Analysis of TDS concentration in relation to oil and gas produced water disposal ponds in Kern County, California

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Introduction and Background

California ranked third in the nation for oil and gas production in 2016 (EIA, 2017). Groundwater is a vital resource for California, supplying approximately 40% of the drinking supply and 43% of water for irrigation in the Central Valley (Faunt et al., 2015). With California's dependence on groundwater, it is crucial that water practices be assessed to determine impacts on groundwater quality. The Environmental Protection Agency (EPA, 2018) has defined a secondary drinking water standard for total dissolved solids (TDS) of 500 mg/L (EPA, 2018) and Federal California regulations generally protect aquifers with less than 10,000 mg/L TDS as underground sources of drinking water (USDW).

Most oil and gas production (72% in 2016) occurs in Kern County, located in the San Joaquin Basin (DOGGR, 2016). On average, for every barrel of oil produced there are 17 barrels of water extracted with it (DOGGR, 2016), known as produced water. Produced water from conventional oil production is usually 10,000- 30,000mg/L TDS (CCST et al., 2014), much higher than protected aquifer and EPA standards. The excess, low quality water is either reused or disposed. 40% of the water not injected into the subsurface for disposal is disposed in unlined ponds which allow for percolation and evaporation (DOGGR, 2017). Unlined ponds are a direct pathway for contamination of the shallow aquifer system. High TDS water with unknown chemical composition or hazards could be percolating and contaminating groundwater.

California Senate Bill 4 (SB4), which passed in 2013, mandated an independent scientific assessment of hydraulic fracturing and well stimulation practices in California. It recommended produced water be analyzed for hazardous constituents and if they are present or not proven to be absent, then use of unlined pits should be phased out to avoid potential groundwater contamination (CCST, 2015). Several other U.S. states have disallowed the use of unlined ponds due to cases of water contamination.

