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VDIL Final Report. PI: Richard Axler (NRRI)

Flash Flood: Interactive Animations of Stormwater and Wastewater Flows in Duluth's Urban Watersheds

N. Zlonis (Sea Grant), J. Schomberg (Sea Grant), R. Axler (NRRI), G. Sjerven (NRRI) and G. Host (NRRI).

Background:

The City of Duluth has unique problems related to the management of drinking water, stormwater and wastewater. Water from Lake Superior is pumped through the drinking water system to storage tanks, homes, and businesses. Residents use the water, get it dirty, and then drain most of it away by a different set of pipes collectively called the sanitary or wastewater system. This wastewater travels to the Western Lake Superior Sanitary District (WLSSD) where it is treated before being discharged indirectly (via the St Louis River) or directly into Lake Superior. Not all of the water we use from the drinking water system goes back into the sanitary sewer. Water from washing cars and watering lawns runs off down the street into the stormwater system - an entirely different set of underground pipes that collect rainwater, snowmelt, water draining from streets and parking lots, and the water you just hosed onto the driveway. This water does not get treated by WLSSD, and is not supposed to, since the treatment plant was only designed to treat the concentrated wastewater from our homes, businesses and industries. It, and stormwater runoff, drains quickly into one of the 42 streams in the city. In an effort to accommodate the activities of its population, the City of Duluth maintains more than 138 miles of roadway ditches and culverts, two lift stations, 13 sediment boxes, 4,716 manholes, and 250 miles of underground storm sewer lines. Ideally, rainfall and snowmelt would percolate slowly through vegetation and soil before seeping into streams. Urbanization short circuits this process, instead leading to polluted runoff and flashier stream flows.

The steep slopes of Duluth, the amount of impervious surface, and historic conditions, such as having house gutters connected to storm systems, provide unique water management problems for the City. This has been compounded by the fact that when it rains hard and during Spring runoff, the sanitary system of pipes and pump stations can become overloaded resulting in spills of raw sewage before the wastewater can even get to WLSSD. Thus, heavy rainstorms and snowmelt runoff cause public and human health risks associated with both systems. Yet the public has a generally poor understanding of the complexity of water management or the consequences. Beginning in 2002, with funding from the U.S. EPA in combination with in-kind efforts from various agencies, the Natural Resources Research Institute (NRRI) and Minnesota Sea Grant at UMD 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 the website <http://duluthstreams.org>. The Partnership's chief goal is to enhance the general public's understanding of aquatic ecosystems and their connections to watershed land use, to improve environmental decision making and provide both

economic and environmental sustainability. A primary tool for educating the public is the use of real-time intensive data from 3 trout streams that is collected automatically, sent via modem to NRRI, processed, animated and posted onto the website along with explanatory information.

Flashflood 2004:

DuluthStreams staff have been exploring other ways to visualize data using the capabilities of the VDIL Lab. In 2003, PI G. Host initiated the development of a model of a gauged watershed using World Construction Set software at the Lab.

1. 2004 Project Concept

The project stemmed from data generated by the Miller Creek Stormwater Modeling Project, conducted by the Natural Resources Research Institute (NRRI). Storm water quantity and quality were modeled for the Miller Creek watershed in Duluth, MN. The EPA-developed Storm Water Management Model (SWMM) was chosen for a variety of reasons. Since its first development in ~ 1970 it has been modified and upgraded over the years by universities, private consultants, EPA, and others. SWMM is widely used, widely documented, supported since its development, and has inexpensive programming available to reduce the required learning time. Specifically, we used PCSWMM 98, which uses the SWMM 4.4 engine. Our goal was to develop an easy to use, interactive tool for investigating the effects of rain events and increased watershed development on stream flow and water quality in Miller Creek.

This modeling process resulted in a large quantity of data which initially was used to create a number of static maps of various features for a variety of scenarios. While these maps provide extensive and detailed information for interpretation, the quantity and complexity of these maps make it difficult and time-consuming to get a general understanding of the creek's response to rain events and land use. We required a better interface for communicating to non-scientific audiences, but which also could be helpful to scientific researchers as well. Providing an easy way to navigate the data can quickly reveal patterns that might otherwise be overlooked.

