Evaluation of Thyne, 2008 "Review of Phase II Hydrogeologic Study"

Mamm Creek Field Area
Garfield County, Colorado

Prepared for the

Colorado Oil & Gas Conservation Commission

By

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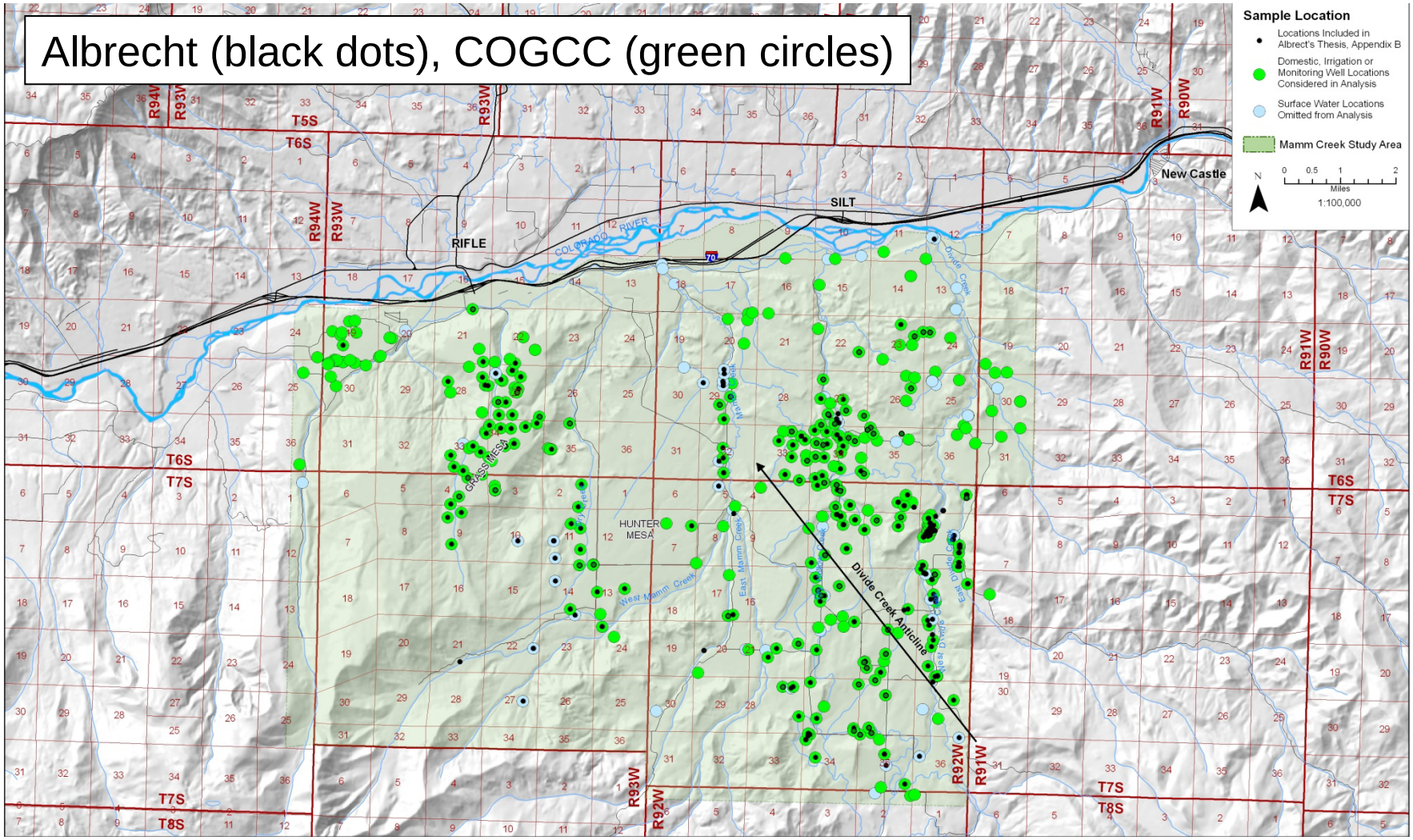
Assertions in Thyne Report

- There is a temporal increase in methane (CH_4), concurrent with the increase in drilling activity.
- There is a temporal increase in chloride (Cl), concurrent with the increase in drilling activity.
- Chloride concentration greater than 10mg/L indicates an impact from gas production
- Stable isotope signatures of methane indicate a thermogenic origin for the majority of samples, and that this methane is due to gas drilling and production activities.

Data Sources

- "Albrecht Data" – data included in Thyne Report
  - 1997 - 2005
  - Non-detect measurements = detection limits
  - 2188 methane records (164 "multiple" measurements)
  - 1433 chloride records (121 "multiple" measurements)
- "COGCC database" – includes more recent water quality data provided by COGCC
  - 1997 – 2008
  - Non-detect measurements = ½ detection limits
  - "Multiple measurements" and Monitoring Well analyses differentiated or removed prior to analysis
  - 2221 unique methane and 2340 unique chloride records

Sample Locations

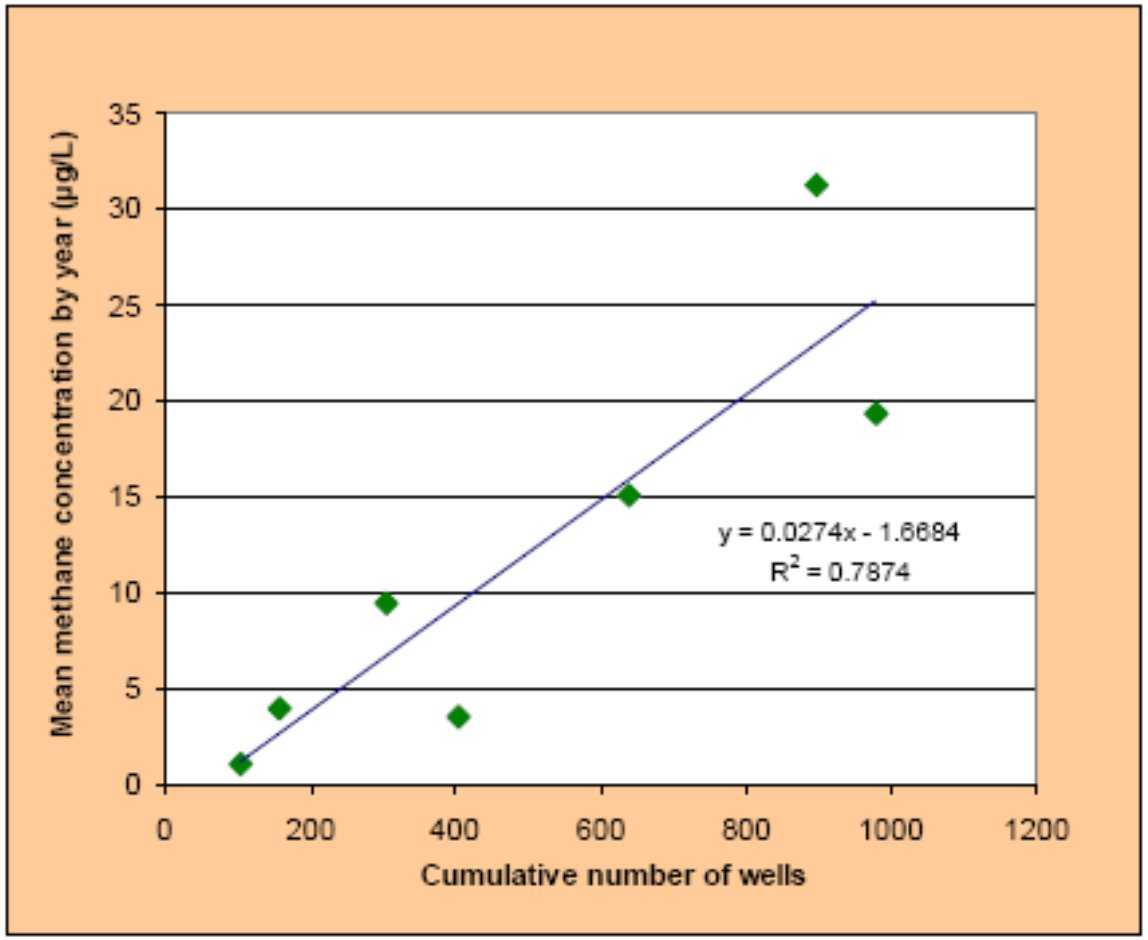


Data Analysis

- Data Visualization: Time series plots, scatter plots, and box-and-whisker plots – visualize the trends and variability in the datasets.
- Statistical Analysis: Mann-Whitney test – a comparison of two sample sets to determine if there is a statistically significant difference in the median values.
- Spatial Distribution: Maps of the distribution of the parameters of interest illustrate the relationship, if any, to drilling activity.

