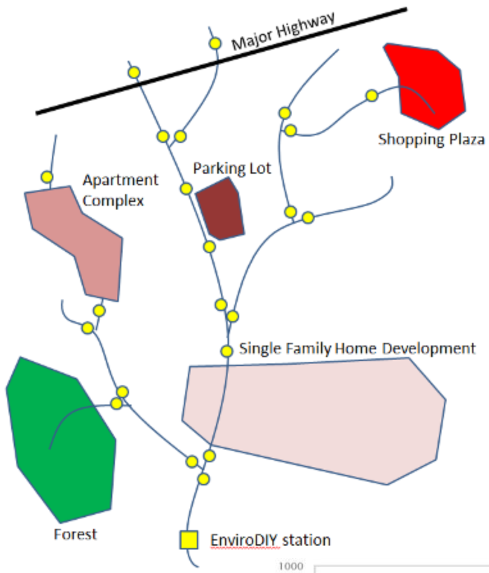
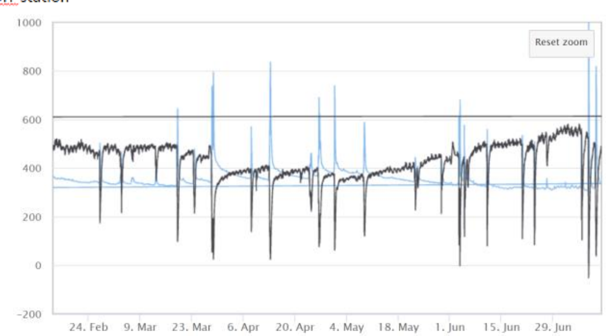
Monitoring salt pollution in streams

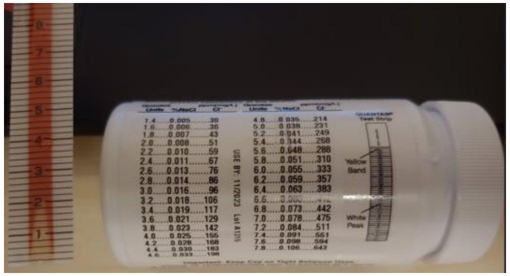
EnviroDIY and monitoring in the DRB monthly meeting

Online, Thursday, October 19, 2023, 2:30-3:30p

David Bressler, Stroud Water Research Center







EnviroDIY

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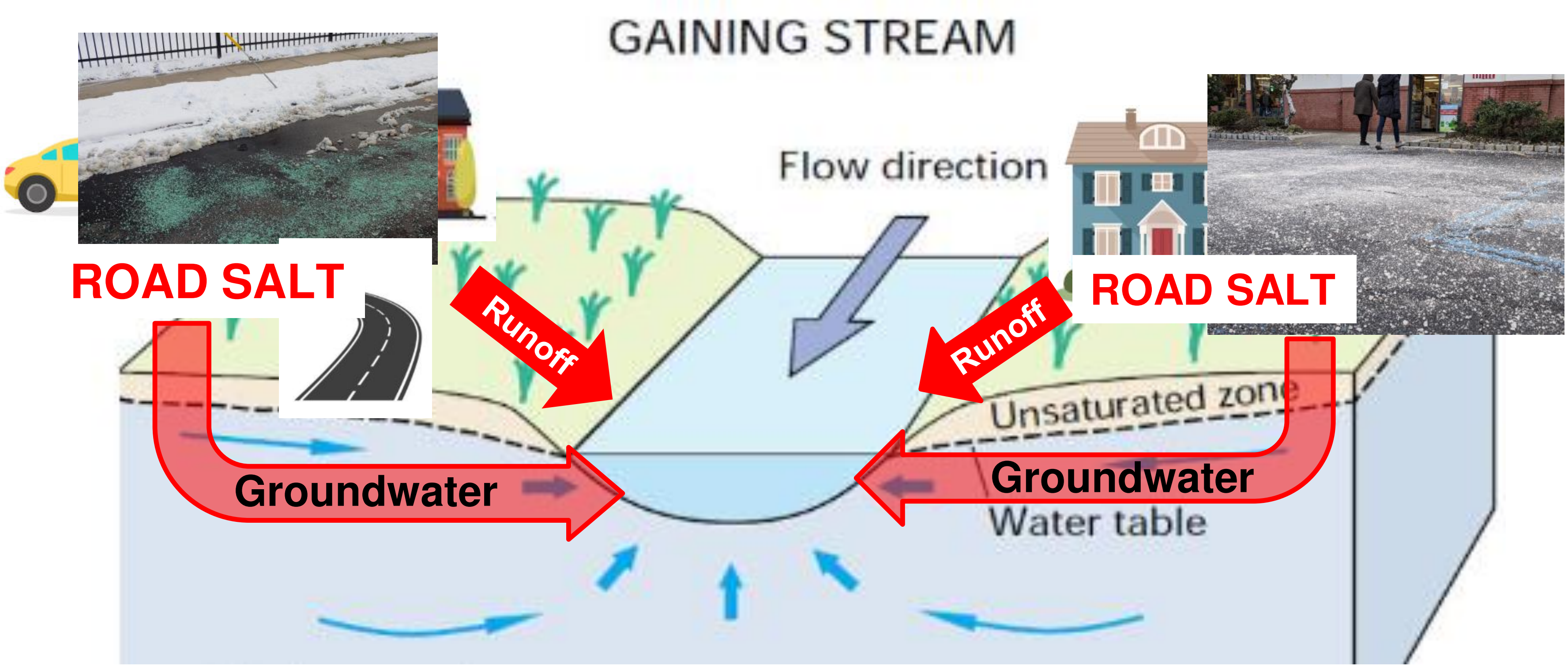
My Watershed®

Groundwater is the main source of water to streams in our region ("Gaining")

If ground water is contaminated then the stream will be contaminated



https://books.gw-project.org/groundwater-in-our-water-cycle/chapter/groundwater-connection-with-streams/

Monitoring salt in streams

Chloride (measured as mg/l, milligrams per liter)

NaCl (Sodium Chloride) – main road salt used

Conductivity (measured as uS/cm, microsiemens per centimeter)

Is a measure of how well water conducts electricity

NaCl is the main road salt used

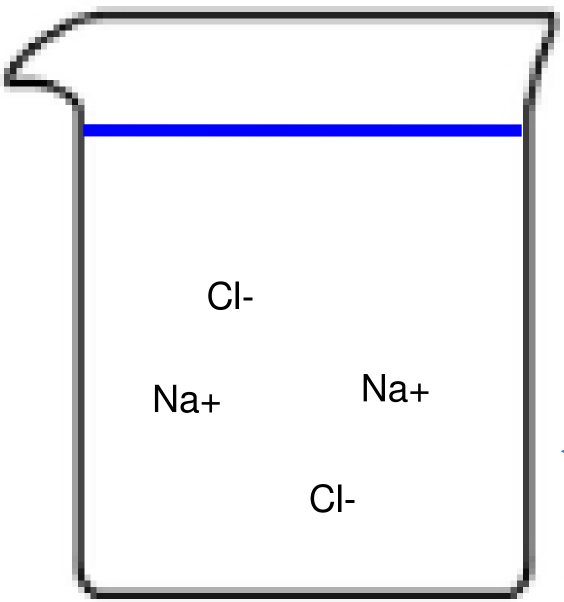
NaCl is rock salt (same as table salt)

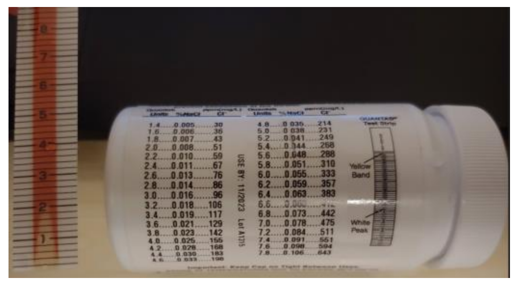
Magnesium Chloride and Calcium Chloride also used

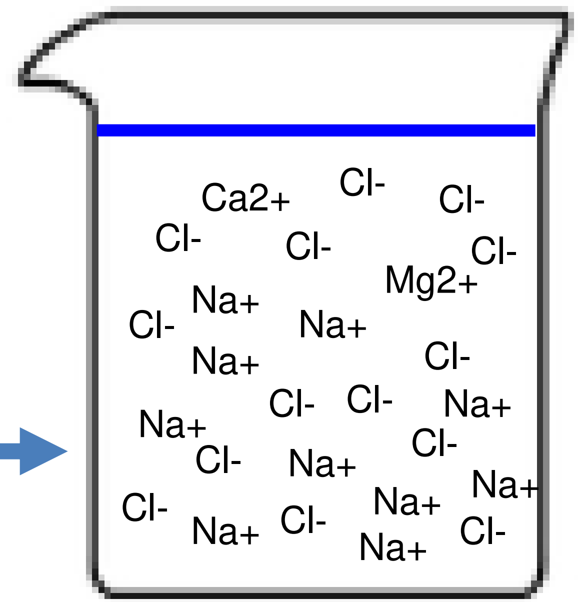
$MgCl_2$ and $CaCl_2$ often look like white pellets

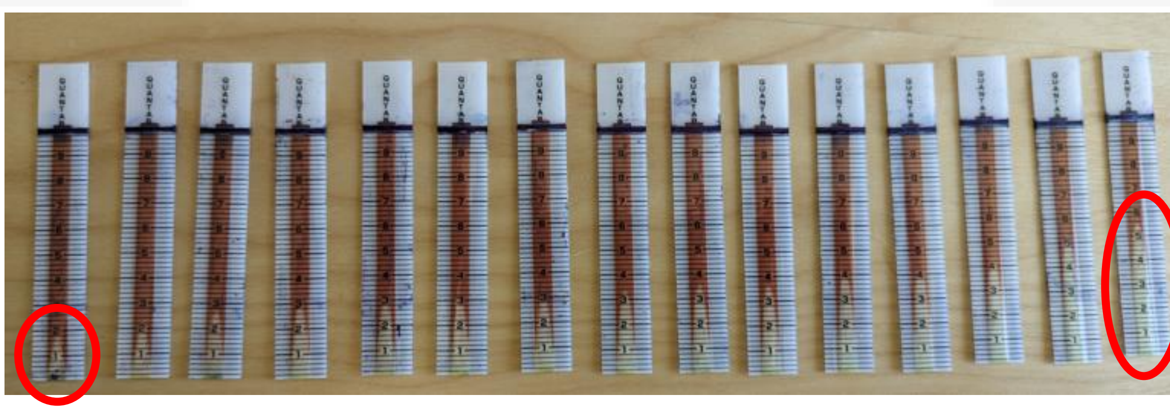
Sodium (Na^+, Mg^+, Ca^+) and Chloride (Cl) ions

- Salt dissolves into cations (+ charge) and anions (- charge) in water
- **Chloride (Cl^-) is easier to measure to measure than Na^+, Mg^{2+}, or Ca^{2+}**





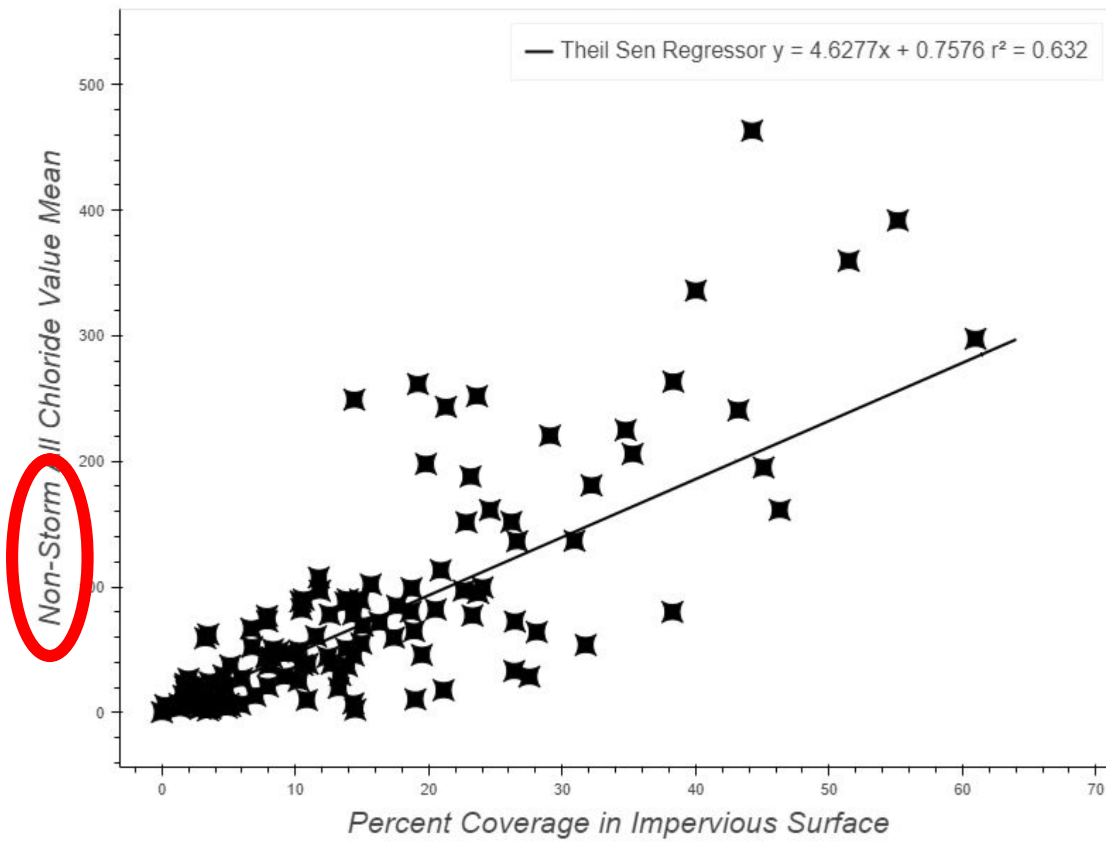




Chloride higher where there are roads and parking lots

Note – this is NOT during winter road salt runoff

Represents baseflow year-round groundwater and stream contamination



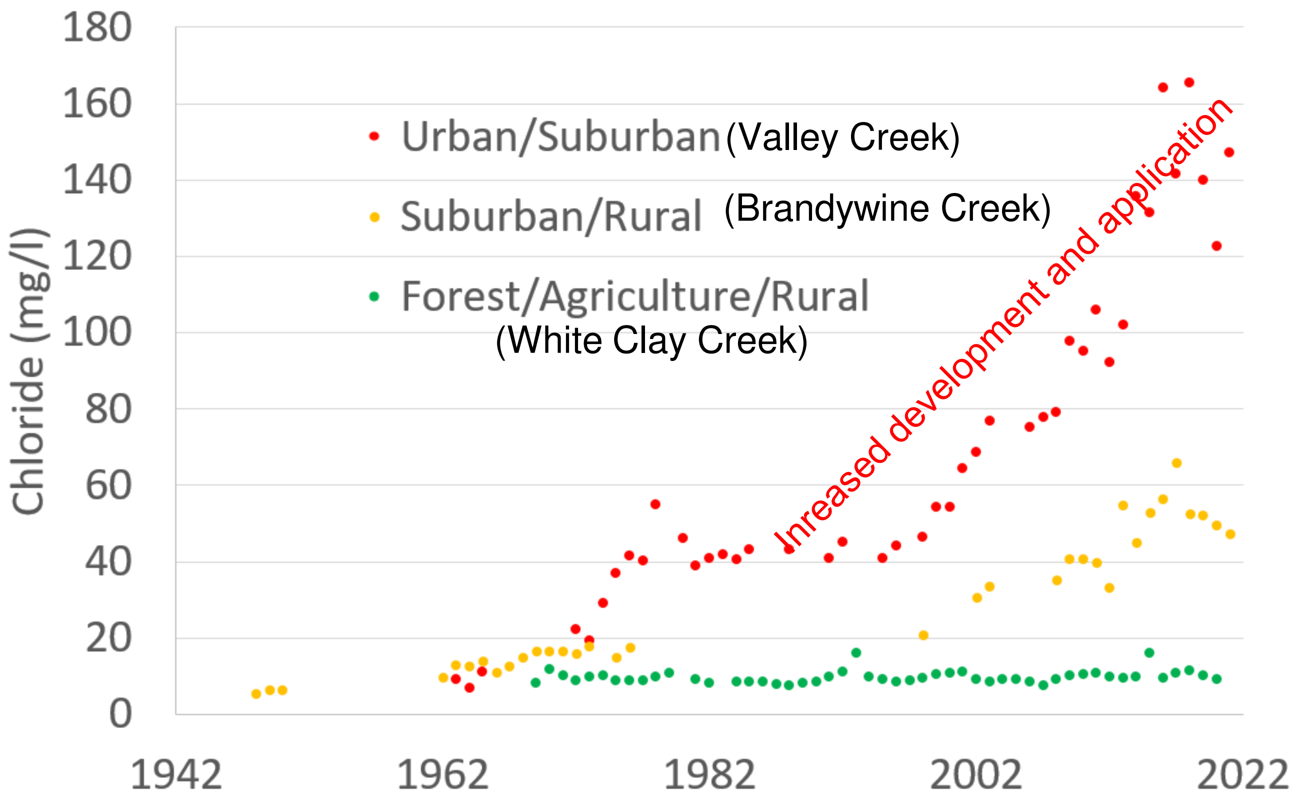
Chloride converted from continuous conductivity data