Utilizing resources from UMD's Visualization and Digital Imaging Laboratory, we created an interactive map of the watershed primarily using data from the model and Macromedia Flash's programming language, Actionscript. Flash was the obvious choice for such a project for a variety of reasons: 1) Macromedia's Flash player is very widespread and over 95% of web users are reported to have it installed, allowing us to create the interactive tool within an HTML document to make it available to nearly anyone with an Internet connection; 2) Flash is vector based, providing a low-bandwidth way to port spatial GIS data to a web-browser without sacrificing resolution; 3) Actionscript's vector-based drawing API provided an elegant way to dynamically generate custom graphs using the model's vast amounts of data; and 4) Flash's animation capabilities lend themselves nicely to the model's time-based scenarios. Utilizing a global timeline control on the map, the user can control the time variable independently of other Interface elements, while watching the results occur in real-time on the map & its graphs.

2. Interface Design

The interactive timeline is one of four main components of the map's interface. In addition to scrubbing the timeline via mouse, the user is provided with on screen stop/play, forward and reverse controls, as well as their keyboard equivalents. Also, the timeline is superimposed over graphs for 6 significant data points along the stream's main channel, as well as a graph of the rainfall event. These points are indicated directly on the map, and have an approximate horizontal alignment to their respective graphs.

The scenario controls, along with the timeline, make up the primary interface for user input. It consists of radio buttons on the bottom-left of the screen that allow the user to select between different combinations of rainfall and impervious surface independent of the map's timeline. This provides a means for the user to toggle directly between various scenarios while seeing the results take place instantaneously on the screen. This is a tremendous advantage over comparing multiple static maps.

The map itself is the third component of the interface. The watershed, stream channel, impervious surfaces, and data points are its primary features. The amount of impervious surface, as determined by the user via the scenario control, is mapped instantaneously. The stream channel contains a gradient mapping of suspended solids, illustrating this data, directly along the stream channel. The map also includes the data points, which when clicked reveal an aerial photo or the area plus additional sub-basin data.

The final main component of the interface is the main data display. This consists of a vertical line graph adjacent to, and spanning the length, of the stream channel on the map. This layout allows for direct comparison of graphed values to their approximate location on the map. The user can roll over any data point to see its exact location for more precise analysis. The graphed parameters are color-coded and their visibility can be toggled by the user. Two tabs at the top of the window allow the user to toggle between Cumulative and Instantaneous values. This particular interface feature is potentially useful for other interactive graphing applications within the DuluthStreams website.

3. Next Steps

The Flash Flood concept is extendable could be developed for a variety of applications. Since graph data is retrieved from a flat data file, any data can be easily applied to the graphing engine. By importing spatial data from Geographic Information Systems (GIS) and quantitative data from the computer model, the program could be applied to any river or stream; similar applications could be developed for lakes, wetlands, coastlines, or sewer systems. Additionally, a similar timeline/scenario concept could be applied to map other subjects, such as biological data or more specific land-use issues. The sophistication of the program can be adjusted for the intended audience. For example, a simplified version could be designed to illustrate basic concepts to high-school classrooms or a more technical precision version could be used as an interface for researchers actually using modeling systems. Our long-term goal is develop an interactive tool to allow users to observe the different patterns of stormwater and wastewater flow through the City's drainage networks in the Miller, Tischer, Chester, Kingsbury and Amity Creek watersheds, and then into the St. Louis River Estuary and Lake Superior. Users could

then modify land use by restoring shoreline zones and wetlands and conducting various build-out scenarios and see how they affect water quality and stream flow during different storm events, whose magnitude is also user controlled

4. FlashFlood Prototype Demo:

The completed Flash animation tool is accessible via the Miller Creek section of the DuluthStreams website at <http://duluthstreams.org/stormwater/simulation.html> .

The attached slides present an overview of the problem, the relevant DuluthStreams website sections and data visualization tools (as static screen captures), the previous SWMM modeling interface for Miller Creek, and screen captures from the VDIL funded FlashFlood data animation tool.