Presented at the 2006 National Water Quality Monitoring Conference, San Jose, CA May 7-11, 2006.
Available on-line at http://www.nwqmc.org/

LakeSuperiorStreams.org: Making stormwater and stream data come alive for citizens, students, teachers, contractors, resource agencies, decision-makers and scientists

Richard Axler[1], Cynthia Hagley[2], George Host[1] and Jesse Schomberg[2]
[1] Natural Resources Research Institute, U. of Minnesota-Duluth,
5013 Miller Trunk Hwy, Duluth, MN 55811
[2] Minnesota Sea Grant, U. of Minnesota-Duluth, 2305 E. Fifth Street, Duluth, MN 55812.

Biographical Sketches of Authors

Richard Axler is a Senior Research Associate at the Natural Resources Research Institute (NRRI), U. of Minnesota-Duluth and on the Graduate Faculty in Water Resources Science and Integrated Biological Sciences. He has a PhD in Ecology/Limnology from the U. of California - Davis (1979). At NRRI, he has done research on northern Minnesota lakes and streams, alternative septic system performance, and using real-time data from lakes and streams for formal, informal and community education.

Cynthia Hagley is a Professor of Extension and Water Quality Extension Educator with Minnesota Sea Grant at the U. of Minnesota-Duluth. She has an M.S. in Ecology/Limnology from the U. of California - Davis (1989). Her many projects have focused on shoreland education, protection and restoration, educating stakeholders and decision makers on the links between land use and habitat and water quality (NEMO), and using real-time data from lakes and streams for formal, informal and community education.

George Host is a Sr. Research Associate at the Natural Resources Research Institute (NRRI), U. of Minnesota-Duluth and on the Graduate Faculty in Water Resources Science and Integrated Biological Sciences. He has a PhD in Forest Ecology from Michigan State University (1987). He does research on landscape/forest ecology, landscape-water quality linkages, biostatistics, simulation modeling, and using real-time data from lakes and streams for formal, informal and community education.

Jesse Schomberg is an Assistant Extension Professor with Minnesota Sea Grant at the U. of Minnesota-Duluth. He has an M.S. in Stream Ecology from Idaho State University (1999). His research focuses on stormwater and hydrologic simulation modeling, impervious surface analysis, and land use-water quality connections. He coordinates the NEMO (Nonpoint Education for Municipal Officials) program for Sea Grant and works to educate local governments on the connections between land use and water resources.

Abstract

Urbanization and rural development are placing pressure on western Lake Superior streams and nearshore zones. Stormwater runoff and overflows of partially treated domestic wastewater threaten public health via pathogens and fish-Hg. Increased flows, temperature, sediments, nutrients and organic matter represent ecological health risks. Stream and coastal zone degradation represents a significant social and economic impact to a region whose economy and character are tied to its pristine natural state. This project uses web-based delivery of real-time stream monitoring data to address issues of sustainability in critical Minnesota watersheds at the headwaters of the Great Lakes. The website delivers intensive real-time values of flow, temperature, turbidity and conductivity in conventional formats and via a unique data animation tool from sensors in three urban trout streams, the St. Louis River discharge to Lake Superior, and two North shore Lake Superior tributaries. *Lakesuperiorstreams.org* (LSS) incorporates interpretive

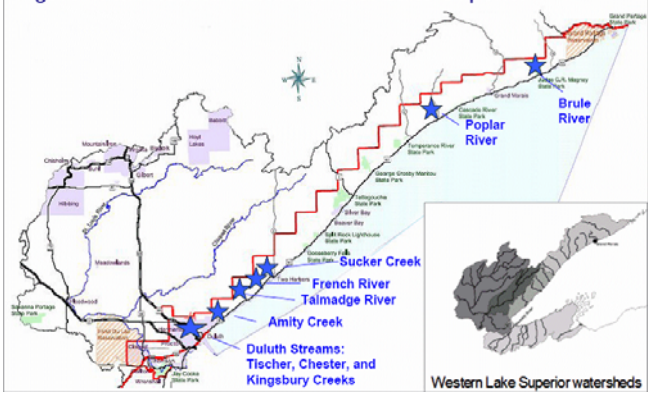
information, curricula, case studies and a site design toolkit to educate contractors, consultants, developers, students, teachers, homeowners, agencies, decision-makers and scientists. It also serves as a data/report reference library for regional streams and promotes event-based volunteer monitoring. LSS led to collaboration with the Minnesota Pollution Control Agency (MPCA) to create MNbeaches.org and the tools were adapted to display Lake Superior Beach Monitoring fecals/E. coli data via animation and mapping utilities. A Regional Stormwater Protection Team of 22 organizations was also created to deliver common educational messages, collaborate on projects and provide tools and training via a variety of formats with the LSS website as a central focus. LSS has now expanded to include data and ancillary information from two *Impaired* tributaries to Lake Superior including a stream restoration initiative. The website averages >200,000 requests/mo and ~ 35,000 page requests/mo. LSS is a partnership between the University, City of Duluth, MPCA and the Western Lake Superior Sanitary District.

