wells are located onshore (about 98%), accounting for 95% of production during 2013–2017. Of the 1,454 operators with any active or idle (unplugged) wells, 1,099 operate only idle wells. At the same time, 91% of idle wells belong to operators that also

1. One BOE represents one barrel of crude oil or 6,000 cubic feet of natural gas.
2. We use first observed production because drilling or completion dates are missing for a large share of wells.

have active wells. As shown later, this reflects the fact that a few companies operate a large share of all wells.

Table 5: Summary statistics for analysis dataset

Wells	228,648
Plugged	121,961
Active/Idle	106,687
Among Active/Idle Wells	
Median Daily Production (BOE)*	2.7
Median Year of First Production*	1989
% of Wells Offshore	2.3
% of Production Offshore	5.3
% of Wells Idle	28
Operators with Active or Idle Wells	1,454
Operators with only Idle Wells	1,099
% of Idle Wells Belonging to Operators with some Active Wells	91

*Starred values calculated using well types OG, GAS, and Multi.

Figure 2 shows average monthly production over the life of a California well. These curves were constructed using all oil and gas wells entering production between 1980 and 2017. The figure shows how production declines over the life of the well due to reservoir depletion. This phenomenon of declining production is central to the orphan well problem. Near the end of a well's productive life, it generates little revenue that can be used to pay for plugging and decommissioning. Consistent with the mature status of California's oil and gas fields, the figure also shows that wells have become less productive in recent decades. For wells drilled in recent years, initial production is lower and declines are steeper than for wells drilled during the 1980s. Production in the fifth year of the life of a well drilled during the 2000s or 2010s is about half of fifth-year production of a well drilled during the 1980s or 1990s.

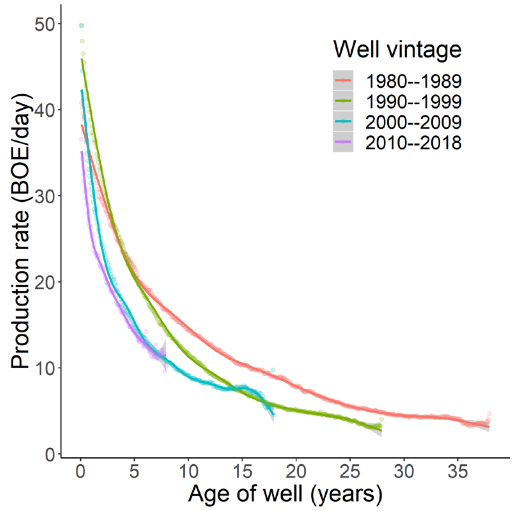

Figure 2. Average production by age of well and decade drilled. This figure shows the average production rate (in BOE/day) in each month of a well's productive life. The four colors represent averages for wells drilled during each decade since 1980. The fitted lines represent smoothed non-parametric fits and 95% confidence intervals (in gray). The first month of a well's productive life is defined as the first month of non-zero production.

RESULTS

Identifying potential orphan wells

Historically, there has been little monitoring of the solvency of operators of idle oil and gas wells in California. While the State maintains a comprehensive list of idle wells, the share of these that are orphan wells is unknown. An orphan well is defined here as an idle well for which no responsible operator exists to undertake plugging and decommissioning.[3] The first step in this analysis was to develop a rough screen for wells that may already have been orphaned or that risk becoming orphan wells in the near future. This approach is based on recent production from the well, as well as production by the operator from other California wells. Six categories of wells are defined, which are summarized in Table 6.[4]

3. Idle wells by definition exclude plugged wells, which are no longer producing but have been properly plugged and abandoned.

4. The statutory definition of an idle well also exempts from idle status wells that produce water to be used in tertiary production methods. Accounting for water production has little practical effect on the number of wells in each category in our analysis.

Table 6: Categorization of oil and gas wells

Active and Idle Wells	
Likely Orphan Wells	2,565
High Risk of Becoming Orphan Wells	2,975
Other Idle and Marginal Wells	69,425
Higher-Producing Wells	31,722
Plugged Wells	
Plugged before modern requirements	41,390
Plugged after modern requirements	80,571
Total	228,648

In this study, wells with no production or injection in the past five years that also belong to operators with no California production or injection in the past five years are considered to be "likely orphan wells." There are 2,565 wells in this category. The lack of observable activity by the operators of these wells is an indication that they may have no viable operator, so the State may bear the costs of plugging and abandoning these wells.[5] The next category in the screen is "wells at high risk of becoming orphan wells," which includes 2,975 wells. These are wells with no production or injection activity during the past five years, where the responsible operator is currently active in California but is small and operates primarily idle and marginal wells. Specifically, this group includes idle wells where the operator's average production rate across all wells is less than five BOE/day, and the operator has fewer than 1,000 actively producing wells. We focus on small operators because research in other states suggests small operators are more likely to orphan wells (Boomhower, in press) and because these small companies are more difficult to recover costs from in the event of default due to the high fixed costs of such collection efforts.

The third category of orphan well risk includes all other idle and marginal wells, where we define marginal wells as wells producing fewer than five BOE/day. It also contains currently active injection wells.[6] This category includes 69,425 wells. Many of these wells belong to a few large operators that are responsible for thousands or tens of thousands of primarily low-producing or idle wells.[7] These major producers likely face lower risk of insolvency than smaller producers. In addition, if they do become insolvent, collection efforts may be more cost-effective because the State would quickly notice such a bankruptcy and because the fixed costs of legal efforts can be spread over the firm's many wells. At the same time, the risk of bankruptcy exists even for large

5. While we use five years of inactivity as our cutoff, many of the wells and operators in this category have been inactive for much longer—in some cases, decades.

6. We include all active injection wells in this category because of the lack of a clear method for identifying which active injection wells are economically marginal. Of the 69,425 wells in this category, 13,057 are injection wells.

7. Aera Energy, Chevron U.S.A., and California Resources Production Corporation together account for 57% of the 33,288 wells that have been inactive for five or more years. These same three operators are responsible for 60% of all oil and gas wells in California. The largest 10 operators account for 90% of inactive wells and 82% of all wells.

producers. A single bankruptcy among one of these large companies could potentially create a large number of orphan wells, at great cost to the State.[8]

The fourth category includes wells that currently produce more than five BOE/day.[9] These higher-producing wells are currently at low risk of becoming orphan wells. Even if their current operators were to become insolvent, other companies would likely find it profitable to take over these wells and continue production.

The final two categories include plugged wells. California implemented modern requirements for well plugging to protect groundwater in February 1978. The 41,390 wells plugged prior to these requirements may not have been plugged to current standards, increasing the risk that they will need to "re-abandoned" in the future. The remaining 80,571 wells were plugged during the modern regulatory period.

It is important to note that this coarse categorization is a rough screen meant to assess the approximate magnitude of the orphan well problem in California using the best available data from the Division. The thresholds used in the analysis to define marginal wells and to categorize operators are by necessity somewhat arbitrary. In the appendix, we investigate the sensitivity of our categorizations to changes in these category thresholds. More broadly, this coarse approach is substantially less detailed than would be required to make legal determinations about the status of any given well. It is also less sophisticated than approaches used by regulators in other jurisdictions (e.g. Alberta, Canada), which rely on detailed, company-specific financial information that is not tracked by the Division.

Another important note about this screen is that oil and gas wells commonly transfer between operators as production decreases, meaning that a marginal well at low orphaning risk today could change risk categories if sold to a less robust operator. Our calculations using data from the Division imply that a typical California oil and gas well has passed between about three different operators by the time it reaches ten years old. While California law makes former operators jointly liable for plugging and decommissioning costs of wells sold after 1996, recovering costs from previous operators may be costly and time-consuming in practice. Thus, in coming years or decades, some of the wells in the "Other Idle and Marginal Wells" and "Higher-Producing Wells" categories could ultimately become orphan wells as they transfer between operators. Despite these limitations, this coarse categorization is useful for approximating the current orphan well problem in California given the available data.

8. The orphan well risk posed by some large operators depends partly on complicated and currently unsettled legal questions. For example, some of these firms are subsidiaries of or receive investments from international corporations. There seems to be disagreement about the degree to which those parent firms would be held liable for costs created by their subsidiaries. In addition, large companies may also consider reputational consequences in addition to direct financial penalties.

9. A common alternative threshold for marginal wells is ten barrels per day. Our conversations suggest that many wells in California operate profitably at lower levels of production, and so we use five BOE/day as our cutoff for economically marginal wells. This is a simplification reflecting our coarse analytical approach. The actual economic limit for any given well depends on field-level production costs, output prices, and other factors.

Finding 3-1: A coarse analysis of readily available information from the Division suggests several thousand wells in California are likely orphan wells or are at high risk of becoming orphan wells in the near future.

Finding 3-2: Tens of thousands of additional idle and low-producing wells could become orphan wells in the future if they are acquired by a financially weak operator or there is a prolonged negative shock to the oil and gas industry. The likelihood of these wells eventually becoming orphan wells depends in part on the practical enforceability of California's rules that make previous well operators jointly liable for decommissioning costs. Old wells plugged prior to modern standards may also pose some risk.

Recommendation 3-1: Refine predictions of wells at risk of becoming orphaned. A more detailed analysis could consider additional factors such as operator financial information, field-level production costs, and output price projections.

Recommendation 3-2: Study the ownership history of orphan wells and wells at high risk of becoming orphan wells. Such research will identify the share of plugging and decommissioning costs that may be recoverable from previous operators. It will also increase understanding of well ownership dynamics, which are thought to involve wells moving to smaller, higher orphan risk operators as production rates decrease.

Finding 3-3: Improved measurement and data management will be important for assessing the orphan wells problem in more detail and monitoring the effectiveness of policy responses.

Figure 3 shows the broad geographic distribution of likely orphan wells and wells at highest risk of becoming orphan wells. The distribution of these wells is similar to the overall geographic distribution of oil and gas activity in the state. Figure 4 shows more detail for southern and central California.

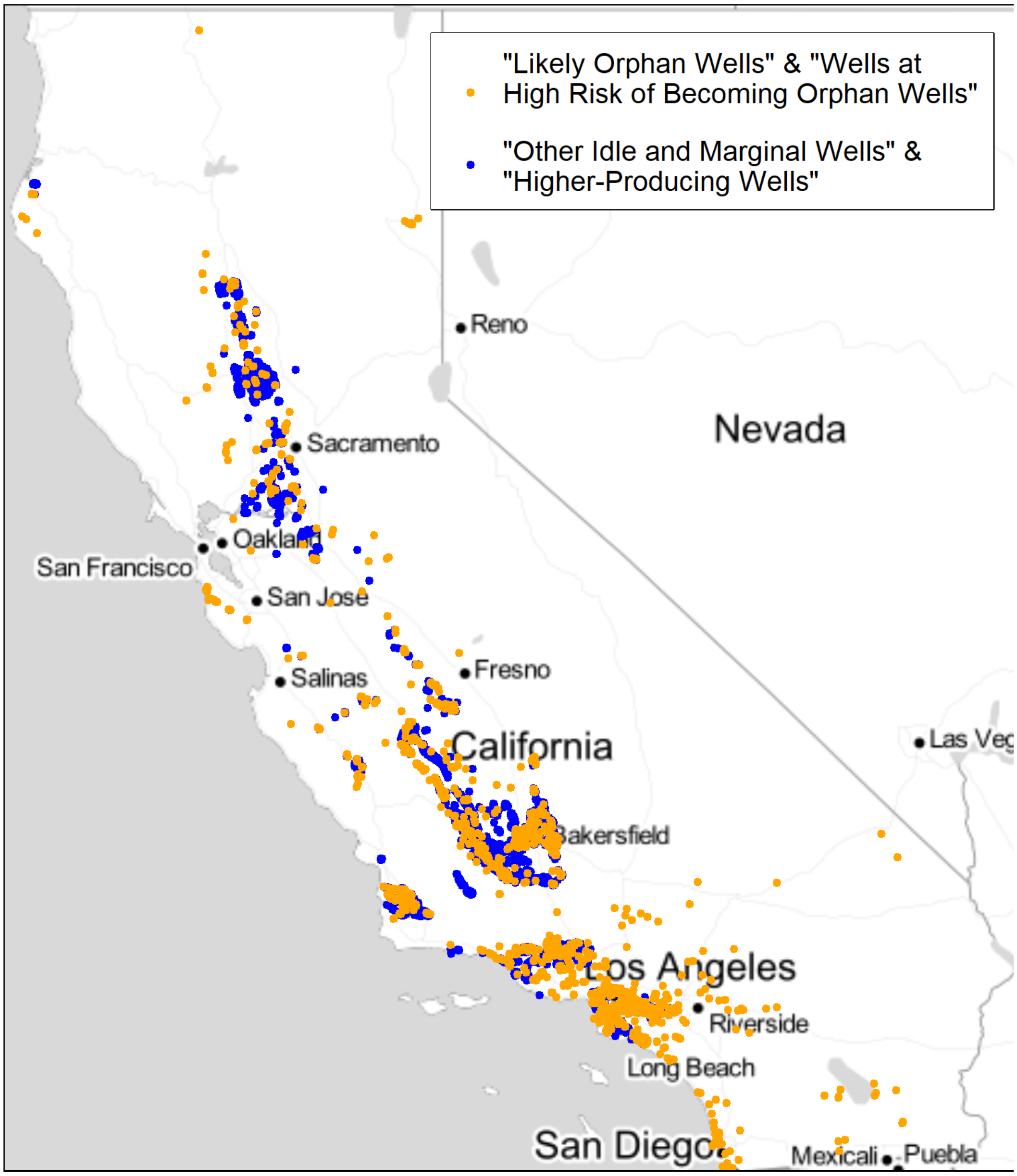

Figure 3. Statewide map of potential orphan and other wells.

