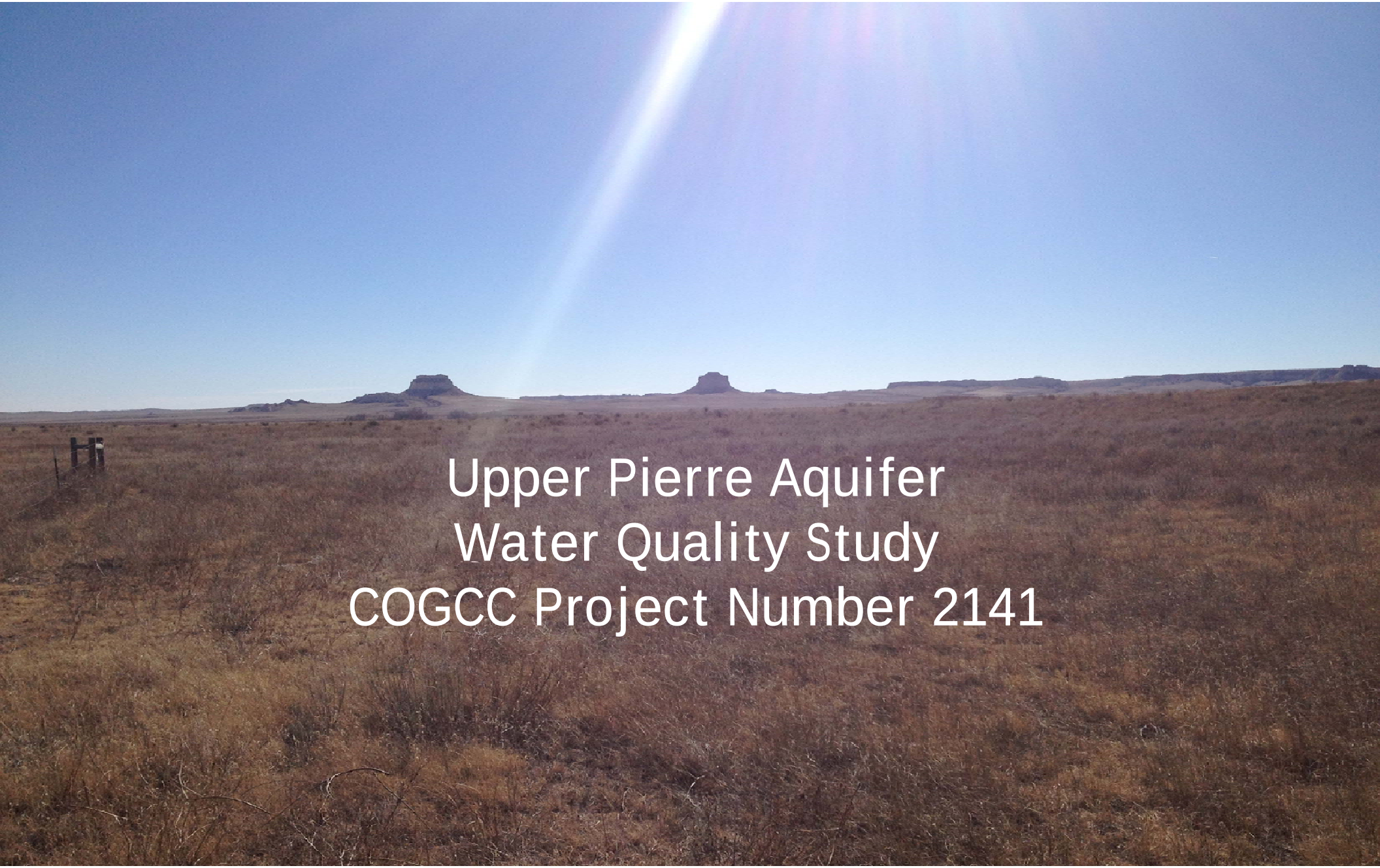


Upper Pierre Aquifer Water Quality Study COGCC Project Number 2141

COLORADO
Oil & Gas Conservation Commission
Department of Natural Resources

Presented by Richard Allison, P.G.
COGCC Environmental Protection Specialist
January 29, 2017

