Evaluation of stream and river water quality in Hamilton Co. OH by volunteers in 2017

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Butler County Stream Team\textsuperscript{4}
Lower Great Miami Citizens’ Water Quality Monitoring\textsuperscript{1}
Saturday Stream Snapshot by Greenacres\textsuperscript{2}
Mill Creek Volunteer Water Quality Monitoring\textsuperscript{3}

integrated by and for

Green Umbrella Watershed Group
July 6, 2018

We monitor 300+ sites monthly for nine months each year using similar methods on the same day, the 2\textsuperscript{nd} and 3\textsuperscript{rd} Saturday of each month.
Here are the rivers we monitor in 5 counties and two states of Greater Cincinnati:

- Whitewater R.
- Great Miami R.
- Mill Creek
- Little Miami R.
- Licking River

Greater Cincinnati inside I-275 Interstate Loop is Drained by 4 Rivers and their flood plains.
Best Studied Metro Area in Country

I. Municipal Sewer District as part of their Consent Decree has had Midwest Biodiversity Institute do ‘stage of the art’ physical, chemical and biological assessment sampling of the MC in 2011 (76 sites), LMR in 2012 (111 sites), GMR in 2013 (62 sites), Ohio R and its tributaries including Taylor Creek in 2014 (45 sites). These will be repeated in 5 years to document impacts of Consent Decree upgrades of CSOs & SSOs.

II. Green Umbrella inaugurates ‘StreamBank Regional Water Quality Database’ containing the chemical water quality of 300 sites monthly in Hamilton, Butler, Warren and Clermont Counties for 2015. The base will soon have 2018 and data from previous years.

Only NSF Long Term Ecological R sites in Baltimore and Phoenix many have better.
Federal Consent Decrees promise abatement in real time

Combined and Sanitary Sewer Overflows
Metropolitan Sewer District funded biosurveys by Midwest Biodiversity Institute in 2011-14 (before) and 2016-2020 (during).

http://msdgc.org/initiatives/water_quality/aboutwebmap.html
Four Volunteer Monitoring Programs in STREAMBANK collect monthly data from > 250 sites in greater Metro Cincinnati.

Little Miami River

Upper Great Miami River

Lower Great Miami R

Mill Creek

http://www.greenumbrella.org/StreamBank-Database
Total Phosphorus Digestion

Total P with DR4000 Nitrate-N with DR3000

Conductivity & Turbidity

Sample labeling & chain of Custody
Each laboratory uses skilled volunteers and EPA approved methods.

- Nitrate with HACH TNT
- Conductivity & turbidity
- Bacterial Petri Dishes with Coli24
- pH foreground & Chlorophyll + Optical Whitners background
Instrumentation