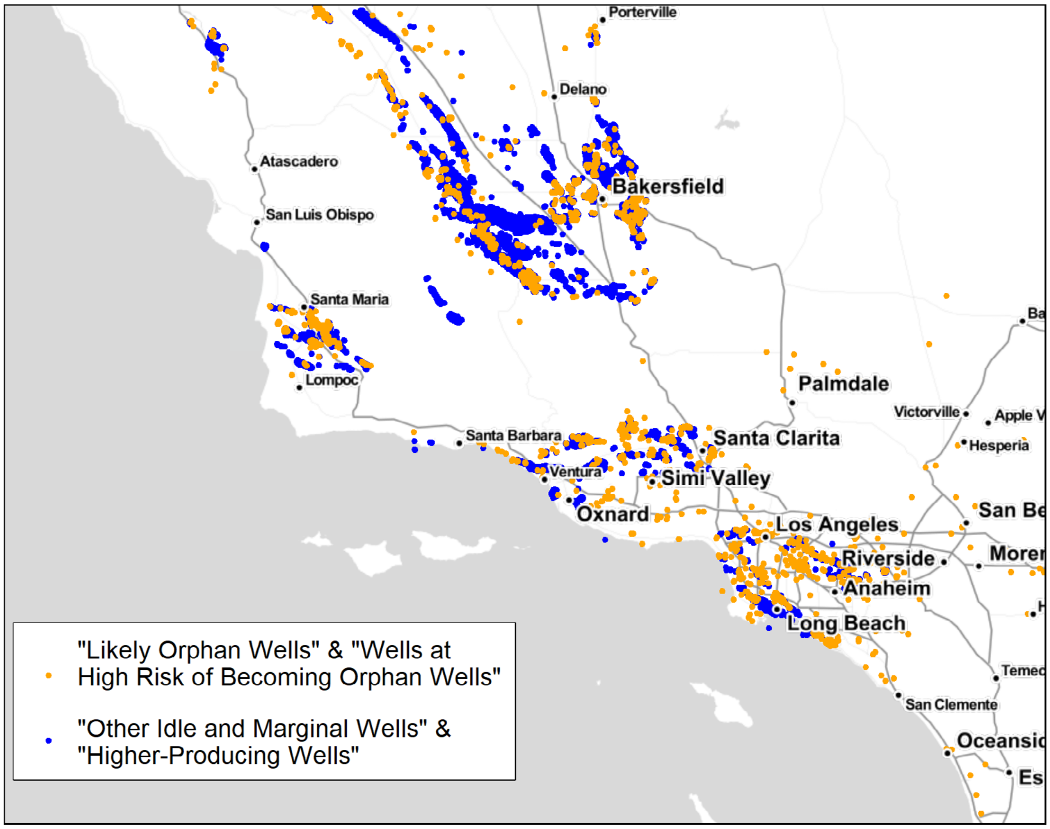

Figure 4. Detailed map of Southern California.

Finding 3-4: The likely and potential orphan wells we identify are located throughout the state matching the overall geographic distribution of oil and gas activity, with greater concentrations near Kern County and Los Angeles County.

Potential costs faced by the State

The costs ultimately imposed on the State by orphan wells depend on plugging and decommissioning costs, as well as any amounts that can be recovered from responsible operators through claims on bond funds. This section considers these elements. A category of potential costs that we do not consider is possible environmental or health damages due to pollution from orphan wells. These impacts are poorly understood and are the subject of ongoing research by geologists and engineers. One priority for future research is to determine the economic significance of these potential damages.

Finding 3-5: The risk of environmental or health damages from orphan wells is poorly understood but may be significant in some cases.

Recommendation 3-3: Investigate the potential environmental impacts of orphan and idle wells in California. Possible impacts may include groundwater contamination, human health impacts, and other issues.

Per-well plugging costs

The Division provided us with information on plugging and abandonment costs for a subset of onshore wells that have been plugged at State expense since 2013. In the various records provided by the Division, we identified 86 wells where expenditures were reported at the individual-well level.[10] The reported costs are the amounts paid by the Division to private contractors to plug and abandon each well. These contracts are negotiated on a case-by-case basis and the exact services procured can vary. Most of the contracts we were able to review included both well plugging and minimal surface restoration.[11] Projects involving more complex surface remediation would likely be costlier.

The average contract cost in this sample is $68,000 per well. The range of costs is large, with a minimum value of $1,200 and a maximum of $391,000. Figure 5 shows this variation is partially explained by district-specific factors. The four box plots describe plugging costs for wells in each the Division district: southern, northern, inland, and coastal. The median plugging cost in the Southern district, which includes urban areas near Los Angeles and Long Beach, is about three times greater than median plugging costs in the other districts.

10. The Division also provided aggregate expenditures on well plugging for an additional several dozen wells. We focus on individual well expenditures in our main analysis so that we can analyze geographic and other variation in costs. Including the aggregate spending on the additional wells has little effect on our estimate of overall average cost.

11. For example, one fairly typical contract stipulates that in addition to plugging and abandonment of the wellbore, "[A]ll equipment, casing, or junk that requires removal to implement restoration to lawful conditions shall be removed and properly disposed of in accordance with environmental laws… All liquid wastes shall be removed and properly disposed of at the nearest approved site... [and] The surface at the site shall be restored."

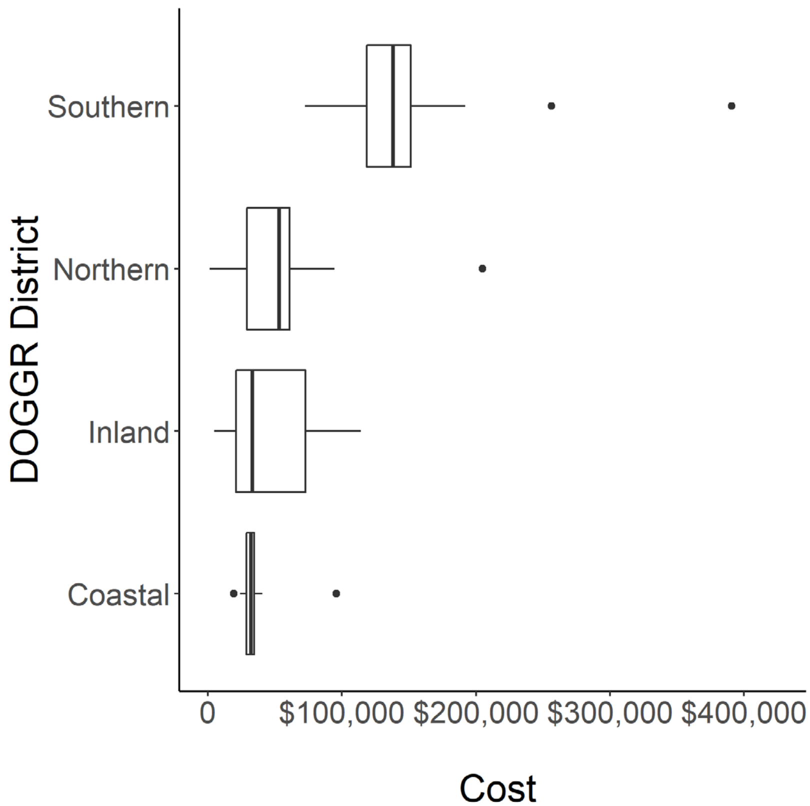

Figure 5. Well-level plugging costs by district. Each of the four panels shows a box-and-whiskers plot for well-level plugging costs in the sample of 86 recent plugging contracts provided by the Division. The thick vertical line indicates the median; thin vertical lines show the interquartile range (i.e., the 25th and 75th percentiles). Black dots represent outliers (values outside of the interquartile range (IQR) by more than 1.5 * IQR).

Figure 6 explores this variation in more detail. Panel (a) plots plugging costs against the date that the well was first drilled. Panel (b) plots plugging costs against population density. Older well ages and greater population densities are correlated with higher plugging costs. With this small sample of wells, it is difficult to disentangle correlation and causation. The Southern district wells in our small sample, which tend to be high cost, are located in more densely-populated areas and are older than average. Both age and population density have been reported to increase plugging and abandonment costs by Ho et al. (2018).[12] We also attempted to study the relationship between historical plugging costs and well depth but

12. Ho et al. (2018) provides a thorough and valuable summary of plugging costs across states, as well as detailed regression analysis of plugging costs using a sample of about 5,000 wells in Kansas. Their reported plugging cost for California is $31,000. That estimate is based on 113 wells in the Division's former District 2, which roughly corresponds to the coastal district in the Division's current four-district system. We find that incorporating costs from other districts yields a higher estimate because the other districts are systematically more expensive.

were limited by the availability of depth data, as we describe in Appendix B3.

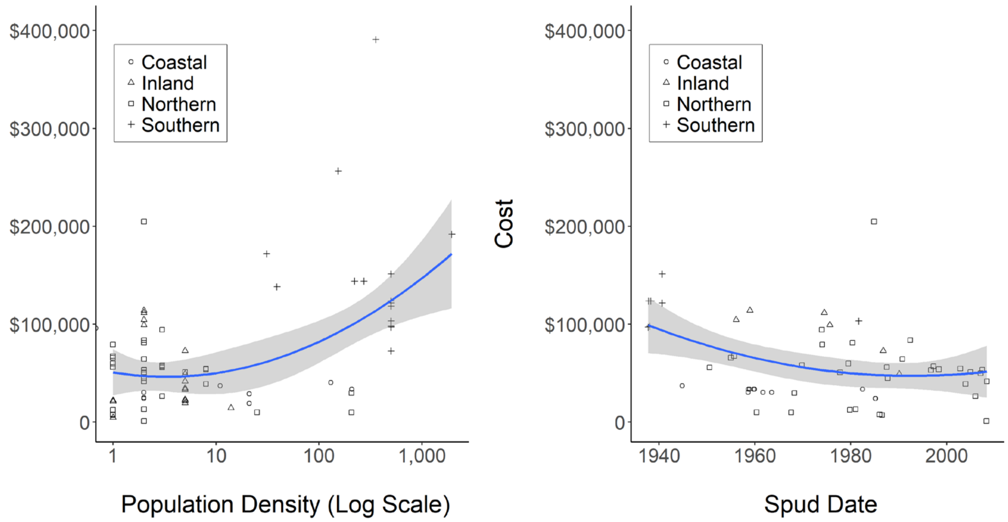

Figure 6. Variation in plugging and abandonment costs. These figures examine variation among the 86 wells with available information on plugging cost. The blue line and gray region indicate a quadratic fit and 95% confidence interval. Marker shapes indicate the four Division districts. Spud date is the date that drilling began. Spud dates were missing for 30 wells, so these are omitted from panel (b).

