Continuous Water Quality Trends Adjusted for Seasonality and Streamflow in the Susquehanna River Basin

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Shale Network Workshop

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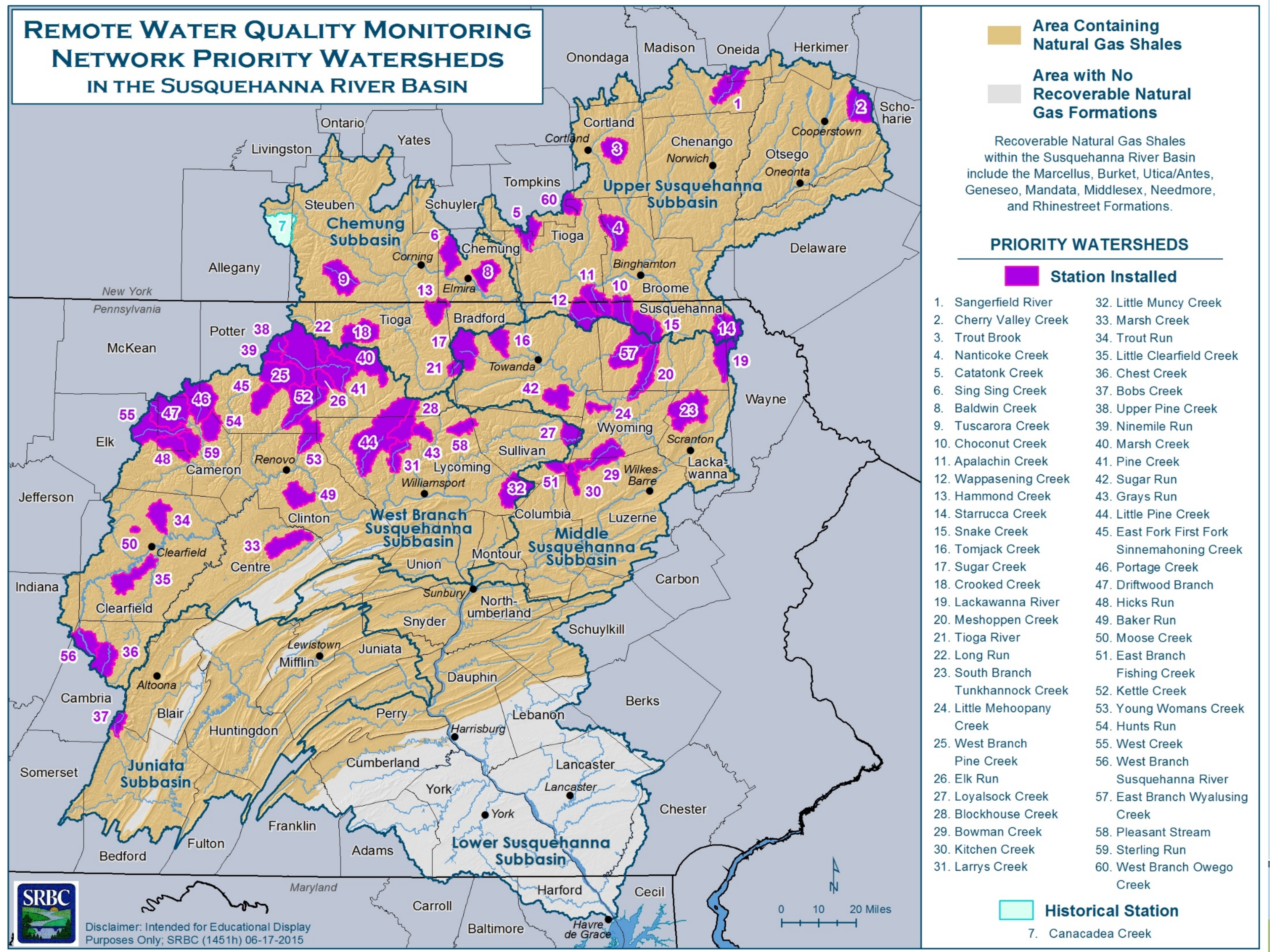
Monitoring Network

- Initiated in 2010
  - Northern PA and southern NY
- 53 stations had 3+ years of continuous data by the end of 2015
- Parameters monitored: pH, temperature, specific conductance, dissolved oxygen, and turbidity