EnviroDIY data

Chloride higher where there are roads and parking lots and increasing

Note – this is NOT during winter road salt runoff

Represents baseflow non-winter (year-round) groundwater and stream contamination



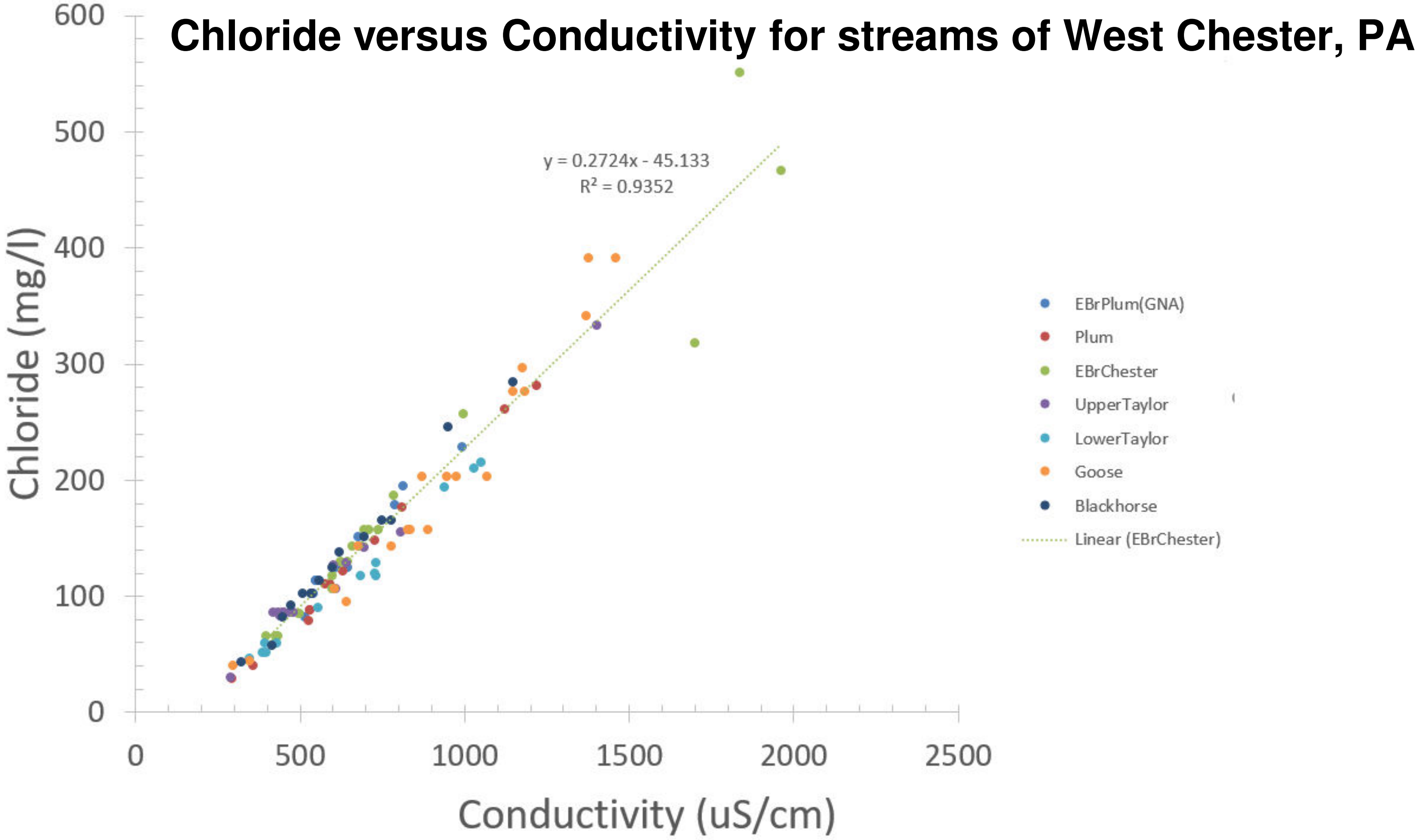
USGS Data

Chronic and acute thresholds for Cl^- toxicity to animals

Organization	Long term (chronic) chloride toxicity criterion (mg/l)	Short term (acute) chloride toxicity criterion (mg/l)
U.S. Environmental Protection Agency (and many states)(1988)	230	860
Canadian Council of Ministers of the Environment (2011)	120	640
Ohio EPA, Macroinvertebrate Hazard Concentration (2021)	52	--
Maryland Biological Stressor Identification Process, Chloride Threshold Value (2009)	50	--
Natural range in southeastern PA	**5-20 mg/l**	

NaCl causes increased conductivity

- Appears to be main contributor to elevated conductivity in southeastern PA

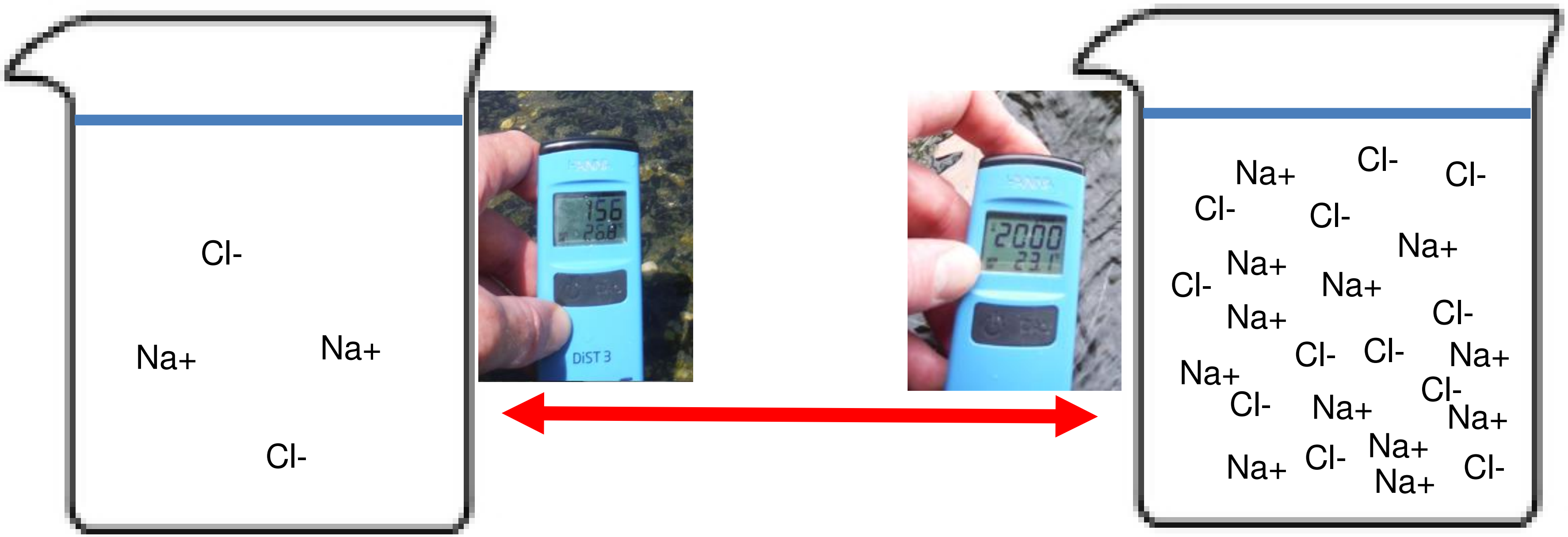


Conductivity– easy to measure, informative

- **Conductivity (measured as uS/cm, microsiemens per centimeter)**
  - Is a measure of how well water conducts electricity
    - More cations (e.g., Na^+) and anions (e.g., Cl^-) = higher the conductivity
  - Is a good general indicator of stream health
    - Higher conductivity = lower stream health
  - Higher in urban/developed areas, but there is natural variability

More cations (+) and anions (–) = higher conductivity

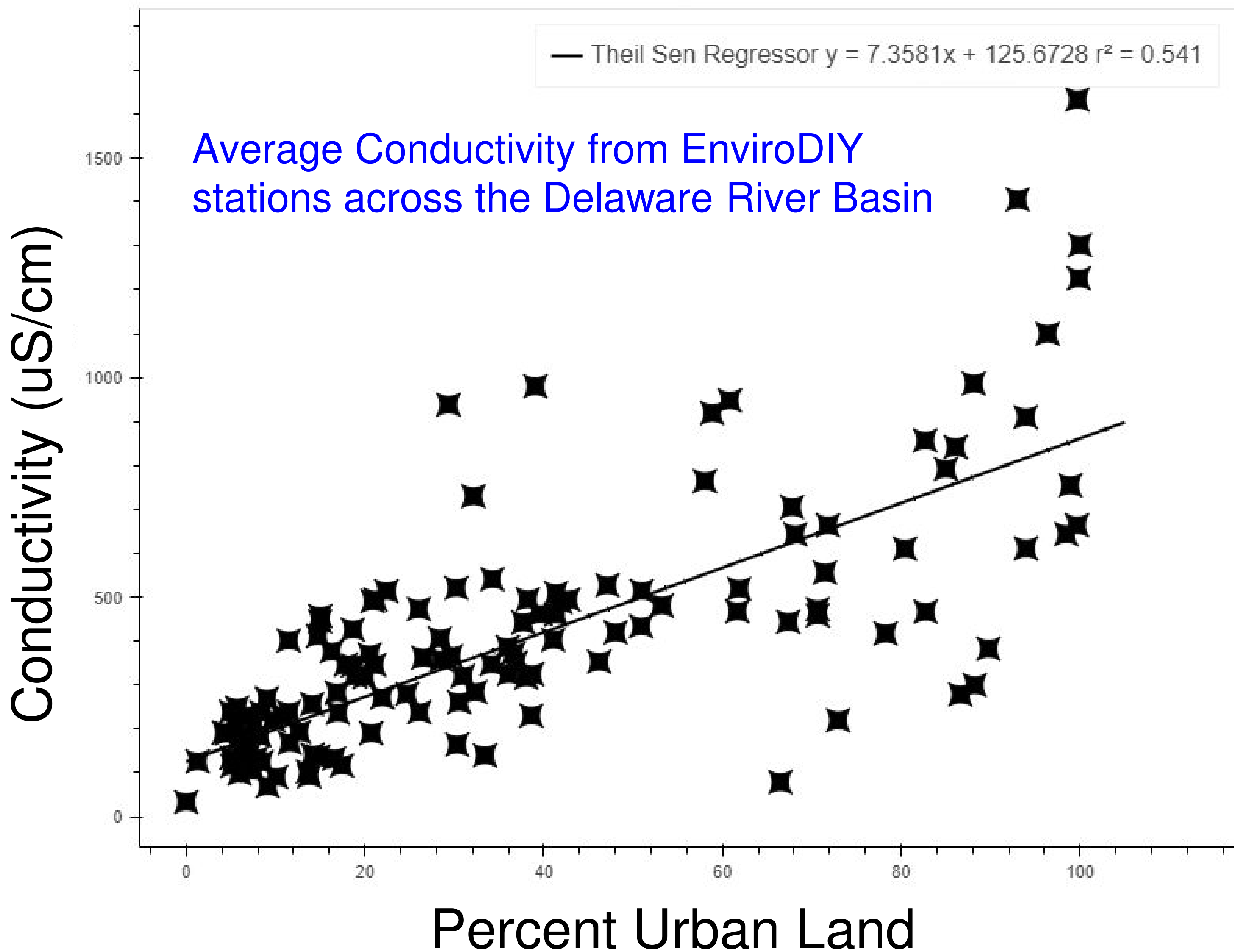
Lower Conductivity **Higher Conductivity**



e.g., <100

e.g., >300 uS/cm (baseflow), 2,000 uS/cm – 100,000 uS/cm (storm flush)

Conductivity is higher in urban areas

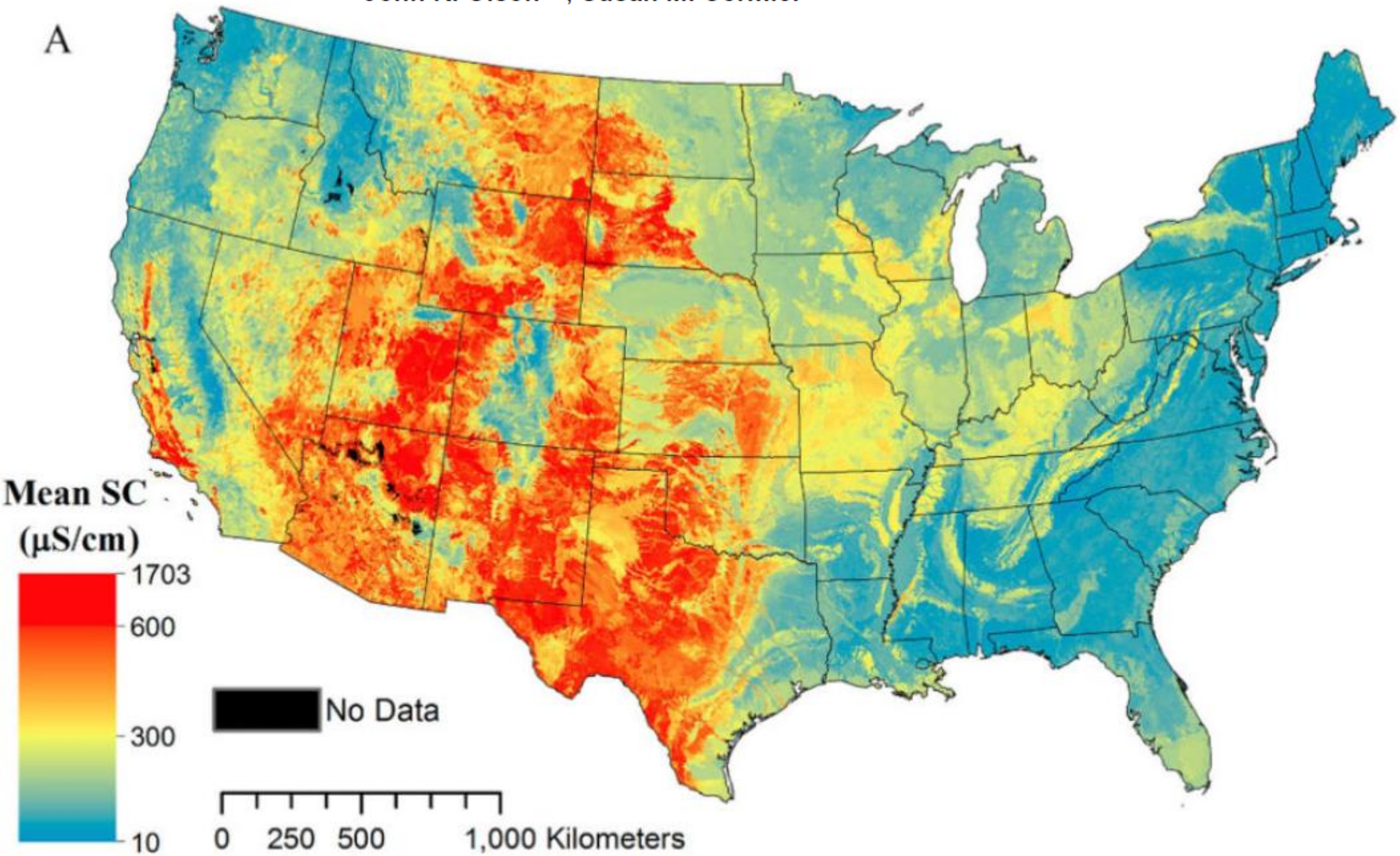


But there is natural variability

Environ Sci Technol. 2019 April 16; 53(8): 4316–4325. doi:10.1021/acs.est.8b06777.

Modeling spatial and temporal variation in natural background specific conductivity

John R. Olson†,*, Susan M. Cormier‡



But there is natural variability

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Modeling spatial and temporal variation in natural background specific conductivity

John R. Olson[†,*], Susan M. Cormier[‡]

model is empirical, it is coherent with factors expected to mechanistically influence the availability and mobility of ion delivery to stream networks.[55–56] Therefore, on this large scale, this empirical model output along with real world data may help to improve mechanistic understanding of geophysical processes influencing stream SC.

