

Known Locations of Groundwater Contamination Across the State

Oklahoma Clean Lakes and Watersheds

April 2-3, 2014

Stillwater, OK

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Roadmap

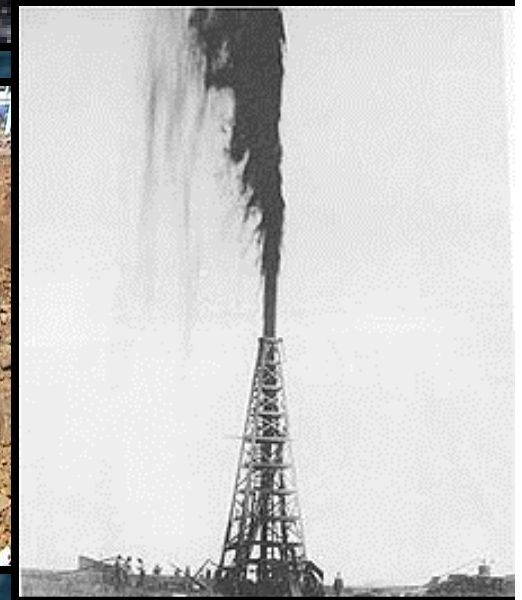
1. Introduction: OCC groundwater data
2. Contamination
 1. Petroleum
 2. Salinity
 3. Metals
 4. Other
3. % of Samples Exceed
4. Data accuracy



1. Introduction

How Contamination Occurred

- Old pipelines corrode & leak to soil, water
- Old spills not cleaned up
- Pressure/blowouts, surface or into subsurface (aquifers)
- Poor maintenance, equipment at well site corroded
- Recent to “Back in the day”



Recent Accidents, and “Back in the day”



Tanks, 2013 storms in Moore:
2 OK, several tipped over &
spilled, 2 found far away!

1940 – saline brine
allowed to flow down
roadside ditch



1. Introduction

Groundwater Data

- OCC has 20 years of groundwater samples from urban, suburban, and rural Oklahoma
- **Over 2,000** groundwater/well samples statewide
- The Process: Citizen Complaint or Field Inspection → Sample taken → Lab (DEQ, OSU, Oil Lab) → OCC (into database, to Field Inspector)
- At right are the lab tests run and analytes measured
 - Irrigation Water
 - Anions and Cations (Na, Ca, Mg, K, nitrates, Cl, SO₄, HCO₃)
 - Boron
 - pH
 - Conductivity
 - TSS
 - Petroleum
 - Benzene
 - Toluene
 - Ethylbenzene
 - Xylenes
 - Total Petroleum Hydrocarbons
 - Metals
 - Arsenic
 - Barium
 - Chromium
 - Lead

Biased-To-The-Bad data

- Because most of our sampling is done following a known spill or complaint!
- OWRB's Groundwater sampling Program will hopefully tell us if there are significant overall pollution problems in aquifers. I hope not!

Data – Maps made

- For each parameter, we mapped:
 - All wells sampled and exceeds
 - Shallow “wells” (seeps, springs, trenches, borings, most monitoring wells) and exceeds -
 - Deep (>25') water wells and exceeds
 - Drinking Water wells sampled, and exceeds

Not all maps are shown for each parameter – no time in talk!

2. Contamination - Petroleum



Recent spill



Old dry oil and
Oil stained soil



Standards, Health Risks, and Sources

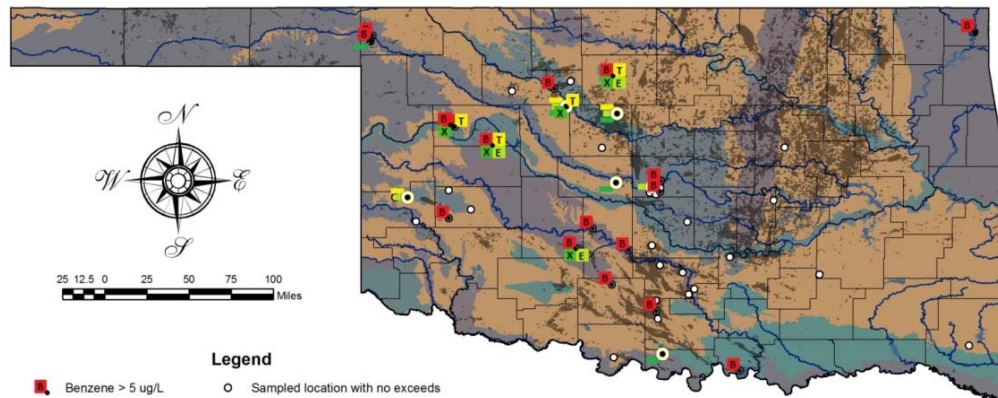
Contaminant		Maximum Contaminant Level (mg/L) - EPA unless specified otherwise	Potential Health Effects, Long-Term Exposure Above the MCL (unless specify short-term)	Sources of Contaminant in Drinking Water
Petroleum	Toluene	>1 mg/L == >1000 ug/L	Nervous system, kidney, or liver problems	Discharge from petroleum factories
	Benzene	>0.005 mg/L > 5 ug/L	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
	Ethylbenzene	>0.7 mg/L == >700 ug/L	Liver or kidneys problems	Discharge from petroleum refineries
	Xylene	>10 mg/L == >10,000 ug/L	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories
	TPH 6-12 (GRO)	> 25 mg/L (OCC Category II cleanup standards)		
	TPH 12-28 (DRO)	> 25 mg/L (OCC Category II cleanup standards)		
	TPH 28-36 (Lube Oil Range)	> 25 mg/L (OCC Category II cleanup standards)		
	TPH 6-36 (Total petroleum)	> 25 mg/L (OCC Category II cleanup		

Source: <http://water.epa.gov/drink/contaminants/index.cfm#InorganicDrinkingWaterContaminants>

Petroleum – Shallow and Deep

Petroleum Exceeds in Shallow Groundwater

All OCC records as of October 2013

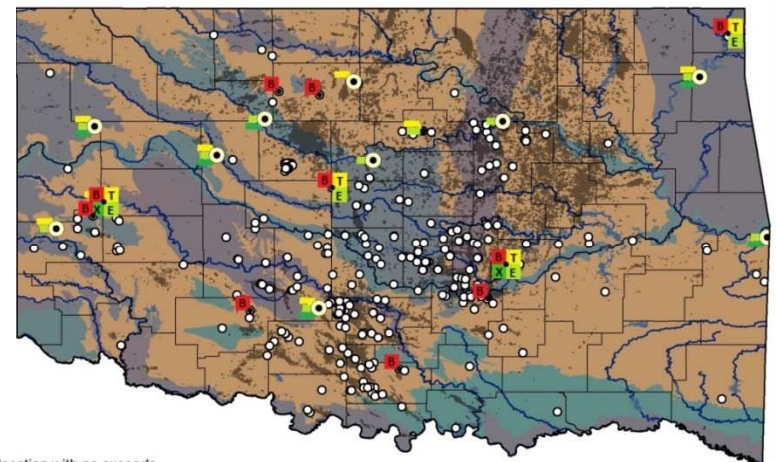


OCC water sample locations are determined by public request and suspicion of contamination. As a result, SAMPLE POINTS DO NOT REPRESENT A COMPREHENSIVE SURVEY OF STATEWIDE WATER CONTAMINATION.

White Dots = Sample locs

Exceeds in Deep Groundwater

All OCC records as of October 2013



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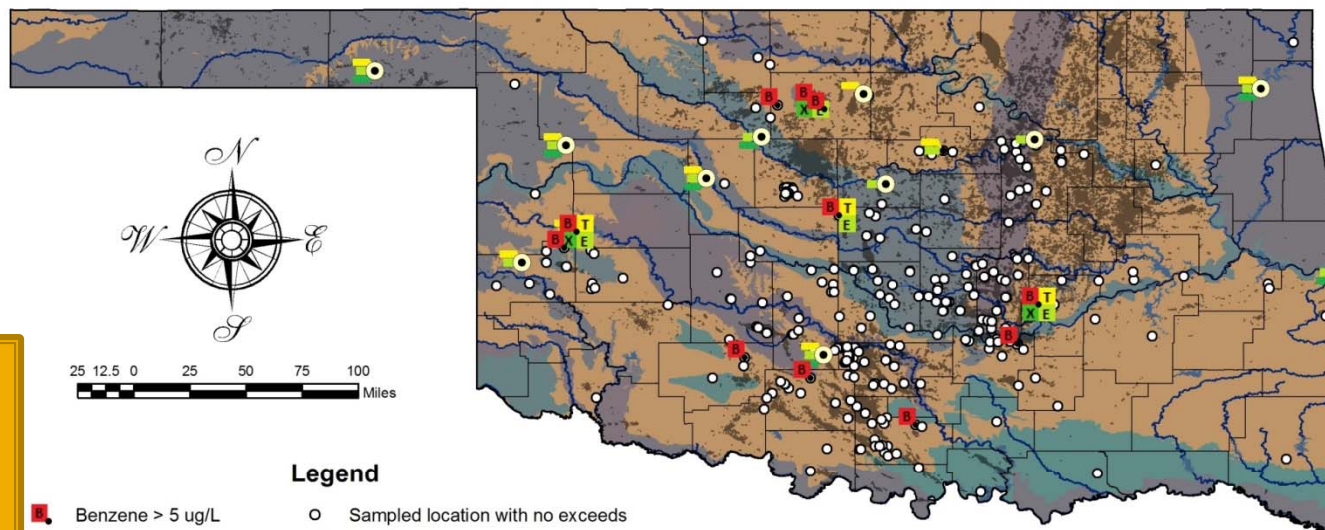
*Note - Fewer shallow locations than deep were sampled