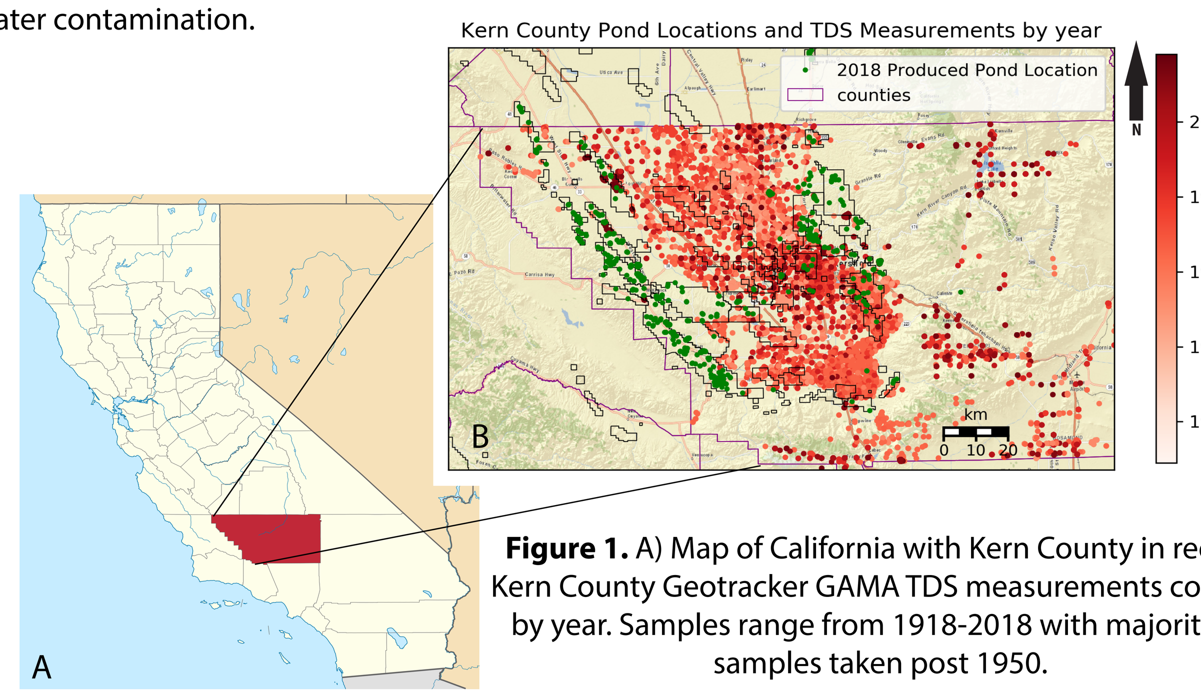


Figure 1. A) Map of California with Kern County in red. B) Kern County Geotracker GAMA TDS measurements colored by year. Samples range from 1918-2018 with majority of samples taken post 1950.

Objective

The objective of this research study was to determine if groundwater quality near ponds exhibits higher or increasing TDS concentrations due to migration of high salinity produced water. This research used public data sources to assess impacts to groundwater quality near produced water disposal ponds using Python programming script in a Jupyter notebook (https://github.com/charuleka/LBNL-CA-ProdWaterDisposal). It is important to note that it may be difficult to identify trends on the western side of the valley where groundwater has a naturally higher TDS concentration.

