The Need for a Uniform Conservative Definition of Protected Groundwater During Oil and Gas Development

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Improved Management Practices for Groundwater Protection and Water Supply

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Literature Reference for Presentation

Available online at www.sciencedirect.com

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Current Opinion in
Environmental Science & Health

ELSEVIER

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

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The Importance of Groundwater: 2010 U.S. Water Budget

Municipal

63% from surface water
47% from groundwater
Serves 86% of population

Agriculture

57% from surface water
43% from groundwater
83% of total use from 17 western states

Aquaculture

81% from surface water
19% from groundwater

Oil & Gas Development/ Mining

27% from surface water
73% from groundwater
(71% of which was saline)

Figure from Maupin et al. (2014)

Domestic

>98% from groundwater
Serves 14% of population or 44.5 million people

Livestock

40% from surface water
60% from groundwater

Industrial

82% from surface water
18% from groundwater

Thermoelectric

>99% from surface water

The Growing Demand for Freshwater:

Projection to 2050:

Impact of Population Growth, Thermoelectric Power Generation and Climate Change on Available Freshwater Resources

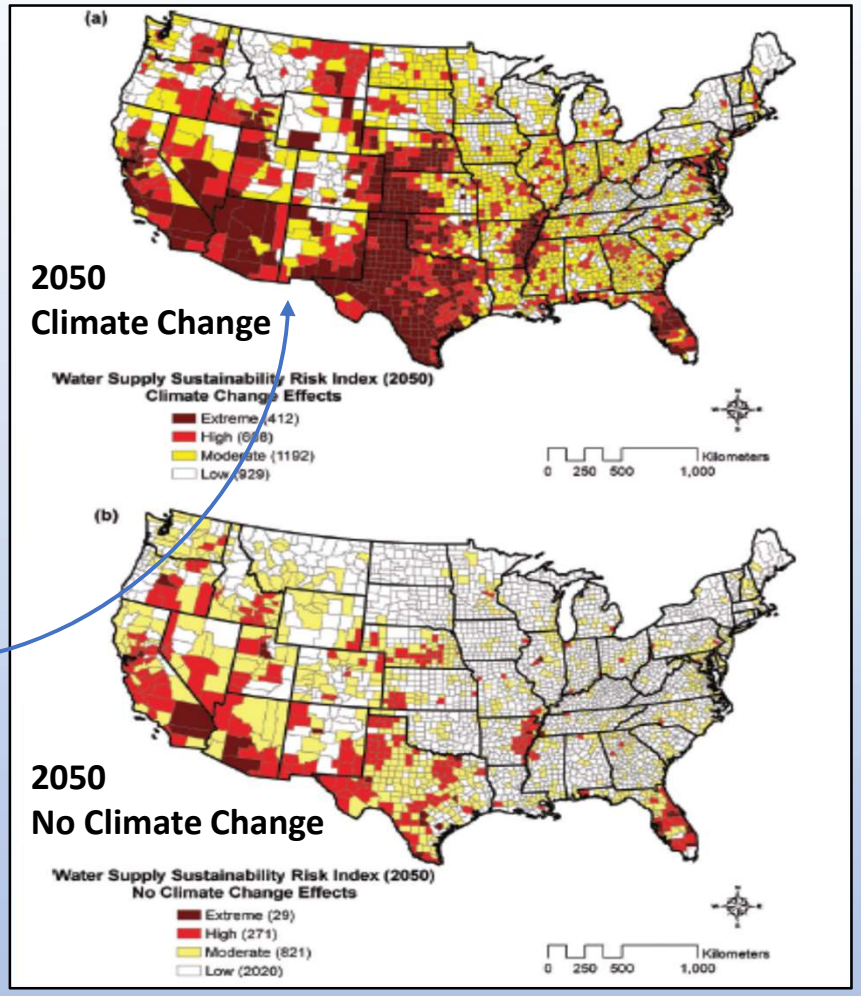
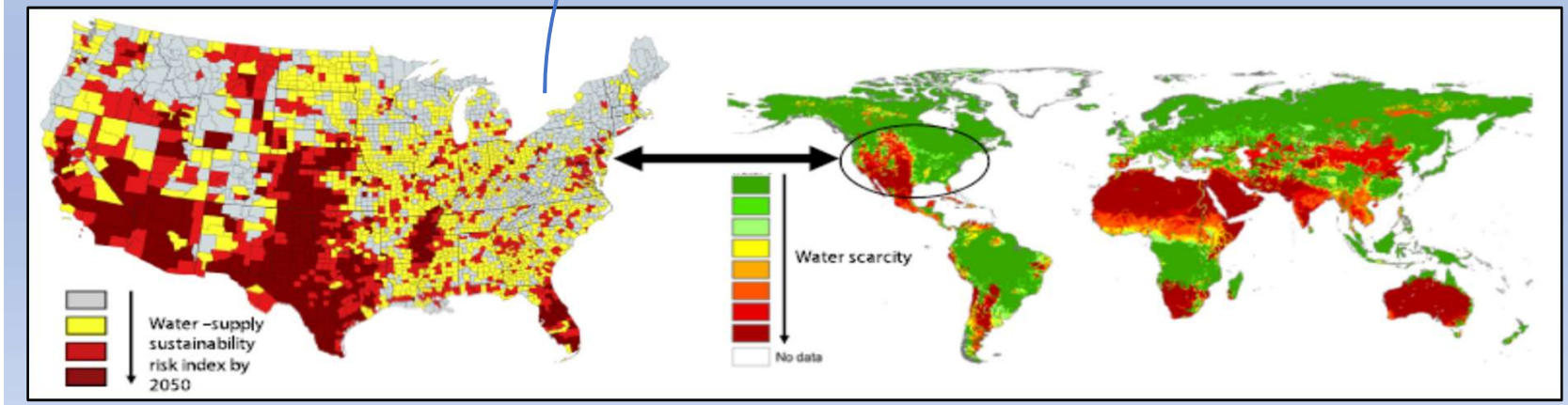


Figure from Roy et al. (2012)

Figure from Ahdab et al. (2018)



Increased Desalination of Brackish Water to Meet Increasing Freshwater Demand

What is Fresh and Brackish Water?

- Freshwater generally water having < 1,000 mg/L total dissolved solids (TDS) (USGS 2017).
- Brackish water TDS between 1,000 and 10,000 mg/L TDS (USGS 2017).

Increased use of brackish water for municipal water supply because:

- Declining freshwater availability
- Difficulty in securing freshwater and groundwater legal rights
- High costs of infrastructure to store and transport fresh water
- Advances in membrane technology that have reduced the cost of desalination

Treatability and energy requirements dependent on geochemical composition (Ahdab et al. 2018, McMahon et al. 2016).

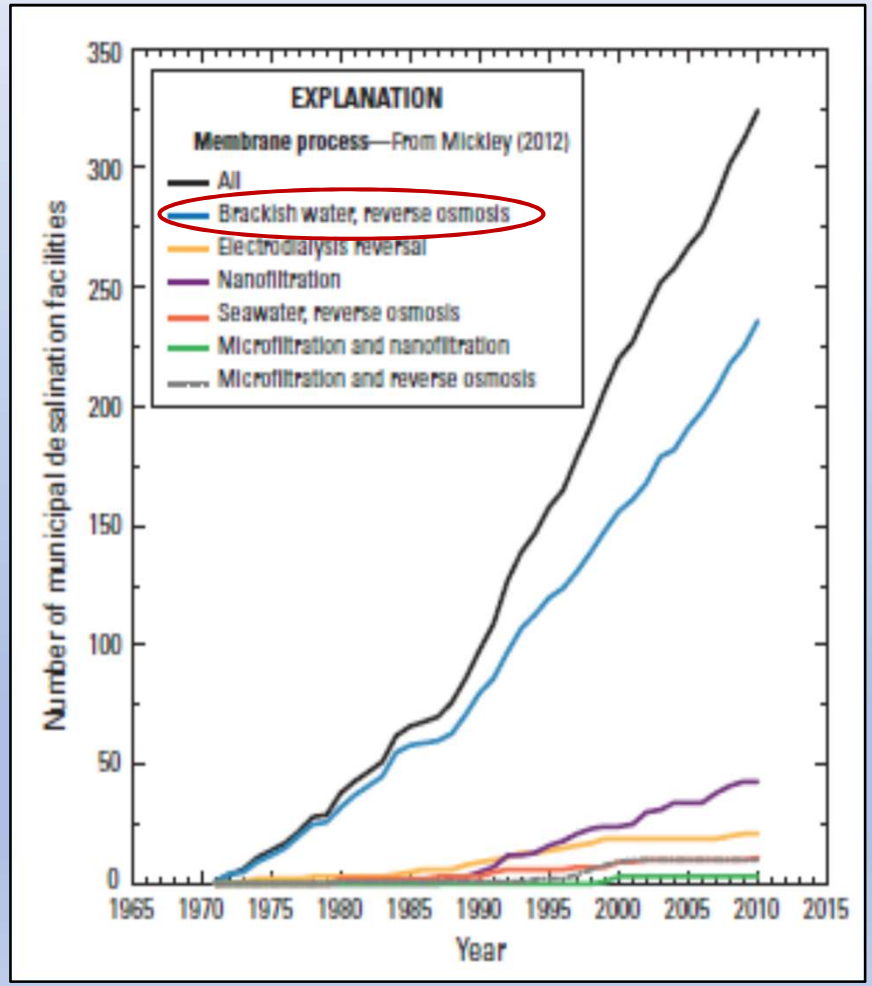


Figure from Stanton et al. (2017)

