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Regulation of Hydraulic Fracturing in California: A Wastewater and Water Quality Perspective

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Regulation of Hydraulic Fracturing in California: A WASTEWATER AND WATER QUALITY PERSPECTIVE

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I. Executive Summary

Oil and gas producers have used hydraulic fracturing (“fracking”) in California for many years. What is new, and potentially alarming, are projections of dramatically increased fracking activity in California brought on by the availability of new techniques. Such developments may have outstripped the ability of responsible agencies to effectively oversee fracking activity. The challenges faced by other states that have experienced fracking booms have not been lost on California’s leaders and concerned citizens – fracking is currently the subject of intense scrutiny, and the need has never been greater for clear information and analysis on the topic.

Hydraulic fracturing is the process of injecting fluids under high pressure to crack underground rocks and release tightly held oil or gas. Hydraulic fracturing, along with the other aspects of unconventional oil and gas production, presents risks to environmental quality and public health. The hydraulic fracturing process also yields byproducts, including wastewater, which must be properly managed in order to reduce any risk to human health and the environment. In this report, we focus on the set of risks related to wastewater from fracking and its attendant activities, and its potential impacts on groundwater and surface water resources in California.

Fracturing “flowback” (fracturing fluid injected into wells that returns to the surface after pressure is released) and “produced water” (all wastewater that emerges from the well after production begins) contain potentially harmful chemicals, some of which are known carcinogens. Produced water is also highly saline and potentially harmful to humans, aquatic life and ecosystems.

Risks to water quality stem primarily from: improper storage and handling of fluids at the well site, including spills and improper lining of pits; injection of wastewater into disposal wells, which can trigger earthquakes; and potential for groundwater contamination due to failure of well integrity. However, uncertainty is high. There are few peer-reviewed scientific studies on the potential risks to

water quality from fracking activities, and fewer still focused on California.

In recent years, many states, including Pennsylvania, Ohio, North Dakota, Wyoming and Texas, have experienced a boom in fracking activity. Many of these states have developed new regulations that can inform California’s efforts to address similar challenges.

In California, the Department of Conservation’s Division of Oil, Gas & Geothermal Resources (DOGGR) is the primary agency with regulatory authority over hydraulic fracturing in the state. The State Water Resources Control Board (SWRCB) and Regional Water Quality Control Boards (RWQCBs) are responsible for the State’s groundwater and surface water resources, including impacts associated with oil and gas operations. However, up to now, there has been little interagency coordination in addressing fracking and its attendant impacts.

Despite increasing attention to the issue, there is a stark lack of clarity among regulators and the concerned public about what fracking is in California, how it differs from fracking in other states, the risks that it presents, and how to best manage and regulate the process.

Purpose and structure of this report

This report focuses on water-related issues surrounding hydraulic fracturing and attendant unconventional oil and gas production processes in California. The report highlights the overarching need for more unbiased information on fracking and its potential impacts, greater public notice and transparency, and increased accountability across all hydraulic fracturing operations and attendant activities.

The report incorporates both the technical and regulatory perspectives that are necessary to design effective regulations. First, in order to present the necessary technical background, the report: (1) reviews technical issues, including how fracking in California may differ from fracking in other states;

(2) identifies technical elements of the production process that impact how fracking should be regulated; (3) identifies management options for oil and gas wastewater; and (4) identifies potential risks to environmental and human health from the practice of fracking.

Second, from a regulatory perspective, the report reviews and synthesizes the relevant federal and state regulatory landscape and identifies current legislative and regulatory actions. Finally, the report provides recommendations for better management and regulation and identifies key uncertainties and knowledge needs.

Near term regulatory, legislative and legal action

This report comes during a time of intense activity in California on the topic. DOGGR, the state agency with primary responsibility for regulating oil and gas activity, is in the midst of a pre-rulemaking process to gather input on “discussion draft” regulations specific to hydraulic fracturing. DOGGR’s discussion draft rulemaking addresses some key elements of hydraulic fracturing: well construction; testing and monitoring requirements; public and agency notice and disclosure; and storage and handling of fracking fluids.

At the time of this report, nine bills on hydraulic fracturing have been introduced to the State legislature for the current session, addressing topics such as advance notice, trade secrets, and baseline water testing. Other bills would require new scientific studies on the risks presented by fracking or impose a moratorium on fracking altogether until further studies are conducted.

Further, several environmental organizations have filed lawsuits against DOGGR seeking to change their process of permitting hydraulic fracturing wells, and myriad interest groups are intensely engaged with the process.

It is against this backdrop that we offer a synthesis of the issues and recommendations for moving forward.

Management options and recommendations

There are three main options for management of oil and gas wastewater in California: injection in disposal wells, reuse and recycling for oil and gas production, and treatment to acceptable standards for discharge or reuse. In addition, hydraulic fracturing events themselves present risks to the environment if not conducted safely. Best practices, ranging from well construction to testing to monitoring, are essential for safety.

Based on our review of existing scientific and legal information, and experiences in other states, we provide recommendations for each management option in California. We also set forth recommendations for increased notice and disclosure before hydraulic fracturing events.

Several themes emerge from our analysis and inform our recommendations:

- Increased transparency and accountability will improve safety and empower citizens and stakeholders. Providing adequate advance notice on where, when, and how fracking will take place allows communities to evaluate and respond to potential risks before they are realized. It also enables regulators and emergency responders to be prepared for potential spills or contamination events. Increased disclosure will also help assess responsibility and liability for any potential contamination of water sources.
- Better technical regulations for production and disposal wells will improve safety and accountability. Because well casing and cementing failure is a primary risk for underground contamination, stringent testing and monitoring of well integrity is critical.
- Baseline water testing and comprehensive information on the contents of fracking fluid are necessary to determine whether a potential contamination event has occurred and what party is responsible. In addition, new techniques such as labeling injected fluids with unique tracers could enable tracing contamination back to individual wells and operators with more precision.

- Scientific uncertainty drives the need for more research on a suite of topics, including but not limited to induced seismicity and the risk of ground or surface water contamination.
- Available and applied technology is rapidly evolving – specifically, the use of multi-stage, directionally drilled, high-volume hydraulic fracturing has increased throughout the country, as well as new techniques such as acid matrix fracturing. This changing technical landscape is difficult to regulate effectively without greater knowledge of such evolving technologies and their attendant risks.
- The legislature and DOGGR should not shy away from finding that there is not enough scientific knowledge or institutional capacity to effectively manage a sharp increase in the expansion of hydraulic fracturing in California. If it makes this determination, it may choose to slow its growth until more knowledge and capacity can be developed. We recognize the political and economic costs of a moratorium on fracking may be significant, so we offer the following analysis and recommendations to guide alternate pathways to manage its growth.
- DOGGR should also provide 30 days advanced notice before any fracturing or injection event on a publicly-accessible website that meets accessibility criteria outlined in the main text.
- DOGGR should convene stakeholders to develop a formal process by which concerned citizens can respond to planned fracking events in their communities.

Trade secret provisions

- Operators and service providers should be required to disclose even trade secret-protected chemicals in fracking fluid to DOGGR.
- Medical professionals should have broader access to full lists of fracking fluid composition in case of emergency, and regulations should protect their right to discuss cases and the chemicals involved with affected patients and communities. Further, the definition of “medical professional” in DOGGR’s discussion draft regulations should be expanded to include public health professionals such as epidemiologists and environmental toxicologists.

Tracking waste and disposal

As detailed in this report, DOGGR should require more extensive recordkeeping and reporting on disposal of wastewater.

- Inserting unique chemical tracers to fracturing fluids could increase accountability. DOGGR and the State Water Resources Control Board should research such methods, and, if tracer efficacy can be validated, require use of tracers in both production and injection well disposal events.

Protecting underground sources of drinking water

- DOGGR should strengthen its definition of underground sources of drinking water to match or exceed that of U.S. EPA.
- SWRCB and the Regional Boards should conduct long-term, coordinated monitoring of groundwater quality in various regions throughout the state to establish a scientific baseline for groundwater quality.

Our recommendations are detailed in the main text. Some key elements include:

Advance notice and disclosure

- Operators should be required to provide DOGGR, SWRCB, and the appropriate Regional Water Quality Control Board at least 30 days advance notice of any hydraulic fracturing event. Such notice should include complete contact details, information on well construction and testing, reasonably anticipated fracturing fluid chemical composition, and planned disposition of waste products. Physical copies of this advanced notice should be mailed to residents in potentially affected areas, as well as to water purveyors with water sources in these areas, at least 30 days in advance.

- DOGGR, SWRCB and the Regional Boards should explore the possibility for using idle wells, sealed above the production zone, to augment existing water wells as groundwater quality monitoring wells.

Well casing

- DOGGR should adopt more stringent requirements for pre-testing well integrity and monitoring pressure during injection and fracturing events.
- DOGGR should adopt a formal, risk-based approach to prioritize witnessing of injection and fracturing events by DOGGR staff.
- DOGGR should require monitoring annulus pressure, and the use of automatic shut-off devices that terminate injection if the permitted maximum allowable injection pressure is exceeded.

Well abandonment

- DOGGR should develop and implement a well closure and post operational monitoring program, which should include EPA's recent recommendations for injection wells, and should adapt those recommendations for production wells as applicable.
- DOGGR should increase the bonds required of well operators to levels that incentivize proper decommissioning and long-term stewardship.

Seismic risk

- DOGGR should fund studies to develop guidelines to define and map faults with risk for induced seismicity and develop safety factors for required setbacks from fault lines based on this risk analysis. Injection should be prohibited near risky faults based on this analysis.

Reuse and minimization

- DOGGR, in collaboration with SWRCB, should develop a public information database that provides the location, quantity and quality of produced water sources.

- DOGGR should collaborate with SWRCB and oil and gas industry groups to provide information to operators on reuse and minimization of fracking fluids and encourage increased such practices. DOGGR and SWRCB should also engage with other potentially affected stakeholder groups, such as water recycling interest groups.

- DOGGR should require fracking operators to develop a source reduction strategy that identifies methods and procedures to maximize recycling and reuse of flowback and produced water.

- The California legislature should consider incentivizing wastewater recycling through tax exemptions for items used specifically to process, reuse, and recycle wastewater used in hydraulic fracturing at oil or gas wells.

Treatment

- SWRCB should fund a scientific review of the risks to California water bodies from fracking wastewater.
- DOGGR regulations should explicitly prohibit direct discharge of flowback or produced water from oil and gas operations to publicly-owned treatment works (POTWs) until EPA issues pretreatment guidelines.

Storage and handling of produced water

- DOGGR should require closed tanks with secondary impoundments for storage of fracking fluids and wastewater.
- DOGGR should regularly inspect all processing and storage areas.
- DOGGR and SWRCB should deter illegal dumping by deploying additional staff to inspect well sites and enforce penalties.

Knowledge gaps and need for more research

- Using proceeds from increased assessment fees, DOGGR should fund and carry out peer-reviewed research on the environmental implications of fracking in California.

- The Department of Conservation should conduct an analysis of environmental justice implications to evaluate the distribution of impacts from projected fracking activity, and evaluate options to mitigate disproportionate impacts.
- To support greater understanding of California's complex geology, data about geological strata revealed from well drilling records could be incorporated into public databases, with an appropriate delay to protect investment in exploration.

Issues beyond the scope of this report

Because this report focuses on hydraulic fracturing wastewater and potential water quality impacts, we do not address in detail other issues highly relevant to fracking in California. These important issues include, but are not limited to:

- Water resource impacts resulting from increased demand for water used in fracking fluid and fracking processes;
- The greenhouse gas intensity of oil and natural gas production, which could have global implications and is relevant to California's efforts to reduce greenhouse gas emissions;
- Air emissions from all stages of the fracking process, including methane, volatile organic compounds (VOCs), and particulate matter from increased trucking and diesel emissions;
- Land use impacts from individual wells and clusters of wells, which can be substantial. For example, it is unknown how well-pad scarring may impact California if exploration intensifies;
- Other potential human health impacts to workers and the general public.

Overarching themes: more transparency, information, collaboration and oversight

Hydraulic fracturing presents risks to our environment and human health, and must be properly regulated and controlled. This report identifies several areas where the State's knowledge base and existing regulatory scheme are deficient. California policymakers and agencies should work to address the gaps in oversight described throughout this report.

The need for increased transparency in the fracturing process is paramount, and drives many of our recommendations for more disclosure, advanced notice and reporting requirements. Better oversight and enforcement is also necessary as the State witnesses potentially increasing fracking activity, as experienced in other areas of the country. In addition, more peer-reviewed studies on the potential impacts on hydraulic fracturing in California will aid refinement of regulations. Finally, more collaboration between state agencies with overlapping regulatory authority would provide more clarity and better regulate this practice, which cuts across physical and bureaucratic boundaries.

II. Introduction

A. This report assesses risks to water resources from hydraulic fracturing in California

Hydraulic fracturing (“fracking”) is a hot button environmental issue nationally and in California. The increase in fracking and oil and gas extraction has been driven by new technology that has enabled exploration of previously inaccessible shale rock formations, as well as demand for less expensive domestic energy.

At the same time, the health and environmental communities have rallied around fracking as a unifying issue that demands increased transparency, regulation, and safety. One potential impact to human health and the environment from fracking is contamination of groundwater or surface water by injected fluids or improper handling and disposal of fracking wastewater.

Fracking involves high-pressure underground injection of chemical mixtures that can include toxic constituents, and carries potential risk of contamination of surface and groundwater. The general practice of fracking is not new – oil and gas producers have employed fracking in California for many decades. What is new, and potentially alarming, are projections of dramatically increased fracking activity in California brought on by the availability of new techniques. Such developments have outstripped the ability of responsible agencies to effectively oversee fracking activity.

This topic is important in part because fracking has long-term implications: once fracking has been conducted, its effects may be impossible to reverse. In addition, there is an immediate opportunity to respond to current legislative, regulatory, and legal activity. Responding to this need and opportunity, this report focuses on the issue of properly regulating fracking wastewater in order to reduce risks to our state’s water resources.

B. The report is structured to synthesize both scientific and regulatory information

This report presents a California-specific review of the scientific and regulatory landscape surrounding hydraulic fracturing in oil and gas production. It assesses current legislative and regulatory activity, identifies knowledge needs, and recommends specific actions. The analysis highlights risks, management options, regulatory gaps, and potential actions for better regulation of oil and gas wastewater in the state. The goal is to lay out relevant issues for policymakers, regulators, and interested members of the public, and to contribute to a constructive dialogue on how California’s regulators and legislators can best meet human and environmental interests in the face of potentially increasing oil and gas production. This report provides a review specific to California, while drawing on a broader knowledge base; for overviews of national fracking activity and regulation, see reports by the Groundwater Protection Council (GWPC),¹ Natural Resources Defense Council (NRDC),² Pacific Institute³ and others.⁴

The report is organized into the following sections: The remainder of Section II provides background on hydraulic fracturing in California. Section III reviews technical information about hydraulic fracturing in California, as well as information gaps. Section IV describes the current regulatory landscape: although no unified statute controls hydraulic fracturing activity in California, state and federal laws apply and several agencies share regulatory responsibility. Section V describes specific pending legislative proposals, a pending rulemaking, and recent lawsuits. Section VI reviews relevant experiences from other states and offers recommendations for actions by California’s legislature and regulatory agencies to reduce risks to human health and the environment from hydraulic fracking.

C. The issues addressed in this report are timely

This report is timely. In December 2012, the California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (DOGGR) released a discussion draft of new regulations governing hydraulic fracturing.⁵ We applaud the agency's attention to this issue. In addition, several new bills have been introduced in the California legislature in 2013 that address hydraulic fracturing. Throughout this report, we discuss the proposed new regulations and legislation, as well as our own recommendations.

Oil and gas production is a multi-faceted process with numerous interrelated impacts, including impacts to water, air, and land use. This report addresses one important aspect of this process: the wastewater produced from fracking and associated activities, its treatment and regulation in California, and opportunities to reduce potential risks to our water supply. As such, this report encompasses a somewhat broader set of issues than are addressed in DOGGR's discussion draft regulations. The agency's process presents an important opportunity to consider additional regulations that will address myriad risks to water quality and increase information and transparency.

D. Hydraulic fracturing could impact California water resources

Hydraulic fracturing is the injection of fluids under pressure to release tightly bound oil or gas by creating cracks within an underground formation, usually of shale rock. From the perspective of its potential impacts, it is conceptually difficult to separate hydraulic fracturing itself from the entire production process of unconventional oil and gas resources, including drilling, completion, oil or gas production, storage and disposal of waste, and decommissioning of the well.⁶ From a regulatory perspective, a more inclusive discussion is more appropriate, because fracking is interrelated with elements beyond the fracturing event itself. A myopic focus would fail to capture the full range of potential impacts, some of which are impossible to disassociate.⁷ In this report, such related issues are addressed where they commonly

occur in the production lifecycle of wells that are fractured.

Wells used in oil and gas production generate wastewater at the wellhead. This "produced water" may contain salts, sediment, naturally occurring radioactive material.⁸ It may also be mixed with a broad suite of substances from fracking fluids, including toxic and hazardous chemicals such as benzene, lead, and methanol.⁹

Contamination by oil and gas wastewater may pose risks to human health and environmental quality. The primary avenues for contamination most likely stem from activities at the drilling site¹⁰ such as mismanagement of produced water by dumping, leakage from storage areas, or spills. Contamination may also result from failure of well casing or cementing.¹¹

E. There is fracking in California, and there may be more in future

While national attention to fracking has only recently increased, hydraulic fracturing has been used to produce oil from vertical wells in California for over 50 years. California has a long history of oil production; the majority of fracking in California has been in pursuit of oil rather than natural gas.¹²

Currently, operators use fracking extensively in operations in California – much of the oil and gas resources in California are inaccessible without well stimulation. Comprehensive information on the scope and prevalence of fracking in the state is lacking,¹³ in part because although oil and gas operators report drilling activity to state agencies, they have not been required to report hydraulic fracturing events. A recent Western States Petroleum Association member survey reported 628 fracturing events in California in 2011, representing about one-third of the total wells drilled in the state that year.¹⁴

California may soon experience more fracking activity. Recent estimates by the U.S. Energy Information Administration¹⁵ project sharp increases in crude oil and natural gas production in the U.S. over the next decade, particularly from tight formations that can be

Nutshell descriptions

Hydraulic fracturing (“*fracking*”) is the injection of fluids under pressure to release tightly bound oil or gas by creating cracks within an underground formation. Fracturing is a well completion and stimulation technique that is meant to prepare a well for production.

Unconventional resources including shale oil and gas are tightly bound to underground rocks and must be extracted using more complex methods than *conventional* wells that require drilling and pumping alone.

Water flooding is a technique where water is injected to increase pressure in a formation and drive oil towards production wells. *Steam flooding* injects steam into shallow wells to raise the temperature of the oil underground, thereby thinning the oil and making it easier to pump. These techniques are geared to increase productivity in an active well.

Injection disposal in Class II wells is a disposal method in which waste fluids from oil and gas production are injected into deep formations.

Whereas a *vertical drilling* operation consists of a single hole bored in one direction down from the surface, *directional drilling* (sometimes called *horizontal drilling*) involves turning the drill at an angle to curve the well bore and follow a productive formation. Directional drilling, and the multi-stage fracturing that often accompanies it, can access larger areas from a single well pad, and can involve higher volumes of fracking fluid and flowback.

Oil wells often produce natural gas as a byproduct. The gas can be flared, released to the atmosphere, used to meet onsite energy needs, or sold if produced in sufficient quantities. *Unassociated gas, or dry gas*, is natural gas that is present in a formation without oil.

accessed with hydraulic fracturing. Indeed, exploratory activity and land transactions suggest by companies including Occidental Petroleum and Venoco indicate that a sharp increase in activity has begun in the state.¹⁶

The San Joaquin Basin and coastal southern California are home to several large oil and gas producing formations, including the Monterey Formation, which holds an estimated 64% of discovered national deep rock resources¹⁷ (Figure 1). The Energy Information Administration has stated that “[t]he largest shale oil formation is the Monterey/Santos play in southern California, which is estimated to hold 15.4 billion barrels . . . of . . . total shale oil resources.”¹⁸ In addition, geologists reported to the Society of Petroleum Engineers that “hydraulic fracturing has a significant potential in many Northern California gas reservoirs,” suggesting that future expansion is possible in the state¹⁹ especially if natural gas prices rise in the future.²⁰

Accordingly, California should prepare for potential increased oil and gas production in the future.

The legislature and DOGGR should not shy away from finding that there is not enough scientific knowledge or institutional capacity to effectively manage a sharp increase in the expansion of hydraulic fracturing in California. If it makes this determination, it may choose to slow its growth until more knowledge and capacity can be developed. For example, a moratorium on high volume hydraulic fracturing has been in place in New York State since 2008, and the state is currently preparing an Environmental Impact Statement to assess risks from high volume hydraulic fracturing.²¹ We recognize that the political and economic costs of a moratorium may be great, so we offer the following analysis and recommendations to guide alternate pathways to manage its growth.

III. The technical context for fracking matters for effective regulation

This section reviews technical aspects of hydraulic fracturing and unconventional oil and gas production in California. An overarching caveat and caution applies to this section: many of the attendant risks have not been adequately studied, pointing to an acute need for further research. However, enough is known to justify specific precautionary action by regulators.

A. Fracking uses toxic chemicals and produces waste fluids

Hydraulic fracturing injects fluid under high pressure, releasing gas and oil that would otherwise be tightly contained,²² thereby increasing well productivity. Fracking fluid typically contains water and a ‘proppant’ such as sand or ceramic beads, and chemicals. The proppant lodges in cracks created by the high-pressure injection, creating fissures so that gas or oil can flow to the wellhead. Chemicals can include friction reducing additives,²³ biocides,²⁴ oxygen scavengers,²⁵ acids,²⁶ and other constituents – including some known to be toxic or hazardous.²⁷

Fracking fluid often contains chemicals listed as hazardous pollutants under the Clean Air Act (CWA) or regulated under the federal Safe Drinking Water Act (SDWA) for risks to human health, such as benzene, lead, and methanol. Further, some ingredients are known or possible human carcinogens (Table 1).²⁸ Between 2005 and 2009, oil and gas service companies used hydraulic fracturing products containing 29 chemicals that are (1) known or possible human carcinogens, (2) regulated under the Safe Drinking Water Act for their risks to human health, or (3) listed as hazardous air pollutants under the Clean Air Act.²⁹ These 29 chemicals were components of more than 650 different products used in hydraulic fracturing. The “BTEX compounds” – benzene, toluene, xylene, and ethylbenzene – appeared in 60 of the hydraulic fracturing products used between 2005 and 2009.³⁰ Each BTEX compound is a regulated contaminant under the Safe Drinking Water Act and

a hazardous air pollutant under the Clean Air Act. Hydraulic fracturing companies reported injecting 11.4 million gallons of products containing at least one BTEX chemical over a five-year period.³¹ Additional additives range from generally harmless to extremely toxic.³²

It is important to note that some information is lacking about the fracturing fluids that have been used. Because of trade secret provisions, companies that voluntarily report fracking fluid ingredients have excluded some items, and further, not all injections have been reported. The picture we have is illustrative, but far from complete.

