

# Applications of the U.S. Geological Survey Produced Waters Geochemical Database for Environmental Oil and Gas Operations

Mark A. Engle<sup>1</sup>, Kathleen D. Gans<sup>2</sup>, Madalyn S.  
Blondes<sup>3</sup>, James J. Thordsen<sup>2</sup>, Mark E. Reidy<sup>3</sup>,  
Yousif K. Kharaka<sup>2</sup>, Elisabeth L. Rowan<sup>3</sup>

U.S. Geological Survey

<sup>1</sup>El Paso, Texas; <sup>2</sup>Menlo Park, California; <sup>3</sup>Reston,  
Virginia

# Acknowledgements and Disclaimer

- Funding provided by the USGS Energy Resources Program

Disclaimer: The information in the USGS National Produced Waters Geochemical Database should be used with careful consideration of its limitations. The database is considered sufficiently accurate to provide an indication of tendencies in water composition from geographically and geologically defined areas. It is not appropriate for depiction of modern produced water compositions or examination of trends on small scales. The USGS makes no warranty regarding the accuracy or completeness of information presented in this database. Specific limitations of the database should be considered. Much of the information in the database cannot be independently verified. Methods of collection, sample preservation, analysis, assignment of geologic units and record keeping were not rigorous or standardized. Because of these uncertainties, users are advised to check data for inconsistencies, outliers, and obviously flawed information. Methods of well construction, sample collection and chemical analysis have changed over time. The distribution and relative amount of water produced within a province and among geologic units may not be fully represented by the samples in the database. No sampling was planned to accurately depict the aggregate water composition of any area whether it be province, state, county or field. The geologic unit nomenclature developed for petroleum production may have changed over time. Data from a province collected 30 years ago may not resemble current production. The composition of produced water within a province, field or even well may change in time as a result of water flooding, recompletion in other intervals, and workovers. Water samples are commonly collected when a well has production problems or during the initial development of a well. Although criteria were applied to remove the obviously contaminated samples, the culling of unrepresentative data is considered incomplete. Most obvious redundant entries were removed from this database, many of the records represent multiple samples of the same well. Therefore aggregate statistics may be weighted by relatively few wells.

# What is the USGS Produced Waters Geochemical Database?

- A compilation of databases and datasets containing compositional data for waters from basinal brines from across the U.S.

Free and  
publicly  
available

Current list  
of data  
sources:

