# Impact of E&P Activity and Terrestrial Produced Water Spills on Stream Water Quality

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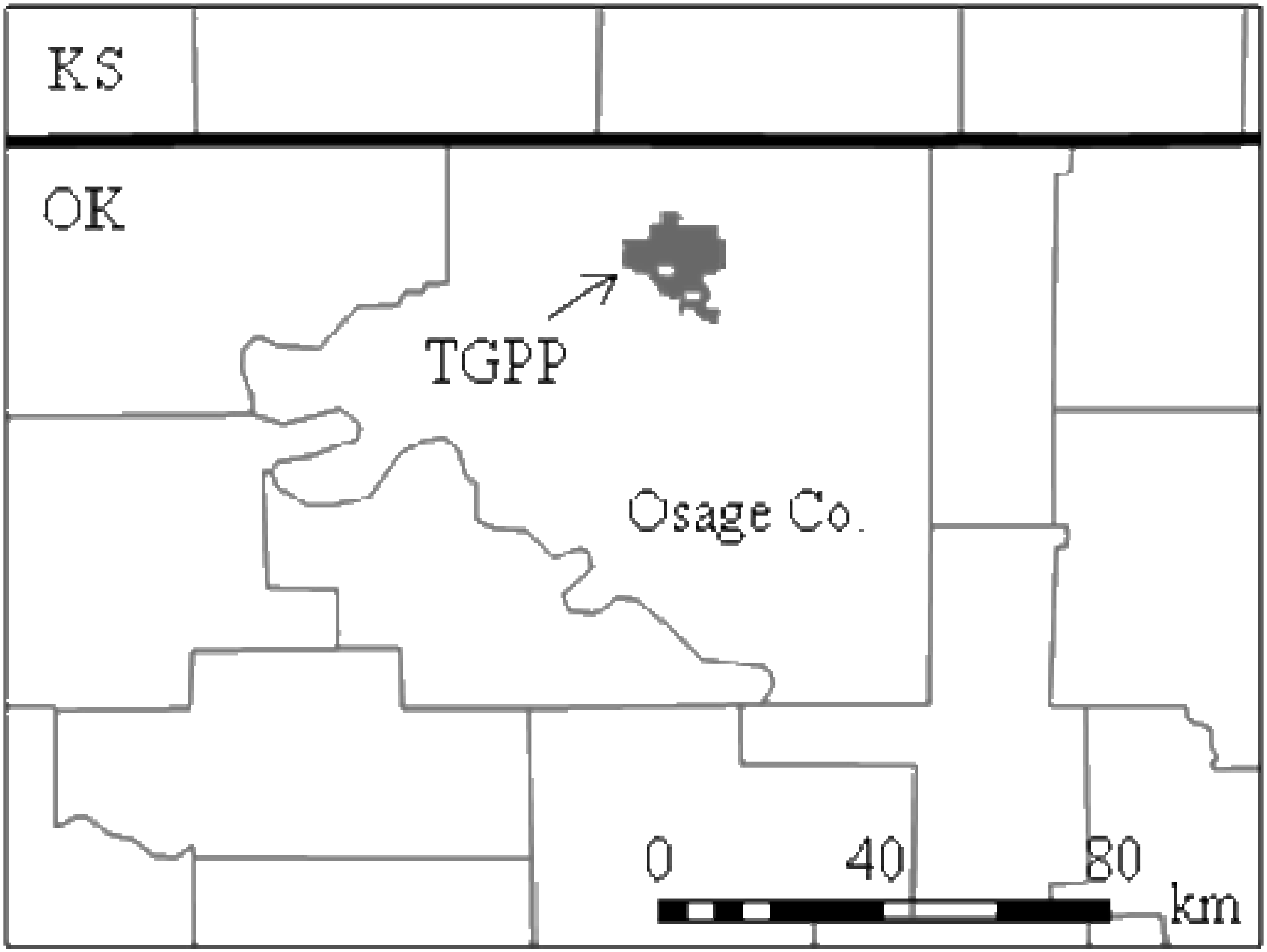
# Objectives

Four streams in the Preserve (three with greater E&P activity in their watersheds and one control with lesser E&P activity) were sampled quarterly for seven quarters and analyzed for water quality parameters relevant to brine contamination.

All data were analyzed to determine if there was statistically significant evidence of brine impacts in the streams and any correlation with oil E&P activity in their watersheds.

All data were also compared to previous analyses from target streams to determine if statistically significant changes in stream water quality, in terms of brine related parameters, have occurred over time.