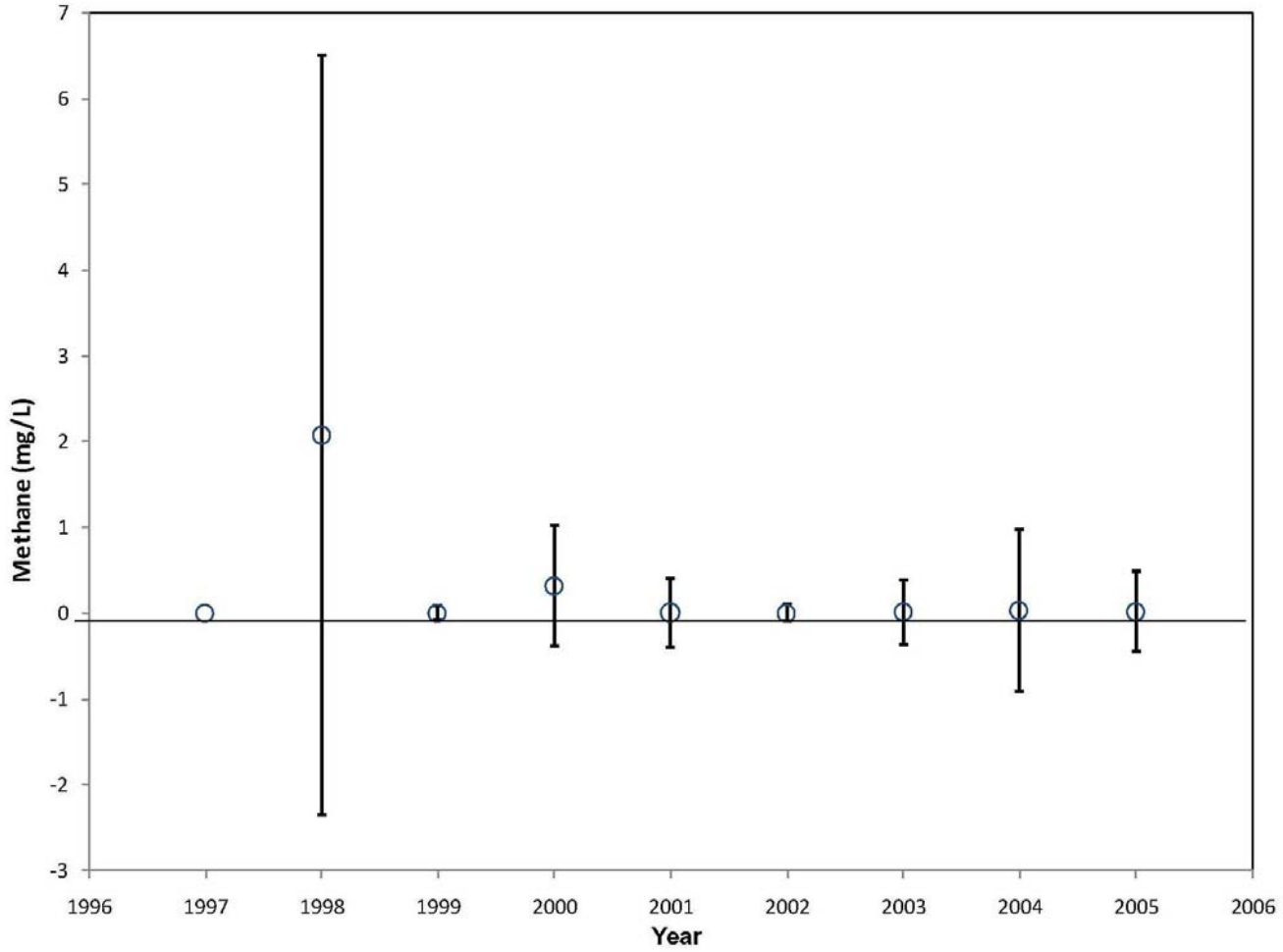
Is there a temporal trend for increasing methane concentration?

Apparent Trend of Increasing Methane Concentration from Thyne Report



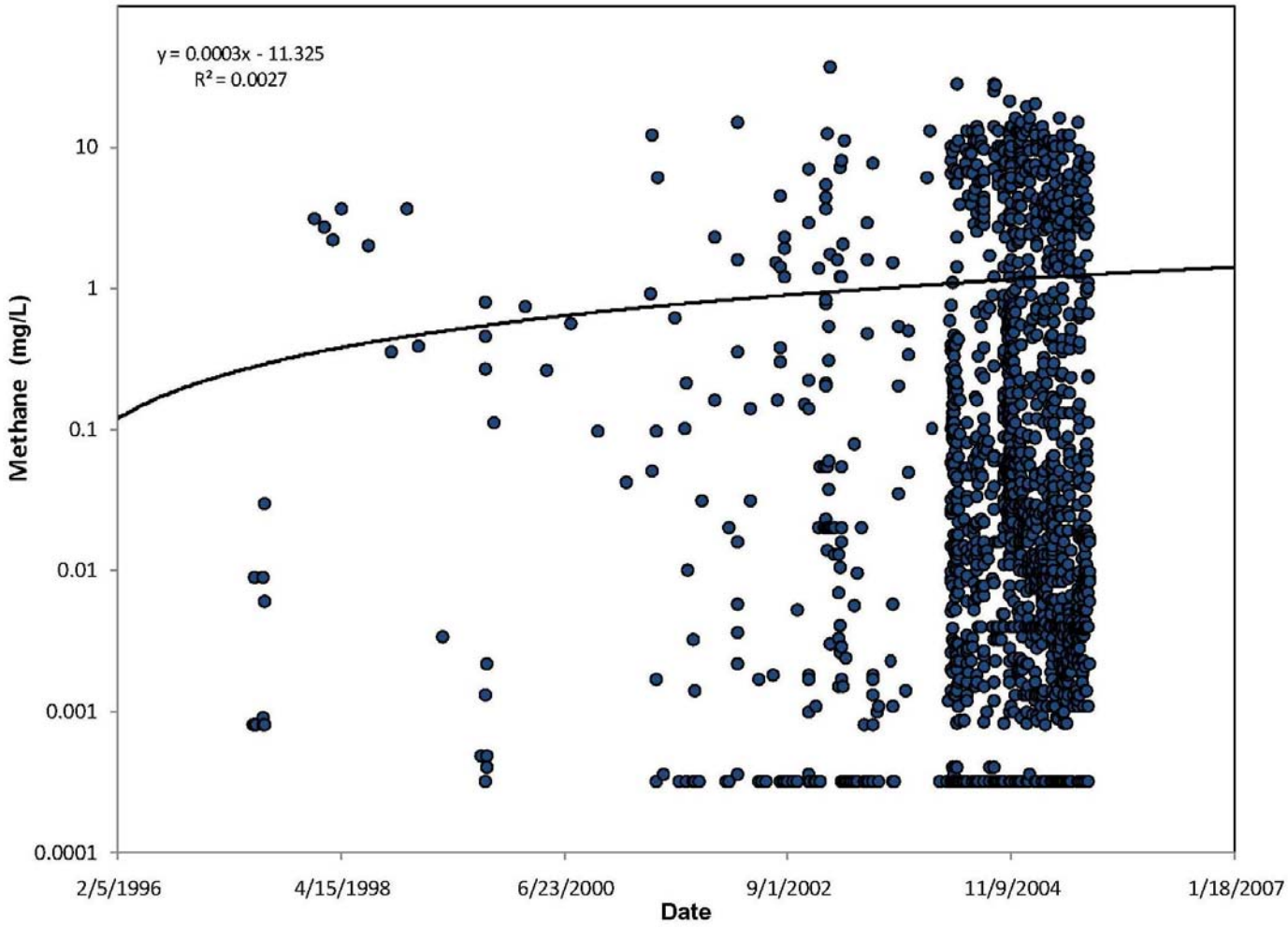
Albrecht Data 1997-2005. Plot shows average annual methane concentration plotted against number of wells. Note that scale is in ug/L, not mg/L as is normal reporting convention..

Annual Methane Mean Concentration is Overwhelmed by Data Variability



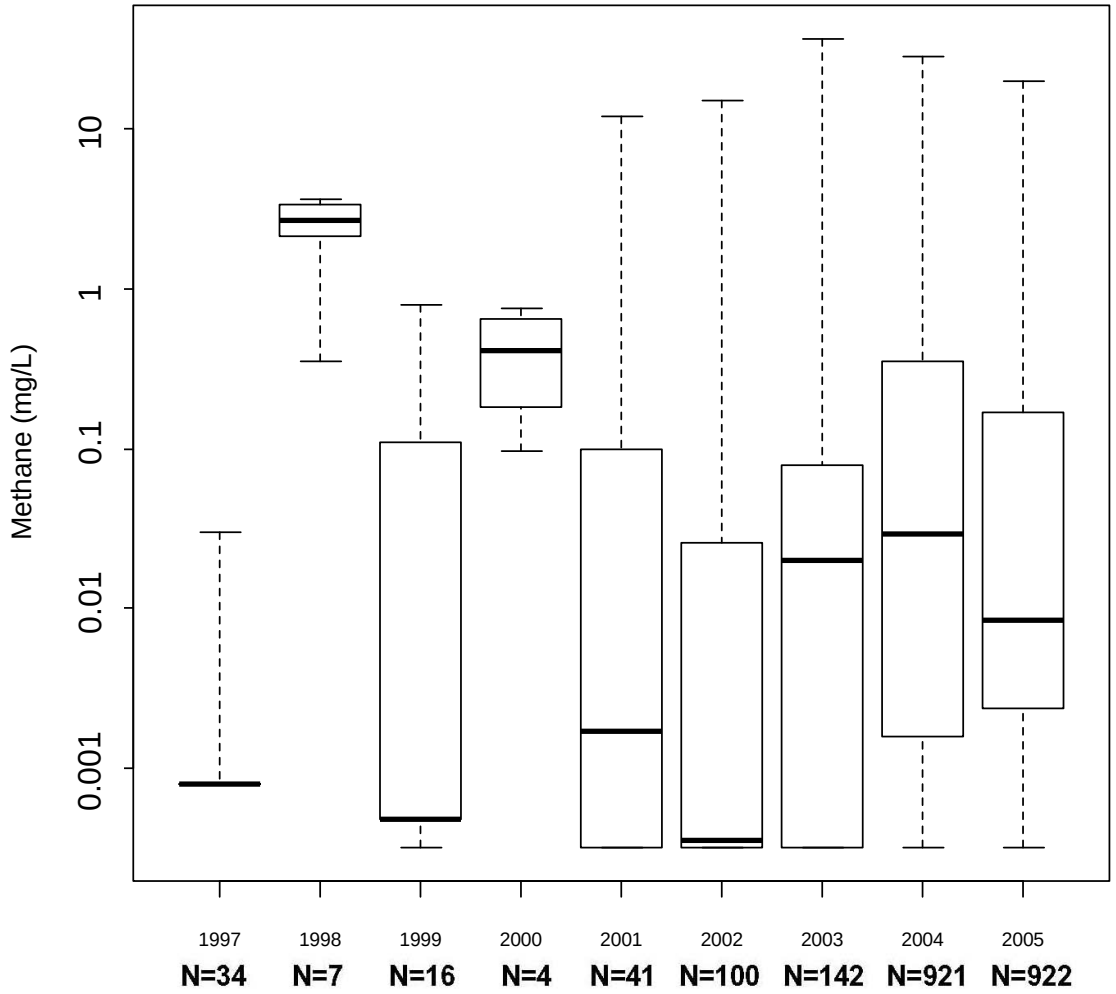
Albrecht Data. Plot shows geometric mean and geometric standard deviation for methane concentrations.

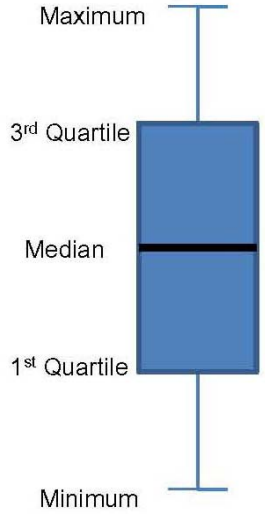
Calculated Methane Trend Line Has No Statistical Significance



Albrecht Data. Time-series (Scatter) plot showing distribution of all data over time. Regression coefficient (R^2=0.0027) shows that trend line is not valid.