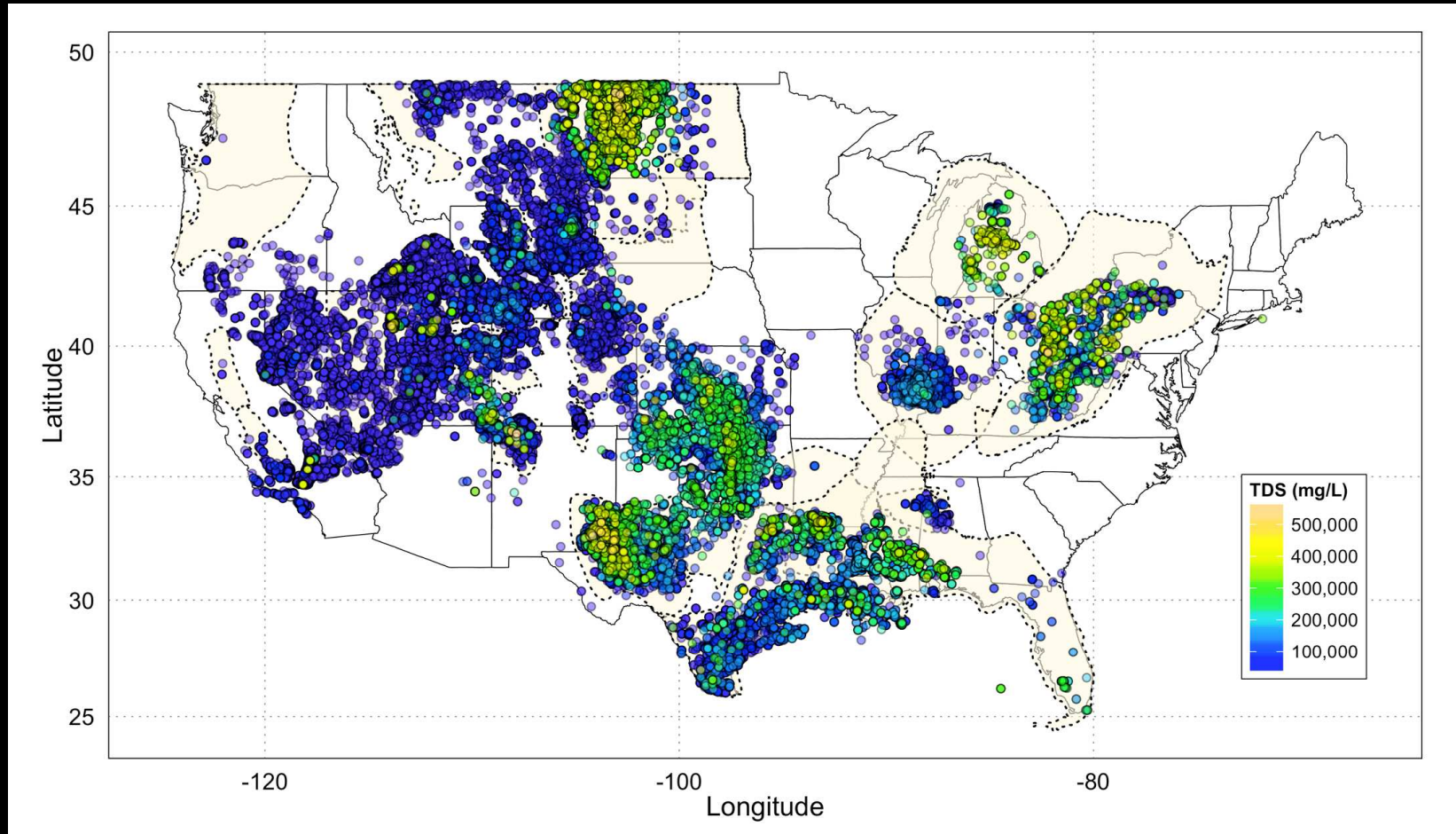


ID of database	Samples	Reference
USGSMAN	62,789	Breit and others (2002)
USGSOK	9,304	Breit and others (2002)
USGSARK	1,125	Breit and others (2002)
ROCKIES	3,188	Department of Energy, National Energy Technology Laboratory (2005)
MICHIGAN	429	Vugrinovich (2013, written communication)
WYOGCC	9,252	Wyoming Oil and Gas Conservation Commission (2013)
WILLISTON	47	Thamke (2014, written communication), USGS OFR 2010-1326, USGS OFR 2012-1149
PARADOX	89	Hanshaw and Hill (1969)
POWDERRIVERCBM	47	Rice and others (2000)
APPALACHIAN	1,647	multiple – see references
INDIANA	396	Keller (1983)
CBM	3,220	Dahm (2013, written communication)
OHBRINE	579	McDonald (2013, written communication)
PASHIN	126	Alabama Geological Survey (2013, written communication)
ARKMOLDOVANYI	41	Moldovanyi and Walter (1992)
CIMAREX	2,891	Cimarex Energy Company (2013, written communication)
FERRON	46	Rice (2003)
ILLINOIS	342	Meents and others (1952)
MISSISSIPPI	82	Carpenter and others (1974)
MONTANACBM	20	Meredith and others (2010)
PALODURO	16	Bassett and Bentley (1983)
NORTHDAKOTA	7,334	North Dakota Oil and Gas Division (2013)
ANTRIM	53	Walter and others (1997)
NATCARB	57,208	Department of Energy, National Energy Technology Laboratory (2013)
<b>Total</b>	<b>161,915</b>	

# What does the database contain?

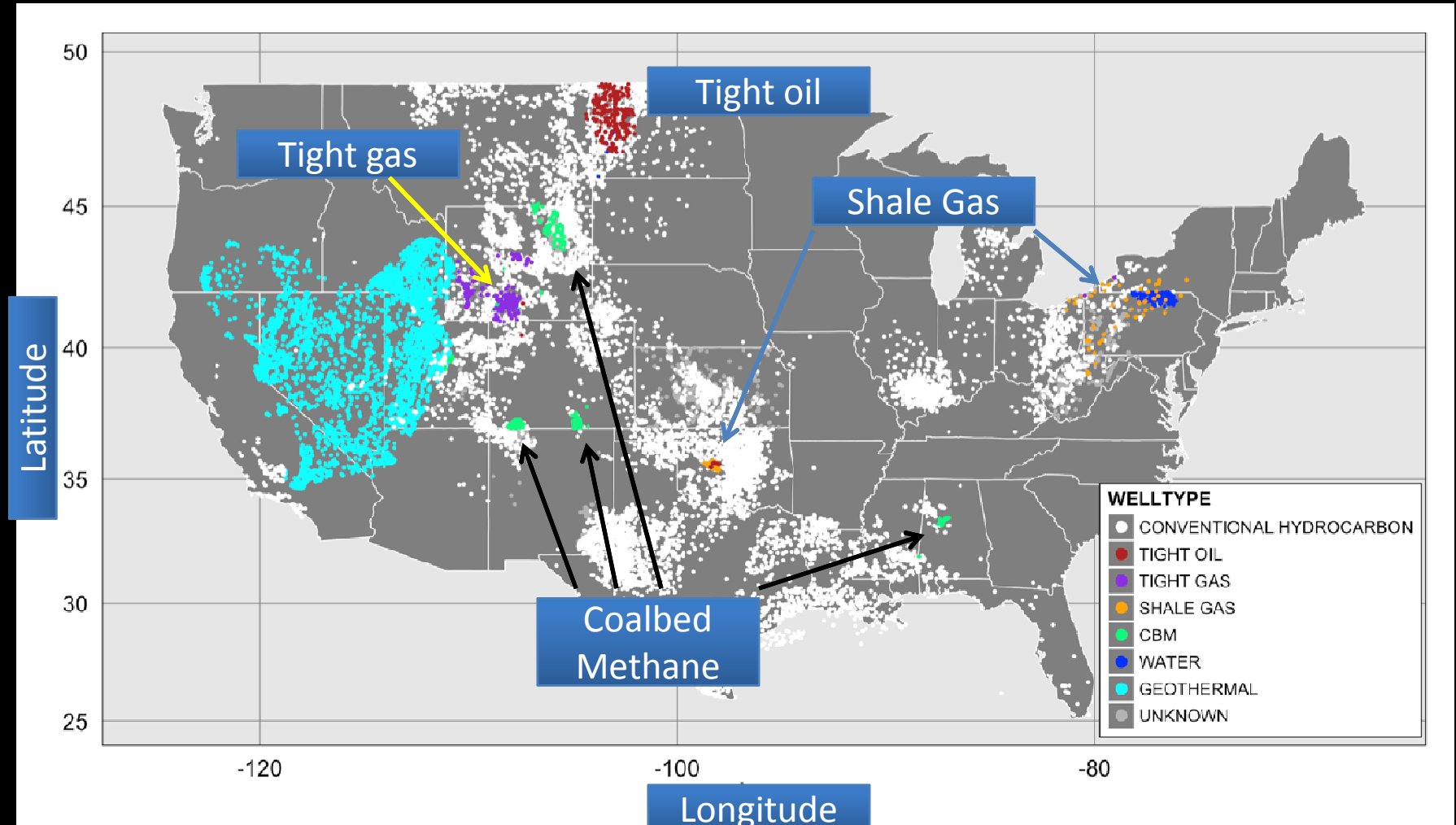
- >160,000 data points
- Location Data
  - Approx. Latitude and Longitude, API
- Chemical Data
  - Major ions (e.g., Na, Ca, Mg, Cl, SO<sub>4</sub>); Minor and trace (e.g., Br, Cu, Fe, Rb, Ni); Isotopes (e.g.,  $\delta^{18}\text{O}$ ,  $\delta^2\text{H}$ ,  $\delta^{11}\text{B}$ ,  $^{87}\text{Sr}/^{86}\text{Sr}$ ); Radionuclides (e.g.,  $^{226}\text{Ra}$ ,  $^{214}\text{Pb}$ ,  $^{40}\text{K}$ ); Organics (e.g., BTEX)
- Physical Data
  - Reservoir age and lithology, conductance, temperature, sp. grav.
- Data quality criteria
  - Charge balance,  $4.5 < \text{pH} < 10.5$ ,  $\text{K} > \text{Cl}$  etc.

