# CHAPTER 5. Data Acquisition and Application

Traditionally, input data are described as a set of parameter values in a format to be read by the model. During the development of this work, a major emphasis was placed on developing the automatic extraction of input data from digital sources. It is this that creates the distinction from the traditional input data methods. The required data are then in the form of digital information files which will be processed to extract the required input values for the models.

## 5.1 DEM and Map Files

RAISON works with relational databases and the different layers in these databases represent various sources of digital information such as DEM, soil and landuse. In order to incorporate different data sources into the database management system of RAISON, several import facilities were developed.

In general terms, three sources of information, DEM, soil and landuse data, are required to take full advantage of the automatic extraction of input data. A detailed description of the source data files and the import process are described in the following examples for the Duffins Creek watershed, east of Metropolitan Toronto, in southern Ontario.

### 5.1.1 Digital Elevation Model Data

The DEM data as described in the previous chapter consist of elevation data for each element, flow direction and flow accumulation. Normally the basic information of a DEM includes the elevation of each element for the full extent of the study area. Some commercial applications include a conditioning process to create depressionless data and to calculate flow directions and flow accumulation values (Jenson *et al*, 1988). The three sets of values are required to create the DEM layer database. Two different options are included on the import facility: using the three datasets as individual ASCII files or using just one comma separated value (CSV) file which includes the three fields. An intermediate process will create the CSV file to be used by the general import program.

The DEM data for the Duffins Creek area was obtained from the United States Geological Survey (USGS) internet site (*http://edcwww.cr.usgs.gov/landaac/gtopo30/gtopo30.html*). The required topographic map files at every 30 second interval for the North America region were already available in CD-ROM at the University of Waterloo. In order to increase the resolution of the DEM, before importing, the data were resampled at every 15 seconds and a conditioning process was performed to create a depressionless DEM, together with the flow directions and flow accumulations data channels. The process was performed with the EasyPace/PCI program as described previously.

The extents and characteristics of the final file are presented in Table 5.1, together with the header and first lines of the CSV file created to be imported into RAISON. Once imported the DEM layer for Duffins Creek consists of 3,360 elements with the three attributes for elevation, flow direction and flow accumulation attached to each record. Figures 5.1 and 5.2 show the DEM elevation data and flow accumulation values respectively. They are displayed using RAISON with a scanned background map from the Duffins Creek from a 1:250,000 scale map of Toronto and surroundings. The background scanned map was then converted to a BMP (bitmap image file) and georreferenced within RAISON.

**Table 5.1** DEM File for Duffins Creek, Description of ASCII and CSV Files for Import

*Duffins Creek extent:*

| | Latitude | Longitude |
|---|---|---|
| Left top corner: | N44° 00' 00" ; | W79° 16' 00" |
| Right bottom: | N43° 48' 00" ; | W79° 02' 00" |

The ASCII files have 56 columns and 60 rows in one vector, each pixel is 0°0'15" in both directions.

*Duffins ASCII files:*

- DuffElev.txt - elevations:

265, 260, 257, 248, 242, 233,...

- DuffDir.txt - flow direction*:

1, 128, 128, 128, 2, 4,...

*The flow direction is encoded to correspond to the orientation of one of the eight cells that surround the cell (x) as follows (PCI convention):

| | | |
|---|---|---|
| 64 | 128 | 1 |
| 32 | x | 2 |
| 16 | 8 | 4 |

- DuffFlow.txt - flow accumulation:

0, 2, 0, 1, 1, 31,...

*Duffins CSV file:*

First line:

Title,Spacing (decimal), # of elements

DEM, 0.0041666, 3360

Lat, Lon, Elevation, Direction**, FlowAcum

44,79.26667,265,2,0

44,79.2708366,260,1,2

44,79.2750032,257,1,0

44,79.2791698,248,1,1

44,79.2833364,242,3,1

44,79.287503,233,4,31

. . .

. . .

. . .

. . .

**The import procedure converts the directions to values for the convention adopted in the interfaces:

| | | |
|---|---|---|
| 8 | 1 | 2 |
| 7 | x | 3 |
| 6 | 5 | 4 |

### 5.1.2 Soil Type and Landcover Files

The map data includes the soil type and landcover information. Both data sources consist of a number of polygons with attached attributes. In the case of soil type the attribute of interest, in order to perform the data extraction, is the soil texture classification. For the landuse layer, the field to use in the extraction is the landcover attribute of the polygon. There are several ways of generating such files. They can be created with a simple digitization of map hard copies or with a more complex process by using automatic image classification techniques.

By means of a standard shape file format, a general import facility was created in order to bring the polygons from the shape file into polygon layers in the RAISON system. The soil data for Duffins Creek were digitized from soil maps by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and made available through the NWRI. This set of data consists of 165 polygons with a total of 6,207 vertices. The files were provided in standard shape format.

Using the shape import utility, the polygon layer import was performed to create the database layer soil. The map code and the soil type are related through the lookup table (see Appendix B) to find the adequate parameter values based on the soil classification convention from the SCS. For the landuse data, two sources of information were used: Landuse maps from OMAFRA for the 1975-83 period and three classified satellite images (1975, 1985 and 1992) obtained from the Metro Toronto Regional Conservation Authority (MTRCA). The OMAFRA file consists of digitized landuse map with extensive classification, imported directly as a layer for a total of 720 polygons and 21,723 vertices.

The MTRCA landcover data derives from landsat imagery. Remote sensing data for 1975 was obtained with a multi-spectral scanner with a resolution of 80m. For 1985 and 1992 the data were captured using a thematic mapper with a 30m resolution (personal communication with MTRCA personnel, 1997). An unsupervised classification technique of spectral signatures was used to classify the images together with airphoto archives and field recognition to validate classified areas. The classification process was achieved with the image analysis package PCI/EasyPace. The classified files (PIX) were saved as ArcInfo grids and converted to ArcInfo polygonal coverage and finally exported to shape files (SHP).

The interfaces for the models and RAISON are 16 bit applications. This poses a particular problem in the layer operations on the database with a limit of 4,000 points per polygon to handle and pass huge arrays. If necessary the source files have to be preprocessed by breaking up and smoothing the polygons. In the case of the MTRCA files, a 2km grid intersection process and 15m interval smoothing were performed with the ArcInfo grid generator. Finally the shape files were imported into RAISON layers by a generic shape import utility. Three final files, one for each year, were created. The 1975 file consists of 1,983 polygons with a total of 33,687 vertices, the 1985 file has 1,391 polygons with 24,718 vertices and the 1992 file contains 1,327 polygons with 24,484 vertices. Figures 5.3 and 5.4 present the soil type layer and the landuse layer (1992 coverage) respectively. They are also displayed in RAISON using the same scanned background map from the Duffins area.