Remote Water Quality Monitoring Network Priority Watersheds
in the Susquehanna River Basin
Area Containing Natural Gas Shales
Area with No Recoverable Natural Gas Formations
Recoverable Natural Gas Shales within the Susquehanna River Basin include the Marcellus, Burket, Utica/Antes, Geneseo, Mandata, Middlesex, Needmore, and Rhinestreet Formations.
PRIORITY WATERSHEDS
Station Installed
1. Sangerfield River
2. Cherry Valley Creek
3. Trout Brook
4. Nanticoke Creek
5. Catatonk Creek
6. Sing Sing Creek
8. Baldwin Creek
9. Tuscarora Creek
10. Choconut Creek
11. Apalachin Creek
12. Wappasening Creek
13. Hammond Creek
14. Starrucca Creek
15. Snake Creek
16. Tomjack Creek
17. Sugar Creek
18. Crooked Creek
19. Lackawanna River
20. Meshoppen Creek
21. Tioga River
22. Long Run
23. South Branch Tunkhannock Creek
24. Little Mehoopany Creek
25. West Branch Pine Creek
26. Elk Run
27. Loyalsock Creek
28. Blockhouse Creek
29. Bowman Creek
30. Kitchen Creek
31. Larrys Creek
32. Little Muncy Creek
33. Marsh Creek
34. Trout Run
35. Little Clearfield Creek
36. Chest Creek
37. Bobs Creek
38. Upper Pine Creek
39. Ninemile Run
40. Marsh Creek
41. Pine Creek
42. Sugar Run
43. Grays Run
44. Little Pine Creek
45. East Fork First Fork Sinnemahoning Creek
46. Portage Creek
47. Driftwood Branch
48. Hicks Run
49. Baker Run
50. Moose Creek
51. East Branch Fishing Creek
52. Kettle Creek
53. Young Womans Creek
54. Hunts Run
55. West Creek
56. West Branch Susquehanna River
57. East Branch Wyalusing Creek
58. Pleasant Stream
59. Sterling Run
60. West Branch Owego Creek
Historical Station
7. Canacadea Creek
Upper Susquehanna Subbasin
Chemung Subbasin
West Branch Susquehanna Subbasin
Middle Susquehanna Subbasin
Juniata Subbasin
Lower Susquehanna Subbasin
New York
Pennsylvania
Maryland
Onondaga
Madison
Oneida
Herkimer
Scho-harie
Ontario
Yates
Livingston
Cortland
Chenango
Otsego
Tompkins
Steuben
Schuyler
Chemung
Tioga
Allegany
Delaware
Broome
Susquehanna
Bradford
Potter
McKean
Elk
Cameron
Wayne
Wyoming
Sullivan
Lycoming
Clinton
Jefferson
Clearfield
Centre
Union
Montour
Columbia
Luzerne
Lacka-wanna
Carbon
North-umberland
Snyder
Schuylkill
Indiana
Cambria
Blair
Huntingdon
Mifflin
Juniata
Dauphin
Perry
Berks
Lebanon
Somerset
Cumberland
Lancaster
York
Chester
Franklin
Fulton
Bedford
Adams
Carroll
Baltimore
Harford
Cecil
Cortland
Norwich
Cooperstown
Oneonta
Binghamton
Corning
Elmira
Towanda
Scranton
Wilkes-Barre
Renovo
Williamsport
Clearfield
Sunbury
Lewistown
Altoona
Harrisburg
Lancaster
York
Havre de Grace
0 10 20 Miles
N
SRBC
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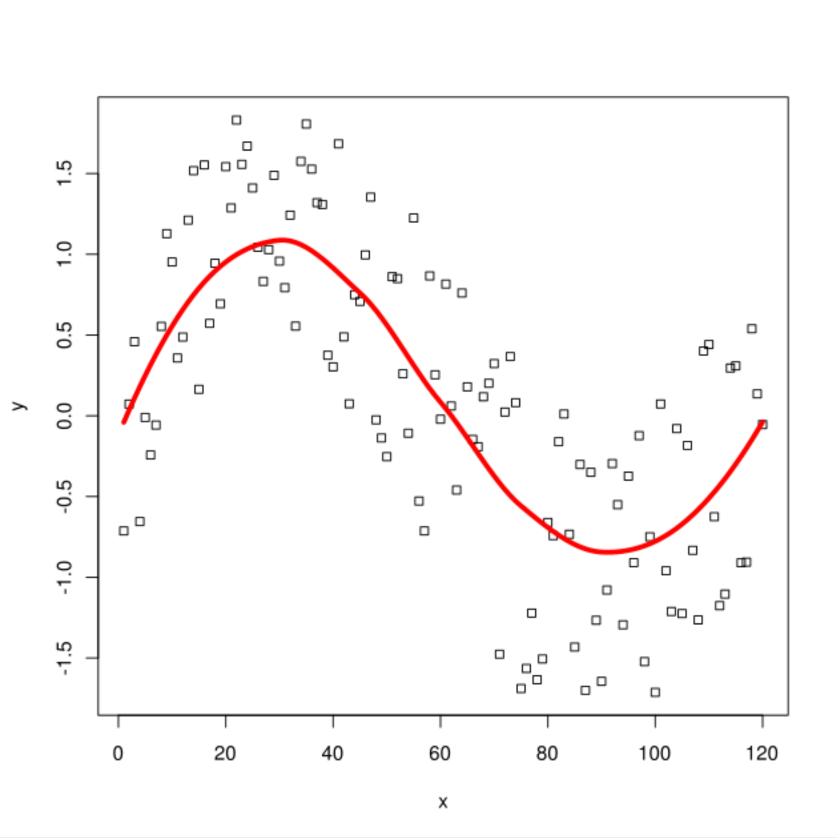
Trend Tests

- Determines if a series of observations generally increases or decreases over time
- Does not attribute trend to a particular cause
- If water quality is changing over time, is it due to:
  - Streamflow variability?
  - Seasonality?
  - External, anthropogenic factors?

