Chapter 1 - An Overview of MIDUSS 98

The following general areas describe the overall purpose of the MIDUSS 98 program, the structure of the main menu, major differences from previous versions of the program and a description of the functionality available in MIDUSS 98.

Refer to the relevant chapter for more information

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An Introduction to MIDUSS 98

The MIDUSS 98 package was developed to help drainage engineers to design the hydraulic elements in a collection network of storm sewers or channels. The program does not make design decisions but rather carries out hydrological and hydraulic analyses and presents you with design alternatives. It is then left to you as the engineer to select values for the design variables and to decide on the acceptability of a design.

MIDUSS 98 is highly interactive in use, and allows engineering judgment to be exercised at all stages of the design process. Moreover, this interaction lets you monitor each step of the process and take corrective action in the event of an error. With most commands, data is input in response to prompts, and you are free from the need to prepare lengthy data files prior to the design session. In many cases a design session will require to be repeated either:

1. to test a previously designed system under a different storm,
2. to continue or modify a previous design session.
3. to modify a hydrology or design parameter.

Using Automatic Mode

When a design session has to be repeated with a modification such as a different storm, it is possible to use an input file which contains a log of the previous session with all the commands and the relevant data. In MIDUSS 98 this input file is in the form of a database which can be produced automatically from a previously created output file. Running MIDUSS 98 in automatic mode eliminates the need to re-enter the commands and data from the keyboard. In this mode, however, design decisions with respect to pipes, ponds, channels or diversion structures can still be altered and changes can be made to the database. The use of files in this way is discussed in more detail later in this Help file. (see Chapter 10 - Running in Automatic Mode)

The hydrology and hydraulics used in MIDUSS 98 is based on well established and accepted principles. The details of these techniques are described under the various command headings in Chapter 3 - *Hydrology Used in MIDUSS 98* and Chapter 4 - *Design*

Sections have been added which presents the relevant background theory. These need not be studied in order to run MIDUSS 98 but have been included for the interested reader or student.

The next section provides a general description of a typical design session A more detailed example is presented in Chapter 11 – *A Detailed Example* .

A Simple Example

A Typical Design Session

Assuming you have pressed the [Yes] button when the initial Disclaimer form is displayed, MIDUSS 98 starts up with the main menu displayed at the top of the window. Depending on the size and resolution of your screen you will probably want to click on the 'maximize window' symbol at the right hand end of the title bar to make the MIDUSS 98 window fill the screen.

With reference to the simple example shown in Figure 1-1, a typical session may be summarized by the sequence of steps described in the following topics. You are first required to define the system of units to be used and the **Options/Units** menu is displayed with the mouse pointer positioned over either **Metric** or **Imperial**. After setting the system of units, your first action should be to define the Output File to record the session.

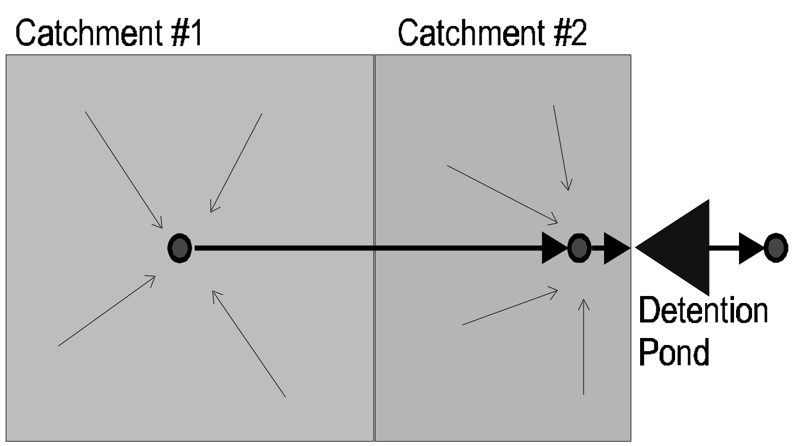


Figure 1-1 – A Simple Two-catchment System

Define the Output File

Using the **File/Output/Create New File** menu item, navigate through the standard Windows95 Common Dialog Box to select an existing file or create a new one in a directory of your choice. This directory will serve as the Job Directory for this session and the file will contain a record of the commands used, the data entered and some of the results. The Job Directory will also contain any files which you create such as storm or hydrograph files.

If you omit this step MIDUSS 98 will use a default output file (called 'default.out') which resides in the Miduss98 directory e.g. C:\Program Files\Miduss98\. Using this file is not recommended since it results in an accumulation of files in the Miduss directory. Also, the default output file may be overwritten during the next design session if you again use the default condition.

After setting the Job Directory the next logical step is to Select your Options

Select your Options

MIDUSS 98 offers a number of features most of which are optional. The most important is the system of units to be employed. Immediately following acceptance of the Disclaimer form you will be prompted to select the system of units to be used for the session. Your choice for units and other options will be remembered when the session is finished and MIDUSS 98 will start the next session with the same selection.

Other options let you show or hide the status bar, use the MIDUSS 98 tool tips, or enable a system of prompts which you may find useful as a first time user of MIDUSS 98.

Before you can proceed to any hydrological modelling you must set the Time parameters and this should be your next step.

Set the Time Parameters

In the **Hydrology** menu all of the options are initially disabled with the exception of the **Time parameters**. This command prompts you to set the time step, maximum storm duration and longest hydrograph duration you expect to use. All of these values are defined in minutes. Be generous with the estimate of storm duration and hydrograph length because if you find you want to define a storm longer than you originally thought a second use of the **Hydrology/Time parameters** command will cause the arrays storing rainfall and hydrographs to be re-initialized with loss of data.

Setting the time parameters will also enable the **Storm** command and your next logical step will be to Define the Design Storm .

Define the Design Storm

Use the **Hydrology/Storms** command to define a single event design storm using one of five methods i.e.

- a Chicago storm,
- one of the four Huff distributions,
- any of the pre-defined mass rainfall distribution (*.mrd) patterns,
- a storm pattern as proposed by the Canadian Atmospheric Environment Service (AES), or
- a historic storm

Alternatively, you could import a previously created storm hyetograph file by means of the **File I/O** command.

Either method causes the **Hydrology /Catchments** command to be enabled. The rainfall defined in this way remains in force until the rainfall is redefined. Normally the storm is defined only once at the start of the session.

Once the storm is defined the next step is to generate the Runoff Hydrograph for the first catchment area.

Generate the Runoff Hydrograph

Using the **Hydrology/Catchments** command you can now define the first catchment and produce the direct runoff hydrograph for the previously defined storm event. The runoff hydrograph is stored in the Runoff hydrograph array.

The runoff is computed separately for the pervious and impervious fractions of the catchment and the two hydrographs are added. Information about the catchment runoff is provided in various ways;

- A table is displayed with the flow for each time step together with the peak flow and the total volume of runoff.
- A graphical display shows the runoff from the pervious and impervious fractions as well as the total runoff.
- A table of rainfall and runoff measures can be displayed by clicking on the [Show Details] button.
- Another summary table shows the history of peak flows in each of the four arrays for Runoff, Inflow, Outflow and Junction hydrographs, but this is not updated until you have accepted the results of the calculation by pressing the [Accept] key.

Accepting the computed runoff hydrograph causes the menu command **Hydrograph /Add Runoff** to be enabled. Using this the Runoff is added to the current Inflow hydrograph which in this case is initially zero. The summary table of hydrographs is updated.

Before you can use this hydrograph to design an element of the drainage network you must add the runoff to the current Inflow hydrograph. This is done by using the **Hydrograph/Add Runoff** command .

Using the Add Runoff Command

The Hydrograph menu contains a number of options to manipulate flow hydrographs. These are initially disabled and become available to you as the pre-requisite steps are completed. Once a new runoff hydrograph has been created by means of the **Hydrology/Catchments** command the **Hydrograph/Add Runoff** command is enabled.

This command causes the last computed runoff hydrograph to be added to the current Inflow hydrograph. The result of this operation is shown in the summary of peak flows. The **Hydrograph/Undo** command is enabled by this action so that you can reverse the process should you wish to do so.

Now that the Inflow hydrograph has been updated the next logical step is to design an element of the drainage network such as a pipe or channel or other facility. Open the Design menu and select an item to design a pipe or channel .

Design a Pipe or Channel

Using one of the options in the **Design** menu, you can now design a pipe or channel to carry the peak flow of the Inflow hydrograph. For each of the **Design** menu items default data is displayed which you should change to suit your requirements. Your data values will become the new default values for the remainder of this session or until changed again.

Design of pipes or channels requires selection of a depth or diameter along with the gradient expressed as a percentage. Pressing the [Design] command button causes a uniform flow analysis to be displayed which shows the actual depth, the flow capacity of the conduit, the average velocity and the critical depth of flow to indicate whether the flow will be sub-critical or super-critical.

In the case of a pipe the design may result in surcharged conditions in which case the hydraulic grade (i.e. the slope of the energy line) is reported. Surcharged flow may result in only a portion of the runoff being captured so that the total runoff must be split between major (i.e. on the surface or street) and minor flows (i.e. in the pipe).

Of course, options other than the Pipe and Channel design may be used but these simple cases are used for this introductory description,

When the design is accepted the **Design/Route** menu item is enabled which lets you route the flow hydrograph through a specified length of conduit.

Route the Hydrograph

The **Design/Route** menu command is used to route the hydrograph through a user-defined length of the most recently designed conduit. After accepting the result, the peak of the outflow hydrograph is displayed in the summary table of hydrograph peaks.

When an outflow hydrograph has been created by some routing operation you may choose from two possible courses of action. Either the outflow can be copied to the inflow array in order to continue to the next downstream link, or the outflow may be stored at a junction node to be combined with other flows at a confluence point.

For this example you should assume that the outflow from the first conduit will form all or part of the inflow to the next downstream conduit. You can do this by using the **Hydrograph/Next Link** menu command in the **Hydrograph** menu.

Using the Next Link command

When a new outflow hydrograph is created, the **Hydrograph/Next Link** menu item is enabled. Using this command causes the outflow hydrograph to be copied to replace the inflow hydrograph and ready to receive the runoff contribution from the next sub-catchment. If no additional catchment runoff enters at this point you can simply use the inflow to design another link in the drainage network such as a detention pond, an exfiltration trench or a diversion structure.

For this example a second catchment area must be defined and the runoff added to the total inflow. The procedure for modelling the second catchment is similar to the previous case. If the parameters describing the rainfall losses and infiltration are unchanged, the effective rainfall for the pervious and impervious areas will also be unchanged and only the calculation of runoff is required. One exception to this rule is when using the SWMM Runoff procedure to model the overland flow. Refer to Chapter 7 *Hydrological Theory* – The SWMM Runoff Algorithm for more information.

Once the runoff from the second catchment has been accepted you can use the Add Runoff command a second time to accumulate the flow in the inflow hydrograph.

Add Runoff Hydrograph #2

The **Hydrology /Catchments** is used a second time to generate the runoff hydrograph from the next catchment area. The **Hydrograph /Add Runoff** command causes this to be added to the Inflow hydrograph. Both changes are reflected in the summary table of peak flows.

For this simple example the next and final step is to design a detention pond to reduce the peak flow.

Design a Detention Pond

To reduce the peak of the Inflow hydrograph, the **Design/Pond** menu command is used to design a detention pond. The process requires the calculation of the Stage - Discharge - Storage Volume data for the pond. A number of options are available in the **Design/Pond** command to let you describe different parts of the outflow control device. These may comprise multiple orifices and weirs from which the Stage - Discharge curve is computed. Options are also available to help you calculate the Stage - Volume Storage curve for a few standard forms of storage geometry such as an idealized pond of rectangular shape, large diameter "super-pipes", wedge storage on graded parking areas or rooftop storage.

When you use the **Design/Pond** command you can specify the desired peak outflow and MIDUSS 98 will suggest values of storage and other parameters which will provide an initial design. You can then fine tune the design until you are satisfied with the result. Since this is a trial and error procedure the Design Log feature of the **Design** options is useful in summarizing the progress of this iterative procedure.

The Outflow hydrograph is obtained by a storage routing procedure and the attenuated peak flow is displayed in the table of peak flows. MIDUSS 98 will automatically adjust the storage routing time-step to ensure numerical stability in the vicinity of highly nonlinear Discharge - Storage Volume curves. Any such adjustment is reported but otherwise the process is transparent to the user.

This concludes this simple illustrative example but you may find it useful to review the summary of modelling procedure which follows. A more detailed example is presented in Chapter 11 – *A Detailed*

Example.

Summary of Modelling Procedure

(1) The total catchment area is subdivided into a series of sub- catchments, each of which generates an overland flow or runoff hydrograph. The hydrograph is assumed to enter the drainage network at a particular point or node associated with the sub-catchment. The drainage network is assumed to be a tree so that each node can have any number of inflow links but only one outflow link. For this reason, each link is given the same number as the node at its upstream end. These sub-catchments are processed in order, starting at the upstream limit of sewer branches and working in the downstream direction.

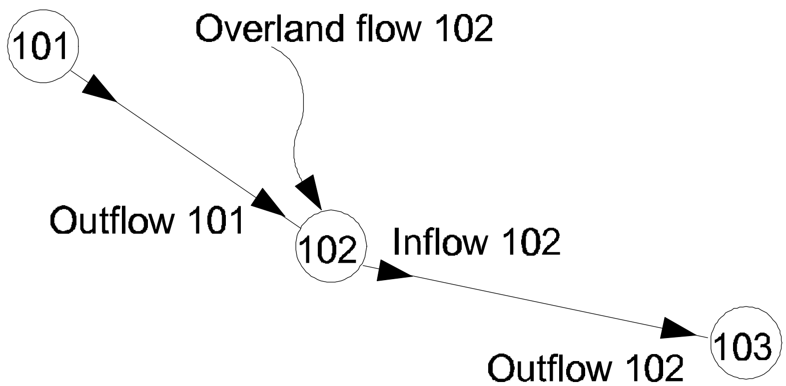


Figure 1-2 – Convention used for Numbering Nodes and Links

(2) Figure 1-2 illustrates a node (102) which receives the outflow from the upstream link (101), adds to this the runoff from catchment (102) and creates the resulting inflow hydrograph to be carried by the downstream link (102). The node number is defined as the ID number of the catchment and sets the reference number for the element of the drainage network from this point to the next downstream node.

(3) The links or branches of the network connecting the nodes are assumed to be pipes, channels, detention ponds, exfiltration trenches or diversion structures. As each runoff flow hydrograph is added to the flow in the system, a pipe, channel, pond, etc. can be proportioned to carry the peak inflow. Once this element has been designed the inflow hydrograph is routed through the link to produce an outflow hydrograph.

(4) Steps (1), (2) and (3) are repeated, moving downstream, accumulating overland flow from each sub-catchment or storing an outflow hydrograph in order to design another branch meeting at a confluence point. Refer to Chapter 5 – *Hydrograph Manipulation* for more details.

Chapter 2 - Structure and Scope of the Main Menu

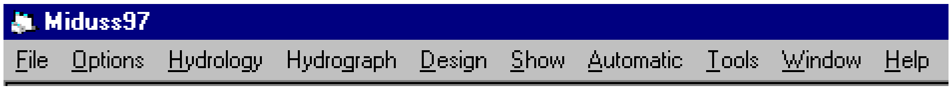


Figure 2-1 – The Main Menu with all items enabled

When you first start MIDUSS 98 a number of the items in the Main Menu will be grayed out or disabled. This indicates that some prerequisite information has not yet been defined. For example, the Storm command is not enabled until you have defined the time step and storm and hydrograph duration to be used. Similarly, the Catchment command cannot be used until a storm has been described. In the Design options, components such as a detention pond or ex-filtration trench require an Inflow hydrograph to have been created.

You will notice an apparent contradiction to this general rule. In the Pipe and Channel commands, it is possible to use these without having previously computed the inflow hydrograph. If no inflow hydrograph exists you can still use the Pipe or Channel command but you will have to enter a value for the peak flow instead of having that supplied as the peak flow of the inflow hydrograph. This allows you to use the Pipe and Channel commands for design purposes without having to go through any hydrological modelling.

The File Menu

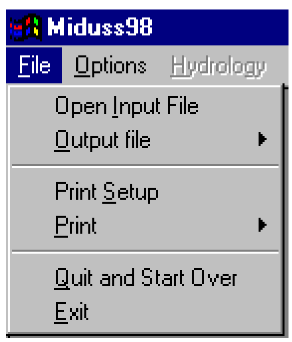


Figure 2-2 – The File Menu Options

The File Menu includes items to:-

(1) Create an Input Database (using a previously created Output file) for use in Automatic mode.

(2) Open an Output file - either creating a new file or overwriting an old one.

(3) Set printer parameters

(4) Set scaling factors and print hardcopy from the MIDUSS 98 window or the whole screen

(5) Abandon results generated up to this point and start over.

(6) Exit from MIDUSS 98

Refer to The Automatic Mode later in this chapter or Chapter 10 *Running MIDUSS 98 in Automatic Mode* for information on creating and using the Input database Miduss.Mdb.

Open Input File

When you run MIDUSS 98 in Automatic mode the input is read from a data base file called Miduss.Mdb. This file is created from an Output file which has been generated during a previous run of MIDUSS 98 - usually in manual mode, or in automatic mode with significant editing changes of the input data. Only one copy of Miduss.Mdb can exist in the MIDUSS 98 directory. However, you can save a copy under in a different directory

The **Open Input File** command allows you to open a previously created output file and convert it to a database with the name Miduss.Mdb. If a previously saved file of this name exists you will be warned that this will be overwritten.

Output File command

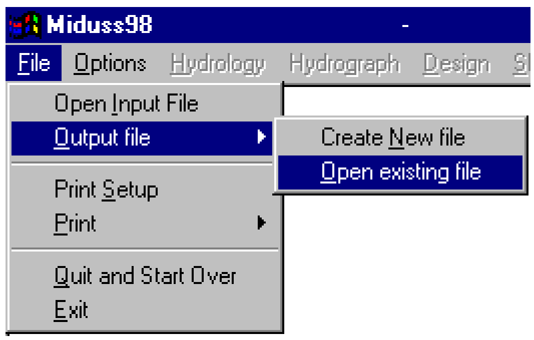


Figure 2-3 – Using the File Menu to define an Output File

During a MIDUSS 98 run the commands used, the data entered and some of the results are always copied to an output file. If you do not specify an output file in a particular Job Directory the output goes to a file called Default.Out which is created in the MIDUSS 98 directory. This menu item allows you to specify an alternative to the default file.