With a larger sample of plugging costs, determinants of California plugging costs could be investigated in more detail with regression analysis. Such analysis may be possible in the future using data from an industry source, or after the state accumulates cost records for future contracts. Given the limited data currently available, plugging costs for wells in each district were instead modeled using district-level averages. These average costs along with the number of observations for each district are in Table 7.[13]

13. All 86 of the well-level cost records provided by the Division are for onshore wells. Later in this section, when we consider future plugging costs, we use a placeholder estimate of $1.5 million for each offshore well based on the approximate per-well costs of plugging and decommissioning at Rincon Island and plugging and abandonment at Platform Holly (California State Lands Commission 2018a). While the large majority of idle wells are onshore, future analyses should consider offshore well costs in more detail.

Table 7: Average onshore plugging and abandonment costs by district

District	Observations	Average Cost
Southern	17	$152,000
Northern	32	$51,000
Inland	17	$47,000
Coastal	20	$40,000
Total	86	$68,000

Finding 3-6: Based on a small sample of well-level plugging costs, the statewide average cost to plug and abandon an onshore orphan well is $68,000. Costs in the densely-populated Southern district near Los Angeles are about three times higher than in other regions. Additional surface reclamation costs may be required for some wells.

Recommendation 3-4: Track expenses for orphan well plugging and surface reclamation at the individual well level in a centralized database. This will allow for more detailed understanding of the determinants of plugging and decommissioning costs, and thus more accurate cost predictions for future orphan wells.

Available bond funds to offset these costs

The Division collects performance bonds from oil and gas operators to align operator's incentives for plugging and decommissioning, and to offset these costs in the event that the operator does not perform their responsibility. This analysis suggests the effective amount of these bond funds is small compared to the predicted plugging costs calculated above. The Division provided information on bonds for all California oil and gas operators. Summing over all of the bonds for operators in the dataset, the total bond funds available to plug and abandon wells in California are about $110 million. Dividing by 106,687 active and idle oil and gas wells, this implies an overall average of just over $1,000 in available bond funds per well. Of course, the actual bond amounts available for each well depend on the bond posted by that well's operator, which are discussed below. But this simple average across all wells illustrates the rough size of bonds relative to the costs of plugging and decommissioning.[14]

The effective bond coverage for every well in California is calculated by dividing each operator's total bond amount by that operator's number of active and idle wells. Figure 7 describes these effective bond amounts for operators of different sizes. Effective bond amounts tend to be larger for operators with fewer wells, because blanket bond rules

14. The dataset provided by the Division does not include some bonds for offshore wells that are held by the State Lands Commission instead of by the Division. Many offshore platforms in California have bond coverage with the State Lands Commission of $20 million or more per platform, meaning that offshore bond coverage is substantially higher than onshore (though decommissioning costs are also substantially higher).

allow larger operators to post small bond amounts per well operated. Regardless of operator size, however, effective bond amounts are well below the predicted plugging and decommissioning costs discussed previously. Blanket bonds are one reason that these effective bond amounts are low. A second reason is that until recent increases, bond requirements in California had been quite limited.[15] Importantly, some California operators may be grandfathered in under prior bond requirements unless they have since undertaken significant rig work or acquired additional wells, or may have had their bonds released prior to plugging and decommissioning under old requirements. That means some operators of old wells in California may have no or very small bonds.[16]

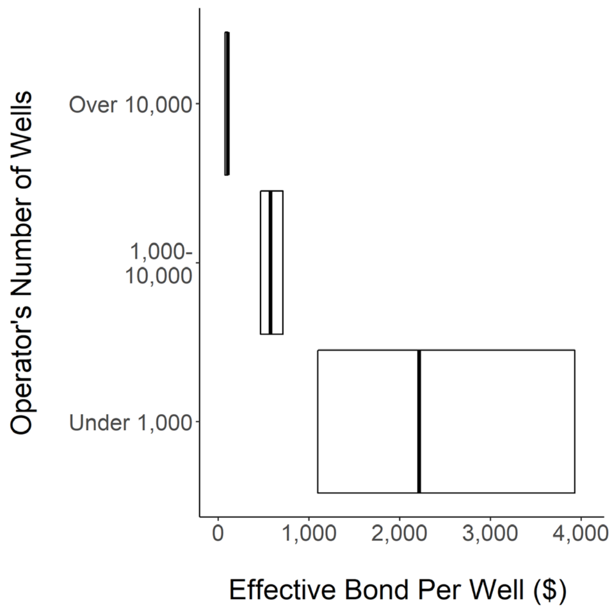

Figure 7. Available bond funds per well, by size of operator. This figure shows the median, 25th percentile, and 75th percentile of effective bond amount for wells with operators of different sizes. Effective bond amount is calculated by dividing each operator's total bond amount by the operator's total number of active and idle wells.

Finding 3-7: The bond amounts available to pay for plugging and decommissioning vary according to operator, but in almost all cases these amounts are substantially lower than the predicted costs.

15. As of January 1, 2018, bonds cannot be released until a well is properly plugged and decommissioned. However, prior to this, bonds could potentially be released upon completion of a well, prior to it being plugged and decommissioned.

16. The Division's records imply that 1,168 operators of active or idle wells have zero bond coverage. Together these companies account for about 3,350 wells.

Idle well fees and idle well management plans

As of 2018, California increased the fees it charges to operators of wells that have been idle for more than two years. Idle well fees provide additional revenue that can be used to fund the costs of plugging orphan wells. Chapter 2, Table 3 shows the current fees are small compared to the costs of plugging wells. For wells that have been idle less than 15 years, the fees are $300 per year or less and thus do little to offset plugging costs.[17] Fees are higher for wells idle longer than 15 years, eventually maxing out at $1,500 per year for wells idle for 20 years or more. These higher fees may contribute more meaningfully to revenues.

Using the Division's Idle Well List, we calculated the fees that would be required for each well, assuming the operator chose not to develop an Idle Well Management Plan.[18] This calculation implies an upper bound on idle well fees of about $16 million per year. The actual amount of idle well fees assessed will be smaller, since some operators will develop Idle Well Management Plans and thus avoid these fees, as explained in Chapter 2. In 2018, the actual amount of idle well fees that operators chose to pay was just under $4 million.

It is also important to note that idle well fees are only collectible while the well still has a viable operator. Fees assessed against defunct operators will not be paid. This is potentially significant because of the increase in idle well fees with years idle. In our calculation, almost two-thirds of the $16 million in possible idle well fee revenue comes from wells idle over 20 years. It may prove difficult to collect fees from operators of these very long-time inactive wells. At the time of this study, there were 2,296 idle wells whose operators had not responded to 2018 idle well letters, or could not be located to send the letter. In comparison, an advantage of bond requirements is to collect financial security at the outset of production, so that funds are guaranteed even if the operator is no longer viable.

The new Idle Well Management Plan (IWMP) requirements also have the potential to reduce the number of wells that may become orphan wells in the future. One additional benefit of the new regulation is to create an annual mechanism to verify the continued viability of operators. Failure to pay idle well fees or file an IWMP allows the Division to immediately identify legally deserted wells, a process that previously may have taken years of administrative effort. An important priority for future analysis will be to evaluate the contributions of idle well fees and the new Idle Well Management Plan requirements to offset orphan well liability and the number of wells at risk of becoming orphan wells. Such an analysis will have to consider the length of time wells are likely to be kept idle before being plugged by the operator or orphaned, the State's success in collecting idle well fees

17. Using the fee schedule from Chapter 2, Table 3, a well kept idle for 14 years before being orphaned would contribute $2,850 in idle well fees. Compare this to the average plugging cost in Table 7 of this chapter, which is $68,000.

18. The statutory definition is "any well that for a period of 24 consecutive months has not either produced oil or natural gas, produced water to be used in production stimulation, or been used for enhanced oil recovery, reservoir pressure management, or injection" (PRC § 3008(d)).

from operators, and other factors.

Finding 3-8: Idle well fees may offset some of the State's eventual liability for orphan wells. A rough calculation suggests that this contribution would be small with the current fee schedule.

Recommendation 3-5: Leverage the new annual Idle Well Fee/Idle Well Management Plan requirement to yield a more detailed count of wells without viable operators. Failure to file the annual idle well fees or an idle well management plan can serve as legal evidence of desertion.

Do plugging and abandonment requirements reduce option value from potential future production?

A common challenge in analyzing and regulating idle wells is understanding whether wells are kept idle because the operator has a reasonable expectation of eventually resuming production, or is simply deferring plugging and decommissioning costs. If it is the former, regulations forcing the well to be plugged create additional economic costs in terms of foregone option value. Plugging the well today increases the cost of resuming production in the future if prices or technology improve. It is impossible to know any individual operator's expectations about future production, but we can use historical data on idle wells to understand the average likelihood of returning to production after a given interval with no production. The most sophisticated existing economic research on this question is Muehlenbachs (2015), which considers idle oil and gas wells in Alberta, Canada. That study concludes that most long-term idle wells are unlikely to return to production even with large increases in output prices or improvements in production technology. Given appropriate data, such a study could be done specifically for California. Appendix B describes a first pass at this type of analysis for California using the data readily available for this study, and describes what would be required to study this question in more detail.

Overall summary of potential orphan well costs

Table 8 summarizes the State's potential liability for orphan oil and gas wells. The "Cost" column presents the total predicted plugging and abandonment cost for wells in each group, based on the district-specific average plugging costs discussed earlier in this chapter. The "Available Bonds" column sums up the total bond funds available for wells in each category. The "Net Liability" column shows the difference, which is the State's potential liability for orphan wells. All dollar values are rounded to the nearest million dollars. For the 2,565 wells we identified as "likely orphan wells", the aggregate predicted plugging cost is about $308 million. These wells are concentrated near Los Angeles and Long Beach, where plugging costs are systematically high. For comparison, the Division's annual budget for orphan well remediation projects has historically been about $1 million per year (though a recent appropriation increased that amount to $3 million per year for three years). The costs of the "likely orphan wells" are partially offset by about $10 million in available bond funds for these wells. That leaves about $298 million of the projected costs of these wells with the State. The group of "wells at high risk of becoming orphan wells" would add another $230 million in net costs to the State if they were all to become orphan wells, for a total potential liability of about $528 million across these two groups.

Table 8: Total potential orphan well costs among active and idle wells

Group	Wells	Cost (M)	Available Bonds (M)	Net Liability[19] (M)
Likely Orphan Wells	2,565	$308	$10	$298
Wells at High Risk of Becoming Orphan Wells	2,975	$246	$16	$230
Other Idle and Marginal Wells	69,425	$5,287	$53	$5,234
Higher-Producing Wells	31,722	$3,385	$27	$3,358
Total	106,687	$9,226	$107	$9,120

After these two groups, there are 69,425 remaining idle and marginal wells. In the unlikely event that 100% of these remaining wells were to become orphan wells, the additional net liability to the State would be about $5.2 billion. While this scenario is unlikely, the number of wells in this category means that the State faces large possible costs, particularly in the event of a prolonged negative shock to the oil and gas industry. Notably, the available bond coverage in the "other idle and marginal wells" category is lower on a per-well basis than in the previous two categories. This reflects the fact that many of these wells are operated by large companies with blanket bonds covering thousands or tens of thousands of wells.

After adding in the 31,722 high-producing wells, the total net cost to the State if it were to have to plug all active and idle California oil and gas wells would be about $9 billion. This total cost estimate is interesting not only as an unlikely "worst-case" scenario for state plugging liability, but also as an estimate of the total plugging and abandonment liability facing the California industry (regardless of whether it is borne by companies or the State). Over the longer run, as these wells decrease in production and potentially change hands between operators, the ultimate share of these wells that are responsibly decommissioned by their operators will depend on policy decisions as well as market fundamentals.

