Preventing New Groundwater Pollution Problems from Old Oilfield Areas

presented by

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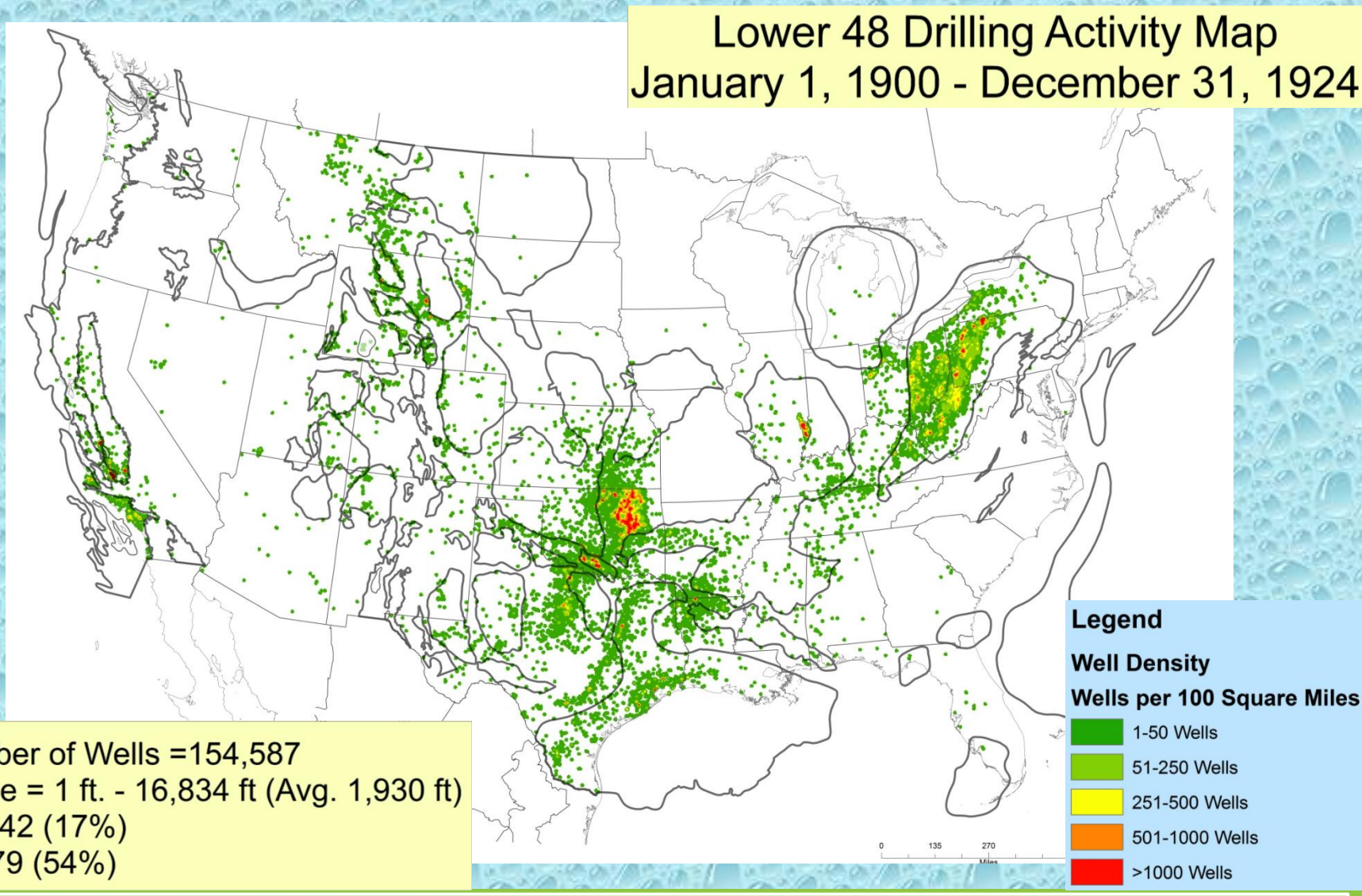
Association Of Central Oklahoma Governments

The Problem

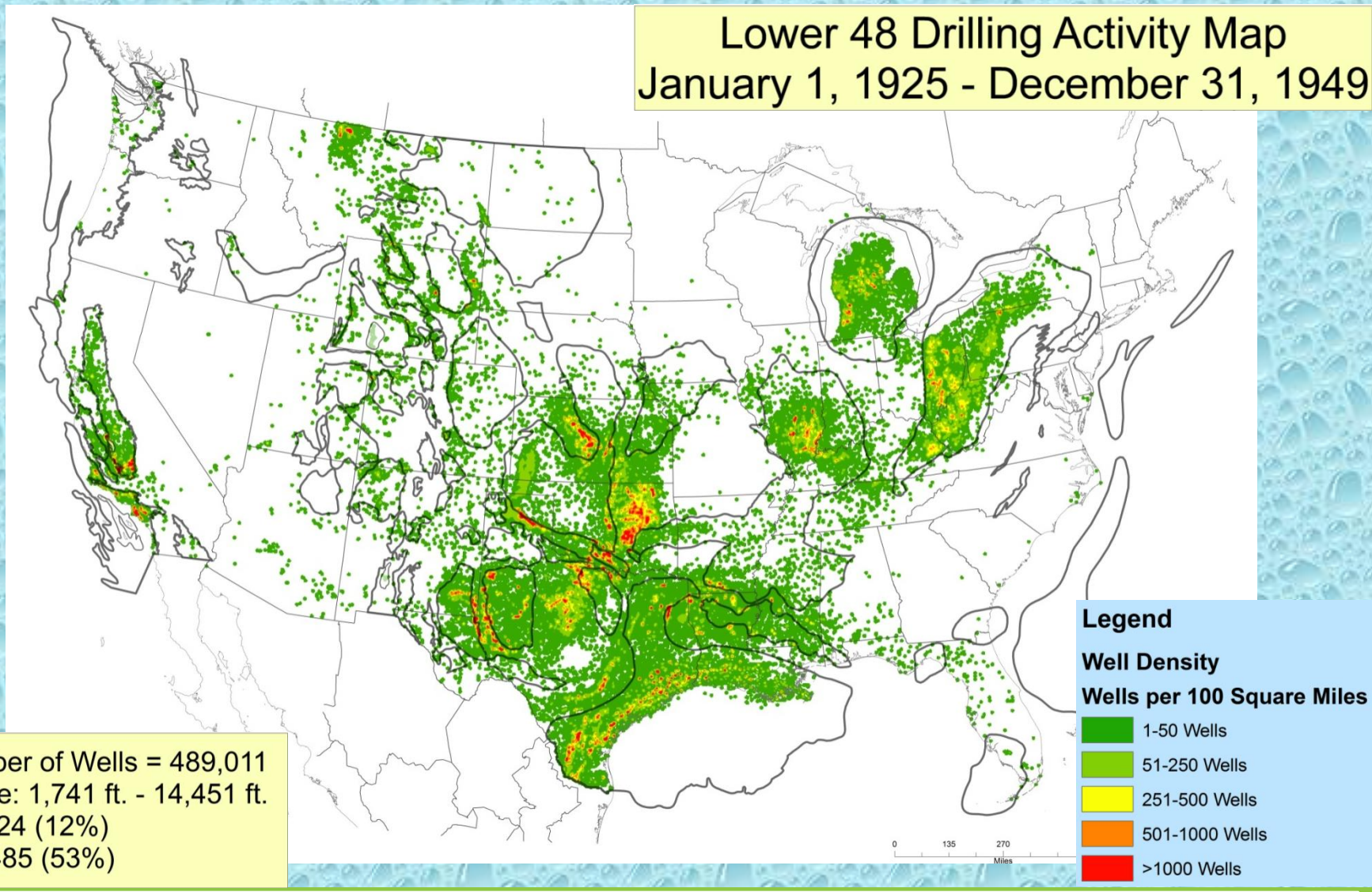
- Like many states, Oklahoma has extensive old oilfields, many now abandoned.
- Businesses, schools, apartments and subdivisions are being built, or people are building their dream country homes, in some of these areas –
- Without knowing what problems might be found, or even that the area was (40 years ago) an oilfield!

Natural Gas and Oil Historic Drilling Activity

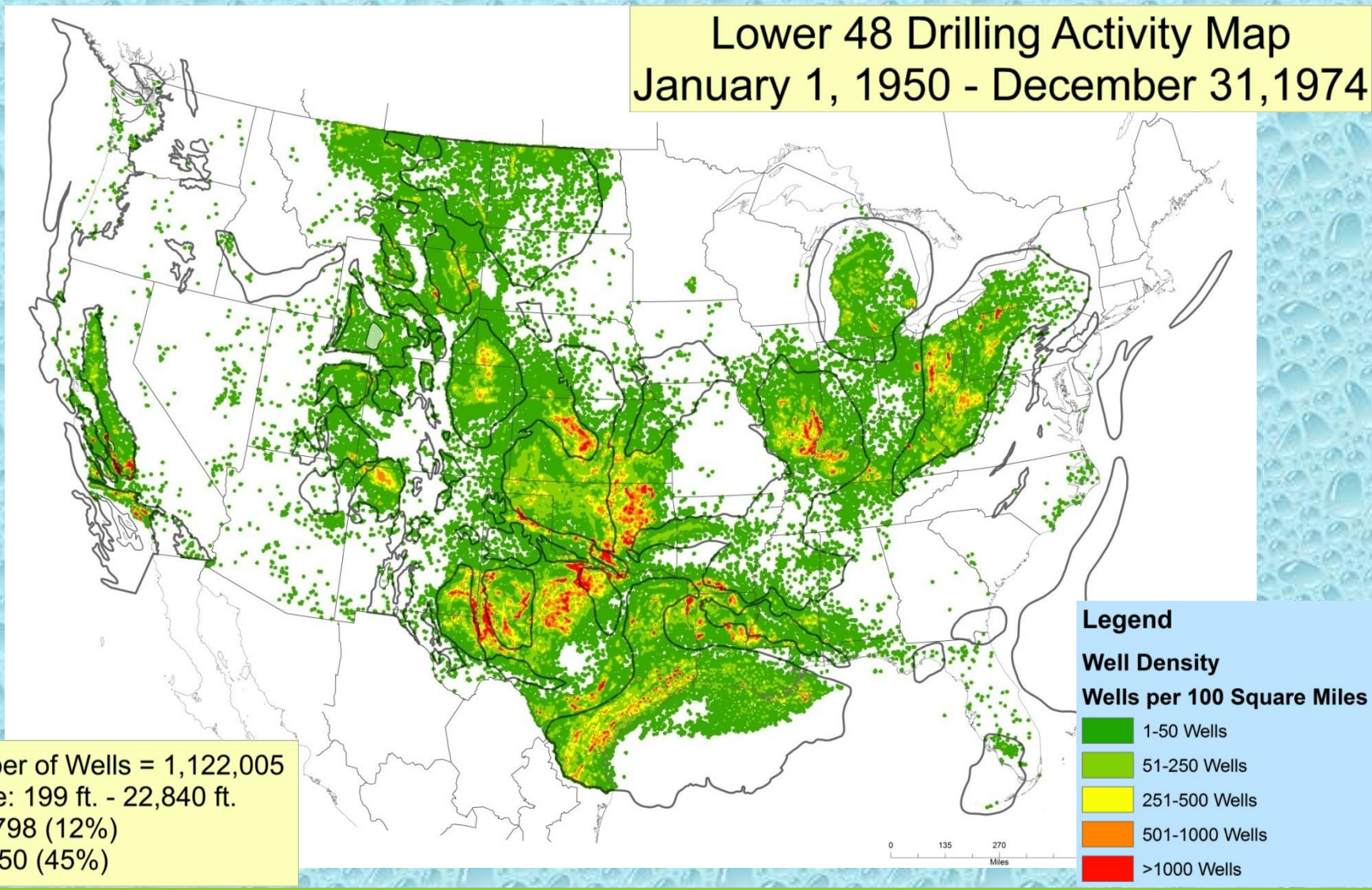


Total Number of Wells =154,587
TVD Range = 1 ft. - 16,834 ft (Avg. 1,930 ft)
Gas= 26,242 (17%)
Oil = 83,779 (54%)

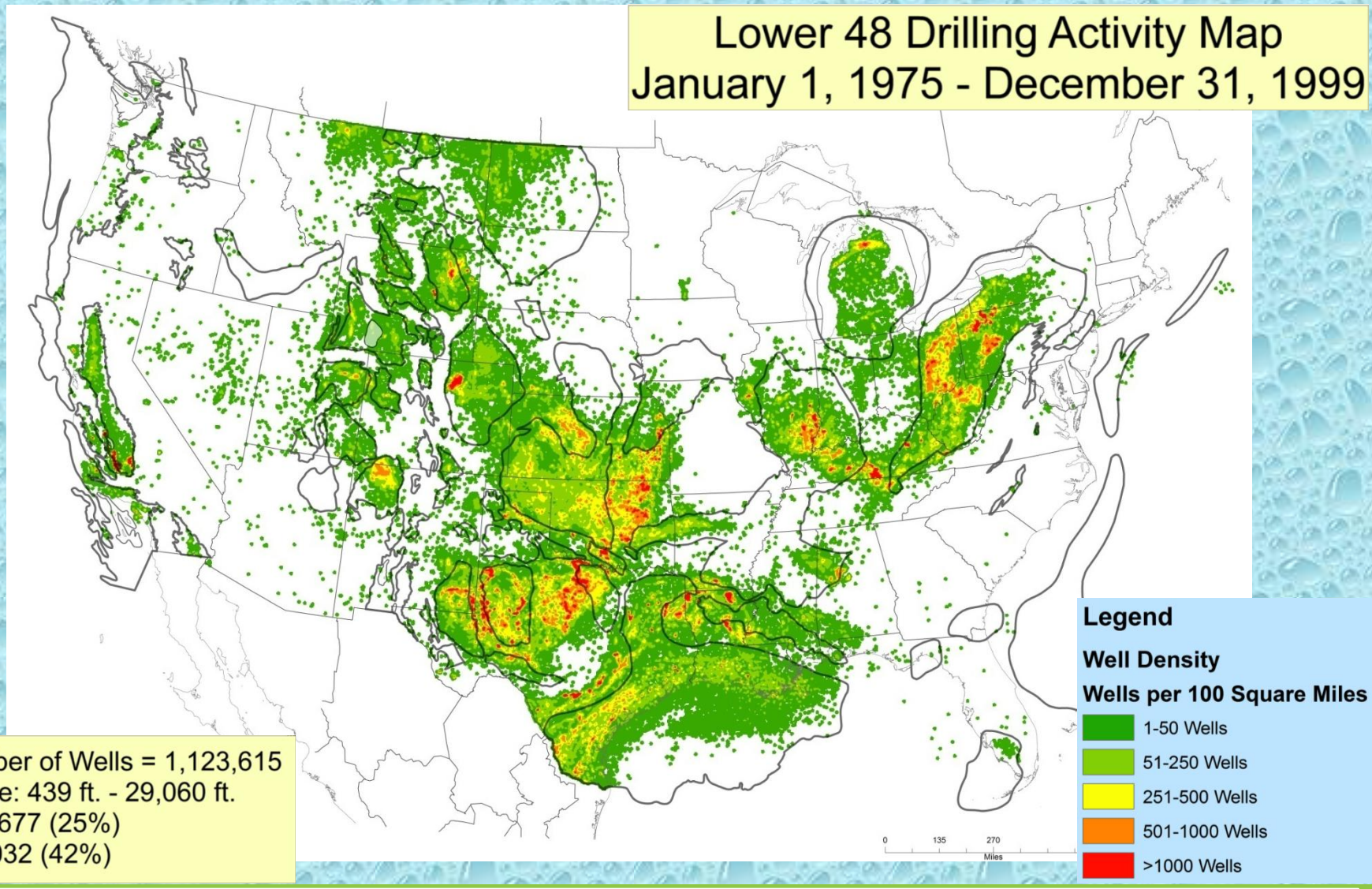
Natural Gas and Oil Historic Drilling Activity



Natural Gas and Oil Historic Drilling Activity



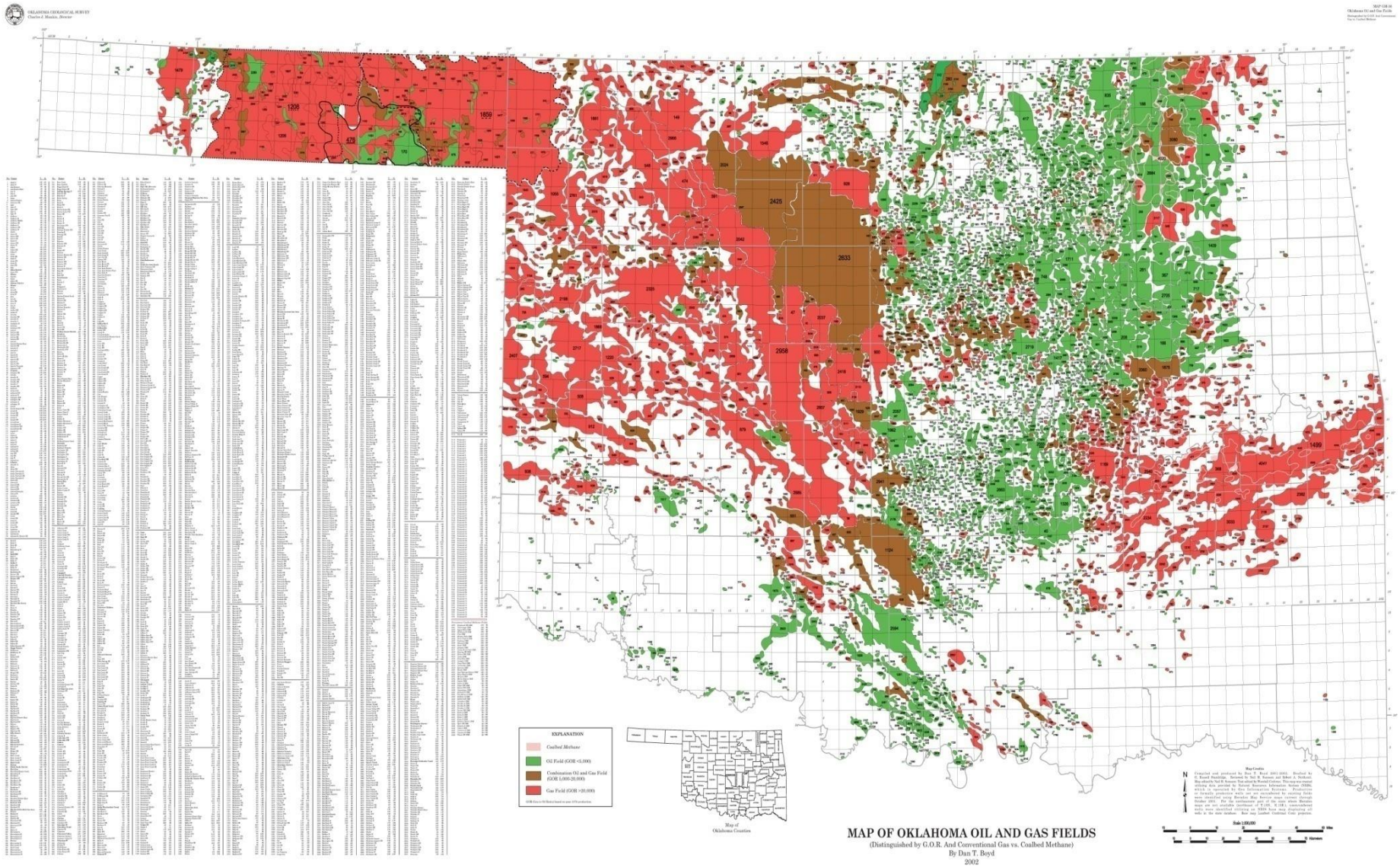
Natural Gas and Oil Historic Drilling Activity



Total Number of Wells = 1,123,615
TVD Range: 439 ft. - 29,060 ft.
Gas= 297,677 (25%)
Oil = 522,032 (42%)

Prudent Development: Realizing the Potential of North America's Abundant Natural Gas and Oil Resources. National Petroleum Council. 2011.