Introduction

Duluth, Minnesota lies at the westernmost end of Lake Superior, the source and headwaters of the entire Laurentian Great Lakes ecosystem. Better known for its extremely cold winters, Duluth residents and visitors know it as a city of forested hills, wetlands and trout streams with 42 named creeks and streams moving through the City in 30 subwatersheds. The City owns and maintains 11,000 acres of parklands, including 125 municipal parks. Streams form the fabric of the aesthetic appeal and character of Duluth, but are also the core of the City's stormwater runoff system, with 250 miles of storm sewer, 93 miles of creek, 4,716 manholes, 2 lift stations, 13 sediment boxes, and over 138 miles of roadway ditches.

Urbanization and rural development have placed increased pressure on the region's coastal communities and on Duluth's urban streams, in particular, on the 13 designated as Trout Streams and 14 classified as Protected Waters (Axler and Lonsdale 2003; Figures 1 and 2). Since the early 1990s, over 50 new lodging establishments were constructed along Lake Superior's North shore and Cook County experienced a 24% population increase from 1990-1996 (MPCA 2000). Stream communities of fish and amphibians and the invertebrates that sustain them are being adversely impacted by increased temperature, excessive turbidity and suspended solids, road salts, organic matter, and nutrients (Anderson et al. 2003). Nine Superior tributaries are now on the Minnesota List of Impaired Waters, with TMDL (Total Maximum Daily Load) studies in development, chiefly for turbidity/TSS and fish-Hg. Further, these streams discharge either directly into ultra-oligotrophic Lake Superior or indirectly via the St. Louis River Estuary-Duluth Superior Harbor. This is particularly important because Lake Superior is designated as a zero-discharge demonstration project by the International Joint Commission for eliminating inputs of persistent toxic chemicals to the Great Lakes system (IJC 1999). Also, the lake's nearshore zone, the source of much of its biological productivity, is extremely nutrient deficient and sensitive to increased inputs of nutrients, suspended solids, turbidity, and organic matter. Lastly, the Harbor itself is one of the 43 Great Lakes Areas of Concern (AOCs) because of serious impairments to its beneficial uses . There are also significant social and economic impacts associated with this region – the Minnesota DNR reports that angling in North Shore streams and Lake Superior produces $63 million in direct sales and income and over 1,200 jobs. For North Shore streams alone, the numbers are over $33

Figure 1. Minnesota North shore of Lake Superior



million direct sales and income, and over 435 jobs. Residents rank the natural environment and outdoor recreation higher than employment opportunities as reasons for choosing to live here (Duluth 2000).

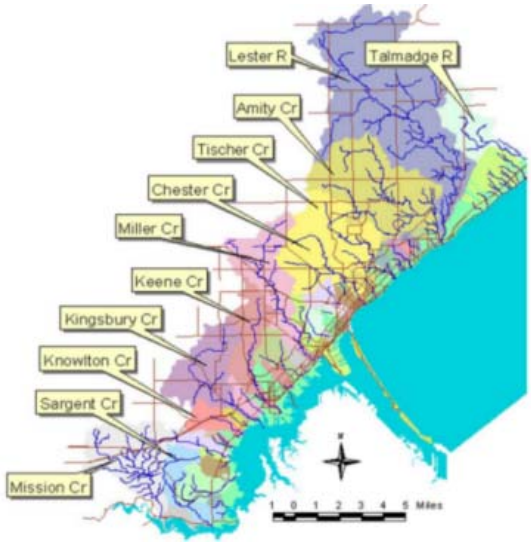


Fig. 2. Major Duluth trout stream watersheds

In 1998 the City of Duluth established a stormwater utility to address the quality and quantity of surface water moving through the City and in 2003 was issued a Stormwater Permit under Phase II of the federal Clean Water Act's National Pollution Discharge Elimination System (NPDES). Beginning in January 2002, with funding by EPA (EMPACT) and in-kind effort from several agencies, the Natural Resources Research Institute (NRRI) and Minnesota Sea Grant formed a partnership with the City of Duluth, the Minnesota Pollution Control Agency (MPCA), the Great Lakes Aquarium, and the Western Lake Superior Sanitary District (WLSSD) to create *DuluthStreams.org (DS)*. The project is now expanding to include the larger western Lake Superior region and is also called *LakeSuperiorStreams.org (LSS)*. Additional partners have since joined to form a Regional Stormwater Protection Team (RSPT).The DS/LSS goal is to enhance the public understanding of aquatic ecosystems and their connections to watershed land use to provide both economic and environmental sustainability. The use of data, particularly real-time data, is central to the project. The RSPT Partnership strives to protect and enhance the region's water resources via coordinated educational programs and technical assistance.

