Lessons Learned from Litigation Involving Historic Oilfield Contamination

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Comparison of aerial photos of a Logan County NRCS-designated oilfield waste land site (1954) and a 1957 aerial photo of the area encompassing the site of a neighborhood today

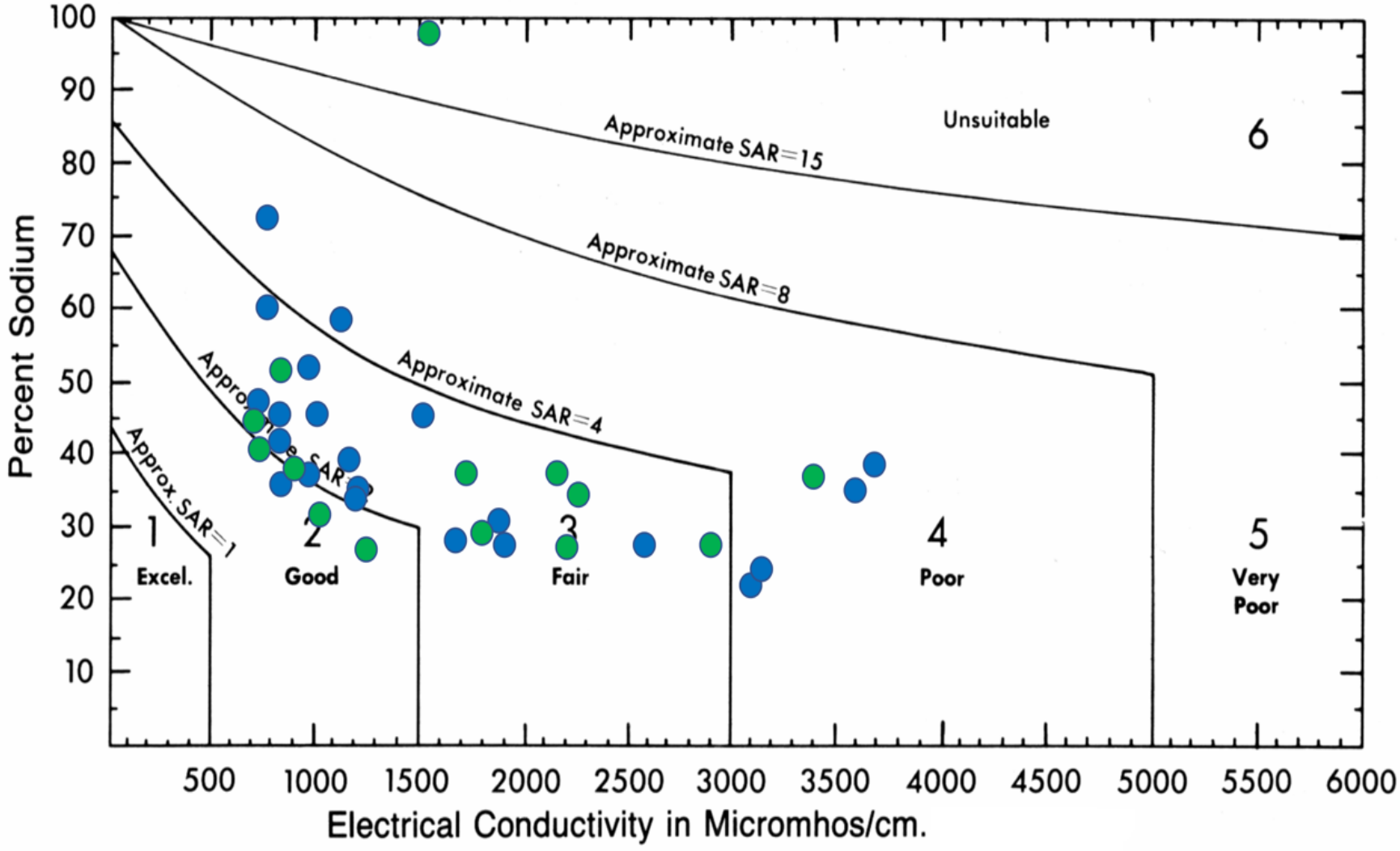
6/26/1954 Conditions
T19N R4W Section 18

7/10/1957 Conditions
Edmond, OK neighborhood

Complaints

- Development began in the early 2000's
- In time problems developed:
  - Salt contamination of groundwater (residents initially all on well water)
  - Salt contamination of surface soils
    - Difficulty growing grass, trees, gardens, ornamentals