Most Desalination Facilities in the U.S. are for Brackish Groundwater

649 plants in 2010 – 67% municipal, 18% industry, 9% power, 6% other

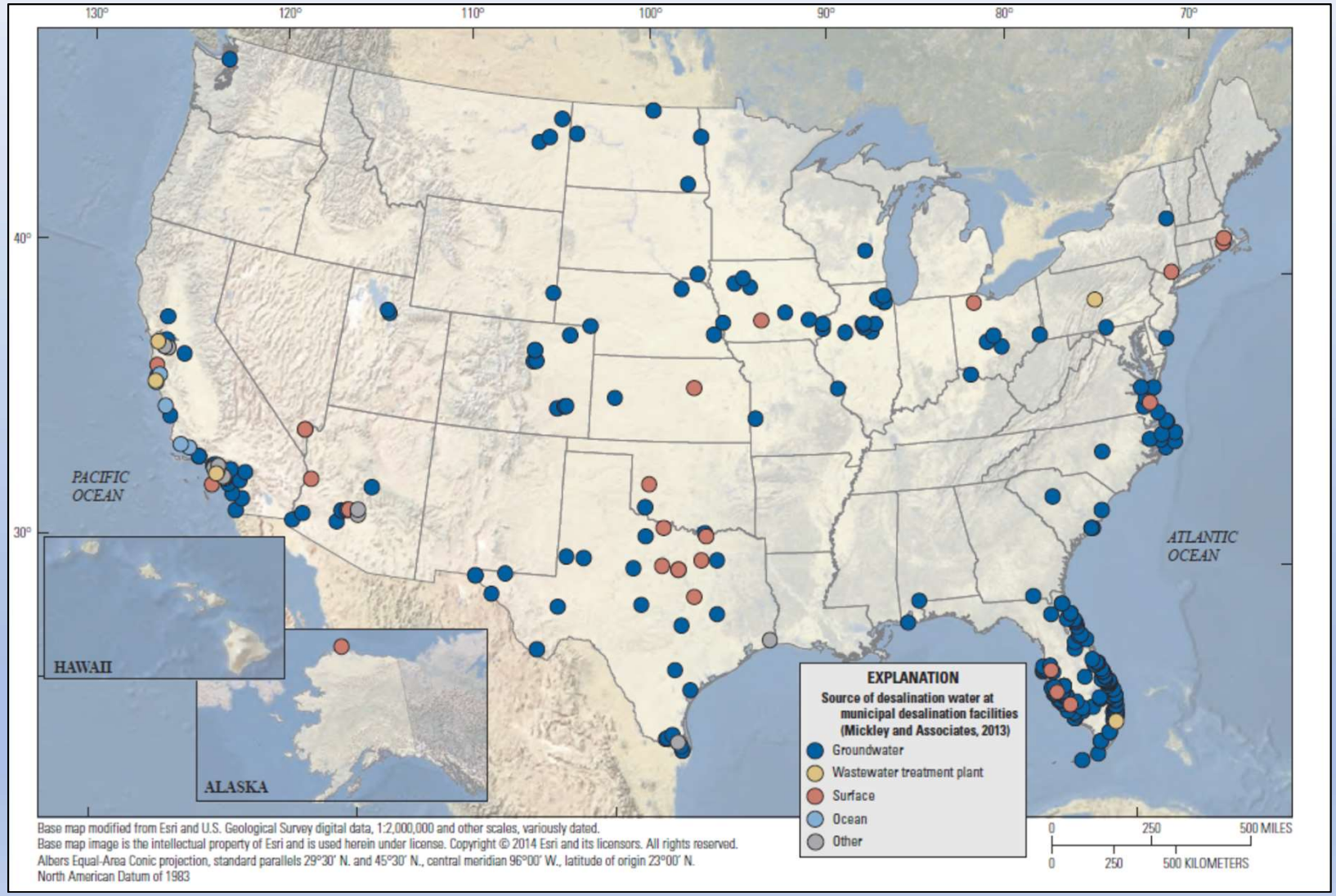
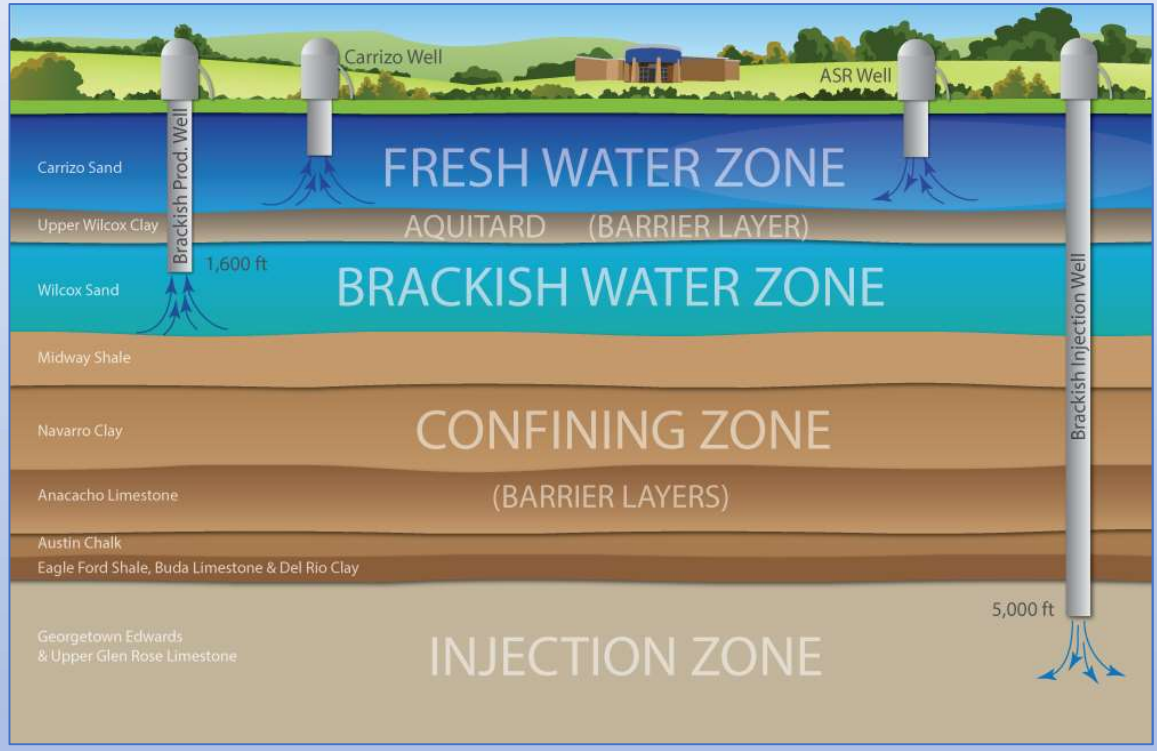


Figure from Stanton et al. (2017)

Increased Trend in Comprehensive Sustainable Groundwater Management (e.g., Desalination + Aquifer Storage and Recovery)

Here in San Antonio (H_2Oaks Center)

- Opened early 2017
- 99.9% dissolved solids removal
- 12 million gallons per day
- Reverse osmosis
- 1 gallon brine produced per 10 gallons treated
- Brine disposed in underlying saline aquifer



http://www.saws.org/Your_Water/WaterResources/Projects/desal.cfm

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Where are Brackish Groundwater Resources Located?

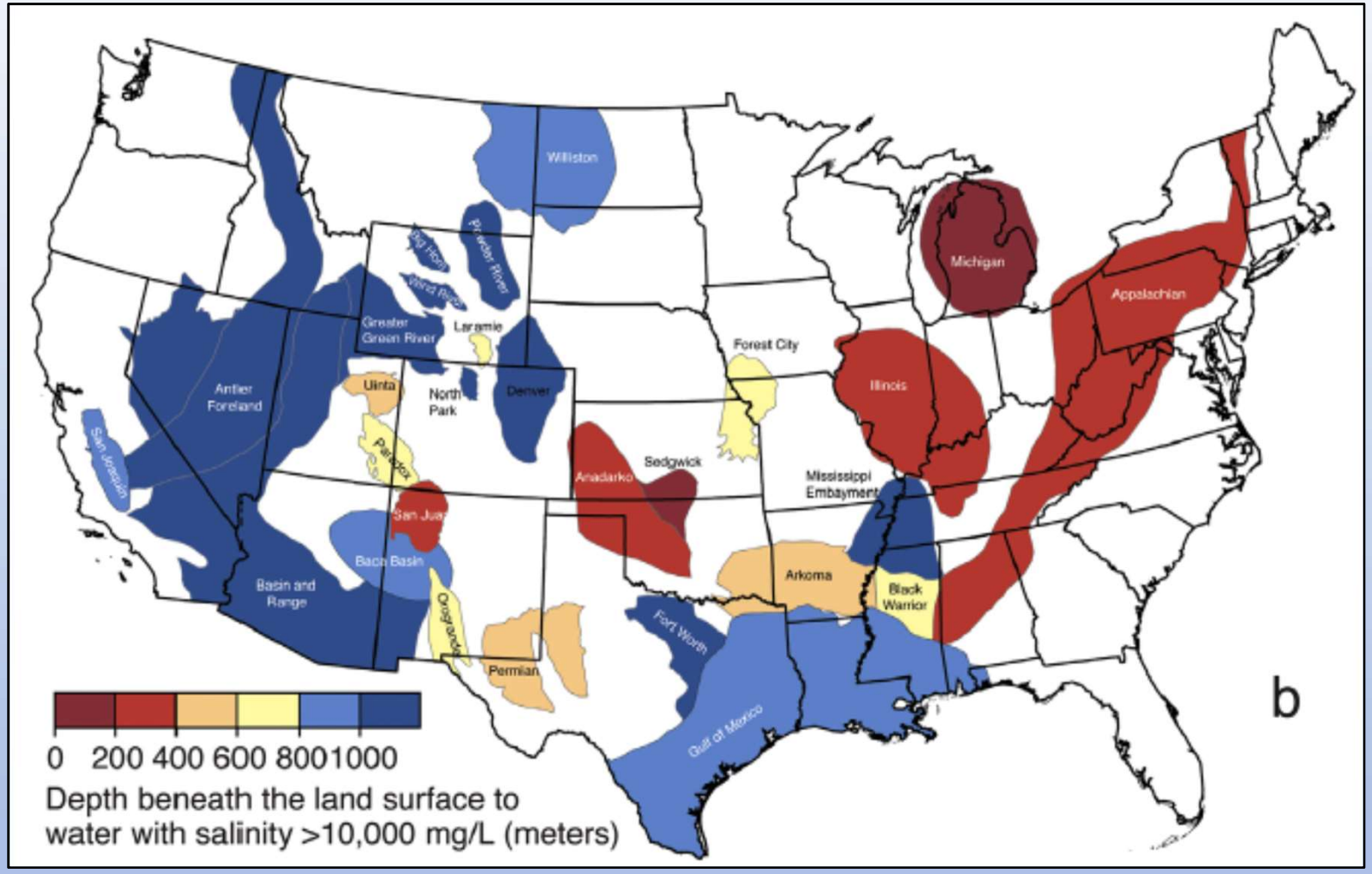


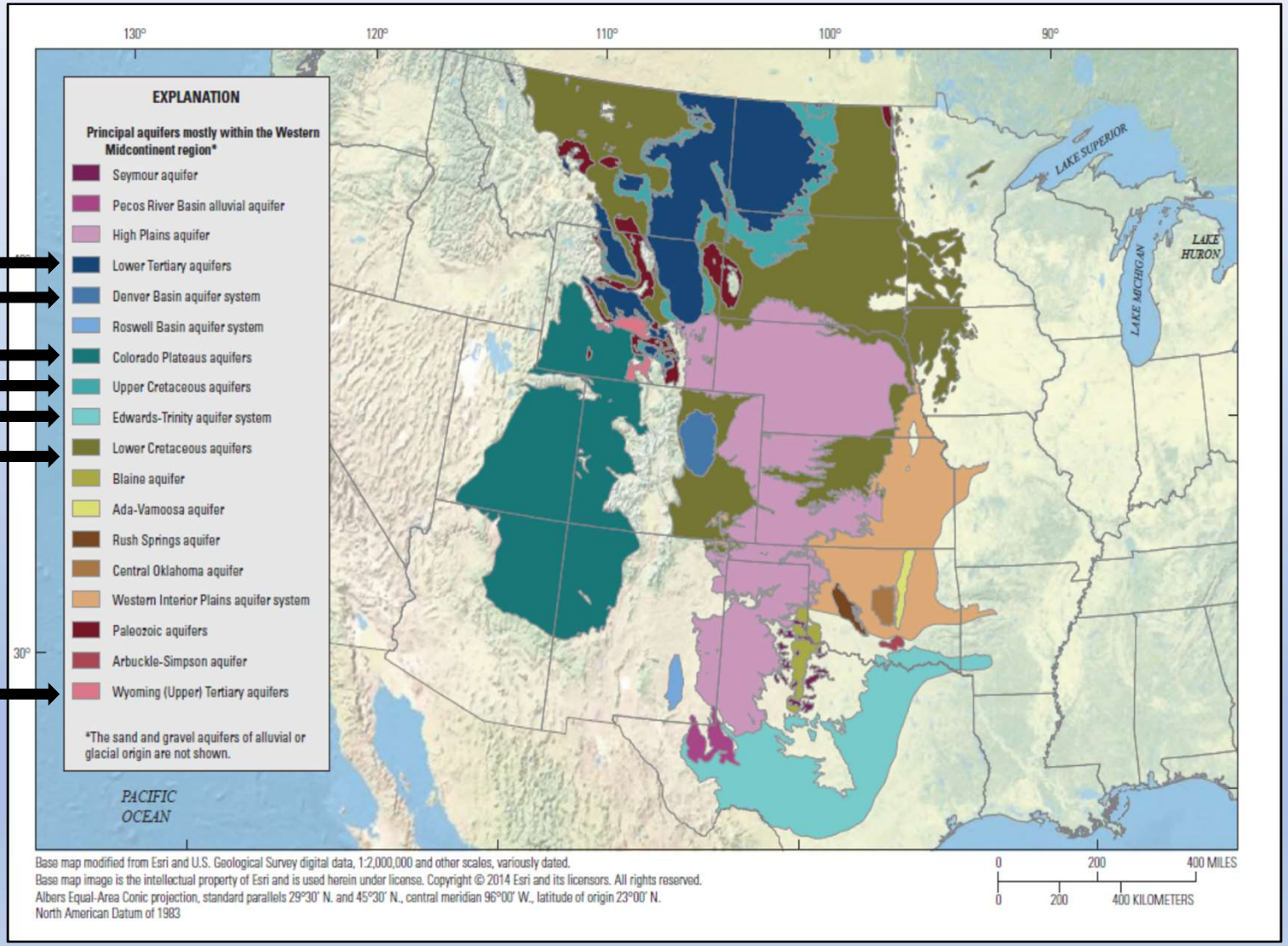
Figure from Ferguson et al. (2018)

