Hydroecological tool: enhancements and results

Marci Meixler
Great Lakes Charter Annex

• establish uniform, regional protections for Great Lakes waters
• ensure that authority over the Lake waters remains in the Great Lakes basin
• establish a process to ensure that ecosystems are improved through water use

ecosystem improvement actions will accompany future water withdrawals
Great Lakes watersheds have many concerns

- Water quality degradation
- Impaired connectivity
- Altered streamflows
- Increasing impervious surfaces
- Land conversion
- Increased streambank erosion
- Increased nutrient inputs
- Sedimentation
- Wetland destruction

Hydroecological tool: enhancements and results
Purpose of this project is to build a GIS model to predict where impairments are most likely to occur and identify the most cost-effective and beneficial improvement opportunities within Lake Ontario watersheds.
Hydroecological tool: enhancements and results

Modeled impairments

Freshwater biodiversity

- Physical habitat
  - Stream degradation
  - Riparian degradation

- Connectivity
  - Barriers to migration

- Hydrology
  - Streamflow alteration

- Water chemistry
  - Nutrient enrichment
  - Sedimentation
Hydroecological tool: enhancements and results

Study areas

- Black Creek
- Lakeshore Marshes
- Twelve Mile Creek
- Duffins Creek
- Napanee River
- Sandy Creek
- Credit River
- Salmon River
- Black Creek
- Sandy Creek
- Lakeshore Marshes
Hydroecological tool: enhancements and results
• Methods and enhancements / Testing
• Study area characteristics
• Results
• Conclusions
• Future tasks
• Ordinal
• Methodological
• Quantitative
Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:
- Riparian degradation too sensitive – revamped whole module including many new factors and metrics
Objective: identify the condition of the riparian zone surrounding each stream segment

Improvement opportunities: decrease bank erosion, lower water temperature, and increase organic inputs and cover necessary for healthy aquatic communities
• Institute for the Application of Geospatial Technology, June 2006

Feedback: use variable width riparian buffer
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Riparian buffers

Riparian degradation
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Fragmentation

- Percent urban/ag
- Percent forest
- Number of forested patches
- Mean patch density per hectare
Edge characteristics

Total forest edge
Spatial heterogeneity

Number of land use classes
<table>
<thead>
<tr>
<th>Landscape parameter</th>
<th>Threshold</th>
<th>Classification</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fragmentation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent forest cover</td>
<td>&lt;47%</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>47-80%</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>&gt;80%</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td>Percent urban and agricultural development</td>
<td>&gt;30%</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>10-30%</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>&lt;10%</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td>Mean patch density (#/ha)</td>
<td>&gt;0.45</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>0.15-0.45</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>&lt;0.15</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td>Number of forest patches</td>
<td>&gt;4</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>2-4</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td><strong>Spatial heterogeneity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of land use classes</td>
<td>&gt;2</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>1-2</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td><strong>Edge characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total forest edge (km)</td>
<td>&gt;21</td>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>15-21</td>
<td>Fair</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>&lt;15</td>
<td>Good</td>
<td>1</td>
</tr>
</tbody>
</table>

**Optimally**

<table>
<thead>
<tr>
<th>Riparian degradation categories</th>
<th>Riparian degradation index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0.33</td>
</tr>
<tr>
<td>Fair</td>
<td>&gt; 0.33 and &lt; 0.66</td>
</tr>
<tr>
<td>Good</td>
<td>&gt; 0.66</td>
</tr>
</tbody>
</table>
• Tug Hill Commission – management experience
• Jefferson Soil and Water Conservation District - with field experience (2)
• DEC - stewardship biologist & fish biologist
• Chemung County Upper Susquehanna Coalition

• Sandy Creek watershed
• December 2006
“East is different kind of agriculture than to the west. East is transitional ag – large blocks of forest. East of Adams should be fairly good quality wildlife habitat and good trout habitat.”
Modelled impairments

- Stream degradation
- Riparian degradation
- Barriers to migration
- Connectivity
- Hydrology
  - Streamflow alteration
- Water chemistry
  - Nutrient enrichment
  - Sedimentation

Freshwater biodiversity

Hydroecological tool: enhancements and results
Doug Carlson – DEC fisheries expert

- All NY watersheds
- Sept 2006

Feedback:

- Streamflow alteration too sensitive
“Variable stream flow is accurate for east. Between dams is green. It is lower gradient in that area. In the east rain comes out of Tug Hill fast. Lake effect – flashy episodes.