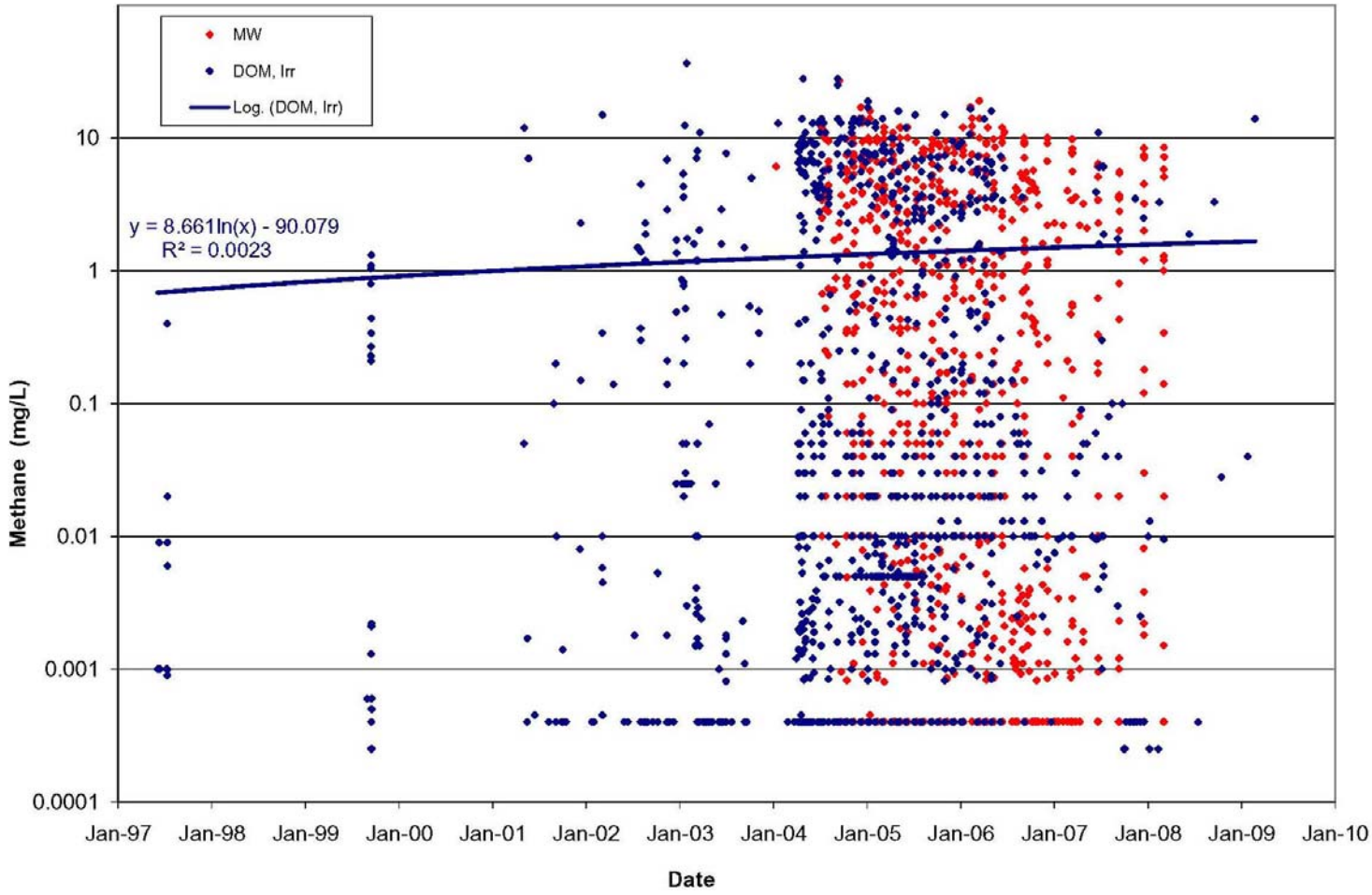
Analysis of Central 50% of Methane Data Shows No Increasing Trend With Time





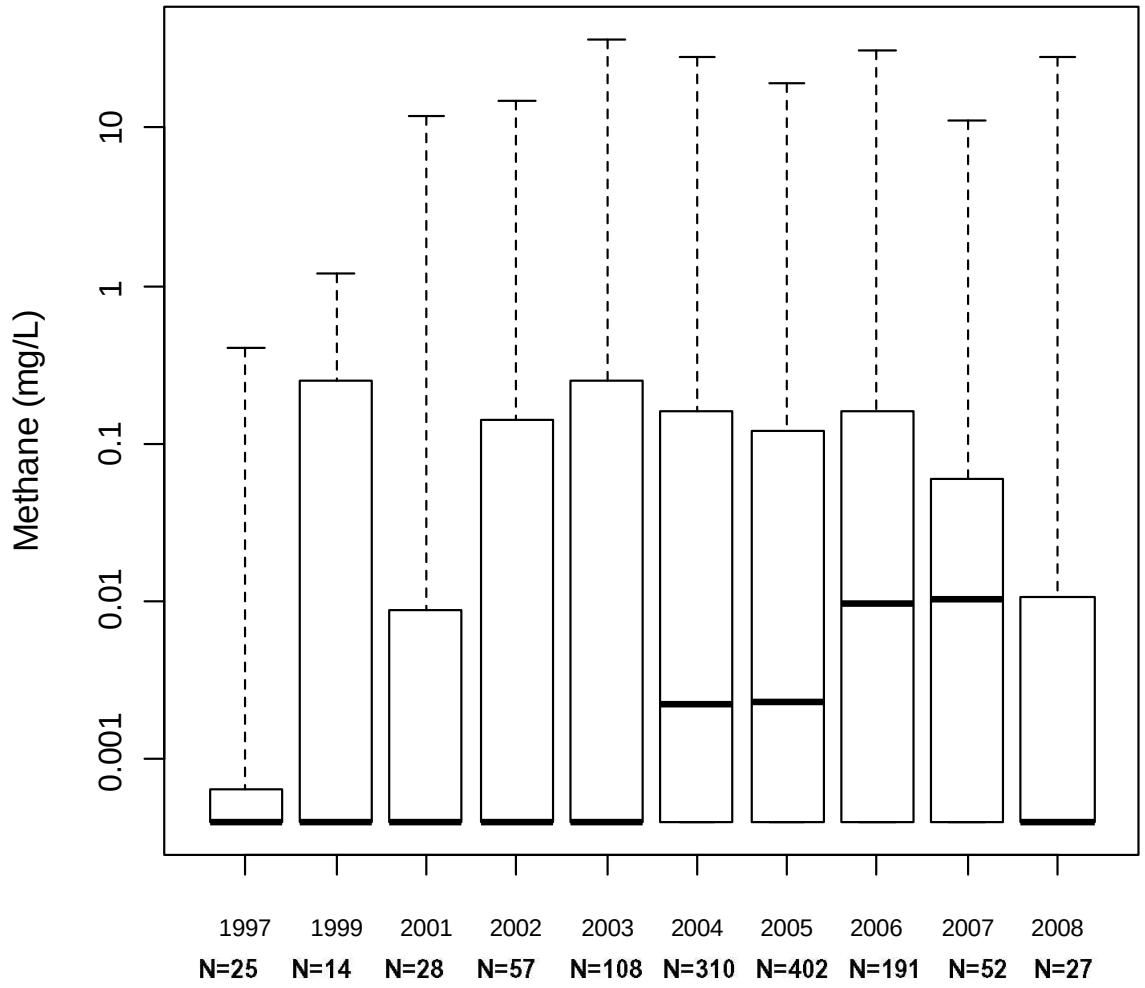
Albrecht Data. Box-and-Whisker plot. Middle 50% of analytical results for each year are within boxes; highest and lowest concentrations for each year are represented by the top and bottom of the dotted lines (whiskers)

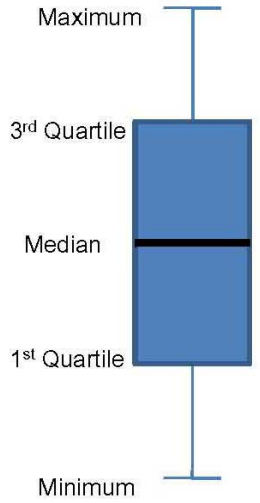
Calculated Methane Trend Line Has No Statistical Significance for Water Wells



COGCC Data. Time-series plot with multiple samples removed and domestic wells and monitor wells differentiated. Domestic well regression coefficient (R2=0.0023) shows that trend line is not valid.

More Recent Data Continues to Show No Significant Trend of Increasing Methane Concentration