# The Tallgrass Prairie Preserve



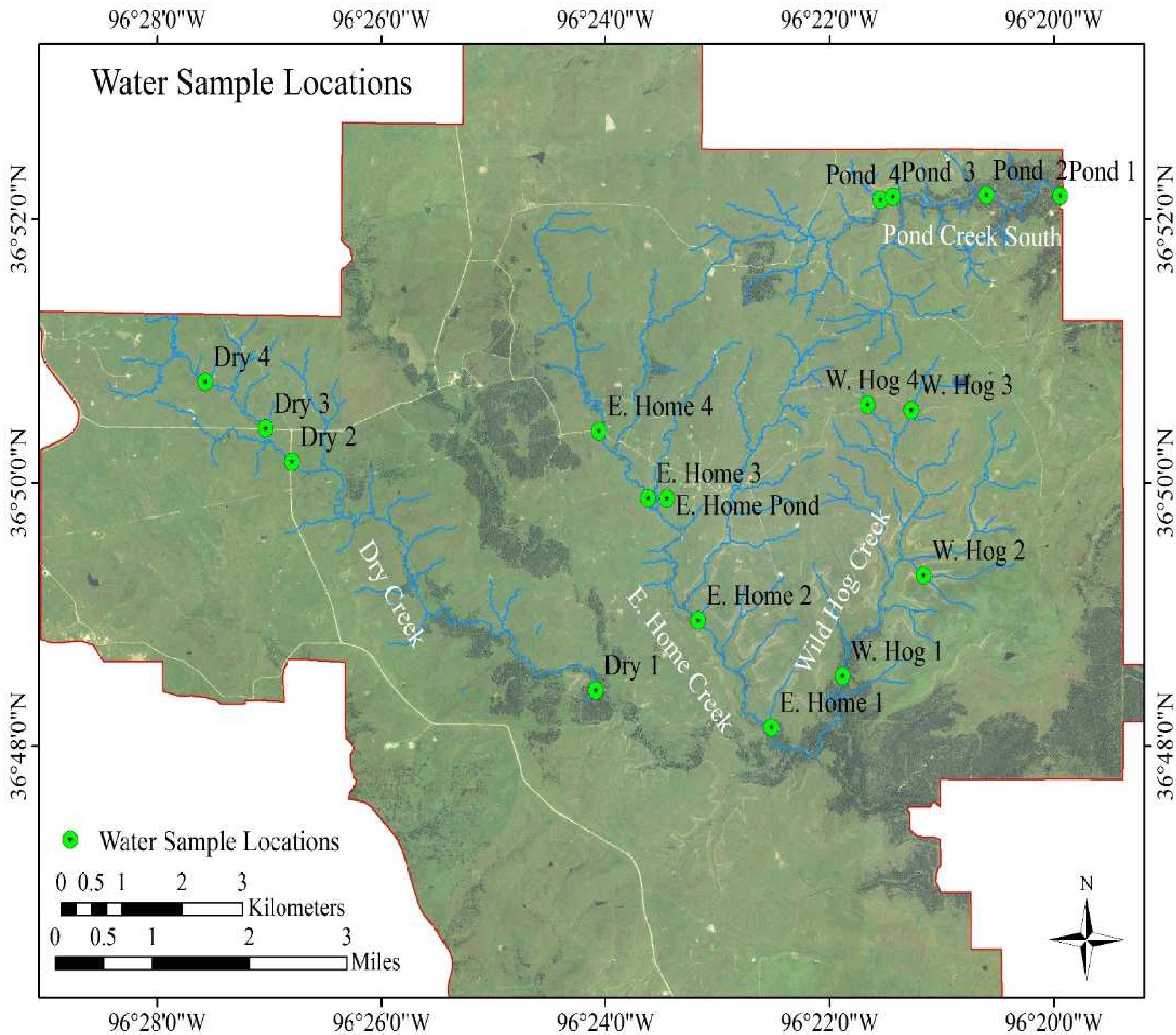



**Figure 1.** **Water sample locations**

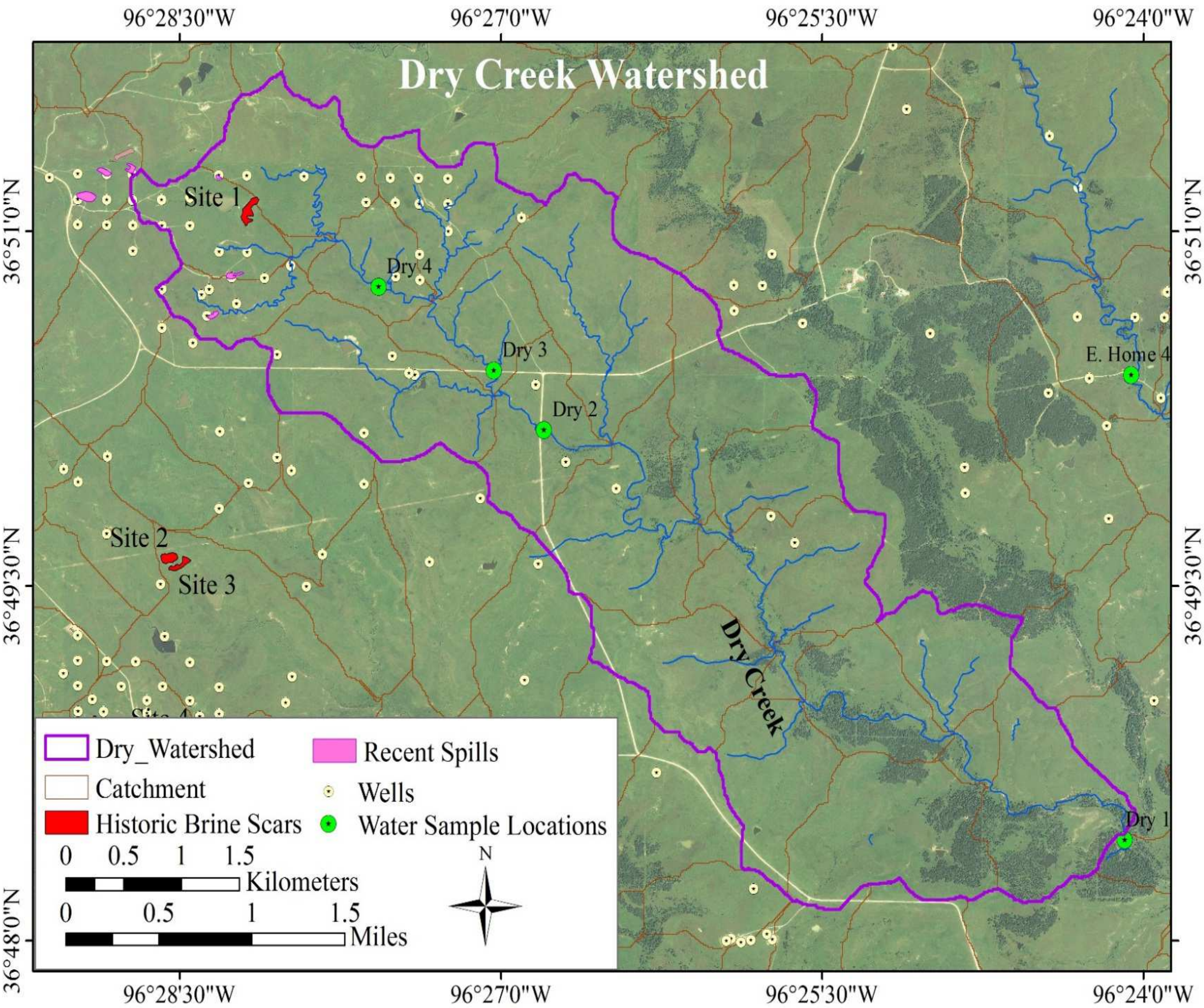



**Figure 2.** **Dry Creek Watershed**

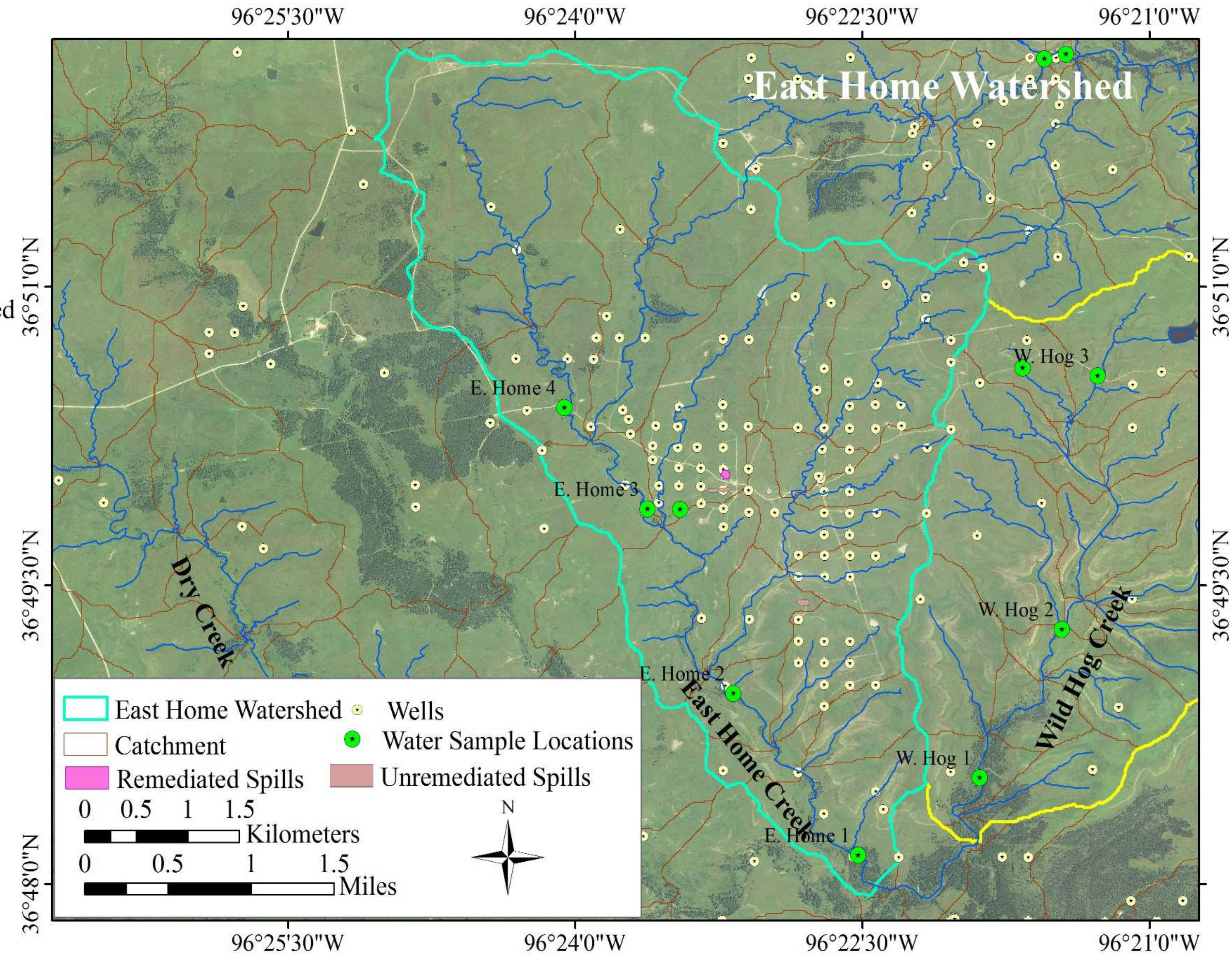



**Figure 3.** East Home Watershed

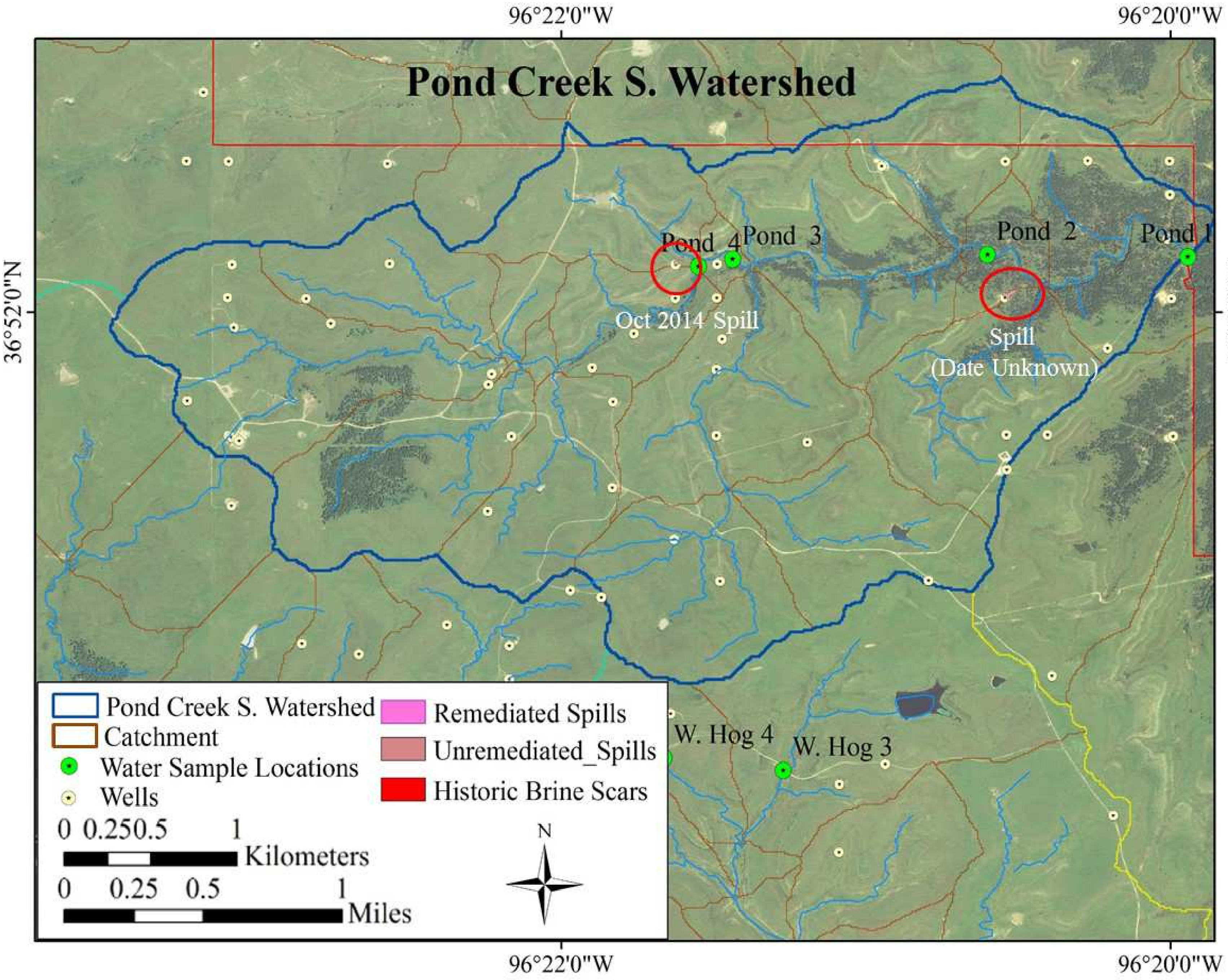