Petroleum – Drinking Water Wells

White Dots =
Sample locs

Petroleum Exceeds in Drinking Water Wells

*Includes domestic, irrigation, livestock, public supply, and unspecified water wells.
All OCC records as of October 2013*



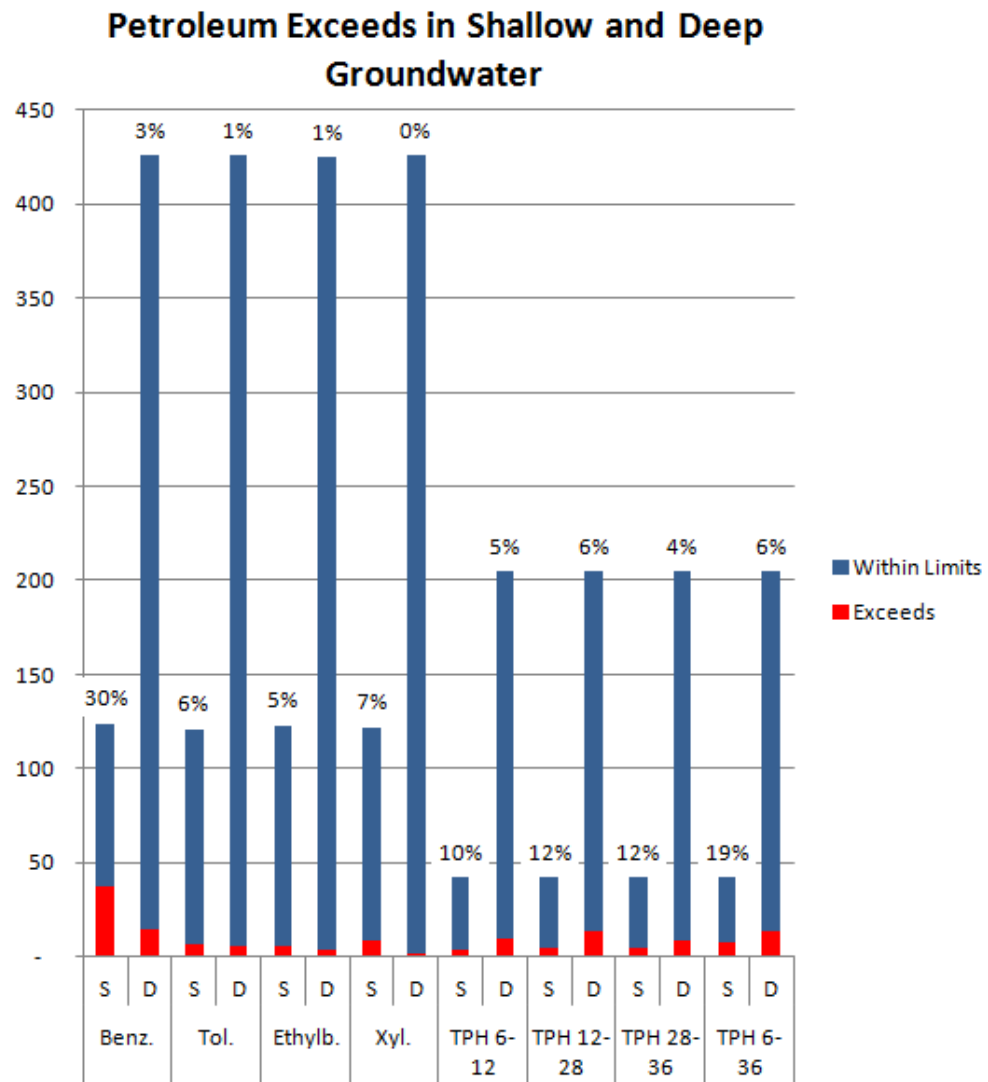
- B** Benzene > 5 ug/L
- T** Toluene > 1,000 ug/L
- E** Ethylbenzene > 700 ug/L
- X** Xylenes > 10,000 ppm
- TPH 6-36 > 25 mg/L
- TPH 6-12 > 25 mg/L
- TPH 12-28 > 25 mg/L
- TPH 28-36 > 25 mg/L

- Legend**
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 - Sampled location with no exceeds
 - Historic dense oilfields and UIC fields
 - OWRB major aquifers


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Few of the locations we sampled for petroleum exceed standards.

Benzene in shallow (monitoring) wells at spill sites is the most common petroleum pollutant

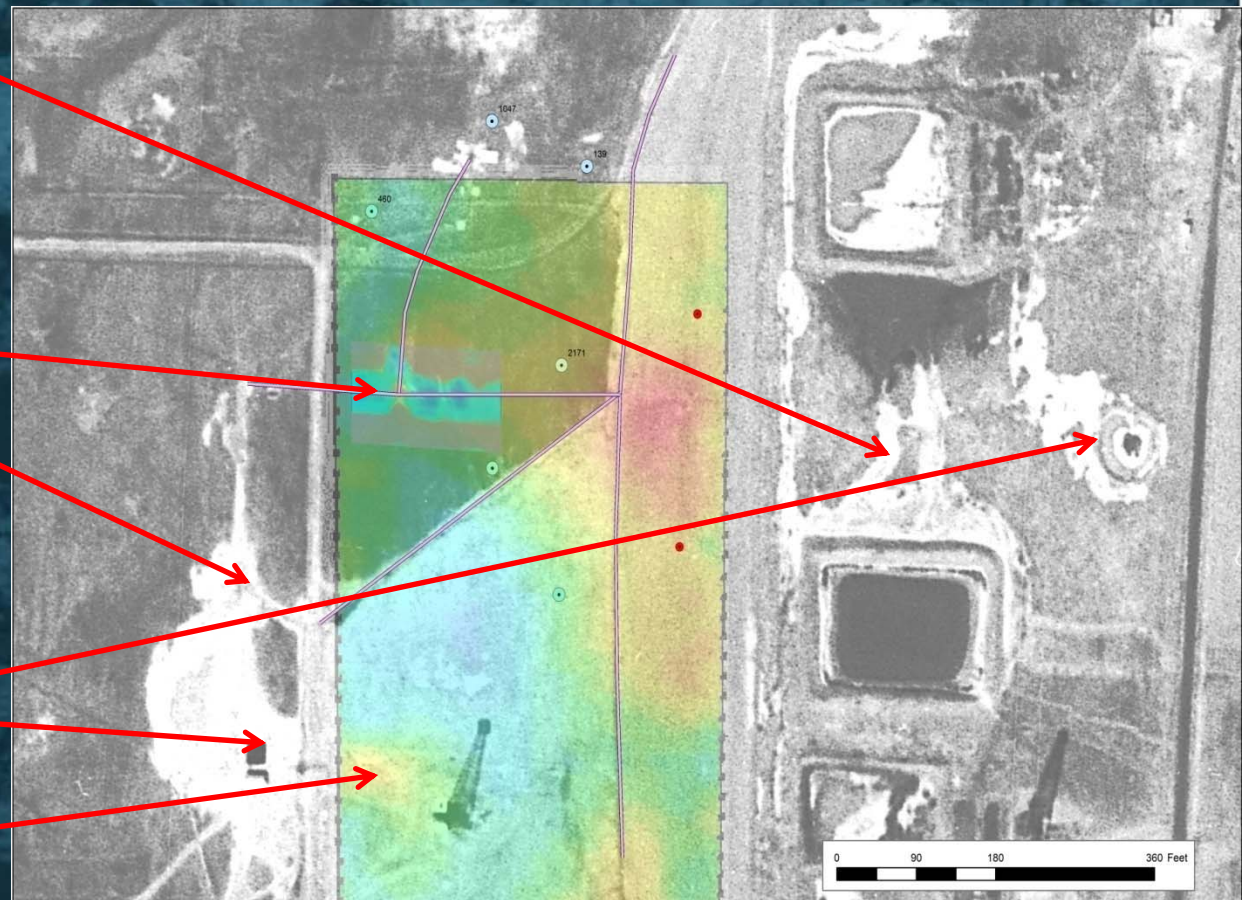


Contamination - Salinity

Contam- inant		Maximum Contaminant Level (mg/L) - EPA unless other specified	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Salinity	TSS	>500 mg/L (OCC, from EPA TDS)	<p>Salinity kills plants, leads to denuded, eroded areas where nothing grows, or only salt-loving plants grow. Tastes bad. Na can affect blood pressure.</p> 	Brine pulled up with oil while drilling, producing; natural brine from salt plains
	TDS	>500 mg/L (EPA secondary standard)		
	Cl	>250 ppm (mg/L) (EPA secondary standard)		Brine pulled up with oil while drilling; natural brine from salt plains
	Na	>250 ppm (OCC) (EPA secondary standard)		Brine pulled up with oil while drilling; natural brine from salt plains

How Contamination Occurred (1950's Aerial Photo)