You can choose between creating a new file or selecting an existing file. If you use the name of an existing file you will be warned that the file will be overwritten and the contents will be lost.

In both cases you select the directory and enter or select a file name by means of the standard File Open dialogue box. You can use long file names to relate the file to the design situation -

e.g. "PineView_5yr_post-dev.out"

Print Setup

This command opens up the standard Windows dialog box to set up certain parameters for your printer. When you press [OK] a message box is displayed giving you the option to print either the full screen or the MIDUSS 98 window. See the **Print Command** for further details.

Print command

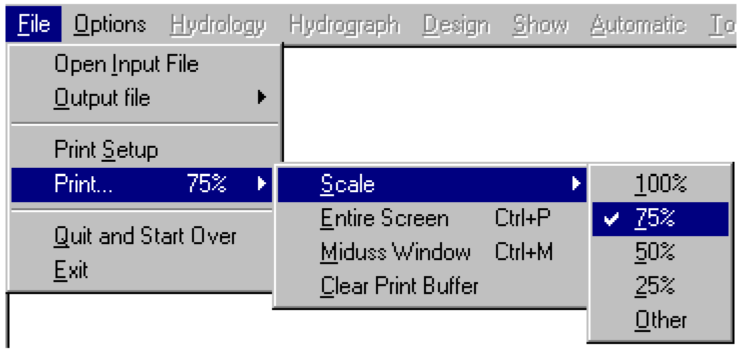


Figure 2-4 – Options available using the File/Print command

As illustrated in Figure 2-4, the print command contains a number of sub-commands which let you:

(1) Set the scale of the hardcopy relative to the page size

(2) Print the entire screen

(3) Print only the MIDUSS 98 window

(4) Clear the buffer containing data to be printed

When you select the **Scale** command you can choose from a number of standard ratios such as 100%, 75%, 50% & 25%. If none of these is suitable you can specify another ratio which will be saved for future use during the current session. After a scale has been selected the **Print** menu item is modified to show the currently selected scale.

Quit and Start Over

You may want to use this command if you realize that the work done so far is of no value and you want to abandon the session but immediately restart MIDUSS 98. It is equivalent to the Exit command followed by an immediate re-run of MIDUSS 98. See **File/Exit** command for more details.

File Exit

This command ends the MIDUSS 98 session. Files created during the session will be closed and the current Options in effect will be saved for use as the initial defaults in the next session.

Two files may be worth saving before your next run of MIDUSS 98.

(a) If you did not specify a Job directory, the output will be stored in the default output file C:\Program Files\Miduss98\default.out. If you want to keep this you must rename it or copy it to another file or another directory. The default output file will be overwritten at the start of the next MIDUSS 98 session which does not use a specified Job directory.

(b) The file C:\Program Files\Miduss98\Design.log will contain a record of any design commands which you used. This may be of use in interpreting the output file or for making comparisons during your next MIDUSS 98 session.

Figure 2-5 – Warning displayed if an Error Log is created.

Sometimes if an error occurs during the MIDUSS 98 session you will see a message that a file Miduss.Log has been created. This will contain information of errors that were trapped by MIDUSS 98. It would be useful if you could forward this file to Alan A. Smith Inc. either by e-mail or by Fax so that the cause of the problem can be corrected.

The Options menu item

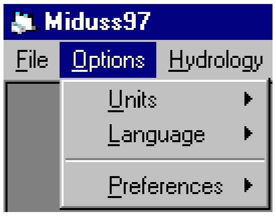


Figure 2-6 – The three main choices in the Options Menu

The fragment of menu illustrated in Figure 2-6 shows the three sub-menu choices available. These allow you to

- Select the system of units to be used,
- Select English or an optional second language for the display of screen text and
- Select and set a number of other options and preferences.

The **Second Language** option is enabled only in copies of MIDUSS 98 which have been customized for a language other than English.

Note: If you exit normally from MIDUSS 98 the preferences in effect will be recalled the next time you run MIDUSS 98. Click on the menu item or the highlighted text for further details.

The Options Units item

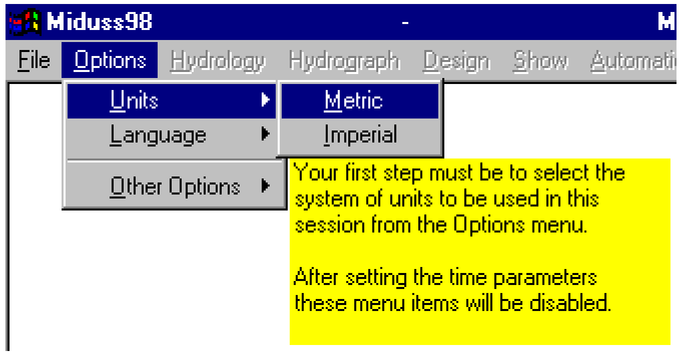


Figure 2-7 – Selecting the units is a required first step.

As shown in Figure 2-7, you can select between two systems of units. In the metric system the unit of length is the metre or millimetre depending on the variable being defined. In the Imperial system (also known as U.S. Customary units) length is defined in feet or inches.

In MIDUSS 98, only kinematic units are employed, i.e. only length, area, volume and time dimensions are used. The Table below shows the units employed for the various quantities used in hydrology and in the design of storm water management facilities.

Table 2.1

Variable dimensions used for SI and Imperial units

QUANTITY	Imperial (US Customary)	Metric (SI units)
Time	seconds, minutes or hours	
Rainfall depth	inches	millimetres
Rain intensity	inches/hour	millimetres/hour
Catchment	acres	hectares
Length	feet	metres
Diameter	feet	metres
Surface area	square feet	square metres
Velocity	feet/second	metres/second
Flow rate	cubic feet/sec	cubic metres/sec
Volume	cubic feet acre-ft	cubic metres hectare-metre

When you start MIDUSS 98 the **Options/Units** menu item is automatically selected and displayed with the mouse pointer on the system of units which is stored in the Registry and which is therefore the current default. As shown in Figure 2-7, most of the menu items are disabled in order to force the user to either confirm the default or change the system of units to be displayed.

Both choices of units will remain enabled until the **Hydrology/Time parameters** menu item has been completed and accepted after which the menu items for both Imperial and Metric units will be disabled but still visible.

When MIDUSS 98 is first installed on your computer the default system of units is the metric system. However, if you change the selection your choice will be recorded in the system registry and will form the new default value for future sessions.

The Options Language item

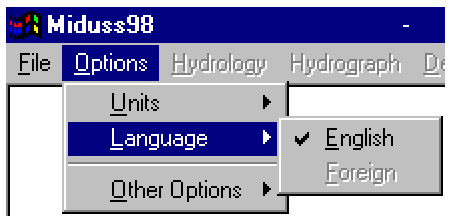


Figure 2-8 – Selecting the Display language

If you have purchased MIDUSS 98 with an optional second language, this menu item allows you to toggle the screen displays between English and the second language. You can switch between languages at almost any point during a design session. One exception is when a warning or information message is displayed which requires you to press one of the command buttons (e.g. [OK] or [Yes]) before the program will continue.

The translations will almost always have been prepared by a third-party (i.e. other than Alan A. Smith Inc.) and in certain cases this Help file may not be available in the second language.

Other Options

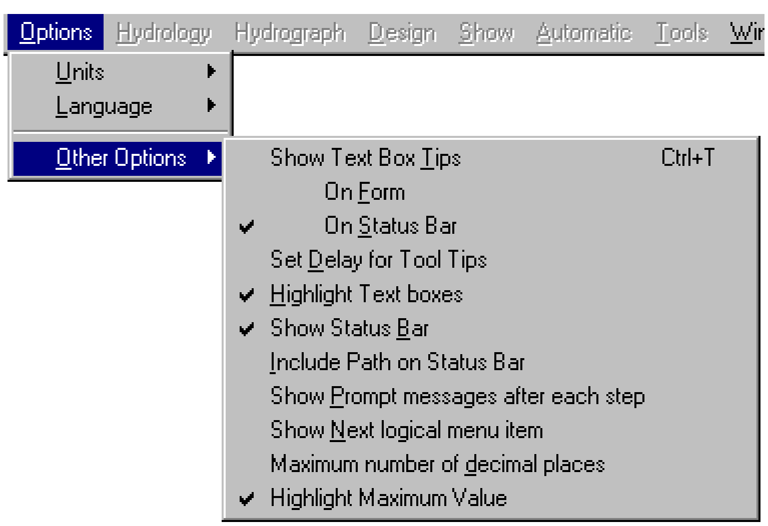


Figure 2-9 – Other options available in MIDUSS 98

As illustrated in Figure 2-9, the available options with the current release of MIDUSS 98 are as follows.

Show Text Box Tips. Selection of this option triggers a display of a brief explanation of the data item when the mouse pointer is over a text box; sometimes a range of typical values is displayed. The tip can be displayed in a small yellow window adjacent to the text box or in the status bar by selecting one or other of the two options shown below.

On Form

On Status Bar

Set Delay for Text Box Tips Specify the delay in milliseconds before the tip is shown.

These menu choices are disabled (grayed out) if **Show Text Box Tips** is not selected. If **Show Text Box Tips** is selected, the active menu item is shown with a check-mark. You can also toggle between showing or not showing the Text Box Tips by pressing Ctrl-T. (i.e. Hold down the Control key and press 'T')

You will probably find the Text Box Tips option useful during your first few sessions with MIDUSS 98. When you are familiar with the data requirements it can be turned off.

Highlight Text boxes. When this option is selected it causes the current contents of a text box to be highlighted when the text box receives the focus. You may find this preferable since it allows you to start typing a value from the left character position instead of having to use the backspace key or an arrow key to position the text entry marker at which keystrokes will be entered. Note that this option does not apply to data entry in a grid.

Show Status bar. When this menu item is checked the status bar is enabled at the bottom of the MIDUSS 98 window. The status bar contains information about the current menu selection, the job directory and output file and whether MIDUSS 98 is in Automatic or Manual mode.

Show Prompt messages after each step. This causes a brief message to be displayed after many commands to advise you on the action taken and suggest one or two logical next steps. When used together with the **Show Next logical menu item** option these options provide useful guidance if you are unfamiliar with the MIDUSS 98 program.

Show Next logical menu item. After completion of a command, and after display of the **Show Prompt messages after each step** message if selected, this option causes the next logical menu item to be displayed with the mouse pointer positioned over the appropriate command as a guide to the user.

Maximum number of decimal places. In some displays of data or results you may require to increase the number of figures after the decimal point to get sufficient accuracy. Selecting this command opens a simple data entry window with a prompt to enter a single digit specifying the maximum number of places.

Highlight Maximum Value. In many commands a rainfall hyetograph or flow hydrograph is displayed in tabular form. Selecting this option causes the cell containing the maximum value to be coloured light cyan.

The Hydrology Menu

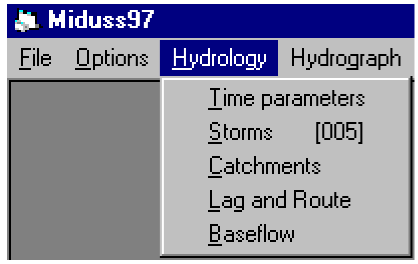


Figure 2-10 – Commands for Hydrologic simulation.

The Hydrology menu allows you to set the Time parameters and use the Storms and Catchments commands to generate the direct runoff hydrograph. Other options include a Lag and Route procedure to allow very large sub-catchments to be modelled with realistic overland flow lengths. An option is also included to let you specify Base Flow.

Hydrology Time Parameters

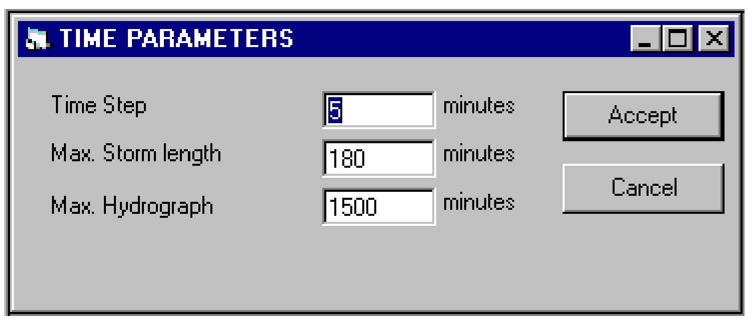


Figure 2-11 – The default time parameters

When you start MIDUSS 98 this is the only item in the Hydrology Menu which is enabled. None of the other options can be used until you have specified the three time parameters shown here. Many of the items in the MIDUSS 98 main menu are also disabled until the time parameters have been specified.

The specification of the time parameters should be preceded only by the specification of the system of units to be used and(if desired) the specification of a job-specific directory and output file.

The three time parameters are:

Time step:- The time interval in minutes to be used for all rainfall runoff calculations and routing operations in pipes, channels, ponds or trenches. A value of 5 minutes is common but a smaller time step is seldom justified. Longer increments of 10 or 15 minutes may be used for long storms. Note that for some routing operations a sub-multiple of the time step is used to ensure numerical stability. If you intend to use the Chicago storm with a very small time step consider using the time step multiplier to avoid very large values of peak rainfall intensity.

Maximum storm duration:- The longest storm duration which you expect to use during the current session. This sets the length of array used for hyetograph storage. A value of 3 to 6 hours (180 to 360 minutes) is common.

Maximum hydrograph length:- The longest expected hydrograph duration for the current session. This sets the length of storage array used for hydrographs. A 24-hour hydrograph (1440 minutes) is not unreasonable.

Hydrology Storm

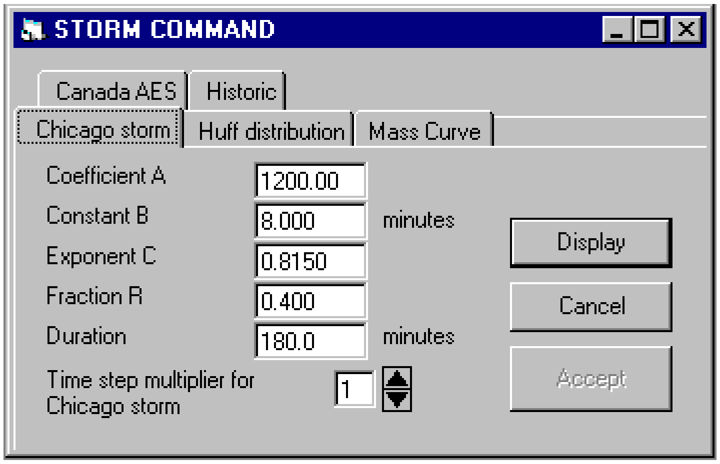


Figure 2-12 – The five options available in the Storm command.

Use this menu option to specify a single event storm hyetograph. Typically this is done only once at the start of the session and applies to all of the catchment areas; however, there may be circumstances when a different storm may be required for a portion of the total area being modelled - e.g. higher elevation or a lagged, travelling storm.

The five tabs on the form provide five options to define four different types of design storm or a historic storm. In every case you are prompted to supply parameter values or use the default values displayed. Pressing the [Display] button causes a table of rainfall intensities and a graphical plot of the hyetograph to be displayed.

You can experiment by changing parameter values or even storm type and update the displays by pressing [Display]. When you are satisfied with the storm press the [Accept] button to cause the storm to be defined. This remains in effect until it is changed by a subsequent use of the command.

Note that you can use the **File Input/Output** command to import a hyetograph file as an alternative to using the Storm command. Such files can be saved by means of the same **File Input/Output** command after a storm hyetograph has been defined – especially a long historic storm.

After you have accepted the design storm, an auxiliary window is opened prompting you to enter a string of up to 5 characters which is used as a descriptor of the storm just defined. This descriptor is used as part of the filename of any hydrographs stored as files during the current session. Refer to the **Hydrology/Storm Descriptor** command for more details.

See Chapter 3 *Hydrology Used in MIDUSS 98* Storm Command for more details.

Hydrology - Storm Descriptor

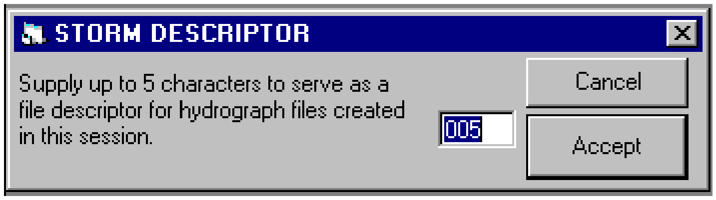


Figure 2-13 – Defining a Storm descriptor

The window shown in Figure 2-13 is opened automatically after you have pressed the [Accept] button in the Storm command form. The string requested will be used as part of the name given to any hydrograph files which are generated in the current session using this design storm.

Typically you may enter the return period for the storm - e.g. "005" to denote a storm with a return interval of 5- years. When you save a hydrograph as a file the default extension used by MIDUSS 98 is ".hyd". The filename which you provide has the Storm Descriptor added to this extension to give a modified extension of ".005hyd".

For example, if you specified a filename of "Pond7aOut" and the Storm Descriptor is "005" the final filename would be "Pond7aOut.005hyd".

Windows 95 allows long filenames and also allows more than one 'period' separator. You can define the Storm Descriptor with a period at the end (e.g. "005."). Using the previous example, the resulting filename will be "Pond7aOut.005.hyd". However, you may find that this results in confusing abbreviations if the filename is displayed in a DOS window.

As a reminder of the descriptor that you have entered it is appended to the **Storms** item in the **Hydrology** menu. Refer to the **Hydrology** menu earlier in this chapter to see this (Figure 2-10).