Although the predictions of natural background SC made by this model have many uses, several limitations should be considered. First, because the model relies on the NHD+ and StreamCat data sets, streams without this data (i.e., some headwater systems and buried urban streams) will not have predictions. Second, predictions in places where SC is driven by factors not included in the model will be inaccurate. Examples include coastal areas influenced by tidal salinity and salt water intrusion or geothermally active areas. Predictions in areas with few minimally disturbed streams, especially the Temperate Plains represented by only eight streams segments, will be less accurate than the model as a whole. Because the model relies on current vegetation as a predictor (Figure 1), predictions for streams where humans have shifted vegetation between forests and either grasses or shrubs over significant portions of a watershed may not be truly representative of natural background conditions.

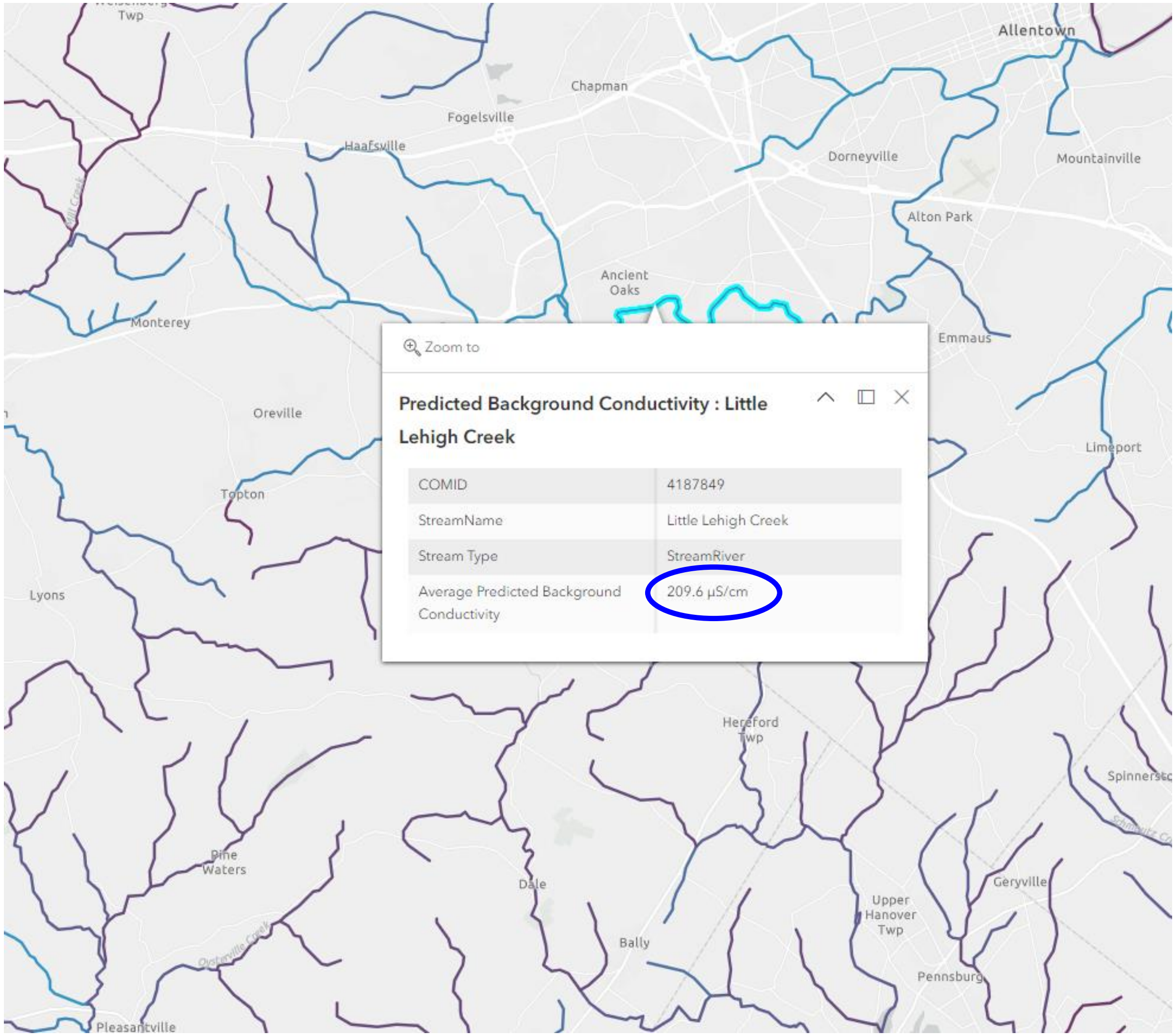
Despite these limitations, the model output is useful for depicting the patterns of natural background SC (Figures 3 and 4). The model is also useful for identifying potential sources of pristine fresh waters and informing the investigations regarding the vulnerability of pristine freshwaters to rainfall variability. For example, the comparison of wet and dry years in California (Figure 5) showed areas with naturally lower SC were more variable than areas with higher SC, suggesting dilution by precipitation was a key factor in seasonal changes in SC. Although we did not attempt to make predictions for scenarios during an ongoing drought or estimate the amount of rainfall required to achieve drought relief thereby lowering stream SC, the model parameters for precipitation could be varied to estimate the dilution needed to reduce SC to a desired level.

To enable the widest possible accessibility of the underlying data, model, and model outputs are all made available on the U.S. Environmental Protection Agency (EPA) Environmental Dataset Gateway (https://edg.epa.gov/metadata/catalog/main/home.page). The predicted background conductivity for individual stream segments in the contiguous U.S.A. and metadata are accessible from the ArcGIS platform Predicted Background Conductivity Data (Olson and Wharton 2019). Data are available in table format (Data Tab at top of page) or by pointing and clicking on a stream segment from the Visualization Tab. Access the Predicted Background Conductivity Data from https://epa.maps.arcgis.com/home/item.html?id=540abb1d015b4bd2b87d30f4c28a58cb&view=table#overview. For access to the Freshwater Explorer contact cormier.susan@epa.gov for password access.

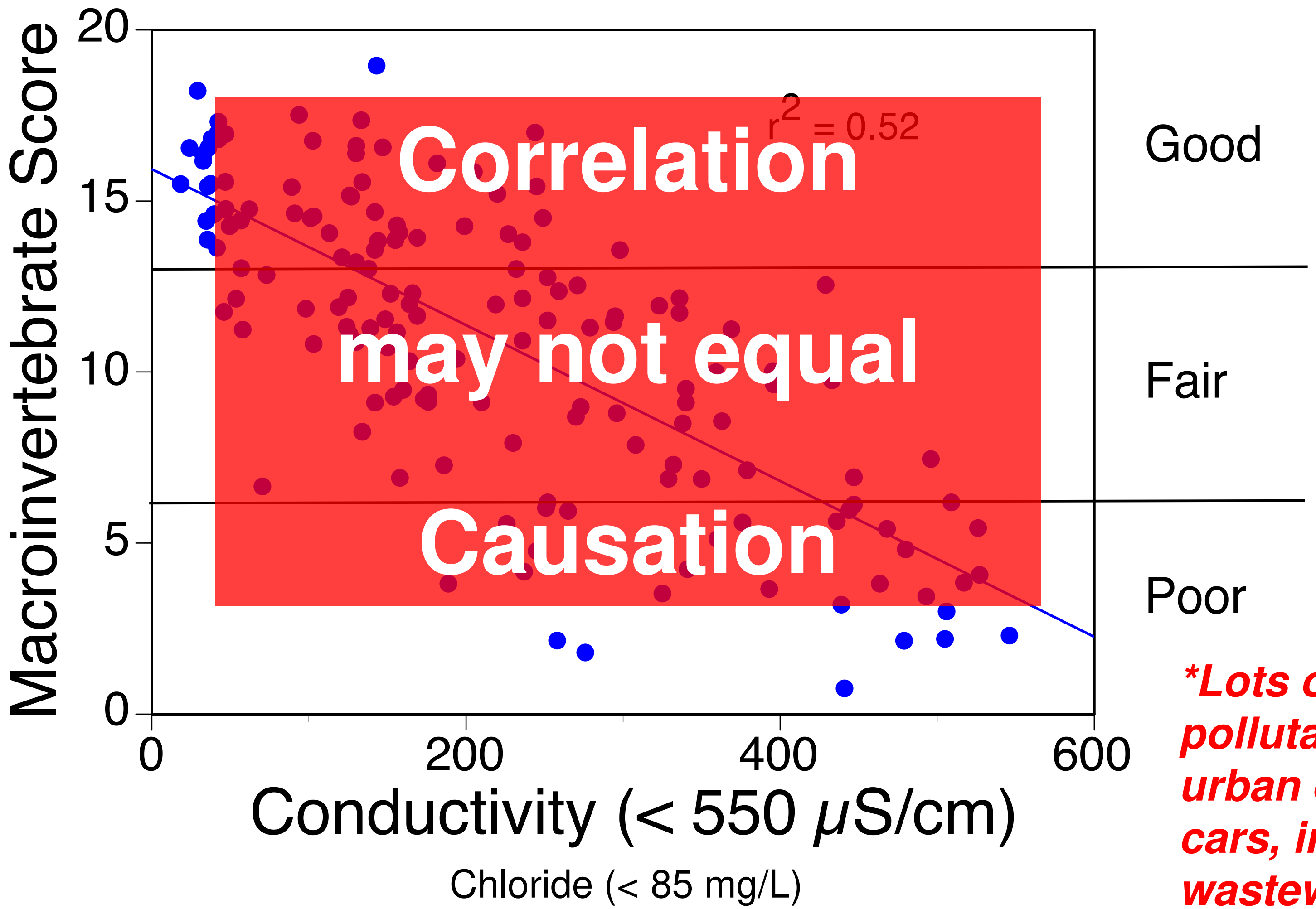
Clickable map with Natural Background Conductivity for U.S. streams

Compare existing conductivity to natural background

https://epa.maps.arcgis.com/apps/mapviewer/index.html?layers=540abb1d015b4bd2b87d30f4c28a58cb



Conductivity is a good general indicator of stream health

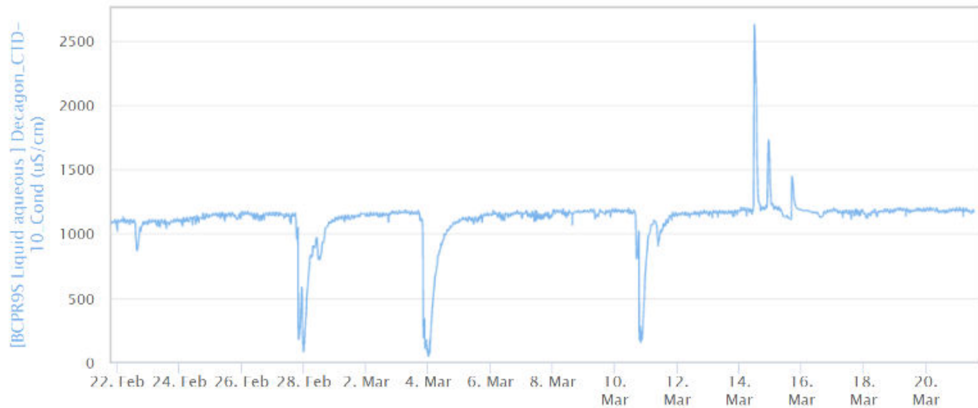


***Lots of other pollutants from the urban environment – cars, industry, wastewater, pesticides, trash, etc.**

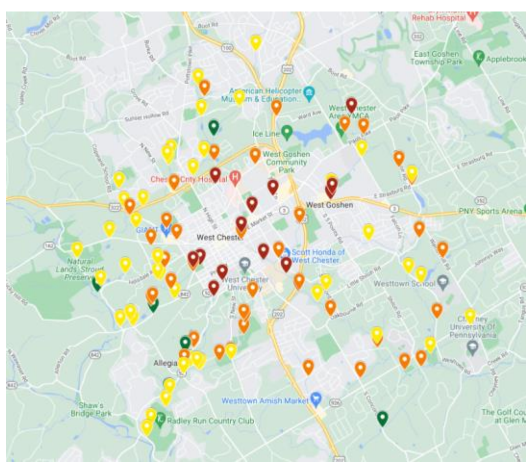
157 sites, primarily in the Schuylkill River Basin