Fig. 3 Website homepage and "business" card

The project is well-timed because of the newness of stormwater regulations (EPA 1999a,b) and concerns about how to maintain infrastructure and streams on private property; how to clean and maintain natural waterways without causing damage to trout breeding areas; what to do with nuisance ponding, how to control erosion and runoff during development and maintain holding ponds after development is complete, and how to reduce the impacts of de-icers and abrasives on trout streams without compromising public safety. Controlling these sources requires working not just with large dischargers, but with individual homeowners and requires monetary resources, which must be generated by increased revenues from the public, such as through taxes. There has already been resistance in Duluth to an increased charge

for the Stormwater Utility. The only way to overcome lack of understanding and resistance is through education. If people better understood the risks and impacts of stormwater inflows to their treasured natural waterways, they would be more inclined to take a proactive, positive role in solving the problem rather than seeing it as another government "taking." Duluth's urban streams are treasured natural resources that make Duluth a unique city in the U.S. The quality of these streams directly relates to the cumulative actions of thousands of individual homeowners and hundreds of small businesses. Consequently, environmental impacts to these streams can best be reduced or eliminated with no or minimal adverse impacts on the economic health of the community by an improved understanding of how stream water quality and organisms respond to stormwater and what controls the nature of stormwater flows.

The project's major objectives were to: 1) link real-time remote sensing of water quality in 4 urban streams and GIS technology to current and historical water quality and biological databases (all 42 Duluth streams) using advanced data visualization tools in World Wide Web and information kiosk formats; 2) incorporate visually engaging interpretive text, animations and videos into the *Duluth Streams* website to illustrate the nature and consequences of degraded stormwater and the real costs to society; and 3) engage the public in the stormwater issue via programmatic activities such as establishing high school directed neighborhood stewardship and/or stream monitoring, developing curricula for high school and college students for inclusion in our *Water on the Web* curriculum, hosting a *Duluth Streams* Congress as a community forum for presenting all project results, and adapting the Nonpoint Education for Municipal Officials (NEMO) program to the greater Duluth Metropolitan Area.

Duluth Streams/LakeSuperiorStreams evolved from a series of EPA (EMPACT) and NSF (Advanced Technology Education) funded projects developed by a team of U. of Minnesota-Duluth research, education and outreach professionals since 1997. *WaterontheWeb.org* (WOW), *LakeAccess.org* and *DuluthStreams.org* form a set of interlinked web-based water science education sites built upon a central core of intensive, remotely sensed, time-relevant data. The technology that is at the core of the included in WOW and the multi-disciplinary high school/college basic and water resource management curriculum, necessitated strong interdisciplinary collaboration first within the university community (aquatic and landscape ecology, formal science education, extension and outreach, and advanced engineering, computer science, and telecommunications skills) and later with resource agencies for help in maintaining the robotic sensors. It is hoped that this broad base of data, visualization tools and interpretive text and curricula will enable *Duluth Streams* to remain a dynamic website with a central core of intensive water quality and GIS data.

This paper summarizes the major features of the *Duluth Streams* project from its inception in January 2002 through December 2005 with emphasis on the stream data and its uses. The website at *http://duluthstreams.org* (now also *http://lakesuperiorstreams.org*) is the focus of the project and offers water quality, biological, and GIS data in the context of a variety of school- and community-oriented educational material.

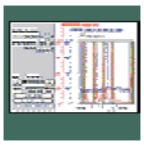
Website Features

HOME PAGE

The home page (Figure 3) is a portal to major sections and immediate access to the following sections:

- Highlights for New Users – These are seasonal pieces that explain the most important features of the streams' ecology with practical information about what citizens can be doing at this time of year to help maintain or improve stream condition.

- View Real-Time Data – This is a direct link to the data visualization tool for viewing animations of water quality in 4 urban streams, the St. Louis River as it enters Lake Superior, the north shore Polar River, and the flow of Western Lake Superior Sanitary District's wastewater discharge into the St. Louis River Estuary. This also accesses water chemistry data collected for the 5 intensively monitored urban streams, and eventually for other intensive or long-term monitoring stream data.



- Local Beach Information – A direct link to the Lake Superior Beach Monitoring Program that the Minnesota Pollution Control Agency and various partners (including *Duluth Streams*) began in 2003. In 2004, *Duluth Streams* staff developed the website *www.minnesotabeaches.org* to make it easier for the general public to access data and information about local beach closings. Recently, a mapping utility and an animated bacteria data viewer were developed for users to better visualize the data and its relationships with other environmental and climatic data.

LAKE SUPERIOR COMMUNITIES

This section provides the user with an overview of the natural and human environment in the region. It is a combination of "processed" information and links to major websites. It's main function is to direct users to specific municipal or agency websites with stormwater information for citizens or businesses. It also includes natural resource related recreation information (e,g, parks, fishing), and regional information about the climate and geology of the region, organisms (both aquatic and terrestrial), photos and facts about the Lake Superior Basin and Lake Superior itself. This section also provides information about natural phenomena that are common, aesthetically interesting, but not well understood by the general public. This includes the foam that is produced naturally in copious amounts in some streams and the ice formations in Lake Superior and its tributaries.