**Figure 5.** Pond Creek S. Watershed

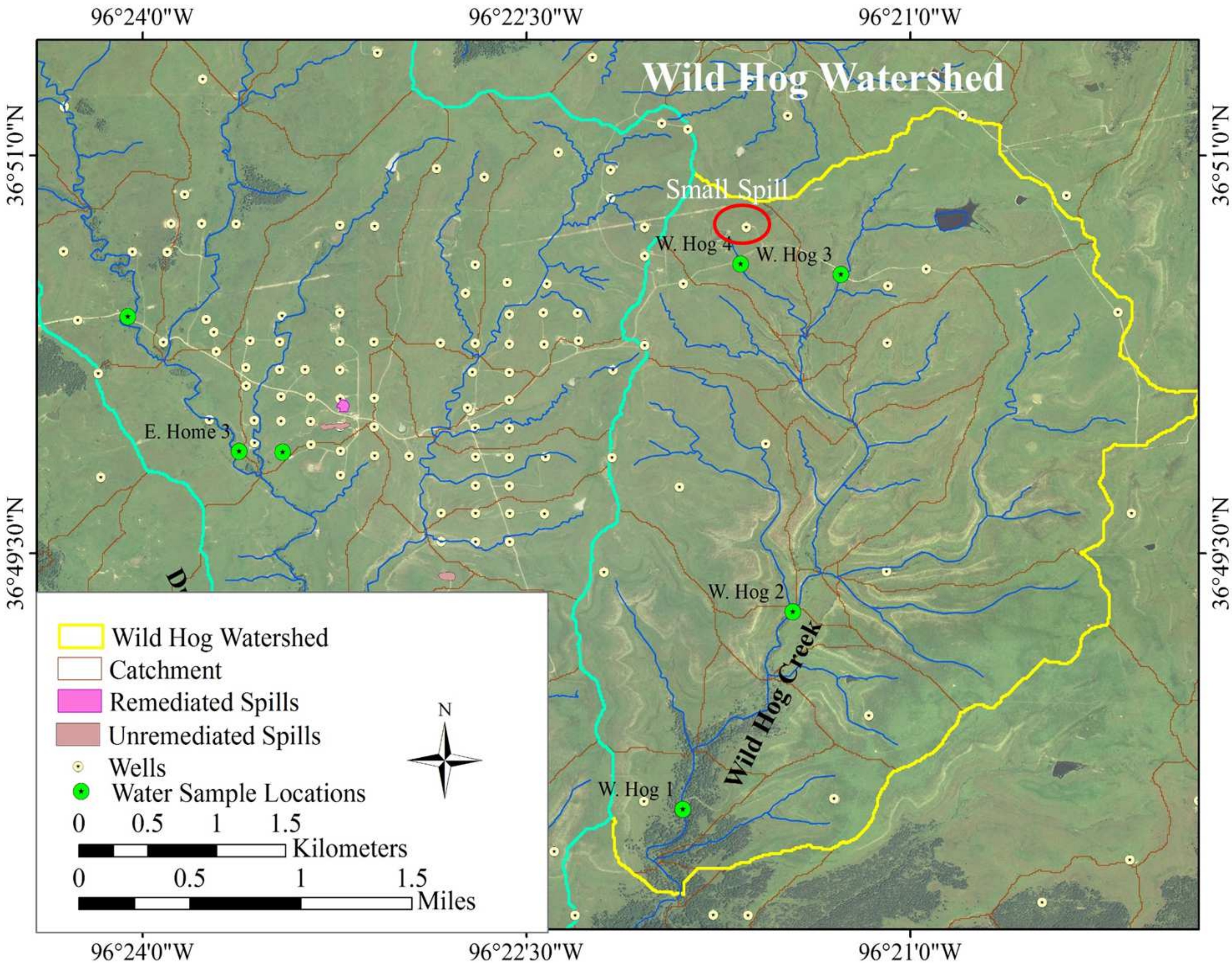



**Figure 6. Wild Hog Watershed**

# Area and number of wells in each study area

| Study Area | Area ($m^2$ X $10^{-6}$) | Number of Wells |
|---|---|---|
| Dry Creek | 17.1 | 42 |
| East Home Creek | 19.4 | 110 |
| Wild Hog Creek | 12.5 | 15 |
| Pond Creek South | 11.3 | 39 |