Water quality 2017

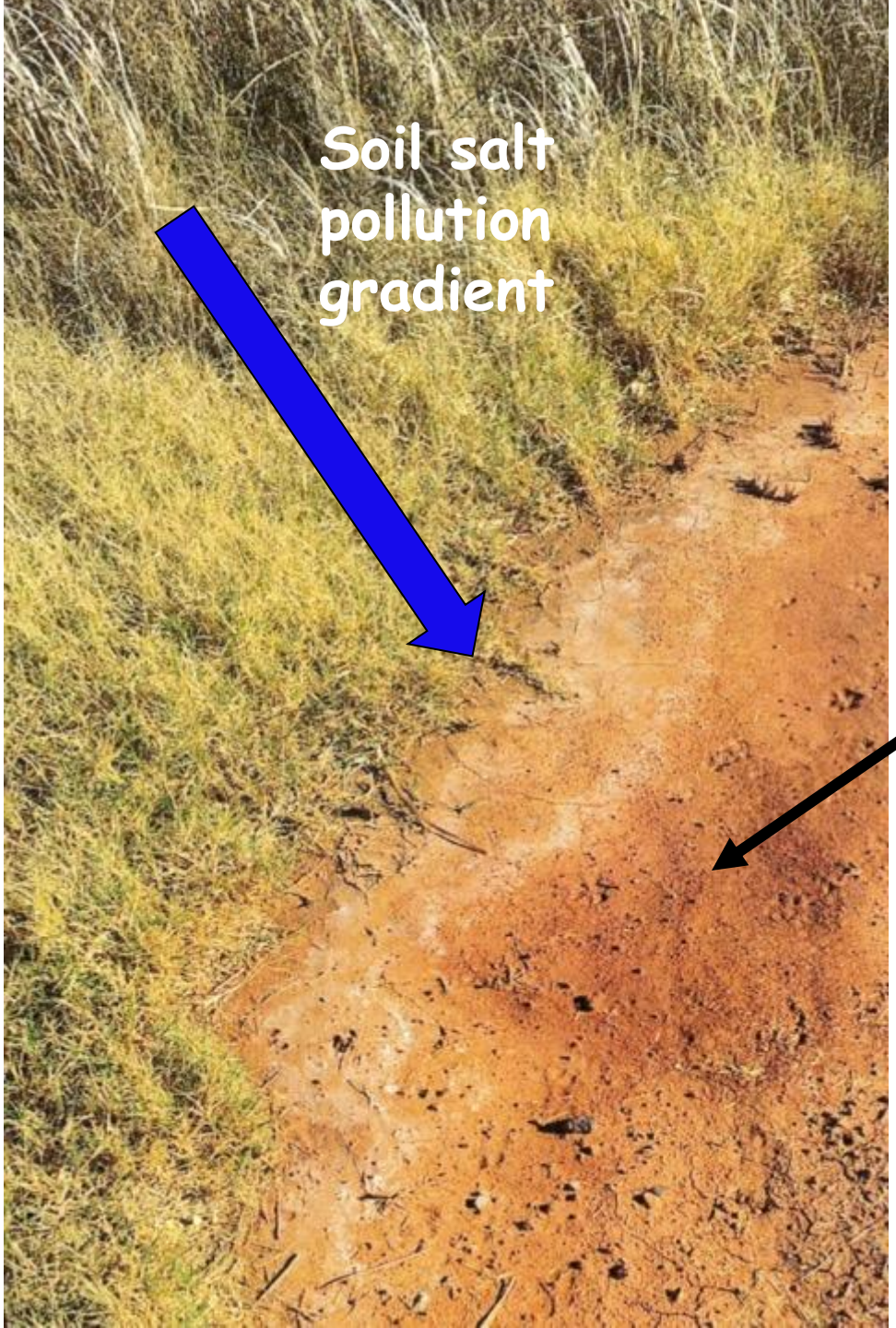


Increasing salinity in the plant root zone inhibits plant growth

Visual indicators of the effects of salinity in the plant root zone

Further proof of capillary rise mechanisms of exposures of buried salt pollution.

Note salt has accumulated on the surface (transported from below by capillary suction).



Note that the salt brought upward into the plant root zone created excess salinity that has resulted loss of vegetation. This is consistent with numerous observations of homeowners.

Disputes of fact

- EM survey results as predictive tool
- Source of shallow salt contamination
- Source of groundwater contamination

EM survey results as predictive tool

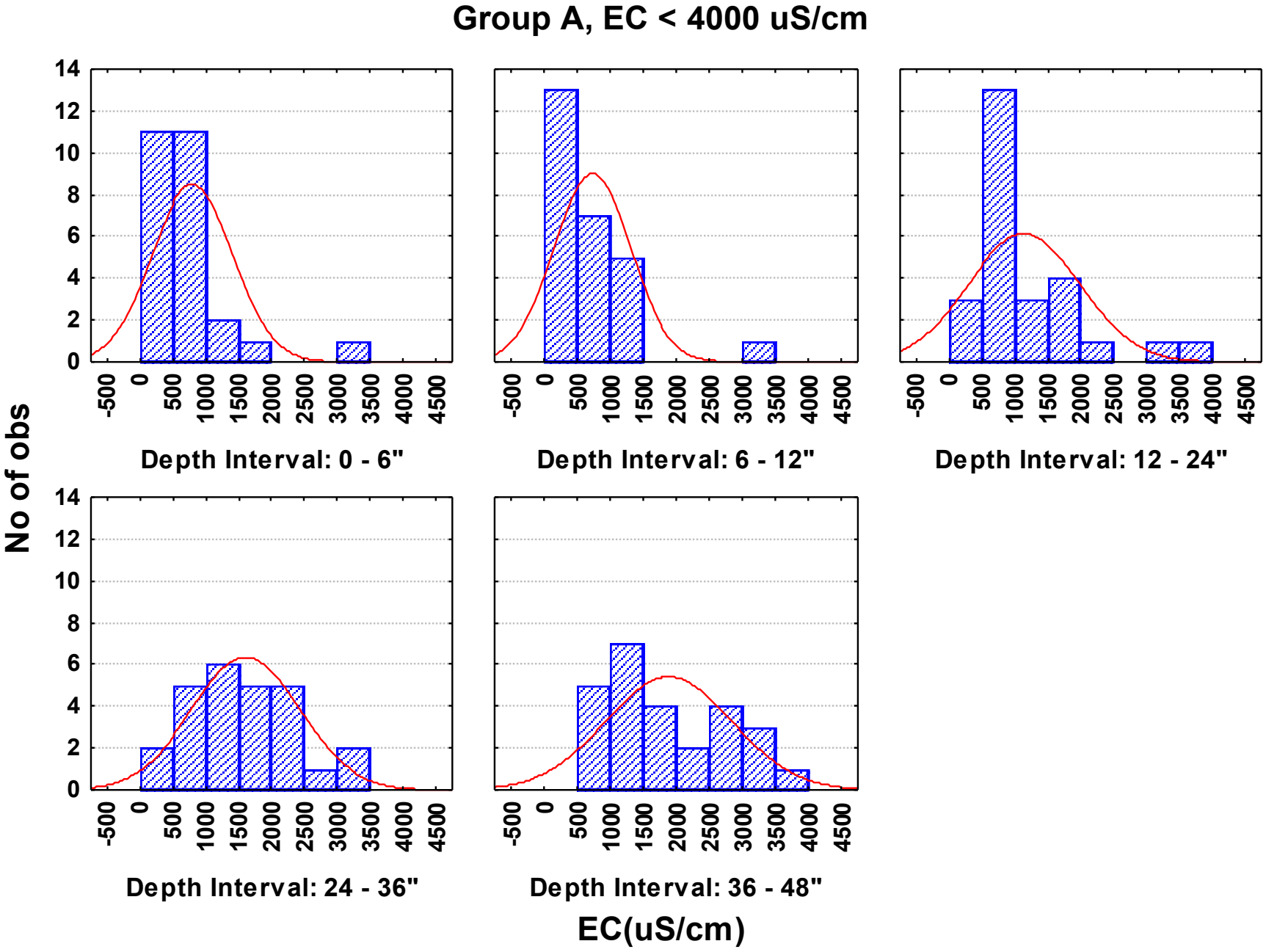
First, we non-invasively measured the subsurface conductivity of the soil (averages over 2.5 ft and 5 ft) using an EM38.

