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Ecological Significance of Specific Conductance in Streams – Part 1

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EnviroDIY
Nov 19, 2020

Stroud Water Research Center

What is Electrical Conductivity and Why is it Important?

- Definitions – electrical conductivity is about salts, ions, cations, anions
- Salts dissolve in water, dissolved salts affect ability of water to conduct electricity
- Some salts more soluble than others
- EC varies geographically and temporally

Terms Describing Salt in Fresh Water

Salinity (ppm)

Total Dissolved Solids (TDS, ppm)

Electrical Conductivity or Specific Conductance (µS/cm)

Salt (mg/L)
(NaCl, KCl, $CaCl_2$, $MgCl_2$)

Chloride (mg Cl/L)

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Definitions

Electrical Conductance

- EC measures how easily electricity flows through a substance (e.g., water). When conductance is high, resistance is low.

Salt

- A salt is a chemical compound consisting of an ionic assembly of cations and anions. Salts are electrically neutral (without a net charge).

Examples of Salts

- Table salt is primarily NaCl = Na^{+}, Cl^{-}
- Limestone is primarily $CaCO_3$ = Ca^{++} ,CO_3^{-2}
- Dolomite is magnesium limestone $CaMg(CO_3)_2$ = Ca^{++}, Mg^{++}, 2 CO_3^{-2}

Definitions

- Ions
  - An ion is an electrically charged atom or group of atoms formed by the loss or gain of one or more electrons
- Cation
  - A cation is a positively charged ion (Na^{+}, K^{+}, Ca^{++}, Mg^{++}) and is attracted to the cathode in electrolysis
- Anions
  - An anion is a negatively charged ion (Cl^{-}, $CO3^{=}$, $SO_4^{=}$) and is attracted to the anode

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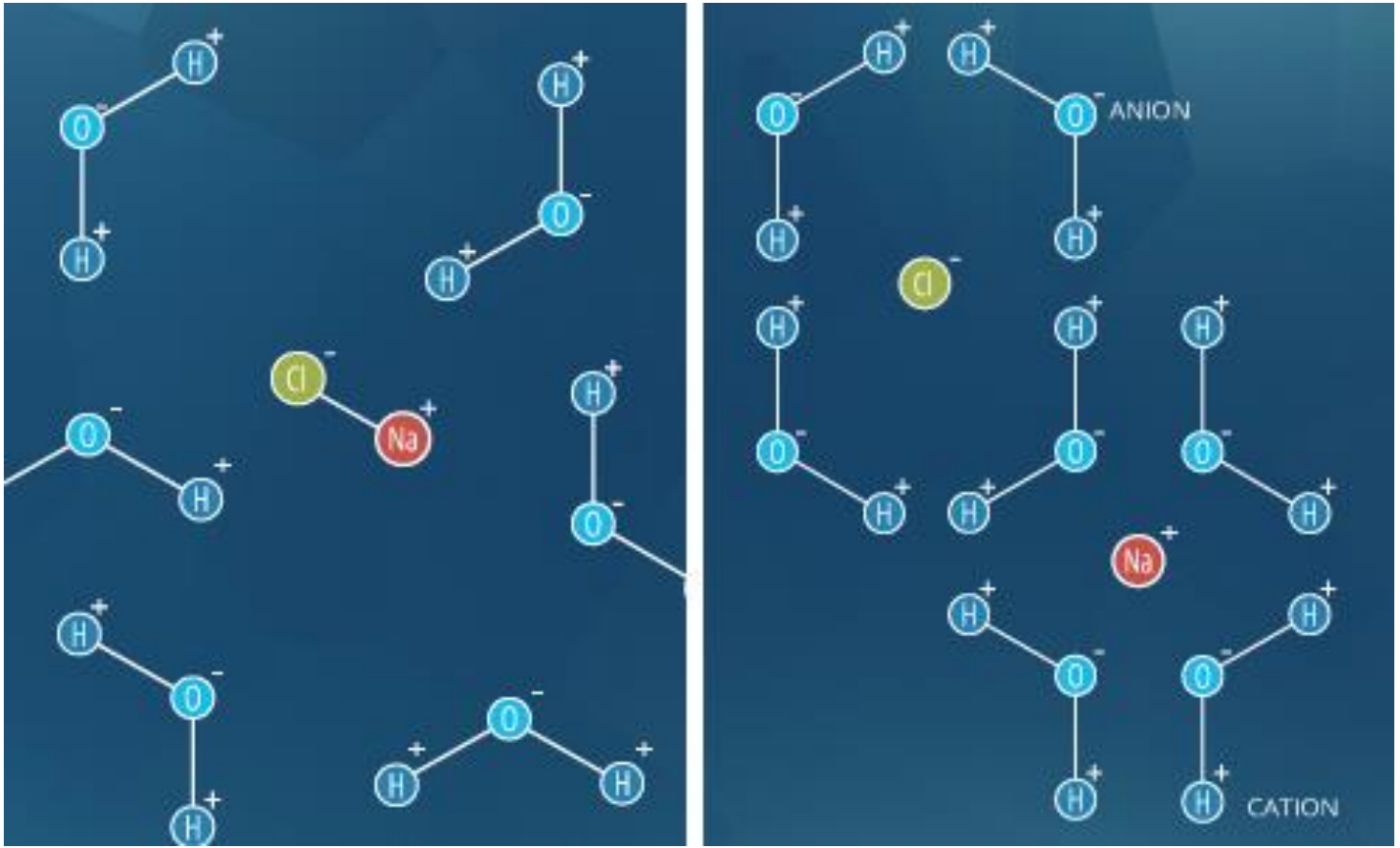
Salts dissolve in water



Salts dissolve in water to produce an anion and a cation.

These ions make up the basis of conductivity in water.

Some molecules dissolve but do not disassociate:
Sugar
Ethanol
Methanol

https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/

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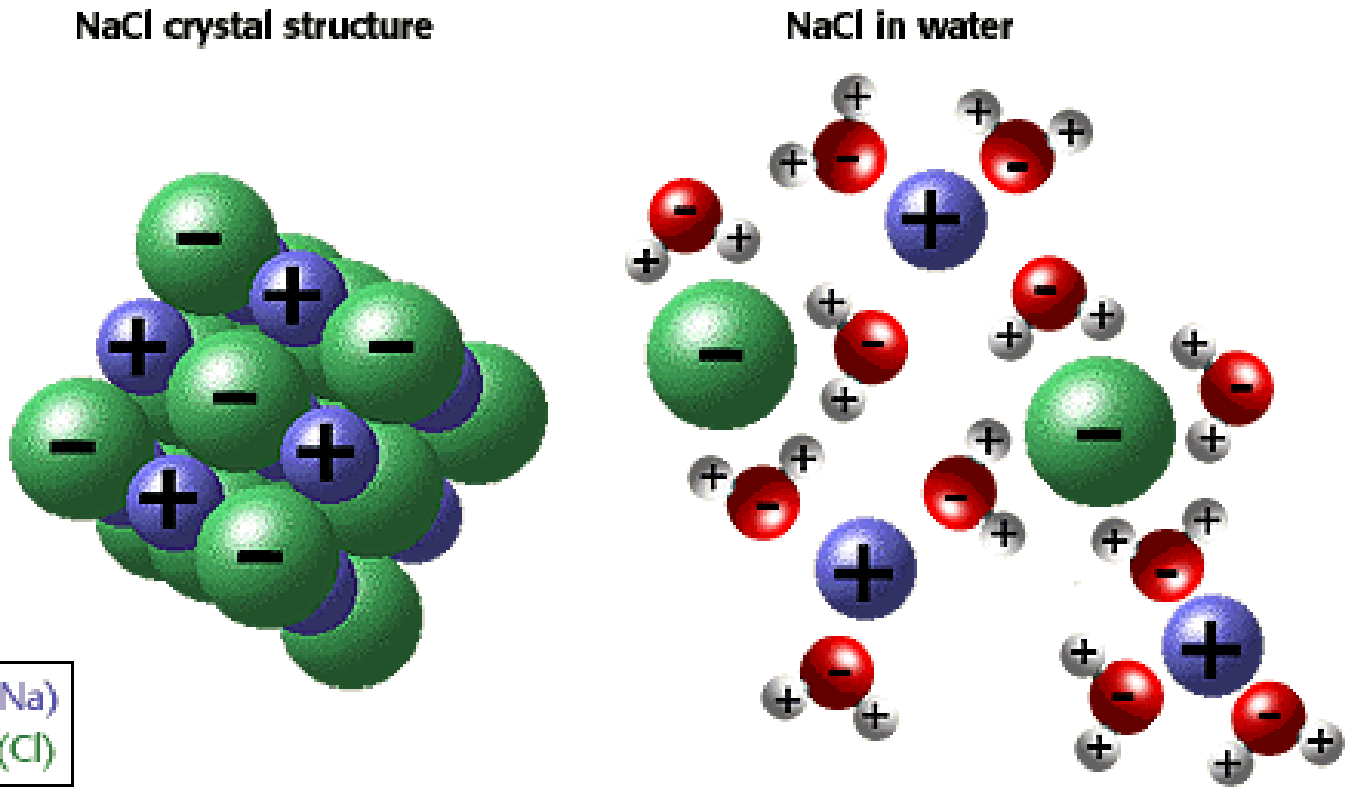
Salts Dissolve in Water



Salts dissolve in water to produce an anion and a cation.