There is a rapid transition from freshwater to saline water in eastern basins.

Recent USGS Efforts to Survey Brackish Groundwater Resources

Principal Aquifers in the Mid-Continent

500 – 3000 ft:

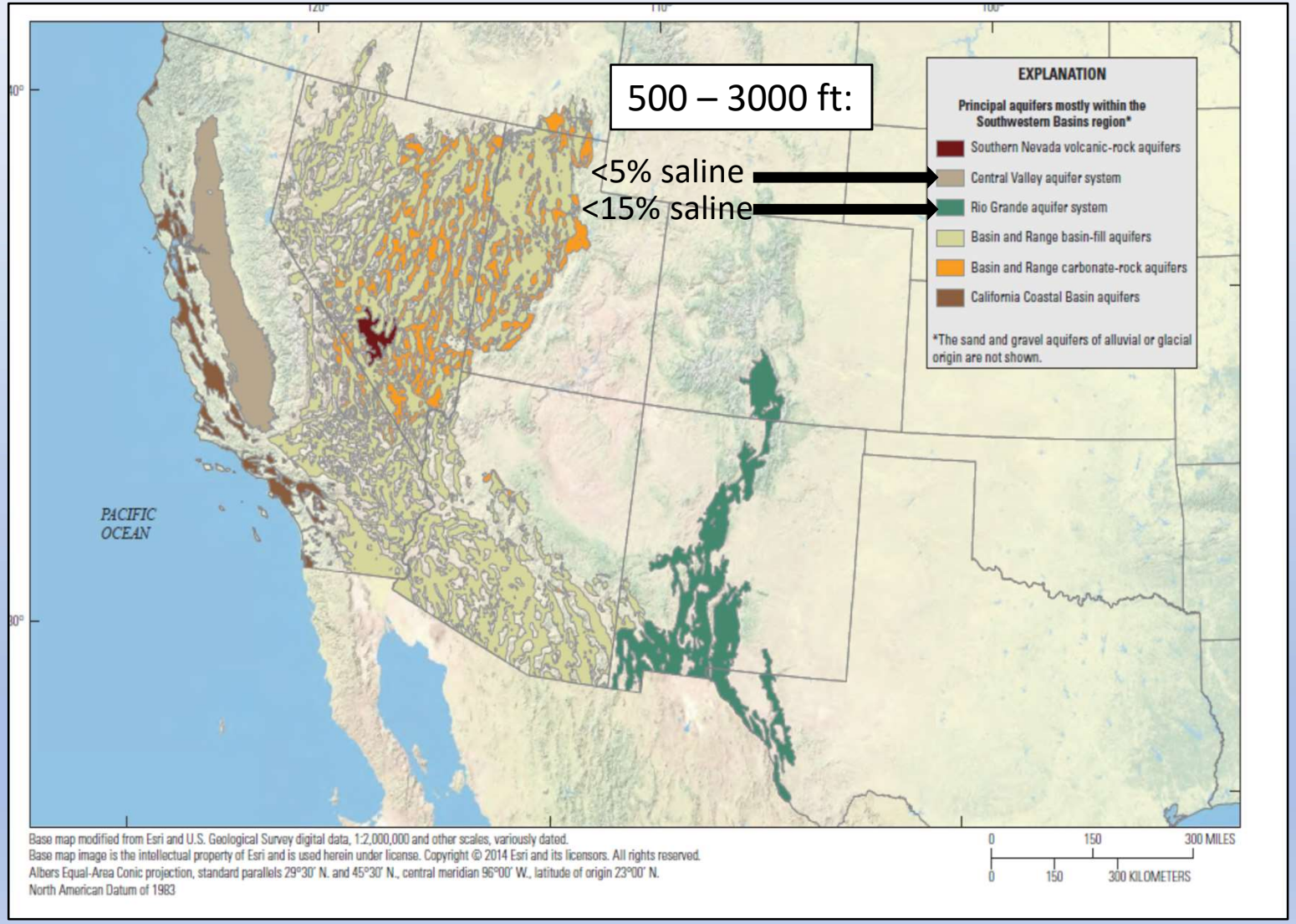


0% saline
0% saline
<25% saline
<5% saline
<15% saline
<10% saline
0% saline

Figure from Stanton et al. (2017)

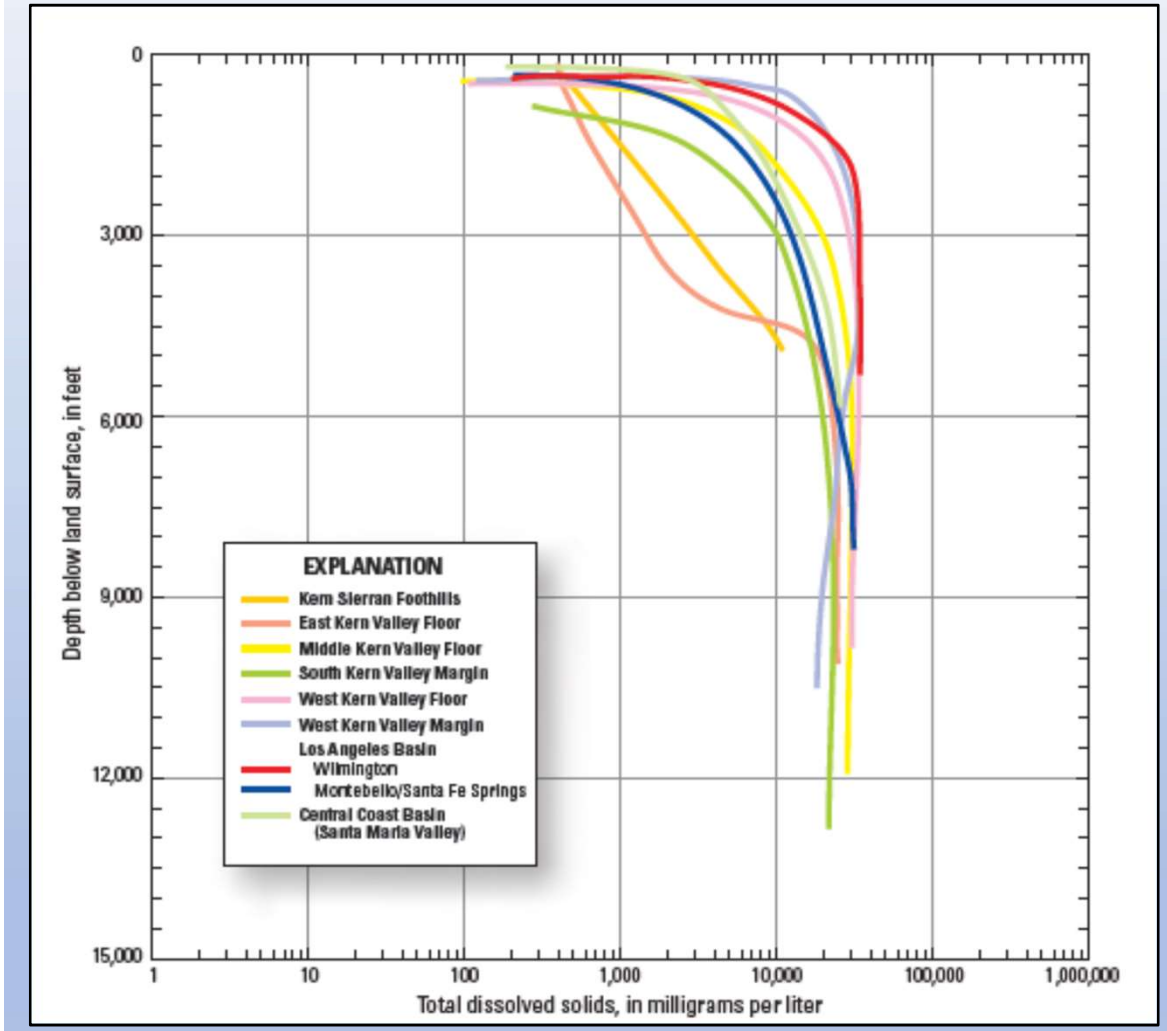
Recent USGS Efforts to Survey Brackish Groundwater Resources

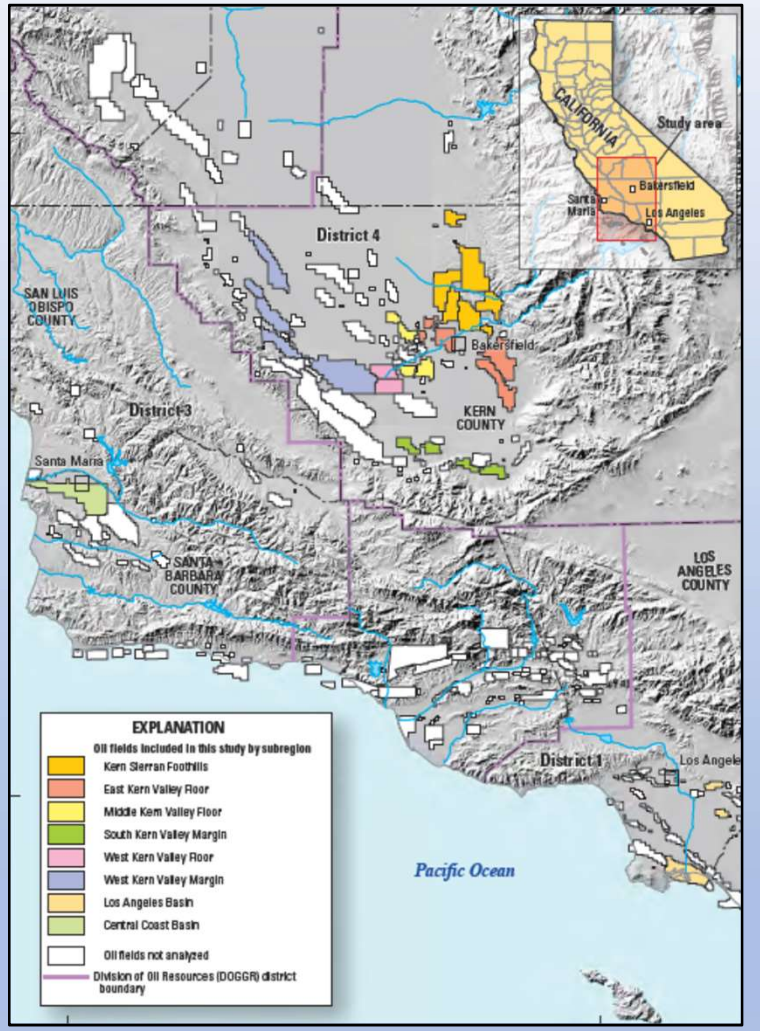
Principal Aquifers within the Southwestern Basins Region



From Stanton et al. (2017)

Recent USGS Efforts to Survey Brackish Groundwater Resources in Oil and Gas Producing Areas





Water well and produced water concentrations used to delineate depths of fresh and brackish groundwater resources.

