A Two-Dimensional, Transient Flow Model of the St. Clair – Detroit River Waterway

A Cooperative Program of the Michigan Department of Environmental Quality, Detroit Water and Sewerage Division, U.S. Geological Survey, U.S. Army Corps of Engineers, and National Oceanic and Atmospheric Administration

Flow simulations will provide a basis for understanding the effects of dredging on flow and sediment transport; predicting the movement of discharges from combined sewer overflows, tributaries, treatment plants, and spills; identifying source areas for public water supply intakes; and analyzing lake circulation patterns affecting critical habitats.

St. Clair River, Lake St. Clair, and Detroit River form part of the international boundary between the United States and Canada. This waterway is major navigational and recreational resource of the Great Lakes region that connects Lake Huron with Lake Erie. A mathematical model of flow in the St. Clair – Detroit River waterway is being developed to help assess the susceptibility of public water-supply intakes to contaminants and to better understand the water-quality characteristics and sediment movements in the waterway.

St. Clair River extends about 39 mi (miles) from its head at the outlet of Lake Huron near Port Huron, Michigan, to an extensive delta area. Through its length, water-surface elevations fall about 5 ft (feet) as it discharges an average of 182,000 ft^3/s (cubic feet per second) from a drainage area of 222,400 mi^2 (square miles). Lake St. Clair receives water from St. Clair River, and lesser amounts from Clinton River in Michigan and Thames River in Ontario. Along the 25-ft deep navigational channel, the lake has a length of about 35 mi. The lake's round shape, with a surface area of 430 mi^2, and shallow depths that average about 11 ft, make it highly susceptible to winds and water-level changes in the connecting channels. Detroit River receives water from Lake St. Clair, where it courses 32 mi to Lake Erie. Water levels fall about 3 ft though Detroit River, which has an average discharge of 186,000 ft^3/s.

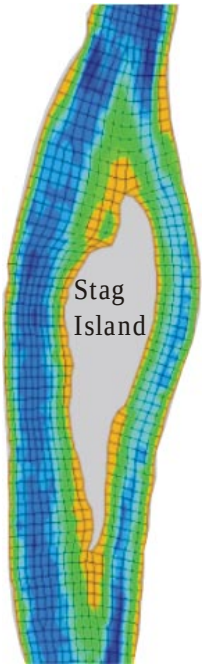
The mathematical model is being developed to compute stream velocities and water-surface elevations (stage) within the waterway. The model is based on the physics of fluid flow and the geometry of the system. Flow resistance and mixing characteristics will be inferred from direct measurements of flow and stage.

Computations are driven by continuously changing stage data at the upstream and downstream limits of the waterway and by available wind information. When completed, the model will provide detailed information on the horizontal (vertically averaged) variations of flow and stage throughout a wide range of hydraulic conditions.

The Michigan Department of Environmental Quality recognized the need for a model as part of the Source Water Assessment Program (SWAP). This program's responsibilities include evaluation of the susceptibility of public water supply intakes to contaminants. The St. Clair-Detroit River waterway contains 13 intakes that supply water to about one third of the residents of Michigan. The Detroit Water and Sewerage Department also is supporting the development of the model because of their interest in maintaining and improving the water quality in Detroit River.

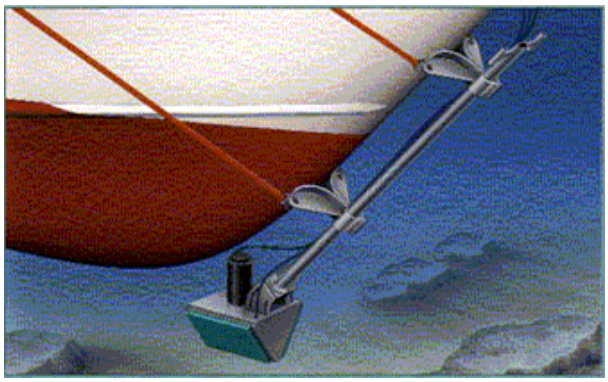
Technical development of a model was initiated in 1998 though a cooperative agreement between the MDEQ, U.S. Geological Survey (USGS) and the Detroit District, U.S. Army Corps of Engineers (USACE). The model is based on a prototype created by the Waterway Experiment Station of USACE in Vicksburg, Mississippi for the Detroit District. The prototype uses an open-source non-proprietary hydrodynamic numerical model for computations, which is referred to as RMA2.