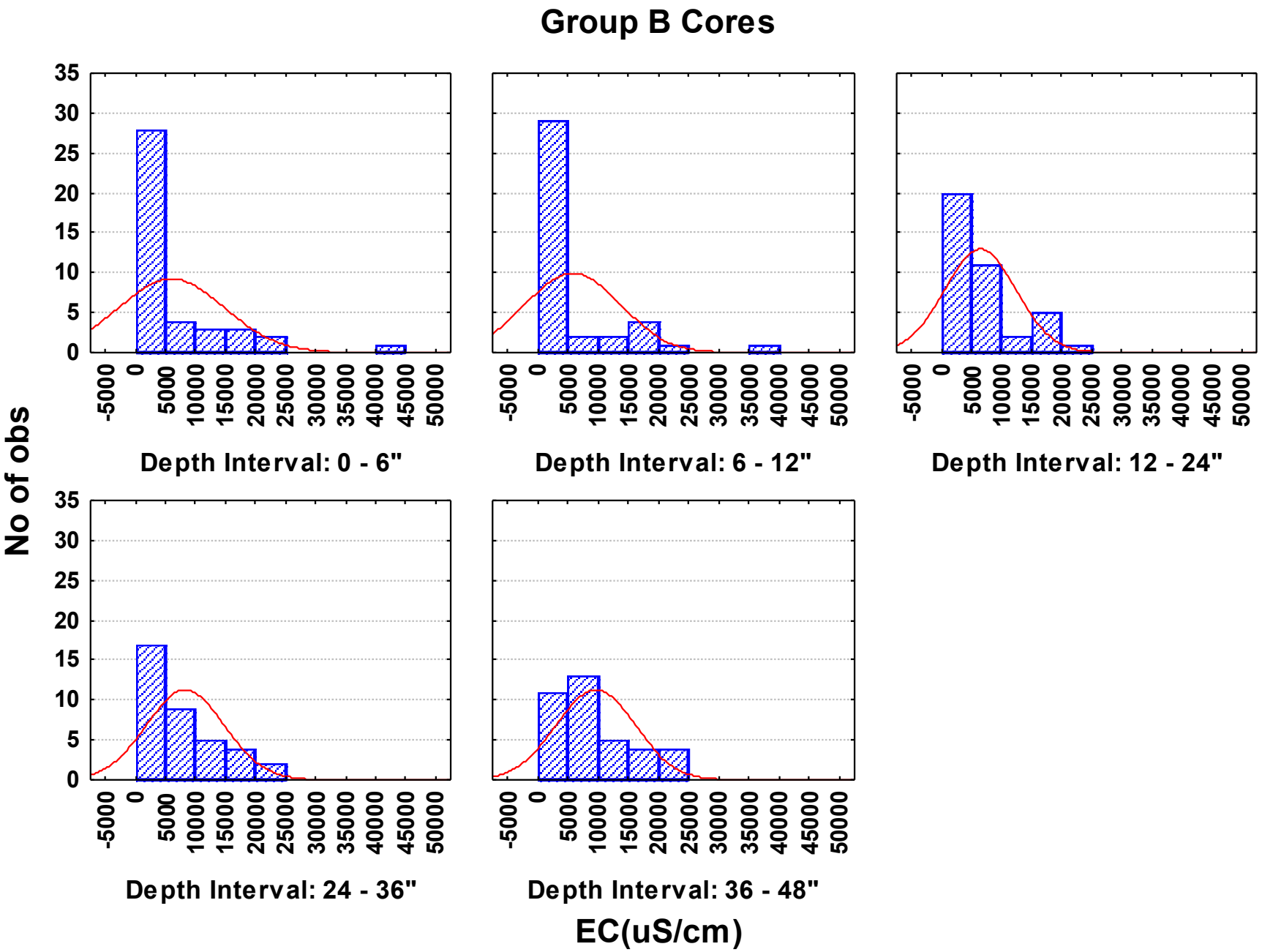
This was the result. Areas of different conductivities (averaged over 5 ft in depth) are shown by different colors.