After well drilling and injection, some of the fracking fluid returns to the surface at the wellhead. This initial portion is called “flowback,” and contains chemicals from the fracking fluid, as well as additional components released during contact with the shale that are potential water quality hazards, such as salts, Naturally Occurring Radioactive Material (“NORM”), organic compounds, and others.³³ (Table 2) A second portion of wastewater, referred to as “produced water,” continues to emerge after oil or gas production begins at a well.³⁴ Produced water tends to have chemical characteristics derived more from the shale formation than from the fracking fluid itself. If there are toxic elements in the formation, there are likely to be toxic elements in the produced water. Produced water is often highly saline, and may have mixed underground with the fracking fluid injected into the formation. In 2010, California onshore oil and gas wells produced about 2.39 billion barrels of produced water as a byproduct— about 9 barrels of water for every 1 barrel of oil in wells.³⁵

Potential water contamination can take several forms. Unintentional spills, improper storage, improper treatment, or illegal dumping present risks to surface water and land. Underground migration of fracking fluid or produced water that uses well

Table 1: Some chemical components of concern in fracking fluids.³¹⁷

Chemical Component	Chemical Category	No. of Products
Methanol (Methyl alcohol)	HAP	342
Ethylene glycol (1,2-ethanediol)	HAP	119
Diesel ¹⁹	Carcinogen, SDWA, HAP	51
Naphthalene	Carcinogen, HAP	44
Xylene	SDWA, HAP	44
Hydrogren chloride (Hydrochloric acid)	HAP	42
Toluene	SDWA, HAP	29
Ethylbenzene	SDWA, HAP	28
Diethanolamine (2,2-iminodiethanol)	HAP	14
Formaldehyde	Carcinogen, HAP	12
Sulfuric acid	Carcinogen	9
Thiourea	Carcinogen	9
Benzyl chloride	Carcinogen, HAP	8
Cumene	HAP	6
Nitrilotriacetic acid	Carcinogen	6
Dimethyl formamide	HAP	5
Phenol	HAP	5
Benzene	Carcinogen, SDWA, HAP	3
Di (2-ethylhexyl) phthalate	Carcinogen, SDWA, HAP	3
Acrylamide	Carcinogen, SDWA, HAP	2
Hydrogen fluoride (Hydrofluoric acid)	HAP	2
Phthalic anhydride	HAP	2
Acetaldehyde	Carcinogen, HAP	1
Acetophenone	HAP	1
Copper	SDWA	1
Ethylene oxide	Carcinogen, HAP	1
Lead	Carcinogen, SDWA, HAP	1
Propylene oxide	Carcinogen, HAP	1
p-Xylene	HAP	1
Number of Products Containing a Component of Concern		652

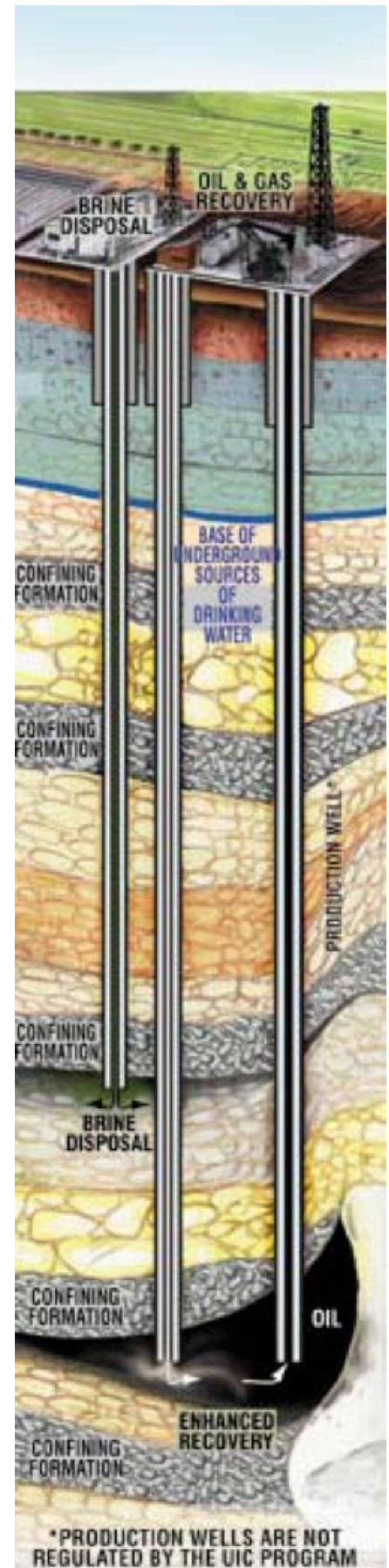


Figure 2: Schematic of Class II injection and disposal wells.³¹⁶

Table 2: Chemical constituents in produced water from Marcellus Shale development.³¹⁸ Extensive, but less detailed, data on produced water in California are available at <http://energy.cr.usgs.gov/prov/prodwat/index.htm>.

Chemical constituent or surrogate parameter	Unit of measure	Range reported in produced water from wells drilled in Marcellus Shale at 5 days post hydraulic fracturing	Range reported in produced water from wells drilled in Marcellus Shale at 14 days post hydraulic fracturing
Total Suspended Solids (TSS)	mg/L	10.8-3,220	17-1,150
Turbidity	NTU	2.3-1,540	10.5-1,090
Total Dissolved Solids (TDS)	mg/L	38,500-238,000	3,010-261,000
Specific Conductance	umhos/cm	79,500-470,000	6,800-710,000
Total Organic Carbon (TOC)	mg/L	3.7-388	1.2-509
Dissolved Organic Carbon (DOC)	mg/L	30.7-501	5-695
Chemical Oxygen Demand (COD)	mg/L	195-17,700	228-21,900
Biochemical Oxygen Demand (BOD)	mg/L	37.1-1,950	2.8-2,070
BOD/COD Ratio (% biodegradable)			0.1 (10%)
Alkalinity	mg/L	48.8-327	26.1-121
Acidity	mg/L	<5-447	<5-473
Hardness (as CaCO ₃)	mg/L	5,100-55,000	630-95,000
Total Kjeldahl Nitrogen (TKN)	mg/L as N	38-204	5.6-261
Ammonia Nitrogen	mg/L as N	29.4-199	3.7-359
Nitrate-N	mg/L as N	<0.1-1.2	<0.1-0.92
Chloride	mg/L	26,400-148,000	1,670-181,000
Bromide	mg/L	185-1,190	15.8-1,600
Sodium	mg/L	10,700-65,100	26,900-95,500
Sulfate	mg/L	2.4-106	<10-89.3
Oil and Grease	mg/L	4.6-655	<4.6-103
BTEX (benzene, toluene, ethylbenzene, xylene)	µg/L		Non-detect-5,460
VOC (volatile organic compounds)	µg/L		Non-detect-7,260
Naturally occurring radioactive materials (NORM)	pCi/L	Non-detect-18,000 pCi/L; median 2,460 pCi/L	
Barium	mg/L	21.4-13,900	43.9-13,600
Strontium	mg/L	345-4,830	163-3,580
Lead	mg/L	Non-detect-0.606	Non-detect-0.349
Iron	mg/L	21.4-180	13.8-242
Manganese	mg/L	0.881-7.04	1.76-18.6

bores as conduits is considered a likely pathway for groundwater contamination.³⁶ And migration of contaminants from deep rock strata to shallow drinking water is controversial and is considered less likely to occur.

There are few peer-reviewed scientific studies on the water-related aspects of fracking, and fewer still focused on California.³⁷ At the request of Congress, EPA is conducting a study on the potential impacts of fracking on drinking water and groundwater.³⁸ The study will include research associated with the fracking water lifecycle, an environmental justice assessment, and analysis of existing data, case studies, and modeling potential impacts, among other topics. EPA planned to release a progress report in late 2012, with a final draft report scheduled for 2014.³⁹

In 2009 in Pavilion, Wyoming, U.S. Environmental Protection Agency scientists found traces of hydrocarbons and other contaminants associated with fracking fluids in samples from private and public drinking water wells.⁴⁰ Further analysis in 2010 and 2011 confirmed these results, showing high levels of carcinogenic chemicals, such as benzene, present in private and public drinking water wells.⁴¹ EPA has noted that these draft findings are “specific to Pavillion, where the fracturing is taking place in and below the drinking water aquifer and in close proximity to drinking water wells.”

In California, wastewater from oil and gas development has already resulted in contaminated groundwater through surface storage leakage. In 2008, a Kern County farmer was awarded \$8.5 million in compensatory damages for groundwater contamination from produced water stored in open pits.⁴² This case, *Starrh and Starrh Cotton Growers v. Aera Energy LLC* (unpublished decision), does not specify whether hydraulic fracturing waste was involved, but the implications are illustrative; wastewater from oil production poses real risks if not managed properly.

More information about the likelihood and extent of groundwater contamination is hindered by limited water quality baseline data, without which it is difficult to evaluate reports of groundwater contamination.⁴³

More peer-reviewed studies, particularly on the risks from underground migration of produced water and fracking fluid, would help add precision to future regulations.

B. Geology and geography influence fracking activity

Geology and the conditions of a given geological formation determine which approach to fracturing will be most effective. The Monterey Formation is not the Marcellus Formation: there are similarities but also important differences that need to be recognized for effective regulatory oversight.

California has extensive oil resources and a long history of oil production using injection methods such as hydraulic fracturing, steam flooding and water flooding, and the majority of produced water in California is injected for such enhanced oil recovery purposes. In contrast to other shale regions such as the Marcellus, most hydraulic fracturing is used for oil production rather than for unassociated natural gas. Oil-bearing shale formations in California are geologically complex and poorly understood. They are also wet; it is not uncommon for produced water from California oil fields to contain 80 to 90 percent brackish water.⁴⁴

Further, the volume of water required for fracking has generally been much smaller in California than in other areas. Whereas millions of gallons of fluid can be employed in a single fracturing event in other states,⁴⁵ in California industry operators report typical volumes of 80,000 to 300,000 gallons of fracking fluid per well.⁴⁶

Relatedly, directional drilling is not as prevalent here as in other areas of the country. Geological heterogeneity in California may be responsible, as most operators use vertical drilling to find ‘pockets’ of oil-bearing rock. This practice has not been commonly complemented by directional drilling here. In California, operators may not yet have discovered the best layers in which to target thick zones for production, nor how variable geology influences well behavior.⁴⁷ In addition, oil-bearing shales in the Monterey Formation are deeper and thicker than shale plays in many other areas, so

vertical drilling may be able to achieve greater access to deep deposits.⁴⁸ Another driver for directional drilling is land access – where land access is more difficult or expensive to obtain, directional drilling becomes more attractive. Projections of future activity need to take all of these factors into account.

Most of the fracturing in California to date has been concentrated in the San Joaquin Valley and southern coastal areas; according to an industry representative, over 80% of hydraulically fractured wells have been located in Kern County. Although there are shale gas formations in the Sacramento Valley, the region has thus far witnessed very little fracturing activity.

While the overarching purpose of hydraulic fracturing – releasing oil or gas from formations in which it is trapped - has remained the same for decades,

there have been shifts in the nature of the practice. Directional drilling extends the reach of a well far beyond the well pad footprint, and, combined with multiple fracturing events, results in greater input and produced water volumes for each well. Further, the range of ingredients in fracking fluids has expanded, which may change the characteristics of injected and wastewater with implications for water quality (for example fracturing fluids with higher acid content may prove effective for California’s clay-rich geology). Other states have experienced trajectories of increasing use of these higher-impact practices. Whether California will follow similar patterns will depend on regulatory and economic factors such as those discussed in the text. Decision-makers need prepare for the possibility that the future of fracking in California may look very different than its past.

How oil and gas are formed

Generally, buried organic geological deposits become oil or gas given enough heat and time. Oil and gas are generally less dense than water, and migrate up through porous spaces filled with water or brine until they encounter an impermeable layer of rock, also known as a cap. The distribution of oil and gas is controlled over geological time by microbes that consume gas molecules or change oil to gas, and by buoyancy - gas, being lighter, sits above oil in a reservoir. It is also influenced by the source of the organic deposits, such as in California where terrestrial deposits in the Sacramento Valley have created gas fields, and oceanic deposits in the San Joaquin have created oil fields.⁴⁹ Reservoirs can leak oil to the surface when rock fractures through natural processes, as evidenced by early Bakersfield oil wells that were initially dug by hand following oil migration to the surface.

Further, not all unconventional reserves are found in shales or deep deposits – diatomite is one example of an oil-rich rock with different characteristics, and resulting concerns, than shales more commonly associated with fracking (see Sidebar below). These and other geological processes affect the geography of petroleum exploration. They also influence the choice of extraction method, and the potential consequences of oil and gas production.

Diatomite formations may have less natural protection for groundwater

Oil production in diatomite carries risks⁵⁰ and is worthy of specific regulatory attention. Diatomite is found in relatively shallow areas, often less than 2,000 feet deep in some areas of the Central Valley. Hydraulic fracturing can be used to connect the pore spaces, releasing rich streams of oil, often aided by steam flooding. However, clay layers in the Central Valley can be very thin or nonexistent around the margins of the Valley. Where no cap rock exists, such areas are vulnerable to upward migration of newly released oil. Diatomite steaming has also proven dangerous and even fatal for workers⁵¹.

C. A variety of management options exist for produced water

There are three main options for management and disposal of flowback and produced water from oil and gas operations: disposal into injection wells; reuse and recycling; and treatment. Injection and reuse and recycling are the most common disposal methods in California.

In this section, we review the three main options for management and disposal of fracking wastewater, the risks presented by these management processes, and procedures and regulations that can ensure greater oversight and protection of human health and the environment.

1. Disposal by underground injection is common in California

Underground injection is carried out for two purposes: production and disposal (Figure 2). Production wells are used to inject brine, water, steam, or other fluids into a formation to enhance the recovery of oil or gas. Disposal wells are used to inject waste fluids associated with oil and gas production.

In California, underground injection of wastewater is currently the most common method for management of produced water.⁵² In California, a reported 90-95% of wastewater is reinjected, either for reuse in production or for disposal in Underground Injection Control (“UIC”) Class II disposal wells.⁵³ Class II injection wells refer to wells used for oil and gas purposes. The prevalence of injection disposal in California is much higher than in some other states, such as Pennsylvania. There are over 31,000 UIC Class II injection wells in California, of which more than 24,000 are active.⁵⁴ Assuming that the cost of underground injection remains lower than other disposal methods, injection will likely continue to be the main fate of produced water in the state.

In many cases, injection wells are drilled directly through aquifers to reach deeper oil or gas producing zones. One key risk from injection is the potential contamination of surrounding aquifers due to well casing or cement bond failure.⁵⁵ Casing or cement failure may cause methane leakage from deep shale layers to shallow groundwater aquifers.⁵⁶

All Class II wells are required to be cased and cemented to prevent fluids from mixing with Underground Sources of Drinking Water (USDWs), as described below in section IV. Casings are metal pipes that line a borehole drilled through rock. Multiple layers of casing typically are used to protect the upper layers. Cement is injected into the annulus, the space between the casings, and between the casings and the surrounding formation. Together, these form a barrier designed to keep injected fluids from contaminating aquifers. This barrier, like any physical barrier, may degrade over time.

Wellbores (the holes drilled to reach oil-bearing deposits) are also a potential source of underground contamination.⁵⁷ This is especially true of abandoned wells or wells constructed without sufficient casing and cementing. Although thick clay layers cap oil deposits in the Monterey Formation, potentially reducing the risk of migration to aquifers,⁵⁸ wellbores can form a conduit through which oil and gas can rapidly rise towards freshwater layers in a matter of hours or days. If casing and cementing are insufficient, oil and gas can penetrate quickly. And if oil or gas enters deep in the saline zone of an aquifer, it may take decades or centuries to appear in drinking water wells.

Abandonment of wells after their productive lifespan is also a crucial issue for water quality protection. Proper capping and sealing of wells may reduce these risks, but even wells abandoned using best practices can leak over time. Active wells can be tested to reduce the risk of leaks and enable repairs if leaks are detected. Standard tests include Radioactive Tracer Tests and Standard Annulus Pressure Tests, which in UIC disposal wells are conducted pursuant to DOGGR regulations.

a. Underground injection has led to seismic events

According to a National Research Council report, injection of fluids to Class II wells can cause seismic events.⁵⁹ A few recent examples in the United States support this conclusion. The Ohio Department of Natural Resources (ODNR) attributed a series of earthquakes near Youngstown in 2011 to injection into UIC disposal wells.⁶⁰ The ODNR report concluded that induced seismicity is rare, and occurred in this case due

to the intersection of the injection zone and an unmapped fault under stress. A University of Texas study found that earthquakes occurred more frequently near injection well sites in the Barnett Shale region, with most of the epicenters located within two miles of injection wells.⁶¹

Magnitude matters - for the most part, induced seismic events have been small, only rarely felt on the surface. However, larger events are not unprecedented: in 1967 and 1968, waste disposal in injection wells triggered a dormant fault and caused a series of small but damaging earthquakes at the Rocky Mountain Arsenal near Denver.⁶²

How this translates to risk of earthquake damage in California, either to surface property or to well bore integrity, is as yet unknown. Given California's well-documented and historically active fault lines and tectonic stress, the state will need to closely evaluate how to properly manage the relationship between seismicity and injection wells in order to reduce any risk of earthquakes.

b. The distinction between production and disposal wells is relevant to understanding the risks they pose to water quality

Hydraulic fracturing uses similar (and in some cases identical) wells as injection disposal, but the risks from fracturing events themselves have not been as well documented. The data we do have indicates some potential risks presented by fracking events themselves.

High-pressure hydraulic fracturing events may cause well casing failure; this is part of the justification cited for proposed regulations requiring pressure standards and testing.⁶³ An analysis of Pennsylvania Department of Environmental Protection records found that more than 6% of wells had compromised structural integrity,⁶⁴ and other recent analysis also suggests that the risk of water contamination from such failure may be significant.⁶⁵ Other potential avenues for water contamination from fracking activities have less scientific support. For example, while migration of contaminants between

geological strata has been discussed,⁶⁶ there is scant empirical evidence for migration of fracking fluids between geologic strata.⁶⁷

Production wells may also lead to induced seismicity. An Oklahoma Geological Survey found increased earthquake activity near hydraulic fracturing sites, often within 24 hours after fracturing events.⁶⁸ However, there is currently less information on the relation between production wells and induced seismicity than there is on injection wells and induced seismicity.

This highlights the need for more scientific information on the risks presented by fracking events themselves, in addition to injection wells and other wastewater management options.

2. Techniques exist to reuse and minimize and reuse produced water

Where reuse and minimization of produced water can be accomplished safely, this can reduce the amount of water that must be obtained for fracking fluid, as well as the amount which must later be disposed of, both of which can reduce costs for operators. Recycling can, however, incur costs where the quality of the produced water necessitates treatment or dilution before reuse. In addition, treatment is often energetically and chemically intensive.⁶⁹

Produced water can be reused for hydraulic fracturing in multi-stage wells, but more commonly, reuse in California has been for non-fracturing uses such as steam flooding or water flooding (see Sidebar page 12, ("Nutshell descriptions")). Oil and gas producers sometimes treat and reuse some of their produced water, for example, to generate steam.⁷⁰ Produced water from shale formations in California is usually managed in closed loop systems that bring up oil to the surface, separate water from oil, and reinject the water either to disposal wells or into the oil-bearing formation to increase production.⁷¹ Closed loop systems that directly connect the wellhead and injection disposal wells also eliminate one source of spills. Flowback can generally be recycled until it reaches very high concentrations of TDS, at which point the wastewater must be disposed of or diluted.

Minimization of fracking water production is most commonly done onsite, where technologies such as downhole oil/water separators and mechanical blocking devices can reduce the amount of produced water that surfaces.⁷² According to industry representatives, such technologies are not commonly used in California.⁷³

3. Produced water can be treated

Produced water can also be treated in order to remove solids and oil in preparation for disposal in injection wells, for subsequent reuse in gas or oil development, or, after treatment to higher standards, for discharge or beneficial reuse (see Sidebar page 40, “Resource recovery and beneficial use of produced water are potential sources of local water supply”).⁷⁴ Treatment for discharge and beneficial reuse is not common in California because, to date, injection has been more economical, and there are regulatory prohibitions on discharge.⁷⁵

Some hydraulic fracturing operators in other states have sent wastewater to treatment facilities that are authorized to discharge pursuant to NPDES permits. These facilities include Publicly Owned Treatment Works (POTWs) or Centralized Waste Treatment facilities (CWTs). POTWs are treatment works that are owned by a state or municipality.⁷⁶ They include any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or liquid industrial wastes. They also include sewers, pipes, and other conveyances if they convey wastewater to a POTW treatment plant.⁷⁷ CWTs are dedicated brine or industrial wastewater facilities. These centralized treatment facilities either have no direct surface water discharge, for example, partially treating the water and sending it to POTWs for further treatment, or treat the wastewater to new discharge standards.

POTWs are generally not designed for the purpose of treating produced water.⁷⁸ In particular, high concentrations of dissolved solids cannot readily be removed by POTWs. In addition, high salt, organics, and heavy metal concentrations can affect or disrupt the treatment process.⁷⁹

A critical point is that without full disclosure, treatment plan operators cannot know what is in the water they are receiving, and therefore may not treat for, let alone monitor and verify, the removal of fracking fluid additives.