Best one of them all.”

Changed thiessen polygons to Inverse Distance Weighting for climate data and made cutoff more robust
Objective: mapping the degree of alteration from natural flow for each stream segment

Improvement opportunities: increase ecological integrity & biological diversity, improve water quality, and experience less frequent and less intense flooding
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Current and natural conditions

Land use

Current

Natural

Soils

Current

Natural

dnr.mo.gov

In.gov

USDA
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Flow model

![Graph showing discharge (CFS) over time (Day)]

- Current
- Natural
- Gage

Day 1 to 31
Discharge (CFS)
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Compared daily current and natural flows over a period of time to determine which factors indicate greatest hydrologic alteration.
33 IHA factors

- Monthly averages
- Magnitude of annual extremes (1- to 90-day highs and lows)
- Timing of annual extremes
- Frequency & duration of high & low pulses
- Rates of flow changes
- Frequency of flow reversals
- Base flow index
Hydroecological tool: enhancements and results

Chosen IHA parameters

One day maximum
Fall rate

Regression equation variables
(R-sq: 91%, 95%)
Runoff coefficients
Cover coefficients
Temperature
Precipitation
Stream flow alteration

Used logistic regression to classify streams into low or high alteration categories with a better than chance accuracy.

Streamflow alteration rating

<table>
<thead>
<tr>
<th>Low alteration</th>
<th>High alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.16+(12.33<em>onedmax)+(-30.54</em>fallrate)</td>
<td>-172.91+(194.06<em>onedmax)+(13.13</em>fallrate)</td>
</tr>
</tbody>
</table>

Stream is classified into category with highest value given by the equations above.
Modeled impairments

Hydroecological tool: enhancements and results

- Stream degradation
- Riparian degradation

Physical habitat

- Hydrology
  - Streamflow alteration

- Barriers to migration
  - Connectivity

Freshwater biodiversity

- Water chemistry
  - Nutrient enrichment
  - Sedimentation
Doug Carlson – DEC fisheries expert
- All NY watersheds
- Sept 2006

Feedback:
- Habitat degradation looks accurate
Stream degradation

Objective: To identify degradation in the valley and floodplain of each stream segment

Improvement opportunities: improve habitat for fish and invertebrates
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Anthropogenic disturbance

Stream degradation

A Intact
B Moderate
C Highly impacted

Urban/residential
Agriculture
Forest
Wetlands
### Anthropogenic disturbance index

<table>
<thead>
<tr>
<th>Anthropogenic disturbances</th>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>&gt; 30%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>10-30%</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>&lt; 10%</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural</td>
<td>&gt; 50%</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>40-50%</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>&lt; 40%</td>
<td>0</td>
</tr>
<tr>
<td>Forest</td>
<td>0-100%</td>
<td>0</td>
</tr>
<tr>
<td>Water</td>
<td>0-100%</td>
<td>0</td>
</tr>
<tr>
<td>Wetland</td>
<td>0-100%</td>
<td>0</td>
</tr>
<tr>
<td>Barren</td>
<td>0-100%</td>
<td>0</td>
</tr>
<tr>
<td>Road/railroad density</td>
<td>≥ 5%</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&lt; 5%</td>
<td>0</td>
</tr>
</tbody>
</table>

\[
\text{Anthropogenic disturbance index} = (0.8 \times (\text{urban score} + \text{ag score})) + (0.2 \times (\text{road score} + \text{railroad score}))
\]