The areas of lowest conductivity are the local background.

The next step was to do actual soil sampling making sure we can get multiple cores in each color zone. In this way we can understand what salt concentrations in the soil correspond to each color. This required 88 cores in the 0-48-in depth interval plus 6 deep cores.

This is standard industry practice in complex and sensitive sites.


Group A, EC < 4000 uS/cm
No of obs
14
12
10
8
6
4
2
0
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Depth Interval: 0 - 6"
Depth Interval: 6 - 12"
Depth Interval: 12 - 24"
Depth Interval: 24 - 36"
Depth Interval: 36 - 48"
EC(uS/cm)


Group B Cores
No of obs
35
30
25
20
15
10
5
0
-5000
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Depth Interval: 0 - 6"
Depth Interval: 6 - 12"
Depth Interval: 12 - 24"
Depth Interval: 24 - 36"
Depth Interval: 36 - 48"
EC(uS/cm)

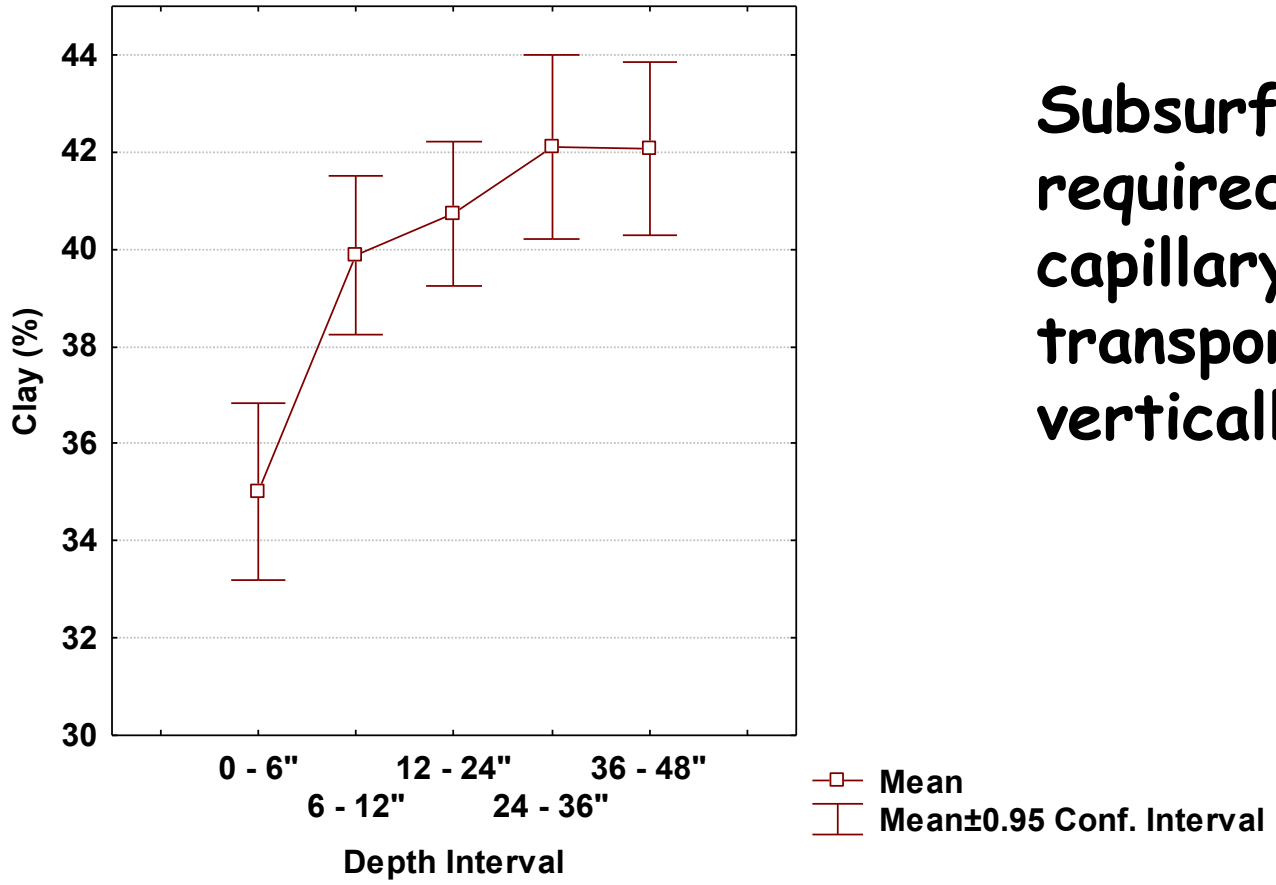
Defendant claimed that EM survey was not predictive

- Over 2.5 ft depth interval coefficient of linear correlation (r) was 0.74 ($p<0.05$)
- Over 5 ft depth interval coefficient of linear correlation (r) was 0.78 ($p<0.05$)

Defendant claimed that historic oilfield contamination was not the source of shallow salt contamination

- Defendant's own data showed Cl/Br ratio in shallow soil samples averaged 270, virtually identical to seawater evaporates