Historic Oil & Gas Fields (>500,000 wells) Affect >60% of Oklahoma

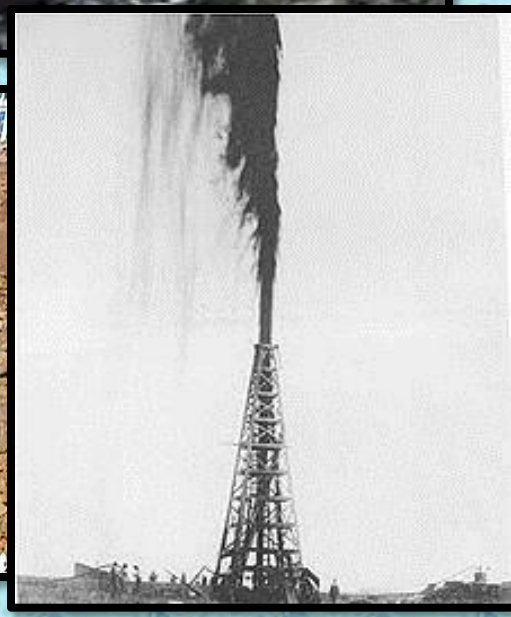


OKC Once Looked Like This – Oilfield Effects Can = Industrial Activity, for Acres

Or this - Tonkawa, 90 years ago

1. Introduction
How Contamination Occurred

- Old pipelines corrode & leak to soil, water; mud pits left.
- Old surface spills (oil, brine, drilling mud) not cleaned up
- Pressure/blowouts, surface or into subsurface (aquifers)
- Poor maintenance, equipment at well site corroded
- Recently or “Back in the Day”



Recent Accidents, and “Back in the day”

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

1940 – saline brine allowed to flow down roadside ditch

If Groundwater is Affected

Groundwater :

- Supplies ~40% of all water used in Oklahoma
- Provides water to > 300 Oklahoma cities and towns
- Supplies water to 295,000 Oklahomans with domestic wells
- Supplies 73% of all Irrigation water for Agriculture - It is our food too!

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

- Most of our groundwater sampling is done following a known spill or a well owner complaint
- So the groundwater sampling Corp Comm has done, that we will be showing you, is biased to the bad, NOT an indicator of overall groundwater quality
- OWRB's new (started 2013) statistically random 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!

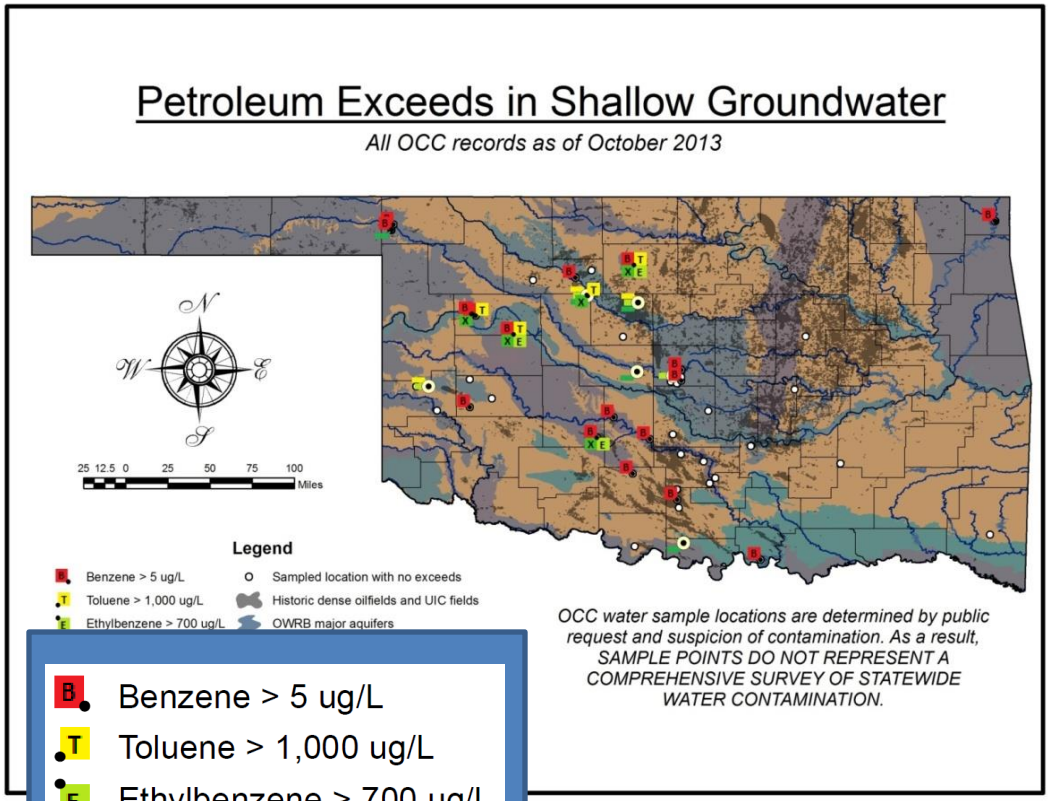
2. Contamination - Petroleum

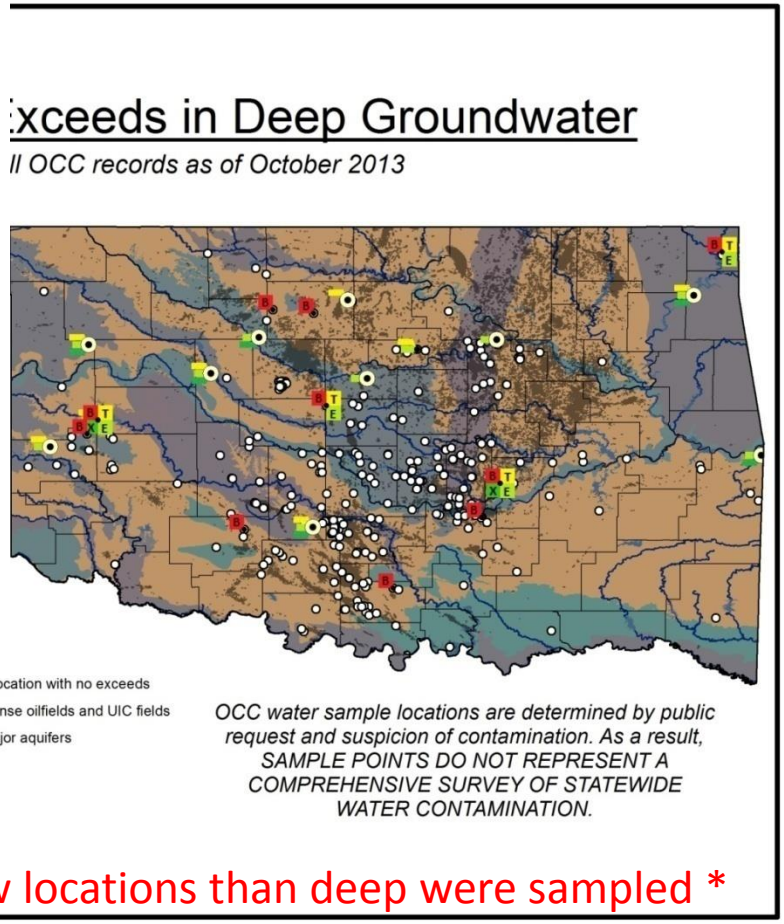
Recent spill

Old dry oil and
Oil stained soil

Petroleum in Groundwater – Shallow and Deep

White Dots = Samples not exceed



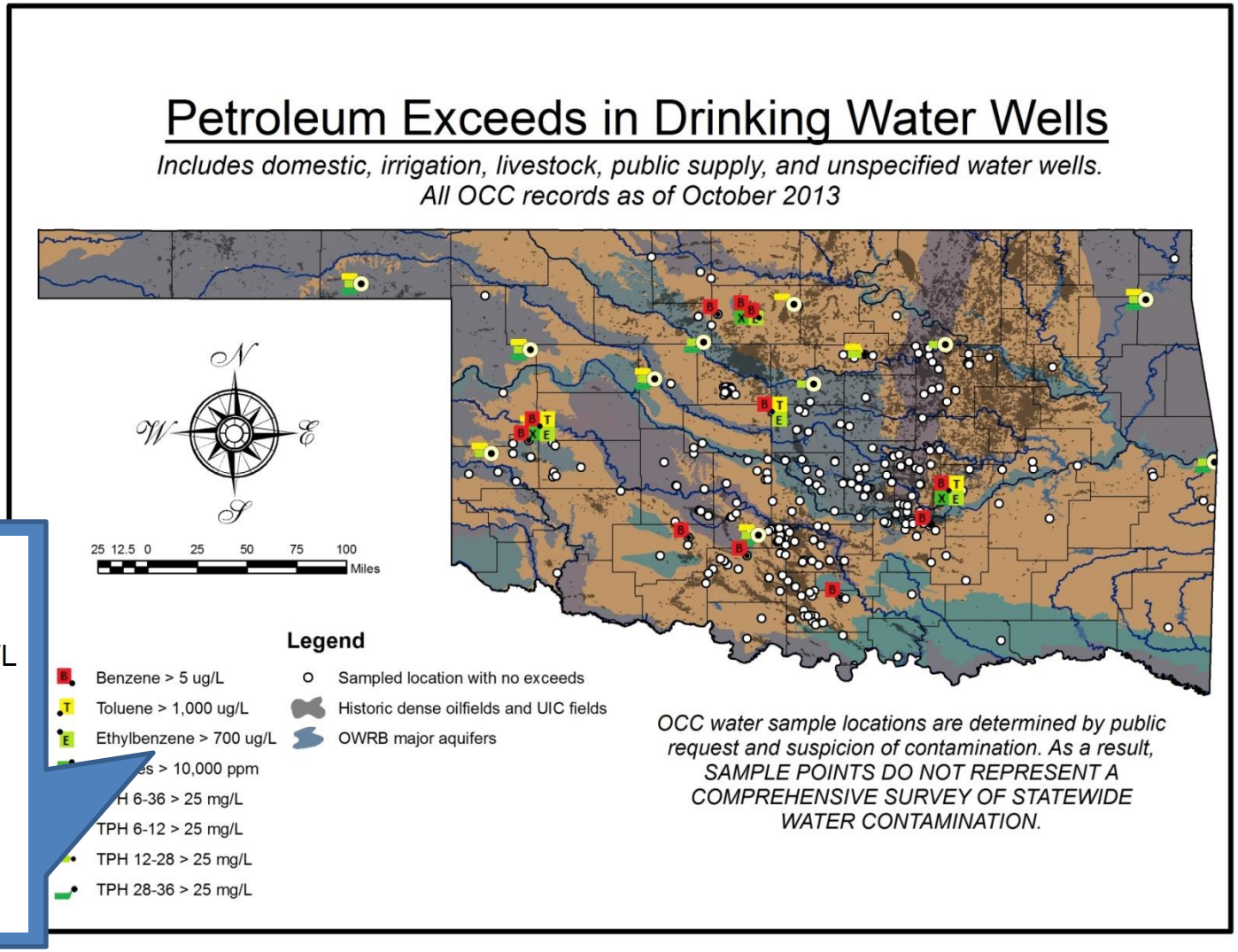


- Benzene > 5 ug/L
- Toluene > 1,000 ug/L
- Ethylbenzene > 700 ug/L
- Xylenes > 10,000 ppm
- TPH 6-36 > 25 mg/L
- TPH 6-12 > 25 mg/L
- TPH 12-28 > 25 mg/L
- TPH 28-36 > 25 mg/L

*Note - Fewer shallow locations than deep were sampled *

Petroleum inDrinking Water Wells

White Dots = Samples not exceed



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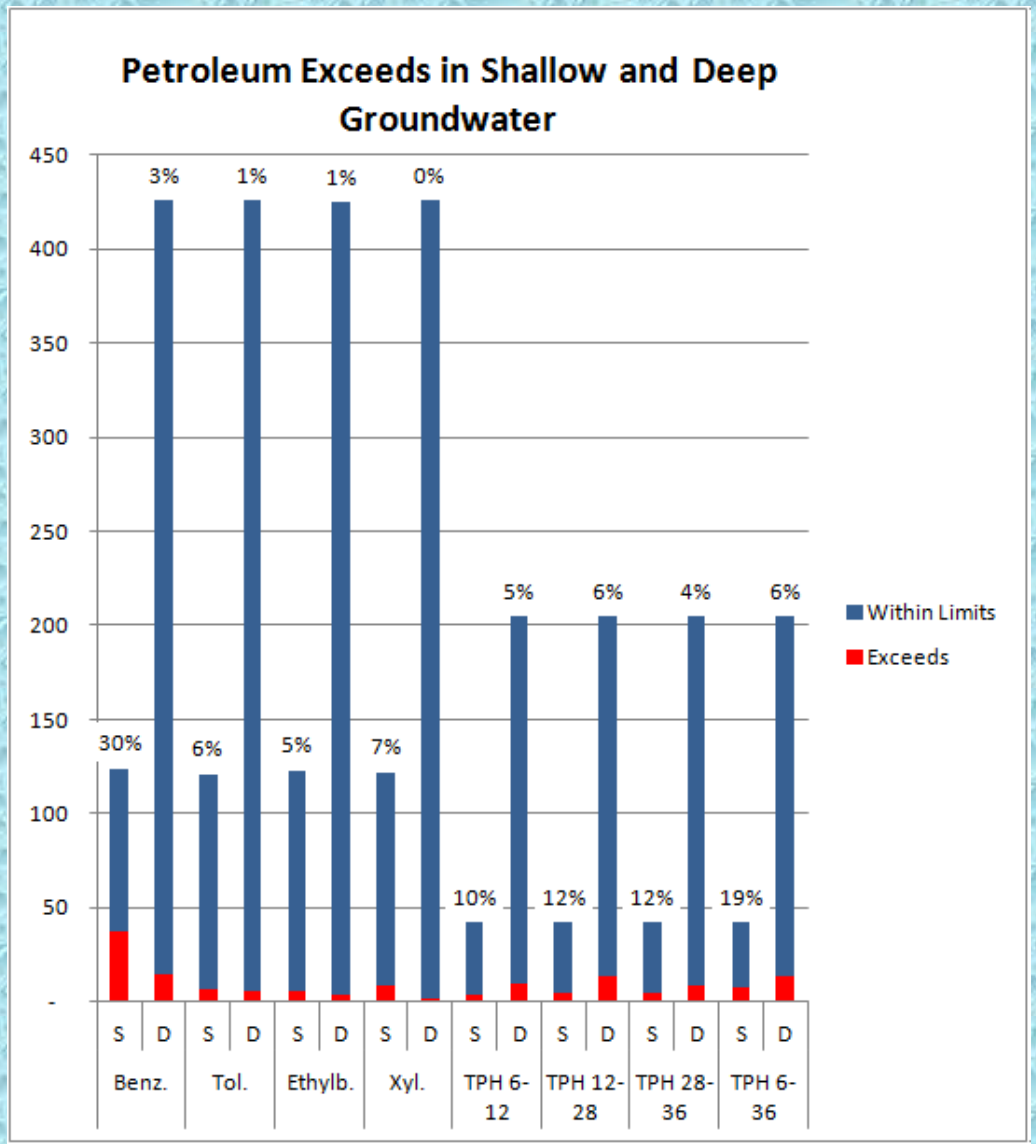
Few of the locations we sampled for petroleum exceed standards.

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



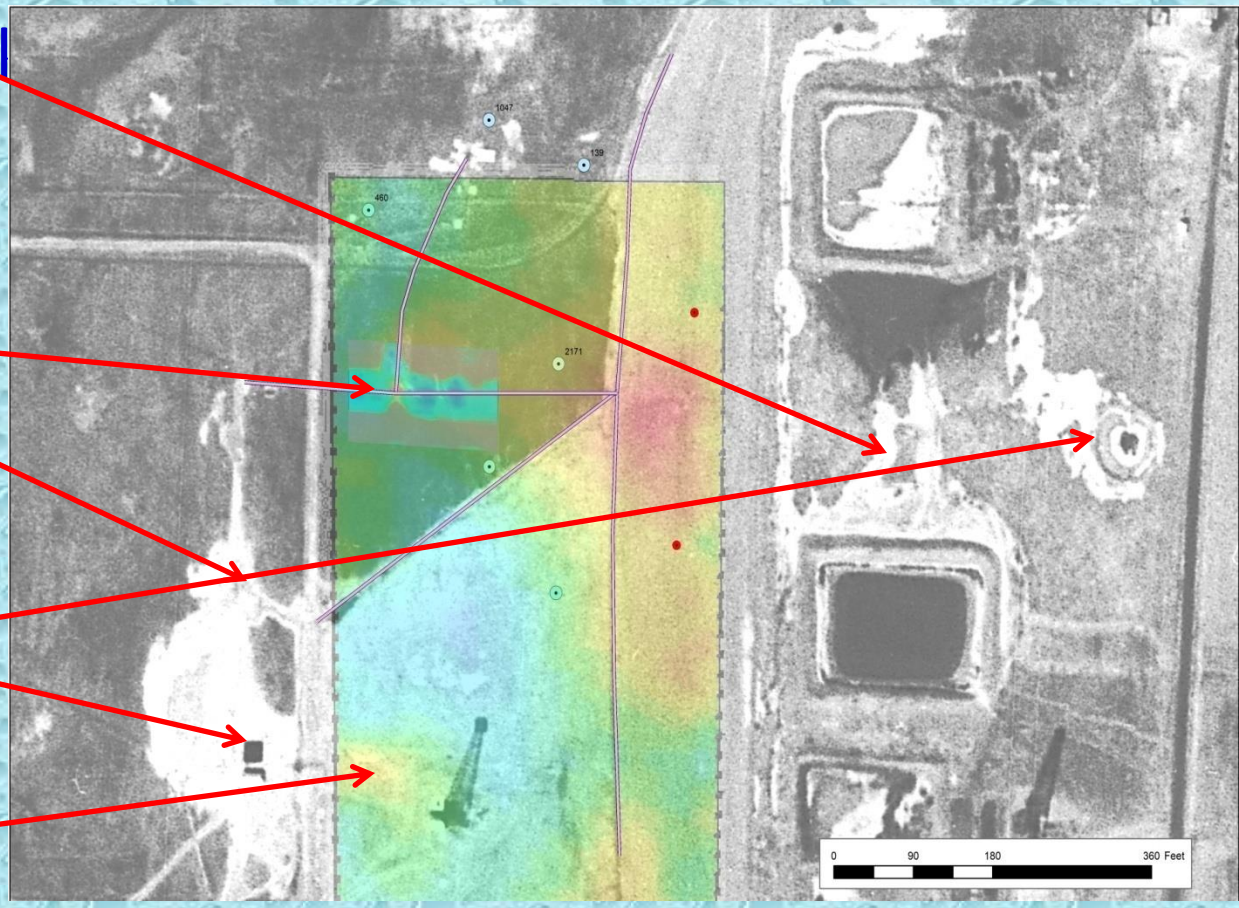
Salinity

- Salinity kills plants, leads to denuded, eroded areas where only a few salt-loving plants grow.
- Much salt tastes bad.
- Na can affect blood pressure.
- -**Saline soil** can ruin foundations, water lines, and other infrastructure

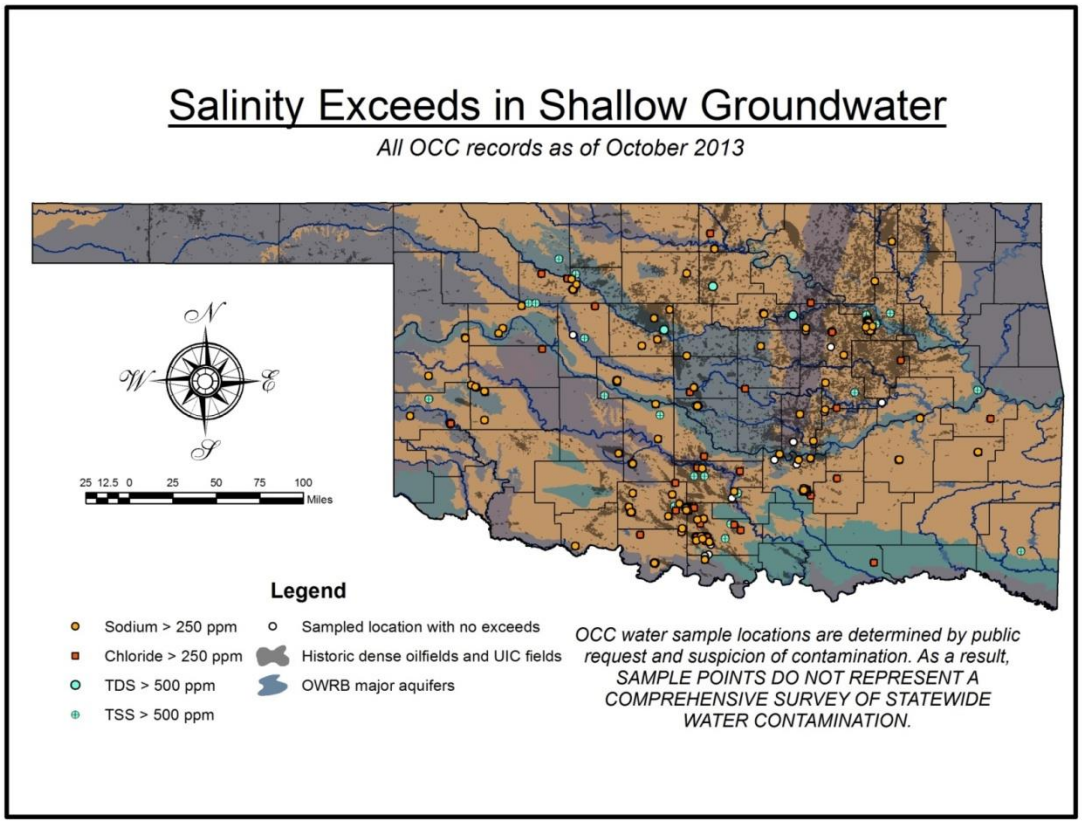
- TDS – EPA secondary low 500 ppm (mg/L)
- Na and Cl EPA secondary standard 250 ppm (mg/L)