Flow Normalized Trend Test Methods

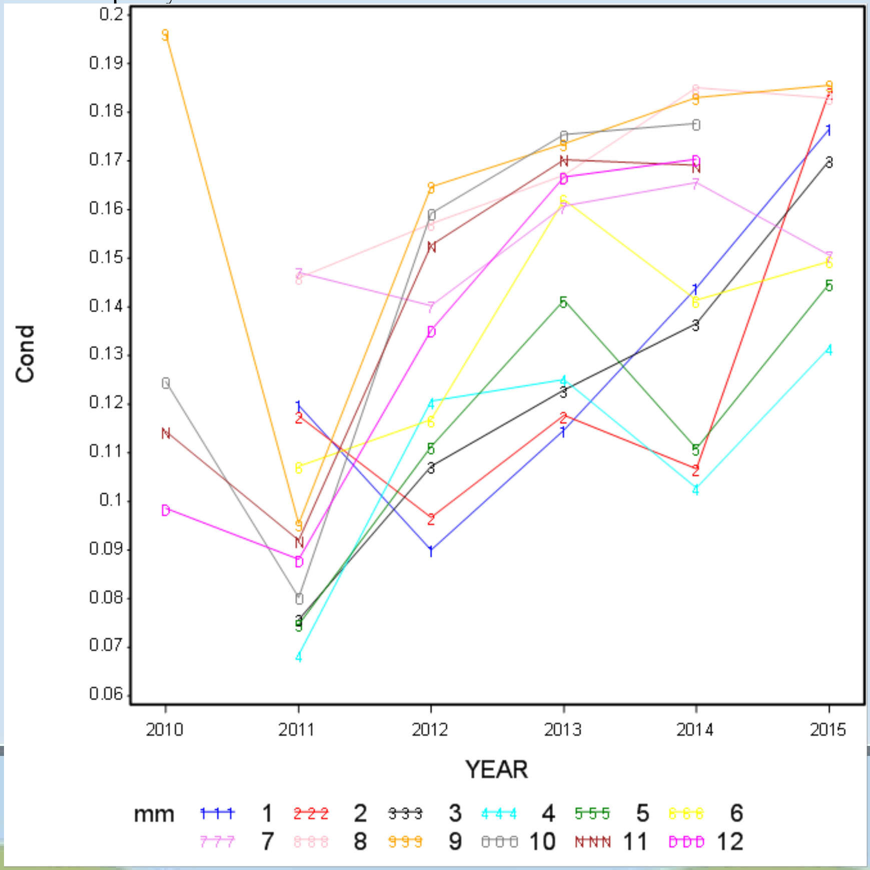
- Locally Weighted Scatterplot Smoothing (LOWESS) algorithm
  - used to define relationship between water quality parameters and streamflows
- Residuals from LOWESS
  - show water quality parameters uninfluenced by streamflow