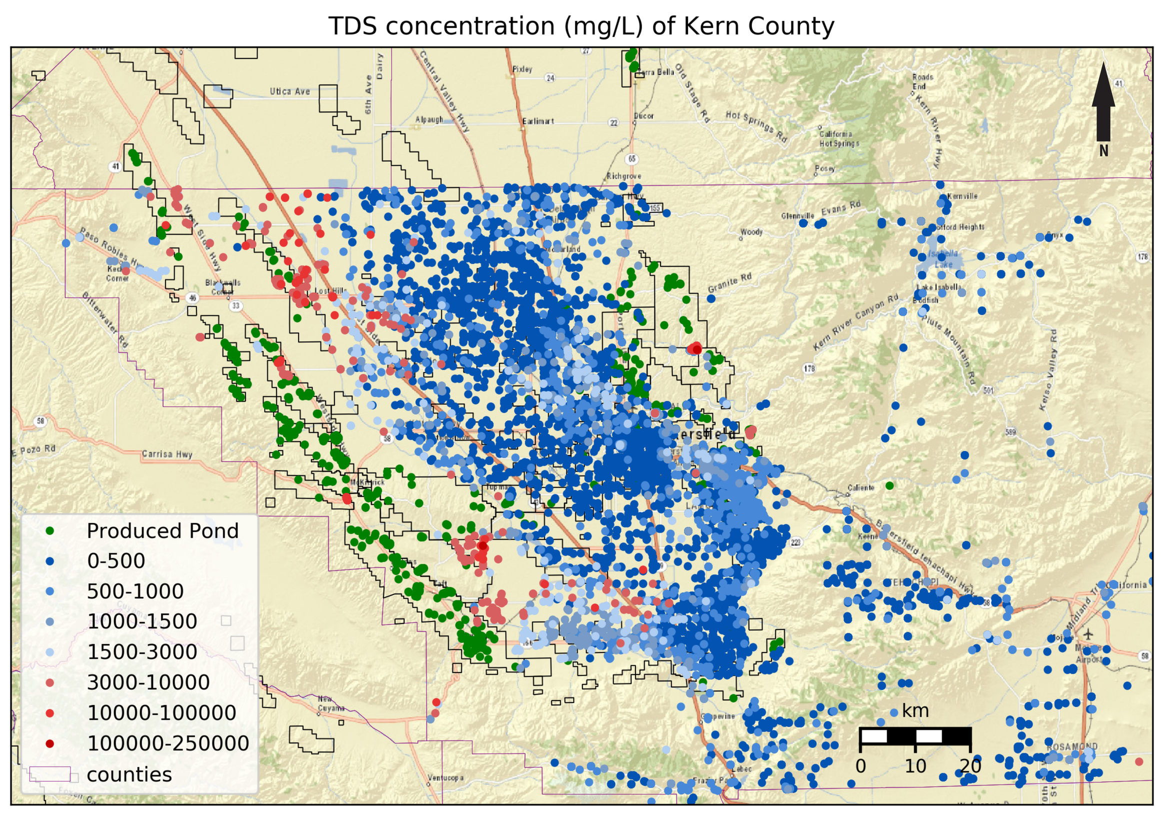


Figure 2. TDS measurements of Kern County colored by concentration. High TDS measurements are concentrated in the western portion of study