Hydrology Catchment

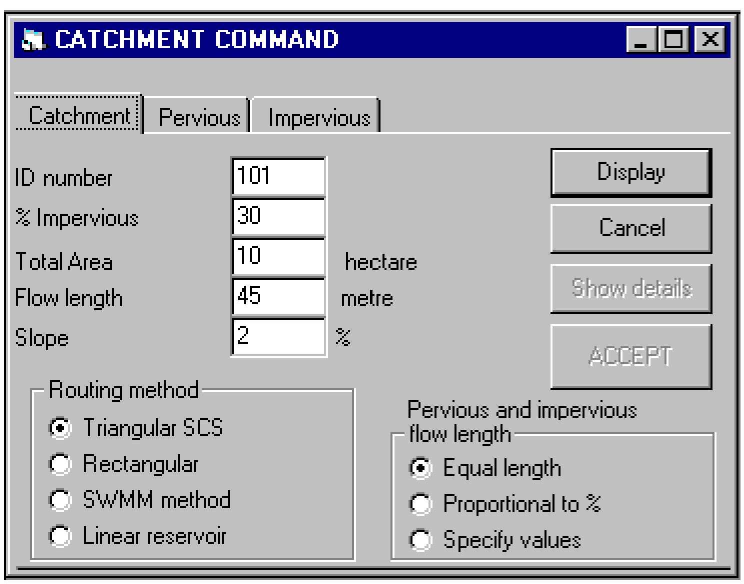


Figure 2-14 – Data input form for the Catchment command

Once a design storm has been defined, you can use the Catchment command to generate the direct runoff hydrograph for a sub-catchment. The three tabs on the form are used as follows.

Catchment Set the methods and parameters for the whole catchment and generate the overland flow hydrograph on the pervious, impervious and total areas.

Pervious Set the rainfall loss model and the appropriate parameters to generate the effective rainfall on the pervious fraction of the area.

Impervious Set the parameters for the impervious fraction and generate the effective rainfall on the impervious fraction of the area.

The command contains a number of options for the overland routing method, the relative flow length on the pervious and impervious fractions of the catchment and the method to be used to estimate rainfall losses by infiltration, interception or surface depression storage.

Before calculating the runoff it is necessary to compute the effective rainfall on both the impervious and pervious surfaces. This can be done explicitly by selecting the appropriate part of the form or it can be done automatically if you select the runoff calculation option.

Special conditions apply if you select the SWMM Runoff algorithm as the overland routing method since it uses a surface water budget method rather than an effective rainfall approach.

The command is described in full in the Hydrology section of this Help System. Refer to Chapter 3 *Hydrology Used in MIDUSS 98,* Catchment Command for more details.

Note that you can use the **File Input/Output** command to import a hydrograph file as an alternative to using the Catchment command. Such files can be saved by means of the same **File Input/Output** command after a runoff hydrograph has been defined.

Hydrology - Lag and Route

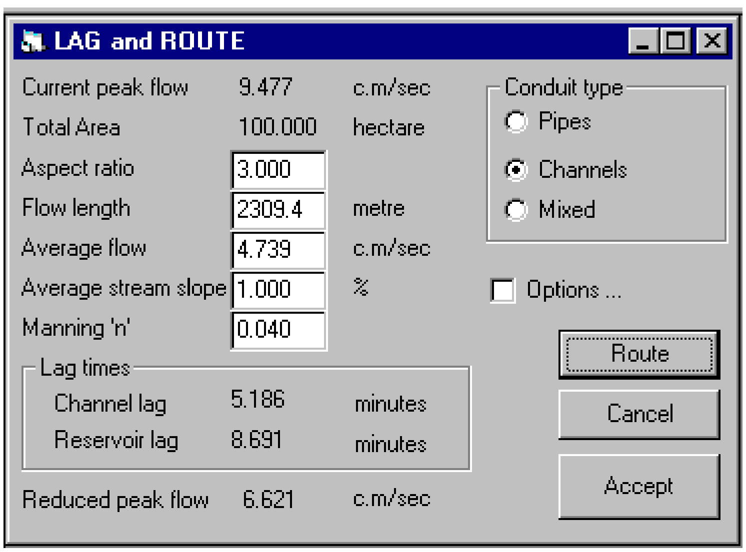


Figure 2-15 – Data input for the Lag and Route command

Calculating the runoff from a large catchment (e.g. more than 100 hectares or 250 acres) is complicated by the fact that the travel time of the runoff from sub-areas close to the outflow point will be much shorter than from sub-areas at the furthest upstream regions of the watershed or sewer-shed. This causes the incremental runoff hydrographs to have peak flows which are spread over time with the result that the peak outflow is significantly less than the sum of the constituent peaks.

MIDUSS 98 incorporates a Lag and Route procedure which can provide an approximation to this effect. Although it is empirical and thus only approximate it is preferable than using unrealistically long overland flow lengths to provide an appropriate amount of peak attenuation. The method assumes that a hypothetical linear channel and linear reservoir are located at the outflow point of the catchment. The result is that the peak outflow is lagged in time and reduced in value.

The key to success is, of course to assign the correct lag times to the linear channel and linear reservoir. The empirical procedure used is described in Chapter 7 *Hydrological Theory*. The procedure to use the **Lag and Route** command is described in Chapter 3 *Hydrology Used in MIDUSS 98,* Lag and Route Command .

Hydrology - Baseflow

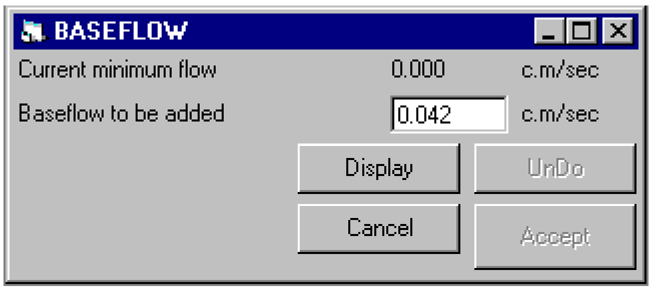


Figure 2-16 – Adding a constant baseflow to the Inflow hydrograph

Even if the first element of the effective rainfall is finite, the direct runoff hydrograph starts with an initial value of zero. If you want to simulate the effect of baseflow in a drainage system you can add a constant flow value to the Inflow hydrograph.

The Baseflow command is enabled only after an Inflow hydrograph has been generated.

Refer to Chapter 3 *Hydrology Used in MIDUSS 98* - Baseflow Command for more details.

Hydrology - Retrieving the Previous Storm

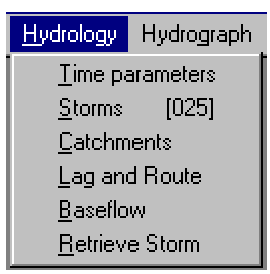


Figure 2-17 – The Hydrology menu after specifying a second storm

If you specify a second design storm during a MIDUSS 98 design session the previous storm hyetograph will be overwritten with the new storm and this new hyetograph will be used for all future uses of the Catchment command. However the first storm is kept in memory and can be recovered if required.

Accepting the second storm causes the Hydrology menu to have a new item added at the bottom as illustrated in Figure 2- 17. Using the Retrieve Storm command causes the first storm to be restored but the second storm is not saved. This command may be useful in two cases.

- You mistakenly define a new storm
- You need to change the storm for only a few sub-catchments.

If you need to switch between two or more storms several times the simplest solution is to store the hyetograph as a file. See the **File Input/Output** command in Chapter 6 *Working with Files*.

The Hydrograph Menu

Figure 2-18 – Hydrograph operations available in MIDUSS 98

This menu item allows you to manipulate hydrographs in a number of different situations. Not all of the options may be enabled unless the appropriate pre-requisites are satisfied, e.g. the **Combine** command is available only after an Output hydrograph has been generated.

Hydrograph Undo

This menu item is enabled only if a hydrograph has been written to the backup hydrograph. This is done in a number of instances to allow you to reverse an operation. For example, you may have used the **Add Runoff** command which causes the Runoff hydrograph to be added to the current inflow hydrograph. You may wish to 'Undo' this action and restore the previous Inflow hydrograph. In such a case, the **Undo** menu item will be enabled and pressing this command will restore the Inflow hydrograph to its previous state.

Hydrograph Start

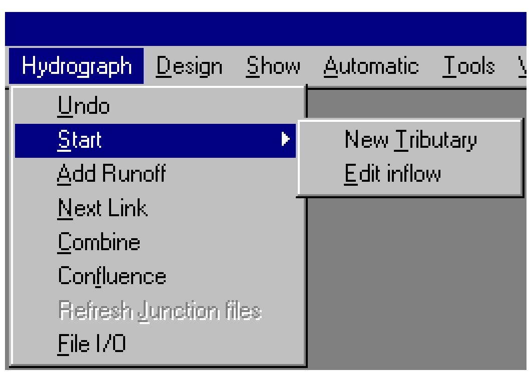


Figure 2-19 – The Hydrograph/Start item offers two choices

The Start menu item has two subsidiary choices to let you either:

- set the Inflow hydrograph to zero or
- edit the current inflow hydrograph.

The first option is generally used after you have stored an outflow hydrograph at a Junction node (by using the **Combine** command) and therefore wish to start a new tributary of the drainage network. If you fail to zero the Inflow hydrograph, the runoff from the first catchment of the new tributary will be added to the furthest downstream Inflow hydrograph of the previous branch.

The second option in the Start command is less commonly used but may be useful to input a hydrograph which represents observed data for comparison with a simulated hydrograph. Alternatively, you may wish to input a hydrograph obtained by use of another model.

Hydrograph Add Runoff

This command causes the Runoff hydrograph to be added to the current Inflow hydrograph so that a new pipe, channel or other drainage element can be designed to carry the increased flow. A message box is displayed to inform you what action has been taken and a new record is added to the database displayed in the Peak Flows table in the bottom right corner of the MIDUSS 98 window showing the change in the peak of the Inflow hydrograph.

Figure 2-20 – Hydrograph operations provide an explanatory message

Note that in general the time to peak for the Runoff and Inflow hydrographs will not be the same. For this reason, the peak of the sum of two hydrographs will usually be less than the sum of the individual peaks.

The original value of the Inflow hydrograph is stored in the Backup hydrograph array and the **Undo** command is enabled. This allows you to reverse the action and restore the Inflow to its previous state. See the Hydrograph - Undo command for details.

Hydrograph Next Link

This command causes the Outflow hydrograph to be copied to the Inflow hydrograph overwriting the previous contents. This command is used when an Outflow hydrograph has been created by a routing process and you want to continue downstream to the next reach of conduit or channel, etc.

Once the Inflow has been updated in this way you may wish to define another catchment area and add the runoff from this area to the inflow before continuing with the design of the drainage network. Thus a typical sequence of commands might be represented by the following fragment of the peak flow summary table.

PEAK FLOWS (8)

No.	Command	Runoff	Inflow	Outflow	Junction
2	Catchment 1231	0.948	0.000	0.000	0.000
3	Add Runoff	0.948	0.948	0.000	0.000
4	Channel Design	0.948	0.948	0.000	0.000
5	Channel Route	0.948	0.948	0.811	0.000
6	Next link	0.948	0.811	0.811	0.000
7	Catchment 1232	0.476	0.811	0.811	0.000
8	Add Runoff	0.476	1.040	0.811	0.000

Figure 2-21 – The peak flow summary table after the Add Runoff command.

As with other hydrograph operations, the Inflow hydrograph is stored in the Backup hydrograph before it is overwritten thus allowing you to use the **Undo** command to reverse the operation and restore the Inflow to its original state.

Hydrograph Combine

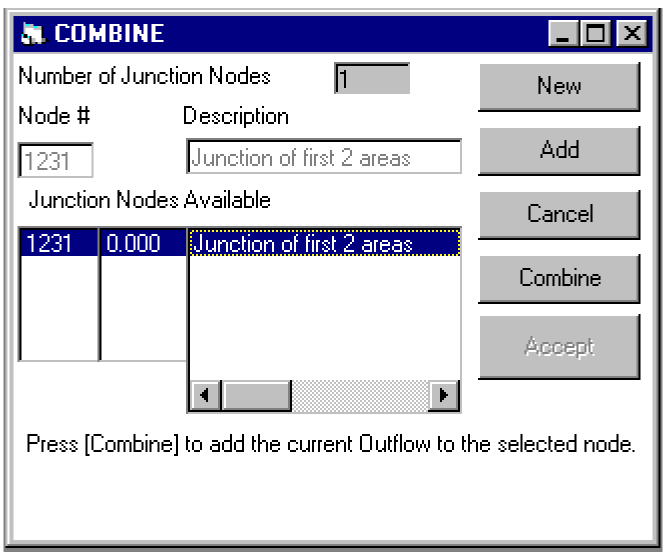


Figure 2-22 – The Hydrograph/Combine form offers step-by-step advice

The **Combine** command is used to store or accumulate an Outflow hydrograph at a junction node. The first time you store a hydrograph at a junction node, the peak flow is shown in the Junction or temporary column of the Peak Flows table, the hydrograph is stored in the current Junction or Temporary array and a file is created with the name Hydnnnnn.jnc where 'nnnnn' is the number of the junction node.

The next logical step is to clear out or set to zero the Inflow hydrograph in preparation for computing the flow in another branch of the drainage network. This branch will eventually terminate at the same junction node or at a different one. If it is added to the same node, the peak flow, the Junction hydrograph and the Junction hydrograph file are all updated.

If a different Junction node is used the peak flow and the Junction hydrograph are overwritten and a new Junction hydrograph file is created. Since junction flows are always stored as a file it is possible to have any number of Junctions nodes active at one time

A more detailed description of the use of Junction nodes is provided in Chapter 5 – *Hydrograph Manipulation,* The Combine Command.

Hydrograph Confluence

The **Confluence** command is used in conjunction with the **Combine** command and allows you to recover the accumulated flow at a junction node and copy it to the Inflow hydrograph, overwriting the previous contents. In this way, the command lets you continue the design of the drainage network downstream of a junction node.

The table in Figure 2-23 has been copied from the summary of peak flows and shows a design sequence in which two tributaries are accumulated at a confluence node.

PEAK FLOWS (12)

No.	Command	Runoff	Inflow	Outflow	Junction
2	Catchment 1201	0.948	0.000	0.000	0.000
3	Add Runoff	0.948	0.948	0.000	0.000
4	Channel Design	0.948	0.948	0.000	0.000
5	Channel Route	0.948	0.948	0.855	0.000
6	Combine 1210	0.948	0.948	0.855	0.855
7	Start - New Tributary	0.948	0.000	0.855	0.855
8	Catchment 1301	0.569	0.000	0.855	0.855
9	Add Runoff	0.569	0.569	0.855	0.855
10	Channel Route	0.569	0.569	0.513	0.855
11	Combine 1210	0.569	0.569	0.513	1.368
12	Confluence 1210	0.569	1.368	0.513	0.000

Figure 2-23 – Sequence of operations adding two branches at a Junction

In carrying out the operation the Inflow hydrograph is first copied to the Backup hydrograph to allow use of the **Undo** command, the junction flow in the Peak Flows window is set to zero, the Junction array is set to zero and the Junction file is deleted. All of these actions can be reversed if you subsequently use the Undo command.

Before continuing with the design of the drainage network downstream of the junction node you may define a local catchment and add the runoff to the inflow if this is appropriate.

Hydrograph Copy To Outflow

This command causes the current inflow hydrograph to be copied to the Outflow hydrograph overwriting the current contents. This may be useful if the current inflow is to be added to a new or existing junction node without the need to use a Design option such as the Pond command or the Pipe & Route commands.

The action can be reversed by means of the **Hydrograph/Undo** command.

Hydrograph Refresh

This command is enabled if there are one or more junction files in the current Job directory and is intended to let the user selectively delete junction files which are no longer required.

Hydrograph File Input-Output

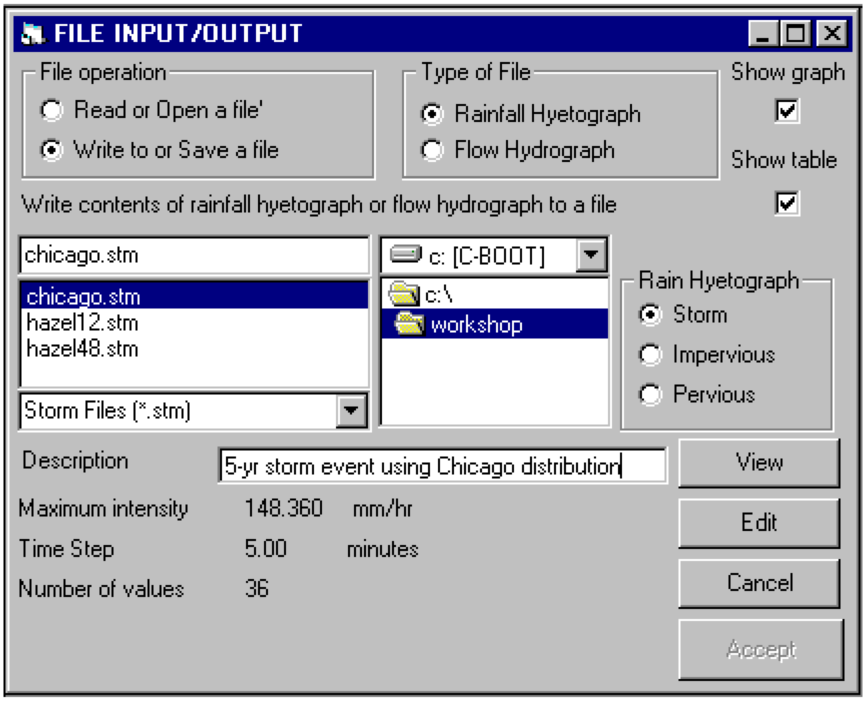


Figure 2-24 – The File I/O command offers many options.

During a MIDUSS 98 session you will create a number of hydrographs at different points throughout the drainage network. Also, the storm hyetograph and the effective rainfall on pervious and impervious surfaces are created. You may wish to save some of this data in the form of files either for subsequent plotting or analysis or for use in a subsequent design session. The **File Input-Output** command lets you do this.

All of the files will be stored in the current Job directory. For this reason, if you expect to be saving files it is strongly recommended that you specify an Output file in a Job specific directory to avoid storing this data in the Miduss98 directory.

Each file contains six records in the header section to store information such as a description, the units employed and the time step, the peak value and the number of elements in the file.