# Example: TDS Color Map



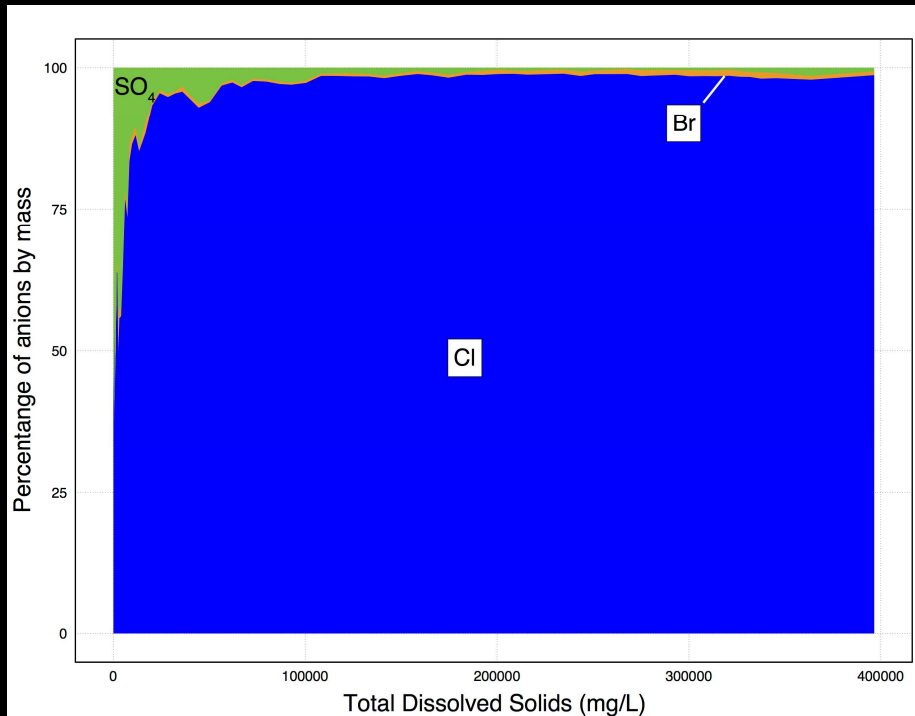
Excellent data coverage for basic measurements, such as TDS and major ions  
>160,000 individual data points  
Covers all major oil and gas basins of the conterminous United States

# Data coverage for continuous plays



- Data for some shale plays but many gaps remain

# Trends in major ion composition with salinity

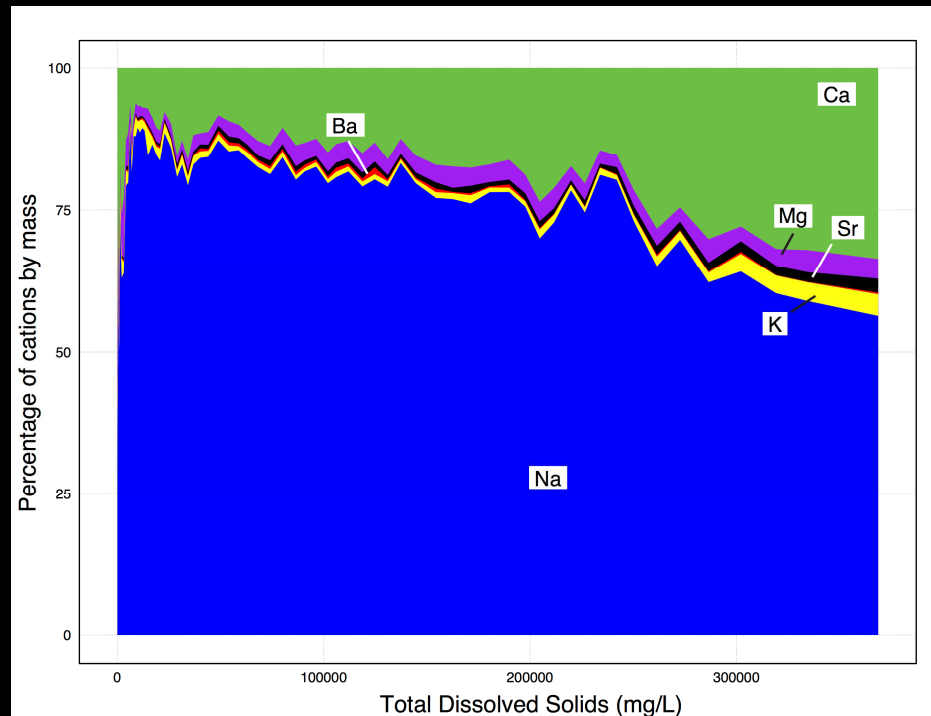


Anions: Cl is the only major anion at TDS > 50 g/L

- SO<sub>4</sub> loss due to sulfate reduction and gypsum ppt.
- HCO<sub>3</sub><sup>-</sup> loss due to carbonate ppt.