area where local geology produces higher salinity water and more produced ponds exist.

TDS Analysis

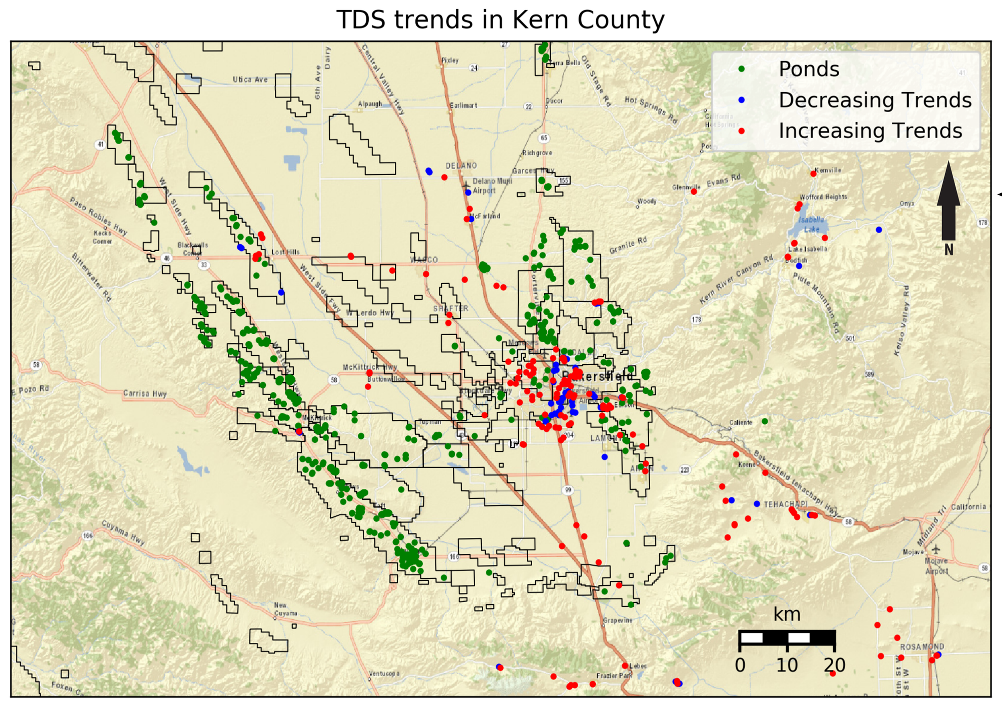
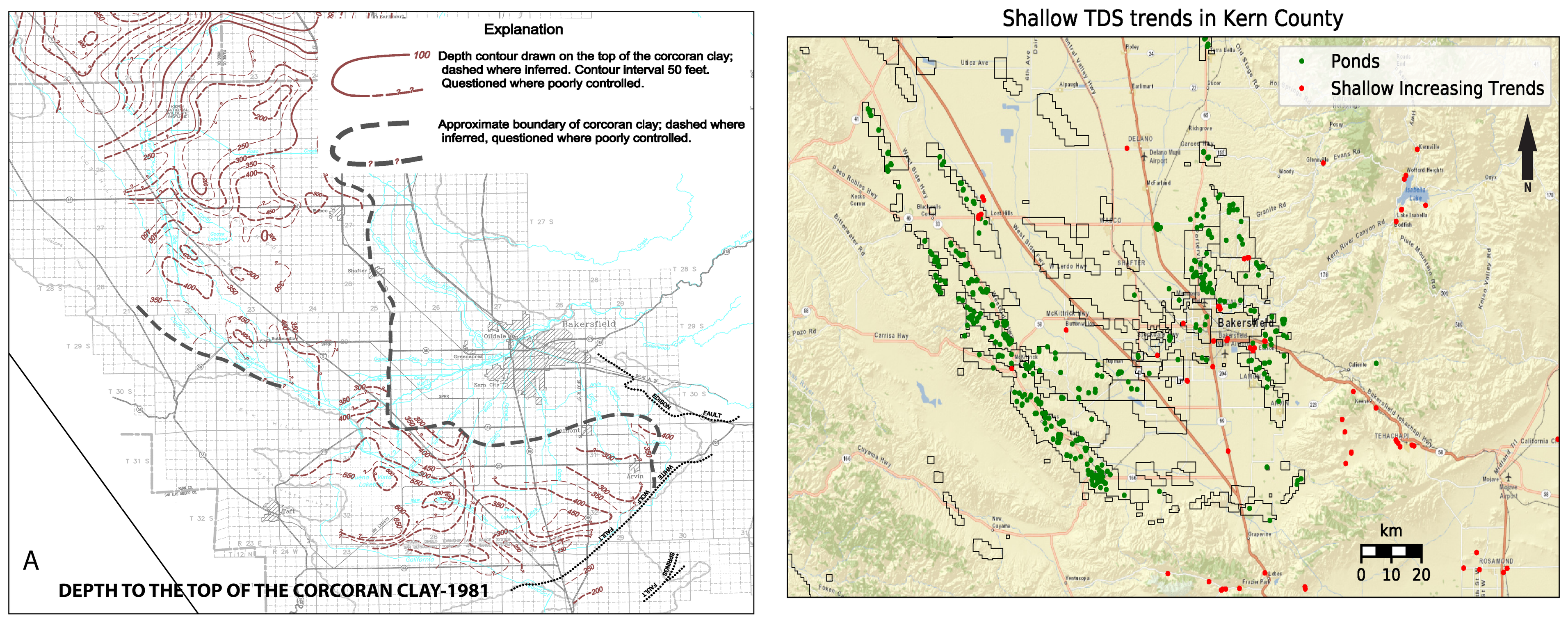