D. Surface storage and illegal dumping present dangers

Disposal and storage options historically included unlined ponds and land application, but both of these methods have become less prevalent as fracking regulations have tightened. Surface impoundments were commonly used in the past, but the State Water Resources Control Board has worked with industry to reduce this practice.⁸⁰ As the *Starrh* case⁸¹ indicates, surface storage seepage could severely impact local shallow groundwater and surface water sources. Surface impoundments have also created problems in other states. The West Virginia Department of Environmental Protection is investigating the recent release of an estimated 95,000 gallons of flowback from a surface impoundment, possibly an overflow due to operator error.⁸²

Illegal dumping of produced water has also been documented in other states, including recently in Ohio.⁸³ Civil⁸⁴ and criminal⁸⁵ penalties under Porter-Cologne and the Clean Water Act exist to discourage dumping in California, and penalties exist for violation of any of DOGGR’s regulations.⁸⁶ Although dumping fracking fluid or produced water has not been widely reported in California, whenever dumping is less expensive than injection or treatment, companies may have an incentive to do so if there is lax enforcement or only minor penalties. As described in Section B. Geology and geography influence fracking activity, the short duration and relatively low volume of fluid employed in fracturing events in California, combined with scant resources allocated to such enforcement, make it difficult to say with confidence that illegal dumping does not occur in the state.

E. Inadequate notice, disclosure and information gaps hinder effective regulation

National, state, and local attention to the issue notwithstanding, detailed information on fracking in California is insufficient. In addition to fracking wastewater, fracking events themselves pose risks to environmental quality. Yet because California's existing regulatory regime for fracking notice and disclosure is inadequate, the State does not currently have comprehensive information on every fracking event that has taken place, the chemicals used, and nor baseline water quality data in the immediate area that is essential to proving a contamination event. For this reason, we also address California's current regulatory regime for notice and disclosure in this report.

DOGGR's planned new regulations would modify California's notice and disclosure requirements slightly, as described below. However, we describe the existing regulatory scheme here, because it currently governs fracking in the State.

California's existing regulatory regime for fracking notice and disclosure is inadequate. In a move towards greater transparency, the vast majority of oil and gas operators in California recently began voluntarily reporting fracking sites, as well as volumes and some ingredients used in fracking fluid.⁸⁷ The information is posted on Frac Focus (www.fracfocus.org) in Material Safety Data Sheets (MSDSs) that list chemical constituents and their concentrations.

However, the existing database has shortcomings. First, it is currently voluntary for California operators, and thus has less than full participation. Second, service companies currently withhold identification of some ingredients in fracking fluids as industry trade secrets, entirely at their discretion, based on California's Uniform Trade Secrets Act.⁸⁸ Third, there is no verification or testing process for the data that is reported; as such, the quality of data reported on the website varies by well and operator.

Fourth, it is in California's interest to have a long-term, unified source for all information on each fracking operation. Consistent with the potential long-term implications of fracking for water quality, this source should meet standards for long-term stewardship and archiving of records. Frac Focus, while supported by strong entities, is a third party whose management and funding are not under control of the State of California.

Fifth, and perhaps most importantly, disclosures to Frac Focus are made after the fact, rather than in advance. Even if most California fracturing events have been relatively small to date,⁸⁹ once they are completed the effects are irreversible and potentially long-term. Because of this, windows for public awareness, monitoring, and action on fracking can be brief, a fact that elevates the importance of transparency and process. The public should have more opportunity to understand and provide input on whether and how oil and gas operators fracture near their homes and water supplies.

Timely public disclosure of fracking site locations, operators, fracking chemicals, and waste handling and disposal are needed to enable better environmental protection. Such data are also needed to enable future research on fracking safety, risks, and environmental impacts.

In addition to inadequate notice and disclosure, other key unknowns about fracking in the State include full information on the constitution, treatment, and disposal of produced water, information on legacy effects, and cumulative impacts of over half a century of fracking and a century of oil and gas production. Further, a more complete understanding of existing practices on the ground, from both industry and regulatory perspectives, would contribute to greater transparency and understanding of how to best manage fracking in the State.

IV. The current regulatory landscape does not ensure safe hydraulic fracturing

A. Several state and federal agencies share responsibility

A number of state and federal agencies share responsibility for regulating aspects of oil and gas production including hydraulic fracturing and injection well disposal and their attendant potential impacts on water resources. These agencies include the U.S. Environmental Protection Agency, federal Bureau of Land Management (BLM), California Division of Oil, Gas & Geothermal Resources (DOGGR), the State Water Resources Control Board (SWRCB), and the nine Regional Water Resources Control Boards (Regional Boards).

Federally, the Clean Water Act regulates the treatment and discharge of wastewater into surface waters of the United States. Point sources associated with oil and gas production are prohibited from discharging wastewater directly to water bodies.⁹⁰ EPA sets requirements for the introduction of industrial discharge to POTWs – known as “indirect discharge”⁹¹ – and to CWTs. States may also adopt more stringent requirements for such discharge.⁹²

Through the Safe Drinking Water Act, U.S. EPA has national responsibility for protection of source water quality, including groundwater through its Underground Injection Control (UIC) program. DOGGR has primacy for implementing the UIC program in California. EPA has recently exercised its oversight by commissioning a review of California’s UIC implementation.⁹³

California’s Division of Oil, Gas & Geothermal Resources (DOGGR), regulates statewide oil and gas activities for the protection of “life, health, property and natural resources.”⁹⁴ DOGGR has oversight responsibility for oil and gas production activities,⁹⁵ including where hydraulic fracturing is used.⁹⁶ DOGGR’s activities include “well permitting and testing; safety inspections; oversight of production and injection projects; environmental lease inspections; idle-well testing; inspecting oilfield tanks, pipelines, and sumps; hazardous and orphan well plugging and abandonment contracts; and subsidence monitoring.”⁹⁷ Until recently, DOGGR did not acknowledge specific responsibility for hydraulic fracturing.⁹⁸ Their recent “discussion draft” regulations are welcome progress, and are discussed below in Section V. DOGGR also has primacy to regulate Class II injection well disposal in California, with EPA oversight.⁹⁹

The State Water Resources Control Board (SWRCB), along with the nine Regional Water Resources Control Boards (Regional Boards), implements the Porter-Cologne Water Quality Control Act, California’s primary water quality regulations,¹⁰⁰ and is the state agency in charge of implementation of the Clean Water Act.¹⁰¹ As such, SWRCB and the Regional Boards issue permits for discharges to surface, coastal or groundwater. The Regional Water Boards issue waste discharge permits, take enforcement action against dischargers who violate permits or harm water quality in surface waters, and monitor water quality. To prevent water quality problems, the Regional Boards implement waste discharge

restrictions through Water Quality Certification, National Pollutant Discharge Elimination System (NPDES) permits, waste discharge requirements/permits (WDRs), discharge prohibitions, enforcement actions, or best management practices. DOGGR and SWRCB have overlapping statutory responsibilities for protecting the state's water resources, and specific roles in regulating potential impacts from oil and gas development, as described in the sidebar on page 24 ("DOGGR and SWRCB jurisdiction"), may benefit from clarification.

The federal Bureau of Land Management (BLM) is responsible for leasing oil and gas resources on all federally owned lands.¹⁰² The BLM manages 248 million acres and is responsible for 700 million acres of subsurface mineral resources in the United States.¹⁰³ Federal land ownership is concentrated in the West; 47% of California is federally owned.¹⁰⁴ California also contains 2.5 million acres of federal split estate land, in which landowners own the surface of their land, but BLM owns the federal oil and gas resources beneath the surface.¹⁰⁵

BLM is responsible for the review and approval of all permits and licenses to explore, develop, and produce oil and gas and geothermal resources on federal lands. The BLM's existing hydraulic fracturing regulations were last revised in 1988, well before the latest hydraulic fracturing technologies became widely used.¹⁰⁶ In May 2012, BLM published new proposed rules governing hydraulic fracturing on lands managed by BLM.¹⁰⁷ The agency's new proposed rules are discussed below in Section V.

BLM and DOGGR have recently updated a Memorandum of Understanding (MOU) that acknowledges their overlapping responsibilities on lands with federal interests in California, including lands where the federal government owns either the surface or mineral rights, or both.¹⁰⁸ The MOU specifies that where mining takes place on these lands, the two agencies will "exchange information and combine resources where possible."¹⁰⁹ The MOU specifies various efforts to develop collaboration, including on inspections, notifications, idle well monitoring, and other areas.

DOGGR and SWRCB jurisdiction over wastewater from oil and gas production

DOGGR and SWRCB¹¹⁰ have overlapping responsibilities related to regulation of Class II injection wells in California,¹¹¹ including preventing damage to ground and surface water and protecting beneficial uses of water. A 1998 Memorandum of Agreement (MOA) attempted to address their respective spheres of responsibility;¹¹² however, more coordination is needed between the two agencies.

The MOA has as three express goals: (i) simplifying reporting; (ii) eliminating duplication of effort; and (iii) better coordinating permitting and reporting for Class II wells. In practice, the agencies may have succeeded in the first two, but there is room for improvement on coordinating the permitting and reporting.

It is unclear whether the agencies have actually achieved the level of active coordination necessary given their overlapping statutory responsibilities. For example, although DOGGR is technically required to inform SWRCB when an operator reports well casing leakage, we were unable to locate details of this type of reporting. Public comments during a DOGGR public workshop¹¹³ posed similar questions and indicated that, at the very least, communication between DOGGR staff and Regional Board staff leaves room for improvement. This suggests that DOGGR's inspection may not be capturing such failures, or that it is not reporting such incidents to SWRCB or Regional Boards.

Greater attention should be paid to the inter-agency responsibilities outlined in the MOA; additional resources may be needed in order to improve inter-agency coordination and communication. We recommend a third party review of the MOA and its implementation.

B. CEQA offers one possible framework for assessing fracking impacts

The California Environmental Quality Act (CEQA)¹¹⁴ applies to discretionary projects proposed to be carried out or approved by a public agency in California.¹¹⁵ Broadly stated, its purposes are to: inform governmental decision-makers and the public about the potential significant environmental effects of proposed projects; identify ways that significant environmental effects can be avoided or significantly reduced; prevent public agencies from approving projects with significant adverse effects if there are feasible alternatives or feasible mitigation measures that would substantially lessen the significant environmental effects; and publicly disclose why a project was approved if it will have significant environmental effects.¹¹⁶ A “significant effect” on the environment is defined as a substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project, including land, air, water, minerals, flora, fauna, ambient noise, and objects of historic or aesthetic significance.¹¹⁷

The analysis of a project required by CEQA usually takes the form of an Environmental Impact Report (EIR), Negative Declaration (ND), or Environmental Assessment (EA). CEQA requires each public agency to prepare an Environmental Impact Report (EIR) when it proposes to approve or carry out a discretionary project that may have a significant impact on the environment, and to mitigate or avoid those significant impacts whenever feasible. Where an agency determines that a proposed project would not have a significant effect on the environment, it may adopt a negative declaration (ND) to that effect. If an EIR is necessary, CEQA requires that the lead agency consult with other public agencies and special experts, provide at least 30 days public notice and opportunity to comment on a draft EIR, and provide a response to public comments.¹¹⁸

Public agencies are entrusted with compliance with CEQA and its provisions are enforced, as necessary, by the public through the comment and response process, and through litigation and the threat of litigation. Since

2010, DOGGR has routinely followed an abbreviated environmental review process for oil and gas well permits. DOGGR typically either, (1) finds the well projects to be “minor alterations to land” or “existing facilities,” which are categories of projects exempt from full environmental review; or, (2) finds the well projects to include mitigation measures that result in the project having no significant impacts, which allows DOGGR to approve the project using a Mitigated Negative Declaration, rather than a more detailed Environmental Impact Report.¹¹⁹ However, some EIRs have been prepared for fracking activities in the state, such as the Baldwin Hills Community Standards District EIR.¹²⁰ We discuss a pending CEQA lawsuit against DOGGR in Section V below.

C. Federal and state law applies to underground injection disposal

The federal Safe Drinking Water Act of 1974 (SDWA) requires that injection of wastewater be regulated by EPA’s Underground Injection Control program (UIC).¹²¹ The UIC program is designed to prevent the injection of liquid wastes from contaminating USDWs by setting standards for safe wastewater injection.¹²²

Injection wells associated with oil and gas wastewater disposal are designated as Class II wells under UIC.¹²³ Because of a regulatory determination by the EPA not to classify oil and gas wastewater as “hazardous,” these fluids do not need to be injected into more rigorously controlled Class I hazardous waste wells.¹²⁴ Class I wells are subject to more stringent requirements than Class II wells, including more comprehensive siting, reporting, and technical requirements.¹²⁵

The UIC program regulates Class II wells that are used for injection purposes. Such purposes include both the disposal of fluids related to oil and gas production, and also the injection of fluids for enhanced oil recovery. The UIC program does not regulate production wells that are used only to bring oil and gas to the surface, without injection.¹²⁶ The 2005 Energy Policy Act revised the SDWA term “underground injection” to explicitly exclude the injection of fluids and propping agents (except diesel fuel) used in the hydraulic fracturing production process. In addition, the CWA exempts water derived

from gas extraction from regulation when the water is injected into a well and will not result in the degradation of other water bodies.¹²⁷

The federal Fracturing Responsibility and Awareness of Chemicals Act (“FRAC Act”), first proposed in 2009, would have eliminated the exemption for hydraulic fracturing operations established in the Energy Policy Act of 2005. It would have amended the term “underground injection” to include the injection of fluids used in hydraulic fracturing operations, providing EPA with the authority to regulate this process under the SDWA. It would also have created broadly applicable disclosure requirements.¹²⁸ In 2011, the FRAC Act failed to clear committee in both houses.

Because DOGGR has primacy for oversight of SDWA provisions in California,¹²⁹ it must adopt and operate “effective program to prevent underground injection which endangers drinking water sources.”¹³⁰ This program must also include “inspection, monitoring, recordkeeping, and reporting requirements.”¹³¹ If an operator captures fluids for injection, they must obtain approval from DOGGR.¹³²

Through its UIC implementation, DOGGR regulates casing integrity for injection wells in California, requiring “water-tight and adequate casing,” to protect groundwater and surface water from contamination.¹³³

In April 2010, Region 9 of U.S. EPA requested an evaluation of DOGGR’s UIC Class II program, which was conducted by a third party contractor and published in June 2011.¹³⁴ The review evaluated of definitions of underground water sources, area of review (AOR) and Zone of Endangering Influence (ZEI) calculations and procedures, compliance and enforcement, idle wells, financial requirements (e.g., bonds), and other topics.

The review found that existing DOGGR practices may not be sufficient to prevent fluid movement in all USDWs affected by Class II wells, and that historical projects do not always meet current standards.¹³⁵ DOGGR has announced an action plan to address EPA’s concerns.¹³⁶ The action plan says that DOGGR will “begin a rulemaking in 2013 to update the

UIC program, well construction, and planning and abandonment regulations.”

By EPA’s definition, an USDW supplies, or contains sufficient water to supply, a public water system with water.¹³⁷ California’s definition is broader, applying beneficial use designations to smaller sources.¹³⁸ Currently, EPA defines sources of underground drinking water as those containing less than 10,000 ppm total dissolved solids (TDS),¹³⁹ while existing DOGGR regulations define “protected water” as water containing less than or equal to 3,000 ppm TDS. This distinction is important because it drives the implementation of measures to protect USDWs, for example the required depth and quality of the well casing and cementing, and it suggests that current DOGGR regulations do not protect USDWs to EPA standards.¹⁴⁰

Despite evidence showing a link between underground injection and earthquakes (see Section III C), the Safe Drinking Water Act does not address induced seismicity.

DOGGR also regulates well abandonment in part to protect underground and surface water from detrimental substances.¹⁴¹ DOGGR is tasked with oversight of “hazardous wells” that pose “potential danger to life, health, or natural resources” that have no operator responsible for their plugging and abandonment.¹⁴² State policy declares that the cost of abatement be charged to oil and gas producers.¹⁴³

DOGGR’s management of well abandonment was also part of EPA’s UIC program review.¹⁴⁴ In its action plan, DOGGR describes its intent to review its abandonment practices and requirements, and to respond to EPA’s recent technical review.¹⁴⁵ Therefore, in this report we touch only briefly on well abandonment. However, based on the geological hazards, this issue requires concerted attention both to address the hazards of existing wells, and to safeguard active and future wells.

In contrast to underground injection, hydraulic fracturing itself is not well covered in California regulations. As DOGGR acknowledges on its website, “[t]here is a gap between the requirements placed on

oil and gas operators to safely construct and maintain their wells, and the information they provide to the Division about hydraulic fracturing operations and steps taken to protect resources and the environment.”¹⁴⁶

DOGGR requires mechanical integrity testing for both production and disposal wells,¹⁴⁷ but no specific regulations are in place distinguishing wells employing hydraulic fracturing. DOGGR currently does not require reporting of hydraulic fracturing: drilling and mechanical changes to wells must be reported, but reporting hydraulic fracturing events themselves is not required.¹⁴⁸ DOGGR’s new proposed regulations would require operators to report all fracturing events in advance.¹⁴⁹

D. California water recycling policy does not specifically consider produced water

The Legislature has tasked the State Water Resources Control Board and the Regional Boards with increasing the use of recycled water.¹⁵⁰ State recycled water policy defines recycled water as “water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefore considered a valuable resource.”¹⁵¹ While much discussion of recycled water centers rightly on municipal sources, wastewater from oil and gas production is consistent with the definition¹⁵² and broader intent¹⁵³ of water policy in California, so long as it is carried out in a way that does not impact human or environmental health.

Regulation of the recycling and reuse of wastewater from oil production depends on how it will be used. Reinjection of oil and gas waste into UIC Class II wells is permissible under the SDWA.¹⁵⁴ Such uses include routine reuse of produced water for water flooding and steam flooding. SWRCB and the Regional Boards are also tasked with achieving the maximum effective use of fresh waters through reclamation and recycling. For recycling for other beneficial uses, suppliers must conform to water reclamation requirements,¹⁵⁵ waste discharge requirements (WDRs)¹⁵⁶ or master recycling permits from Regional Boards for reuse of water.¹⁵⁷ In California, discharges of wastewater to land

usually require Waste Discharge Requirements (WDRs) issued by the appropriate Regional Board in compliance with the applicable water quality control plan.¹⁵⁸ SWRCB has issued a general permit for landscape irrigation, but it excludes non-municipal wastewater, including produced water.¹⁵⁹ This and other general permits could be used as models to develop general permits for beneficial reuse of produced water.

E. State regulations apply to treatment of produced water

Under the Clean Water Act, point sources associated with oil and gas production are prohibited from discharging wastewater directly to water bodies.¹⁶⁰ However, some fracking operators may send wastewater to treatment facilities, POTWs or CWTs, which are authorized to discharge. The national pretreatment program regulates discharges from industrial and commercial wastewater to POTWs. Because these discharges enter a POTW before entering a water of the US, they are considered indirect discharges.

Discharges by covered entities into POTWs are required to comply with pretreatment requirements. EPA regulations prohibit the introduction of wastes that interfere with, pass through or are otherwise incompatible with POTW operations.¹⁶¹ EPA’s federal regulations also set categorical pretreatment requirements for the introduction of industrial wastewater to POTWs and for the discharge of industrial wastewater from CWTs.¹⁶²

There are no federal pretreatment requirements specifically for oil or gas wastewater. EPA plans to develop pretreatment standards for the shale gas extraction and coal bed methane extraction industries in 2013 and 2014.¹⁶³ These standards will require that wastewater associated with those industries be treated to set standards before being discharged into POTWs.

The EPA has approved California’s program to regulate discharges of wastewater from point and nonpoint sources to “waters of the United States.” The State, through the Regional Water Boards, issues the NPDES permits, reviews discharger self-monitoring reports, performs independent compliance checking, and takes

enforcement actions as needed. States may establish pretreatment requirements that are stricter than current federal standards.¹⁶⁴ States may also flatly prohibit discharge of fracking wastewater to surface bodies, including through POTWs and CWTs. Ohio is one state that has banned treatment of fracking wastewater at POTWs and CWTs.

Because national pretreatment standards for direct dischargers have not yet been established for the hydraulic fracturing industry,¹⁶⁵ NPDES permits for POTWs must reflect site-specific discharge controls.¹⁶⁶ For indirect discharges with no specified pretreatment standards, state or local agencies are responsible for developing local technology or water quality-based limits.¹⁶⁷ The NPDES permits for POTWs and CWTs must include any requirements necessary to meet water quality standards, including water-quality limits on pollutants discharged to a particular water body.¹⁶⁸

California regulations do not specifically address whether wastewater from fracking can be disposed of in POTWs or CWTs. Therefore, fracking wastewater discharge to POTWs and CWTs is governed similarly

to other industrial discharge: operators determine whether they can meet their discharge limits before deciding whether to accept the flow.¹⁶⁹ State Water Resources Control Board and Regional Board representatives stated that they have no knowledge of fracking wastewater being sent to POTWs in California.¹⁷⁰ However, if hydraulic fracturing accelerates in the State, there may be a significantly larger amount of produced water that must be managed and disposed of, potentially placing more pressure on treatment facilities to accept and process such wastewater.

In addition, there is a potential regulatory gap with regard to oil and gas wastewater sent to POTWs and CWTs. The Clean Water Act's general prohibition against pass-through and interference may be difficult to implement and enforce for fracking wastewater because some POTWs and CWTs are not required to test their discharges for the pollutants that such wastewater contains.¹⁷¹ This also highlights the need for greater transparency and disclosure of chemicals used in fracking fluids.

V. Possible near-term changes may alter California's regulatory landscape

Intense interest in the topic of hydraulic fracturing has motivated recent state legislative and agency activity, including the introduction of several bills and a new rulemaking. Many environmental¹⁷² and industry¹⁷³ groups are engaging with these processes. In addition, a recent California Environmental Quality Act (CEQA) lawsuit could change the regulatory context if successful.¹⁷⁴

A. DOGGR's proposed new regulations would increase protections, but leave gaps

DOGGR is currently in the process of developing new regulations governing hydraulic fracturing operations. The agency released "discussion draft" regulations in December 2012, in advance of a formal rulemaking slated for 2013.¹⁷⁵ The "discussion draft" includes provisions for advance notification

to DOGGR; pre-fracturing well testing; monitoring during and after fracturing operations; disclosure of materials used in fracturing fluid after a fracking event; and requirements for storage and handling of hydraulic fracturing fluids.