19. This net liability figure ignores offsetting revenues earned through idle well fees, as discussed in this chapter. Our analysis suggests these fee revenues are likely small compared to plugging costs, but further study of idle well fee revenues is required, as we describe.

This summary calculation omits an additional difficult-to-quantify financial risk posed by 121,961 wells that have already been plugged (see Table 6). The plugging and abandonment procedure must provide an effective isolation of the well fluids all along the well. Wells plugged according to older technologies and regulations may still pose some risk of contamination. Table 6 shows that 41,390 wells were plugged prior to modern plugging requirements. The precise risk posed by these older plugged wells is unknown.

Conclusion 3-1: If all of the roughly 5,000 wells that we identify as having the highest orphaning risk were to become orphan wells, the State’s net costs after subtracting out bond funds could be about $500 million. The total net difference between plugging costs and available bonds across all oil and gas wells in the state is about $9.1 billion.

Recommendation 3-6: Study potential changes to blanket bond rules that would increase the effective per-well bonds for economically marginal wells. The Division should consider whether securing larger effective per-well bonds while wells are still profitable would avoid enforcement challenges once wells become idle.

Recommendation 3-7: Use the results of a more detailed investigation beyond the limited scope of this study to conduct an economic analysis of policy alternatives. The Division should identify specific policy changes with the greatest promise to manage costs from existing orphan wells and to efficiently regulate the number of additional orphan wells going forward.

Chapter 4

The Policies and Practices of Plugging and Decommissioning in Other States and Regions

Regulation overview: California in comparison with other states and regions

Ensuring that state policy adequately manages idle and orphan wells and their potential costs to the state is difficult to achieve. With an annually increasing inventory of historical wells—some many decades old—which for one reason or another require some form of remediation, most states have struggled to ensure they are able to adequately manage their well populations.

Most states regulate at least four principal aspects of potential or actual well decommissioning:

1. Financial assurance
2. Idle (or inactive) well status
3. Plugging and restoration
4. Notification, inspection, and approval

California is comparable to many other states in this regard. Like most regions, California's regulations have not been entirely sufficient to effectively monitor the scope of the orphan well problem, nor to ensure adequate financial resources to plug them. However, the State has been proactive in recent years and taken numerous steps that make its current financial assurance requirements among the strictest in the nation. Many other states and regions are in the process of re-evaluating their own orphan well management, and it remains to be seen whether and to what extent they choose to emulate the approach taken by California.

Finding 4-1: Relative to other states, California has been proactive in enacting some of the strictest financial assurance requirements in the nation, although the requirements still do not cover the full costs of plugging orphan wells.

Finding 4-2: Many states and regions have been forced to re-evaluate their regulations and financial assurance systems for orphan wells in recent years due to challenges in funding orphan well plugging.

Financial assurance

In every state, operators have to provide some form of financial assurance for a well at the time that it is drilled. This assurance is intended to cover or mitigate the eventual costs of plugging the well and/or environmental impacts caused by the well, in the event the operator at the time the well is terminated is unable or unwilling to do so. The type and scope of the assurance has changed considerably over time, with states attempting to ensure the most effective way to cover the price of decommissioning wells. Some states also express concern that operators, particularly smaller ones, may be less willing to invest in wells in states where more costly financial assurances are required (Ho et al., 2016). Broadly speaking, economic and policy analysis finds that financial assurance requirements improve operators' behavior, and the actual amounts required in most jurisdictions may be too low (Davis, 2015; Ho et al., 2016; Boomhower, in press)

Finding 4-3: Financial assurance requirements across states, such as indemnity bonds and fees, are broadly found to improve operator behavior.

States accept various types of financial assurance, including surety bonds, letters of credit, certificates of deposit, cash, escrows or trust accounts, liens, government bonds, or annual fees. California accepts bonds, certificates of deposit (CDs), or cash (it used to accept escrow accounts, but no longer does). Operators may choose between individual and blanket bonds as forms of assurance. Individual bonds cover a single well, while blanket bonds cover a number of wells. The amount of these bonds varies, but generally, most states do not collect sufficient financial assurance to cover the entire costs of decommissioning orphan wells (Louisiana Legislative Auditor, 2014; Ho et al., 2018).

The bond amount required depends upon the characteristics of the well and/or the operator. In terms of physical well characteristics, California determines individual bond amounts by well depth, idle status, and location (onshore or offshore). Well depth is the most common characteristic employed by states to determine bond amount, but not the only one; a few states also differentiate between the type and location of the wells. Like most states, California also differentiates between large and small operators, allowing a range of blanket bonds whose costs depend on an operator's total number of wells in the state. As discussed in Chapter 2, blanket bonds in California range from $200,000 to $3,000,000, depending on the total number of wells operated in the state. California requires a $1,000,000 blanket bond for one or more offshore wells, and also requires a security to cover the full cost of plugging and decommissioning an operator's offshore wells. At present California's current requirements for new or newly-transferred wells are at the upper end of the scale in terms of minimum bonds required. Unlike other states, however, existing wells in California may be grandfathered in under previous bond requirements if operators have not reworked or acquired any wells since the most recent requirements were implemented.[1] Additionally, some wells may have had their bonds released upon completion of the well under old requirements, prior to plugging and decommissioning. This situation contrasts with a universal bond requirement, as implemented by Texas, where all qualifying operators would be required to file the new bond amount at the time of the policy's implementation. Most states, and the Bureau of Land Management, have a minimum blanket bond amount set at $25,000. California also requires idle well fees—or an Idle Well Management Plan—even if an idle well is already covered by a bond.

Finding 4-4: California is now at the upper end of minimum bond amounts currently required, but existing wells in California may be covered by older bonds or no bond at all depending on when they were last drilled, reworked, or acquired, and whether the bond was released prior to plugging. This contrasts with a universal bond requirement, as implemented by Texas, where all qualifying operators would be required to file the new bond amount at the time of implementation.

Financial assurance requirements in most states do not fully cover orphan well-related costs. Wyoming, which has bonding requirements similar to California, spent $11 million plugging orphan wells between 1997-2014, but only $3 million was covered by bonds put up as financial assurance by operators (Joyce & Wirfs-Brock, 2015). Another study found the average and median decommissioning costs exceeded average bond amounts in all 22 states examined (Ho et al., 2016). A separate study of average bond amounts and average costs of well plugging in 13 states found that two states, Texas and Oklahoma, did have average bond amounts which exceeded the average cost of orphan well plugging (Ho et al., 2018). Texas's introduction of a universal bond requirement in the early 2000s changed the composition of the industry, re-allocating production to companies less likely to avoid liability through bankruptcy and improving environmental compliance (Boomhower, in press).

One of the issues in estimating financial assurance requirements is that well plugging costs are variable depending not only on the specific location and characteristics of the well, but also on the price of oil at the time. When oil prices and production are high, there are higher prices for drilling wells, and consequently more competition for the service providers contracted to plug orphan wells. One recent study (Ho et al., 2018) found a $1 per barrel increase in oil price correlated with a 1.6% increase in plugging costs.

California has modified its bonding requirements repeatedly over the past five years (Wolk, 2013; Williams et al., 2016) and increased potential bonding requirements for offshore drilling as recently as September 2018 when SB 1147 (Hertzberg) was signed by the Governor. Some have suggested that an effective way to ensure that states would be

1. PRC § 3204: "An operator who…engages in the drilling, redrilling, deepening, or in any operation permanently altering the casing, of a well, or who acquires a well, shall file with the supervisor an individual indemnity bond for each well so drilled, redrilled, deepened, or permanently altered, or acquired."

able to cover the cost of orphan wells would be to tie bonding requirements to production (Andersen et al., 2009); others indicate that bonding requirements should be a minimum of $250,000 per well (Dutzik et al., 2013). However, these are not approaches states have opted for (Joyce & Wirfs-Brock, 2015). Instead, they all have specific bond amounts, generally linked to well depth, starting in some cases as low as $500 per well.

California law does not require a test of financial capability, but where an operator has a history of violating legal requirements or has outstanding financial liabilities, as of 2018 they may be required to provide a separate life-of-well bond adequate to ensure the full costs of proper plugging and decommissioning of each well.[2]

Compared to other states, California has been somewhat proactive in attempting to modulate its financial assurances to better provide for costs relating to orphan wells. However, its requirements have been insufficient to cover costs. Along with the Division's annual expenditure authority for hazardous or orphan wells and facilities, recently increased to up to $3 million per fiscal year, the State has relied on two funds supported by industry fees to plug priority orphan wells annually: the Acute Orphan Well Account and the continuously appropriated Hazardous and Idle-Deserted Well Abatement Fund (HIDWAF). At the end of fiscal year 2016-17, the combined total in these funds was just over $1.1 million. In cases where costs of plugging wells are higher than normal, such as for offshore wells or wells in highly populated areas, the funds are not sufficient to pay the costs. This lack of funds has occasionally required special appropriations in the State budget.

It should be noted that regions outside the US have adopted different strategies. The Canadian province of Alberta, which had more than 3,200 orphan wells in 2017, generally relies on two policy tools to address potential well plugging costs: an orphan well levy collected from all well operators, and a form of contingent bonding called the Liability Management Regime (LMR; Dachis et al., 2017). The well levy, which is set as a proportion of firms' share of total liabilities, does not differentiate between financially strong and weak producers, and is not reflective of environmental risk. The LMR system does account for the financial strength of producers, and uses a three-year netback to calculate the value of their assets in order to account for fluctuating energy prices, which affect the value of the well. While Alberta's system has been adequate to cover costs in the past, a rising number of operator insolvencies, in combination with lower oil and gas prices, mean the existing system will not remain sustainable unless modifications are made. Further, Canada is confronting major legal questions regarding the order of priority for decommissioning costs in bankruptcy proceedings.

Finding 4-5: In Canada, Alberta collects an orphan well fee from all operators and utilizes contingent bonding based on the financial strength of the operator to pay for orphan wells. However, Alberta is facing an increase in insolvencies in combination with lower

2. CCR, Title 14, § 1722.8.

oil and gas prices and hearing major legal questions regarding the order of priority for decommissioning costs in bankruptcy proceedings.

Idle well management and regulation

When a well's production drops below a certain threshold the decision to continue producing will depend upon oil or gas prices. Operators may choose to stop production on a well that is not performing at an economical rate, keeping it officially active but maintaining it in an idle state rather than decommissioning it. Most states impose a limit on the amount of time a well can remain idle, after which the operator has a choice of restarting production, adopting a status called temporary abandonment (which is also generally limited), or decommissioning the well altogether. Generally, wells that are idle or temporarily abandoned come with stipulations that operators take some steps to limit or mitigate potential environmental impacts. States allow this as an incentive for operators who may reactivate the wells in the future, as it's more expensive to reactivate a fully decommissioned well than one which is simply idle. However, research has shown that the longer a well is idle, the greater the environmental risks, and that there is a low likelihood of returning a well to production (Muehlenbachs, 2017).

California in some respects has been more permissive than most states, with no specific limit on the time a well may remain idle before it must resume production or be decommissioned. Previously, California had a 300-month limit on a state of temporary abandonment, which was significantly longer than most states. Most states (19 out of 22 surveyed by Ho et al. (2016)) imposed a limit of no more than 24 months for idle wells, and (excluding California) an average maximum of 28 months for temporary abandonment; only six other states had default time limits as high as 60 months. All of the states but New Mexico, which regulates the duration of temporarily abandoned well status, allowed for some form of extension. Outside of the U.S., the provinces of Alberta and Saskatchewan also had no time limits for suspended wells (Dachis et al., 2017).

Finding 4-6: In contrast to California, many states imposed a limit on the length of time a well may be idle. However, in practice the impact of these rules tends to be limited by exemptions and extensions.

California was one of only two states (along with Texas) that didn't have explicit notification, approval, and inspection requirements for idle wells. Of the other states surveyed, only four require simple notification; the remaining 16 require some form of approval and/or inspection from the state before a well can be declared idle.