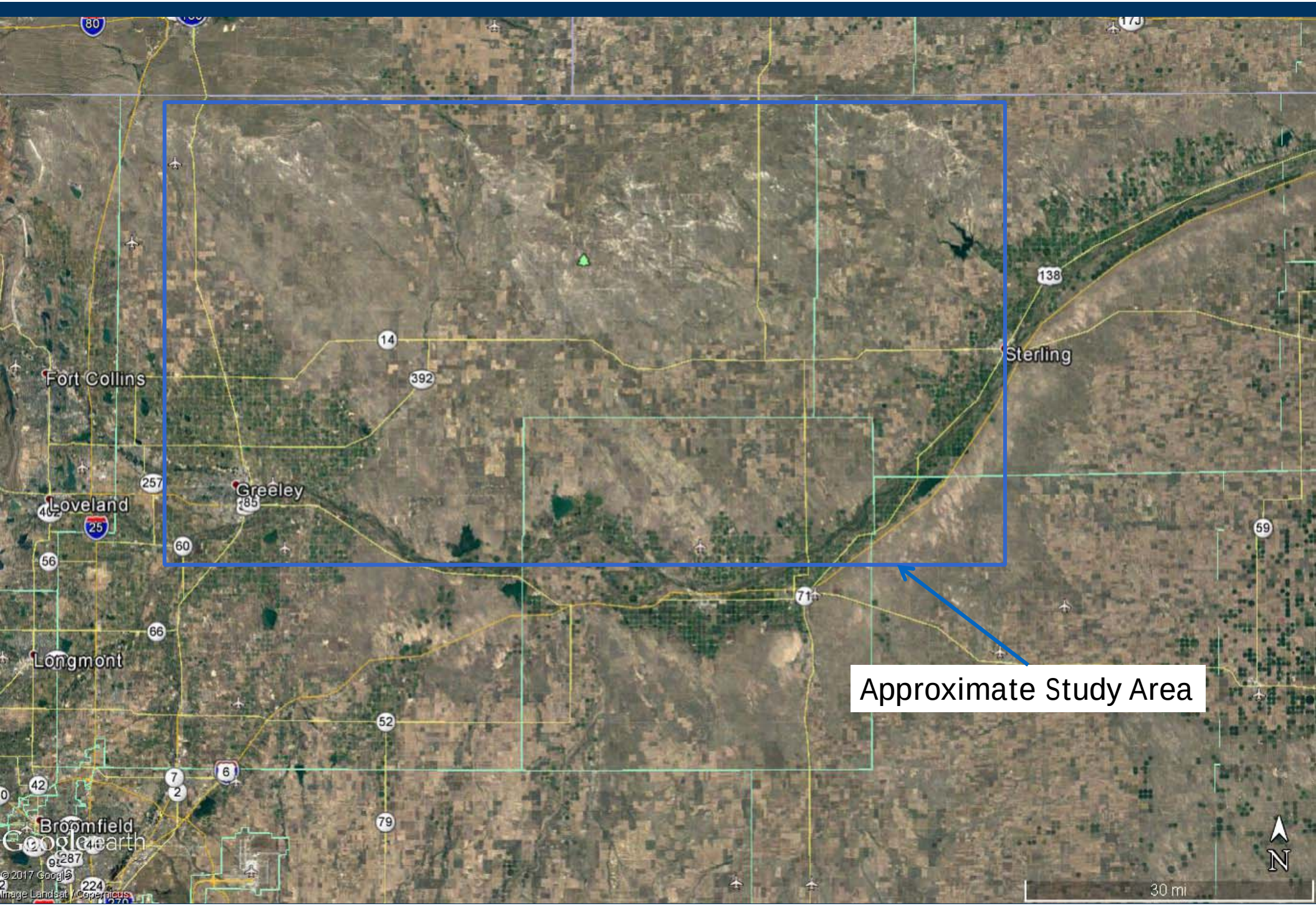
Upper Pierre Aquifer Water Quality Study

1. Hydrogeology and use of Upper Pierre Aquifer

2. Sample locations

3. Document water quality of aquifer

4. Document presence and origin of methane and liquid hydrocarbons in aquifer


Fort Collins
Loveland
Greeley
Sterling
Longmont
Broomfield
Approximate Study Area
N
30 mi
© 2017 Google
Image Landsat / Copernicus

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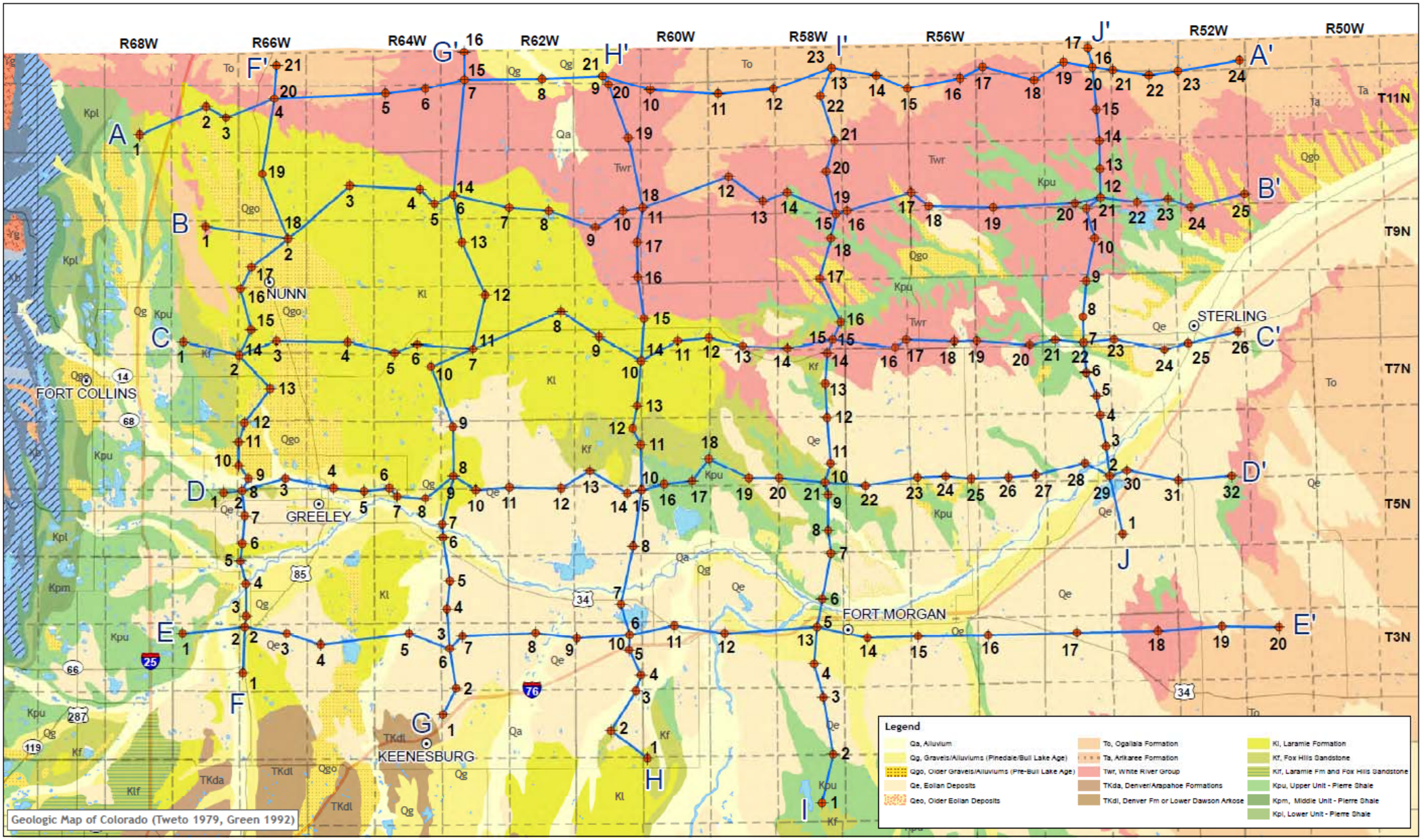
Geologic Map of Colorado