1. DOGGR proposes increased disclosure and transparency

DOGGR's proposed new regulations would modify the State's disclosure and transparency requirements in some important respects. DOGGR would require oil and gas well operators to publicly disclose to Frac Focus after a fracking operation: the operator's name, the well location, well depth, the name of the geologic formation fractured, the list of chemicals used, the total volume of fluid used, and the disposition of the fluid used for fracturing.¹⁷⁶

In addition, DOGGR proposes a 10-day pre-fracturing well integrity test and advance notice to the agency, which it will post on its website "as soon as possible after receipt, but no less than 7 days after receipt."¹⁷⁷ Thus, the public would have between 3 and 10 days to see the pre-fracturing test form before fracturing takes place. However, this form would not contain information on the chemicals or approximate volume of fluid to be used. DOGGR also addresses trade secrets in its proposed new regulations. Its new regulations would require the owner of a trade secret to show that the trade secret gives the owner a significant economic advantage, that disclosure would compromise that advantage, that the information has not already been disclosed, and that the fluid or substance cannot be reverse engineered to discover its composition. The owner would also be required to declare under penalty of perjury that the substance in question was a trade secret.¹⁷⁸ Further, in the event of an emergency, the identity of any trade secret-protected fluid must be immediately disclosed to emergency personnel and to DOGGR, as well as to doctors or other medical professionals treating a patient suspected of exposure to the fluid.¹⁷⁹

DOGGR's proposed notice requirements are a step in the right direction, but longer lead time, more comprehensive pre-fracking information, and formal

opportunities for the public to report concerns, ask questions, and potentially change whether and how fracking occurs would be more empowering and meaningful. For example, DOGGR could use CEQA's notice provisions as a model and require at least 30 days advanced public notice and opportunities to comment before any fracturing event takes place (see also Section D. Recent lawsuits charge that DOGGR and BLM failed to appropriately consider risks). In addition, DOGGR's proposed regulations do not require this 10-day advance notice to be posted on Frac Focus before fracturing takes place. Thus, the new regulations seem to create two separate, incomplete sources of information – Frac Focus and DOGGR's own website.

In addition, DOGGR should require advanced disclosure of fluid composition, rather than post-fracking disclosure only. Regional water boards and local residents should know what chemicals are being used before fracking starts to enable baseline water sampling and assist in identification of potential sources of contamination.¹⁸⁰ This is especially true because contamination may take place immediately, yet according to DOGGR's discussion draft regulations, operators would have up to 60 days after a fracking event to report information on the chemicals used. We find this inadequate.

DOGGR itself has acknowledged that its "discussion draft" trade secret provision is inadequate – for example, if an oil developer or service provider goes out of business or is unreachable, there may be no way to obtain trade secret-protected information during an emergency or otherwise.¹⁸¹ Environmental groups have also criticized DOGGR's draft trade secret provisions, as well as its narrow definition of "health professionals," which excludes toxicologists, epidemiologists, chemists, and biologists, as well as researchers and regulators from agencies including EPA.¹⁸² As our recommendations below make clear, we believe DOGGR should require that even trade-secret protected information be disclosed to the agency, to ensure immediate emergency personnel access and long-term record keeping.

DOGGR's discussion draft recommendations show DOGGR's recognition of the importance of increased disclosure. However, in addition to points discussed above, gaps remain. Our recommendations set forth below are intended to fill some of these gaps and strengthen the regulatory requirements for notice and disclosure in California.

2. DOGGR proposes regulations specific to hydraulic fracturing events

DOGGR's discussion draft regulations contain general hydraulic fracturing requirements,¹⁸³ including requirements for sufficient cementing,¹⁸⁴ isolation of protected water zones¹⁸⁵ and potentially productive or corrosive zones,¹⁸⁶ and mechanical integrity testing.¹⁸⁷

These draft requirements are aimed specifically at hydraulic fracturing events. DOGGR's draft makes explicit the proposed distinction – “well stimulation operations, including hydraulic fracturing, are not underground injection or disposal projects.”¹⁸⁸ For injection well disposal more broadly, DOGGR has published an “action plan” indicating that it will respond to EPA's review of its UIC program.¹⁸⁹

DOGGR's discussion draft regulations describe evaluation prior to fracturing. Physical testing requirements include pressure testing of cemented casing strings, surface equipment testing, and cement evaluation.¹⁹⁰ Required fracture radius analysis would include modeling to simulate the extent of the fractures expected. This modeling would be used to estimate whether fractures would encounter existing active or inactive wells (i.e., possible conduits for migration), and to indicate whether additional geological evaluation would be required.¹⁹¹ These analyses are meant to ensure that the “operator shall design the hydraulic fracturing treatment so as to ensure that the fracturing fluids or hydrocarbons do not migrate and come in contact with a strata or zone that contains protected water.”¹⁹² DOGGR's discussion draft regulations do not specify details of how decisions will be made to “ensure” these outcomes, nor do they specify additional penalties for operators who fail to do so.

DOGGR's discussion draft regulations also contain provisions for monitoring after fracturing.¹⁹³ These include a 30-day daily monitoring period, with annular pressure, tubing pressure, and casing pressure monitored by the operator, and immediate notification to DOGGR required if specified pressure thresholds are exceeded. Rather than immediately reporting comprehensive monitoring data, the operator is required to maintain the data for five years and report it upon request by DOGGR.¹⁹⁴

DOGGR's proposed regulations define “protected water” as water that either:

- (1) Contains no more than 3,000 mg/l total dissolved solids; or
- (2) Contains no more than 10,000 mg/l total dissolved solids and is suitable for irrigation or domestic purpose.¹⁹⁵

This definition is more restrictive, and less precise, than EPA's quantitative definition, which defines sources of underground drinking water as those containing less than 10,000 ppm total dissolved solids (TDS). The definition of protected waters must be broad enough to protect water affording any beneficial uses, especially given California's scarce and highly valued water resources.

DOGGR's discussion draft regulations do not address reuse or recycling of fracking fluid or produced water. In addition, the discussion draft regulations do not mention treatment of oil and gas wastewater.

3. DOGGR proposes changes to storage and handling requirements

DOGGR's discussion draft contains proposed storage and handling regulations specific to fracturing fluids, excluding unmixed freshwater.¹⁹⁶ The requirements would include secondary containment storage equivalent to that required for other oil production facilities.¹⁹⁷ The regulations prohibit storage in unlined pits, but do not specify the need for tank storage, let alone any regulations for tank construction or maintenance.¹⁹⁸ The proposed regulations require an operator to conduct clean up and remediation in the event of a spill, and to notify DOGGR within five days.¹⁹⁹

B. New BLM rules would require increased notice and disclosure

In May 2012, BLM published a proposed rule that would require companies employing hydraulic fracturing on lands managed by BLM to provide: a detailed description of the well stimulation engineering design, an estimate of the total amount of fluid to be used, the content of the fracturing fluid, the maximum injection pressure anticipated, and information about the anticipated volume and handling of the flowback.²⁰⁰ After completing a well, a federal lessee would have to supply the trade name and purpose of each additive, the precise CAS (Chemical Abstracts Service) number for each chemical, and the percentage of each ingredient in the total volume of fracking fluids.

BLM has stated that it is its intention “to implement on public lands whichever rules, state or Federal, are most protective of Federal lands and resources and the environment.”²⁰¹ Therefore, companies carrying out fracking on BLM lands in California would be required to meet these requirements, at minimum, in addition to other California-specific requirements.

C. Several recent state bills would increase transparency or impose a moratorium

Nine bills addressing hydraulic fracturing have been introduced to the California Legislature for the current session as of March 24, 2013.

AB 7 (Wieckowski)²⁰² calls for stronger oversight than DOGGR’s new “discussion draft regulations.” The bill would require DOGGR, in consultation with other state agencies, to adopt rules on hydraulic fracturing focused mostly on notice and disclosure. For example, it would require operators to provide written notice to DOGGR 30 days prior to commencing a hydraulic fracturing treatment on a well.

SB 4 (Pavley)²⁰³ was recently amended to impose a *de facto* moratorium on hydraulic fracturing if state regulators do not complete a comprehensive study on the safety of fracturing by January 1, 2015. It would also require that DOGGR enter into formal agreements with the Department of Toxic Substances Control, the State Air Resources Board, and the

State Water Resources Control Board, delineating respective authority, responsibility, and notification and reporting requirements associated with hydraulic fracturing. The bill would require DOGGR, starting on January 1, 2016, and continuing annually, to transmit to the Legislature and make available publicly a “comprehensive report on hydraulic fracturing in the exploration and production of oil and gas resources in the state,” to include aggregated data detailing the disposition of any produced water from wells that have undergone hydraulic fracturing, as well as the number of emergency responses to a spill or release.

SB 395 (Jackson)²⁰⁴ would define produced water, including that from hydraulic fracturing operations, as a hazardous substance and require Department of Toxic Substances Control to develop regulations governing its handling and disposal. Currently, oil and gas waste has an exemption from designation as a hazardous waste under federal RCRA provisions.²⁰⁵

AB 982 (Williams)²⁰⁶ would require fracking operators to provide a groundwater monitoring plan to DOGGR and the appropriate regional water quality control board. The plan would include baseline data “sufficient to characterize the quality of the aquifer and identify the zone of influence of the proposed well,” and provide locations for monitoring wells to identify contamination during or after fracturing.

AB 1301 (Bloom)²⁰⁷ would impose a moratorium on hydraulic fracturing in California until “the Legislature enacts subsequent legislation that determines whether and under what conditions hydraulic fracturing may be conducted while protecting the public health and safety and the natural resources of the state.”

In 2011, the California Legislature also considered several bills that would regulate hydraulic fracturing operations. AB 591 was similar to AB 7, and would have required operators to disclose all fracking activities and the contents of fracking fluids, subject to exemptions for proprietary or trade secret information.²⁰⁸ AB 972 would have imposed a moratorium on all fracking operations in the State pending adoption of new regulations developed by DOGGR.²⁰⁹ In August 2012, both bills failed to clear the Senate Appropriations Committee.

D. Recent lawsuits charge that DOGGR and BLM failed to appropriately consider risks

In October 2012, the Center For Biological Diversity, Earthworks, Environmental Working Group and the Sierra Club filed a lawsuit against DOGGR, charging that it failed to consider or evaluate the risks of fracking.²¹⁰ The lawsuit challenges DOGGR's alleged "pattern and practice of approving oil and gas wells without any mention, let alone evaluation or mitigation, of the environmental and public health impacts of oil and gas development, including the effects of hydraulic fracturing," which they claim is a violation of the California Environmental Quality Act (CEQA).²¹¹

According to the complaint, DOGGR's approval of more than 38 projects for oil and gas wells since 2011 has followed the issuance of either (1) a Notice of Exemption from the requirements of CEQA based on a categorical exemption for "Minor Alterations to Land"²¹² or for "Existing Facilities"²¹³ or (2) a Negative Declaration or Mitigated Negative Declaration finding that such projects will not have a significant effect on the environment. Plaintiffs contend that these exemptions and negative declarations do not apply to fracking wells, and that the agency must prepare an EIR before approving such projects.²¹⁴

In response to a Public Records Act request, DOGGR sent Plaintiffs' attorneys a letter stating that it "does not specifically track or monitor the practice of hydraulic fracturing, on a well-by-well basis or otherwise," and that "oil and gas operators are not required to notify [DOGGR] of planned or projected hydraulic fracturing operations."²¹⁵

This lawsuit could have important implications for the applicability of CEQA to fracking activity in California.

In December 2011, the Center for Biological Diversity and the Sierra Club filed a lawsuit against the BLM, regarding BLM's decision to lease lands in California for oil and gas development.²¹⁶ The lawsuit alleges violation of the National Environmental Policy Act ("NEPA") and the Mineral Leasing Act of 1920 ("MLA"). Plaintiffs claim that BLM relied upon an environmental assessment prepared pursuant to NEPA that failed to analyze many of the significant environmental effects of oil and gas development that could occur upon approximately 2,700 acres of land in Monterey and Fresno counties that BLM leased to private parties. Among other claims, plaintiffs allege that BLM failed to address the impacts to water quality and other resources that result from hydraulic fracturing. The case is still pending.

VI. Moving forward: recommendations for near-term actions

This section presents our recommendations for near-term regulatory and legislative actions to safeguard against the water-related risks posed by hydraulic fracturing in California. The section builds on the technical and regulatory review presented above, and also draws on the experiences of other states that have grappled with hydraulic fracturing. Much of the rapid growth in shale oil and gas production has taken place in other part of the United States, including the Barnett Shale formation in Texas, the Marcellus Shale in Pennsylvania, Ohio, New York and West Virginia,

the Haynesville Shale in eastern Texas and Louisiana, and the Baaken shale in North Dakota. Many of these states have had active hydraulic fracturing operations for several decades. Consequently, they have addressed the regulation of fracking, including the regulation of fracking wastewater, in a more substantial manner than California has to date. The following sections highlight selected actions in other states where lessons may be useful for California decision-makers confronting similar issues.

A. Improving notice and disclosure will help protect local communities risks

1. Transparency motivates improved outcomes

As detailed above, California's current system of voluntarily reporting fracking activity to Frac Focus after the fact is inadequate. It is also considerably weaker than other state requirements.

While new fracking techniques have unlocked new sources of energy, safety questions center on the hundreds of chemicals used, many of them known carcinogens. Notice of the contents of fracking fluids helps communities, regulators, and emergency responders be better prepared for potential spills or contamination events. Disclosure also allows the public to better assess the risks of transport and storage of fracking wastewater.

Increased disclosure will also help determine responsibility and liability for any chemical contamination of underground water supplies or surface areas. In order to prove causation in a case claiming contamination from fracking activities, plaintiffs need to show that contaminants in question were not naturally present in groundwater.²¹⁷ And in order to defend against such lawsuits, developers will need to show that the chemicals they used are not the source of contamination. Thus, baseline testing of water quality before fracking takes place, as well as full disclosure of fracking chemicals used, will assist all parties in determining liability.

2. Other states have improved transparency in fracking operations

Advanced notice and disclosure laws at the state level vary widely, but examples of measures taken can be useful as conceptual guidelines.²¹⁸

Five states – including Montana and Wyoming – require pre-fracturing disclosure of all the chemicals that may be used in a fracking job. As of July 2012, seven states require that CAS numbers be disclosed for all additives used in fracking fluids, excepting trade secrets: Arkansas, Colorado, Montana, Ohio, Pennsylvania, Texas, and Wyoming.²¹⁹ Two

of these states, Montana and Wyoming, require the concentrations of all additives with their corresponding CAS numbers. Only a handful of states, including Wyoming, Colorado and West Virginia, require notice to landowners before fracking occurs on their property.²²⁰

Wyoming and Colorado's experience is particularly instructive because both states have a significant amount of BLM-controlled land, and have also developed new state regulations for fracking in the last three years.²²¹ Wyoming's regulations are particularly strong as compared to other states, and might serve as a model or baseline for California's new regulations. For example, Wyoming requires advanced public disclosure of the chemical additives, compounds and concentrations proposed to be mixed and injected prior to stimulation, including CAS numbers.²²² Wyoming's Oil and Gas Commission catalogs these data while maintaining the confidentiality of any trade-secret protected information.²²³ The state also requires advance written notice to all property owners within 1/2 mile of a proposed fracking or injection well site.²²⁴ Since the new regulations took effect in 2010, Wyoming regulators have seen no reduction in fracking activity in the state, but do report taking a few additional days, on average, to review permit applications before approving a well.²²⁵

Wyoming also requires that operators or service providers submit factual information to substantiate a claim that information should be kept confidential pursuant to trade secret law.²²⁶ It is reported that trade-secret exemptions were claimed for more than five ingredients for every well in Texas, undermining a new Texas law's purpose of informing people about fracking chemicals.²²⁷ This illustrates the need to have even trade secret-protected information disclosed to the state agency, as well as placing the burden on service providers to prove a claim of trade secret protection.

Our specific recommendations below incorporate many of these measures to increase notice and disclosure. In most cases, our recommendations go beyond DOGGR's proposed new requirements for advance notice.

3. Recommendations: DOGGR should increase notice and disclosure

Advance Notice

- Operators should be required to provide DOGGR, SWRCB, and the appropriate Regional Water Quality Control Board at least 30 days advance notice of any hydraulic fracturing event. Such notice should include complete contact details, information on well construction and testing, reasonably anticipated fracturing fluid chemical composition, and planned disposition of waste products.
- Physical copies of this advanced notice should be mailed to residents in potentially affected areas, as well as to water purveyors with water sources in these areas, at least 30 days before any fracturing event. In the short term, we recommend mailing all residents and property owners within a ½ mile radius of a fracking well.²²⁸ Similarly, DOGGR or operators should notify all water purveyors whose drinking water sources lie within this potentially affected area. DOGGR should then fund independent research based on peer-reviewed risk analysis and stakeholder input to determine a more reasonable distance to establish such notification, possibly related to a multiple of modeled fracture length. DOGGR's new proposed regulations do not require notice to property owners.
- DOGGR should also provide 30 days advanced notice to the public before any fracturing or injection event. This notice should be posted on a publicly accessible and location-specific website. This advance notice should include the operator's name, the well and location, well depth, the name of the geologic formation to be fractured, and details of well construction and well integrity testing. Also included should be what the operator reasonably anticipates as their list of chemicals to be used, the total volume of fluid to be used, and the planned disposition of the flowback and produced fluids. This notice should be followed by actual data after the fracturing event happens. This would go beyond DOGGR's new proposed regulations.

- DOGGR should ensure that public notice of fracturing events is served using a unified, accessible online source that is properly archived. Accessibility should include geographically searchable data, a map interface, and the ability to download data in formats readily useable by researchers. If data are stored and accessed via a third party such as Frac Focus, DOGGR should securely archive the same data.
- DOGGR should adopt a formal process by which concerned citizens can respond to planned fracking events in their communities. We recommend that the agency convene stakeholders to develop such a public process, which is also absent from DOGGR's proposed regulations.

Public Records

- DOGGR should post permits and testing records for well drilling, casing and cementing on Frac Focus, or, if Frac Focus will not accommodate this additional information, in an accessible, location-specific database on the Department of Conservation website. Criteria for accessibility include the ability to search (according to geographic area, additive, CAS number, time period, and operator), aggregate, map, and export data in formats that enable independent analysis across all database fields.²²⁹
- Operators should be required to post fracturing fluid composition and disposition information within 60 days after hydraulic fracturing.²³⁰
- The State Legislature should require DOGGR to transmit and make available publicly an annual comprehensive report on hydraulic fracturing in the state, including (but not limited to) aggregated data on the disposition of any produced water, trade secret claims, and the number of emergency responses to a spill or release.²³¹

Fracking Fluid and Trade Secrets

- As set forth in its new proposed recommendations, DOGGR should require the holder of proprietary information to declare under penalty of perjury that the information withheld

is a trade secret.²³² The agency should also require that operators submit factual information to substantiate a claim that information should be kept confidential.

- If trade secret protection is warranted, the company should still be required to disclose trade secret information to DOGGR.
- DOGGR should consider establishing a process for the public to challenge trade secret exemptions.
- Medical professionals should be able to obtain complete information on fracking fluid make-up, including trade secret-protected information, immediately in the case of an emergency. They should be able to obtain this information from both the regulatory agency and the company in order to avoid any delay.²³³ Further, DOGGR should adopt a broad definition of medical professionals that does not restrict out-of-state consulting professionals or medical researchers from accessing data, and remove draft provisions that could effectively prevent medical professionals from informing the public or conferring with colleagues.
- DOGGR and well operators should maintain a complete inventory of chemicals and other ingredients in fracking fluid at each site, available to emergency responders immediately, and to local governments at their request.²³⁴
- DOGGR should require that CAS numbers be disclosed for all additives used in fracking fluids, and that proposed and actual concentrations of all fracking fluid components be reported to DOGGR and online to Frac Focus or a state-run online database.

Tracking Waste and Disposal

- DOGGR should require operators to monitor and report the type and amounts of waste generated, as well as the location and ultimate disposition of fracking fluids, flowback, and produced water,²³⁵ closely tying the fluids to responsible parties through their life cycle. The exact form of such monitoring should be determined in conjunction with a stakeholder process involving regulated parties.
- DOGGR should research methods for unique chemical labeling of injected fluids, including but not limited to fracking fluids, with the goal of certifying methods for labeling requirements. Such research should include convening stakeholders and scientists to assess practical methods to achieve tracking.
- If tracer efficacy can be validated, DOGGR should consider requiring operators to label all injection fluids by assigning unique tracers to the fluid in any injection site (see Sidebar page 36, “Tracers could increase accountability for operators”). Each fracking job in California could have its fluids chemically labeled with unique tracers using methods certified by the State, to aid identification, proper response, and accountability in the event of a release. This recommendation applies to both production and disposal wells.
- DOGGR should consider requiring long-term, well-specific bonds that are large enough to incentivize long-term safety and stewardship by operators. This recommendation also applies to both production and disposal wells.

Tracers could increase accountability for operators

Ensuring that injected fluids can be traced back to their source would increase accountability for underground migration, as well as spills and leaks. Operators would have a greater incentive to maximize the safety of their operations. Responsibility for cleanup and abatement²³⁶ could be more directly assessed.

‘Tracers’, chemicals that can be mixed with a fluid and used to track its movement underground, are widely used in hydrologic studies and could be adapted to meet this need for hydraulic fracturing. The ideal tracer has specific chemical characteristics,²³⁷ and is uniquely identifiable. One promising set of tracers includes the benzoic acid family, which has been tested in fractured dolomite in New Mexico. These chemicals have the necessary chemical properties²³⁸ and possibility for unique identification.²³⁹ Further, new methods are being developed by innovative startups, such as nanoparticles²⁴⁰ or inert DNA,²⁴¹ which can uniquely mark a batch of fracking fluid. If their efficacy can be validated, these types of new technology may enable better short and long-term safety and accountability.

B. Better oversight can improve management and disposal of oil and gas wastewater

As described above, there are three main options for management and disposal of flowback and produced water from fracking operations: disposal into injection wells; reuse and recycling; and treatment. Most produced water in California is disposed of through injection in Class II wells; as such, DOGGR and SWRCB should increase attention to this practice. In addition, reuse and recycling has the potential to reduce the need for injection disposal and conserve water. We provide recommendations for incentivizing reuse and recycling in this section. Finally, we recommend steps to reduce the risk of harmful impacts from improper treatment, surface storage, and illegal dumping.

1. Regulators should safeguard against mismanagement of produced water by better regulating injection wells

The primary risk from underground injection of produced water is casing and cementing failure, which can cause migration of fluid through well bores to drinking water aquifers. Abandoned wells pose similar risks, which, in principle, require caution about nearby groundwater quality in perpetuity. Finally, seismic events induced by fluid injection have been documented in other states, and demand serious consideration and study in California.

a. Other states have improved regulation of management and disposal of produced water

In recent years, many states have strengthened regulations governing injection wells. New regulations include mandatory continuous mechanical integrity monitoring, automatic shut-off devices, disposal fees to fund regulatory oversight, mandatory waste tracking, and seismic risk management.