Cations: Ca/Na ratio increased with salinity

- Halite saturation, ion exchange and albitization play a role
- K and Sr abundance increase with salinity

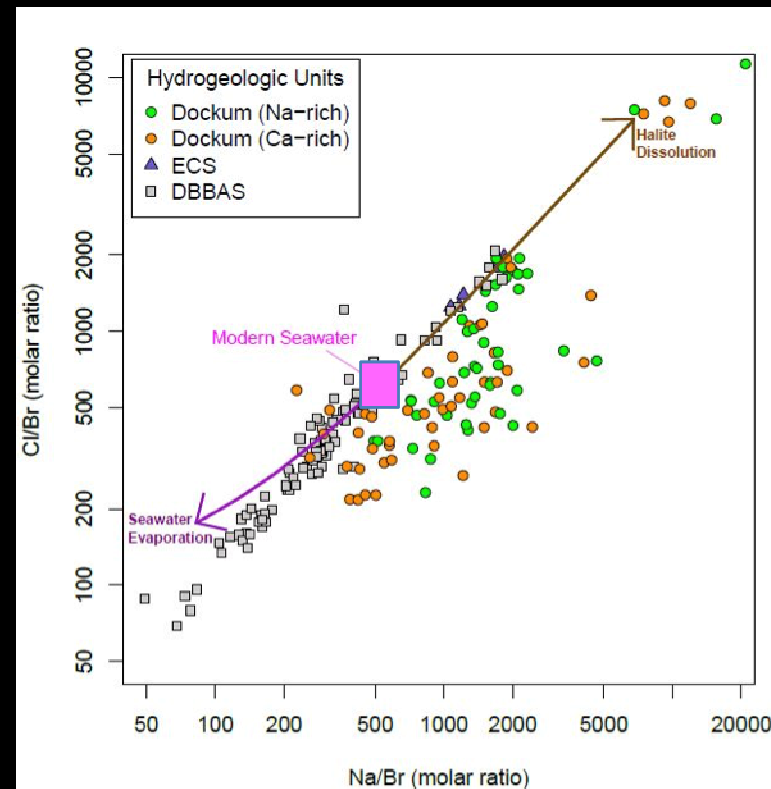


# Fingerprinting oil and gas brines Na-Cl-Br system (Permian Basin)

- Produced waters can exhibit unusual patterns in the Na-Cl-Br system which is distinct from surface waters

**Question:** Connection between brackish (Dockum) groundwater with basinal brines in the Permian Basin.

Combined database data for the Evap. Confining System (ECS) and Deep Basin Brine Aquifer System (DBBAS) from the produced waters database with new data from the Dockum aquifer.



Reyes, 2014



# Fingerprinting oil and gas brines

## $\delta^2\text{H}$ and $\delta^{18}\text{O}$

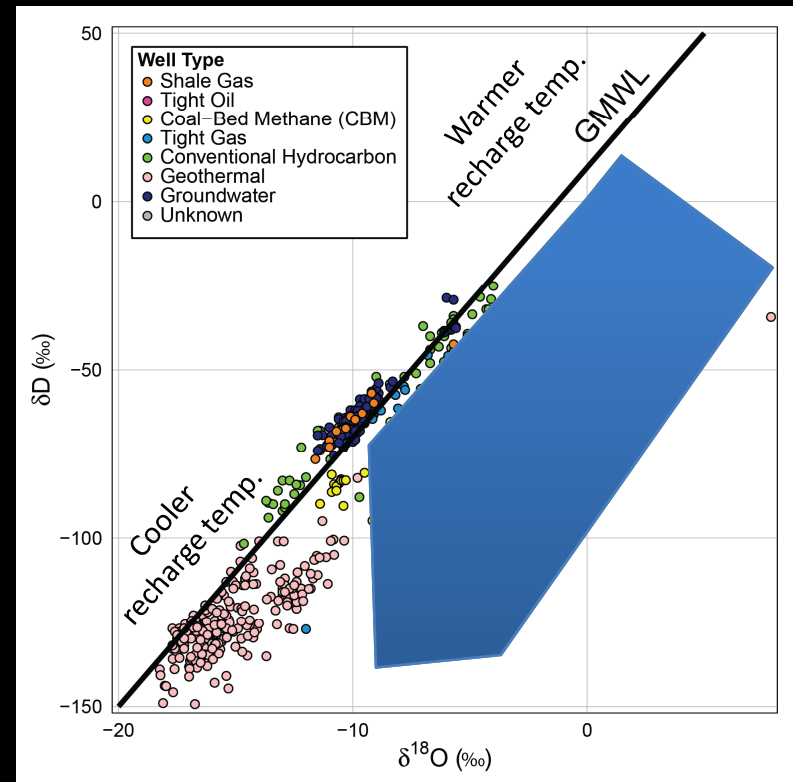
- Isotopes of O and H can help determine origin of water from oil and gas wells

Water derived from precipitation lands on the global meteoric water line (GMWL)

Paleo-evaporated seawater or very old meteoric water plot to the right on the GMWL

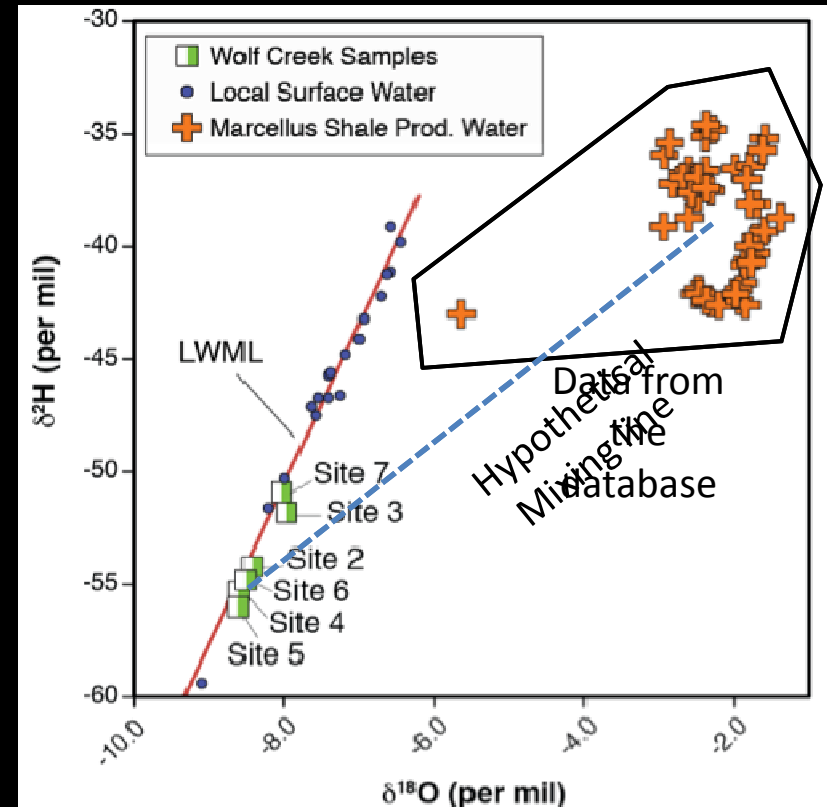
Can be used to identify mixing or reservoir connectivity