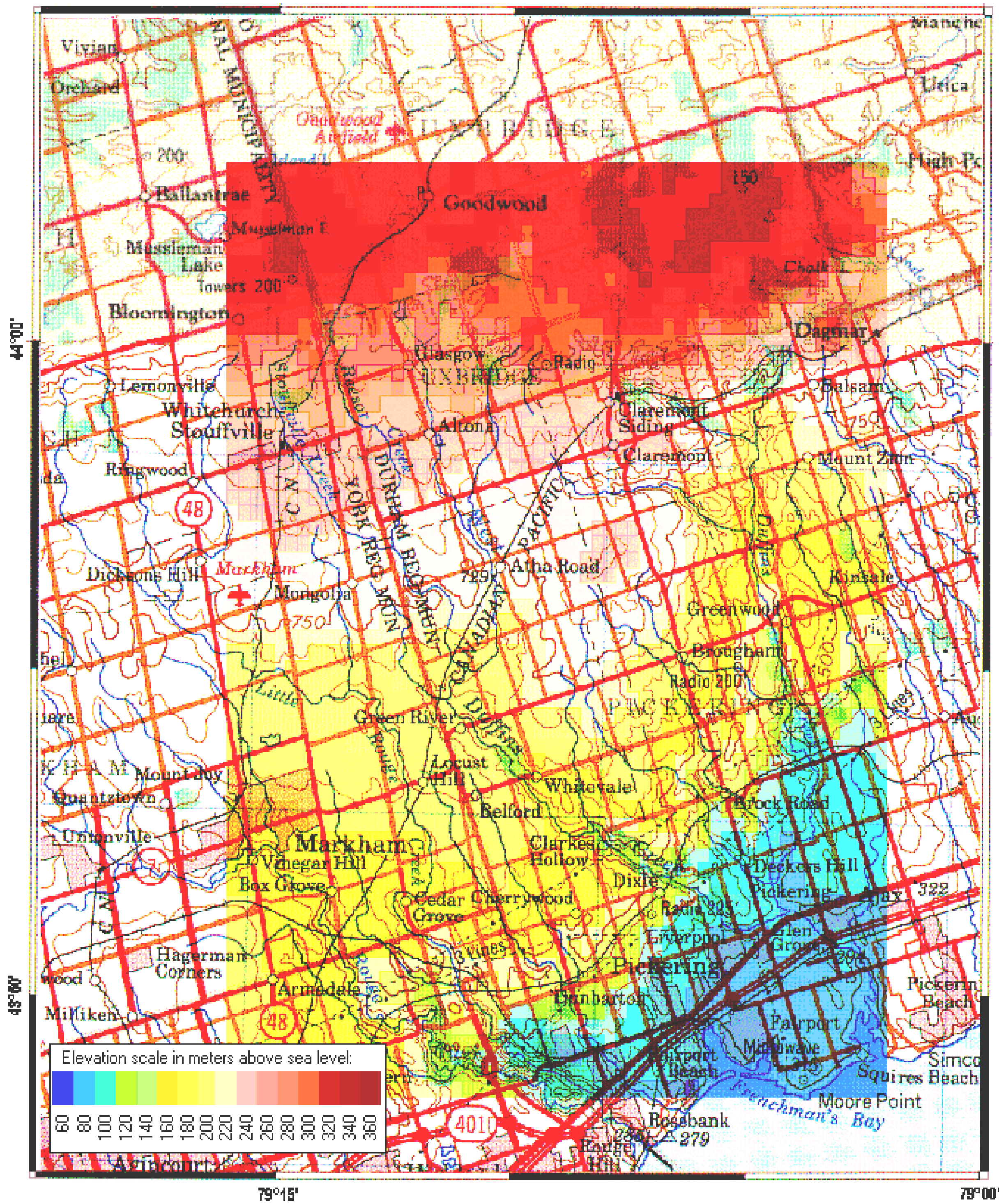



**Figure 5.1** DEM file - elevations for the Duffins Creek area.

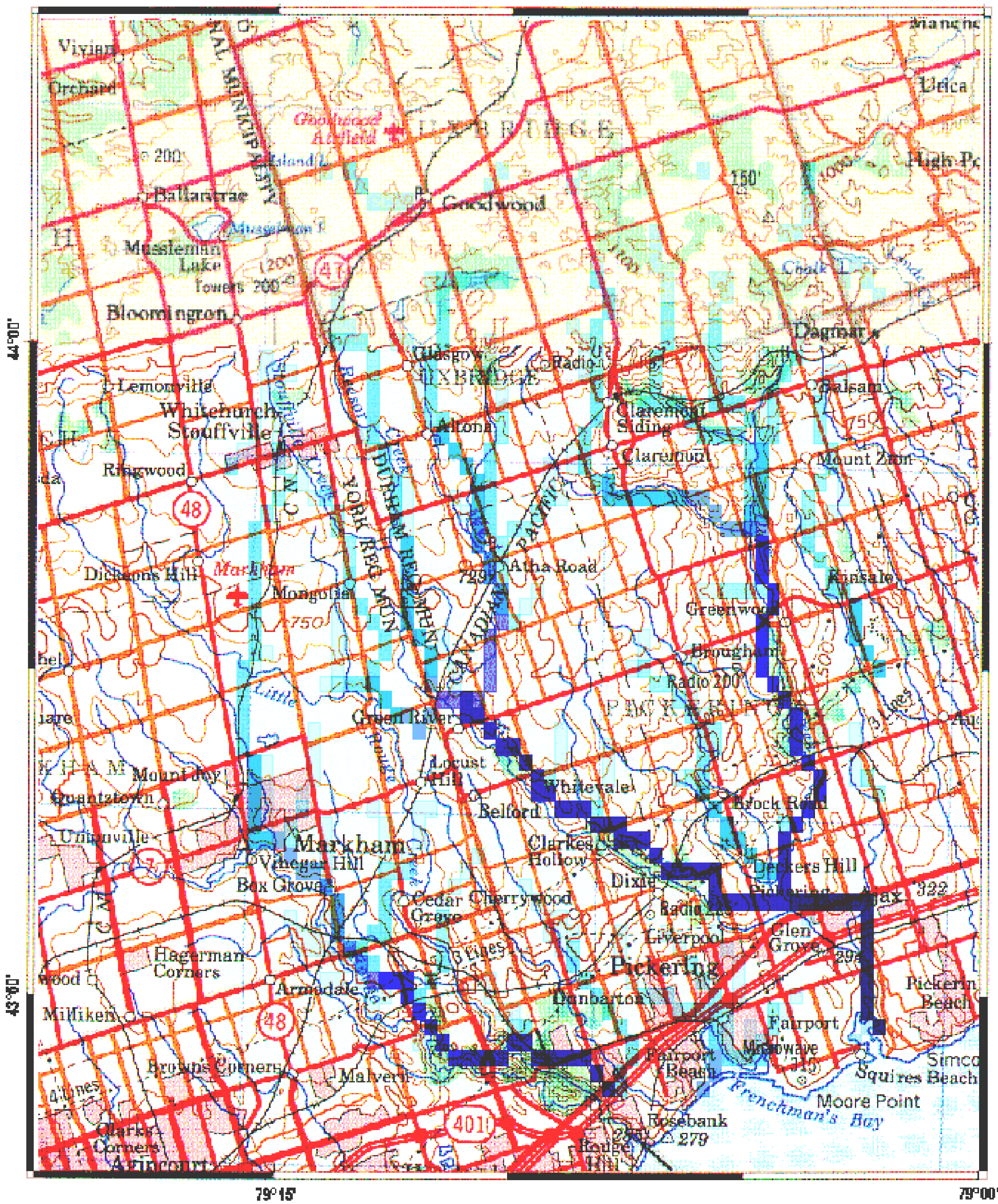



**Figure 5.2** DEM file - flow accumulation for the Duffins Creek area.

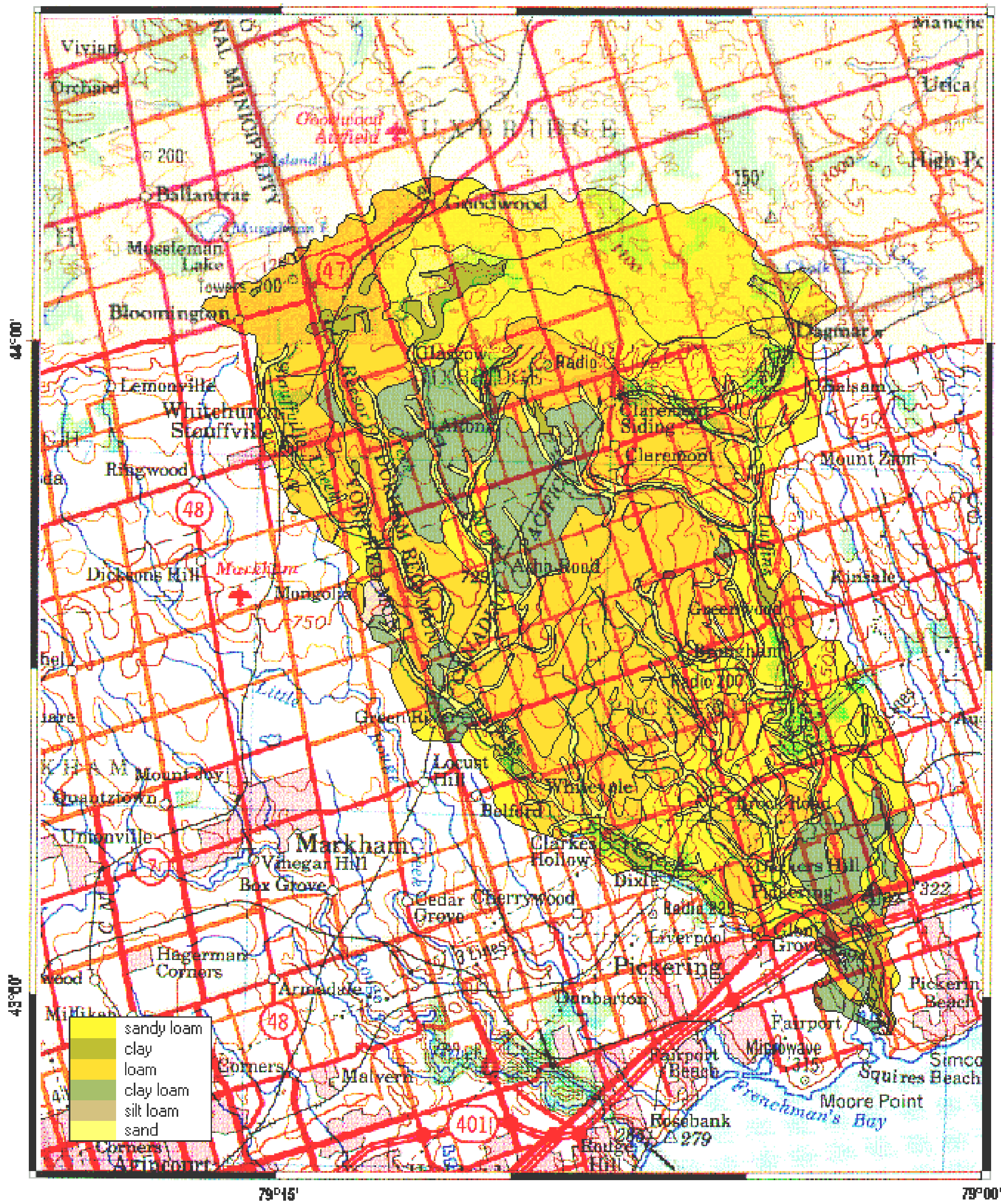


**Figure 5.3** Map layer file - soil textures for the Duffins Creek area.

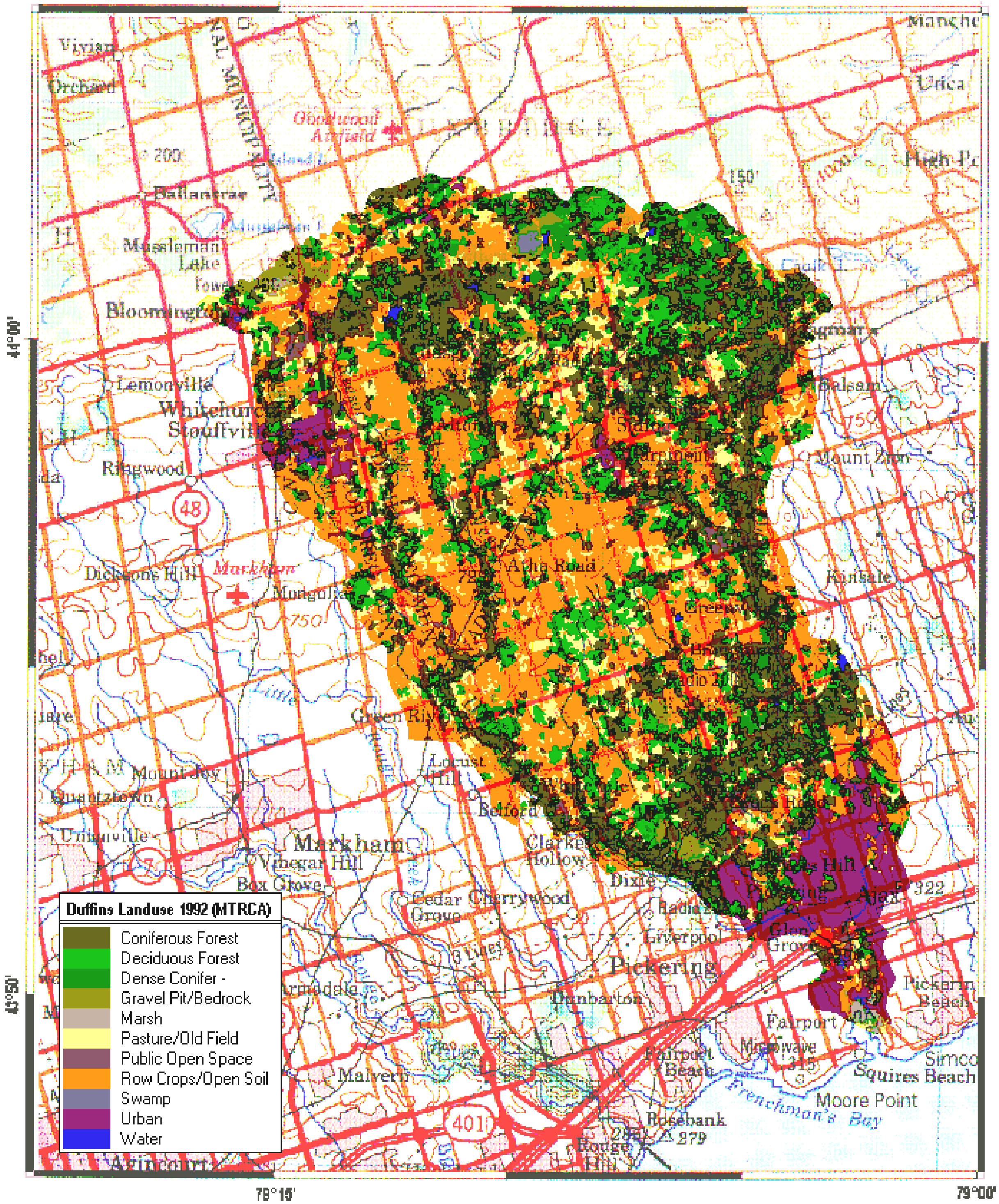
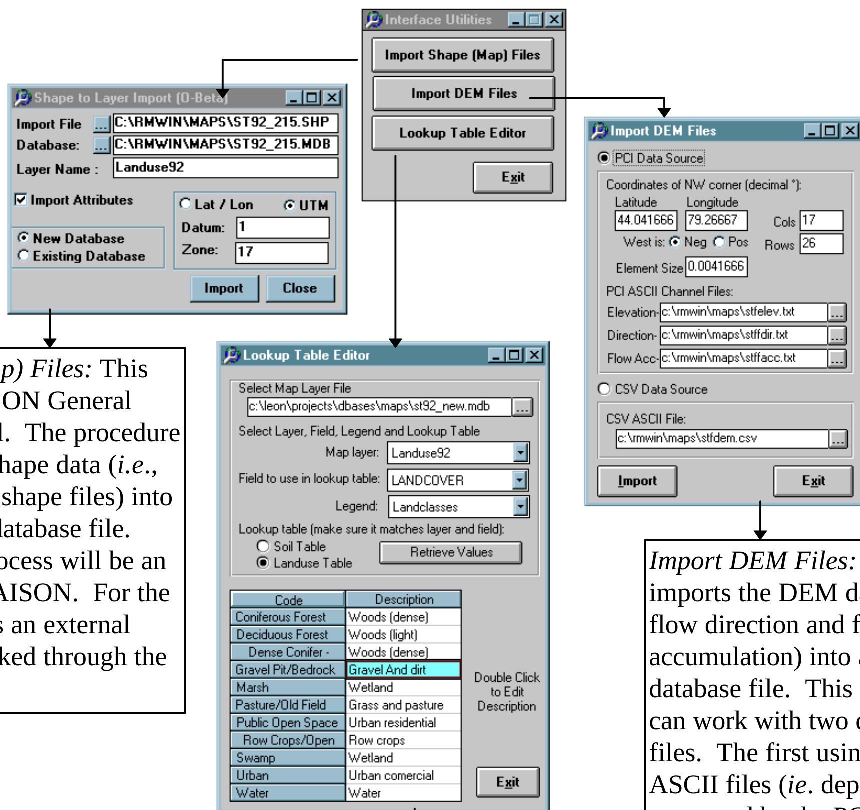



**Figure 5.4** Map layer file - landuse for the Duffins Creek area.

### 5.1.3 Utilities to Incorporate Source Data in RAISON

To import the described digital information into RAISON database layers, three program utilities where created. The first one imports the shape file into a database layer. The second tool facilitates the DEM import. The third one provides a set of tools to edit and modify the lookup table that allows the link between the imported files and the extraction process requirements. Figure 5.5 shows the tools and how they are accessed through a control window.




*Import Shape (Map) Files:* This accesses the RAISON General Layer Import Tool. The procedure reads and writes shape data (*i.e.*, ArcInfo/ArcView shape files) into a RAISON layer database file. Eventually this process will be an integral part of RAISON. For the moment is used as an external executable file linked through the utilities menu.

*Import DEM Files:* The procedure imports the DEM data (elevation, flow direction and flow accumulation) into a RAISON layer database file. This import facility can work with two different types of files. The first using individual ASCII files (*ie*. depressionless data processed by the PCI Easy/Pace software), and the second with any CSV (comma separated value) ASCII file with the proper format.

*Lookup Table Editor:* This accesses the Lookup Table Editor. The procedure can create new or edit existing lookup attributes from map files for both AGNPS and WatFlood tables. When a new map file is loaded and the layer and field are selected, it will search for the assigned description in the active lookup table. The values will display in a spreadsheet type form in order to edit or create new links to the tables (see Appendix B for details on the lookup tables).

**Figure 5.5** Utilities to import and link digital source data into the RAISON interfaces.

Using the utilities, all the source files were imported to be used with the interfaces. Table 5.2 summarizes the digital data processed and resulting files for the Duffins Creek and Stouffville areas. Additional radar, streamflow and water quality data were also collected for this research. This data will be described later on the application section of this chapter.

**Table 5.2** Summary of Digital Information Acquisition

| Source File | Utility | Target File | Size | Characteristics |
|---|---|---|---|---|
| *Duffins Shape Files:*<br>-rivers, roads, etc. | None | None | Variable | Used directly to draw RAISON maps and snapshots (no import required). |
| *Watershed Files:*<br>- DuffShed.shp<br>- StfShed.shp | ImportShape | DuffShd.mdb<br>StoufShd.mdb | 160 Kb<br>128 Kb | Watershed files contain just 1 polygon and are used for automatic selection of grid elements within the borders of the basin. |
| *DEM Files:*<br>- DuffDEM.csv<br>- StffDEM.csv<br>- StffDEM5.csv | ImportDEM | DuffDEM.mdb<br>StfDEM.mdb<br>StfDEM5.mdb | 2.4 Mb<br>448 Kb<br>3.3 Mb | CSV files from ASCII-PCI elevation, flow accumulation and flow direction files:<br>- Duffins: 3,360 elements (56x60 @ 15")<br>- Stouffville: 442 elements (17x26 @ 15") and 4,536 elements (63x72 @ 5") |
| *MAP Files:*<br>- DuffMaps.shp | ImportShape | DuffMAP.mdb | 2.1 Mb | OMAFRA files (DuffMAP):<br>-Soil layer: 165 polygons (10,094 points)<br>-Landuse: 720 polygons (17,836 points) |
| - Stouffville | Reduce Duff | StfMAP.mdb | 544 Kb | -Soil layer: 25 polygons (1,868 points)<br>-Landuse: 150 polygons (3,843 points) |
| *Remote Sensing Landuse Maps:*<br>Duffins Creek<br>- Duff75.shp<br>- Duff85.shp<br>- Duff92.shp | ImportShape | Df75_215.mdb<br>Df85_215.mdb<br>Df92_215.mdb | 18.3 Mb<br>11.8 Mb<br>12.5 Mb | MTRCA files (2km grid/15m weed) for both Duffins and Stouffville areas:<br>1975 - 15,725 polygons (229,703 points)<br>1985 - 8,926 polygons (148,988 points)<br>1992 - 9,357 polygons (158,285 points) |
| Stouffville Creek<br>- Stf75.shp<br>- Stf85.shp<br>- Stf92.shp | ImportShape | St75_215.mdb<br>St85_215.mdb<br>St92_215.mdb | 2.75 Mb<br>2.10 Mb<br>1.99 Mb | 1975 - 1,983 polygons (33,687 points)<br>1985 - 1,391 polygons (24,718 points)<br>1992 - 1,150 polygons (19,020 points) |

At this point, only the digital mapping information is described together with the tools used to import them into a format that can be used by the decision support system. As can be seen, there are more than 58 megabytes of digital data to represent all the different sources of data for the Duffins region. A lesson learned in this process is to keep files organized at a regional basis and only for the extent of the study area in order to keep manageable file sizes.

Once all the information is in the same platform, several shortcuts can be made to speed up the display of the maps. Taking advantage of the RAISON features, different snapshots can be created using the original source information (*ie*. previous examples for the DEM, soil and landuse maps around Duffins Creek). Though these maps are quite detailed, they can be too cluttered to use for displaying grids and results. Additional screens were created with less map information in order to facilitate the use of the interface and the display of results. Figure 5.6 shows, as an example, one of such RAISON snapshots for the Duffins Creek area. It displays the river system, the main roads and the two watersheds, Duffins and Reesor Creek, where the modelling was performed.

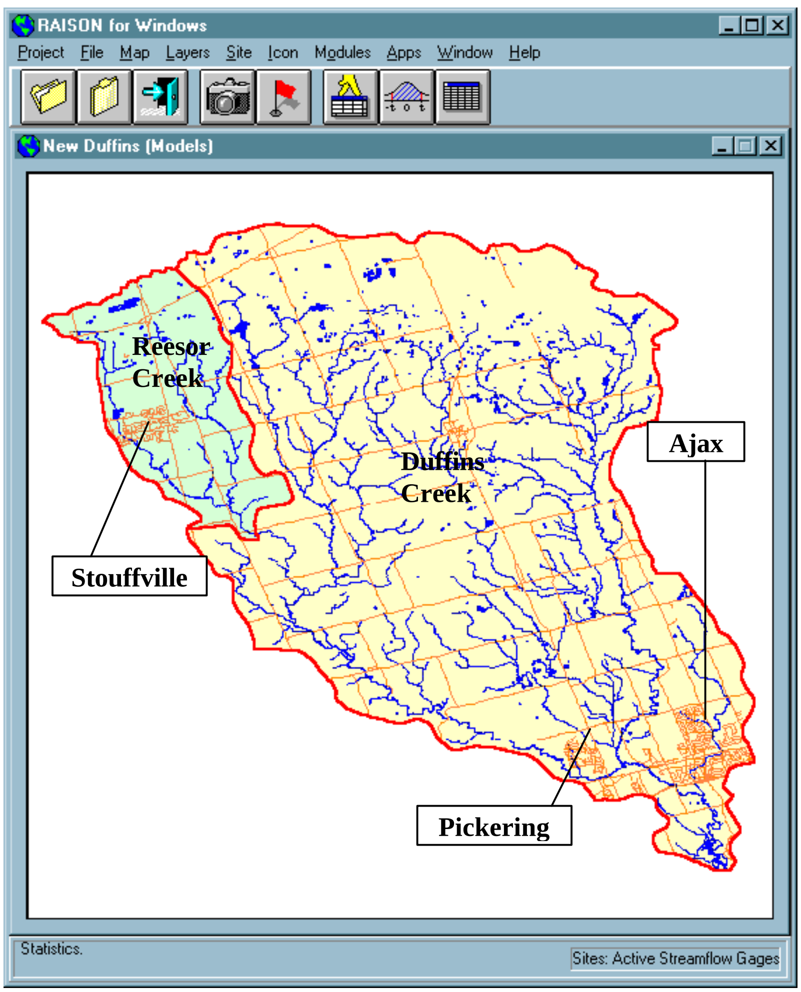



**Figure 5.6** Snapshot of Duffins Creek (rivers , roads and watersheds)

## 5.2 Duffins Creek Application

The Duffin's Creek Project is a collaborative research project between Environment Canada and the Ontario Ministry of Environment and Energy. The main objective of this project is to provide planning groups with improved scientific procedures to assist them in achieving their program targets (Bowen *et al.*, 1995). Use of the AGNPS model was one of the components of the project. The linkage with a decision support system was then proposed and a further technology transfer, described later in this Chapter, was aimed at providing the required tools to achieve such objective.

