CHAPTER 7. Summary, Conclusions and Recommendations for Future Work

Summary

The main result achieved in this research is the creation of an integral system to model NPS pollution in surface waters. This work has demonstrated the feasibility of applying advanced technologies in order to integrate models in a uniform platform with GIS capabilities. The work developed in this research produced an integrated support system that helps in the modelling tasks and in the decision making process of NPS studies.

One of the major contributions to NPS modelling was adding a water quality component to WATFLOOD based on the GRU approach. The spatial variability of the physical processes occurring in the watershed is an essential characteristic to take into account. As part of the research, a water quality component was developed to simulate the processes governing the fate and transport of NPS pollutants. The distributed approach based on the GRU concept was extended to the algorithms selected to simulate the sediment and nutrient processes.

A simple sediment yield model for single storm events (Hartley, 1987) was successfully linked to the WATFLOOD model. The contaminant relationships coupled with the hydrologic model were taken from the CREAMS and AGNPS models. The methods selected for the water quality component in WATFLOOD were developed by Frere *et al*. (1980) and adapted by Young *et al*. (1986) in AGNPS. The relationships were modified to perform based on landcover to follow the GRU concept at a watershed scale.

The AGNPS and WATFLOOD models were included in a decision support system through the development of interfaces into RAISON, a decision support system with GIS capabilities. This integrated approach was then tested in different applications and validated against measured data. The development of the interfaces includes the creation of pre- and post-processing tools, the former to allow the interactive process of setting up model grids and automate data input and the latter to analyze the output. The integration effort was conducted with the idea that better modelling capabilities need to be combined with the application of new technologies, such as the use of GIS capabilities, to resolve problems associated with ease of model use. The sensitivity analysis and the decision support tools provide additional means to identify the importance of the variables and to track the simulation process for different scenarios.

One of the major assets of this work was the automatic data extraction from digital maps. Two basic procedures were created to achieve the extraction of data. One deals with the DEM files to extract topographic related data such as flow direction and slope. The other uses landcover and soil type maps with polygon attributes to extract the relevant data for each model according to land cover and soil information. The procedures to extract polygon information from digital maps developed in this research are unique achievements in the field of input data acquisition. They differ from traditional GIS applications where raster or pixel values of attributes are used to create average parameter values for the grid. In this case, a more general procedure was developed and optimized. It actually uses polygon values to calculate the input data through the use of lookup tables. This allows the use of almost any type of map file as long as it is converted to the standard shape format and the linkage to the lookup table is provided.

Even for this data intensive task, the procedure was developed for completion in reasonable times for a desktop computer. As technology on PC evolves to provide even faster machines, this issue will become less important. But, in the meantime, it is essential to have procedures that can be run in minutes rather than in days. A complete setup for the Duffins Creek application can be achieved, using the developed system in a Pentium II-233Mhz desktop, in less than an hour.

The application of the AGNPS model provided the opportunity to compare results from both approaches. Initial testing of the system, including automation of input data from vector maps (soil type, land use, and digital elevation) was done using data from Duffins Creek. On the other hand WATFLOOD has already been tested for hydrologic responses and achieved satisfactory results in the proposed areas. The objective was to test the water quality component performance without further calibration for the runoff prediction. The results from the WATFLOOD and the water quality component developed in this research, support the hypothesis behind this work, that is, if the parameters are related to landcover and the response for each element is weighted on results and not on the coefficients, the model will perform quite accurately and will represent a major improvement in NPS modelling.

Conclusions

The conclusions and contributions from this research are presented in the following categories:

a) Model Development

- Blending of a water quality component into WATFLOOD in the context of the GRU is a key contribution of this research.
- A physical based sediment yield model was successfully used as the soil erosion component for the water quality component of WATFLOOD.
- The algorithms to simulate the nutrient processes were based on the CREAMS and AGNPS models and modified to take into account the GRU approach.
- These procedures were coded as subroutines in WATFLOOD giving the flexibility to modify them if further research is aimed towards improving the algorithms.

b) Data Management

- An integral system was constructed with the development of interfaces for the AGNPS and WATFLOOD models.
- Pre- and post-processing tools were created to help in the setup of the model, automate data input and analyze the results of the simulations.

- Specific procedures were created to automatically extract model data from digital information sources, such as DEM, soil and landuse maps.
- Sensitivity analysis utilities were included in the system to provide the user with the means to identify the importance of the variables involved in a simulation.
- Decision support tools were developed to allow the creation and testing of different gaming scenarios to support the decision making process on NPS studies such as in BMPs evaluations.

c) Model Application

- Application of the system was done at the Duffins Creek watershed. The integral system was successfully used to setup both models and automatically extract the data for the study area.
- The performace of the models were tested with hydrology data and the comparisons for the calculated and measured peak flows were accurate for both models.
- The comparison between models provided close matches for sediment and nutrients results.
- Hourly sampled events were used to test the performance of the model. The results from the tests were excellent. Nearly perfect matches between calculated and measured values for sediment and nutrients were achieved for the hourly sampled events.

Recomendations for Future Work

Some improvements in the AGNPS interface can still be made. To get better results from the DEM extraction process in the borders of the watershed being simulated, tools to include flow direction auto-check and to highlight cells with flow direction problems for easier on screen identification can be implemented. To facilitate the fertilizer input data, it would be of help to develop a process to assist in the fertilizer propagation in the cells. A first approach based on landuse could be attempted. Fertilizer rates and availability can be linked to landuse through lookup tables in order to populate the cells with the fertilizer data.

Current development of AGNPS98 from the USDA features modifications to the hydrology component to increase the capabilities for continuous modelling. The new version actually in beta testing mode is consistent with older versions for data import. For this work to be compatible with the new version of AGNPS, straightforward extension of the interface to accommodate the changes in the new version can be easily achieved. At the same time, as RAISON moves to a 32 bit object oriented application, it would be useful to modify and recompile the interface and extraction code to take advantage of the new 32 bit capability. This will eliminate the 4,000 points per polygon limit to handle and pass very large arrays.

With respect to the WATFLOOD model, and because the code development is an ongoing process, the water quality component has to be incorporated into the latest version of the model code. This should pose no problem; thanks to the modular approach all the subroutines will merge effortlessly into the most recent code. In fact, if further research is aimed towards improving the methods for sediment or nutrients calculations or routing this can be easily incorporated into the model. For the interface, additional integration can be achieved by linking the WATFLOOD utilities with RAISON directly. For example the streamflow data can be captured directly from RAISON databases by clipboard copy or code. Radar visualization is another area that can take advantage of the system capabilities and can be pursued in future work as well as the output display for sediment and nutrient concentrations.

Further work on validating the model capabilities to simulate sediment and nutrient transport has to be done. It is recognized that additional field sampling has to be done. The Duffins Creek application produced excellent results but more than one field trial is needed to confirm this conclusions. This field testing should accommodate a wide range of field conditions, climate, topography, landuse, etc. The transferability of model parameters to other watersheds, especially those in remote areas without enough data for calibration, is a major problem with current NPS models.