- HACH HQ14d Conductivity Meter
- HACH H160 pH meter
- HACH DR3900 Spectrophotometer for TP and chlor a calibration
- 2100Q Turbimeter
- Turner Aquafluor for Chl a & OW
- HACH DR1900 Spectrophotometer for nitrate
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equipment/ Reagents</th>
<th>Standard Method</th>
<th>Precision</th>
<th>Accuracy</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Phosphates</td>
<td>Grab Sample in 250 mL container/ Digestion with Sulfuric Acid and Potassium Permanganate; then Sodium Hydroxide and Hach PhosVer 3 PO4 Reagents/ Hach DR3900 Spectrophotometer</td>
<td>8190</td>
<td>±0.06 mg/L PO$_4^3$</td>
<td>0.07 mg/L PO$_4^3$</td>
<td>0.00 to 3.50 mg/L PO$_4^3$</td>
</tr>
<tr>
<td>Nitrate-Nitrogen</td>
<td>Grab Sample 250 mL container/ Hach NitraVer 5 Reagent and Hach DR1900 Spectrophotometer</td>
<td>8171</td>
<td>0.04 mg/L NO$_3^-$ N</td>
<td>0.04 mg/L NO$_3^-N$</td>
<td>0.1 to 10.0 mg/L NO$_3^-N$</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Grab Sample 250 mL container with Hach HQ440d Bench top Meter Package with PHC201 pH probe and CDC401 Conductivity Cell</td>
<td>Hach 8160 &amp; USEPA 2510-B</td>
<td>0.01 μS/cm with 2 digits</td>
<td>+/- 0.01 μS/cm</td>
<td>0.01 - 200,000 μS/cm</td>
</tr>
<tr>
<td>pH</td>
<td>Grab Sample 250 mL container with Hach HQ440d Bench top Meter Package with PHC201 pH probe and CDC401 Conductivity Cell</td>
<td>8156 &amp; USEPA Method 150.1</td>
<td>0.00 to 14.00 pH units</td>
<td>+/-0.01</td>
<td>+/- 0.02 pH units</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Grab Sample 250 mL container with Hanna Turbidimeter HI93703</td>
<td>2130B</td>
<td>0.0-50.00 FTU 50.00-1000.00 FTU</td>
<td>+/-0.01 FTU</td>
<td>+/- 5% FS 0-10 FT +/ 10% FS 10-50 FTU</td>
</tr>
<tr>
<td>E. Coli/ Total Coliform</td>
<td>Grab Sample in sterile 125 mL container, m-ColiBlue24®/ membrane filtration and dry incubation in Salvis Programmable Incucenter Natural Convection Incubator, 1.8 cu ft, 115 VAC; 24 hours at 35°C</td>
<td>10029</td>
<td>one colony forming unit (CFU) of coliform bacteria per 100 mL of sample</td>
<td>Sensitivity 96.8% Specificity 80.1% Overall Agreement 85.7%</td>
<td>0-200 colony forming units on readable plate, estimate min to 1000 colonies.</td>
</tr>
<tr>
<td>Optical Brightener/ In Vivo Chlorophyll a</td>
<td>Grab Sample 250 mL container with AquaFluor® Handheld Fluorimeter/Turbidimeter</td>
<td>N/A</td>
<td>Calibrated with extracted chlor a confirmed by absorbance in 90% acetone.</td>
<td>1 ug/l chlor a 1 ug/l PTSA for OW</td>
<td>10 ug/l for chlor a. 2 ug/l for PTSA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1 ug/l chlor a</td>
<td>Optical Brighteners 0.5 ppm – 30,000 ppm Chl in vivo 0.3 μg/L - 300 μg/L</td>
</tr>
</tbody>
</table>
E. Coli and Coliforms

Hach ColiBlue Filtration Method

Filter 1 & 2 ml on Millipore filter, Incubate 25 hrs at 35C and count
Standard Method 10029

Hach's m-ColiBlue24® Broth. Count red & blue
$63 for 60 plates (30 samples)

Colilert Quanta-Tray Method

Most probable number per 100 ml sample. Read visible yellow and UV fluorescence for most probable numbers in 1 ml and 10 ml trays.
Data Source: Citizens Volunteer Cooperative Water Quality Monitoring Programs in Cincinnati Metro area.

1. Water collected on same date (on 2nd Saturday of month between 7-10 am from March-Nov.).

2. Water Analyses use same or similar methods on the same day in each of 4 laboratories.

3. Advantage: No agency could sustain this level of output with person power required to sample on same day, 120 volunteer samplers & 35 laboratory workers.

4. Cost of all analytical methods is about $40,000/year for the four programs ($10,000/yr per program)

5. Major cost is a laboratory location contributed by a university, a well-funded non profit, a water treatment plant laboratory.

6. Each program has one person who is paid by some source to take responsibility for the laboratory operation and data.
Methods

• We use **Level 2** methods approved by Ohio’s Credible Data Law (2003), although programs not all approved yet (Butler County Stream Team level 2 for 2016).

• We use QA/QC appropriate for what we do.
  
  Chain of custody follows each sample.
  Calibration before and after each analytical run.
  Duplicates for 10% of samples in the laboratory (lab dup's.)
  Duplicates for 5-10% of samples in the field (field dup's.)
  Well trained volunteers doing the same parameter most of each year.

• We collected 1936 samples in Hamilton Co. for 2017 for 6-8 parameters on each over 9 months of the year at 200 sites = 14,000 measurements.