Particles orient based on positive and negative charges.

https://www.quora.com/Why-will-chalk-not-dissolve-in-water

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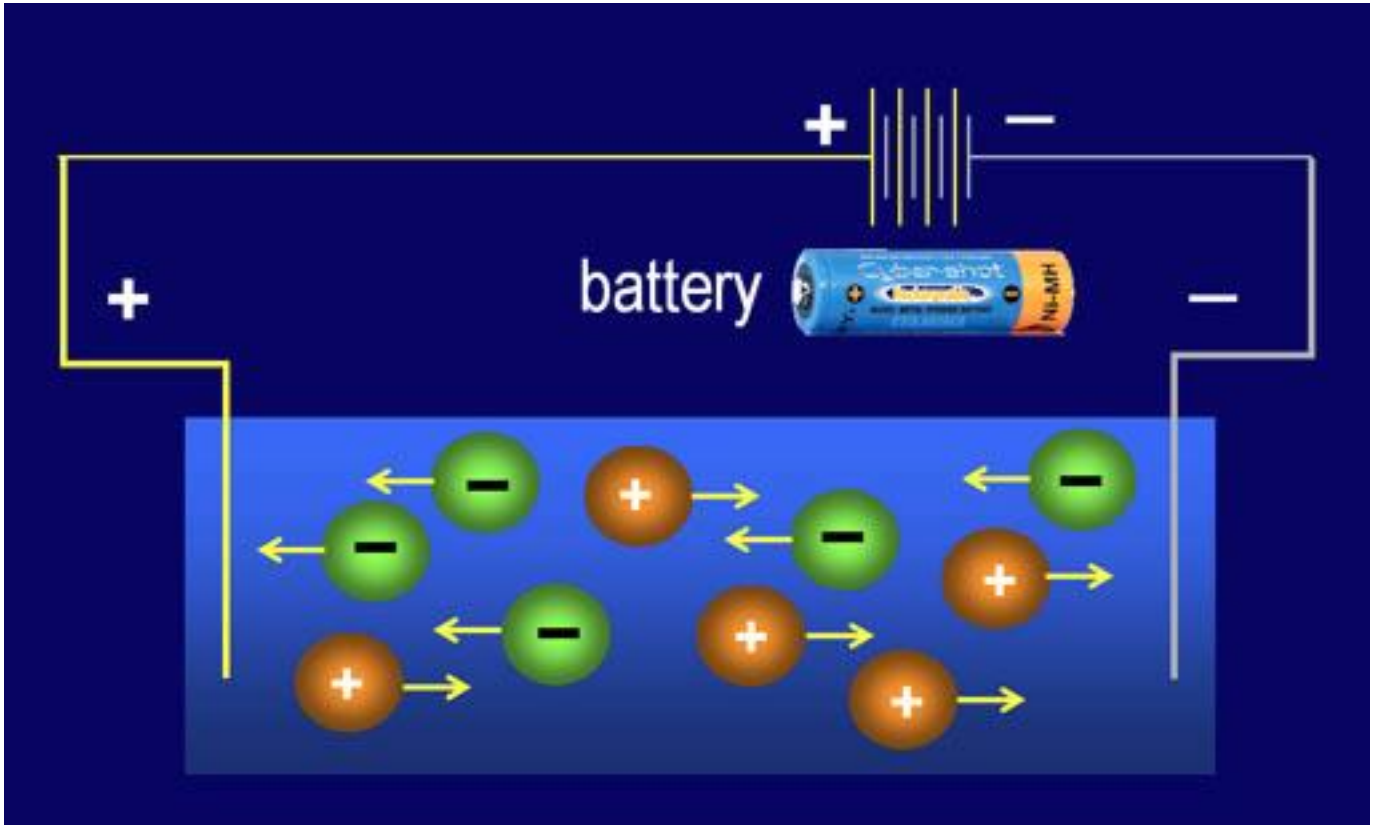
Electrical Conductivity Measures Movement of Ions



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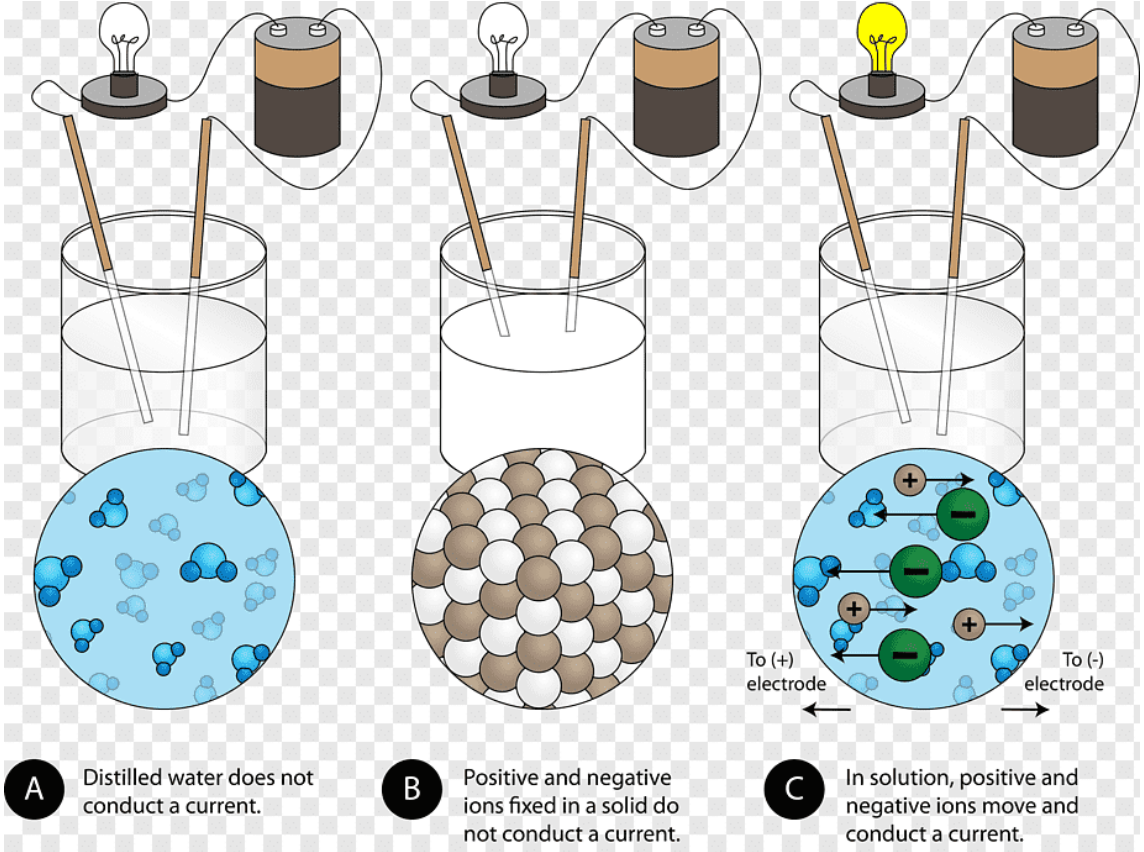
Electrical Conductance Reflects Dissolved Salts



https://www.pngwing.com/en/free-png-xnlbo

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Electrical Conductance Increased with Dissolved Solids (Salts)

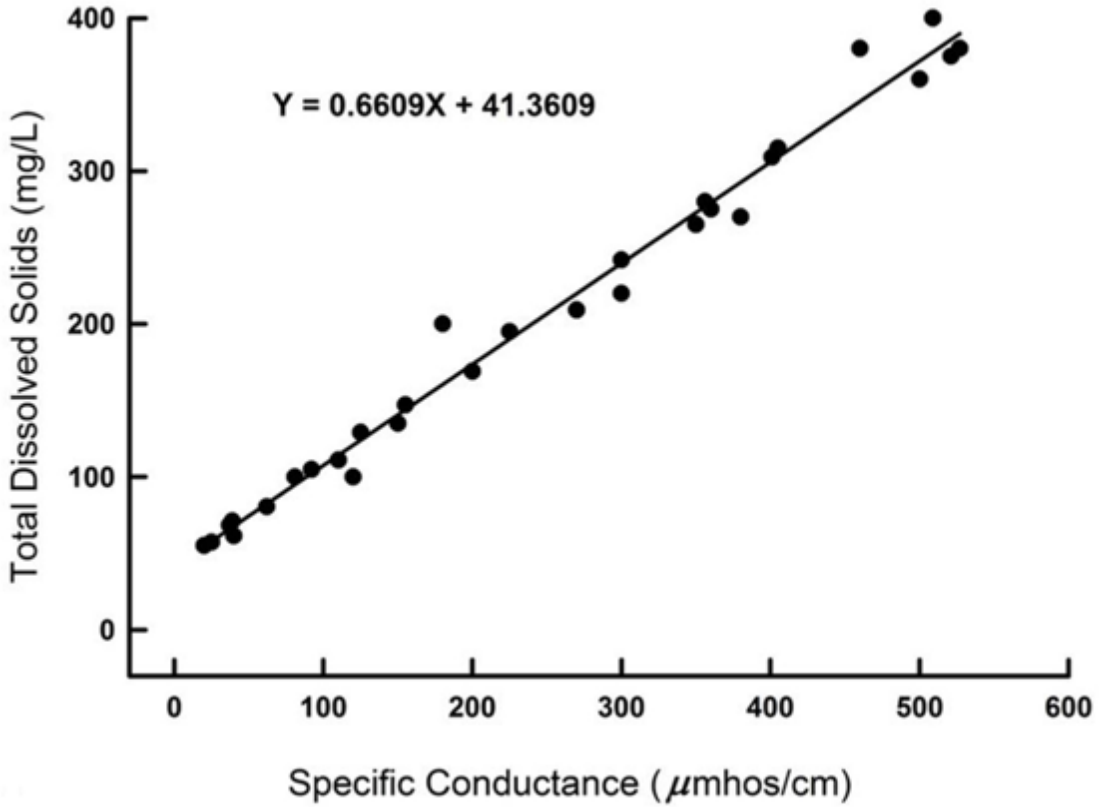

Fig. 1: Regressions between specific conductance and **total dissolved solids** in surface water in the Blackland Prairie region of Alabama (USA).

https://www.aquaculturealliance.org/advocate/electrical-conductivity-water-part-2/

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Electrical Conductance Increased with Dissolved Salts

https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/

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Some salts more soluble than others

Inorganic compound	Solubility per 100 g of water at 20 °C
Potassium carbonate (K_2CO_3)	111.5
Sodium hydroxide (NaOH)	107.0
Calcium chloride ($CaC1_2$)	74.5
Magnesium chloride ($MgCl_2$)	54.3
Ammonium chloride (NH_4CI)	37.4
Sodium chloride (NaCl)	35.9
Barium chloride ($BaCl_2$)	35.7
Magnesium sulphate ($MgSO_4$)	35.6
Potassium chloride (KCl)	34.4
Sodium carbonate (Na_2CO_3)	21.6
Sodium sulphate (Na_2SO_4)	19.1
Calcium sulphate ($CaSO_4$)	2.0
Barium hydroxide $Ba(OH)_2$	3.5
The calcium hydroxide $Ca(OH)_2$	0.17
Calcium carbonate ($CaCO_3$)	0.06

Analysis of the application for the magnetohydrodynamic effect in the hydrocarbon production
December 2019
Journal of Physics Conference Series 1441:012023