The Design Menu

Figure 2-25 – Design tools available in MIDUSS 98

The Design functions are generally all enabled once an Inflow hydrograph has been created. One exception is the **Route** command which requires that a **Pipe** or **Channel** conduit has been designed. Another difference is that the **Pipe** and **Channel** commands are always enabled to allow you to enter a flow value and design a pipe or channel for that flow without having to define a storm and generate a flow hydrograph.

Design Design-Log

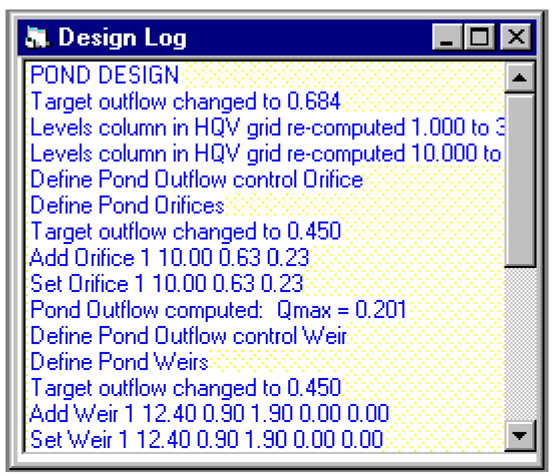


Figure 2-26 – A typical Design Log during a Pond design

Each of the six options in the Design menu causes a Design Log window to be opened in the top right corner of the screen. This is used to record a summary of the steps taken during a design process. For simple elements such as a pipe design, the data requirements are limited to the roughness and to successive trials with different diameters and/or slopes. However, for a more complex drainage element such as a detention pond, there are many options which can be employed and the trial and error process can be complicated. In these cases the Design Log can be useful as a reference to earlier trials and also serves as a reminder should you be interrupted during the design process.

The current design log can be printed out at any time for convenience of reference.

At the end of the design of each element the Design Log is copied to a file which can be saved or printed out at the end of the MIDUSS 98 session. The total Design Log can also be viewed by using the **Show/Design log** menu item. Refer to the Show menu for more details.

Design Pipe

The **Pipe** command lets you design a pipe to carry the peak flow of the current Inflow hydrograph. If no hydrograph has been calculated you can specify a desired flow directly by entering it in the text box. For the specified peak flow you will be shown a table of diameters, gradients and average velocities which represent feasible designs. You can either choose one of these diameter-gradient pairs by double clicking on a row in the table or you can enter explicit values for diameter and gradient.

MIDUSS 98 carries out a uniform flow analysis and reports the actual depth and velocity and also the critical depth. You can experiment by changing either the pipe roughness (i.e. the Manning 'n') or the diameter or gradient and press the [Design] button to see the results. When satisfied with the design press the [Accept] button to copy the data and results to the Output file.

Design Channel

MIDUSS 98 lets you design channels with two types of cross-section to carry the current peak flow in the Inflow hydrograph. If no hydrograph has been calculated you can enter a flow value directly by entering it in the text box. The cross-section can be:

(1) A general trapezoidal shape defined by a base width and left and right sideslopes.

(2) An arbitrary shape defined by up to 50 pairs of coordinates.

In both cases a table of depth, gradient, velocity values is displayed which represent feasible designs. You can select from this list by double clicking on a row of the table or you can specify a total depth and gradient explicitly. MIDUSS 98 carries out a uniform flow analysis for the given flow, roughness and geometry and reports the depth of flow, the average velocity and the critical depth in the channel.

You can experiment by changing the data and pressing the [Design] button. When satisfied, press the [Accept] button to save the data and results to the output file.

Design Route

Once a drainage conduit has been designed - either a pipe or channel - you can route the Inflow hydrograph through a reach of specified length to obtain the Outflow hydrograph at the downstream end.

For each trial design MIDUSS 98 checks that the time step and reach length are acceptable to ensure stability in the routing process. If the time step is too long it will be reduced to an appropriate sub-multiple. If the reach length is too long it also will be subdivided. In both cases the information is reported on the screen but no further action is required by the user.

The result of the routing operation is displayed in both graphical and tabular form. Once you are satisfied with the result you can press the [Accept] button and the peak flow summary table will be updated.

Design Pond

MIDUSS 98 helps you to design a detention pond to achieve a desired reduction in the peak flow of a hydrograph. The current peak flow and the total volume of the inflow hydrograph are reported and you are prompted to specify the desired peak outflow. MIDUSS 98 estimates the maximum storage requirement to achieve this.

The storage routing through the pond requires a table of values defining the outflow discharge and the storage volume corresponding to a range of stage or depth levels. You can enter this data directly into the grid if you wish, but it is usually easier to use some of the features of the **Pond** command to automate this process.

The outflow control can be designed using multiple orifices and weir controls. The Stage - Storage values can be estimated for different types of storage facility. These may be a multi-stage pond with an idealized rectangular plan shape and different side slopes in each stage; one or more "super-pipes" or oversized storm sewers; wedge storage formed on graded parking lots; or a combination of these types of storage.

Rooftop storage can also be modelled to simulate controlled flow from the roof of a commercial development.

Design Trench

The **Trench** command lets you proportion an exfiltration trench to provide underground storage for flow peak attenuation and also to promote return of runoff to the groundwater. The trench usually consists of a trench of roughly trapezoidal cross-section filled with clear stone with a voids ratio of around 40% and with one or more perforated pipes to distribute the inflow along the length of the trench.

The exfiltration trench splits the inflow hydrograph into two components. One of these is the flow which exfiltrates into the ground water; the balance of the inflow is transmitted as an outflow hydrograph. Obviously an exfiltration trench requires reasonable porosity of the soil and a water table below the trench invert in order to operate effectively.

The design involves several steps including definition of the trench and soil characteristics, definition of the number, size and type of pipes in the trench and description of the outflow control device comprising orifice and weir controls as used in the Pond command.

More detailed information is contained in Chapter 4 *Design Options Available*, Design Exfiltration Trench.

Design Diversion

A diversion structure allows the inflow hydrograph to be split into two separate components, the outflow hydrograph and the diverted flow hydrograph. Below a user-specified threshold flow all of the inflow will be transmitted to the outflow hydrograph. When the inflow exceeds the threshold value, the excess is divided in proportion to a specified fraction.

For example, if the inflow is 25 cfs and the threshold is 5 cfs the excess flow is 20 cfs. Now if the fraction F = 0.8 meaning that 80% of the excess flow is diverted the diverted flow will be 16 cfs and the outflow will be 9 cfs.

Instead of specifying the diverted fraction F you can define this implicitly by specifying the desired peak outflow. MIDUSS 98 will then work out the necessary fraction to be diverted.

The diverted flow hydrograph is written to a file so that it may be recovered at a later time and used to design the necessary conduit or channel.

Use of the diversion command is the only instance in which the topology of the network changes from a tree to a circuited network.

Refer to Chapter 4 *Design Options Available*, Diversion Structure Design for more information.

The Show Menu

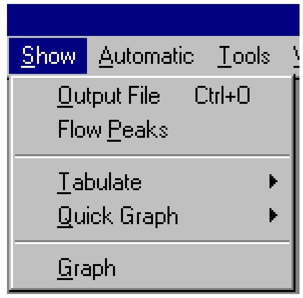


Figure 2-27 – Options available for displaying your results

The options in this menu allow you to display the results of your hydrologic modelling and design. Results for inclusion in a report can be displayed in tabular format or in graphical form. For each of these choices you can specify the particular data items to be displayed. The menu items are not enabled until there is data available to be displayed.

Show Output File

This command causes the Microsoft program Notepad to be opened with the current Outflow file. You can review the contents of the file, print all or part of the file or save it with a name other than that initially assigned to the file. (You can use the same filename but in a different directory).

However, you cannot make changes to the file since it must be re-opened when the Notepad window is closed.

Show Design Log

This command lets you review the contents of the current Design Log file. The Microsoft editor Notepad is opened with the current Design Log. As with the Output file, you can review it, print it or save it with a different path or name but you cannot change the contents.

When the Notepad window is closed the Design Log file is re-opened in Append mode so that additional records written to the Design Log will be added.

Show Flow Peaks

If for some reason you have closed the window showing the summary of flow peaks (usually in the lower right corner of the MIDUSS 98 window) this command will restore the table and refresh the values. The records for each row of the table are contained in a text file called Qpeaks.txt which resides in the Miduss98 directory. Normally you will have no need to refer to this but should you wish to do so it can be viewed and printed or saved by another name or path by using the Microsoft editor Notepad which can be run from the **Tools** menu or from the desktop after the MIDUSS 98 session has been completed.

Show Tabulate

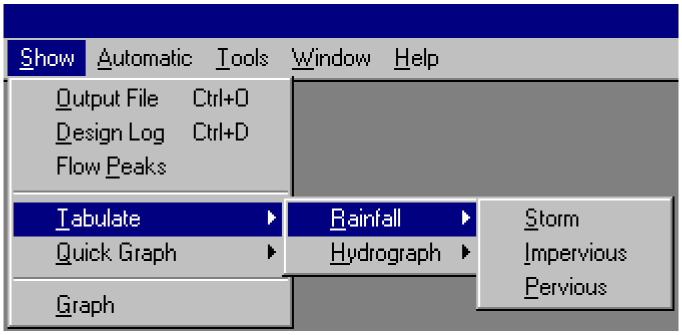


Figure 2-28 – Some of the options available with the Show/Tabulate command

A tabular display of each rainfall hyetograph or flow hydrograph is displayed - usually in the lower left corner of the MIDUSS 98 window - as the MIDUSS 98 session proceeds. This command lets you display the table for any of the three hyetographs or four hydrograph arrays which are currently in use.

Show Quick Graph

With each step of the MIDUSS 98 session a graphical display is opened in the top right corner of the MIDUSS 98 window. This command lets you open a similar graphical window to display any of the current 3 rainfall hyetographs or 4 flow hydrographs.

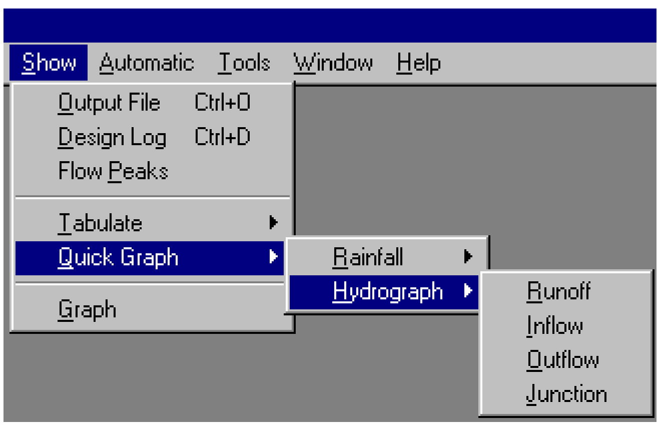


Figure 2-29 – Some of the Options available with the Show/Quick Graph command

Show Graph

This command lets you construct a graphical display comprising several hydrographs and hyetographs. If a rainfall hyetograph is plotted first it may be drawn either on the bottom axis or along the top edge of the plotting window.

However, if one or more hydrographs have been plotted, the addition of a hyetograph will be automatically placed on the top edge with the scale reading downwards.

The scale for both time and ordinate value can be set when the first object is plotted but subsequent objects are plotted to the same scale.

You can annotate the graphic by adding text, arrows, lines, rectangles or circles.

The graphic can be saved as a file or a previously saved graphic file can be imported to the empty graphic window. To conveniently store the graphic for addition of other objects later in the MIDUSS 98 session the form can be iconized from a menu item and restored by re-invoking the **Show/Graph** command.

The colour, line thickness and fill pattern can be selected by the user. The preferred styles are automatically saved as default values when the MIDUSS 98 session is ended.

The Automatic Menu

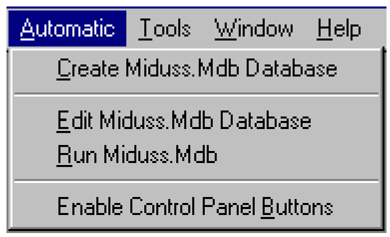


Figure 2-30 – Commands available for running in Automatic mode

The four options in this menu allow you to run MIDUSS 98 in Automatic mode. When MIDUSS 98 runs in normal, Manual mode the commands, data and some of the results are copied to an output file. To use this file for input in Automatic mode it must be converted into a Database file. The data base can be reviewed and edited prior to running in Automatic mode.

Automatic - Create Input Database

When running in Automatic mode MIDUSS 98 uses a specially created Database file called Miduss.Mdb which resides in the Miduss98 directory. This file can be created from an existing Output file by means of this menu command.

When you use this command a standard File Open dialogue box is opened. You should navigate to the appropriate directory and select the Output file which you wish to use in creating the Input Database file. During processing a small window opens to show the number of records processed and the number of commands read.

You can immediately make use of the **Edit Miduss.Mdb Database** or **Run Miduss.Mdb** commands.

See Chapter 10 – *Running MIDUSS 98 in Automatic Mode* for more details.

Automatic- Edit Miduss.Mdb Database

This menu command lets you review and edit the contents of the current Input Database file 'Miduss.Mdb' in the Miduss98 directory. Editing is limited to changing data values in a field of a particular record. It is not possible to insert new commands in the Database using this command.

If you want to make major changes such as adding or deleting an entire command you can do this by interrupting a run in Automatic mode and entering the necessary manual commands. You may do this also by editing the Output file in a text editor such as Notepad. However, you should attempt such editing only after you are fully conversant with the sequence and format of the required data.

See Chapter 10 – Running MIDUSS 98 in Automatic Mode for more details.

Automatic - Run Miduss.Mdb

This command causes a control panel to be displayed which contains a grid and several command buttons. The grid shows the current contents of the database file Miduss.Mdb

The command buttons let you run the input database automatically in three different modes.

(1) EDIT mode lets you see the result of each command and you may make any changes to the data prior to pressing the [Accept] key on the command form. Any changes will be reflected in the new Output file being created.

(2) STEP mode advances the input file one command at a time but you do not have the opportunity to make changes to the data.

(3) RUN mode causes the commands to be processed sequentially without a pause until any one of the STEP, EDIT or MANUAL buttons is pressed or until the end of file is reached or until a negative command number is read..

See Chapter 10 – *Running MIDUSS 98 in Automatic Mode,* Using the Automatic Control Panel for further details.

Automatic - Enable Control Panel Buttons

Sometimes when running in Automatic mode you may find that all of the command buttons are disabled or ‘grayed out’. This command allows you to re-enable the command buttons to let you continue in either automatic or manual mode.

The Tools Menu

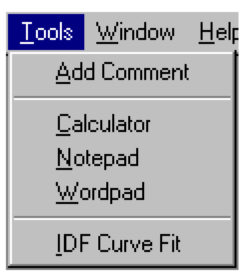


Figure 2-31 – Choices available in the Tools menu

The **Tools** menu provides access to the Microsoft Calculator, the Notepad text editor or the Wordpad editor from within MIDUSS 98. Other links will be added in future releases for tools such as the IDF Curve Fit auxiliary program and the Microsoft EXCEL spreadsheet.

In addition, a menu item is provided to let you add comments to the currently defined output file.

Tools - Add Comment

When you run MIDUSS 98 there is always an Output file, whether one is specified explicitly by the user in a Job Directory or the default output file 'Default.Out' which resides in the directory C:\Program Files\Miduss98\. This menu command lets you add explanatory comments to the output file.

You simply type in the text box using normal text editing features such as BackSpace, Delete or mouse controls. The font used is a uniformly spaced Courier font to allow columns to be aligned if desired. The text box entry provides automatic word wrap but this may not correspond exactly to the location of new lines in the output file.

The double quote character cannot be included in a comment and is automatically trapped and converted to a single quote.

The comment window can be re-sized by dragging the right side or the bottom of the window. The text entry box will also be re-sized. You can enter as many lines of comment ass you wish. A vertical scroll bar appears when there are more lines than the text box can display.

The maximum line length which is written to the output file is 60 characters and you cannot use a ‘word’ or string of characters more than 59 characters in length.

Another use for the **Add Comment** command is to add a visual description to the MIDUSS 98 window before printing hardcopy of the screen. If you don’t want this added to the output file press [Cancel] to close the window.

Tools - the Microsoft Calculator

Clicking on this menu item causes the Microsoft Calculator Accessory to be opened. This may be useful if some hand calculation is required during a MIDUSS 98 session.

When MIDUSS 98 starts up it attempts to locate the directory where Calculator resides and stores this for later use. However, if the file Calculator.exe cannot be found for any reason you will be prompted to locate this manually in a standard File Open dialogue box. Once located, the directory will be stored in the Windows 95 registry for future use.

When you finish using Calculator you should close it in the normal way rather than merely clicking on the MIDUSS 98 window which will place the Calculator window behind the MIDUSS 98 window and probably out of sight. This may lead to multiple instances of Calculator being opened simultaneously.

Tools - the Microsoft Notepad editor

This command opens the Microsoft text editor Notepad. You can load, view and edit text files with this facility. Notice however, that files which are currently in use by MIDUSS 98 - such as the current output file - cannot be changed. You can, however, print out the file in whole or in part or save it with a different filename.

When you save a file from Notepad, check to see if Notepad has added the default extension ".txt" to the filename which you have specified.

When MIDUSS 98 starts up it attempts to locate the directory where Notepad resides and stores this for later use. However, if the file Notepad.exe cannot be found for any reason you will be prompted to locate this manually in a standard File Open dialogue box. Once located, the directory will be stored in the Windows 95 registry for future use.

When you finish using Notepad you should close it in the normal way rather than merely clicking on the MIDUSS 98 window which will place the Notepad window behind the Miduss98 window and probably out of sight. This may lead to multiple instances of Notepad being opened simultaneously.

.Tools - the Microsoft Wordpad editor

This command causes the Microsoft text editor Wordpad.exe to be opened. You can load, view and edit text files with this facility with more flexibility than is possible with Notepad. Notice however, that files which are currently in use by MIDUSS 98 - such as the current output file - cannot be changed. You can, however, print out the file in whole or in part or save it with a different filename.

When MIDUSS 98 starts up it attempts to locate the directory where Wordpad resides and stores this for later use. However, if the file Wordpad.exe cannot be found for any reason you will be prompted to locate this manually in a standard File Open dialogue box. Once located, the directory will be stored in the Windows 95 registry for future use.

