Detecting surface water contamination from drilling operations in Pennsylvania using publicly available water quality databases

Anna K. Wendt[1], Matt S. Gonzales[1], Fei Wu[2], Zhenhui Li[2], Cheng You[3], Susan L. Brantley[1]

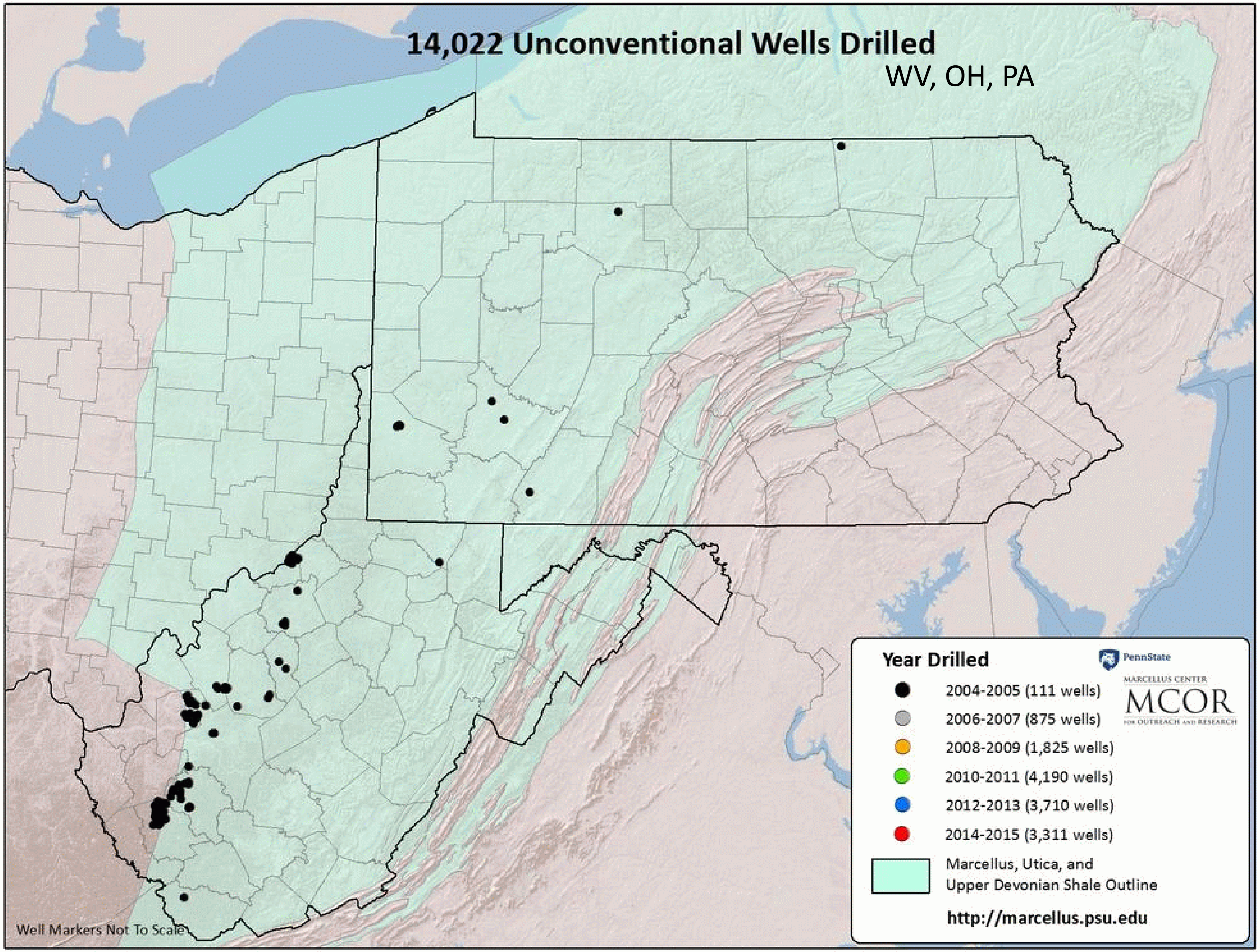
[1] Pennsylvania State University, Earth and Environmental Systems Institute

[2] Pennsylvania State University, College of Information Sciences and Technology

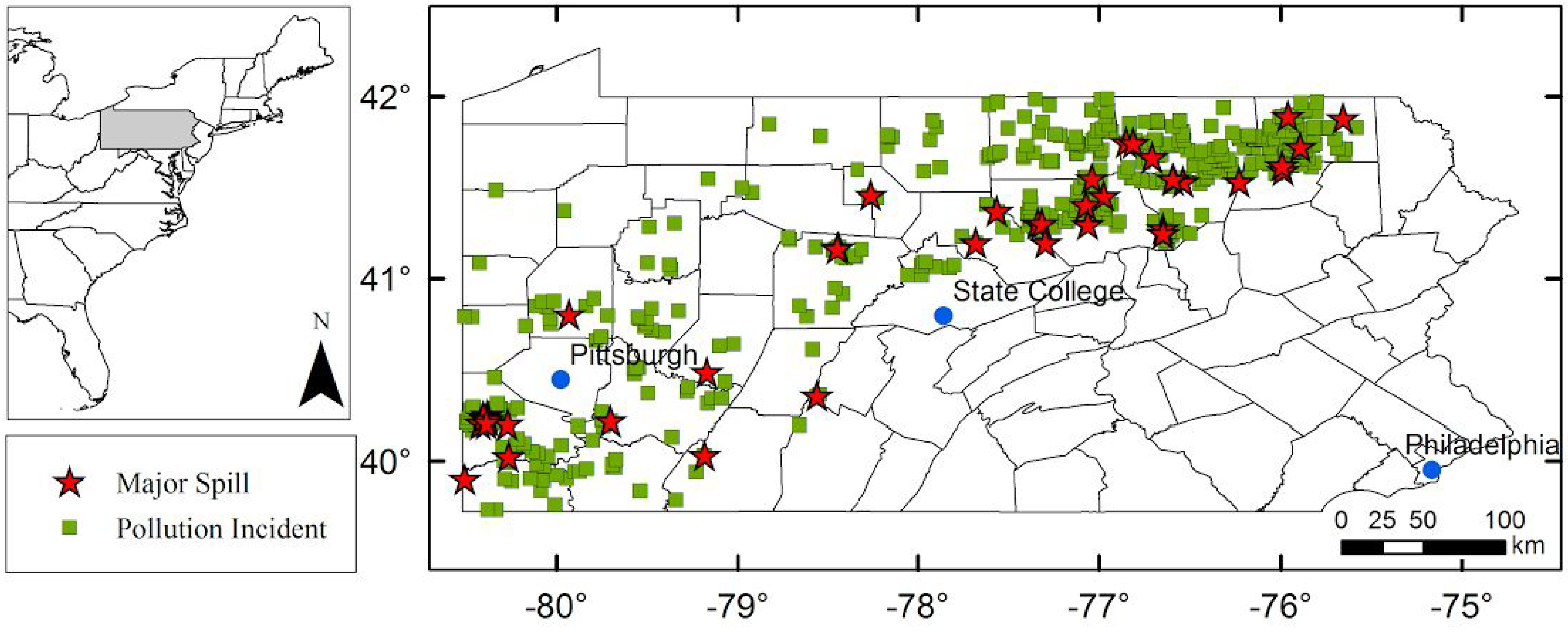
[3] Pennsylvania State University, Department of Statistics

PENNSTATE

1855


14,022 Unconventional Wells Drilled
WV, OH, PA
Year Drilled
PennState
MARCELLUS CENTER
MCOR
FOR OUTREACH AND RESEARCH
2004-2005 (111 wells)
2006-2007 (875 wells)
2008-2009 (1,825 wells)
2010-2011 (4,190 wells)
2012-2013 (3,710 wells)
2014-2015 (3,311 wells)
Marcellus, Utica, and
Upper Devonian Shale Outline
http://marcellus.psu.edu
Well Markers Not To Scale

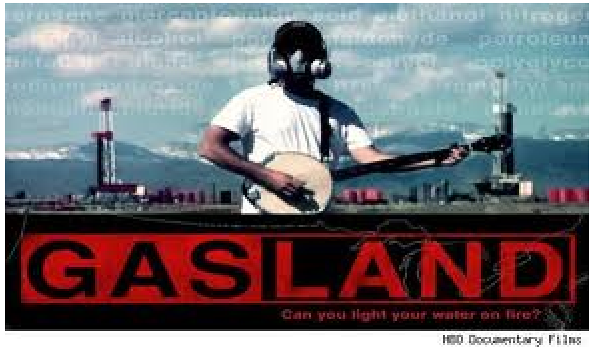
Since 2008 855 pollution related violations (green squares) and major surface water spills (red stars) in PA



From A. Wendt, Penn State. Data from PADEP as of March 2015 (violations), Dec 2014 (spills).