THE UPPER PIERRE AQUIFER OF THE CHEYENNE BASIN, NORTHEASTERN COLORADO, GEOLOGIC CROSS SECTIONS

Ralf Topper, Clinton D. Meyer, Marshall Haworth, Kevin C. Donegan, Hillary Banks, Aaron Bandler, Andrew Flor, and Matthew A. Sares

WRI 2017-1a

0 3 6 9 12 Miles

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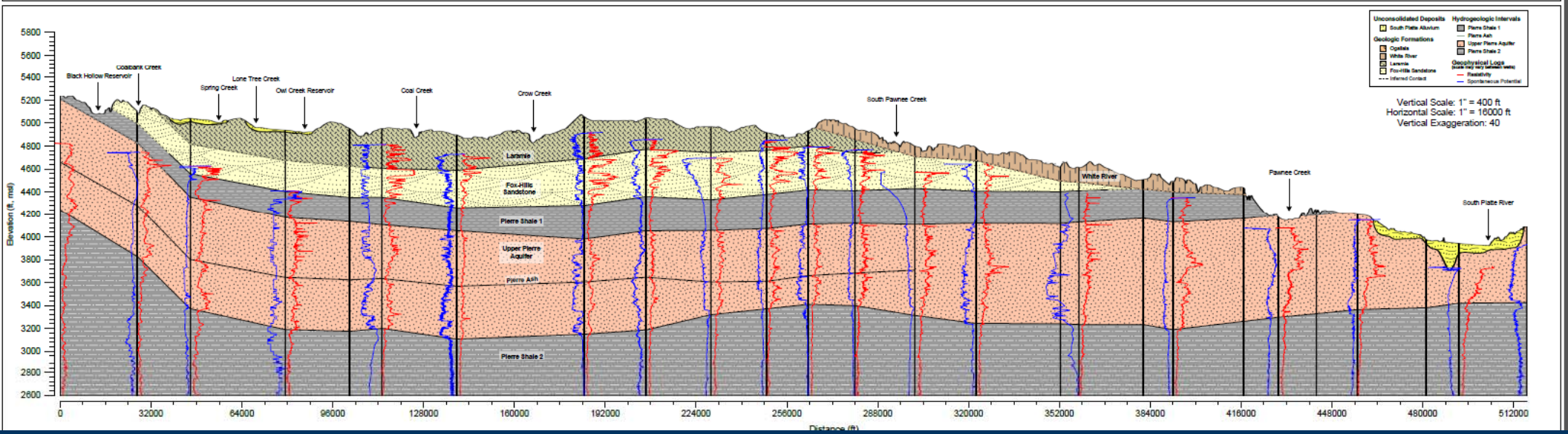
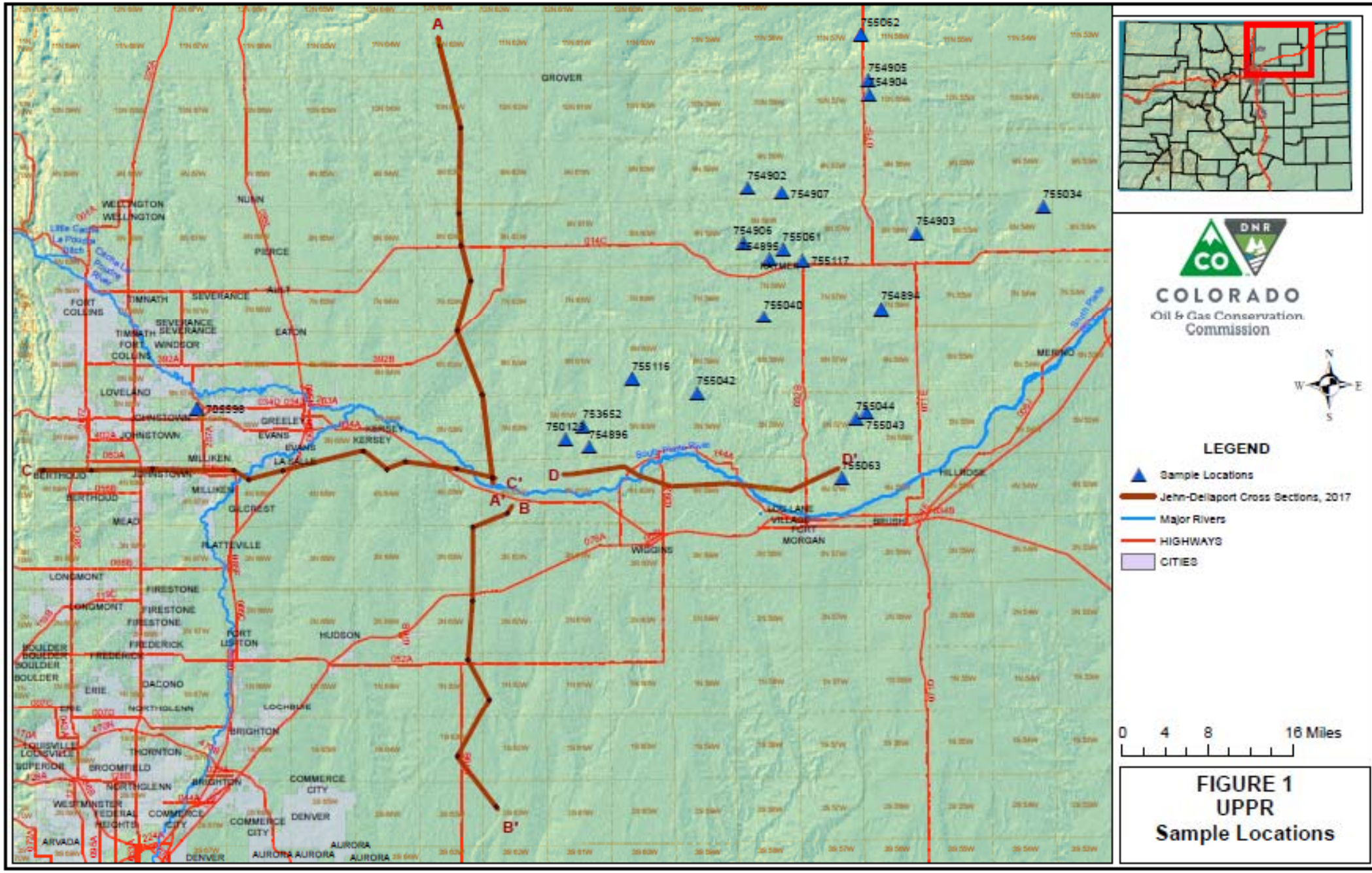
Department of Natural Resources