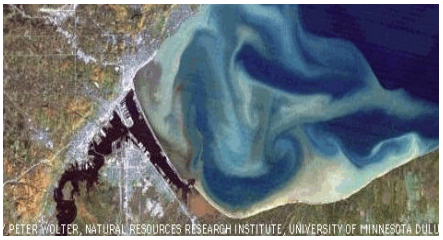


Fig. 4. Western Lake Superior

UNDERSTANDING

This section is primarily intended to provide a set of detailed "Primers" that describe the basics of: (1) how stream ecosystems work; (2) the key water quality parameters needed to characterize regional streams; (3) the major types of water quality impacts most relevant to the condition of streams in Duluth, and more generally, in the Lake Superior Basin; (4) the organisms that inhabit the streams and their watersheds; (5) regional hydrology; and (6) drinking water, wastewater, and related issues.

A central feature of the water quality related sections is the integration of real data from our instrumented streams into the explanatory materials, including the use of animated "gif" graphic sequences to illustrate certain points and to simulate how relevant data may be viewed using *the DS/LSS* data visualization tool (easily accessed via the "DATA VIEWER" at the bottom of each page). Users are also referred to the more comprehensive set of slide modules viewable or downloadable from our companion website, *Water on the Web* (www.waterontheweb.org).


Fig. 5 Pet waste impacts

Major water quality issues that are highlighted for the western Lake Superior area include: bacteria, erosion, impervious surfaces, lawn care, motor oil, pet waste, road salt, temperature, and litter. Some of the stream monitoring units (SMUs) have operated for four years, and, because of their high-frequency (15 minute) data collection, have revealed a number of interesting phenomena in these urban streams, including extended conductivity spikes from salt-laden snowmelt, the identification of unauthorized sediment releases from urban construction activities, and sudden increases in water temperature from rain running across sun-warmed parking lots and roads to levels exceeding EPA water quality criteria for trout. The Impacts list is not all inclusive but emphasizes those which can be mitigated in the near-term by changes in citizen habits, management and training for government/agency staff, contractors, and local

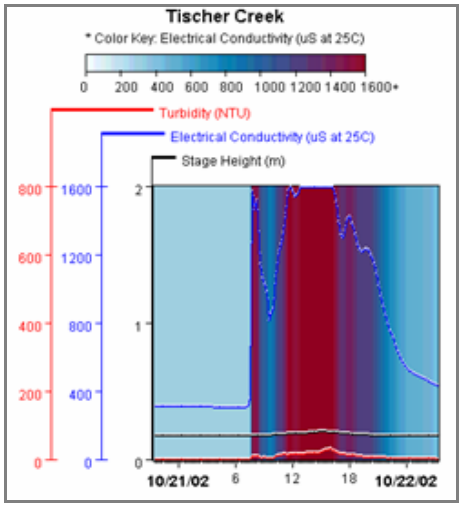


Fig. 6. Conductivity from winter salt

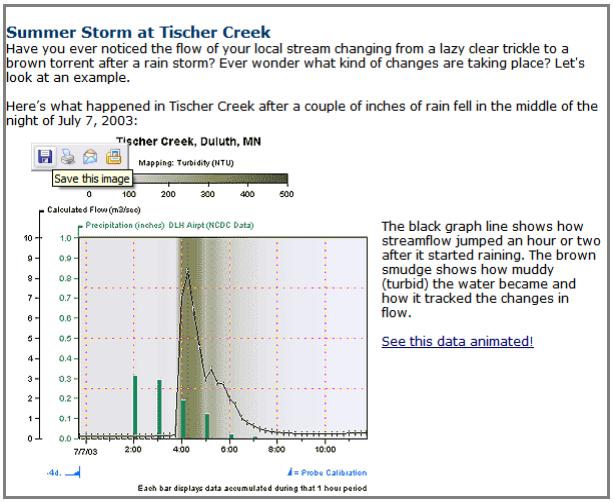


Fig. 7. Turbidity from summer storm

policy decision-makers. Each section is closely tied to data, either real-time data or current and historical traditional monitoring data. Examples include :

(1) data remotely sensed by our SMUs, e.g., turbidity caused by erosion off a road construction site adjacent to Tischer Creek in September 2003; road salt runoff captured by dramatic increases in EC25 in the creeks each spring; or sharp thermal increases from summer rainstorms on hot days (Figs. 6 and 7).

(2) Lake Superior Beach Monitoring Program bacteria data where manually collected fecal coliform and E.coli data are animated using a derivative visualization tool for examining patterns over time or within small or large geographic regions (Figures 8 and 9).