Although aspects of California's idle well regulations may be less stringent than other states, California has taken steps to try and limit the amount of time operators maintain wells in this status by increasing the fees required as in AB 2729 (Williams et al., 2016). This was intended as a financial disincentive to keeping wells idle for longer periods of time, during which time they may be more likely to have negative environmental impacts. As an alternative to fees, operators may file an idle well management plan, which requires the operator to eliminate a specific percentage of their long-term idle wells each year based on how many idle wells they have. In addition, AB 2729 also established requirements for idle well testing, beginning at least two years after a well becomes idle.[3] For idle wells that have been idle for 15 or more years, they will be required to be tested through an engineering analysis to show that they could potentially return to production. As of September 2018, the Division has proposed updated testing and management regulations with a deadline for public comment of September 13, 2018.

Plugging and restoration regulations and procedures

There exists significant variation among state regulations concerning how a well should be properly decommissioned. There are multiple aspects of well decommissioning that regulations may cover, including the types of material used, whether a surface casing plug is required, how or if the casing needs to be removed, and subsurface geography, such as oil- and gas-producing strata, water-bearing strata, and so forth. While pertinent regulations in virtually all states contain some general language about plugging the wells adequately, only some states offer specific requirements as to what kinds of materials and/or methods need to be used, and under what circumstances.

California regulations are more specific than most states in many respects, although the state has gaps in some areas compared to others. Ho et al. (2016) identified 17 regulatory elements which they used to survey 22 states and the BLM; they found California regulations to address 13 of these, placing the state in the bottom tier of the survey group. In terms of the stringency of their regulations overall, California placed ninth and sixteenth respectively in their quantitative and qualitative assessment of these regulations.

However, where California does have regulations in place, they tend to be more specific than many other states. For example, California was one of only three states surveyed with prescriptive requirements for different types of well plugs depending on the location within the well (bottom, middle, or top). Only Colorado and Ohio had similarly specific regulations for all three. California also requires permanent marking of decommissioned wells, a requirement in only half of the states surveyed. Both operators and regulators are required to report idle wells—a situation shared only by Wyoming and BLM lands. California's plugging regulations require plugs to be placed at the surface casing shoe, across oil and gas bearing strata extending 100 feet above the strata, extending from 50 feet below to 50 feet above water-bearing strata, and a 50-foot plug at the surface of the wellbore (NPC, 2011).

Notification, approval, and inspection requirements

California policy is similar to most other states with regard to reporting idle wells, the

3. This testing includes fluid level tests and casing pressure tests, with a follow-up schedule dependent upon the psi of the initial pressure tests.

plugging of wells, and decommissioning. California requires both regulators and operators to file reports detailing idle wells. It requires inspection pre- and post-plugging of the wells, but not post restoration of an abandoned well. In this, it is comparable to most other states reporting. Of those states which have evaluated their own abandoned well policies, most have concluded that they have not sufficiently ensured that operators comply with regulations (Louisiana Legislative Auditor, 2014; Joyce & Wirfs-Brock, 2015). California is no different in this regard. Outside the US, some Canadian provinces have a more rigorous and transparent system for ensuring required inspections and compliance. The Alberta Energy Regulator (AER) requires inspections at each stage and publishes regular reports on compliance violations and punitive actions taken.[4]

Most analyses which examine orphan well plugging and decommissioning costs warn that the price of plugging is likely to continue rising, if for no other reason than that the strongest single predictor of plugging cost appears to be the depth of the well, and well depths continue to rise. These rising costs, along with a potential need for older wells to be remediated in the future, suggests any financial assurance model based on static costs may require periodic revision. California's continual revisions to the regulations governing financial assurances indicate the state is more proactive than most in recognizing and attempting to manage the issue of orphan well closures. However, like most states, the state has (until recently) not had an enforcement infrastructure or adequate policy framework in place to effectively gauge the true scope of its potential and actual orphan well issues. California is implementing changes, including the recently updated idle wells program and the establishment of an Office of Enforcement, which should provide both more information about the scope of the issues and more effectively enforce regulations going forward.

Finding 4-7: As the total number of wells, cost to plug each well, and number of older wells requiring remediation is likely to increase for the foreseeable future, it is likely that any financial assurance model based on a static cost level will require periodic revision.

Conclusion 4-1: Historical experience and policy analysis in oil-producing regions throughout North America demonstrate the urgency and importance of orphan and idle well regulation. Most studies agree that higher bond requirements for operators will more fully internalize orphan well liabilities. Laws governing the priority of decommissioning costs are also important in determining potential costs to governments when operators become insolvent.

4. http://www1.aer.ca/compliancedashboard/enforcement.html

Conclusion

Significant financial concerns exist about decommissioning inactive wells—that is, permanently plugging the wells and reclaiming the surrounding well sites. All producing states and regions face challenges with managing and decommissioning what are known as orphan wells, those without a responsible owner. Since drilling began in the United States in the 1850's, over 2.5 million wells have ceased production. As of 2007 at least 149,000 of these are known to be orphan wells, though the actual number of orphan wells requiring potential remediation is almost certainly significantly higher.

Even the most productive well has a certain useful lifetime. Plugging the well properly at the end of this lifetime can be an expensive procedure whose cost can fluctuate significantly depending on numerous factors, including the well's depth, location, and the price of oil. Wells often pass through the hands of multiple operators through their operational lifetime; frequently operators controlling wells near the end of their lifetime are smaller companies more vulnerable to bankruptcy or dissolution, resulting in orphan wells which the state must then step in and plug itself.

As the overall number of wells has increased, so too has the number of orphan wells, and concomitantly the various states' financial burden. In recent years, state legislatures and oil and gas regulators have increased funding for well cleanup by appropriating more money and increasing bonding requirements. They also have tried to make it harder for companies to walk away from their wells, such as by intervening earlier to prod companies to reactivate or plug wells that are sitting idle.

California, like many states, has devoted increasing effort in recent years to designing a regulatory framework which seeks to both reduce the number of operators orphaning wells in the first place and secure financial assurances adequate to pay for plugging the well when necessary. Currently, California requires well operators to obtain individual or blanket bonds prior to drilling, reworking, or acquiring a well or wells. The amount of the bond required depends on the depth of the well, the number of wells owned by the operator, and the location of the well; bond amounts for most wells range from $25,000 for a single well to $3,000,000 for a blanket bond covering multiple wells. Offshore wells, which comprise only 2% of wells in California but are much more expensive to plug, require an additional bond. The State also collects fees on wells that are kept idle by operators. While the effective amount of bond funds varies across wells, an analysis of the Division data shows that bond funds are typically far below likely plugging and remediation costs.

The Division is currently in the process of implementing updates to their idle well fee and management requirements, including new idle well testing and reporting requirements. These requirements are intended to improve management of this population of wells and protect the State and public against both environmental and financial costs. Future evaluation efforts will gauge the success of these new regulations. For now, at least, there remain significant financial concerns about the existing inventory of orphan wells and the stock of inactive wells that could be orphaned.

While the State currently maintains a comprehensive list of idle (non-producing) wells, the share of these wells that are orphan wells is unknown. A coarse analysis of data provided by the Division on 228,648 wells suggests there are 2,565 “likely” orphan wells belonging to operators with no reported California activity in five years, and an additional 2,975 wells at high risk of becoming orphaned, which have had no production over the past five years and are owned by smaller operators with primarily low-producing wells (which other research suggests are more likely to orphan wells). After subtracting out bond funds associated with the wells, the potential net liability to the State for wells in these categories is about $500 million. There are an additional 69,425 idle and marginal wells and 31,722 higher-producing wells. The eventual cost to plug and abandon all existing wells in California is found to be about $9.1 billion. The share of this long-run cost that will be borne by the State (as opposed to operators) will depend on policy, market outcomes, and other factors.

It is too soon to tell whether California’s current bond requirements and idle well fee collection will prove adequate to cover the cost of orphan well plugging in upcoming years. One of the most significant challenges facing California, along with every other state, is inadequate data. It is not possible to adequately assess the scope of the problem when information about the status of idle wells is incomplete and gathered intermittently. For one thing, existing wells in California may be grandfathered in under previous bond requirements if operators have not reworked or acquired any wells since the most recent requirements were implemented. Also, some wells may have had their bonds released upon well completion, prior to plugging and decommissioning, under old requirements. This contrasts with the approach taken in other states such as Texas, which has implemented a universal bond requirement applicable to all wells, and which was one of the few whose available bond funds have been sufficient to offset the cost of plugging orphan wells in recent years.

As noted earlier, California’s situation is not unique. Analyses have found that most states struggle to meet the costs of plugging orphan wells and typically decommission only a fraction of known orphan wells each year. Like California, the states surveyed have updated their regulations in recent years but these efforts have generally proven insufficient to meet expenses so far.

The estimates we provide in this paper are preliminary and based on coarse sorting criteria using available data. As the Division implements the updated idle well regulations, with mandatory annual reporting requirements, California will gain a more comprehensive and accurate list of remaining hazardous and orphan wells, along with a better sense of responsible operators based on compliance with the updated requirements.

Historical experience and policy analysis in oil-producing regions throughout North

America demonstrate the urgency and importance of orphan and idle well regulation. Most studies agree that higher bond requirements for operators will more fully mitigate the State’s orphan well liabilities. Laws governing the priority of decommissioning costs are also important in determining potential costs to governments when operators become insolvent.

California’s recent regulatory changes are encouraging. However, it is essential that California continue to evaluate the status of its potential financial liability in upcoming years. A more detailed analysis will be necessary once the State’s new idle well reporting requirements are in place, in order to ascertain the State’s actual and potential liability more accurately.

The State must also be prepared to accept the fact that, due to the rising number of wells overall, cost to plug each well, and number of older wells requiring remediation, it is likely that any financial assurance model based on a static cost level will require periodic revision. Hopefully, the new information collected and subsequent analyses will help ensure that the State is in a better position to understand its liability, and that such revisions may be implemented in a timely manner.

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Glossary

Abandon – to properly plug and/or decommission a well

Blanket bond – a single bond or bond amount to cover one or more wells

Decommission – to remove all of the components of a production facility and restore the site where it is located

Idle well – a well that has not, for 24 consecutive months, produced oil or natural gas, produced water to be used in production stimulation, or been used for enhanced oil recovery, reservoir pressure management, or injection

Indemnity bond – also known as a surety bond, an agreement between three groups, the principal conducting the work (operator), the obligee to whom money is owed if obligations are not met (the State), and a surety bond company (surety)

Insolvent – unable to pay one's debts or when liabilities are greater than assets held

Long-term idle well – a well that has been an idle well for 8 or more years

Marginal well – a well that produces fewer than 10 barrel-of-oil equivalents per day

Orphan well – a well for which there is no known responsible operator or no financially viable operator capable of plugging and decommissioning the wells

Plug – to properly isolate, using cement and cement plugs and other required materials, the oil or gas containing components of a well from their surroundings, including from water reservoirs