Ohio tracks and monitors the activity of brine haulers and requires injection well owners to electronically transmit quarterly reports to the appropriate agency with information about each brine shipment they receive and process.²⁴² Since 2010, Ohio has charged a disposal fee of five cents per barrel on Ohio brine, and twenty cents for waste originating out of state. Ohio collected \$1.45 million for these fees in 2011, supporting the expansion of its oversight and regulatory programs.²⁴³ Ohio’s Senate Bill 315 also mandated more stringent requirements for inspection of injection wells and continuous mechanical integrity monitoring. Ohio also adopted a process for citizens to report concerns to the agency before an underground injection event takes place.²⁴⁴

Due to controversy surrounding earthquakes found to be caused by injection wells, Ohio's Division of Oil & Gas Resources Management recently proposed new Underground Injection Control rules to address seismic risk.²⁴⁵ The new guidelines require companies to submit more comprehensive seismic data and prohibit injection into the formation where previous earthquakes originated, near Youngstown.²⁴⁶ The proposed rules also require monitoring annulus pressure and automatic shut-off devices that terminate injection if the permitted maximum allowable injection pressure is exceeded.²⁴⁷

New Ohio regulations governing production wells also require well owners to "sample all water wells within three hundred feet of the proposed well location in urbanized areas prior to drilling."²⁴⁸

Texas also recently strengthened its production and underground injection regulations. Texas is the nation's number one oil and gas producer with more than 216,000 active wells, and more than 50,000 permitted oil and gas injection and disposal wells. In terms of production, several amendments to the Texas Administrative Code relate to drilling, casing, and cementing of wells. These include new requirements for isolating usable-quality water zones, potentially productive zones, and over-pressured zones in order to prevent contamination and the migration of fluids beyond well casing.²⁴⁹

For Class II underground injection wells, the permitting process in Texas includes: notice to the public; hearing opportunities; a review of area geology; and required areas of review near the proposed wells to determine if there are other wells penetrating the same geologic horizon proposed for disposal.²⁵⁰ Any permit application may be protested by an affected party (those who must be notified, including surface owners, offset oil and gas well operators, and local governments if the is well within city limits), and a hearing will be conducted by the Texas Railroad Commission to evaluate protest issues.²⁵¹

Texas also requires operators to monitor the injection pressure and injection rate of each disposal well on at least a monthly basis and report any significant pressure changes or other monitoring data indicating the presence of leaks in the well within 24 hours.²⁵²

Tracking the state provisions described above, we recommend more transparency in DOGGR's injection well permitting process, including opportunities for affected parties to comment on proposed injection wells, more inspection and monitoring, and more information on the relationship between injection wells in California and the potential for induced seismicity.

b. Proposed regulations do not go far enough to regulate injection events

As described above in Section A. (DOGGR's proposed new regulations would increase protections, but leave gaps), DOGGR has proposed to address hydraulic fracturing events with new regulations that are currently in "discussion draft" form. The proposed regulations touch on well evaluation, physical integrity testing, storage and handling.

Our recommendations go a bit farther to protect underground drinking water from contamination and reduce risks from induced seismicity, particularly dangerous in California.

c. Recommendations: DOGGR should better regulate injection well disposal

Underground Sources of Drinking Water

- DOGGR should strengthen its water quality definition to match or exceed U.S. EPA's. DOGGR should define USDWs according to EPA's 10,000 ppm TDS standard, and also account for beneficial use designations accorded to small systems. USDWs should be protected using this standard from the permitting to abandonment phases of injection wells.²⁵³

- SWRCB and the Regional Boards should conduct long-term, coordinated monitoring of groundwater quality in various regions throughout the state to establish a scientific baseline for groundwater quality,²⁵⁴ starting with a peer reviewed plan detailing the parameters necessary to establish an appropriate baseline.
- DOGGR and SWRCB should jointly explore the possibility for using idle wells, sealed above the production zone, as groundwater quality monitoring wells.
- Operators should be required to sample all water wells within ½ mile of the proposed wellhead, and submit the results to DOGGR and the appropriate Regional Board prior to commencing drilling. DOGGR may require modification of this distance if necessary to protect water supplies (see recommendation on page 34, “Physical copies of this advanced notice...”).²⁵⁵
- DOGGR staff should be required (not simply permitted, per current regulations) to witness mixing and pumping of cement for plug placement.²⁵⁹
- DOGGR should require monitoring annulus pressure and automatic shut-off devices that terminate injection if the permitted maximum allowable injection pressure is exceeded.

Well Abandonment

DOGGR should develop and implement a well closure and post operational monitoring program, including the following actions:

Well Integrity

- DOGGR should require all operators to monitor pressure and well integrity during any injection event.
- For injection wells, DOGGR should adopt EPA’s recommendations for more stringent well casing and cement integrity, as set forth in EPA’s review of DOGGR’s UIC program,²⁵⁶ including mechanical integrity testing for UIC wells. Such tests would include Radioactive Tracer Tests and Standard Annulus Pressure Tests where appropriate, conducted while DOGGR staff are present, and comprehensive annual reviews of active UIC wells.²⁵⁷
- DOGGR should require continuous mechanical integrity monitoring or monthly mini-tests to demonstrate continuous mechanical integrity.²⁵⁸
- DOGGR should respond to and adopt EPA’s recommendations for improving its idle well planning and testing program for injection wells, and adapting those standards to production wells as applicable. In particular, standards should be made consistent across districts, and pressure testing, in addition to monitoring fluid levels, should be required in order to maintain well integrity.
- Because an abandoned well is a potential hazard to USDWs forever, DOGGR and SWRCB should require long-term monitoring of USDWs near abandoned wells.
- DOGGR should increase the bonds required of well operators to levels that incentivize proper decommissioning and long-term stewardship.²⁶⁰
- DOGGR should disclose the location and status of all abandoned wells in a web-accessible database.

Seismic Risk

- The Department of Conservation should fund studies on seismic risk from hydraulic fracturing and injection wells in California to reduce uncertainties and guide refinement of regulations. These studies should define and map faults with risk for induced seismicity, and develop methods to determine safe distances from faults for fracturing and injection disposal, examining both risk at the surface, and risk of damage to well casing and cementing.
- DOGGR should develop guidelines to define and map faults with risk for induced seismicity and develop safety factors for distance from fracturing based on this risk analysis. Injection should be prohibited near risky faults based on this analysis.
- DOGGR should consider requiring companies to generate and submit comprehensive seismic data before any fracking or injection event. DOGGR may require additional tests or evaluations of any proposed injection well before issuing a permit.

C. There is potential for greater reuse and minimization in California

California could increase the sustainability of its oil and gas production by incentivizing or requiring the safe recycling and reuse of oil and gas production wastewater. Wise stewardship of water resources is particularly important as California adapts to climate change impacts such as longer and more severe droughts and rising temperatures.

1. Improving reuse and minimization of fracking wastewater could have broad benefits

One way to reduce the amount of necessary wastewater management is to reduce the amount of wastewater that is produced by a well. Such minimization can occur through available technology may not yet be commonly used in California. Reuse

also has the potential to reduce necessary water inputs and disposal requirements. Reuse opportunities vary greatly depending on produced water quality and local demands, and may need to be incentivized by regulators.

2. Other states have incentivized the reuse and minimization of produced water

Texas has increasingly incentivized the recycling of oil and gas wastewater through regulatory reform since 1992, when it established the voluntary Oil and Gas Waste Reduction and Minimization Program.²⁶¹ This program provides guidance on source reduction and recycling concepts, cost effective and practical examples of source reduction and recycling opportunities, and information on how to develop an individualized waste minimization plan.

In 2012, the Texas Railroad Commission (RRC) released several proposed amendments to the Texas Administrative Code relating to the recycling of produced water and flowback. The regulations are intended to encourage recycling and reusing produced water – particularly useful for a state susceptible to drought. The new Texas regulations also clarify appropriate uses for partially treated or fully treated recycled wastewater.²⁶² After partial treatment, oil and gas wastewater can be used as makeup water for a hydraulic fracturing fluid treatment, or other oilfield fluid to be used in the wellbore of an oil, gas, geothermal, or service well. After complete treatment to national drinking water standards established under the SDWA,²⁶³ an operator may use or dispose of the treated hydraulic fracturing flowback fluid in any manner other than discharge to surface water or irrigation of edible crops.²⁶⁴

Texas also provides monetary incentives to recycle. Items specifically used to process, reuse, or recycle wastewater that will be used in hydraulic fracturing work performed at an oil or gas well are exempt from sales, excise, and use taxes.²⁶⁵

Pennsylvania requires that operations with fracking wastewater develop a source reduction strategy and identify methods and procedures to maximize recycling and reuse of flowback or produced water.²⁶⁶

The Pennsylvania Department of Environmental Protection (PADEP) has issued a general permit for recycling fracking wastewater, intended to promote and monitor recycling.²⁶⁷ The permit requires weekly inspection of all processing and storage areas, physical requirements limiting proximity to wetlands, floodplains and dwellings, and a host of other requirements intended to both increase safety and

facilitate recycling. The rule requires that processed wastewater meet set limits for TDS and other constituents, and requires permittees to send samples of processed water to PADEP regional facilities on a regular schedule.²⁶⁸ Finally, the new regulations require that any oil and gas wastewater having TDS of less than 30,000 mg/L cannot be discharged but must be recycled and reused.

Resource recovery and beneficial use of produced water are potential sources of local water supply

Produced water is in some cases a potential source of freshwater.²⁶⁹ The 2.39 billion barrels of produced water²⁷⁰ generated by California onshore oil and gas wells in 2010 amounts to about 300,000 acre-feet, approximately the amount of clean water used by 1.4 million Californians in one year for residential use, or enough to irrigate around 87,000 acres of farmland at statewide average irrigation rates. Produced water could be considered not only as something to be disposed of, but rather, if it can be treated to appropriate standards, a valuable resource that can be recovered from the oil and gas waste stream.²⁷¹

Cost estimates for reclaiming oilfield brine vary tremendously, but are often less than the cost of obtaining fresh water and disposal of produced water.²⁷² The reuse of produced water from Chevron's Kern River Oil Field by Cawelo Water District, for example, shows that economically viable solutions that develop such water supplies while reducing disposal costs for oil operations are possible.²⁷³ This field is exceptional for the relative quality of its produced water.²⁷⁴ Even where water quality is sufficient,²⁷⁵ lack of familiarity with regulatory requirements for reuse as described below may discourage producers from pursuing beneficial reuse, even where it might be economically feasible.

In at least one pilot project, the Placerita Oil Field in Southern California, produced water has been considered as a possible drinking water source.²⁷⁶ In such cases, the permitting would be guided by Department of Public Health (DPH), which has specifically addressed the possibility for produced water and recommended guidelines that include source assessment, quality testing, monitoring and treatment, risk assessment, and CEQA review.²⁷⁷ DPH notes that lower quality source waters should be used for nonconsumptive uses that pose lower health risk. Produced water quality must be evaluated carefully and aligned with appropriate uses only. Complete information on any fracking fluid chemicals must also be available in order to safely reuse produced water for any uses other than reuse in fracking.

Because the monetary value of water is less than that of oil, oil producers may not perceive the benefits possible from engaging with water wholesalers about such transactions without additional information and outreach. Similarly, oil producers may be wary of overcoming perceived regulatory barriers to recycling and selling this wastewater. Regulations that encourage safe reuse and recycling could help increase the use of produced water as a water supply for California, although they must ensure appropriate water quality.

Texas Recycling Success

Some Texas companies have a strong track record of recycling and reusing fracking wastewater. For example, Fountain Quail Water Management of Jacksboro reuses approximately 80 percent of its returned fracture fluids. It uses on-site distilling in a mobile unit to apply heat that separates the brine from a larger volume of distilled water that is reused to fracture additional wells in the Barnett Shale. The fracture flowback fluid is stored in tanks on location and piped into treatment equipment, and natural gas produced on location is used to fire the distilling units. As of October 2010, Fountain Quail processed over 12.7 million barrels of returned fracture fluid to recover over 9.9 million barrels of reusable distilled water.²⁷⁸

Because DOGGR's proposed new regulations do not address recycling and reusing water, Texas and Pennsylvania's regulations, among others, can be instructive in designing new regulations to facilitate safe recycling and reuse of produced water in California.

3. Recommendations: DOGGR and SWRCB should improve regulations for reuse and minimization

Information

- DOGGR, in collaboration with SWRCB, should develop a public information database that provides the location, quantity and quality of produced water sources. This, in conjunction with studies of the economics²⁷⁹ of treatment and use of produced water of varying qualities, would advance understanding and potential use of appropriately treated recycled water for beneficial uses.
- DOGGR and SWRCB should collaborate with oil and gas industry groups to provide information to operators on reuse and minimization and encourage increased use of such practices. They should also engage with other potentially affected stakeholder groups such as water recycling interest groups²⁸⁰ and other groups intimately involved with beneficial use and management of groundwater resources.²⁸¹

Financial Incentives

- The California Legislature should consider whether to incentivize wastewater recycling through tax exemptions for items used specifically to process, reuse, and recycle wastewater used in hydraulic fracturing at an oil or gas well.

Permitting

- DOGGR or industry groups should study the potential for benefits (and unintended consequences) from downhole separation devices²⁸² and closed loop systems that could be increasingly applied to wells in California.

- In order to streamline reuse and recycling, SWRCB should consider developing a general permit for recycling produced water to streamline beneficial reuse in appropriate cases.²⁸³
- As implemented in Pennsylvania, DOGGR should require fracking operators to develop a source reduction strategy that identifies methods and procedures to maximize recycling and reuse of flowback or produced water.
- DOGGR should study or incentivize the use of more environmentally benign fracking fluids, including those that are not water-based. For example, deep Monterey formation wells might be effectively stimulated using supercritical CO₂ instead of water.²⁸⁴ The goal would be to potentially reduce flowback or water-borne contaminants.

D. Treatment regulations can safeguard POTWs

1. Treatment regulations will fill a gap

Treatment of produced water to varying degrees is necessary in situations ranging from treatment before disposal in injection wells to treatment before release to POTWs. Treatment has received little attention in California to date, likely because disposal via injection is much more common. However, given an anticipated increase in fracking in the state, and consequent increase in the amount of wastewater produced, some careful attention to this issue is warranted.

2. Other states have addressed treatment of produced water

Pennsylvania's early experience with treatment of produced water may be instructive to California regulators. As Pennsylvania experienced a shale gas boom from 2008 through 2010, total dissolved solids levels in major Pennsylvania watersheds increased significantly. In 2010, PADEP revised state regulations to authorize new or increased discharges of shale gas wastewater only from centralized treatment facilities (CWTs) that have no direct surface water

discharge.²⁸⁵ The regulations also tightened discharge limits for total dissolved solids, chlorides, barium and strontium.²⁸⁶ After persistent water quality concerns even after the new regulations were implemented, PADEP directly requested that the oil and gas industry stop sending oil and gas wastewater even to “grandfathered” existing POTWs.²⁸⁷ This led to a significant decrease in TDS levels in Pennsylvania from 2011 to 2012.²⁸⁸

Many states, including Ohio, prohibit the discharge of flowback water to surface waters pursuant to state law.²⁸⁹ Ohio also bans the treatment and discharge of oil and gas wastewater through POTWs and CWTs.²⁹⁰ In part, this outright ban on treatment at POTWs and CWTs may be possible in Ohio but not in Pennsylvania due to their varying geography: Pennsylvania ships much of its fracking wastewater to Ohio for injection underground, as its own geography is not well suited for injection well disposal.

Other states, such as Texas, allow the discharge of shale gas wastewater to POTWs.²⁹¹ By a letter of request, a company may also apply to the Railroad Commission of Texas for a permit to discharge treated wastewater to inland waters or to the Gulf of Mexico, as long as the produced water complies with the Texas Water Surface Quality Standards.²⁹²

Thus, in the absence of federal pretreatment standards, states are taking varied approaches to treatment and discharge of fracking wastewater. Our recommendations are designed to avoid the negative environmental effects experienced in states like Pennsylvania, and flag relevant issues for more careful attention.

3. Recommendations: California should evaluate and better regulate treatment

- SWRCB should fund a scientific review of the risks to California water bodies from fracking wastewater.
- DOGGR regulations should explicitly prohibit direct discharge of flowback or produced water from oil and gas operations to POTWs until EPA issues pretreatment guidelines.

- If SWRCB or the Department of Public Health choose to issue pretreatment requirements, regulations should require pretreatment before release to POTWs to numerical water quality standards that take into account the broad suite of potential contaminants present in fracking wastewater. Particular attention should be given to constituents that are known to pass through or interfere with treatment operations, and to those that are present in fracking fluid and produced water, but not targeted in standard monitoring.
- If treatment increases in prevalence, treatment regulations should require permittees to send samples of processed water to SWRCB regional facilities on a regular schedule, and fund additional staff for testing and verification.

E. Surface storage and dumping pose risks

1. Surface storage and dumping deserve attention

Dumping and surface storage present risks to surface and groundwater, as evidenced by incidents in other states and in California (Section III). The absence of publicized dumping events in California does not verify that dumping has not happened or will not happen: monitoring and enforcement of disposal procedures are currently weak. The severity of potential human health and ecosystem impacts warrants greater attention.

DOGGR’s new proposed regulations state that “[n]on-freshwater fluids associated with hydraulic fracturing shall not be stored in unlined sumps or pits.” Best practices (derived from hazardous waste storage) go farther, incorporating closed tanks with secondary impoundments to guard against leakage.²⁹³

DOGGR’s discussion draft regulations would also allow operators to wait five days before reporting an unauthorized release of fracking fluid or wastewater – including spills onto land or into surface or groundwater.²⁹⁴ Such spills should be reported to the agency and to affected parties immediately.

2. Other states have addressed surface storage, and have witnessed cases of illegal dumping or disposal

Many states, including Wyoming and Ohio, have prohibited storage of fracking fluids and wastewater in unlined pits. In Wyoming, for example, storage must be in tanks or lined pits. The state must approve the construction of reserve pits and may require special precautions, including impermeable liners and/or membranes, monitoring systems, or closed systems, depending on proximity to water sources and other risk factors.²⁹⁵

While reported cases of illegal disposal of fracking wastewater or illegal dumping are rare, there has been at least one reported case of illegal disposal into injection wells. The owner and operations manager of Texas Oil and Gathering were convicted of conspiring to dump illegal waste and violating the Safe Drinking Water Act, as they illegally disposed of hazardous chemicals from a petroleum refining plant into Class II wells, rather than into more stringently controlled Class I wells.²⁹⁶ And in Ohio, a fracking company was recently accused of illegally dumping fracking wastewater down a storm drain.²⁹⁷ Such incidents underscore the need for more agency personnel on the ground to conduct inspections and closely review documentation.

3. Recommendations: Surface storage and illegal dumping should be addressed with specific regulations

- DOGGR should ban the use of surface impoundments or sumps to store flowback and produced water, requiring closed tanks with secondary impoundments.
- DOGGR should regularly inspect all processing and storage areas.
- DOGGR and SWRCB should deter illegal dumping by deploying additional staff to inspect well sites and enforce penalties.

F. Diatomite fracking deserves regulatory attention

Diatomite areas carry unusual risks that differ from fracking in the deeper Monterey Formation (see Sidebar page 18, “Diatomite formations may have less natural protection for groundwater”). These risks have not been appropriately analyzed. Given geological information, fracking in diatomite is worthy of immediate and specific regulatory attention.

- DOGGR should develop and enforce standards for increased monitoring of sub-surface oil flows in diatomite areas. Based on these data, DOGGR should fund a risk analysis study of the practice of fracking, steam flooding, and water flooding in shallow diatomite formations, including evaluation of the short- and long-term risks of the practice.
- If monitoring data and analysis suggests that local risks may be present, DOGGR should consider a moratorium on activity in diatomite areas until producers can demonstrate that they have developed extraction techniques that safeguard water quality.
- In the immediate term, DOGGR should fund an expert review of existing information on the risks from diatomite fracking, and consider whether and where interim measures are necessary.

G. Additional technical research and synthesis are necessary to fill information gaps

As the data reviewed in this document suggests, enough is known to implicate fracking as a potential risk to human and environmental health. However, many unknowns exist. Researchers lack data and analysis on key areas that bear on safety, in a rapidly changing landscape. Investing in basic data and analysis could help regulators gain better understanding of the risks involved, and reduce the current climate of regulatory uncertainty.

Additional Research

- Using proceeds from increased assessment fees, DOGGR should fund, through an independent mechanism such as the California Energy Commission's Public Interest Energy Research program, peer-reviewed research on the environmental implications of fracking in California.
- An analysis of environmental justice implications should be conducted to evaluate the distribution of impacts from projected fracking activity, and the mitigation of disproportionate impacts on marginalized groups.
- To support greater understanding of California's complex geology, data about geological strata revealed from well drilling records could be incorporated into public databases, with an appropriate delay to protect investment in exploration.
- DOGGR should fund peer-reviewed economic analysis of scenarios for changes in regulation and revenue. Specific topics for inquiry would include analysis of the potential regulatory and tax burdens on the competitiveness of oil and gas production in California, and the potential for an increased revenue stream not only to support oil and gas regulation and enforcement activities, but also for other state spending purposes.

H. Fracking activity could generate resources to enable more effective oversight

The California Legislature should consider funding this important research through severance taxes and designated fees for oil and gas production. California has among the lowest assessment rates in the country for natural gas, an order of magnitude lower on either a value percentage or volumetric basis than most other

states,²⁹⁸ and is the only major oil-producing state with no severance tax on oil or gas.²⁹⁹

There is substantial room for increasing revenue necessary to implement regulatory improvements such as those described in this report, while still leaving gas and oil production tax-competitive with other states. For example, well permit fees in Pennsylvania allowed the state to hire thirty-seven oil and gas staff members and largely funded Pennsylvania's Bureau of Oil and Gas Management.³⁰⁰

Note that for most purposes, any additional "tax," as defined by the California Constitution, would require a 2/3 vote of each house of the Legislature, or passage of a ballot initiative.³⁰¹ Such taxes would include those funding activities in completely unrelated spheres such as education.³⁰² In contrast, exactions funding a regulatory program are excluded³⁰³ from the definition of a tax, such as the assessments currently used to fund DOGGR activities. Funding for research would also be important to the regulatory activities surrounding oil and gas production, thus giving a "specific benefit conferred or privilege granted directly to the payor."³⁰⁴ Models exist for similar funding mechanisms for research, such as through California's Electric Program Investment Charge.³⁰⁵

Funding

- Increasing the severance tax on oil and gas in California could help fund more effective oversight, while maintaining profitable oil operations.
- DOGGR should calculate its needs for greater enforcement, analysis and other programmatic growth based on the recommendations above and elsewhere. In conjunction with legislative activity where necessary, DOGGR should increase its severance taxes and assessment fees accordingly.