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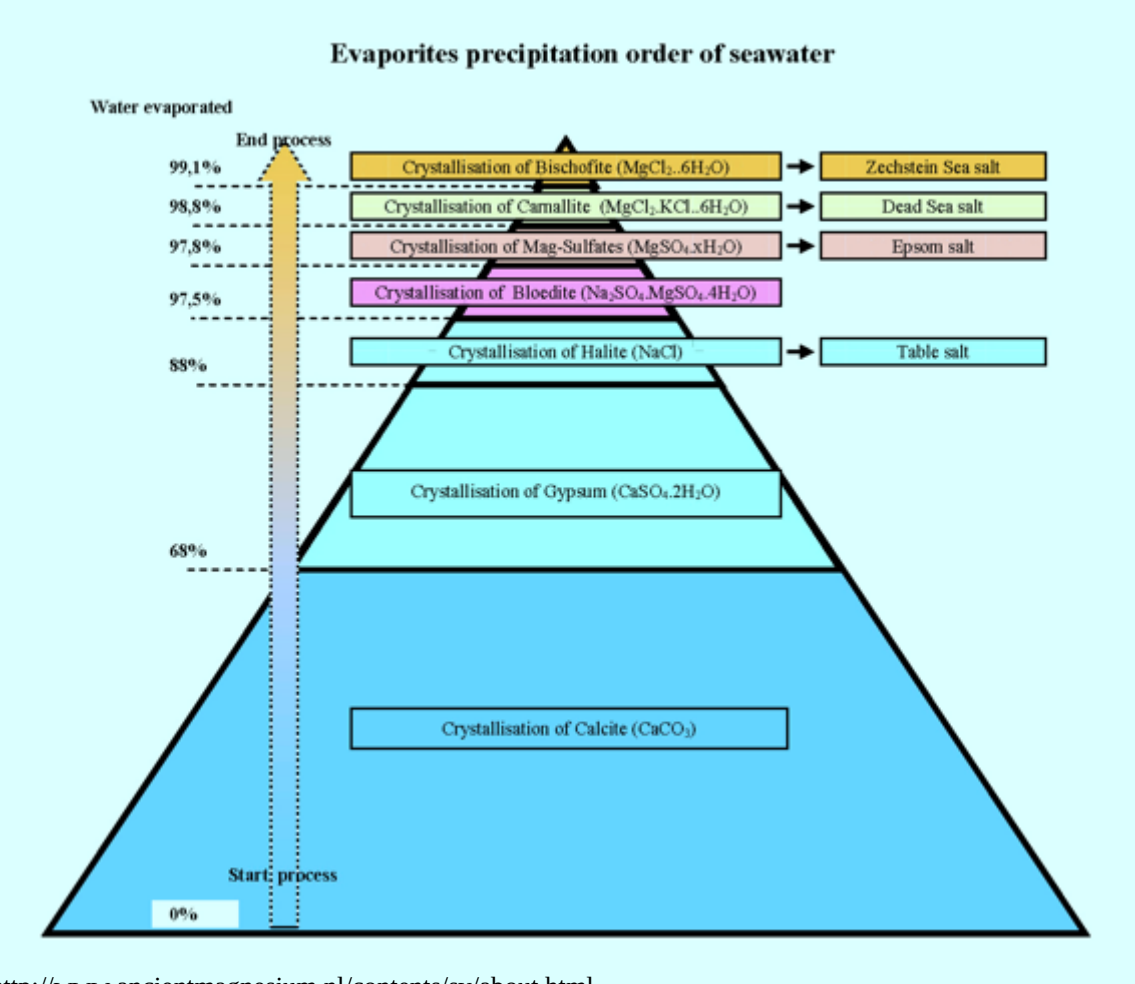

http://www.ancientmagnesium.nl/contents/sv/about.html

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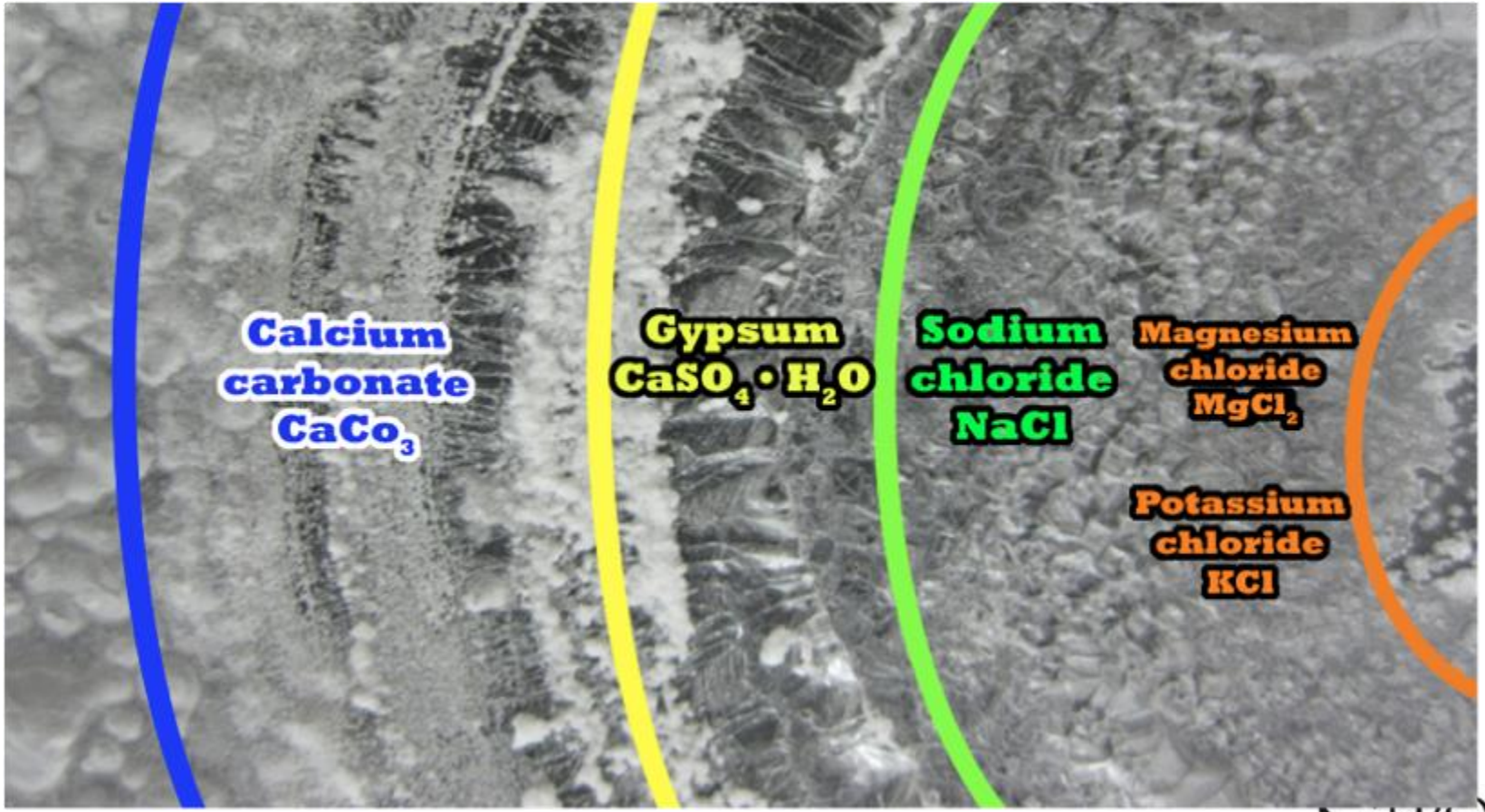
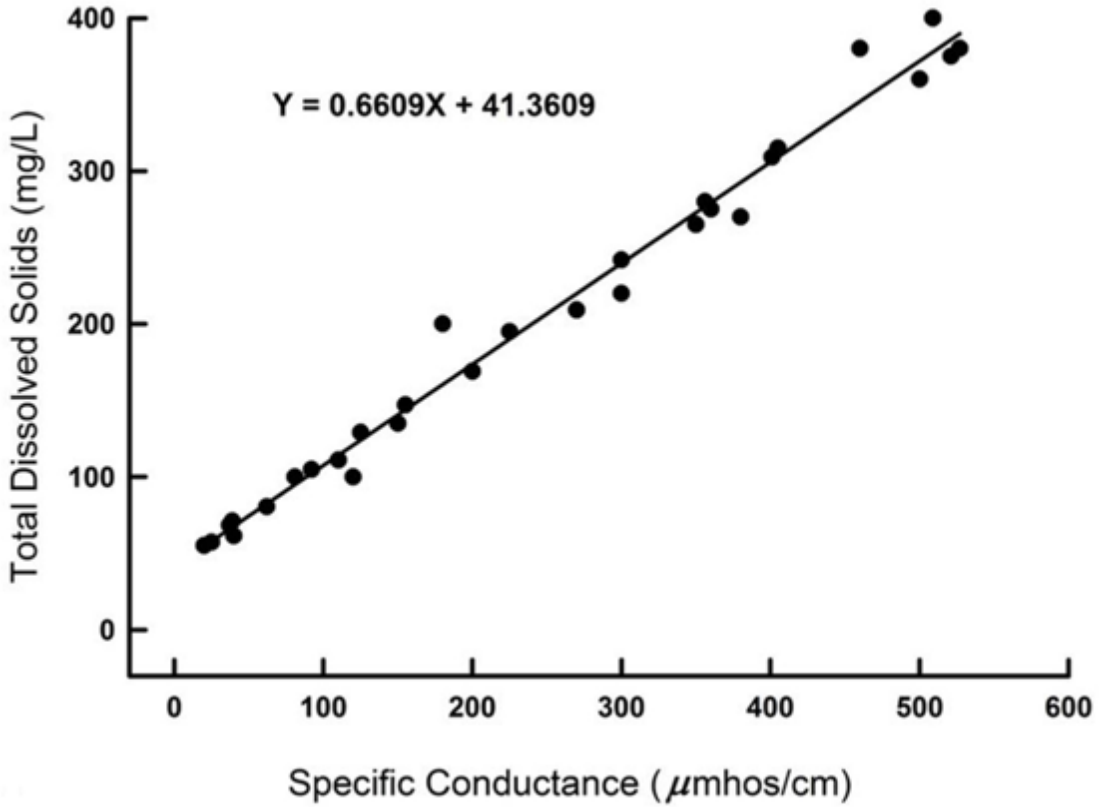


SF Fig. 2.1. Salt rings formed by evaporation of seawater on watch glass. The blue ring is the outermost, least soluble salt. The orange salt ring is the most soluble salt. Image by Joanna Philippoff and Brittany Supnet

Electrical Conductance Increased with Dissolved Salts



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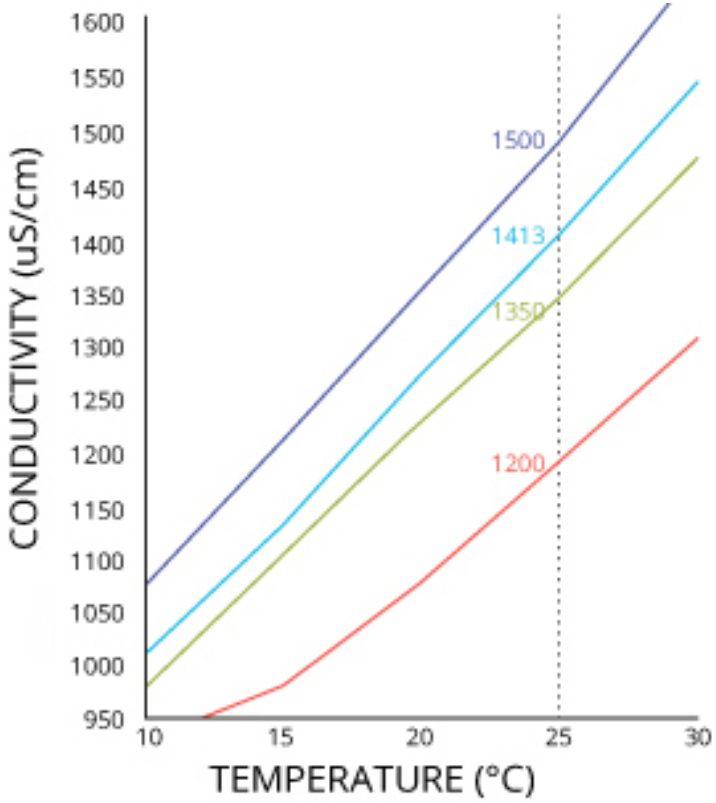
Electrical Conductivity increases with Temperature