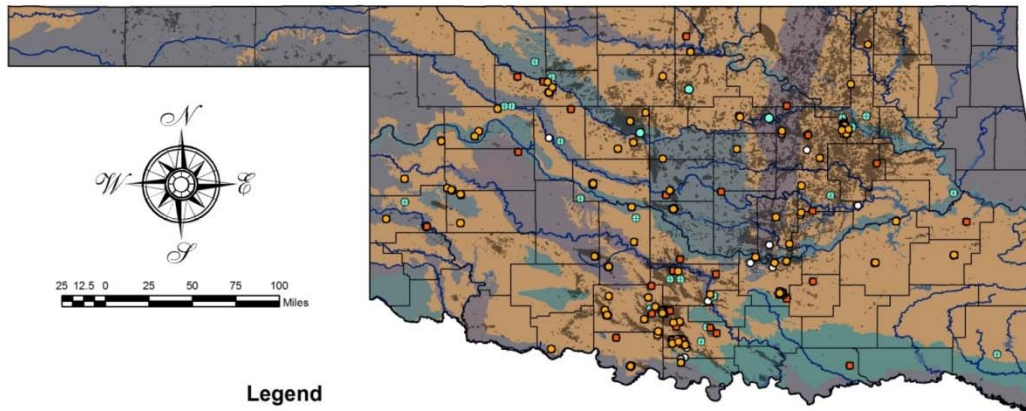
- Old unlined pits leak and overflow
- Gathering lines break
- Maintenance - corroded lines and tanks at well sites leak/spill
- Misc. spills while drilling



Salinity - Shallow verses Deep Wells

Salinity Exceeds in Shallow Groundwater

All OCC records as of October 2013



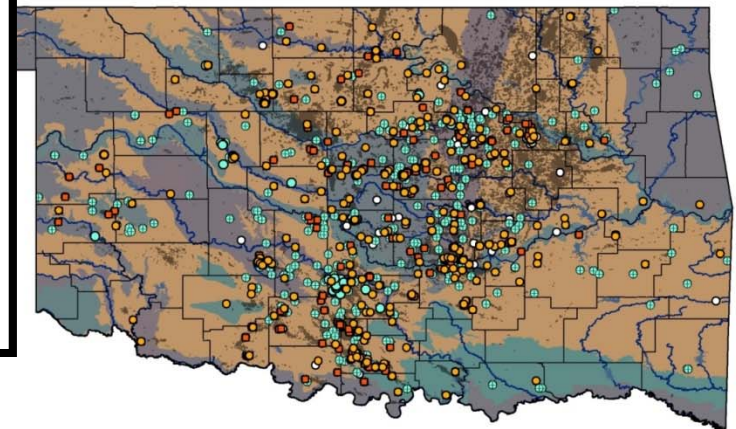
Legend

- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- ⊕ TSS > 500 ppm
- Sampled location with no exceeds
- ⬮ Historic dense oilfields and UIC fields
- ⬮ OWRB major aquifers

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Salinity Exceeds in Deep Groundwater

All OCC records as of October 2013



Legend

- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- ⊕ TSS > 500 ppm
- Sampled location with no exceeds
- ⬮ Historic dense oilfields and UIC fields
- ⬮ OWRB major aquifers

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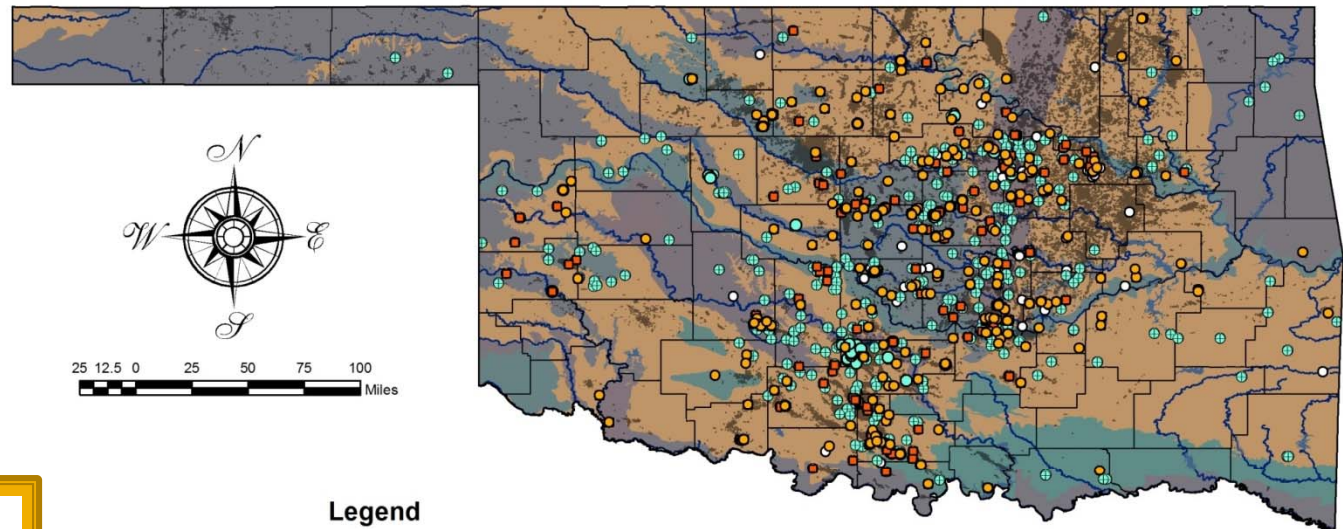
- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- ⊕ TSS > 500 ppm

***Note - Fewer shallow locations than deep were sampled ***

Salinity – all Drinking Water Wells

Salinity Exceeds in Drinking Water Wells

*Includes domestic, irrigation, livestock, public supply, and unspecified water wells.
All OCC records as of October 2013*

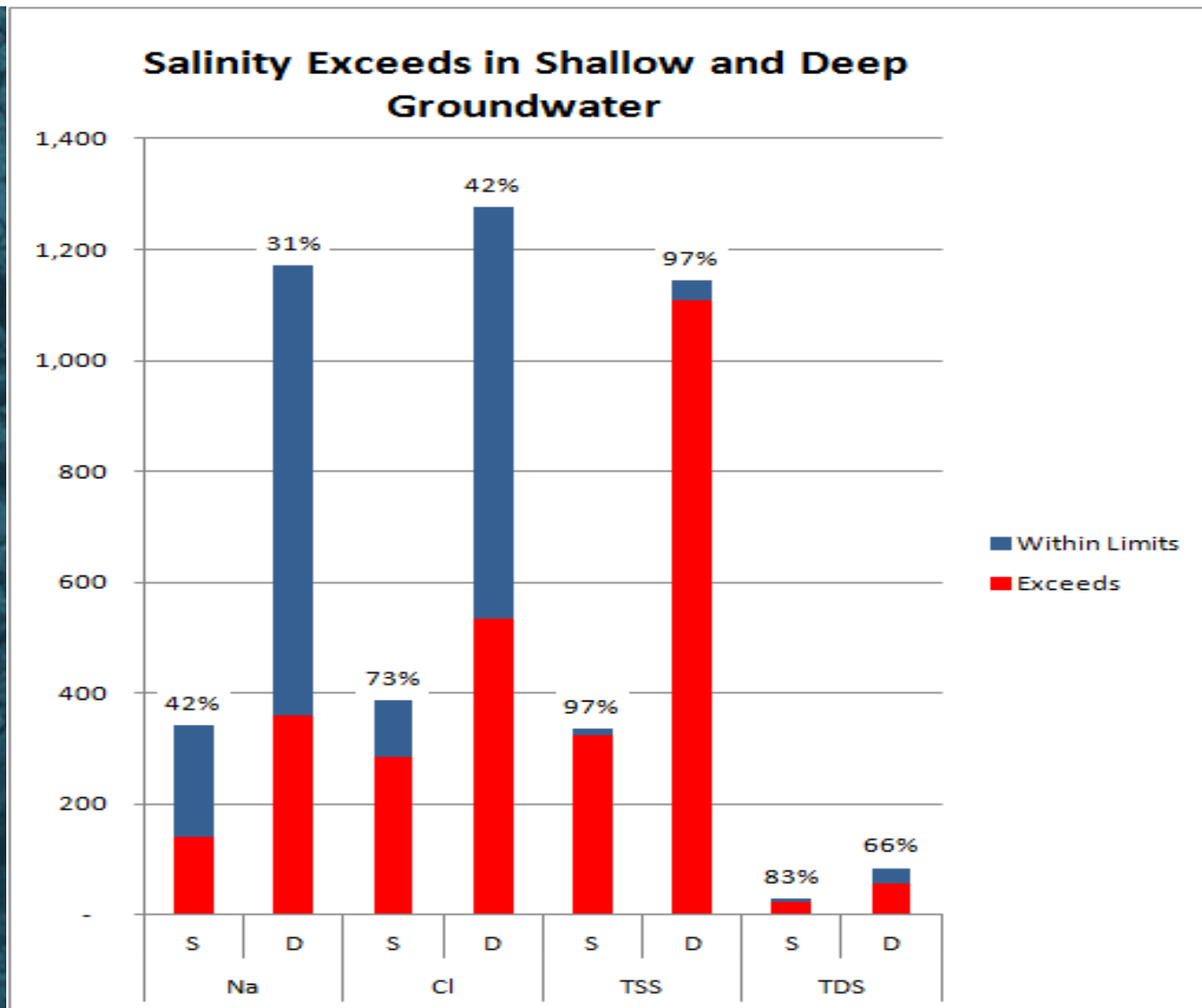


- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- ⊕ TSS > 500 ppm

- Legend**
- Sodium > 250 ppm
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Many of the locations we test for salinity DO exceed standards.