- Materials released directly into nearby streams
- Pollution events included contamination by flowback/produced waters, fracturing fluids, fuels, test waters or drilling materials
- Greater than 75% of municipal water supplies in PA are sourced from surface waters

Water quality incidents related to spills and leaks since 2004 in Pennsylvania led to public push-back that spawned an anti-fracking movement among some in the U.S. and abroad



What might surface water quality impacts look like?

- Measurable contamination versus aesthetic impact only
- Surface water versus ground water
- Water impact versus sediment impact
- Inorganic contamination versus organic contamination
- Chemical impact versus ecological impact

What might surface water quality impacts look like? Our focus:

- Measurable contamination versus aesthetic impact only
- Surface water versus ground water
- Water impact versus sediment impact
- Inorganic contamination versus organic contamination
- Chemical impact versus ecological impact

What might surface water quality impacts look like? Our focus: publically available data

- Measurable contamination versus aesthetic impact only
- Surface water versus ground water
- Water impact versus sediment impact
- Inorganic contamination versus organic contamination
- Chemical impact versus ecological impact
- **Public water data versus unreleased water data**

We are asking the question........... can we observe the effects of shale-gas contamination in PA surface waters using publicly available data? We looked at:

- 43 spills in PA > 400 gallons as of December 2014
- 7 different analytes considered
- 18 watersheds
- 16 counties
- Included both filtered and unfiltered samples (Predominantly filtered samples)
- 4 sources of publically available data

Shale Network has published data online from many sources as part of Shale Network database:

- Data from 6 universities
- 8 government entities
- 41 volunteer groups
- Several publications
- 9 oil/gas companies
- 2 environmental companies

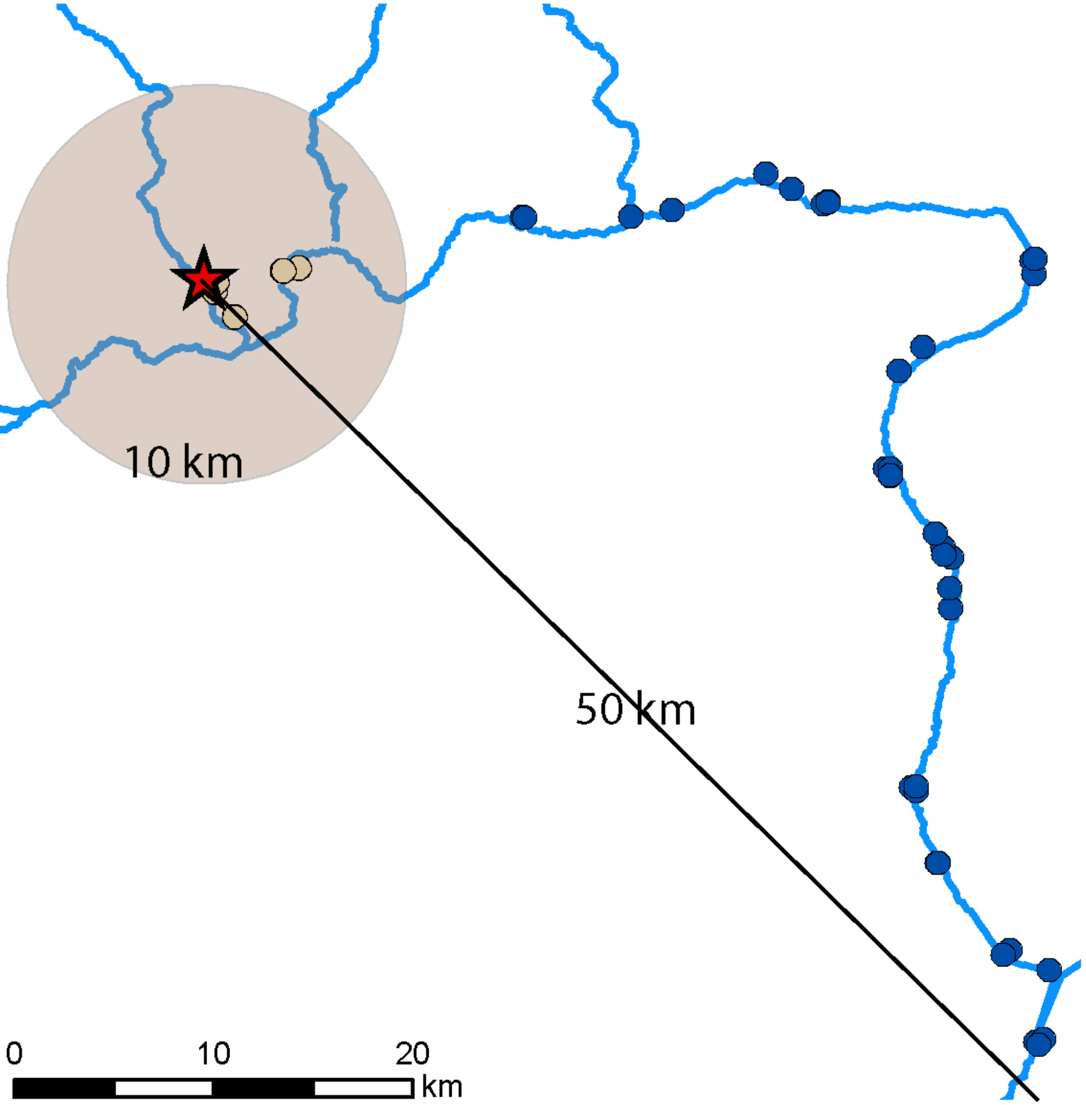
The CUAHSI HydroClient allows easy discovery of data from any data tagged appropriately online:

- USGS National Water Information System;
- Shale Network (doi:10.4211/his-data-shalenetwork), including data from 6 universities, 8 government entities, 41 volunteer groups, 11 private companies
- EPA STORET Data Warehouses;
- Susquehanna River Basin Commission;

Why the problem is hard

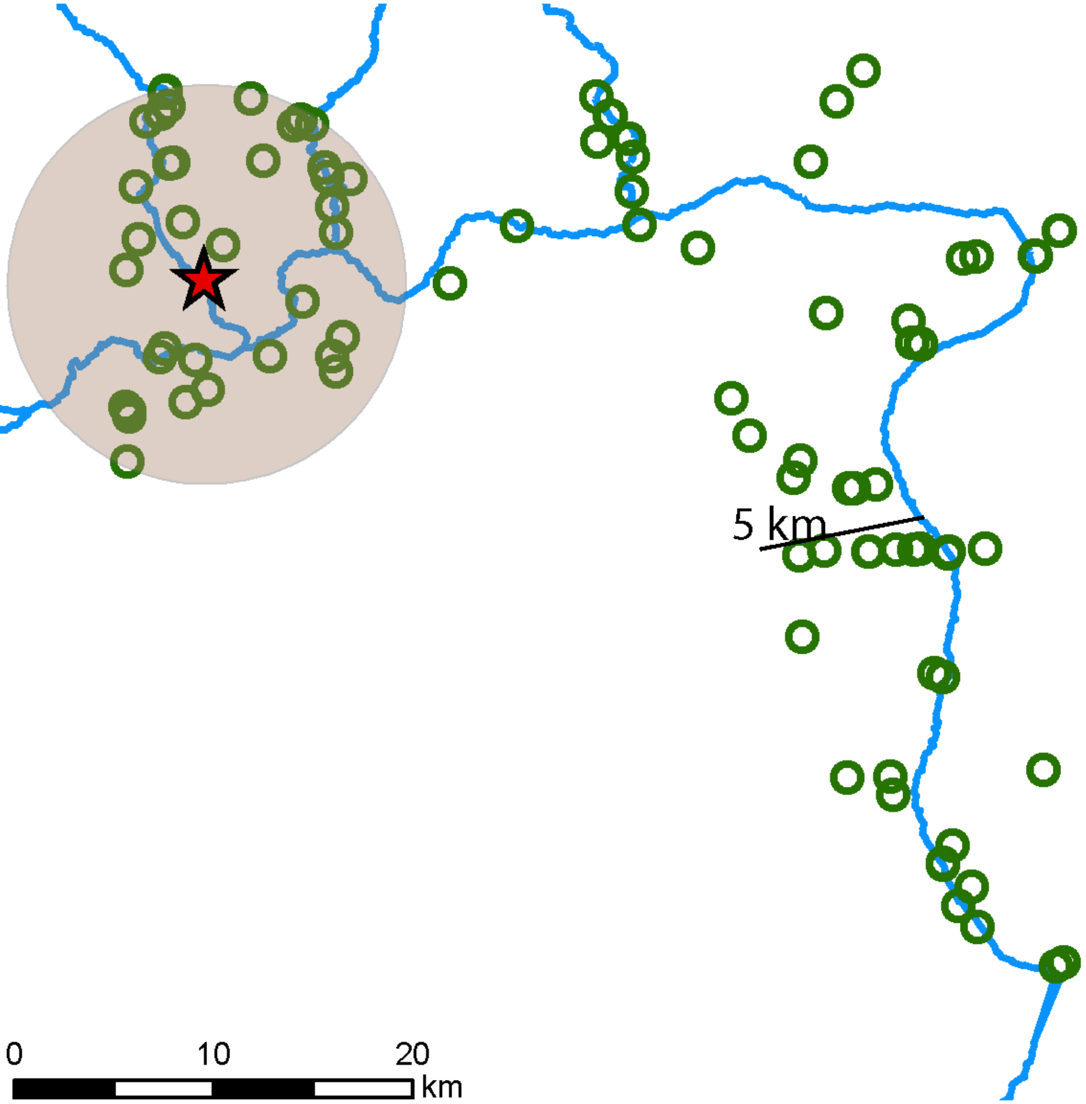
- Only a few analytes can be measured accurately with sensors in the field for long periods of time and the sensors are pricey and must be maintained and protected in the field
- Grab sampling and water analysis is labor-intensive and therefore expensive
- Because of these characteristics, water sampling is intermittent and data are spatially and temporally sparse in the U.S.A.
- Water quality varies due to geological differences in some areas (like PA)
- Difficult to define background or baseline concentrations before potential impacts