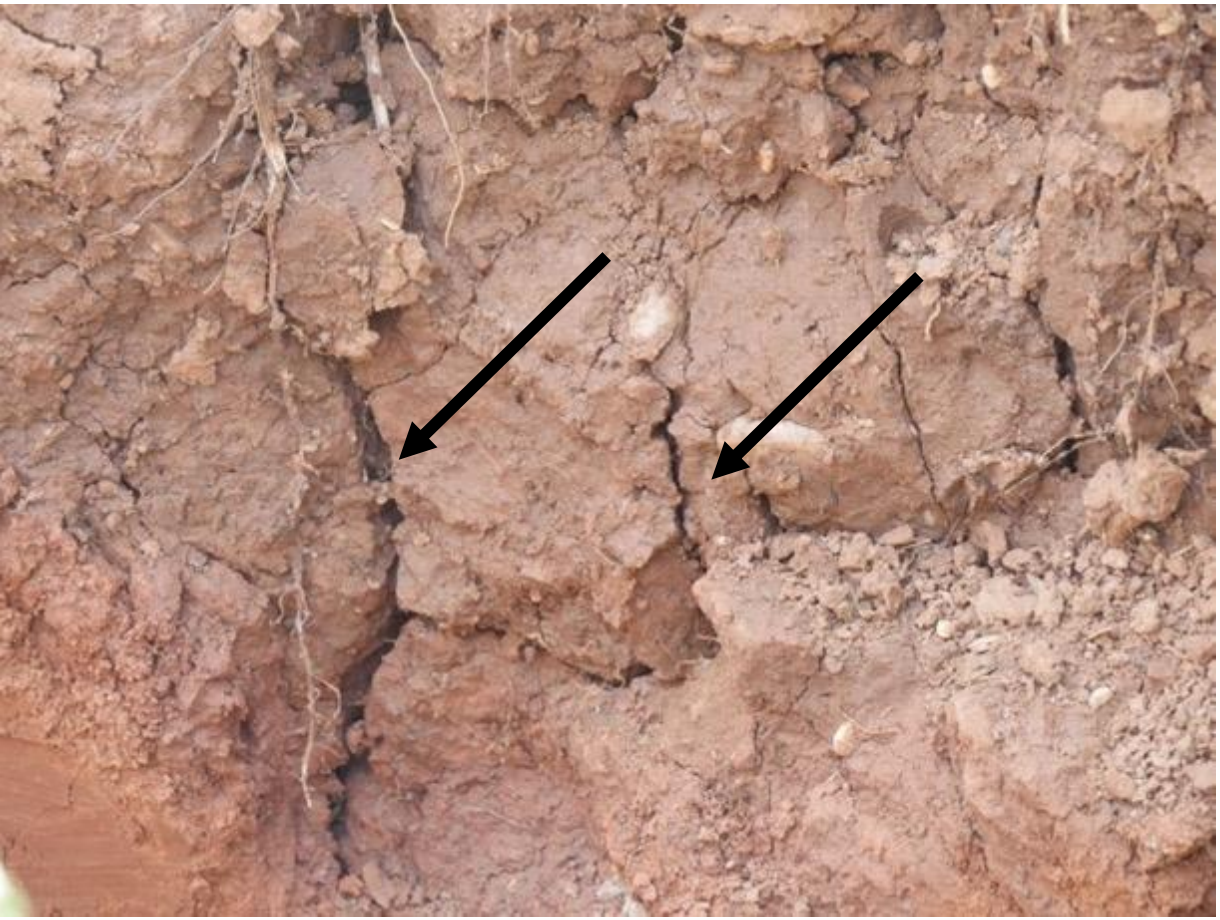
Defendant claimed that historic oilfield contamination could not be transported into shallow soils due to high clay content of the soil



Subsurface water required for capillary suction to transport salts vertically

Notice how the clay on the left (an Oklahoma clay) swells when wet and shrinks forming cracks when dry.

Vertical fractures in soil with swelling clays during a drying cycle

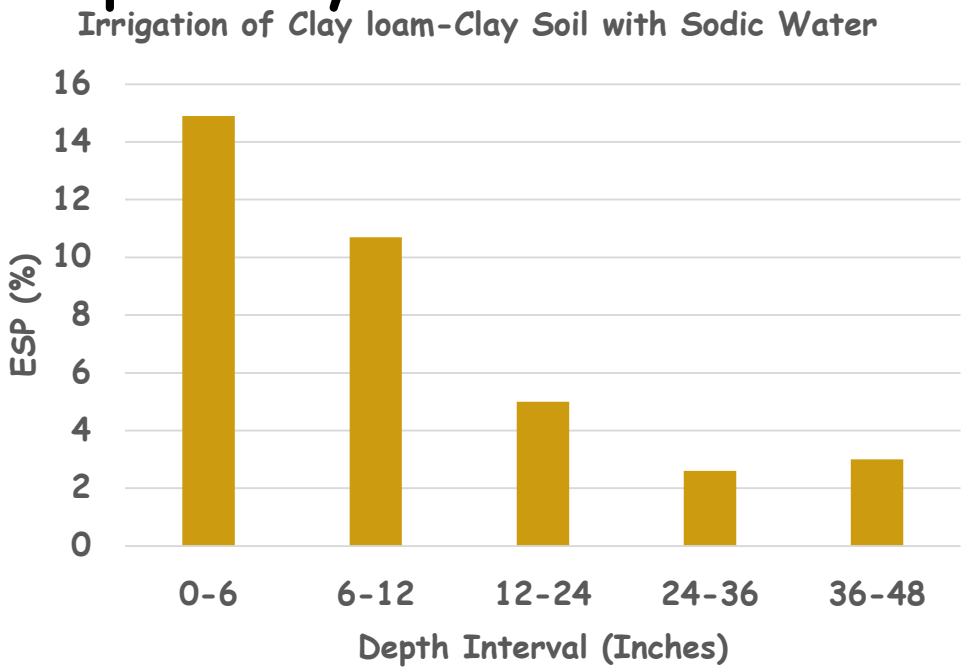


When it rains, water moves downward in the soil profile, slow through clayey soil, but rapidly through fractures when the soil is dry resulting in contact with buried salt.