Cross Section C-C'

C West — East C'



Water Well Sample Locations



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Field Effort

Review Hydrobase query provided by Division of Water Resources

- *134 records returned as potential candidates – Weld, Morgan, Logan Counties*

- *Final sample locations totaled 20 water wells in Weld, Morgan and Logan Counties sampled for study*

Pinyon Environmental

- *Contact Well Owners on behalf of COGCC*

- *Collect Water Samples*
  - *Field Parameters = pH, conductivity, dissolved oxygen, turbidity, oxidation reduction potential*

Laboratory Analysis

ALS Environmental – analytical laboratory

- *pH, conductivity, TDS, alkalinity*
- *Major cations and anions*
- *Dissolved trace metals*
- *Dissolved Gas (methane, ethane, propane)*
- *Volatile Organic Compounds*

Dolan Integration Group

- *Gas composition*
- *Stable isotope ratios*
  - *$\delta\,^{13}C$ and δ Deuterium ^{2}H of methane*
  - *$\delta\,^{13}C$ in dissolved inorganic carbon (DIC)*
  - *δ D and $\delta\,^{18}O$ in water*

Water Quality Analytical Results

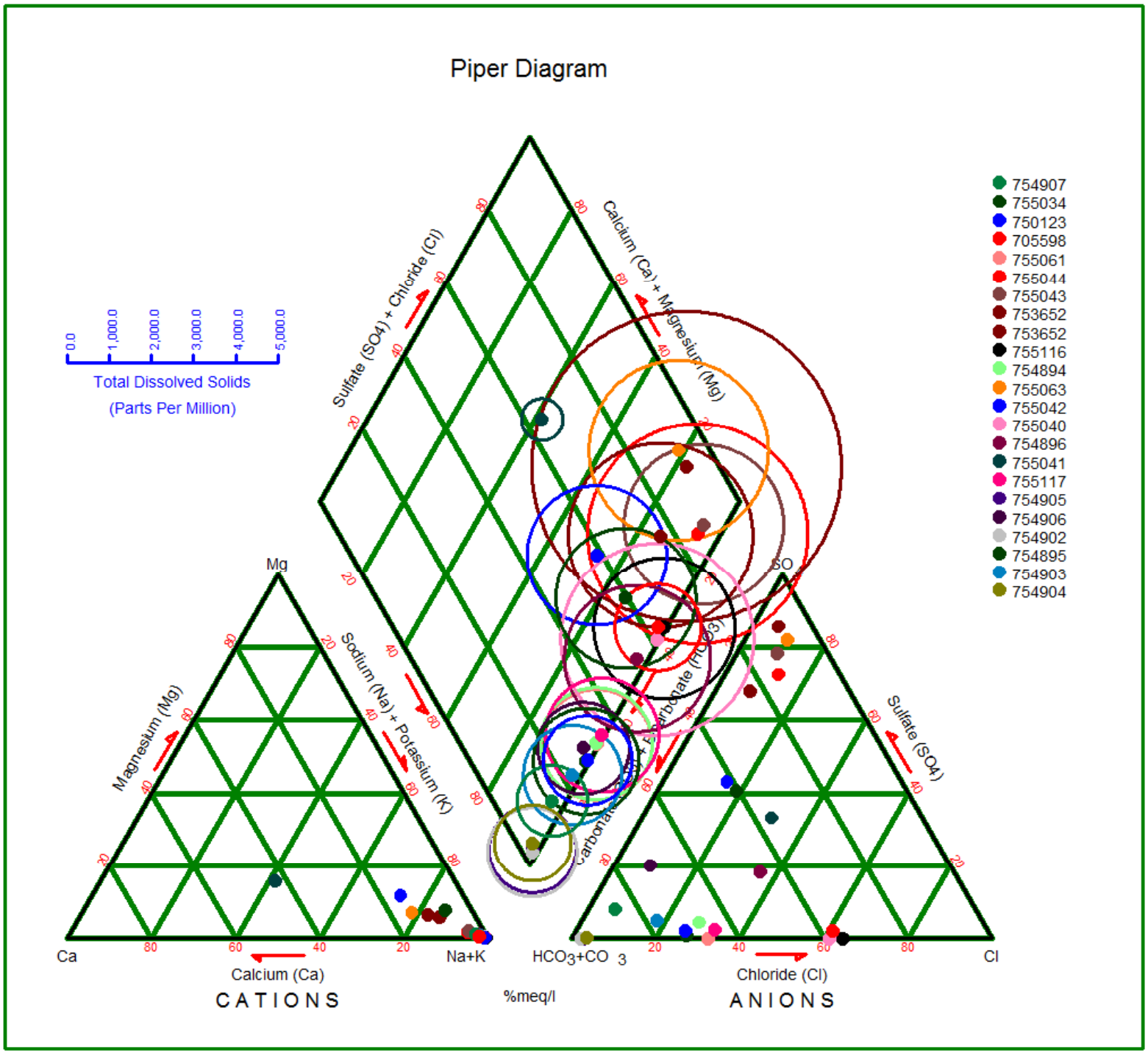
Major Anions and TDS

	Bicarbonate	Chloride	Sulfate	Total Dissolved Solids
Minimum Concentration	140 mg/l	10 mg/l	ND < 1 mg/l	560 mg/l
Average Concentration	519 mg/l	175 mg/l	457 mg/l	1430 mg/l
Maximum Concentration	770 mg/l	710 mg/l	2200 mg/l	2700 mg/l

Major Cations

	Calcium	Magnesium	Sodium	Sodium Adsorption Ratio
Minimum Concentration	1.1 mg/l	0.33 mg/l	71 mg/l	2
Average Concentration	21 mg/l	8.4 mg/l	445 mg/l	41
Maximum Concentration	110 mg/l	40 mg/l	950 mg/l	101

Trilinear Diagram



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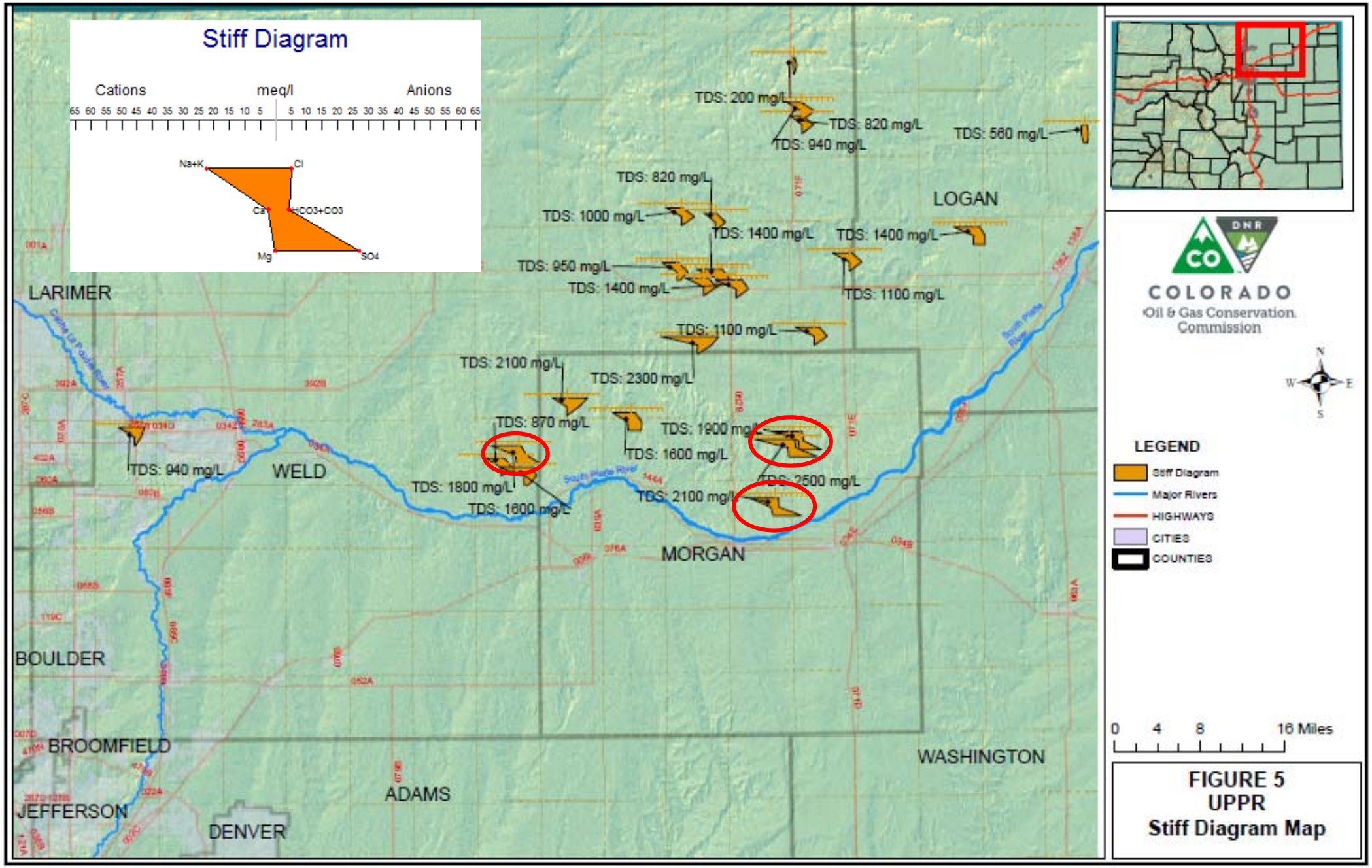
Stiff Diagrams and TDS in Map View



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Water Quality Analytical Results

Other Notable Detections

	Boron	Fluoride
Minimum Concentration	0.33 mg/l	0.5 mg/l
Average Concentration	1.2 mg/l	2 mg/l
Maximum Concentration	3.3 mg/l	3.4 mg/l