Specific Conductivity is electrical conductance at 25° C

SC is a standard of comparison for different water sources as conductivity ratios change with temperature.

https://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/

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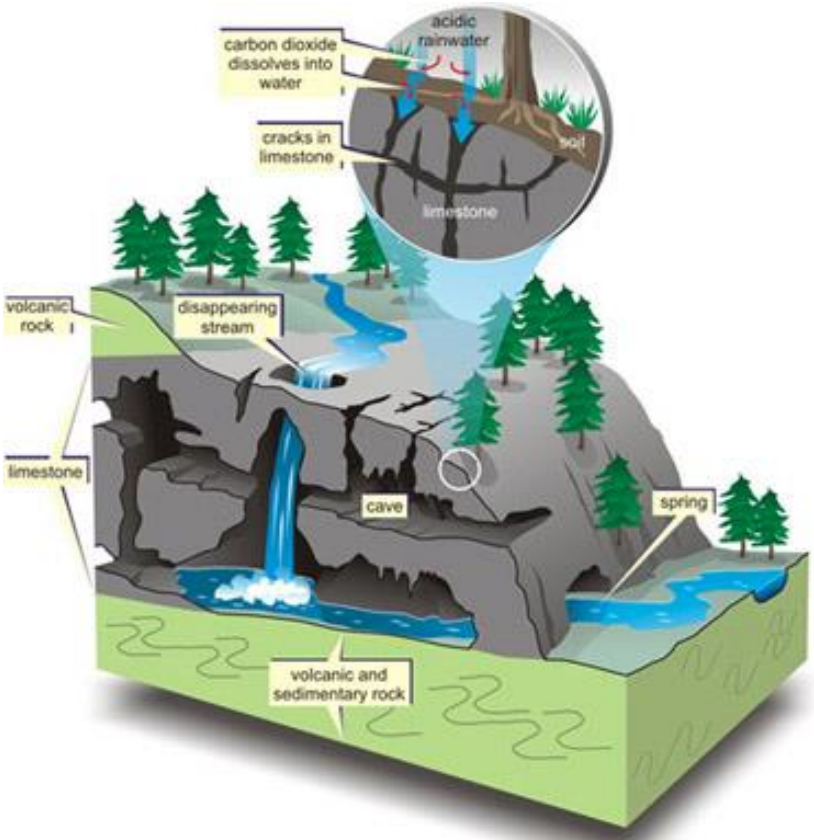
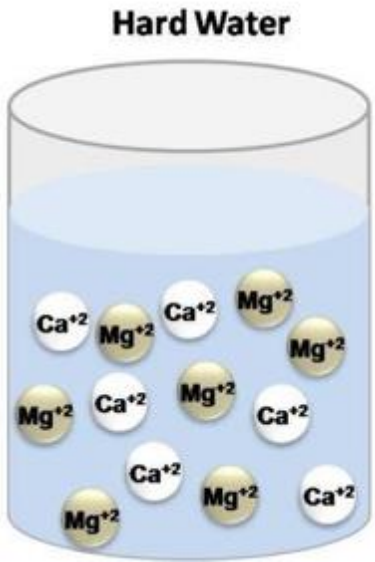
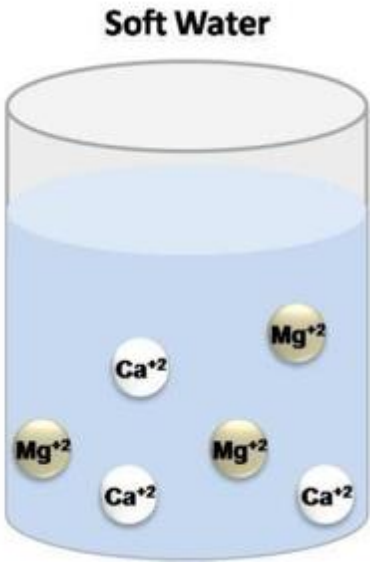
Dissolved Salts Naturally in Streams Reflect Underlying Geology







https://www.geocaching.com/geocache/GC1WEW0_keyhole-cave?guid=c13c7f73-3789-47e9-b4e6-f30687dcede1

https://steemit.com/steemstem/@yusvelasquez/water-hardness-do-yo-1558703762

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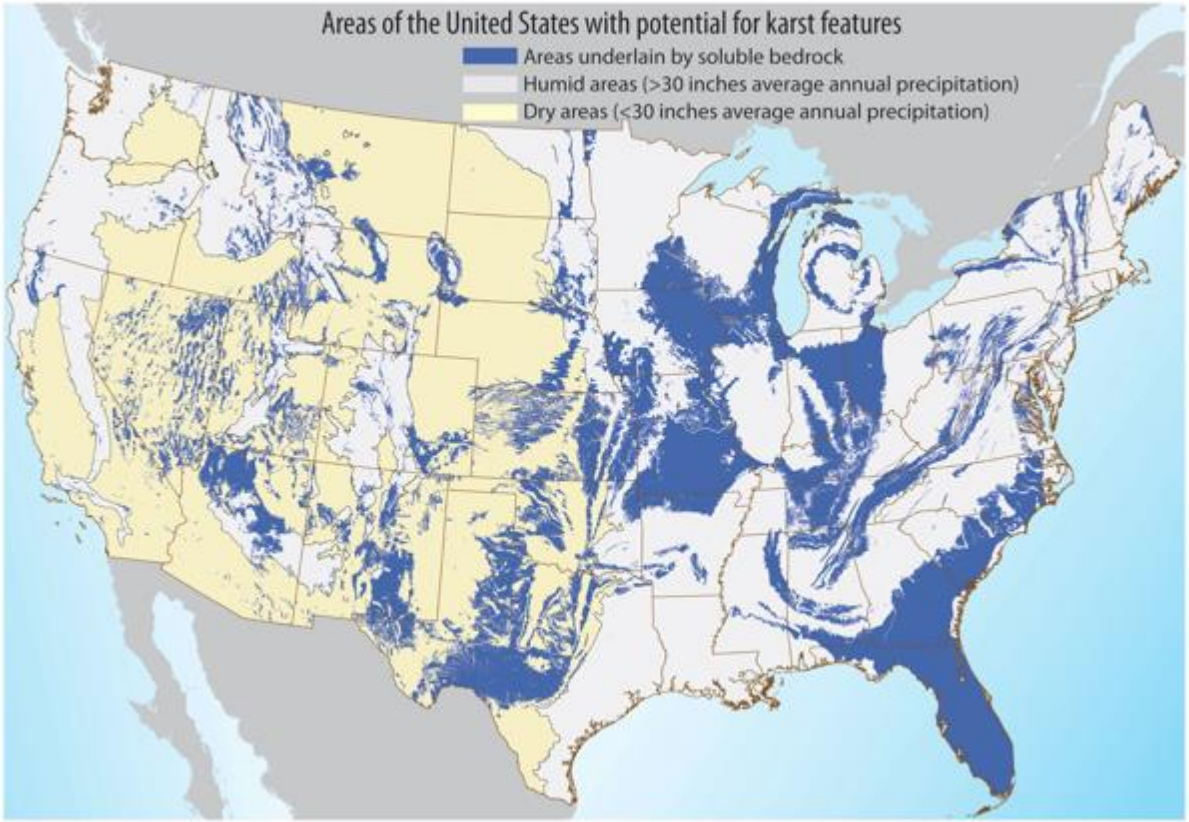
Dissolved Salts Naturally in Streams Reflect Underlying Geology (and precipitation)



https://geology.er.usgs.gov/egpsc/graphics/06_karst_studies_weary.jpg

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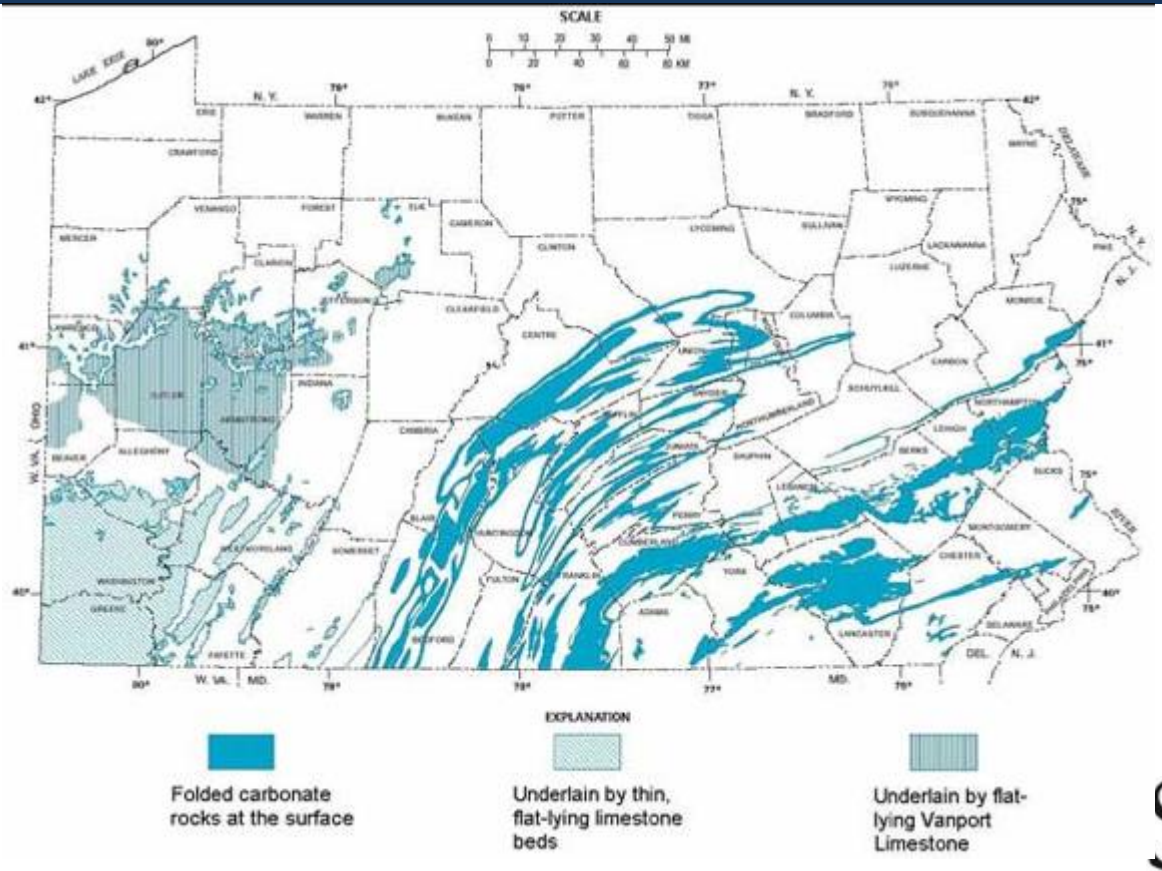
Dissolved Salts Naturally in Streams Reflect Underlying Geology



https://pubs.usgs.gov/of/2003/of03-471/reese/index.html

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Dissolved Salts Vary Greatly - Locally