This application focuses on Duffin's Creek, a 293 $km^2$ watershed draining into Lake Ontario at Ajax, 10 km east of Metropolitan Toronto. The headwaters originate in the northern regions of the watershed in the Oak Ridges Moraine where sub-surface drainage predominates (Bowen *et al.*, 1995). The landuse in the basin is mainly non-intensive agricultural with growing urban areas in the lower parts of the watershed at Pickering and Ajax. Towards the western area is Stouffville, with a flood control reservoir and a water treatment plant that discharges into the Duffins Creek west river system.

Duffins Creek was chosen for three reasons: i) the Federal and Ontario governments are major owners of the land, expropriated in the 1970s to build an international airport, ii) the watershed has a comprehensive environmental database to work with and iii) project plans proposed the need for non-point source pollution modelling in the watershed. As additional advantages, it is located near the Atmospheric Environment Service (AES) King City Weather Radar Research Station so hourly radar data and temperature measurements are available for the area. It also has a comprehensive record of streamflows at several flow gauges. As part of the project for his Master degree, Cranmer (1998), compiled the required radar and streamflow data and helped with the setup of WATFLOOD for the Duffins Creek watershed. Warm weather data, from April-November 1995, were used for this application. Due to the lack of operating rain gauges during the study period, radar data were the only source for rainfall.

The high spatial and temporal resolution of rainfall is taken into account when using radar data to estimate precipitation. Event models, such as AGNPS, require total rainfall amounts. To get the total precipitation for specific events, the compiled radar files (MET) were processed to hourly values of rainfall. This was achieved through the use of a mask which consists of the percentage of area for each cell within the watershed. The filtering process through the mask produces the required hourly rainfall values for each cell. The total amount for the watershed is then calculated as an average of the cell values. Table 5.3 shows a sample of the radar file were the mask of the watershed is highlighted in bold style.

**Table 5.3** Sample of a Radar (MET) File with Hourly Precipitation Values (mm)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HOUR= | 256 | 1 | Radar | | | | | | | | |
| 3.5 | 3.5 | 3.0 | 2.5 | 3.0 | 3.5 | 2.0 | 2.0 | 2.0 | 2.0 | 1.5 | 2.0 |
| 4.0 | 3.0 | **2.5** | **3.0** | **3.5** | **2.0** | **2.0** | **2.0** | **2.0** | 1.5 | 2.0 | 1.5 |
| 3.0 | **3.5** | **3.5** | **4.0** | **3.0** | **3.0** | **2.0** | **2.0** | **2.5** | **2.0** | 2.0 | 1.0 |
| 3.5 | **3.0** | **3.5** | **3.0** | **2.5** | **2.0** | **2.0** | **2.0** | **2.0** | **1.5** | 1.5 | 2.0 |
| 4.0 | 3.5 | **3.5** | **2.0** | **2.0** | **2.5** | **2.5** | **1.5** | **2.0** | **2.0** | 1.5 | 2.0 |
| 3.5 | 3.0 | **2.0** | **2.0** | **2.0** | **2.5** | **3.5** | **2.0** | **2.5** | **2.5** | 2.0 | 1.5 |
| 2.5 | 2.5 | **2.5** | **1.5** | **2.5** | **2.5** | **2.5** | **2.5** | **2.5** | **2.0** | 2.0 | 2.0 |
| 3.0 | 2.0 | **2.0** | **2.0** | **1.5** | **3.5** | **3.0** | **4.0** | **2.5** | **3.5** | **3.0** | 1.5 |
| 3.0 | 2.5 | 2.5 | **2.0** | **2.0** | **2.5** | **3.0** | **4.0** | **4.0** | **3.5** | **3.5** | 2.0 |
| 3.0 | 3.0 | 2.5 | **2.0** | **2.0** | **2.0** | **3.0** | **3.0** | **3.5** | **3.5** | **2.5** | 2.0 |
| 3.0 | 3.5 | 3.0 | 2.5 | **2.0** | **3.0** | **2.5** | **4.5** | **3.0** | **2.5** | **2.5** | 2.0 |
| 3.5 | 3.0 | 3.0 | 2.0 | 2.5 | 3.0 | 3.5 | 3.5 | **2.5** | **2.5** | **2.5** | 2.0 |
| 3.0 | 4.0 | 3.0 | 2.0 | 2.5 | 3.0 | 2.0 | 2.0 | 2.5 | **2.5** | **2.5** | 1.5 |
| 3.5 | 3.0 | 3.0 | 2.5 | 3.0 | 3.0 | 2.5 | 2.5 | 2.5 | 2.0 | **2.0** | 1.5 |
| 3.0 | 2.0 | 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 1.5 | 1.5 |
| | | | | | | | | Average value = **2.63** | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HOUR= | 257 | 1 | Radar | | | | | | | | |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.5 | 2.0 | 2.0 | 1.5 | 2.5 | 2.5 | 2.5 |
| 2.0 | 2.5 | **1.5** | **2.0** | **2.0** | **1.5** | **2.0** | **2.0** | **2.5** | 2.0 | 2.0 | 3.0 |
| 2.0 | **2.0** | **2.0** | **1.5** | **2.0** | **2.0** | **2.0** | **2.0** | **2.5** | **1.5** | 1.5 | 2.5 |
| 2.0 | **2.5** | **1.5** | **2.0** | **1.5** | **1.5** | **1.5** | **2.0** | **2.0** | **3.0** | 1.5 | 2.0 |
| 2.0 | 3.0 | **2.0** | **2.0** | **1.5** | **2.0** | **2.5** | **2.0** | **2.0** | **2.5** | 2.5 | 3.0 |
| 2.0 | 2.5 | **2.0** | **2.0** | **2.0** | **2.0** | **2.5** | **2.0** | **2.5** | **2.5** | 2.0 | 2.5 |
| 1.5 | 2.0 | **3.0** | **1.5** | **2.0** | **2.5** | **2.0** | **2.0** | **2.5** | **2.0** | 2.5 | 2.0 |
| 2.0 | 2.0 | **2.0** | **2.5** | **3.0** | **2.5** | **3.0** | **2.5** | **2.0** | **2.0** | **2.0** | 2.0 |
| 2.0 | 2.0 | 2.0 | **2.5** | **2.5** | **3.0** | **3.0** | **2.0** | **2.0** | **2.5** | **2.5** | 2.0 |
| 2.0 | 2.5 | 2.5 | **2.5** | **2.0** | **2.5** | **2.5** | **2.5** | **2.0** | **2.5** | **1.5** | 2.0 |
| 2.5 | 2.0 | 2.0 | 3.0 | **2.5** | **2.0** | **3.0** | **2.5** | **2.5** | **2.0** | **2.0** | 2.0 |
| 2.5 | 3.0 | 2.5 | 2.5 | 3.5 | 3.0 | 2.5 | 3.0 | **1.5** | **2.5** | **2.5** | 2.0 |
| 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 2.5 | 2.5 | 3.0 | 2.0 | **2.0** | **2.5** | 2.5 |
| 2.5 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 3.0 | 3.5 | 2.0 | 2.5 | **2.5** | 2.5 |
| 3.5 | 2.5 | 3.0 | 2.0 | 2.0 | 3.5 | 2.5 | 3.0 | 2.0 | 3.0 | 2.5 | 3.0 |
| | | | | | | | | Average value = **2.76** | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HOUR= | 258 | 1 | Radar | | | | | | | | |
| 2.0 | 2.0 | 2.5 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.5 | 3.0 | 3.5 | 3.5 |
| 2.5 | 2.0 | **2.5** | **3.5** | **3.5** | **3.5** | **3.5** | **3.0** | **3.0** | 3.5 | 3.5 | 3.5 |
| 1.5 | **1.5** | **2.5** | **4.0** | **3.0** | **3.5** | **3.5** | **3.5** | **3.5** | **3.5** | 4.0 | 4.5 |
| 2.0 | **2.0** | **2.5** | **3.0** | **3.0** | **3.5** | **3.0** | **3.0** | **3.0** | **3.5** | 4.0 | 3.5 |
| 1.5 | 2.5 | **2.5** | **2.5** | **3.0** | **3.0** | **3.5** | **3.5** | **3.0** | **3.5** | 3.5 | 3.0 |
| 1.5 | 2.0 | **2.0** | **2.5** | **2.5** | **3.0** | **3.5** | **3.0** | **2.5** | **3.5** | 3.0 | 3.0 |
| 1.5 | 2.0 | **2.0** | **2.0** | **3.0** | **2.5** | **4.0** | **3.0** | **3.0** | **3.0** | 3.5 | 3.0 |
| 2.0 | 2.0 | **2.0** | **2.0** | **3.0** | **3.0** | **3.5** | **3.0** | **3.0** | **4.0** | **2.5** | 3.5 |
| 2.0 | 1.5 | 2.0 | **2.5** | **3.0** | **2.5** | **4.0** | **3.0** | **3.0** | **2.5** | **3.0** | 3.0 |
| 1.5 | 1.5 | 2.5 | **2.5** | **2.5** | **3.0** | **4.0** | **4.0** | **2.5** | **2.5** | **2.5** | 3.0 |
| 2.0 | 2.5 | 2.5 | 2.5 | **2.0** | **3.0** | **3.0** | **2.5** | **3.0** | **2.0** | **2.5** | 2.5 |
| 1.5 | 2.0 | 2.0 | 2.5 | 2.0 | 2.0 | 4.0 | 3.0 | **2.0** | **3.5** | **3.0** | 2.5 |
| 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.5 | 3.0 | 2.0 | 2.5 | **2.5** | **2.5** | 2.5 |
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.5 | 3.0 | 3.5 | 2.5 | **2.5** | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.5 | 2.5 | 2.5 | 2.0 | 3.0 | 2.0 | 2.5 | 2.0 | 2.5 |
| | | | | | | | | Average value = **3.01** | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HOUR= | 259 | 1 | Radar | | | | | | | | |
| 1.5 | 1.5 | 2.0 | 2.0 | 2.0 | 2.5 | 2.5 | 2.0 | 2.5 | 3.0 | 2.5 | 3.0 |
| 1.5 | 1.5 | **2.0** | **2.0** | **3.0** | **2.0** | **2.5** | **2.0** | **2.0** | 3.0 | 2.5 | 2.0 |
| 2.0 | **2.0** | **1.5** | **2.0** | **1.5** | **1.5** | **2.0** | **2.0** | **1.5** | **2.5** | 2.5 | 3.0 |
| 1.5 | **2.0** | **2.0** | **2.0** | **2.0** | **1.5** | **2.0** | **2.0** | **2.5** | **2.0** | 2.0 | 2.5 |
| 1.5 | 2.0 | **2.0** | **2.0** | **1.5** | **2.0** | **1.5** | **1.5** | **2.0** | **3.0** | 2.0 | 2.5 |
| 1.5 | 2.0 | **2.5** | **2.0** | **1.0** | **2.0** | **2.0** | **1.5** | **2.0** | **2.5** | 2.5 | 2.5 |
| 1.5 | 1.5 | **1.5** | **1.5** | **2.0** | **1.5** | **2.0** | **2.0** | **2.5** | **3.0** | 3.0 | 2.0 |
| 2.0 | 1.5 | **1.5** | **1.5** | **2.0** | **1.5** | **1.5** | **1.5** | **2.0** | **2.0** | **2.5** | 3.0 |
| 2.0 | 1.5 | 2.0 | **2.0** | **2.0** | **1.5** | **2.0** | **1.5** | **2.0** | **2.0** | **2.0** | 3.0 |
| 2.0 | 1.5 | 1.5 | **2.0** | **2.0** | **2.0** | **2.5** | **2.0** | **1.5** | **2.5** | **2.5** | 2.5 |
| 1.5 | 2.0 | 2.0 | 2.0 | **2.5** | **2.0** | **2.5** | **2.5** | **2.5** | **2.5** | **3.0** | 3.5 |
| 2.5 | 1.5 | 3.0 | 3.0 | 3.5 | 2.0 | 2.5 | 3.5 | **3.0** | **3.5** | **3.5** | 3.0 |
| 2.0 | 2.0 | 2.5 | 2.5 | 2.5 | 3.5 | 3.0 | 3.5 | 3.5 | **3.0** | **3.0** | 4.0 |
| 2.5 | 2.0 | 1.5 | 2.5 | 4.0 | 4.0 | 3.0 | 4.5 | 3.5 | 3.0 | **3.5** | 4.0 |
| 2.5 | 3.0 | 3.0 | 3.0 | 2.5 | 3.0 | 2.5 | 4.0 | 4.5 | 4.0 | 3.5 | 3.0 |
| | | | | | | | | Average value = **2.26** | | | |

Processing all the compiled radar files (MET) with an average of 744 hours per month, hourly precipitation amounts were calculated for April-November 1995. Figure 5.7 shows the rainfall values extracted from radar data for Duffins Creek. For the AGNPS initial watershed data, the storm precipitation and duration for the individual events were extracted from these records. Appendix E contains the detailed hourly rainfall graphs for each of the individual events.

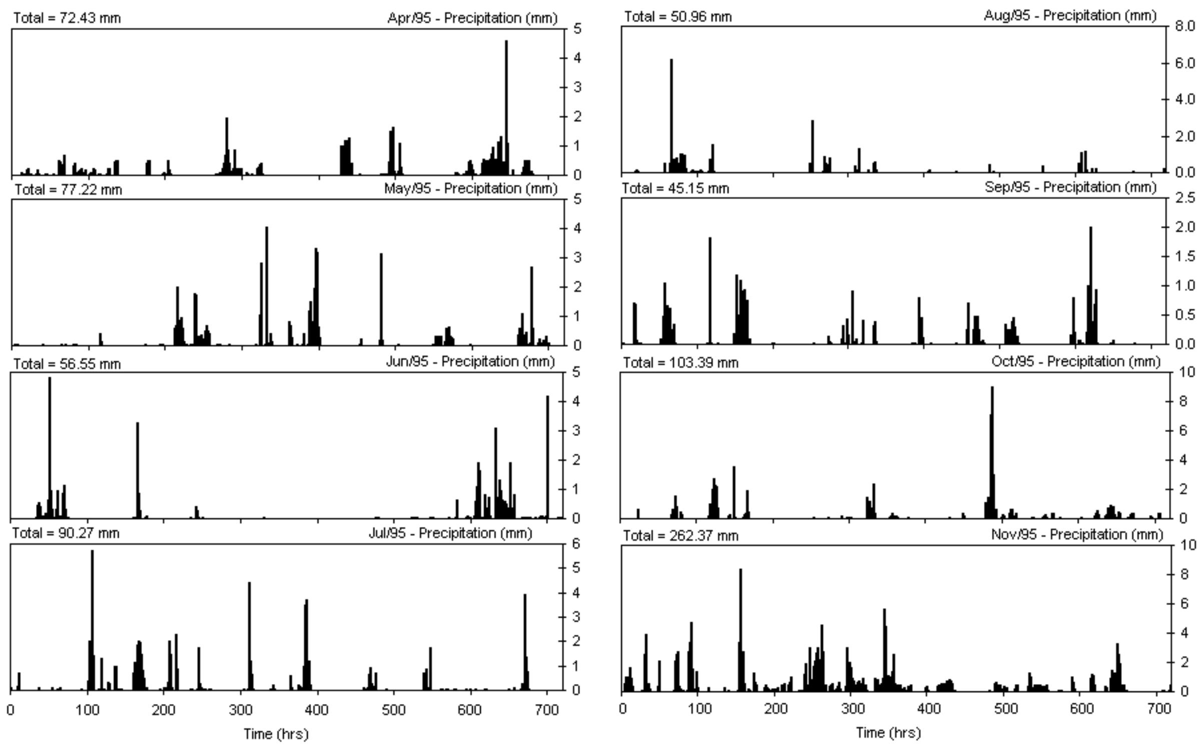



**Figure 5.7** Hourly precipitation in Duffins Creek (extracted from RADAR data)

Hourly streamflow data were provided by the Monitoring and Systems Branch of Environment Canada for the three stream gauge stations in current operation. Table 5.4 shows the gauge summary information for the three stations.

