# Wastewater Injection Wells in Proximity to Fault Lines in Southern California

GSP 270

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## Abstract

To meet demands of increasing populations, energy companies have created new techniques for extracting natural resources, including hydraulic fracturing, that have created a magnitude of impacts. The injection of wastewater generated by hydraulic fracturing deep into the earth's crust has resulted in increased seismicity, especially in the Midwest. Insufficient scientific research has been done to observe the nature of these well sites in regards to their influences on seismic activity, so our current understanding of how these well sites behave stands on shaky ground.

Our project analyzes the location of these wastewater injection sites in four counties of southern California, one of the most seismically active regions in the United States. Through geospatial analysis we created maps showing the location of these well sites and separated them into three categories based on their distances from a fault line. We found that the majority of these sites were a reasonable distance from any fault lines, but there were still over 500 sites within a half-mile of fault lines. The direct correlation between class II wastewater injection well sites and increased seismicity means these sites have the potential to cause ecological and economic impacts, of which the scale is unknown at this point.

## Introduction

In a world that continues to see rapid growth in global populations and environmental pollution, efficient fuel sources are increasingly important. In the United States, the mining and extraction of natural gas has become progressively more common within the energy resource industry due to its abundant reserves and relatively low carbon dioxide emissions when compared to burning coal. Between the years 2008 and 2014, power plants in the U.S. saw a 22.2% increase in the amount of natural gas deliveries (Gilbert and Sovacool, 2017). One key aspect of extracting natural resources and fuels is the manner in which they are mined and the processes involved for disposing of the generated waste. Horizontal drilling and hydraulic fracturing, or *fracking*, of geological formations that hold carbon fuel beds are the current methods used in extracting natural gas. Both of these methods produce large amounts of wastewater, which gets pumped back into the earth for disposal to deep-well injection sites called Class II disposal wells. Deep-well injection has always been the preferred method for wastewater disposal in relation to hydraulic fracking, but in recent years some Class II disposal wells have created significant environmental and economic challenges in the form of increased seismicity and human-induced earthquakes (Folger and Tiemann, 2016).

Induced seismicity is caused by pressure changes and strains on the earth's crust; these can include processes such as filling large reservoirs, specific types of mining practices, and wastewater injections into geological formations. The resulting increase in subsurface pore pressure can activate movement along existing faults, resulting in tremors or earthquakes. (Davies, Foulger, Bindley, & Styles, 2013). Many states in the U.S. have experienced induced earthquakes from wastewater injection related to natural gas extraction, especially those most involved in the extraction industry such as Oklahoma. Since 2009 the state of Oklahoma has seen an unprecedented increase in induced seismicity largely due to Class II disposal wells. In 2016 a series of the largest induced earthquakes in Oklahoma's history occurred near the cities of Fairview, Pawnee and Cushing, with each quake exceeding a magnitude of 5.0. The induced earthquake that occurred in Pawnee was at a magnitude of 5.8, while the one that occurred in Cushing was 5.0 and incurred structural damage to the city (McGarr and Barbour, 2017).

Considering the recent increase in seismicity related to Class II disposal sites in the Midwest, this project aims to locate current wastewater injection and disposal sites that are in the vicinity of mapped fault lines in the southern region of California. The direct correlation between Class II injection sites and induced seismicity could have broader implications, both economically and environmentally, as the state is already predisposed to tectonic activity and natural earthquakes.

## METHODS

First, we obtained data layers containing the county boundaries of California from the state government data portal, a layer of California fault lines from ArcGIS, and a layer of class II wastewater injection well sites from Fracktracker.org. After loading all these layers into ArcMap, we projected them into the NAD 1983 (2011) geographic coordinate system.

Once all the layers were loaded into ArcMap and projected into the same GCS, we could begin spatial analysis. We wanted to analyze the counties with the highest number of well sites so we used select by attribute to export Kern, San Luis Obispo, Santa Barbara, and Ventura counties as a new layer. Then we clipped the fault line and injection well site layers to our counties of interest.

To count only *active* well sites, we used select by attribute to export only “A” (active) from the well site status column of the attribute table as a new layer. Once we were working with only active well sites, we used select by location to create three data layers showing the number of wells within 0.5 miles, between 0.5 and 2 miles, and between 2 and 10 miles of a fault line. We then combined each of these layers on one map and color-coded each (red, yellow and green respectively) to represent the number of wells within each distance range. Using each layer’s attribute table, we created a table in excel showing the numeric values and percentages of the wells to go along with the maps.