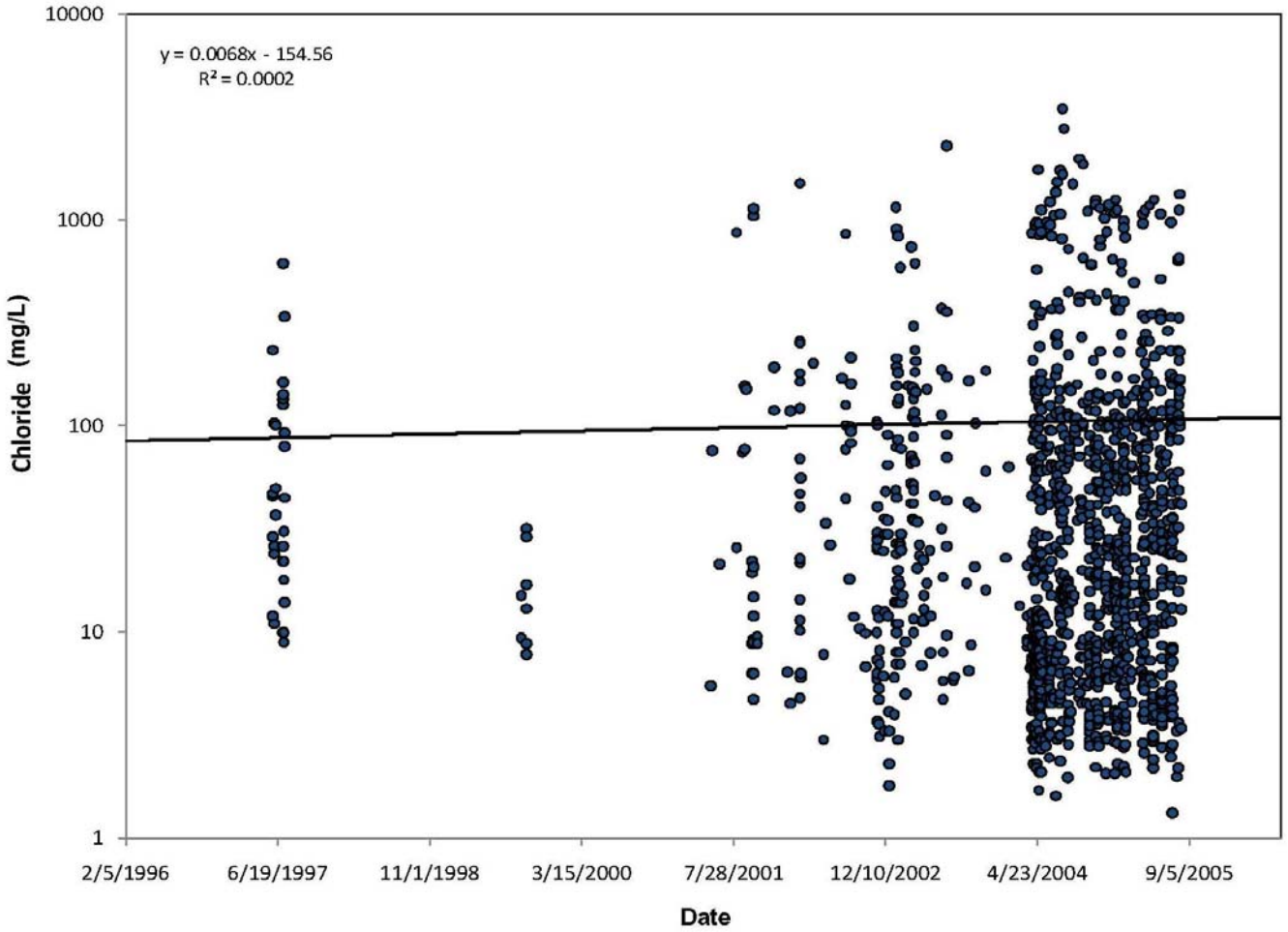




COGCC Data. Box-and-Whisker plot. Range of concentrations for middle 50% of analytical results for each year (within boxes) does not increase with time.

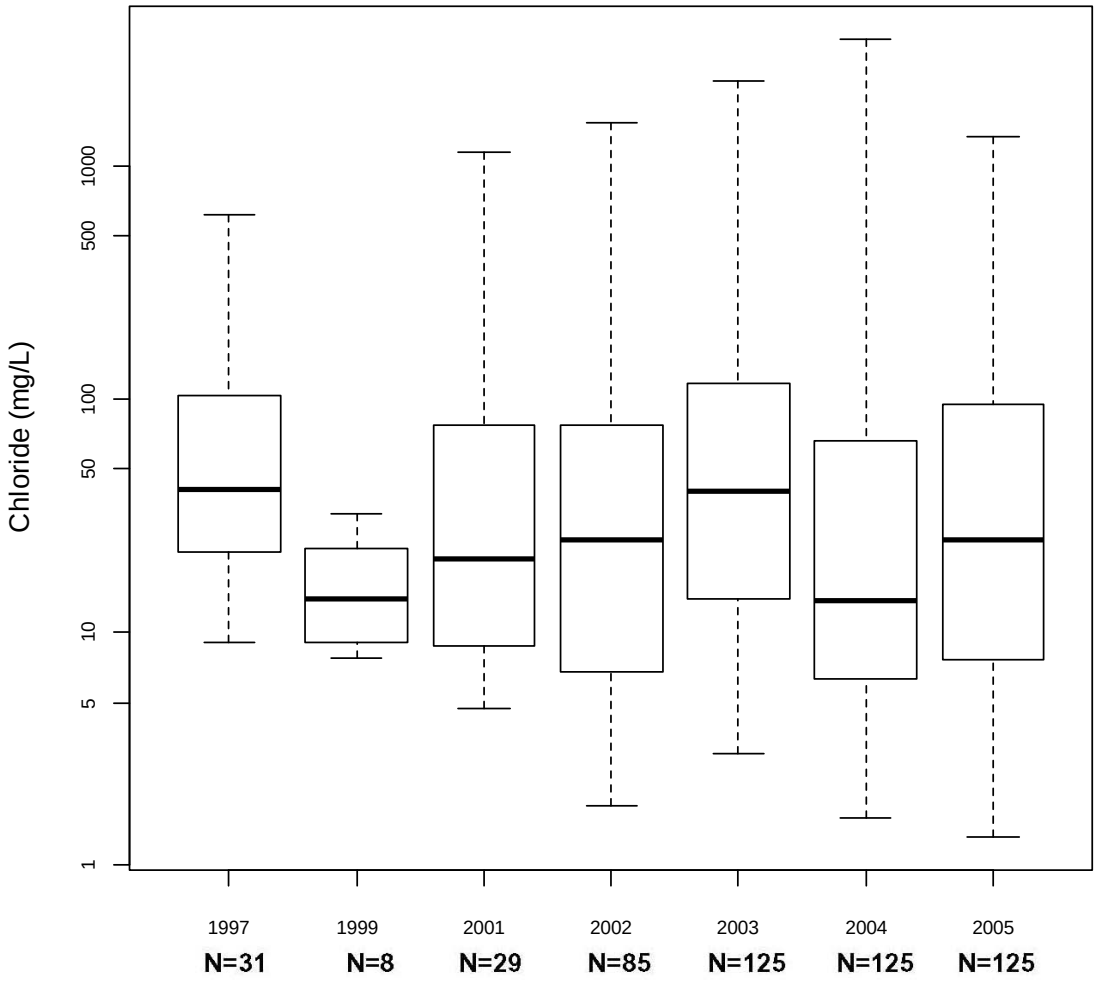
Is there a temporal trend for increasing chloride concentration?

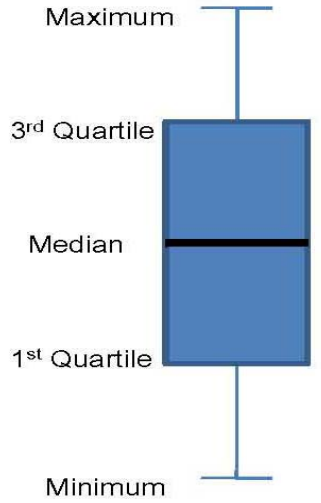
Calculated Chloride Trend Line Has No Statistical Significance



Albrecht Data. Time-series (Scatter) plot showing distribution of all data over time. Regression coefficient (R^2=0.0002) shows that trend line is not valid.

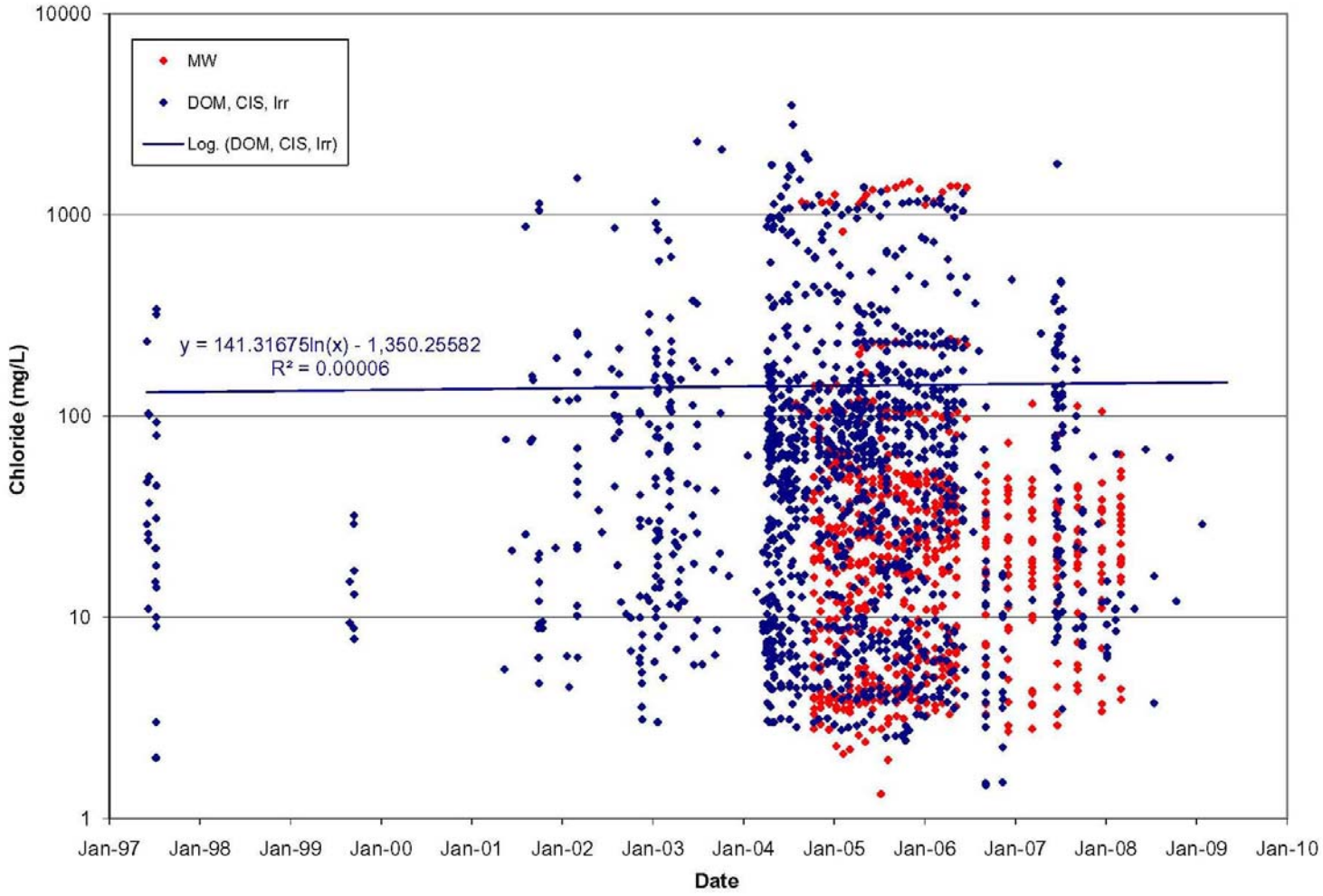
Analysis of Central 50% of Chloride Data Shows No Increasing Trend With Time