Figure 3. Results from Mann-Kendall statistical test on wells with 3 or more TDS measurements show 190 increasing trends and 67 decreasing trends.

Figure 4. A) Map of depth to the top of Corcoran Clay modified from DWR (2008). B) Wells with screens or completion above 300ft with increasing trends in TDS. 300ft chosen to define "shallow" based off least depth to top of the Corcoran Clay (regionally confining unit) or well type. 85 wells were classified as shallow.



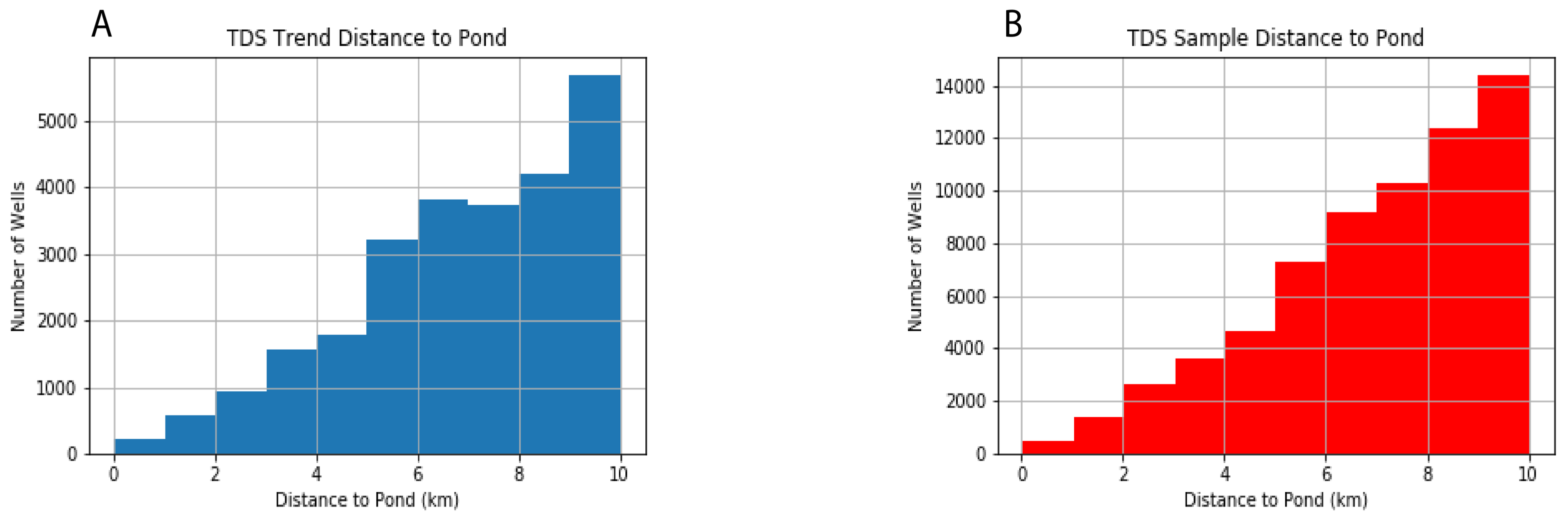


Figure 5. A) Histogram of each well's distance to each pond within 10 km. B) Histogram of wells with increasing TDS trends and distance to each pond within 10 km. Figures show similar frequencies with positive correlation of number of wells to distance.