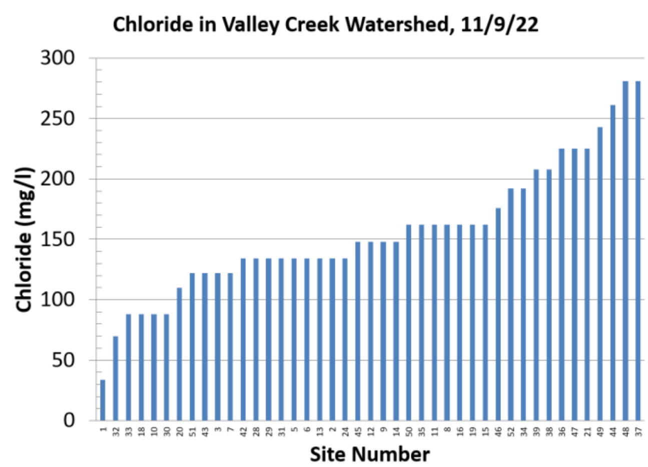
Some ways to monitor salt pollution

- **Continuous data**



- **Point-in-time (by hand) – e.g., synoptic, longitudinal, targeted**

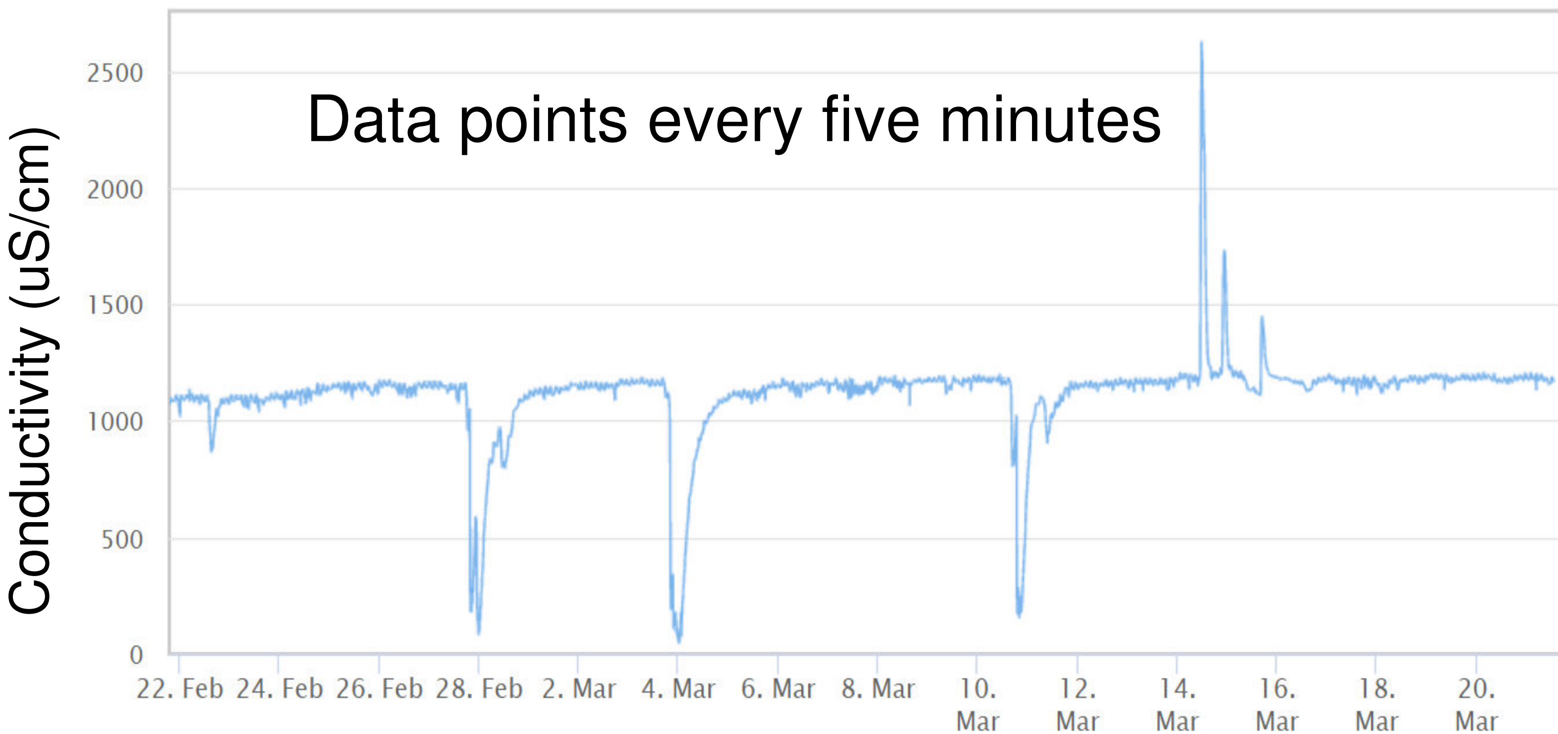




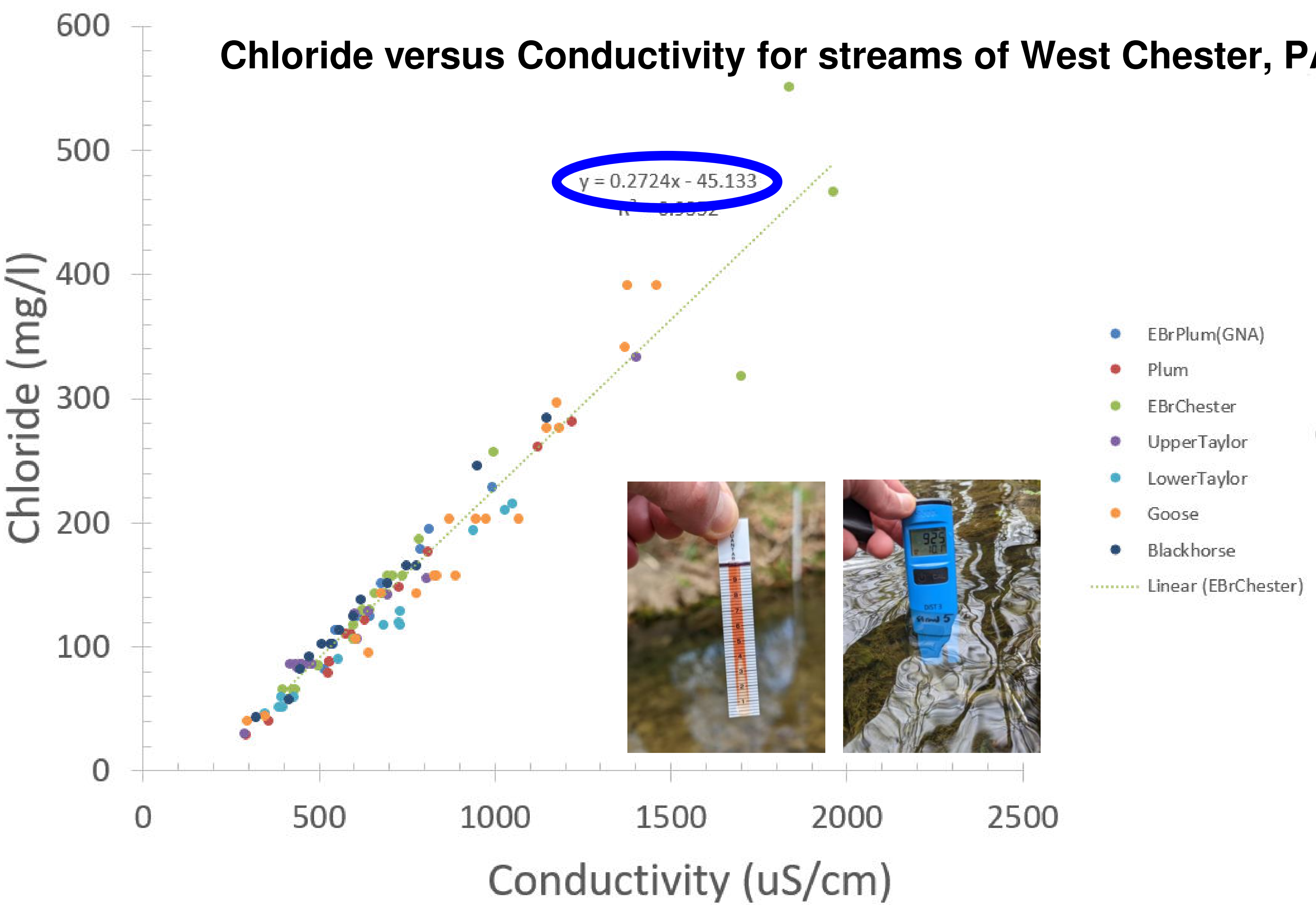
Continuous monitoring data

EnviroDIY

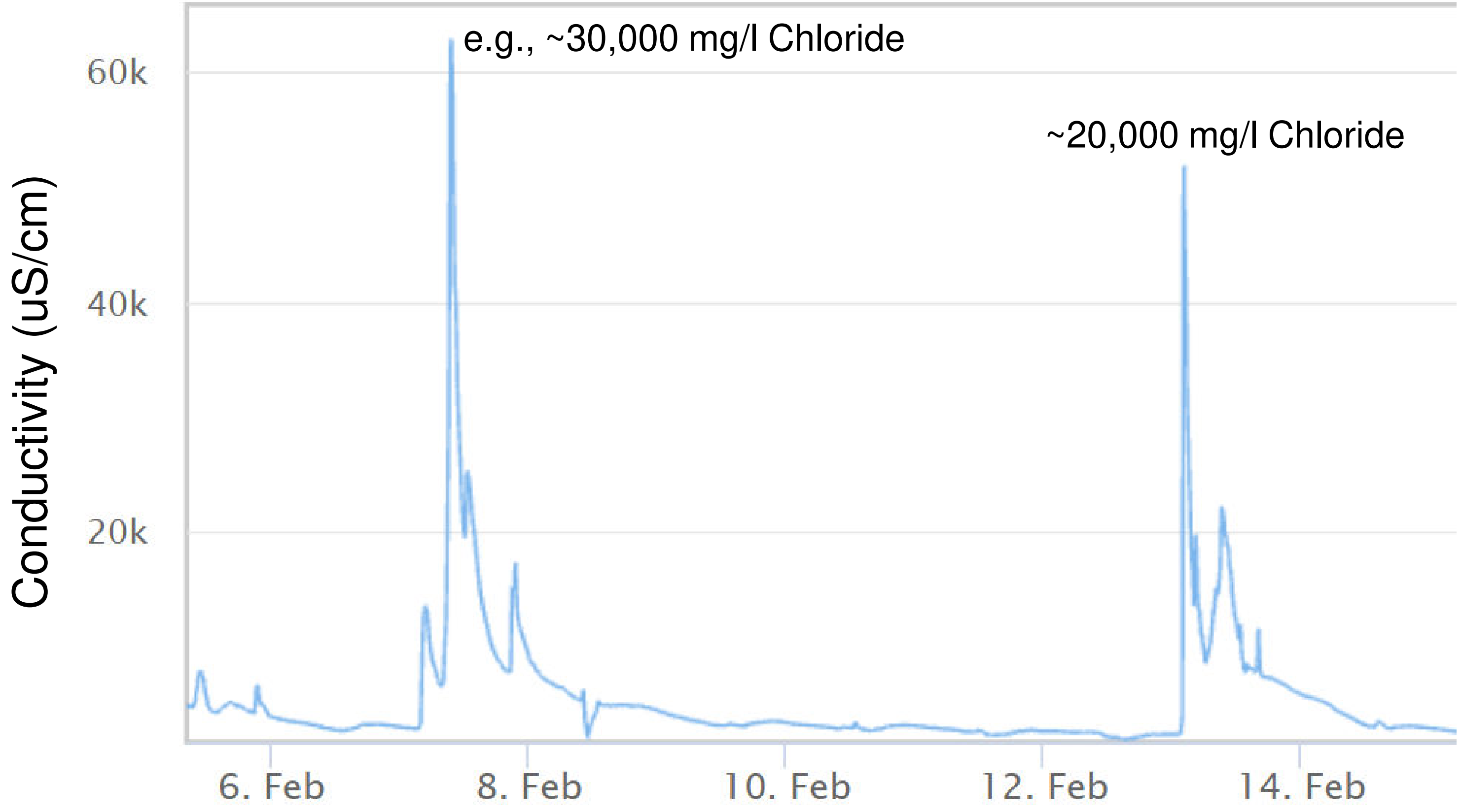
Monitor My Watershed®



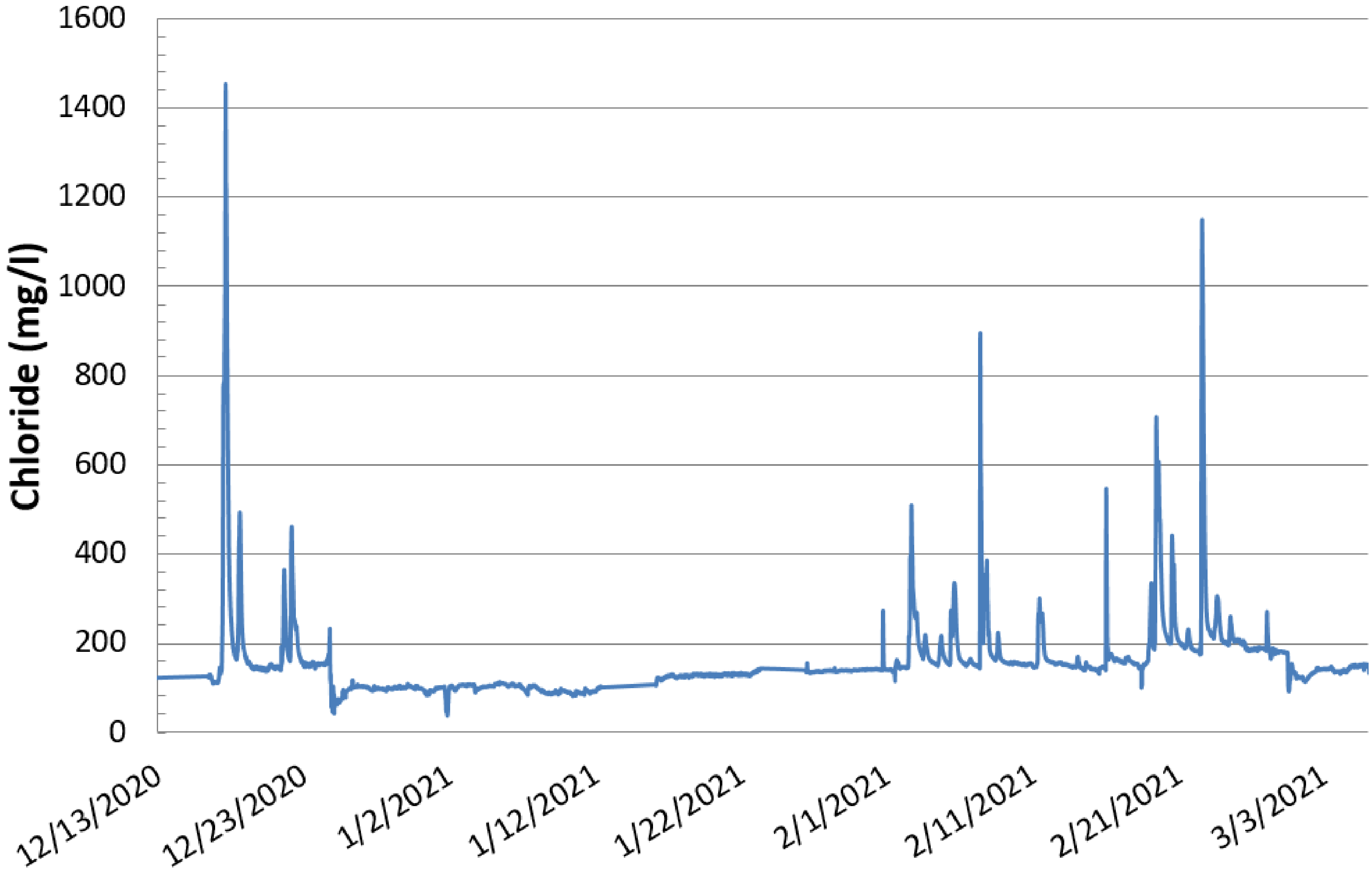
Conductivity can be converted to chloride



Then infer what chloride is



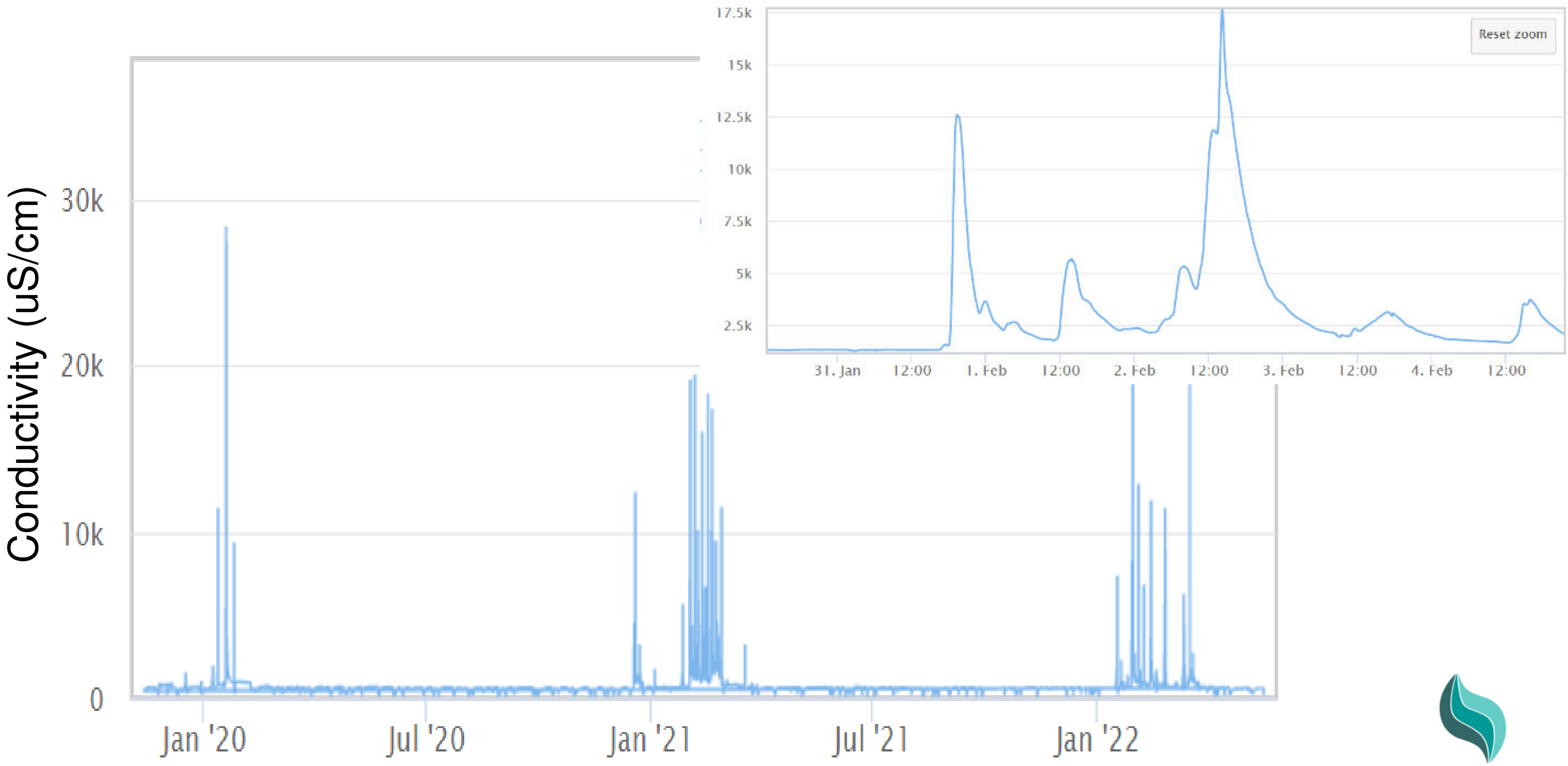
Or convert continuous conductivity data to Chloride