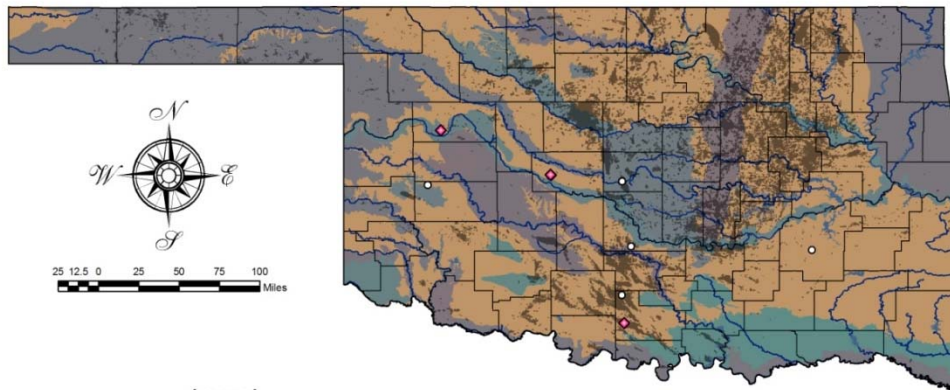
Contamination - Heavy metals

Contaminant		Maximum Contaminant Level (mg/L) - EPA unless specified otherwise	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Metals	As	>0.01 mg/L == >10 ug/L	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass and electronics production wastes
	Ba	>2 mg/L == >2000 ug/L	Increase in blood pressure	Discharge of drilling mud waste; discharge from metal refineries; erosion of natural deposits
	Cr	>0.1 mg/L == >100 ug/L	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
	Pb	>0.015 mg/L == >15 ug/L	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

Barium (drilling mud additive) – leaks from old pits

Barium Exceeds in Shallow Groundwater

All OCC records as of October 2013



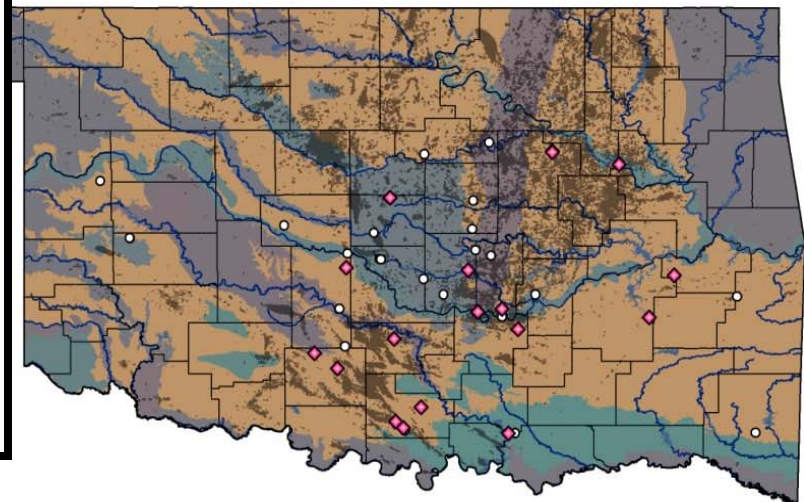
Legend

- ◆ Barium > 2 mg/L
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
- OWRB major aquifers

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Barium Exceeds in Deep Groundwater

All OCC records as of October 2013



Legend

- ◆ Barium > 2 mg/L
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
- OWRB major aquifers

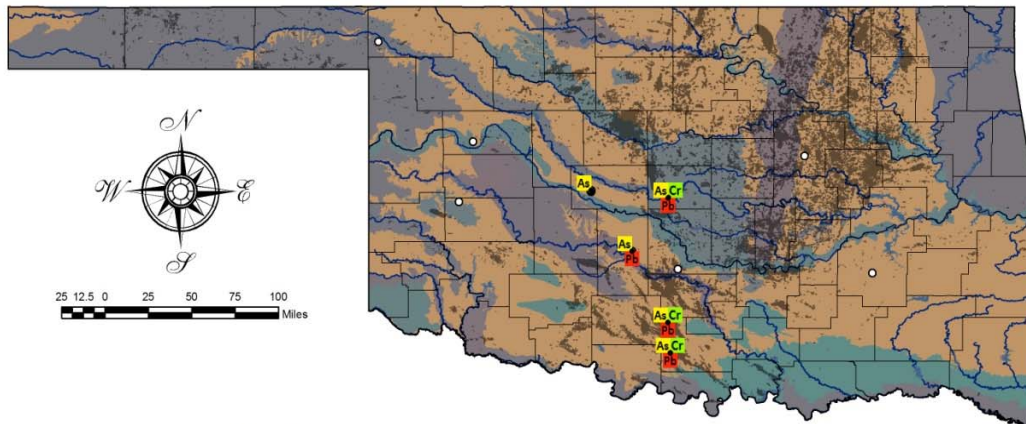
OCC water sample locations are determined by public request and suspicion of contamination. As a result, SAMPLE POINTS DO NOT REPRESENT A COMPREHENSIVE SURVEY OF STATEWIDE WATER CONTAMINATION.

Note – Only < 50 Barium and <80 other Metals samples collected at suspect locations

Arsenic, Chromium, and Lead (1920s-40s mud additives & biocides)

Heavy Metals Exceeds in Shallow Groundwater

All OCC records as of October 2013



Legend

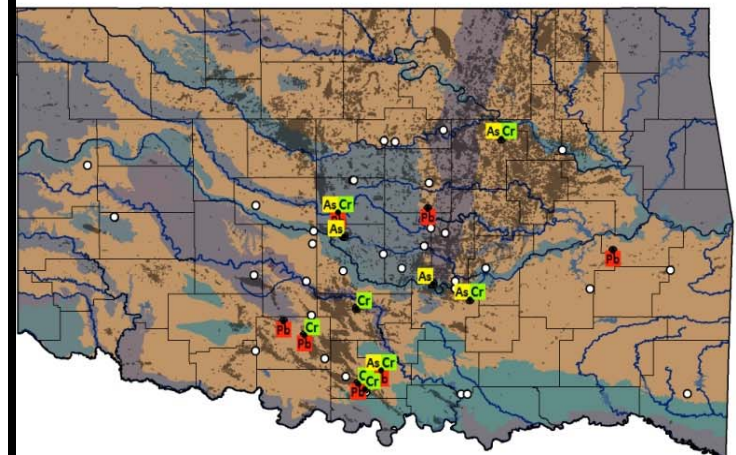
- As exceeds 18 selection
- Cr exceeds 18 selection
- Pb exceeds 17 selection
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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White Dots = Sample locs

Exceeds in Deep Groundwater

All OCC records as of October 2013



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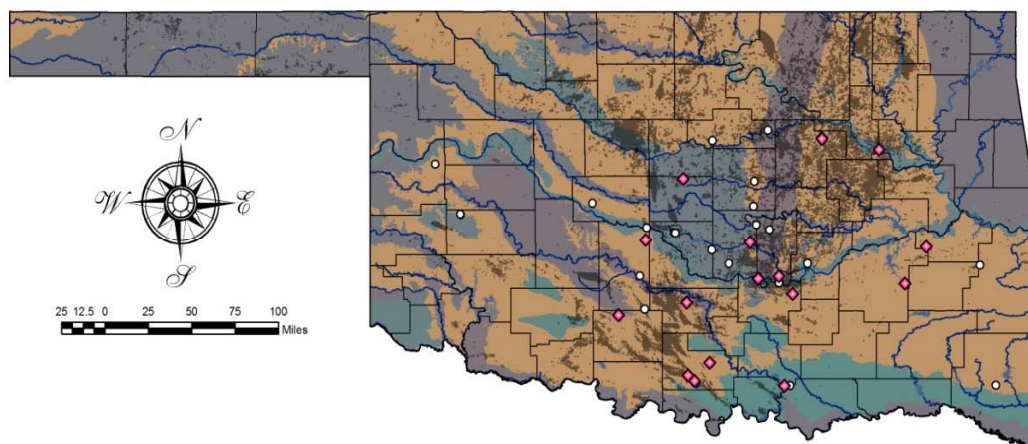
- Arsenic > 0.01 mg/L
- Chromium > 0.1 mg/L
- Lead > 0.015 mg/L
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
- OWRB major aquifers

Note - Only < 50 Barium and < 80 other Metals samples collected at suspect locations

Barium; Arsenic, Chromium, Lead; in Drinking Water Well Samples

Barium Exceeds in Drinking Water Wells

*Includes domestic, irrigation, livestock, public supply, and unspecified water wells.
All OCC records as of October 2013*