Appendix A

Additional Background

A1. Select history of bonding requirements in California

Table 9: Select history of bonding requirements in California

Bill, Chapter	Year Bill	Individual PRC § 3204	Blanket Bonds PRC § 3205	Offshore Bonds PRC § 3205.1	Cash Bonds PRC § 3205(3)(b)	Idle Well Bonds and Fees PRC § 3206	Idle Well Mgmt. Plan PRC § 3206	Idle Testing/Reporting PRC § 3206.1
SB 724	**2017** SB 724							
AB 2729	**2016** AB 2729		Adds $2,000,000 > 500 and ≤ 10k $3,000,000 > 10k wells Repeals $2M all-inclusive bond		Removes explicit cash bond language in PRC, referencs Code of Civil Procedure bonding section	Fees for idles, even if bonded: 3 to under 8 yrs: $150 each 8 to under 15 yrs: $300 each 15 to under 20 yrs: $750 each 20 or longer: $1,500 each OR Idle Well Plan Repealed escrow option	≤ 250: 4% reduct.* 251 to 1,250: 5% reduct.* ≥ 1,250: 6% reduct.* *not less than one well/yr	Est. testing; 15 years+ tested that could return to production, not req. until at least 2 years after idle unless within 1/2 mile to underground drinking water. Reporting reqs for idle/orphan wells
SB 665	**2013** SB 665	$25,000 < 10k ft $40,000 ≥ 10k ft	When altering 20 or more wells: $200,000 ≤ 50 in state + Idle fees/bonds $400,000 > 50 in state + Idle fees/bonds $2,000,000 All, covers idle fees/bonds	$1,000,000				
AB 2581	**2000** AB 2581	Revised operator liability for reabandonment; expanded supervisor authority						
SB 1763	**1998** SB 1763	$15,000 < 5k ft $20,000 — $30,000 > 10k ft	When altering 1 or more wells: $100,000 if 50 or fewer in state $250,000 if more than 50 in state $1,000,000 All wells and idle fees extra		Blanket: If prior to 1/1/1999 increased minimum $30k per yr until matching	Less than 10 yrs: $100 10 to under 15 yrs: $250 15 yrs or longer: $500 OR $5,000 escrow per ($500 per year for 10 yrs) OR $5,000 indemnity per OR Management Plan AND Acquired idles need bonds	≤ 20 idle wells: 1 per yr. 21 to 50: 2 per yr. 51-100: 5 per yr. 101-250: 10 per yr. > 250 wells: 4% per yr.	
SB 2007	**1996** SB 2007	Fallback to transfers on or after 1/1/1998						
AB 1504 Ch. 1179	**1993** AB 1504			Allowed full cost security for plugging all offshores				
SB 2693	**1990** SB 2693					$5,000 bond/well or $100,000 blanket or $100/well annually		
Ch. 112	**1977** Ch. 112	$10,000 < 5k ft $15,000 -- $25,000 > 10k ft	When altering 1 or more wells: $100,000	$250,000	$12,000 $18,000 $30,000 Blanket: $120,000 Offshore: $300,000			
Ch. 794	**1976** Ch. 794	$25, 000 / well	When altering 1 or more wells: $250,000		$30,000 Blanket: $300,000			
Ch. 898	**1972** Ch. 898	Need bond to plug						
Ch. 1670	**1955** Ch. 1670		When altering 1 or more wells: $25,000					
Ch. 93	**1939** Ch. 93	$5,000 / well	When altering 5 or more wells: $25,000 (Covers all wells)					
Ch. 718	**1915** Ch. 718	Division established						

Appendix B

Additional Results

B1. Alternative rules for identifying orphan wells

Our analysis in Chapter 3 proposes a rough screen for categorizing wells according to their risk of becoming orphan wells. This section explores how the results of that exercise vary if we change the assumptions used to classify wells.

Figure 8 shows the number of "likely orphan wells" and "wells at high risk of becoming orphan wells" under a range of assumptions. The 40 markers in this figure represent well counts under different classification rules. The green circles show how the number of "likely orphan wells" varies with the minimum required period of inactivity at all of an operator's wells. Varying this period between one and ten years has a small effect on the implied count of likely orphan wells.

The three other marker types explore the number of wells "at high risk of becoming orphan wells." Recall that these are currently inactive wells whose operators are active but potentially vulnerable to insolvency or otherwise at risk of not plugging and abandoning wells. Each symbol type corresponds to a different rule for identifying potentially vulnerable operators. The various points for each symbol type show the number of wells that have been idle for the number of months on the horizontal axis, and whose operators are vulnerable under the given vulnerability rule. In our main analysis, we define operators as vulnerable if they have fewer than 1,000 wells and their average production is less than five BOE per well per day. That rule is shown with the orange triangles. The purple squares and pink crosses vary the number of wells threshold up and down, while maintaining the five BOE per well per day threshold.

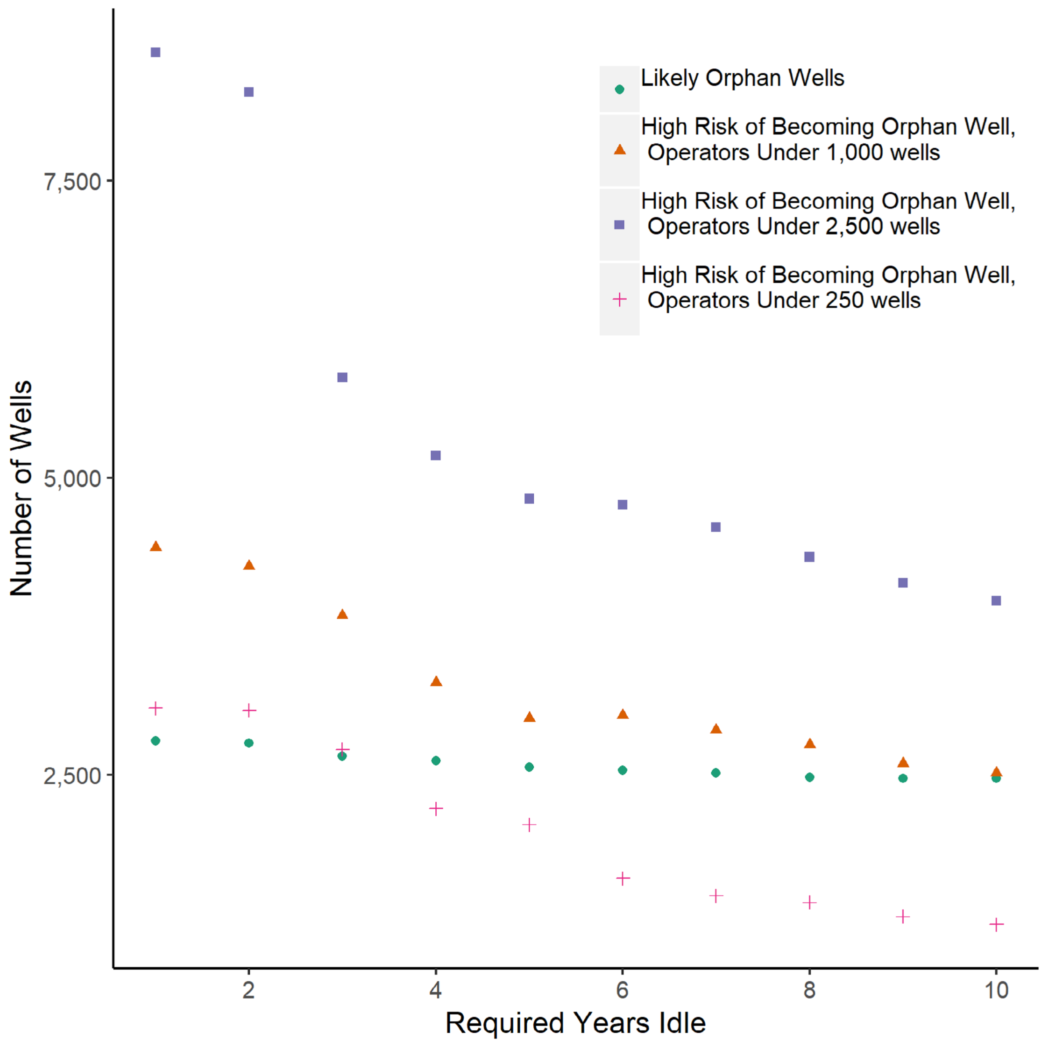

Figure 8. Alternative assumptions for orphan well risk assessment. Each marker shows a count of wells in a given category, using various assumptions about orphan well risk. The marker styles correspond to four different sets of related assumptions. See text for details.

B2. Probability of restarting production

A common challenge in analyzing and regulating idle wells is understanding whether wells are kept idle because the operator has a reasonable expectation of eventually resuming production, or simply to defer decommissioning costs. If it is the former, plugging the well creates additional economic costs in terms of foregone option value. Plugging the well today increases the cost of resuming production in the future if prices or technology improve. It is impossible to know any individual operator's expectations about future production, but we can use historical data on idle wells to understand the average likelihood of returning to production after a given interval with no production. The most sophisticated existing economic research on this question is Muehlenbachs (2015), which considers idle oil and gas wells in Alberta, Canada. That research concludes most long-term idle wells are unlikely to return to production even with large increases in output prices or improvements in production technology. Given appropriate data, a similar study could be carried out for California. This appendix describes a first pass at this type of analysis for California using the data that were readily available and describes what would be required to study this question in more detail.

One relatively straightforward statistic to calculate is the share of wells kept idle in the past that have eventually returned to production. Specifically, conditional on reaching a given length of time without producing (and without being plugged), what is the probability that an idle well will eventually return to production? Figure 9 reports the results of such a calculation. For wells with a given period idle during 1977—2008, the figure shows the probability that the well resumed production prior to the end of 2017. Intuitively, the probability of resuming production decreases with the length of time since the well last produced. After one year idle, there is an almost 50% chance of resuming production on average. Once a well has been idle for 25 years, that probability falls to about 12%. This retrospective analysis represents a historical average across all wells and should be interpreted with caution. There may be substantial heterogeneity in restart probabilities across different fields, well types and operators. A detailed study of option value associated with idle wells in California would need to consider these factors. In addition, it would be important to consider a range of future price and technology projections.

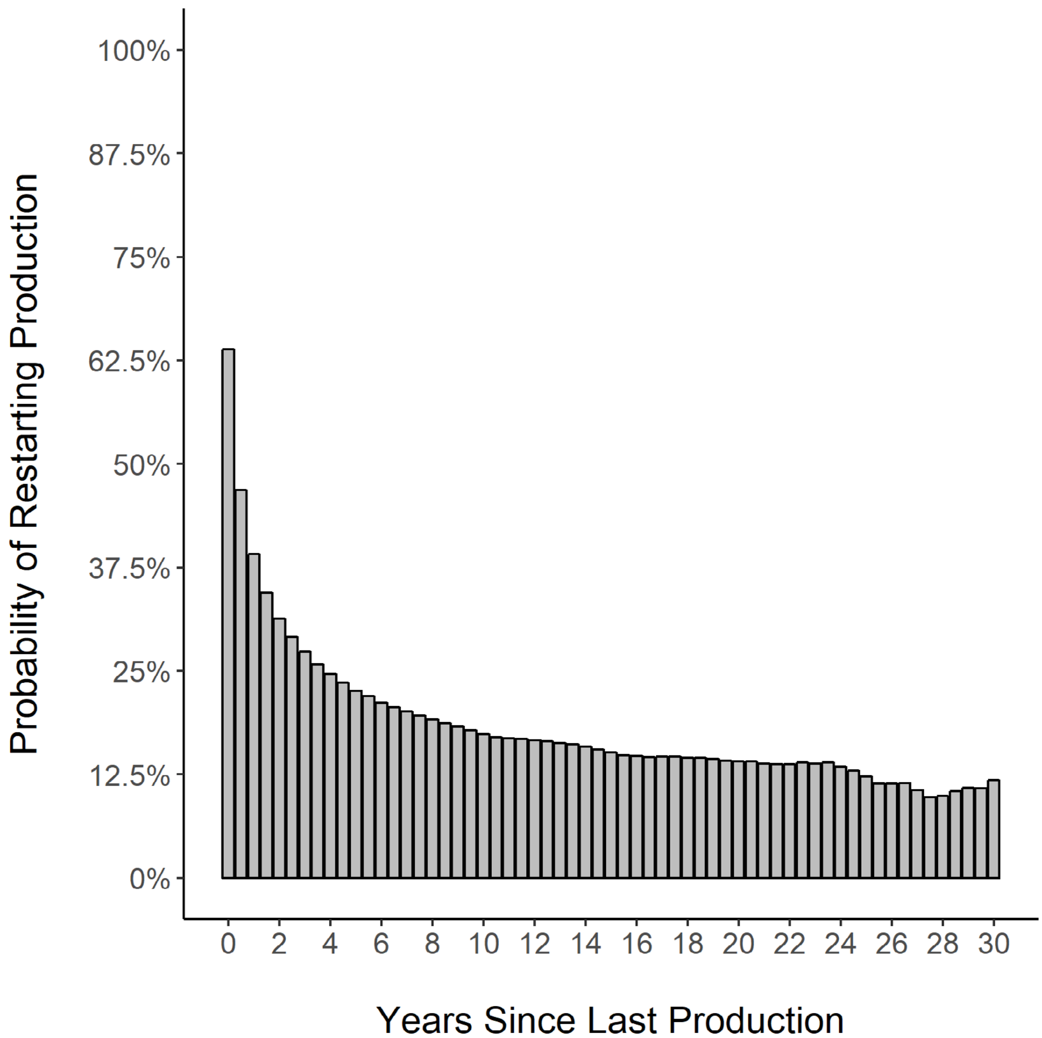

Figure 9. Historical probability of restarting production after a given idle interval. This figure shows the probability a well will restart production following a given period idle. To allow at least 10 years for production to resume, this figure is limited to 1977–2008. Wells that produced oil or natural gas in at least one month before the end of 2017 are considered to have resumed production. See text for details.

