

An Independent Scientific Assessment of Well Stimulation in California

Volume 1

**Well Stimulation Technologies and
their Past, Present, and
Potential Future Use in California**

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of oil from California's source rocks, the undertaking would likely require well stimulation technology. Future exploration of Monterey source rock could improve our understanding of the potential, challenges, costs, and rewards for production in these reservoirs (Chapter 4).

Stimulation of dry gas wells¹: Almost all wells that produce primarily gas are located in Northern California. These dry (non-associated) gas wells are rarely stimulated, and we do not expect this to change in the near future.

- Operators rarely stimulate California dry (non-associated) gas wells. Approximately ten dry gas wells per month were installed on average from 2002 through 2011, of which about one was hydraulically fractured. We found no records of hydraulic fracturing of gas wells since 2011 and no records of acid stimulation in these wells. However, most of the gas production in the state is not from dry gas wells, but from wells that primarily produce oil. As such, about a fifth of the gas produced in the state is facilitated by hydraulic fracturing (Chapter 3).
- Geologic assessment indicates that significant unconventional natural gas resources on a basin-wide scale, such as the Marcellus or Barnett shales or in the Piceance basin, probably do not exist in California. Most of the remaining undiscovered non-associated natural gas in California is likely to be similar to reservoirs in production today that currently do not use well stimulation technology. The geologic conditions in California are unlikely to have created large basin-wide gas plays (Chapter 4).
- Operators hydraulically fracture gas storage wells. Hydraulic fracturing facilitates about a third of the subsurface storage of natural gas in the state. We expect this to continue given the importance of these facilities to balance urban natural gas demand from season to season. About two times a year on average, operators of gas storage facilities use hydraulic fracturing to enhance storage, mostly in one facility serving southern California (Aliso Canyon) (Chapter 3).

Hydraulic fracturing offshore: Hydraulic fracturing is used in a small proportion of offshore wells; we expect hydraulic fracturing to continue to play an incidental role in offshore production.

- The majority of offshore production takes place without hydraulic fracturing. Most of this limited hydraulic fracturing activity is conducted on man-made islands

1. Wells typically produce both oil and gas. The distinction between a dry gas well and an oil well is in the relative amount of oil and gas produced. Dry gas wells produce a large amount of gas compared to oil, sometimes called "non-associated" gas. Oil wells produce a small amount of gas relative to oil, known as "associated" gas.