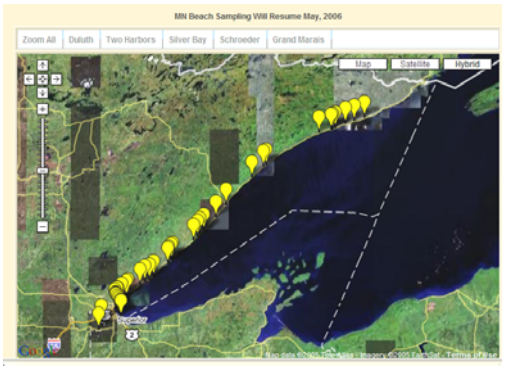


Fig. 8. Western Lake Superior beach monitoring sites

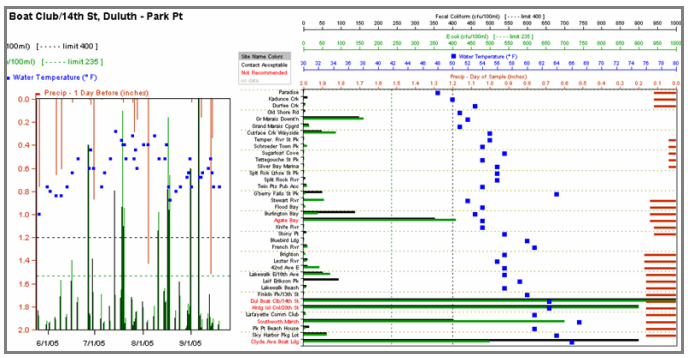


Fig. 9. Beach monitoring bacteria data viewer snapshots. Left: time trends for a site; Right: Spatial differences on a given date

CITIZENS and SCHOOLS

The focus in this section is on activities and tools that homeowners and schools can pursue to become better informed and better stewards of our streams. Guidance and curricula are provided that are oriented toward reducing the amount of runoff leaving property, and reducing the amount of soil, nutrients, leaves and grass, and salts in that runoff. The Citizen and Stormwater Management (below) sections in particular are intended to educate citizens and also to provide detailed guidance to help them reduce their impacts on stormwater, to take action as volunteers, or to become active politically. The website serves as a clearinghouse for water-related information – emphasizing streams, stormwater, and stormwater mitigation. This information has been scattered over numerous agency websites. Compiling the information in one organized location benefits resource and regulatory agencies (county, region, state and federal), the private sector (engineering and consulting firms, contractors, vendors), and private citizens and students. DS/LSS has also worked with the St. Louis River *RiverWatch* program in an attempt to blend their snapshot intensive biological and chemical monitoring program with the event-intensive transparency tube based program coordinated by the Minnesota Pollution Control Agency. An example of this approach can be found at the Washburn-Edison school section at http://duluthstreams.org/citizen/washburn.html .

STORMWATER

This section is devoted to stormwater management, with subsections devoted to Stormwater Plans, Inflow and Infiltration issues, the activities of the Regional Stormwater Protection Team (RSPT), and a Site Design Toolkit developed primarily for contractors and developers. It includes detailed information about BMPs, local examples and case studies, contractor training materials, and policy and model local ordinance information for small municipalities and townships trying to address new federal and state stormwater regulations to improve stormwater management, erosion and sediment control, subdivision design, etc.

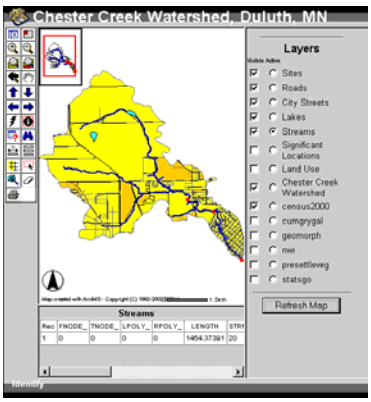


Figure 10. Output from the Internet Map Server GIS utility

STREAMS

Individual sections for all streams and their watersheds were created with emphasis on trout streams. These sections are intended to serve as data repositories for historical and current water quality, habitat, and watershed data. For all of the intensively monitored streams, the website features Internet Map Server, a technology designed to allow users to access and manipulate on-line GIS data, including the ability to query

across data layers (e.g., calculate the area of forested wetlands within a 100 m riparian buffer of 2nd and higher order streams) and to create tabular and mapped summaries of the results. Spatial data analyses performed for this project in cooperation with other projects in the region included hydrography, transportation, landuse/landcover, geology and soils, ownership and administrative boundaries (Figure 10; www.nrri.umn.edu/coastalgis). The DATA INDEX link opens a main index for water quality and other information about all of Duluth's streams and the trout streams along the north shore of lake Superior. It provides a map that allows the user to link to a particular stream section via mouse-rollover and or via a comprehensive table that summarizes all information available for each stream, with appropriate links (http://duluthstreams.org/streams/stream_selector.html).

Stream water quality data is at the heart of the project. It is collected intensively in real-time via automated data logging sensors, transmitted via cell phone to the home base, filtered, and then displayed on the website in multiple formats including a unique data animation and visualization tool (Host et al. 1999, 2000).