Figures from Metzger and Landon (2018)

Vertical separation Between Depth of Well Stimulation and Groundwater Resources

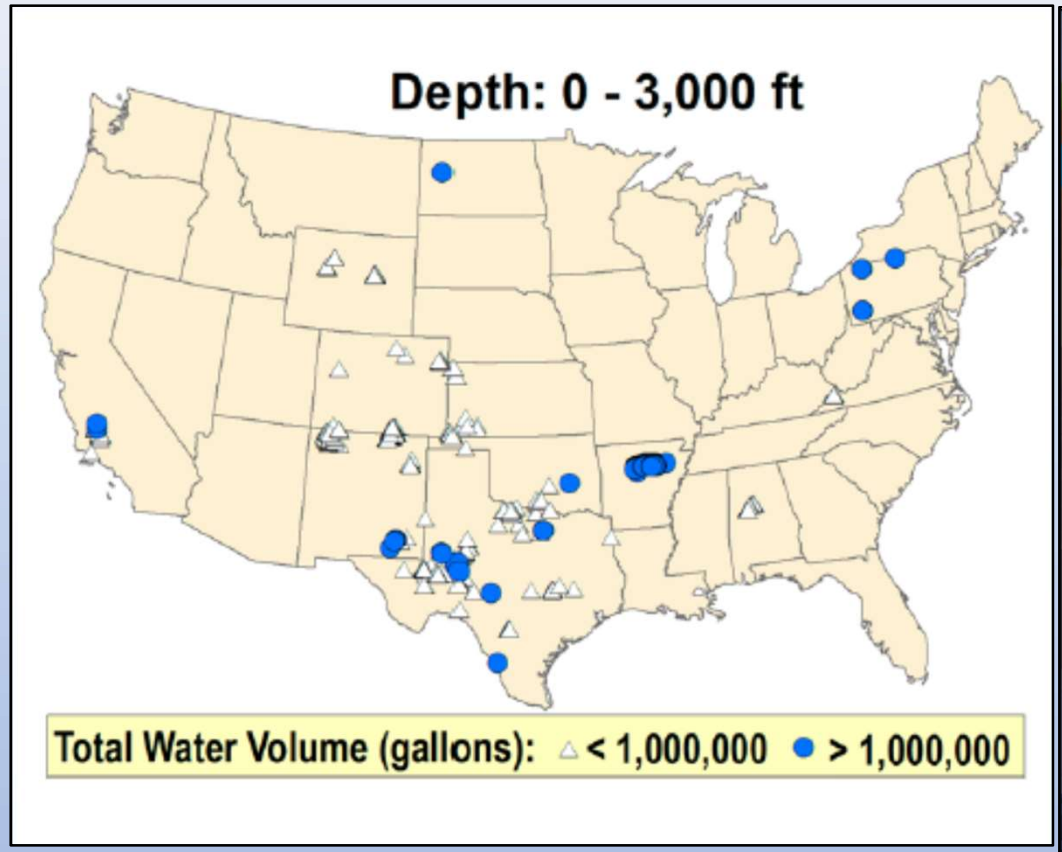


Figure from Jackson et al. 2015

Shallow hydraulic fracturing primarily in mid-continent area and California

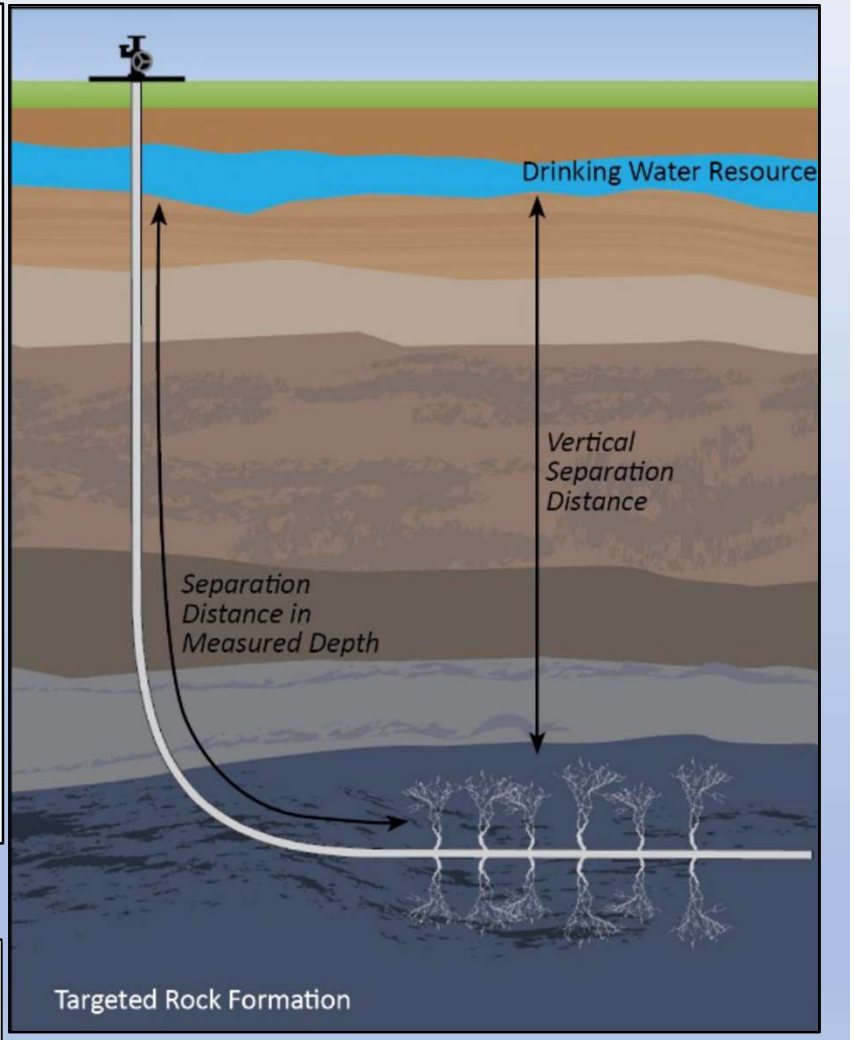


Figure from EPA 2016

Well Stimulation Directly into Groundwater Resources

Primary applicable to coal bed methane (CBM recovery) and fluvial depositional environments where oil and gas deposits occur in close proximity (vertical and lateral) to fresh or brackish water saturated units.

EPA Definition of Protected Groundwater During Subsurface Injection of Fluids

Underground Source of Drinking Water (USDW) is defined in 40 C.F.R. 144.3 as an aquifer that currently or could supply drinking water, contains less than 10,000 mg/L TDS and is not an exempted aquifer.

However

The Energy Policy Act of 2005 excluded *"underground injection of fluids or propping agents (other than diesel fuel) pursuant to hydraulic fracturing operations"* from the term *"underground injection"* in the Safe Drinking Water Act.