VII. Next steps and open issues

While the focus of this report is on wastewater and potential water impacts in California, fracking presents other challenges³⁰⁶ that are beyond the scope of this report. The following important issues should be addressed in future work:

- Water resource impacts resulting from increased demand or withdrawals of water for use in fracking fluid. Many states are considering legislation to require operators to report volume of water used and sources of water used in fracking operations.
- The greenhouse gas intensity of oil and natural gas could have global implications, and may be relevant to California's efforts to reduce greenhouse gas emissions under AB 32.³⁰⁷ Reports of considerable methane leakage³⁰⁸ emerging in other states are alarming, as methane is a potent greenhouse gas, and the large amounts of produced water pumped from many mature oil fields in California increases the energy required for production of California oil.³⁰⁹ The California Air Resources Board and DOGGR need to decide how the greenhouse gas emissions from the hydraulic fracturing industry should be regulated, and if the Low Carbon Fuel Standard Program³¹⁰ provides an appropriate framework under which to do so.
- If methane leakage is common, it could challenge the potential for natural gas to serve as a “bridge fuel” to renewable energy sources. At minimum, new measures should be implemented to track and control methane leakage.³¹¹
- Air emissions from all stages of the fracking process have impacts, including methane, volatile organic compounds (VOCs), and particulate matter from increased trucking and diesel emissions.³¹²
- Land use impacts from individual wells, and clusters of wells, can be substantial. For example, DOGGR should fund research to project of how well-pad scarring will manifest in California if exploration intensifies.
- Other potential human health impacts to workers³¹³ and the general public³¹⁴ have only begun to be explored.

These issues deserve more attention by researchers, regulators, policymakers and all stakeholders going forward.

VIII. Conclusion

The recommendations set forth in this report are intended to shine a light on specific areas where additional studies, oversight, transparency, innovation, and enforcement can avoid potentially severe risks to our water supply and environment. DOGGR's discussion draft regulations are an important step towards more environmental and public health protection, yet we believe the agency should go farther in order to properly manage fracking wastewater and risks to water supplies.

Other states are ahead of California on the issue of hydraulic fracturing regulation. This presents California—often a leader on environmental issues—with an unusual opportunity to learn from

the experience of other states, and move to set a higher bar for environmental stewardship. California policymakers and agencies, including DOGGR and SWRCB, should work to address the gaps in oversight described throughout this report.

A decision to delay proper regulation risks ignoring important lessons learned in other states, where gaps in regulatory oversight enabled water quality problems, earthquakes, and more. In this case, a proactive stance is justified even with incomplete information because fracking and its attendant impacts cannot be undone. If wells and wastewater are mismanaged, the results can be expensive, harmful to human health and the environment, and potentially impossible to repair.

IX. Acknowledgements

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Naturally, any errors are the responsibility of the authors alone.

X. Endnotes

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³ HEATHER COOLEY & KRISTEN DONNELLY, PACIFIC INSTITUTE HYDRAULIC FRACTURING AND WATER RESOURCES: SEPARATING THE FRACK FROM THE FICTION (2012); GWPC & ALL, *supra* note 1

⁴ Reports surveying subsets of state fracking regulations include GROUNDWATER PROTECTION COUNCIL, STATE OIL AND GAS REGULATIONS DESIGNED TO PROTECT WATER RESOURCES (2009), *available at* <http://www.gwpc.org/resources/publications>; RESOURCES FOR THE FUTURE, MANAGING THE RISKS OF SHALE GAS: IDENTIFYING A PATHWAY TOWARD RESPONSIBLE DEVELOPMENT: A REVIEW OF SHALE GAS REGULATIONS BY STATE, Table 2. Flowback/Wastewater Disposal Options (2012), *available at* http://www.rff.org/centers/energy_economics_and_policy/Documents/Shale_Maps/Table2_wastewater_disposal_options.pdf; STATE REVIEW OF OIL AND NATURAL GAS ENVIRONMENTAL REGULATIONS, [HTTP://WWW.STRONGERINC.ORG](http://www.strongerinc.org) (last visited Mar. 28, 2013).

⁵ CAL. DEP'T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., NARRATIVE DESCRIPTION OF HYDRAULIC FRACTURING DRAFT REGULATIONS (2012), *available at* http://www.conservation.ca.gov/dog/general_information/Documents/121712NarrativeforHFregs.pdf; see also Section V. A "discussion draft" and the workshoping and other procedures accompanying it are precursors to a rulemaking (CAL. GOV'T CODE § 11346.45) that, under the Administrative Procedures Act, must be completed within one year of initiation.

⁶ See, e.g., Cooley & Donnelly, *supra* note 3; Comments from Damon Nagami, Senior Attorney, Natural Resources Defense Council, to Div. of Oil, Gas, & Geothermal Res. & Dep't of Conservation Re: Recommendations for Fracking Regulations (July 23, 2012) (*available at* <http://switchboard.nrdc.org/blogs/dnagami/NRDC%20ltr%20to%20DOC%20re%20fracking%20recommendations%207.23.12.pdf>).

⁷ For example, there is no physically discernible boundary between flowback and produced water in oil production, but both are inherent byproducts of hydraulic fracturing where it is used to stimulate oil production in California's Central Valley. See also Comments from Damon Nagami, Senior Attorney, Natural Resources Defense Council, *supra* note 6.

⁸ See data compiled by HAMMER, VANBRIESEN, *supra* note 2, from sources cited therein; Bethany Alley, Alex Beebe, et al., *Chemical and physical characterization of produced waters from conventional and unconventional fossil fuel resources*, 85 CHEMOSPHERE 74 (2011).

⁹ STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING, (Comm. Print 2011), *available at* <http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic-Fracturing-Chemicals-2011-4-18.pdf>.

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¹¹ Stephen G. Osborn, et al., *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing*. 108 PROCEEDINGS OF THE NAT'L ACAD. OF SCIENCES 8172 (2011); Claudio Brufatto, Jamie Cochran, et al., From Mud to Cement - Building Gas Wells, OILFIELD REV., Aug. 2003, at 62; Theresa Watson & Stefan Bachu, Evaluation of the Potential for Gas and CO₂ Leakage along Wellbores, 24 SPE DRILLING & COMPLETION 115 (2009).

¹² N. El Shaari & W.A. Miner, *Northern California Gas Sands - Hydraulic Fracture Stimulation Opportunities and Challenges*, Conference Paper Presented at SPE Western Regional and Pacific Section AAPG Joint Meeting, Bakersfield, Cal., March 31-April 2, 2008.

¹³ In January 2011, State Senator Fran Pavley wrote to the California Division of Oil, Gas and Geothermal Resources, or DOGGR, asking for information about the number and location of fracked wells in the state, the amount of water used, the permitting process, and what was known about the risk to groundwater. The agency responded with a detailed four-page letter, stating that it was “unable to identify where and how often hydraulic fracturing occurs within the state.” It also said that “the Division has not yet developed regulations to address this activity.”

¹⁴ WSPA represents 80% of operators in the state, so this survey is important information, but not complete; DOGGR representative, pers. comm.; industry representative, pers. comm.

¹⁵ U.S. ENERGY INFORMATION ADMIN., ANNUAL ENERGY OUTLOOK 2013 EARLY RELEASE OVERVIEW (2012) available at [http://www.eia.gov/forecasts/aeo/er/pdf/0383er\(2013\).pdf](http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2013).pdf).

¹⁶ Norimitsu Onishi, *Vast Oil Reserve May Now Be Within Reach, and Battle Heats Up*, N.Y. TIMES, Feb. 3, 2013, http://www.nytimes.com/2013/02/04/us/vast-oil-reserve-may-now-be-within-reach-and-battle-heats-up.html?pagewanted=all&_r=0.

¹⁷ U.S. ENERGY INFORMATION ADMIN., REVIEW OF EMERGING RESOURCES: U.S. SHALE GAS AND SHALE OIL PLAYS (2011) available at <http://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf>.

¹⁸ Id.

¹⁹ N. El Shaari & W.A. Miner, *supra* note 12.

²⁰ Industry representative, pers. comm.; see J. David Hughes, *Energy: A reality check on the shale revolution*, 494 NATURE 307 (2013) for another perspective.

²¹ New York Department of Conservation, High Volume Hydraulic Fracturing Proposed Regulations: 6 NYCRR Parts 52, 190, 550-556, 560, and 750 (2013), available at <http://www.dec.ny.gov/regulations/77353.html> (“If DEC decides that hydraulic fracturing cannot be safely done in New York, these regulations will not have any practical effect and the process will not go forward. If DEC decides that the process can be done safely, these regulations would be adjusted in accordance with the health and safety requirements and issues addressed in the Supplemental Generic Environmental Impact Statement.”)

²² See, e.g., HALLIBURTON ENERGY SERVICES, U.S. SHALE GAS: AN UNCONVENTIONAL RESOURCE. UNCONVENTIONAL CHALLENGES (2008) available at [HTTP://WWW.HALLIBURTON.COM/PUBLIC/SOLUTIONS/CONTENTS/SHALE/RELATED_DOCS/H063771.PDF](http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf)

²³ Aaron Ketter, John L. Daniels, et al., A Field Study in *Optimizing Completion Strategies for Fracture Initiation in Barnett Shale Horizontal Wells*, 23 SPE PROD. & OPERATION 373 (2008).

²⁴ Id.

²⁵ Id.

²⁶ What Chemicals are Used, FRAC FOCUS CHEMICAL DISCLOSURE REGISTRY, [HTTP://FRACFOCUS.ORG/CHEMICAL-USE/WHAT-CHEMICALS-ARE-USED](http://fracfocus.org/chemical-use/what-chemicals-are-used) (last visited Mar. 28, 2013).

²⁷ STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING, *supra* note 9. <http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf>; Theo Colborn, Carol Kwiatkowski, et al., *Natural Gas Operations from a Public Health Perspective*, 17 HUMAN AND ECOLOGICAL RISK ASSESSMENT: AN INT’L J. 1039 (2011).

²⁸ STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING, *supra* note 9.

²⁹ Id.

³⁰ Id.

³¹ Id.

³² GWPC & ALL, *supra* note 1; What Chemicals are Used, FRAC FOCUS CHEMICAL DISCLOSURE REGISTRY, *supra* note 25 (e.g., friction reducing additives reduce the necessary water pressure. Biocides reduce fouling of the fractures. Oxygen scavengers prevent corrosion of equipment Acids prevent corrosion and scale deposits, dissolve minerals, prevent precipitation of metal oxides, and to adjust pH for other ingredients to function more effectively.)

³³ HAMMER, VANBRIESEN, *supra* note 2 at 11. Note that detailing the quality of California’s oil and gas wastewater is challenging – as noted below there is no data source for either inputs or well outputs. Some generalizations about fracking fluid are possible. However, they are based mostly on reports from other regions than California.

³⁴ The definition of produced water can be somewhat ambiguous, as the term “produced water” can also be used to refer to the total wastewater, including flowback. In this report, we use “flowback” and “produced water” to refer to the two separate fractions, and use “wastewater” to refer to all waste product produced over the entire fracking process.

³⁵ CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., 2010 PRELIMINARY REPORT OF CALIFORNIA OIL AND GAS PRODUCTION STATISTICS (2010), *available at* ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2010/PR03_PreAnnual_2010.pdf; For context, that amounts to about 300,000 acre-feet, approximately the amount of clean water that would be used in a year by 1.4 million Californians for residential use, or to irrigate around 87,000 acres of farmland.

³⁶ Rozell & Reaven, *supra* note 10.

³⁷ Osborn, *supra* note 11.

³⁸ The study will include research associated with the fracking water lifecycle (both in terms of quality and quantity), an environmental justice assessment, analysis of existing data, case studies, and modeling of impacts, among other topics. EPA plans to release a progress report in late 2012, with a final draft report scheduled for late 2012; OFFICE OF RESEARCH AND DEVELOPMENT, U.S. EPA, EPA/600/R-11/122, PLAN TO STUDY THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES. (2011), *available at* http://www.epa.gov/hfstudy/HF_Study__Plan_110211_FINAL_508.pdf

³⁹ Id.

⁴⁰ DOMINIC C. DIGIULIO, RICHARD T. WILKIN, ET AL., U.S. EPA, EPA 600/R-00-000, DRAFT REPORT: INVESTIGATION OF GROUND WATER CONTAMINATION NEAR PAVILLION, WYO., (2011) *available at* http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf.

⁴¹ U.S. EPA, EXPANDED SITE INVESTIGATION – ANALYTICAL RESULTS REPORT, PAVILLION AREA GROUNDWATER INVESTIGATION (2010), *available at* <http://www.epa.gov/region8/superfund/wy/pavillion/PavillionAnalyticalResultsReport.pdf>.

⁴² Christine Bedell, *Oil-ag fight back on after court rejects local ruling*, THE BAKERSFIELD CALIFORNIAN, Jan. 30 2012, <http://www.bakersfieldcalifornian.com/business/x1827696906/Oil-ag-fight-back-on-after-court-rejects-local-ruling>; More details can be found in an unpublished opinion, Starrh & Starrh Cotton Growers v. Aera Energy. LLC, 2012 Westlaw 210452 at 1 (5th Dist. 2012).

⁴³ Cooley & Donnelly, *supra* note 3 at 20.

⁴⁴ CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., NARRATIVE DESCRIPTION OF HYDRAULIC FRACTURING DRAFT REGULATIONS, *supra* note 5 at 2.

⁴⁵ See, for example, National Research Council, Induced Seismicity Potential in Energy Technologies 76 (2012) (pre-publication draft)(on file with the National Academies Press), describing typical fracturing volumes of 2 million to 5.6 million gallons per well.

⁴⁶ CAL. INDEPENDENT PETROLEUM ASS’N, HYDRAULIC FRACTURING (WHITE PAPER) (N.D.).

⁴⁷ Jan Gillespie, California State University Bakersfield, pers. comm.

⁴⁸ Cal. Dep’t of Conservation, *Hydraulic Fracturing Information Seminar*, YOUTUBE (July 6, 2012), <http://www.youtube.com/watch?v=bHmzL6st4S0>.

⁴⁹ Stephen A. Graham, *Tectonic controls on petroleum occurrence in central California*, IN CENOZOIC BASIN DEVELOPMENT OF COASTAL CALIFORNIA: RUBEEY VOLUME VI, 47 (Raymond V. Ingersoll and W. Gary Ernst eds., 1987).

⁵⁰ Prof. Jan Gillespie, California State University Bakersfield, pers. comm.; Prof. Steven Graham, Stanford University, pers. comm.; Prof. Anthony Kovscek, Stanford University, pers. comm.; A Review of the Division of Oil, Gas, and Geothermal Resources’ “Oil and Gas Issues Road Map, Assembly Committee on Natural Resources Oversight Hearing, August 14, 2012, http://antr.assembly.ca.gov/sites/antr.assembly.ca.gov/files/hearings/Agenda_and_Background_Information.8.14.2012.DOGGR_Oversight_Hearing.pdf.

⁵¹ Carol Ferguson, *Fatal sinkhole accident brings new state regulations*, BAKERSFIELD NOW, May 21, 2012, <http://www.bakersfieldnow.com/news/local/152403665.html>.

⁵² SWRCB, DOGGR and industry representatives, pers. comm.; Resources for the Future found that underground injection is currently the most common disposal method in the U.S., with more than 30 states allowing this practice. RESOURCES FOR THE FUTURE, MANAGING THE RISKS OF SHALE GAS: IDENTIFYING A

PATHWAY TOWARD RESPONSIBLE DEVELOPMENT: A REVIEW OF SHALE GAS REGULATIONS BY STATE, *supra* note 4.

⁵³ Regional Board and industry representatives, pers. comm.

⁵⁴ JAMES D. WALKER, HORSLEY WITTEN GROUP, CALIFORNIA CLASS II UNDERGROUND INJECTION CONTROL PROGRAM REVIEW (2011) *available at* <http://www.conservation.ca.gov/dog/Documents/DOGGR%20USEPA%20consultant's%20report%20on%20CA%20underground%20injection%20program.pdf>.

⁵⁵ M. Dusseault, M. Gray, et al., *Why oilwells leak: cement behavior and long-term consequences*, Society of Petroleum Engineers International Oil and Gas Conference and Exhibition in China, Beijing, China (2000).

⁵⁶ Osborn, *supra* note 11.

⁵⁷ Jan Gillespie, California State University Bakersfield, pers. comm.

⁵⁸ *Id.*

⁵⁹ National Research Council, *Induced Seismicity Potential in Energy Technologies* (2012) (pre-publication draft)(on file with the National Academies Press) (“Recent work by USGS scientists concludes that dramatic recent increases in the number of earthquakes in Midwestern oil and gas producing regions are ‘almost certainly manmade,’ leaving attribution to a specific cause for later research”); W.L. Ellsworth, S. H. Hickman, et al., *Are Seismicity Rate Changes In The Midcontinent Natural Or Manmade?*, Seismological Society of America, San Diego, (2012).

⁶⁰ OHIO DEP’T OF NATURAL RES., (PRELIMINARY REPORT ON THE NORTHSTAR 1 CLASS II INJECTION WELL AND THE SEISMIC EVENTS IN THE YOUNGSTOWN, OHIO, AREA (2012) *available at* <http://ohiodnr.com/downloads/northstar/UICReport.pdf>.

⁶¹ Cliff Frohlich, *Two-year survey comparing earthquake activity and injection-well locations in the Barnett Shale, Tex.*, 109 PROCEEDINGS OF THE NAT’L ACAD. OF SCIENCES 13934 (2012).

⁶² D.B. Hoover, *Waste Disposal and Earthquakes at the Rocky Mountain Arsenal, Derby, Colo.*, 22 J. OF PETROLEUM TECH. 983 (1970); Robert Herrmann, Sam-Kuen Park, et al., (1981) The Denver earthquakes of 1967-1968, 71 BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA 731(1981).

⁶³ CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., NARRATIVE DESCRIPTION OF HYDRAULIC FRACTURING DRAFT REGULATIONS, *supra* note 5.

⁶⁴ ANTHONY INGRAFFEA, PHYSICIANS, SCIENTISTS, & ENGINEERS FOR HEALTHY ENERGY, FLUID MIGRATION MECHANISMS DUE TO FAULTY WELL DESIGN AND/OR CONSTRUCTION: AN OVERVIEW AND RECENT EXPERIENCES IN THE PENNSYLVANIA MARCELLUS PLAY (2013) *available at* http://www.psehealthyenergy.org/data/PSE__Cement_Failure_Causes_and_Rate_Analysis_Jan_2013_Ingraffea1.pdf; note that these wells were mostly high-volume, multi-stage wells.

⁶⁵ Rozell & Reaven, *supra* note 10.; L.A. Browning, J.B. Smith, et al.,. Analysis of the rate of and reasons for injection well mechanical integrity test failure, presented at SPE/EPA Exploration and Production Environmental Conference, March 7–10, 1993, San Antonio, TX., cited in Rozell & Reaven, *supra* note 10; MICHIE & ASSOCIATES OIL AND GAS INDUSTRY WATER INJECTION WELL CORROSION, report prepared for the American Petroleum Institute, Feb. 1988.

⁶⁶ Nathaniel Warner, Robert Jackson, et al., *Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania*, 109 PROCEEDINGS OF THE NAT’L ACAD. OF SCIENCES 11961(2012).

⁶⁷ Osborn, *supra* note 11.

⁶⁸ AUSTIN HOLLAND, OKLA. GEOLOGICAL SURVEY, OPEN-FILE REPORT OF1, EXAMINATION OF POSSIBLY INDUCED SEISMICITY FROM HYDRAULIC FRACTURING IN THE EOLA FIELD, GARVIN COUNTY, OKLA., (2011), *available at* http://www.ogs.ou.edu/pubsscanned/openfile/OF1_2011.pdf.

⁶⁹ Ebenezer T. Igunnu and George Z. Chen, *Produced water treatment technologies*, 0 INT. J. LOW-CARBON TECH 1-21; HAMMER, VANBRIESEN, *supra* note 2.

⁷⁰ Jeremy Miller, *The Colonization of Kern County: A story of oil and water*, ORION MAGAZINE. Jan.-Feb. 2011, *available at* <http://www.orionmagazine.org/index.php/articles/article/6047>.

⁷¹ CARDNO ENTRIX , HYDRAULIC FRACTURING STUDY: PXP INGLEWOOD OIL FIELD (2012), *available at* <http://www.inglewoodoilfield.com/res/docs/102012study/Hydraulic%20Fracturing%20Study%20Inglewood%20Field10102012.pdf>; industry representative, pers. comm.

⁷² See John A. Veil, Bruce G. Langhus, and Stan Belieu, *Feasibility Evaluation of Downholed Oil/Water Separator (DOWS) Technology*, report prepared for the U.S. Department of Energy, January 1999, *available at* <http://www.evs.anl.gov/pub/doc/dows.pdf>; Bill Bailey, Mike Crabtree, et al., *Water control*, 12 OILFIELD REV. 30 (2000).

⁷³ Industry representative, pers. comm.

⁷⁴ Igunnu & Chen, *supra* note 69.; CORRIE CLARK, & JOHN VEIL, ARGONNE NATIONAL LABORATORY, *PRODUCED WATER VOLUMES AND MANAGEMENT PRACTICES IN THE UNITED STATES* (2009), *available at* http://www.ead.anl.gov/pub/doc/ANL_EVS__R09_produced_water_volume_report_2437.pdf.

⁷⁵ Regional Board representative, pers. comm.

⁷⁶ Clean Water Act, 40 C.F.R. § 212 (2012).

⁷⁷ 40 C.F.R. § 403.3 (2012).

⁷⁸ HAMMER, VANBRIESEN, *supra* note 2.

⁷⁹ *Id.*

⁸⁰ Regional Board representative, pers. comm.

⁸¹ See *supra* note 42.

⁸² Pam Kasey, *Flowback spill into Marshall County creek under investigation*, W. VA. ILLUSTRATED, Feb. 27, 2013, <http://www.wvillustrated.com/story/21417313/flowback-spill-into-marshall-county-creek-under-investigation>.

⁸³ *Ohio company accused of dumping fracking wastewater down storm drain*, Akron Beacon J., Feb. 7, 2013, <http://www.ohio.com/news/ohio-company-accused-of-dumping-fracking-wastewater-down-storm-drain-1.371297>.

⁸⁴ CAL. WATER CODE § 13265 (2013)

⁸⁵ CAL. WATER CODE § 13387 (2013).

⁸⁶ CAL. PUB. RES. CODE § 3236.5 (2013).