## RESULTS

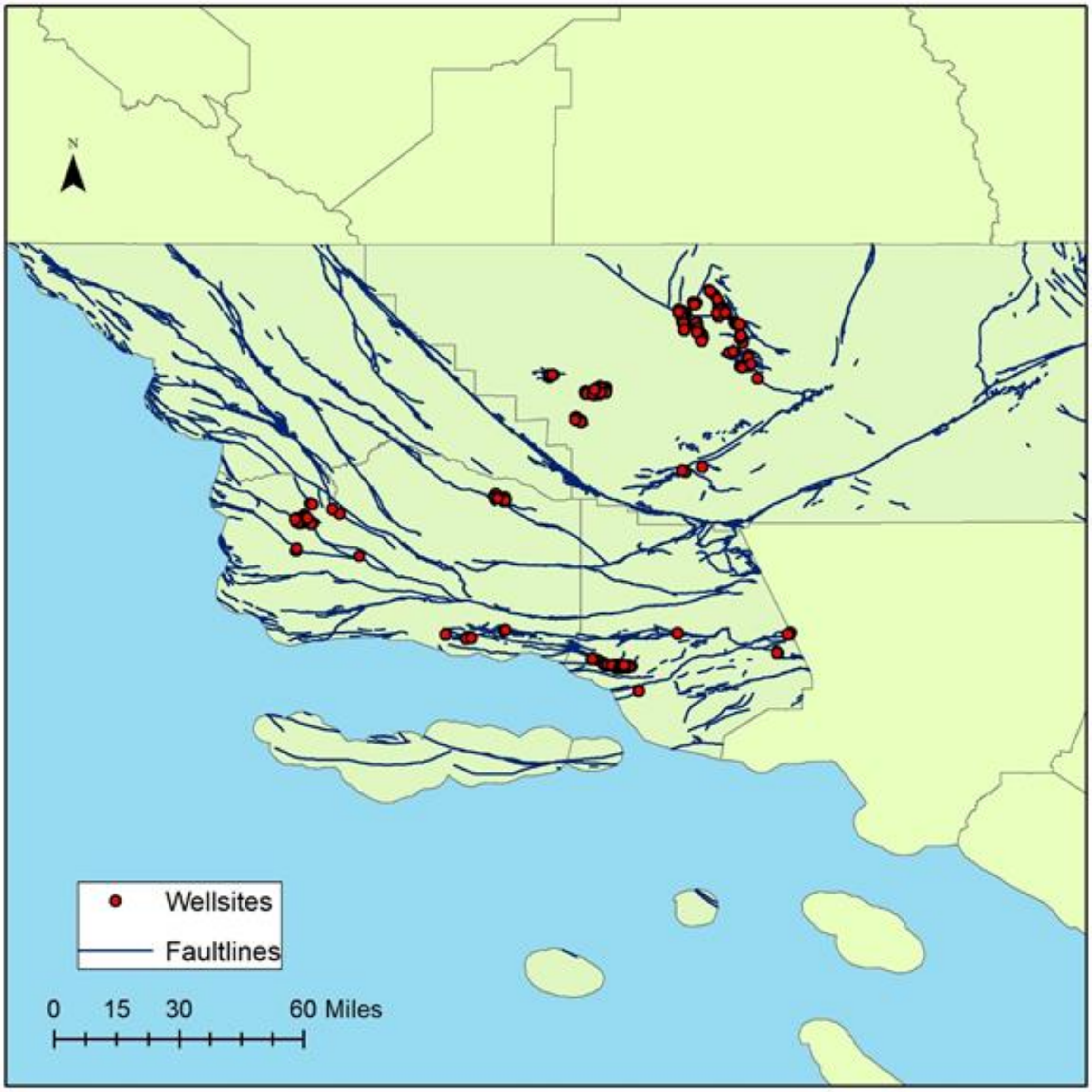


**FIGURE 1.** WASTEWATER INJECTION WELL SITES WITHIN 0.5 MILES OF A FAULT LINE.

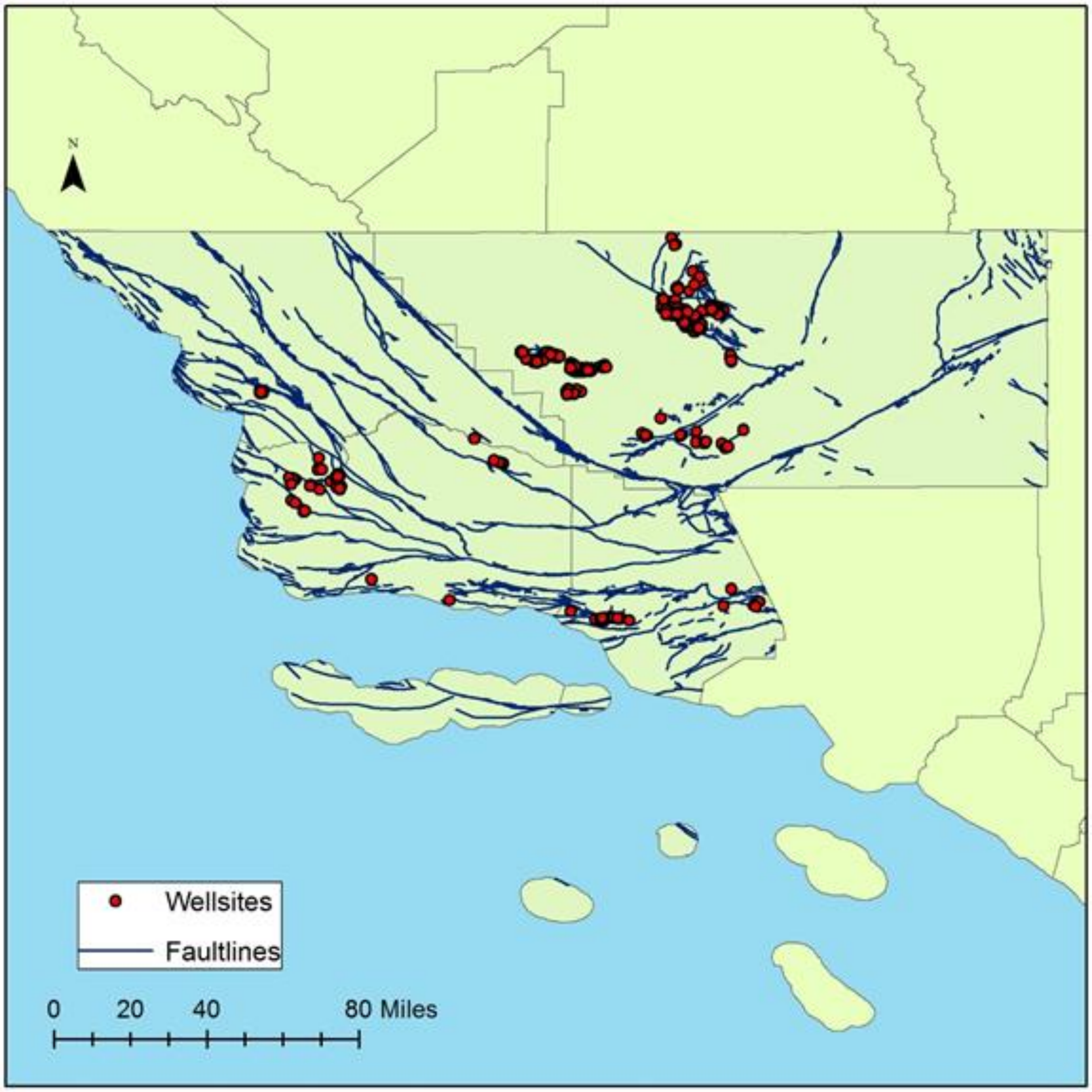


**FIGURE 2.** WASTEWATER INJECTION WELL SITES BETWEEN 0.5 AND 2 MILES OF A FAULT LINE.

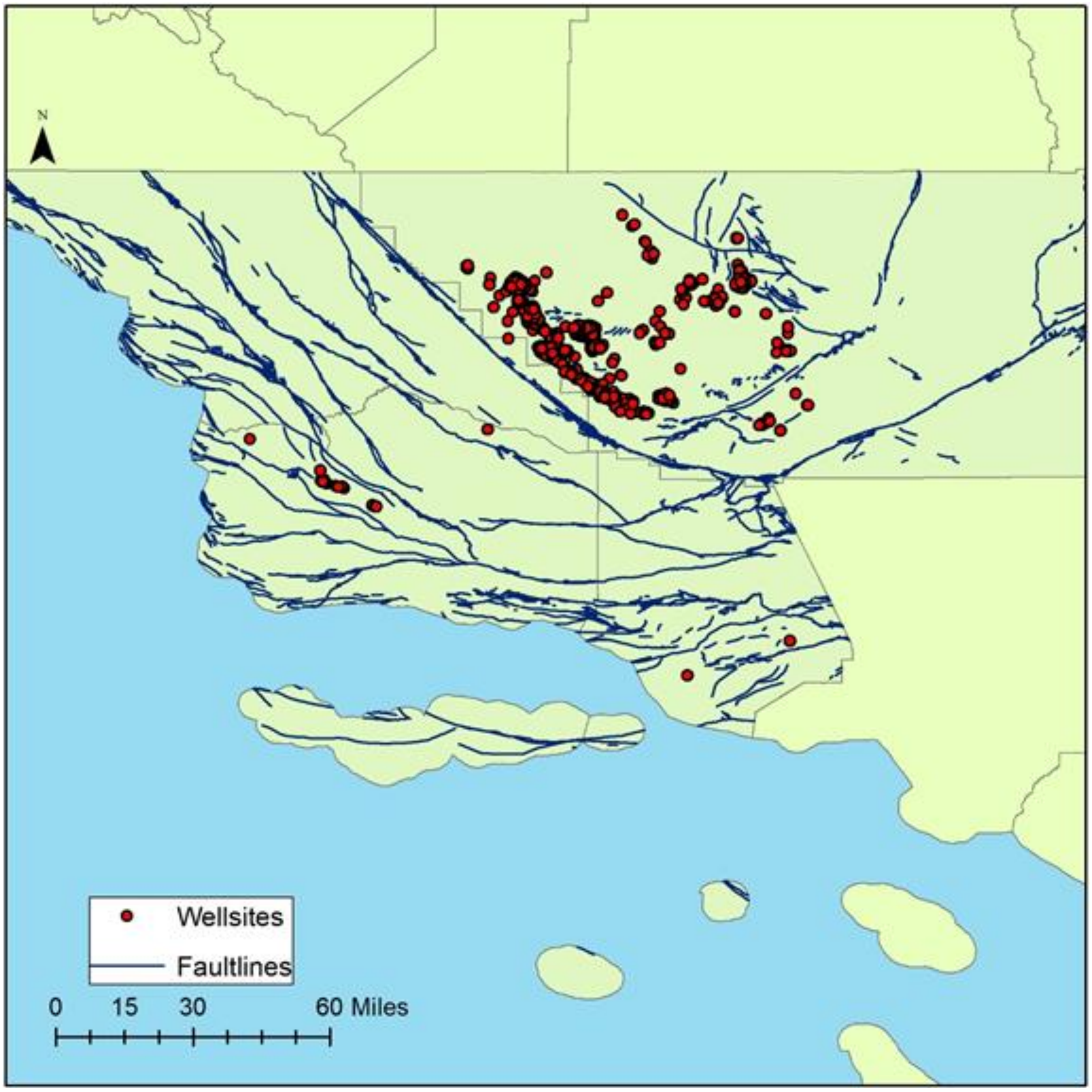


**FIGURE 3.** WASTEWATER INJECTION WELL SITES BETWEEN 2 AND 10 MILES OF A FAULT LINE.

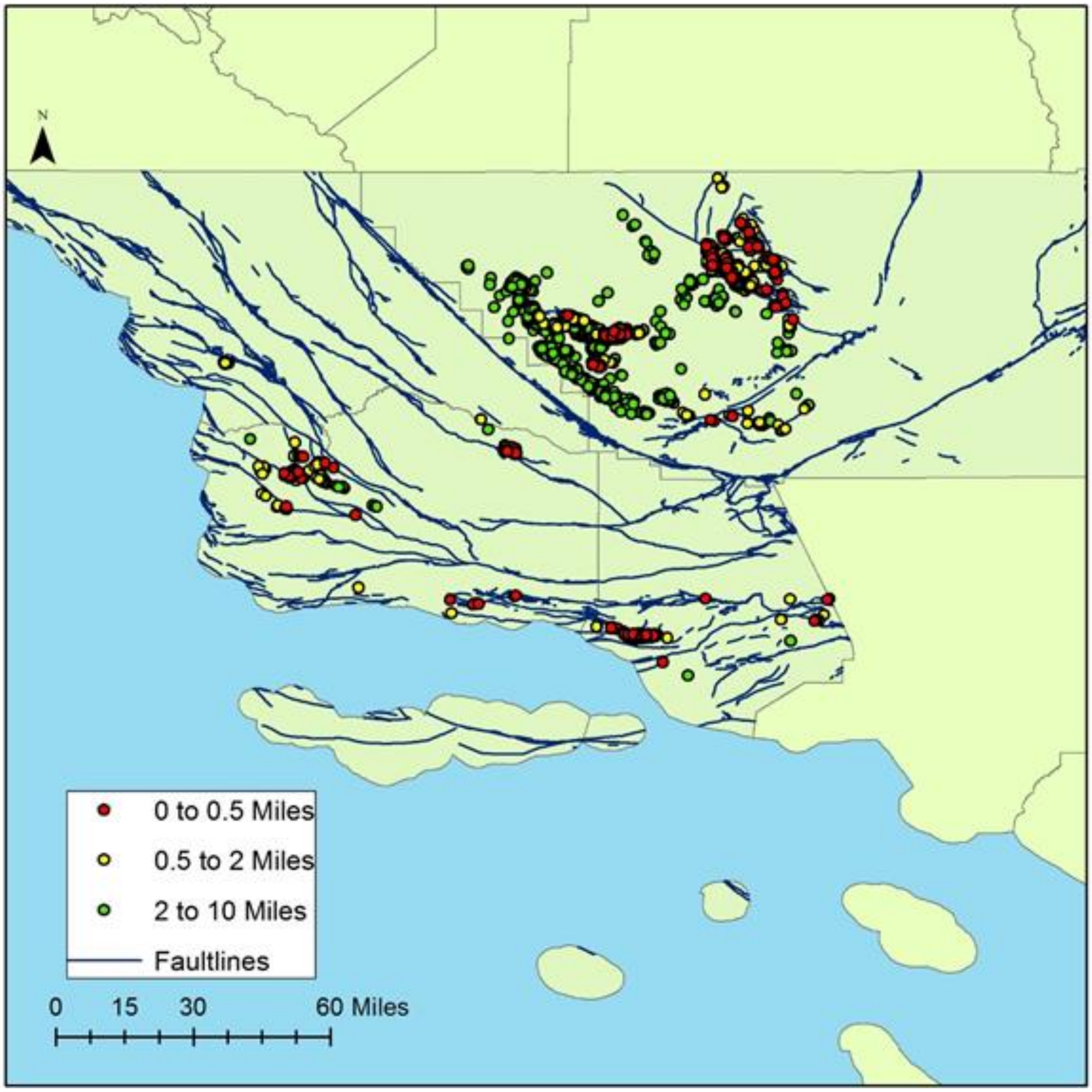


**FIGURE 4.** WASTEWATER INJECTION WELL SITES IN RELATION TO DISTANCE RANGES FROM FAULT LINES.

**Table 1.** Numerical values and percentages of well sites in relation to distance ranges

| Distance | 0-0.5 Miles | 0.5-2 Miles | 2-10 Miles | Total |
|---|---|---|---|---|
| Number of Well Sites | 522 | 1219 | 4468 | 6209 |
| Percentage of Well Sites | 8.41 | 19.63 | 71.96 | |

There are a total of 6,209 class II wastewater injection well sites within ten miles of a fault line in the four counties we analyzed. The least amount of wells are within half of a mile of a fault line (figure 1). The second largest group of wells are between half and