**Table 5.4** Active Streamflow Gauges in Duffins Creek

| Station Number | Location | Latitude (dd°mm‘ss“ N) | Longitude (-dd°mm’ss” W) | Drainage Area (km$^2$) |
|---|---|---|---|---|
| 02HC039 | Reesor Creek above Green River | 43°56’07” | -79°12’03” | 38.3 |
| 02HC019 | Duffins Creek above Pickering | 43°53’30” | -79°03’33” | 93.5 |
| 02HC049 | Duffins Creek at Ajax | 43°50’57” | -79°03’25” | 251.0 |

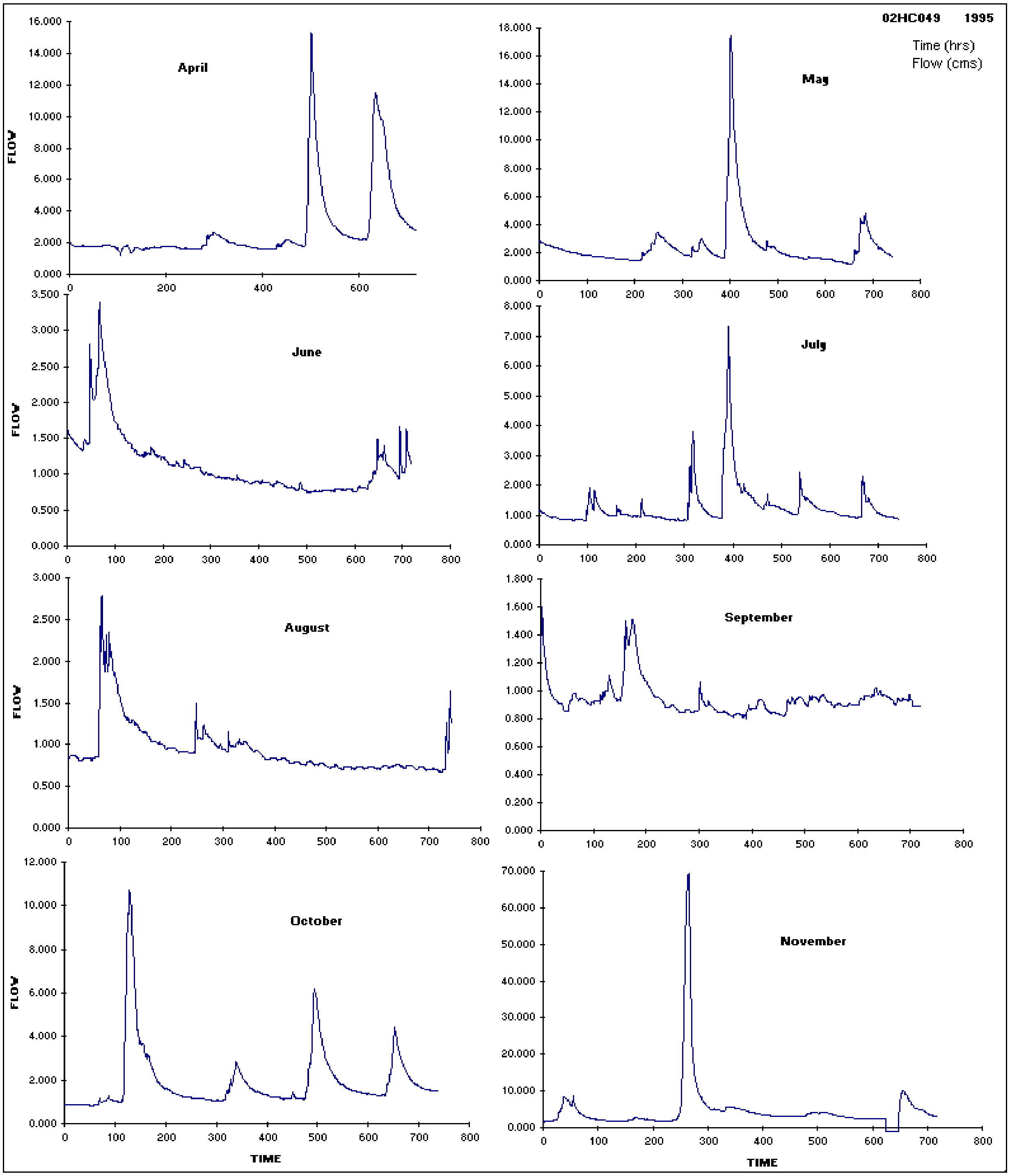



**Figure 5.8** Streamflows April-November, 1995 in Duffins Creek at Ajax (02HC049)

### 5.2.1 Hydrology with the AGNPS and WATFLOOD Models

The objective of this application is to calibrate and validate the hydrology results of the models for the study period. Eight events where selected to test the models (Table 5.5), one for each of the available months of data. The periods for each event were selected from the precipitation values extracted from the radar data and the measured runoff flows.

Care was taken when selecting the events to avoid the effects of over estimation of rainfall due to the “bright band” condition, a radar phenomenon which causes a false over-estimate of rainfall (Garland, 1986). This was also supported when the WATFLOOD model was run for the entire period (Cranmer, 1998), optimizing the rainfall radar scale, where the results show a response from the model to spurious precipitation values that measured flows did not reflect.

With the rainfall data, the 5-day antecedent rain was calculated and the events from April, May and November are considered to have nearly saturated soil conditions (type III) according to the SCS classification for Antecedent Moisture Condition (AMC). For the rest of the events the condition was estimated to have an average moisture content (AMC II).

Two different grid sizes were created in order to run AGNPS for Duffins Creek. The first grid is a 1km cell size with 205 cells of 351 acres (1.37km$^2$) of area for each cell. The 1km size is the width of each cell and a perfect square in lat/long coordinates was selected in order to create the grid. This means that the actual size of a cell for a 1km grid is 1x1.37km. In the same context, the second grid is a 2km cell size (2x2.85km) with 57 cells of 1,406 acres (5.69km$^2$) of area for each cell.

It is worth mentioning that the AGNPS manual suggests single cell resolutions between 2.5 to 40 acres, with more detailed sizes of 10 acres (200x200m) recommended for watersheds <2,000 acres (8 km2) and 40 acres (400x400m) for watersheds >2,000 acres. Even though, AGNPS has being used successfully with cell sizes up to 250 acres (1,000x1,000m).

The sizes used in this application were selected to exceed these recommendations to test the assumption that more accurate results can be obtained by reducing the cell size. On the other hand, enlarging the cell size reduces time and labor, but the savings must be balanced against the loss of accuracy resulting from treating larger areas as homogeneous units.

The data extraction for both grids was accomplished using the DuffDEM file for the elevation, slopes and flow directions. The DuffMAP file was used to extract the soil dependent data and the Df92_215 file for the most recent available landcover data (1992). Figure 5.9 presents the 2km grid showing the extracted flow directions and highlighting the streamflow gauges where the comparison between calculated and measured flows was made.

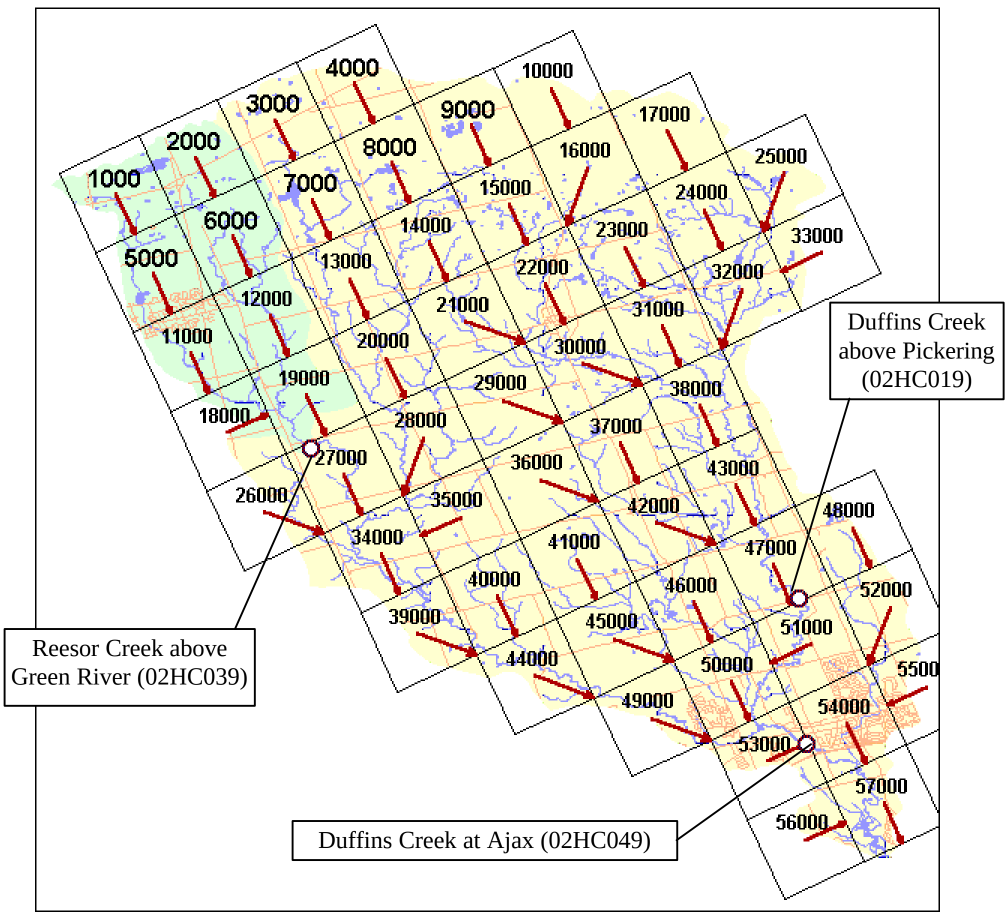


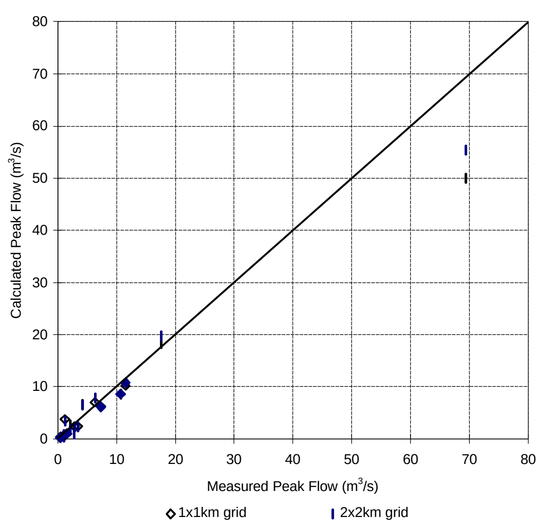

**Figure 5.9** AGNPS 2km grid showing flow directions and streamflow gauge stations.

Once the 16 simulations were done, eight for each grid size (the results for these simulations are presented in Appendix E), the peak flows were recorded for the outlets of Stouffville and Duffins to be compared with the Reesor Creek and Ajax gauging stations respectively. Table 5.5 presents the results comparing the two grids and figure 5.10 shows the graph for measured and calculated peak flows for all the gauge locations.

**Table 5.5** AGNPS Results (1 and 2 km grids*)

| Event | Rainfall (mm) | Duration (hrs) | Peak Meas ($m^3/s$) | Calc 1x1km ($m^3/s$) | Calc 2x2km ($m^3/s$) | Gauge Station |
|---|---|---|---|---|---|---|
| 25-29 Apr/95 | 16.5 | 18 | 11.50 | 10.24 | 10.77 | Duffins Creek at Ajax |
| (AMC-III) | | | 1.72 | 3.76 | 3.44 | Reesor Creek above Green River |
| 16-20 May/95 | 20.0 | 15 | 17.50 | 18.32 | 19.79 | Duffins Creek at Ajax |
| (AMC-III) | | | 4.14 | 6.64 | 6.50 | Reesor Creek above Green River |
| 1-6 Jun/95 | 10.7 | 20 | 3.40 | 2.40 | 2.30 | Duffins Creek at Ajax |
| (AMC-II) | | | 1.00 | 0.70 | 0.39 | Reesor Creek above Green River |
| 13-18 Jul/95 | 24.4 | 10 | 7.34 | 6.20 | 6.14 | Duffins Creek at Ajax |
| (AMC-II) | | | 2.70 | 1.77 | 0.98 | Reesor Creek above Green River |
| 2-6 Aug/95 | 18.1 | 20 | 2.79 | 2.42 | 2.37 | Duffins Creek at Ajax |
| (AMC-II) | | | 1.01 | 0.43 | 0.85 | Reesor Creek above Green River |
| 2-10 Sep/95 | 14.2 | 15 | 1.51 | 1.06 | 1.06 | Duffins Creek at Ajax |
| (AMC-II) | | | 0.40 | 0.38 | 0.28 | Reesor Creek above Green River |
| 4-16 Oct/95 | 26.9 | 13 | 10.70 | 8.61 | 8.65 | Duffins Creek at Ajax |
| (AMC-II) | | | 2.06 | 2.71 | 1.84 | Reesor Creek above Green River |
| 8-12 Nov/95 | 29.7 | 14 | 69.40 | 49.98 | 55.36 | Duffins Creek at Ajax |
| (AMC-III) | | | 6.29 | 7.03 | 7.84 | Reesor Creek above Green River |

*A 1km grid in lat/lon is 1x1.37km (1.37$km^2$=340acres) and a 2km grid in lat/lon is 2x2.85km (5.69$km^2$=1,406acres)



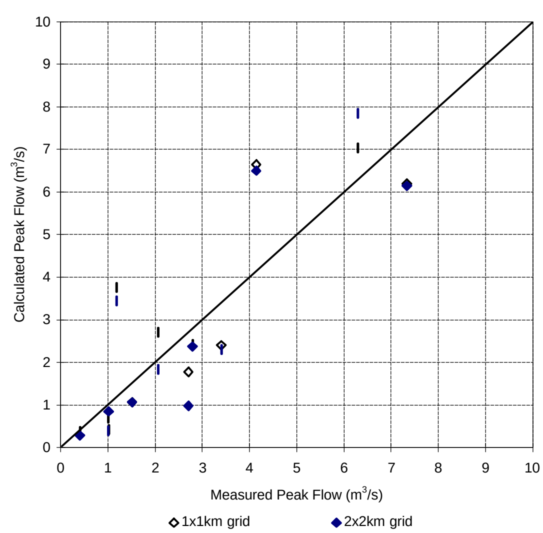




**Figure 5.10** AGNPS results, measured and calculated peak flows for all gauge stations.

In a very similar approach, two grids were created for the WATFLOOD model, one with a 2x2 km cell size (in this case the option for perfect squares in UTM coordinates was selected) and a second one with a 4x4 km size. The files used for the data extraction were the same as for the AGNPS application. Figure 5.11 shows the 2x2 km grid with flow directions and the location of the streamflow gauges.

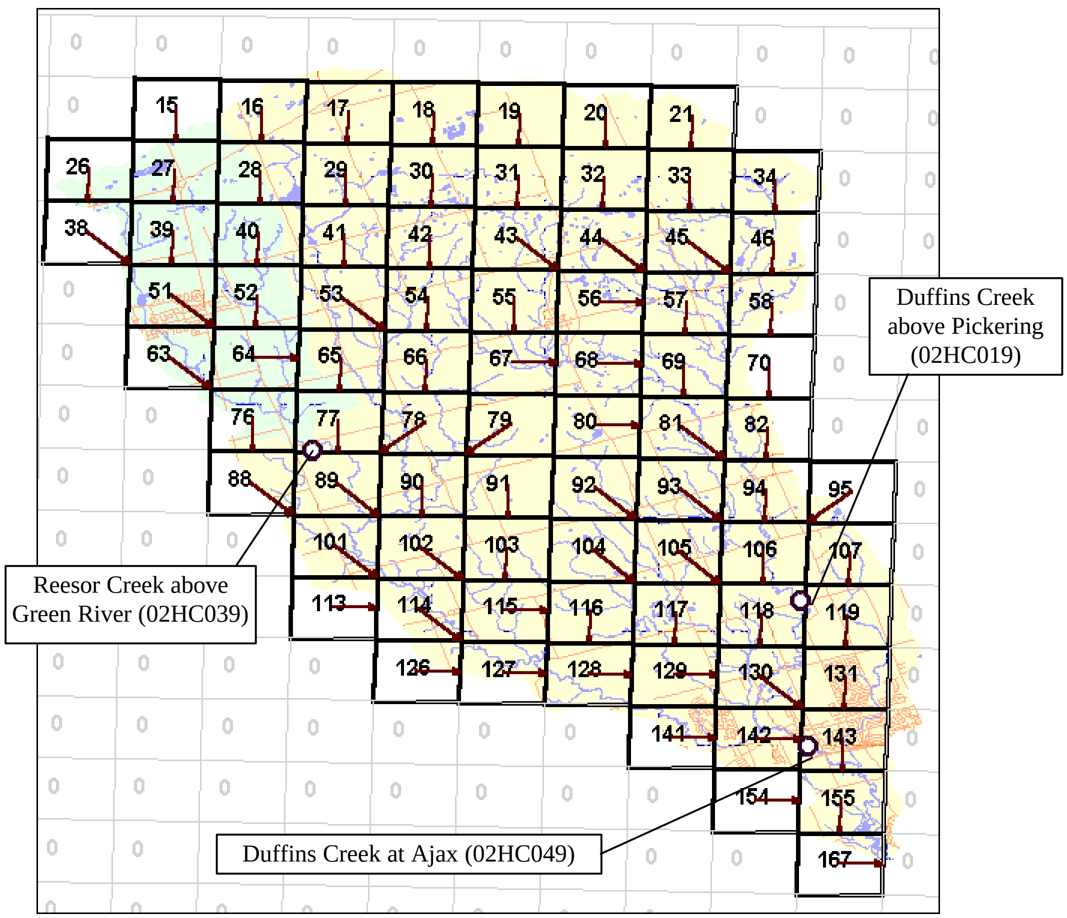



**Figure 5.11** WATFLOOD 2km grid showing flow directions and streamflow gauge stations.

After the simulations, the output files where processed to get the calculated peak values at the required cells. Table 5.6 presents the WATFLOOD results and compares them with the measured flows for the two grids at the three different gauging stations. Figure 5.12 shows graphically the measured and calculated peak flows. As can be seen there is no important difference between the values calculated with the 2x2 or the 4x4 grids.