The RMA2 code is a finite-element formulation that is widely used for far-field hydrodynamic problems in which vertical accelerations of flow are negligible and averaged vertical velocities are needed. Detroit District and Environment Canada have recently adapted the prototype to meet the special needs associated with investigating potential effects of channel encroachments on water levels on Lake St. Clair and Lake Huron.



Model development to support the SWAP also requires several major refinements of the prototype. First, the density of the finite-element grid was increased throughout the waterway to provide more detail on flow paths in the vicinity of water-supply intakes. To illustrate the grid density, part of the model for St. Clair River near Stag Island is shown to the right. In the image, shallow areas in the channel are depicted in yellow and deeper areas are depicted in blue.

Second, a new bathymetry (streambed elevation) survey is planned for the summer of 2000 within the connecting channels. The bathymetry of the prototype is based on a 1955 hydrographic survey. This survey, however, preceded a 2-ft deepening of the navigational channel in 1962. The National Oceanic and Atmospheric Administration (NOAA) is scheduled to conduct the hydrographic survey using a single-bean echo sounder, (as depicted in the image below), according to International Hydrographic Organization Chart accuracy standards. Approximately 1139 cross sections will be collected at a 100-meter line spacing. The new bathymetry data will be available by September of 2000 to more accurately describe the current flow geometry.



Finally, a formal parameter estimation analysis will be conducted to quantify the reliability of flow simulation results. This analysis will utilize a series of Acoustic Doppler Current Profile (ADCP) velocity measurements and corresponding stage data. The Detroit Office of the USACE has obtained a series ADCP measurements at numerous locations within the St. Clair and Detroit Rivers. Measurement sets have been obtained at about 6-week intervals during the open-water periods since 1996. Each set contains about 7,000 point measurements of flow velocity. Together with stage data, the velocity measurements will allow estimation of the magnitude and uncertainty of model parameters describing flow resistance and mixing characteristics. Possible seasonal variability of model parameters, perhaps caused by aquatic growth, will be analyzed.

A U.S. Geological Survey report will be prepared in spring of 2001 to document the development process and the capabilities of the flow model. The model is expected to provide a basis for further studies of particle movements, water chemistry, and sediment transport within the waterway. An electronic version of the report and model input will be accessible for public information.

Development and on-going utilization of the flow model will depend on the continued availability of stage data at the model boundaries and interior points. In 1999, however, six of the gaging stations in the St. Clair – Detroit River waterway were targeted for elimination. Loss of these stations would have diminished the accuracy and limited extent to which the model could have been applied. Through the efforts of the Great Lakes Commission and other organizations, however, funding was obtained to modernize the stations so that NOAA could effectively continue maintenance and operations.

Wind has a major effect on the circulation of water in Lake St. Clair, much like water-surface elevations control the movement of water within the connecting channels. Continuous wind data for Lake St. Clair, however, is not currently available. One potentially suitable location for the establishment of a wind monitoring station is on the Lake St. Clair Lighthouse (pictured to the right). This lighthouse is situated near the middle of the lake, just off the navigational channel in United States territorial waters. Such a station would provide data needed for this and other research activities on Lake St. Clair. Further, availability of this data in real time through the Internet would help improve the safety of recreational activities and commercial navigation on the Lake.

For Further Information:

To obtain information on the Source Water Assessment Program in Michigan, please contact
Brad Brogren of the Department of Environmental Quality,
Drinking Water and Radiological Protection Division,
Baker-Olin North,
3423 N. Martin L. King, Jr. Blvd.,
P.O. Box 30630,
Lansing, MI 48909-8130 or
access the Internet at:
http://www.deq.state.mi.us/dwr/SWA/swa.htm

To obtain additional information on the development of the flow model, please contact
Dave Holtschlag
U.S. Geological Survey, 6520 Mercantile Way, Suite 5,
Lansing, MI 48911 or access the Internet at:
http://mi.water.usgs.gov

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