<table>
<thead>
<tr>
<th>Anthropogenic disturbance categories</th>
<th>Anthropogenic disturbance index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal</td>
<td>&lt; 0.33</td>
</tr>
<tr>
<td>Moderately disturbed</td>
<td>0.33 - 0.66</td>
</tr>
<tr>
<td>Highly disturbed</td>
<td>&gt; 0.66</td>
</tr>
</tbody>
</table>
Canopy density

A: Closed canopy
B: Open canopy

<table>
<thead>
<tr>
<th>Riparian density rating</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed</td>
<td>&gt; 28% forested riparian area</td>
</tr>
<tr>
<td>Open</td>
<td>&lt; 28% forested riparian area</td>
</tr>
</tbody>
</table>
Substrate composition

<table>
<thead>
<tr>
<th>Substrate composition</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine sediment</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>Coarse sediment</td>
<td>&gt;1.5</td>
</tr>
</tbody>
</table>
Substrate composition

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Stream degradation

Low gradient
Fine substrate

High gradient
Coarse substrate
Stream degradation

- Anthropogenic disturbance
- Canopy density
- Substrate composition

Optimal scenario:
- Minimal
- Closed
- Coarse

Stream degradation:
- Poor
- Fair
- Good
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Ordinal: Tug Hill

Tug Hill: East of Mannsville has no ground disturbance or change in area in years other than mowing hay. No significant development in that area.

Downstream reaches & to the west and south of Adams is heavy agriculture. Those areas have lots of land clearing particularly hedgerows and streambank clearing and more straightening and ditching.

Moderately altered from Mannsville to Adams.
Modeled impairments

- Stream degradation
- Riparian degradation
- Physical habitat
- Barriers to migration
- Connectivity
- Hydrology
- Water chemistry
  - Nutrient enrichment
  - Sedimentation
- Streamflow alteration
Doug Carlson – DEC fisheries expert
• All NY watersheds
• Sept 2006

Feedback:
• Barriers to migration: Steelhead (rainbow trout) get to Adams in Sandy Creek (yes, they go up to exactly Adams, no further)
• No migratory salmonids in upper Genesee (right, they are blocked in lower Black Creek)
Objective: Identify extent of streams block to fish movement
Improvement opportunities: increased connectivity to fish spawning habitat
**Migrating fish**

**White sucker**
- Spring migrator
- Jumping height: 0.6 m
- Darting speed: 3.43 m/s
- Body length: 0.38 m

**Atlantic salmon**
- Fall migrator
- Jumping height: 3.3 m
- Darting speed: 4.95 m/s
- Body length: 0.55 m
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Barriers data

Known information

- Dam height
- Drainage area above dam

Modeled information

- Plunge pool depth in spring and fall
- Velocity in spring and fall
Which dams are barriers?

1) Is the maximum jumping height of the fish higher than the structure?

2) Is the darting speed of the fish faster than the water velocity?

3) Is the plunge pool depth greater than the length of the fish?

If all three are “Yes”, then the structure is not a barrier.
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Barriers to migration

Categories

- Always blocked
- Blocked in fall
- Blocked in spring
- Never blocked

[Legend]

- Poor
- Fair
- Good
Ordinal: Tug Hill

“Looks accurate.”
Modeled impairments

Freshwater biodiversity

- Physical habitat
  - Stream degradation
  - Riparian degradation

- Hydrology
  - Streamflow alteration

- Connectivity
  - Barriers to migration

- Water chemistry
  - Nutrient enrichment
  - Sedimentation

Hydroecological tool: enhancements and results
Objective: estimating the nutrient and sediment load that will end up in stream reaches given physical characteristics, climatic conditions, and land use practices in the study watersheds

Improvement opportunities: improve water quality and increase biotic diversity
### 1. Hydrologic Soil Groups