Data from across the US



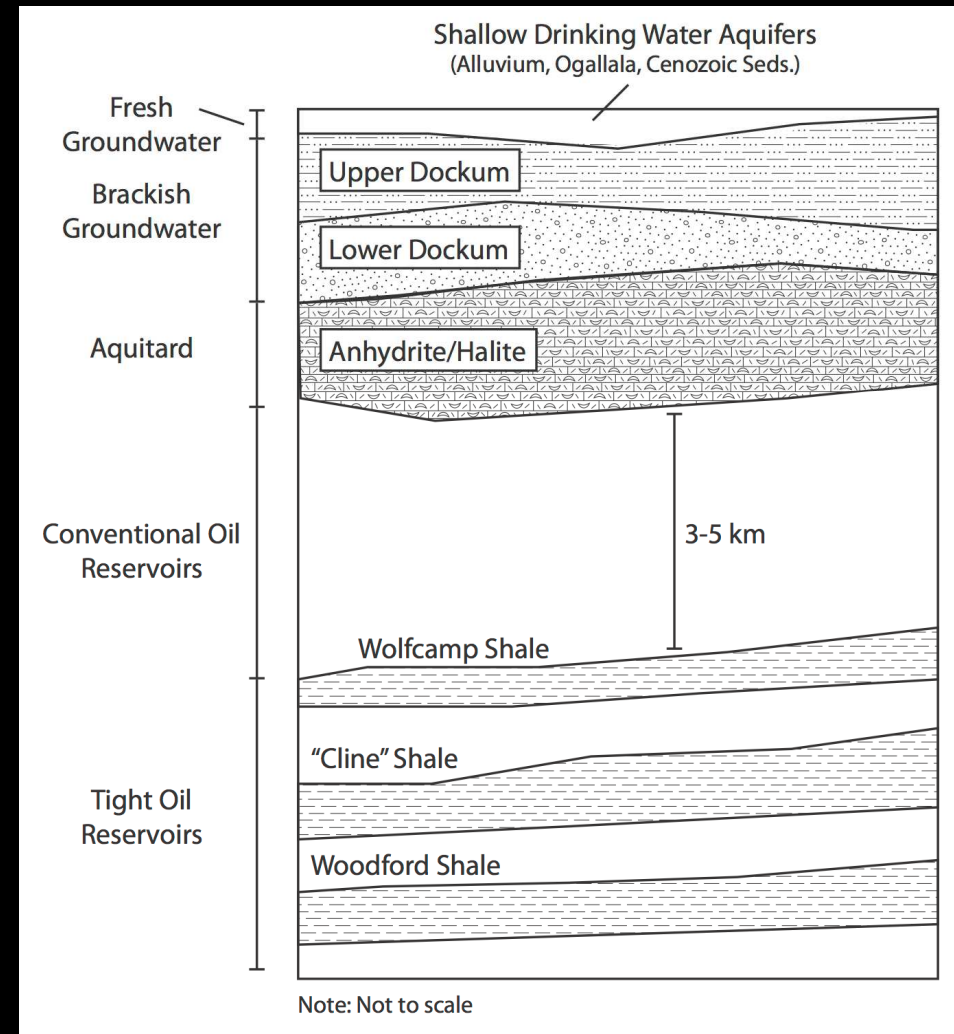
# Example from a possibly leaking disposal site

- Class II UIC site in West Virginia with ponds
- Accepted waste from several gas wells
- Stream sees increased Sp. Cond., Cl, Fe, etc. (sites 3, 7)
- Hypothesis: Is this contamination from Marcellus Shale Produced Water?



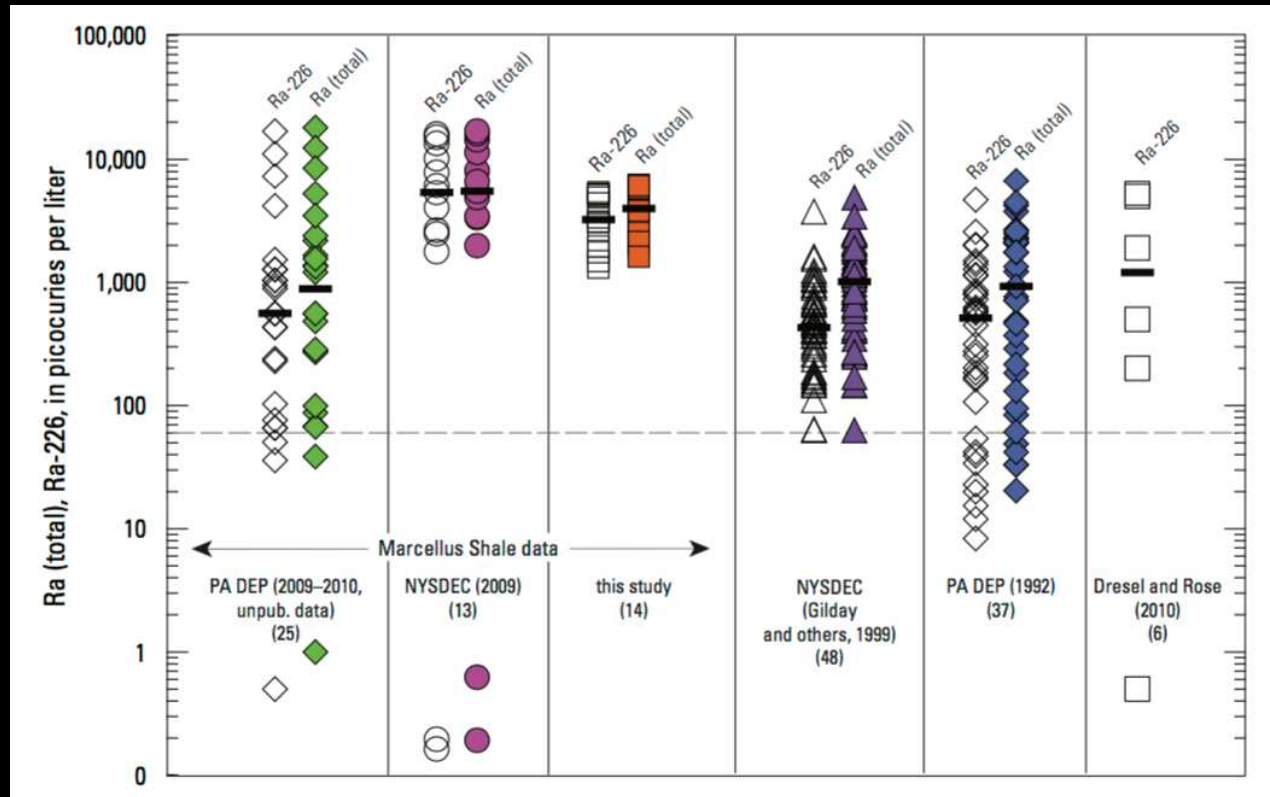
# Example: Potential for scale formation during waste injection in the Permian Basin

