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

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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
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

\[ Q_{\text{ungaged}} = \frac{D_{\text{A Ungaged}}}{D_{\text{A Gaged}}} \times Q_{\text{gaged}} \]

• Linear Regression (Correlation)

\[ Y' = bX + a \]
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Increasing</th>
<th>Decreasing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Conductance</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>pH</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Temperature</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Turbidity</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Watershed Characteristic</th>
<th>p-value</th>
<th>Range of stations with increasing trends</th>
<th>Range of stations with no trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Agriculture Land Use</td>
<td>0.067</td>
<td>1% – 55%</td>
<td>0% – 51%</td>
</tr>
<tr>
<td>Percent Developed Land Use</td>
<td>0.144</td>
<td>0 – 9.6%</td>
<td>0 – 3.7%</td>
</tr>
<tr>
<td>Percent Forested Land Use</td>
<td>0.110</td>
<td>42% – 93%</td>
<td>35% – 99%</td>
</tr>
<tr>
<td>Drainage Area</td>
<td>0.553</td>
<td>11 – 83 mi²</td>
<td>3 – 385 mi²</td>
</tr>
<tr>
<td>Well Density</td>
<td>0.812</td>
<td>0.0 – 3.86 wells/mi²</td>
<td>0.0 – 3.69 wells/mi²</td>
</tr>
<tr>
<td>Fracked Well Density</td>
<td>0.416</td>
<td>0.0 – 2.48 wells/mi²</td>
<td>0.0 – 3.04 wells/mi²</td>
</tr>
</tbody>
</table>

### Watershed Characteristics & Specific Conductance

![Watershed Characteristics & Specific Conductance](image_url)
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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