Legend

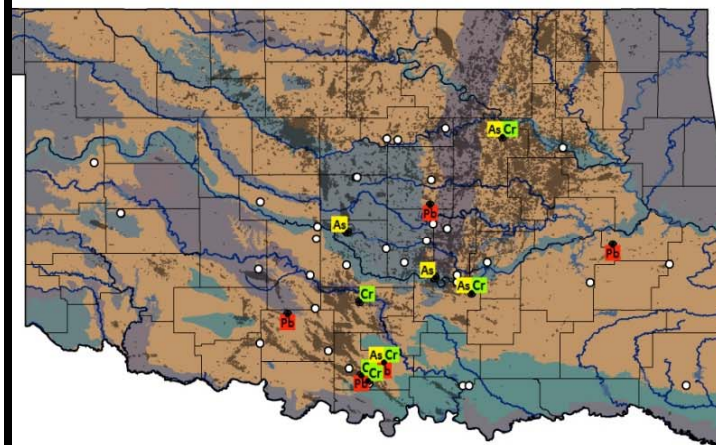
- ◆ Barium > 2 mg/L
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
- OWRB major aquifers

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Exceeds in Drinking Water Wells

*Includes domestic, irrigation, livestock, public supply, and unspecified water wells.
All OCC records as of October 2013*

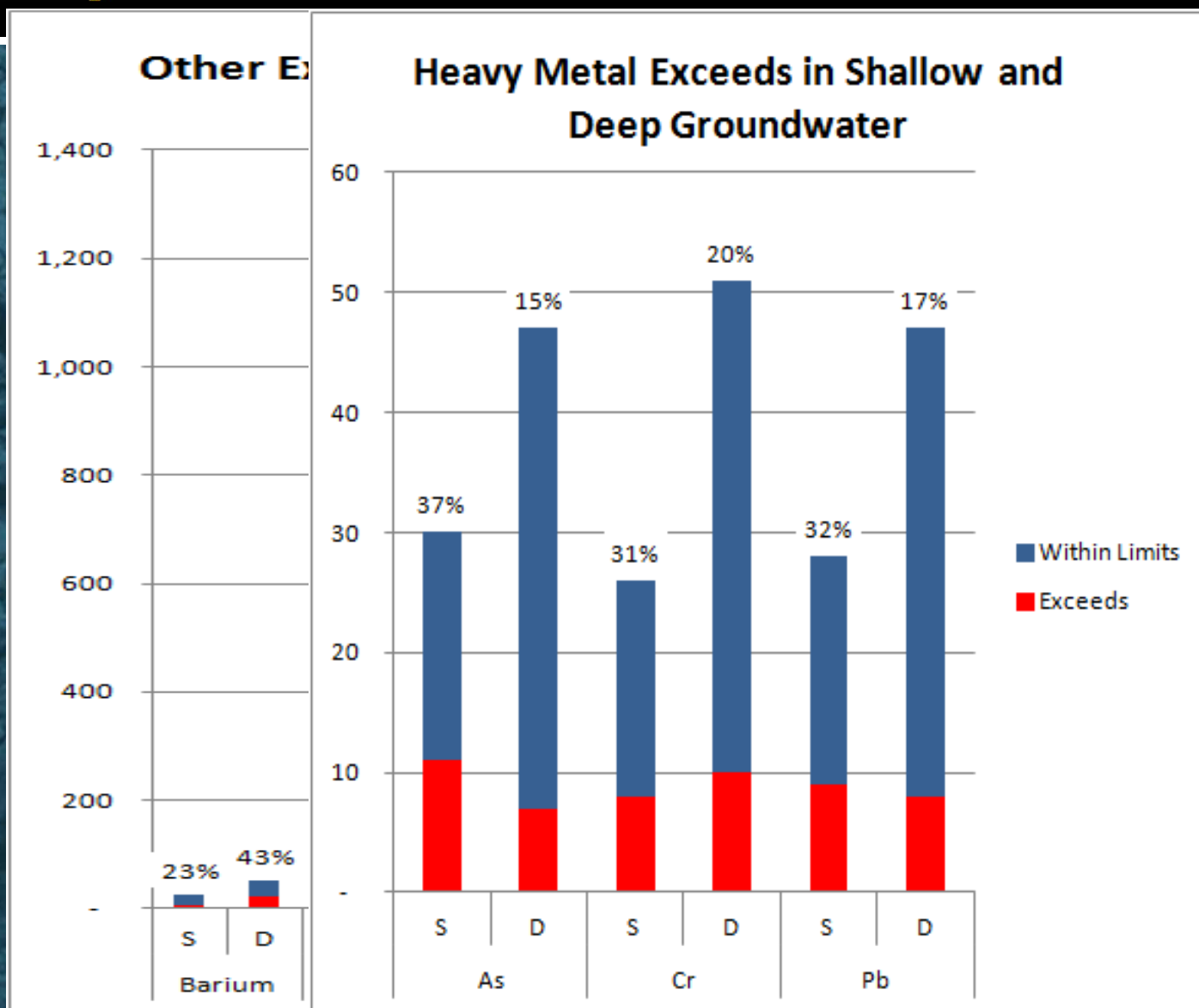


- ◆ As exceeds 10 selection
- ◆ Cr exceeds 18 selection
- ◆ Pb exceeds 17 selection
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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Note - < 50 Barium and <80 other Metals samples collected at suspect locations

At *Some* of the locations we tested, heavy metals exceeded standards



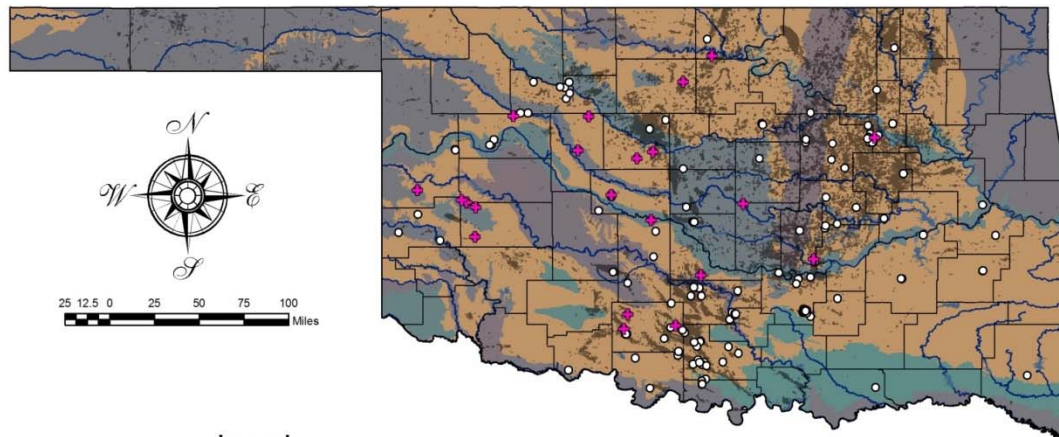
4. Other contaminants seen – NOT all are oilfield

Contaminant		Max. Contaminant Level (mg/L) - EPA unless specify other	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Other	Boron	>0.1mg/L (OCC)	High levels bad for many plants	Drilling fluid additive; natural in some produced H ₂ O (http://oilfield.gnsolidscontrol.com/oil-well-drilling-mud-fluids-conditioner/)
	Nitrates – NOT OILFIELD	>10 ppm	Infants <six months old who drink water with nitrate >10 ppm can become ill. Symptoms are shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
	pH	<6.5 or >8.5 (EPA secondary standard)		NaOH -drilling fluid additive, can be illegally dumped (https://www.osha.gov/SLTC/etools/oilandgas/drilling/msds.html)
	SO ₄ – Natural or Oilfield	>250 ppm (mg/L) (EPA secondary standard)		Natural sulfate (barium sulfate rose rocks), or oil drilling applications

Nitrate (NOT oilfield – fertilizers, septic)

Nitrates Exceeds in Shallow Groundwater

All OCC records as of October 2013



Legend

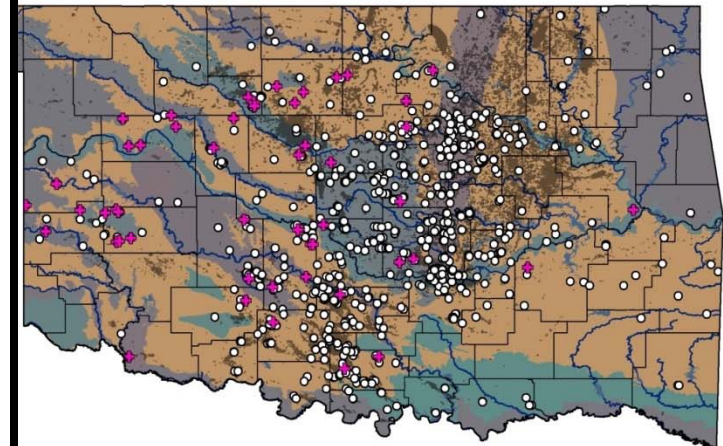
- ✚ Nitrates > 10 ppm
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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Exceeds in Deep Groundwater

All OCC records as of October 2013



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- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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Many more deep than shallow samples