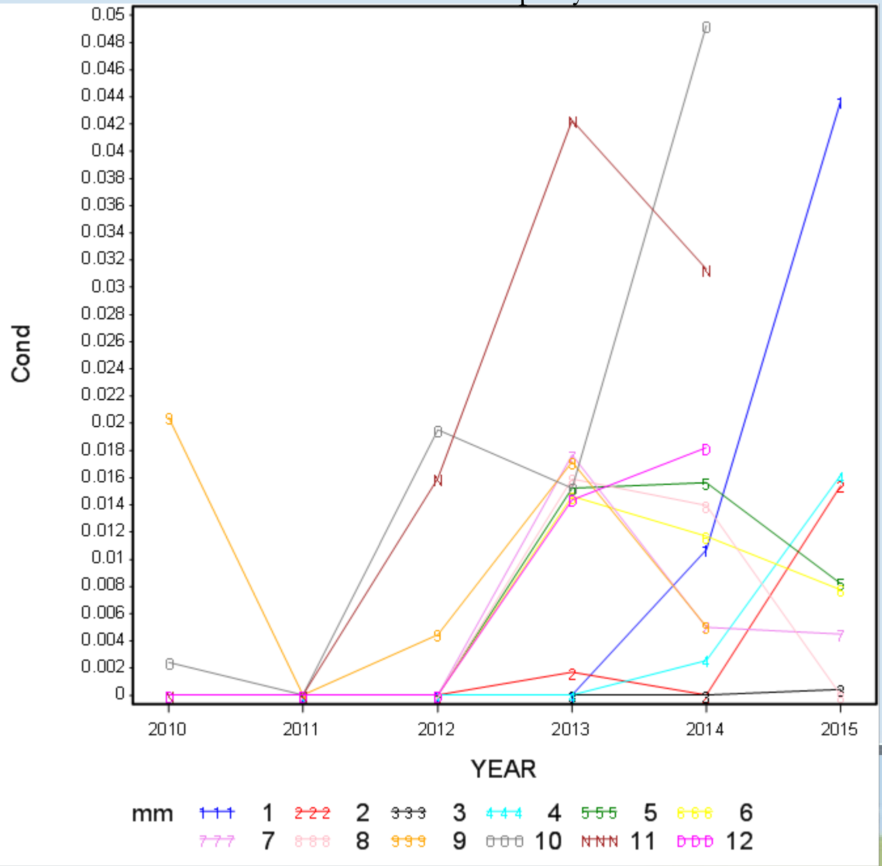
Flow Normalized Trend Test Methods

- Mann-Kendall (non-parametric) trend test performed on average, monthly residual values from LOWESS operation
  - excludes influences of seasonality

Raw, average monthly conductance values at Little Mehoopany Creek



Average monthly, flow normalized (LOWESS residuals) conductance values at Little Mehoopany Creek



Streamflow Estimation

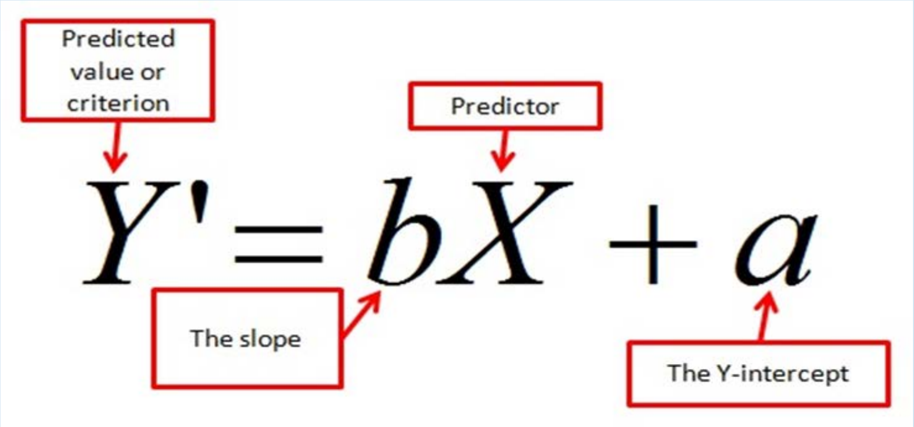
- Instantaneous streamflow data not available for 49 out of 53 RWQMN stations
- Used USGS Reference Gage information to estimate streamflow at RWQMN stations
- Considerations
  - Time step of analysis (hours, days, weeks, seasons, years)
  - Accuracy of estimation vs. cost of applying a more complex method

Select Methods

- Drainage Area Ratio

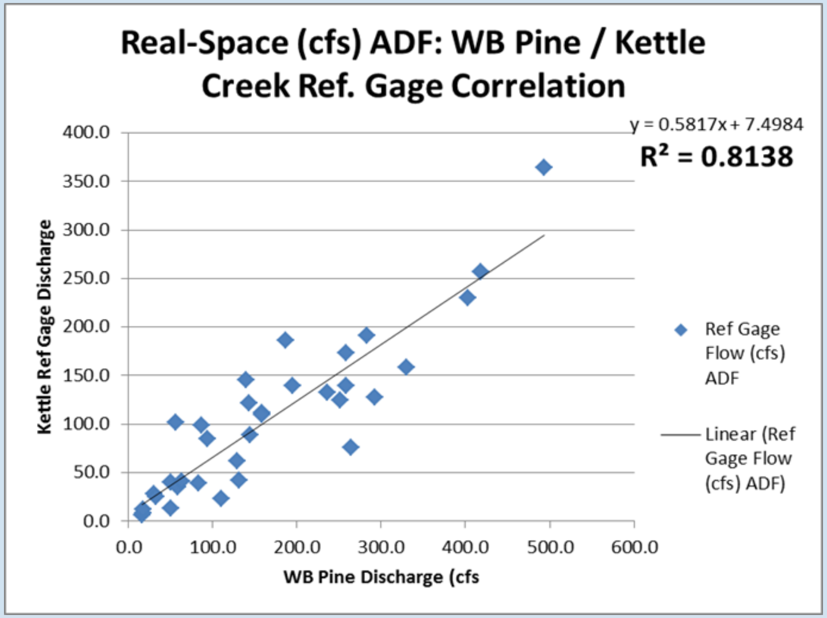
$$Q_{ungaged} = \frac{DA_{ungaged}}{DA_{gaged}} x Q_{gaged}$$