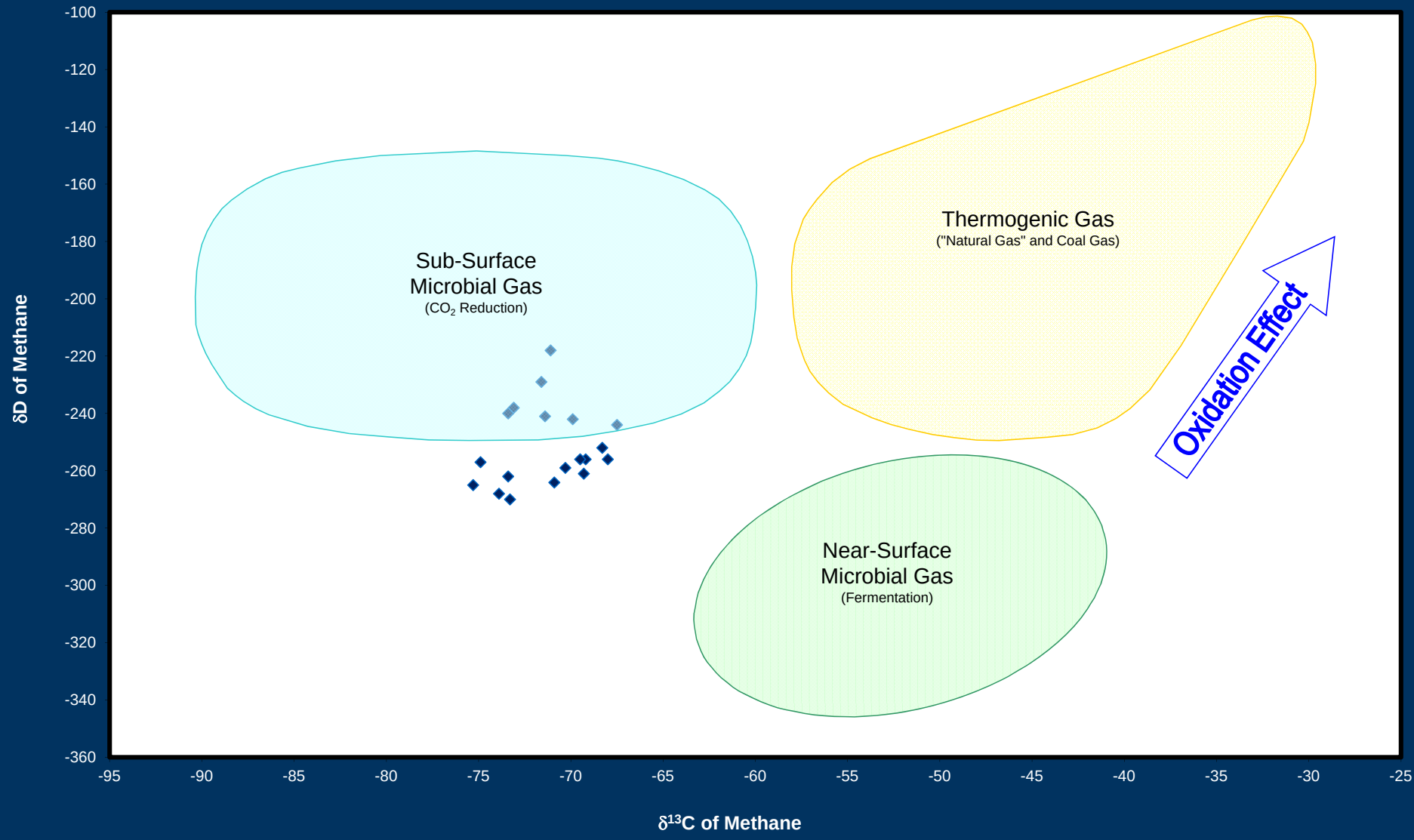
Volatile Organic Compounds
Trace BTEX in one sample, below Table 910-1 Concentration Levels (MCLs)

Dissolved Gases

Methane and Ethane

	Methane	Ethane	Propane
Minimum Concentration	ND <1 mg/l	ND <1 mg/l	ND < 1 mg/l
Average Concentration	11 mg/l	0.022 mg/l	ND < 1 mg/l
Maximum Concentration	33 mg/l	0.065 mg/l	ND < 1 mg/l
Number Non-Detect or detected below 1 mg/l	4	5	21