### 2. Landuse

### 3. Runoff

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Hydrologic soil groups</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/residential</td>
<td></td>
<td>0.4</td>
<td>0.48</td>
<td>0.55</td>
<td>0.63</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>0.15</td>
<td>0.23</td>
<td>0.32</td>
<td>0.4</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td>0.045</td>
<td>0.1</td>
<td>0.127</td>
<td>0.14</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wetland</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Barren</td>
<td></td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>
1. Hydrologic Soil Groups

2. Landuse

3. Runoff

4. Slope

5. Runoff adjusted for slope

<table>
<thead>
<tr>
<th>Percent rise</th>
<th>Slope effect coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2</td>
<td>0.6</td>
</tr>
<tr>
<td>2-8</td>
<td>0.7</td>
</tr>
<tr>
<td>8-15</td>
<td>0.8</td>
</tr>
<tr>
<td>&gt; 15</td>
<td>1</td>
</tr>
</tbody>
</table>
1. Hydrologic Soil Groups

2. Landuse

3. Runoff

4. Slope

5. Runoff adjusted for slope

6. Average Annual Rainfall (L/YR)

7. Average Annual Runoff (L/YR)

Nutrients & sedimentation
1. Hydrologic Soil Groups

2. Landuse

3. Runoff

4. Slope

6. Average Annual Rainfall (L/YR)

5. Runoff adjusted for slope

7. Average Annual Runoff (L/YR)

10. Pollutant Concentrations TN, TP, SS (MG/L)

11. Pollutant Loads (MG/YR)

POLLUTANT CONCENTRATIONS (MG/L)

<table>
<thead>
<tr>
<th>Land use type</th>
<th>TP</th>
<th>TN</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban/residential</td>
<td>0.15</td>
<td>1.18</td>
<td>81</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.34</td>
<td>2.32</td>
<td>55.3</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>0.5</td>
<td>11.1</td>
</tr>
<tr>
<td>Water</td>
<td>0.11</td>
<td>1.25</td>
<td>3.1</td>
</tr>
<tr>
<td>Wetland</td>
<td>0.19</td>
<td>1.6</td>
<td>10.2</td>
</tr>
<tr>
<td>Barren</td>
<td>0.15</td>
<td>1.18</td>
<td>93.9</td>
</tr>
</tbody>
</table>
Based on average width of forest in riparian zone
1. Hydrologic Soil Groups
2. Landuse
3. Runoff
4. Slope
5. Runoff adjusted for slope
6. Average Annual Rainfall (L/YR)
7. Average Annual Runoff (L/YR)
10. Pollutant Concentrations
   TN, TP, SS (MG/L)
11. Pollutant Loads (MG/YR)
12. Buffer Impacts
13. Adjusted Pollutant Loads (MG/YR)
14. Basins

15. Cumulative Pollutant Loading per Basin
   Exceeding EPA criteria for TN, TP, SS (MG/YR)
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Cumulative loadings

Cumulative load: 23 mg/yr
Cumulative runoff: 18000 L/yr
Cumulative concentration: 0.001 mg/L
Nutrient enrichment & sedimentation

EPA CRITERIA VALUES

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN</td>
<td>0.54</td>
</tr>
<tr>
<td>TP</td>
<td>0.033</td>
</tr>
<tr>
<td>SS</td>
<td>30</td>
</tr>
</tbody>
</table>

Concentration of TP, TN or SS

- Above EPA criteria level: Poor
- Within EPA criteria level: Good
• Threats to the Upper Allegheny Basin - TNC (Dec 2006)
• Using GIS to identify impairments in the Lake Ontario watershed, AFS meeting (Sep 2006)
• Lake Ontario improvement opportunity assessment modeling – Tug Hill, NYS Dept of State, IAGT (June 2006)
Methodological

- Close consultation with Professors Bain and Loucks at Cornell (throughout project)
  Advice: Add community capacity information; use statistical methods for classifying results (i.e. genetic algorithm)

