Eastern Boulder County Well Water Quality Assessment

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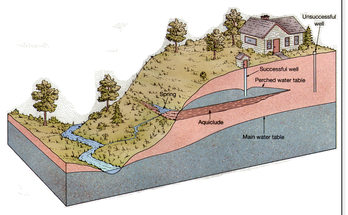
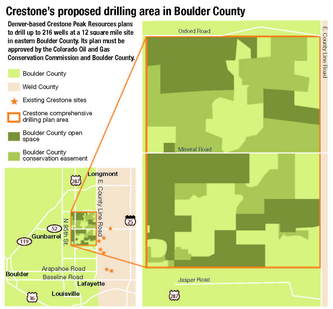
Background & Motivation

- Significant increase in horizontal drilling and hydraulic fracturing in Colorado in 2010
- Denver-Julesburg (DJ) Basin has become one of the highest-producing basins in the last decade
- Crestone Peak plans to drill 216 wells in eastern Boulder County to access the DJ Basin





- Increased risk for contamination of surface and groundwater by chemical additives in fracturing fluids
- Surface spills are the most likely groundwater contamination pathway for oil- and gas-related compounds (Vidic et al.) In DJ, only three water wells contaminated by spills; but 51 wells contaminated by oil and gas wells (Schroeder et al., in prep).
- In the DJ Basin of Colorado, from 2010-2014 operators reported about 90 surface spills per year which contaminated groundwater (Armstrong et al., in prep). But only 0.17% reach water wells.

Objective: Develop a thorough baseline groundwater quality assessment for eastern Boulder County and make data publicly available for assessing any changes in water quality as a result of oil and gas development

Groundwater Sampling

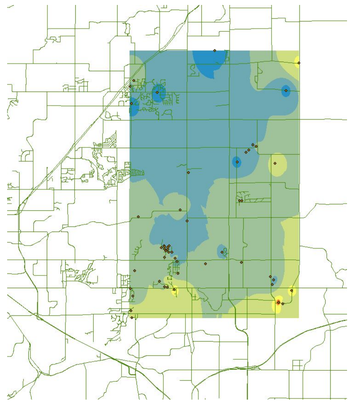
Current Procedure:

- Plan to sample groundwater for 400 volunteers in eastern Boulder County
- Purge 50-100 gallons of groundwater until initial water quality measurements stabilize using In-Situ Aqua TROLL 600 multi-parameter sonde – pH, temperature, conductivity, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity
- Collect samples to be analyzed for:
  - ⇨ Volatile Organic Compounds
  - ⇨ Trace Elements
  - ⇨ Major cations and anions
  - ⇨ Methane and $\delta^{13}C$
  - ⇨ Total organic carbon
  - ⇨ Alkalinity

Trace Elements & Major Ions:

Samples containing trace elements that exceeded current drinking water quality standards were identified. ArcGIS Inverse distance weighting method (IDW) was used to identify spatial trends for the varying concentrations of the metals. IDW uses a linear combination of sample data points and determines the influence of a point based on its distance and value compared to the other points.

Chromium:

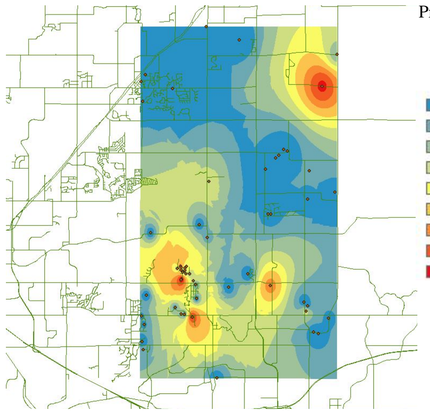


Primary Drinking Water Quality Standard: **100 ug/L**

- 0.737 - 6.223
- 6.224 - 19.56
- 19.57 - 40.57
- 40.58 - 77.6
- 77.61 - 100
- 100.1 - 103.5
- 103.6 - 107.1
- 107.2 - 110.4
- 110.5 - 114.8

Potential Sources: geologic
Adverse Health Effects: kidney damage, liver disease, diabetes

Selenium:

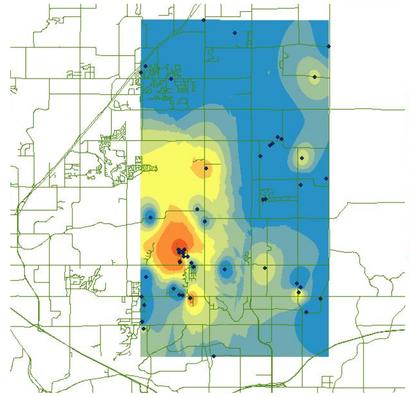


Primary Drinking Water Quality Standard: **50 ug/L**

- 0.9615 - 6.315
- 6.316 - 11.7
- 11.71 - 20.32
- 20.33 - 32.06
- 32.07 - 50
- 50.01 - 74.06
- 74.07 - 101.2
- 101.3 - 130.5
- 130.6 - 167.3

Potential Sources: coal and organic-rich fine sediments
Adverse Health Effects: endocrine disruptor

Nitrate [NO_3^-]:

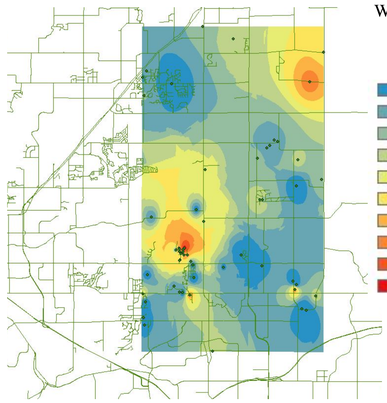


Primary Drinking Water Quality Standard: **44.3 mg/L**

- 0.09301 - 10.61
- 10.62 - 16.01
- 16.02 - 23.05
- 23.06 - 31.65
- 31.66 - 44.3
- 44.31 - 57.1
- 57.11 - 70.69
- 70.7 - 84.26
- 84.27 - 94.78