B3. Relationship between plugging costs and imputed well depth

Data on well depth were not available for any of the 86 wells with historical plugging costs (Table 7). As an attempt to impute well depth, the average depth of other wells in the field containing the well was used as a proxy. Figure 10 shows the relationship between plugging costs and the imputed depth measure. Instead of indicating no relationship between cost and well depth, this figure likely serves as evidence that imputed well depth is a poor proxy for actual well depth.

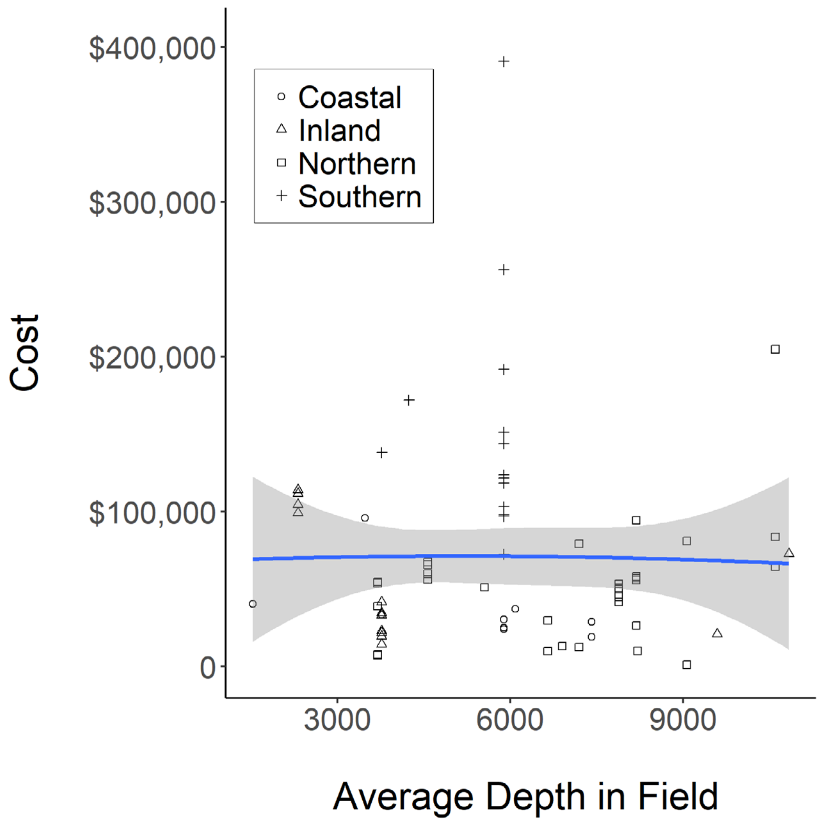

Figure 10. Relationship between plugging costs and imputed well depth. Data on well depth were not available for any of the 86 wells with historical plugging costs. This figure likely serves as evidence that imputing well depth using the average depth of other wells in the field containing the well is a poor proxy for actual well depth.

Appendix C

Construction of the Dataset

This section describes how the raw datasets provided by the Division were combined to create the final analysis dataset.

Monthly production and injection data

The raw monthly production data consist of 43,875,893 monthly observations for 176,823 wells. We drop a small number of observations prior to January 1, 1977, since reporting for most wells begins in 1977. We also drop observations after December 31, 2017, since the completeness of the data for 2018 appears to vary across wells. Missing values are reported for some monthly production observations. We replace these values with zeros if they occur after the first observed non-zero production for a given well. We drop these observations if the month is earlier than the first month of non-zero production for the well. There are also gaps in the production records for some wells. We fill in zero production in any missing months after the first reported production from each well. We further incorporate data on monthly injection volumes from the Division's monthly well injection dataset to identify wells currently being used for injection.

Well-level characteristics files

The well-level characteristics data include 270,524 records. We exclude 29,783 duplicate records with identical API numbers and wellbore codes. We further exclude 12,093 wells with a status of "Cancelled", which indicates that these wells were permitted but never actually drilled.

We successfully merge 94% of active and idle wells and 61% of plugged wells to the production dataset. In our analysis of active and idle wells, for the remaining 6% of wells that do not appear in the production dataset, we assume that there was no reported production during the period of the data, and so assign these wells zero production in every month.[1]

Plugging cost data

As described in the main text, the Division provided various records of plugging costs for wells that have been plugged at state expense. By combining these records, we were able to

1. Hand checking of a subsample of the unmerged records with the Division's online well search tool supports our assumption that the unmerged records represent very old wells with no recent production.

identify 86 unique wells where costs were reported at the individual well level and an API number was included in the record.

Well depth data

The Division provided information on well depth for a subsample of 27,530 wells. We generate an interpolated depth for as many wells as possible by using these observed depths to calculate an average depth in field for every oil field where we observe at least one well depth.

Appendix D

CCST Study Team

Full curricula vitae for the Study Team members are available upon request. Please contact California Council on Science and Technology (916) 492-0996.

Study Team Members:

- **Judson Boomhower**, PhD, University of California, San Diego
  Lead Author

- **Terence Thorn**, JKM Consulting
  Steering Committee (Chair)

- **Mikel Shybut**, PhD, California Council on Science and Technology
  Author and Project Manager

- **M. Daniel DeCillis, PhD**, California Council on Science and Technology
  Author

- S**arah E. Brady, PhD**, Interim Deputy Director, California Council on Science and Technology
  Project Director

- **Amber J. Mace, PhD**, Interim Executive Director, California Council on Science and Technology

Judson Boomhower, Ph.D.

Lead Author
Assistant Professor, Department of Economics, UC San Diego

Judson Boomhower is an applied microeconomist who studies environmental and energy economics and policy. His research covers a range of topics and industries including oil and gas extraction, electricity markets, energy efficiency, and the economics of climate change. He received a PhD in Agricultural and Resource Economics from the University of California, Berkeley. He earned his bachelor's and master's degrees from Stanford.

Terence Thorn

Steering Committee Chair
President, JKM Energy and Environmental Consulting

Terence (Terry) Thorn is a 43-year veteran of the domestic and international natural gas industry and has held a wide variety of senior positions beginning his career as Chairman of Mojave Pipeline Company and President and CEO of Transwestern Pipeline Company. He has worked as an international project developer throughout the world.

As a Chief Environmental Officer, Terry supported Greenfield projects in 14 countries to minimize their environmental impact. He wrote and had adopted company wide Environmental Health and Safety Management Standards and implemented the first environmental management plan for pipeline and power plant construction. In attendance at COP 1 and 2, Terry has remained involved in the climate change discussions where he is focusing on international policies and best practices to control methane emissions.

Residing in Houston, Terry is President of JKM Energy and Environmental Consulting and specializes in project development and management, environmental risk assessment and mitigation, business and policy development, and market analysis. He has done considerable work in the areas of pipeline integrity management systems, management systems auditing, safety and reliability and the reduction of methane emissions from natural gas facilities.

He also serves as Senior Advisor to the President of the International Gas Union where he helps drive the technical, policy and analytical work product for the 13 Committees and Task Forces with their 1000 members from 91 countries. He also serves on the Advisory Boards for the North American Standards Board where he co-chaired the gas electric harmonization task force, and the University of Texas' Bureau of Economic Geology's Center for Energy Economics. Terry is also on the Board of Air Alliance Houston. He served on the CCST California Council on Science and Technology steering committee for the report that provided the state with an up-date and independent technical assessment of the thirteen natural gas storage fields in California. Currently he is on the CCST team that will estimate the liability and costs to the state of plugging and abandoning oil and gas wells and decommissioning their attendant facilities.

Terry has published numerous articles on energy, risk management and corporate governance and was author of the International Energy Agency's 2007 North American Gas Market Review. As advisor to European gas companies and regulators he co-authored The Natural Gas Transmission Business -a Comparison Between the Interstate US-American and European Situations, Environmental Issues Surrounding Shale Gas Production, The U.S. Experience, A Primer. As a participant in the National Petroleum Council Study Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources (September 2011), Terry wrote the section on electric gas harmonization, co-authored the chapter on electric generation, and advised on the residential commercial chapter. Most recently he has completed market research projects on electricity markets, gas markets including modeling the US gas markets 2015-2050. Gas Shale Environmental Issues and Challenges was just published by Curtin University in 2015. His most recent papers are "The Bridge to Nowhere: Gas in An All Electric World," "The Paradigms of Reducing Energy Poverty" and "Making Fossils Fuels Great Again: Initial Observations About Trump's Energy Policy."

Mikel Shybut, Ph.D.

Author and Project Manager
Program Associate, California Council on Science and Technology

Mikel Shybut is a CCST Program Associate. Previously he was a CCST Science and Technology Policy Fellow appointed to the California State Senate on the Transportation and Housing Committee, which analyzes legislation covering policy areas from essential infrastructure needs to autonomous vehicles and affordable housing.

Shybut received his PhD in Plant Biology from UC Berkeley, where he studied the molecular mechanisms of cassava bacterial blight, a disease of agricultural significance in the tropics. Shybut completed his BA in Biological Chemistry and in Russian at Grinnell College in Iowa.

M. Daniel DeCillis, Ph.D.

Author

Senior Research Associate, California Council on Science and Technology

M. Daniel DeCillis is Senior Research Associate & Director of Web Operations at the California Council on Science and Technology, where he has worked since 2001. He has been principal project writer on studies including the Overview of California State-Funded R&D, 2004-2007 (2008), Critical Path Analysis of California's Science and Mathematics Teacher Preparation System (2007), An Industry Perspective of the Professional Science Master's Degree in California (2005), Opportunities for Collaboration in High-tech Research and Teacher Professional Development (2004), the Critical Path Analysis of California's Science and Technology Education System (2002), and The Preparation of Elementary School Teachers to Teach Science in California (2010); he has also contributed substantially to CCST projects on nanotechnology, energy, and intellectual property. In addition he designed and edited the Workforce Investment Board Online Toolkit (2008), a major component of CCST's contributions to the California Innovation Corridor project. In 2011, he edited and reviewed Imagining the Future: Digitally Enhanced Education in California and components of California's Energy Future. In 2012, he completed the California Climate Change Research Database website. He was part of the team that produced the 2014 report Achieving a Sustainable California Water Future through Innovations in Science and Technology and a co-author on Promoting Engagement of the California Community Colleges with the Maker Movement (2016) and The Maker Movement and K-12 Education (2017).

DeCillis has presented CCST's work on a variety of projects in numerous venues (including the Legislature and the National Academies) both in California and abroad. Since 2002, he has served as primary writer and editor for CCST's Annual Report and newsletter; he is also responsible for design and management of the CCST website. From 2001- 2004 he served as the Managing Editor for the Journal of Robotic Systems. Prior to this, he worked as a paleographer and French instructor; he holds an M.A. and a Ph.D. in Romance Studies from Duke University and a B.A. with High Honors in French and Latin from Oberlin College.

Sarah E. Brady, Ph.D.

Project Director
Interim Deputy Director, California Council on Science and Technology

Sarah Brady, Ph.D. is the Interim Deputy Director for CCST. In addition to managing large-scale commissioned projects requested by the Legislature and state agencies, Sarah leads outreach efforts to connect CCST's network of experts with state decision makers.