  Hundreds of volunteers bring in samples to the 4 labs run by 8-15 volunteers each month.
What our 8 base Parameters Tell Us

Eutrophication

- Total Phosphorus + Nitrate-Nitrogen
- Chlorophyll a in algal cells
- Turbidity at low flow = algal biomass scattering light.
- pH elevation by algal growth, especially above pH 8.3

Sewage Effluent

- Conductivity is salts from effluent treated or raw sewage, elevated by deicers in winter.
- E. Coli are human fecal bacteria primarily from bad septic systems, SSOs and CSOs.
- HIGH Nitrogen & PO4 from WWTPs, CSOs, SSOs, poor Septic Systems and raw sewage.
- Optical Whiteners from detergents in failing septic system (HST)

O₂ → CO₂ + H₂O → CO₂ + OH⁻
1 unit of PO4 makes 2500X that in biomass of algae. PO4 limits algal biomass possible in freshwater.

$O_2 + OH^-$

$pH$ increases 8.0 to 8.5

$O_2 + OH^-$

$O_2^+$

100 CO$_2$

$PO_4$ limits algal biomass possible in freshwater.

E. Coli + Cryptosporidium + Giardia + E.coli O157:H7

$>1030/100ml = no canoeing & kayaks$

$>geomean 126/100ml = no swimming$

OXYGEN & HYDROXYL ION PRODUCED ($O_2$ and $O_2+OH^-$)
“Of the 33 sites that were evaluated in 2016 under the Warmwater Habitat suite of uses and biocriteria, 12 were in full attainment of the applicable use, 15 in partial attainment, and 6 were in non-attainment, using fish, macroinvertebrates, habitat quality and water chemistry.

**Proximate causes** were delineated for impaired sites (i.e., partial and non-attainment) and typified the urban setting being predominated by sedimentation, the effect of elevated nutrients, elevated urban parameters, habitat alterations, elevated PAH compounds, and occasional low D.O. values.

The **sources of impairment** were mostly related to wet weather sources and hydromodification.
Wadeable streams that meet WWH of CWA (1972) have TP ca. 0.1 mg P/l.

River systems in OH that have TP less than 0.1 mg/l keep Chlor a to less than 100ug/l just meeting WWH standard.

Invertebrate Index

Figure 14. Background concentrations of TP (mg/l) at ALL sites by IBI range (top) and ICI range (bottom) for headwater and wadeable streams in the ECBP ecoregion.
Phosphorus & inorganic Nitrogen input from sewers, farmland or seepage enriches streams causing dense algal blooms.

Dense algae on bottom or in water column cause high dissolved oxygen and pH during the late afternoon and low D.O. and reduced pHs before sunrise stressing fish and invertebrates.

Attached algae on riffle rocks and suspended ‘planktonic’ algae in MC and WWR above.
OEPA regulates TP to achieve WWH

Figure 21. Nutrient criteria for TP in the context of the bio-condition gradient (y-axis) and land use. The box plot shows the distribution of TP concentrations in the ECBP ecoregion. Land use categories are positioned over the range of phosphorus concentrations typical of the category (i.e., 100% forest cover over igneous bedrock is shown for perspective, though that clearly is not found in the ECBP). The solid and dashed lines are the LOWESS trend lines from Figure 19, and shown to scale (IBI solid, ICI dashed).
Total P distribution in our rivers showed that the median was less than target 0.1 mg P/l in the Ohio R and Whitewater R, and was the highest in the Great Miami R.
Median Nitrate in Metro Rivers varies widely, highest in LMR > GMR > WWR > Ohio R > Mill Creek. Mill Ck effluent is denitrified (NO$_3^-$ → N$_2$ gas) at the UMCWRF. Our three big rivers receive ag. runoff.
Great Miami Nutrient Loads are dominated by Nonpoint sources (agriculture)

Figure 41 — Proportion of total phosphorus and nitrogen load from different sources for the Great Miami watershed, average of 5-years (wy13-wy17).
GMR runs through industrial heart of Ohio: Hamilton, Middletown, Miamisburg, Franklin, Dayton, Vandalia, Troy, Piqua and Sidney
Landuse of **GREAT MIAMI R** near Mouth is agricultural and gravel mining.

Developed & impervious = 21.5%
**WHITETWATER RIVER** is surrounded by greenspace and farming. Develop & Impervious = 9.56%
LITTLE MIAMI R is our first National and State Scenic Rivers, 54% of riparian zone protected.

