Research Brief

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Deep groundwater is poorly safeguarded in California

Administrative definitions of groundwater are creating loopholes for sustainable groundwater management and increasing contamination risk from oil and gas.

Photo Credit: The Nature Conservancy

Background

Groundwater is a critical resource that supplies water to communities, farmlands, industries, and ecosystems. Administrative definitions of groundwater in many places within California rely upon the "base of fresh water" – a term that is defined as "the depth in a well where the water in overlying aquifers has less than or equal to 3,000 mg per liter of total dissolved solids (TDS)" [1]. The base of fresh water is being used to delineate basin bottoms subject to sustainable groundwater management law and define where oil and gas operations are permissible. The application of the base of fresh water assumes that salinity monotonically increases with depth and that groundwater users are unlikely to use brackish or saline waters. New research published in PNAS test these assumptions. Researchers characterize salinity in groundwater across California (216,754 TDS in groundwater measurements) and use this information to compare historical estimates of bases of freshwater. The historical estimates of bases of freshwater are also compared to groundwater-well depths (399,454 well locations and depths). The high density of TDS data enables groundwater salinities to be mapped at an unprecedented spatial scale across California, allowing researchers to test how realistic historical estimates of base of fresh water are and to assess how frequently groundwater wells encroach upon defined bases of fresh water.

About the Research & Authors

This brief is based on the paper "Base of fresh water, groundwater salinity, and well distribution across California" published December 2020 in the Proceedings of the National Academy of Sciences (PNAS) of the United States of America.

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Key Findings

Fresh groundwater exists below defined bases of freshwater.
Fresh water is found at depths more than 100 m below base of fresh water estimates in some places. In the Central Valley, fresh water is found deeper than bases of freshwater in Colusa, Solano, Delta, Kern County, and Westside groundwater basins. The data also show that salinity can increase and decrease with depth in a given location, questioning a key assumption embedded in the base of freshwater--that groundwater salinity increases monotonically with depth.

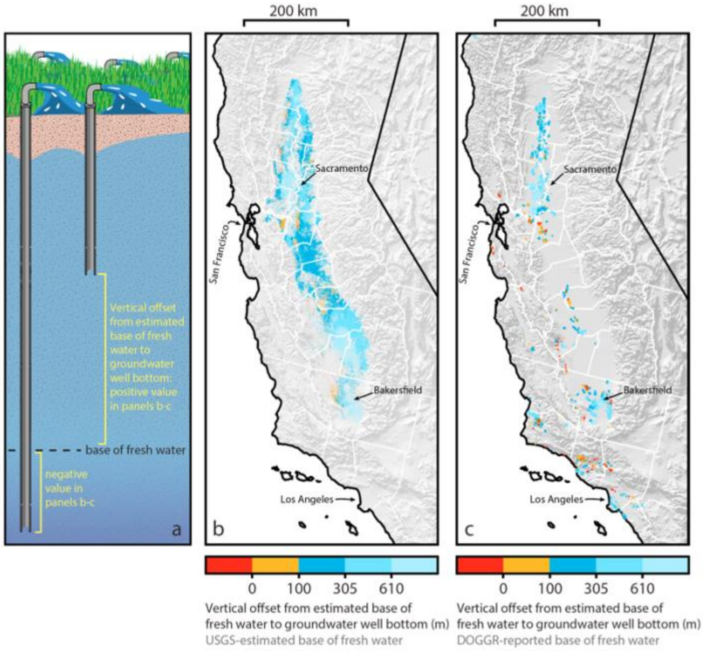

Figure 1. Location of production wells that are deeper (A) than estimated (B) USGS base of fresh water and (C) DOGGR base of fresh water.

Groundwater-pumping wells in some areas are deeper than or encroaching upon bases of freshwater.
Nearly 4% of existing groundwater wells penetrate defined bases of freshwater, and nearly 16% of wells overlie the base by no more than 100 m (Fig.1). All well types (i.e., domestic, agricultural, and industrial) are found deeper or encroaching on the defined bases of fresh water, but the majority are agricultural and industrial wells.

