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The need to protect fresh and brackish groundwater resources during unconventional oil and gas development

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Abstract

Freshwater shortages in the United States have led to increased use of treated brackish groundwater for domestic, agricultural, and municipal uses. This increased use highlights the need for protecting groundwater resources, especially during unconventional oil and gas development. We analyzed the criteria that define protected groundwater in 17 oil- and natural-gas-producing states. In general, we find that these criteria are ambiguous and do not protect brackish groundwater to criteria established for Underground Sources of Drinking Water (USDWs) in the United States Environmental Protection Agency's Underground Injection Control Program. This lack of consistent protection, and continuing unconventional oil and gas development in formations containing USDWs, highlights the need for all states to protect groundwater to the same federally defined standard for USDWs to safeguard fresh and brackish groundwater for present and future use.

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Introduction

Water resources are vital to economic development and the health and well-being of people and ecological communities. Groundwater is the primary source of domestic water supply in the United States for approximately one-half of the population [1,2]. Furthermore, the proportion of groundwater to total overall water use for irrigation in the United States increased from 23% to 43% between 1950 and 2010 [1,3]. Groundwater resources are especially important in arid regions of the United States, and globally, experiencing rapid population growth, where surface water rights for irrigation are often fully appropriated [4], and where climate change is expected to further exacerbate water demands in hotter and drier conditions [5]. Balancing groundwater exploitation has become increasingly difficult with the need to maintain baseflow to streams, wetlands, and riparian zones, to prevent land subsidence caused by the compression of depleted aquifers, and to prevent saltwater intrusion in coastal regions [2].

Freshwater is generally defined as water having <1000 mg/L total dissolved solids (TDS) [6], although states such as California define it more broadly (<3000 mg/L) [7]. The United States Geological Survey (USGS) and the National Groundwater Association define brackish groundwater as water having between 1000 and 10,000 mg/L TDS [6,8]. Others have defined brackish water as water having between 1000 and 35,000 mg/L (seawater) TDS [9]. The use of treated brackish groundwater for municipal water supply has substantially increased in the United States [10–12] in part because of declining freshwater availability, the difficulty in securing surface water and groundwater legal rights, the high costs of infrastructure required to transport and store fresh water, and advances in membrane technology that have reduced the cost of desalinization.

The increased use of brackish groundwater prompted the USGS to conduct an ongoing national assessment of brackish aquifers containing ≤10,000 mg/L TDS [4,13,14]. Given the increased demand for fresh and brackish groundwater, the protection of groundwater resources is especially important, including during unconventional oil and gas development. During hydraulic fracturing and acid stimulation, stimulation fluids can be injected into or near formations that contain fresh water or brackish groundwater resources of potential current and future use. Stimulation fluids can also enter fresh water or brackish groundwater through diverse pathways, including compromised cement between the wellbore and the production casing.

The criteria for USDWs established by the United States Environmental Protection Agency (EPA) in its Underground Injection Control (UIC) program under the Safe Drinking Water Act (SDWA) are reasonable starting points for protecting fresh and brackish groundwater in all states. The EPA defined an USDW in the United States Code of Federal Regulations (40 CFR Section 144.3) through two requirements, as an aquifer or part of an aquifer that: 1) supplies any public water system, or that contains a sufficient quantity of groundwater to supply a public water system, and 2) currently either supplies drinking water for human consumption or contains ≤10,000 mg/L TDS and is not an exempted aquifer. Aquifer exemptions enable disposal of waste fluids into formations containing USDWs and can be granted through the EPA's UIC program under the SDWA. Hydraulic fracturing was exempted from the SDWA under the Energy Policy Act (EPAct) of 2005, except when diesel fuel is used for well stimulation, rendering criteria for a USDW as protected groundwater unenforceable during these activities.

Statues and regulations on federal and tribal lands are determined by the United States Department of Interior's Bureau of Land Management (BLM). On March 26, 2015, the BLM issued a Final Rule in 43 CFR Part 3160 [15] on the regulation of hydraulic fracturing. The BLM defined "usable" water for protection as water having TDS ≤10,000 mg/L. BLM stated that this criterion is consistent with existing BLM Onshore Oil and Gas Order No. 2 and that "given the increasing scarcity and technological improvements in water treatment, it is not unreasonable to assume aquifers with TDS levels above 5000 ppm [5000 mg/L] are usable now or will be usable in the future" [15]. However, on June 21, 2016, the United States District Court for the District of Wyoming set aside the BLM rule based on the legal ruling that the EPAct of 2005 precluded BLM's rulemaking [16]. As a result, the BLM rule has not taken effect on federal lands. "To reduce the burden of Federal regulations that hinder economic growth and energy development," the BLM published a proposal on July 25, 2017 to repeal the BLM rule [17].

Industry has best practices for protecting groundwater, as well. In its guidelines on oil and gas well construction and integrity for hydraulic fracturing, the American Petroleum Institute (API) stated that "at a minimum, it is recommended that surface casing be set at least 100 feet below the deepest USDW" [18]. The Groundwater Protection Council (GWPC), an organization representing regulatory agencies from oil and gas producing states with input from industry, stated that hydraulic fracturing should not occur in formations containing USDWs that have not received an aquifer exemption [19]. In 2015, as a result of recommendations from a water and well stimulation expert panel [20], the California State Water Resources Control Board (CA SWRCB) required monitoring groundwater (monitoring well installation and sample collection) with TDS levels up to 10,000 mg/L during acid stimulation and hydraulic fracturing [21]. The panel stated that monitoring at this TDS level is appropriate because it aligns with EPA's UIC program and it is "technically and economically feasible to desalinate" water at this level of salinity [20].

Approach

In sum, statements by BLM [15], API [18], GWPC [19], and the water and well stimulation expert panel convened by the CA SWRCB [20] clearly indicate that the use of criteria established for an USDW to define protected groundwater is both technically and economically reasonable. However, definitions of protected groundwater during oil and gas production vary substantially among states [22]. In this paper, we examine definitions of protected groundwater in states where development has either occurred or has the potential to occur in formations containing USDWs to determine equivalency and divergence of definitions used by these states with criteria established for an USDW.

We assessed the USGS National Produced Waters Geochemical Database [23] to identify states where unconventional oil and gas development may be occurring in USDWs. We screened this database for locations of oil and gas production wells with produced water having concentrations of TDS ≤10,000 mg/L. The USGS database contains an identifier for whether produced water samples came from conventional or unconventional production wells, but the accuracy of this identifier is questionable. For instance, produced water samples in the database from the Pavillion, WY, Field are identified as coming from conventional production wells when in reality they came from hydraulically fractured wells [24]. As such, we did not use these identifiers to distinguish produced water samples coming from conventional and unconventional oil and gas production wells. Additionally, we examined regulations in states where unconventional oil and gas development may be occurring in USDWs. Because criteria for protected groundwater are often unclear, we also examined regulations stipulating the minimum depth of surface casing — given that shallow and improperly cased and cemented wells are a primary mechanism through which groundwater can become contaminated from oil and gas development.