Background and QA/QC

This project evolved from two NSF-ATE and two EPA-EMPACT funded projects that allowed the creation of *www.waterontheweb.org* and *www.lakeaccess.org* for college/high school and community education. Real-time and time-relevant data acquisition, visualization, and dissemination are central to these lake and stream monitoring-based educational programs, including *Duluth Streams*. The primary QA/QC objective for all of these studies is to assure accurate and representative measurements of the biological, physical and chemical parameters that are monitored. The historical and current manual monitoring data, plus the intensive data collected by the stream monitoring units (SMUs) are intended for both public education and for inclusion in the City of Duluth (City), Western Lake Superior Sanitary District (WLSSD), Minnesota Pollution Control Agency (MPCA/STORET), and Minnesota Department of Natural Resources (MDNR) databases.

Measurements comply with EPA QA guidelines (EPA 1998) and follow previously established and documented QA/QC plans developed by NRRI, certified by the MN Dept of Health and the MPCA (Ameel et al. 1998; APHA 2003), and used for previous EMPACT projects performed by our group. EPA used our *Lake Access* EMPACT project as the national model for technology transfer to other aquatic EMPACT projects (Peterson et al. 2000). Details are at *http://duluthstreams.org/streams/aboutdata.html.*

Site selection and sampling

Manual water and flow sampling began during the spring runoff in April 2002 at three primary urban, designated trout streams – Chester, Tischer and Kingsbury Creeks. The streams were chosen on the basis of usage, geographic coverage of the city, and varieties of land-use in the watershed. Automated stream monitoring units (SMUs) with dataloggers, modems, and flow, temperature, EC25 (specific or temperature-compensated electrical conductivity) and turbidity sensors were deployed during summer 2002 at each stream. A rain event-triggered sampler was installed at Kingsbury Creek at a site within the Duluth Zoo (for security, telecommunications, and educational reasons), and additional . Additional water samples are collected manually at the Chester and Tischer Creek sites and analyzed for nutrients – nitrogen (N) and phosphorus (P) series, biochemical oxygen demand (BOD_5), total suspended solids (TSS), chloride (Cl) and fecal coliform bacteria to estimate seasonal water quality variations and loading. A fourth water quality sonde was installed in the St. Louis River outflow to Lake Superior at the Duluth Inlet (Aerial Lift Bridge channel) where a flow gauge had been previously installed and is operated by the USGS. In 2005/2006, SMUs were installed in the north shore of Lake Superior Amity Creek and Poplar River. Each is listed as *Impaired* for turbidity (MPCA 2004) and has been monitored manually since 2002 by the MPCA as a part of a long-term monitoring program for Lake Superior tributaries. Sampling is

weighted towards high flow events from rainstorms and snowmelt runoff to provide accurate estimates of seasonal and annual loading (typically > 20 samples/year; Anderson et al. 2003).

Automated sensors, measuring temperature, EC25, turbidity, depth (for flow estimation) on the SMUs, are checked ~weekly for cleaning and/or re-calibration by comparison to a YSI 85 or 556 multi-probe water quality analyzer and as per manufacturer's recommendations. Manual measurements include daily calibrations. The SMU control modules (CR10X and sensors) are programmed to collect temperature, EC25, turbidity, and stream elevation data at 15 minute intervals, which is relevant to the time-scale of storms. Flow-weighted water chemistry samples are collected at Kingsbury Creek using an ISCO 6700 autosampler slaved to the CR10X stream elevation probe.

Sensor data transfer and visualization: Interactive data visualization applets are used to create interactive visual representations of the data. Through *Water on the Web* and our current and previous EMPACT projects, a suite of JAVA applications and spreadsheet templates were developed to process and summarize the data at different temporal and spatial scales (Host et al. 2000; Munson et al. 2003; Axler and Lonsdale 2003). A major product of this work was the development of the stream and lake Data Visualization Tools (DVT) for exploring stream parameters with an animated ECG-type display of variables over time (see Figures 6,7, and 9). The tool allows comparison of multiple stream systems as they respond to similar storm events over different time scales. Data can also be easily accessed and downloaded in both HTML tables and Excel tables; real time data viewed in Excel can also be easily graphed using a simple Excel graphing utility.

Data vignettes

Perhaps the most unique feature of the DS/LSS website is the use of animated real-time data series from the DVT to illustrate how watershed activities affect water quality. These data vignettes utilize animated gifs from the actual data set and have been used to illustrate:

- erosion from summer storms and poor construction (Fig. 7)
- transient and chronic effects of road salt on trout streams (Fig. 6)
- the speed at which runoff can transport particulate and soluble pollutants into streams (Fig. 6,7)
- temperature spikes from hot asphalt parking lots (Fig. 11)
- inflow and infiltration by animating intensive discharge values from the Western Lake Superior Sanitary Sewer District's wastewater treatment plant (Fig. 12). This has been the preeminent water quality issue in the region.