- Seminar on methods to the Environmental and Water Resources Systems Analysis Group at Cornell (March 2007)
  Advice: put results on a 0-1 continuous scale

- Institute for the Application of Geospatial Technology
  Advice: variable width riparian buffer
Hydroecological tool: enhancements and results

Quantitative: Bode data

- Black Creek: 9 sites, 1%
- Lakeshore Marshes: 4 sites, <1%
- Salmon River: 8 sites, 1%
- Sandy Creek: 9 sites, <1%
The Waterbody Inventory/Priority Waterbodies List is...
A statewide inventory (database) of New York State surface waters which characterizes water quality, the degree to which a waterbody supports its designated uses, and progress toward the identification and resolution of water quality problems, pollutants, and sources.

Same resolution streams
• No Known Impacts: Segments where monitoring data and information indicate that there are *no use restrictions or other water quality impacts/issues.*

• Threatened: Waterbodies for which uses are not restricted and *no water quality problems currently exist, but where specific land use or other changes in the surrounding watershed are known or strongly suspected of threatening water quality.*

• Minor Impacts: Waterbodies where *less severe water quality impacts are apparent* but uses are still considered fully supported.

• Impaired Segments: Waterbodies with *well documented water quality problems* that result in precluded or impaired uses.
Checked PWL against combined nutrient enrichment and sediment data:

**Sediment/TP/TN**

<table>
<thead>
<tr>
<th>Good</th>
<th>Good</th>
<th>Good</th>
<th>=</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Good</td>
<td>Bad</td>
<td>=</td>
<td>Good</td>
</tr>
<tr>
<td>Good</td>
<td>Bad</td>
<td>Bad</td>
<td>=</td>
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<tr>
<td>Bad</td>
<td>Bad</td>
<td>Bad</td>
<td>=</td>
<td>Bad</td>
</tr>
</tbody>
</table>

**PWL**

<p>| No known impacts | = | Good |
| Threatened       | = | N/A  |
| minor impacts    | = | Bad  |
| Impaired         | = | Bad  |</p>
<table>
<thead>
<tr>
<th>Waterbody</th>
<th>% Matched</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Creek</td>
<td>80.06%</td>
</tr>
<tr>
<td>Salmon River</td>
<td>99.15%</td>
</tr>
<tr>
<td>Black Creek</td>
<td>99.3%</td>
</tr>
<tr>
<td>Lakeshore marshes</td>
<td>99.5%</td>
</tr>
<tr>
<td>Hydroecological tool: enhancements and results</td>
<td>Lakeshore marshes</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>No known impacts</td>
<td>N/A</td>
</tr>
<tr>
<td>Threatened</td>
<td>N/A</td>
</tr>
<tr>
<td>Minor impacts</td>
<td>24%</td>
</tr>
<tr>
<td>Impaired</td>
<td>N/A</td>
</tr>
<tr>
<td>Unassessed /Needs verif</td>
<td>76%</td>
</tr>
</tbody>
</table>
Routine Statewide Monitoring Program

More information from this division:

Division of Water
Bureau of Water Assessment and Management

Related information:

Statewide Monitoring and Assessment Schedule

The bureau is responsible for the routine monitoring of the waters of the state to allow for the determination of the overall quality of waters, trends in water quality, and identification of water quality problems and issues. This monitoring effort is coordinated through the Rotating Integrated Basin Studies (RIBS) Program. Specific component monitoring programs include Stream Biomonitoring, Lake Classification and Inventory, Citizens Statewide Lake Assessment Program (CSLAP)

A number of published reports and monitoring information are available.

Rotating Integrated Basin Studies

Contact: Margaret Novak, Chief, Statewide Waters Monitoring Section
The RIBS Program represents the coordination of a number of monitoring efforts that focus on two or three of 14 drainage areas of the state each year. Components of the RIBS program include stream biomonitoring, physical/chemical monitoring, lake monitoring and evaluation, sediment sampling and toxicity testing.