**Table 5.6** WATFLOOD Results (2x2 and 4x4 km grids)

| Event | Rainfall (mm) | Duration (hrs) | Radar Scale | Peak Meas ($m^3/s$) | Calc 2x2km ($m^3/s$) | Calc 4x4km ($m^3/s$) | Gauge Station |
|---|---|---|---|---|---|---|---|
| 25-29 Apr/95 | 16.5 | 18 | 0.5 | 11.50 | 17.15 | 16.16 | At Ajax |
| | | | | 4.93 | 8.01 | 6.51 | Above Pickering |
| | | | | 1.72 | 1.50 | 2.33 | Reesor Creek |
| 16-20 May/95 | 20.0 | 15 | 0.6 | 17.50 | 21.80 | 17.64 | At Ajax |
| | | | | 10.20 | 9.44 | 6.29 | Above Pickering |
| | | | | 4.14 | 4.16 | 4.50 | Reesor Creek |
| 1-6 Jun/95 | 10.7 | 20 | 0.8 | 3.40 | 3.17 | 2.22 | At Ajax |
| | | | | 1.38 | 1.44 | 0.83 | Above Pickering |
| | | | | 1.00 | 0.51 | 0.61 | Reesor Creek |
| 13-18 Jul/95 | 24.4 | 10 | 0.5 | 7.34 | 10.42 | 7.16 | At Ajax |
| | | | | 3.99 | 4.92 | 3.42 | Above Pickering |
| | | | | 2.70 | 2.02 | 2.53 | Reesor Creek |
| 2-6 Aug/95 | 18.1 | 20 | 0.5 | 2.79 | 4.85 | 3.9 | At Ajax |
| | | | | 1.76 | 2.09 | 1.95 | Above Pickering |
| | | | | 1.01 | 0.78 | 1.13 | Reesor Creek |
| 2-10 Sep/95 | 14.2 | 15 | 0.5 | 1.51 | 2.68 | 1.85 | At Ajax |
| | | | | 0.78 | 0.98 | 0.58 | Above Pickering |
| | | | | 0.40 | 0.72 | 0.25 | Reesor Creek |
| 4-16 Oct/95 | 26.9 | 13 | 0.7 | 10.70 | 13.78 | 13.10 | At Ajax |
| | | | | 8.04 | 6.03 | 5.68 | Above Pickering |
| | | | | 2.06 | 1.79 | 2.79 | Reesor Creek |
| 8-12 Nov/95 | 29.7 | 14 | 1.0 | 69.40 | 73.39 | 55.02 | At Ajax |
| | | | | 31.20 | 29.16 | 22.01 | Above Pickering |
| | | | | 6.29 | 13.30 | 13.89 | Reesor Creek* |

*The measured flow is probably indicating the effect of the Stouffville reservoir upstream of the water treatment plant.

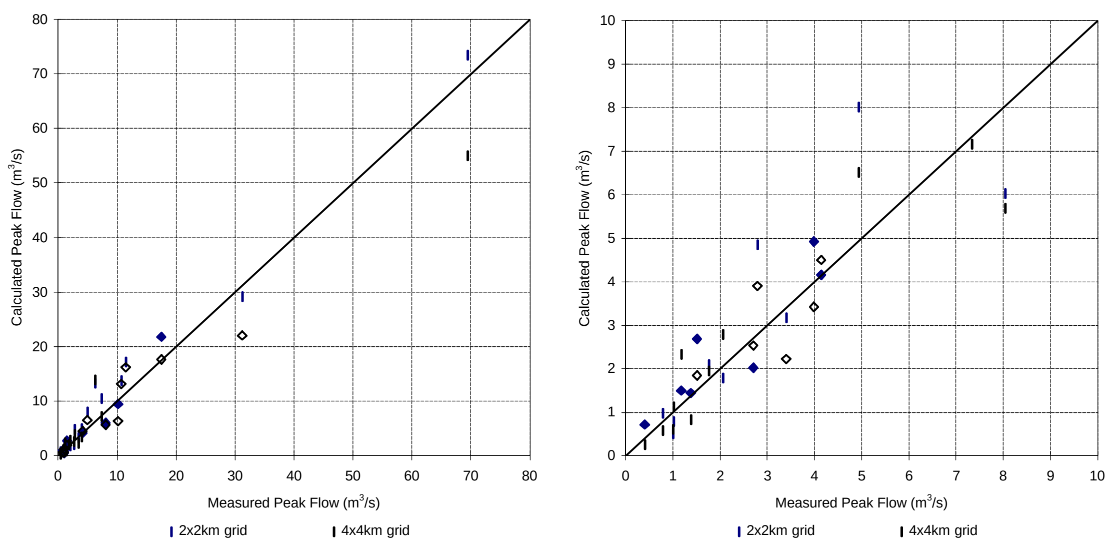



**Figure 5.12** WATFLOOD results, measured and calculated peak flows for all gauge stations.

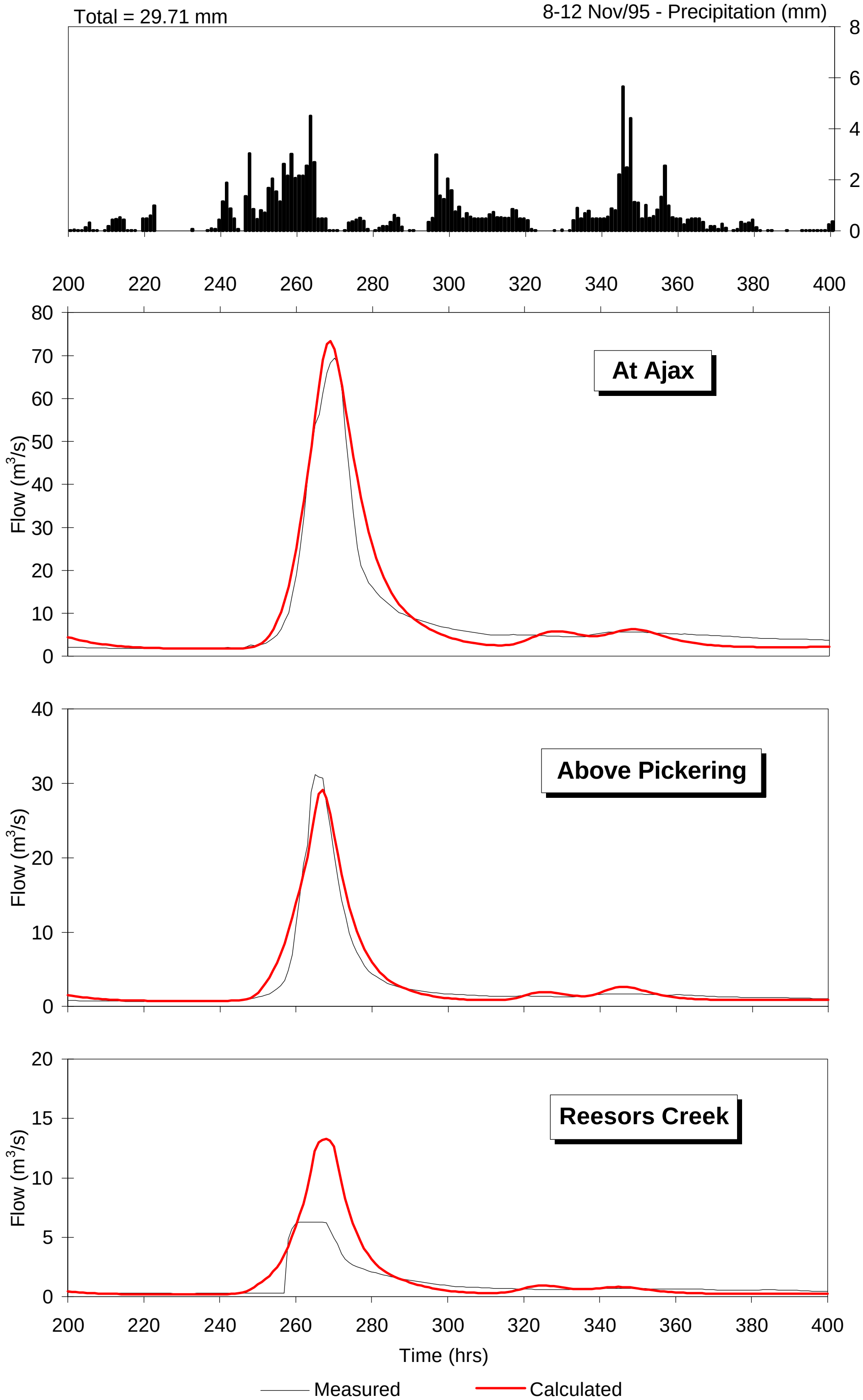
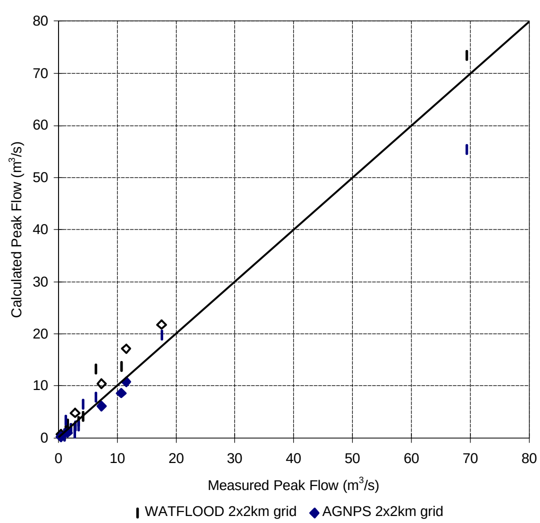



**Figure 5.13** WATFLOOD results for November 8-12, 1995
(2x2 Grid - Uncalibrated Radar Data - Radar Scale 1.0)

While the results from the WATFLOOD simulations compare hydrographs for the complete event, peak flows were extracted from the output. Figure 5.13 shows one of these comparisons between measured and calculated flows for the event of November 8-12, 1995 (for all the hydrographs see Appendix E). Table 5.7 presents a summary of the results and compares the AGNPS and WATFLOOD peak flows using the 2x2 km grid from both models. Figure 5.14 shows graphically the comparison for the two models together with the measured peak flows.

**Table 5.7** Hydrology Comparison Between AGNPS and WATFLOOD Results

| Event | Rainfall (mm) | Duration (hrs) | Peak Meas ($m^3/s$) | WatFl 2x2km ($m^3/s$) | AGNPS 2x2km ($m^3/s$) | Gauge Station |
|---|---|---|---|---|---|---|
| 25-29 Apr/95 | 16.5 | 18 | 11.50 | 17.15 | 10.77 | Duffins Creek at Ajax |
| | | | 1.72 | 1.50 | 3.44 | Reesor Creek above Green River |
| 16-20 May/95 | 20.0 | 15 | 17.50 | 21.80 | 19.79 | Duffins Creek at Ajax |
| | | | 4.14 | 4.16 | 6.50 | Reesor Creek above Green River |
| 1-6 Jun/95 | 10.7 | 20 | 3.40 | 3.17 | 2.30 | Duffins Creek at Ajax |
| | | | 1.00 | 0.51 | 0.39 | Reesor Creek above Green River |
| 13-18 Jul/95 | 24.4 | 10 | 7.34 | 10.42 | 6.14 | Duffins Creek at Ajax |
| | | | 2.70 | 2.02 | 0.98 | Reesor Creek above Green River |
| 2-6 Aug/95 | 18.1 | 20 | 2.79 | 4.85 | 2.37 | Duffins Creek at Ajax |
| | | | 1.01 | 0.78 | 0.85 | Reesor Creek above Green River |
| 2-10 Sep/95 | 14.2 | 15 | 1.51 | 2.68 | 1.06 | Duffins Creek at Ajax |
| | | | 0.40 | 0.72 | 0.28 | Reesor Creek above Green River |
| 4-16 Oct/95 | 26.9 | 13 | 10.70 | 13.78 | 8.65 | Duffins Creek at Ajax |
| | | | 2.06 | 1.79 | 1.84 | Reesor Creek above Green River |
| 8-12 Nov/95 | 29.7 | 14 | 69.40 | 73.39 | 55.36 | Duffins Creek at Ajax |
| | | | 6.29 | 13.30 | 7.84 | Reesor Creek above Green River |



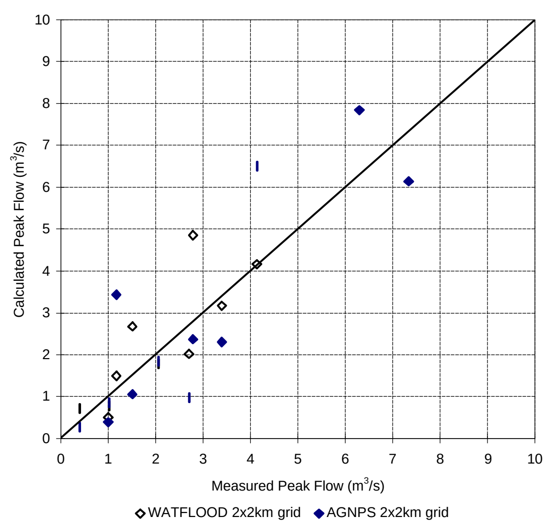




**Figure 5.14** WATFLOOD and AGNPS results, peak flows for all gauge stations.

### 5.2.2 Sediment and Nutrient Transport

The objective of this section is to test how the sediment and nutrient transport components coupled to the WATFLOOD model perform. The results will be compared with the output from the AGNPS model. Using the same events as in the hydrology section, several runs were conducted using both models to test the results from the sediment and nutrient transport. The sediment tests were performed on all grids while the 2x2 km grids were selected to test the fertilizer component. The fertilizer amounts were assigned as a function of the percentage of agricultural land. This was done in order to achieve similar levels of nutrients applied to the surface for the two grids. The spatial distribution of agricultural land where the fertilizer is applied for the AGNPS and WATFLOOD grids are shown in Figures 5.15 and 5.16.