# Effects of produced water releases

Primary brine components

- $Na^+$ (interacts with soil and sediment matrix)
- $Cl^-$

$Na^+$ + Clays

→

$Ca^{+2}$ $Mg^{+2}$ $H^+$

→

$CaCO_3$

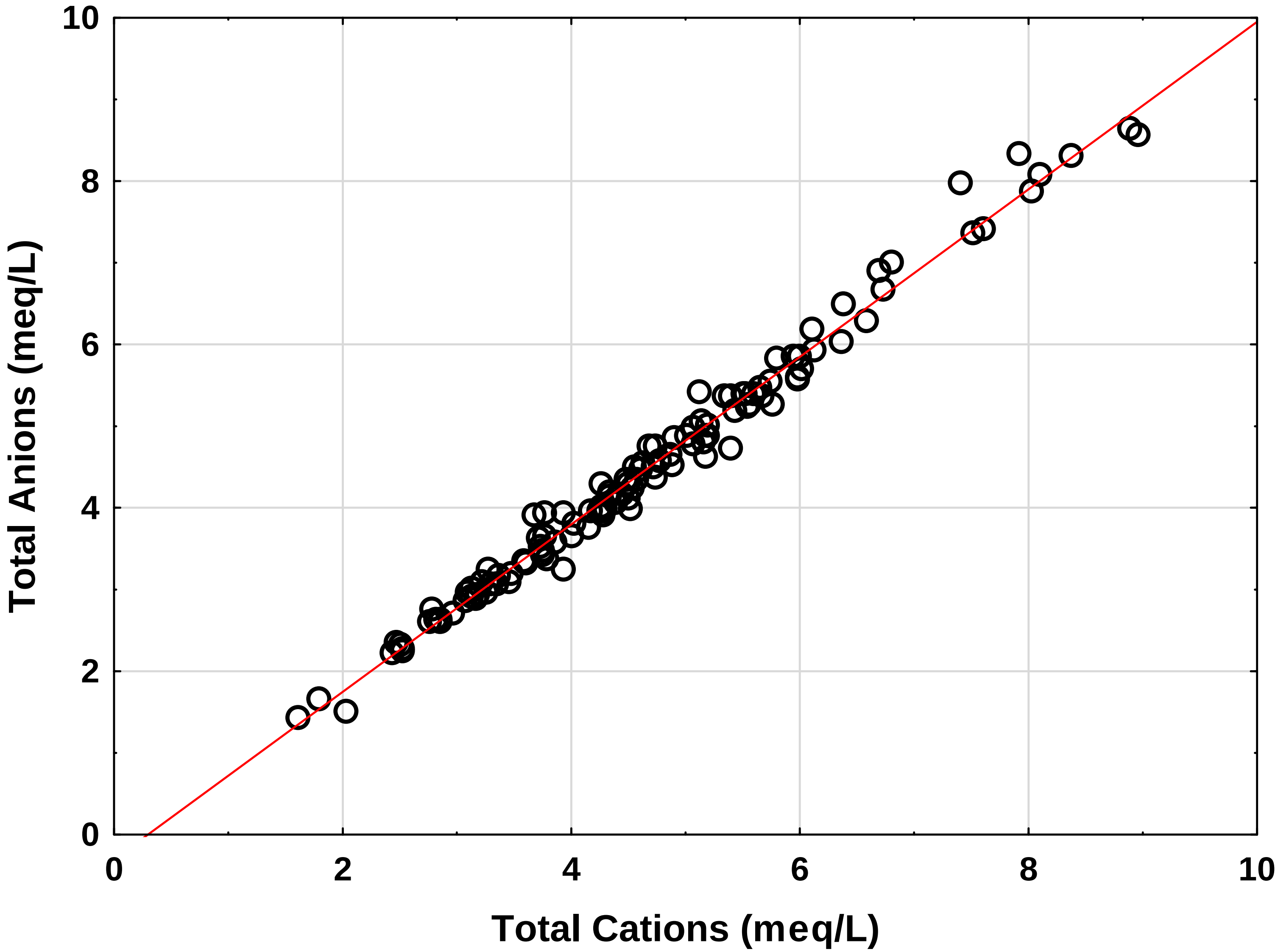
→

$HCO_3^-$

# Surface water analysis

- Cations
  - $Na^{+}$
  - $Ca^{+2}$
  - $Mg^{+2}$
  - $K^{+}$
- Anions
  - $Cl^{-}$
  - $SO_4^{-2}$
  - $HCO_3^{-}$
- Derived
  - EC

# Results of water quality data assessment for completeness



# lean values of brine contamination parameters in ne study creeks during the period of observation

| Creek | $Cl^-$ (mg/L)* | $Na^+$ (mg/L)* | EC (µS/cm)* |
|---|---|---|---|
| East Home | 17.9 ± 17.9 b | 14.1 ± 6.7 b | 418 ± 127 a |
| Wild Hog | 8.2 ± 11.6 a | 10.9 ± 7.9 b | 424 ± 127 a |
| Dry | 19.6 ± 15.5 b | 19.1 ± 12.4 a | 449 ± 190 a |
| Pond South | 16.2 ± 10.7 b | 12.6 ± 8.5 b | 452 ± 117 a |

*Mean ± std. dev., n = 28 (East Home), n = 32 (Wild Hog), n = 29 (Dry and Pond South). Mean values indicated with different letters (a,b) were statistically different at $p < 0.05$ (ANOVA).

## Values for statistically significant linear correlations ($p < 0.05$) etween brine contamination parameters in the study creeks

| | $Na^+$ | $Cl^-$ | $Ca^{+2}$ | $Mg^{+2}$ | $HCO_3^-$ | EC |
|---|---|---|---|---|---|---|
| $Na^+$ | | 0.81 | | | | 0.77 |
| $Cl^-$ | | | 0.42 | 0.63 | 0.33 | 0.71 |
| $Ca^{+2}$ | | | | | | 0.88 |
| $Mg^{+2}$ | | | | | | 0.86 |
| $HCO_3^-$ | | | | | | 0.87 |
| EC | | | | | | |

**Values for statistically significant correlations ($p < 0.05$) etween *chloride* concentration and watershed characteristi**

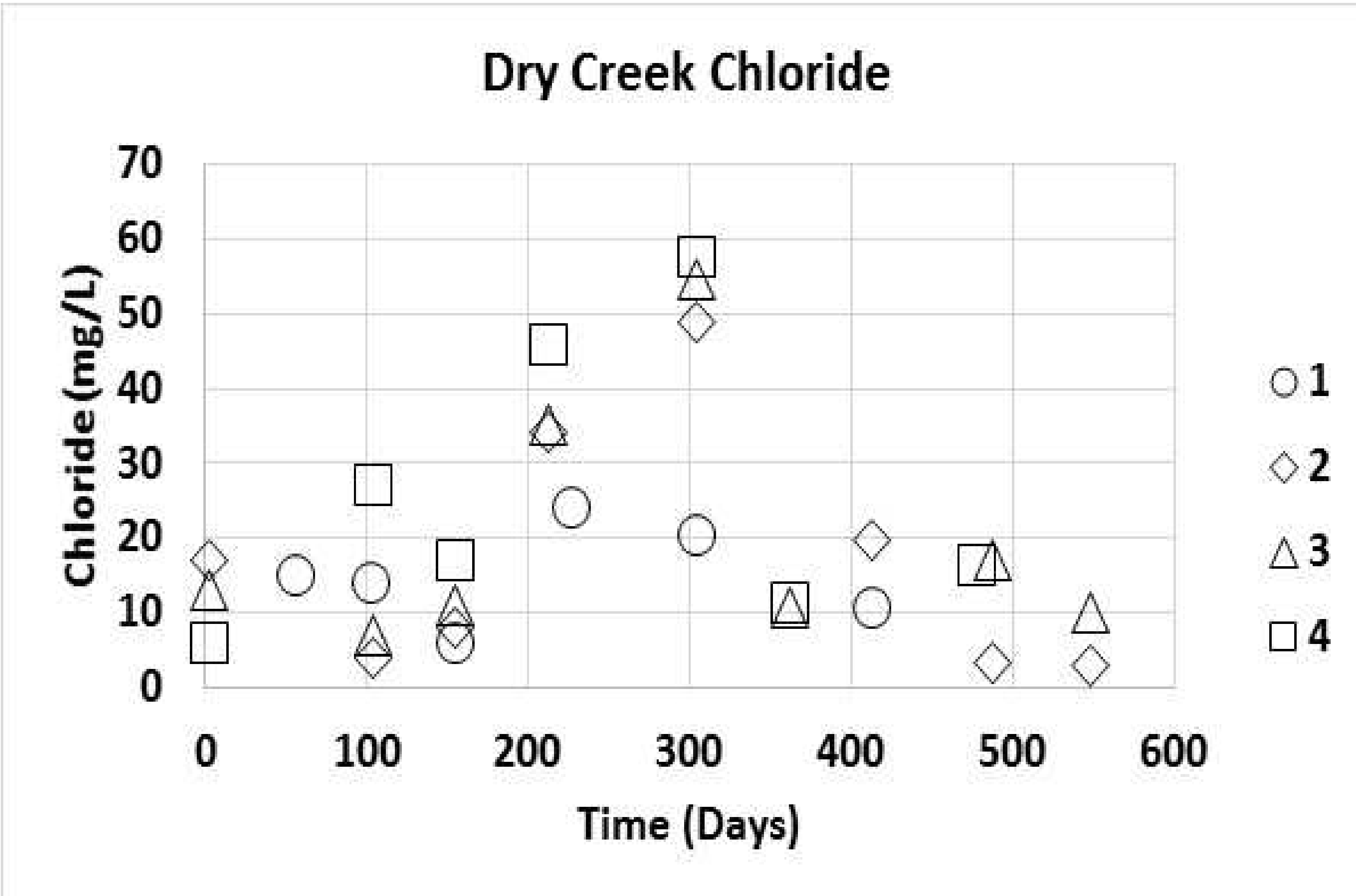
| Correlation | Pearson's | Spearman's |
|---|---|---|
| # wells/watershed | 0.18 | 0.29 |
| # wells/area | 0.20 | 0.31 |