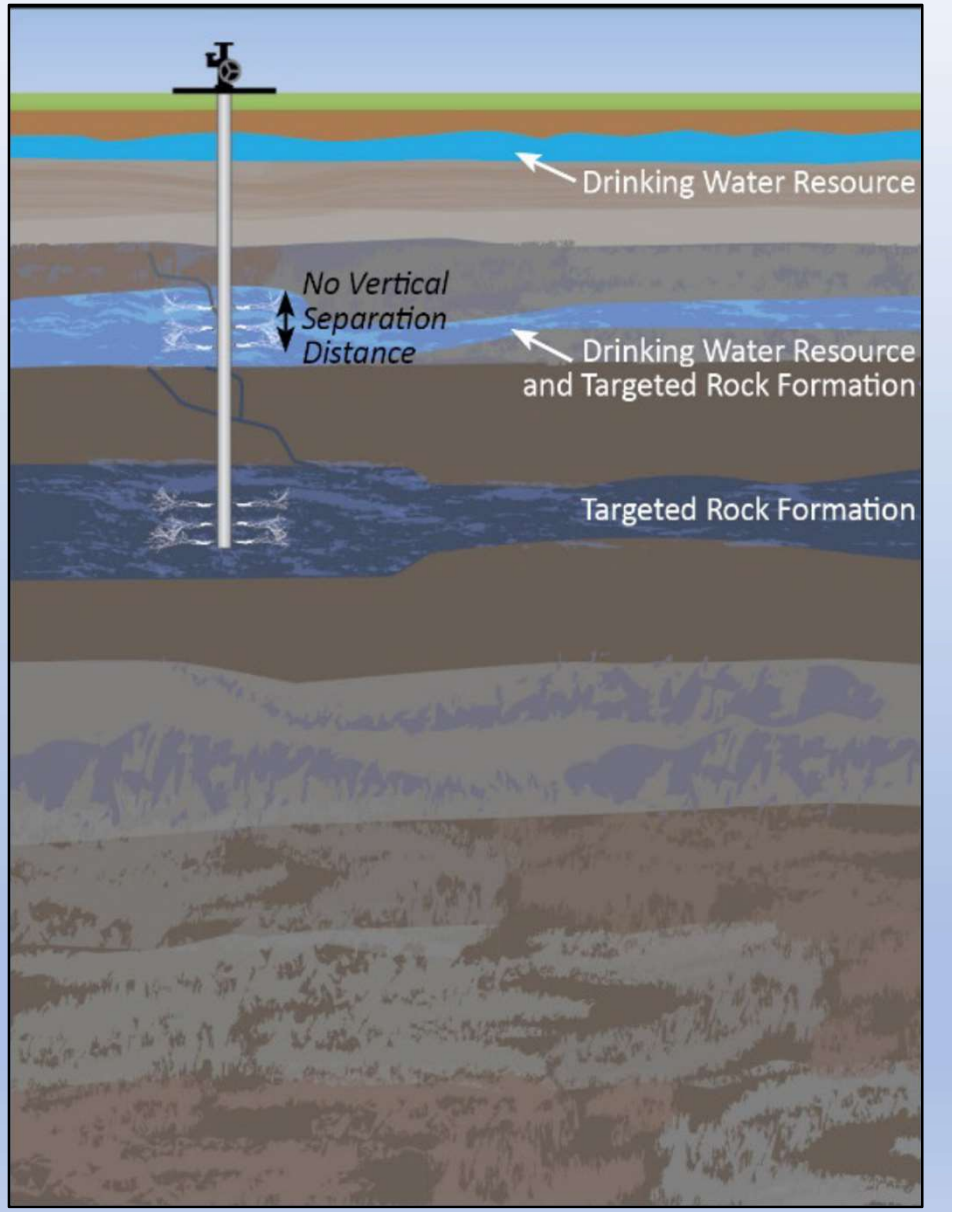


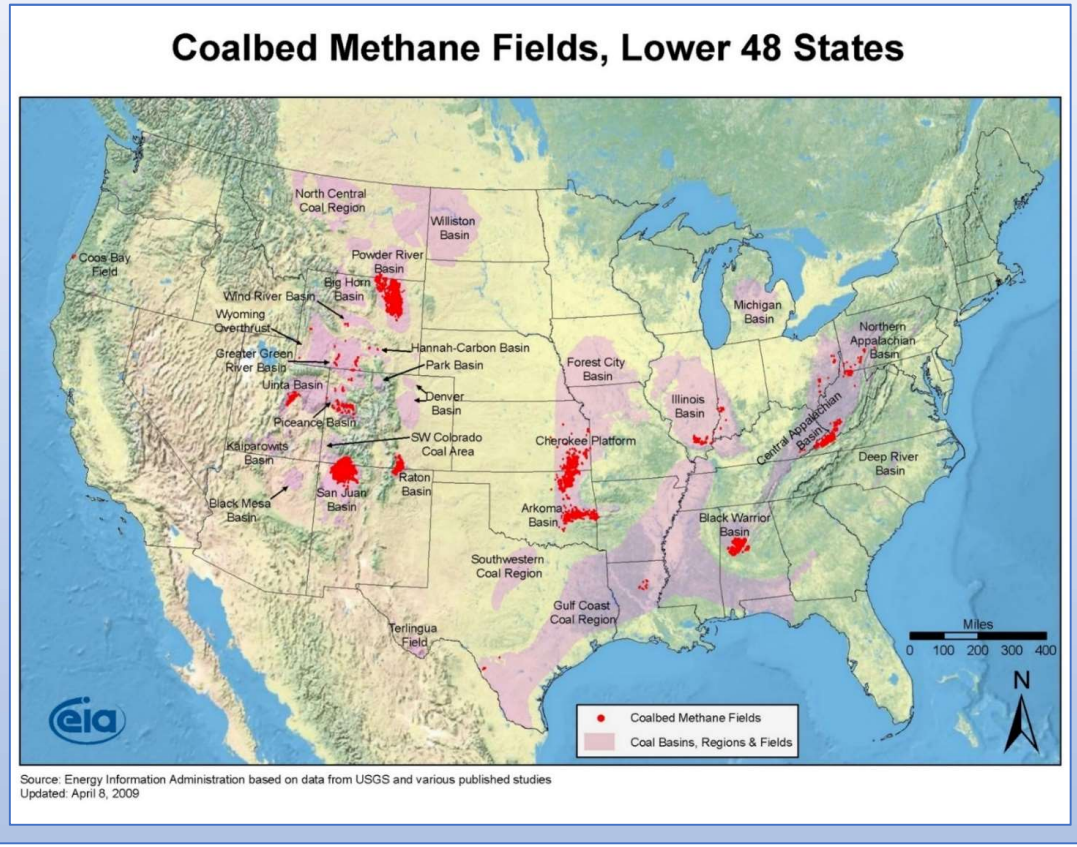
Figure from EPA 2016

Hydraulic Fracturing in USDWs During CBM Recovery

Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs

Final

Basin	Has hydraulic fracturing occurred in USDWs?
San Juan	**yes**
Black Warrior	**yes**
Piceance	unlikely
Uinta	**likely**
Powder River	Infrequently
Central Appalachian	**likely**
Northern Appalachian	**yes**
Arkoma	no
Cherokee	**yes**
Forest City	unlikely
Raton	**yes**
Sand Wash	**yes**
Pacific Coal Region	**yes**



"In many CBM-producing regions, the target coalbeds occur within USDW, and the fracturing process injects 'stimulation' fluids directly into the USDWs." (EPA 2004)

"Direct injection of fluids into or above a USDW…presents an immediate risk to public health because it can directly degrade groundwater, especially if the injected fluids do not benefit from any natural attenuation." (EPA 2014)

Fluvial Depositional Environment: Well Stimulation Directly into Groundwater Resources in the Pavillion, WY Field

- Injection of stimulation fluids (e.g., undiluted diesel fuel) directly into water-saturated sandstone units.
- Fracture propagation and leakoff of stimulation fluids into water-bearing sandstone units (distance to water-bearing units meters or tens of meters)
- Pressure build-up during stimulation far in excess of drawdown during production.
- Loss of zonal isolation in production wells during hydraulic fracturing.
- Detection of organic compounds and degradation products of organic compounds associated with well stimulation in two deep EPA monitoring wells.

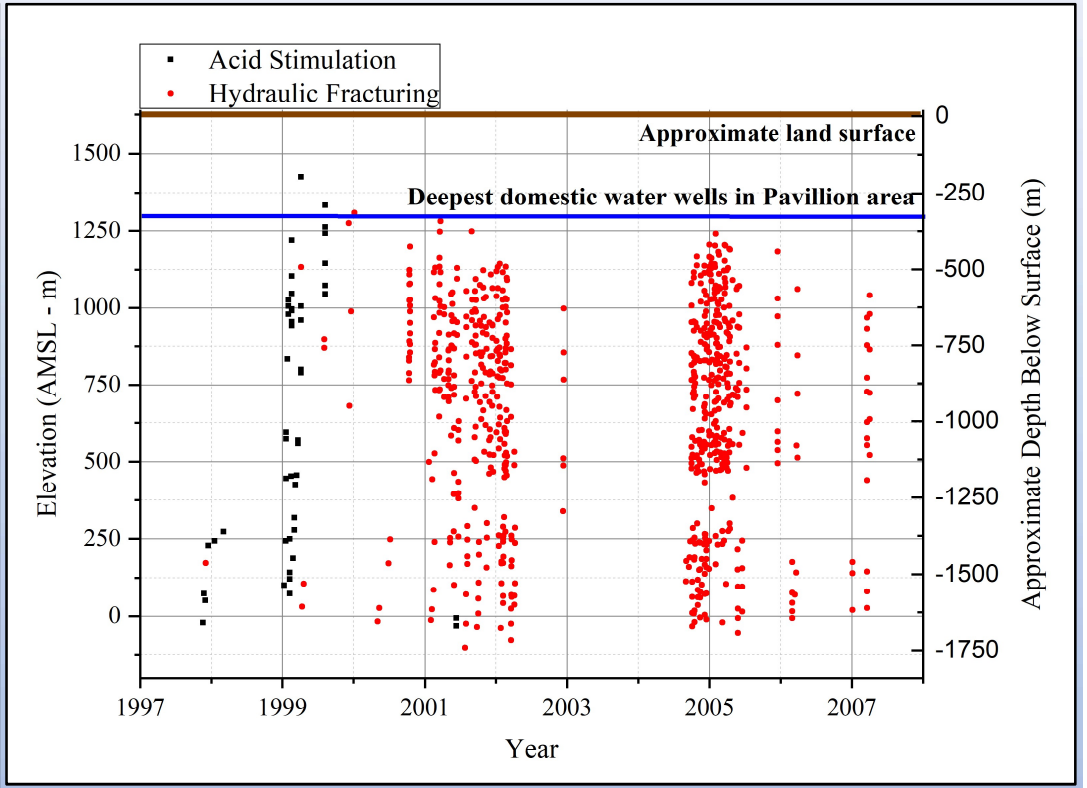


Figure from DiGiulio and Jackson 2016

Frequency of Hydraulic Fracturing in USDWs

- EPA looked at USGS produced water database and found that it did not accurately differentiate whether or not hydraulic fracturing occurred.
- EPA narrowed search to produced water samples from tight gas, tight oil, shale gas, and coalbed methane.
- This resulted in 1650 produced water samples from 5 states (AL, CO, ND, UT, WY).
- 1200 samples had TDS concentrations < 10,000 mg/L (~73%).
- Conclusion: *"The overall frequency of this occurrence is relatively low, but is concentrated in particular areas of the country."* (EPA 2016)

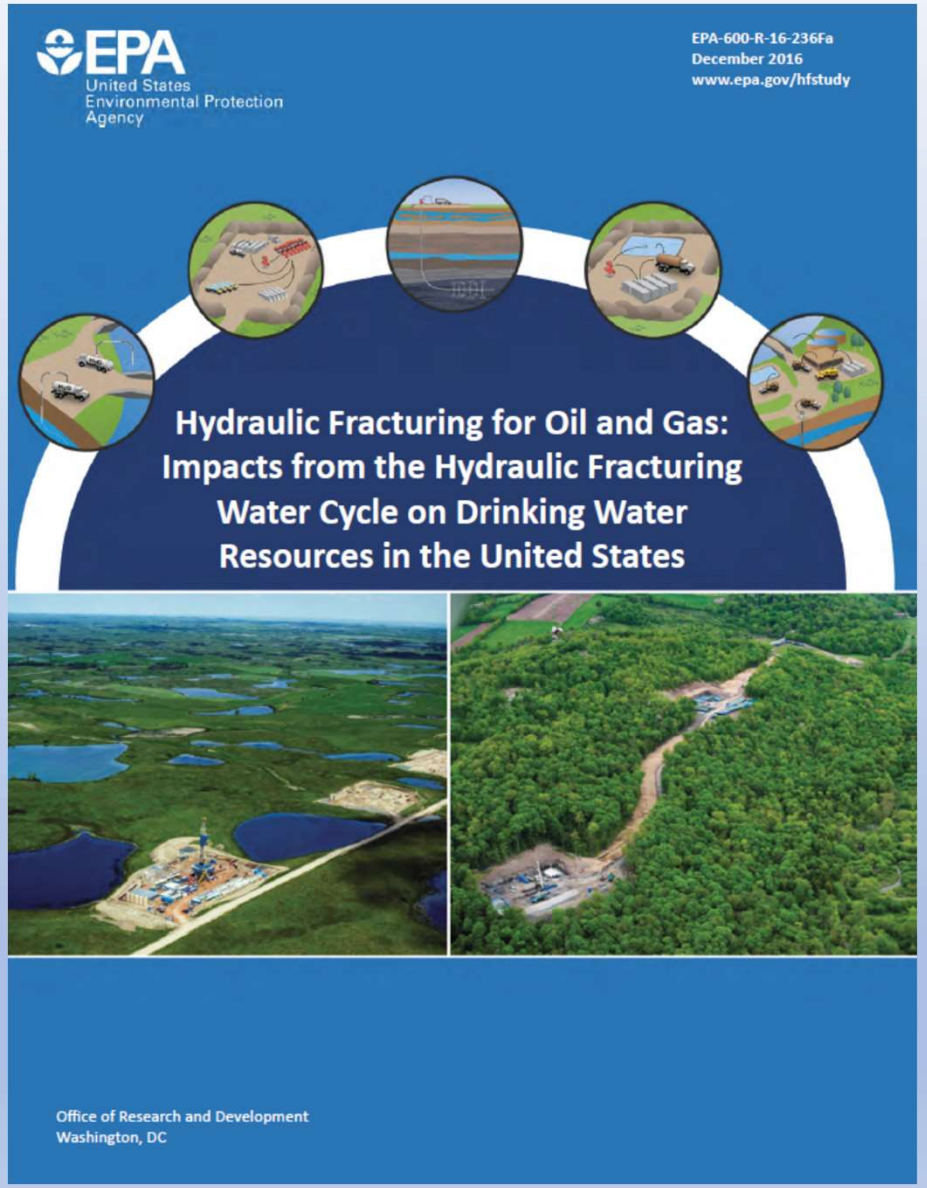


Figure from EPA 2016

BLM Definition of Protected Groundwater

- 43 CFR. § 3162.5-2(d) (1982) *"isolate freshwater-bearing and other usable water containing 5,000 ppm or less total dissolved solids."*
- Onshore Oil and Gas Order No. 2 (53 Fr 46798) (1988) requires operators to *"protect and/or isolate all usable water zones…generally those water waters containing up to 10,000 ppm total dissolved solids."*
- The BLM Rule Oil and Gas: Hydraulic Fracturing on Federal and Indian Lands (Federal Register 2015) corrected this inconsistency and required protection to 10,000 ppm.