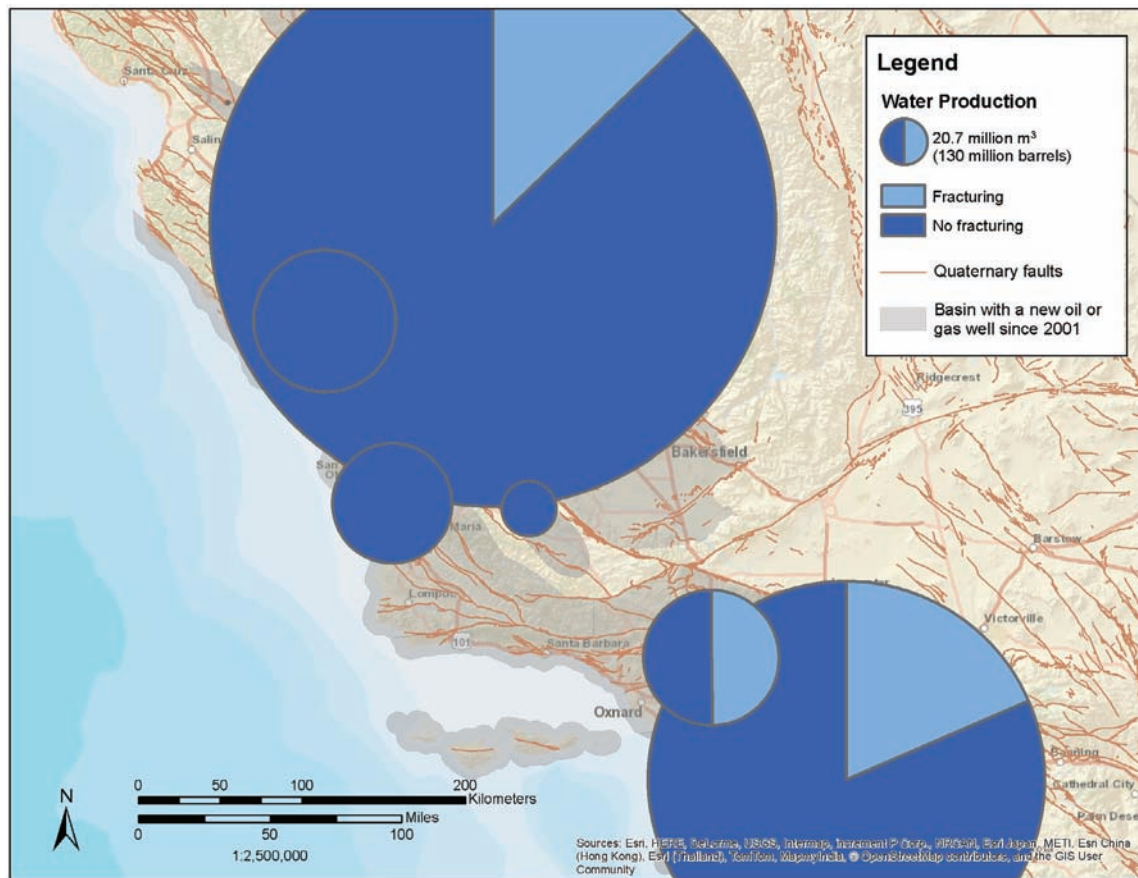


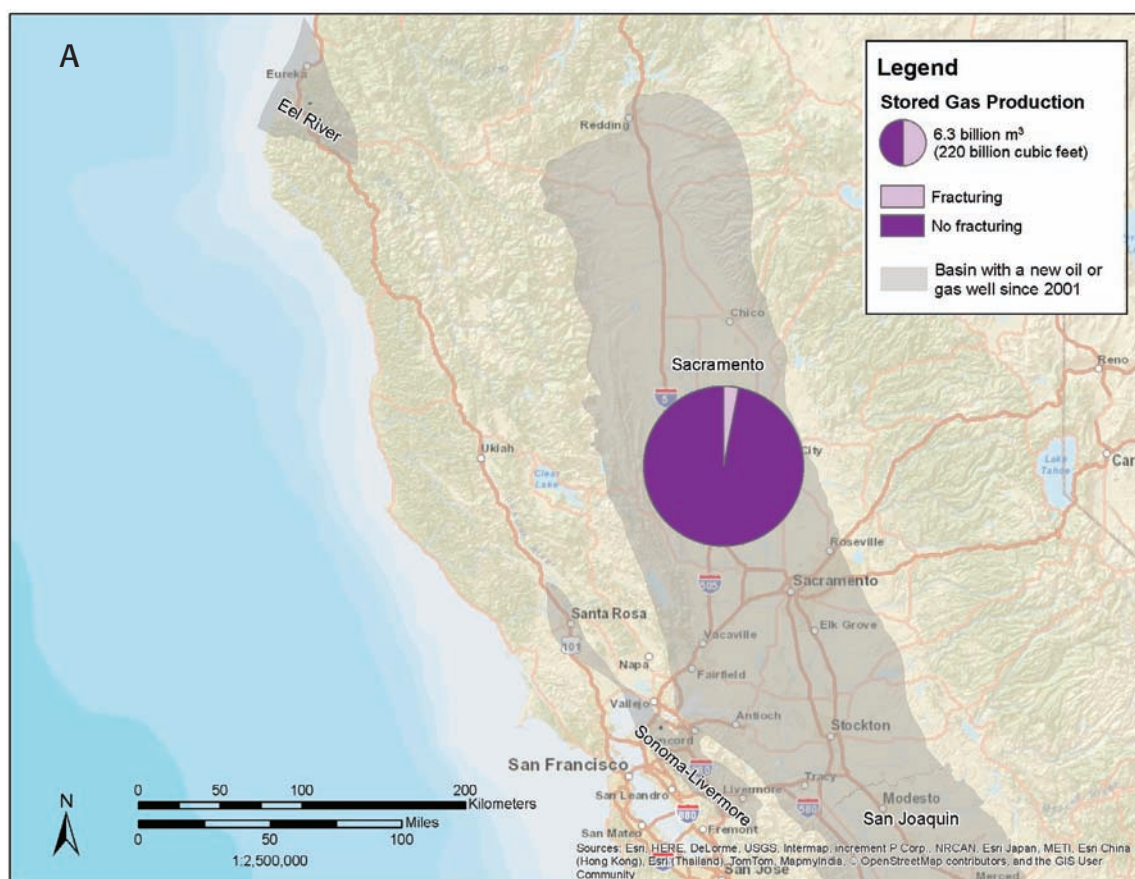
Figure 3-13. Water produced with oil and gas with and without hydraulic fracturing in each basin with a new well since 2001 in southern California from 2002 through May 2014. Total water production in the northern California basins is smaller than the smallest water production in a single southern California basin. The area of each circle is proportional to the production volume in each basin.

About 2% of all gas production in California was facilitated by hydraulic fracturing in pools identified as non-associated gas (dry gas)³ by DOGGR. About 3% of all gas production in the state was facilitated by hydraulic fracturing in pools whose production meets the United States Energy Information Administration's (EIA) definition of a gas well.⁴ The remaining gas production facilitated by hydraulic fracturing was from oil pools.