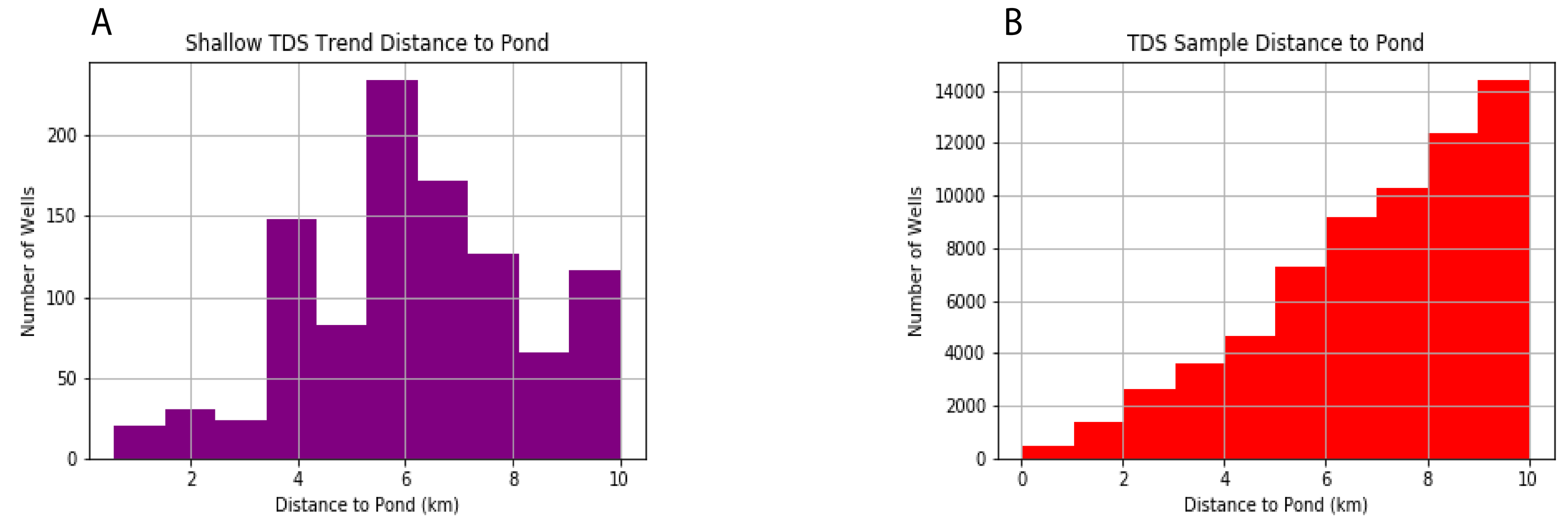


Figure 6. A) Histogram of wells with shallow increasing trends in TDS and distance to each pond within 10 km. B) Histogram of each well's distance to each pond within 10 km. In contrast to 6B, 6A has peak frequency between 5 and 6 km.

Chemical Analysis

Figure 7. Results from Mann-Kendall statistical test on wells with increasing trends in TDS. GeotrackerGAMA data includes 245 chemical constituents. These chemicals were chosen because their monitoring is commonly requested during oil and gas regulatory procedures and may act as a proxy for produced water indicators when present in high or increasing amounts.

Constituent	# of Increasing Trends
Benzene	12
Boron	7
Chloride	114
Ethylbenzene	11
Methane	0
Nitrate as N	77
Nitrite as N	0
Nitrate + Nitrite	0
Sulfate	95
Toluene	10
Total petroleum hydrocarbons	0
Xylenes	11

Conclusions

- **Shallow wells are more likely to be influenced by produced water ponds due to fluid migration**
- Of 6,053 wells with TDS observations, 1,956 wells had three or more measurements
  - More continuous time-series data are required to further test hypothesis
- Mann-Kendall trend analysis showed 190 wells with increasing trends and 67 wells with decreasing trends
- 85 wells with increasing trends in TDS were classified as shallow
- 46% percent of wells with three or more TDS measurements and 42% percent of shallow wells with increasing TDS trends were within 10 km of a disposal pond

Future Work

- Determine further produced water indicators
  - Refine proxy chemical list and rerun analysis
  - Incorporate DOGGR or operator provided geochemical water analysis
- Calculate percolation potential of ponds to determine spatial extent of produced water movement
- Create model to predict TDS concentration based off distance from pond

References

- CCST , 2015, Lawrence Berkeley National Laboratory.An Independent Scientific Assessment of Well Stimulation in California, vol.2
- EIA (U.S. Energy Information Administration), 2017, Petroleum & Other Liquids- Crude Oil Production: https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm
- Faunt, C.C., Sneed, M., Traum, J., Brandt, J.T., 2015, Water availability and land subsidence in the Central Valley, California, USA: Hydrogeology Journal, v.24, iss. 3, p. 675-684. DOI 10.1007/s10040-015-1339-x
- EPA (Enviromental Protection Agency), 2018. General content. https://www.epa.gov/dw - standardsregulations/secondary-drinking-water-standards-
- DOGGR (Division of Oil, Gas, and Geothermal Resources), 2016, Well Count and Production of Oil, Gas, and Water by County-2016 ftp://ftp.consrv.ca.gov/pub/oil/annual_reports/2016/Wells_and_Production_by_County_2 016.pdf
- CCST (California Council on Science and Technology), 2014, Lawrence Berkeley National Laboratory, and Pacific Institute , 2014 , Advanced Well Stimulation Technologies in California: An Independent Review of Scientific and Technical Information. http://ccst.us/publications/2014/2014wst.pdf
- DOGGR, 2017, SB 1281 Water Report Summary Division of Oil Gas and Geothermal Resources Quarterly Reports: http://www.conservation.ca.gov/dog/SB%201281/Pages/SB_1281DataAndReports.aspx
- Department of Water Resources 2008, Depth to the top of Corcoran Clay-1981, https://water.ca.gov/LegacyFiles/pubs/groundwater/depth_to_top_of_corcoran_clay_map__1981/depth_to_the_top_of_corcoran_clay-1981.pdf

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