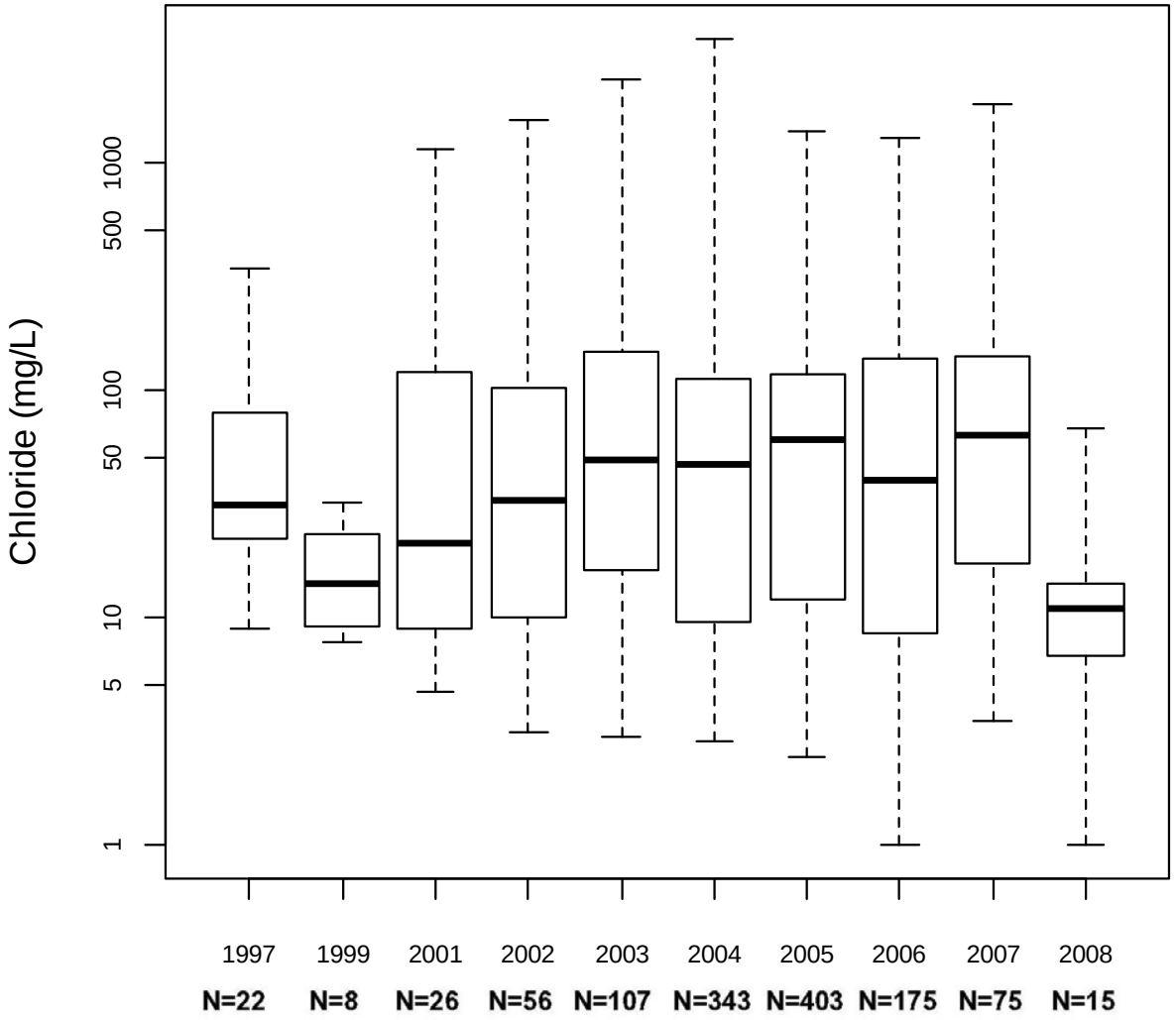
Albrecht Data. Box-and-Whisker plot. Range of concentrations for middle 50% of analytical results for each year (within boxes) does not increase with time.

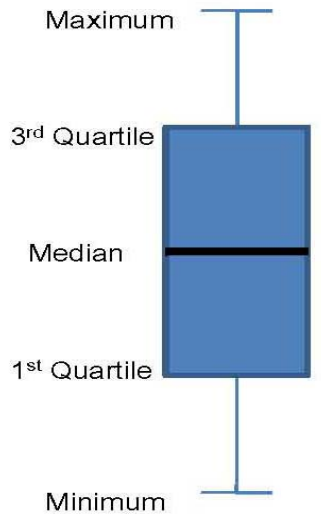
Calculated Chloride Trend Line Has No Statistical Significance for Water Wells



COGCC Data. Time-series plot with domestic wells and monitor wells differentiated. Domestic well regression coefficient (R2=0.00006) shows that the trend line is not valid.

2008 Data Shows Significant Decrease in Chloride Concentration

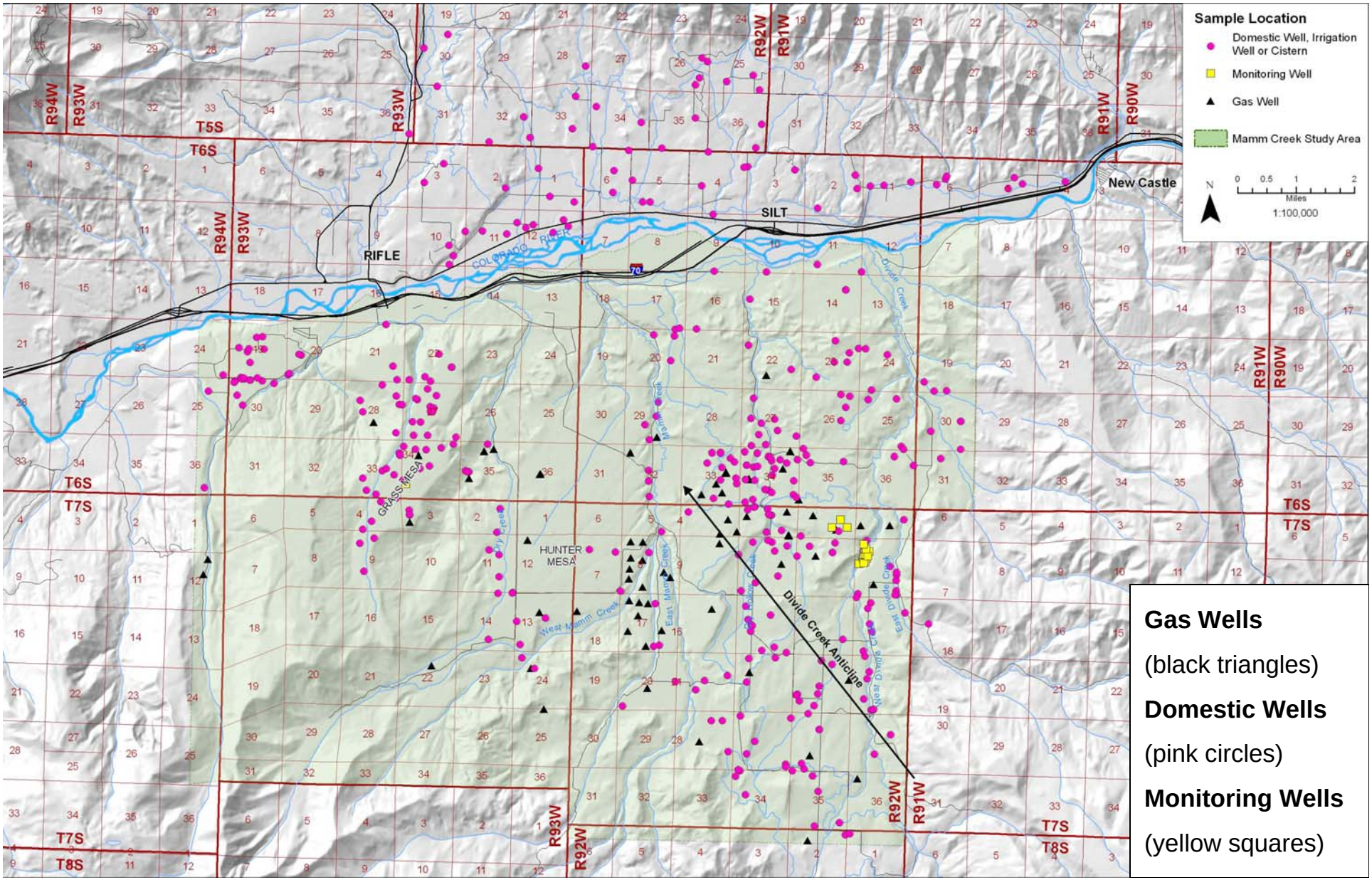




COGCC Data. Box-and-Whisker plot. Range of concentrations for middle 50% of analytical results for each year (within boxes) does not increase with time.

Does chloride concentration above 10 mg/L indicate impact from produced water?