⁸⁷ Industry representative, pers. comm.; What Chemicals are Used, FRAC FOCUS CHEMICAL DISCLOSURE REGISTRY, *supra* note 26.

⁸⁸ CAL. CIVIL CODE §3426-3426.11 (2013) (Defines “trade secret” as information that “Derives independent economic value, actual or potential, from not being generally known to the public” and “Is the subject of efforts ... to maintain its secrecy.”)

⁸⁹ See, for example, National Research Council, *Induced Seismicity Potential in Energy Technologies* 76 (2012) (pre-publication draft)(on file with the National Academies Press), describing typical fracturing volumes of 2 million to 5.6 million gallons per well.

⁹⁰ 40 C.F.R. § 435.32 (2013). Note that some exceptions exist for agricultural and grazing uses. See 40 C.F.R. § 435.50-435.60.

⁹¹ 40 C.F.R. § 403.3(i) (2013).

⁹² 33 U.S.C. § 1370 (2013).

⁹³ See note 132 and associated text.

⁹⁴ State law pertaining to DOGGR is outlined in Section 3000 et seq. of the Public Resources Code and Title 14, Chapter 4 of the California Code of Regulations. Distillation of relevant laws can be found in DOGGR, “California Laws For Conservation Of Petroleum & Gas,” Publication No. PRC01, October 2012, *available at* <ftp://ftp.consrv.ca.gov/pub/oil/laws/PRC01.pdf>, and relevant chapters from CAL. CODE REGS.tit. 14, div. 2 *available at* ftp://ftp.consrv.ca.gov/pub/oil/publications/PRC04_January_11.pdf.

⁹⁵ CAL. PUB. RES. CODE § 3106 (2013)

⁹⁶ *Id.*

⁹⁷ Oil, Gas & Geothermal - About Us, CAL. DEP’T OF CONSERVATION, [HTTP://WWW.CONSERVATION.CA.GOV/DOG/PAGES/ABOUTUS.ASPX](http://www.conservaion.ca.gov/DOG/PAGES/ABOUTUS.ASPX) (last visited Mar. 25, 2013).

⁹⁸ See notes 13, 208 and associated text.

⁹⁹ California has applied for, and received, primacy from EPA for the UIC Class II injection well program,” 42 U.S.C. §300h-4(a) (2006); 48 Fed. Reg. 6336, Effective Date March 14, 1983

¹⁰⁰ STATE WATER RES. CONTROL BD. (2012). PORTER-COLOGNE WATER QUALITY CONTROL ACT, WITH ADDITIONS AND AMENDMENTS EFFECTIVE JUNE 27, 2012. CAL. WATER CODE, Div. 7.

¹⁰¹ CAL. WATER CODE § 13160 (2013); 33 U.S.C. § 1251, et seq (2013).

¹⁰² 40 C.F.R. & 43 C.F.R. (2013).

¹⁰³ CONG. RESEARCH SERV., R42346, FEDERAL LAND OWNERSHIP: OVERVIEW AND DATA 2 (2012), available at <http://www.fas.org/sgp/crs/misc/R42346.pdf>.

¹⁰⁴ Id. at 4.

¹⁰⁵ Ninety percent of split estate lands fall within eight states west of the Mississippi – California, Montana, Wyoming, New Mexico, Colorado, North Dakota, Idaho, and Arizona. BUREAU OF LAND MGMT., PUBLIC LAND STATISTICS (2011), Table 1-3: Mineral and Surface Acres Administered by the Bureau Of Land Management, Fiscal Year 2011,7 available at http://www.blm.gov/public_land_statistics/pls11/pls2011.pdf.

¹⁰⁶ See 43 C.F.R. § 3162.3 et. seq.

¹⁰⁷ Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian Lands, 77 Fed. Reg. 27,691 (May 11, 2012).

¹⁰⁸ Memorandum of Understanding Between Cal.State Office, Bureau of Land Mgmt. and Cal. Dep't of Conservation, Div. of Oil, Gas and Geothermal Res., (October 16, 2012) available at <ftp://ftp.consrv.ca.gov/pub/oil/regulations/DOGGR-BLM-%20MOU%202012.pdf>.

¹⁰⁹ Id.

¹¹⁰ Memorandum of Agreement between the State Water Res. Bd and the Dep't of Conservation Div. of Oil and Gas, (May 19, 1988) available at ftp://ftp.consrv.ca.gov/pub/oil/publications/MOU_DOG_SWRQB_UIC.pdf; the California Department of Conservation, Division of Oil and Gas (CDOG) was renamed the Division of Oil, Gas and Geothermal Resources (DOGGR). We use the newer term in this text although the MOA refers to CDOG.

¹¹¹ The MOA does not specifically mention hydraulic fracturing, steam flooding or other particular types of injection, but given that all such types of injection were in widespread use when the memo was drafted we presume that they are all included in its intent.

¹¹² See also Memorandum of Understanding Between Cal. State Office U.S. Bureau of Land Mgmt. and Cal. Dep't of Conservation, Div. of Oil, Gas and Geothermal Res. (Oct. 2008) available at ftp://ftp.consrv.ca.gov/pub/oil/MouMoa/BLMMOU_2008.pdf for a Memorandum of Understanding between Bureau of Land Management and DOGGR regarding division of responsibilities on BLM land in California.

¹¹³ DOGGR stakeholder workshop, March 21, 2013, Sacramento, CA.

¹¹⁴ Cal. Pub. Res. Code §§ 21000-21177, et. seq.

¹¹⁵ CAL. PUB. RES. CODE § 21080.

¹¹⁶ Cal. Pub. Res. Code § 21002-21002.1.

¹¹⁷ CAL. PUB. RES. CODE § 21068; see also Title 14, Cal. Code Regs., § 15382.

¹¹⁸ CAL. PUB. RES. CODE § 21091(a), (b).

¹¹⁹ Oil, Gas & Geothermal - California Environmental Quality Act Notices, CAL. DEPT. OF CONSERVATION, <http://www.conservation.ca.gov/dog/CEQA/Pages/CEQANotices.aspx> (last visited Mar. 26, 2013).

¹²⁰ Baldwin Hills CSD Final EIR (October 2008), available at http://planning.lacounty.gov/view/baldwin_hills_csd_adoption/ (last visited Mar. 26, 2013).

¹²¹ 42 U.S.C.A. § 300h (2012).

¹²² Basic Information about Injection Wells, U.S. EPA, <http://water.epa.gov/type/groundwater/uic/basicinformation.cfm> (last visited Mar. 27, 2013)

¹²³ Technically, both oil and gas production and disposal wells are classified as Class II wells, but only disposal wells are subject to SDWA regulation. Typically, in a single operation these two functions are carried out in separate wells that access the same or similar geological formations. These disposal wells typically are physically separate from the production wells, but access the same or a similar geological formation.

¹²⁴ U.S. EPA, EXEMPTION OF OIL AND GAS EXPLORATION AND PRODUCTION WASTES FROM FEDERAL HAZARDOUS WASTE REGULATIONS 1, 6 (2001) (“The oil and gas exemption was expanded in the 1980 legislative amendments to RCRA to include ‘drilling fluids, produced water, and other wastes associated with the exploration, development, or production of crude oil or natural gas. . . .’”). EPA’s 1987 report to Congress preceding the exemption stated that water and sludge samples gathered by the agency contained hazardous

substances including benzene, penanthrene, lead, arsenic, and barium in concentrations exceeding the levels of potential concern in their risk analysis. U.S. EPA, REPORT TO CONGRESS: MANAGEMENT OF WASTES FROM THE EXPLORATION, DEVELOPMENT, AND PRODUCTION OF CRUDE OIL, NATURAL GAS, AND GEOTHERMAL ENERGY, VOLUME 1 OF 3, OIL AND GAS (1987).

¹²⁵ 40 C.F.R. § 138, *et. seq.*; *see also*, U.S. EPA, REQUIREMENTS FOR ALL CLASS I WELLS AND CLASS I HAZARDOUS WASTE WELLS (2012) *available at* http://www.epa.gov/ogwdw/uic/pdfs/page_uic-class1_summary_class1_reqs.pdf.

¹²⁶ 40 C.F.R. § 144.6(b) (2012); Class II Wells - Oil and Gas Related Injection Wells, U.S. EPA, <http://water.epa.gov/type/groundwater/uic/class2/> (last visited Mar. 26, 2013).

¹²⁷ 33 U.S.C. § 1362(6)(B); *c.f.* Sierra Club, Lone Star Chapter v. Cedar Point Oil Co., 73 F.3d 546, 568 (5th Cir.1996) (“produced water” is a pollutant if its discharge does not meet exemption criteria); Northern Plains Resource Council v. Fidelity Exploration and Development Co., 325 F.3d 1155 (9th Cir. 2003)(holding that coal bed methane produced water is a pollutant pursuant to the CWA).

¹²⁸ H.R. 1084, 112th Cong. (2011) and S. 587, 112th Cong. (2011).

¹²⁹ *Supra* note 129; note that for wells on federal lands, the states and BLM have dual permitting authority.

¹³⁰ 42 U.S.C. § 300h(b)(1) (2012).

¹³¹ 42 U.S.C. § 300h(b)(1)(C) (2012).

¹³² CAL. CODE REGS. §1724.6 (2012).

¹³³ CAL. PUB. RES. CODE § 3220 (2012).

¹³⁴ WALKER, *supra* note 54.

¹³⁵ *Id.*

¹³⁶ Response to the U.S. EPA June 2011 Review of California’s UIC Program, Cal. Dep’t of Conservation, Div. of Oil, Gas and Geothermal Res. (Nov. 2012), *available at* <http://www.conservation.ca.gov/dog/Documents/DOGGR%20response%20to%20USEPA%20underground%20injection%20report.pdf>

¹³⁷ 40 C.F.R. § 144.3 (2012).

¹³⁸ Adoption of Policy Entitled “Sources of Drinking Water”, Resolution No. 88-63, Cal. State Water Res. Control Bd. (May 19, 1988), *available at* http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1988/rs1988_0063.pdf

¹³⁹ 40 C.F.R. § 144.3 (2012).

¹⁴⁰ WALKER, *supra* note 54.

¹⁴¹ CAL. PUB. RES. CODE § 3208 (2012).

¹⁴² CAL. PUB. RES. CODE § 3251 (2012).

¹⁴³ CAL. PUB. RES. CODE § 3250 (2012).

¹⁴⁴ WALKER, *supra* note 54.

¹⁴⁵ Response to the U.S. EPA June 2011 Review of California’s UIC Program, *supra* note 136.

¹⁴⁶ Hydraulic Fracturing in California, CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., http://www.conservation.ca.gov/dog/general_information/Pages/HydraulicFracturing.aspx, (last visited Mar. 27, 2013).

¹⁴⁷ Mechanical integrity tests are required every year for water disposal wells, every two years for waterflood wells, and every five years for steamflood wells. 14 CAL. CODE REGS. § 1724.10.

¹⁴⁸ Cal. Dep’t of Conservation, Div. of Oil, Gas and Geothermal Res. representative, *pers. comm.*

¹⁴⁹ Pre-rulemaking discussion draft at §1783, Cal. Dep’t of Conservation, Div. of Oil, Gas and Geothermal Res., (Dec. 17, 2012) *available at* http://www.conservation.ca.gov/dog/general_information/Documents/121712DiscussionDraftofHFRegs.pdf

¹⁵⁰ CAL. STATE WATER RES. CONTROL BD., RECYCLED WATER POLICY, (May 14, 2009) *available at* http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf

¹⁵¹ CAL. WATER CODE § 13050(n)(2012).

¹⁵² CAL. WATER CODE §13050(d)(2012). (“Waste” includes sewage and any and all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation, including waste placed within containers of whatever

nature prior to, and for purposes of, disposal.”)

¹⁵³ CAL. STATE WATER RES. CONTROL BD., *supra* note 150.

¹⁵⁴ See note 121 and associated text.

¹⁵⁵ CAL. WATER CODE § 13523 (2012).

¹⁵⁶ CAL. WATER CODE § 13263 (2012).

¹⁵⁷ CAL. WATER CODE § 13523.1 (2012).

¹⁵⁸ 27 CAL. CODE REGS. § 20090 (2012).

¹⁵⁹ General Waste Discharge Requirements For Landscape Irrigation Uses Of Municipal Recycled Water (General Permit), Water Quality Order No. 2009-0006-Dwq, Cal. State Water Res. Control Bd., *available at* http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/wqo_2009_0006_general_permit.pdf

¹⁶⁰ 40 C.F.R. § 435.32 (“There shall be no discharge of waste water pollutants into navigable waters from any source associated with production, field exploration, drilling, well completion, or well treatment (i.e. , produced water, drilling muds, drill cuttings, and produced sand”).

¹⁶¹ 40 C.F.R. §§ 403.5 (prohibiting pass through and interference), § 403.3 (defining pass through and interference).

¹⁶² 33 U.S.C. § 1317; 40 C.F.R. §§ 405-471.

¹⁶³ Notice of Final 2010 Effluent Guidelines Program Plan, 76 Fed. Reg. 66,286, 66,296.; Press Release, U.S. EPA, EPA Announces Schedule to Develop Natural Gas Wastewater Standards (Oct. 20, 2011)(*available at* <http://yosemite.epa.gov/opa/admpress.nsf/0/91E7FADB4B114C4A8525792F00542001>).

¹⁶⁴ RESOURCES FOR THE FUTURE, MANAGING THE RISKS OF SHALE GAS: IDENTIFYING A PATHWAY TOWARD RESPONSIBLE DEVELOPMENT: A REVIEW OF SHALE GAS REGULATIONS BY STATE, *supra* note 4. (At least 13 states allow oil and gas wastewater disposal at a fluid disposal facility such as a POTW.)

¹⁶⁵ EPA’s federal regulations set pretreatment requirements for the introduction of industrial wastewater to POTWs and for the discharge of industrial wastewater from CWTs. But, there are no federal pretreatment requirements specifically for oil or gas wastewater.

¹⁶⁶ 40 C.F.R. § 403.5, 403.8; see also NPDES Permit Writers’ Manual, U.S. EPA, http://cfpub.epa.gov/npdes/writermanual.cfm?program_id=45 (last visited Mar. 27, 2013).

¹⁶⁷ 33 U.S.C. § 1311; 40 C.F.R. § 122.44(d)(1)(i).

¹⁶⁸ See 40 C.F.R. § 131.3(b).

¹⁶⁹ See 40 C.F.R. §§ 122.44(d)(1), 125.3(c)(3)

¹⁷⁰ Cal. State Water Res. Control Bd. representatives, pers. comm.

¹⁷¹ 40 C.F.R. §§ 403.5 (prohibiting pass through and interference), 403.3 (defining pass through and interference).

¹⁷² See, e.g., *infra* note 182.

¹⁷³ E.g., Western States Petroleum Association; California Independent Petroleum Association.

¹⁷⁴ See *infra* note 210.

¹⁷⁵ CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., NARRATIVE DESCRIPTION OF HYDRAULIC FRACTURING DRAFT REGULATIONS, *supra* note 5

¹⁷⁶ *Id.* at 5.

¹⁷⁷ *Id.* at 5.

¹⁷⁸ *Id.* at 4.

¹⁷⁹ *Id.* at 4.

¹⁸⁰ Osborn, *supra* note 11 (“systematic and independent data on groundwater quality, including dissolved-gas concentrations and isotopic compositions, should be collected before drilling operations begin in a region, as is already done in some states. Ideally, these data should be made available for public analysis...”).

¹⁸¹ Letter to Fran Pavley and Michael Rubio of the California Senate Committee on Natural Resources and Water (page 3), Cal. Dep’t of Conservation, Div. of Oil, Gas and Geothermal Res. (Feb. 8, 2013), (*available at* <http://sntr.senate.ca.gov/sites/sntr.senate.ca.gov/files/DOGGER%20Response%20to%20questions.pdf>)

¹⁸² Letter Re: Comments on December 17, 2012 Discussion Draft of Proposed Hydraulic Fracturing Regulations, Environmental Coalition (Baldwin Hills Oil Watch, California Coastal Protection Network, Citizens Coalition for a Safe Community, Citizens Water Watch, Clean Water Action, Earthworks, Environmental Working Group, Grassroots Coalition, Greenaction for Health and Environmental Justice, Natural Resources Defense Council, Physicians for Social Responsibility, Los Angeles, Progressive Democrats of the Santa Monica Mountains, San Diego 350.org, Sierra Club California, SLO Clean Water Action, Transition Culver City, The Wildlands Conservancy)(February 22, 2013) (*available at* <http://www.becnet.org/sites/default/files/file-attachment/FinalFrackDiscDraftSignOn2-22-2013.pdf>).

¹⁸³ Pre-Rulemaking Discussion Draft, *supra* note 149 at §1782.

¹⁸⁴ *Id.* at §1782(1).

¹⁸⁵ *Id.* at §1782(2).

¹⁸⁶ *Id.* at §1782(3).

¹⁸⁷ *Id.* at §1784.

¹⁸⁸ *Id.* at §1781.

¹⁸⁹ Response to the U.S. EPA June 2011 Review of California's UIC Program , *supra* note 145.

¹⁹⁰ Pre-Rulemaking Discussion Draft, *supra* note 149 at §1784.

¹⁹¹ *Id.* at §1784(a)(4)

¹⁹² *Id.* at §1785

¹⁹³ *Id.* at §1787

¹⁹⁴ *Id.* at §1787(b)(2)

¹⁹⁵ *Id.* at §1780(d)

¹⁹⁶ *Id.* at §1786

¹⁹⁷ CAL. CODE REGS.Ch.14, Div. 2, Ch. 4, Subchapter 2, Article 3, §1773.1.

¹⁹⁸ See, e.g., CAL. CODE REGS.Ch.14, Div. 2, Ch. 4, Subchapter 2, Article 3, § 1773.

¹⁹⁹ Pre-Rulemaking Discussion Draft , *supra* note 149 at §1786.

²⁰⁰ Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian Lands, 77 Fed. Reg. 27,691 (May 11, 2012).

²⁰¹ *Id.*

²⁰² Assemblyman Bill Wieckowski (D-Fremont) AB-7 Oil and gas: hydraulic fracturing. (2013-2014), “An act to amend Section 3213 of, and to add Article 3 (commencing with Section 3150) to Chapter 1 of Division 3 of, the Public Resources Code, relating to oil and gas.” http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB7&search_keywords=.

²⁰³ Senator Fran Pavley (D-Agoura) SB-4 Oil and gas: hydraulic fracturing.(2013-2014) , “An act to amend Section 3213 of, and to add Article 3 (commencing with Section 3150) to Chapter 1 of Division 3 of, the Public Resources Code, relating to oil and gas.” http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB4&search_keywords=.

²⁰⁴ Senator Hannah-Beth Jackson (D-Santa Barbara) SB-395 (2013-14), “An act to add Article 17 (commencing with Section 25258.3) to Chapter 6.5 of the Health and Safety Code, relating to hazardous substances,” *available at* http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB395&search_keywords=

²⁰⁵ See note 124 and associated text.

²⁰⁶ Assemblymember Das Williams (D-Santa Barbara) AB-982, “An act to add Sections 3017, 3203.1, and 3203.2 to the Public Resources Code, relating to oil and gas,” *available at* http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB982&search_keywords=

²⁰⁷ AB-1301 Oil and gas production: hydraulic fracturing (2013-2014), *available at* http://www.leginfo.ca.gov/cgi-bin/postquery?bill_number=ab_1301&sess=CUR&house=B&author=bloom.

²⁰⁸ AB-591 Oil and gas production: hydraulic fracturing (2011-2012), *available at* <http://leginfo.legislature.ca.gov/faces/billStatusClient.xhtml>.

- ²⁰⁹ AB-972 Oil and gas: hydraulic fracturing: moratorium (2011-2012), *available at* <http://leginfo.ca.gov/faces/billStatusClient.xhtml>.
- ²¹⁰ Verified Complaint for Injunctive and Declaratory Relief, Center for Biological Diversity, Earthworks, Environmental Working Group, and Sierra Club v. Cal. Dep't of Conservation, Div. of Oil, Gas, and Geothermal Res. (filed October 16, 2012).
- ²¹¹ *Id.* at 16.
- ²¹² 14 CAL. CODE REGS., § 15304 (2012).
- ²¹³ 14 CAL. CODE REGS., § 15301 (2012).
- ²¹⁴ Verified Complaint for Injunctive and Declaratory Relief, *supra* note 210 at 16-17.
- ²¹⁵ *Id.* at 15.
- ²¹⁶ Complaint for Declaratory and Injunctive Relief, Center for Biological Diversity and Sierra Club v. The Bureau of Land Management et al., No. 5:2011cv06174 (filed Dec. 8, 2011), *available at* http://www.biologicaldiversity.org/programs/public_lands/energy/dirty_energy_development/oil_and_gas/pdfs/California_Oil_and_Gas_Complaint_12-08-2011.pdf.
- ²¹⁷ See, e.g., William G. Strudley v. Antero Resources Corporation, et al., No. 2011CV2218, 2012 WL 1932470 (Colo. Dist. Ct. May 9, 2012) (stating, “the Court required Plaintiffs, before full discovery and other procedures were allowed, to make a prima facie showing of exposure and causation,” and ultimately dismissing the case for lack of evidence of causation); see also Lore v. Lone Pine Corp., No. L-33606-85, 1986 WL 635707 (N.J. Sup. Ct. Nov. 18, 1986) (requiring plaintiffs to demonstrate a prima facie case of causation before allowing a case to proceed to discovery).
- ²¹⁸ Matthew McFeeley, Natural Resources Defense Council, State Hydraulic Fracturing Disclosure Rules and Enforcement: A Comparison, NRDC Issue Brief (July 2012) <http://www.nrdc.org/energy/files/Fracking-Disclosure-IB.pdf>.
- ²¹⁹ *Id.* at 10.
- ²²⁰ *Id.* at 8.
- ²²¹ BUREAU OF LAND MGMT., PUBLIC LAND STATISTICS (2011), Table 1-3: Mineral and Surface Acres Administered by the Bureau Of Land Management, Fiscal Year 2011,7 *available at* http://www.blm.gov/public_land_statistics/pls11/pls2011.pdf.
- ²²² WYOMING OIL & GAS CONSERVATION COMM'N, DOC. 7928, OPERATIONAL RULES, DRILLING RULES (2010) at Ch. 3, § 45(d), *available at* <http://sos.wy.state.wy.us/Rules/RULES/7928.pdf>
- ²²³ *Id.* at Ch. 45(f).
- ²²⁴ OPERATIONAL RULES, DRILLING RULES, *supra* note 222 at Ch. 4, § 5(b).
- ²²⁵ WYOMING OIL & GAS CONSERVATION COMM'N, ANNUAL REPORT (2011), *available at* http://wogcc.state.wy.us/2011_Annual_Report.pdf.
- ²²⁶ McFeeley, *supra* note 218 at 12-13.
- ²²⁷ 16 TEX. ADMIN. CODE § 3.29.
- ²²⁸ In the absence of scientifically justified basis for the distance for notification, we base our initial recommendation for a half mile radius on Wyoming's rules. See OPERATIONAL RULES, DRILLING RULES, *supra* note 222 at Ch. 3, § 8(f) (“If the application is for a permit to drill a horizontal well, notice of the application shall be given by certified mail to all Owners within one-half (1/2) mile of any point on the entire length of the horizontal wellbore, from the surface location through the terminus of the lateral.”).
- ²²⁹ See Cal. S.B 4, 2013-14 Reg. Sess. (Cal. 2013).
- ²³⁰ *See id.*
- ²³¹ *See id.*
- ²³² CAL. DEP'T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., NARRATIVE DESCRIPTION OF HYDRAULIC FRACTURING DRAFT REGULATIONS, *supra* note 5 at 4.
- ²³³ See McFeeley, *supra* note 216 at 6.
- ²³⁴ 2 COLO. CODE. REGS. § 404-1:205A (2012), cited in Francis Gradijan, *State Regulations, Litigation, and Hydraulic Fracturing*, 7 ENV'T'L & ENERGY L. & POL'Y J. 47 (2012).