Data selection around a discharge site (red star)



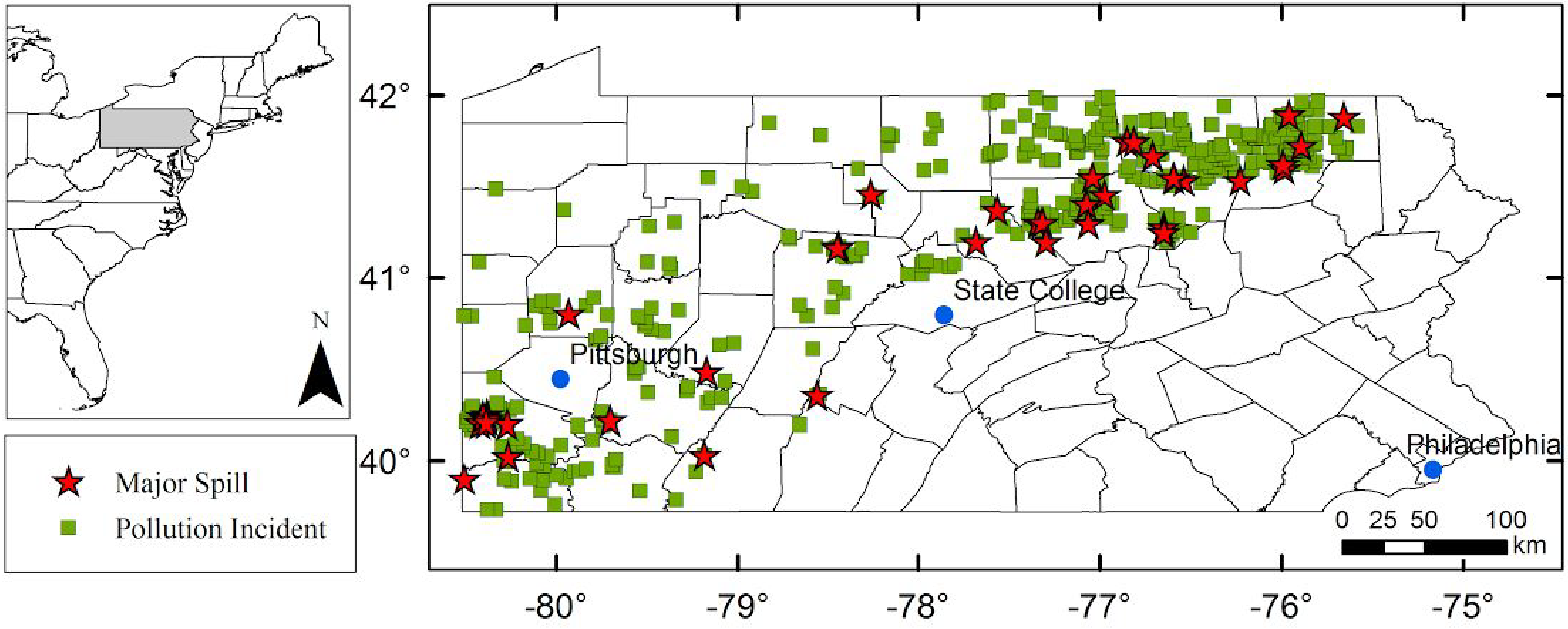
- **Close downstream** sites = downstream on the mainstem of the contaminated river within a 10 km circle of radius from the contamination discharge point.
    - These sites are the most likely to show contamination.
- **Far downstream** sites = downstream on the mainstem of the contaminated river but not within a 10 km circle of radius from the discharge point.
    - These sites could show contamination but it should be diluted, and other potential contamination could be present from downstream locations.

Data selection



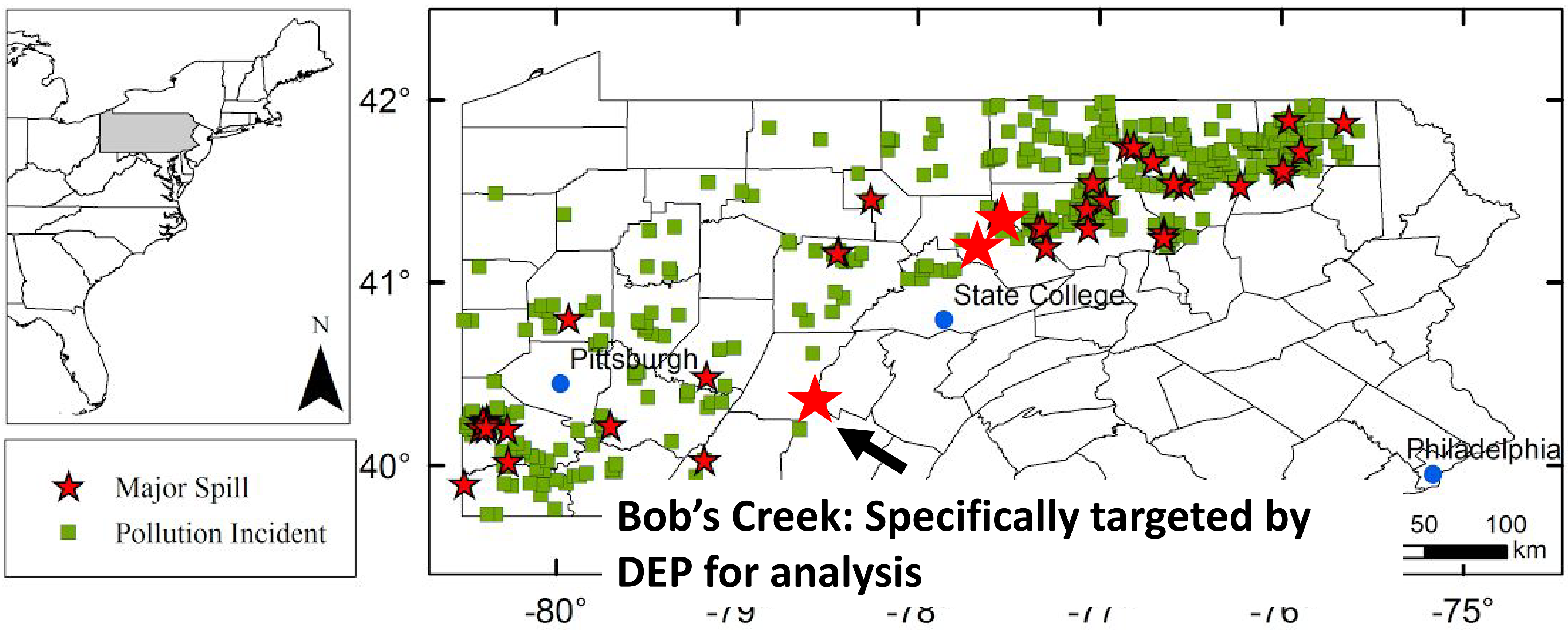
- **Upstream sites** = located within 10 km upstream of discharge point or from tributaries feeding into the contaminated river (when tributaries were within 5 km of the mainstem and within 10 km of the discharge site).
  - These sites could not have been affected and can be considered to show baseline or background conditions.