Methane (CH_4) Isotopic Ratios



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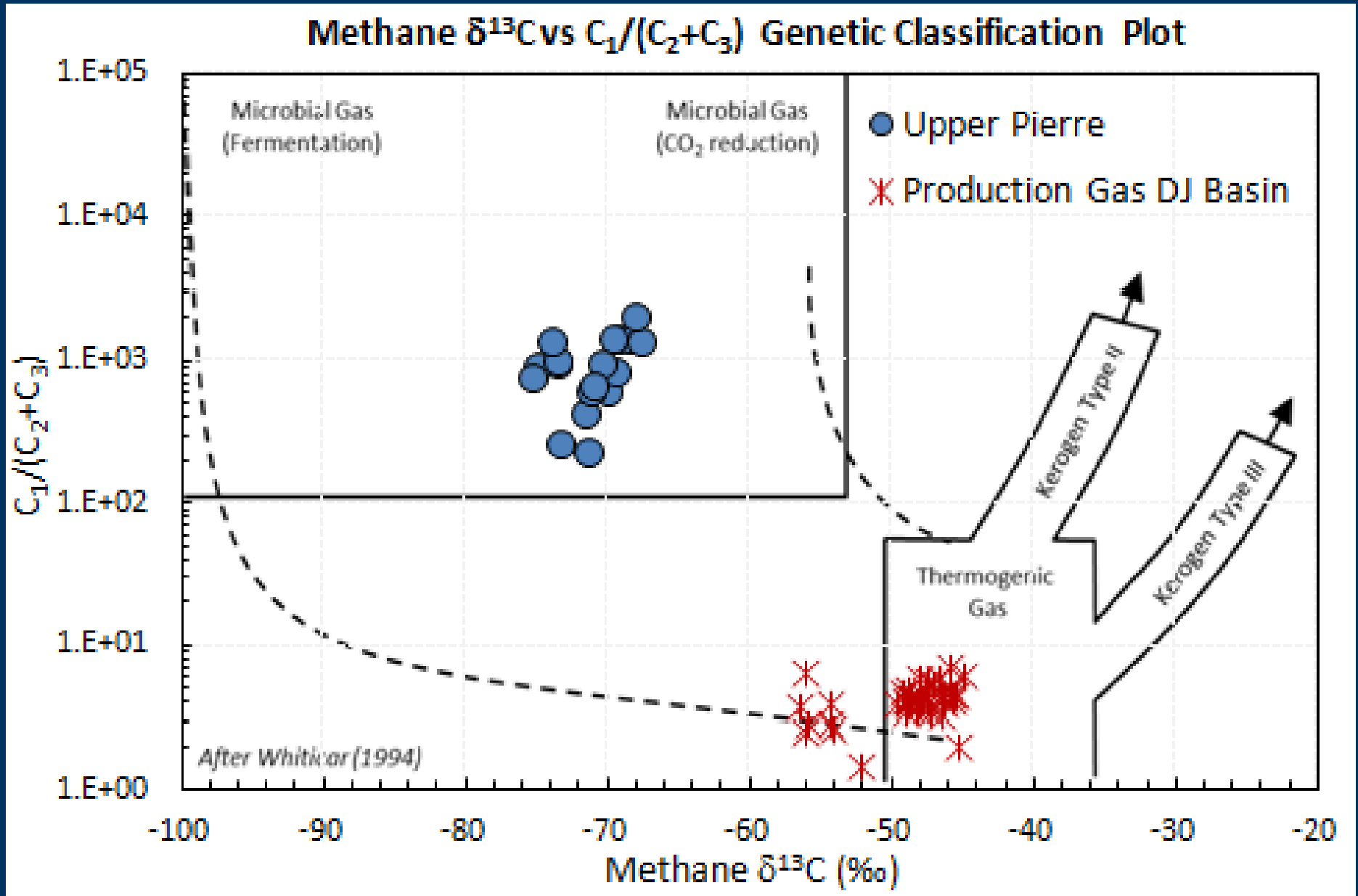
Upper Pierre Water Wells compared to DJ Basin Production Gas



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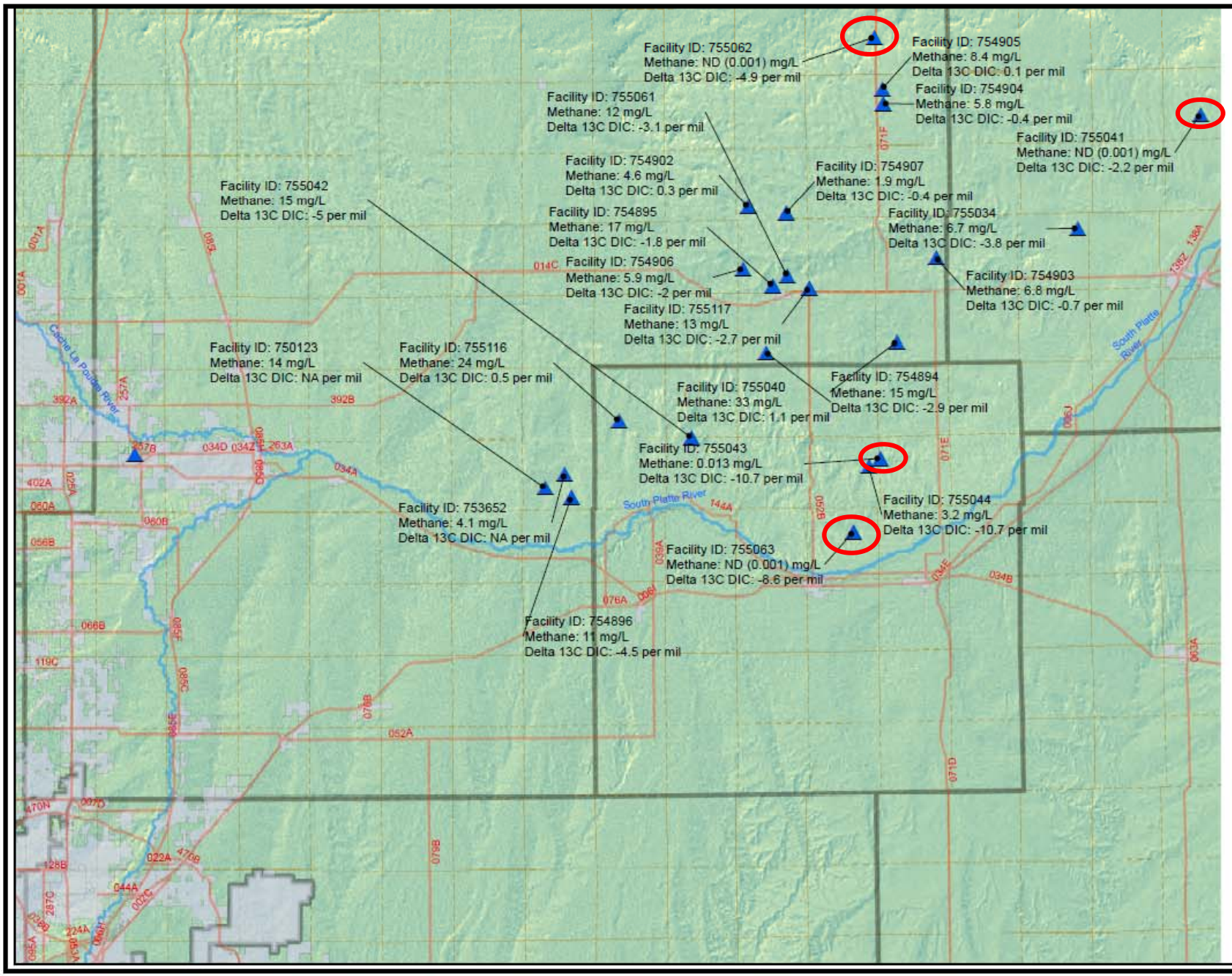
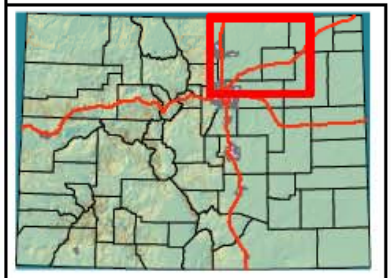
Distribution of Dissolved Methane





