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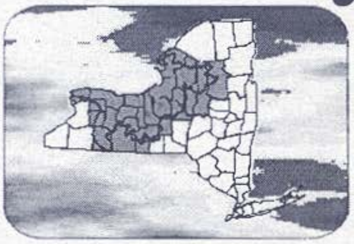

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A Technique for Identifying Pollution Sources in a Watershed: Stressed Stream Analysis Revisited

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Introduction

Freshwater resources have historically played an instrumental role in community development and economic sustainability. Over the last four decades, a concerted effort has been made to protect vital water resources of considerable value through the enactment of legislation (like the Clean Water Act) and the development of programs and initiatives (such as Phosphorous Abatement Program for the Great Lakes) to be carried out by agencies such as the Environmental Protection Agency. Although point sources of pollution are still a major water quality concern, progress has been made through enforcement of regulatory programs and technological innovations. Attention has shifted in recent years to nonpoint sources of pollution to lakes and rivers; that is, the extent to which various land-use practices in a watershed contribute pollutants that cumulatively degrade the receiving water body. A difficulty in dealing with nonpoint source pollution arises in how to economically identify sources and types of pollutants in large watersheds that cover hundreds of square miles.

An Assessment Tool

We first wrote about an approach to identifying nonpoint sources of pollution in a lake watershed in a 1993 issue of *Waterworks*, a publication of the New York State Federation of Lake Associations. This approach, called **stressed stream analysis**, is used to identify and prioritize sub-watersheds by their relative contribution to the deterioration of the lake ecosystem and, subsequently, to locate point and nonpoint sources within priority sub-watersheds. Once sources are identified on a sub-watershed basis, site-specific remedial actions and best management practices can be designed and implemented having optimal beneficial impact on the water body.

Since 1989, we have applied this economical and scientific technique to assess eleven watersheds in New York State in conjunction with local organizations (including county soil and water conservation districts, health departments, watershed task forces, and lake associations). The approach may be used for other watersheds where water quality deterioration is evident, but the causes of the problem are unknown or unconfirmed. Stress stream analysis fits within the comprehensive watershed management process (undertaken locally for an increasing number of New York State lakes) in the early stages of data collection and problem definition. Stress stream analysis is an excellent tool for guiding cost-effective management decisions based on quantitative information from the local setting.

What is Stressed Stream Analysis?

Stressed stream analysis is an integrative, comprehensive approach for determining the environmental health of a watershed and its constituents. Stressed stream analysis identifies individual sources of pollution in a lake watershed, and assesses their extent and severity. A watershed assessment using this technique is conducted in two phases: 1) priority ranking of subwatersheds and 2) segment analysis.

Prioritizing Sub-watersheds

In the first phase, losses of nutrients and soils from a watershed to a lake, or *loadings*, are calculated by monitoring tributary discharge and concentrations. Minimally, non-event sampling should be monthly and extend for a period of at least a year, but any sampling regime must consider hydrometeorologic events. In many watersheds in western and central New York, over 80 percent of some pollutants, especially particulate fractions, are washed off the watershed during rain and meltwater events. Event sampling can be done manually, but automated, event-responsive samplers are ultimately more efficient when labor costs are considered.

Mean daily loads, normalized for the

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area of the sub-watershed associated with the tributary, are calculated for each variable and graphed for each sub-watershed. The graphs show which, if any, sub-watersheds are delivering excessive amounts of pollutants to the lake compared to other sub-watersheds. The sub-watersheds can be prioritized based on loadings; those sub-watersheds with relatively high loadings may become candidates for Phase Two, or segment analysis.

Targeting Sources Along a Stream

Because nutrients are easily dissolved in water, and a flowing creek transports suspended solids (like soil), pollutants can be traced back to their points of origin along a tributary through systematic stream monitoring. **Segment analysis** is a technique that divides the affected sub-watershed into small, distinct geographical units. Samples are taken at the beginning and end of each stream segment to determine if a source arises within that reach. If segment analysis indicates a new source is present, the cause and location of either a point or nonpoint source is determined by inventorying land uses along the segment. Segment analysis sometimes leads to an easily identified source, such as a stormwater drainage pipe extending out of a streambank. Other times the sources are less obvious, but careful inventory of the area can reveal problem(s), such as failing septic systems, runoff from a barnyard, etc.