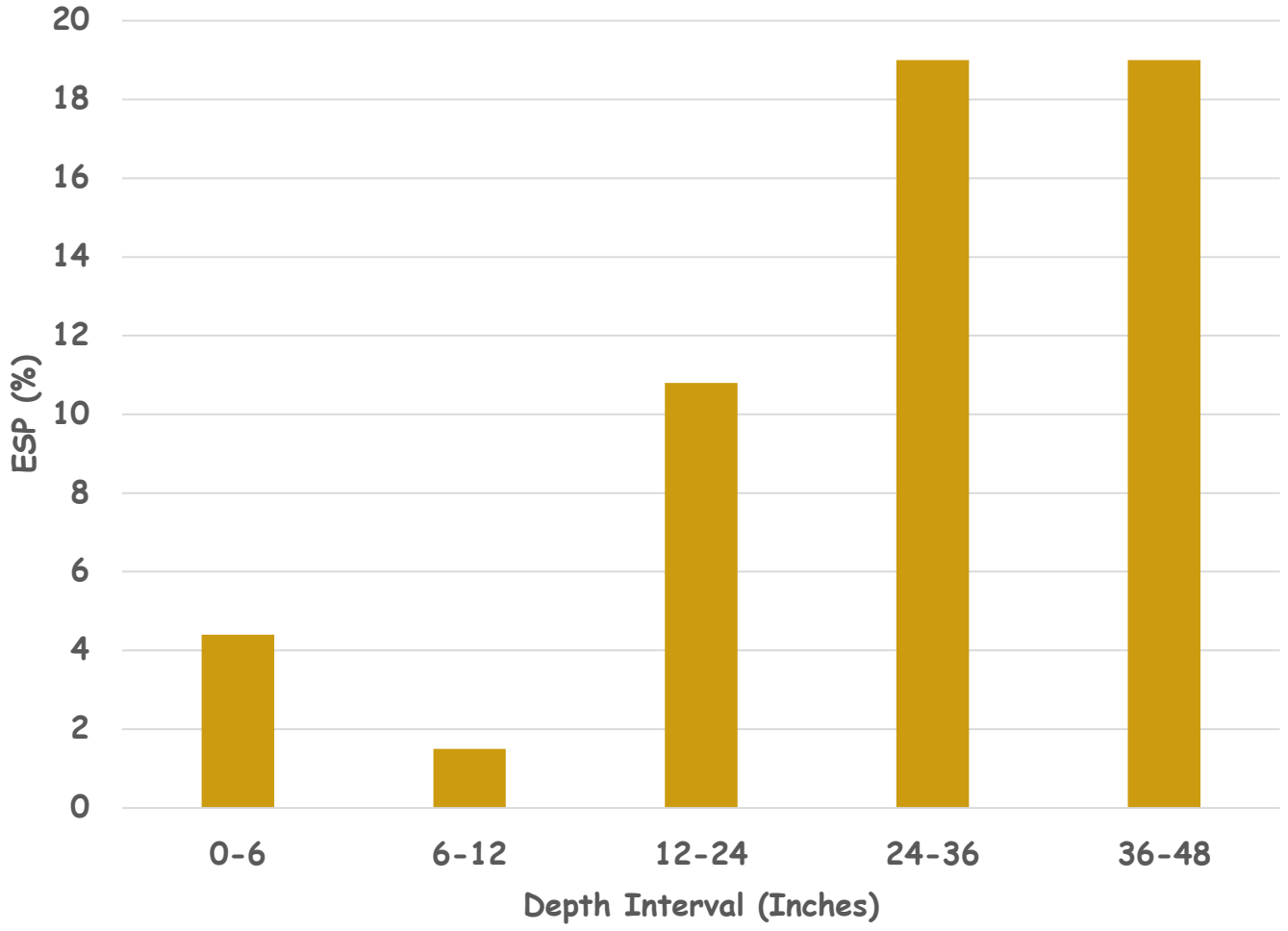
During drying periods after rain, water carrying salt moves up in the soil profile by capillary suction into the root zone of plants.