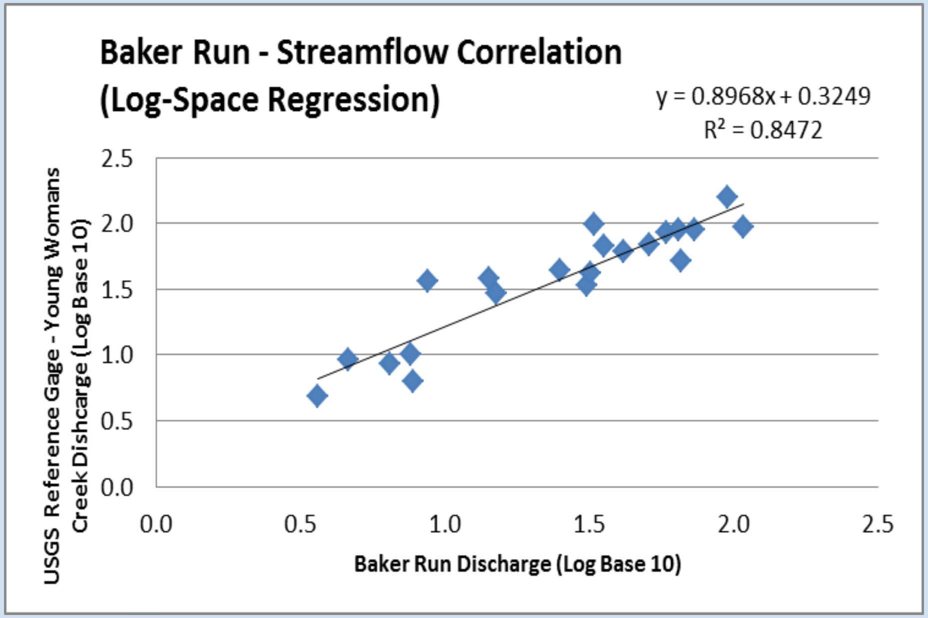
- Linear Regression (Correlation)



Considerations

- Average daily streamflow vs 15 minute timeseries
  - mitigates lag effect of rainfall and runoff between drainage areas (Hawkins and Simas, 2000)
- Real vs. log base 10 transformed data
  - mitigates scaling effects and the issues involving low (negative) flows (EPA, 2009)





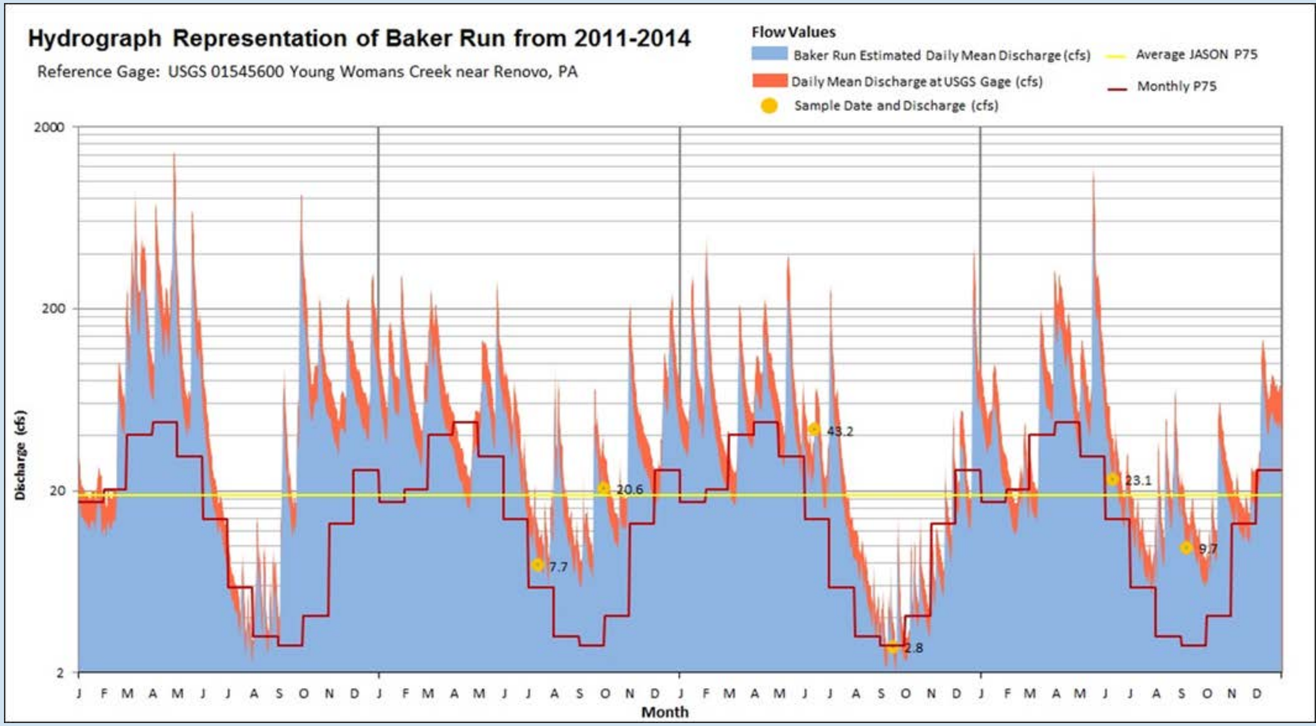
Data Inputs

- 1216 independent discharges at partial record stations
- 6 sites were located at active USGS stations or records were made available
- 11 had less than 10 independent flow measures acquired in the field
- 30 independent USGS gages
  - Streamflow that was minimally altered by regulation, diversion, or mining
  - At least 10 years of continuous record
  - Identified via USGS Baseline Streamflow Estimator (BaSE) tool using map correlation techniques