The vignettes are woven into various sections throughout the website and will also be used in the Stream Ecology modules of the *www.waterontheweb.org* curriculum.

Project Impacts

Website usage has grown steadily since the site was unveiled and is now > 200,000 hits/month and >20,000 page requests/month excluding City and University members of the *Duluth Streams* Partnership. Website use is in part linked to the WOW curricula which now receives > 1.5 million "hits" per month and has received requests from more than 120 countries. Website use will also grow as the Regional Stormwater Protection Team continues to rely on *DS/LSS* while developing more media materials, flyers and bookmarks, technical workshops, public water festivals, and school activities .

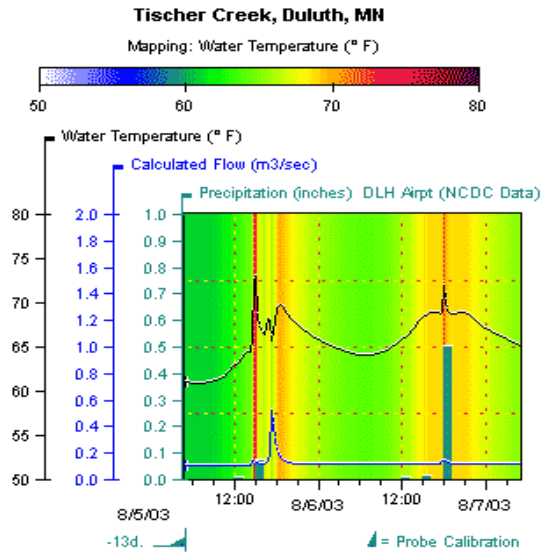


Fig. 11. Temperature spikes from summer storm

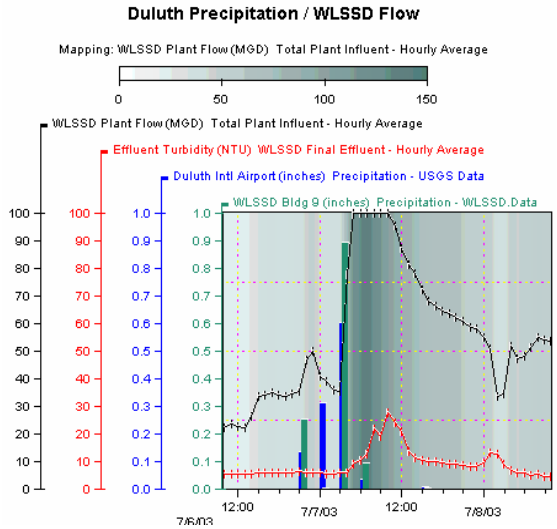


Fig. 12. WLSSD discharge jumps from ~ 40 to 140 mgd from I&I problems during a summer storm

While not originally intended to include school curricula, it soon became apparent that helping to establish school stewardship and volunteer monitoring programs was important to the overall education goal. In addition there appeared to be relatively little coordination of water-related activities among area schools. The St. Louis River *Riverwatch* program began in 1997 and had expanded to include >32 schools, but lacked the resources for a comprehensive website. Therefore, we developed a website for *Riverwatch* to use in late 2002 (it is still their main website) and included its field and lab worksheets, a list of participating schools, and site maps and linked it to aquatic invertebrate keys on the *Duluth Streams* website. The website also has provided a home for the *Environmental Youth Leadership* curriculum which includes 25 lessons of which seven involve high school level water and watershed learning activities. The Stowe School Watershed Curriculum that is downloadable from the site was developed via a state collaborative educational grant between the City of Duluth, the U. Of Minnesota-Duluth Education Department, Stowe Elementary School (K-6). Its 31 lessons are linked to local streams and Lake Superior whenever possible. DS staff revised the set of lesson plans to make them more technically accurate and to include the various "messages" of *Duluth Streams* whenever possible.

Additional pilot projects were developed for one middle school and three high schools that introduced flow-related spring and fall sampling for clarity (via the transparency tubes used in the Minnesota volunteer Citizens Stream Monitoring Program-CSMP), EC25, and estimates of relative flow to be integrated into the existing monitoring program – a once a year aquatic invertebrate survey. Results from their fall sampling, which included water chemistry test kit measurements plus additional measurements made by *Duluth Streams* staff were submitted to the database developed for National/International Monitoring Day (URLs: *www.yearofcleanwater.org/events/volunteer.htm* and *www.green.org/sites/*). A section entitled *Water in the Classroom* was created to assist teachers in creating water-based curriculum for elementary and high school students.