With completion of both phases of stressed stream analysis, actual data is generated — as opposed to an estimate from a computer simulation model — that allows 1) ranking of sub-watersheds by amounts of nutrients and soils lost from the watershed to the lake and 2) identification of specific sources within those sub-watersheds. These data provide insight to answer several watershed management questions: Are nutrients being lost during hydrometerological events only or also during baseline conditions? What season of the year does maximum loss from the watershed or loading to the lake occur? Are losses high or low compared to other watersheds in New York State? Are losses from agricultural, suburban or urban settings? Best management practices and remediation strategies can be individually tailored to pollution sources on a sub-watershed basis.

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Presented here are two local applications of stress stream analysis in western and central New York assisted by scientists from the Center for Applied Aquatic Sciences and Aquaculture at the State University of New York at Brockport.

Assessing Loadings to Canandaigua Lake

Besides the obvious aesthetic value of one of the most scenic Finger Lakes, properties associated with the Canandaigua Lake are valued in excess of $600 million, and lake-related tourism sustains an estimated 4,000 jobs and annual payroll in excess of $40 million. A community-initiated action group, the Canandaigua Lake Watershed Task Force, expressed concern about im-

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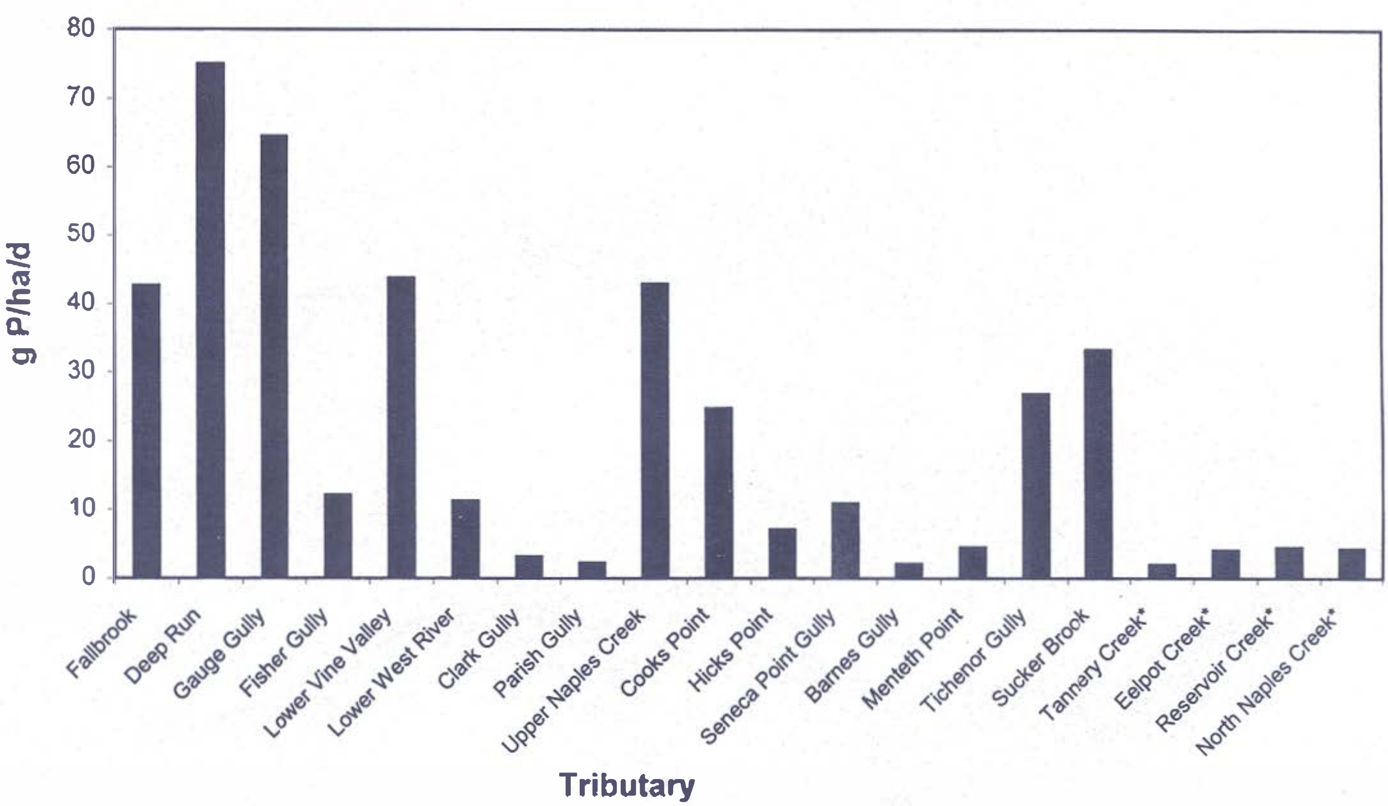
Figure 1. Phosphorus loss from Canandaigua Lake tributaries during precipitation events, 1997-1998 (n=10).