Impervious & developed land = 21.36%
**Mill Creek** is surrounded by impervious surfaces of commercial businesses and residential.}

Impervious & developed land = 73.21%
Water Year 2017

Rainfall runoff and effluent add water flows to our rivers throughout the year. 6 days had greater than average max for year with 50” of rainfall.
When max flow/median flow is high the stream is flashy from impervious surface area.
Ohio Nutrient Mass Balance 2018

Muskingum R  1.3 P  18.7 N kmta  7420 mi^2
Scioto R.  2.1 P  28.1 N kmta  3854 mi^2
G.Miami R.  1.4 P  22.1 N kmta  2685 mi^2

Avg. Load at gaging station on sample days SSS

Great Miami R.  3630 mi^2  1.1280P  14.095 N kmta
Whitewater R   1224 mi^2  0.227P   5.087 N kmta
Mill Creek     115 mi^2   0.030P   0.123 N kmta
Little Miami R. 1203 mi^2  0.189 P   4.173 N kmta

OEPA
Nutrient loss/acre is high for similar for all ag-dominated watersheds, lowest for Muskingum and N-poor in Mill Ck.
Nitrate-N is least in Mill Ck < WWR < GMR
Conductivity is least in WWR < LMR < GMR.
**Avg E. Coli** is indicative of fecal contamination.

*Eschercheri coli* contamination was least in the WWR < LMR < GMR < MillCk in 2017.
### Water Quality Ranking System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>5.0 - 4.0 (excellent)</th>
<th>3.9 - 3.5 (good)</th>
<th>3.9 - 3.0 (enriched)</th>
<th>2.9 - 2.5 (fair)</th>
<th>&lt;2.5-1.5 (poor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrates (mg/L)</td>
<td>&lt;0.5</td>
<td>0.6 - 1.0</td>
<td>1.1 - 2.0</td>
<td>2.1 - 10.0</td>
<td>&gt;10.0</td>
</tr>
<tr>
<td>Total Phosphates (mg/L)</td>
<td>&lt;0.06</td>
<td>0.06 - 0.15</td>
<td>0.16 - 0.29</td>
<td>0.30 - 0.49</td>
<td>&gt;0.50</td>
</tr>
<tr>
<td>pH (pH units)</td>
<td>6.5 – 8.1</td>
<td>8.1 – 8.3</td>
<td>8.4 – 8.7</td>
<td>8.7 - 9.0</td>
<td>&gt;9.0</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>&lt;5</td>
<td>6 - 20</td>
<td>21 - 50</td>
<td>51 - 100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Conductivity uS</td>
<td>&lt;600</td>
<td>601 - 700</td>
<td>701 - 800</td>
<td>801 - 1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>E. coli (cfu) (Total Coliforms not used.)</td>
<td>&lt;298</td>
<td>299 - 523</td>
<td>524 - 940</td>
<td>941 - 1030</td>
<td>&gt;1030</td>
</tr>
</tbody>
</table>

Meets WWH water quality
74.6% of sites meet WWH water quality in 2017.
Effluent Indicators

**Conductivity** was higher in the tributaries of each river than in the mainstem. Order shows $\text{MC} > \text{GMR} > \text{LMR} > \text{WWR} = \text{Ohio R}$. Could this be that tribs are fed by groundwater during most of our sample dates, or winter road salt? This is the only parameter where tribs are uniformly higher conc. Than mainstem.

**E.Coli** are a direct measure of untreated sewage. Geomeans of E. coli were highest in MillCk $> \text{GMR} > \text{LMR} > \text{WWR} > \text{Ohio River}$. Tributaries were not potentially a source of E. coli in all Rivers. Urban MC tribs were similar to mainstem, apparently receiving E.coli at the same rate as the mainstem. Sewer pipes run under the streams overflowing by CSOs discharge and manhole covers in the streams.
Average pH was highest in mainstem rivers except in the Mill Creek, normally where canopy is more open and pools slow the flow of water allowing algae to use the nutrients. The algae in Ohio R is light limited by its depth & turbidity, having lowest pH.