457 Wells monitored
Chester County PA

Table 6. *Summary statistics for specific conductance in ground water, by rock type, based on samples collected from 1990 to 2001*

[—, too few samples to compute statistics]

Rock type	Total number of samples	Specific conductance, in microsiemens per centimeter at 25° Celsius				
		Minimum	25th percentile	Median	75th percentile	Maximum
All wells	457	23	154	228	358	1,460
Carbonate	54	132	415	648	804	1,460
Diabase	1	396	—	—	—	—
Gneiss	150	50	159	218	317	740
Quartzite	37	23	100	157	266	1,010
Schist	170	52	146	194	257	849
Triassic sedimentary	34	66	162	249	343	608
Serpentinite	11	69	228	298	431	938

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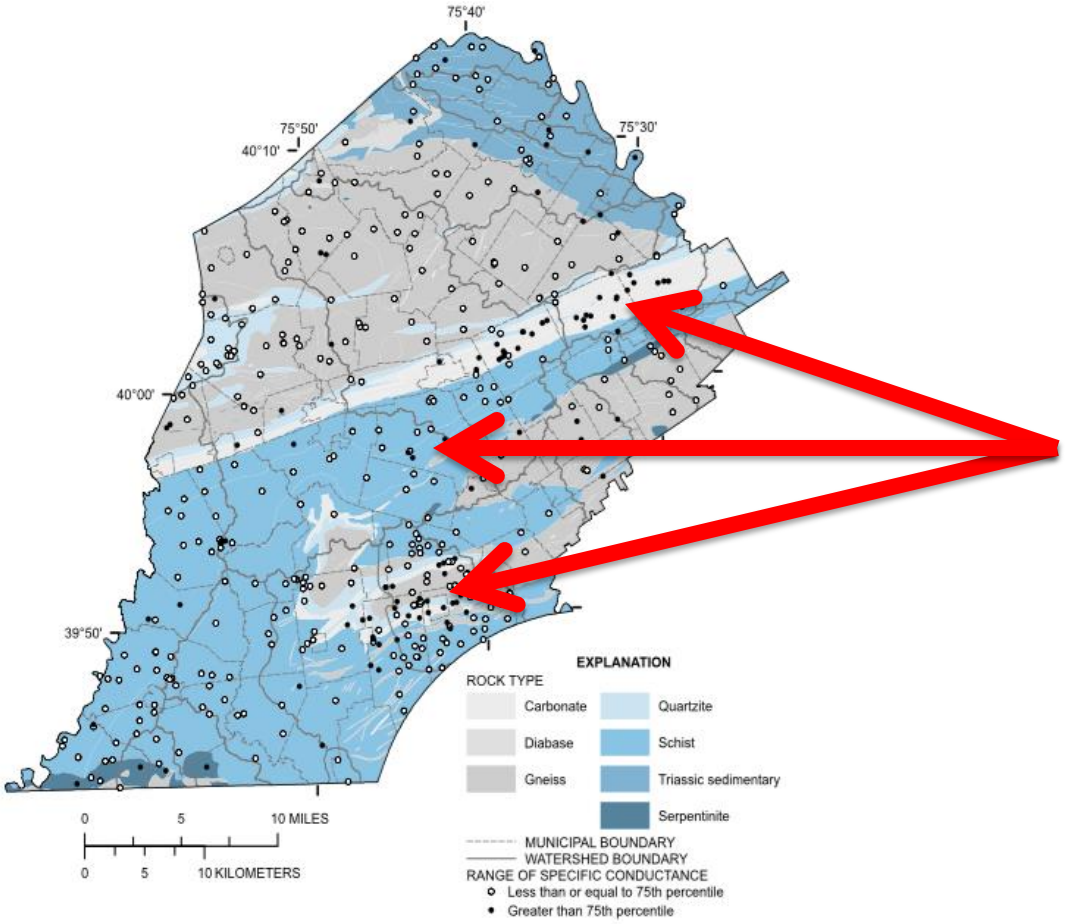

Figure 3. Distribution of specific conductance relative to generalized rock types.

457 Wells monitored
Chester County PA

Complex geology

Black dots = > 385 µS/cm

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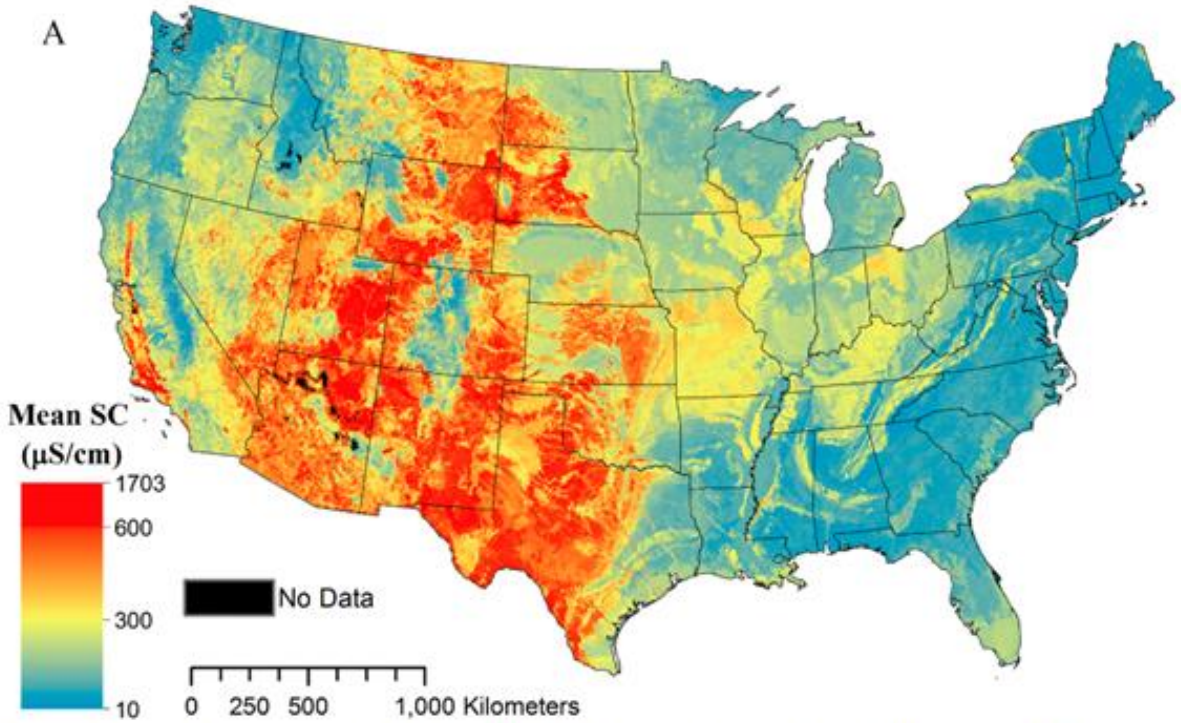
Dissolved Salts Vary Greatly – Regionally/Nationally



Olson, J.R. and Cormier , S.M., 2019. Modeling Spatial and Temporal Variation in Natural Background Specific Conductivity. *ES&T, 53*.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7153567/

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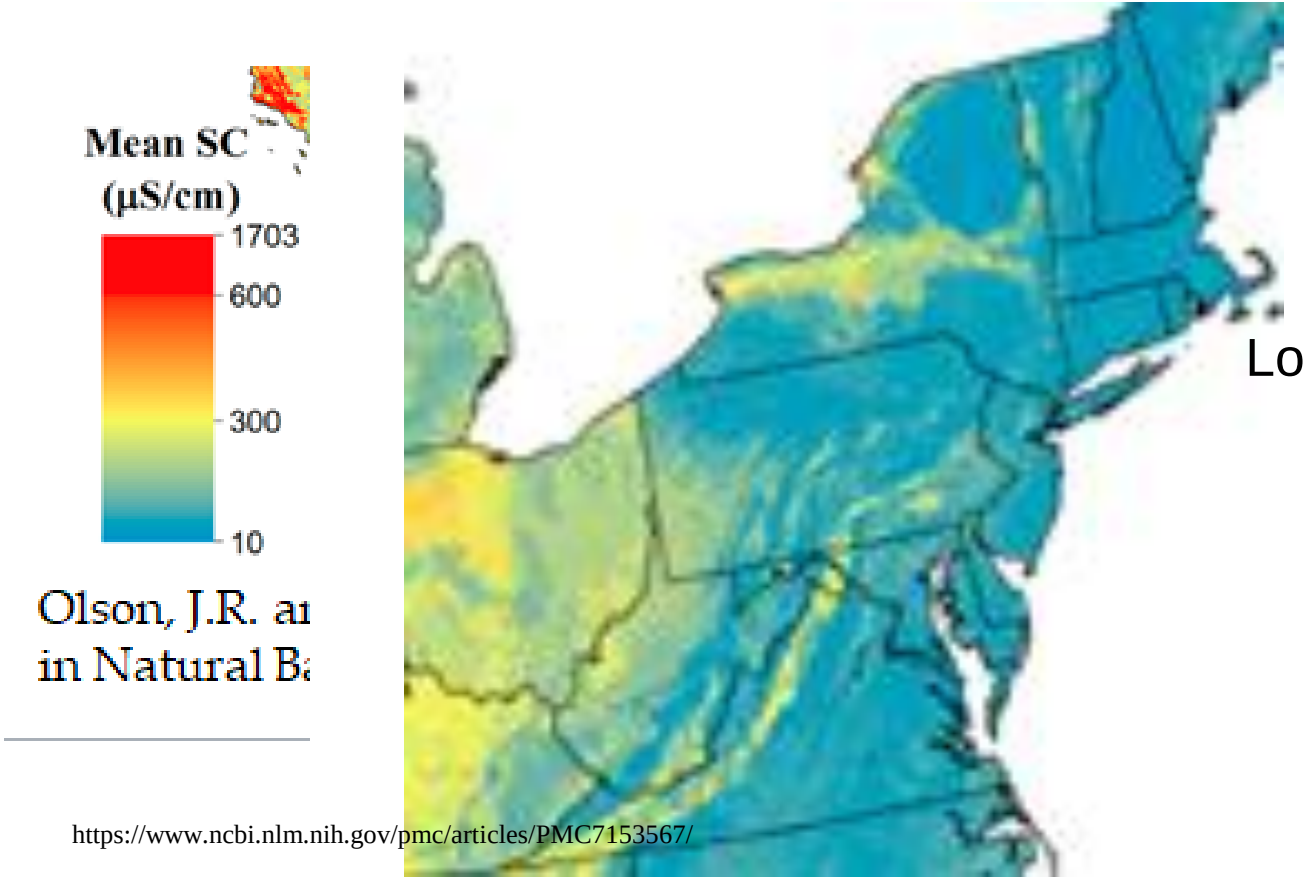
Dissolved Salts Vary Greatly – Regionally/Nationally