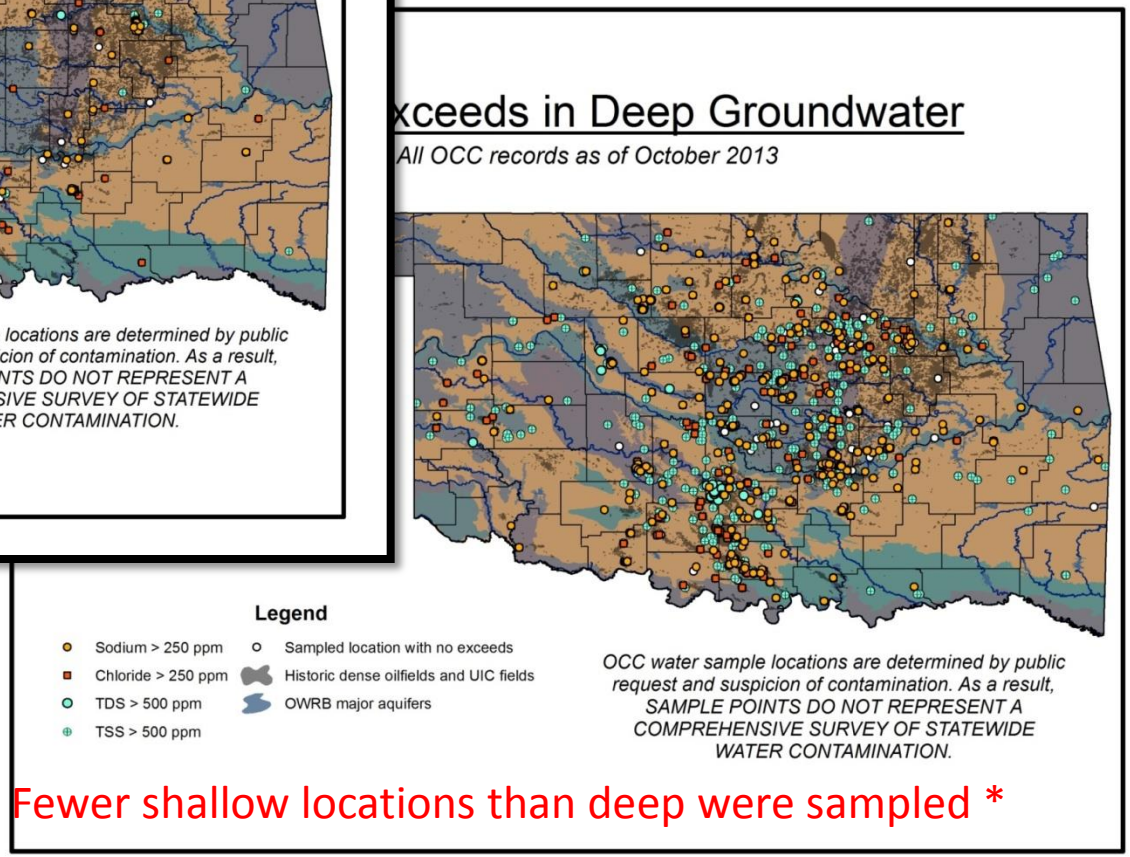
How Contamination Occurred (1950's Aerial Photo)

- 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

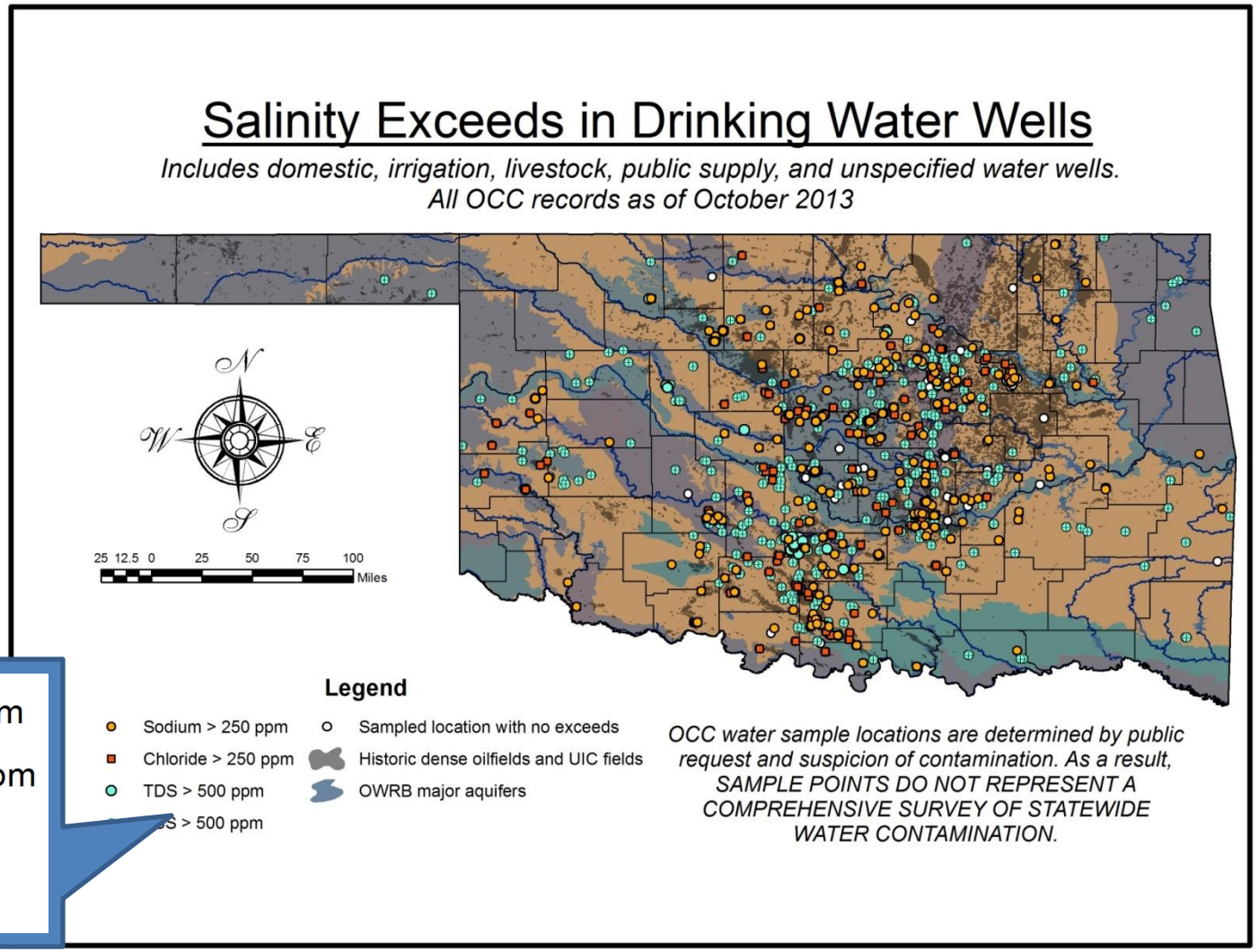




- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- TSS > 500 ppm

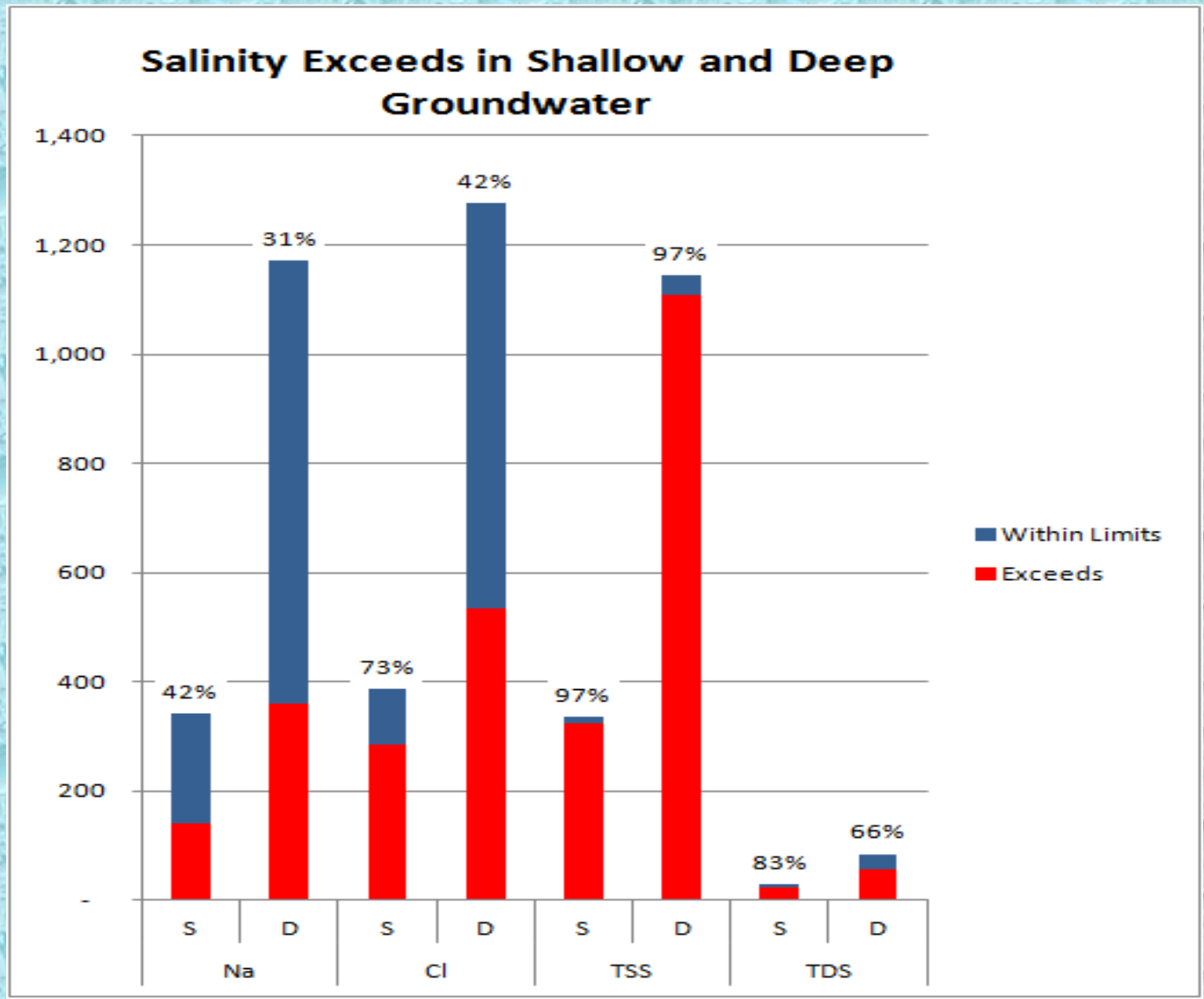
*Note - Fewer shallow locations than deep were sampled *

Salinity – all Drinking Water Wells



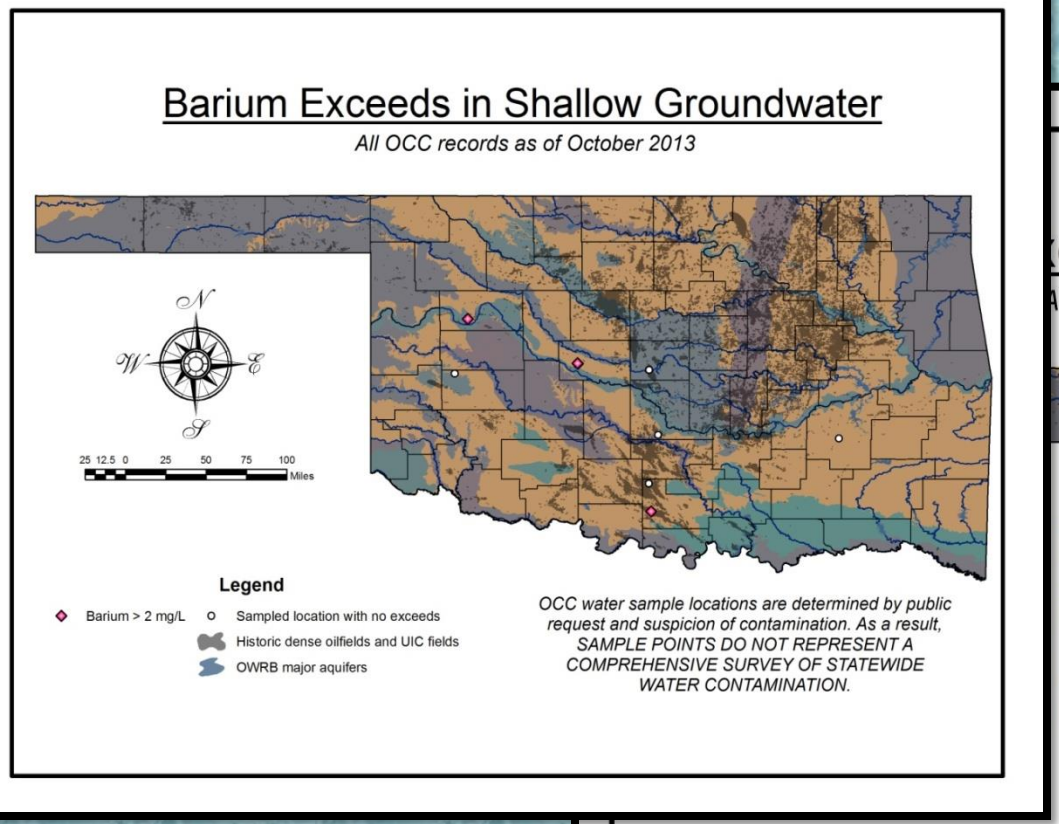
- Sodium > 250 ppm
- Chloride > 250 ppm
- TDS > 500 ppm
- TSS > 500 ppm

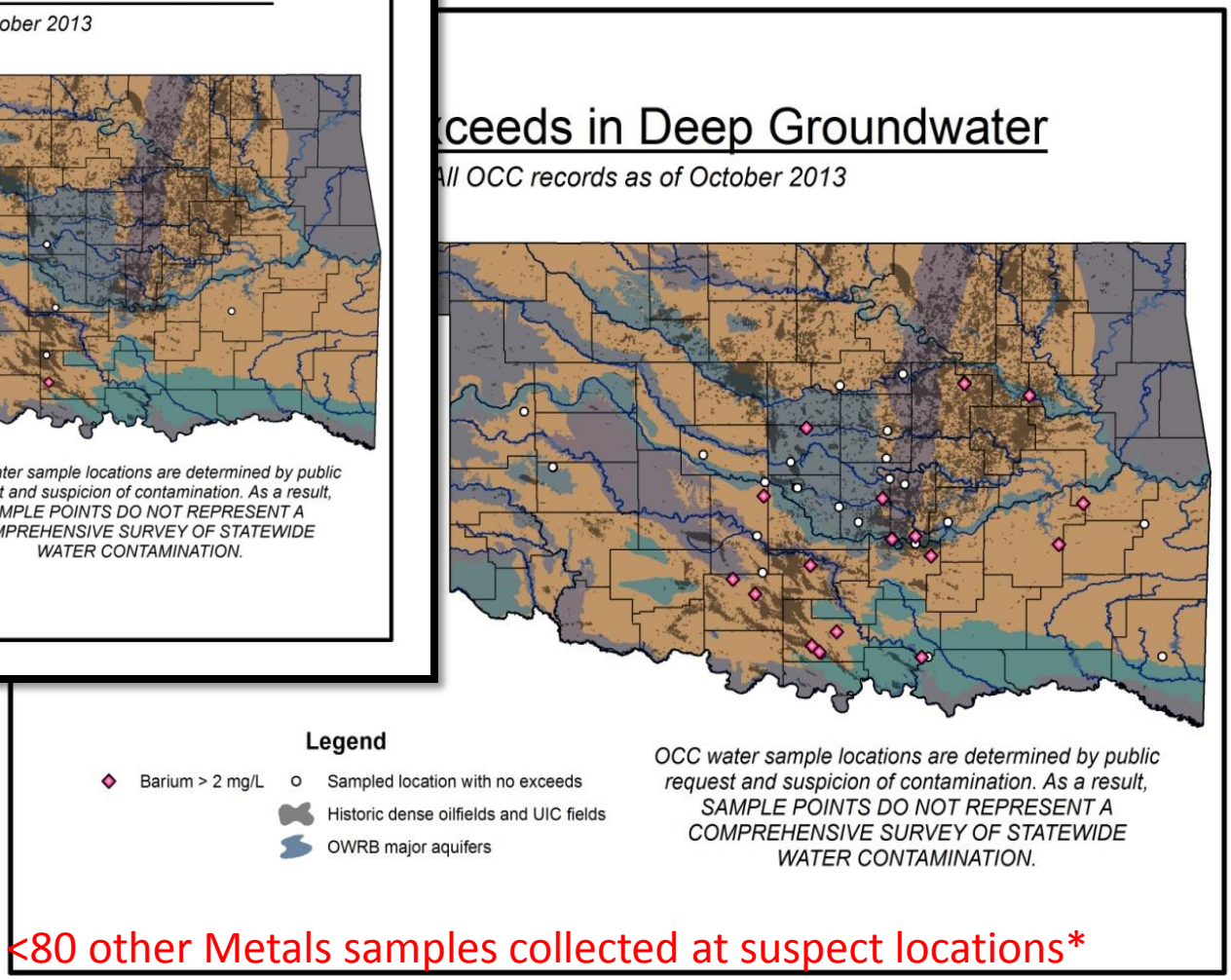
Many of the locations we test for salinity DO exceed standards.