Jenkintown Ck at Osceola Rd

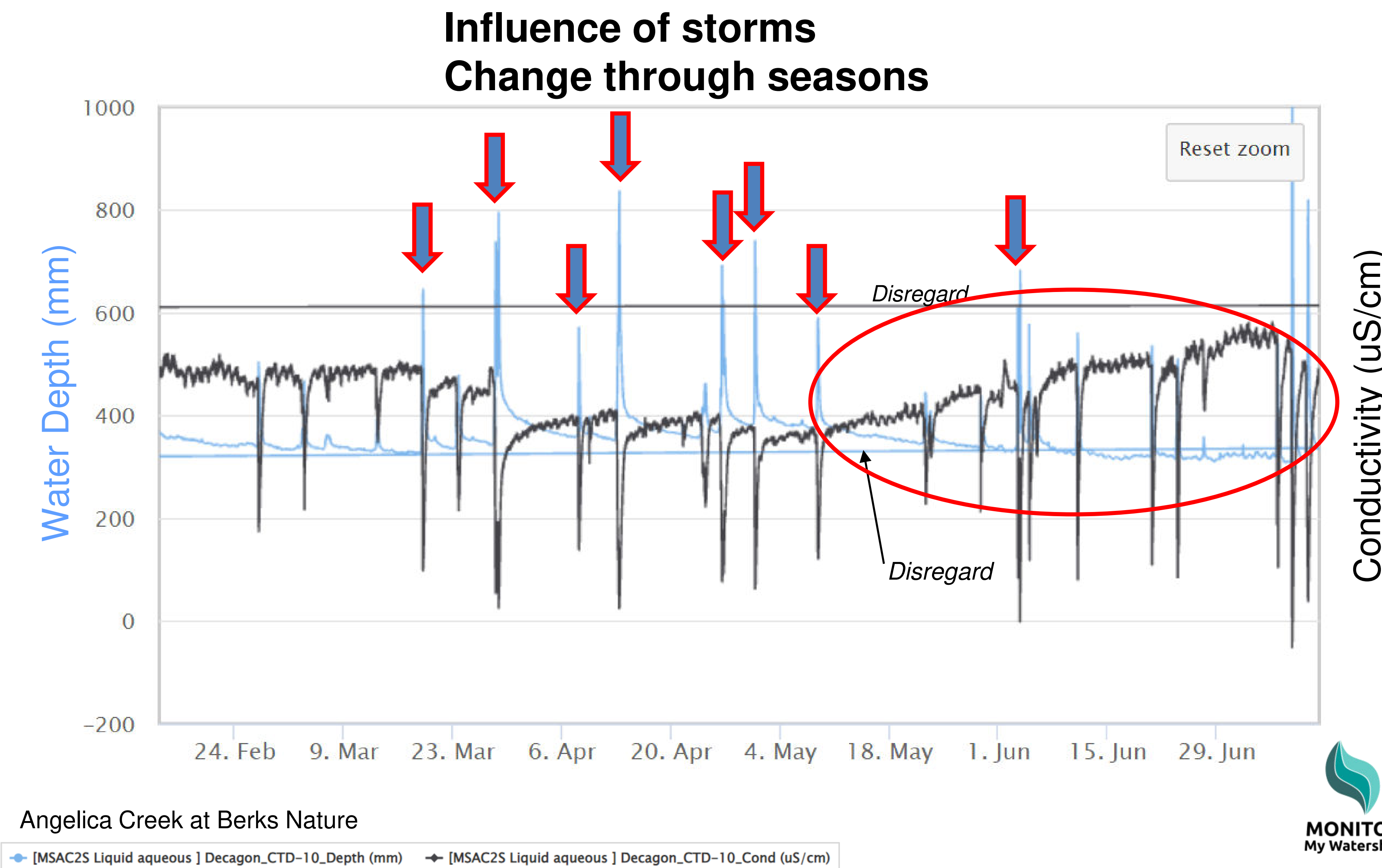
Continuous monitoring data

- Continuous data inform on severity and variability of pollution throughout the year, month, day, hour



MONITOR My Watershed®

Continuous data to understand changes through the year



Angelica Creek at Berks Nature

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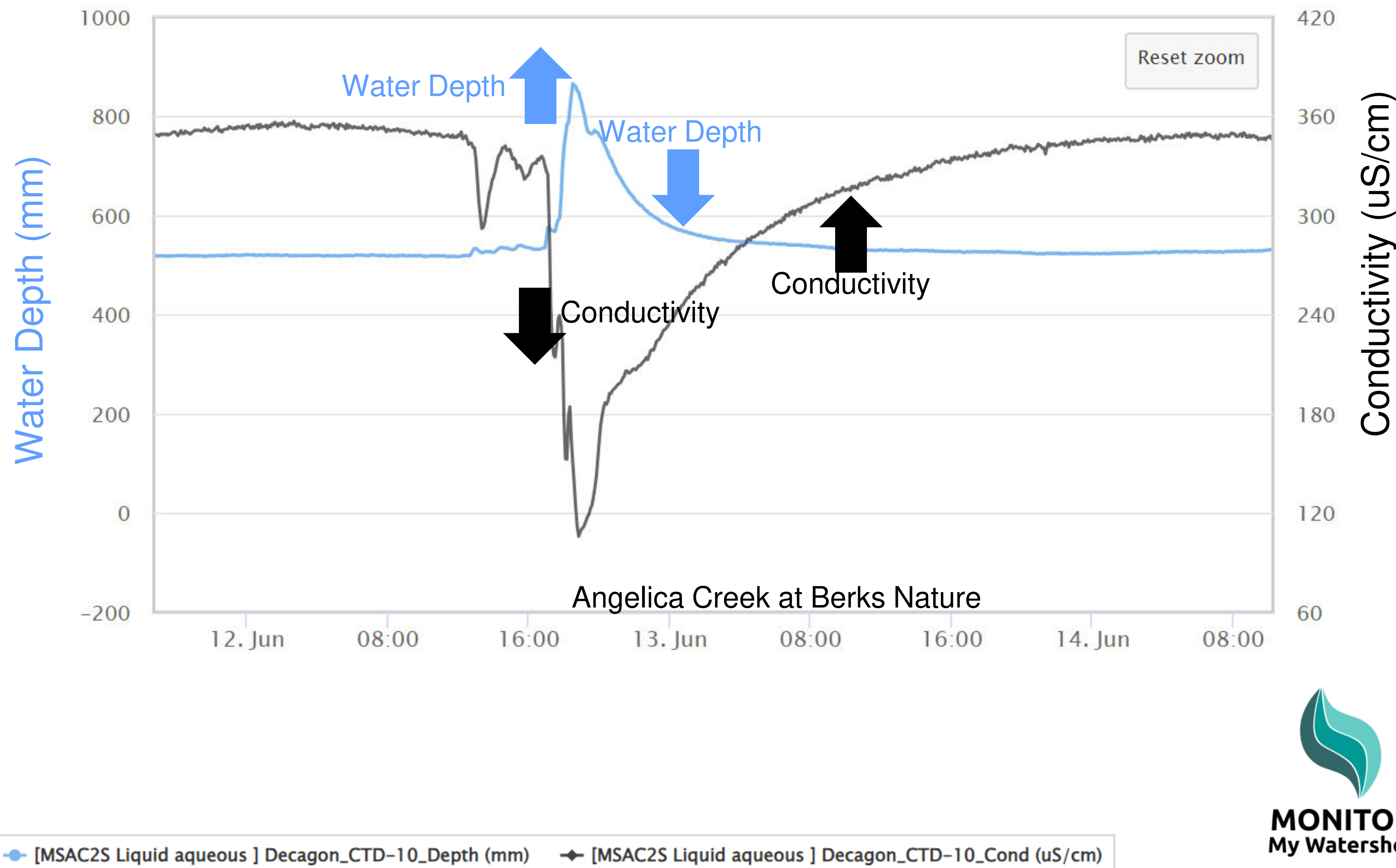
Runoff from storms usually dilutes stream water



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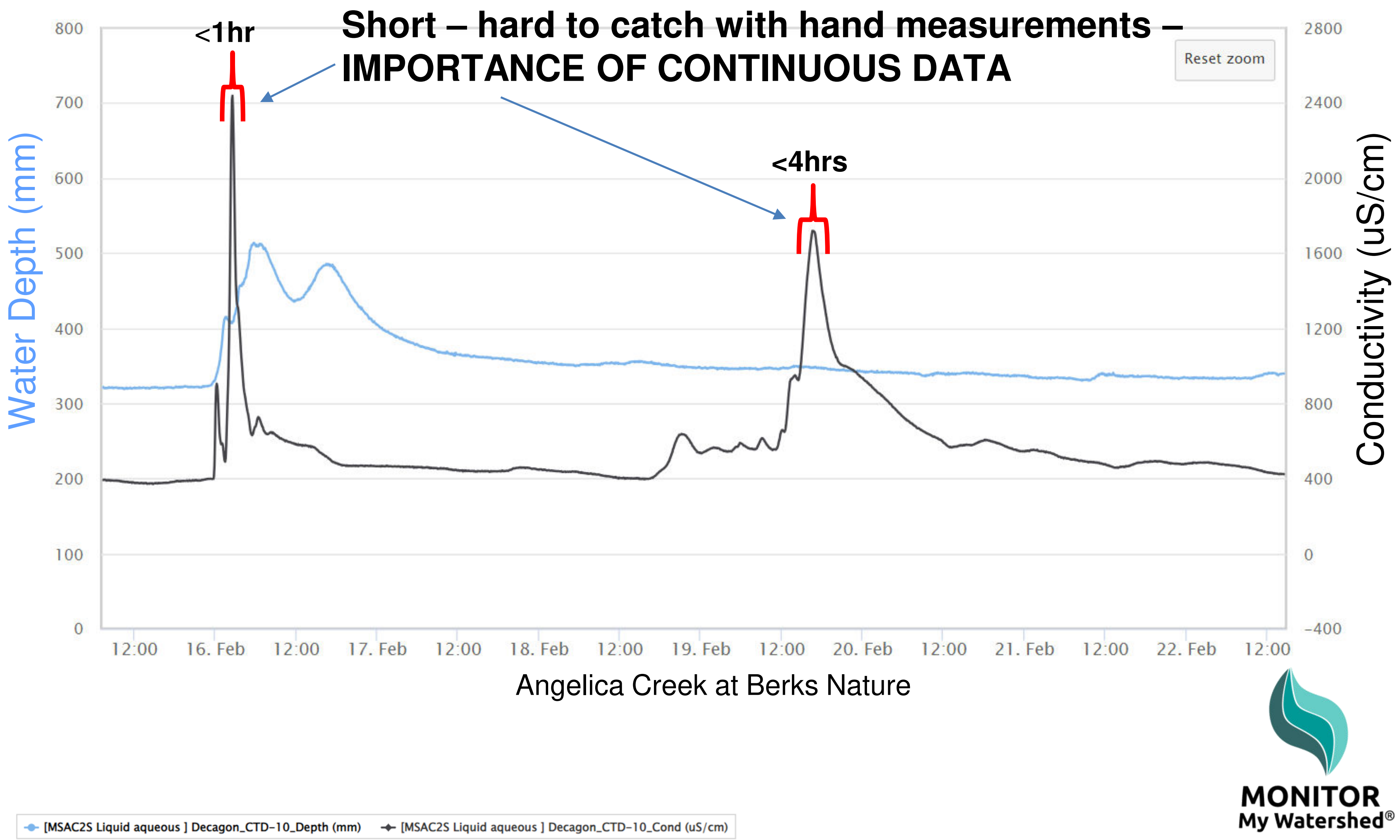
But road salt runoff (or other pollutants) can cause "spikes"



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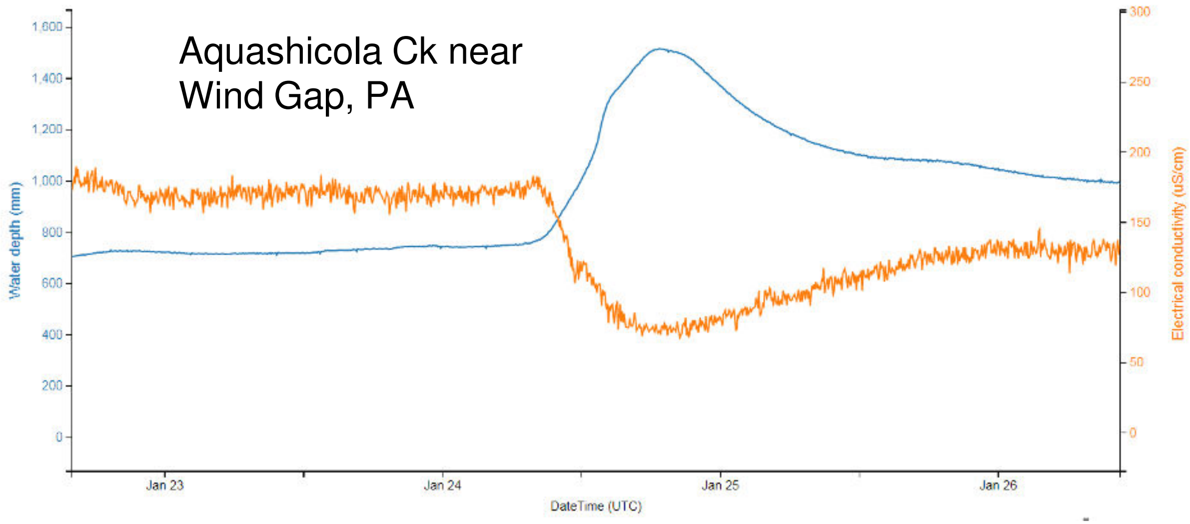
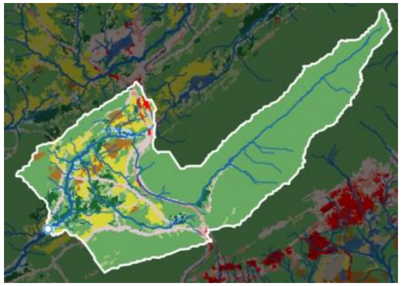
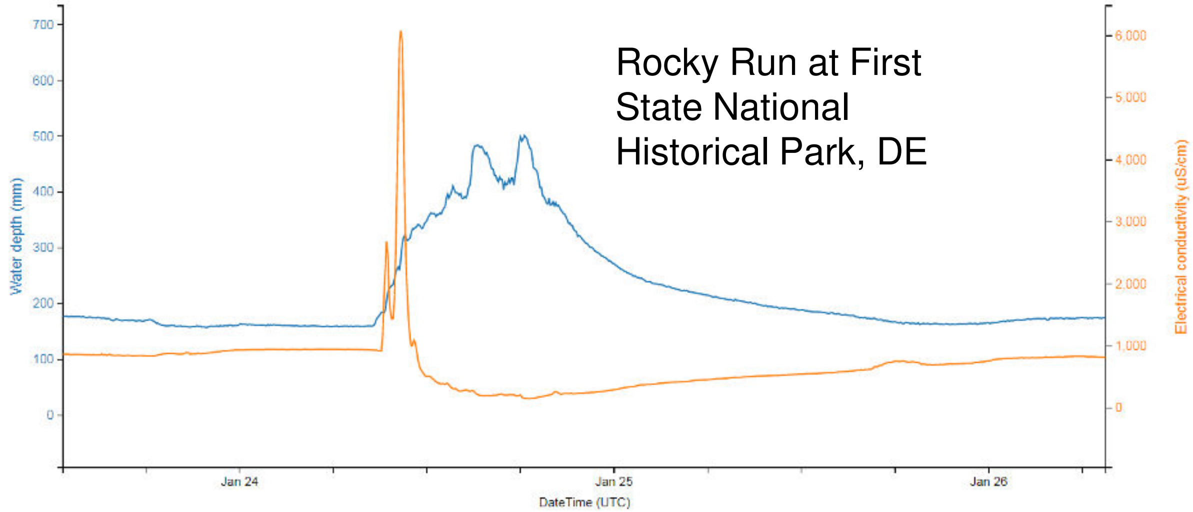
Continuous data to see details of storm response from different landscapes