Three examples to be discussed



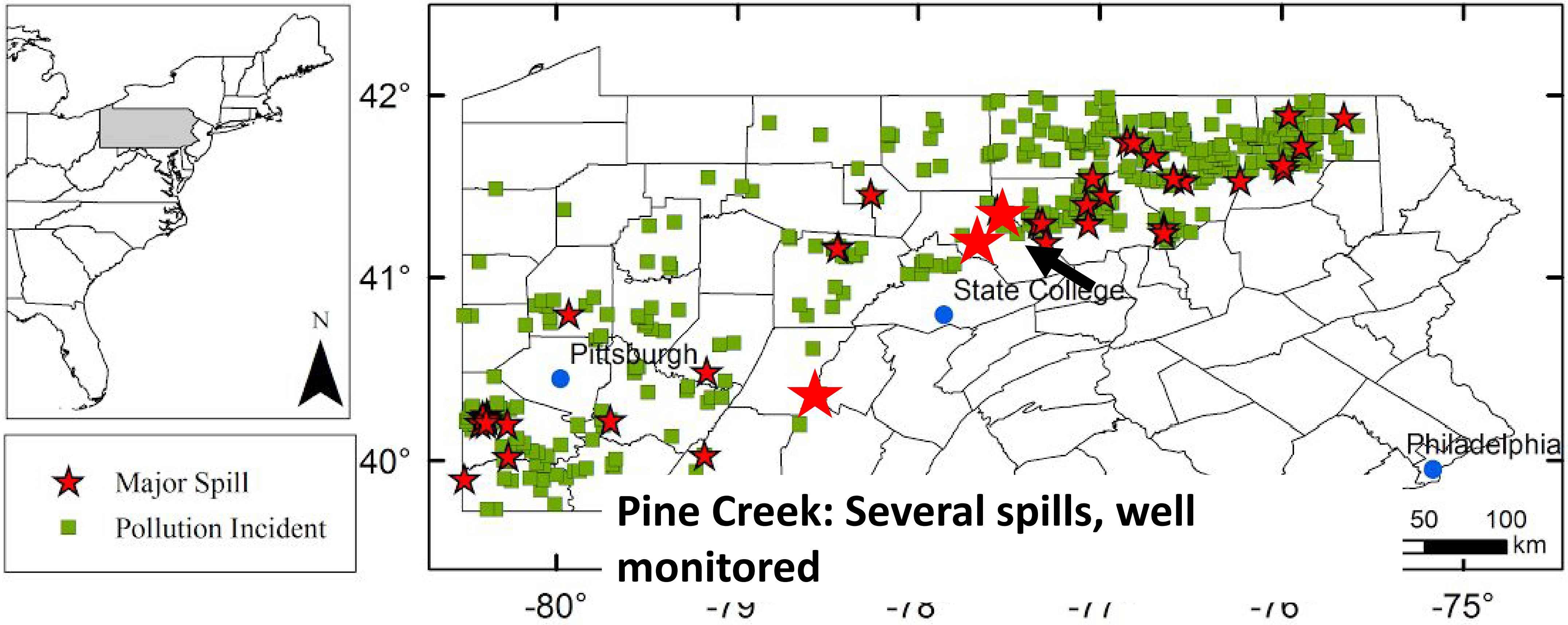
From A. Wendt, Penn State. Data from PADEP as of March 2015 (violations), Dec 2014 (spills).

Three examples to be discussed



From A. Wendt, Penn State. Data from PADEP as of March 2015 (violations), Dec 2014 (spills).

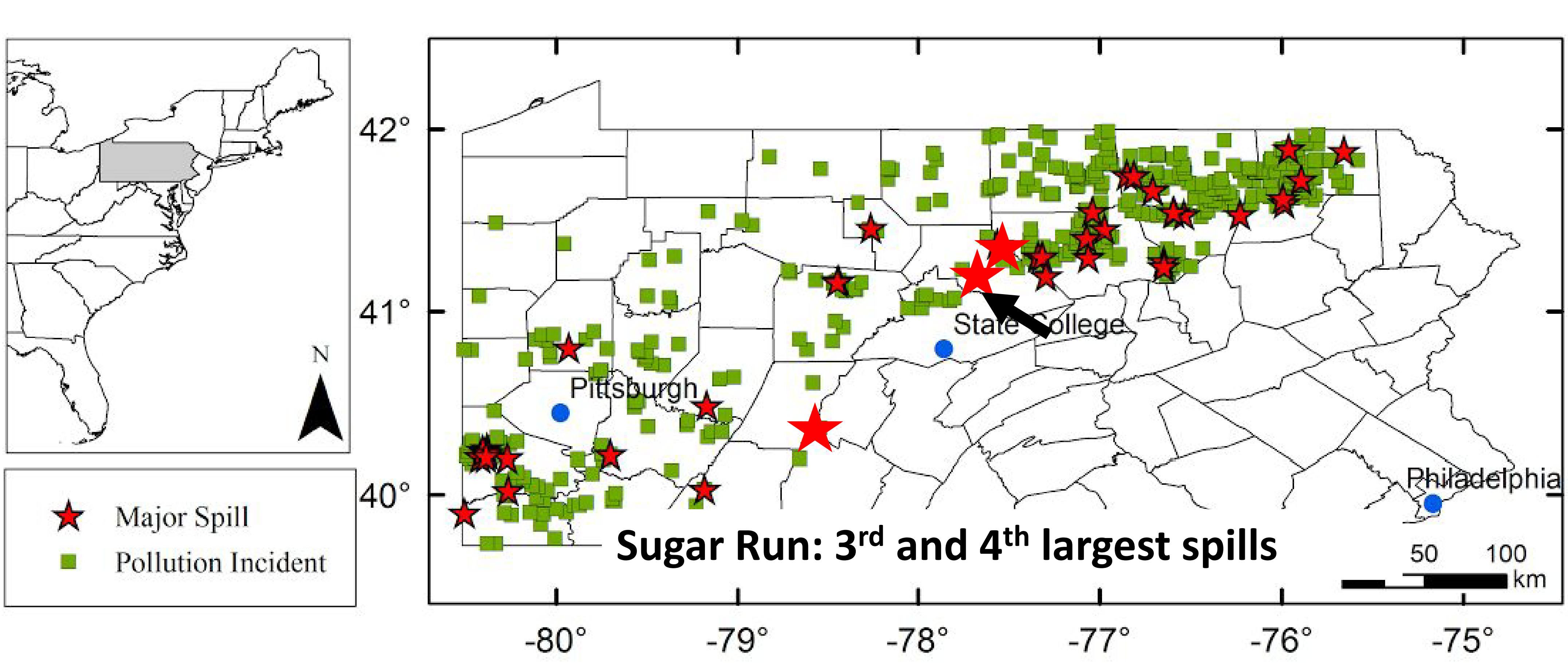
Three examples to be discussed



Pine Creek: Several spills, well monitored

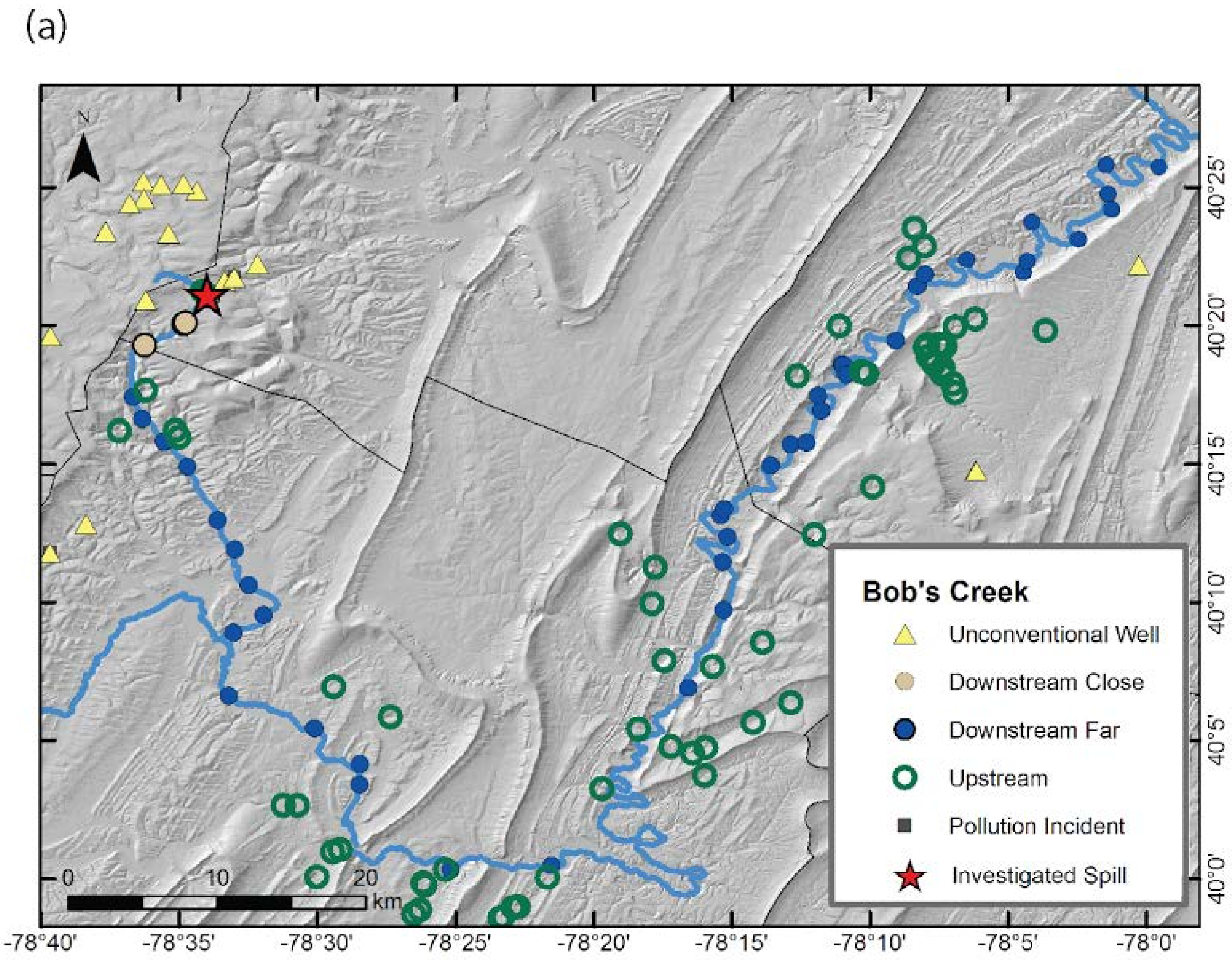
From A. Wendt, Penn State. Data from PADEP as of March 2015 (violations), Dec 2014 (spills).