Barium (drilling mud additive) – leaks from old pits

White Dots = Samples not exceed

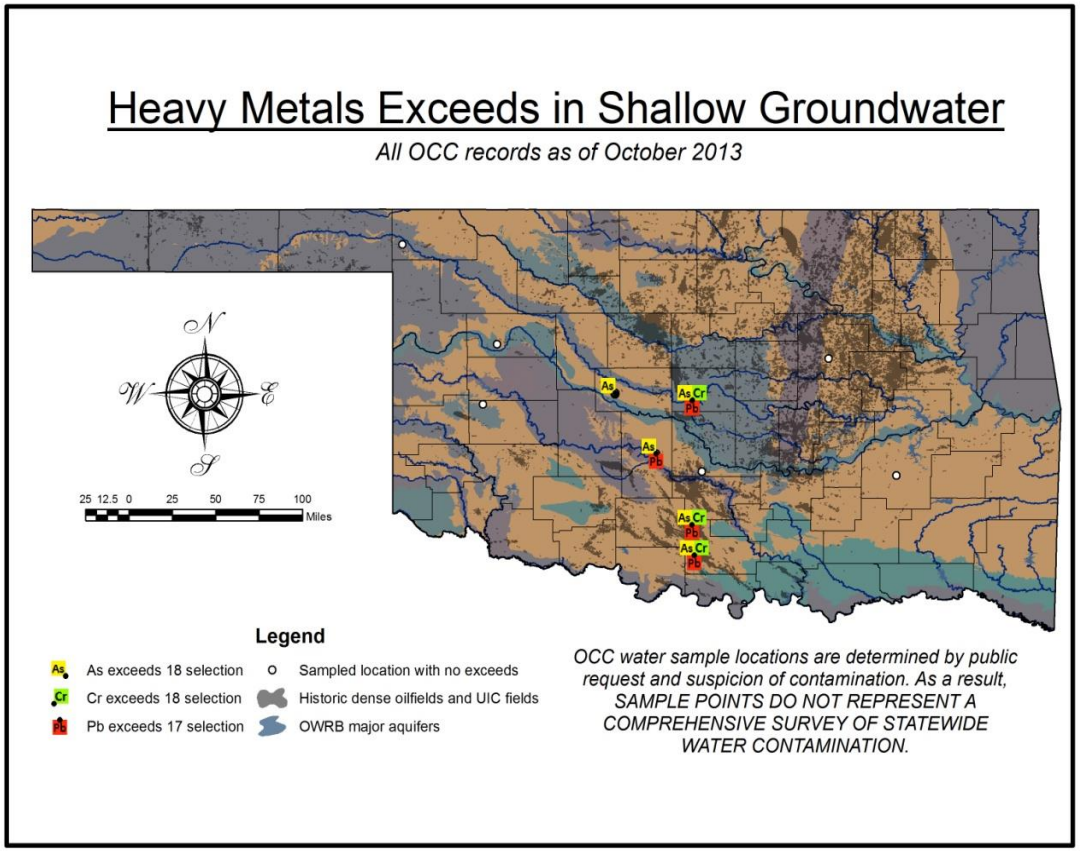


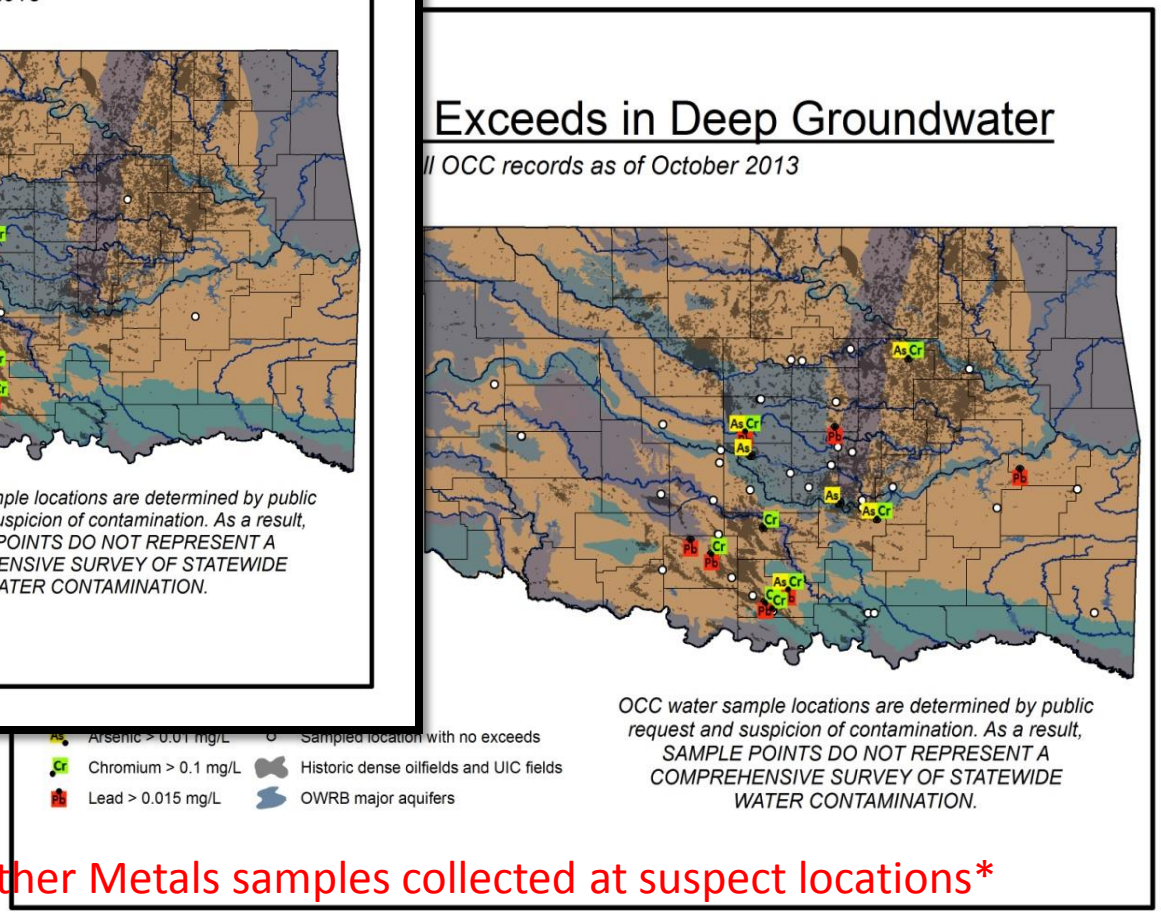


Note – Only < 50 Barium and <80 other Metals samples collected at suspect locations

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

White Dots = Samples not exceed





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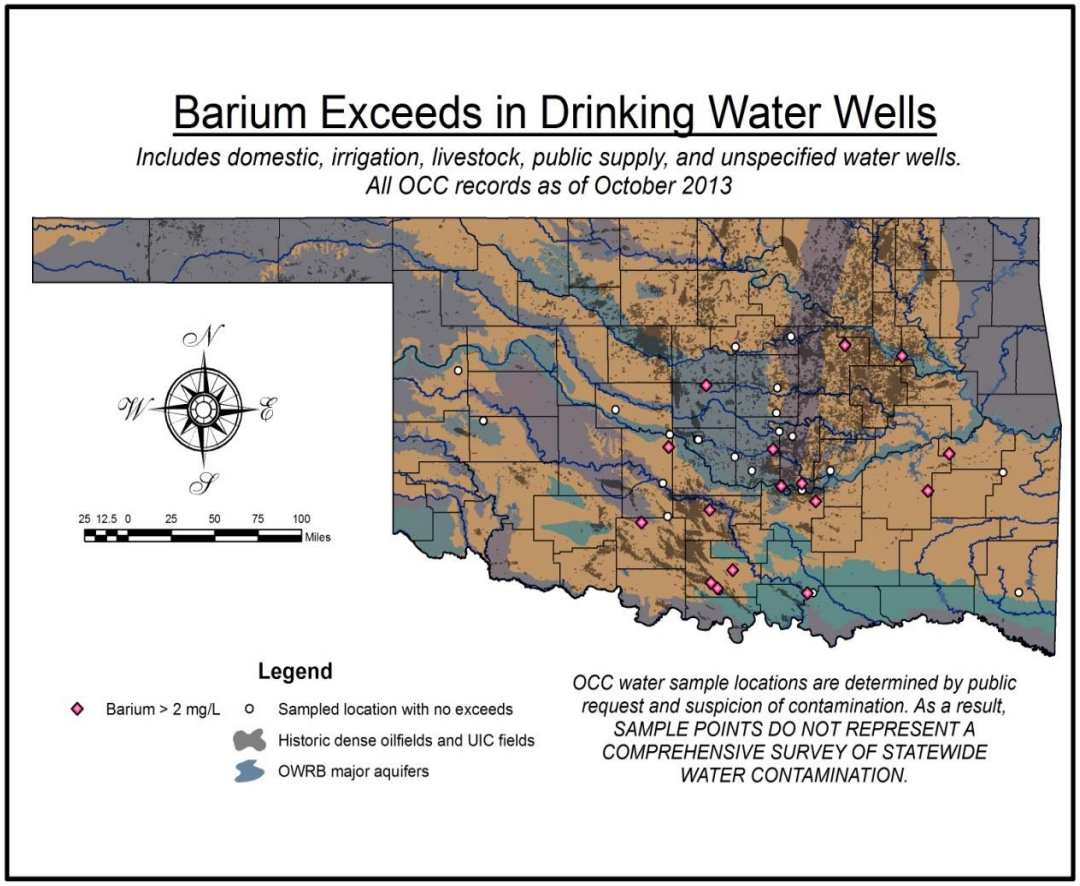
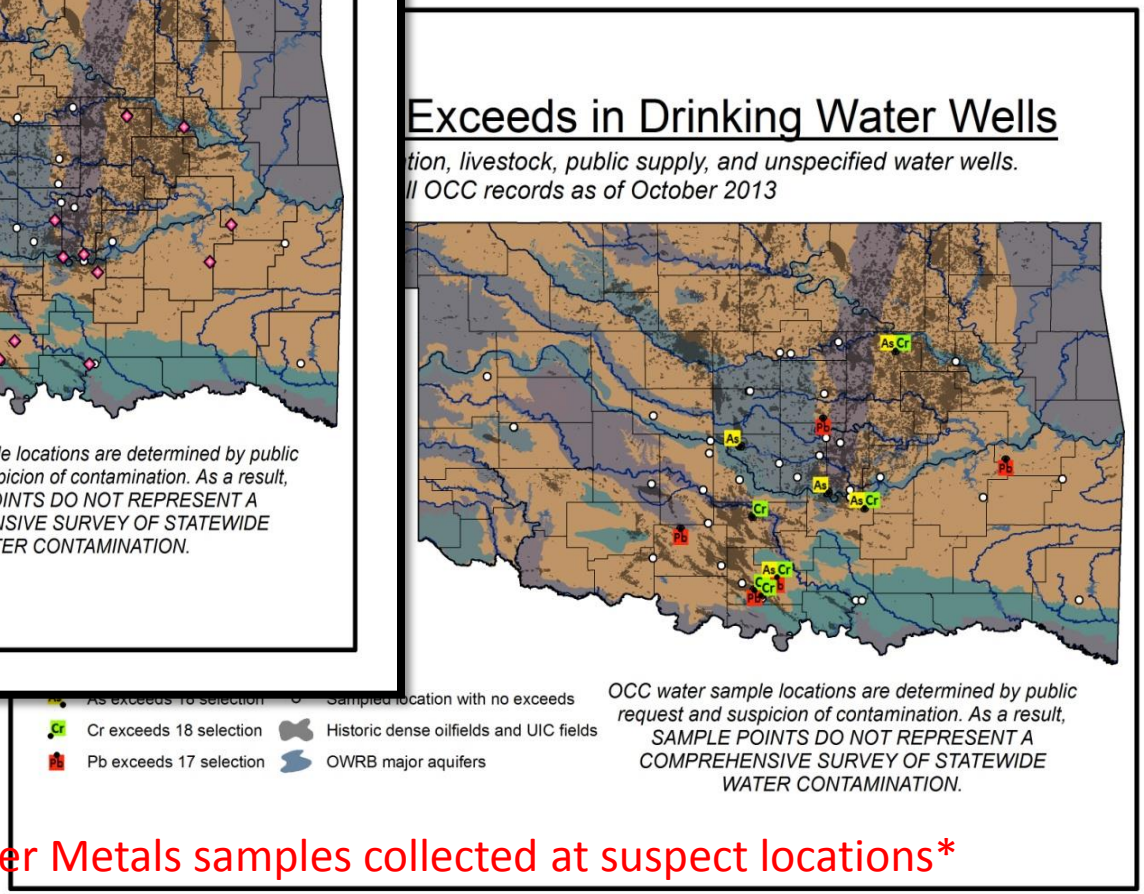
Barium; Arsenic, Chromium, Lead; in Drinking Water Well Samples

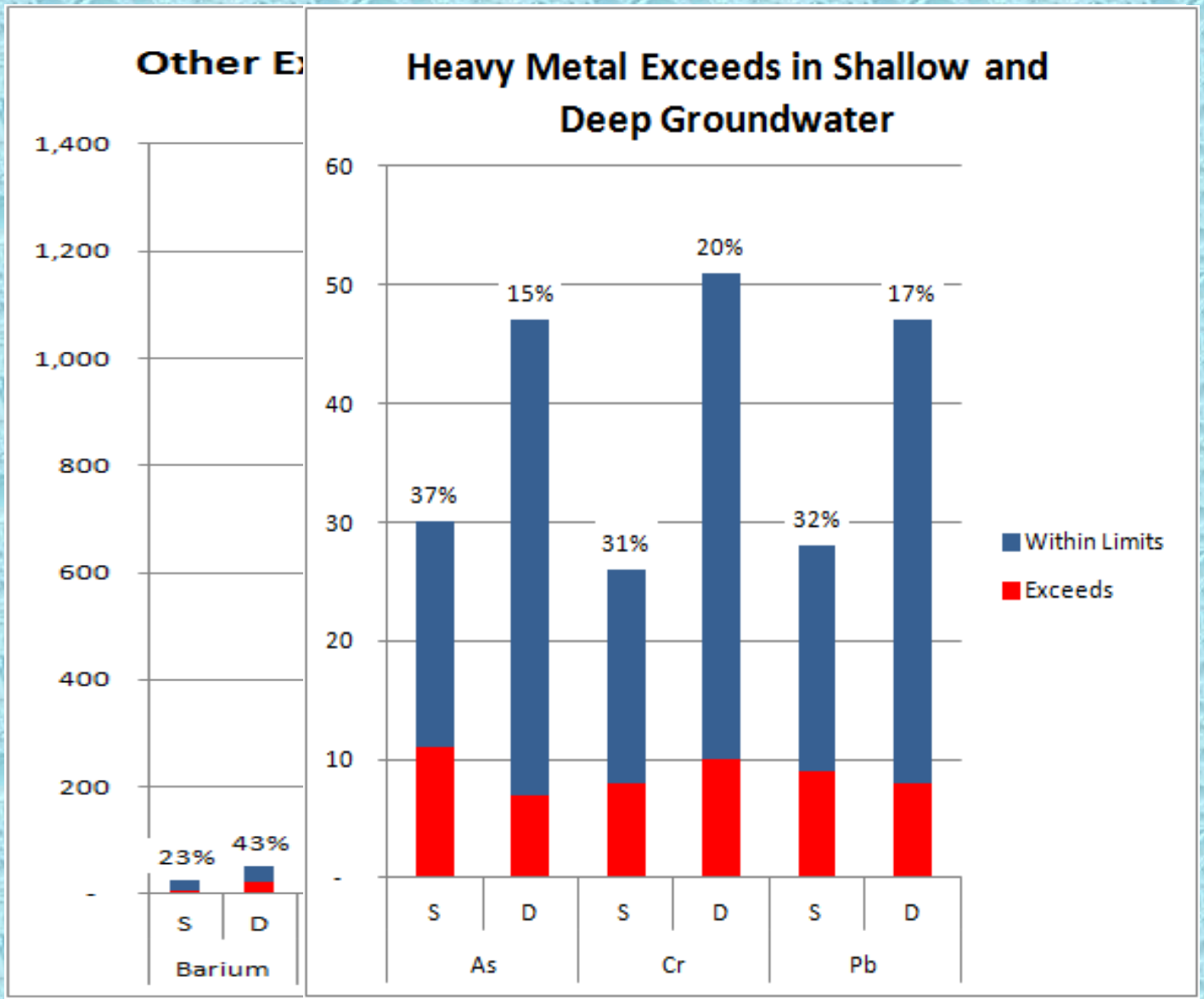
White Dots = Sample locs



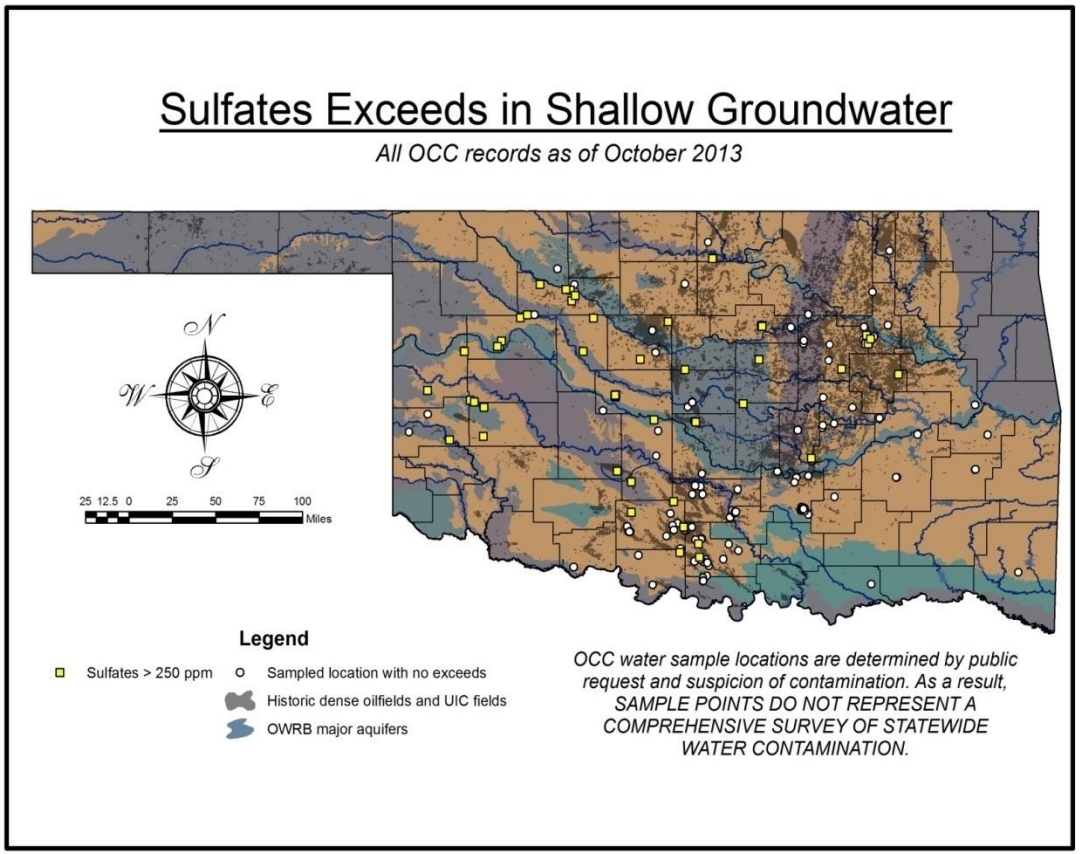


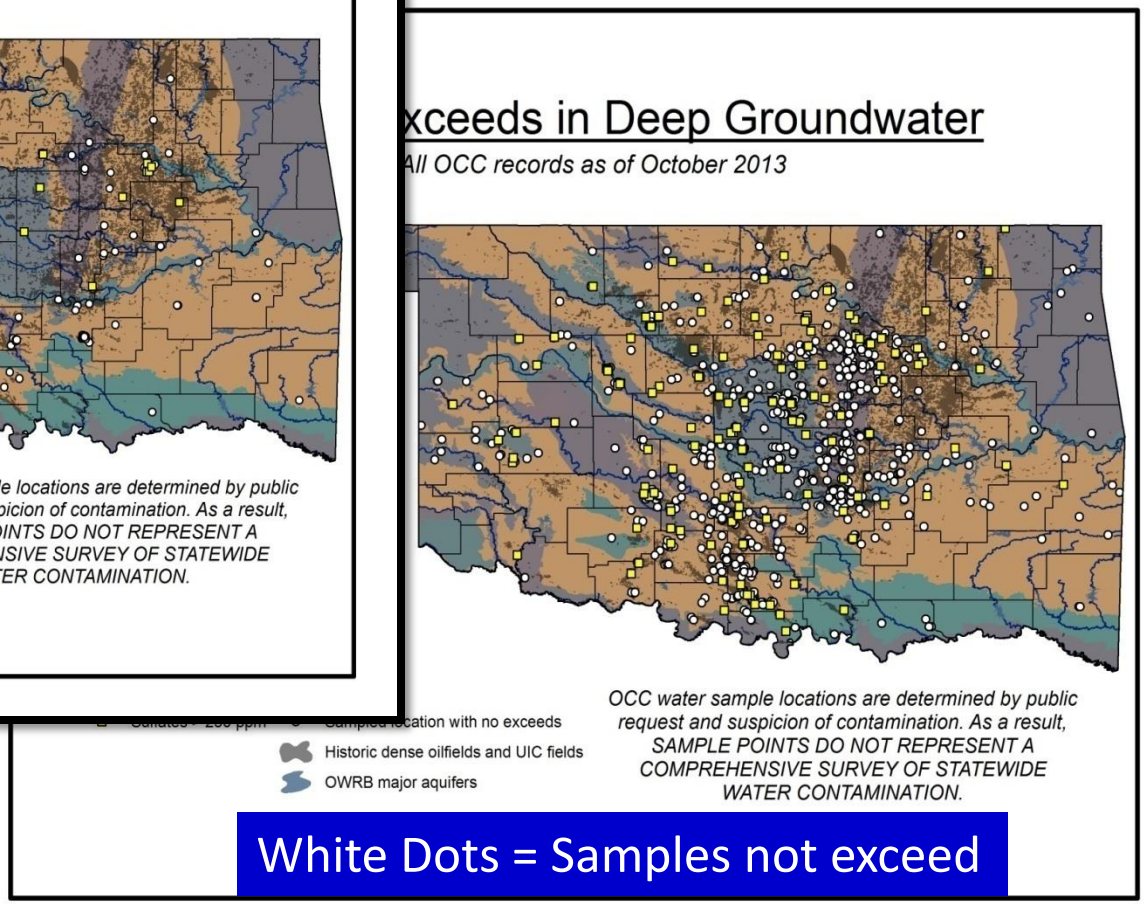
Note - < 50 Barium and <80 other Metals samples collected at suspect locations

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



Sulfate
(oilfield and other sources)