- Injecting Wolfcamp shale produced water into the San Andres
- Mixed average compositions for both in a geochemical model
  - Pitzer-based model
  - Determined mineral saturation indices



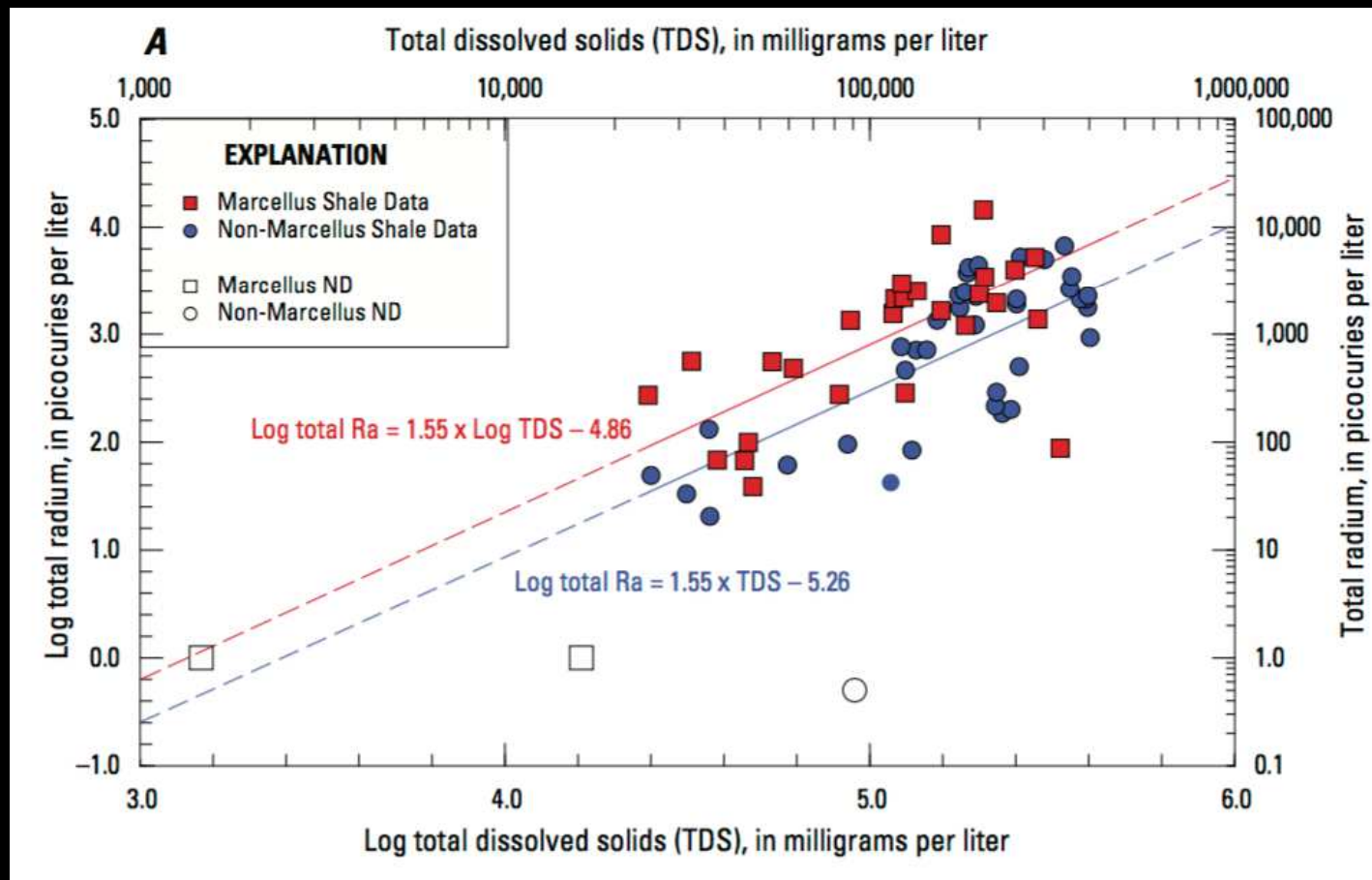
# Developing a screening tool for NORM (radium) in the Appalachian Basin

- Radium content of Appalachian Basin waters ranges considerably.