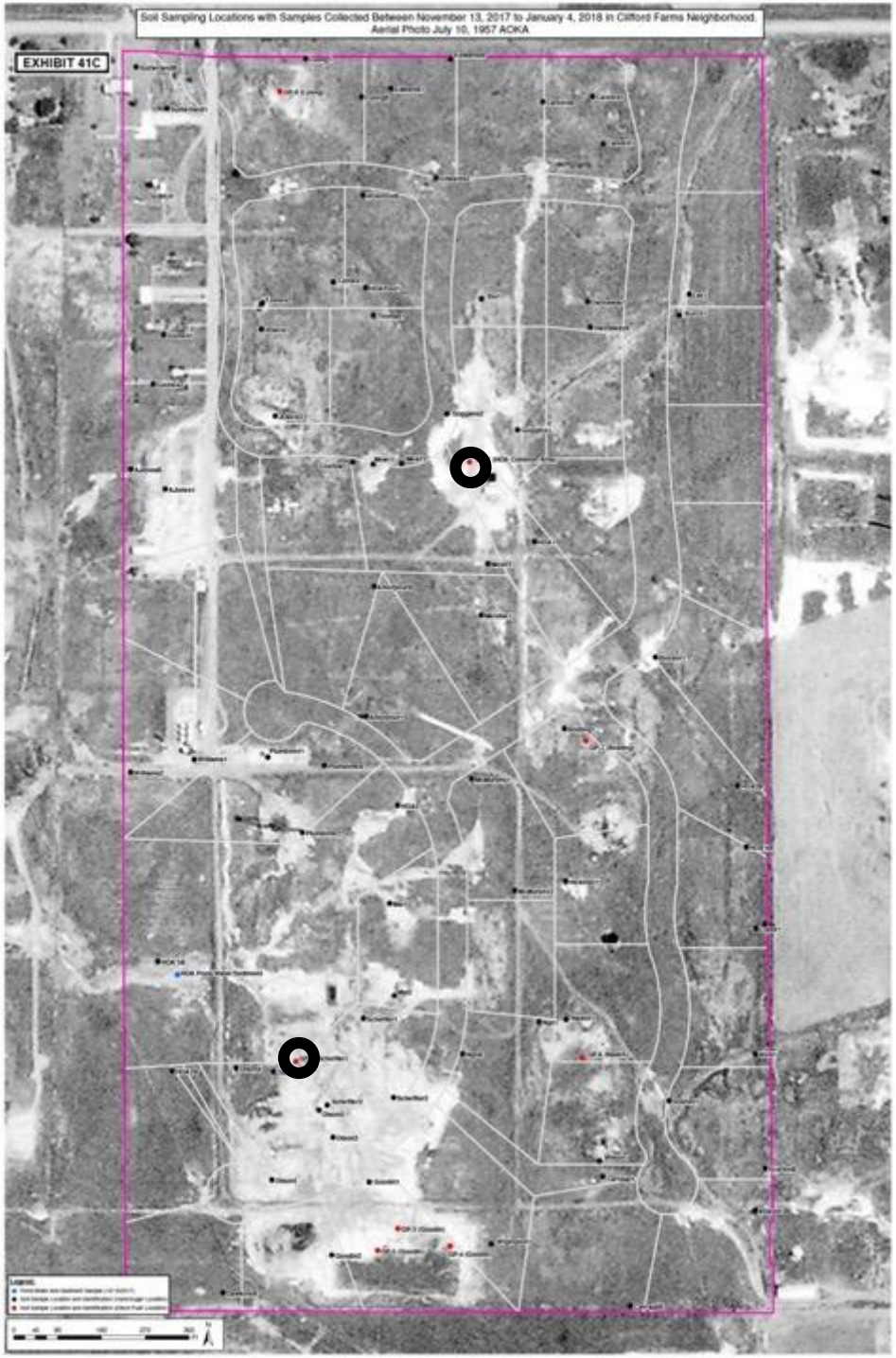
Defendant claimed that aerobic septic systems were the source of salt contamination in shallow soils

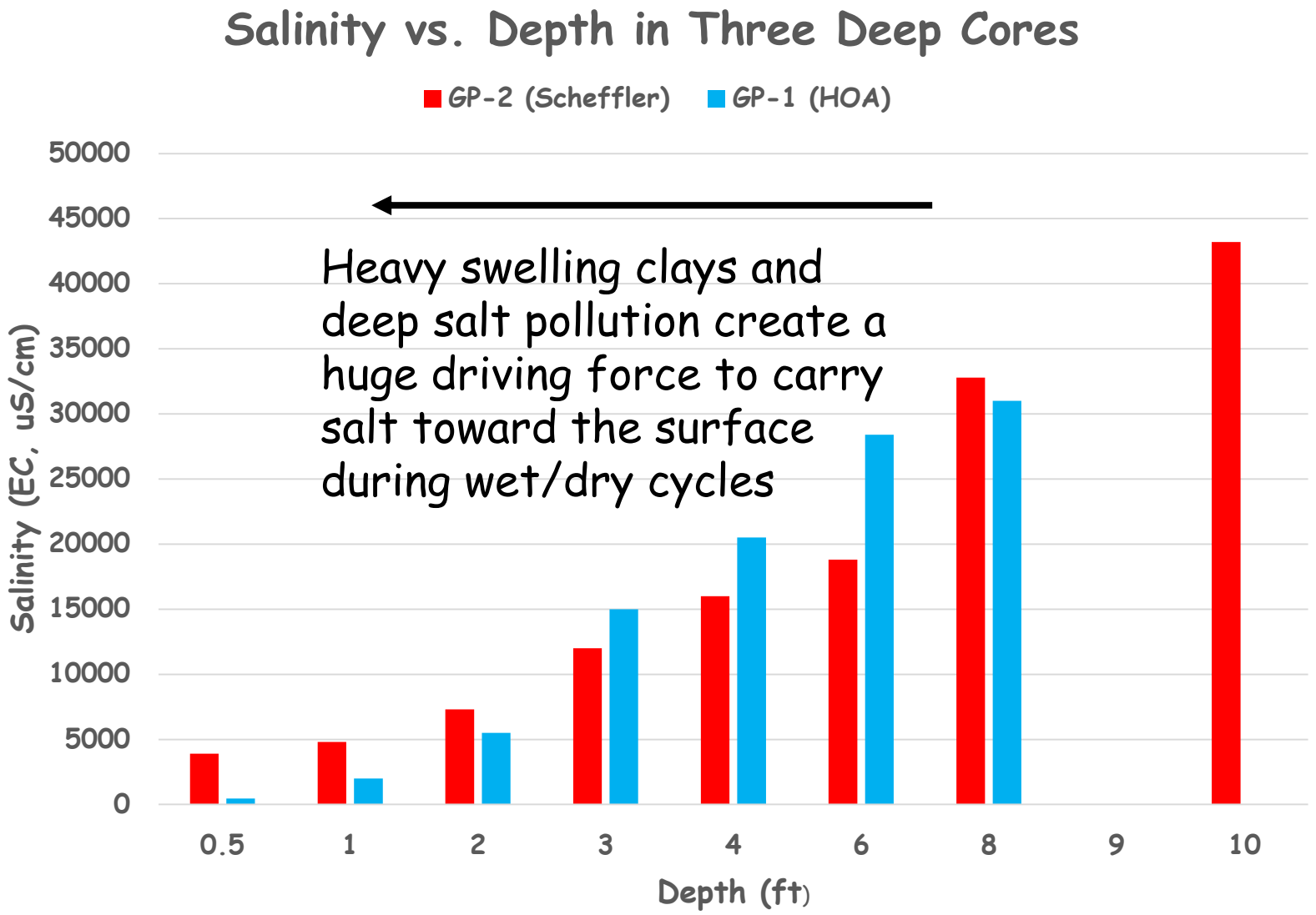
- Ion exchange resins were regenerated with brine which entered the septic systems