3. Non-associated (dry) gas is produced from pools that do not also contain oil.

4. The EIA classifies wells producing more than 6,000 standard cubic feet of natural gas per barrel of oil produced as gas wells.

Hydraulic fracturing also facilitated seasonal storage of gas underground in some locations. Gas was stored in 11 pools near the major urban areas in California during all or some of the period since 2001. Gas is stored in the period of low gas demand, typically late spring through early fall, and produced during the period of high gas demand, typically late fall through early spring. This storage allows the construction of smaller long distance pipelines with a constant flow of gas toward the urban areas. Four pools (reservoirs) in which more than half of the wells commencing gas storage since 2001 are estimated to have been hydraulically fractured (including frac-packing) were identified from the well-record search results (listed in Appendix N). This analysis was based on the well-record search results because it was the only data set for which sampling statistics were available. The volume of gas pumped from all the storage in California since 2001 was about three quarters of the volume of new gas produced from natural reservoirs in the state. The four gas storage reservoirs where most new wells were hydraulically fractured provided about a third of the total gas storage in the state. Most of this storage is in southern California, as shown on Figure 3-14.



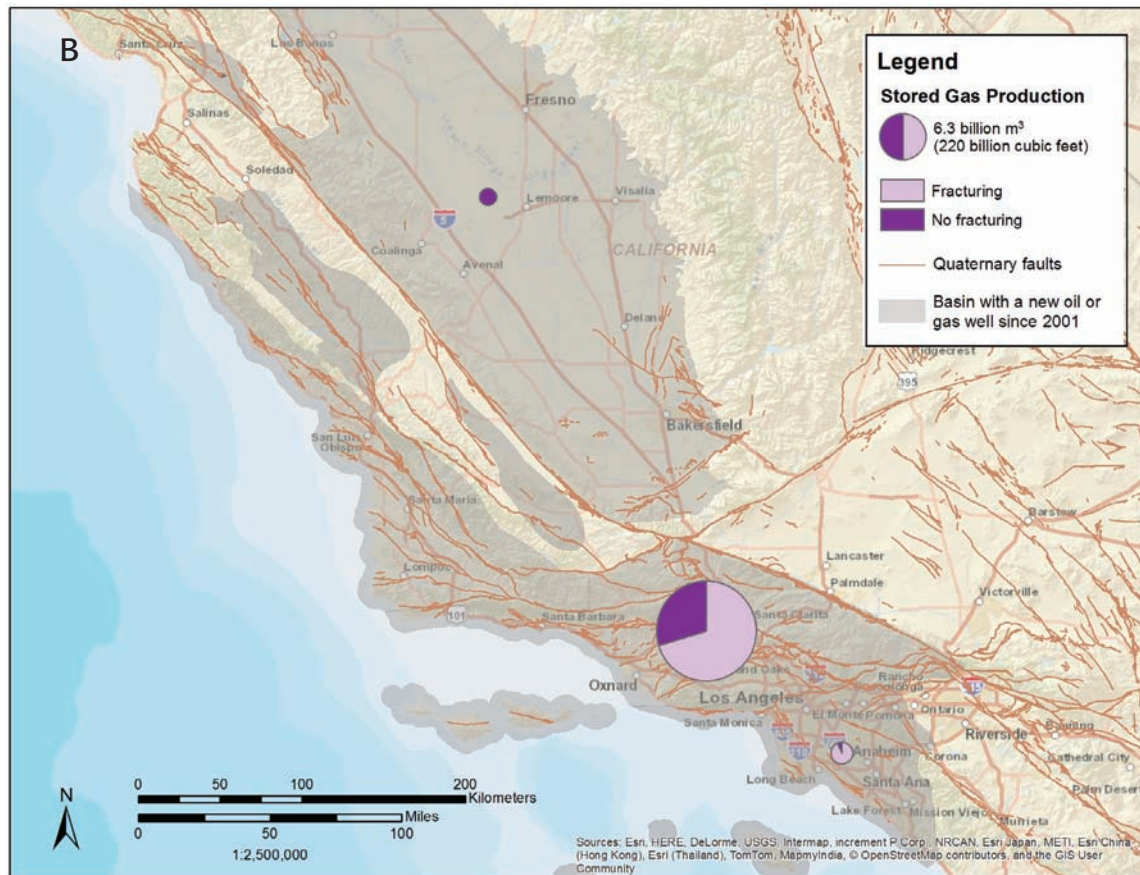


Figure 3-14. Production of stored gas with and without hydraulic fracturing in each basin with a new well since 2001 in (A) northern and (B) southern California from 2002 through May 2014. Note that many of the basins do not have any gas storage facilities. The area of each circle is proportional to the production volume in each basin.