https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7153567/

Local variation not visible

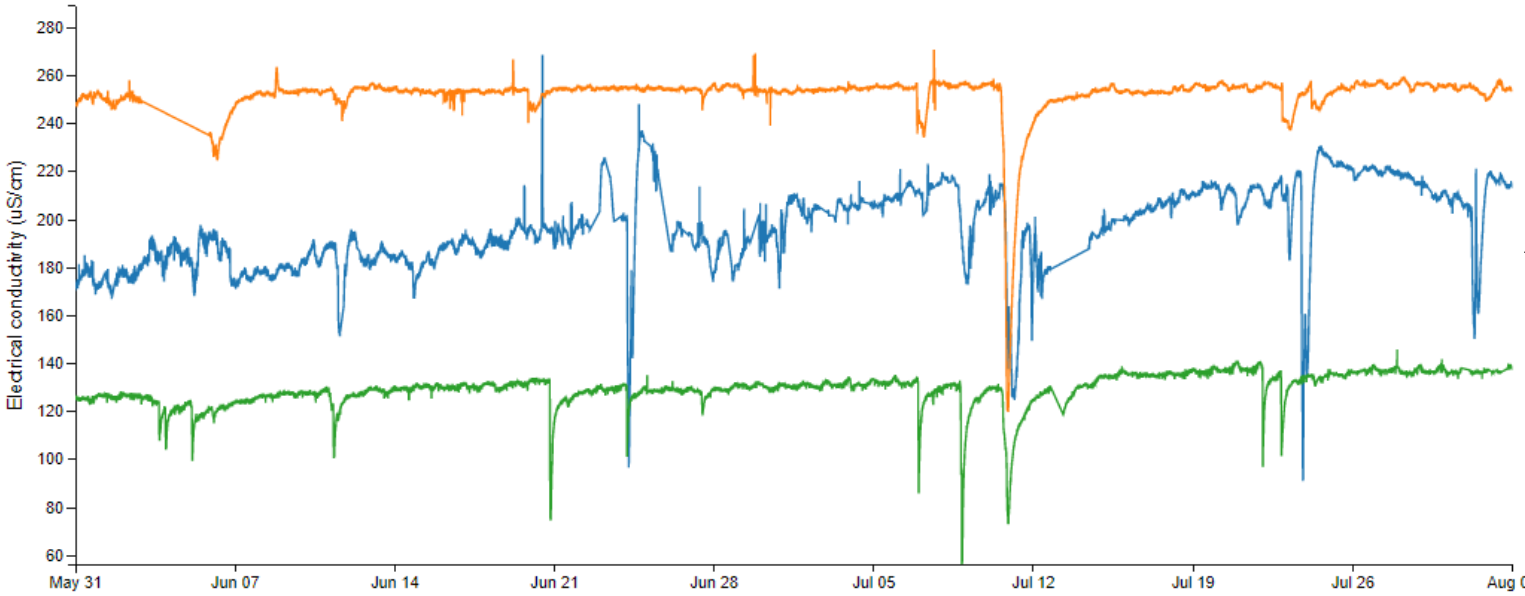
>800 µS/cm

Limestone stream
Valley Creek
Chester Co, PA

Dissolved Salts Vary Greatly – Regionally/Nationally

Variation in specific conductance among tributaries of the Delaware River

May 31 to Aug 2, 2020



Valley Cr
>800 µS/cm

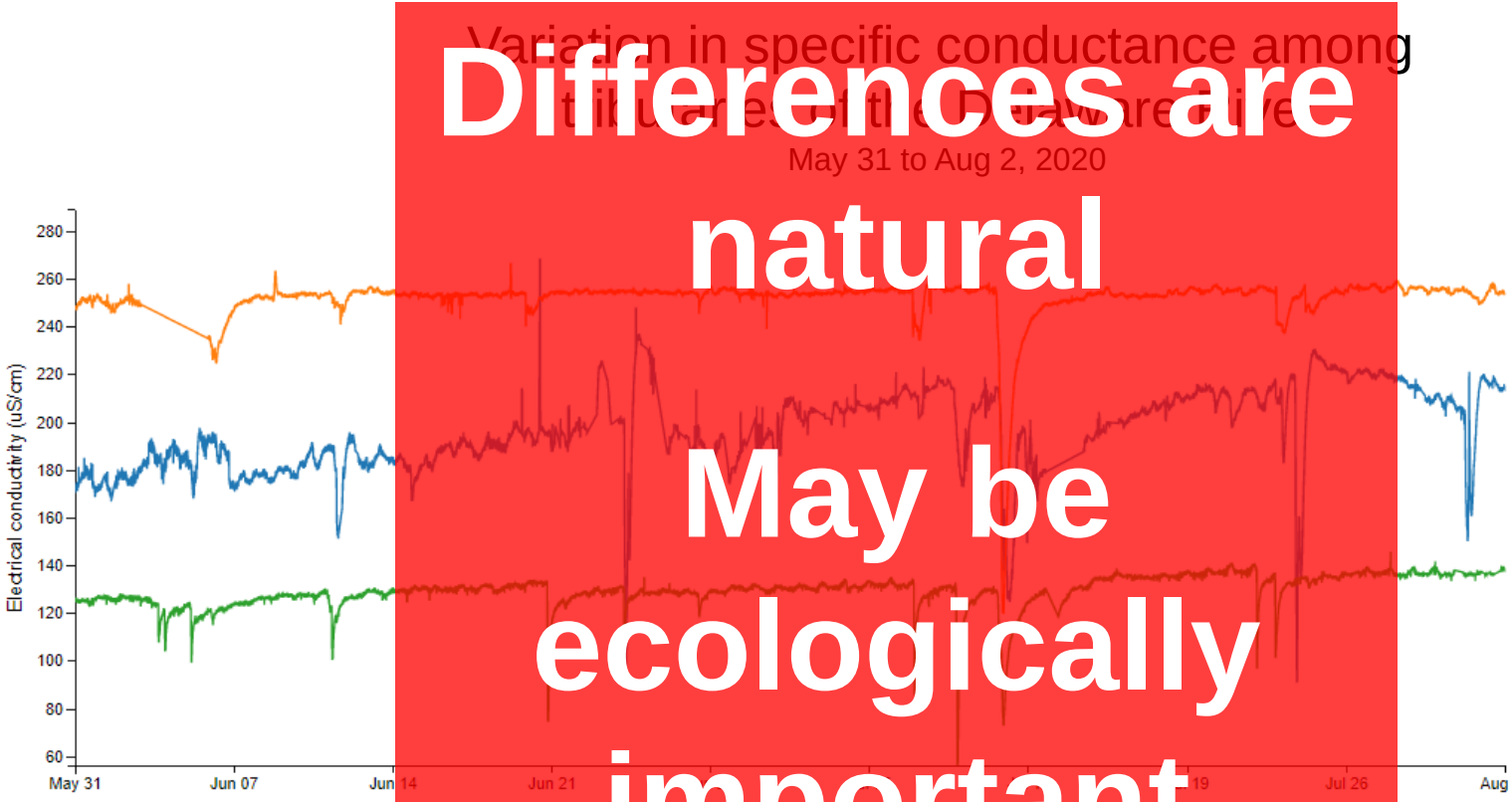
White Clay Cr
252 µS/cm

Aquashicola Cr
196 µS/cm

Punches Run
129 µS/cm

Buckwha Cr
93 µS/cm

Dissolved Salts Vary Greatly – Regionally/Nationally



Differences are natural

May be ecologically important

Valley Cr
>800 µS/cm

White Clay Cr
252 µS/cm

Aquashicola Cr
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Punches Run
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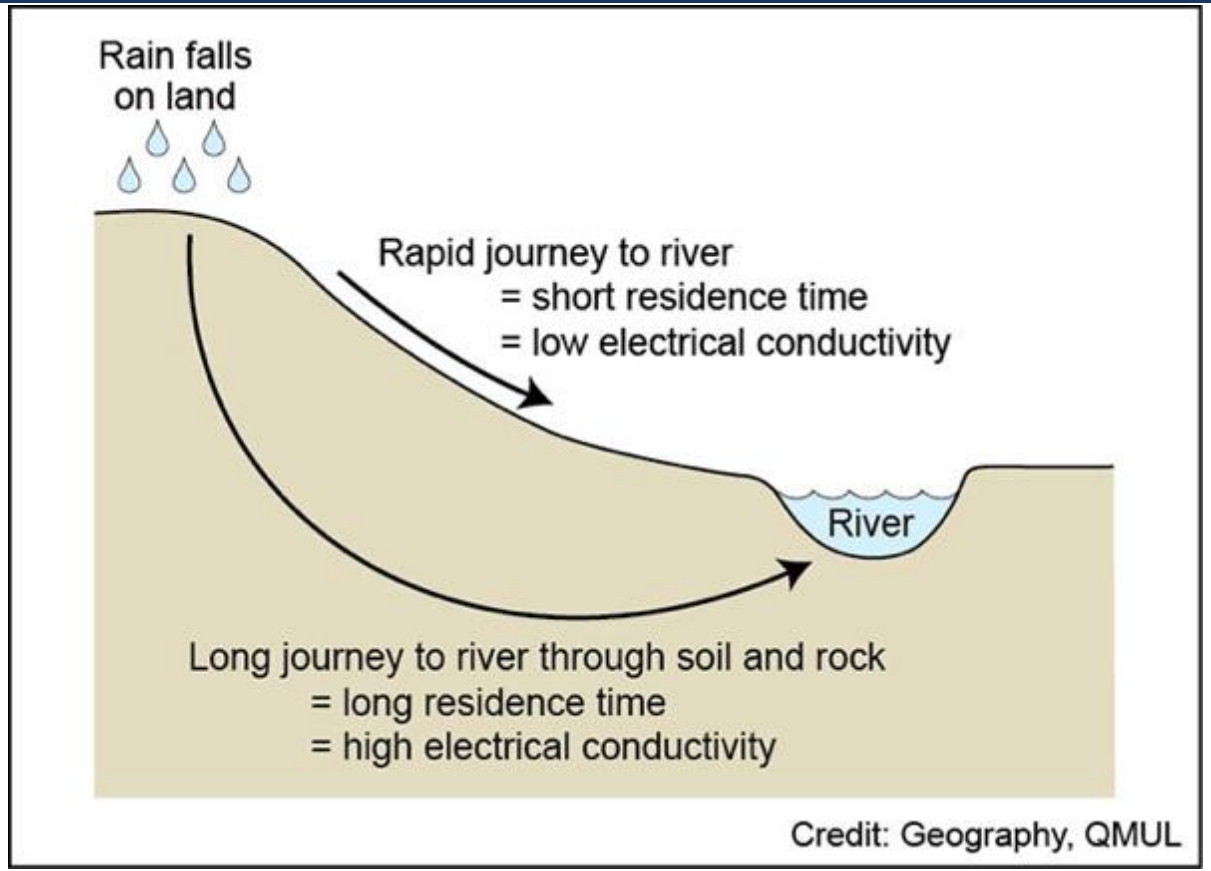
Dissolved Salts Vary Greatly – Temporal – rain vs baseflow