*1998 data only

pacts on the lake from various land-use practices in the watershed. Nonpoint and point source pollution from various land uses within the Canandaigua Lake watershed have potential to significantly alter the water quality of the lake and reduce its value as a resource. Identification of existing sources within the many sub-watersheds of Canandaigua Lake, followed by implementation of remedial and preventative measures, would serve to protect the lake's high water quality. To the Task Force, where to begin and how to identify pollution sources within the 174 square-mile watershed were daunting questions.

In 1998, we began work with the Task Force on the Phase 1 process of ranking sub-watersheds by pollutant loadings through a monitoring program on 16 streams at 19 sites during both hydrometerological events and non-event periods. Though the Canandaigua Lake watershed can be divided into 34 sub-watersheds, preliminary work by the Task Force narrowed down the candidates for Phase 1 stress stream analysis to 16 sub-watersheds.

We considered measures for several potential types of pollution in this watershed. These included phosphorus (a key nutrient that stimulates algae growth in lakes); total suspended solids (as an indicator of soil loss or erosion); sodium (a measure of the loss of deicing salts); nitrate, (which also plays a role in stimulating plant and algae growth); and organic nitrogen (indicating loss of manure or human sewage inputs). We limit our discussion here, for the purpose of illustration only, to loss of phosphorus from the watershed.

By considering the total amount of phosphorus (dischargetimes concentration) entering the lake from the 16 streams monitored, Figure 1 shows that at least six sub-watersheds delivered the majority of this nutrient of concern into Canandaigua Lake during hydrometeorological events. The sub-watersheds monitored could be ranked from highest to lowest as candidates for Phase 2 segment analysis, and followed by remediation or implementation of best management practices tailored to their specific problem situations.

Guidelines for maximum permissible pollutant loadings (known as **Total Maximum Daily Loadings**, or TMDLs) are now under development by New York State Department of Environmental Conservation for priority water bodies (those on DEC's 303.d list), so there currently are no established standards to evaluate phosphorus loadings in a watershed. Comparisons to loadings for other area watersheds are useful, however (Table 1).

Table 1. Phosphorus losses (g P/ha/d) from watersheds having various land-use patterns in central and western New York.

Creek/Watershed	Land Use	Total Phosphorus Loading (g P/ha/d)	County
Irondequoit Creek/Irondequoit Bay (1975-1977 pre-diversion)	Several sewage treatment plants (STP)	5.6	Monroe
Lower Northrup Creek/Long Pond	STP present	6.6	Monroe
Wolcott Creek/Port Bay (1990, 1991)	STP/Agriculture	2.8 to 5.0	Wayne
Sheldon Creek/Lake Neatahwanta (1994, 1998, 1999)	Agriculture, Muckland	27.4 to 30.0	Oswego
Glenmark Creek/Sodus Bay (1990-1993)	Agriculture	7.0 to 11.3	Wayne
Oak Orchard/Lake Ontario (1998)	Agriculture/Rural	3.5	Orleans
Johnson Creek/Lake Ontario (1998)	Agriculture/Rural	1.8	Orleans
Sandy Creek/Lake Ontario (1998)	Agriculture/Rural	0.98	Orleans
Sucker Brook/Canandaigua Lake (1998)	**Urban/Agriculture**	**7.6**	**Ontario**
Upper Northrup/Long Pond (1987-1988)	Urban	3.2	Monroe
Buttonwood/Braddock Bay (1987-1988)	Suburban	1.6	Monroe
Irondequoit Creek/Irondequoit Bay (1978-1979)	STP removed, Suburban	2.0	Monroe
Irondequoit Creek/Irondequoit Bay (1982)	STP removed, Suburban	0.92	Monroe
Larkin Creek/Buck Pond (1987-1988)	Suburban	0.70	Monroe
First Creek/Sodus Bay (1990-1992)	Forested	0.11 to 0.17	Wayne
Bobolink Creek/Sodus Bay (1992)	Forested	0.02	Wayne
Clark Creek/Sodus Bay (1990-1992)	Forested	0.03 to 0.22	Wayne
Sodus Creek West Branch/Sodus Bay (1990-1992)	Forested	0.43 to 0.60	Wayne