²³⁵ See, e.g., 25 PA. CODE § 287.55(a)(1) (2013); Comments from Damon Nagami, Senior Attorney, Natural Resources Defense Council, *supra* note 6.

²³⁶ Cal. Water Code § 13304(a), (c)(1)

²³⁷ Roy Haggerty, Oregon State University, pers. comm. For a conceptual overview, see Flury, M., and N. N. Wai (2003), Dyes as tracers for vadose zone hydrology, *Reviews of Geophysics*, 41, doi:10.1029/2001RG000109. An ideal tracer for long-term tracking of underground fluid movement is conservative, not biodegradable, does not sorb or degrade, and will behave well under harsh environments such as high temperatures, pH, salinity, and redox conditions and be insensitive to changes in solution chemistry. It will also have known, and low, background concentrations, be detectable at low concentrations, and have low toxicological impact. The use proposed here is for long-term tracking of the presence of the fluid in cases of migration and contamination, not for the detailed understanding of the hydrogeological processes.

²³⁸ A suite of articles describing the exhaustive use and testing of benzoic acid tracers at a Waste Isolation Pilot Plant site in New Mexico suggests that they exhibit the necessary properties. Meigs, L. C. and R. L. Beauheim (2001). “Tracer tests in a fractured dolomite 1. Experimental design and observed tracer recoveries.” *Water Resources Research* 37(5): 1113-1128; Haggerty, R., S. W. Fleming, et al. (2001). “Tracer tests in a fractured dolomite 2. analysis of mass transfer in single-well injection-withdrawal tests.” *Water Resources Research* 37(5): 1129-1142; McKenna, S. A., L. C. Meigs, et al. (2001). “Tracer tests in a fractured dolomite: 3. Double-porosity, multiple-rate mass transfer processes in convergent flow tracer tests.” *Water Resources Research* 37(5): 1143–1154.

²³⁹ About twenty different benzoic acid species exist, but mixing different combinations of the available tracers would in principle give a large number of unique identifiers, on the order of 2×10^{18} combinations, far more than the number of wells expected to be drilled. The concept is new and would need to be tested for this purpose, but the basic science has been conducted and could be developed into a method and protocol.

²⁴⁰ Andrew C. Revkin, “Ideas to Watch in 2013: Traceable Gas-Drilling Fluids”, New York Times Dot Earth, January 8, 2013. <http://dotearth.blogs.nytimes.com/2013/01/08/ideas-to-watch-in-2013-traceable-frackin-fluids/>. Accessed January 14, 2013.

²⁴¹ Andrew C. Revkin, “Ideas to Watch in 2013: Traceable Gas-Drilling Fluids”, New York Times Dot Earth, January 8, 2013. <http://dotearth.blogs.nytimes.com/2013/01/08/ideas-to-watch-in-2013-traceable-frackin-fluids/>. Accessed January 14, 2013.

²⁴² Summary of Ohio Senate Bill 315, OHIO DIV OF NATURAL RES., <http://ohiodnr.com/tabid/23947/Default.aspx>.

²⁴³ Mark Niquette, *Fracking Fluid Soaks Ohio*, BUSINESS WEEK (Mar. 22, 2012), <http://www.businessweek.com/articles/2012-03-22/fracking-fluid-soaks-ohio>.

²⁴⁴ OHIO ADMIN. CODE § 1501:9-3-06 (2012), *available at* http://www.ohiodnr.com/portals/11/oil/pdf/final_1501_9-3-06.pdf (“Any person desiring to comment or to make an objection with reference to an application for a permit to construct, convert to, or operate a brine injection well shall file such comments or objections, in writing, with the “Underground Injection Control Section...”).

²⁴⁵ OHIO DEP’T OF NATURAL RES., OPERATING, MONITORING AND REPORTING OF SALTWATER INJECTION WELLS, OAC 1501:9-3-06 (2012) *available at* http://www.ohiodnr.com/portals/11/oil/pdf/final_1501_9-3-07.pdf; OH. DEP’T OF NATURAL RES., Permit, OAC 1501:9-3-07 (2012) *available at* http://www.ohiodnr.com/portals/11/oil/pdf/final_1501_9-3-06.pdf.

²⁴⁶ OHIO DEP’T OF NATURAL RES, PRELIMINARY REPORT ON THE NORTHSTAR 1 CLASS II INJECTION WELL AND THE SEISMIC EVENTS IN THE YOUNGSTOWN, OHIO, AREA (2012), *available at* <http://ohiodnr.com/downloads/northstar/UICReport.pdf>

²⁴⁷ Notably, Ohio’s new UIC regulations do not require seismic tests to be performed uniformly by all operators; the language states that the “chief *may require* the following tests or evaluations of a proposed brine injection well, in any combination that the chief deems necessary” (emphasis added). These tests include: (1) pressure fall-off testing; (2) geological investigation of potential faulting within the immediate vicinity of the proposed injection well location; (3) submittal of a plan for monitoring seismic activity; (4) Testing and recording the original bottomhole injection interval pressure; and (5) Gamma ray, compensated density-neutron, and resistivity geophysical logging suite on all newly drilled injection wells. See OHIO DEP’T OF NATURAL RES., *supra* note 244.

- ²⁴⁸ See, e.g., Ohio Admin. Code § 1501:9-1-02 (“Permits”) (2012).
- ²⁴⁹ 16 TEX. ADMIN. CODE § 3.13 (2013)
- ²⁵⁰ 16 TEX. ADMIN. CODE, Part I, Ch. 3 § 3.9 (2013).
- ²⁵¹ Id.
- ²⁵² Id.
- ²⁵³ WALKER, *supra* note 54.
- ²⁵⁴ See, e.g., Osborn, *supra* note 11.
- ²⁵⁵ See, e.g., OHIO ADMIN. CODE § 1501:9-1-02 (2012) (“Permits”).
- ²⁵⁶ WALKER, *supra* note 54.
- ²⁵⁷ Id. at ES-6.
- ²⁵⁸ OHIO ADMIN. CODE § 1509:22 (2012).
- ²⁵⁹ WALKER, *supra* note 54.
- ²⁶⁰ Id.
- ²⁶¹ Waste Minimization Program Home Page, R.R COMM’N OF TEX., [HTTP://WWW.RRC.STATE.TX.US/ENVIRONMENTAL/ENVIRONSUPPORT/WASTEMIN/INDEX.PHP](http://www.rrc.state.tx.us/ENVIRONMENTAL/ENVIRONSUPPORT/WASTEMIN/INDEX.PHP) (last visited Mar. 26, 2013)
- ²⁶² See 16 TEX. ADMIN. CODE, Ch. 4, Subchapter B, Divisions I-VI. The September 11, 2012 amendments can be found at <http://www.rrc.state.tx.us/rules/prop-amend-3-8-comm-recycling-Sept2012.PDF>; 16 TEX. ADMIN. CODE § 3.8, subsection (d)(7)(B).
- ²⁶³ 42 U.S.C. §300f et. seq. (1974).
- ²⁶⁴ See. Proposed TEX. ADMIN. CODE § 3.8 § 3.8(d)(7)(A)-(B) & § 3.8(d)(3). Memorandum from Christina Self to the R.R. Comm’n of Tex., *available at* <http://www.rrc.state.tx.us/rules/prop-amend-3-8-comm-recycling-Sept2012.PDF>.
- ²⁶⁵ In 2007, H.B. 4 amended the Tax Code, relating to Water-Related Exemptions. Texas Severance Tax Incentives, R.R COMM’N OF TEX., <http://www.rrc.state.tx.us/programs/og/presenttax.php> (last visited Mar. 26, 2013)
- ²⁶⁶ PA. DEP’T OF ENVTL. PROT., PERMITTING STRATEGY FOR HIGH TOTAL DISSOLVED SOLIDS (TDS) WASTEWATER DISCHARGES (2009), *available at* http://files.dep.state.pa.us/Water/Wastewater%20Management/WastewaterPortalFiles/MarcellusShaleWastewaterPartnership/high_tds_wastewater_strategy_041109.pdf; Wastewater Treatment Requirements, 40 Pa. Bull. 4835 (August 21, 2010) at Annex A, § 95.10(b)(2).
- ²⁶⁷ PA. DEP’T OF ENVTL. PROT., WMGR121 FOR PROCESSING AND BENEFICIAL USE OF GAS WELL WASTEWATER FROM HYDRAULIC FRACTURING AND EXTRACTION OF NATURAL GAS FROM THE MARCELLUS SHALE GEOLOGICAL FORMATION (2012), *available at* http://files.dep.state.pa.us/Waste/Bureau%20of%20Waste%20Management/WasteMgtPortalFiles/SolidWaste/Residual_Waste/GP/WMGR123.pdf
- ²⁶⁸ Id. at 8; Id. at Appendix A.
- ²⁶⁹ Peter Vorster, The Bay Institute, pers. comm.
- ²⁷⁰ CAL. DEP’T OF CONSERVATION, DIV. OF OIL, GAS AND GEOTHERMAL RES., 2010 PRELIMINARY REPORT OF CALIFORNIA OIL AND GAS PRODUCTION STATISTICS, *SUPRA* NOTE 35.
- ²⁷¹ Igunnu & Chen, *supra* note 69; Peter Vorster (The Bay Institute), pers. comm.
- ²⁷² David Burnett, *Desalinating brine from oil and gas operations in Texas*, SOUTHWEST HYDROLOGY, Nov.-Dec. 2005, at 24. (Cost estimates for reclaiming water (\$1200 to \$2500 per AF including brine disposal) are less than the costs of disposal in injection wells (\$3,000 to 5,000 per ac-ft.); URS CORP., WATER SUPPLY STUDY: DEVELOPMENT OF WATER SUPPLY ALTERNATIVES FOR USE IN HABITAT RESTORATION FOR THE SAN JOAQUIN RIVER (2002), at Appendix E, Section 1, Oil Field Water (“Typically the cost of the oil field water ranges from approximately \$76 to \$155 per acre-foot but could cost as much as \$755 per acre-foot at other fields if pumping is required.”); (“One water agency charges an oil company \$34 per acre-foot to take the water into its system. Another agency purchases the water from the oil company at \$10 per acre-foot. More typically, according to the Central Valley Regional Board, oil field water is generally either reinjected into wells or left to drain into sumps”); Most of the oil fields in the San Joaquin Valley are small producers of less than 500 acre-feet/year, so understanding the scale economies of treatment and conveyance would be important.
- ²⁷³ CAL. REG’L WATER QUALITY CONTROL BD., CENTRAL VALLEY REGION, ORDER No. R5-2012-0058,

WASTE DISCHARGE REQUIREMENTS FOR CHEVRON USA, INC., AND CAWELO WATER DISTRICT PRODUCED WATER RECLAMATION PROJECT KERN RIVER AREA STATION 36, KERN RIVER OIL FIELD, KERN CITY.(N.D.); Jim Waldron, *Produced Water Reuse at the Kern River Oil Field*, SOUTHWEST HYDROLOGY, Nov.-Dec. 2005, at 26. Note that the economics of the arrangements described in this article are not described in detail.

²⁷⁴ Id.

²⁷⁵ URS CORP., WATER SUPPLY STUDY: DEVELOPMENT OF WATER SUPPLY ALTERNATIVES FOR USE IN HABITAT RESTORATION FOR THE SAN JOAQUIN RIVER, *supra* note 272 (Water quality varies tremendously for produced water. Comprehensive statistics about the quality of this water are not available, but variation results from differences in underlying geology. One study reported that salinity in the major water producing fields ranged from 128 to 28,914 ppm, with an average TDS of 13,033 ppm. In some oil fields in Kern County, produced water is fresh enough to be sold to farmers for irrigation water with filtering and blending, but no treatment for salinity. In others, salinity is greater than seawater.)

²⁷⁶ Darrell Fruth et al., *Developing a New Water Resource from Oilfield Produced Water*, presented at American Water Works Association Water Resources Conference, Seattle, Wash. (1997).; L.Y.C. Leong, Darrell Fruth, et al., *Developing a Cost Effective Environmental Solution for Produced Water and Creating a "New" Water Resource*, Presented at The 4th International Petroleum Environmental Conference, San Antonio, Tex. (1997).; Joseph Drago, Kennedy]Jenks, pers. comm.

²⁷⁷ CAL. DEP'T OF PUB. HEALTH, POLICY MEMO 97-005, POLICY GUIDANCE FOR DIRECT DOMESTIC USE OF EXTREMELY IMPAIRED SOURCES (1997), *available at* <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/memo97-005.pdf>.

²⁷⁸ Water Use in the Barnett Shale, R.R COMM'N OF TEX., http://www.rrc.state.tx.us/barnettshale/wateruse_barnettshale.php. (last updated Jan. 24, 2011).

²⁷⁹ Fundamental economic questions include a) whether treatment and conveyance of a given supply to irrigation-acceptable standards can be done for less than the cost of disposal, or less than the cost of developing new water supplies, b) whether the cost of treatment for discharge can leave viable oil and gas production viable economically, and c) how one can incorporate the value of avoided water supply costs and potential income from sale of treated water. Such studies would need to describe the matches between quantity, quality, and location for supply and demand of water, as conveyance is not always readily available from oil fields to even nearby sites of demand.

²⁸⁰ E.g., WateReuse Association, Water Environment Foundation.

²⁸¹ E.g., American Water Works Association (AWWA), see AMERICAN WATER WORKS ASSOC'N, WATER AND HYDRAULIC FRACTURING: A WHITE PAPER FROM THE AMERICAN WATER WORKS ASSOC'N (2013). A White Paper From the American Water Works Association."

²⁸² PA. DEP'T OF ENVTL. PROT., PERMITTING STRATEGY FOR HIGH TOTAL DISSOLVED SOLIDS (TDS) WASTEWATER DISCHARGES, *supra* note 266; Wastewater Treatment Requirements, *supra* note 266.

²⁸³ PA. DEP'T OF ENVTL. PROT., WMGR121 FOR PROCESSING AND BENEFICIAL USE OF GAS WELL WASTEWATER FROM HYDRAULIC FRACTURING AND EXTRACTION OF NATURAL GAS FROM THE MARCELLUS SHALE GEOLOGICAL FORMATION, *supra* note 267.

²⁸⁴ Anthony Kovscek, Stanford University, pers. comm.

²⁸⁵ 25 PA. CODE § 95.10 (2010), *available at* <http://www.pacode.com/secure/data/025/chapter95/chap95toc.html>.

²⁸⁶ 25 PA. CODE § 95.10(b)(3) (2010).

²⁸⁷ Letter from Pa. Dep't of Env'tl Prot. (PADEP) to EPA Re: PADEP's Call to Gas Drillers to Cease Delivering Wastewater from Shale Gas Extraction to 15 Facilities That Accept It, (July 26, 2011) (*available at* http://www.epa.gov/region3/marcellus_shale/#epawpadep).

²⁸⁸ Kevin Begos, *Water quality improves in Pennsylvania river near drilling*, researcher says TULSA WORLD, Nov. 9, 2012, http://www.tulsaworld.com/business/article.asp?articleid=20121109_49_E6_PT-SUGe155219.

²⁸⁹ OHIO REV. CODE ANN. § 1509.22(C)(1) (West 2011)

²⁹⁰ OHIO REV. CODE ANN. § 1509.22(C)(1) (West 2011)

²⁹¹ See 16 TEX. ADMIN. CODE § 3.8; see also Water Use in the Barnett Shale, *supra* note 278 (“Brazos Bend Energy Services . . . received authorization to dispose of produced water and drilling fluids in the City of Fort Worth’s wastewater system in July 2009. The authorization to dispose of these waste streams is contingent upon Brazos Bend also receiving authorization from the Texas Commission on Environmental Quality and the City of Fort Worth.”)

²⁹² Texas Surface Water Quality Standards, TEX. COMM’N ON ENV’T’L QUALITY, http://www.tceq.texas.gov/waterquality/standards/eq_swqs.html (last visited Mar. 27, 2013).

²⁹³ HAMMER, VANBRIESEN, *supra* note 2.

²⁹⁴ Pre-Rulemaking Discussion Draft, *supra* note 149 at §1786(a).

²⁹⁵ Operational Rules, Drilling Rules, *supra* note 224 at Ch. 3, § 22(b).

²⁹⁶ Abrahm Lustgarten, *The Trillion-Gallon Loophole: Lax Rules for Drillers that Inject Pollutants Into the Earth*, PROPUBLICA, Sept. 20, 2012, <http://www.propublica.org/article/trillion-gallon-loophole-lax-rules-for-drillers-that-inject-pollutants> (linking to indictment in Southern District of Texas Case No. 4:07-cr-00466).

²⁹⁷ *Ohio company accused of dumping fracking wastewater down storm drain*, *supra* note 83.

²⁹⁸ RESOURCES FOR THE FUTURE, 2012 A REVIEW OF SHALE GAS REGULATIONS BY STATE, *available at* http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx.

²⁹⁹ Oil, Gas, and Geothermal – Assessment Process, CAL. DEP’T OF CONSERVATION DIV. OF OIL, GAS, AND NATURAL RES., http://www.conservation.ca.gov/dog/for_operators/Pages/assessments.aspx (last visited Mar. 27, 2013); Ken Jacobs, Laurel Lucia, and T. William Lester, University of California, Berkeley Center for Labor Research and Education *The Economic Consequences of Proposed California Budget Cuts* (May 2010), *available at* http://laborcenter.berkeley.edu/californiabudget/budget_impact10.pdf.

³⁰⁰ Francis Gradijan, *State Regulations, Litigation, And Hydraulic Fracturing*, 7 ENV’T’L & ENERGY L. & POL’Y J. 47 (2012).

³⁰¹ CAL. CONST. art. XIII A, as amended by Proposition 26.

³⁰² For example, the “California Modernization & Economic Development Act,” proposes to impose a 9.5% extraction fee on oil and natural gas extracted for California. The initiative proposes to use those funds for a number of programs, the largest of which is education. Summary, CAL. MODERNIZATION & ECON. DEV. ACT, www.cmedact.org/summary (last visited Mar. 27, 2013).

³⁰³ CAL. CONST. art. XIII A, § 3(b)(3) (“A charge imposed for the reasonable regulatory costs to the State incident to issuing licenses and permits, performing investigations, inspection, and audits, . . . and the administrative enforcement and adjudication thereof.”)

³⁰⁴ CAL. CONST. art. XIII A.

³⁰⁵ Electric Program Investment Charge, CAL. ENERGY COMM’N, <http://www.energy.ca.gov/research/epic/index.html> (last visited Mar. 27, 2013).

³⁰⁶ HAMMER, VANBRIESEN, *supra* note 2.

³⁰⁷ AB 32, (2006) <http://www.arb.ca.gov/fuels/lcfs/ab32.pdf>

³⁰⁸ Robert W. Howarth, Renee Santoro, et al. *Methane and the greenhouse-gas footprint of natural gas from shale formations* 106(4) CLIMATIC CHANGE 679 (2011) (“...methane emissions are at least 30% more than and perhaps more than twice as great as those from conventional gas.”), but see Frances O’Sullivan and Sergei Paltsev, *Shale gas production: potential versus actual greenhouse gas emissions*, 7 ENVIRONMENTAL RESEARCH LETTERS 044030 (2012) and references therein for a review of this as yet unsettled topic, as well as Jeff Tollefson, *Methane leaks erode green credentials of natural gas*, NATURE, Jan. 3, 2013, at 12, 12.

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³¹² Theo Colborn, Kim Schultz, et al., *An Exploratory Study of Air Quality near Natural Gas Operations*, HUMAN & ECOLOGICAL RISK ASSESSMENT: AN INT'L J.121130060641008.; HAMMER, VANBRIESEN, *supra* note 2.

³¹³ Gayle Nicoll, *Radiation Sources in Natural Gas Well Activities*, OCCUPATIONAL HEALTH AND SAFETY October 1, 2012, <http://ohsonline.com/articles/2012/10/01/radiation-sources-in-natural-gas-well-activities.aspx?admgarea=ht.HandProtection>

³¹⁴ STAFF OF H. COMM. ON ENERGY AND COMMERCE, 112TH CONG., CHEMICALS USED IN HYDRAULIC FRACTURING, *supra* note 9.; Valerie J. Brown, *Industry Issues: Putting the Heat on Gas*, ENVTL. HEALTH PERSPECTIVES, Feb. 2007, at A76.

³¹⁵ Figure source: Oil, Gas and Geothermal Fields in California, 2001, CAL. DEP'T OF CONSERVATION DIV. OF OIL, GAS AND GEOTHERMAL RES., ftp://ftp.consrv.ca.gov/pub/oil/maps/Map_S-1.pdf, (last visited Mar. 27, 2013).

³¹⁶ Figure source: Class II Wells - Oil and Gas Related Injection Wells (Class II), U.S. EPA, <http://water.epa.gov/type/groundwater/uic/class2> (last visited Mar. 27, 2013).

³¹⁷ Data compiled by Staff of H. Comm. on Energy and Commerce, 112th Cong., Chemicals Used in Hydraulic Fracturing, *supra* note 9.

³¹⁸ Data compiled by R. Hammer & J. VanBriesen, *supra* note 2, from sources cited therein.

³¹⁹ Note that this document has been updated to repair typographical errors from the original version.