Three examples to be discussed



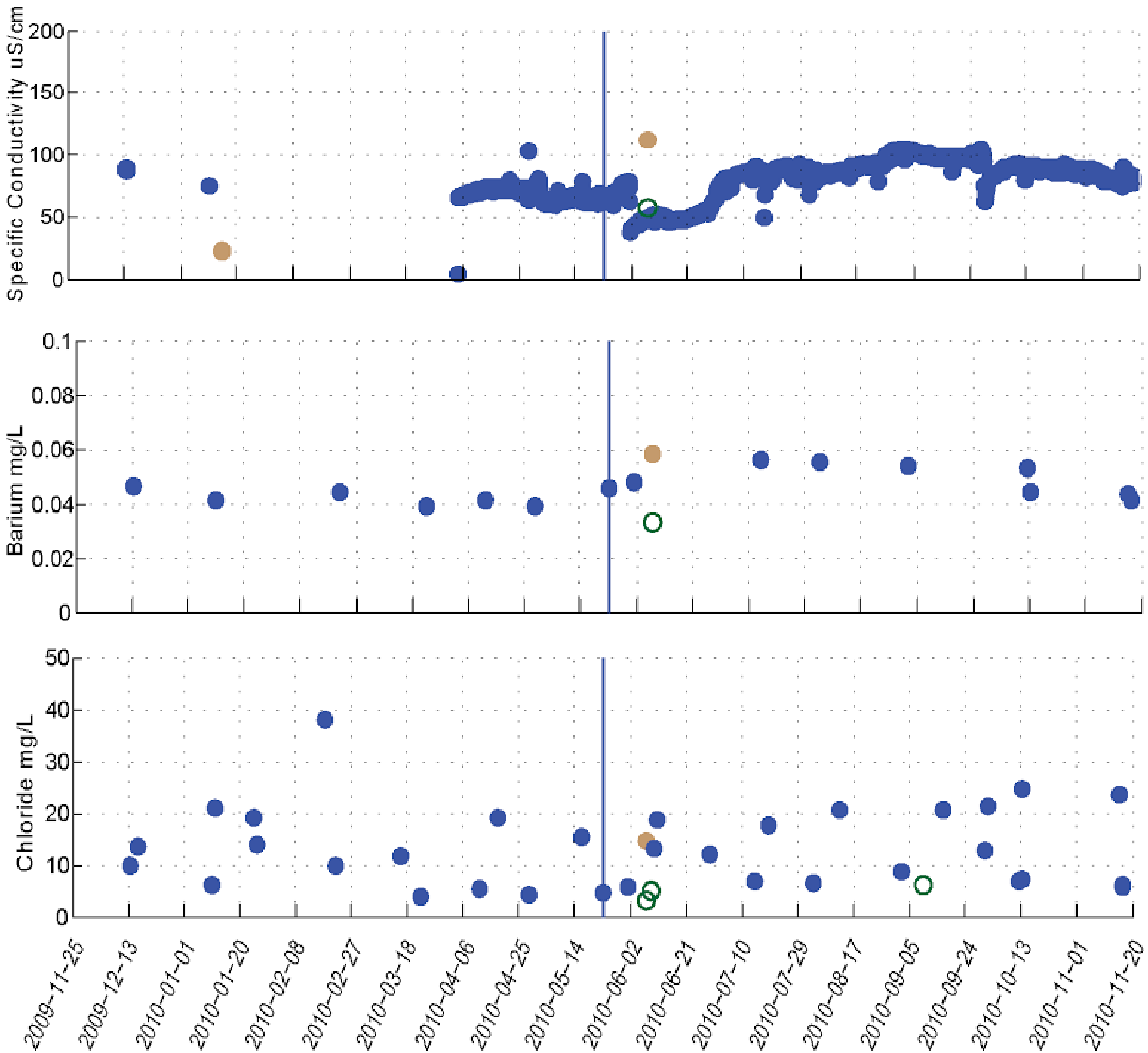
From A. Wendt, Penn State. Data from PADEP as of March 2015 (violations), Dec 2014 (spills).

Bob’s Creek, Blair County



- A spill of flowback fluid occurred on May 24, 2010

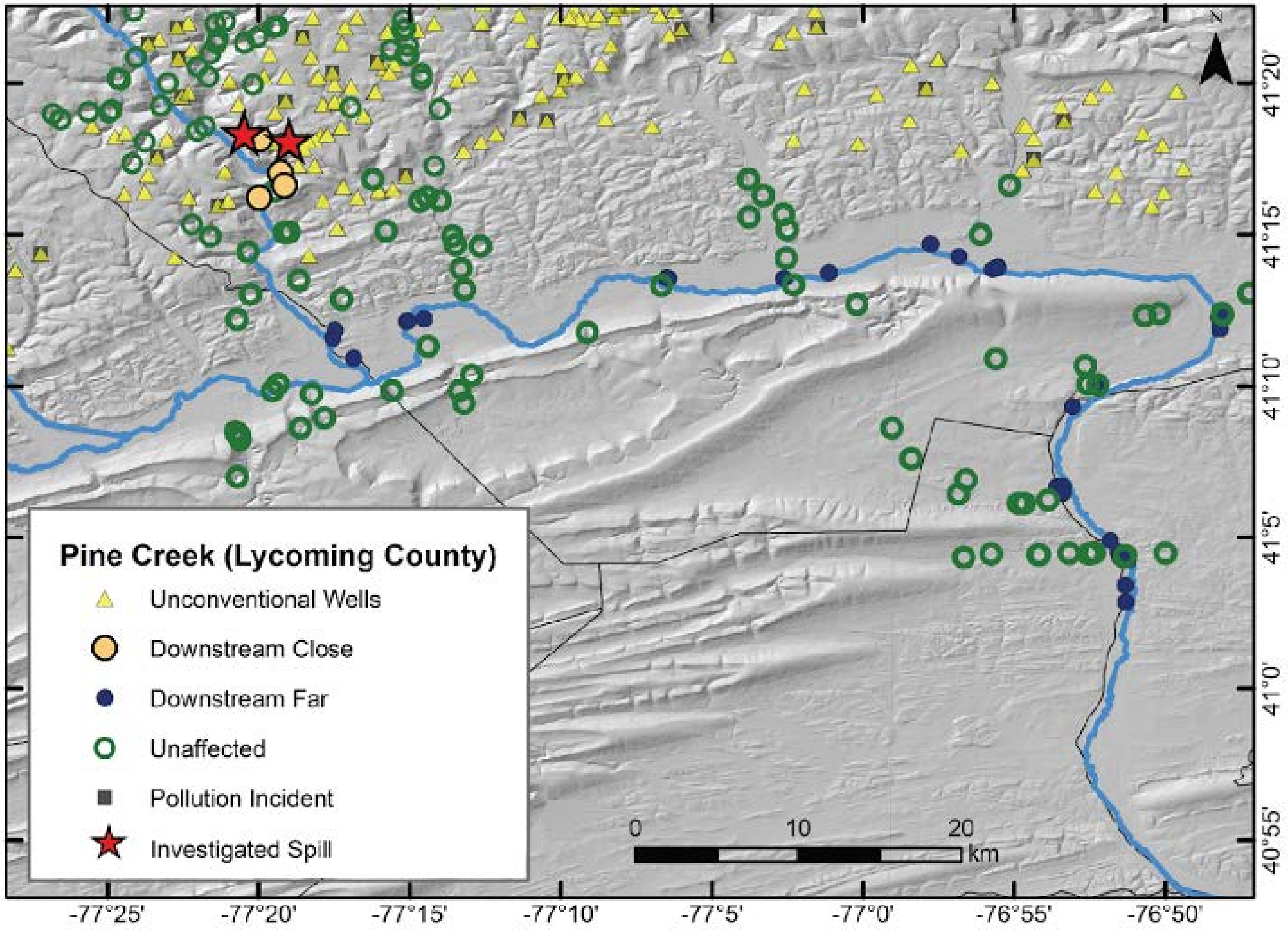
Bob's Creek, Blair County



- A leak in a liner allowed flowback water to run off a well pad site (leak discovered 5/24/2010 but was presumed to have started earlier) and PA DEP thought that some contaminant got into Bob's creek, a Class A trout stream in Juniata Township, Blair County.
- Increases in barium, chloride, and specific conductance were detected within approximately 2 weeks of the spill and were documented by DEP
- Analyte concentrations show a general increase after the incident at downstream sites.