Bases of freshwater are currently informing sustainable groundwater management in California.
In 2014, California passed the Sustainable Groundwater Management Act (SGMA) to regulate groundwater use and achieve sustainability by 2040. While the state has taken the lead in delineating the horizontal extent of basin boundaries, local groundwater sustainability agencies are tasked with defining the basin bottom at their discretion. The basin bottom can be delineated using physical attributes (e.g., depth to bedrock), geochemical properties (e.g., base of fresh water), or the deepest groundwater well. Basin bottoms are crucial for establishing accurate hydrogeologic conceptual models, water budgets, and the extent of numerical groundwater modelling domains.

A review of the 2020 groundwater sustainability plans submitted under SGMA reveals that most groundwater sustainability agencies are using decades-old base of freshwater estimates to define the basin bottom. Defining the vertical extent of aquifers using base of freshwater data are problematic for four reasons: 1) Salinity profiles do not always monotonically increase with depth; 2) defining base of fresh water requires a specific definition for fresh water, which varies depending on the jurisdiction or agency; 3) salinity gradients are not static and are heavily influenced by pumping activities and groundwater flow gradients; and 4) using base of freshwater data without taking into account well depths can provide a loophole for groundwater pumpers seeking to evade pumping restrictions within SGMA basins by pumping from below bases of fresh water. Furthermore, as technology evolves, it has become economically feasible to use brackish and saline water to increase water supply for a range of beneficial uses (Fig. 2).

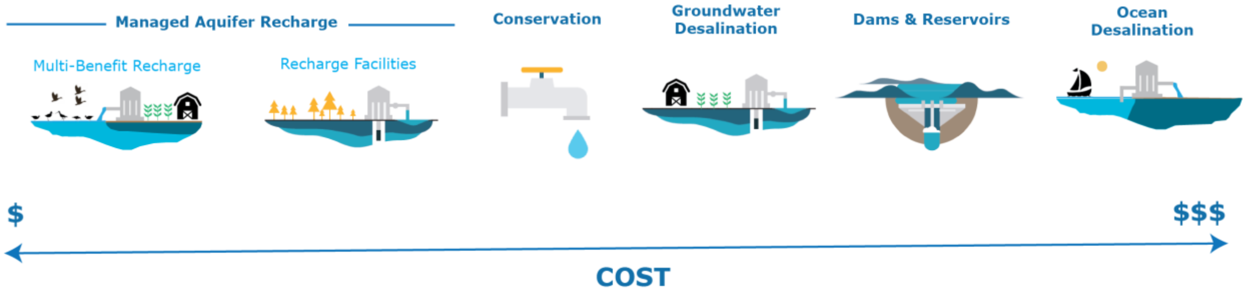

Figure 2. Water supply cost comparison, with the cost per unit of water increasing left to right (Modified from [2]. Data sources: Dynamic Recharge [3]; On-Farm Recharge [4]; Recharge Facilities [5]; Conservation [6]; Groundwater Desalination [7]; Dams & Reservoirs [8]; Ocean Desalination [9].

Deep groundwater is being increasingly accessed.

Groundwater wells are being constructed deeper over time. By requiring groundwater sustainability agencies to rely on total well depth data to define basin bottoms and promoting data sharing between groundwater sustainability agencies and the oil and gas industry, groundwater can be better safeguarded from overuse and contamination. To protect and manage this immense reservoir of groundwater, it needs to be administratively defined as groundwater and continually monitored.

Conclusion

This new research suggests that groundwater sustainability in California may be poorly safeguarded in some places and that the base of fresh water concept needs to be reconsidered as a means to define and manage groundwater. The authors highlight the importance of managing deep groundwater and eliminating loopholes and contamination threats, where groundwater wells can drill deep and beyond the reach of current sustainable groundwater management regulations. Groundwater management can continue to be based on static definitions or can evolve with water demands, technologies, and economics of the time.

References and Notes

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