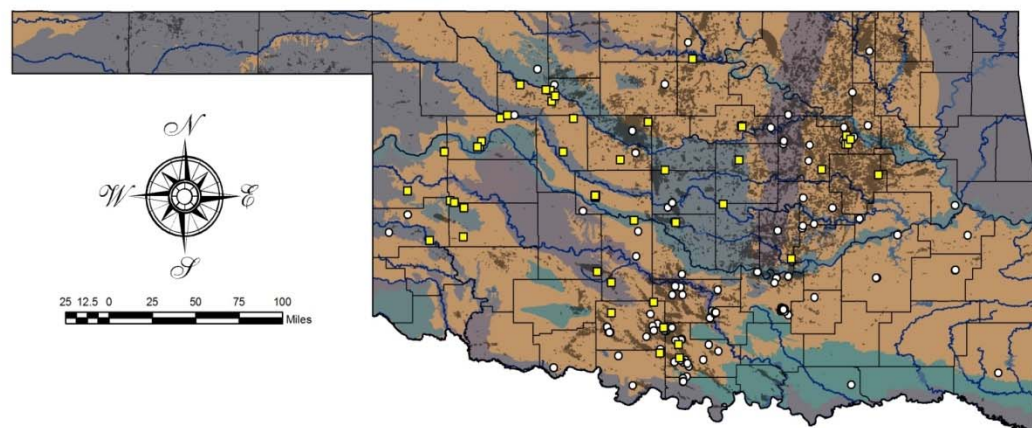
Sulfate (oilfield and other sources)



White Dots = Sample locs

Sulfates Exceeds in Shallow Groundwater

All OCC records as of October 2013



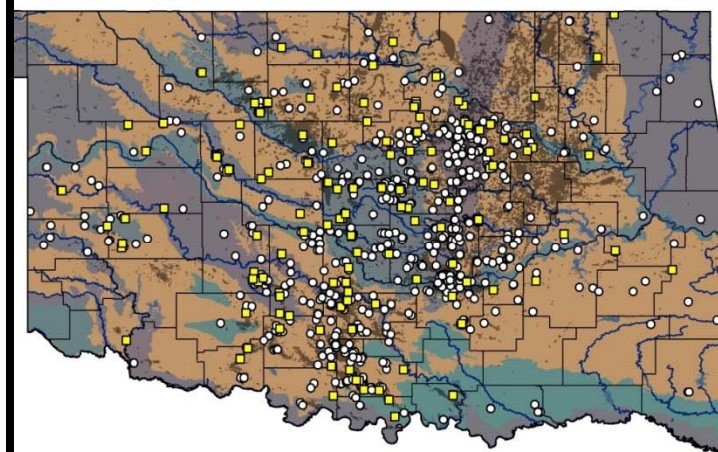
Legend

- Sulfates > 250 ppm
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
- OWRB major aquifers

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exceeds in Deep Groundwater

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Many more deep than shallow samples

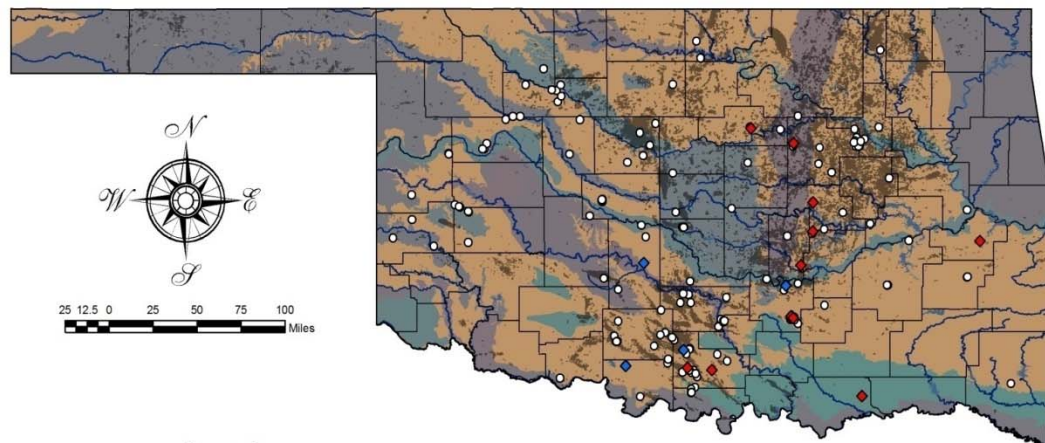
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pH (O&G brine acidic; NaOH additive Basic)

basic, pH high - NaOH; acidic, pH low – O&G brines

pH Exceeds in Shallow Groundwater

All OCC records as of October 2013



Legend

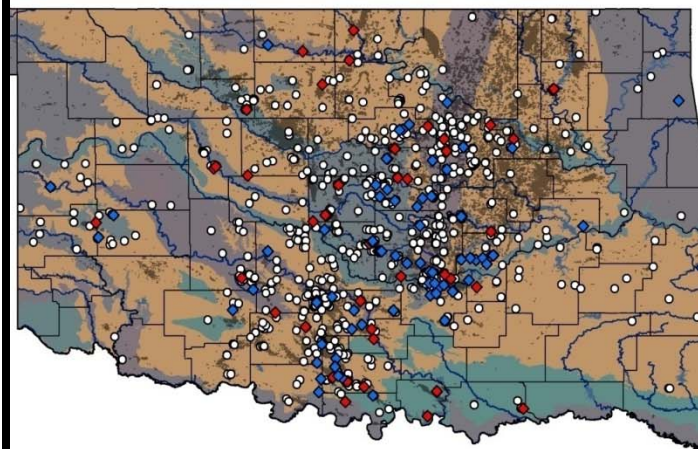
- ◆ pH > 8.5
- Sampled location with no exceeds
- ◆ pH < 6.5
- Historic dense oilfields and UIC fields
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pH Exceeds in Deep Groundwater

All OCC records as of October 2013



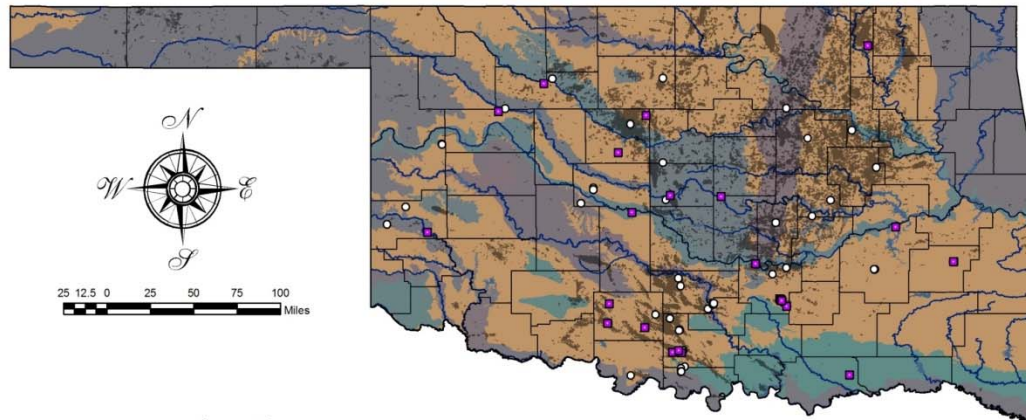
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Many more deep than shallow samples

Boron (in some O&G produced water, or can be natural)

Boron Exceeds in Shallow Groundwater

All OCC records as of October 2013



Legend

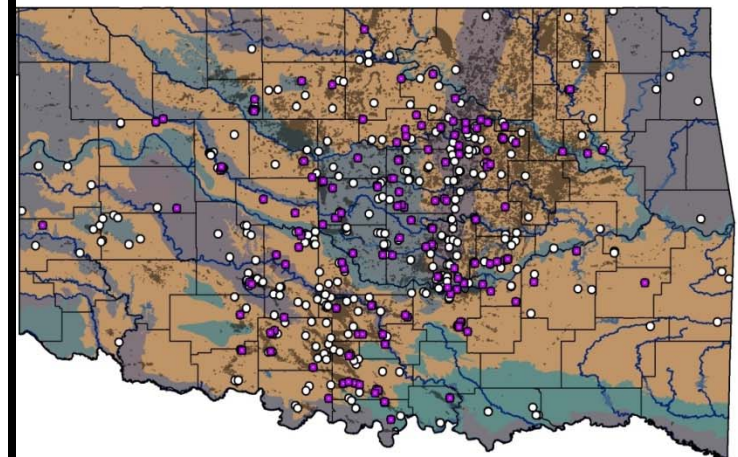
- Boron > 1 ppm
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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Exceeds in Deep Groundwater