When you finish using Wordpad you should close it in the normal way rather than merely clicking on the MIDUSS 98 window which will place the Wordpad window behind the Miduss98 window and probably out of sight. This may lead to multiple instances of Wordpad being opened simultaneously.

The Windows Menu

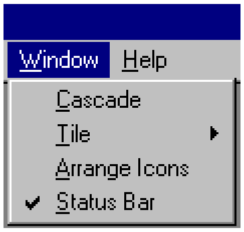


Figure 2-32 – You can arrange windows in different ways

The Window menu lets you modify the way the windows are displayed and also lists the windows which are currently open.

Windows - Cascade

This causes all of the currently open windows to be displayed in the standard Windows cascade style.

Windows - Tile

This causes all of the currently open windows to be displayed in the standard Windows tile arrangement.

Windows - Arrange Icons

Incomplete -Temporary Topic

Windows - Status Bar

This command has the same effect as the **Show Status Bar** command in the **Options** menu.

The Help Menu

Figure 2-33 – The standard Help menu is available

This menu has the normal choices available in most Windows applications plus one extra item.

Help - Contents

Help - Using Help

Help - Tutorials

Help - About Help for details.

Help - Contents

This command causes the contents of the MIDUSS 98 Help System to be displayed. This follows the normal standard for Windows 95 Help documents. You can access help in three ways.

(i) You can double click on a closed volume to expand the contents of that book and search for the topic of interest.

(ii) You can search for references to a particular word.

(iii) Using the '<' and '>' buttons you can browse through the topics in the order in which they appear in the help documents.

In general the help topics cover the following contents.

- Chapter 1 - Introduction to MIDUSS 98
- Chapter 2 - Overview of the Main Menu
- Chapter 3 - Hydrology Used in MIDUSS 98
- Chapter 4 - Design Options Available
- Chapter 5 - Hydrograph Manipulation.
- Chapter 6 - Working with Files
- Chapter 7 – Hydrological Theory
- Chapter 8 - Theory of Hydraulics
- Chapter 9 - Displaying your Results.
- Chapter 10 - Running MIDUSS 98 in Automatic Mode
- Chapter 11 - A Detailed Example

Help - Using Help

This menu item opens the standard help files that explain in detail how to make best use of the Windows 95 Help system.

Help - Tutorials

The MIDUSS 98 CD contains a folder called Tutorials which holds a number of audio-visual lessons on the main features and operations of MIDUSS 98. These can be accessed directly from the CD or from the **Help/Tutorial** menu command.

Your computer must have a sound card in order to hear the audio track.

Many of the lessons are taken from the steps in Chapter 11 *A Detailed Example*.

You can copy the lesson files on to your hard disk if you wish, in order to allow the CD to be stored in your software repository. Currently the disk space required is close to 150 MB and provides over 100 minutes of lessons.

Help - About Help

This menu command causes a window to display a copyright notice with respect to Miduss98 and details of the registered user of the program.

Chapter 3 - Hydrology used in MIDUSS 98

This part of the MIDUSS 98 Help System describes the hydrology commands used to model the rainfall runoff process and generate the hydrographs for which your stormwater management facilities will be designed.

The hydrology incorporated in MIDUSS 98 is based on relatively simple and generally accepted techniques. There are four commands to control the fundamental operations.

(1) **STORM -** This command allows you to define a rainfall hyetograph either of the synthetic, design type or a historic storm. You should remember that as an alternative to using the STORM command, a previously defined rainfall hyetograph may be read in from a disk file, by means of the FILE Input/Output command.

(2) **CATCHMENT** - The Catchment command lets you define a single sub-catchment and computes the total overland flow hydrograph for the currently defined storm. The runoff hydrographs from the pervious and impervious areas are computed separately and added to give the total runoff. The roughness, degree of imperviousness, overland flow length and surface slope of both the pervious and impervious fraction are defined in this command. In addition you can choose from different rainfall loss models. The effective rainfall on these two fractions is computed and stored for future use. Different methods for routing the overland flow are available.

(3) **LAG and ROUTE**. - This command is useful for modelling the runoff from very large sub-catchments without having to resort to specifying unrealistically long overland flow lengths. The command computes the lag time in minutes of a hypothetical linear channel and linear reservoir through which the runoff hydrograph is routed. Typically this results in a smaller, delayed runoff peak flow.

(4) **BASE FLOW**: - This command lets you specify a constant positive value of base flow to be added to the current inflow hydrograph. The command is enabled only after an inflow hydrograph has been defined.

This chapter describes how to use these commands and discusses the hydrological techniques in general terms. More information on the background theory can be found in Chapter 7 – *Hydrological Theory*. If you need further information refer to any standard text on the subject. A number of references for this purpose are provided in Appendix 'A'. You may also find it useful to subscribe to one or more of the relevant discussion groups which are available on the Internet.

MIDUSS 98 offers a choice between four alternative methods for routing the overland flow and three different models for estimating infiltration and rainfall losses. In general these different methods will result in significantly different results. MIDUSS 98 may therefore be used to compare methods and to examine the sensitivity of the resulting runoff hydrograph to the methods used. This flexibility means, however, that the engineer must exercise some care and consistency in the selection of procedures and parameter values for a particular application.

An important distinction must be made between the three overland flow routing methods which are based on the notion of effective rainfall and the SWMM Runoff method which uses a surface water budget approach which computes both runoff and rainfall loss as a function of rainfall. The difference is particularly noticeable when the runoff from the pervious fraction is significant This is discussed in more detail in Chapter 7 – *Hydrological Theory,* Rainfall-Runoff Models..

Storm Command

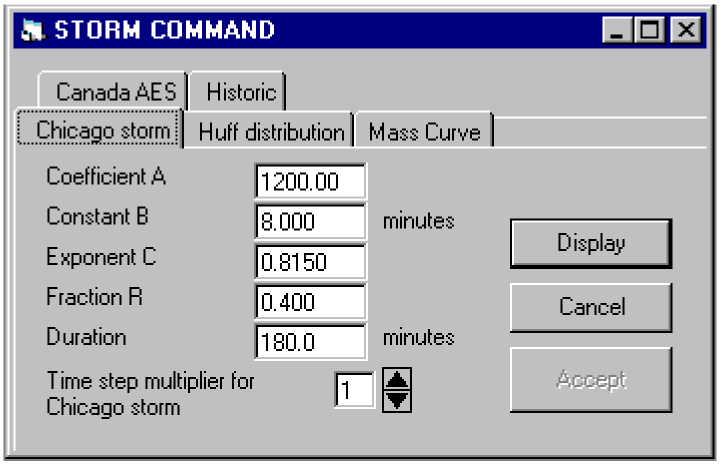


Figure 3-1 – Five design storms are available

The rainfall hyetograph can be defined in five ways using this command. You may choose to define either:

(1) a synthetic design storm from four different types available,

or (2) a historic rainfall record based on observed data.

The form for the Storm command offers five alternate Tabs and selection is made by clicking on one of these. Select from the first four for a design storm or choose the fifth option for a historic storm.

Chicago Storm Hyetograph

Huff Storm

Mass Rainfall Distribution

Canadian AES 1-hour Storm

Historic Storm

After you have defined or accepted the parameters for the selected storm type you can press the [Display] command button to compute the storm hyetograph. This is displayed in both a graphical and tabular form. Since these features are common to all types of design storm they are described first.

Refer to Graphical Display of the Storm to see a typical graph of a Chicago storm.

Refer to Tabular Display of the Storm Hyetograph to see the corresponding table of rainfall intensities.

You can experiment by changing one or more of the parameter values and press [Display] again. When you are satisfied with the design storm you should press the [Accept] command button to store the hyetograph. The design storm will remain unchanged until you change it by a second use of the Storm command or by importing a hyetograph file.

The description of each of the design storms referenced above describes how these options can be used. A more detailed description of some of the design storm options is contained in Chapter 7 *Hydrological Theory*.

Graphical Display of the Storm

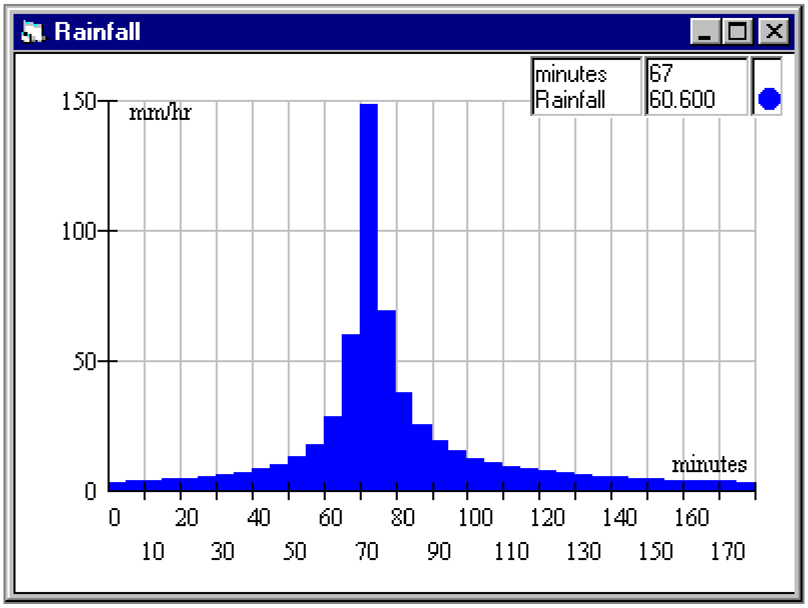


Figure 3-2 – A typical plot of the design storm.

A graph of the storm hyetograph is presented when you press the [Display] command button. The graph illustrated in Figure 3-2 is for a Chicago hyetograph. You can test the sensitivity of the storm to changes in any of the parameters by altering the data and pressing [Display] again. The storm will not be stored until the [Accept] command button is pressed.

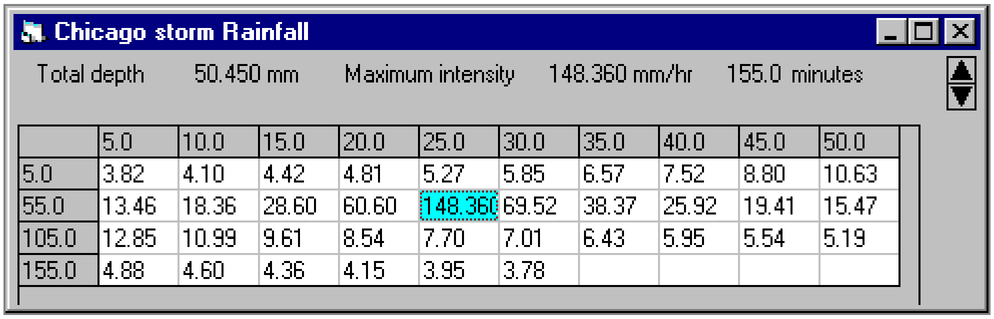
A similar graphical display is also shown for hydrographs following any of the commands which result in some change in the hydrograph data.

When you move the mouse pointer over the graph a small window displays the time and either a rainfall intensity or a hydrograph flow value corresponding to the position of the vertical cross-hair. If you hold down the right Mouse button a pair of cross-hairs will follow the mouse pointer. The position of the horizontal cross-hair has no significance but the vertical cross-hair should intersect the time axis at the time value shown in the small data window.

You can position the graph window by clicking on the title bar and dragging the window to a new location. You can also resize the graph window by dragging any corner of the graph window. The graph is automatically scaled to fit the window. The graph window can also be shown in full screen mode or reduced to an icon by clicking on the window size controls at the top-right corner of the window.

If you click with the primary mouse button anywhere in the plot area, the window is restored to its default size and position in the upper right corner of the MIDUSS 98 window.

Tabular Display of Storm Hyetograph


Chicago storm Rainfall

Total depth 50.450 mm Maximum intensity 148.360 mm/hr 155.0 minutes

	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
5.0	3.82	4.10	4.42	4.81	5.27	5.85	6.57	7.52	8.80	10.63
55.0	13.46	18.36	28.60	60.60	148.360	69.52	38.37	25.92	19.41	15.47
105.0	12.85	10.99	9.61	8.54	7.70	7.01	6.43	5.95	5.54	5.19
155.0	4.88	4.60	4.36	4.15	3.95	3.78				

Figure 3-3 – A tabular display of Mass Curve storm hyetograph.

When the [Display] command button is pressed a table of rainfall intensities is displayed in the lower left corner of the screen. When you move the mouse pointer over the table, the time in minutes corresponding to the cell beneath the pointer is displayed in the top-right corner of the grid. The Spin Button on the top right corner lets you vary the number of figures after the decimal point between a minimum of 0 and a maximum of 5.

A similar tabular display is also shown for hydrographs following any of the commands which result in the generation of a new set of hydrograph data.

Basic statistics are shown in the header of the table defining:

- For hyetographs, the total depth of rainfall and the peak intensity.
- For hydrographs, the total volume and the peak flow rate.

By altering the data for the command and pressing the [Display] button again the table is updated. In the Storm command, this is useful for checking the sensitivity of the design storm to changes in the parameters or even in the type of design storm. For other commands a similar capability exists for sensitivity analysis.

If the number of rows of data is greater than the number of rows in the table you can do one of two things.

- use the scroll bar on the right side of the table
- click on and drag the top edge of the form to increase the height of the form.

The second method is useful if you need to print out the entire contents of the table.

Accepting the Storm

The [Accept] command button is initially disabled when you first use the Storm command. When you press the [Display] button to show the graph and tabular display, the [Accept] button is enabled. However, if you change any of the parameter values, the [Accept] button is again disabled until the [Display] button is used to refresh the storm hyetograph.

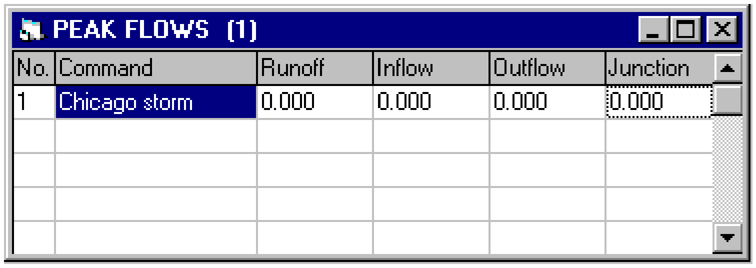


Figure 3-4 – The peak flow summary table with a single record.

Once you are satisfied with the storm you can cause it to be stored by pressing the [Accept] button. The graph and tabular display windows are closed and the small summary window shown in Figure 3-4 is displayed in the lower right corner of the screen. This table will be updated with hydrograph information as you define sub-catchments and design components. For this initial display only the storm has been defined and no runoff hydrographs have been generated.

Chicago Hyetograph

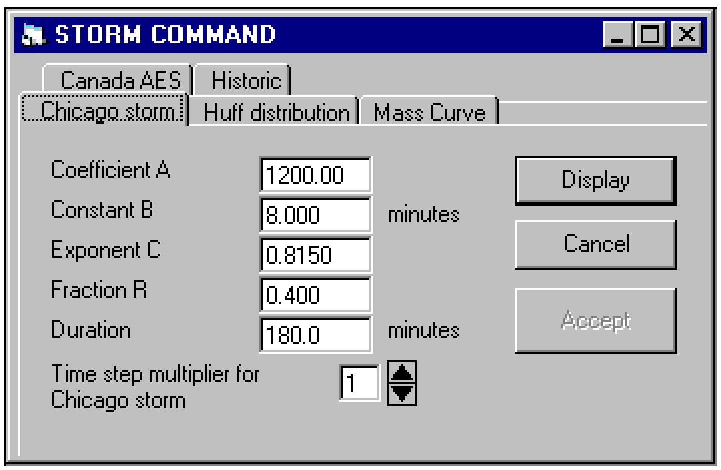


Figure 3-5 – The Chicago storm tab of the Storm command

When you select the Chicago hyetograph tab the data entry form shown in Figure 3-5 is displayed. The synthetic hyetograph computed by the Chicago method is based on the parameters of an assumed Intensity - Duration - Frequency (IDF) relationship, i.e.

[3.1] $$i = \frac{a}{(t_d + b)^c}$$

where i = average rainfall intensity (mm/hr or inch/hr)

t_d = storm duration (minutes)

a,b,c = constants dependent on the units employed and the return frequency of the storm.

The asymmetry of the hyetograph is described by a parameter r (where $0 < r < 1$) which defines that point within the storm duration t_d at which the rainfall intensity is a maximum.

In hypertext you can click on any of the data entry text boxes in Figure 3-5 for a brief explanation of each parameter; in hardcopy the same information is given below. When data has been entered press the [Display] command button to see a graphical plot of the storm hyetograph and a table of rainfall intensities. You can change any value and press [Display] again to see the effect of the change. When you are satisfied with the storm, press [Accept] to define the storm.

Although widely used in North America, the Chicago storm has been criticized because it combines the characteristics of many different events and does not necessarily provide a reasonable simulation of an actual storm. In particular, the peak intensity is very sensitive to the time step employed. For that reason some engineers prefer to use a multiple of the time step in the vicinity of the peak. The time step multiplier can be used for this purpose. The volume of rainfall is unaffected but the peak intensity is significantly reduced. The best way to understand this is to experiment by increasing the multiplier to 2 or 3 and press [Display] to see the effect.

If you have access to data defining either depth or average intensity for different times, you can use the IDFCurveFit program to estimate the values of a, b and c which give the closest fit to the observed IDF data.

The 'a' coefficient

The value of the 'a' coefficient depends on (i) the return interval in years of the storm and (ii) the system of units being used. e.g.

Years	Metric	Imperial
2	250	10
5	400	17
10	700	25
25	950	36
50	1250	50
100	1800	75

Use these default values only as a last resort.

The b-constant

This constant in minutes is used to make the log-log correlation as linear as possible. Typical values range from 2 to 12 minutes. A value of zero for this parameter represents a special case of the IDF equation where

$$[3.2] \qquad i = \frac{a}{t_d^c} .$$

In general, this results in poor agreement between observed values of intensity and duration and those represented by the IDF equation.