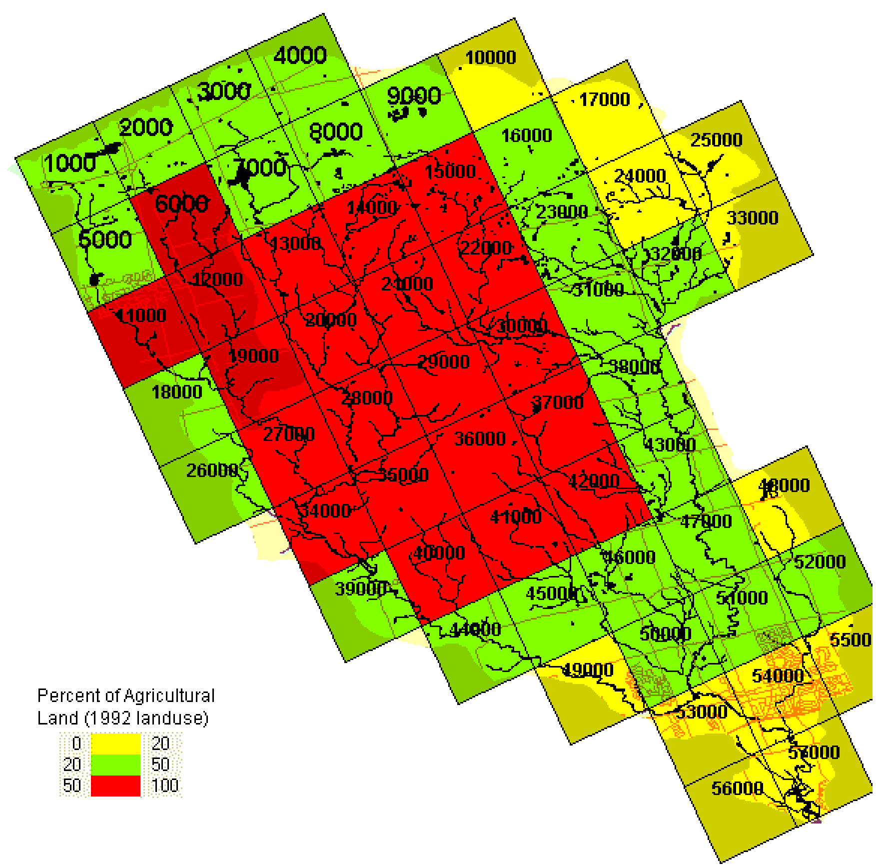



**Figure 5.15** Agricultural land distribution in the AGNPS 2x2km grid.

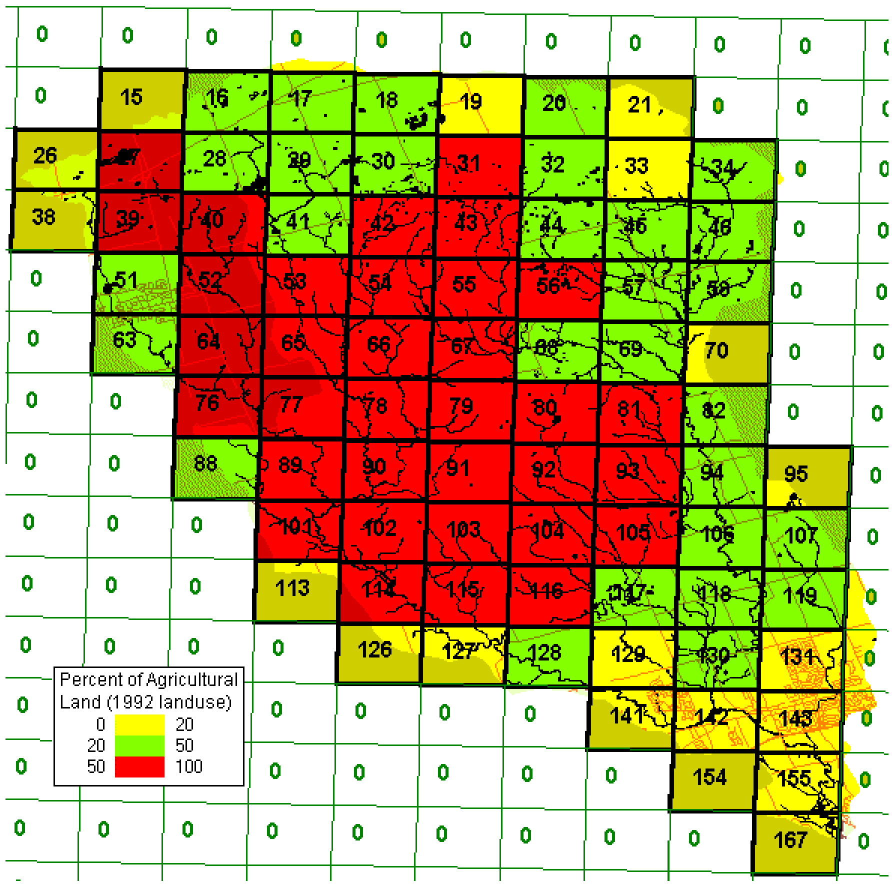



**Figure 5.16** Agricultural land distribution in the WATFLOOD 2x2km grid.

With this distribution, the criteria to indicate the level of fertilization on the field were selected as follows: Cells with 0 to 20% of agricultural land have a low fertilization level, 50 lb/acre of nitrogen and 20 lb/acre of phosphorus. Cells representing between 20 and 50% of agricultural land, 100 lb/acre of N and 40 lb/acre of P were applied. Finally for cells with percentages of agricultural land above 50%, a high level of fertilization was assigned, 200 lb/acre of N and 80 lb/acre of P. For all cells with fertilizer application, the availability factors for both nitrogen and phosphorus was 50%. This factor is the percentage of fertilizer left in the top half inch of the soil at the time of the storm. It is a function of the tillage practices and the worst case, having a factor of 100%, would be when none of the fertilizer had been incorporated into the soil and all is available for dilution in the runoff.

Duplicates of the grids were created and modified to include the fertilizer inputs. The rest of the parameters were kept unchanged so flow calculations remain the same and comparisons would reflect only the effect of fertilizer application. To compare with the AGNPS total loads for the event, the WATFLOOD results (Figures 5.17 and 5.18) were post-processed to calculate the loads for sediment, nitrogen and phosphorus. This was done by calculating the area under the curve for the total mass graphs. Table 5.8 compares results at the basin outlet.

**Table 5.8** Water Quality Results. Models Comparison at Duffins Creek Outlet

| Event/Model Result | Peak Flow (m3/s) | Sediment yield (ton) | Nitrogen load (Kg) | Phosphorus load (Kg) |
|---|---|---|---|---|
| Event: 25-29 Apr/95 | Meas=11.50 | | | |
| AGNPS (1x1) | 10.24 | 143.13 | na | na |
| (2x2) | 10.77 | 137.93 | 140.04 | 16.48 |
| WATFLOOD (2x2) | 17.15 | 171.92 | 133.62 | 13.93 |
| (4x4) | 16.16 | 165.64 | na | na |
| Event: 16-20 May/95 | Meas=17.50 | | | |
| AGNPS (1x1) | 18.32 | 232.43 | na | na |
| (2x2) | 19.79 | 230.98 | 215.01 | 29.66 |
| WATFLOOD (2x2) | 21.80 | 225.47 | 214.09 | 29.77 |
| (4x4) | 17.64 | 182.14 | na | na |
| Event: 1-6 Jun/95 | Meas=3.40 | | | |
| AGNPS (1x1) | 2.40 | 43.34 | na | na |
| (2x2) | 2.30 | 37.88 | 37.89 | 2.47 |
| WATFLOOD (2x2) | 3.17 | 46.64 | 22.80 | 1.20 |
| (4x4) | 2.22 | 34.66 | na | na |
| Event: 13-18 Jul/95 | Meas=7.34 | | | |
| AGNPS (1x1) | 6.20 | 141.14 | na | na |
| (2x2) | 6.14 | 130.19 | 71.67 | 4.94 |
| WATFLOOD (2x2) | 10.42 | 154.53 | 85.66 | 4.27 |
| (4x4) | 7.16 | 123.21 | na | na |
| Event: 2-6 Aug/95 | Meas=2.79 | | | |
| AGNPS (1x1) | 2.42 | 44.28 | na | na |
| (2x2) | 2.37 | 37.13 | 28.01 | 1.65 |
| WATFLOOD (2x2) | 4.85 | 61.08 | 33.14 | 1.69 |
| (4x4) | 3.90 | 49.88 | na | na |
| Event: 2-10 Sep/95 | Meas=1.51 | | | |
| AGNPS (1x1) | 1.06 | 22.99 | na | na |
| (2x2) | 1.06 | 20.58 | 31.30 | 0.82 |
| WATFLOOD (2x2) | 2.68 | 25.88 | 25.68 | 1.28 |
| (4x4) | 1.85 | 20.61 | na | na |
| Event: 4-16 Oct/95 | Meas=10.70 | | | |
| AGNPS (1x1) | 8.61 | 193.52 | na | na |
| (2x2) | 8.65 | 186.91 | 88.97 | 6.59 |
| WATFLOOD (2x2) | 13.78 | 260.85 | 83.28 | 8.38 |
| (4x4) | 13.10 | 242.35 | na | na |
| Event: 8-12 Nov/95 | Meas=69.40 | | | |
| AGNPS (1x1) | 49.98 | 536.07 | na | na |
| (2x2) | 55.36 | 549.23 | 415.18 | 59.31 |
| WATFLOOD (2x2) | 73.39 | 676.26 | 547.58 | 49.47 |
| (4x4) | 55.02 | 538.56 | na | na |

**Note**: For the AGNPS 1x1 km and the WATFLOOD 4x4 km grids no fertilizer runs were made (na on table)

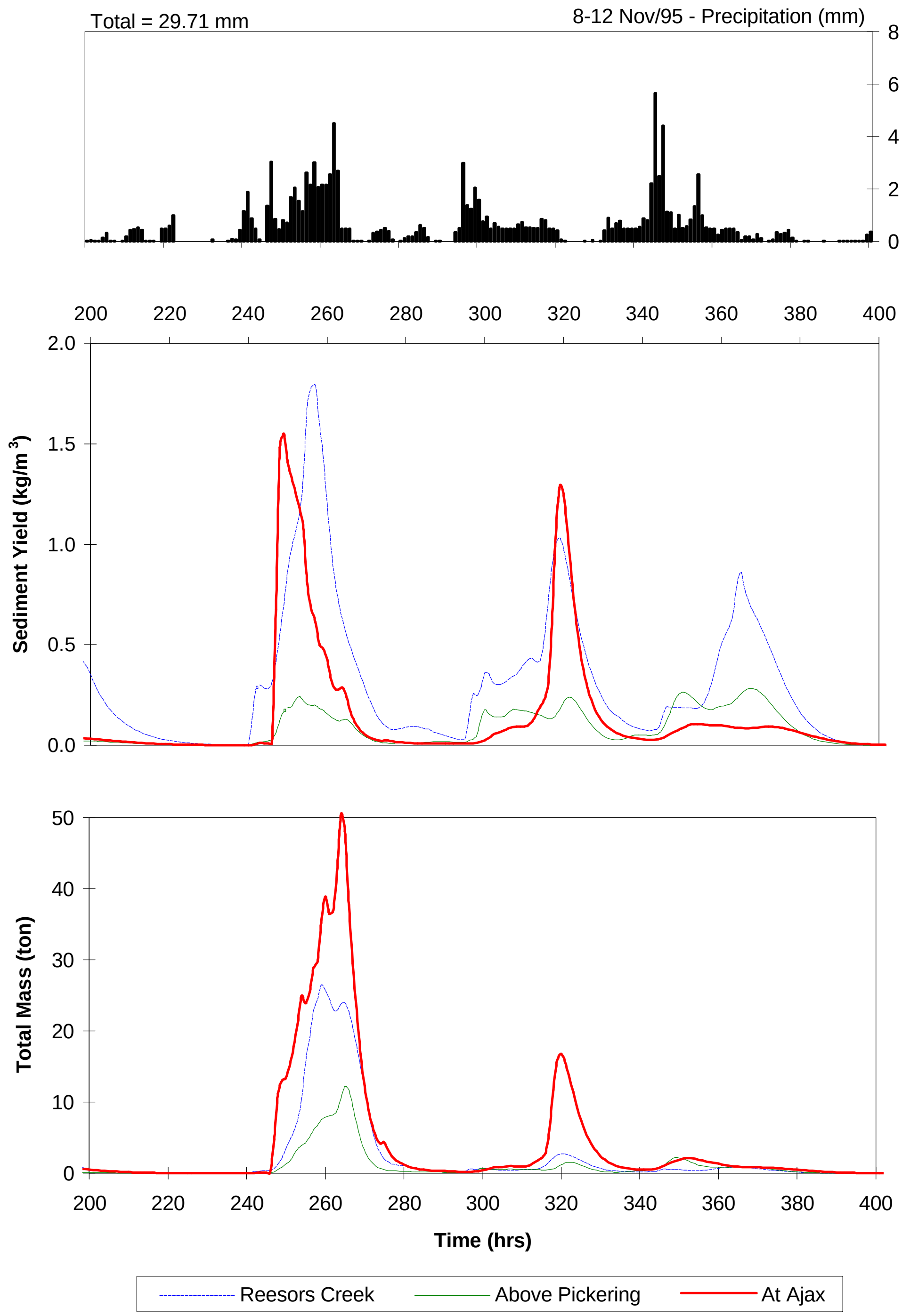



**Figure 5.17** WATFLOOD/Sediment results for November 8-12, 1995 (2x2 km Grid - Sediment Yield and Total Mass - Deposition Factor 20%)

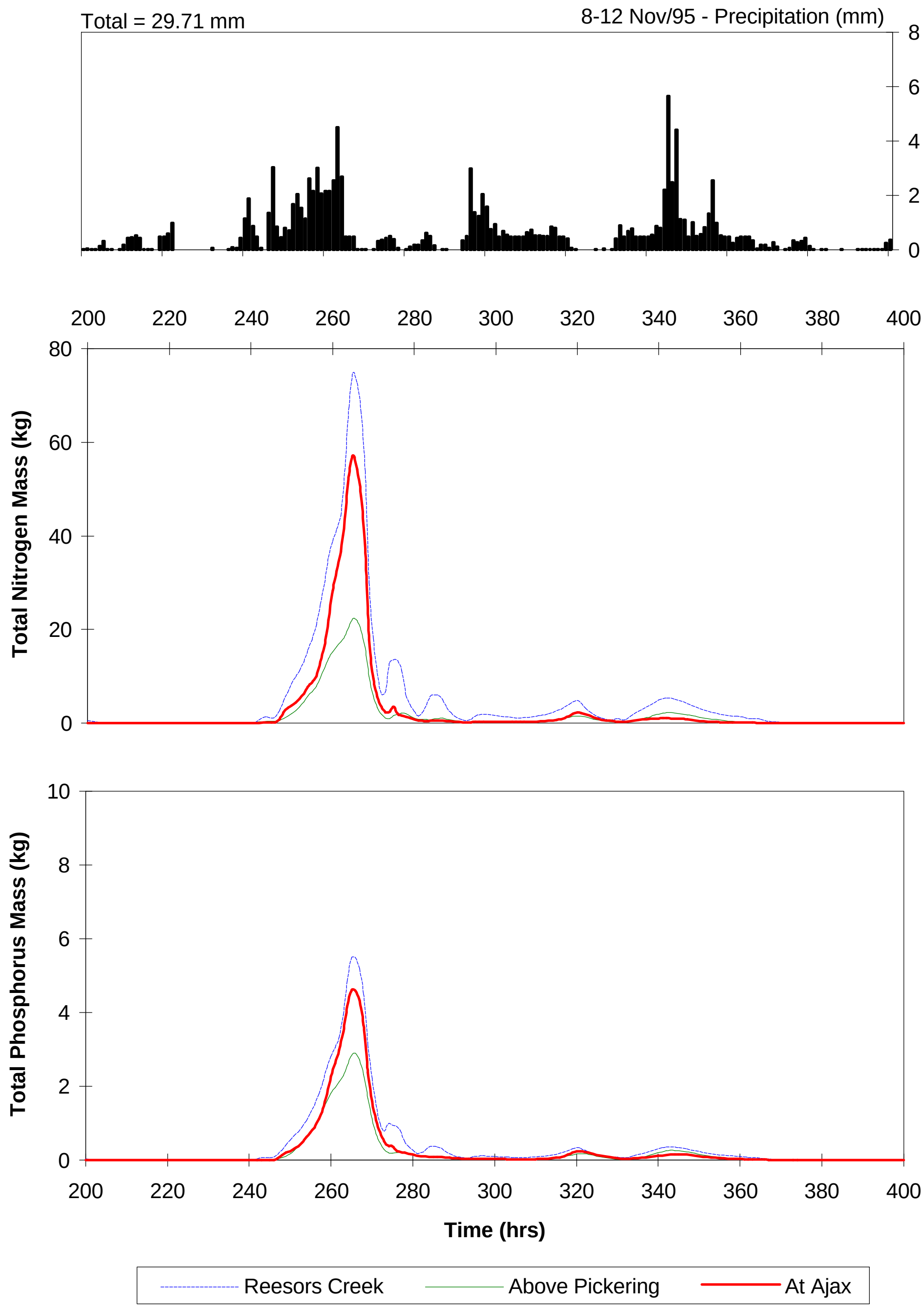



**Figure 5.18** WATFLOOD/Nutrient results for November 8-12, 1995
(2x2 km Grid - Nitrogen and Phosphorus Total Mass - Decay 60-40%)

As with the hydrology results, the water quality component provides time series output for sediment and nutrients. Figures 5.17 and 5.18 are examples of results, showing the sediment yield and nitrogen load respectively for the November 1995 event. All of the sediment and nutrient figures for the simulations can be found in Appendix E. Figure 5.19 compares the sediment yields and nutrient loads results from both models for all the tested events.

