CHAPTER 1. Introduction

1.1 General

Water resource management was focused initially on water quantity issues. Solving water quality problems did not constitute a primary objective for regulatory agencies until recent years. Interest in water quality only arose with the increase in water degradation and the decrease in available water supplies of acceptable quality. Until the mid-1970s, the problem of Non-Point Source pollution (NPS) was an unknown phenomenon to the general population (Novotny and Chesters, 1981). Environmental engineering and science were basically oriented toward water conveyance, supply, treatment, and disposal.

In the last two decades, NPS has become a topic for research that resulted in the development of numerous models and modelling techniques. Most models simulate hydrologic, chemical, and physical processes involved in the entrainment and transport of sediment, nutrients, and pesticides. The difficulty in modelling NPS is the problem of identifying sources and quantifying loadings. In contrast to a point source, where a known volume of contaminant is discharged from a single identifiable source, diffuse pollution is an aggregate of small contaminant inputs. Such concentrations are released from many sources spatially distributed through a watershed. Thus, NPS models require a distributed modelling approach. The difficulty is that traditional distributed models are limited in scope by the requirement of within element homogeneity and by the need to manipulate extensive data sets.

This thesis addresses these two issues. First, to deal with heterogeneity, a group response unit (GRU) approach is used in the water quality component coupled to a hydrologic model. Its performance is compared with a well established NPS model based on classical hydrologic response unit methods. Second, to handle the extensive data requirements of both models, an integrated system, constructed with powerful data management capabilities, is developed to help in the setup, data input and result analysis.

Application of the GRU concept is another step in the evolution of NPS models. Early models used the lumped approach, considering an area or field to be homogeneous and calculating a hydrologic response from the unit. For larger areas the watershed was divided into individual elements, each with its own set of model parameters, in an effort to account for the spatial variability. This led to so-called distributed models, in which many sub-basins are used.

As the area of the basin to simulate increases, the size of the grid-cells has to increase in order to maintain a manageable number of elements. Most distributed models use the hydrologic response unit approach (HRU), which assumes homogeneity for each cell, and thus restricting the size of the cell to be modelled. Recently a different approach, based on the GRU concept, described by Kouwen *et al*. (1993), calculates the response for each landcover class within the element making larger cells a practical alternative. This approach is included in the hydrologic model WATFLOOD (Kouwen, 1988). Part of this research is to test the GRU concept by adding a water quality component to WATFLOOD and comparing it against an established HRU model. The AGNPS (Young *et al*., 1986) is the selected HRU reference model.

The successful use of distributed models, either GRU or HRU based, requires the ability to handle large amounts of data, increasing the effort required to collect and compile the input files. Preparing data input for models and analyzing results are probably the most common problems encountered by model users. “Interactive programs are needed to assist model developers and users in processing data, initiating model simulations, and analyzing model results using a variety of statistical and graphical techniques” (Leavesley *et al*., 1988).

To this end, a integral system is developed in this research, first, to facilitate the GRU-HRU comparison and second, to provide a general tool for NPS studies. The system involves linking the two NPS models to a decision support system with GIS capabilities in such a way to take full advantage of digital mapping information. This provides data compilation for the models thus helping in the setup and operation of the simulation process. Post-processing features are included to assist with the interpretation of model results. For example, the system therefore includes tools for comparative analysis of different scenarios provided with a measure of the confidence limits of the simulation results.

1.2 Research Plan and Contributions

The principal objective of this research was to produce an integral system for nonpoint source pollution modelling in surface waters. Diffuse pollution models, AGNPS and WATFLOOD with the water quality component, were included in a decision support system with a unique platform, common interfaces, and GIS capabilities. The system accommodates pre- and post-processing tools, decision support tools and sensitivity analysis for the models. This integrated approach can be used in further investigations to explore the effects of modifying model parameters. The specific tasks included:

i) Incorporate a water quality component for sediment and nutrients, into WATFLOOD using the GRU approach.

ii) Integrate the AGNPS model for use as a reference for the nonpoint source models.

iii) Create the integral system through the development of interfaces for the two models to interact with a decision support.

iv) Apply and test the performance of the models at a watershed level.

The coupling and testing of the water quality component based on the GRU approach into WATFLOOD formed the major part of this work. A distributed approach based on the GRU concept for landcover characteristics, led to a simplified method to specify the parameters in each grid cell and improve NPS modelling. As part of the research, a water quality component was developed to simulate the processes governing fate and transport of NPS contaminants. The water quality relationships were based on landcover at a watershed scale, and at the same time, accounted for the physical processes.

The application of the AGNPS model provided the opportunity to compare results from both approaches. The initial testing of the system, including automation of input data from vector maps (soil type, land use, digital elevation), was done in Duffins Creek (a watershed located east of Metro Toronto). Available data files and runs of the AGNPS model helped to test the pre-processing tools.

WATFLOOD had already been tested for hydrologic response and achieved satisfactory results in the proposed areas. The objective was to test the water quality component without further calibration for the runoff component. The transferability of model parameters to other watersheds, especially those in remote areas without enough data for calibration, is a major problem with existing NPS models. If the hypothesis behind this work be true, that is, the parameters are related to landcover and the response for each element is weighted on results and not on the coefficients, model portability will increase substantially, which is a significant achievement in NPS modelling.

The main task of creating the integral system for nonpoint source pollution modelling in surface waters was achieved through the linkage of the two distributed models with a decision support system. This provided easy data compilation for the models, facilitated the setup, the operation of the simulation processes and the interpretation of model results. It included the creation of pre- and post-processing tools to automate data input and analyze output. The system components were created in modular form in order to facilitate future improvements.

In order to test the applicability and performance of the models, simulations on the Duffins Creek watershed were conducted and the results compared between the models and against field sample data. Results were compared for peak flows, sediment yields and nutrient loading. Hourly event sampling was used to evaluate the performance of the WATFLOOD model with the water quality component attached.

Due to the simplifying assumptions in current models, the uncertainties in the values of input parameters, and the difficulty in validation with field data, no model can predict absolute quantities with proven accuracy (Leonard and Knisel, 1989). Providing a measure of the confidence limits in the simulation results and its behavior due to the values of input data is a crucial step in the simulation process. As a preliminary analysis on the sensitivity of the parameters in the model outcome, normalized sensitivity coefficients were used to study the importance of parameter variation in the results. The system tools for comparative analysis of different scenarios include different techniques to analyze the sensitivity associated to the models and scenario comparison capabilities.