# Analysis of covariance

- Using data from the database, we can estimate total radium from TDS, by reservoir:





# Accessing the database – the Web App



Do I need to download the whole database?  
[eerscmap.usgs.gov/pwapp](https://eerscmap.usgs.gov/pwapp)

# Filtering – Are there any Bakken data?

**Filter** [X]

Well Type:

ID Database:

Formation: **BAKKEN**

State:

Basin:

Chem:

Chem:

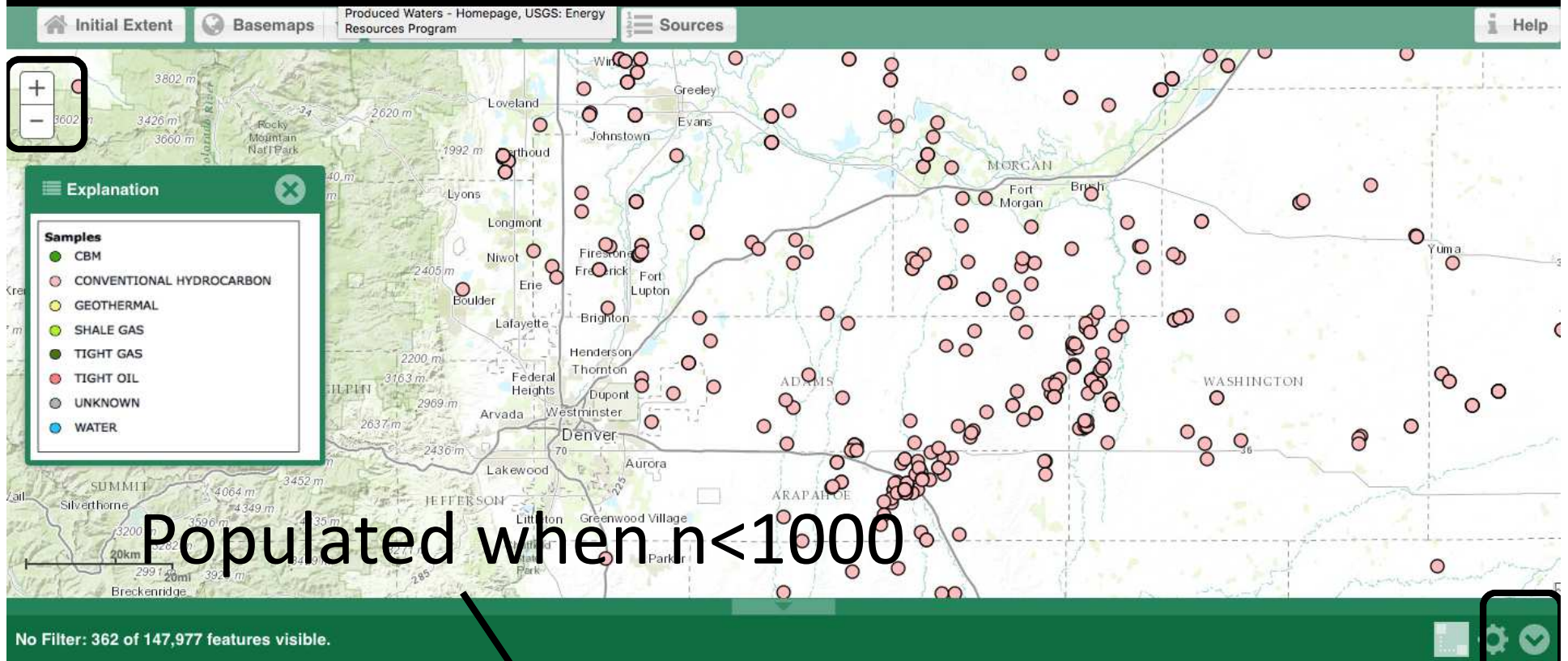
Chem:

**Submit** **Reset** **Close**

Map labels: CANADA, UNITED STATES, MEXICO, ROCKY MOUNTAINS, APPALACHIAN MTS, Hudson Bay, Great Lakes, Mississippi, Rio Grande, Gulf of Mexico, Caribbean Sea.