https://www.qmul.ac.uk/chesswatch/water-quality-sensors/electrical-conductivity/

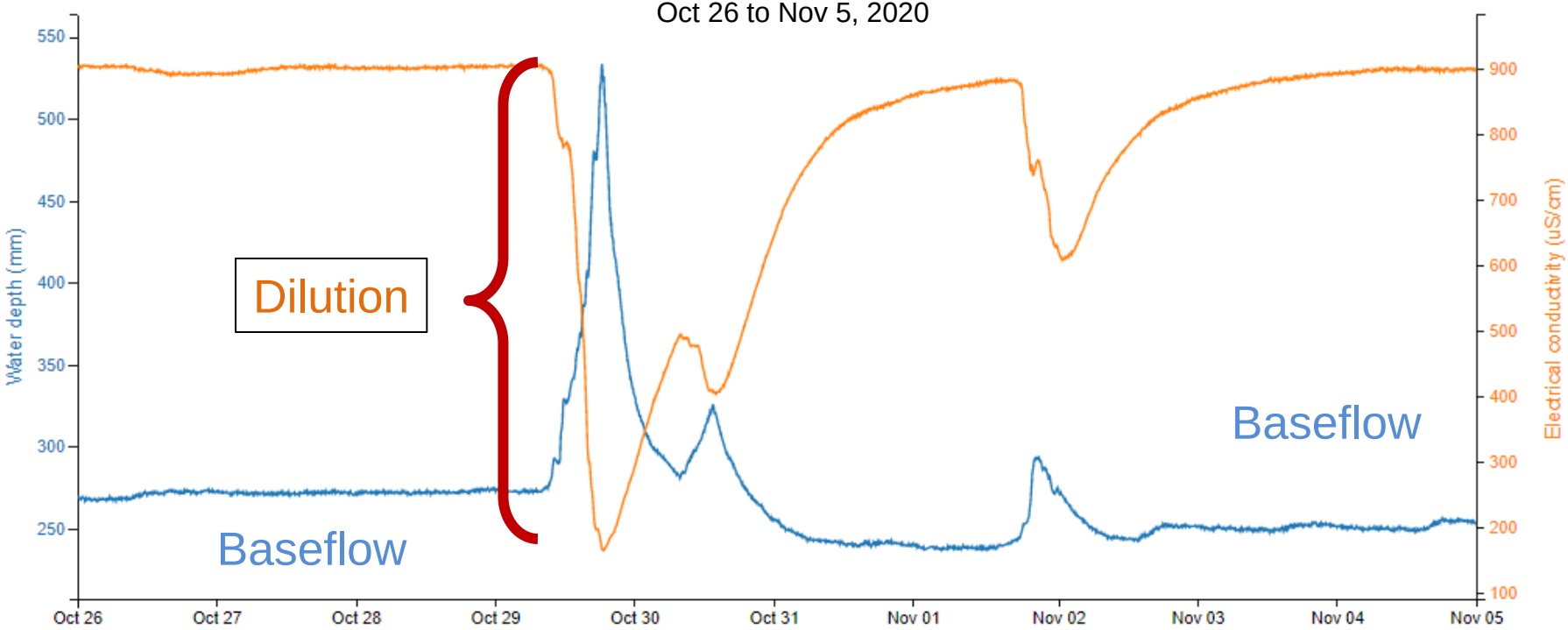
Dissolved Salts Vary Greatly – Temporal – rain vs baseflow

Dilution of dissolved salts because of rain events

Water depth (blue) and Specific Conductivity (orange)

Valley Creek at Ecology Park

Oct 26 to Nov 5, 2020



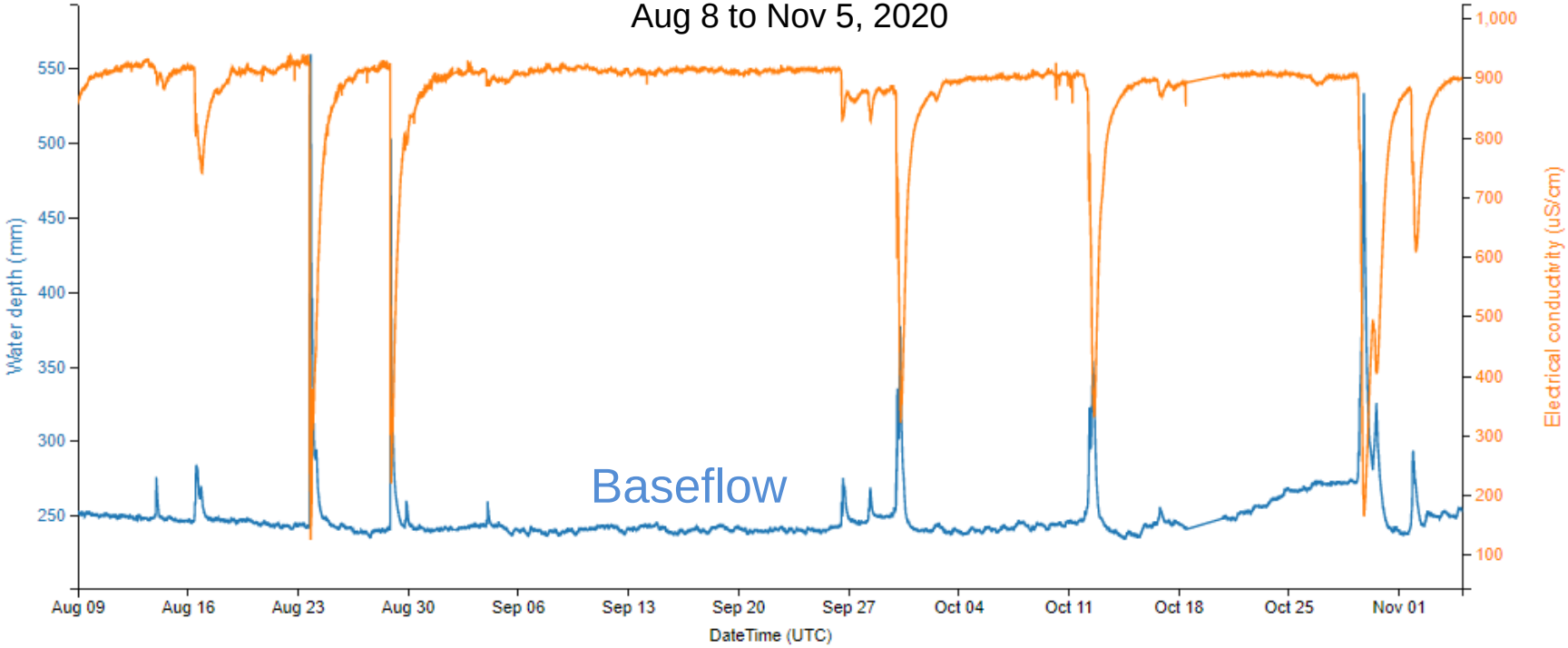
Dissolved Salts Vary Greatly – Temporal – rain vs baseflow

Dilution of salts because of rain events

Water depth (blue) and Specific Conductivity (orange)

Valley Creek at Ecology Park

Aug 8 to Nov 5, 2020



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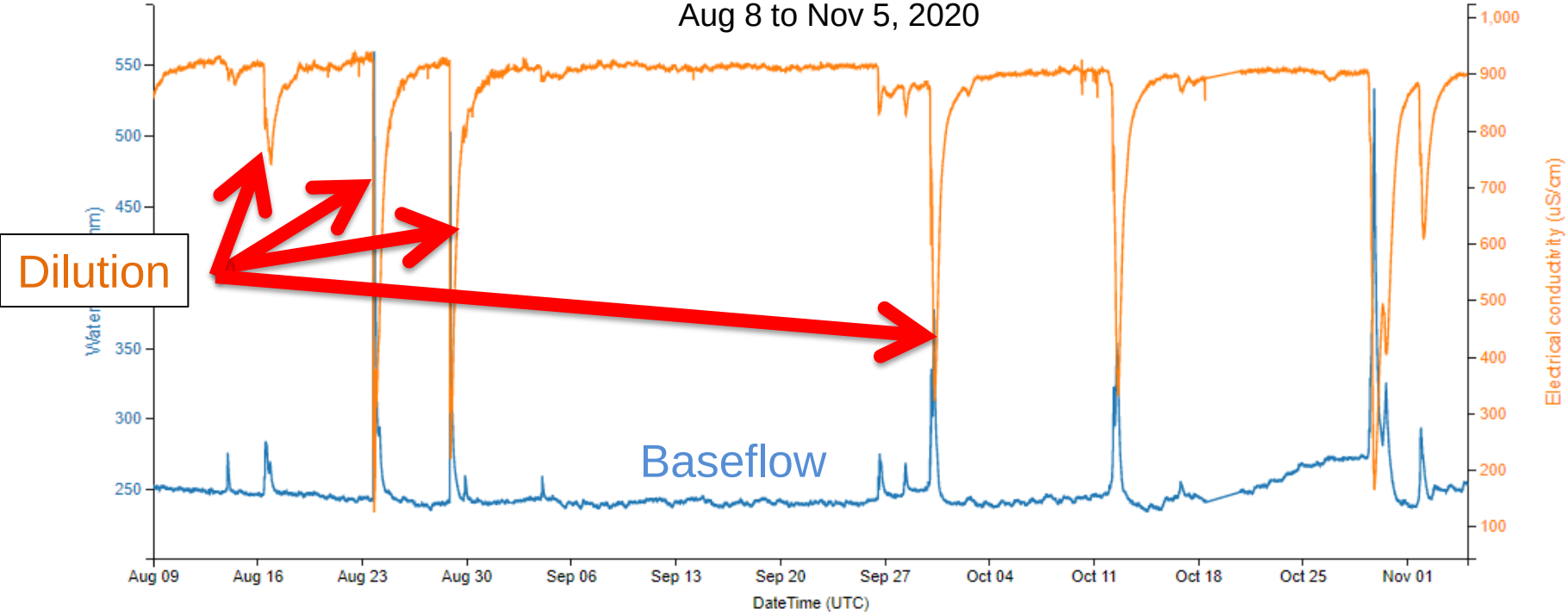