Prior to joining CCST, Sarah served as Legislative Director in Assemblywoman Susan Bonilla's office where she was hired after her placement as a CCST Science and Technology Policy Fellow in 2014. During her time with Assemblywoman Bonilla, Sarah initiated policy work to retain women in STEM careers by preventing pregnancy discrimination in graduate programs. As a result of legislation that she conceptualized and staffed through the process, the law now requires all California colleges to establish a family leave policy for their graduate students. Sarah also spearheaded legislation to increase the use of biomethane, reduce the cost of college textbooks, and improve access to computer science education. In addition, she conducted bill analysis and provided vote recommendations to Assemblywoman Bonilla on all bills related to utilities and commerce, energy, water, natural resources, and environmental toxicity.

Sarah earned Bachelor's degrees in Chemistry and French from North Central College and a Doctorate in Chemistry at the University of Oregon researching the degradation of plastics. She was also a GK-12 Fellow and an NSF-IGERT Fellow where she worked at the Hong Kong Baptist University. In her free time, Sarah likes to watch the Green Bay Packers, brew beer, camp, and is the Co-Chair for the CCST Science Fellows Alumni Group.

Amber J. Mace, Ph.D.

Interim Executive Director, California Council on Science and Technology

Amber Mace, Ph.D. is the Interim Executive Director of the California Council on Science and Technology (CCST) and is a Policy Fellow with the UC Davis Policy Institute for Energy, Environment and the Economy. Mace devotes her time to building new and revitalizing existing programs and organizations that are dedicated to increasing the impact and value of science-informed decision-making. Prior to this, Mace served as the Associate Director of the UC Davis Policy Institute for Energy, Environment and the Economy. She also served as the Executive Director of the California Ocean Protection Council (OPC) and Assistant Secretary for Coastal Matters at the California Natural Resources Agency. In this role she applied her background in ocean policy and marine ecology and collaborative leadership skills to guide the state in developing policies that promote the sustainable use of California's ocean ecosystem. Prior to that, she served in the dual roles of science advisor to the OPC and executive director of the California Ocean Science Trust, a non-profit whose mission is to provide objective, high-quality science to decision makers.

She learned firsthand about the challenges of public policy-making at the federal level as a Knauss Fellow in the U.S. Senate Commerce, Science and Transportation Committee, and at the state level as a California Sea Grant state fellow at the California Natural Resources Agency. Amber was recognized as a Coastal Hero by Sunset magazine in 2011 and her California coastal research experience includes piloting a submersible with the Sustainable Seas Expedition. She earned a Bachelor of Arts in geography from UC Berkeley and a doctorate in ecology from UC Davis and the Bodega Marine Laboratory.

Appendix E

Expert Oversight and Review

Oversight Committee:

- **Richard C. Flagan**, California Institute of Technology, CCST Board Member
- **Samuel J. Traina**, University of California, Merced, CCST Board Member
- **Robert F. Sawyer**, University of California, Berkeley, External Member

Report Monitor:

- **Robert F. Sawyer**, University of California, Berkeley

Expert Reviewers:

- **Scott Anderson**, Environmental Defense Fund
- **Dan Arthur**, ALL Consulting, LLC
- **Peter Maniloff**, Colorado School of Mines
- **James McCall**, National Renewable Energy Laboratory
- **Lucija Muehlenbachs**, University of Calgary
- **Samuel J. Traina**, University of California, Merced

Appendix F

CCST Study Process

California Council on Science and Technology (CCST) studies are viewed as valuable and credible because of the organization's reputation for providing independent, objective, and nonpartisan advice with high standards of scientific and technical quality. Checks and balances are applied at every step in the study process to protect the integrity of the studies and to maintain public confidence in them.

Study Process Overview—Ensuring Independent, Objective Advice

For 30 years, CCST has been advising California on issues of science and technology by leveraging exceptional talent and expertise.

CCST enlists the state's foremost scientists, engineers, health professionals, and other experts to address the scientific and technical aspects of society's most pressing problems.

CCST studies are funded by state agencies, foundations and other private sponsors. CCST provides independent advice; external sponsors have no control over the conduct of a study once the statement of task and budget are finalized. Authors and the Steering Committee gather information from many sources in public and private meetings, but they carry out their deliberations in private in order to avoid political, special interest, and sponsor influence.

Stage 1: Defining the Study

Before the author(s) and Steering Committee selection process begins, CCST staff, Board Members, Council Members and other relevant experts work with the study sponsors to determine the specific set of questions to be addressed by the study in a formal "statement of task," as well as the duration and cost of the study. The statement of task defines and bounds the scope of the study, and it serves as the basis for determining the expertise and the balance of perspectives needed for the study authors, Steering Committee members, and peer reviewers.

The statement of task, work plan, and budget must be approved by CCST's Project Director in consultation with CCST leadership. This review sometimes results in changes to the proposed task and work plan. On occasion, it results in turning down studies that CCST believes are inappropriately framed or not within its purview.

Stage 2: Study Author(s) and Steering Committee (SC) Selection and Approval

Selection of appropriate authors and SC members, individually and collectively, is essential for the success of a study. All authors and SC members serve as individual experts, not as representatives of organizations or interest groups. The size of the SC depends on the size and scope of the study.[1] Each expert is expected to contribute to the project on the basis of his or her own expertise and good judgment. Each provisional SC member and author complete a COI form and submit current resumes. CCST staff send all of this information to outside counsel for a thorough COI review and then organize all results and recommendations from the outside counsel. CCST organizes an in-person meeting for the provisional SC and lead authors to discuss the balance of the committee and evaluate each person for any potential COIs based on the outside counsel feedback. Any issues raised in this discussion are investigated and addressed. CCST sends the list and COI information of the provisional SC and lead authors, including any recommendations or concerns from the in-person meeting, to the Oversight Committee (created by the Board and made up of two CCST Board Members and an outside expert) for final approval. While the lead authors attend the meeting for the discussion of their own potential COIs they do not contribute to the discussion of the provisional SC Member's COIs. Members of a SC and the lead author(s) are anonymous until this process is completed. The lead author(s) maintain continued communication with the SC as the study progresses through frequent updates and background meetings.

Careful steps are taken to convene SCs that meet the following criteria:

An appropriate range of expertise for the task. The SC must include experts with the specific expertise and experience needed to address the study's statement of task. A major strength of CCST is the ability to bring together recognized experts from diverse disciplines and backgrounds who might not otherwise collaborate. These diverse groups are encouraged to conceive new ways of thinking about a problem. The size of the SC depends on the size and scope of the study.

A balance of perspectives. Having the right expertise is not sufficient for success. It is also essential to evaluate the overall composition of the SC in terms of different experiences and perspectives. The goal is to ensure that the relevant points of view are, in CCST and the Oversight Committee's judgment, reasonably balanced so that the SC can carry out its charge objectively and credibly.

Screened for conflicts of interest. All provisional SC members are screened in

1. Due to the short duration of this study, the study had only a Steering Committee Chair. Authors drafted findings and conclusions and the lead author drafted recommendations in coordination and with final approval from the Steering Committee Chair.

writing and in a confidential group discussion about possible conflicts of interest. For this purpose, a "conflict of interest" means any financial or other interest which conflicts with the service of the individual because it could significantly impair the individual's objectivity or could create an unfair competitive advantage for any person or organization. The term "conflict of interest" means something more than individual bias. There must be an interest, ordinarily financial, that could influence the work of the SC or that could be directly affected by the work of the SC. Except for those rare situations in which CCST and the Board appointed Oversight Committee determine that a conflict of interest is unavoidable and promptly and publicly disclose the conflict of interest, no individual can be appointed to serve (or continue to serve) on a SC used in the development of studies if the individual has a conflict of interest that is relevant to the functions to be performed.

Point of View is different from Conflict of Interest. A point of view or bias is not necessarily a conflict of interest. SC members are expected to have points of view, and CCST attempts to balance these points of view in a way deemed appropriate for the task. SC members are asked to consider respectfully the viewpoints of other members, to reflect their own views rather than be a representative of any organization, and to base their scientific findings and conclusions on the evidence. Each SC member has the right to issue a dissenting opinion to the study if he or she disagrees with the consensus of the other members.

Other considerations. Membership in CCST are taken into account in SC selection. The inclusion of women, minorities, and young professionals are additional considerations.

Specific steps in the SC selection and approval process are as follows:

CCST staff solicit an extensive number of suggestions for potential SC members from a wide range of sources, then recommend a slate of nominees. Nominees are reviewed, as a provisional SC, at several levels within CCST. Prior to final approval, the provisional SC members complete background information and conflict-of-interest disclosure forms. The SC balance and conflict-of-interest discussion is held at the first SC meeting. Any conflicts of interest or issues of SC balance and expertise are investigated; changes to the SC are proposed and finalized. Finally, the provisional SC is presented to the Oversight Committee for formal approval. SC members continue to be screened for conflict of interest throughout the life of the committee.

CCST uses a similar approach as described above for SC development to identify study authors who have the appropriate expertise and availability to conduct the work necessary to complete the study. In addition to the SC, all authors, peer reviewers, and CCST staff are screened for COI.

Stage 3: Author and Steering Committee Meetings, Information Gathering,

Deliberations, and Drafting the Study

Authors and the Steering Committee typically gather information through:

1. meetings;
2. submission of information by outside parties;
3. reviews of the scientific literature; and
4. investigations by the study authors and/or SC members and CCST staff.

In all cases, efforts are made to solicit input from individuals who have been directly involved in, or who have special knowledge of, the problem under consideration.

For larger reports, lead authors may request additional authors to ensure the appropriate expertise is included. Every author must be approved by the SC and CCST staff. Some of the additional authors may become section leads. The lead author reviews and approves the work of all other chapter authors, including section leads.

During the course of a report, authors' duties may shift which may change the lead author or section lead designations. Any such changes must be made in conjunction with CCST staff and the SC. If the reorganization of author responsibilities or the addition of a new author raises conflict of interest concerns, they are presented to and resolved by the Oversight Committee.

The authors shall draft the study and the SC shall draft the Executive Summary which includes findings, conclusions, and recommendations (FCRs). In some cases, the authors write the first draft of the FCRs to ensure they are based on the information and analysis contained in the full report. The draft FCRs are then edited and approved by the SC. The SC deliberates in meetings closed to the public in order to develop draft FCRs free from outside influences. All analyses and drafts of the study remain confidential.

Stage 4: Report Review

As a final check on the quality and objectivity of the study, all CCST full commissioned reports must undergo a rigorous, independent external peer review by experts whose comments are provided anonymously to the authors and SC members. CCST recruits independent experts with a range of views and perspectives to review and comment on the draft report prepared by the authors and the SC. The proposed list of peer reviewers is approved by the Oversight Committee to ensure all report sections are adequately reviewed.

The review process is structured to ensure that each report addresses its approved study charge, that the findings are supported by the scientific evidence and arguments presented, that the exposition and organization are effective, and that the report is impartial and objective.

The authors and the SC must respond to, but need not agree with, reviewer comments in a detailed “response to review” that is examined by one or more independent “report monitor(s)” responsible for ensuring that the report review criteria have been satisfied. After all SC members and appropriate CCST officials have signed off on the final report, it is transmitted to the sponsor of the study and the sponsor can release it to the public. Sponsors are not given an opportunity to suggest changes in reports. All reviewer comments and SC deliberations remain confidential. The names and affiliations of the report reviewers are made public when the report is released.

Appendix G
Acknowledgements

The study leads would like to acknowledge the support and efforts of many individuals involved in making this report possible.

Dr. Sarah Brady, the Interim Deputy Director of CCST, served as the project director, overseeing the study from initial concept to development and implementation. Dr. Mikel Shybut, project manager, coordinated the study process from finding appropriate experts to contracting and scheduling, and also served as an author. Dr. M. Daniel DeCillis, CCST Senior Research Associate, served as an author for this study. Puneet Bhullar, CCST project assistant, provided additional support and coordinated the peer review process. Other staff at CCST, including Dr. Brie Lindsey who provided insightful feedback in discussions, and CCST's Interim Executive Director Amber Mace who guided the project from its earliest stages. We would like to thank the Technical Editor Becky Oskin as well as the CCST staff who proofread, including Dr. Christine Casey, Donna King, and Christy Shay.

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CCST
1130 K Street, Suite 280
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