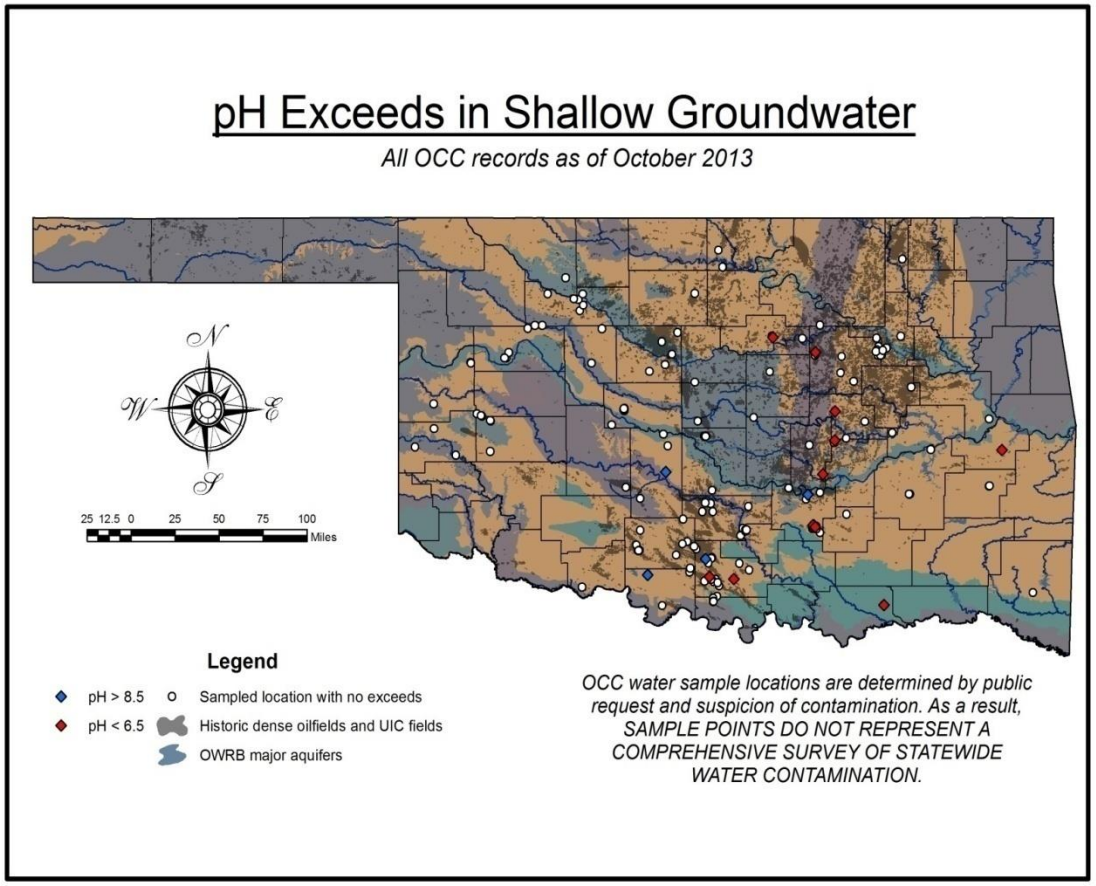
Many more deep than shallow samples

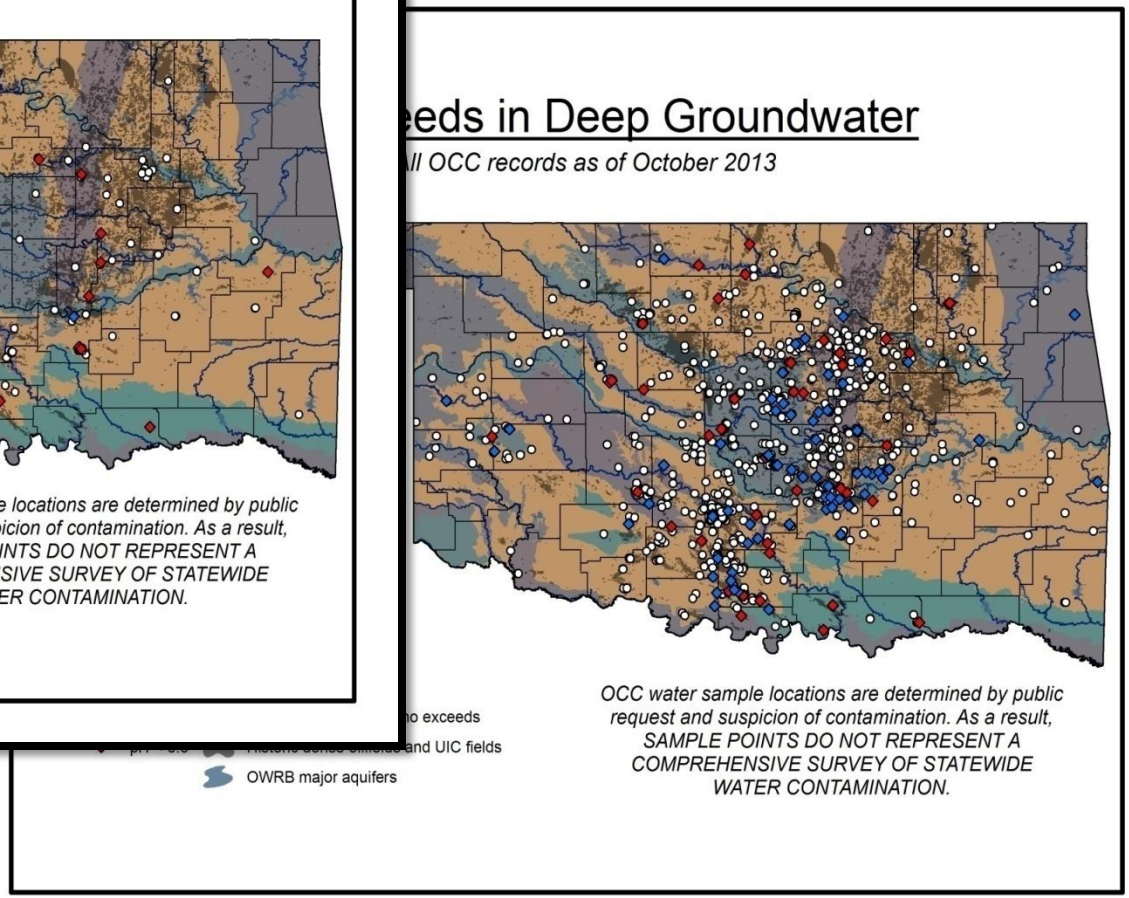
White Dots = Samples not exceed

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

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

White Dots = Samples not exceed

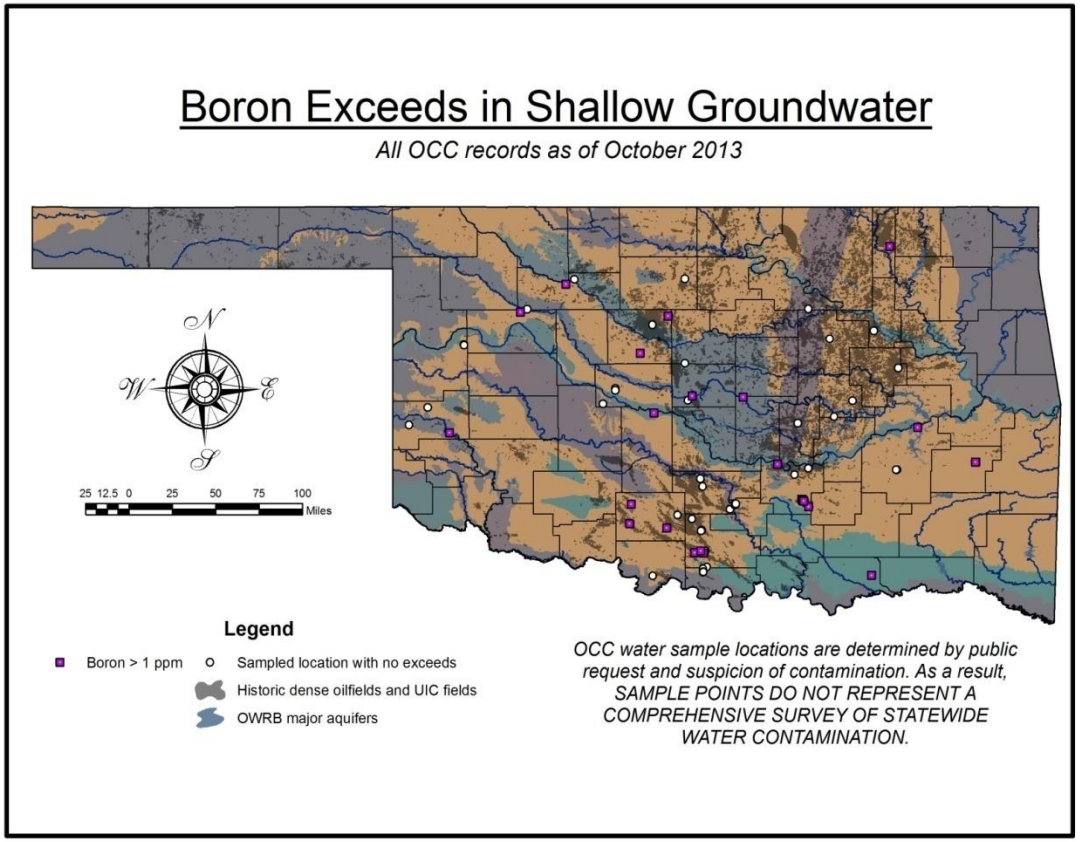


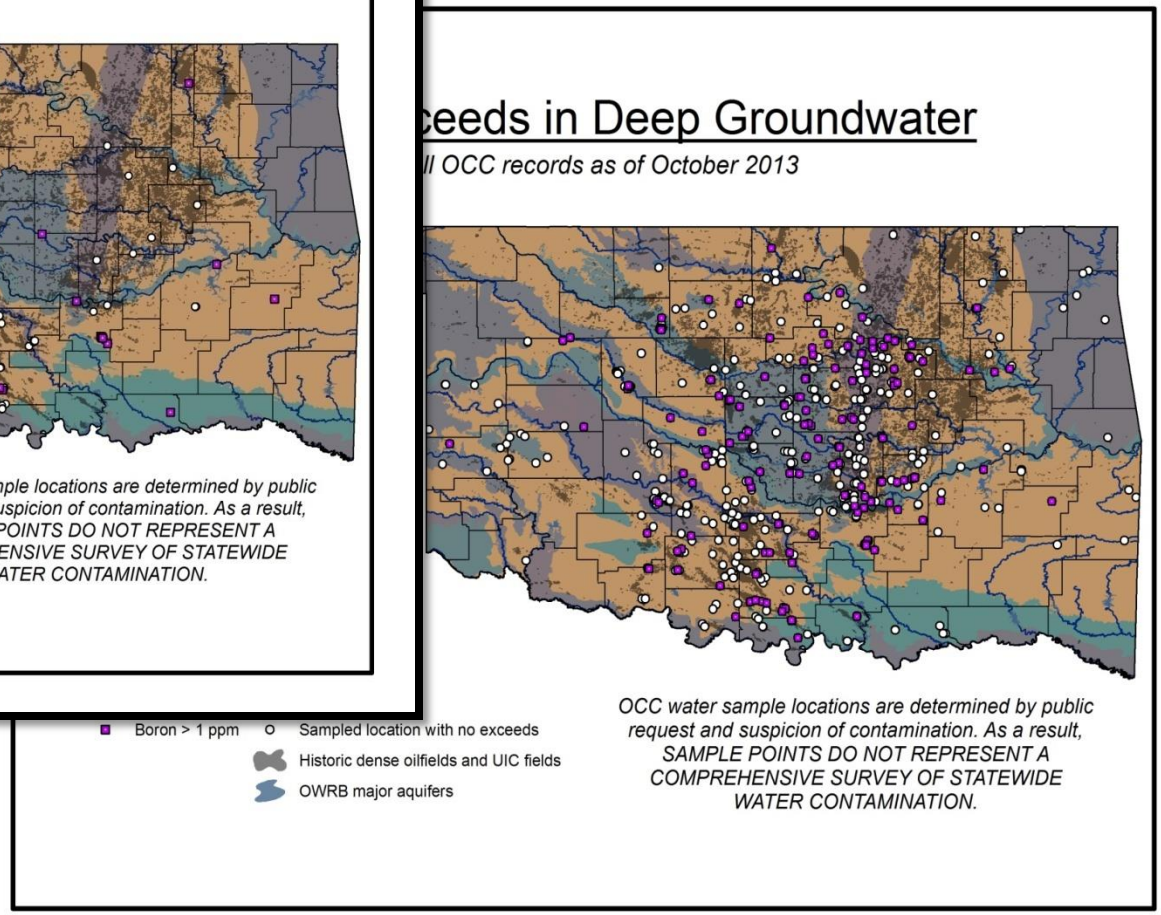


Many more deep than shallow samples

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

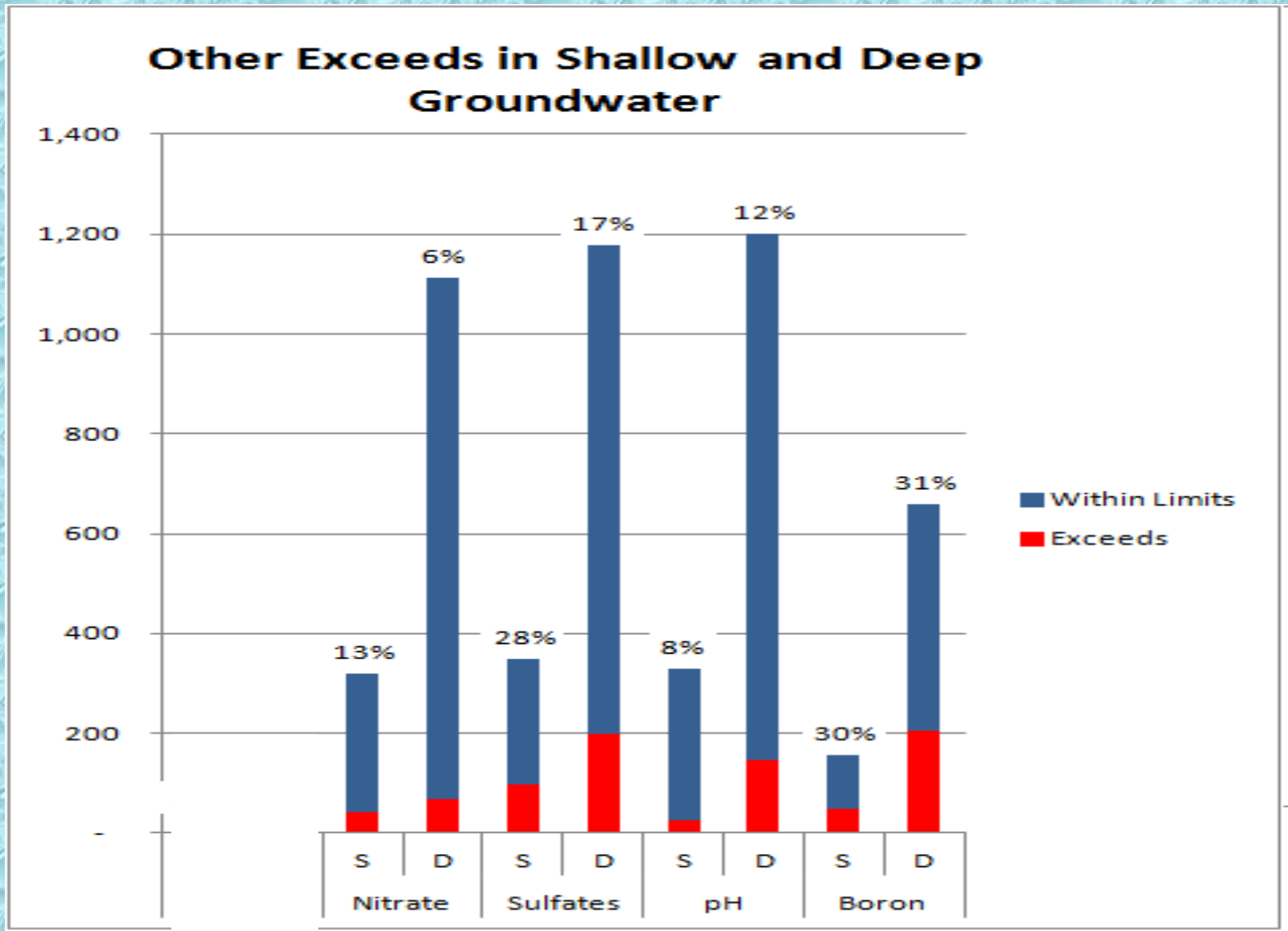
White Dots = Samples not exceed





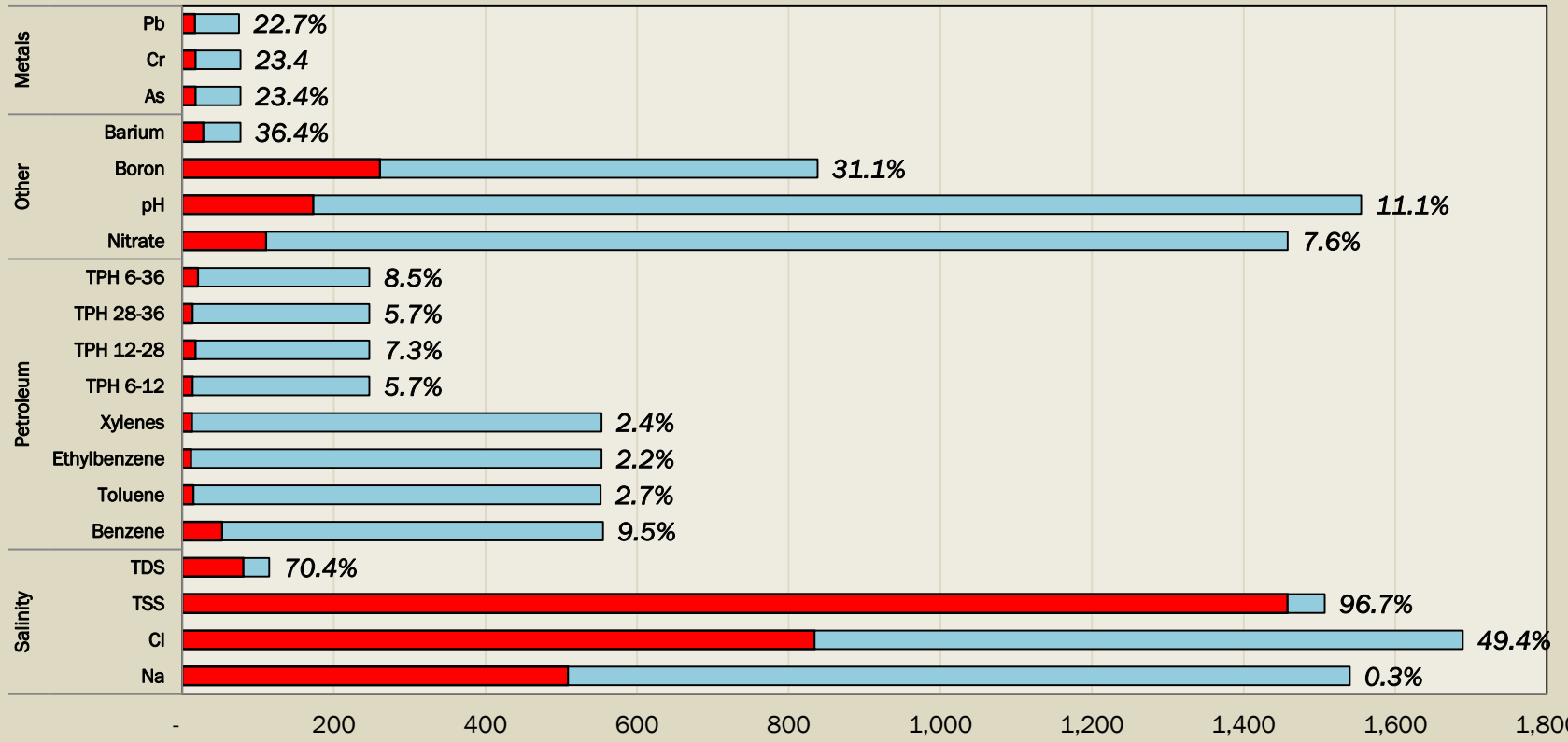
Many more deep than shallow samples

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	Benzene	Toluene	Ethylbenzene	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

Salt/Salinity Is The Biggest Old Oilfield-Related Soil And Water Problem

- Why?
- Oil and gas wells produce more water than oil – 252,000,000 gallons PER DAY in OK, in 2012
- The USGS database of Produced Oilfield water show **Oklahoma oilfield brines contain up to 18% salt - seawater is only ~3% salt!**
- So it takes very little oilfield brine to pollute