All OCC records as of October 2013

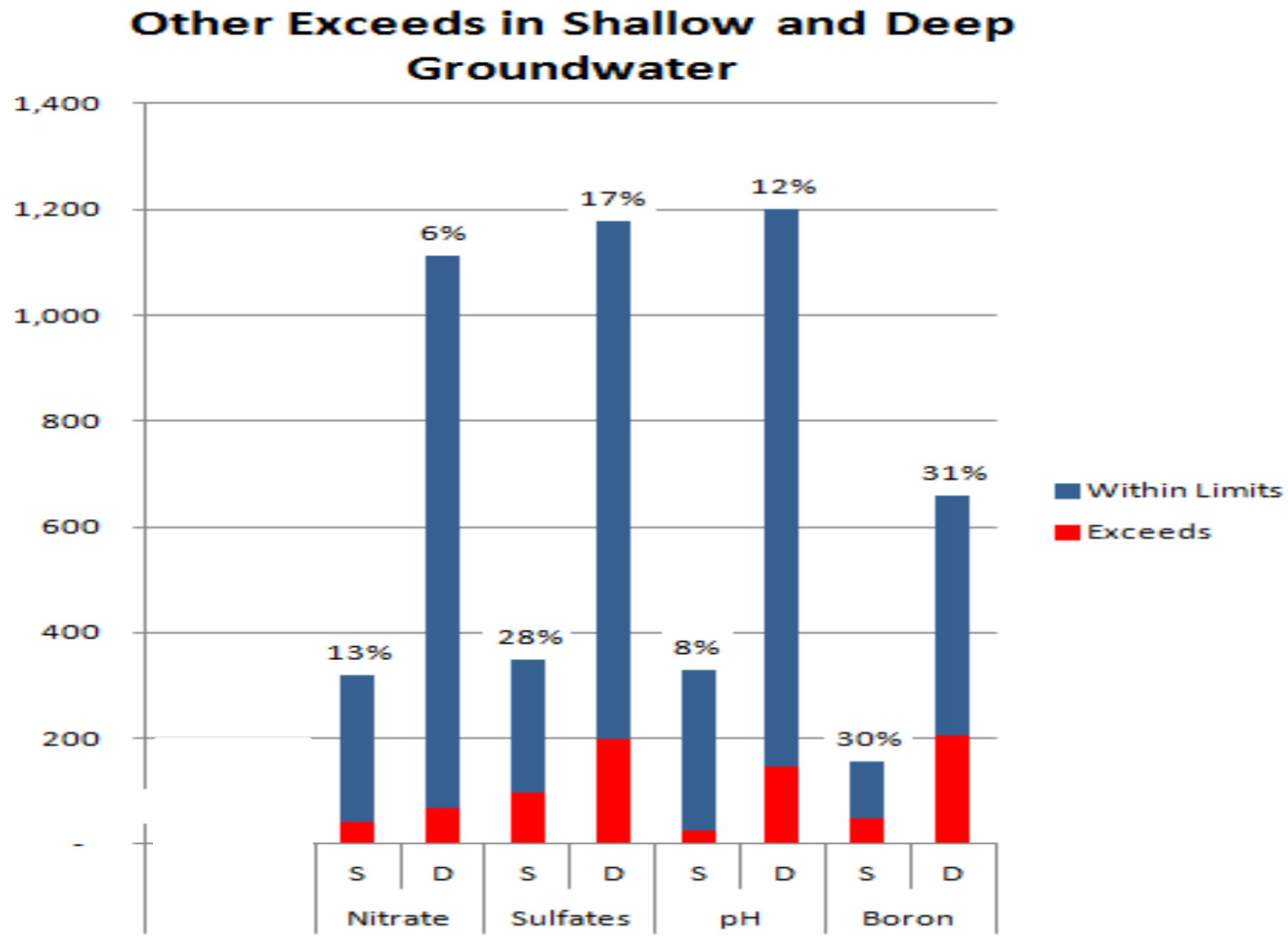


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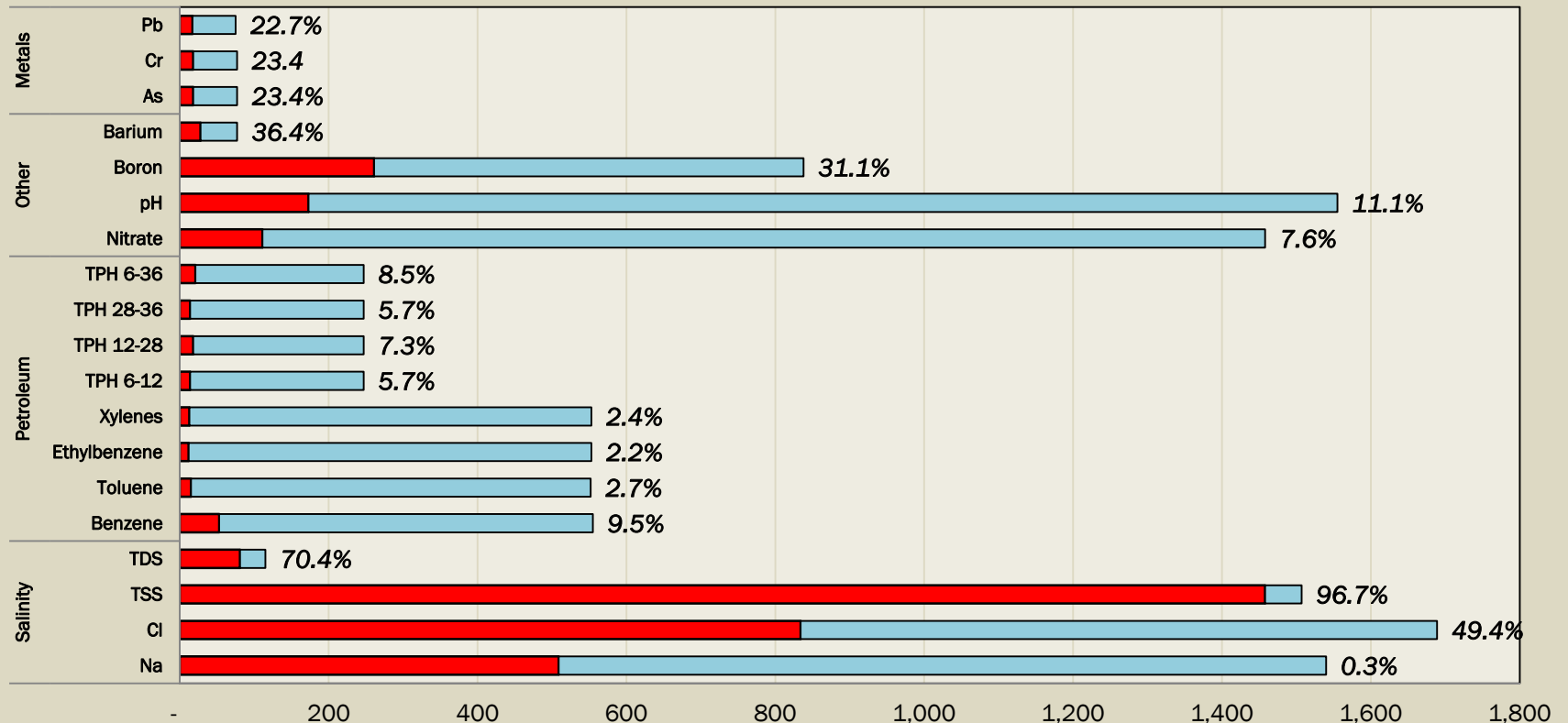
- Boron > 1 ppm
- Sampled location with no exceeds
- Historic dense oilfields and UIC fields
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Some of the locations we sample for nitrates, sulfates, pH, and boron exceed standards.



Summary, Groundwater Sample Results

Groundwater Sampling Locations and Exceeds



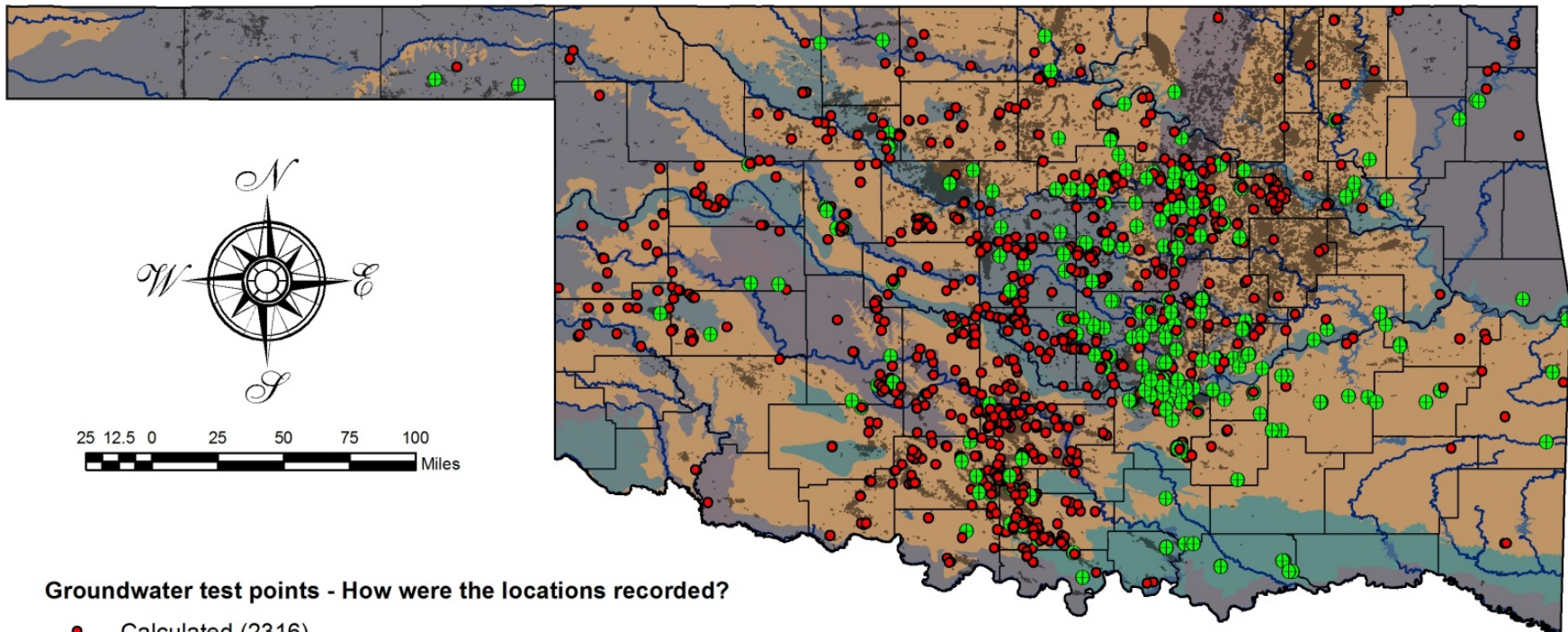
	Salinity				Petroleum								Other				Metals		
	Na	Cl	TSS	TDS	Benzen e	Toluene	Ethylbe nzene	Xylenes	TPH 6- 12	TPH 12- 28	TPH 28- 36	TPH 6- 36	Nitrate	pH	Boron	Barium	As	Cr	Pb
■ Characteristic exceeds standards	509	834	1,458	81	53	15	12	13	14	18	14	21	111	173	261	28	18	18	17
▢ Characteristic within standards	1,031	855	49	34	502	537	541	540	233	229	233	226	1,347	1,382	577	49	59	59	58
% of sampled locations with exceeds	0.3%	49.4%	96.7%	70.4%	9.5%	2.7%	2.2%	2.4%	5.7%	7.3%	5.7%	8.5%	7.6%	11.1%	31.1%	36.4%	23.4%	23.4%	22.7%

Number of Sampled Locations

4. Data Location Accuracy - GPS

Locations of Groundwater Test Points

*Only 18% were recorded with GPS coordinates. The rest were calculated from given Township, Range, Section and any quarters.
All OCC records as of October 2013*



Groundwater test points - How were the locations recorded?