In the BLM Rule on hydraulic fracturing, BLM stated that, *"Given the increasing water scarcity and technological improvements in water treatment equipment, it is not unreasonable to assume aquifers with TDS levels above 5000 ppm are usable or will be usable in the future…It is foreseeable that a TDS threshold higher than 10,000 ppm may be established under applicable law in the future for aquifers supplying agricultural, industrial, or ecosystem needs"* (Federal Register 2015).

- Legal challenge by the Attorney Generals for the States of Wyoming, Colorado, North Dakota, Utah, and the Ute Tribe in 2016 set aside the BLM Rule (U.S. District Court for the District of Wyoming 2016)
- The BLM repealed the rule on 7/25/2017 *"to reduce the burden of Federal regulations that hinder economic growth and energy development"* (U.S. BLM 2017).

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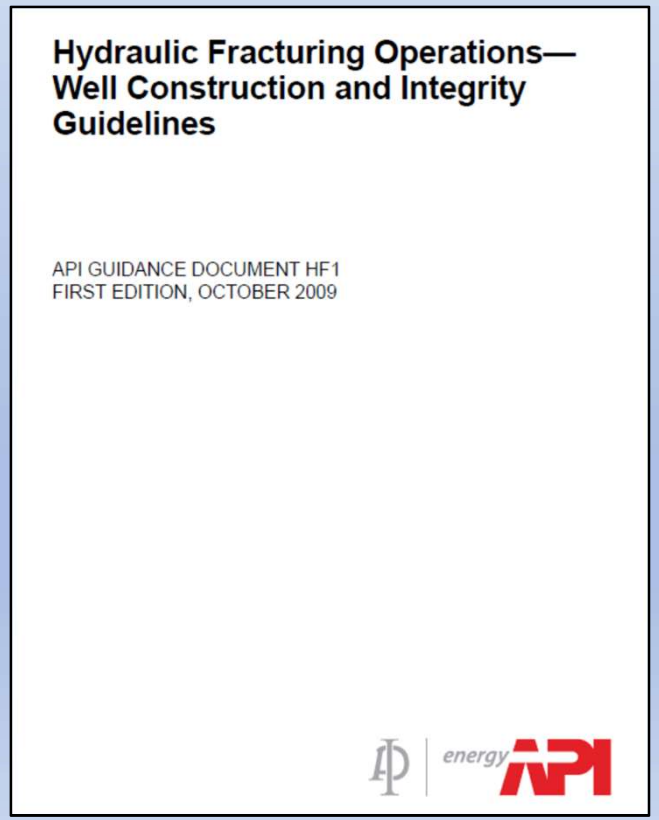
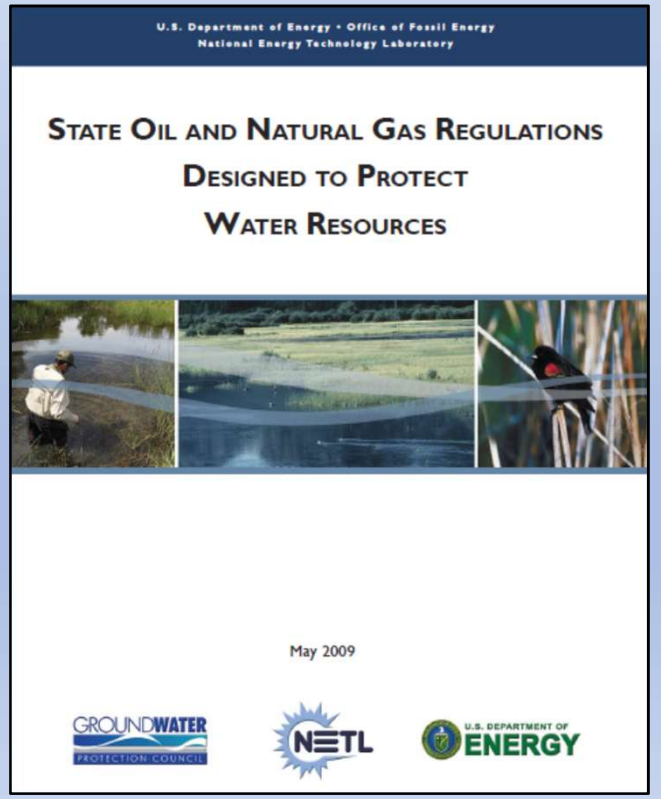
American Petroleum Institute (API)

"At a minimum, it is recommend that surface casing be set at least 100 ft below the deepest USDW encountered while drilling the well…If intermediate casing is not cemented to the surface, at a minimum the cement should extend above any exposed USDW or any hydrocarbon bearing zone." (API 2009)



Groundwater Protection Council (GWPC)

"Hydraulic fracturing in oil or gas bearing zones that occur in non-exempt USDW's should either be stopped, or restricted to the use of materials that do not pose a risk of endangering ground water and do not have the potential to cause human health effects." (GWPC 2009)



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Recommendations for Groundwater Monitoring in California

LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-TR-669645

Recommendations on Model Criteria for Groundwater Sampling, Testing, and Monitoring of Oil and Gas Development in California

Bradley K. Esser[1], Harry R. Beller[2], Susan A. Carroll[1], John A. Cherry[3], Jan Gillespie[4], Robert B. Jackson[5], Preston D. Jordan2, Vic Madrid[1], Joseph P. Morris[1], Beth L. Parker[3], William T. Stringfellow[2], Charuleka Varadharajan[2], and Avner Vengosh[6]

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[4]*California State University, Bakersfield, California*
[5]*Stanford University, Stanford, California*
[6]*Duke University, Durham, North Carolina*

June, 2015

Final Report
California State Water Resources Control Board

State of California Contract 14-050-250;
LLNL Work for Others Proposal L15606

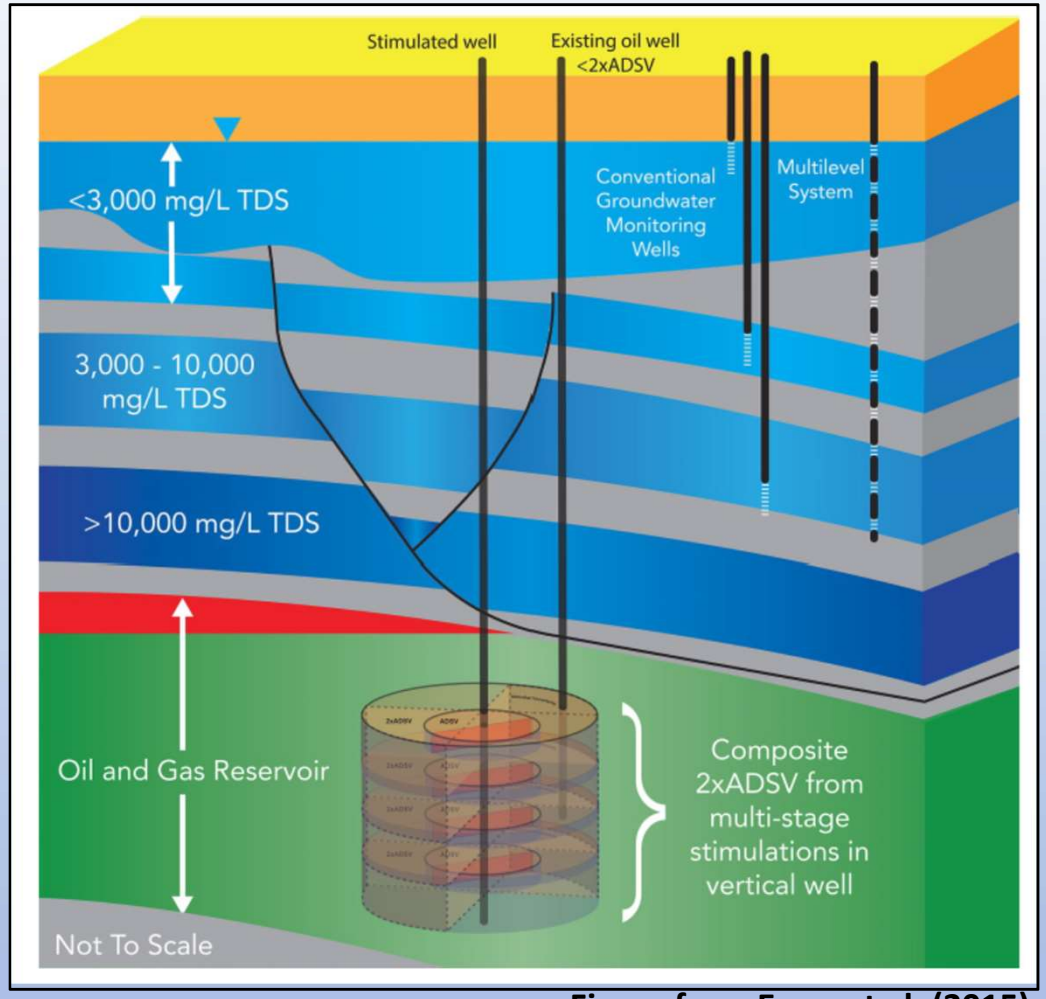

Figure from Esser et al. (2015)

The panel stated monitoring at 10,000 mg/L TDS is appropriate because it aligns with EPA's UIC program and is "technically and economically feasible to desalinate" water at this level of salinity (Esser et al. 2015).