2 miles from a fault line (figure 2). The largest amount of wells are between two and ten miles from a fault line (figure 3).

Kern County contained the most well sites, with a large group running adjacent to the western border and another large group in the central-northern section of the county. Many wells in western Kern county are about seven miles from the San Andreas Fault zone, while many in the northern section are within half a mile from many fault lines including the Poso Creek, New Hope, Kern Front, and other unnamed fault lines (figure 4).

Wells between two and ten miles away from a fault line make up the majority of the wells we analyzed. There are 522 well sites within half a mile of a fault line, making up 8.41% of the total wells analyzed. There are 1,219 between half and two miles, making up 19.63%. There are 4,468 wells between two and ten miles away, making up 71.96% (table 1).

## CONCLUSION

The relationship between economically advantageous practices, such as the various drilling methods, and their effects on the environment are often in conflict with one another. California is famous for its tectonic activity and abundance of fault lines. Referring to the various maps we made, it is clear that there is a spatial connection between wastewater injection sites and fault lines within some of the southern counties of California. Most importantly though these counties are home to a large portion of the population of California, which happens to reside within close proximity to the San Andreas Fault; this fault line is expected to cause a sizable earthquake within the next few decades. Other environmental impacts from wastewater sites can occur, including potential pollution of water supply and the potential for waste water to resurface overtime. Furthermore the increase in seismic activity has economic effects including property damage, which can devalue housing markets.

By using the trends that have been occurring in states like Oklahoma and Ohio, we are able to look into California and find the possibility of an increase in seismic activity. Although it is difficult to measure the actual chance of an earthquake being caused by an injection site in an area that has as many fault lines as it does, it’s still beneficial to compare the evidence found in other states to the current spatial relation between the two in California.

The end result of our project showed an obvious spatial relationship between wastewater sites and the location of fault lines in southern California. Using the experience that other areas have had regarding injection sites and seismic activity, we can approach wastewater injection in California with a better understanding of its environmental consequences. With evidence that multiple other states are experiencing wastewater injection induced earthquakes it should be within California and its residents' best interest to reconsider the location of the injection sites.

## Works Cited


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