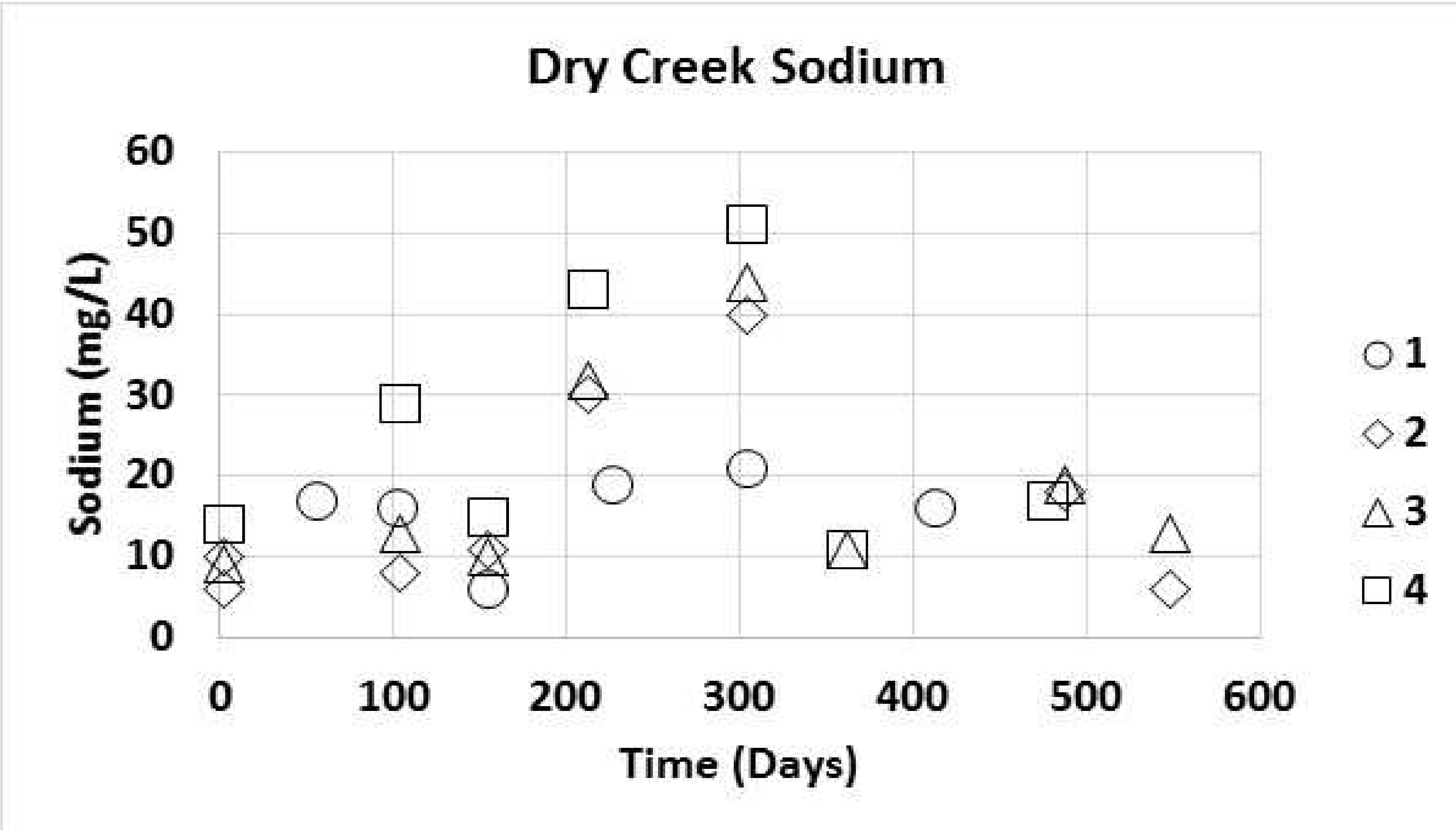
Indicators of brine contaminations positively correlated with greater historical E&P activity

Values for statistically significant correlations ($p < 0.05$) between revious 5-day rainfall and brine contamination parameters in the tudy creeks. Short term effect of rainfall is dilution.

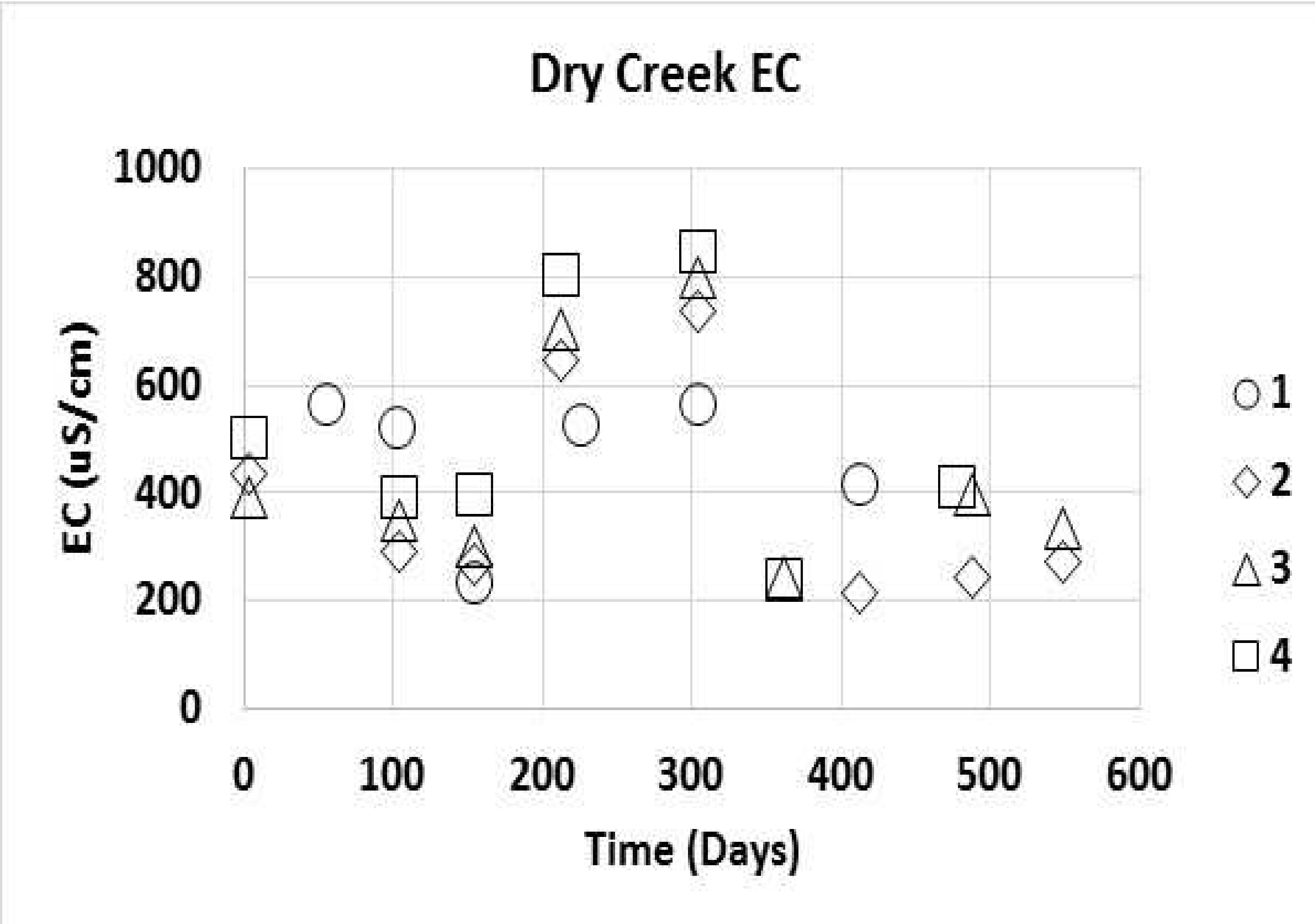
| ek | $Cl^-$ Pearson's | $Na^+$ Pearson's | EC Pearson's | $Cl^-$ Spearman's | $Na^+$ Spearman's | EC Spearm |
|---|---|---|---|---|---|---|
| d g | | | | | | |
| t e | | -0.48 | -0.67 | | -0.51 | -0.5 |
| | | | -0.47 | | -0.61 | |
| S | | | | | | |