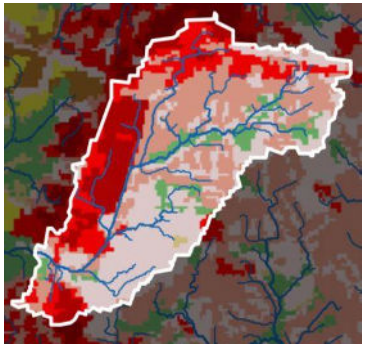


79% Forest

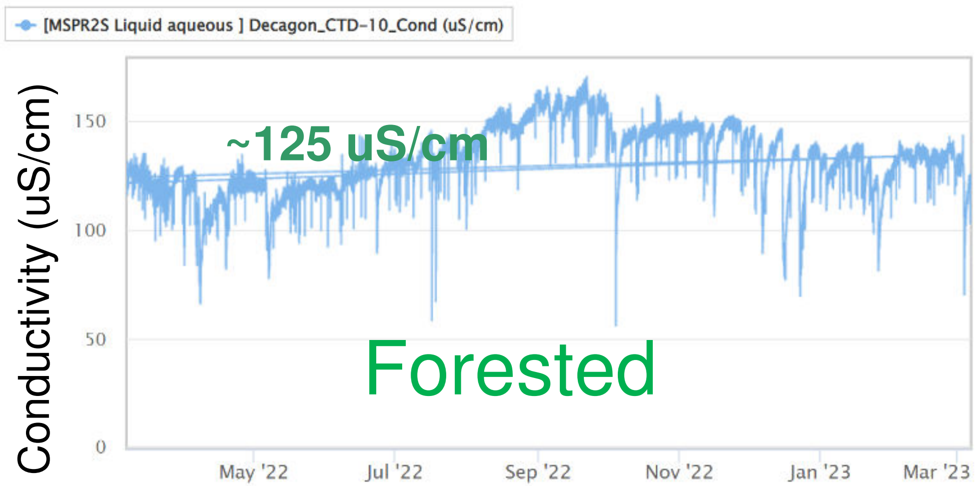


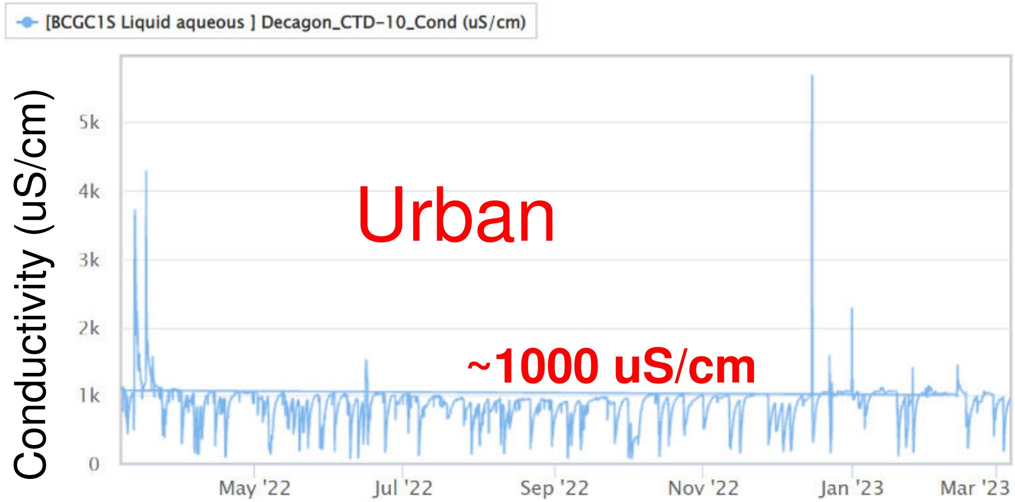


60% Urban



Continuous data to see detail throughout the year on different landscapes





MONITOR My Watershed®

Hand measurements

- A person goes to the stream and
  - takes a measurement
  - or collects a sample for measurement later

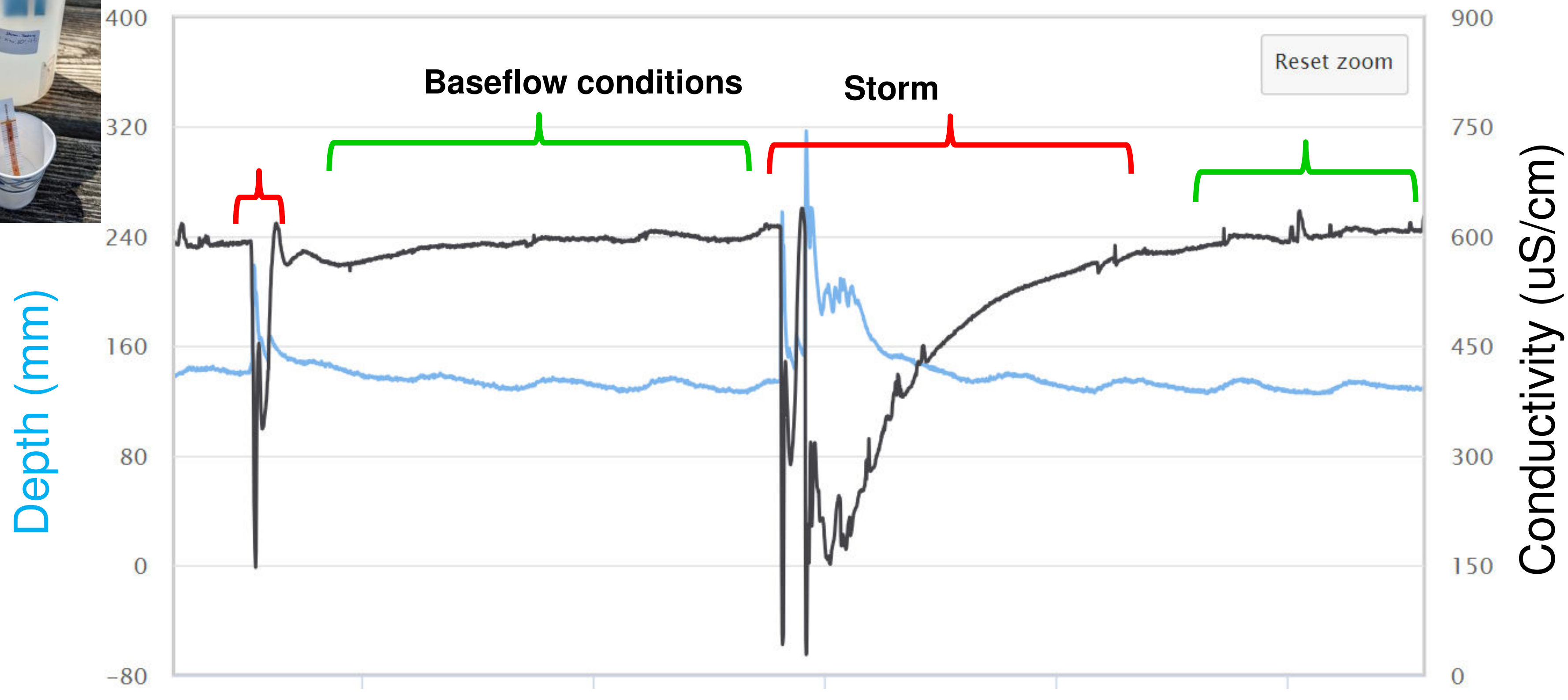
- Gives a data point from a single moment in time – can repeat but requires a person to be there

Hand measurements

- **Hand measurements – some variations:**
  - **Synoptic sampling** (i.e. salt "snapshots" or "blitzes") – many sites at one time
  - **Longitudinal** – headwaters to larger downstream reaches
  - **Targeted** – in concert with continuous data signals

Importance of timing for point-in-time sampling

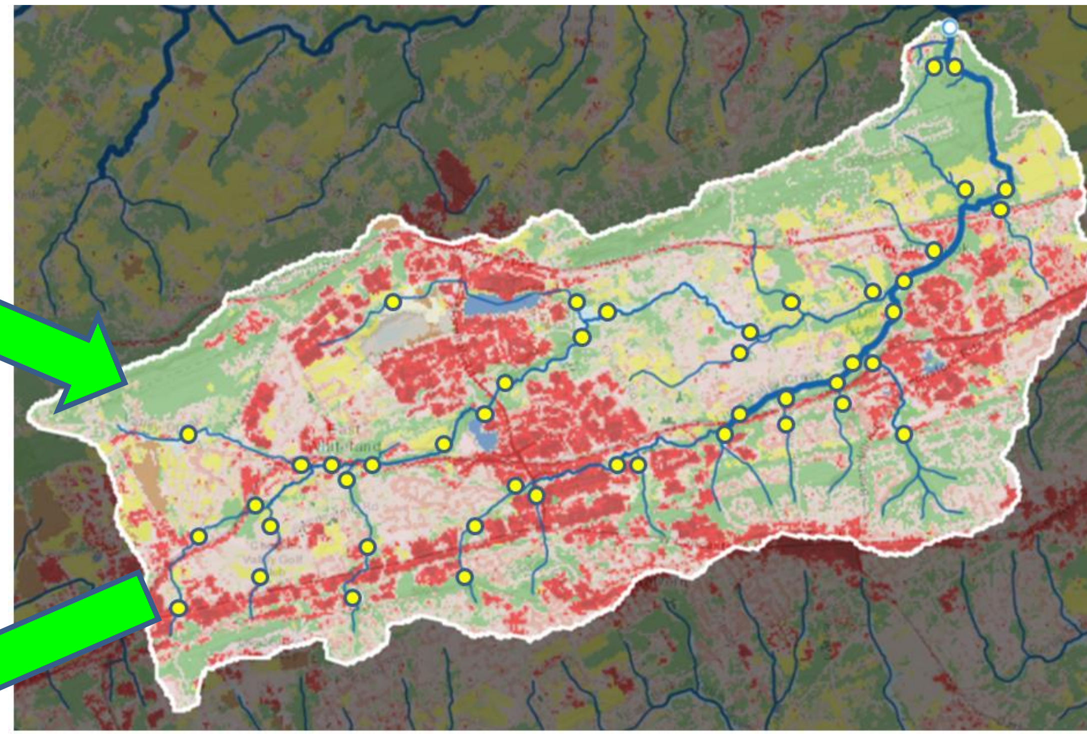
To understand normal stream conditions sample during BASEFLOW



EnviroDIY station at Goose Ck in West Chester, PA

Snapshot – on a day(s) when flow is normal (i.e., baseflow)…

Participants collect water samples at pre-determined sites OVER A SHORT PERIOD OF TIME WITH LITTLE OR NO PRECIPITATION



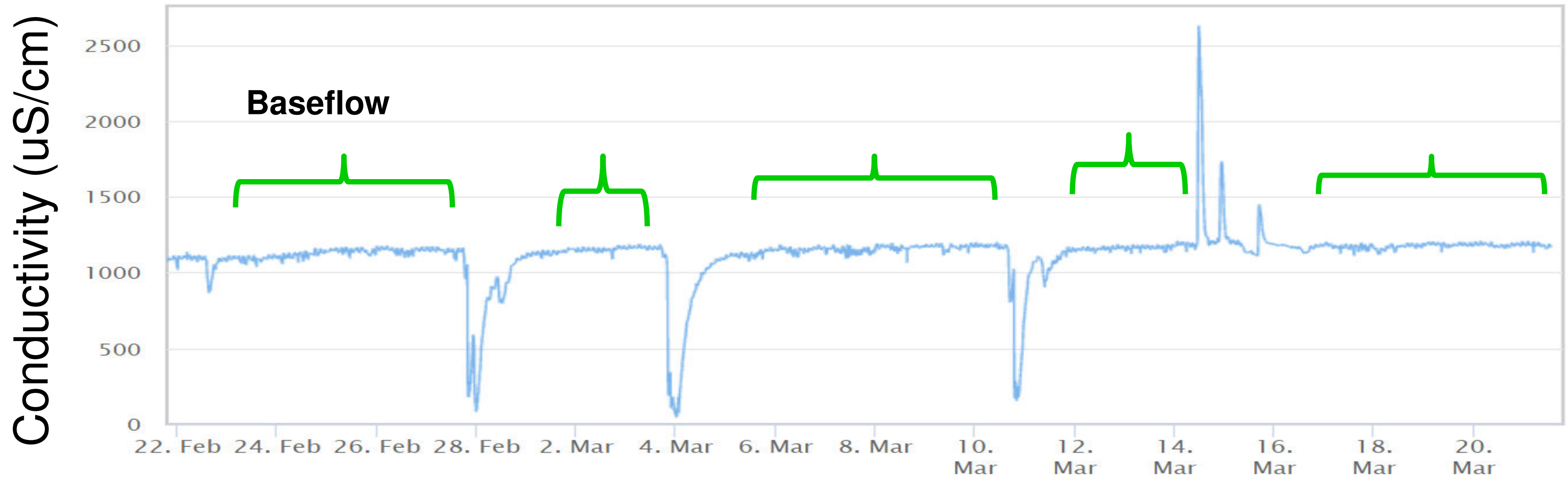
Return to central location and measure Chloride (mg/l) and Conductivity (uS/cm) (or measure on-site)

Don't sample storm conditions

Find a real-time continuous station nearby (EnviroDIY or USGS)

Data can help to confirm baseflow

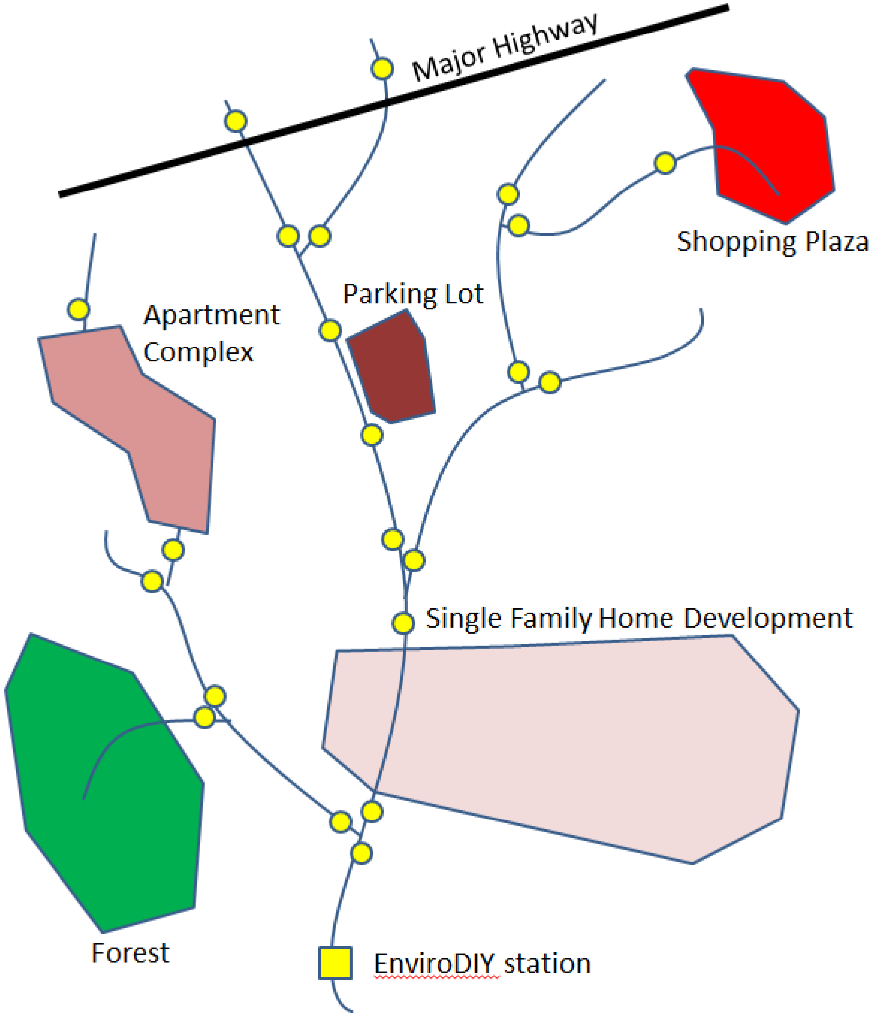
Allow enough time after storms (24-72 or more hours)



Choose sites purposefully to get detailed picture

See where pollution maybe worst and what may be causing it

And see where things are better and possibly why

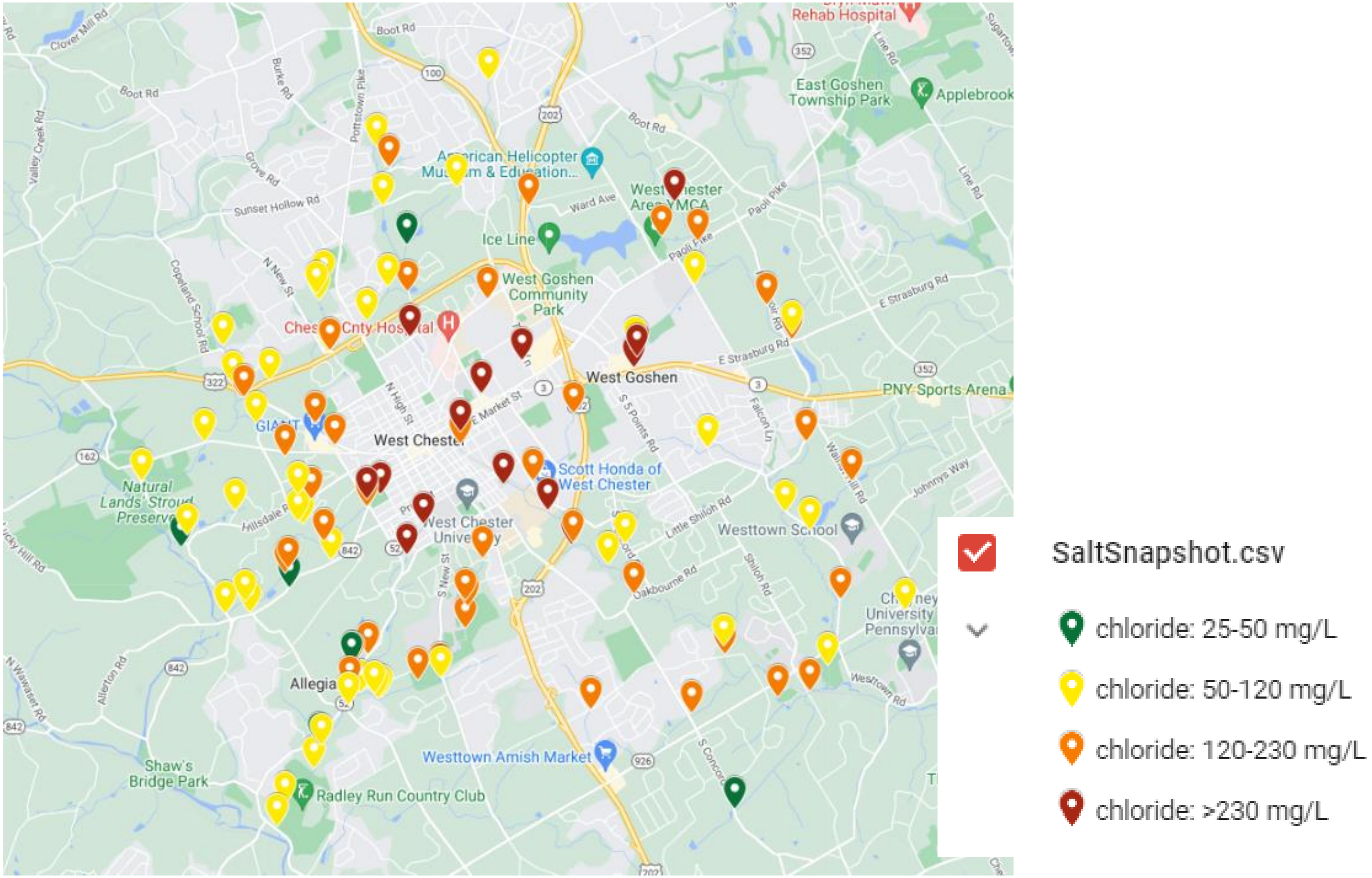


Synoptic sampling, aka "Snapshots"