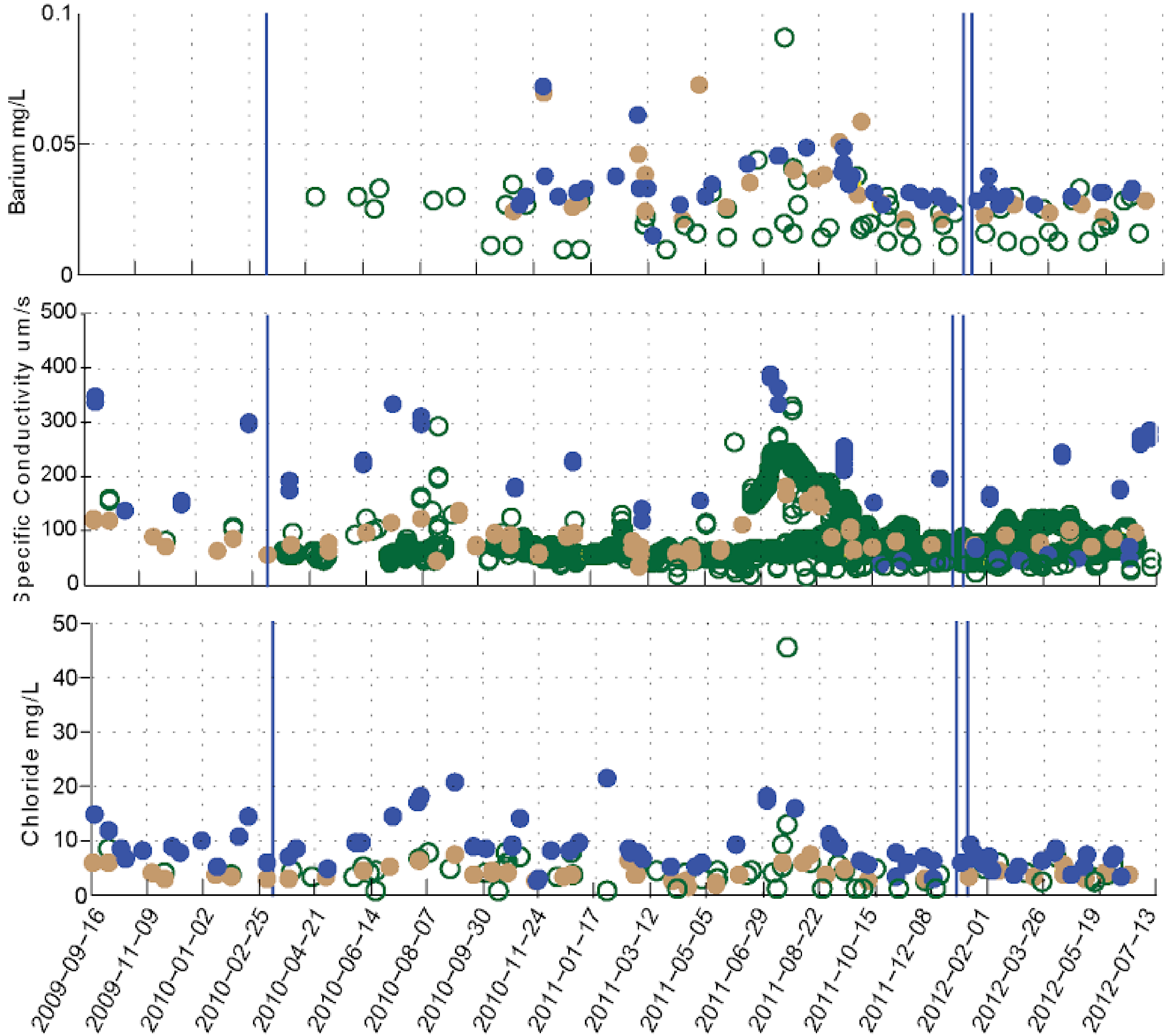
Pine Creek, Lycoming County

(a)



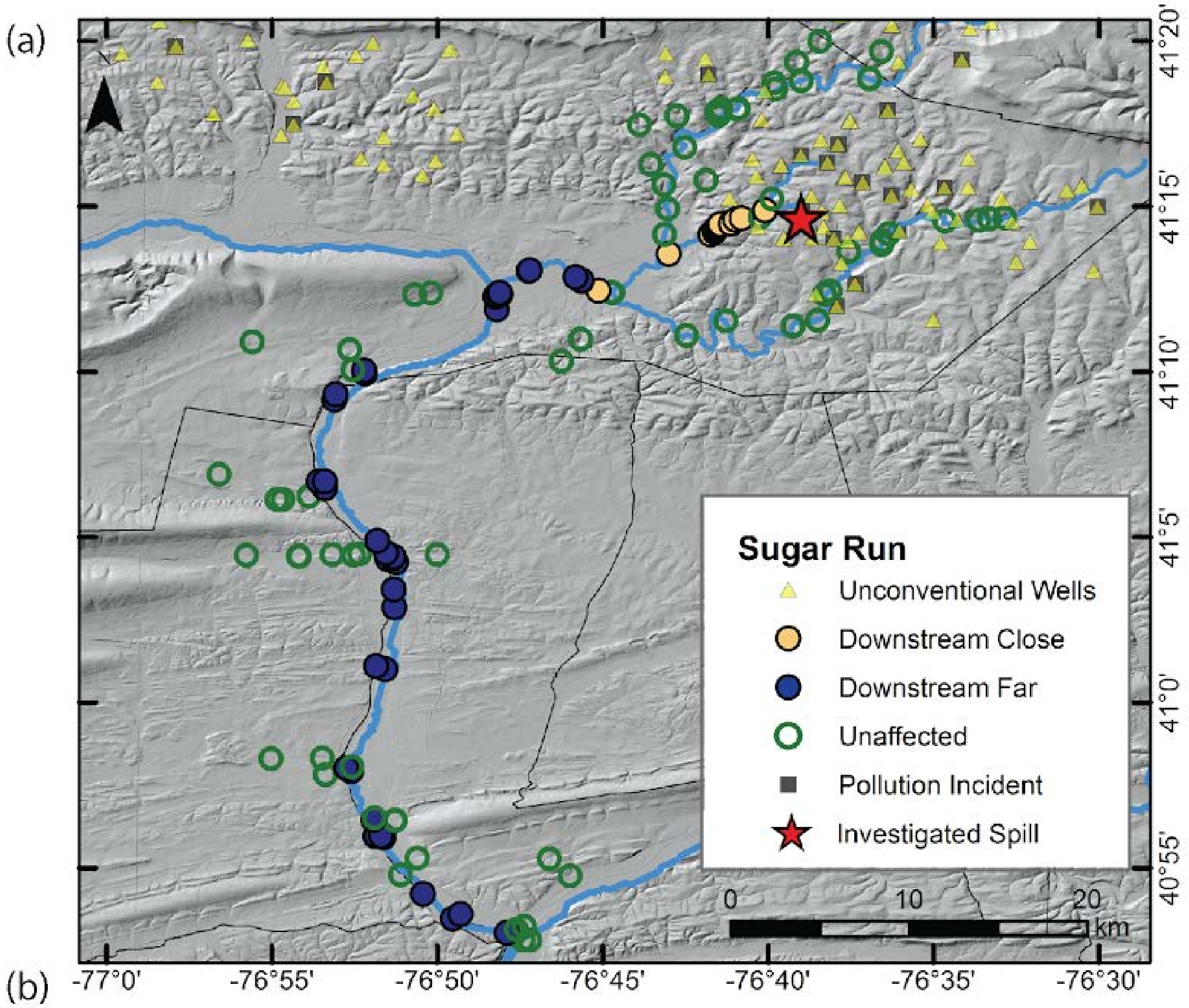
- A spill of Airfoam occurred on March 13 and March 14, 2010
- A spill of 8200 gallons of brine occurred on 1/6/2012
- A spill of 89 gal of diesel occurred on 1/15/2012