# Response to a 3.1-inch rainfall event at 150 days?





Dry Creek Sodium
60
50
40
30
20
10
0
Sodium (mg/L)
0
100
200
300
400
500
600
Time (Days)
1
2
3
4



Dry Creek EC
1000
800
600
400
200
0
EC (uS/cm)
0
100
200
300
400
500
600
Time (Days)
1
2
3
4


**Figure 4-41: East Home Vertical Fracture Outcrop**

Is this a delayed effect of the heavy rain event ?

Fracture flow?

Do fractures represent a point discharge into streams?

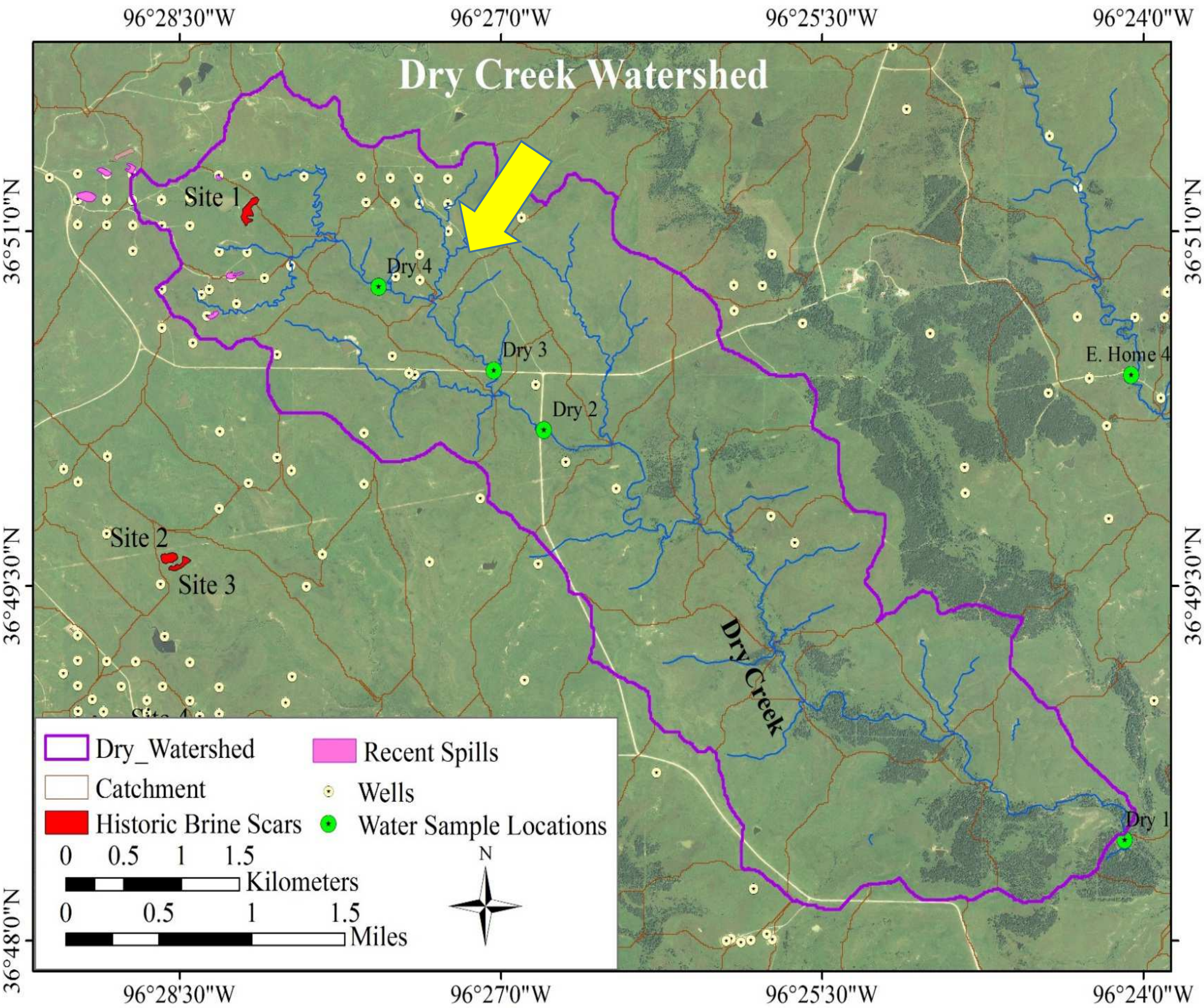
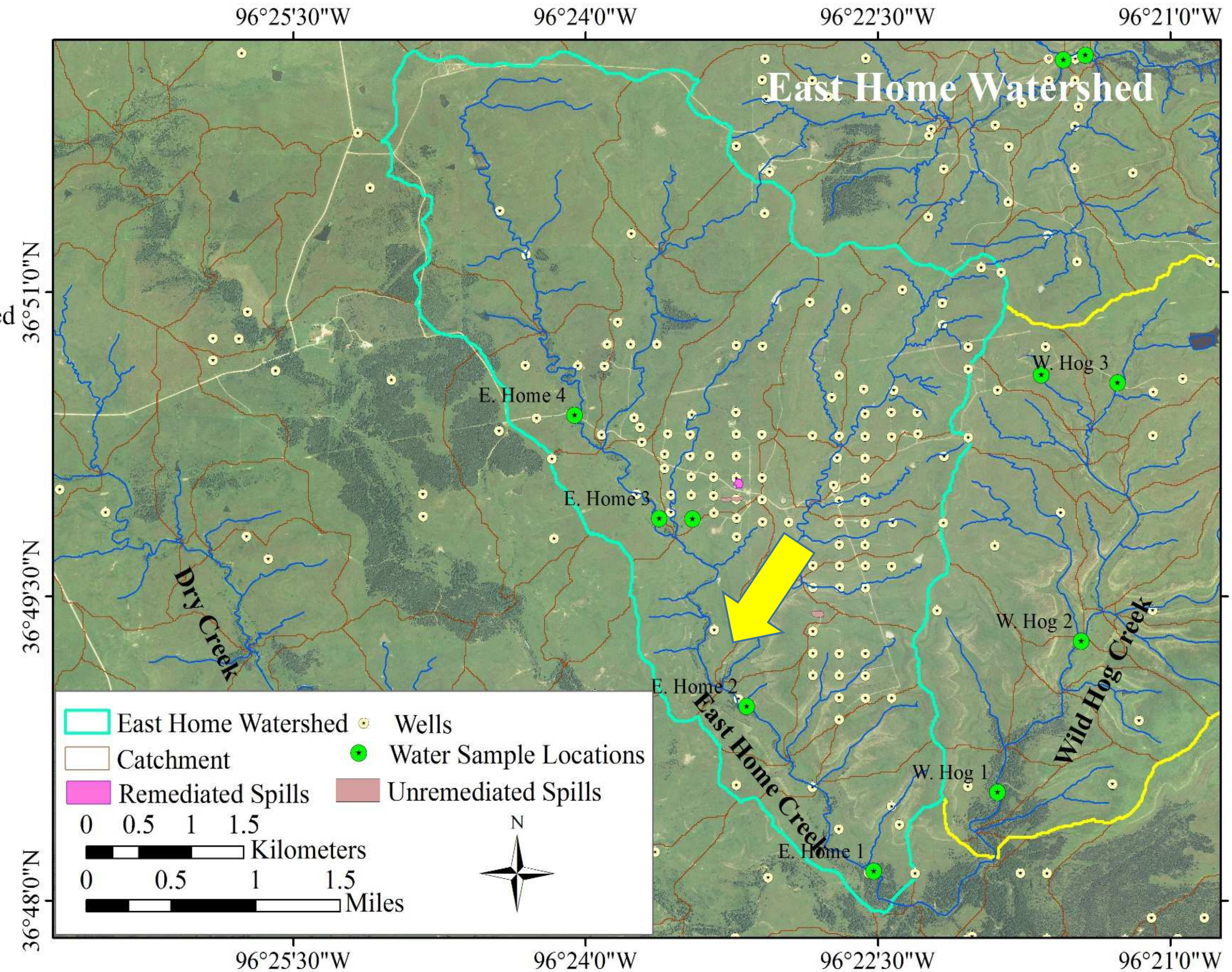