- People power – a few (or a lot) of people can gather a lot of information with a bit of organization and time

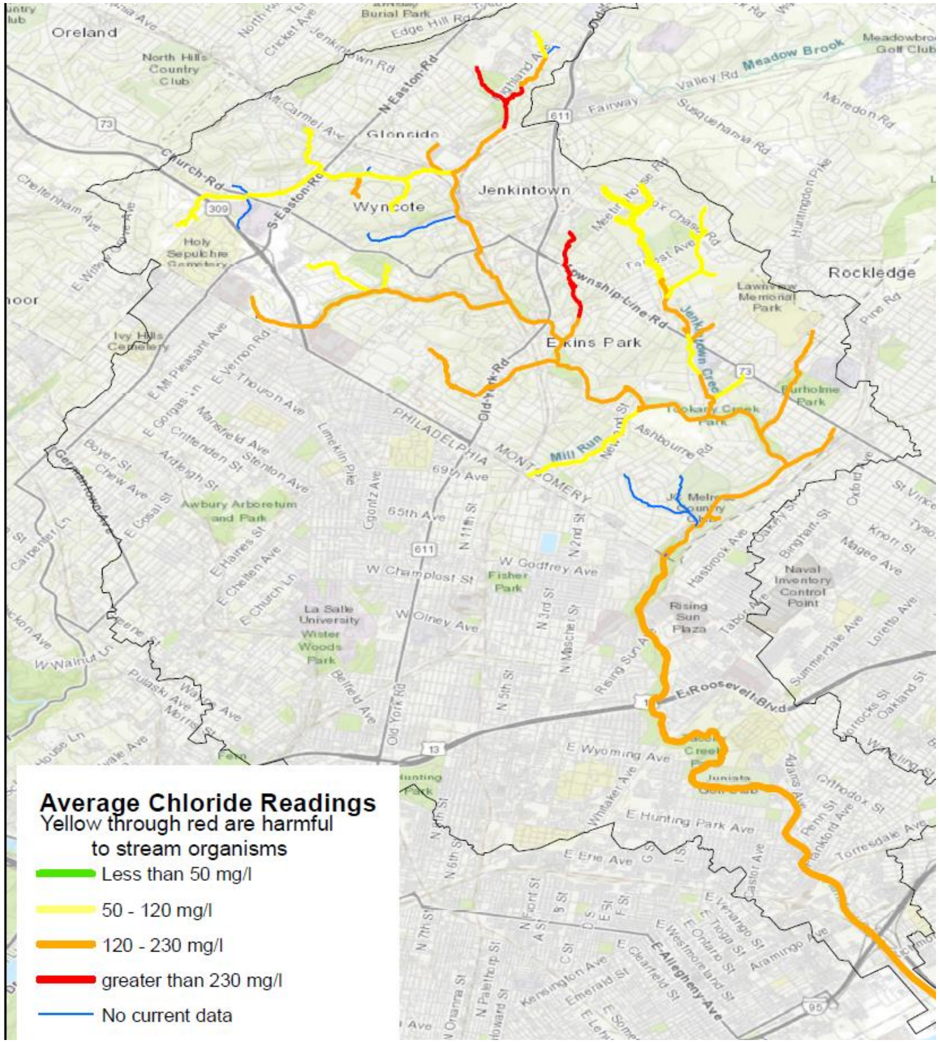
Detailed picture of a region

- Snapshot data inform on extent and location of pollution

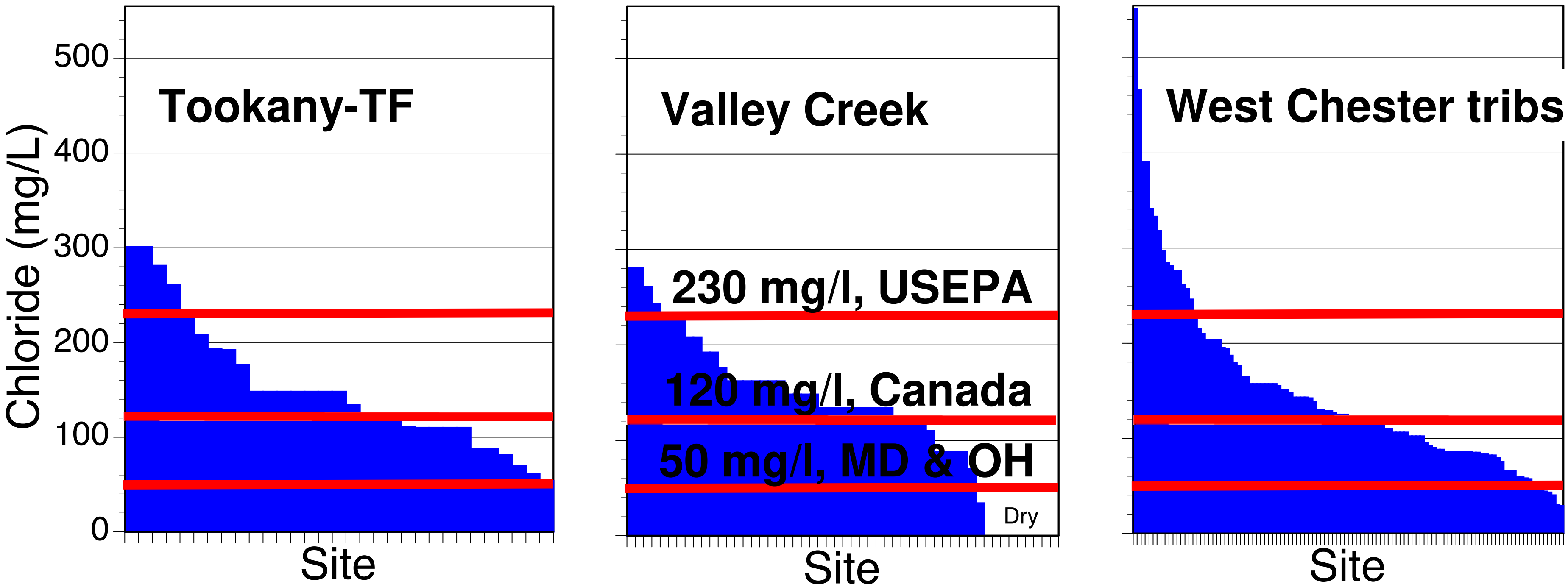


Detailed picture of a watershed

- Snapshot data inform on extent and location of pollution



Compare to chronic toxicity thresholds

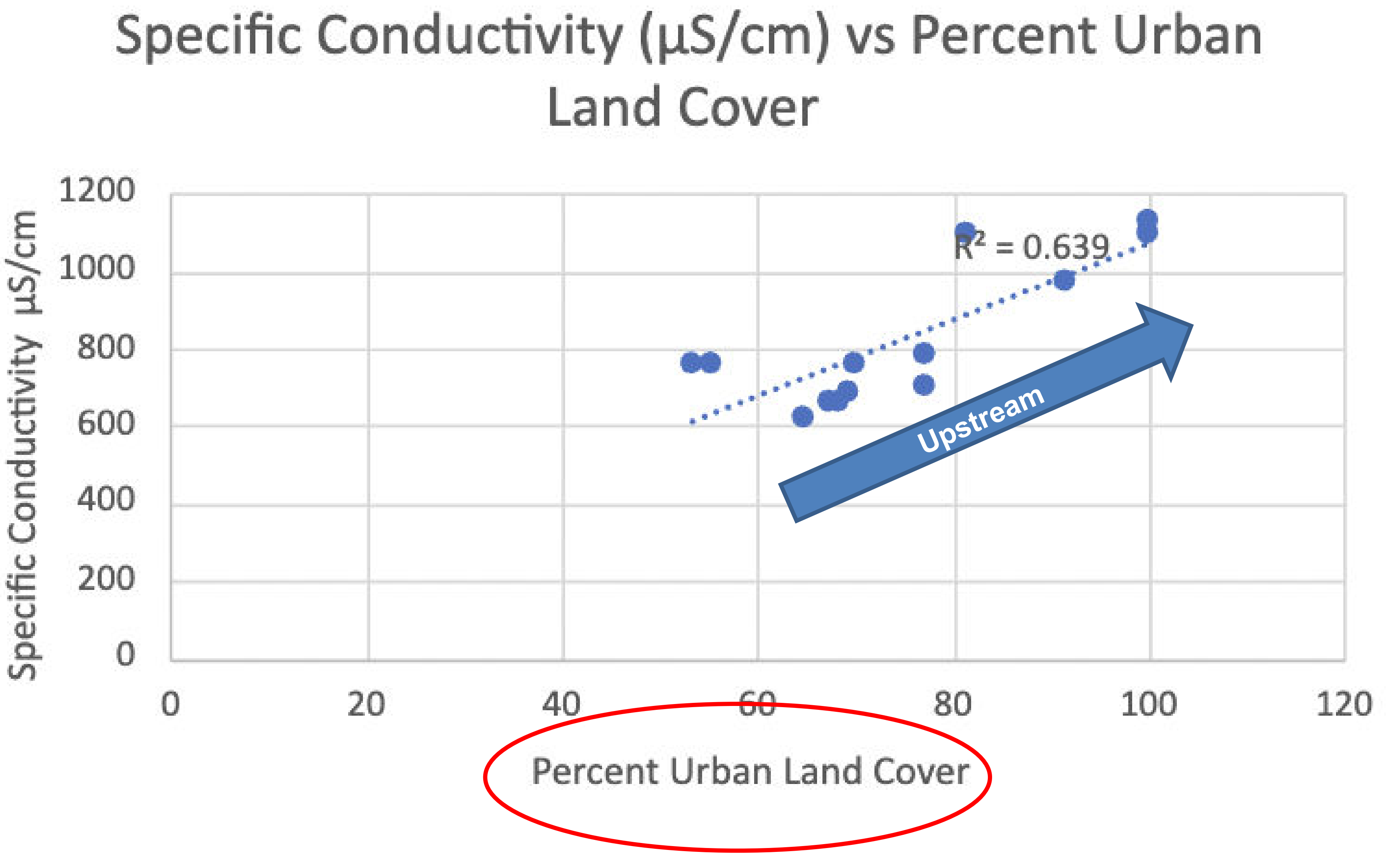


Three urban/suburban areas of the Delaware River Basin

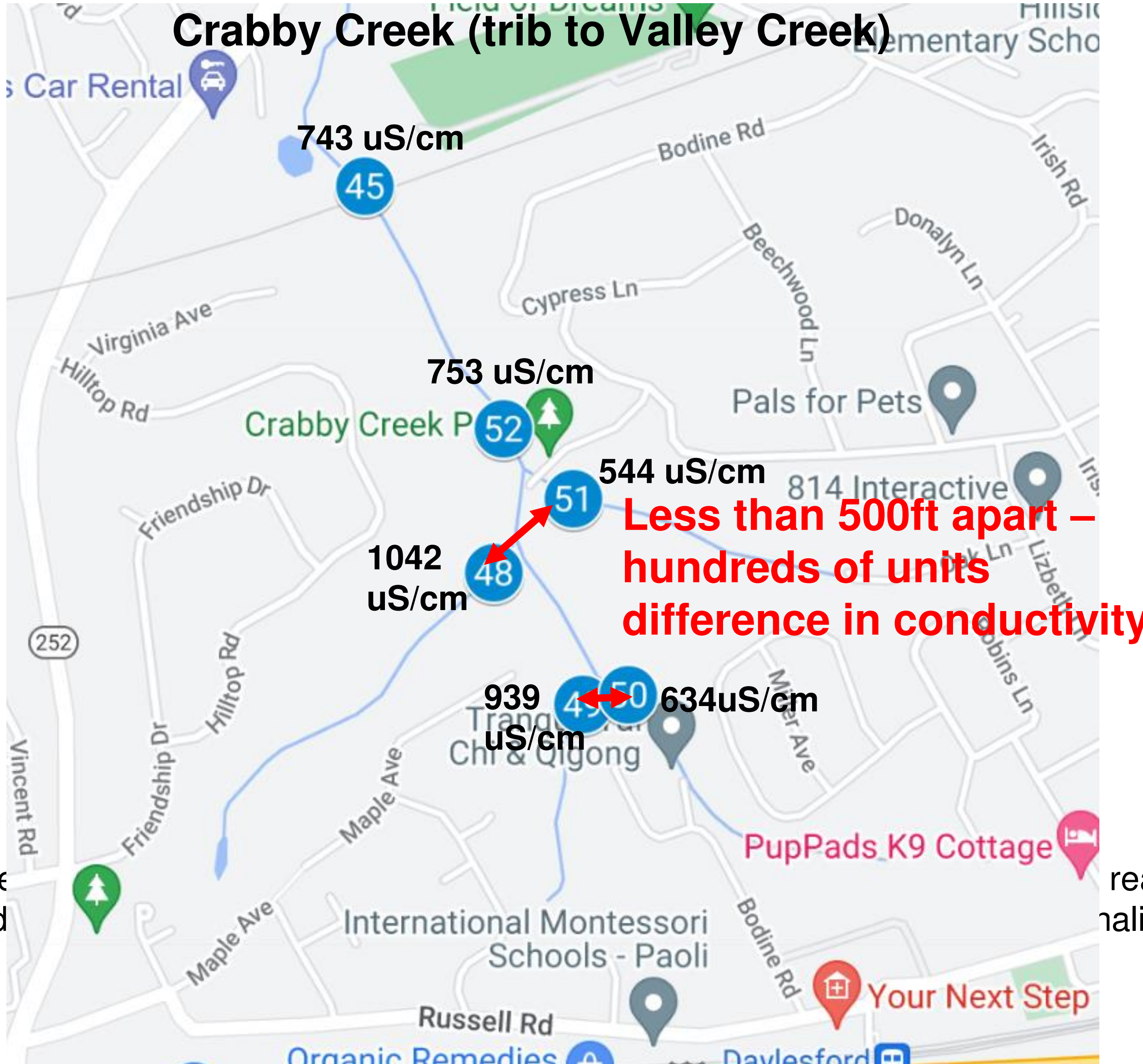
Longitudinal sampling

- Same idea as snapshot – but isolating to a single stream – maybe fewer sites, maybe visited multiple times

Longitudinal sampling to understand spatial differences



Importance of location



Inse … readings;

and … nality)