Sample Locations North of the Colorado River and in the Mamm Creek Area



Gas Wells

(black triangles)

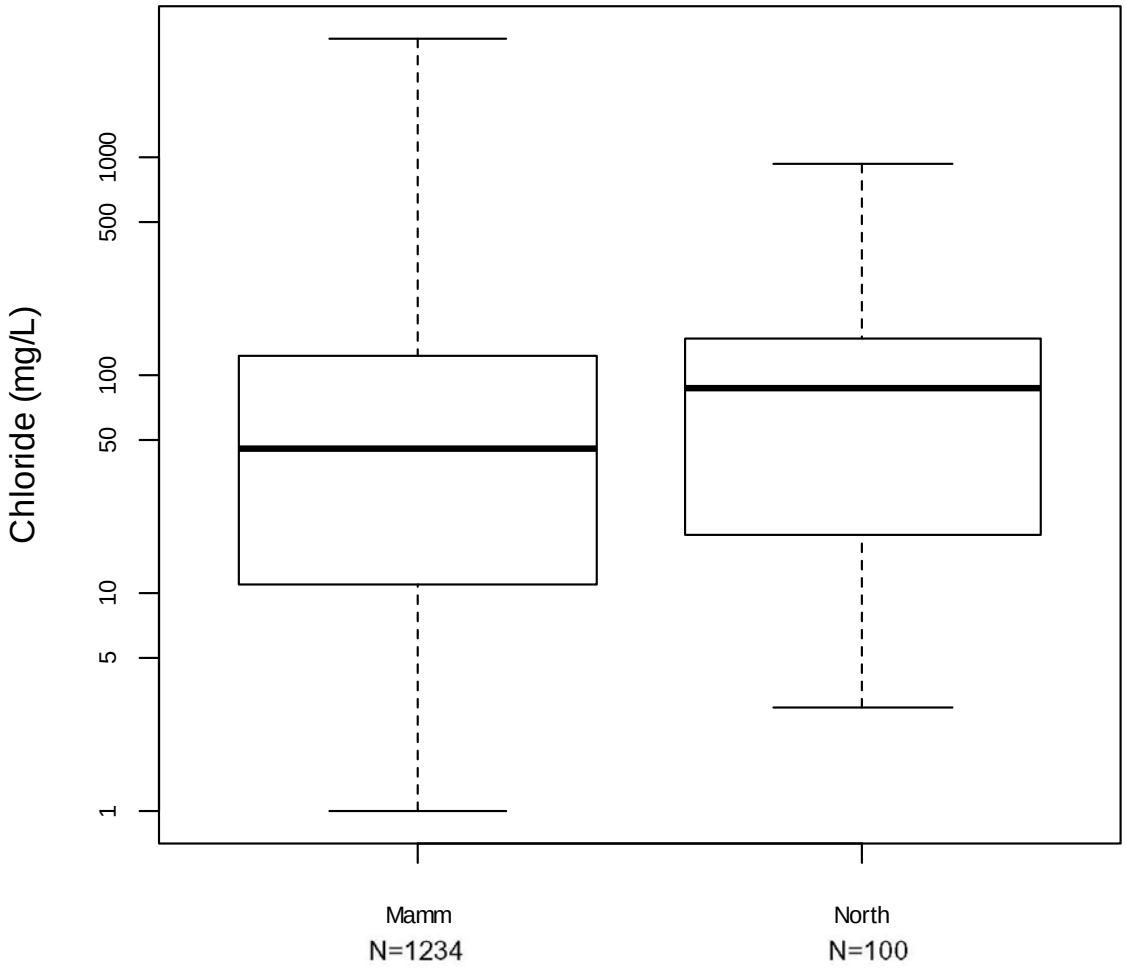
Domestic Wells

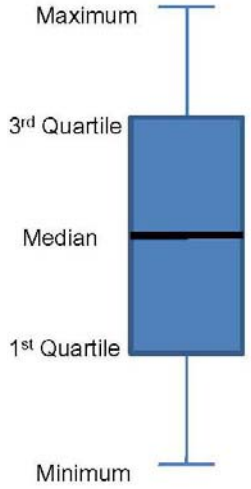
(pink circles)

Monitoring Wells

(yellow squares)

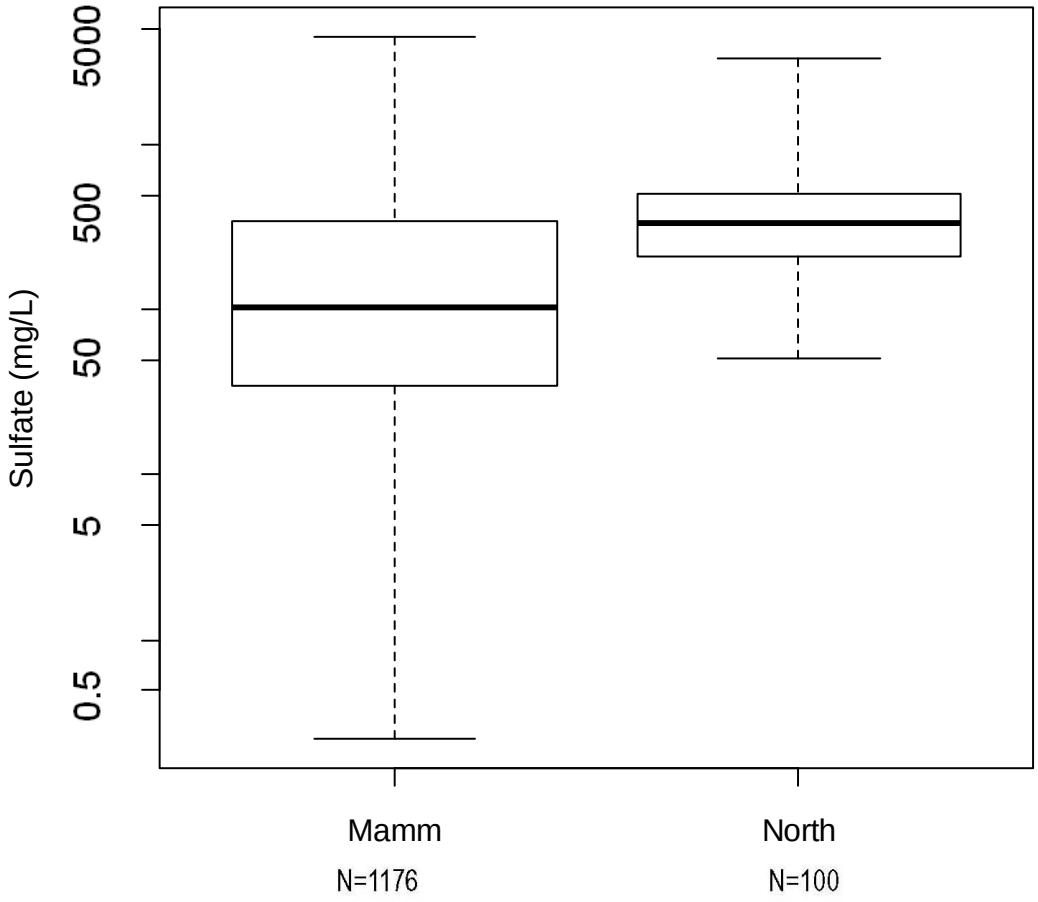
Similar or Higher Concentrations for Chloride in Area North of River Where No Gas Drilling Has Occurred

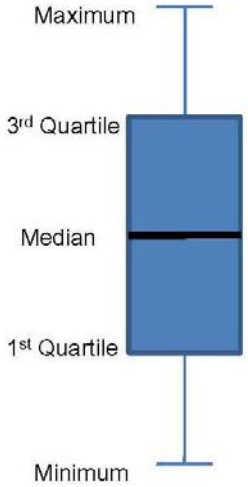




COGCC Data. Box-and-whisker plot (log-scale) of chloride concentrations in wells North of the Colorado River and in the Mamm Creek Area.

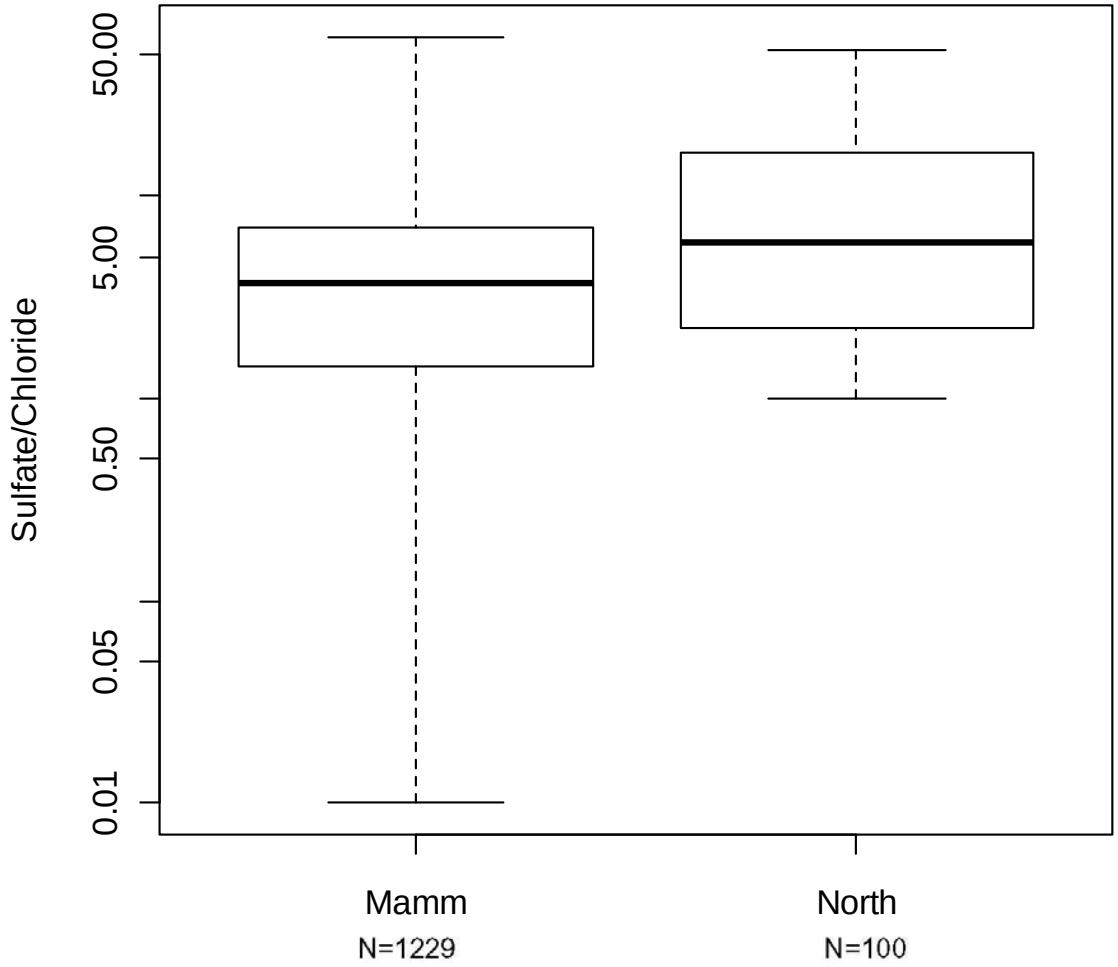
Higher Sulfate Concentrations for the Area North of the Colorado River

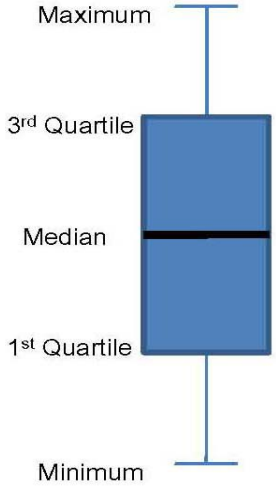




COGCC Data. Box-and-whisker plot (log-scale) of sulfate concentrations in domestic wells North of the Colorado River and in the Mamm Creek Area. Plot shows high variability in the Mamm Creek area.