Results

- With use of both methods, average correlation coefficient at 0.88

- 32 sites most correlated with DA Ratio method
- 17 sites most correlated using log-space regression equation



Limitations/Caveats

- Five years of monthly data required for monotonic trend (continuous rate of change, increasing or decreasing) analysis
- Two years of monthly data is required for step trend (abrupt shift up or down) analysis (Hirsch, 1988)
- Inaccuracies exist with predicting high flows
  - affected by local temporal variations in the timing and duration of precipitation, infiltration, and runoff

Trend Test Results

- 57 individual parameters saw trends at 40 stations
- More specific conductance trends than other parameters

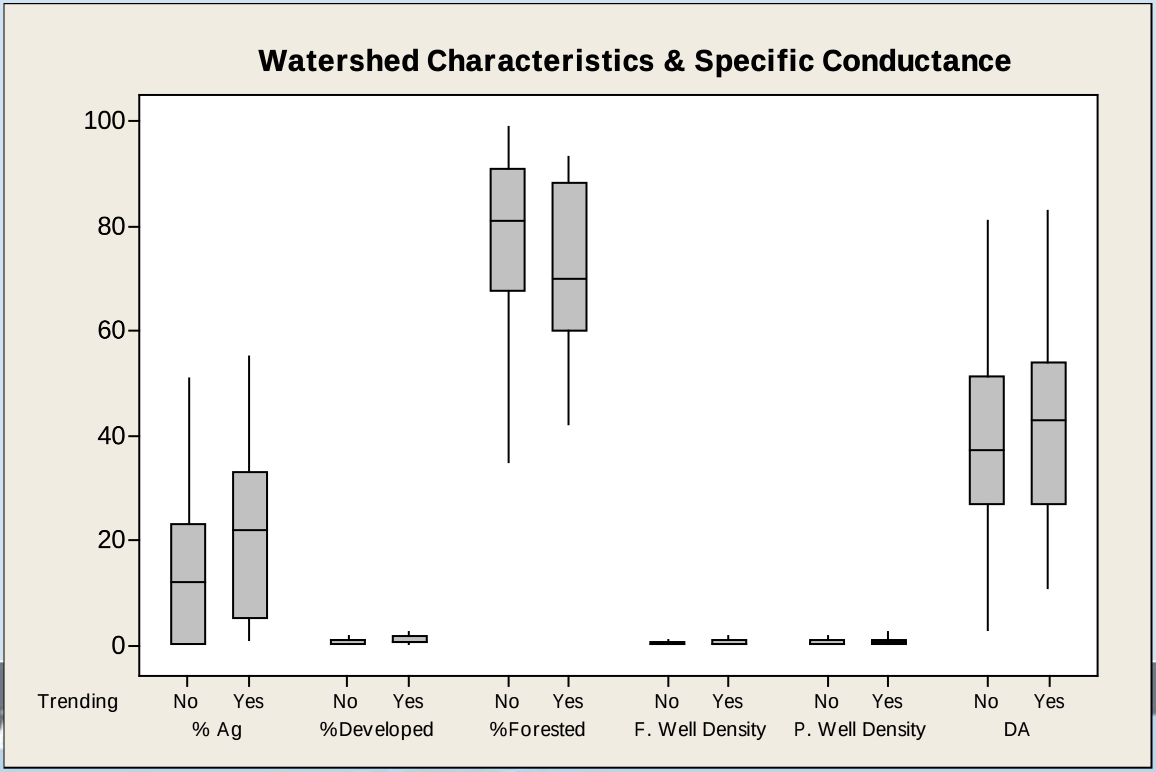
Parameter	Increasing	Decreasing
Specific Conductance	**24**	**1**
pH	1	9
Dissolved Oxygen	8	2
Temperature	3	2
Turbidity	3	4

Specific Conductance

- 24 sites showed increasing conductance trends
- Watershed characteristics were evaluated to determine if stations trending were significantly different from those not trending
- Characteristics included:
  - Drainage area
  - Well Density
  - Land Use (forested, urban, agriculture)
  - Geology