The c-exponent

This parameter is usually less than 1.0 and is obtained in the process of fitting the data to the power expression. Values are usually in the range 0.75 to 1.0

The r-peak fraction

This parameter is the fraction of the storm duration to the point of maximum rainfall intensity (e.g. in Figure 3-2 the value of *r* is 0.4). Values are usually in the range 0.25 to 0.6 but any value less than 1.0 may be used. Notice that on pervious surfaces a high (i.e. late) value of *r* will result in a higher runoff peak since the ground tends to be more saturated when the peak intensity occurs.

Duration

This defines the duration of the storm in minutes. It must be not greater than the maximum storm duration defined in the time parameters. Usually some multiple of the time step is used.

Time step multiplier

If a very small time step is used with the Chicago hyetograph it can result in a very high peak rainfall intensity. You can use an integer multiplier to use a small time step but avoid the unrealistically high peak. Experiment to see the difference.

Huff Rainfall Distribution

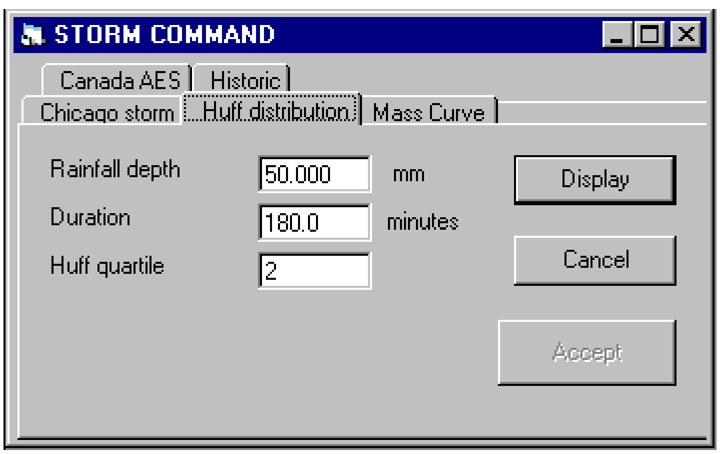


Figure 3-6 – The Huff distribution tab of the Storm command

Selection of the Huff Distribution tab on the Storm command form causes the form shown in Figure 3-6 to be displayed. The non-dimensional rainfall distribution patterns suggested by Huff were divided into four groups in which the peak intensity occurs in the first, second, third or fourth quarter of the storm duration. Within each group the distribution was plotted for different probabilities of occurrence. MIDUSS 98 uses the median curve for each of the four quartile distributions. (See Chapter 7 *Hydrological Theory*; Derivation of the Huff Storm).

To define a storm of this type you must provide values for the total depth and duration of the storm and select the quartile distribution required. Refer to the topics which follow for a brief explanation of each parameter. When data has been entered press the [Display] command button to see a graphical plot of the storm hyetograph and a table of rainfall intensities. You can change any parameter value and press [Display] again to see the effect of the change. When you are satisfied with the storm, press [Accept] to define the storm.

Canadian users who want to employ the Atmospheric Environment Service 1-hour of 12-hour distribution suggested by Hogg can do so with the Mass Rainfall Distribution option.

Huff Quartile

The Huff quartile takes a value of 1, 2, 3 or 4 and defines the quartile of the storm duration in which the maximum intensity occurs. Refer to Chapter 7 *Hydrological Theory* for background information on the Huff distribution or the dimensionless quartile curves.

See Huff Distribution for background information or Huff Quartile Curves for the data used for this distribution.

Rainfall depth

For this storm type you must specify the total depth of rainfall in millimetres or inches. This will depend on climatic factors and the return interval in years. It is common to use the Intensity - Duration - Frequency curve for the area from which the total depth can be estimated for a given storm duration and return interval in years.

The values below are typical for some regions in Southern Ontario, Canada.

Return period	**Depth**		**% of 5 year**
(years)	(mm)	(inch)	(%)
2	38.0	1.50	78%
5	48.6	1.90	100%
10	55.7	2.20	115%
25	64.5	2.55	133%
50	71.1	2.80	146%
100	77.6	3.05	160%

See also Gumbel Distribution

Gumbel Distribution

Estimates for extreme rainfall events can be expressed in terms of the average and standard deviation of the annual maximum series. Thus:

[3.3] $$x_T = m_x + K_T s_x$$ where

x_T = magnitude of the T year event

m_X = mean of the annual maximum series

s_X = standard deviation of the annual maximum series

K_T = frequency factor which depends on return period T

The Gumbel (double exponential) distribution is often used to describe the frequency factor for extreme rainfall. This is expressed as:

[3.4] $$K_T = \frac{-\sqrt{6}}{p}\left(0.5772 + \ln.\ln\frac{T}{T-1}\right)$$

e.g.

T (years)	2	5	10	25	50	100
K	0.164	0.719	1.305	2.044	2.592	3.137

Values for the mean and standard deviation of the annual maximum series can often be estimated from rainfall frequency maps.

Mass Rainfall Distribution

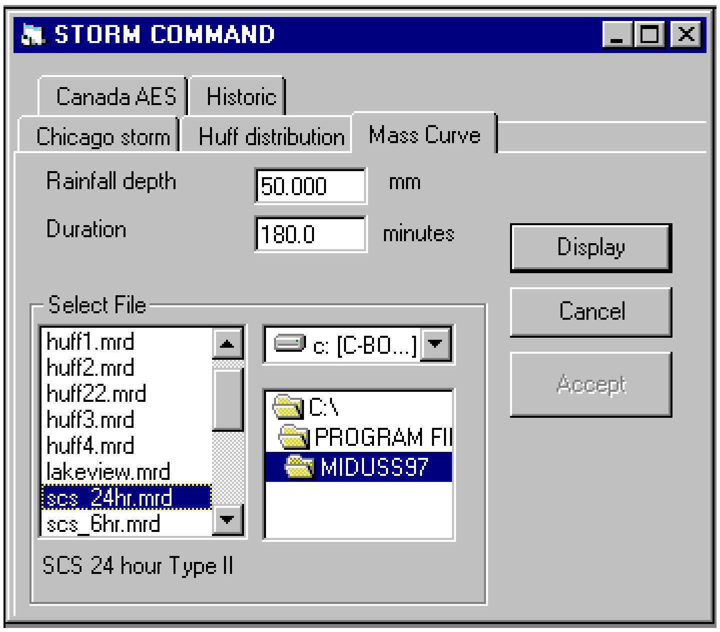


Figure 3-7 – The Mass Curve distribution tab of the Storm command

MIDUSS 98 contains a number of files with the extension '**.mrd**' which stands for Mass Rainfall Distribution. These files reside in the Miduss98 directory (typically **C:|Program Files\Miduss97**..). You can use one of these pre-defined patterns or create a special one for your own use to define a customized non-dimensional mass rainfall distribution curve similar to the patterns used for the Huff storms.

The data form shown above is opened when you select this option. The default location of the *.mrd files is indicated by the Drive (e.g. C:\) and Directory (e.g. C:\Program Files\Miduss97\) and all files with the extension .mrd are listed in the Files List box. (Hint: If the file List box shows 'All Files', double click on the drive and then the directory to show only files with the extension *.mrd)

By selecting (i.e. clicking on) one of the files a brief description is displayed below the list box. In addition to the selected non-dimensional distribution you must specify the total depth and duration for the storm. Refer to the topics below. When data has been entered press the [Display] command button to see a graphical plot of the storm hyetograph and a table of rainfall intensities. You can change any of the values or the distribution pattern and press [Display] again to see the effect of the change. When you are satisfied with the storm, press [Accept] to define the storm.

Irrespective of the number of points used to describe the distribution, the rainfall intensities are discretized in terms of the time step defined for the MIDUSS 98 session using linear interpolation. The interpolated values are then scaled up by the total depth of rainfall. More details are provided in Chapter 7 *Hydrological Theory*. Derivation of the User Defined Distribution.

Drive for *.MRD file

When you install MIDUSS 98 all the files of type *.MRD are located in the Miduss98 directory. If this is typically C:\Program Files\Miduss98\ then the Drive for the *.MRD files will be 'C:' If you create special mass rainfall distribution files - either an edited copy of the pre-defined ones, or a customized one of your own choosing - you may wish to store these in a particular job directory. You can use the Drive list box to navigate to where your *.MRD files are located.

Directory for *.MRD file

When you install MIDUSS 98 all the files of type *.MRD are located in the Miduss98 directory. If this is typically C:\Program Files\Miduss98\ then the Directory for the *.MRD files will be 'C:\Program Files\Miduss97\'. If you create special mass rainfall distribution files you may wish to store these in a particular Job directory. You can use the Directory list box to navigate to where your *.MRD files are located.

Select *.MRD file

Once the drive and directory of the path have been selected you can click on the particular *.MRD file to be used. The description in the text box below helps to ensure you have made the right choice. The file will not be processed until you press the [Display] command button. Note that the [Display] button is not enabled until a file has been selected.

Customized *.MRD files

If you create a customized mass rainfall distribution file you should copy the format of one of the pre-defined files as illustrated below

`SCS 6 hour distribution`	# 1 - Description
`51`	# 2 - Number of values N
`0.000`	# 3 - Initial zero value
`0.008`	
`0.016`	Intermediate values
`0.024`	defining (N-1)
`0.032`	increments.
`0.040`	
`:`	You can use
`0.976`	any number of
`0.984`	points > 2.
`0.992`	
`1.0`	# N+2 - Final value of 1.0

Canadian AES 1-hour Storm

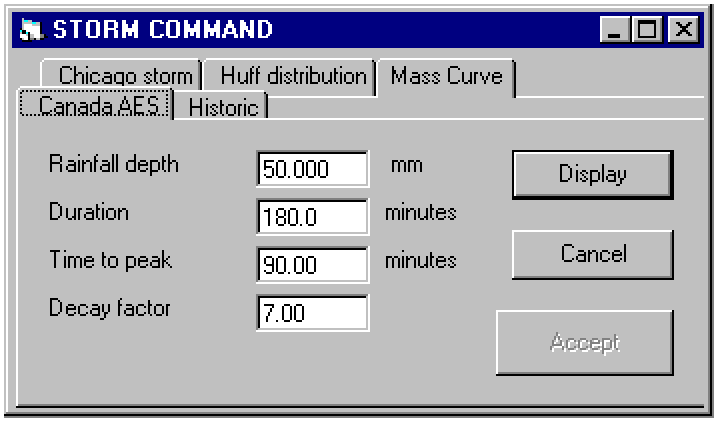


Figure 3-8 – The Canadian AES tab of the Storm command

The form shown in Figure 3-8 is used to define a simple two parameter design storm which has a linear rising portion followed by an exponentially decreasing curve. The possibility of reversing the linear and exponential segments is suggested in the original publication (Watt *et al*) but this option is not currently supported in MIDUSS 98. A definition sketch is shown in Chapter 7 *Hydrological Theory*, Canadian 1-hour storm derivation

The parameter values required for this option are the depth (mm or inches) and duration (minutes) of the rainfall the time to peak intensity (minutes) and the decay coefficient K.

You should note that the proposal by Watt *et al* is intended to be used only for 1-hour storms since the data used for the work was limited to this duration. However, MIDUSS 98 allows you to define other values of the duration. Be careful if suggested values for the time to peak are taken from the original reference since these are intended specifically for 60 minute storms. For that reason, suggested values in Chapter 7 *Hydrological Theory*, 'Suggested tp values for locations in Canada' show time to peak in minutes and also as a fraction of the duration but care should be taken in using these.

When the data has been entered press the [Display] command button to see a graphical plot of the storm hyetograph and a table of rainfall intensities. You can change any of the values and press [Display] again to see the effect of the change. When you are satisfied with the storm, press [Accept] to define the storm.

AES Time to Peak

Suggested values of time to peak are intended for 60 minute storms. For other values of duration use the values of **Tp /Duration** with caution.

Location	Tp (minutes)	Tp/ Duration
Yukon	20	0.33
B.C.(coast)	28	0.47
B.C.(interior), Prince George	13	0.22
Alberta	17-18	0.29
Saskatchewan	23-24	0.39
Manitoba (Brandon, Churchill)	31	0.52
Manitoba (Winnipeg)	25	0.42
Ontario (Timmins, Thunder Bay)	24-25	0.41
Ontario (Ottawa, Kingston, Windsor)	26-27	0.44
Ontario (Toronto, Sudbury)	21	0.35
Quebec (Montreal)	27	0.45
Quebec (Val D'Or, Quebec City)	23	0.38
New Brunswick (Fredericton)	17	0.28
Nova Scotia, Newfoundland	26-28	0.45

AES Decay factor

Values of the decay coefficient taken from the original publication are shown below.

Province	K value
B.C.(coastal region)	5
Yukon, New Brunswick, Nova Scotia, Newfoundland	6
B.C.(interior), Alberta, Saskatchewan, Manitoba, Ontario, Quebec	7

Historic Storm

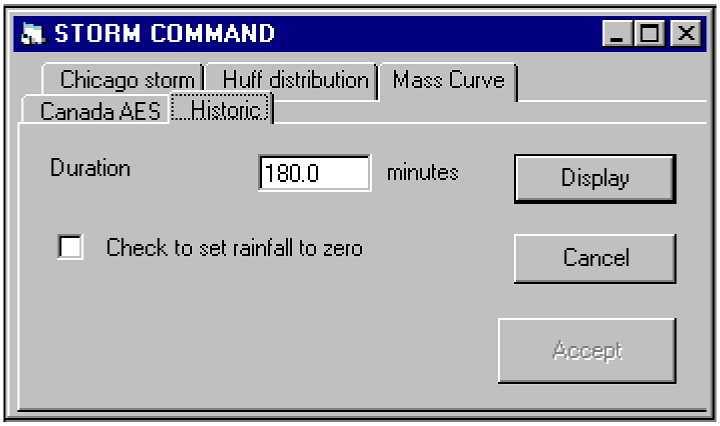
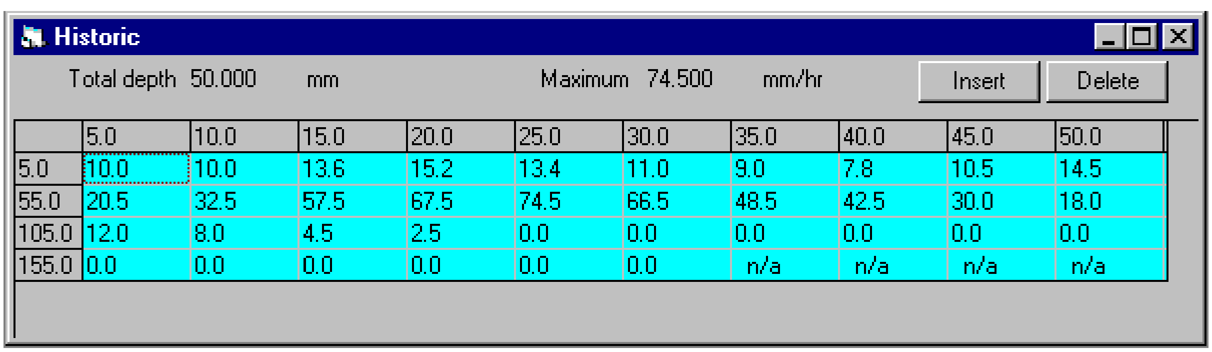


Figure 3-9 – The Historic storm tab of the Storm command

This storm option lets you define an observed or historic rainfall event. The form illustrated here prompts you to specify the duration in minutes. Depth, intensity and distribution are defined by entering intensity values in a Table that is opened when you press the [Display] button.

If you set a check mark in the box labeled 'Check to set rainfall to zero' the table will be opened with all values set to zero. Otherwise, the intensity values for the currently defined storm are copied into the table where they can be edited. Notice that when you are using any of the other four options in the Storm command, the rainfall intensities displayed do not become the "currently defined storm" until you have pressed the [Accept] button. Thus, if you wish to generate (say) a 3rd quartile Huff storm and then edit it using the Historic storm option you must invoke the Storm command twice; once to create and save the Huff storm and a second time to import it into the Historic storm table for editing.



	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
5.0	10.0	10.0	13.6	15.2	13.4	11.0	9.0	7.8	10.5	14.5
55.0	20.5	32.5	57.5	67.5	74.5	66.5	48.5	42.5	30.0	18.0
105.0	12.0	8.0	4.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
155.0	0.0	0.0	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a

Figure 3-10 – The Historic storm data entry grid

The table shown above was generated by first creating and 'Accepting' a 3rd quartile Huff storm with a duration of 120 minutes and a total depth of 50 mm. Then the Storm command was used with the Historic option for a storm duration of 180 minutes and with the 'Check to set rainfall to zero' checkbox left empty (unchecked). Note the extra 12 cells (60 minutes) with zero values.

You can navigate around the table using the arrow keys or by clicking the mouse pointer on a cell of the table. You will notice a slightly heavier outline around the selected cell. You can type a new value into the current cell and move to the next cell with an arrow key. This will:

- overwrite the cell contents

- change the total depth in the table and the peak intensity if the new value is large enough.

- change the total depth in the **Storm/Historic** form

- update the graphic display of the Historic storm.

You can use the [Delete] button to delete the current cell and move all of the cells after this point back in time by one time step. The [Insert] button opens up an empty cell in front of the currently defined cell and moves all of the cells forward by one time step.

When you are satisfied with the historic storm press the [Accept] key in the **Storm/Historic** form.

Check to set Rainfall to Zero

If this checkbox is left empty the Historic storm table will be opened to show the rainfall intensity values for the currently defined storm. The currently defined storm is one which has been created and accepted by a previous use of the Storm command or a storm hyetograph which has been imported by use of the File Input-Output command.

If a check is entered in the box by clicking on it the values in the Historic storm table are all set to zero.