Pine Creek, Lycoming County



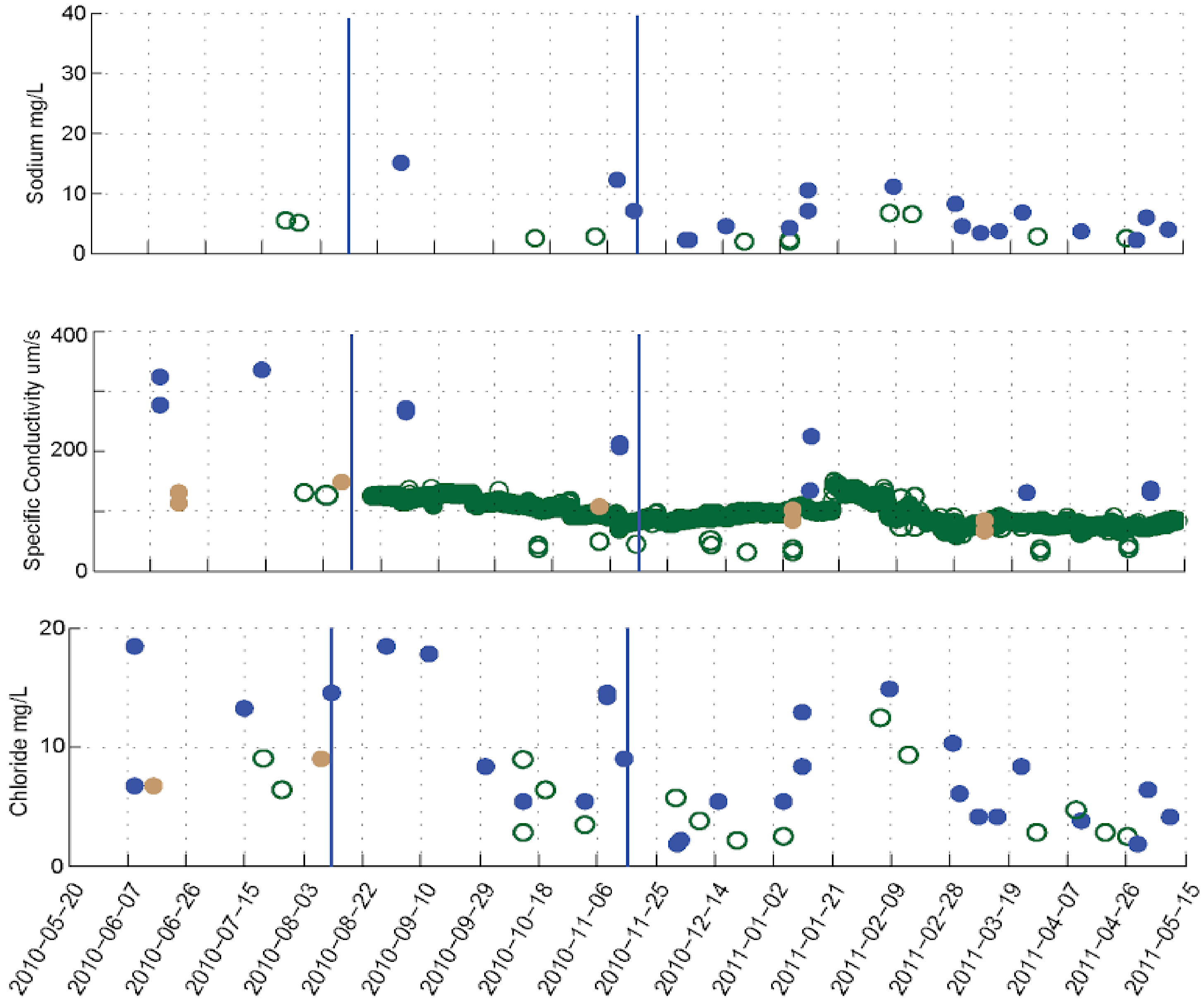
- A spill of Airfoam occurred on March 13 and March 14, 2010
- A spill of 8200 gallons of brine occurred on 1/6/2012
- A spill of 89 gal of diesel occurred on 1/15/2012
- Increases in barium, chloride, and Specific Conductance were detected approximately 2 weeks after the spill
- Barium and chloride concentrations increase approximately a month after the third spill
- Increases in concentrations of analytes in upstream waters are observed in July 2011
    - No documented incident to explain this increase

Sugar Run, Lycoming County



- A spill of 25200 gallons of hydrostatic testing fluid occurred on August 12, 2010.
- A spill of 6300 - 57373 gallons of flowback and produced water and bentonite occurred over 65 days before being detected on November 16, 2010

Sugar Run, Lycoming County



- A spill of 25200 gallons of hydrostatic testing fluid occurred on August 12, 2010.
- A spill of 6300 - 57373 gallons of flowback and produced water and bentonite occurred over 65 days before being detected on November 16, 2010
- Increase over 65 day period in Chloride and Spec. Cond. that decreases after detection

Conclusion I:

Out of 43 large spills in PA we really only see elevated concentrations in

- Ba, Cl and Sp. Cond at Bob’s Creek, Blair
- Ba, Cl and Sp. Cond at Pine Creek, Lycoming
- Cl and Sp. Cond at Sugar Run, Lycoming

Conclusion I:

Out of 43 large spills in PA we really only see elevated concentrations in

- Ba, Cl and Sp. Cond at Bob’s Creek, Blair
- Ba, Cl and Sp. Cond at Pine Creek, Lycoming
- Cl and Sp. Cond at Sugar Run, Lycoming

- In every case, documented impact is ephemeral

Conclusion I:

Out of 43 large spills in PA we really only see elevated concentrations in

- Ba, Cl and Sp. Cond at Bob's Creek, Blair
- Ba, Cl and Sp. Cond at Pine Creek, Lycoming
- Cl and Sp. Cond at Sugar Run, Lycoming

- In every case, documented impact is ephemeral

Preliminary statistical analysis:

- No Statistical difference between values before or after spill

We also looked at 3 of the sites with the best data coverage or with some indication of contamination and analyzed:

- Mean concentrations before drilling commenced in the watershed upstream
- Mean concentrations after drilling commenced in the watershed upstream
- Mean concentrations before drilling commenced in the watershed close downstream
- Mean concentrations after drilling commenced in the watershed close downstream
- Mean concentrations before drilling commenced in the watershed far downstream
- Mean concentrations after drilling commenced in the watershed far downstream

We also looked at 3 of the sites with the best data coverage or with some indication of contamination and analyzed :

		Pine Creek, Lycoming County			Sugar Run, Lycoming County		
		Mean	Stnd. Dev	N	Mean	Stnd. Dev	N
Chloride (mg/L)	Downstream Close Before Drilling	5.50	2.80	35	--	--	0
	Downstream Close After Drilling	3.85	1.40	153	6.57	2.05	33
	Downstream Far Before Drilling	13.71	32.84	66	11.2	5.1	43
	Downstream Far After Drilling	8.24	4.00	163	13.68	7.04	255
	Upstream Before Drilling	5.51	2.19	62	7.26	4.93	336
	Upstream After Drilling	5.24	4.43	153	5.80	3.84	130
Magnesium (mg/L)	Downstream Close Before Drilling	2.81	3.45	230	2.10	0.39	69
	Downstream Close After Drilling	2.33	0.77	153	2.00	0.34	63
	Downstream Far Before Drilling	9.01	4.52	241	5.74	3.90	367
	Downstream Far After Drilling	5.77	4.14	190	5.59	2.96	280
	Upstream Before Drilling	3.20	3.47	381	7.41	5.80	257
	Upstream After Drilling	2.47	1.87	274	2.59	2.98	242
Spec. Cond (uS/m)	Downstream Close Before Drilling	112.19	122.52	243	101.33	23.64	70
	Downstream Close After Drilling	89.74	29.56	321	112.38	22.89	94
	Downstream Far Before Drilling	233.57	104.91	487	206.45	91.06	716
	Downstream Far After Drilling	194.65	95.77	336	199.18	74.30	560
	Upstream Before Drilling	111.21	71.67	413	203.11	98.61	1013
	Upstream After Drilling	32.00	12.03	290933	104.78	22.78	6530

- Mean values appear to decrease after drilling begins

We also looked at 3 of the sites with the best data coverage or with some indication of contamination and analyzed :

		Pine Creek, Lycoming County			Sugar Run, Lycoming County		
		Mean	Stnd. Dev	N	Mean	Stnd. Dev	N
Chloride (mg/L)	Downstream Close Before Drilling	5.50	2.80	35	--	--	0
	Downstream Close After Drilling	3.85	1.40	153	6.57	2.05	33
	Downstream Far Before Drilling	13.71	32.84	66	11.2	5.1	43
	Downstream Far After Drilling	8.24	4.00	163	13.68	7.04	255
	Upstream Before Drilling	5.51	2.19	62	7.26	4.93	336
	Upstream After Drilling	5.24	4.43	153	5.80	3.84	130
Magnesium (mg/L)	Downstream Close Before Drilling	2.81	3.45	230	2.10	0.39	69
	Downstream Close After Drilling	2.33	0.77	153	2.00	0.34	63
	Downstream Far Before Drilling	9.01	4.52	241	5.74	3.90	367
	Downstream Far After Drilling	5.77	4.14	190	5.59	2.96	280
	Upstream Before Drilling	3.20	3.47	381	7.41	5.80	257
	Upstream After Drilling	2.47	1.87	274	2.59	2.98	242
Spec. Cond (uS/m)	Downstream Close Before Drilling	112.19	122.52	243	101.33	23.64	70
	Downstream Close After Drilling	89.74	29.56	321	112.38	22.89	94
	Downstream Far Before Drilling	233.57	104.91	487	206.45	91.06	716
	Downstream Far After Drilling	194.65	95.77	336	199.18	74.30	560
	Upstream Before Drilling	111.21	71.67	413	203.11	98.61	1013
	Upstream After Drilling	32.00	12.03	290933	104.78	22.78	6530

- Mean values appear to decrease after drilling begins
- Preliminary Analysis suggest that there is no statistical difference between mean values before or after drilling

Conclusion II:

- Thus far, the publicly available data document that the mean concentration of 2 analytes (Cl- and Spec Cond) were higher in concentration downstream after drilling commenced as compared to before drilling commenced at 2 sites

For the 3 sites with 7 analytes there was no statistical significant difference between **before and after upstream concentrations** for any site or analyte.