- Calculated (2316)
- ⊕ GPS coordinates taken (516)

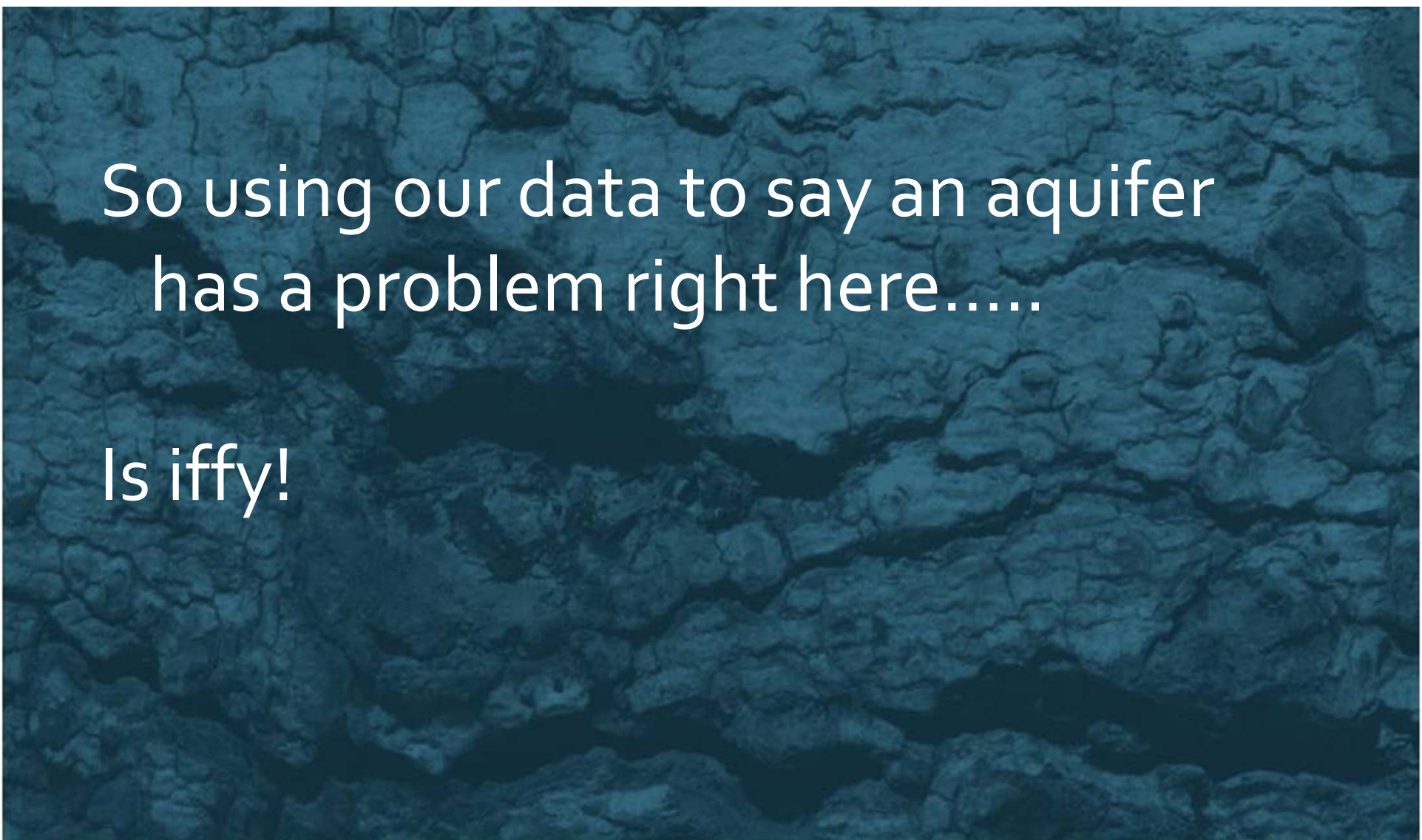
*OCC water sample locations are determined by public request and suspicion of contamination. As a result,
**SAMPLE POINTS DO NOT REPRESENT A
COMPREHENSIVE SURVEY OF STATEWIDE
WATER CONTAMINATION.***

How Accurate are Sampling Locations?

- Only 18% (and growing) of our sampling locations had GPS sampling locations, accuracy within a few feet.
- While a location that gives all of the relevant quarters (e.g. NWNWSWSE of section 1.....) is also fairly accurate,
- Many older sampling locations had only partial quarters (NW/4 of section 1);
- For some older sampling locations we only have the section-Twp-Rng, no quarters!.

How Accurate are Sampling Locations?

- The locations vary a lot in sampling location accuracy
 - A possible ~10' location error (have Qtr-Qtr-Qtr-Qtr) to
 - Somewhere near the center of 160 acres (1 Qtr only) to
 - Somewhere in a square mile (have only the section#).
 - And a few of the calculated locations had the township as the smallest unit, which gives you an error of up to 4.3 miles ($3\sqrt{3}$ miles, from centroid to corner of square).

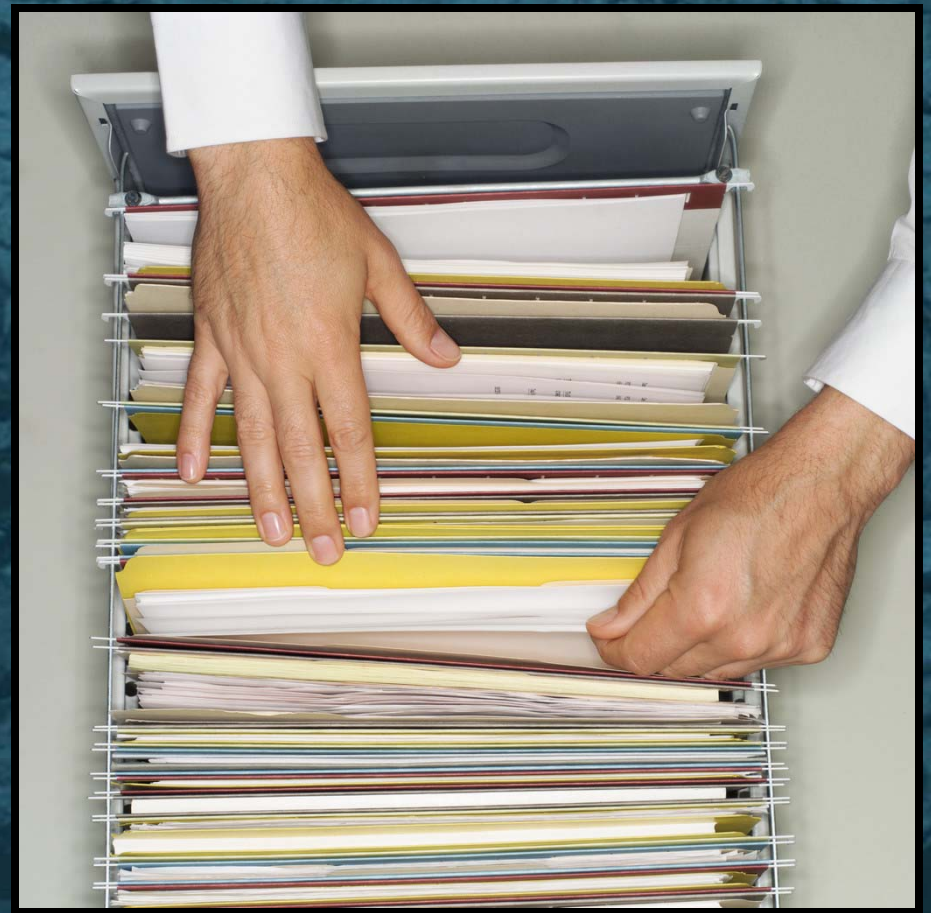


So using our data to say an aquifer
has a problem right here.....

Is iffy!

Improving the data (if have time)

- Many paper records may have the water well address written on the form, but it was not recorded in the database.
- We can go back, enter it, and geocode it.
- Must go through the ~2800 old paper records.....Someday!



Questions?

Thanks!