Salt

- This problem starts when produced water (brine) spills onto soil, is left behind in mud pits, or leaks from old well into an aquifer.
- SALT DOES NOT DEGRADE – It just moves, eg. From a soil spill into stormwater into a stream, or downward into an aquifer

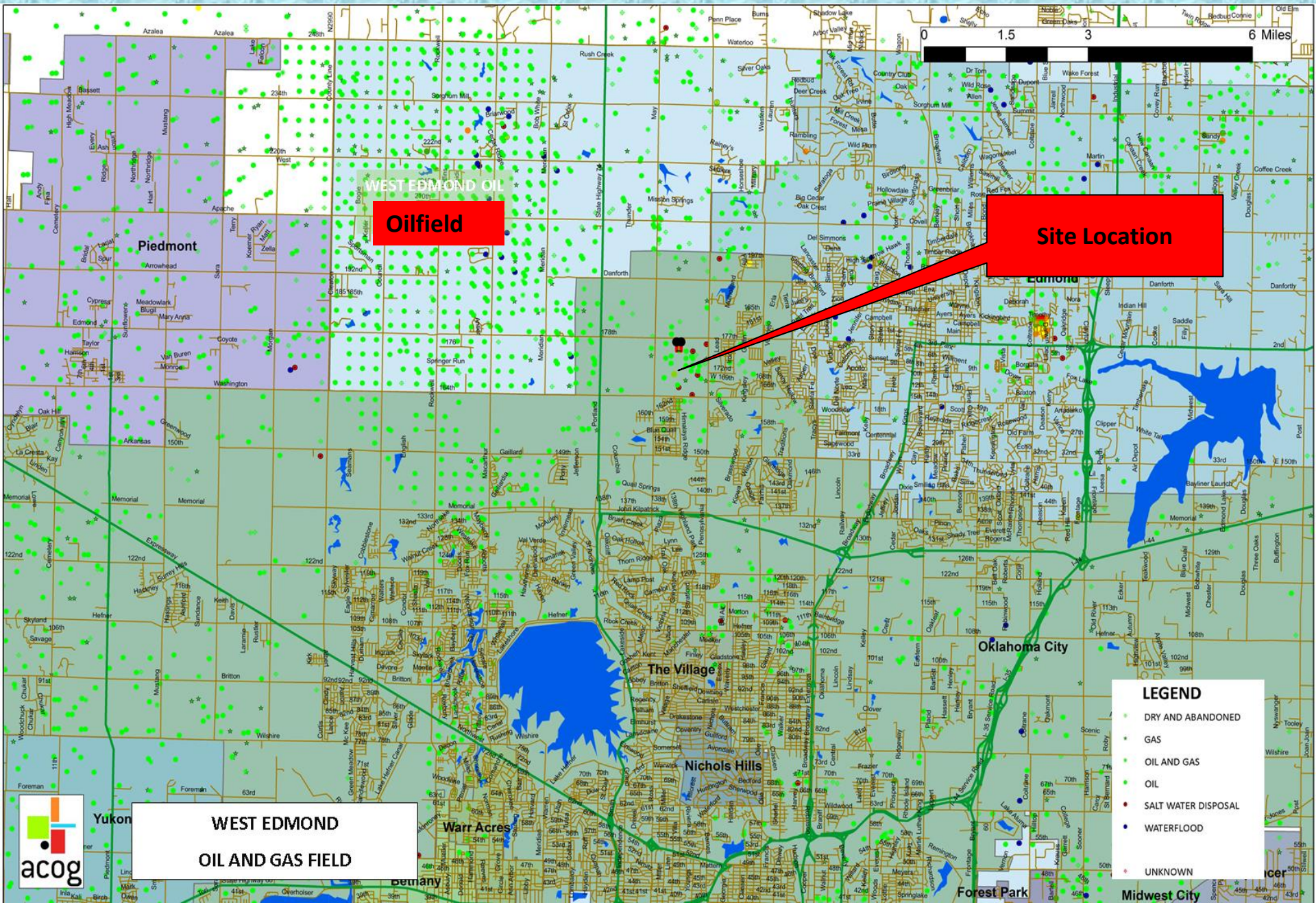
Groundwater

- I am going to summarize 2 typical case studies in Central OK.
- Where I also have geophysical data, so
- We can show **where the pollution originated**, and
- **How it is moving through the subsurface**.

Example 1 - Recent Case, 2011

- 15 year old gated community in NW OKC
- Homeowner complaints of salty water, 2011.
- Was a historic, until 1980s, oilfield area, so
- Our Field Inspector sampled their water wells.
- We later learned that two original homeowners had had bad wells in their backyard, with later new wells in the front yards. Red Flag!

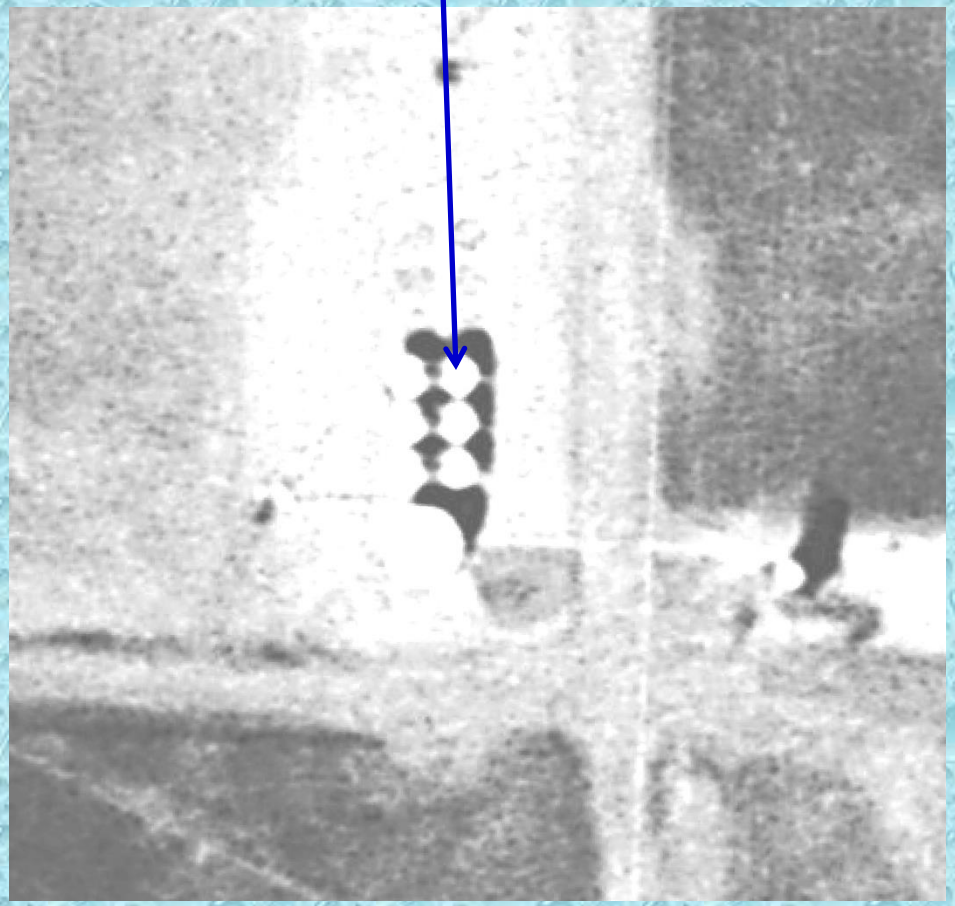
Area was once an oilfield-green dots



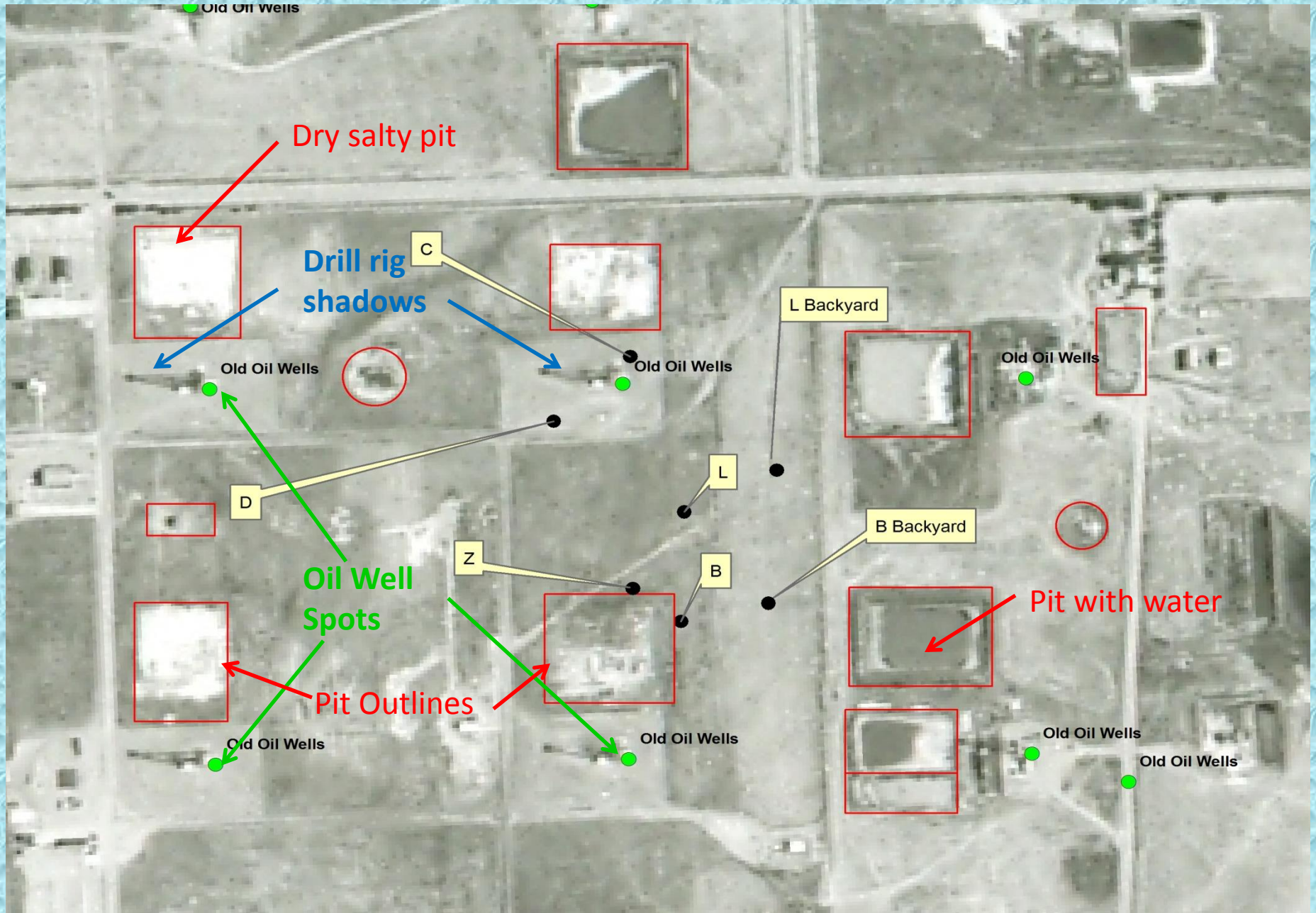
WEST EDMOND OIL FIELD CIRCA 1945

Where there were Oilfield Tanks, now we have New Homes

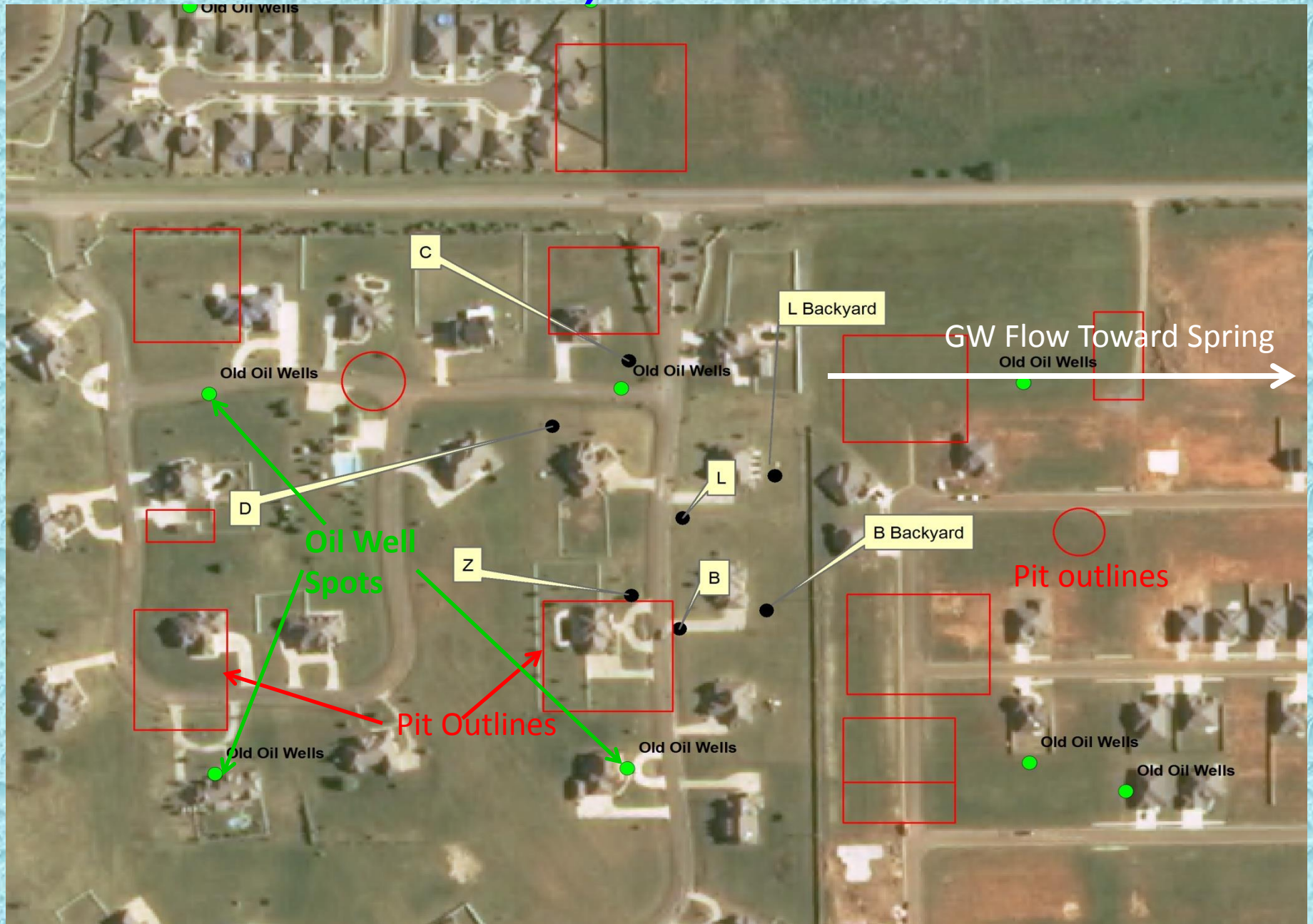
Tanks, @ end of multi-well oil and salt water gathering system



1941 Aerial Showing Drill Rigs, Pits



Old Pits & Wells, Modern Air Photo



Sampling Results

Wells ~300’ deep; only reached ~150’ backyard

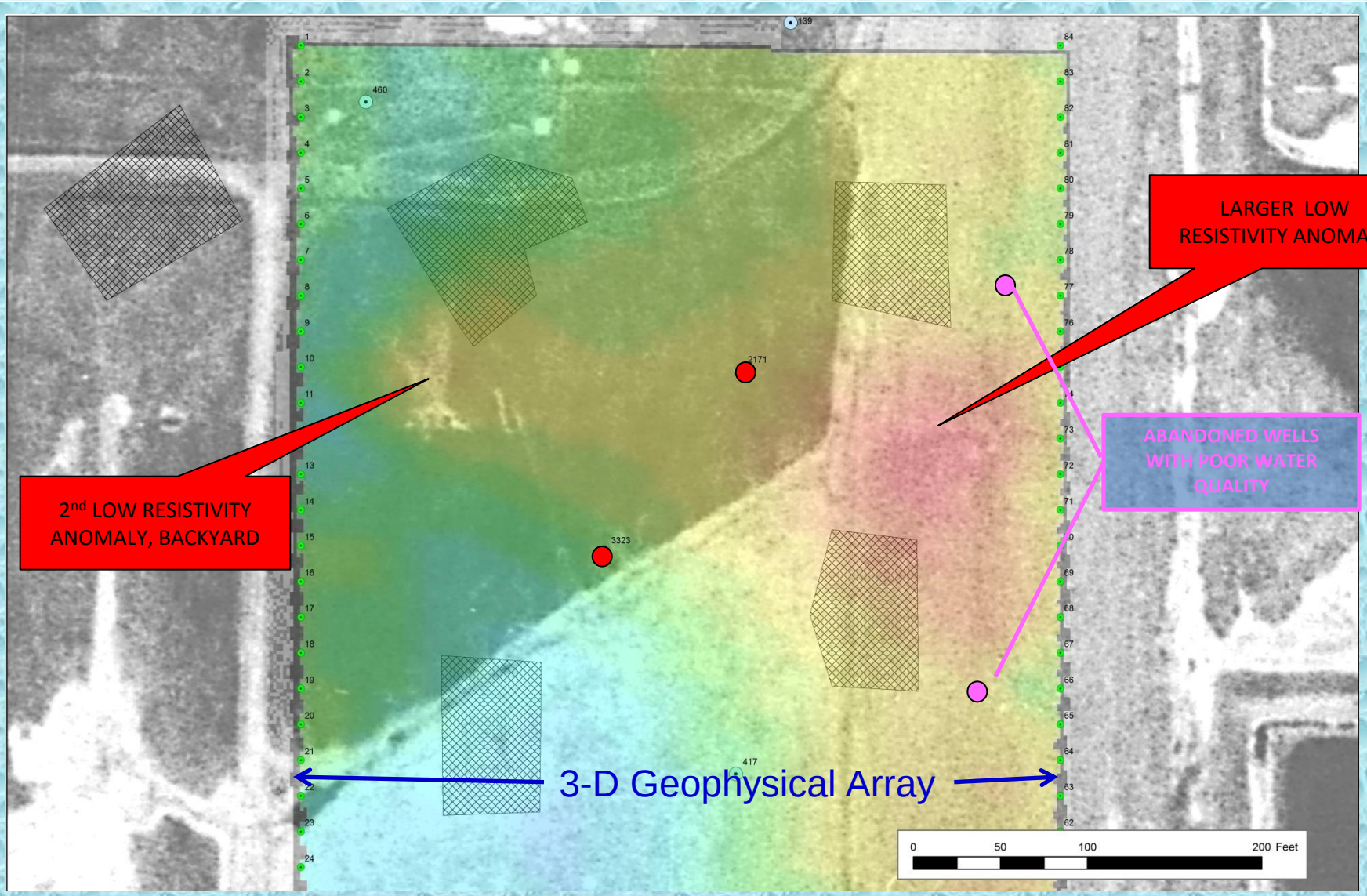
Who	Na ppm	Cl ppm	SO4 ppm	TDS or TotlSolSalts	Na/Cl
Z	1314	3323	798	7597	0.395
L	665	2171	370	4996	0.306
C	438	1047	722	3247	0.418
D	210	460	357	1756	0.457
N	184	139	302	1095	0.662
B Front yard	92	417	79	1327	0.441
B Backyard				1600	