**Figure 2.** Dry Creek Watershed

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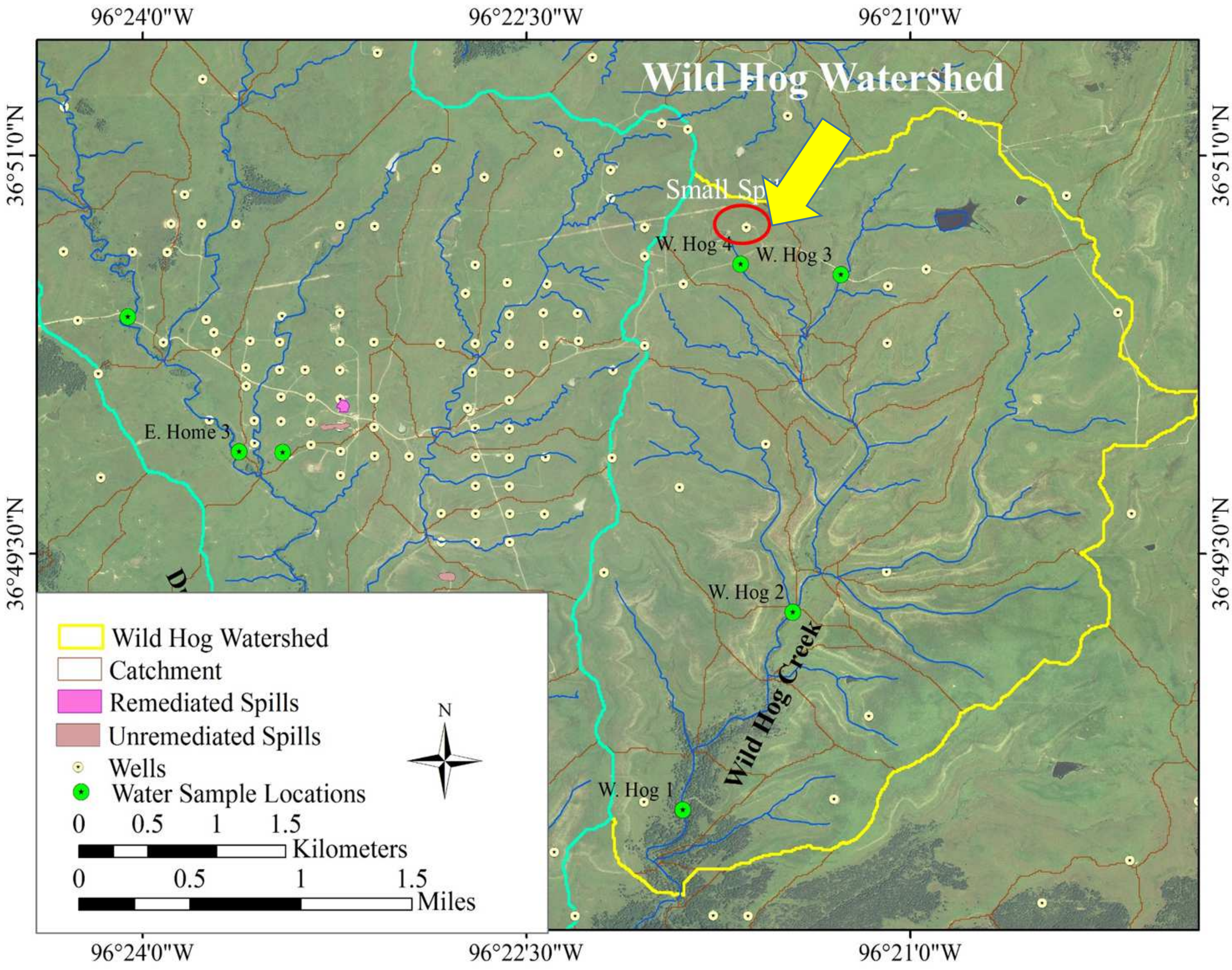



**Figure 6. Wild Hog Watershed**

## Mean values of EC (µS/cm) in 1996 vs. 2014/15

| Creek | 1996 | 2014/2015 | p |
|---|---|---|---|
| Dry | 356 | 449 | 0.07 |
| Wild Hog | 359 | 442 | 0.12 |

## Mean values of $Na^+$ (mg/L) in 1996 vs. 2014/15

| Creek | 1996 | 2014/2015 | p |
|---|---|---|---|
| Dry | 7.2 | 19.1 | 0.0004 |
| Wild Hog | 6.0 | 10.9 | 0.06 |