The mean annual phosphorus loading for Canandaigua Lake's Sucker Brook, one of the six high priority sub-watersheds for this nutrient identified in Phase 1, was 7.6 g P/ha/d (grams of phosphorus per hectare per day). Compared to other watersheds in the area, this rate of loss is high, and representative of watersheds that have sewage treatment plants discharging into creeks. Although we do not yet know the specific causes of the phosphorus loading in this sub-watershed, we know it is a concern. It is high not only for Canandaigua Lake, but also compared to creeks in other watersheds previously identified as being polluted due to known land-use practices associated with different types of point and nonpoint sources of pollution.

Identifying Pollutant Sources to Glenmark Creek, Sodus Bay

But what are the causes of the high levels of phosphorus entering a lake from any creek identified as a high priority in Phase 1 stressed stream analysis? The next step in the analysis is to systematically sample the concentration of total phosphorus along the stream to point us toward a source.

In Wayne County, at Sodus Bay, we have performed this step. Like Canandaigua Lake, annual monitoring of nutrients and discharge allowed us to prioritize the sub-watersheds and their streams to identify the stream/sub-watershed having the greatest impact on the Bay. In this case, Glenmark Creek accounted for over 80% of the phosphorus entering the Bay.

Systematic sampling of the watershed was undertaken to determine the origin(s) of the phosphorus loss from this watershed. Several different sources were eventually identified. Figure 2 shows the sampling pattern that was developed, and how a small but important source of phosphorus was identified. In a previous sampling, a site identified as MAG1 at the base of a second-order tributary showed relatively high levels of several pollutants including phosphorus (35.6 µgP/L) as compared to the main stem of Glenmark Creek (site MAG1X, 15.8 µgP/L). By sampling systematically at various locations along the

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stem of this second-order creek, and above its junction with a primary-order stream, we were able to track the high phosphorus concentrations to a failed septic system from a home above Site MAG1G. Upon closer investigation, leachate was observed emanating from the ground and moving down the stream bank into the creek. Phosphorus concentrations at this location reached nearly 93 µgP/L. Once this source was targeted, the Wayne County SWCD was able to advise the homeowner on how to remedy the problem.

Determining sources of pollutants and their magnitude is prerequisite to making cost-effective land management and remedial action decisions. Stressed stream analysis uses an iterative measurement process to reduce the likelihood of costly miscalculations based on assumptions of nutrient sources and modeling. We have found this process provides hard data that enhances the ability of concerned local groups to obtain external funding for remedial or demonstration projects. In Wayne County, for example, funds were secured for a constructed wetland to remediate milkhouse wastes identified by stressed stream analysis. At Canandaigua Lake, funds were secured for a segment analysis after the priority ranking phase identified one sub-watershed (Sucker Brook) as providing a major load of phosphorus into the lake. In another county, high losses of sodium from a watershed were attributed through segment analysis to a poorly managed deicing salt pile, which has now been completely enclosed.

By following the stressed stream analysis approach to identify and prioritize pollution problems, managers are able to make cost-effective decisions with increased confidence. Stressed stream analysis recognizes the fundamental importance of defining the problem clearly before determining the solution. It is a proactive tool that recognizes the long-term value of stewardship of natural resources.

For more information on stress stream analysis, contact Joseph C. Makarewicz at (716) 395-5747 or Theodore W. Lewis at (716) 395-5746, or Department of Biological Sciences, Center for Applied Aquatic Science and Aquaculture, SUNY Brockport, Brockport, New York 14420.❑

Figure 2. Segment analysis of a second order tributary of Glenmark Creek. Values are in µg/L.