Importance of location

Left side - mall/parking lot

Right side – residential

Lateral variations in stream conditions

>600 unit difference – less than 10ft apart

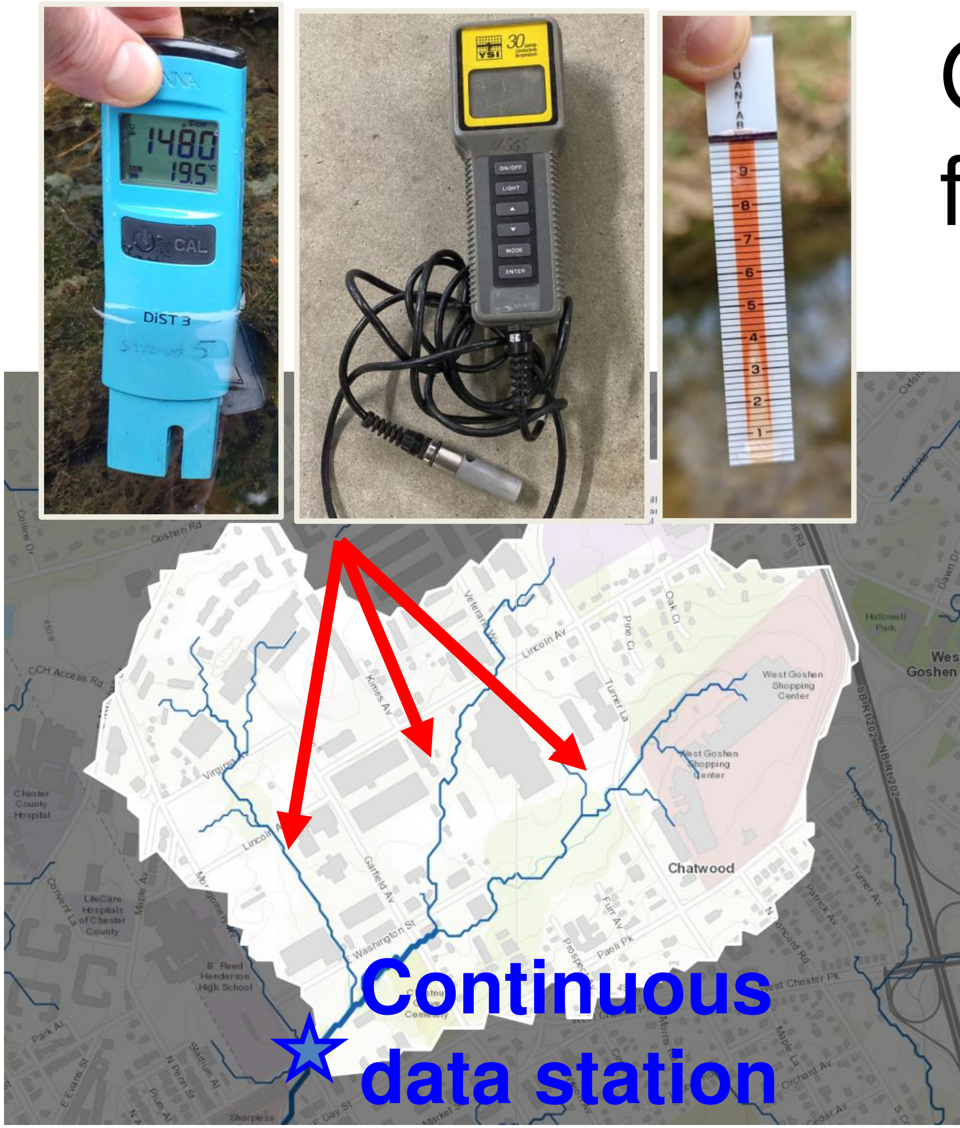
Rocky Run in northern Delaware

Targeted problem investigations

*Not associated with a winter storm salt flush event

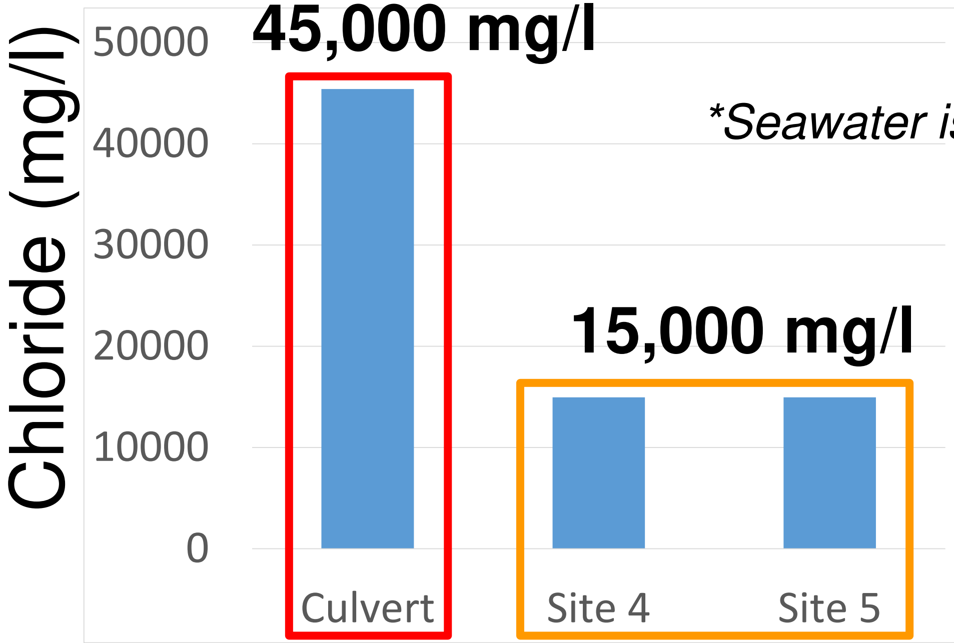
Sleuthing to figure out sources of salt

Targeted problem investigations

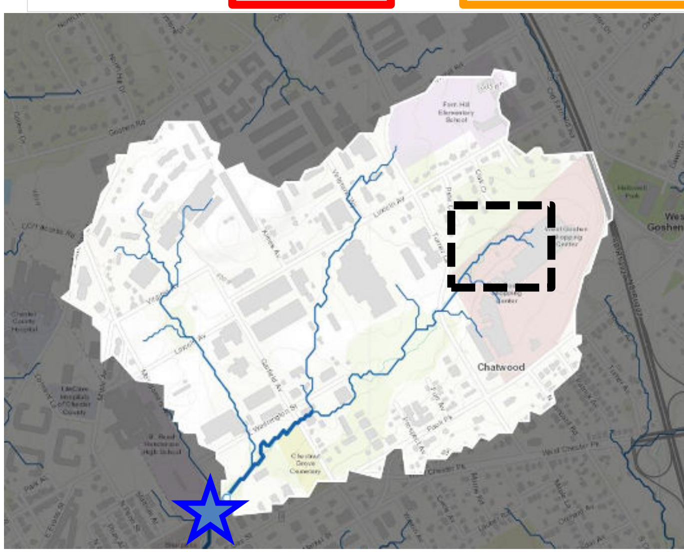


Go upstream to figure out the source

Targeted problem investigations



**Seawater is about 19,000 mg/l*



Cations and other chemistry – Grab samples and lab analysis

- Sodium, Na^{+}
- Magnesium, Mg^{2+}
- Calcium, Ca^{2+}
- Potassium, K^{+}
- Other metals, chemicals (can be liberated from soil, pipes, roads, due to salt pollution)

PHILOSOPHICAL TRANSACTIONS B

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Research

Check for updates

Cite this article: Kaushal SS *et al.* 2019 Novel 'chemical cocktails' in inland waters are

Novel 'chemical cocktails' in inland waters are a consequence of the freshwater salinization syndrome

Sujay S. Kaushal[1], Gene E. Likens[3,4], Michael L. Pace[5], Shahan Haq[1], Kelsey L. Wood[1], Joseph G. Galella[1], Carol Morel[1], Thomas R. Doody[1], Barret Wessel[2], Pirkko Kortelainen[6], Antti Räike[6], Valerie Skinner[7], Ryan Utz[7] and Norbert Jaworski[8]

Concept is simple(?), timing, planning, and organization may be the challenge

LITTLE LEHIGH Watershed Stewards

STROUD WATER RESEARCH CENTER

Salt Snapshot Protocol

Snapshot in action: The following synoptic sampling procedure (aka "snapshot") was used by members of the Little Lehigh Watershed Stewards in August 2023. 48 sites in the watershed were tested by four teams of two volunteers each. The sampling took an average of three hours per team.

Procedure:

1. Select sampling area and sites

Using the maps in Model my Watershed (https://modelmywatershed.org/) in the WikiWatershed Toolkit (https://wikiwatershed.org/), select the area you want to study.

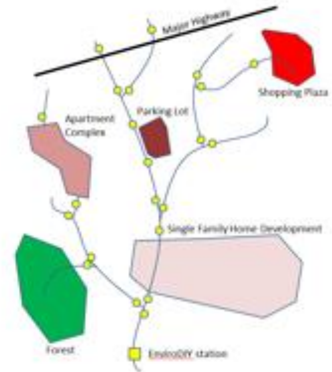
Use the overlay tool to select an area with a variety of different types of land use so you can study their effect on the salt levels of nearby streams.

When selecting sites, take the following into account (and see figure below for an example site layout):

- To acquire a comprehensive picture of salt contamination throughout a watershed or region position sites across the range of urban and forested areas found in your study area.
- Position sampling sites upstream and downstream of any significant land uses such as an industrial, residential, major roads, and parking lots or other areas that may cause contamination.
- Position sites in natural areas, especially headwater areas that are heavily forested, to represent (most likely) the most natural/uncontaminated conditions in the study region.
- Try to position sites whenever there will be a change in stream conditions due tributary inputs (e.g., position a sampling site downstream of the confluence of two tributaries).
- If the sampling site is on private property, you will need to get the owner's permission. If you want to avoid doing this, select sites where the stream is crossed by a road: volunteers will be able to collect samples by lowering a bucket down to the steam.

LITTLE LEHIGH Watershed Stewards

STROUD WATER RESEARCH CENTER



2. Make map of potential sampling sites:

- Using Padlet or a similar app (e.g., Google maps), create an interactive map of the sampling area.
- Create flags on the map using a different color for each stream in the watershed.
- Padlet will automatically give you the GPS Coordinates for each location. Select this for the flag.
- Enter the GPS coordinates in Google Street View and check the viability of sampling from each location. Google Street View will also give you the precise addresses of most locations. You can copy and paste it into the flag information.
- For some sites, parking will be some distance from the sampling spot. For these sites, you should create two locations – one with GPS coordinates so the volunteers know where to park, and a second one for where they actually sample the water. Record both on the spreadsheet, but add only the actual sampling spot to the map.
- Add the stream name to each flag on the map.

Customize monitoring event according to your situation and needs

- **Large group, community educational event**
  - Lots of people
  - Low number of sites/person
  - Lots of prior site scouting, directions, parking, etc.
  - Participants just collect samples
  - Organizer(s) do measurements
-
-
-
-
- …
- **Participants are independent**
  - Experienced field people
  - Generally a small group or individual
  - Participants generate data on their own – send to organizer when done

Variations, mix/match methods

Data Sheets, Protocols available

Name of watershed/event:
Date(s) of event:
Name of data recorder(s):

SiteID	Stream Name	Loca

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Watershed Salt Snapshot – Instructions

Overview

The following is a method for documenting salt levels in streams and rivers across a watershed by measuring the concentration of chloride (Cl^-)(milligrams/liter, mg/l) during baseflow conditions. Measuring electrical conductivity is also recommended as it can provide explanatory information and is directly related to chloride concentration.

The intent of this method is to 1) determine salt levels that aquatic life is exposed to the majority of the time (i.e., during baseflow conditions) in streams of a watershed(s) and 2) identify specific areas of the watershed(s) that may be contributing to or preventing salt contamination of nearby streams.

The basic method:
Over a short period of time (less than a week, to ensure consistency in data) a group of people fans out across a watershed (or other area of interest) during baseflow conditions and collects water samples from pre-determined stream sites. Sites are strategically chosen to help identify specific areas of the landscape that may be contributing to or protecting nearby streams from salt contamination. The samples are returned to a central meeting location where they are measured for chloride (mg/l) and specific conductivity (uS/cm). Because sampling is recommended to occur over a relatively short time period, it is important to consider the number of people available to conduct the work and the number of sites that can be visited in the allotted time. Judgment will be required to balance desired number of sites with personnel and time availability.

> *Baseflow: the resting state of a stream between precipitation events; a stream or river's normal flow state when not influenced by recent precipitation runoff, often composed primarily of groundwater; the flow that would exist in a stream without the contribution of direct overland runoff from rainfall or melting snow/ice.*

Equipment/Supplies

- Chloride QuanTab® Test Strips, 30-600 mg/L or other chloride measurement method
- Conductivity meter (e.g., Hanna DiST®3 Waterproof EC Tester)
- Conductivity meter calibration solution (e.g., 1413 µS/cm Conductivity Standard)
- 500-1000mL clean plastic or glass bottles with lids (one bottle per site).
- Waterproof bottle labels (if possible). Bottles can be directly labeled if necessary or labels can be prepared with normal paper and covered with packaging tape after labeling is completed
- Small plastic cups/containers (one per site) – for chloride strip measurements, should be small enough so chloride

Direct assistance from the Stroud Center and/or Master Watershed Stewards

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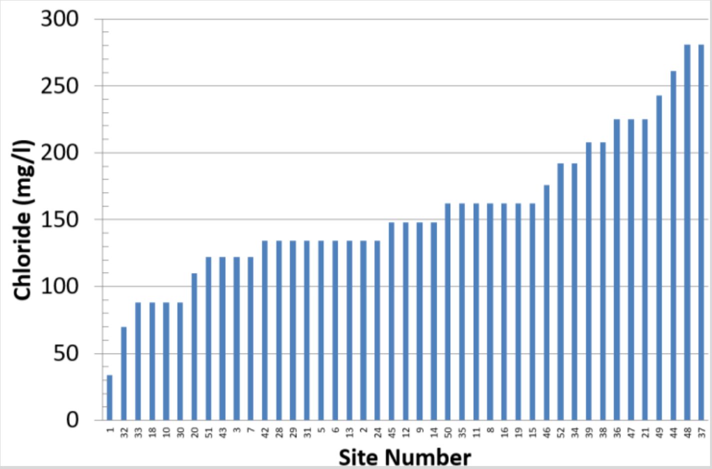
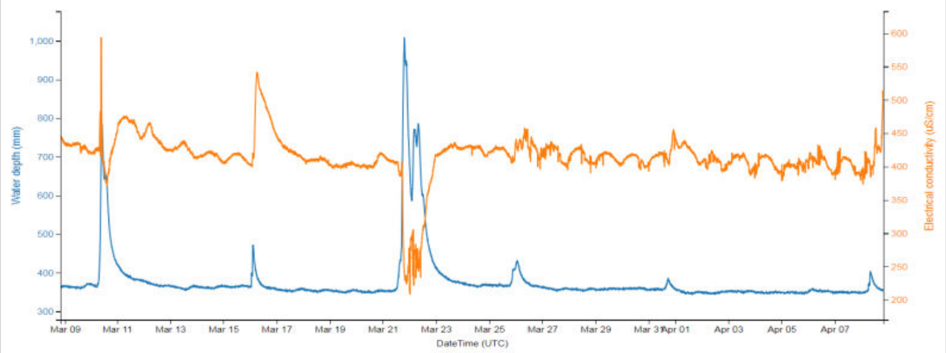
PennState Extension

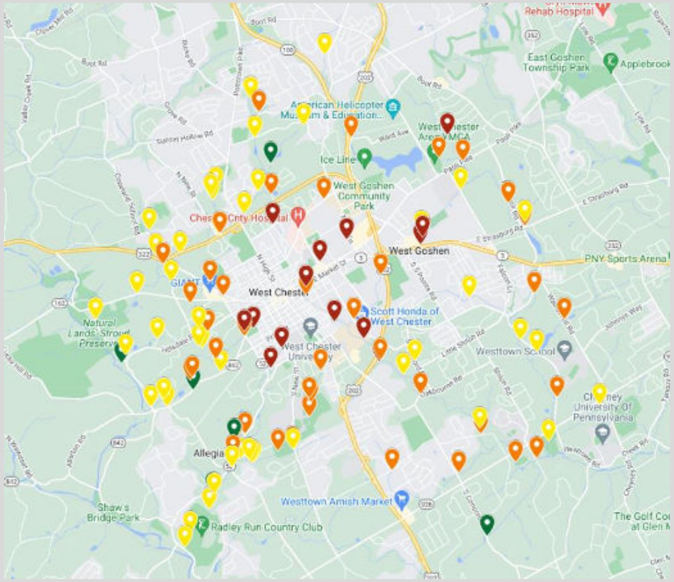
The Basic Logistics of the Watershed Salt Snapshot

1. Everyone (organizers and participants) gather at one central location on a day or short period of time when streams are at baseflow.
2. Participants receive sampling materials, travel to assigned sites, and collect one sample per site.
3. Participants return samples to central location by an agreed upon time.
4. Organizer(s) do Chloride (mg/l) and Conductivity (uS/cm) measurements on samples and record results.
5. Group discussion of sample results – consider reasons for observed salt levels and compare to known criteria and thresholds.
6. Event organizers and participants use results as needed – advise EACs and municipalities, work with local businesses and property owners, inform the community.

Questions???







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