Potential Sources: fertilizers, feed lots, permeable soils are more susceptible
Adverse Health Effects: blue baby syndrome (methemoglobinemia), lowers the body's ability to deliver oxygen to tissue

Uranium:

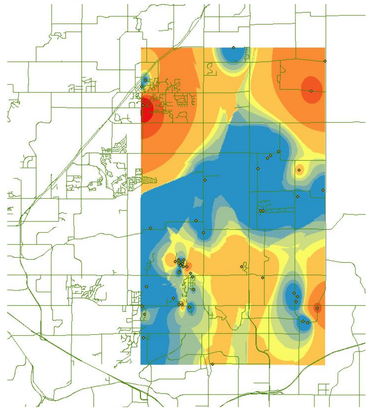


Primary Drinking Water Quality Standard: **30 ug/L**

- 0.011 - 6.599
- 6.6 - 10.22
- 10.23 - 13.85
- 13.86 - 18.13
- 18.14 - 23.22
- 23.23 - 30
- 30.01 - 37.86
- 37.87 - 43.82
- 43.83 - 59.64
- 59.65 - 84.01

Potential Sources: geologic, historically mined in Colorado
Adverse Health Effects: kidney damage, carcinogen

Manganese:

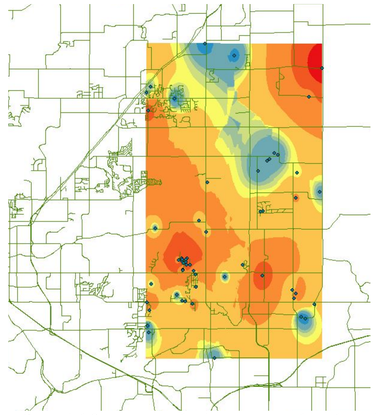


Secondary Drinking Water Quality Standard: **50 ug/L**

- 0.2033 - 19.64
- 19.65 - 25.29
- 25.3 - 36.39
- 36.4 - 43.22
- 43.23 - 50
- 50.01 - 103.5
- 103.6 - 291.4
- 291.5 - 459.2
- 459.3 - 720

Potential Sources: geologic, manganese belts present west of Denver
Adverse Health Effects: respiratory irritant, nerve damage

Sulfate [SO_4^{2-}]:



Secondary Drinking Water Quality Standard: **250 mg/L**

- 1.0 - 59.45
- 59.451 - 131.58
- 131.59 - 161.3
- 161.31 - 197.63
- 197.64 - 250
- 250.01 - 592.02
- 592.03 - 1,424.5
- 1,424.6 - 2,453.3
- 2,453.4 - 3,514.4

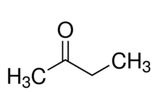
Potential Sources: coal mines, power plant depositions
Adverse Health Effects: gastrointestinal irritant

Volatile Organic Compounds:

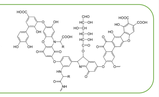
Samples containing volatile organic compounds were identified

Trihalomethanes
- Bromodichloromethane
- Bromoform
- Chloroform
- Dibromochloromethane

2-butanone
- Paint solvent
- Smells like butterscotch



Disinfection Byproduct (DBP) precursors = Natural Organic Matter (NOM)



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Inorganic DBP precursors = Bromide (Br^-), Iodide (I^-), Nitrite (NO^-_2)

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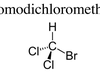
Disinfectant = Chlorine (Cl_2), Chloramines (NH_2Cl), Chlorine Dioxide (ClO_2)

Inorganic DBP precursors = Trihalomethanes

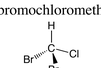
Bromoform

Bromodichloromethane



Chloroform

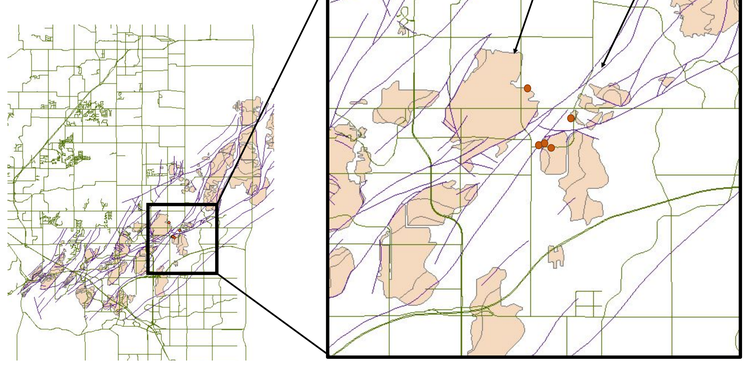
Dibromochloromethane

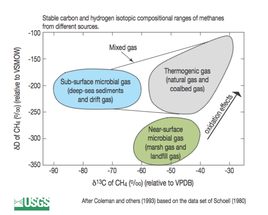


Potential Sources: well disinfectants
Adverse Health Effects: carcinogen, adverse reproductive effects

Methane:

Samples containing dissolved methane were identified. ArcGIS was used to investigate spatial correlations and proximity to coal beds and coal faults.





Methane Concentration (mg/L)	Isotope Value $\delta^{13}C_{CH4}$ (‰)
0.62	-82.6
1.15	-75.4
0.71	-83.6
0.15	-63.4
6.21	-77.3

Potential Sources: microbial, thermogenic
Safety Concerns: flammable, explosive

Application and Future Directions

- Continue sampling more volunteers
- Make data available to the public
- Investigate methane sources and obtain duplicate results
- Identify spatial trends for VOCs & discuss potential sources with volunteers

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