Turbidity is elevated by high flows in the biggest rivers, the GMR and WWR. Without sampling in a rain event the Mill Creek is lowest on our sample dates. Summer turbidity is raised by suspended algae common in the slow flowing GMR and WWRs.
1. N:P Molar ratio showed Ag. Rivers (GMR, LMR & WWR) had highest N and urban River (Mill Ck) had lower ratio (P-rich).

2. Avg. Chlor a was much higher in the biggest and nutrient richest river open to sunshine. The Ohio R. plankton are light-limited by depth most of the year and tribs by vegetation.

3. Optical whiteners were highest in tribs where septic system discharge and GMR where WTTPS are few.
Whitewater River is the cleanest water in our area by far. Most of the watershed is forested and row crop, with few towns, but E. coli and NO3 were higher than normal in 2017.

Most sites reach EWWH, the highest in Ohio ~ Reference reaches of clean water.
Downstream pattern shows marked enrichment upriver from TP, Nitrate, and conductivity indicating effluent from WWTPs and agriculture on an annual basis.

pH and turbidity both increase towards the mouth as nutrient enhanced algal growth accumulates in the water column.
Minimum Discharge has been increasing with population growth and use of groundwater from aquifers. Effluent loading in GMR (122 cfs), LMR (171 cfs) & MC (15 cfs) make them all WWTP-dominated rivers.

This increased low water discharge is well water pumped from groundwater, used in homes and businesses and discharged by WWTPs to the surface water in the dry periods of the year. The increase in discharge is similar to the increase in effluent over the period. The minimum discharge has increased 100 cfs in LMR and in GMR over the years of population growth since 1990 in both, not caused by rainfall differences.
Median discharge has increased since sprawl began about 1960.

Minimum and median discharge have been increasing with population growth, use of groundwater from aquifers and climate change. Approved Effluent loading in GMR(122cfs), LMR(171cfs) & MC(15cfs) make them all WWTP-dominated rivers at low flow.
TP point source load GMR OEPA 2017

GMR TP daily load from point sources = 122 cfs south of Hamilton = 21% of lowest flow last 10 yrs.

TP load 2580 lbs P/day in 2015 from 11 effluents below Dayton.

Many more small WWTPs exist on the LMR putting out 111 mgd or 171 cfs of treated effluent, doubling lowest flow of LMR measured.
Little Miami River-longterm monitoring

Our first in the nation State and National Scenic River now suffers enrichment by many WWTPs and row crop agricultural in its headwaters. But is beginning to suffer from growth of impervious surfaces from development.
Little Miami River is enriched with TP with no year equal to target 0.1 mg TP/liter. Effluent discharges occur along its length in our reach but trend is decreasing.

Dissolved Nitrate-N shows no pattern in our data since 2006 and average exceeds target of 1.0 mg NO3-N/liter.
Summary

• Using our mutlimetric index, the Whitewater River is the cleanest river except for Nitrate in 2017, equivalent to the upper Mill Creek (>RM19). However continued development and effluent loading compromise the other urbanized rivers?

• Great Miami River is challenged by nutrient loading upriver from row crop agriculture but also WWTP effluent from upriver. Little Miami River is overloaded with effluent and threatened by development. The Mill Creek suffers from hydromodification, pulsed flow events and effluent loading of TP in 2017 and salts (all years).

• Who would have guessed that we could do all this with citizen volunteers concerned about their environment. Clean water pays for itself in home values, increased property tax and visitation for canoeing, kayaking, and cycling and river events.

• Value of our data is that it directly comparable, collected on the same day within a two hour window, will be available within a month. The data set extends 3 to 14 years back from as well so we can look at trends in water quality.
You can do it. Upgrade

• You need **two trained persons in water quality** measurements to train volunteers, calibrate instruments, enter & analyze data.

• You need a **home**: University lab., University field station, WWTP laboratory use on Sat., dedicated building for environmental education.

• You need **volunteers (6-15)** who are dependable on most dates **for laboratory work 4-5 hours** on Sat. More water collectors must visit 2-7 sites each for our 220 sites.

• You need **$7-10,000/yr for supplies** and a donor for the instrumentation on day a month or grant to purchase for $10,000 one time.