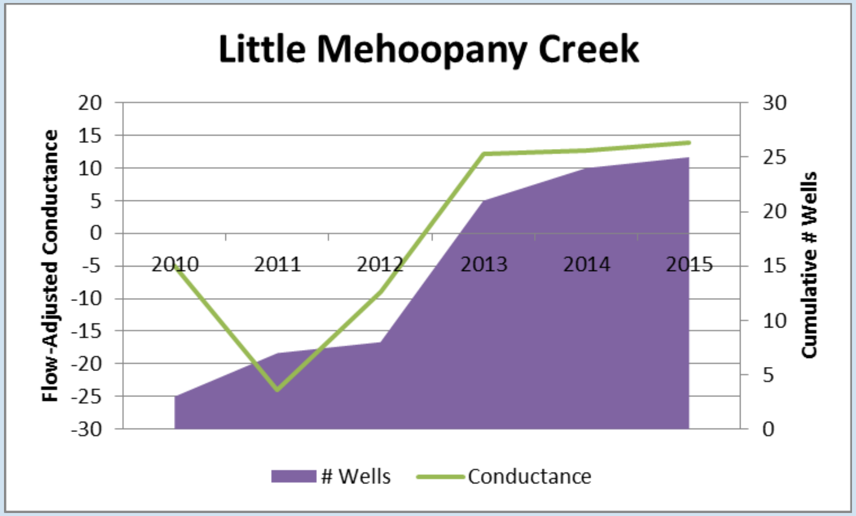
Watershed Characteristics

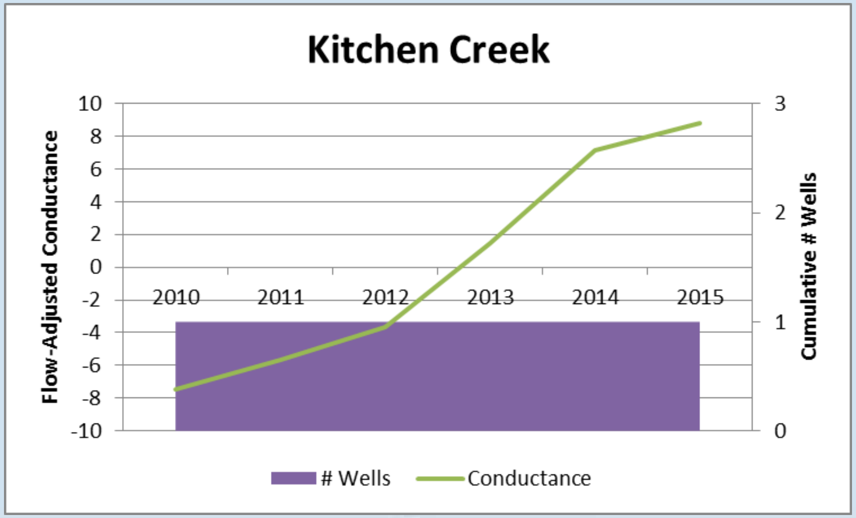
Watershed Characteristic	p-value	Range of stations with increasing trends	Range of stations with no trends
Percent Agriculture Land Use	0.067	1% – 55%	0% – 51%
Percent Developed Land Use	0.144	0 – 9.6%	0 – 3.7%
Percent Forested Land Use	0.110	42% – 93%	35% – 99%
Drainage Area	0.553	11 – 83 mi^2	3 – 385 mi^2
Well Density	0.812	0.0 – 3.86 wells/mi^2	0.0 – 3.69 wells/mi^2
Fracked Well Density	0.416	0.0 – 2.48 wells/mi^2	0.0 – 3.04 wells/mi^2