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LEGEND

- Sample Locations
- Major Rivers
- HIGHWAYS
- CITIES
- COUNTIES

Notes:
NA - Not Analyzed
ND - Below the laboratory Detection Limit
d13C DIC reported in per mil VPDB

0 4 8 16 Miles

FIGURE 18
UPPR
Dissolved Methane and d13C Dissolved Inorganic Carbon

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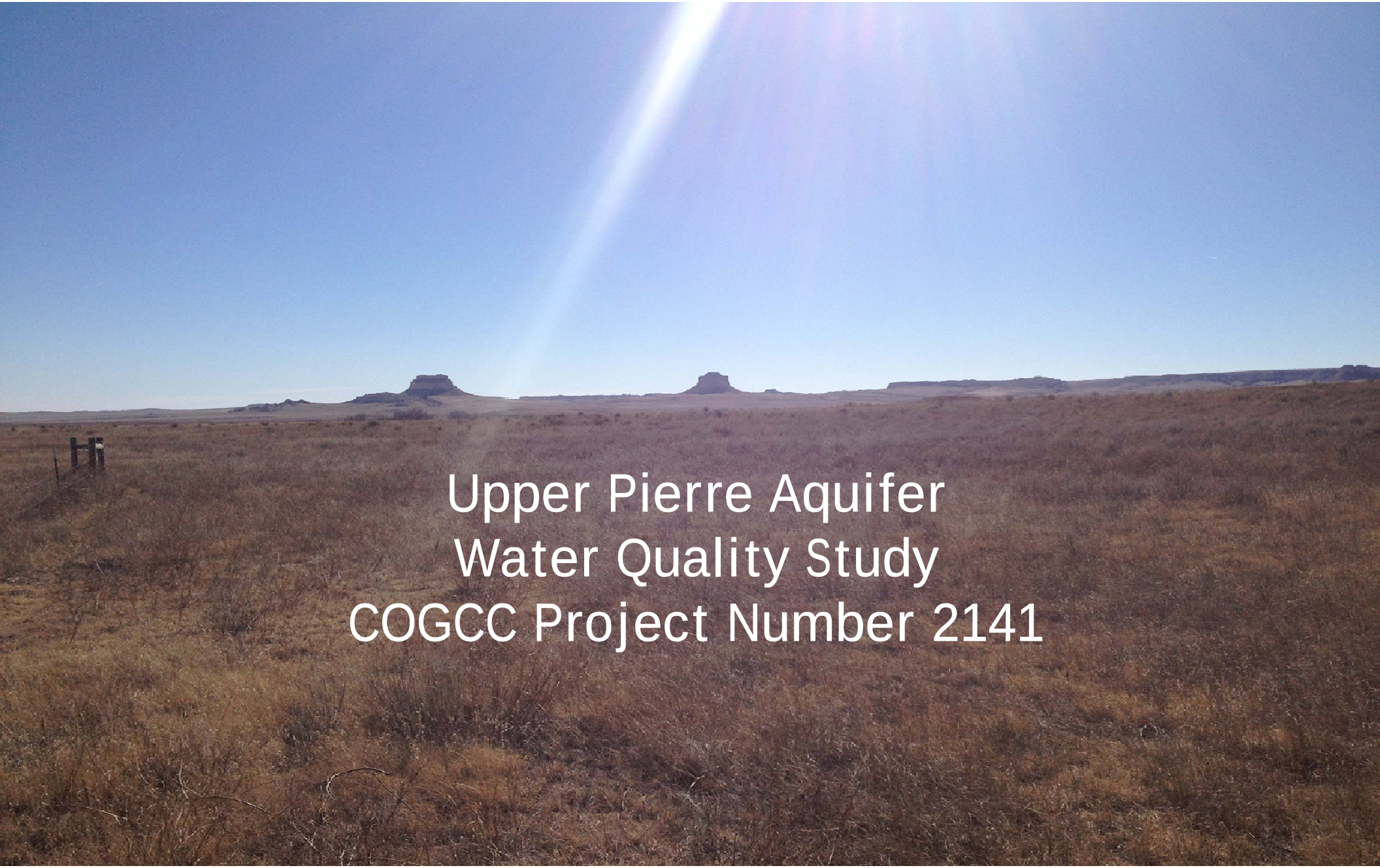
Summary

Upper Pierre Aquifer is a freshwater source: average TDS =1430 mg/l and maximum TDS = 2700 mg/l

Water type is dominated by sodium-bicarbonate, approaching sodium-bicarbonate-chloride with depth. Higher concentrations of sulfate present in wells nearest the South Platte River.

High sodicity and boron concentration may prohibit use for irrigation, but acceptable for livestock, industrial and even domestic uses (with treatment)

Microbial methane is present and geographically widespread. Thermogenic methane was not detected in any sample collected.



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