# Zooming and Detailed Results around Denver

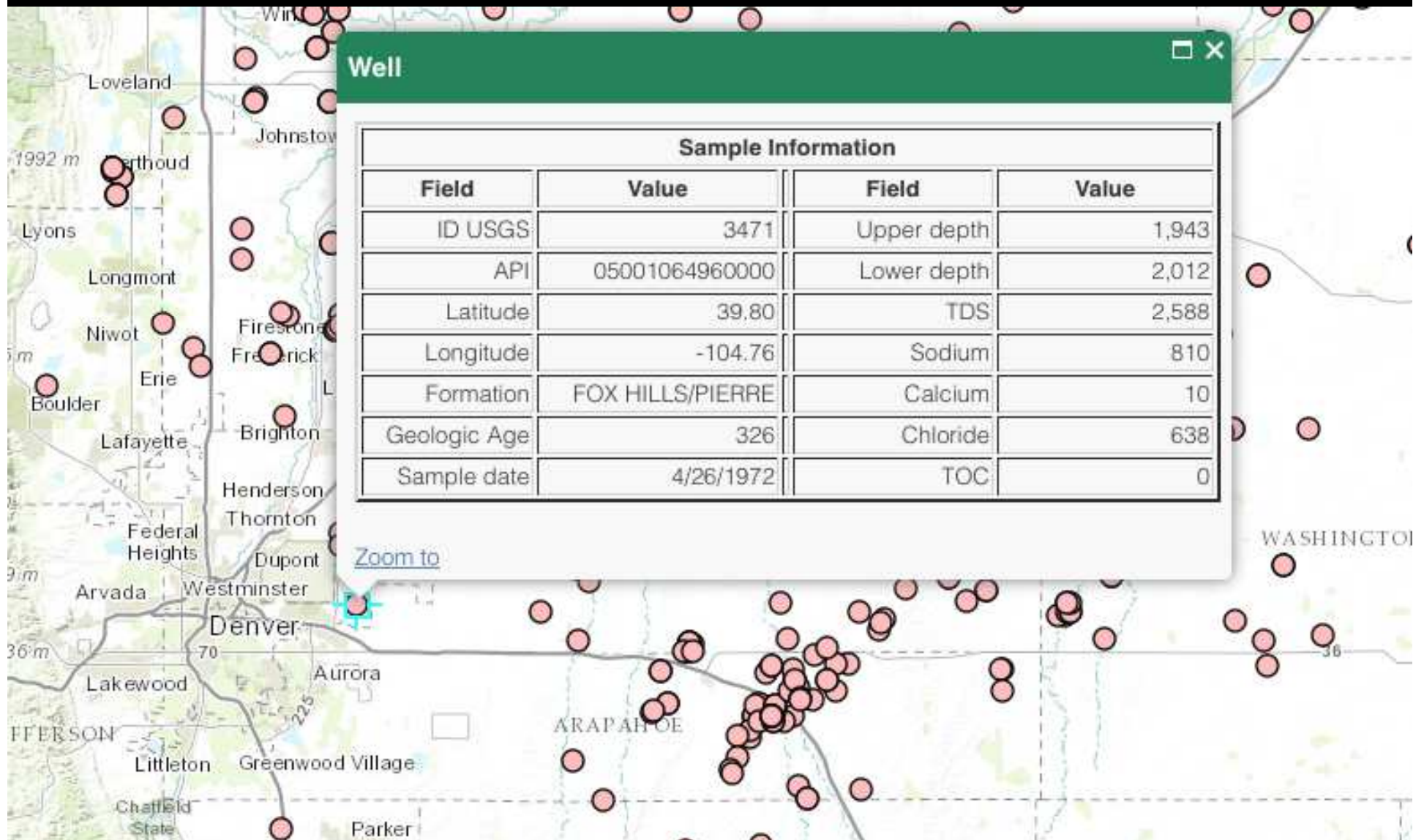


Populated when  $n < 1000$

ID ...	API	Latit...	Long...	STATE	Well Type	Formation	Geologic Age	Upper Dept...	Lower Dept...	Reference
1137	05001052360000	39.86	-103.73	COLORADO	CONVENTI...	D	218	5,348	5,372	3,730
1155	05087056030000	40.11	-103.82	COLORADO	CONVENTI...	DAKOTA	218	5,583	5,595	13,400
1156	05087057310000	40.14	-103.53	COLORADO	CONVENTI...	DAKOTA	218	4,942	4,948	9,290
1157	05087059970000	40.23	-103.97	COLORADO	CONVENTI...	J	218	6,042	0	14,300
1159	05121053370000	39.76	-103.27	COLORADO	CONVENTI...	DAKOTA J	218	4,490	4,497	3,830

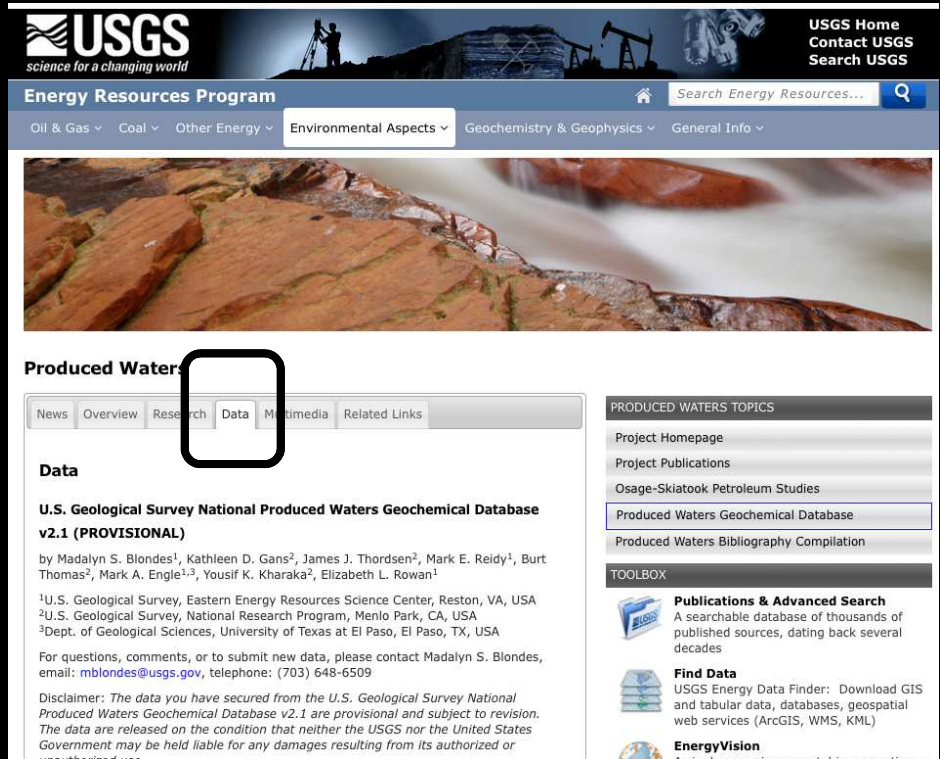


# Pointing and clicking



# Getting the full dataset

- Google “USGS produced waters database” and look for the data tab
- Lots of documentation
- Is available in 2 formats:
  - .xlsx (66.8 MB)
  - .Rdata (10.8 MB)



The screenshot shows the USGS Energy Resources Program website. The header includes the USGS logo and navigation links. The main content area features a large image of a rocky landscape. Below the image, the 'Produced Waters' section is visible, with a 'Data' tab highlighted by a black box. The 'Data' section contains the title 'U.S. Geological Survey National Produced Waters Geochemical Database v2.1 (PROVISIONAL)' and lists authors and contact information. A disclaimer is also present at the bottom of the section.

Version 2.2 -  
Forthcoming

# Data needs – A plea for help

- Arkoma Basin
  - Any and everything
- Any isotopic data
- Tight oil plays
  - Eagle Ford, Barnett, Monterey, Bone Spring, Niobrara, Granite Wash
- Shale gas plays
  - Utica, Woodford-Cana, Haynesville, Fayetteville, Mancos, Antrim, New Albany

# Further contact information

- Questions or new data:
  - Madalyn Blondes
  - [mblondes@usgs.gov](mailto:mblondes@usgs.gov)

Questions?