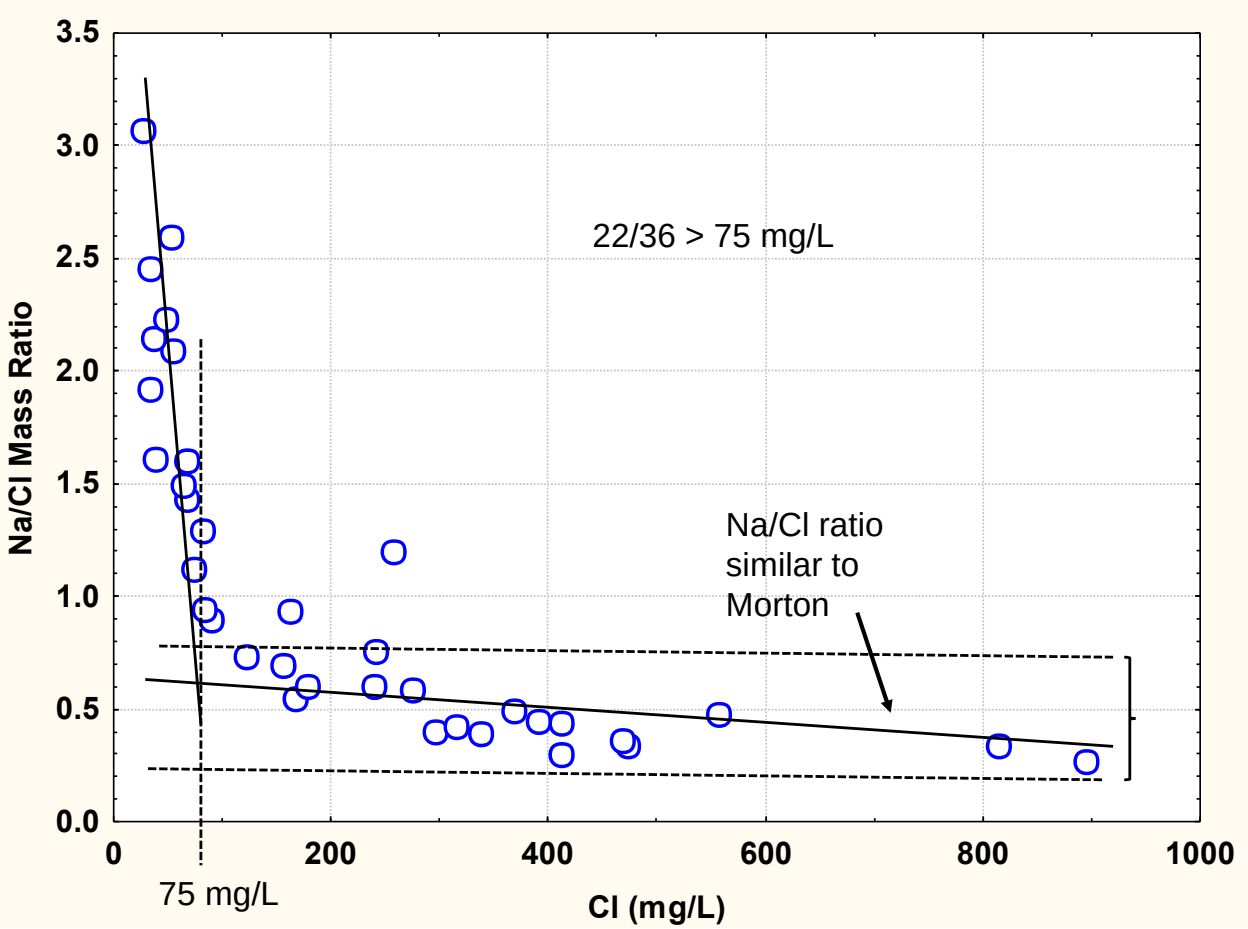
Typical site results: ESP vs. Depth




Soil Sampling Locations with Samples Collected Between November 13, 2017 to January 4, 2018 in Clifford Farms Neighborhood.
Aerial Photo July 10, 1957 ACKA
EXHIBIT 41C


Salinity vs. Depth in Three Deep Cores
GP-2 (Scheffler)
GP-1 (HOA)
Heavy swelling clays and deep salt pollution create a huge driving force to carry salt toward the surface during wet/dry cycles
Salinity (EC, uS/cm)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.5
1
2
3
4
6
8
9
10
Depth (ft)

Defendant claimed that groundwater contamination was unrelated to historic oilfield operations



USGS method

Conclusions

- EM surveys are excellent predictive tools for soil salinity (correlation not correspondence)
- Historic oilfield contamination is a threat to beneficial use of surface soils
- Historic oilfield contamination is a threat to groundwater when a pathway exists