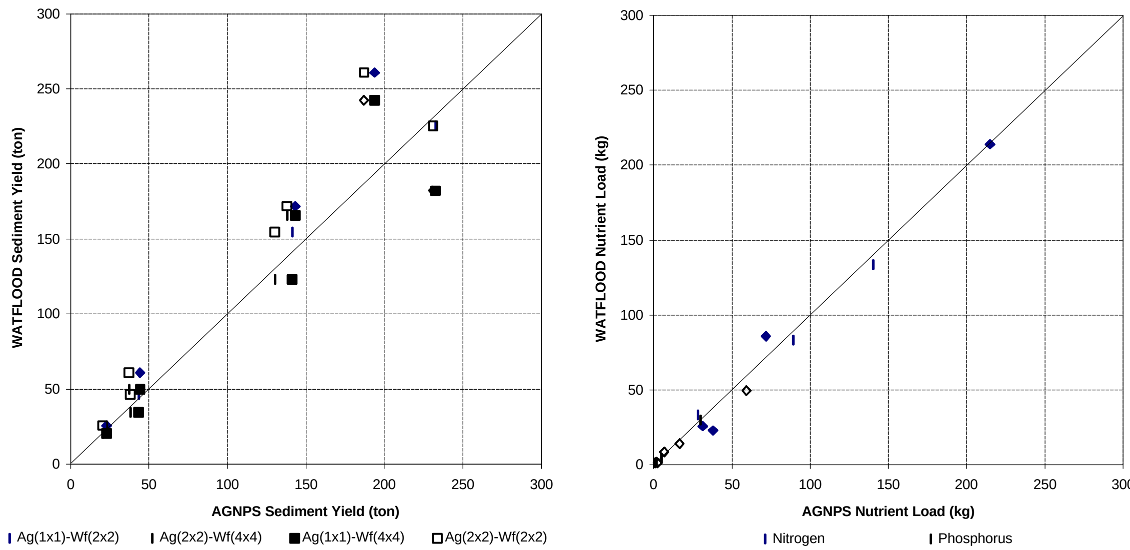



**Figure 5.19** WATFLOOD and AGNPS results comparison for sediment yields and nutrients

The following section shows the work done to test the validity of the models against measured data. A sampling campaign was undertaken during 1996-1998 by the MOE together with the NWRI and, though oriented to the calibration-validation process for the AGNPS model, some hourly events were sampled to compare the time series capabilities of the water quality component coupled to the WATFLOOD model. The events sampled during June, 1997 and March, 1998 were selected to perform the validation tests. Radar files were extracted from the University of Waterloo archives for the two months. Again the first tests were performed on the hydrology section and as expected the results correlate quite well with the measured values at the outlet of Reesor Creek, where the hourly event sampling was conducted. Figure 5.20 shows the comparison for the calculated and measured flows together with the hourly rainfall values extracted from radar data.

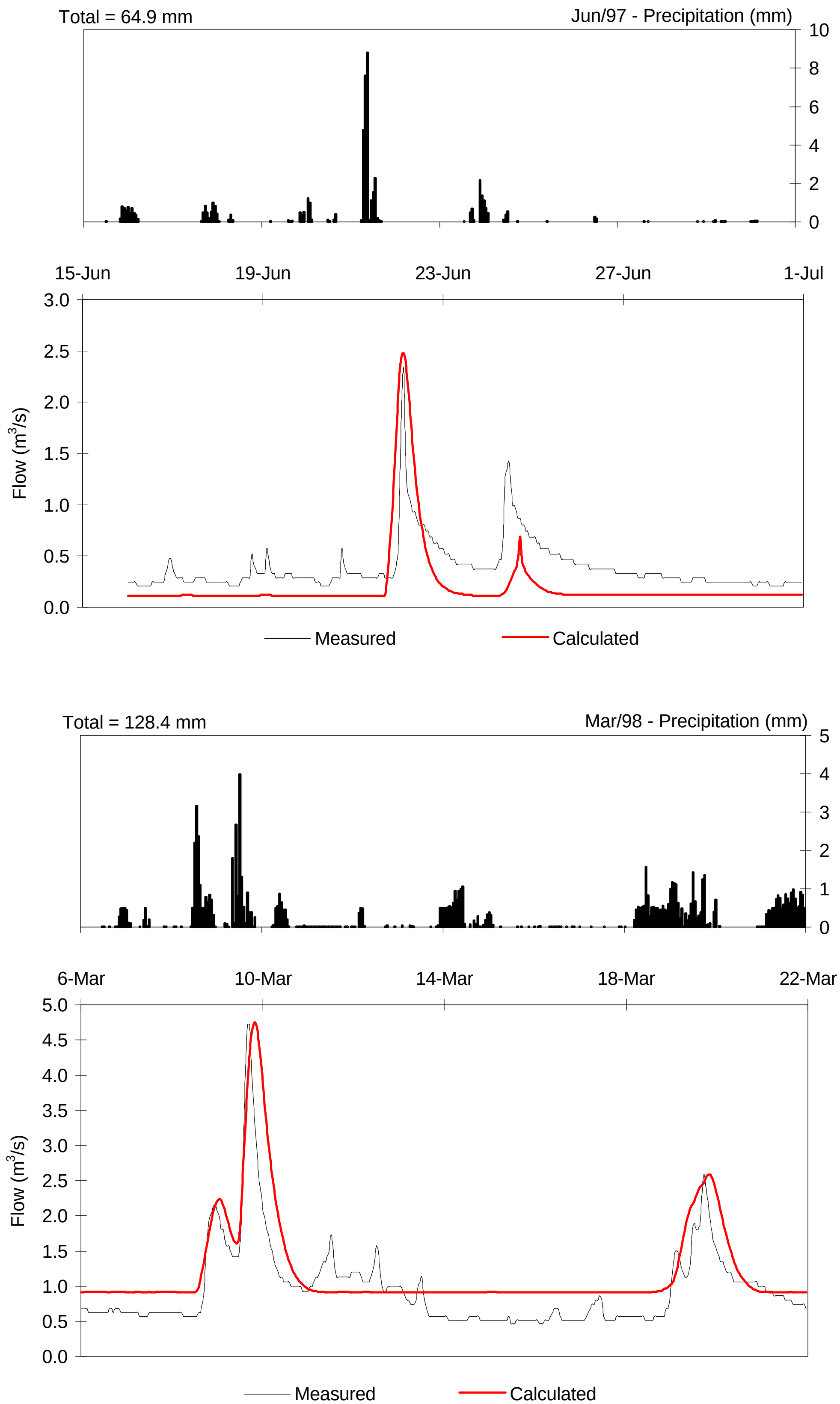



**Figure 5.20** WATFLOOD flow results for the sampled events (Jun/97 and Mar/98)

For the sediment and nutrient validation, the output was post-processed to extract the results for the specific dates of the events (June 22, 1997 and March 8-10, 1998). Figures 5.21 and 5.22 present the sediment (total suspended solids) and nutrient (total nitrogen concentration) comparisons between calculated and measured values for the two events.

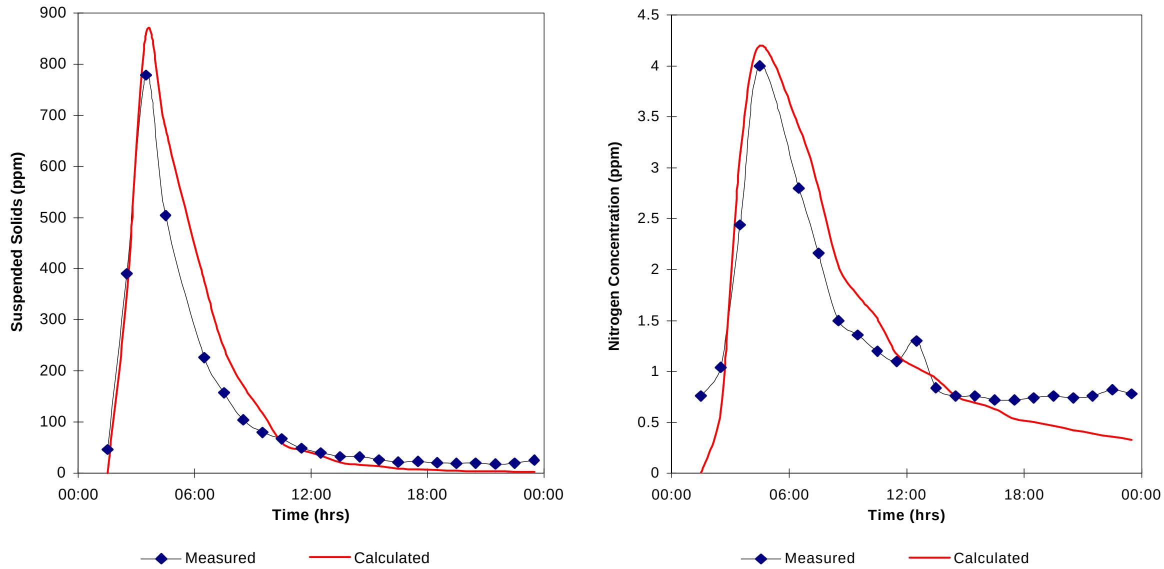



**Figure 5.21** WATFLOOD sediment and nutrient comparison for the June 22, 1997 event

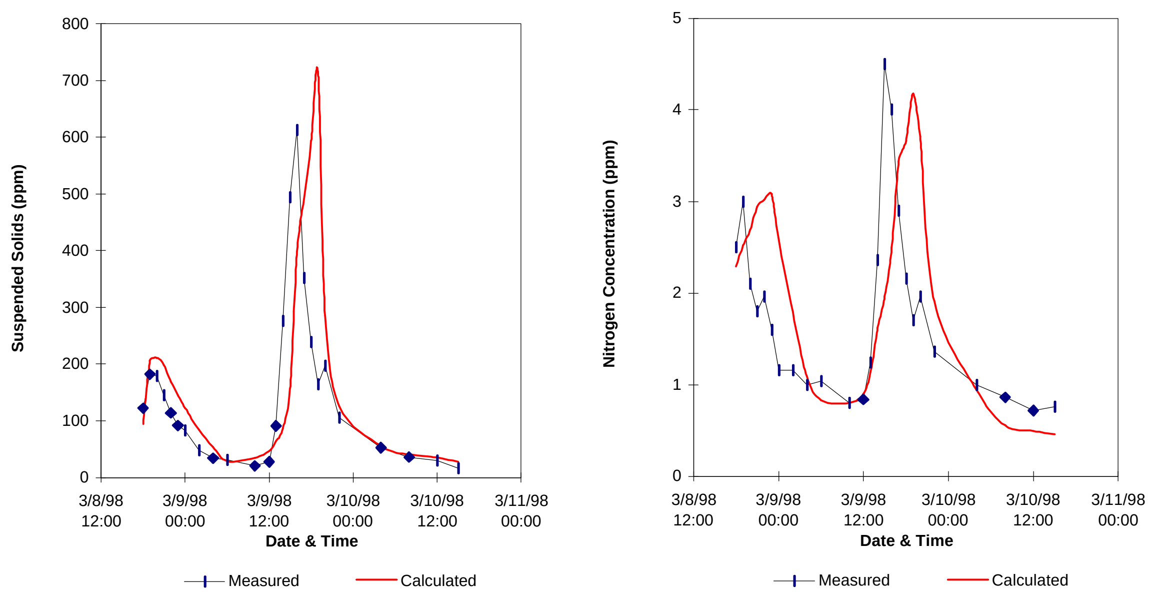



**Figure 5.22** WATFLOOD sediment and nutrient comparison for the March 8-10, 1998 event

Finally, to compare the results between models for the hourly sampled events, the required input data for the AGNPS model was prepared from the radar files and the two runs made for the events. For the June 1997 event the precipitation was 26.6mm in 8hr with AMC-II and for March 1998 the rainfall was 22.5mm in 15hr and AMC-III. The total sediment yield and nutrient loads were recorded at the Reesors Creek outlet for the AGNPS model. For WATFLOOD the time series at the outlet were used to calculate the yield and loads. Table 5.9 shows the comparison between model results and measured values for peak flow, sediment yields and nutrient loads at the Reesors Creek outlet.

**Table 5.9** Comparison of Model Results for the Hourly Sampled Events

| | Jun 1997 | | | Mar 1998 | | |
|---|---|---|---|---|---|---|
| **Parameter/Event** | **Meas** | **AGNPS** | **WATF** | **Meas** | **AGNPS** | **WATF** |
| Peak Flow (m3/s) | 2.06 | 1.84 | 2.48 | 4.72 | 4.45 | 4.75 |
| Sediment Yield (ton) | 18.52 | 24.06 | 21.21 | 33.70 | 37.76 | 38.70 |
| Nitrogen Load (Kg) | 147.15 | 157.81 | 156.75 | 448.77 | 491.28 | 514.68 |
| Phosphorus Load (Kg) | 3.59 | 3.89 | 3.15 | 84.11 | 93.27 | 86.33 |

### 5.2.3 Discussion of Results

As can be seen from the simulations, the model predictions match the measured values for peak flow very well using both models. The different grid sizes for the AGNPS model did not have a major impact on the results. In the case of WATFLOOD the computed hydrographs for the selected events matched the observed hydrographs extremely well. It is worth noticing that a larger grid size (4x4 km) tends to be more accurate in the prediction of peak flows. This is consistent with the concept behind the model and its ability to simulate larger areas. Normally WATFLOOD uses a 10x10 km grid size for larger basins providing that the cell drainage areas are described appropriately. Larger elements can be used but the resolution for the resulting hydrographs may be compromised. On the other side, smaller elements are possible as long as they contain at least a first order current within the cell. Another practical limitation is the data resolution itself. A recommended minimum should be at least four times the size of a single DEM element, so that the flow direction and slope data extraction will be accurate.

Most of the WATFLOOD calculated hydrographs compare well with the measured values. In some cases the effect of the "bright band" condition, overestimated rainfall values from radar data, is evident as the model predicts runoff not present on the measured records. It is worth mentioning that, for low intensity rainfall, the computed results tend to present a lag off for the peak flows on the hydrographs and larger values than the ones recorded at the gauging stations. This is probably caused by the interflow-infiltration component in the model causing it to overestimate the surface runoff.

For both AGNPS and WATFLOOD comparisons, the trend or regression between measured and calculated peak flows has a correlation value $R^2$ quite high, in the range of 0.91-0.98. It is important to mention, as stated before, that no specific calibration was performed on the simulations. WATFLOOD was originally calibrated on the Grand River watershed and has been used successfully in neighboring basins with similar physiography by transferring the calibrated parameters based on particular land covers (Kouwen *et al.*, 1993).

The parameter files for the Duffins Creek were created using the Grand River watershed files without further calibration. The input data for the model was produced from the extraction process developed in this research project. The results from the simulations suggest that the approach was adequate and provides further evidence of the benefit of the GRU method.

On the other hand, AGNPS is a robust and well tested model. It has being used in different circumstances to calculate sediment and nutrient loadings due to nonpoint source pollution in watersheds (Koelliker and Humbert, 1989, Binger *et al.*, 1989, Young *et al.*, 1989, Finney *et al.*, 1995, Mostaghimi *et al.*, 1997). In almost all the cases it was found that the predicted sediment and nutrient yields agreed reasonably well with the measured data. It is important to remember that AGNPS was conceived on the basis of the CREAMS model, which was developed with the intention of minimizing the calibration efforts. For the AGNPS application the coefficients used in the model were the recommended default values. Adjusting of such values is possible if the results were poor, but in this case to do so was not necessary.