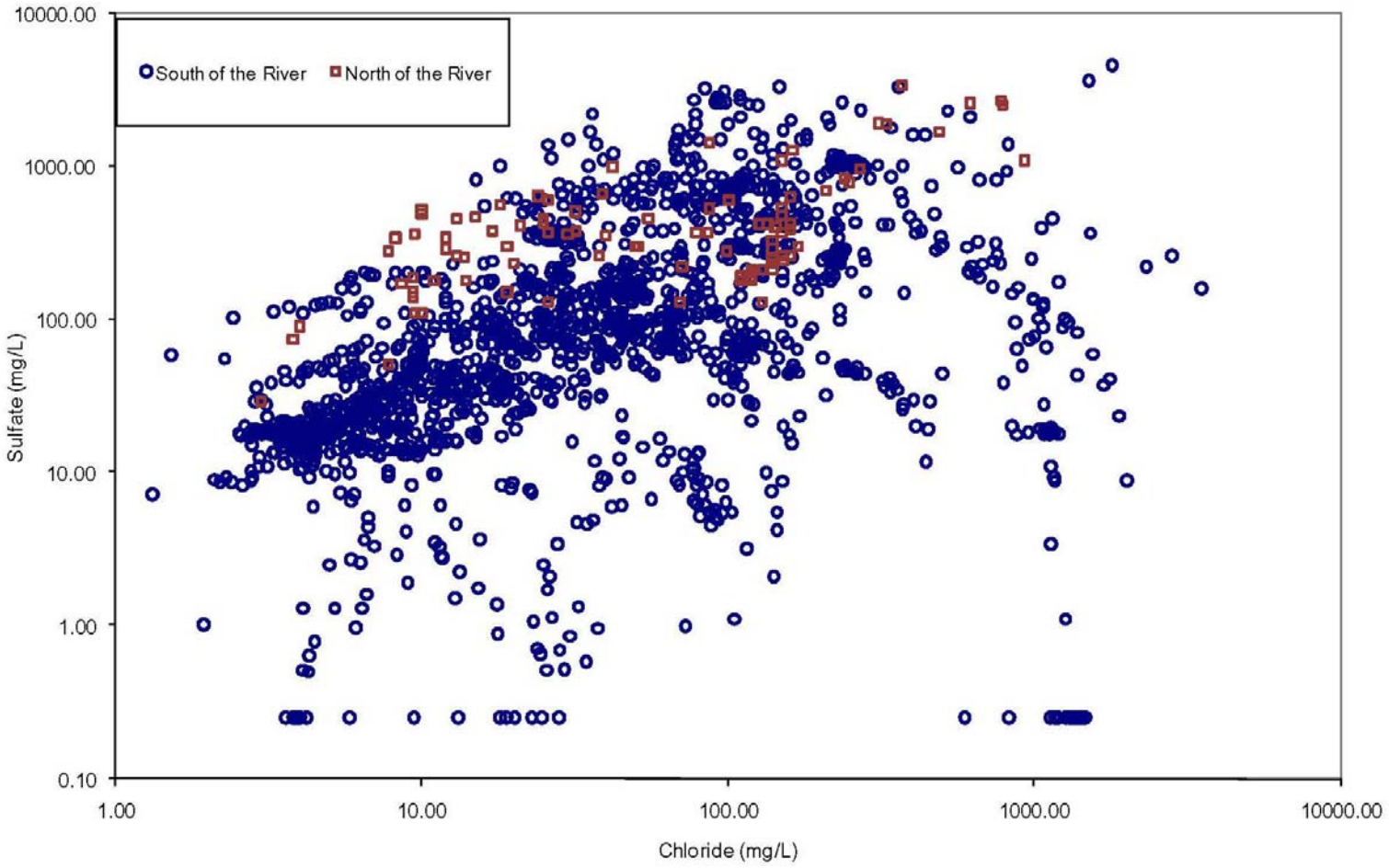
Similar or Slightly Lower Sulfate to Chloride Concentration Ratios for the Mamm Creek Area





COGCC Data. Box-and-whisker plot (log-scale). Sulfate/chloride ratios for domestic wells North of the Colorado River and in the Mamm Creek Area. Plot shows high variability in the Mamm Creek area.

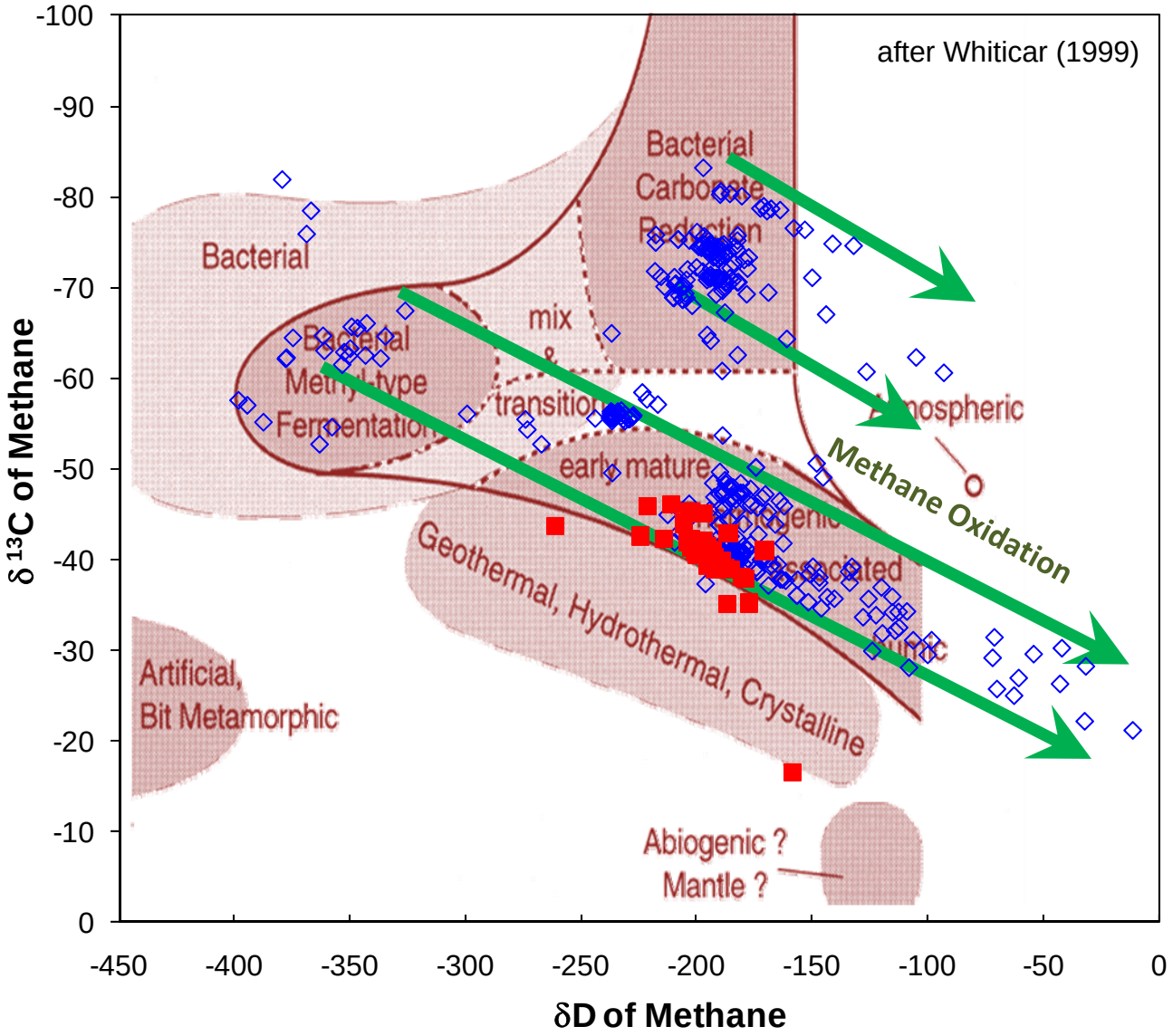
High Chloride Concentrations Do Not Necessarily Indicate Impacts from Produced Water



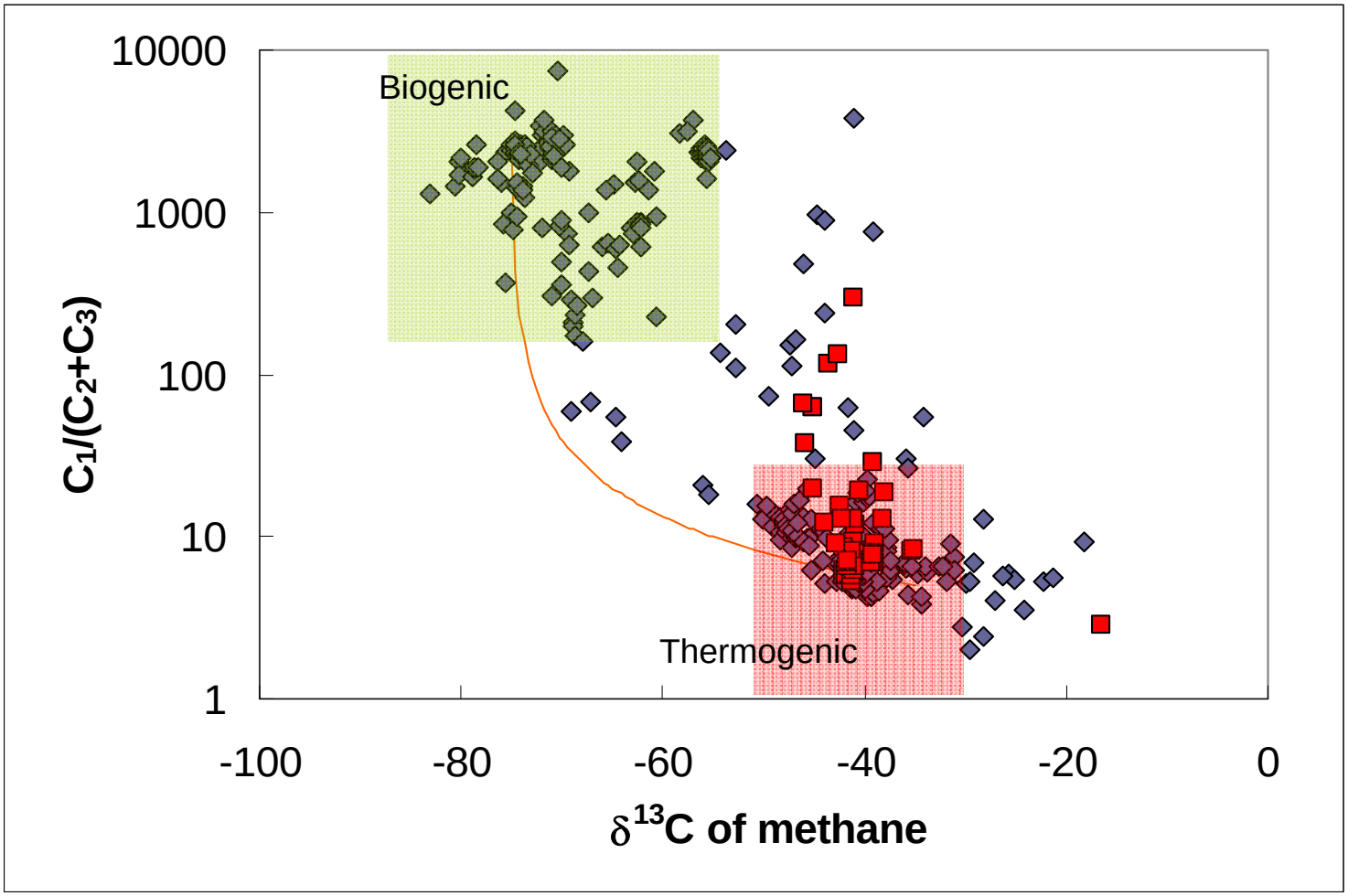
COGCC Data. Scatter plot showing relationship of sulfate and chloride with north (red squares) and south (blue circles) areas differentiated.

