Chapter 18

Real Time Flood Forecasting with GIS

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Many new applications are being found for Geographical Information Systems (GIS). Indeed, the vast quantities of environmental data being generated today challenge the imagination to create useful and innovative techniques, simply in order to make the data more meaningful.

GIS integrates spatial and tabular data to make information both powerful and effective. The application presented here is somewhat unusual: water level predictions from a hydrodynamic model are converted into a flood surface and then a network of streets, houses and rail lines is overlaid on top of it. The generation of the display occurs within minutes and is transparent to the user. This GIS model has been given the acronym SMIFF (Spatial Mapping for Integrated Flood Forecasting) and was initially written for the DWOPER hydrodynamic model; it was recently expanded to accept HEC-II files and will soon be available for SWMM EXTRAN. A schematic of the associated hydrotechnical linker is shown in Figure 18.1.

Traditionally, water resources engineers have had to wade through long tables of numerical data to determine the results of river flood forecast models. Providing graphical representation of such information, and including analysis capability (e.g. tabular reports of potentially flooded homes, contact names,

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Figure 18.1
Hydrotechnical linker

phone numbers, etc.), is a significant improvement in facilitating the interpretation of a flood forecast and the implementation of an effective emergency response.

Tabular reports in SMIFF, in addition to containing the above mentioned information, also access other database files containing historical flooding data, building type(s), their assessed value(s), survey notes, etc.

18.1 Study Background

The Saint John River at Fredericton, New Brunswick has experienced several significant historical flood events. While the Mactaquac Dam upstream is essential to flood mitigation, retarding the surge in river elevation which would otherwise occur, it has limited storage and is therefore limited in its ability to prevent downstream flooding. When water must be released, it is necessary to know how much the water surface will rise, otherwise costly damages may occur.

There are several hydrodynamic computer models which readily calculate dynamic or steady state water surface profiles, but much of the data they produce is of no immediate use, especially when it comes to accurately evaluating which houses on the flood plain will be at risk for a given flood event. Traditional flood plain mapping techniques are time-consuming; hence the need for an improved technology.

The Federal Government identified the usefulness of applications such as these in their Green Plan. Specific goals can be found in that document. Goal 7 is one of note:

"minimizing the impacts of environmental emergencies"

These environmental emergencies have further objectives described as follows:

"Quick and effective response to threats posed by pollution emergencies due to human activity and naturally-occurring environmental emergencies."

As part of the Plan, the Government announced a five year program to improve early detection, prediction and warning of extreme weather events, to upgrade weather and emergency surveillance systems, and to enhance public awareness of the risks of natural disasters and appropriate responses to them. Flooding is considered a natural disaster, the impacts of which can be mitigated through upgrading emergency surveillance equipment; in this regard, GIS is an extremely effective tool.

The project team comprised CH2M-Hill Engineering Ltd., Nolan, Davis & Associates Ltd. and the New Brunswick Department of the Environment (NBDOE), the agency using the SMIFF model.

To others -conservation authorities, insurance agencies, etc.- the usefulness of an early warning system is obvious: floods result in loss of life and property damage. Furthermore, flood forecasting centres are presently quite constrained in their ability to convey the implications of their flood predictions to the public. With the power of today's computing tools and their economic viability, this situation need not exist.

18.2 Study Approach

The NBDOE currently uses the DWOPER hydrodynamic model for flood forecasting on the Saint John River below the Mactaquac Dam. The first task therefore involved the development of a linker to translate water levels and other pertinent data within the study area (such as flow rate, date, time and station description) from DWOPER to the GIS model.

At the same time, maps were digitized with all the appropriate contour and point elevations, roads, railway lines, houses, etc. Data were obtained from the Water Resources Branch of the NBDOE (23 FDRP maps, scale 1:1000) and from the Canadian Hydrographic Service (bathymetric survey).

The SMIFF model enables the user to view either a flood surface for a specified date and time, or, alternatively, a flood surface envelope of maximum flooding over the forecast period. The desired water surface elevations are subsequently transferred to the specified cross section coverage within the GIS. Figure 18.2 shows the cross sections used in this particular application.

The mapping technology which has been developed in general can readily be applied to any watercourse. However, it should be noted that the number and spacing of cross sections needs to be uniquely determined in each application based on hydraulic considerations. The SMIFF model generates a triangulated irregular network (TIN) of the water elevations, creating a flood surface which is overlaid on the topography (land elevation). The derived flood plain is then defined as the area within the boundary. An example of a derived flood polygon is given in Figure 18.3.

SMIFF contains a series of user-friendly menus to facilitate zoom-in and query procedures within the flood zone (Figure 18.4). In fact, the user need not even be familiar with the GIS software to run the SMIFF model.

When the projected flood surface is overlaid by the road and house network, it is a simple procedure for the user to pull up the database and display particulars of the potentially affected areas, including specific information (such as address, home owner and phone number) on the homes which are expected to be flooded.

18.3 Tools and Resources

The GIS chosen for the development of SMIFF was PC ARC/INFO,

Figure 18.2
Study area and station locations.

Figure 18.3
Flood polygon using DWOPER predictions.

Figure 18.4
Zoom in with database display.

Version 3.4D Plus. There were several reasons for this. First, ARC/INFO has the analytical capability necessary to create both 2- and 3- dimensional representations of the study area, which enabled the digital terrain model to be developed. ARC/INFO also has flexibility of use and is compatible with Autocad software and the dBase IV database manager.

18.4 Validation

Although a sufficient body of measured data is normally required to calibrate and validate the results of any model, the number of flood events for which the flood plain has been determined is relatively low. Nonetheless, the NBDOE has already completed a great deal of work in determining the extent of the 1973 flood from the use of aerial photographs. This information was used to validate the flood surface.

A comparison of the ARC/INFO surface with a manually delineated flood limit was carried out for the 1973 flood event (Figure 18.5). This was done by enlarging a portion of the SMIFF calculated flood polygon (shaded) and overlaying it with one interpreted from aerial photographs (heavy dark line). Some of the inaccuracies of the SMIFF model can be attributed to:

- 1) insufficient ground surface accuracy,
- 2) inability to spatially convey flow transported under roads through culverts, and
- 3) boundary effects, i.e., mapping did not extend beyond flood zone in some areas.

18.5 Other Applications

The NBDOE has indicated their desire to use the model for low flow predictions during summer months. This application will give them the ability to determine locations within the channel which are suitable for aquatic habitat, given certain specifications such as depth and velocity. Alternatively, the mapping of suitable aquatic habitat zones could be carried out for a number of low flow conditions in an effort to determine minimum desirable low flows in a reach.

Another application with a great deal of benefit to municipal engineers involves the use of the SMIFF model in evaluating overland and basement flooding impacts attributable to inadequate inflow or conveyance capacity of storm, combined or sanitary sewer systems. This is illustrated in Figure 18.6.

Figure 18.5
Comparison of SMIFF predicted and aerial photo interpretation of 1973 flood.

Figure 18.6
Conceptual municipal GIS application

18.6 Conclusions

There are many existing environmental models being used today by engineers and planners. Interfacing the output of such models with graphical/analytical software is at the forefront of GIS technology in water resources and several other areas of study. At this time, when GIS technicians are struggling to master complicated software, they should look to the future when the coupling of GIS technology will be an expected addition to most modelling exercises.

References

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