Furthermore, Mostaghimi *et al.*, (1997) found that, based on several simulations, the AGNPS was a suitable model for their watershed conditions. At the same time, they also noted that the input data preparation for the model was very time consuming and pointed out the difficulties for determining the accuracy of the input values. The interface created in the present research, drastically reduces such time consuming task and provides good input data based on the digital information of the watershed. Results of this research support the fact that, as long as the input parameters are well established, the model performs accurately. If point sources are present, the model has the capability to include them as direct inputs into the river system; or the grid sizes can be reduced by subdivision, for example, to simulate buffer areas near a stream.

With respect to the hourly sampled event tests, the results are encouraging. The good match between observed and calculated values for both sediment and nutrient yields give further proof that the approach followed in this research can eventually improve the modelling of non-point source pollution. Again no major calibration was performed except for the fine tuning of the decay factors for nutrients and the deposition coefficient for sediments. The values used in the two models were exactly the same to allow comparison of results without any bias. The sediment deposition was in the 25-35% range for the two events and the decay factors were maintained around a 50% value. This is consistent with the findings of Rode and Frede (1997) in their calibration efforts of the AGNPS model.

## 5.3 AGNPS Applications in Other Watersheds

The part of this research dealing with the integration of the AGNPS model in a decision support system was conducted in a cooperative research program under the umbrella of the 1994 Canada-Ontario Agreement (COA). The overall objective of these research projects is to provide Ontario planning centres with better procedures, models and tools to aid in the design and implementation of watershed management programs (Bowen *et al.*, 1995). The planning centres involved in the project include the South Nation Conservation Authority, Lake Simcoe Conservation Authority and the Metro-Toronto and Region Conservation Authority.

As part of COA, the National Water Research Institute (NWRI) of Environment Canada and the Science and Technology Branch of the Ministry of the Environment and Energy (MOEE) have been working in collaboration with conservation authorities and other groups to research, develop and transfer new technologies and planning tools to assist the planning centres in achieving their program objectives. Because nonpoint source pollution is a major component that must be considered when carrying out watershed environmental studies, this AGNPS Interface project and its link with RAISON were central parts of this project

### 5.3.1 Technology Transfer

The goal for the regional conservation authorities was to assess the use of the AGNPS model as a tool to evaluate the effectiveness of management strategies for water quality, sediments and nutrients, in southern Ontario watersheds. In a two phase technology transfer program, in October, 1997 and January, 1998, staff from the MOEE and Conservation Authorities attended training sessions on RAISON and the AGNPS Interface. Participants included personnel from the Grand River Conservation Authority, the Credit Valley Conservation Authority, the South Nation Conservation Authority, the Lake Simcoe Region Conservation Authority, the Metro-Toronto Region Conservation Authority and the Ministry of the Environment and Energy.

The author was the principal instructor at these sessions and his research procedures and model interfaces were the main topics. Deliverables included: i) installation of the executable files of the AGNPS Interface, ii) a seminar on AGNPS dealing with model description, input requirements, capabilities, etc., iii) a tutorial on how to create a project in RAISON, iv) training on the use of the AGNPS interface, and v) a description of the utilities needed to incorporate digital data into RAISON. What follows is a discussion and presentation of a particular application of this research in the Lake Simcoe Region after the two training sessions were conducted. This is done with the intention of showing how the interface work developed in this research is starting to be used by planning centres in their own environmental studies.

### 5.3.2 Lake Simcoe Application

After the technology transfer sessions, personnel from the Lake Simcoe Region Conservation Authority (LSRCA) applied the RAISON-AGNPS Interface in two watersheds draining to Lake Simcoe, Maskingonge and Uxbridge. The following information presents partial results with respect to the use of the interface on the applications (Peat, 1998). Note that the setup of the scenarios and conclusions from this study are the sole responsibility of the LSRCA.

The study on the Maskinonge watershed had the objective to outline a remedial strategy to reduce water quality degradation in the Maskinonge river and its 60 $km^2$ watershed. The main cause of pollution in the river system since the mid 1980's is nutrient availability, which has produced excessive growth of algae and aquatic plants, most noticeably duckweed. Nitrogen in the form of nitrates has been linked to this excessive growth Phosphorus has been recognized as the key nutrient driving pollution problems with Lake Simcoe. In order to evaluate different alternatives for remediation, several Best Management Practices (BMPs) were tested by means of modelling different scenarios with the AGNPS model.

Preliminary work provided by the author for the LSRCA included the extraction and conditioning of the DEM data as well as the setup of the soil and landuse maps. The DEM data was obtained, as previously, from the United States Geological Survey (USGS) internet site (*http://edcwww.cr.usgs.gov/landaac/gtopo30/gtopo30.html*). The topographic map files at every 30 second interval where resampled at 10 second interval to increase the DEM detail for the study area. The conditioning process was performed and files were imported into RAISON database files. Figure 5.23 shows the DEM data for the two selected watersheds. Use of the integrated system AGNPS-Interface-RAISON developed in this research project was the critical step in this part of the study. Original OMAFRA landuse data were updated using a vegetation coverage from the Ministry of Natural Resources. Together with digital soil survey maps, the database layers for the model data extraction were created. The discretization of the watershed was achieved by dividing it into 87 uniform square cells. Figure 5.24 shows the soil and landcover layers on the Maskinonge watershed and the 750x750 m model grid.

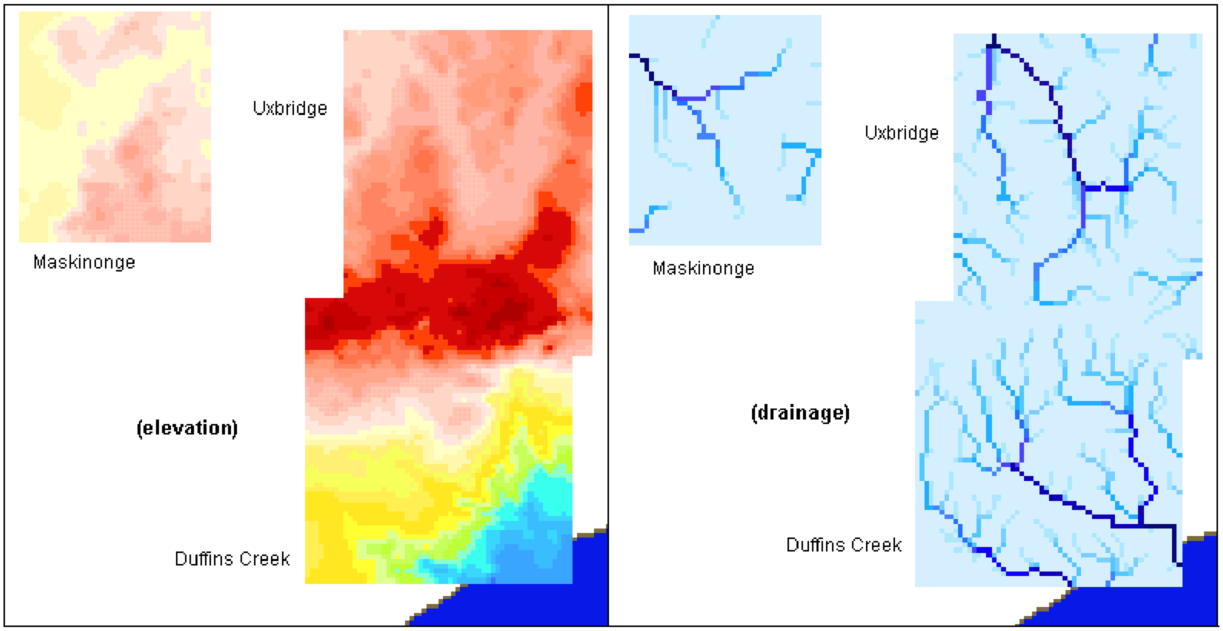



**Figure 5.23** DEM files for Southern Ontario showing Lake Simcoe extracted watersheds.

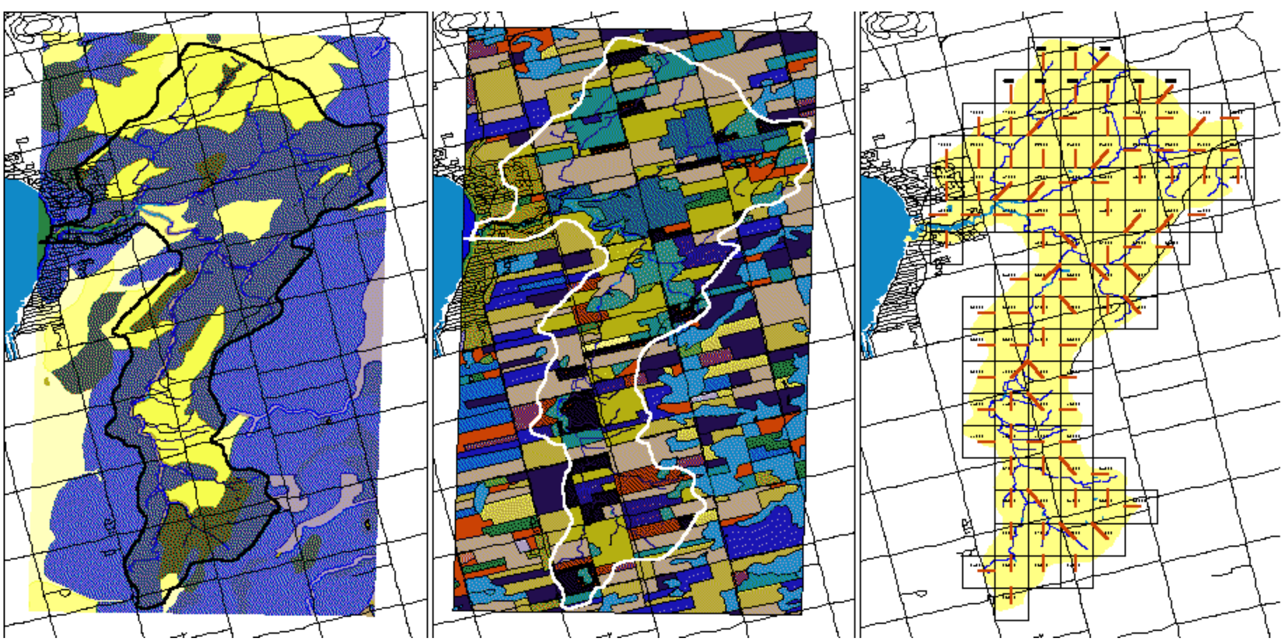


**Figure 5.24** Maps on the Maskinonge watershed (soils, landuse) and model grid

A number of future growth scenarios within the Maskinonge river watershed were evaluated using the AGNPS model. The modelling efforts focused only on the nitrogen and phosphorus loading. The idea of using the AGNPS model was to simulate what changes in water quality might occur for different BMPs and potential landuse scenarios. The testing scenarios were:

A) Existing conditions. Describes the present-day conditions of the Maskinonge River watershed. These include present land use as well as current farming practices

B) Existing conditions implementing rural BMPs. Looks at the implementation of various remedial BMPs. These include an increase of forest cover to approximately 25% in all catchments, a 25% decrease in fertilizer application rate, an increase in conservation tillage and the elimination of cattle access to streams.

C) Future growth (Official Plan Designation). Looks at future urban growth, with no implementation of rural BMPs. This will predict how the watershed will react to an increase in urban area with a status quo with respect to remedial measures and landuse practices.

D) Existing conditions and increase in forest cover of 25%. Looks at existing conditions with an increase in forest cover to 25% in all catchments.

E) Existing conditions and reduction of fertilizer application by 25%. Looks at existing conditions with a 25% reduction in fertilizer application on agricultural land.

All the simulations were done for a single two inch rain storm and the results are reported at the outlet of the watershed. Table 5.10 shows a summary of the modelling results, including the nutrient loading for the various scenarios and compares the present day conditions of the first scenario (A) to the different possible alternatives investigated. It is worth mentioning that no field data were used to validate these results and the following discussion will be based only on their relative differences to assess the impact of the proposed scenario.

**Table 5.10** Summary of Model Results Based on Different Scenarios.

| Model Result | Scenario "A" | Scenario "B" | Scenario "C" | Scenario "D" | Scenario "E" |
|---|---|---|---|---|---|
| Runoff (in) | 0.37 | 0.29 | 0.42 | 0.29 | 0.37 |
| Sediment yield (ton) | 308.66 | 185.33 | 306.58 | 255.55 | 308.66 |
| Phosphorus load* (Kg) | 74.25 | 38.80 | 84.29 | 53.35 | 55.69 |
| Phosphorus Conc (ppm) | 0.12 | 0.08 | 0.12 | 0.11 | 0.09 |
| Nitrogen load* (Kg) | 433.15 | 242.50 | 470.61 | 310.39 | 352.70 |
| Nitrogen Conc (ppm) | 0.7 | 0.5 | 0.76 | 0.64 | 0.57 |

Scenario "B" involves the implementation of a full range of BMPs to address rural mostly non-point sources such as runoff from livestock and cropland erosion. The total phosphorus load under this scenario was estimated to be 38.80 kg, while the total nitrogen loading was 242.5 kg. This means that the implementation of BMPs could potentially reduce phosphorus loading by almost 48% and nitrogen loading by 44% as compared to the existing conditions of scenario A.

Scenario "C" represents the worst case scenario based on future urban growth within the watershed and no implementation of BMPs. Phosphorus loading to the Maskinonge river is estimated at 84.3 kg, that is an increase of 13.5% above current conditions. Nitrogen loading increased to 470.61 kg, up by 8.6%.

Scenario "D" illustrates the changes which occurs if a landuse change increases forest cover in all catchments to approximately 25%. Phosphorus loading decreased by 28% to 53.35 kg. The nitrogen loading also decreased by 28% to 310.4 kg. Most of this load reduction was due to a decrease in total runoff during the rain event.

Scenario "E" illustrates what changes would occur if the fertilizer application rates were reduced by 25%. The total phosphorus loading decreased more than 25% to 55.69 kg, while the nitrogen decreased by 18.6% to 352.7 kg. The amount of total runoff water from this scenario remained the same as the base case scenario and therefore all of the load reduction was due to a decrease in the concentration of phosphorus and nitrogen in the runoff.

It is apparent from these results that the various scenarios have a large impact on nitrogen and phosphorus loadings. The increase in these loadings with respect to the increment of algae and duckweed growth should be further investigated. The loading increase of 13.5% in phosphorus and 8.6% in nitrogen for the worst case scenario may not have much of an impact above the current conditions.

On the other hand the application of BMPs do make a large difference in the nutrients loading, so it is a good recomendation to state that future development in the watershed should occur accompanied by the implementation of some of the BMPs. Although only some of the BMPs may actually be implemented, these modelling results have shown that there would be overall gains in water quality in doing so.

Furthermore, some actions such as reduced fertilizer application rates and increased forest cover would be highly beneficial to water quality improvement. With the previous example, the author's intention was to demonstrate the usefullness of the work being developed in the present research. As mentioned before, the main conclusions of the Maskingonge study were taken from the draft report of the project.

The model application appears to have performed well. According to LSRCA personnel (Peat, 1998), the AGNPS Interface was a critical tool that they used extensively in the study allowing them a stable and reliable integration of the geographical data and the running of the AGNPS model. It provided them also with an easy and straightforward way to create alternative scenarios to simulate.

## 5.4 Chapter Summary

This chapter presented the data acquisition from the integration perspective. It describes in detail the different digital files (DEM, soil and landuse) required, showing the information gathered for the Duffins Creek application. Additional utilities were developed to incorporate such files into a layer database, which includes the import of shape and DEM files as well as capabilities to edit the lookup table. Once the information was in the proper format, the integrated models, AGNPS and WATFLOOD, were applied to the same storm events. Several tests were conducted to test the validity of the models. The hydrology results were compared together with the outlet values for sediment and nutrient transport. Since the AGNPS Interface section of this research forms a part of a collaboration agreement with the NWRI and MOEE, the technology transfer to the Conservation Authorities was described and a partial example of the application in the Maskinonge watershed from the Lake Simcoe Region Conservation Authority was presented.