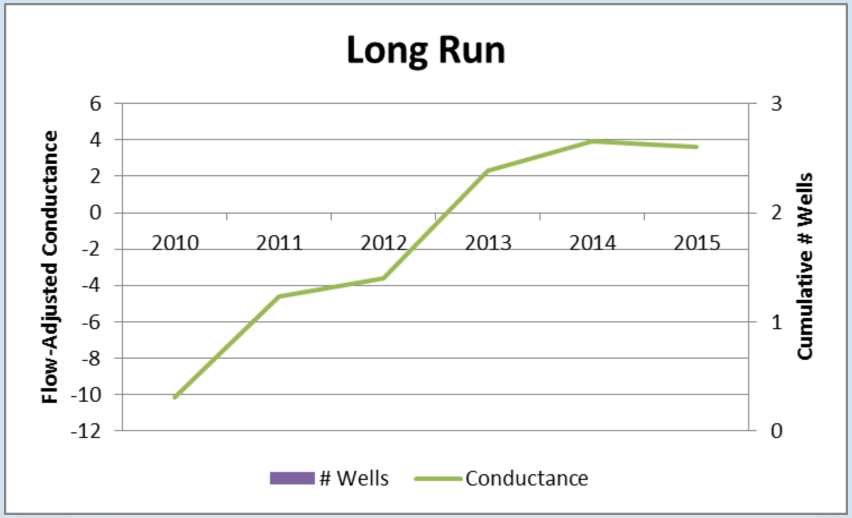


Approved Wells and Conductance

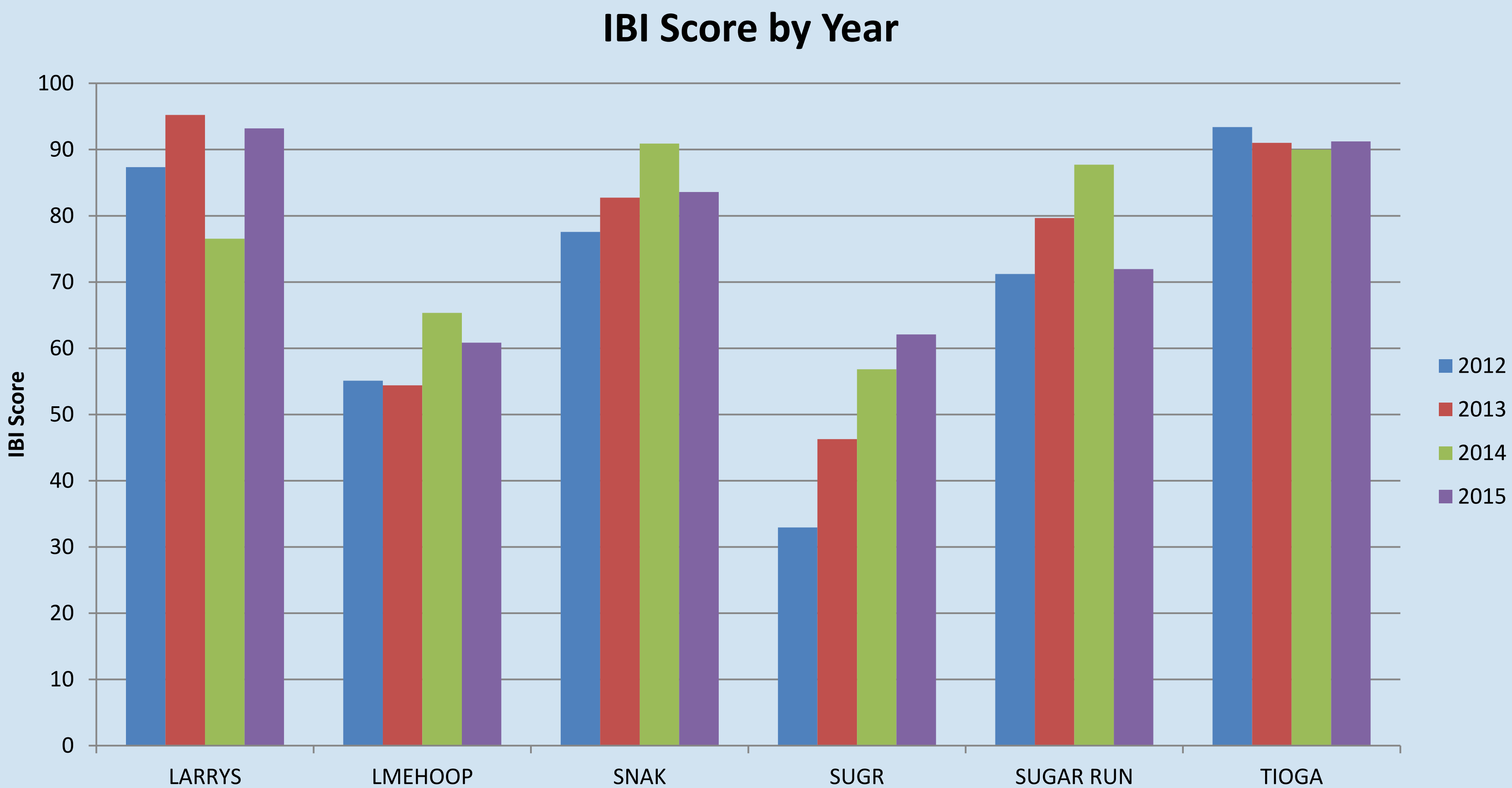
- Is the increasing number of wells causing the increase in conductance?
  - Inconclusive:
    - 6 watersheds – no wells
    - 3 watersheds – no increase in # of wells
    - 15 watersheds – increase in # of wells
    - Results for watersheds with no conductance trends are similar







Macroinvertebrate IBI scores at Stations with Increasing Conductance Values



Conclusions

- Watershed characteristics (watershed size, land use, natural gas well density, etc.) for stations with increasing conductance were not statistically different from those at stations with no observable trends.
- Overtime, the increase in conductance did not correlate to the increase in fractured natural gas wells as increasing conductance trends were observed in watersheds experiencing both natural gas and non-gas related activities.
- IBI scores showed no significant changes to the aquatic biological community, as a function of increased conductance trends.

Next Steps

- Revisit water quality trends when 10 years of continuous data are available at each site
- Select a subset of stations with conductance trends to study further – watersheds with drilling and without drilling
- Continue to build on the streamflow estimation models

Questions

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