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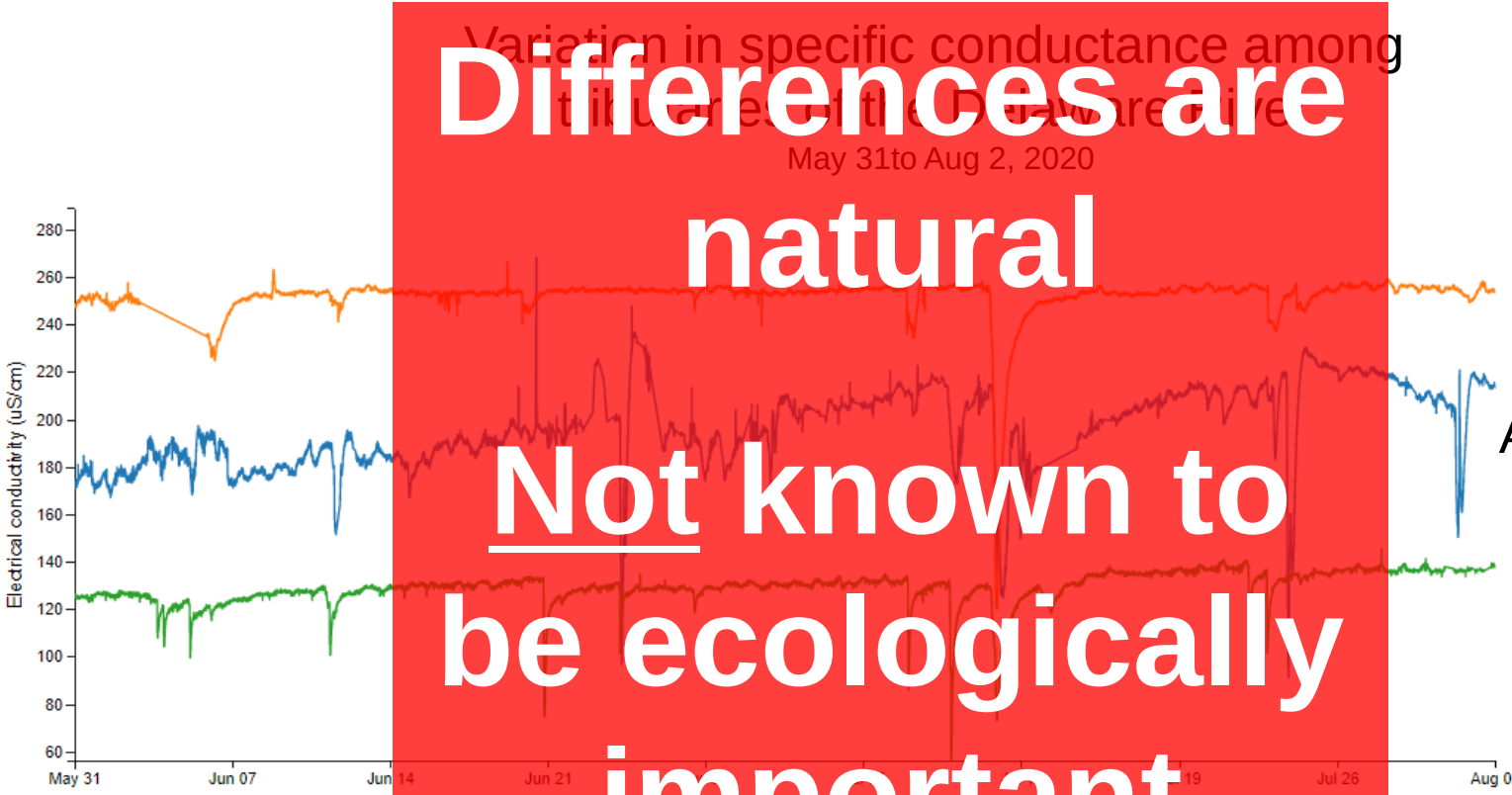

Differences are natural

Not known to be ecologically important

White Clay Cr
252 µS/cm

Aquashicola Cr
196 µS/cm

Punches Run
129 µS/cm

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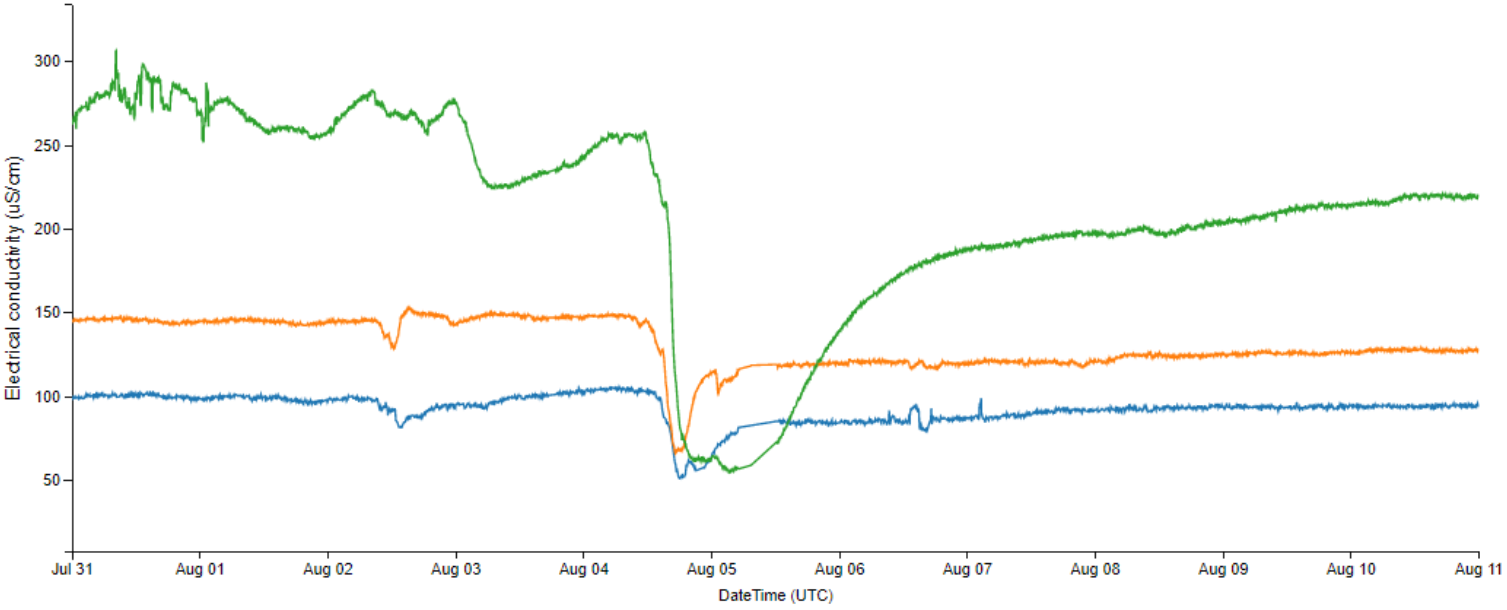
Dissolved Salts Vary Greatly – Temporal – rain vs baseflow

Temporal variation can be parallel among regional sites



Cherry Cr
214 µS/cm

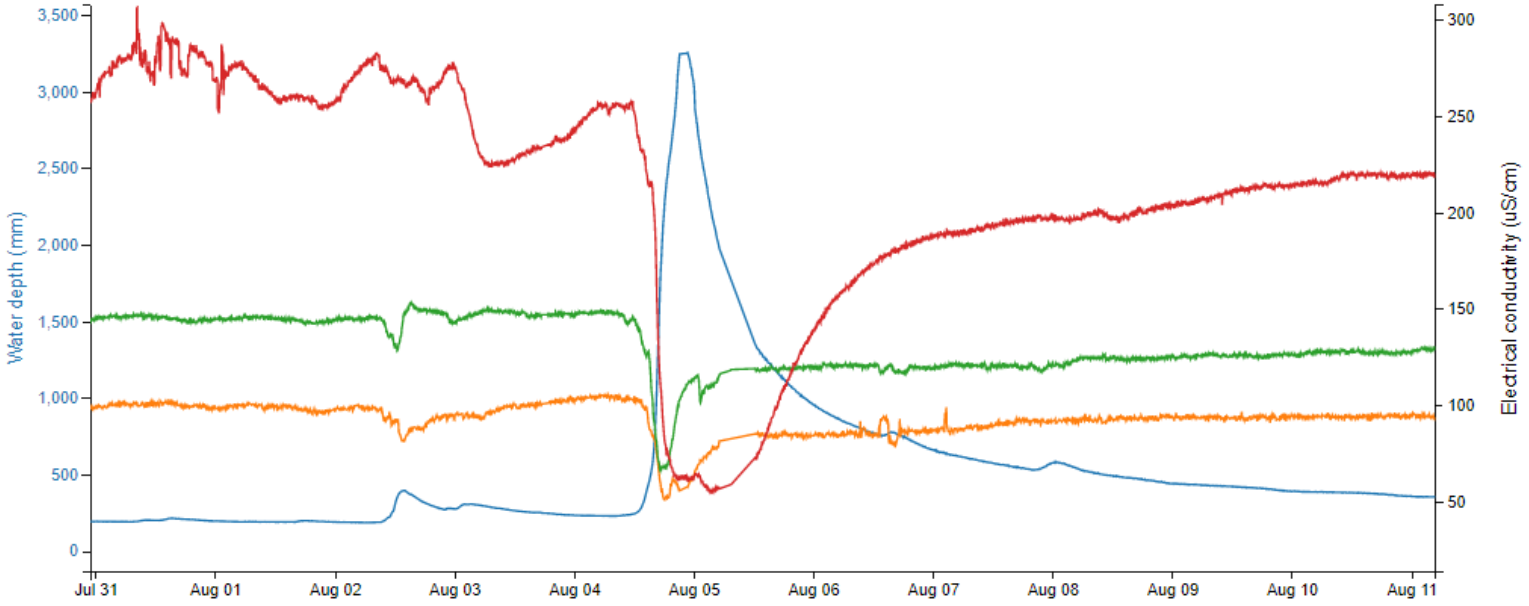
Hunter Cr
131 µS/cm

Buckwha Cr
93 µS/cm

Buckwha Cr
Water depth

Dissolved Salts Vary Greatly – Temporal – rain vs baseflow

Dilution of salts because of rain events
Larger storm events contribute to parallel patterns regionally



Cherry Cr
214 µS/cm

Hunter Cr
131 µS/cm

Buckwha Cr
93 µS/cm

Buckwha Cr
Water depth

Points to Remember

- Electrical Conductivity/Specific Conductance measures dissolved salt concentration
- SC does not tell you about specific salts
- SC naturally varies 100 – 200 µS/cm in response to precipitation, and 500 – 1000 µS/cm with a region
- Natural spatial variation may be more important than natural temporal variation


Questions?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