Catchment Command

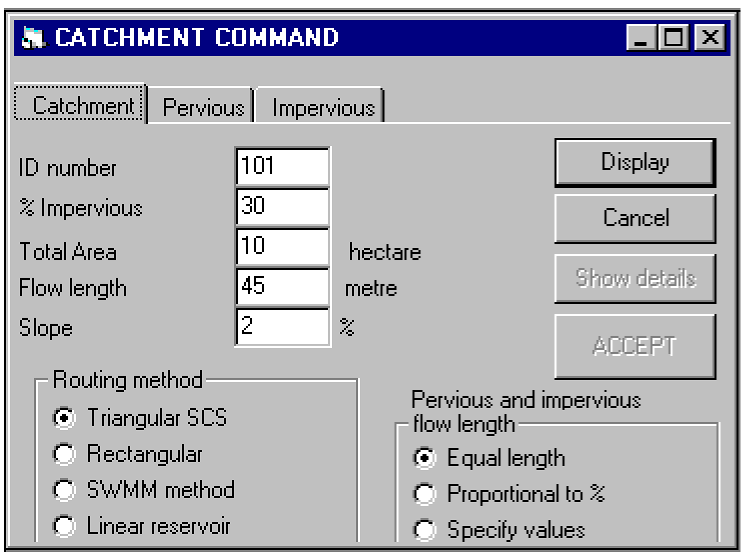


Figure 3-11 – The total Catchment tab of the Catchment command

The Catchment command allows you to describe a sub-catchment and generate the runoff hydrograph for the design storm previously defined in the Storm command. The pervious and impervious fractions of the catchment are modelled separately and the two hydrographs are then added together. The process generally involves the following steps.

Define the total catchment area and percent impervious etc.

Select a method to define overland flow length on the pervious and impervious areas

Select a model to estimate rainfall losses

Compute the effective rainfall hyetograph for the impervious fraction

Compute the effective rainfall hyetograph for the pervious fraction

Select a model for routing the overland flow

Compute the runoff hydrographs (pervious, impervious and total)

The available options for overland flow routing are:

Combine effective rainfall with a triangular response function

Combine effective rainfall with a rectangular response function

Combine effective rainfall with a response function defined as a linear reservoir

Compute runoff from a surface water budget as in the SWMM Runoff block

The same rainfall loss model is used for both pervious and impervious areas. The models available to estimate rainfall losses are:

The SCS method (not available for the SWMM Runoff routing option)

The Horton equation (moving curve method)

The Green and Ampt method

On the Pervious (Tab #2) form you can also click on any of the three options for infiltration method to see the data requirements and get specific information for each of the parameters.

The results displayed by the catchment command are described in the next topic

Reviewing the Catchment Command Results

The results of the catchment command can be reviewed in a number of ways.

A graphical display in the top right corner shows the runoff from the pervious and impervious areas and the total runoff from the catchment. This time to peak for the two components may be different and it is not uncommon to see a total runoff hydrograph which exhibits two peaks. The graph window contains some additional features which help you to interpret the plot. The topic Graph Window Features describes these in more detail.

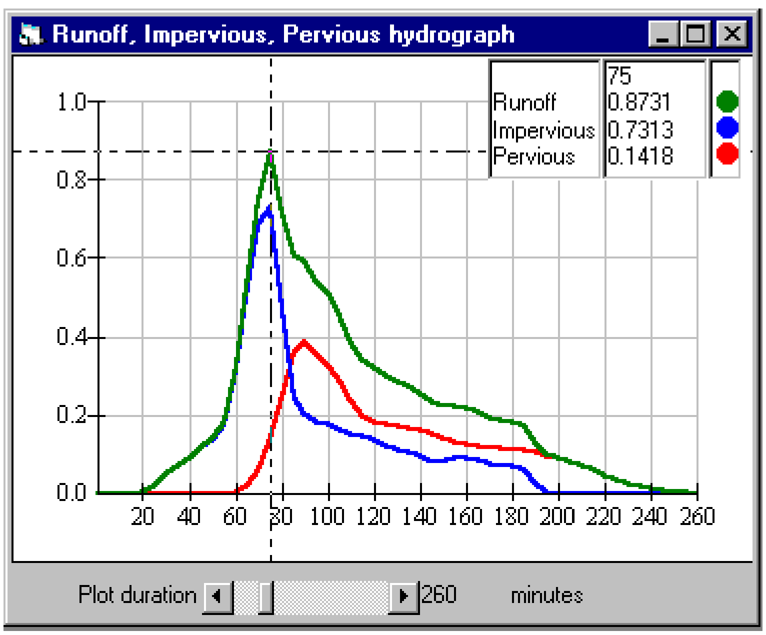
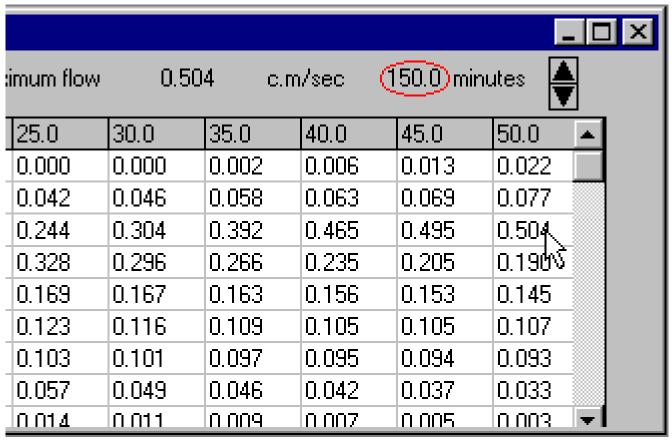


Figure 3-12 – A typical plot of hydrograph components

A tabular display of the total hydrograph is shown in the lower left corner of the screen. If the [Display] button is pressed from either the Pervious or impervious tabs on the form, the effective rainfall on the relevant area is displayed in the table. An exception to this is when the SWMM Runoff algorithm is used which uses a surface water budget rather than the effective rainfall.

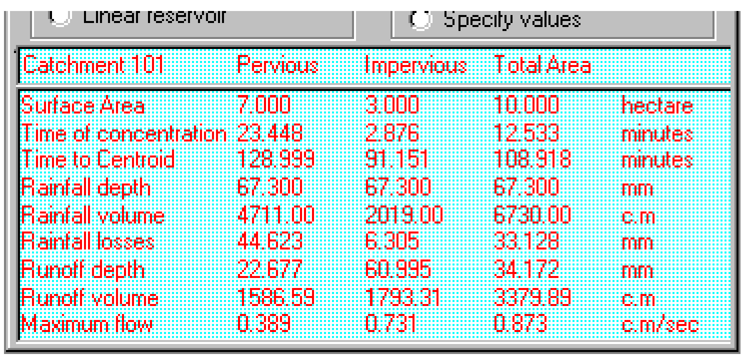
The fragment of table shown here has been increased in height by 'dragging' the top edge upwards to display as many rows as you wish. Also, the figure shows the cursor over the right hand cell in the third row. This causes the time for that cell to be displayed as circled in red.



25.0	30.0	35.0	40.0	45.0	50.0
0.000	0.000	0.002	0.006	0.013	0.022
0.042	0.046	0.058	0.063	0.069	0.077
0.244	0.304	0.392	0.465	0.495	0.504
0.328	0.296	0.266	0.235	0.205	0.190
0.169	0.167	0.163	0.156	0.153	0.145
0.123	0.116	0.109	0.105	0.105	0.107
0.103	0.101	0.097	0.095	0.094	0.093
0.057	0.049	0.046	0.042	0.037	0.033
0.014	0.011	0.009	0.007	0.005	0.003

Figure 3-13 – Part of the tabular display of the Runoff hydrograph

Some summary statistics can be displayed by pressing the [Show Details] button. A typical display is shown below. You may find that a portion of the details is lost if a window is opened on top of it. The information can be restored by clicking on the button labelled [Hide Details] and again on the same button when it is relabelled [Show Details]



Catchment 101	Pervious	Impervious	Total Area	
Surface Area	7.000	3.000	10.000	hectare
Time of concentration	23.448	2.876	12.533	minutes
Time to Centroid	128.999	91.151	108.918	minutes
Rainfall depth	67.300	67.300	67.300	mm
Rainfall volume	4711.00	2019.00	6730.00	c.m
Rainfall losses	44.623	6.305	33.128	mm
Runoff depth	22.677	60.995	34.172	mm
Runoff volume	1586.59	1793.31	3379.89	c.m
Maximum flow	0.389	0.731	0.873	c.m/sec

Figure 3-14 – The Catchment command provides details as an option.

The final step is to Accept the results of the catchment command .

Graph Window Features

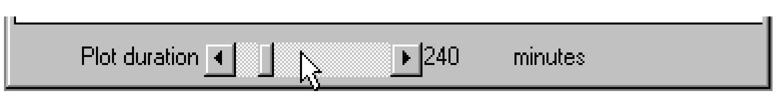


Figure 3-15 – The displayed time-base of the hydrograph plot can be adjusted.

At the bottom of the graph window a slider control lets you vary the time base which is plotted in the window. You can adjust the time by clicking either on the bar or on the arrow at the extremity. Clicking on the right increases the time (thus compressing the plot); clicking on the left reduces the time. Click on the arrows for greater control. The time base is displayed to the right of the slider

Figure 3_16 illustrates some of the details which are available in any plot of a hyetograph or hydrograph

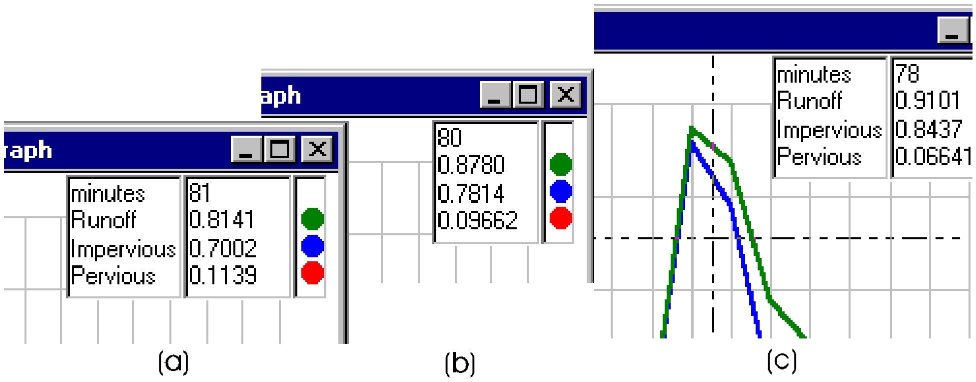


Figure 3_16 – Some details in the plot window

Figure 3_16(a) shows the default state of the legend which is displayed whenever the mouse pointer is over the plotting area. The small windows show respectively the time and name of the functions displayed, the values for each of these and a colour code keyed to the plotted functions. Typically the legends contain two or more rows of information.

By clicking with the primary mouse button on the window showing the coloured circles, the name legend can be toggled off or on as shown in Figure 3_16(b). The values displayed change dynamically when the mouse pointer is moved. Moving the mouse out of the left side of the plot window causes the legend windows to be closed.

If you hold down the secondary mouse button while moving the mouse, a pair of cross-hairs is displayed as in Figure 3_16(c). The cross-hairs are removed when the cursor is moved without the secondary button held down.

Clicking with the primary mouse button in the legend window containing the numerical values can alter the type of grid display. The options are selected in the following revolving sequence – no grid, horizontal, vertical, both. The style in use when you exit MIDUSS 98 is remembered and used as the default in the next session.

Accepting the Catchment Command

You can change any of the parameters in the catchment form and press the [Display] button to update the graph, the table and the "details" window. Each time a parameter is altered the [Accept] button is disabled and is re-enabled only when the [Display] button is pressed to refresh the screen. This prevents you from mistakenly 'accepting' a display which has not been updated.

When you are satisfied with the result you can press the [Accept] button to save the data and results to the output file. All of the windows are closed and the peak flow summary table is updated by adding a row with the new runoff hydrograph.

Data for the Total Catchment

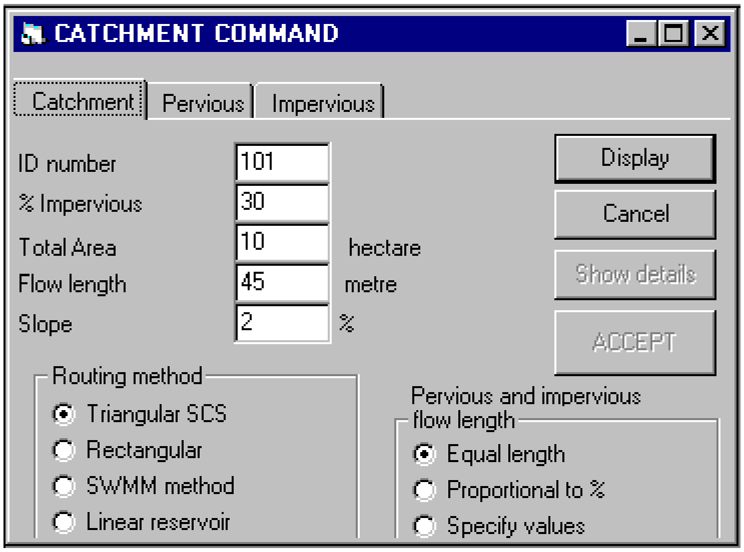


Figure 3-17 – Data required for the total Catchment area

As illustrated, the data required comprises an ID number for the catchment, the percentage of impervious area, the total catchment area and the length and average slope (as %) of the overland flow surface.

If you are viewing on-line help, you can click on any of the text boxes to obtain a more detailed description of the item with some suggestions for typical values; otherwise, these descriptions can be found below. As you might expect, the total area and the percentage of impervious surface are the most important in determining the volume of runoff and the peak flow of the runoff hydrograph.

On this form you can select the overland routing method from:

The SCS triangular response function

A rectangular response function

The SWMM Runoff algorithm

A response function equivalent to the response of a linear reservoir to an instantaneous unit input (sometimes referred to as a Dirac δ-function),

Catchment ID Number

This number is used to identify the sub-catchment being defined.

Use a positive integer of not more than 1,999,999,999.

Percent Impervious

The percentage of impervious area can be any positive value from 0% to 100%.

This parameter is second only to the total area in importance in determining the runoff.

Total Catchment Area

This is the total contributing area including both pervious and impervious fractions. The units must be either hectares (metric or SI) or acres (imperial or US Customary). The area is the most significant parameter in determining peak and volume of runoff.

Overland Flow length

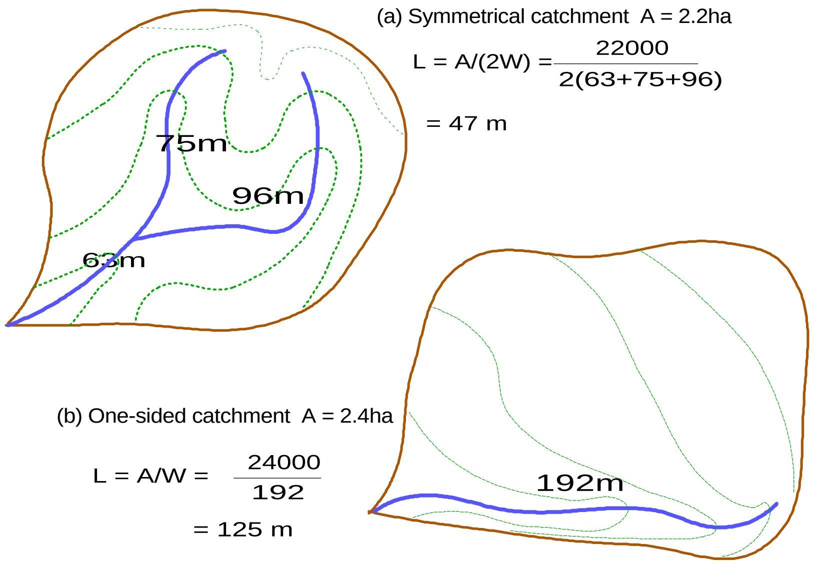


Figure 3-18 – Approximate ways of estimating overland flow length

The overland flow length is the average overland flow length in metres or feet from the edge of the sub-catchment to the main drainage conduit (i.e. pipe, gutter or channel). An approximate estimate for a symmetrical area such as Figure 3- 18(a) is:

$$[3.5] \qquad Length = \frac{Area}{2 \times Channel\,Length}$$

A one-sided catchment as in sketch (b) may often result from highway or railway construction. The length can be approximated as:

$$[3.6] \qquad Length = \frac{Area}{Channel\,Length}$$

Overland Slope

The slope of the overland flow is the average surface slope from the edge of the catchment to the main conduit or channel estimated along a line of greatest slope (i.e. normal to the contours). Do <u>not</u> use the maximum height difference in the sub-catchment divided by the length of the main drainage channel.

Data for the Pervious Area

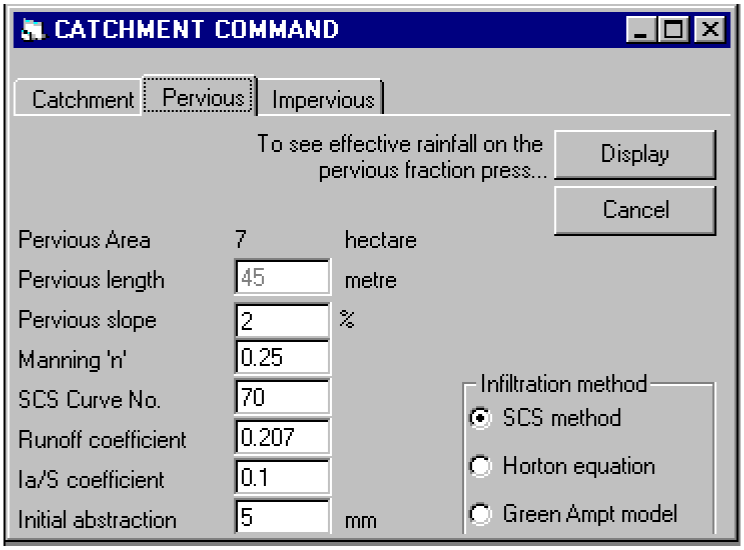


Figure 3-19 – Data required for the Pervious fraction (SCS method selected)

Figure 3-19 above displays the catchment data form when the Pervious tab has been clicked.

The form shows the parameters required to define the rainfall losses when the SCS Infiltration model is selected. The required infiltration parameters will change with the selection of different infiltration methods.

You can also click on any of the text boxes to get more details of a particular parameter.

The area of the pervious fraction is indirectly defined in terms of the total area and the percentage of impervious surface. You can change this from the Catchment tab.

Definition of the Pervious flow length can be done either explicitly or can be indirectly defined by the option choice for Pervious and Impervious flow length in the Catchment tab form.