Acknowledgments

We first acknowledge the contributions of the individuals that were not listed as co-authors because of the four author limit: Marion Lonsdale (City of Duluth), Jane Reed (NRRI-UMD), Jerry Henneck (NRRI-UMD), Norm Will (NRRI-UMD), Elaine Ruzycki (NRRI-UMD), Gerry Sjerven (NRRI-UMD), and Bruce Munson (Education-UMD). We thank the following individuals for conceptual, technical, field, laboratory, communication, extension and educational help: T. Carlson, J.Walker, A. Odean, City of Duluth Stormwater Utility; M.Guite, J.Stepun, J.Mayasich, Western Lake Superior Sanitary District; J. Anderson, J.Dexter, C. Butler, T.Estabrooks, M. Rauner and H,Bauman, Minnesota Pollution Control Agency, Duluth Regional Office; N.Meyer, U. of Minnesota Extension Service, U. of Minnesota; Z.Zwiebel and M.Zuikov, Minnesota Sea Grant, U. of Minnesota-Duluth; J.Ameel, V.Brady and J.Kallestad, Natural Resources Research Institute, U. of Minnesota-Duluth; K.Rezanka and C.Kowalczak, St. Louis River Watch, Fond du Lac Tribal Community College; L.Leith, Washburn Edison Middle School, Duluth, MN; M.Janus, Lake Superior Zoo-Duluth.

This project was funded primarily by U.S. Environmental Protection Agency Grant R82932101 (Project # G1J10127) under the Environmental Monitoring for Public Access and Community Tracking (EMPACT) and Science to Achieve Results (STAR) programs to ML and RA. Additional funding support for 2004-05 was granted from the City of Duluth and from Minnesota's Lake Superior Coastal program grants to ML and RA (MLSCP Project No. 306-12-06 and Project No. 306-03-07). Significant additional in-kind match was provided by the City of Duluth Stormwater Utility, the Natural Resources Research Institute and Minnesota Sea Grant at the U. of Minnesota-Duluth, the Western Lake Superior Sanitary District, and the Minnesota Pollution Control Agency – Duluth Office. Although this project was funded largely by the U.S. Environmental Protection Agency, this paper was not subjected to any EPA review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

References

Ameel, J., E. Ruzycki and R.P. Axler. 1998. Analytical chemistry and quality assurance procedures for natural water samples. 6th edition. NRRI Tech. Rep. NRRI/TR98/03.

Anderson, J., M. Evenson, T. Estabrooks, and B. Wilson. 2003. An assessment of representative L. Superior Basin tributaries. MN Pollution Control Agency, St. Paul 55155.

APHA. 2003. Standard methods for the examination of water and wastewater. Amer. Publ. Health Assoc. Washington, D.C.

Axler, R. and M. Lonsdale. 2003. *Duluth Streams*: Community Partnerships For Understanding Water Quality and Stormwater Impacts at the Head of the Great Lakes (*www.duluthstreams.org)* . Coastline Issue 13.1: 10-15. *www.epa.gov/owow/estuaries/coastlines*), February 2003.

Duluth. 2000. Duluth Vision 2000 – Duluth in the 21st Century. City of Duluth Planning Department, December 2000.

EPA. 1999a. National pollution discharge elimination system – regulations for revision of the water pollution control program addressing storm water discharges. Federal Register 64(235): 68722-68735.

EPA. 1999b. Report to Congress on the phase II storm water regulations. EPA 833-R-99-001. Environmental Protection Agency, Washington, D.C.

EPA. 1998. EPA Guidance for Quality Assurance Project Plans EPA QA/G-5. EPA/600/R-98/018, February 1998. (http://www.epa.gov/quality1/qs-docs/g5-final.pdf) /600/9-89/087.

Host, G. E., N. R. Will, R. P. Axler, C.J. Owen, and B. H. Munson. 2000. Interactive technologies for collecting and visualizing water quality data. Journal of the Urban and Regional Information Systems Association 12:39-45.

IJC. 1999. Lake Superior Binational Program. Final. 1999. Protecting Lake Superior–Lakewide Management Plan, Stage 2. Load Reduction Targets for Critical Pollutants. Prepared by the Superior Work Group: Chemical Committee. 162 pages. Thunder Bay and Chicago.

MPCA.2004. Minnesota's Impaired Waters and Total Maximum Daily Loads (TMDL):2004 Final List of Impaired Waters (approved by the U.S. EPA on May 13, 2004). *www.pca.state.mn.us/water/tmdl/index.html#tmdl*

MPCA. 2000. North Shore land use issues: The real costs of growth. Publication WQ/Lake Superior Basin #2.03.

Munson, B., R. Huber, R. Axler, G. Host, C. Hagley, C. Moore and G. Merrick. 2003. Investigating water quality through the Internet. The Science Teacher 70(1): 44-49.

Peterson, D. (EPA ed). 2000. Delivering timely water quality information to your community: The *Lake Access*-Minneapolis project. EPA/625/R-00/012, September 2000, U. S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, 45268, USA (contributing authors: R. Axler, J. Barten, J. Goin, C.Hagley, G.Host, B. Liukkonen, B.Munson, B.Peichel, C.Owen, B.Vlach, N.Will). EPA-625/R-00/012, 104 p.