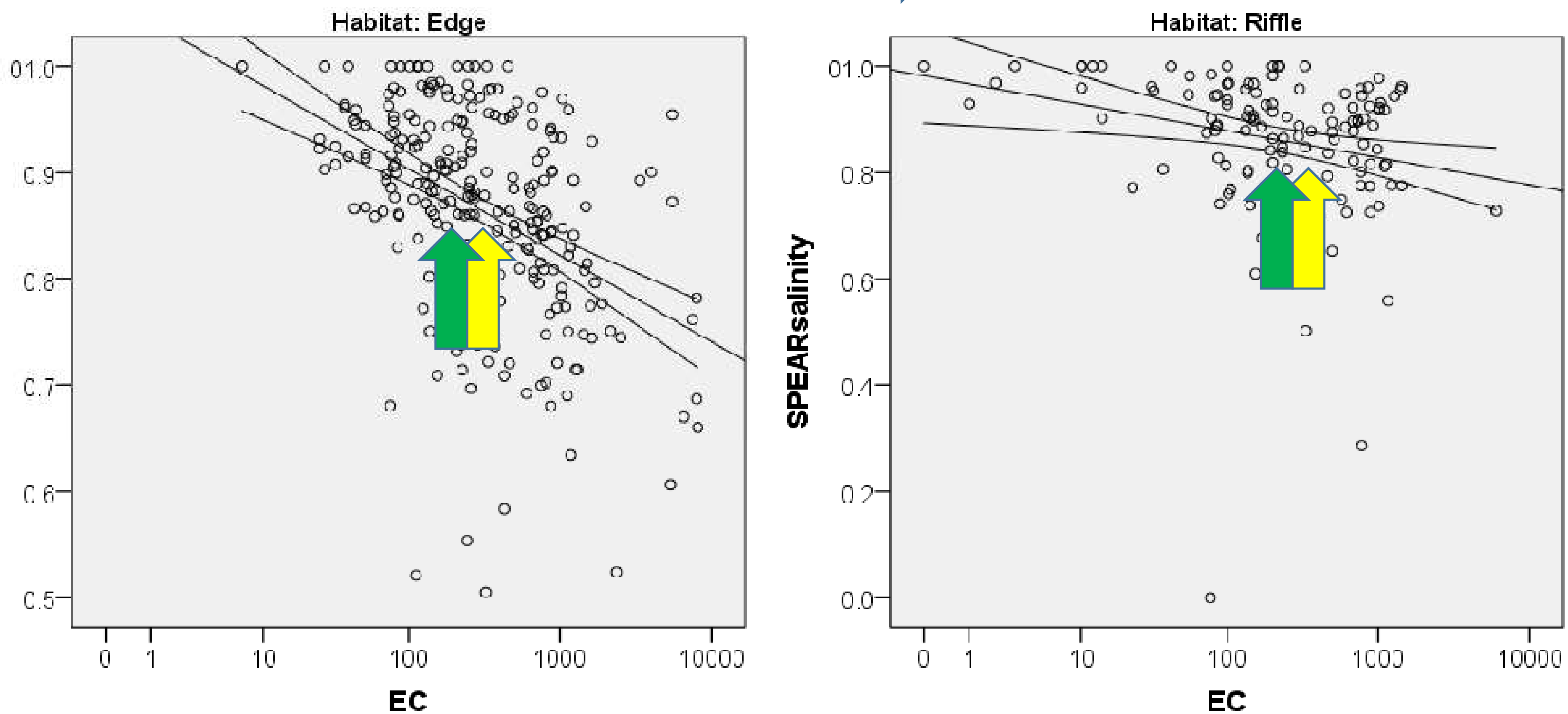
## Mean values of $Cl^-$ (mg/L) in 1996 vs. 2014/15

| Creek | 1996 | 2014/2015 | p |
|---|---|---|---|
| Dry | 14.0 | 19.6 | 0.16 |
| Wild Hog | 5.4 | 8.2 | 0.46 |

**ecies at risk with**
**ous exposure**

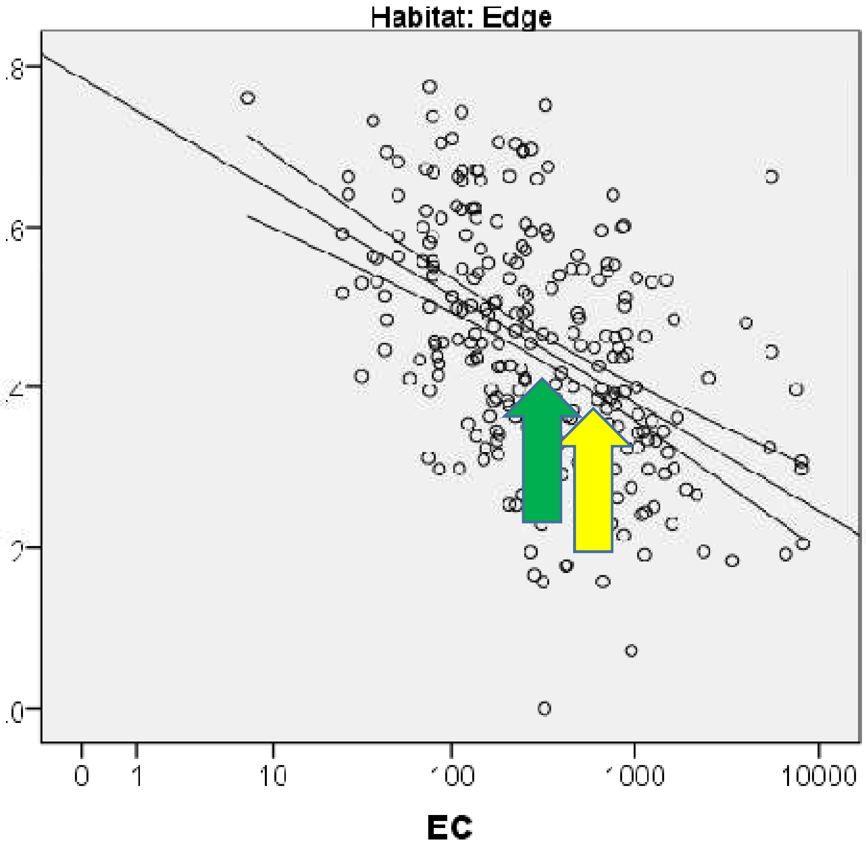
Avg EC (μS/cm) Preserve study streams (2

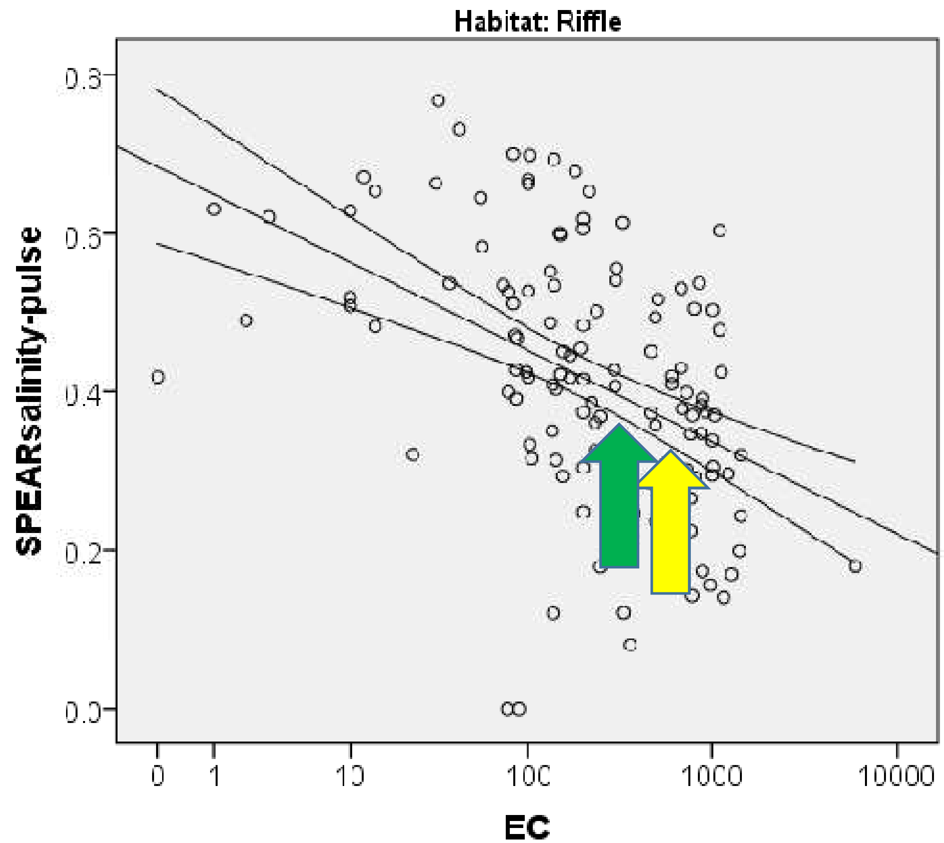
Avg EC (μS/cm) Preserve study streams (1




Kroug et al., "Salinity and stream invertebrate community structure – Hunter River catchment, eastern Australia, NSW EPA (2013)

## ecies at risk pulse
## e



# Conclusions

- Chloride concentrations in streams correlated with concentrations of species known to be displaced from clays by sodium from a produced water release on soil and EC
- Chloride concentrations positively correlated with # of wells in the watershed or # of wells/area
- Evidence suggests infiltration of rainwater from significant rain events, contact with brine components and subsequent communication of brine-impacted soil water with streams through fractures.
- Salinity in TGP Preserve streams has increased over the last 20 years
- Stream salinity is likely affecting macroinvertebrate diversity and that diversity is apparently declining over time.

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# What do these results mean for *in situ* remediation by dispersing and dilutions salts?


Any Questions?
SCENIC
TURNOUT
AHEAD