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Produced Water < 10,000 mg/L TDS

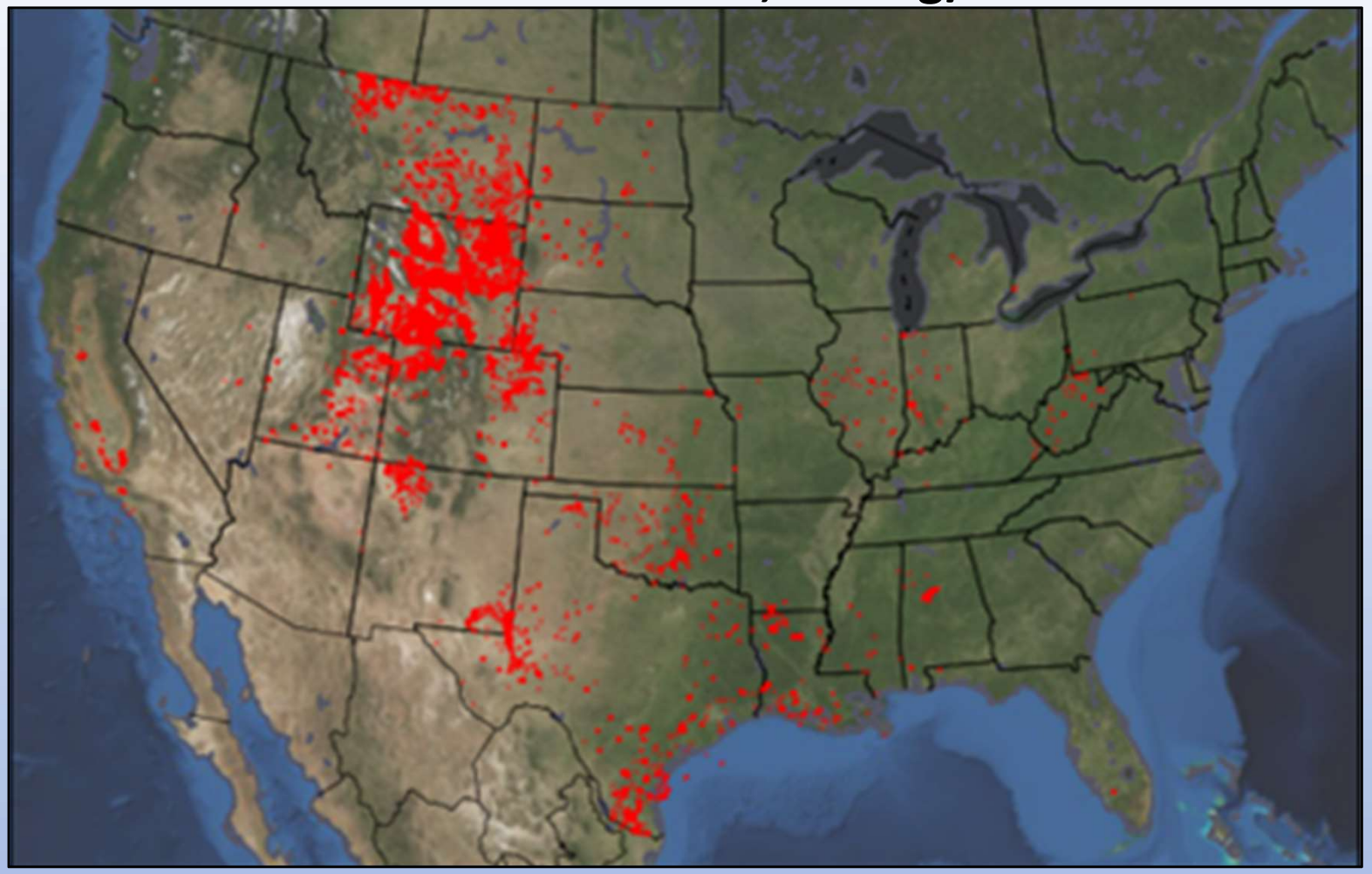
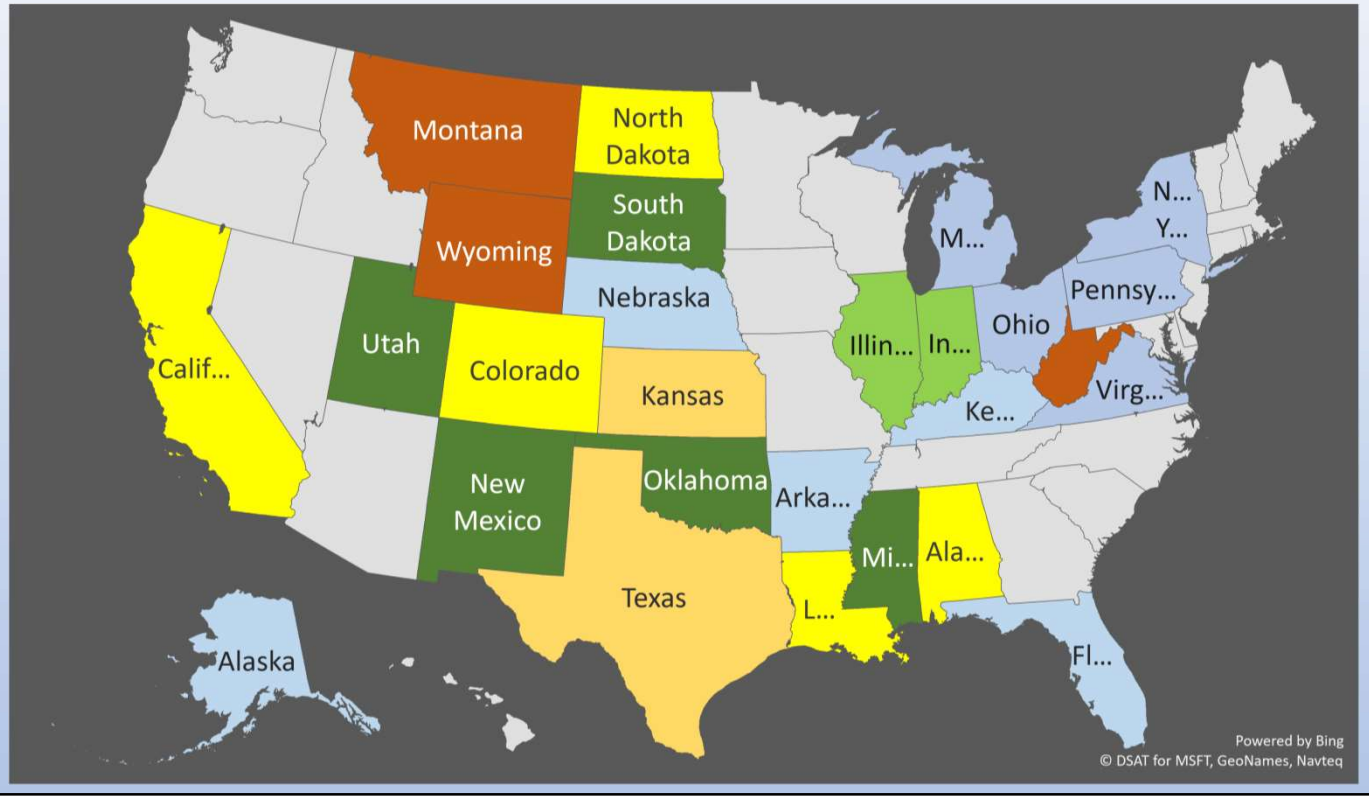


Figure from DiGiulio et al. (2018)

Data (n=18,762) from the USGS National Produced Waters Geochemical Database (Blondes et al. 2014)

Oil and gas development in 27 states but development in brackish groundwater primarily in 17 states.

Definitions of Protected Groundwater during Well Stimulation Equivalent to an USDW in 5 States



MS – Surface casing > 100 ft below base of USDW
UT – Surface casing to base of "freshwater" defined as an USDW.
OK – Surface casing > 50 ft below base of "treatable water" defined as < 10,000 mg/L TDS
SD – Surface casing to depth of "freshwater" defined as <10,000 mg/L TDS
NM – Protect "freshwater" defined as <10,000 mg/L TDS unless "no present or reasonably foreseeable beneficial use."

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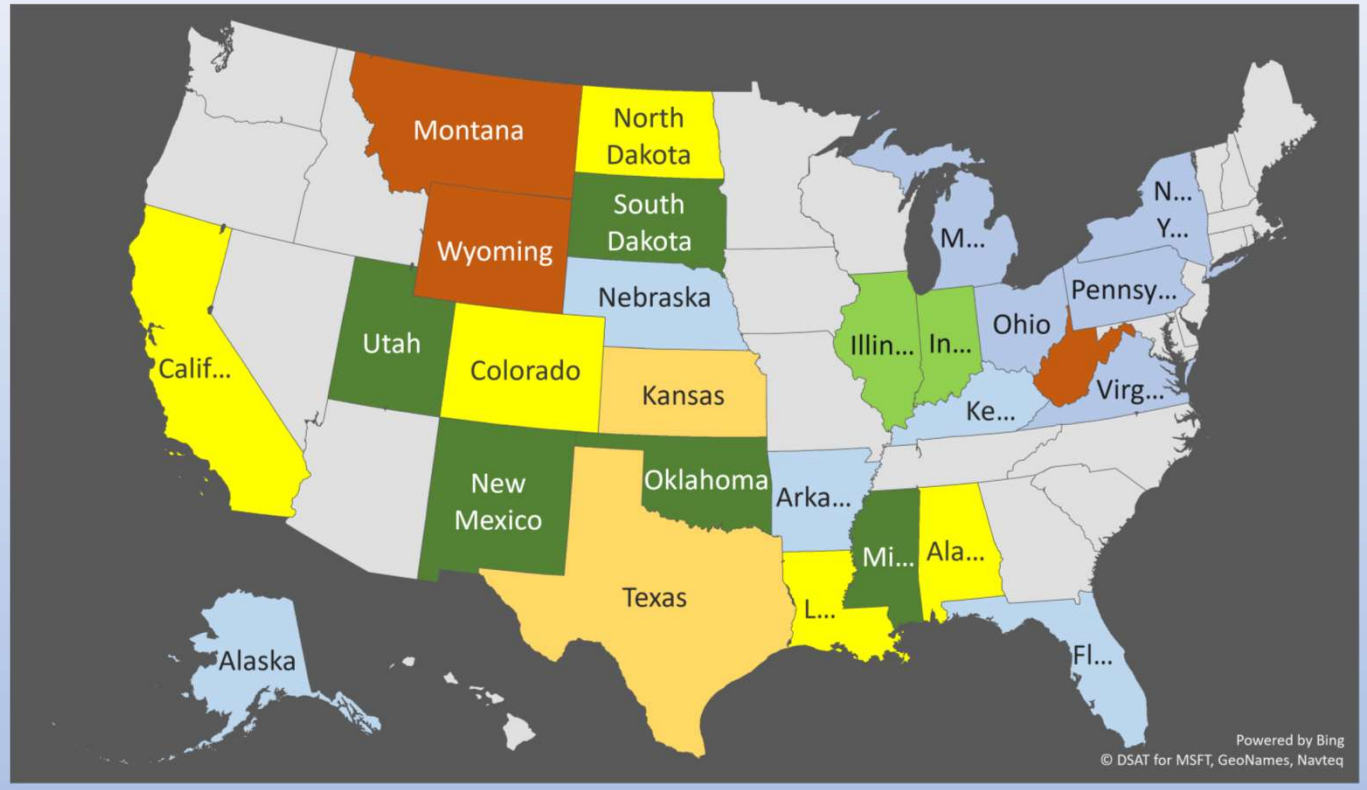
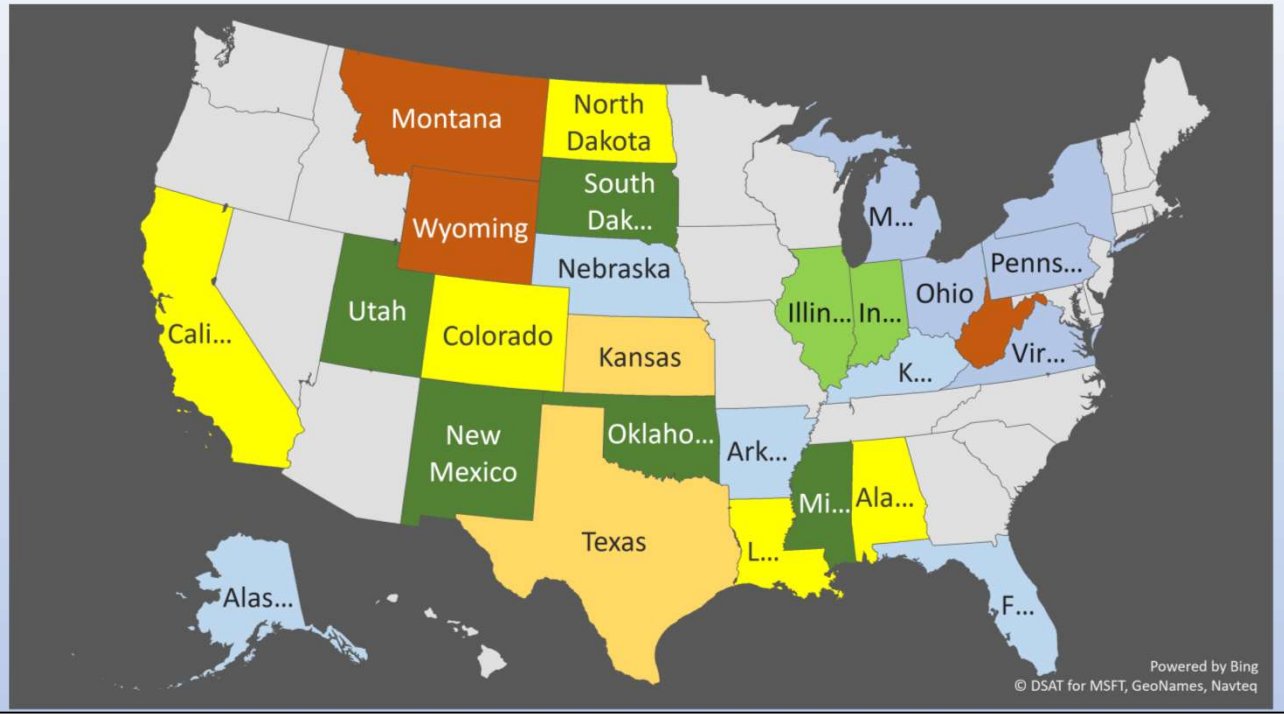
Definitions of Protected Groundwater during Well Stimulation Equivalent to an USDW in Some Instances in 2 States