Exceeds **Chloride** secondary drinking water standards

Na/Cl Ratio <0.6 indicates oilfield source

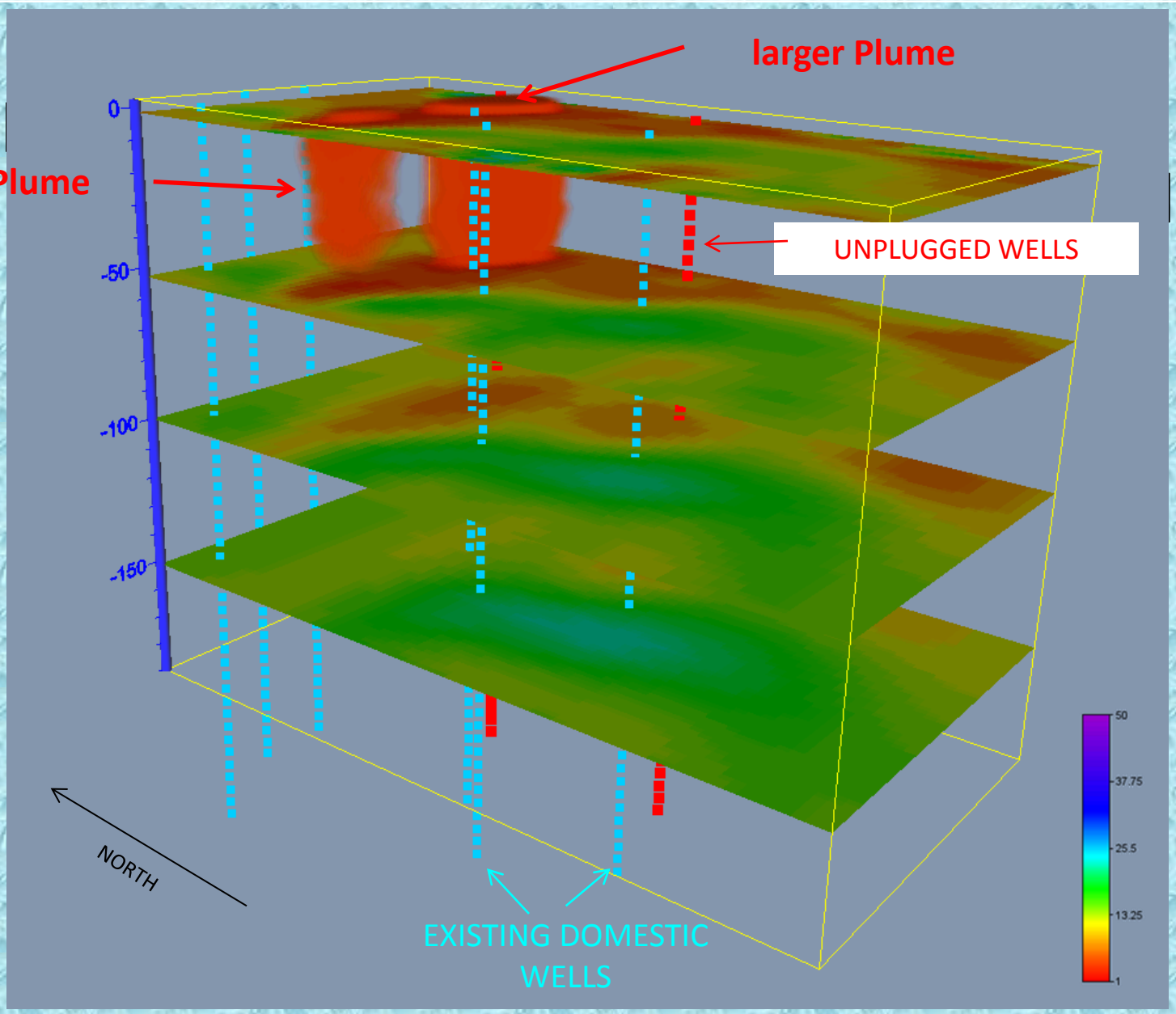
Sulfate SO4 – from **natural** BaSO4, which makes Rose Rocks

1951 Aerial Photo – Definite Scar; Note Linear Features Also



1951 Aerial Photo

Geophysics – 3D, both saline plumes



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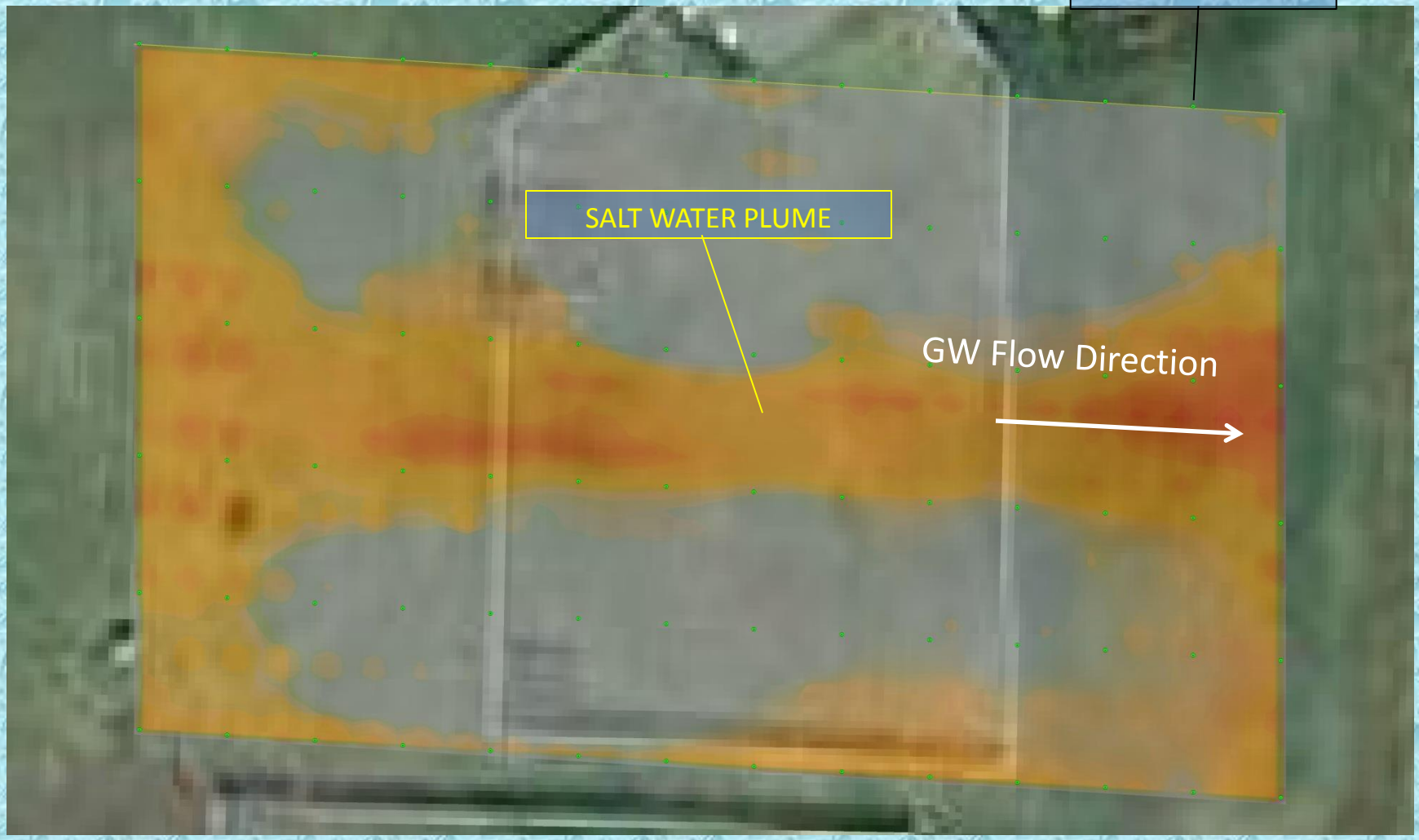
Geophysics – Linear Saline Plume, Backyard



Geophysical Array CF03
Resistivity Values <= 1 ohm-meter
Depth ~ 20 Feet

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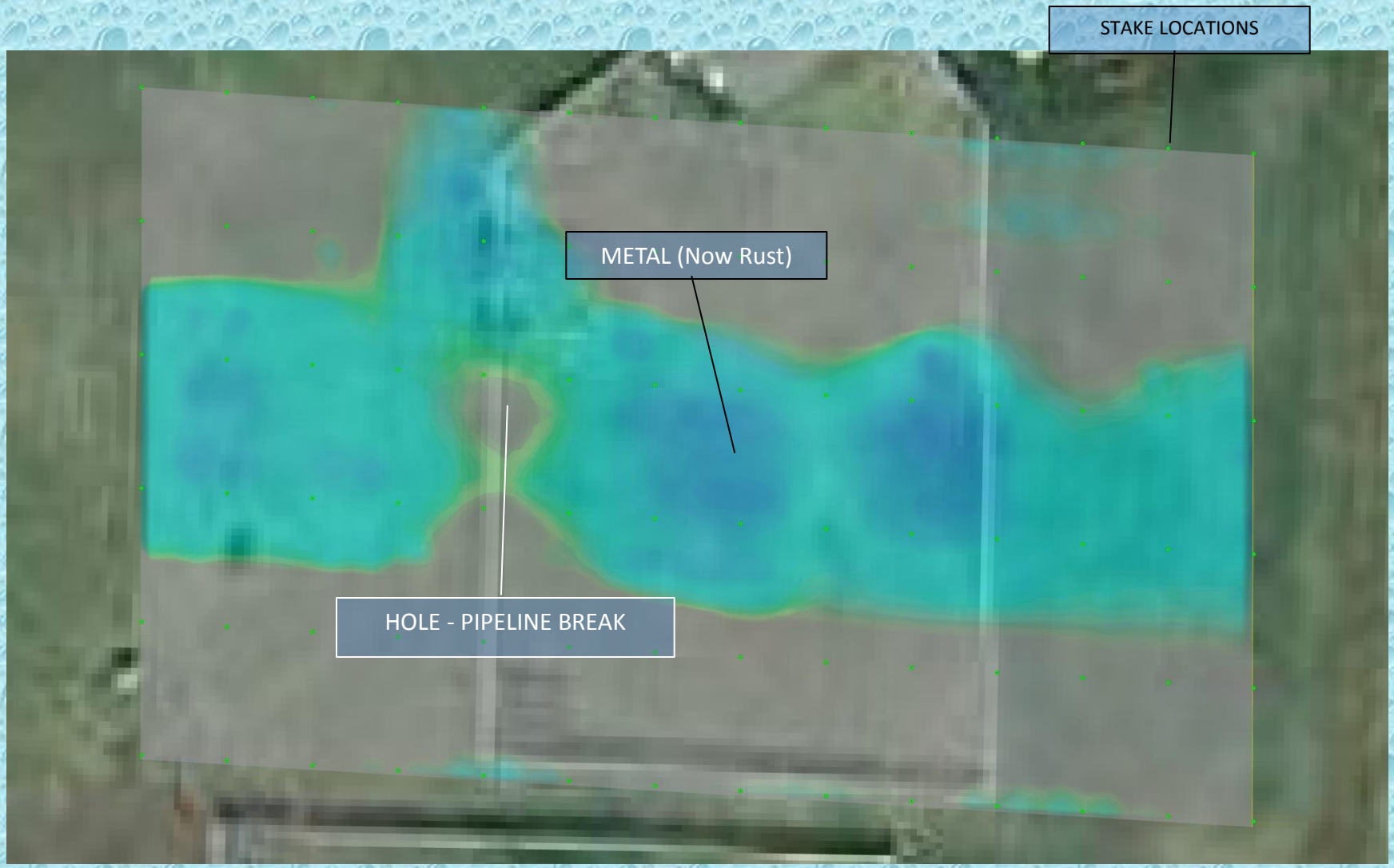
Geophysics, IP – METAL! Was A Gathering Line – With a Hole



Geophysical Array CF03 IP
Induced Potential Values > 100 ms
Depth ~ 20 Feet

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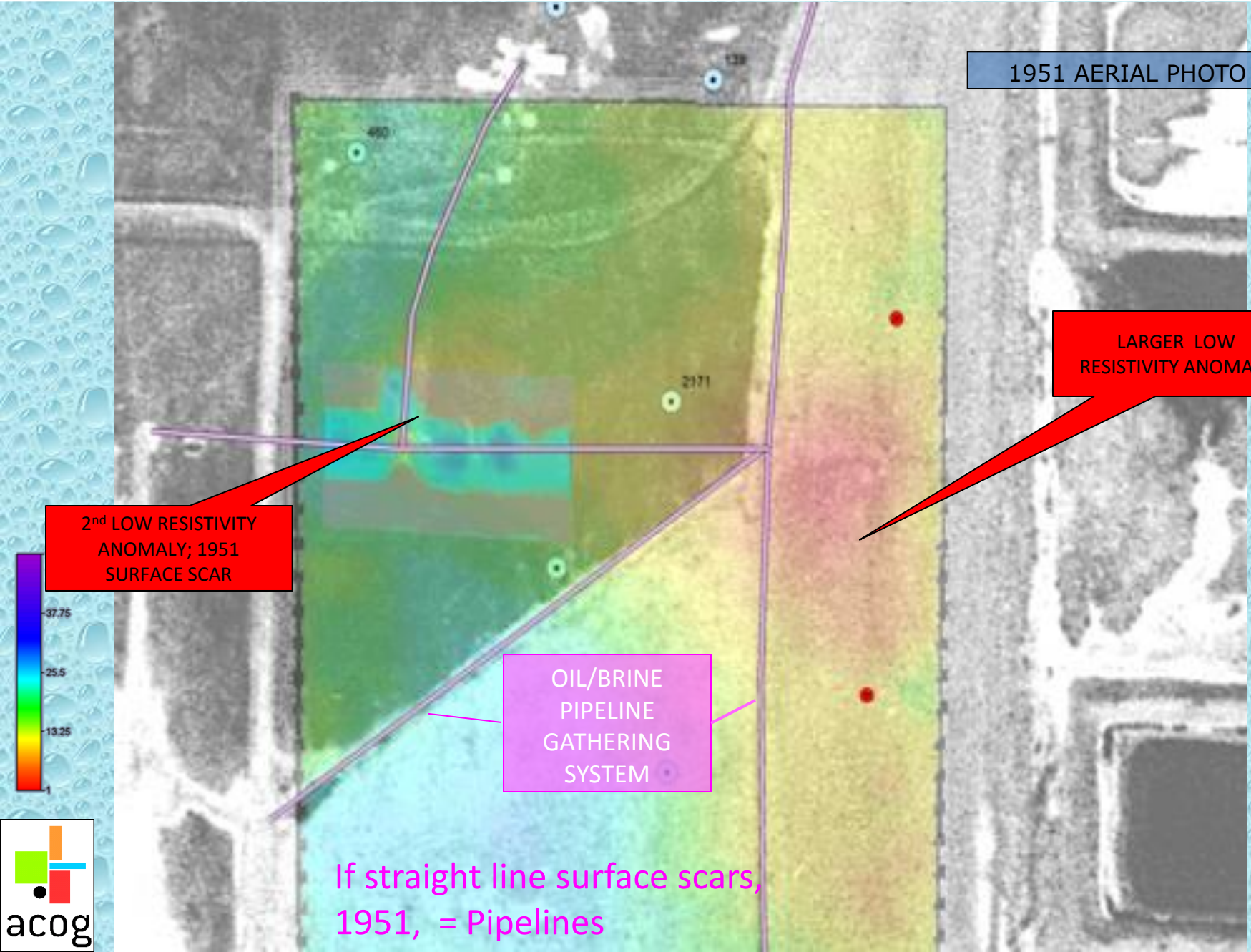
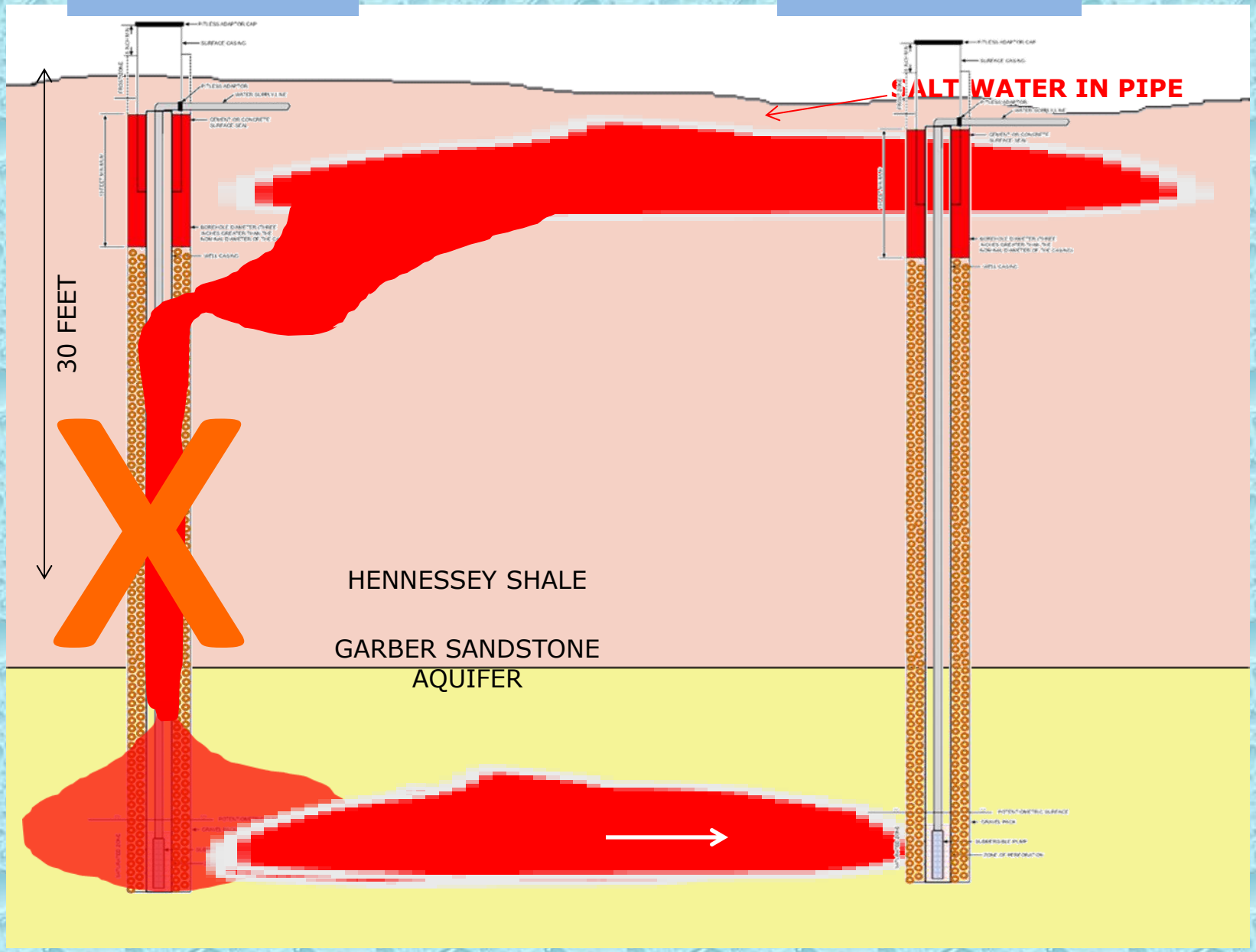
1951 Aerial –Linear Scars Were Gathering Line System?



What Happened



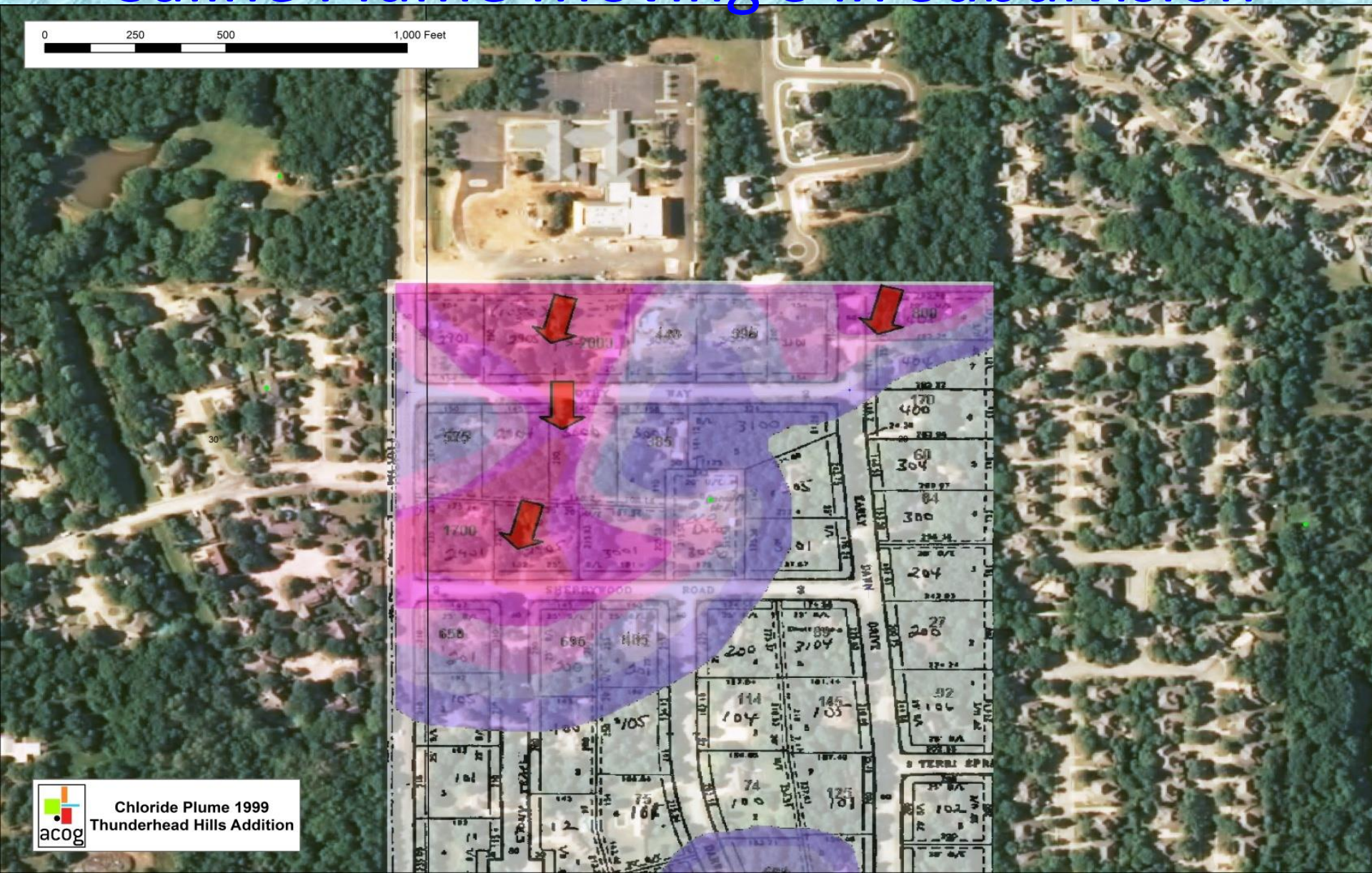
Conclusions

- **Old (1940's-80s) Oilfield Activity Source – saline brine in soil/shallow H2O zones;**
- Open, surface to 300' deep gravel pack water well construction channeled shallow pollutants down into the Garber Aquifer.
- **In effect, the water wells, by their standard design, polluted themselves - and the aquifer**
- Especially the unplugged backyard wells.
- Water wells are now plugged by Brownfields.