We can call mean of the entire upstream data the "background":

Upstream or Background Mean Values

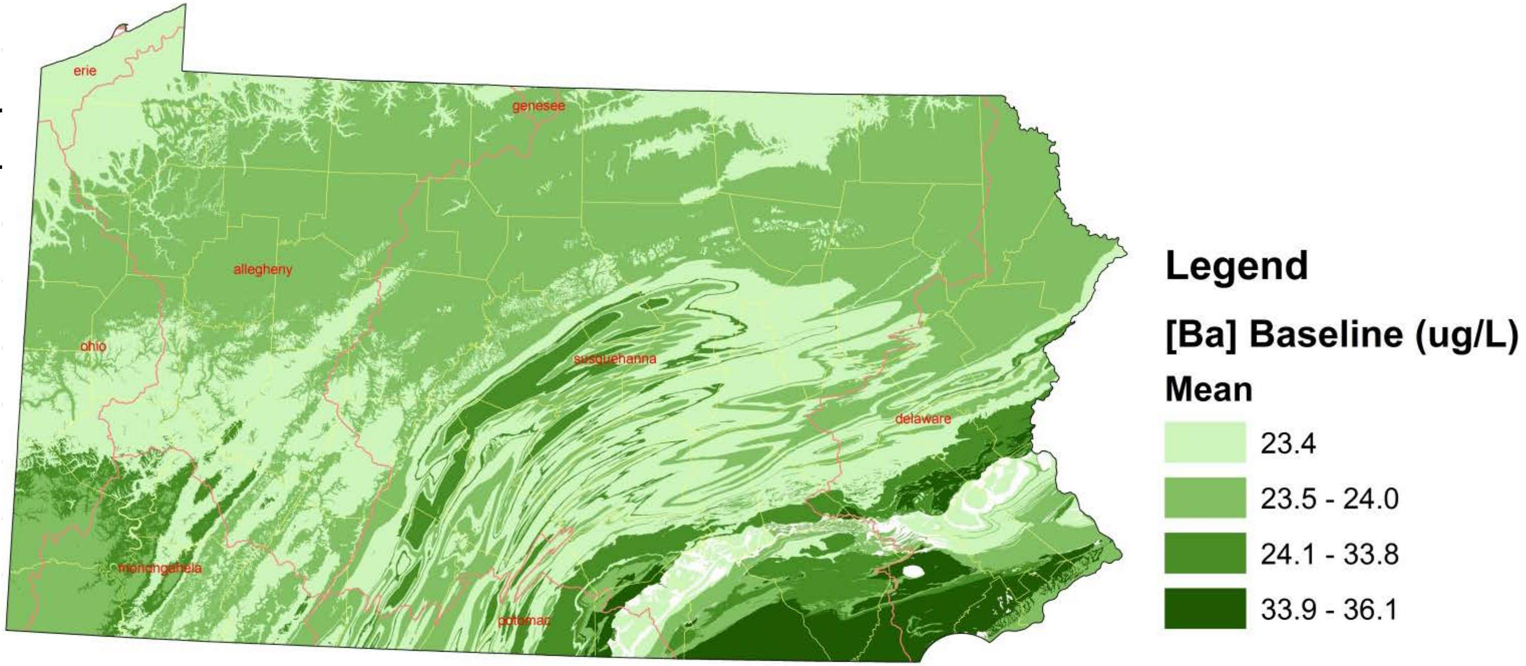
Analyte	Mean
Barium ug/L	35.5
Bromide ug/L	103.0
Chloride mg/L	7.04
Magneisum mg/L	3.52
Sp. Conudc uS/m	116.5
Sodium mg/L	5.43
Strontium mg/L	75.0

For the 3 sites with 7 analytes there was no statistical significant difference between **before and after upstream concentrations** for any site or analyte.

We can call mean of the entire upstream data the “background”:

Upstream or Background Mean Values

Analyte	Mean
Barium ug/L	35.5
Bromide ug/L	103.0
Chloride mg/L	7.04
Magneisum mg/L	3.52
Sp. Conudc uS/m	116.5
Sodium mg/L	5.43
Strontium mg/L	75.0



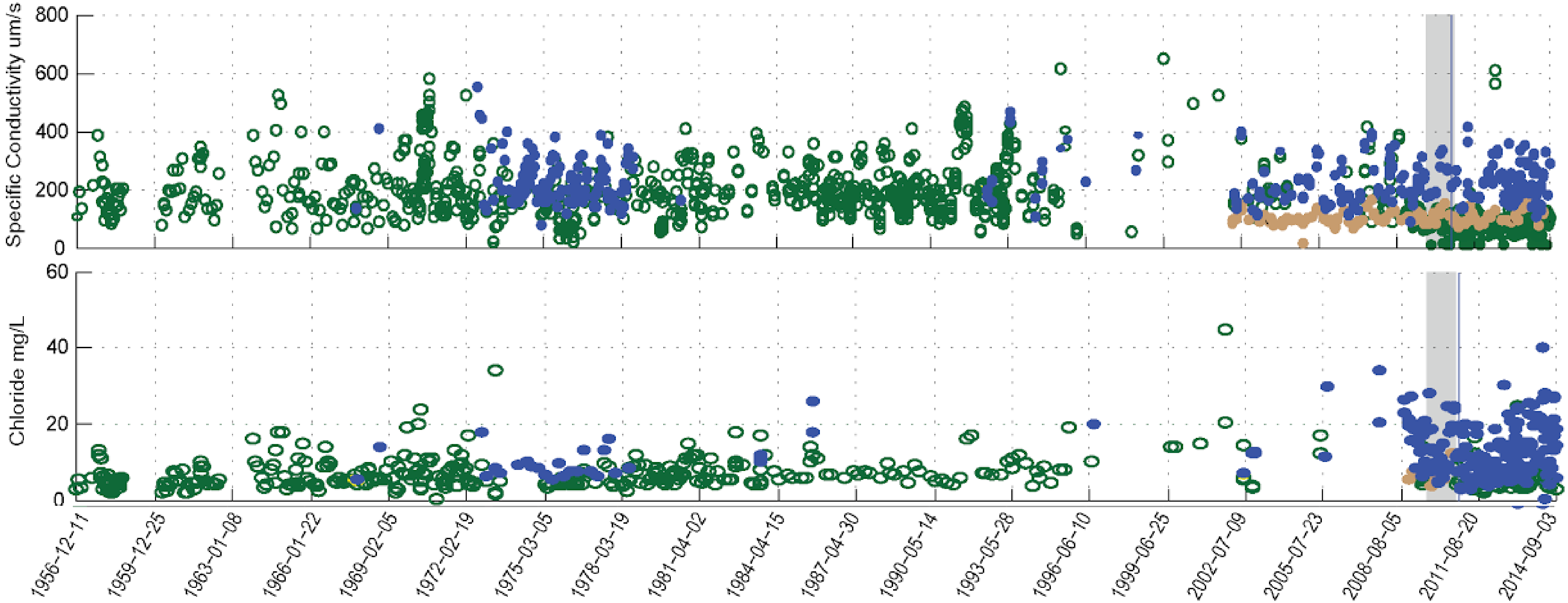
Map from Niu’s talk this afternoon

Thus far, only 2 sites showed differences between downstream (close or far) after drilling and this upstream background concentration:

- Chloride and Sp. Conductivity at Sugar Run, Lycoming

Thus far, only 1 sites showed differences between downstream (close or far) after drilling and this upstream background concentration:

- Chloride and Sp. Conductivity at Sugar Run, Lycoming



Conclusion III:

- Out of 3 impacted spill areas in PA, we observed in the publicly available data that the mean concentration of 2 analytes (Cl and Sp Cond) downstream was higher after drilling commenced as compared to before drilling commenced at Sugar Run, Lycoming County.

What does this say about the impact of drilling at the 3 sites?

- While small variations in concentration are observed:

- Averages before and after drilling are statistically the same
- Averages between upstream and downstream sites are statistically the same

Conclusions

- We only see change in the water chemistry when spills were specifically targeted but not statistically significant
  - We see a change at Bob's Creek
  - We don't have the sampling density even for the biggest spills
- Upstream sites can be used to assess background water quality values and compare with Niu's work
- Concentrations are not statistically different before or after drilling, or upstream or downstream of the spill site for these specific watersheds observed in the publically available database

Acknowledgements

- Shale Network, Sue Brantley, Fei Wu, Matt Gonzales, Niu, Jessie Li