Which methane in the Mamm Creek area is thermogenic in origin?

Methane Stable Isotopes for Mamm Creek Area

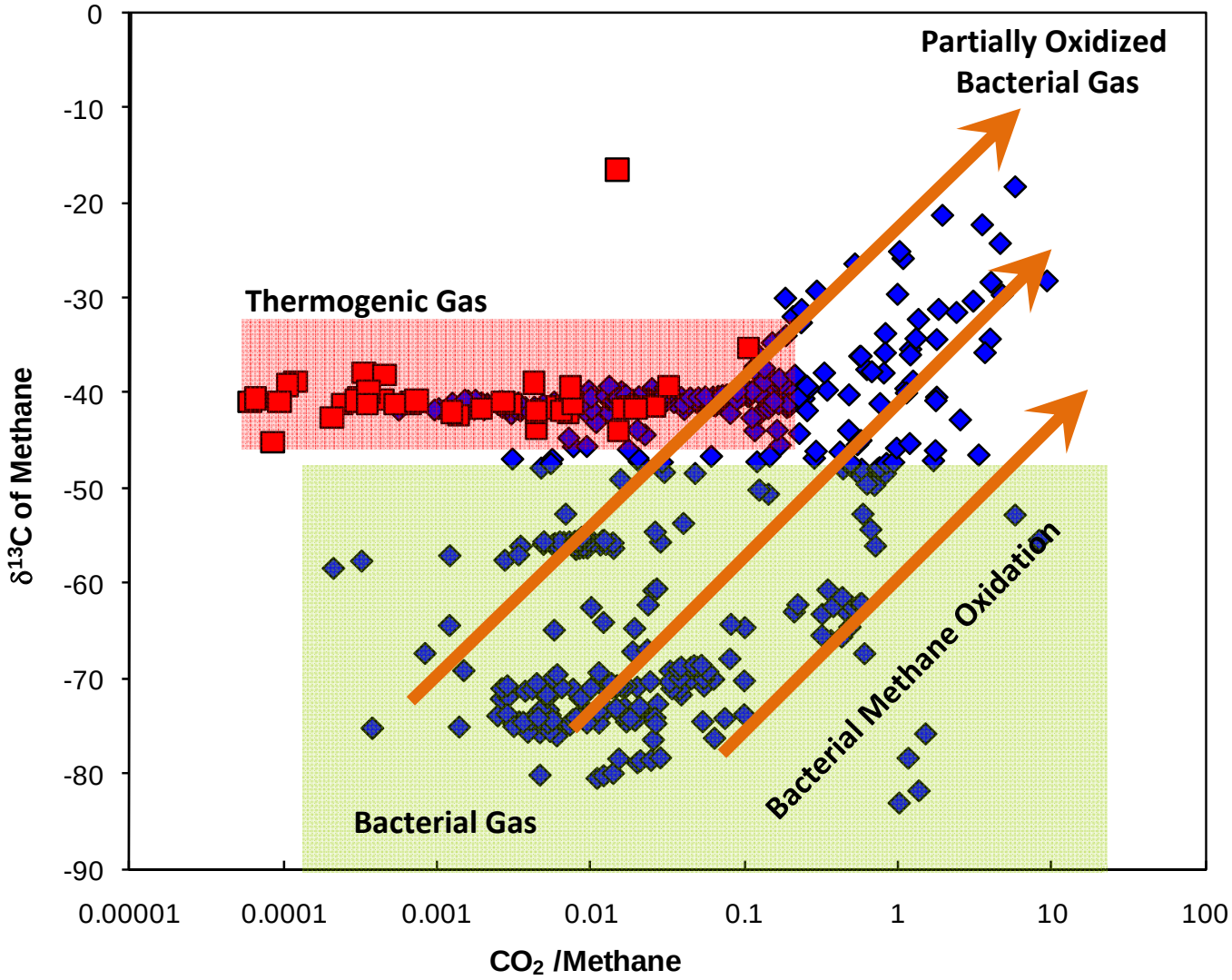


Gas Dryness Can Sometimes Distinguish Gases That Appear to Be Thermogenic From Normal Produced Gases

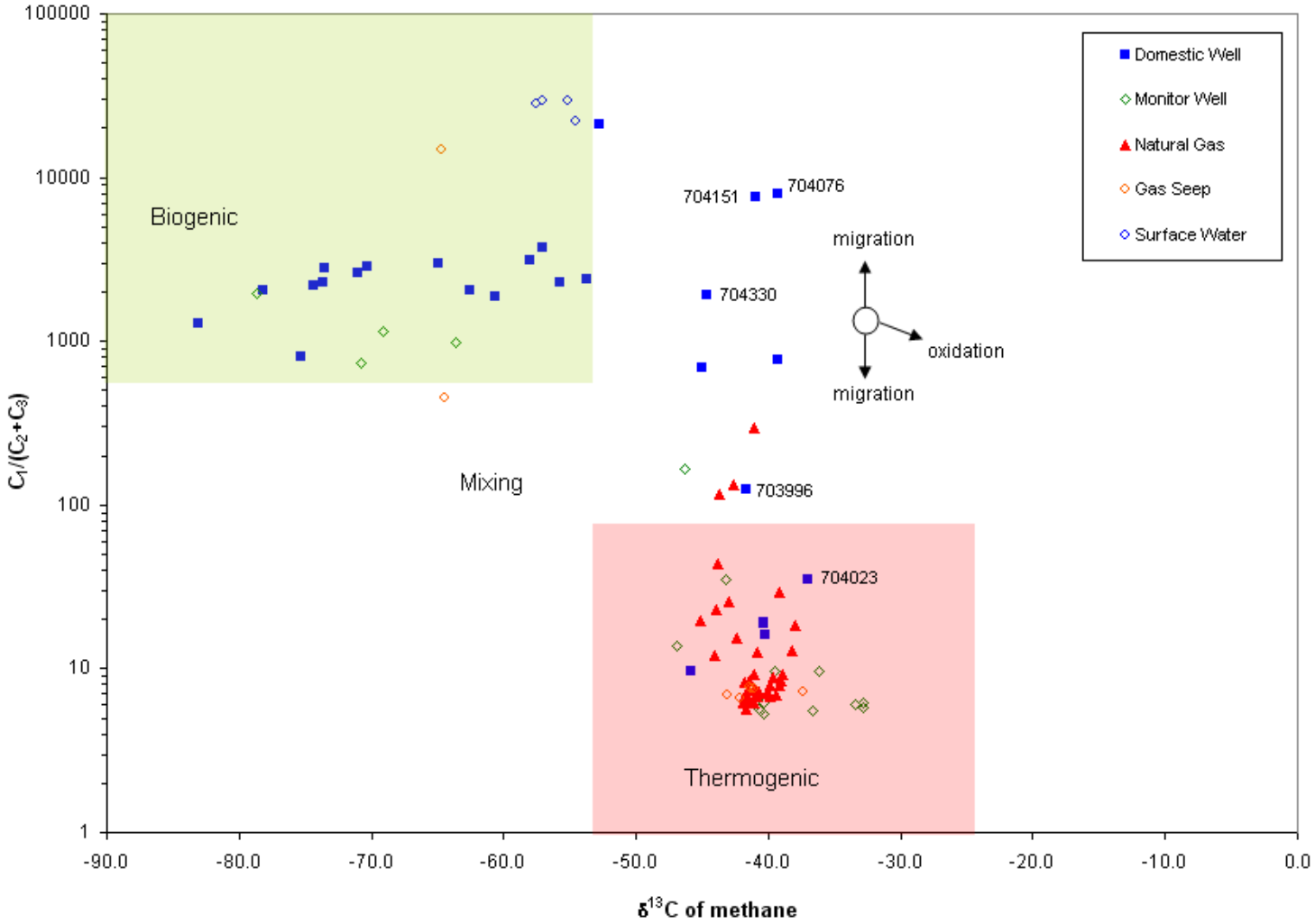


Bernard Diagram (after Whiticar, 1990). Red squares are natural gas samples or gas samples from produced water. Blue diamonds are monitoring wells and domestic wells.

Oxidation of Methane to Carbon Dioxide Can Sometimes Result in Biogenic Gases That Appear to Be Thermogenic



The Number of Domestic Wells with Thermogenic Methane is Relatively Small



Bernard Diagram (after Whiticar, 1990). Domestic wells are shown by Blue Squares.

Conclusions

- There is no statistically significant trend for increasing methane or chloride concentrations in the Mamm Creek area.
- Chloride concentrations above 10 mg/L do not necessarily indicate impacts from produced water.
- Most domestic wells in the Mamm Creek area contain biogenic methane. Wells with known thermogenic methane are known and are being investigated by the COGCC.
- Wells in the southeast area may contain or include thermogenic methane, but that methane is not compositionally the same as the methane in conventional natural gas produced from the Williams Fork Formation.