Another Example – started late 1990's Water Well Samples, T Hills Edmond

Address	Sodium ppm	Chloride ppm	Total Soluble Salts
3101 Sherrywood	153	577	1518
3009 Timothy	308	928	2066
200 Stony Trail	377	1001	2363
3005 Sherrywood	410	1056	2373
2901 Sherrywood		1237	2402
3001 Timothy Way	575	1258	2924
Produced Water, Darwin #1 T Hills Oil Well	79,830	123,947	222,996

Another Example
Saline Plume Moving S in Subdivision

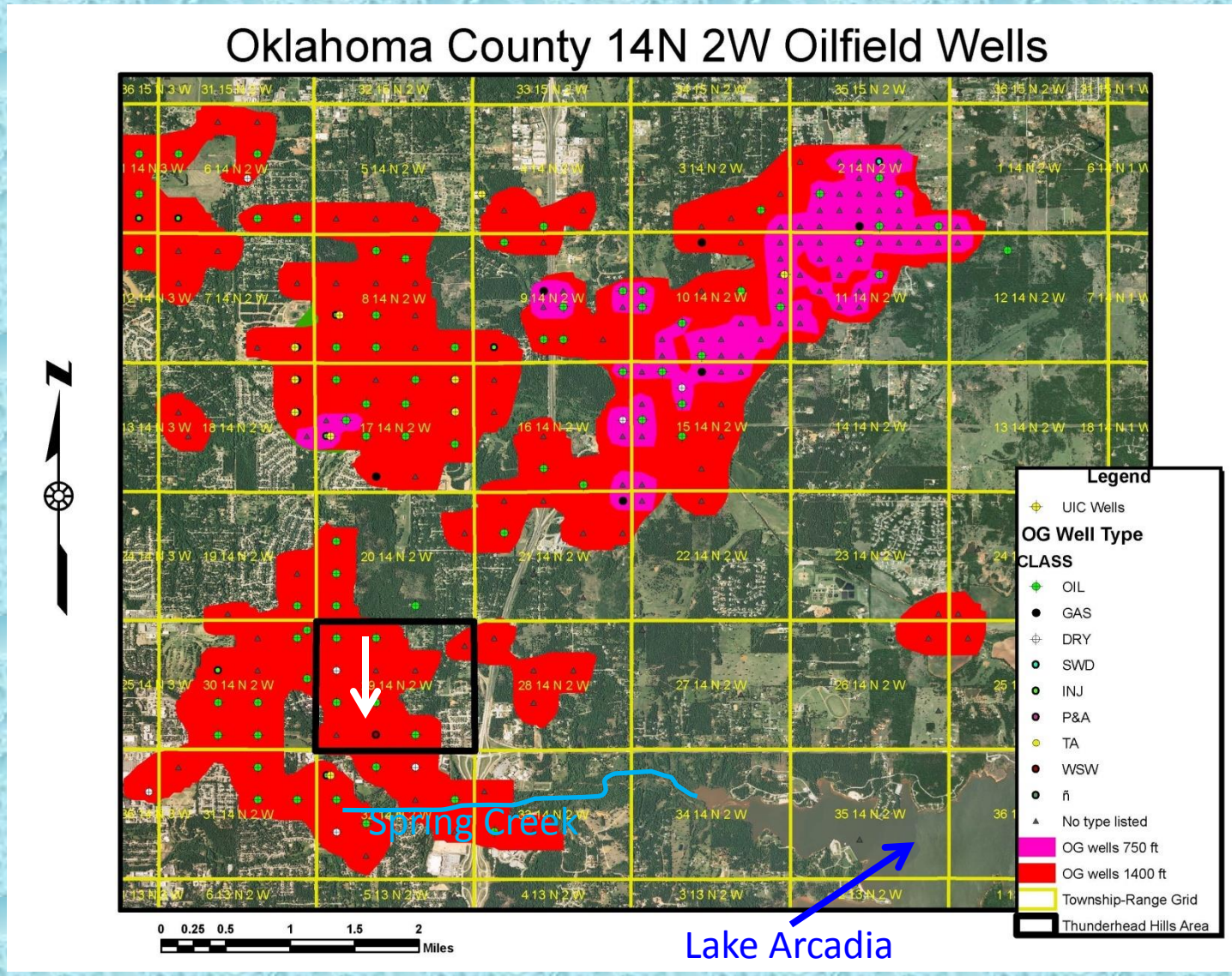


Edmond – A Bonus!

T Hills homes: groundwater pollution plume moving SOUTH since 1990s 90’ per year, dozens of water wells being ruined

Apparent Source: Old pits

Special “Bonus” – stream and reservoir



Because of problems in old oilfields and cases like the above, Corp Comm is has mapped old (1st well drilled pre 1980) well fields, especially on Oklahoma's aquifers

- Before 1980, pit design, well plugging oversite, field inspection etc. not as "rigorous" as after; For example, no regular Mechanical Integrity testing of injection wells was done then, is done now.

Unfortunately, many of these old pre-1980 oilfields are just open fields today

So Pollution Risks are often NOT obvious to developers or well drillers

So

All of our Old Oilfield maps are being loaded onto map viewers, for viewing by anyone on the internet

New Rules Request Made to OWRB

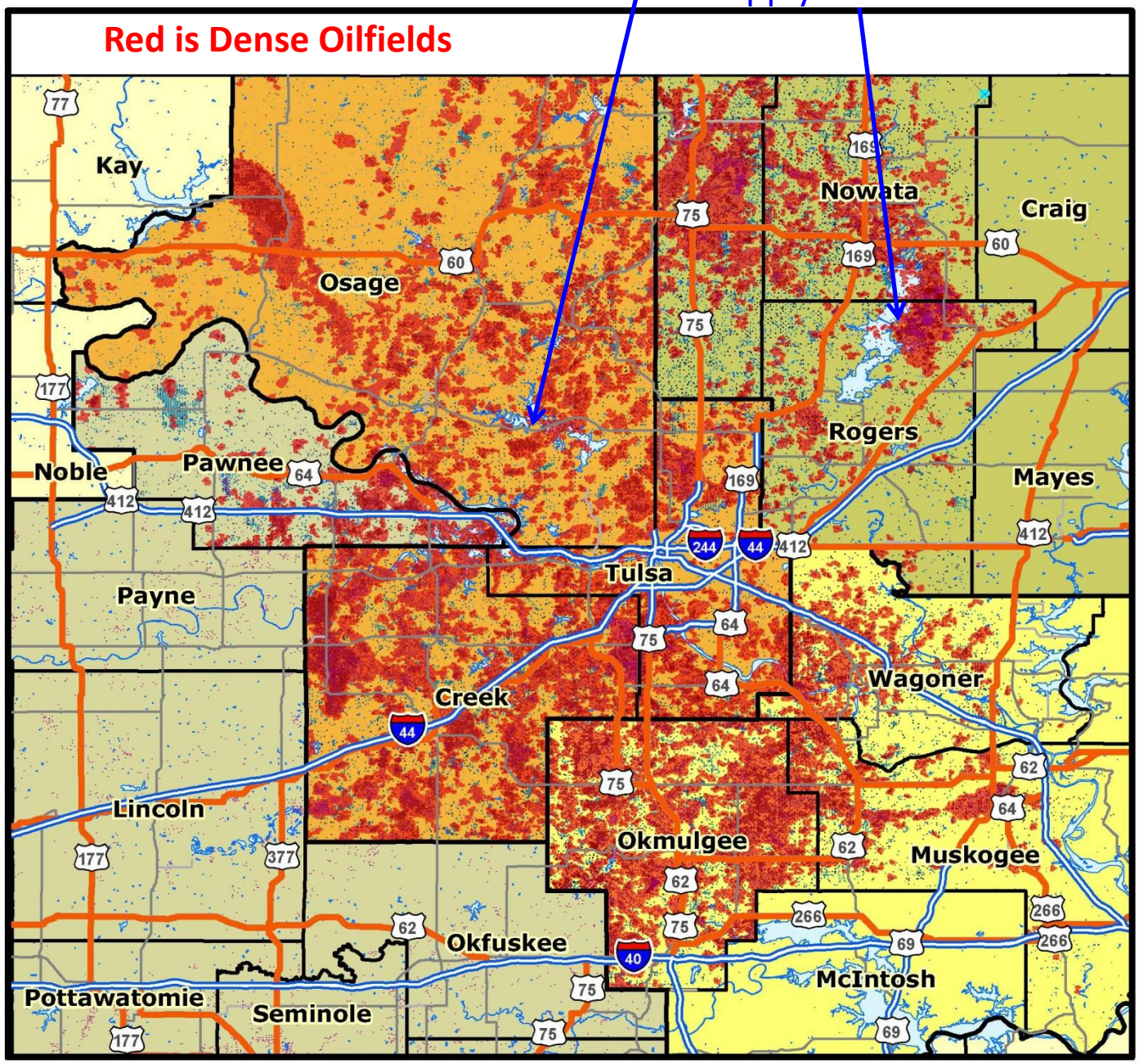
- To prevent shallow pollutants from traveling down water well gravel packs into aquifer(s) -
- In the higher risk areas Corp Comm has mapped (old oil wells were spaced <1400' apart, >16 per square mile), where >70% of well sampling exceeds are -
- Corp Comm has requested a New Rule requiring future water wells to be cased and cemented from the surface to at least 30'deep, gravel pack only BELOW 30' –
- RULEMAKING THIS FALL

Agency, Town, Water District Maps

- We realized that these GIS maps can be made by aquifer, county, town, or Water District.
- Regional planners (COGS) & town building permit departments can also use them???
- So far, 3 COGs – ACOG, INCOG, and ASCOG – with the highest OK population density - **have our map coverages and have agreed to make old oilfield maps for any city/town that wants them,** for planning purposes; we are working on the rest

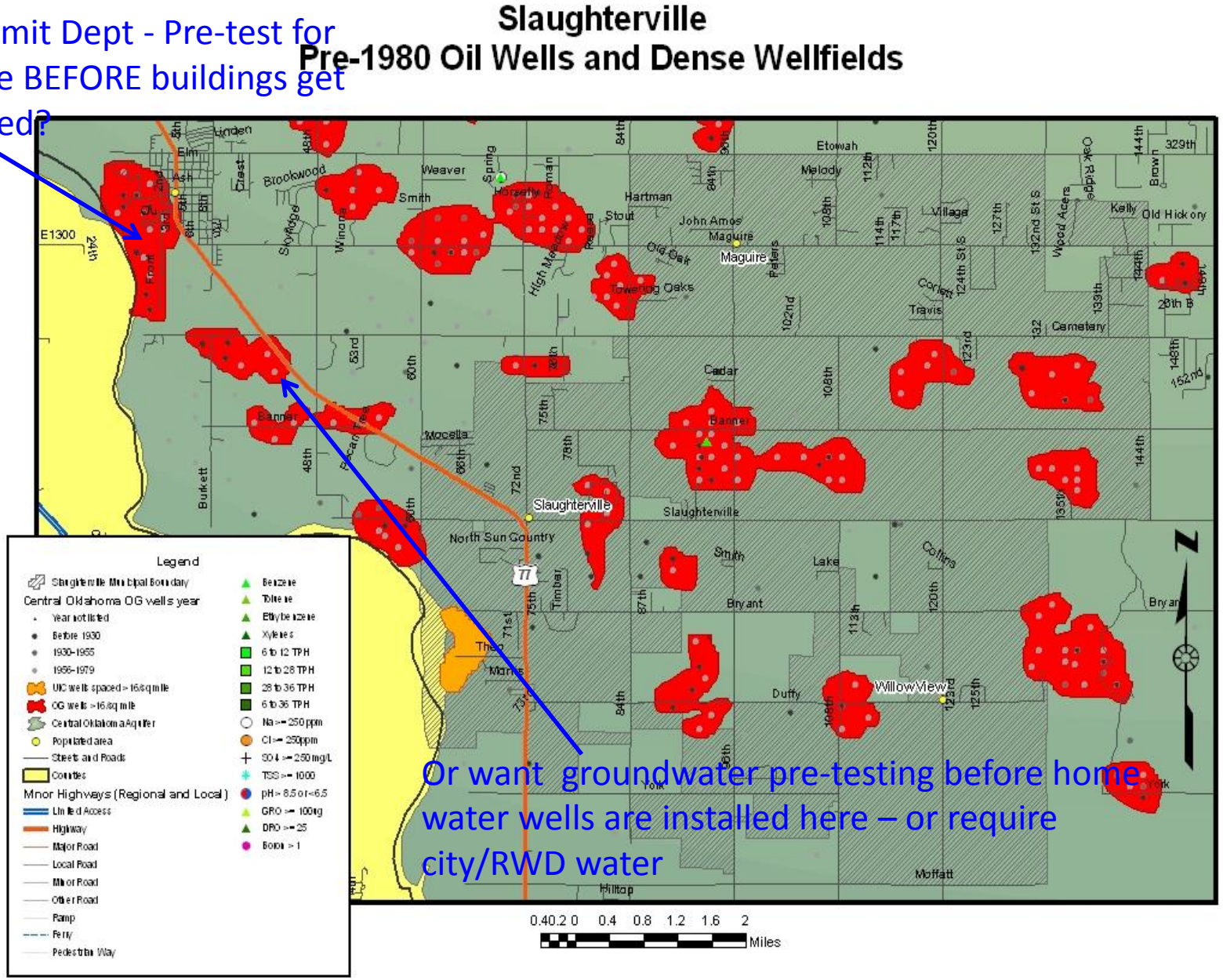
Indian Nations Council of Governments Area

Dense OG Fields and All UIC Wells



Town Example -Map for Slaughterville

City permit Dept - Pre-test for salt here BEFORE buildings get permitted?

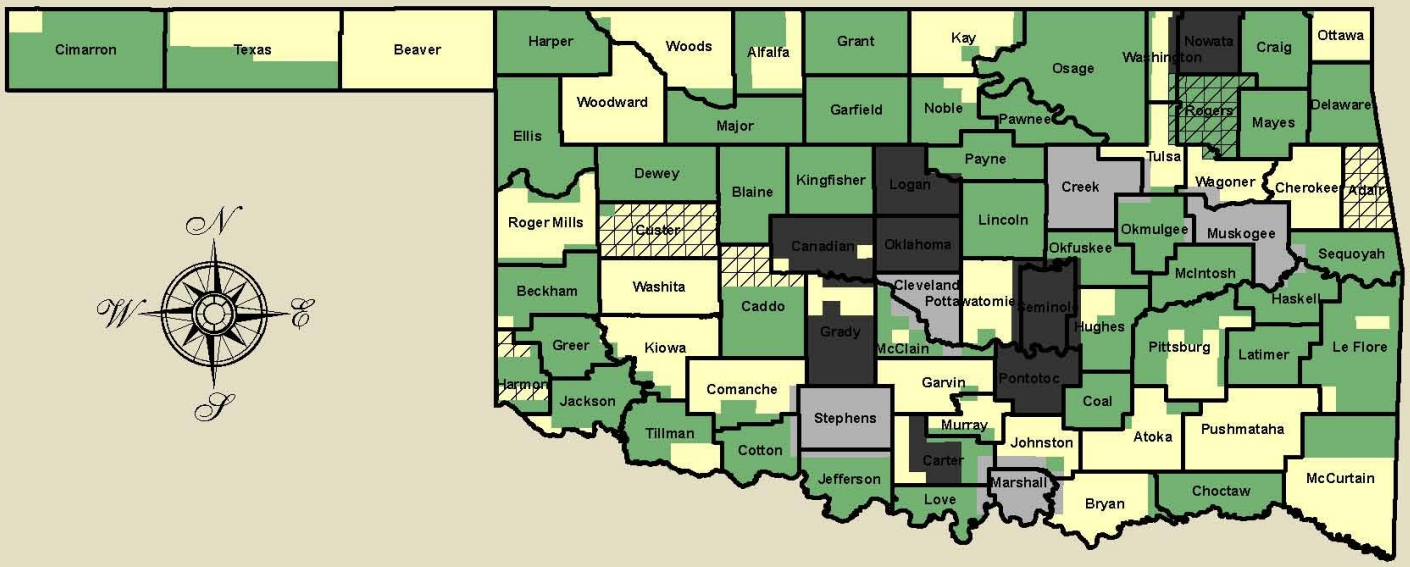


Or want groundwater pre-testing before home water wells are installed here – or require city/RWD water

Other Map Images

- Corp Comm has also been acquiring, digitizing, and georeferencing old aerial photos from the 1930' to 1980s; we now have good statewide coverage for 1940s-1960s, as I have shown you.
- Using these, our staff, or a COG or town planner, can "see" the long-gone 1940's oilfields, 1960s corner gas station, or 1970's industrial building.
- We supply these free upon request, and are working to get these up on the OK maps website where anyone can view or download them.

OCC Historical Aerial Photo Inventory
1950-1959



Current as of: August 14, 2013

Legend

- Scanned, not separated by township
- Scanned, separated by township
- Scanned, separated by township, and georeferenced
- Scanned, not separated by township, and georeferenced

Cleveland 1957
Creek 1956
Marshall 1956
Muskogee 1952
Stephens 1956
Canadian 1951
Carter 1956
Cleveland 1957
Grady 1955
Logan 1957
Marshall 1956
Nowata 1952
Oklahoma 1957
Oklahoma 1951
Pontotoc 1956
Seminole 1956

Bryan 1953
Blaine 1957
Beckham 1955
Beckham 1950
Atoka 1955
Alfalfa1954
Caddo 1955
Carter 1954
Cimarron 1959
Choctaw 1955
Cleveland 1951
Coal 1956
Coal 1955
Comanche 1950
Cotton 1950
Cotton 1957

Craig 1958
Craig 1952
Custer 1955
Delaware 1958
Dewey 1951
Dewey 1957
Ellis 1951
Ellis 1959
Garfield 1951
Garfied 1954
Garvin 1956
Grant 1954
Greer 1950
Greer 1957
Harmon 1950
Harper 1951

Haskell 1952
Hughes 1955
Hughes 1956
Jackson 1950
Jackson 1957
Jefferson 1950
Jefferson 1957
Johnston 1954
Kingfisher 1951
Kingfisher 1957
Latimer 1955
Le Flore 1952
Le Flore 1955
Lincoln 1954
Love 1954
Love 1956

Major 1954
Marshall 1953
Mayes 1958
Mayes 1952
Mayes 1958
McClain 1956
McClain 1955
McCurtain 1955
McIntosh 1956
Noble 1954
Okfuskee 1956
Okmulgee 1956
Osage 1954
Pawnee 1954
Payne 1956
Pittsburg 1955

Roger Mills 1955
Rogers 1958
Sequoyah 1952
Sequoyah 1958
Texas 1959
Tillman 1950
Tillman 1957

Blaine 1951
Adair 1952
Caddo 1956
Custer 1955
Harmon 1957
Logan 1951
Rogers 1952

EMPOWERING OKLAHOMA

Oklahoma Corporation Commission
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Questions?