IN – Surface casing below lowest USDW during CBM only.
IL – For horizontal wells with > 80,000 gallons stimulation, surface casing > 100 ft below deepest "freshwater" defined as <10,000 mg/L TDS.

Definitions of Protected Groundwater during Well Stimulation Undefined in 5 States



CA –"Freshwater" (undefined) protected. Monitoring during hydraulic fracturing to 10,000 mg/L TDS

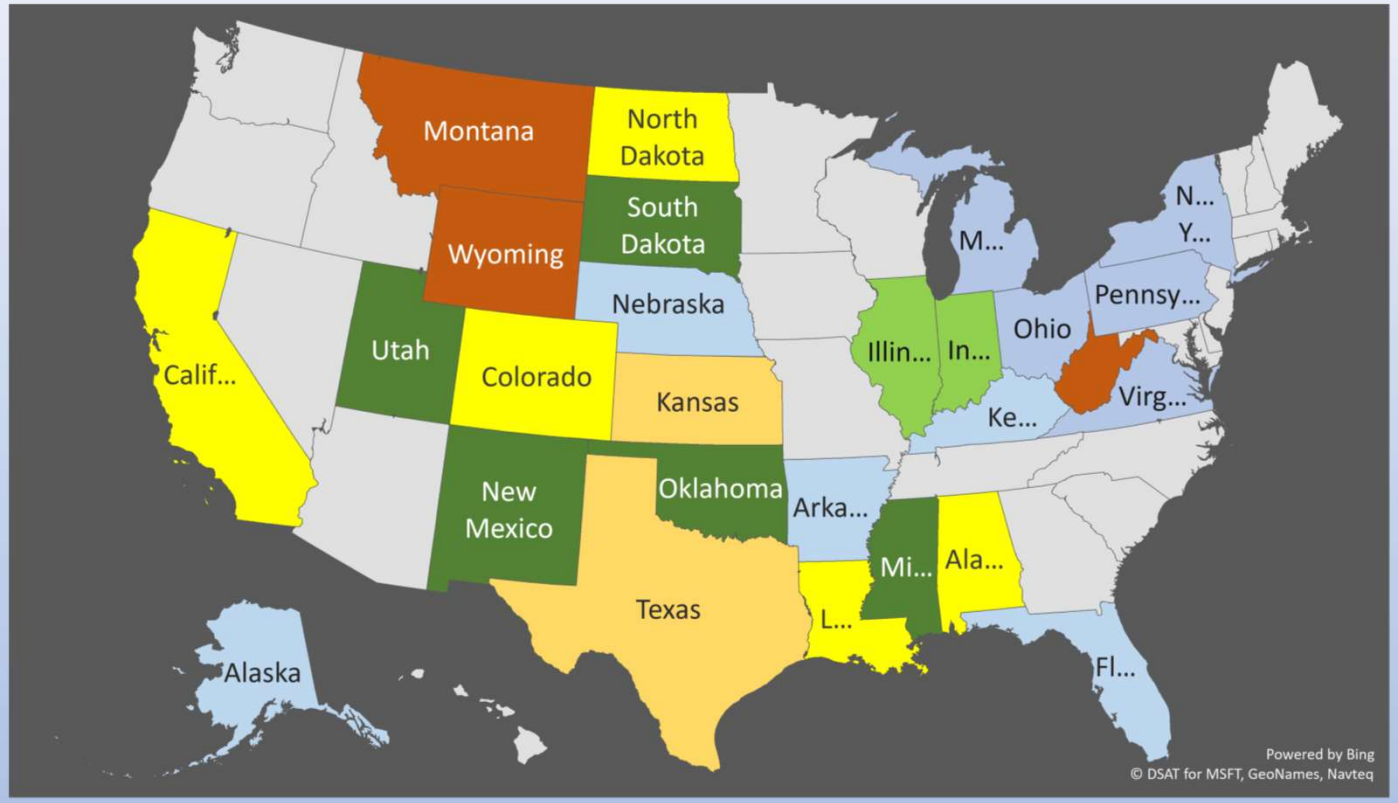
LA – Surface casing must protect "freshwater" (undefined)

AL – Surface casing set at base of "freshwater-bearing strata" defined as having present or probable future use (no TDS criterion). No hydraulic fracturing during CBM above 399 ft.

CO – When hydraulic fracturing < 2000 ft, surface casing > 50 ft below base of "freshwater" (undefined) otherwise depth of surface casing is geographically dependent.

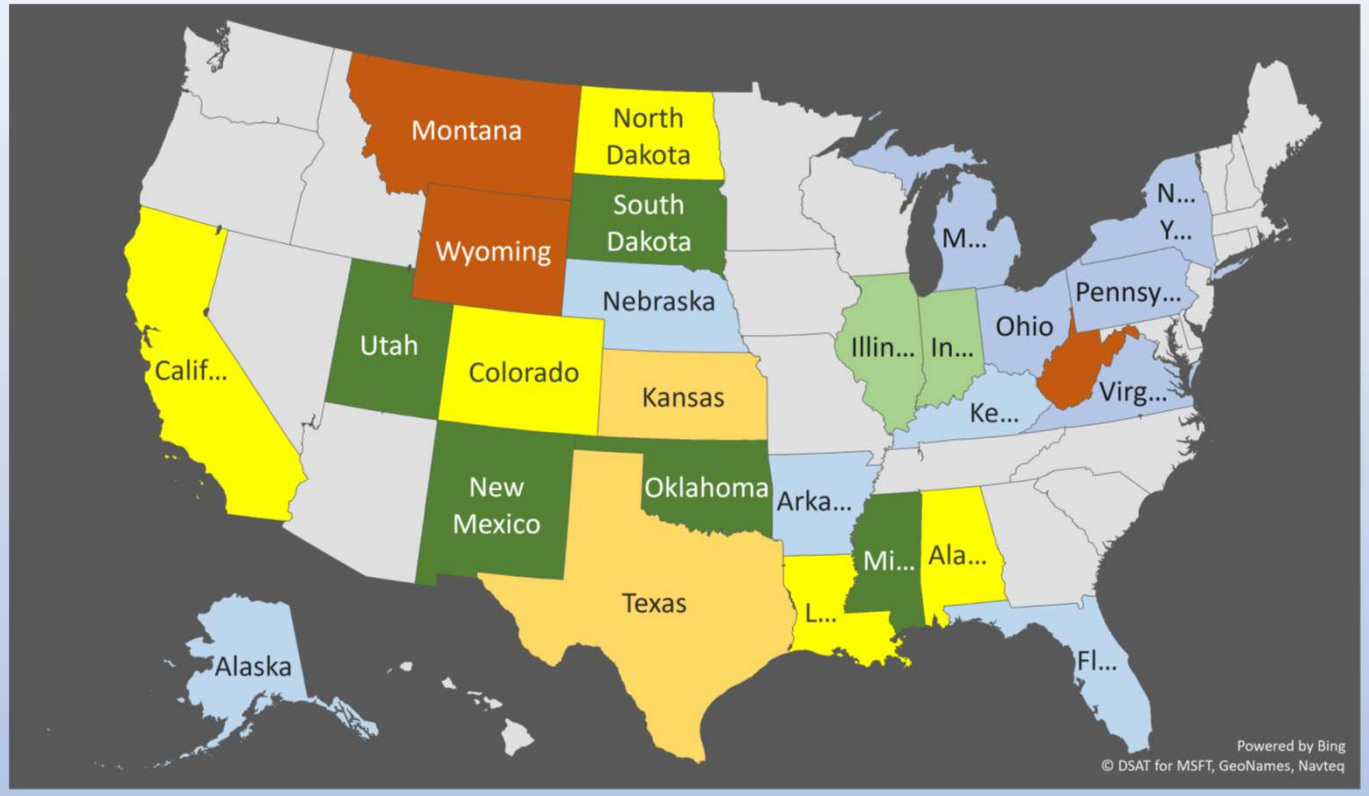
ND – Surface casing must protect "freshwater" (undefined) of present or probable use.

Definitions of Protected Groundwater during Well Stimulation Less than USDW in Two States



TX – surface casing below "Base of Usable-Quality Water", generally < 3000 mg/L TDS unless identified as source of desalination water.
KS – Depth of surface casing tied to counties but based on "fresh" (< 1000 mg/L TDS) and "usable" (<10,000 mg/L TDS).

Groundwater Protection Removed During Well Stimulation in 3 States



WV – "Water" associated with oil and gas development or "fresh" water during hydraulic Fracturing is exempted from protection.

WY – "Class V" groundwater is associated with oil and gas development, has no TDS standard and no stated protection.

MT – Groundwater having between 2500 – 15000 µS/cm specific conductance is defined as "Class III" water that is not subject to "non degradation" provisions.

Findings, Conclusions, and Recommendations

Findings

- Population growth and climate change will necessitate the increased use of brackish groundwater to supplement freshwater demand.
- Desalination of brackish groundwater to 10,000 mg/L TDS is economically and technically feasible.
- Oil and gas development threatens brackish groundwater resources.
- The federal government, some states, and professional organizations have recommended the use of a 10,000 mg/L TDS criterion to define protected groundwater during oil and gas development.
- Criteria for protected groundwater in many states during oil and gas development are ambiguous and do not protect brackish groundwater to 10,000 mg/L TDS.

Conclusion

A definition of protected groundwater using a criterion of 10,000 mg/L TDS or criteria established for an USDW during oil and gas development is reasonable and defensible.

Recommendation

A criterion of 10,000 mg/L TDS or criteria established for an USDW should be used to define protected groundwater during oil and gas development throughout the U.S.

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