Pervious Manning 'n'

The values listed below are typical for overland sheet flow on pervious surfaces with various types of vegetation. These are not suitable for flow in channels.

Surface	Manning 'n'
Dense growth	0.4 – 0.5
Pasture	0.3 – 0.4
Lawns	0.2 – 0.3
Bluegrass sod	0.2 – 0.5
Short-grass prairie	0.1 – 0.2
Sparse vegetation	0.05 – 0.13
Bare clay/loam soil	0.013 – 0.03

Pervious Flow length

There are three options to specify the overland flow length on the pervious and impervious areas.

- Use the same length for both
- Make the length proportional to the percentage of the area
- Specify the lengths

These are illustrated in terms of an idealized rectangular catchment in Figure 3-20.

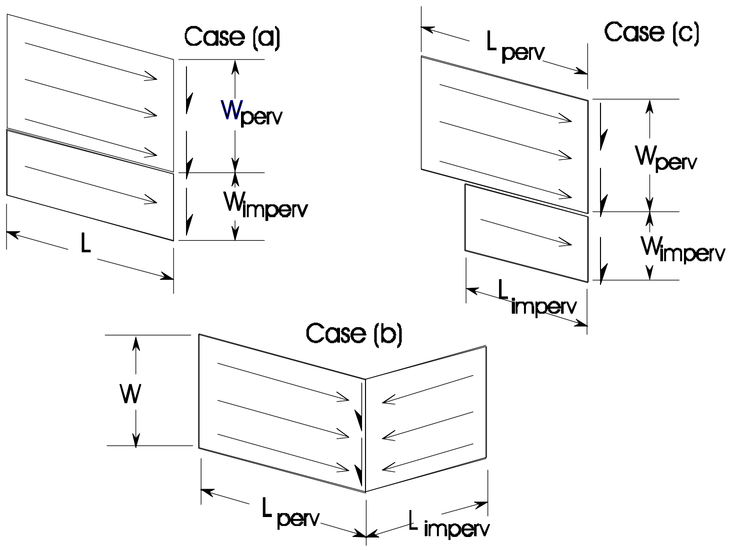


Figure 3-20 – Options for defining overland flow length

For the second option the pervious flow length is set equal to the overland flow length defined in the Catchment tab. The impervious flow length is then calculated as

$$[3.7] \qquad L_{impervious} = L_{pervious} \frac{\%I}{(1-\%I)}$$

As an example assume L = 100 m and %I = 20%, then the impervious flow length is 100 x 0.2/0.8 or 25 m. and the pervious flow length is 100m.

If you select the third option text boxes are opened to allow you to specify any positive value.

Pervious Slope

The default value is the same as the average overland slope for the total area. However, you can specify a different value if you wish.

Pervious Data for SCS Infiltration

When the SCS Infiltration option is selected you have some choice as to how the required data values are entered. The basic parameter is the SCS Curve number which depends on the soil type and land use.

As an alternative, you can define a value for the volumetric runoff coefficient. This will cause the equivalent SCS CN value to be computed for the current rainfall event and displayed. Likewise, entry of a SCS CN value causes the equivalent runoff coefficient to be computed and displayed.

Another important parameter is the depth of the initial abstraction. This can be specified explicitly or you can provide a coefficient to define the initial abstraction as a fraction of the storage potential S which is a function of CN. The relationship is given below for both metric and U.S. Customary units.

[3.8] $$S = \frac{1000}{CN} - 10$$ S is in inches for U.S Customary units.

[3.9] $$S = 25.4\left(\frac{1000}{CN} - 10\right)$$ S is in millimetres for metric/SI units

Pervious SCS Curve number

CN depends on Soil Type, Antecedent Moisture and Land Use.

Land Use **Soil type**	**A**	**B**	**C**	**D**
Cultivated land with no conservation treatment	72	81	88	91
Cultivated land with conservation treatment	62	71	78	81
Pasture in poor condition	68	79	86	89
Pasture in good condition	39	61	74	81
Woodland - poor cover	45	66	77	83
Woodland - good cover	25	55	70	77
Park land - >75% grass	39	61	74	80
Park land - 50-75% grass	49	69	79	84

In some texts you may see values of CN quoted as a function of the percentage of impervious area. These are usually calculated as a weighted average assuming $CN_{impervious}$ = 98 and $CN_{pervious}$ equal to the value for 'Pasture in good condition' for the various soil types A, B, C or D. This is often done using an equation of the form:

[3.10] $$CN_{equiv} = \left(\%I\ CN_{imperv} + (100 - \%I)CN_{perv}\right)/100$$

where $\%I$ is the percentage of impervious area.

Values of CN estimated in this way are intended to be applied to the **total** catchment assuming other parameters to be the same for both pervious and impervious areas. Many programs (including MIDUSS 98) compute the runoff from the pervious and impervious fractions separately and then add the two hydrographs. In such cases, it is most important that you **do not use** a composite value of CN since this would 'double count' the impervious fraction and greatly exaggerate the runoff prediction.

SCS Soil Types

The following four classifications of soil are used.

Type A	Deep, very well drained sand or gravel
Type B	Moderately well drained soil with medium texture
Type C	Fine soil with an infiltration impeding layer
Type D	Clay; soil over rock; soil with a permanent high water table

Dry and Wet CN values

With normal moisture conditions the Curve number is defined as *CN2*. For very dry or very wet antecedent conditions the corresponding values *CN1* and *CN3* can be expressed approximately as simple functions of *CN2*.

Dry:

[3.11] $$CN1 = CN2 - 2.45(100 - CN2)^{0.62}$$

$$S1 = 2.3\ S2$$

Wet:

[3.12] $$CN3 = CN2 + 0.60(100 - CN2)^{0.953}$$

$$S3 = 0.4\ S2$$

Runoff coefficient

The runoff coefficient in MIDUSS 98 is defined in volumetric terms, i.e. C = Runoff depth/Rainfall depth

In the SCS Infiltration method the time history of runoff depth (or the effective rainfall) is computed as:

[3.13] $$Q(t) = \frac{(P(t) - I_a)^2}{(P(t) + S - I_a)}$$

where $Q(t)$ = accumulated depth of runoff to time t

$P(t)$ = accumulated depth of rainfall to time t

Ia = initial abstraction

Ia/S Coefficient

This ratio indirectly defines the Initial Abstraction as a fraction of the potential storage depth *S*. Values of 0.05 to 0.1 are reasonable. The value of 0.2 originally recommended by SCS is now considered by many engineers to be too high. It is often easier to define the initial abstraction directly as a depth. If you do this MIDUSS 98 will compute the corresponding value of *Ia/S* as a function of *S*.

Initial Abstraction

For impervious surfaces this value may range from 0.5 - 1.5 mm (0.02 - 0.06 inch) depending on the type and steepness of the surface. It is roughly equivalent to the surface depression storage.

For pervious areas the initial abstraction may be between 5 - 10 mm (0.2 - 0.4 inch) depending on vegetative cover and tree canopy.

Pervious Data for Horton Equation

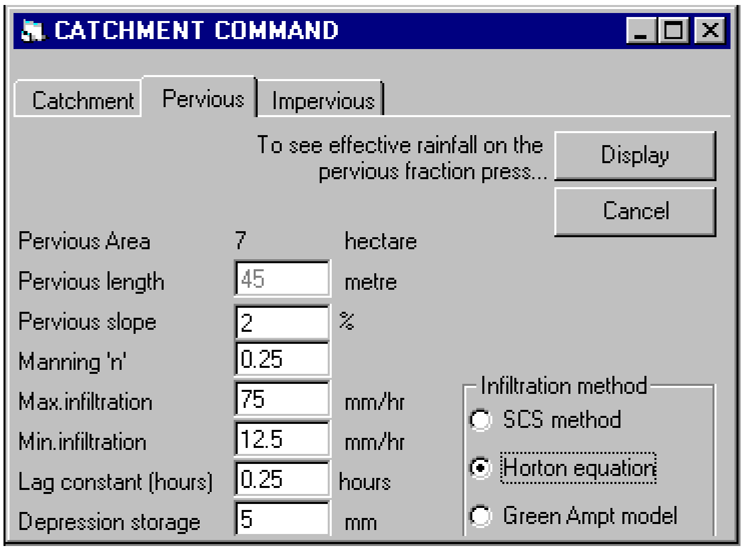


Figure 3.21 – Data required for the pervious fraction (Horton method selected)

The Horton Infiltration option requires four parameters to compute the rainfall losses. These are:

The initial infiltration rate f_o

The final infiltration rate f_c

The exponential decay time constant K

and The surface depression storage Y_{sd}

For a more complete understanding of the method you should refer to the section in Chapter 7 *Hydrological Theory*; The Horton Equation.

Horton fo for Pervious Areas

Soil Group and Type		mm/h	inch/h
A	Sand/gravel, sandy loam	250	10.0
B	Silty loam	200	8.0
C	Sand-clay-loam	125	5.0
D	Clay, soil over rock	75	3.0

Values are for dry soil. Allow for pre-wetting

Horton fc for Pervious Areas

Soil Group and Type		mm/h	inch/h
A	sand/gravel, sandy loam	25	1
B	Silty loam	13	0.5
C	Sand-clay-loam	5	0.2
D	Clay,	3	0.1
	Shallow soil over rock	0	0.01

Horton Lag Constant

For pervious surfaces the lag K may vary from 0.25 to 0.5 hours depending on the soil type. The lag K has little or no physical significance. For impervious surfaces the lag K will be very short, e.g. 0.05 hours. If fo = 0.0 set K =0 also. Notice that in MIDUSS 98, the lag is specified as a time in hours whereas in many other models which use the Horton equation the lag coefficient is expressed as the reciprocal of the lag and is often expressed in units of 1/sec or sec^{-1}. Thus a lag of 0.25 hours is equivalent to a coefficient of (1/900 sec) or 0.001111 sec^{-1}.

Depression Storage

For pervious surfaces this may be 5 - 10 mm (0.2 - 0.4 inch) depending on surface type and slope. In general, steep surfaces retain less depth.

For impervious surfaces the value may be 0.5 - 1.5 mm (0.02 - 0.06 inch) depending on surface type and slope. Steep slopes retain less depth.

Pervious Data for Green & Ampt Method

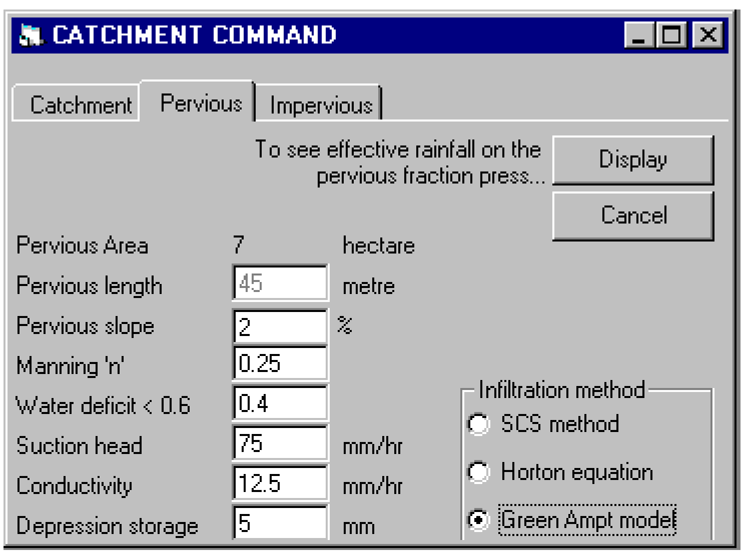


Figure 3.22 – Data required for the pervious fraction (Green and Ampt method selected)

The Green & Ampt Infiltration option requires four parameters to compute the rainfall losses. These are:

The initial soil moisture deficit *M*

The suction head across the wetting front *S*

The hydraulic conductivity in the soil *K*

and The surface depression storage *Ysd*

For a more complete understanding of the method you should refer to the sections in Chapter 7 *Hydrological Theory* which deal with the Green and Ampt method and also the Green and Ampt Parameter Evaluation.

Water deficit

This is the difference between the initial water content of the surface layers of the soil and the saturated water content after the wetting front has passed through a layer. It is a dimensionless number normally less than 0.6. For a fully drained specimen of the following soil types the maximum effective porosity is as shown. The actual initial soil moisture deficit will depend on the antecedent rainfall.

Soil Type	**M**
sand	0.417
loamy sand	0.401
sandy loam	0.412
loam	0.434
silt loam	0.486
sandy clay loam	0.330
clay loam	0.309
silty clay loam	0.432
sandy clay	0.321
silty clay loam	0.423
clay	0.385

Suction Head

Soil type	Suction head S	
	inch	mm
Sand	1.949	49.5
Loamy sand	2.413	61.3
Sandy loam	4.335	110.1
Loam	3.500	88.9
Silt loam	6.567	166.8
Sandy clay loam	8.602	218.5
Clay loam	8.220	208.8
Silty clay loam	10.748	273.0
Sandy clay	9.410	239.0
Silty clay loam	11.504	292.2
Clay	12.453	316.3

Soil Conductivity

Soil type	Hydraulic conductivity	
	inch/h	mm/h
Sand	4.638	117.8
Loamy sand	1.177	29.9
Sandy loam	0.429	10.9
Loam	0.134	3.4
Silt loam	0.256	6.5
Sandy clay loam	0.060	1.5
Clay loam	0.039	1.0
Silty clay loam	0.039	1.0
Sandy clay	0.024	0.6
Silty clay loam	0.020	0.5
Clay	0.012	0.3

Depression Storage

For pervious surfaces this may be 5 - 10 mm (0.2 - 0.4 inch) depending on surface type and slope. In general, steep surfaces retain less depth.

For impervious surfaces the value may be 0.5 - 1.5 mm (0.02 - 0.06 inch) depending on surface type and slope. Steep slopes retain less depth.

Data for the Impervious Area

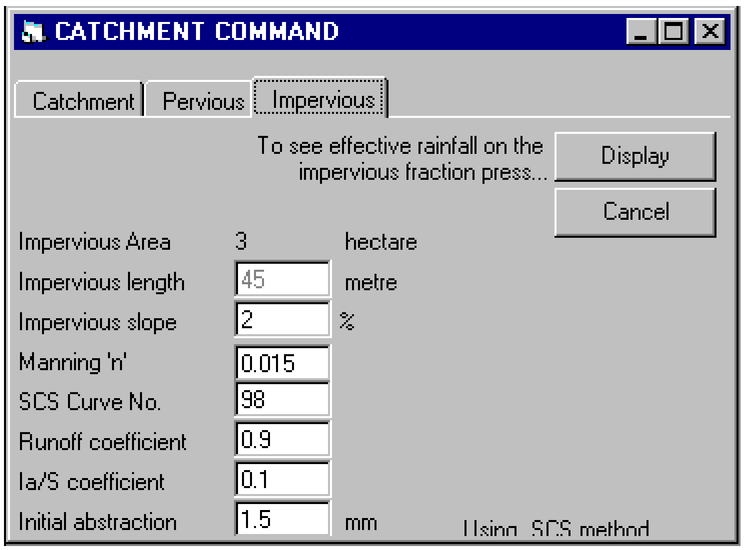


Figure 3.23 – Data required for the impervious fraction (SCS method selected)

Figure 3-23 displays the catchment data form when the Impervious tab has been clicked. You can see the other parts of the form in Figures 3-24 and 3-25.

The form shows the parameters required to define the rainfall losses when the SCS Infiltration model is selected. The required infiltration parameters will change with the selection of infiltration model. To change the infiltration option you must use the Option buttons in the Infiltration method frame on the Pervious tab. When you return to the Impervious tab your choice is shown on the lower right corner of the form.

The area of the impervious fraction is indirectly defined in terms of the total area and the percentage of impervious surface. You can change this from the Catchment tab.

Definition of the Impervious flow length can be done either explicitly or can be indirectly defined by the option choice for Pervious and Impervious flow length in the Catchment tab form.

Impervious Flow Length

There are three options to specify the overland flow length on the pervious and impervious areas.

- Use the same length for both
- Make the length proportional to the percentage of the area
- Specify the lengths

Refer to Figure 3-20 Overland Flow length for more details.

Impervious Slope

The default value is the same as the average overland slope for the total area. However, you can specify a different value if you wish.

Impervious Manning 'n'

Estimates vary widely depending on the surface and depth of flow.

Surface	**'n'**
Very smooth asphalt	0.013
Very smooth concrete	0.015
Normal concrete	0.02
Rough concrete, paved areas	0.04
Rough paved areas with flow depth < 5 mm or 0.2 inch	0.10

Impervious Data for SCS Infiltration

When the SCS Infiltration option is selected you have some choice as to how the required data values are entered. The basic parameter is the SCS Curve number CN which depends on the type of surface.

As an alternative, you can define a value for the volumetric runoff coefficient. This will cause the equivalent SCS CN value to be computed for the current rainfall event and displayed. Likewise, entry of a SCS CN value causes the equivalent runoff coefficient to be computed and displayed.

Another important parameter is the depth of the initial abstraction. This can be specified explicitly or you can provide a coefficient to define the initial abstraction as a fraction of the storage potential S which is a function of CN. See Pervious Data for SCS infiltration for further details.

Impervious SCS Curve number

A totally impervious surface has a CN = 100. However, many apparently impervious surfaces have a small but finite degree of perviousness due to cracking or porosity. Suggested values are shown below.

Surface	CN
Well laid asphalt	100
Jointed concrete paving	99
Paved roads & parking lots	98
Well compacted gravel	91-96

Impervious Ia/S Ratio

This ratio indirectly defines the Initial Abstraction as a fraction of the potential storage depth S. Since S is very small for an impervious surface it is difficult to define Ia/S with accuracy. For example if CN=98 then S = 5.2 mm (0.2 inch) so that Ia/S might reasonably be between 0.2 and 0.3.
It is often easier to define the initial abstraction directly as a depth. If you do this MIDUSS 98 will compute the corresponding value of Ia/S as a function of S.

Impervious Initial Abstraction

For impervious surfaces this value may range from 0.5 - 1.5 mm (0.02 - 0.06 inch) depending on the type and steepness of the surface. It is roughly equivalent to the surface depression storage.

Impervious Data for Horton Equation

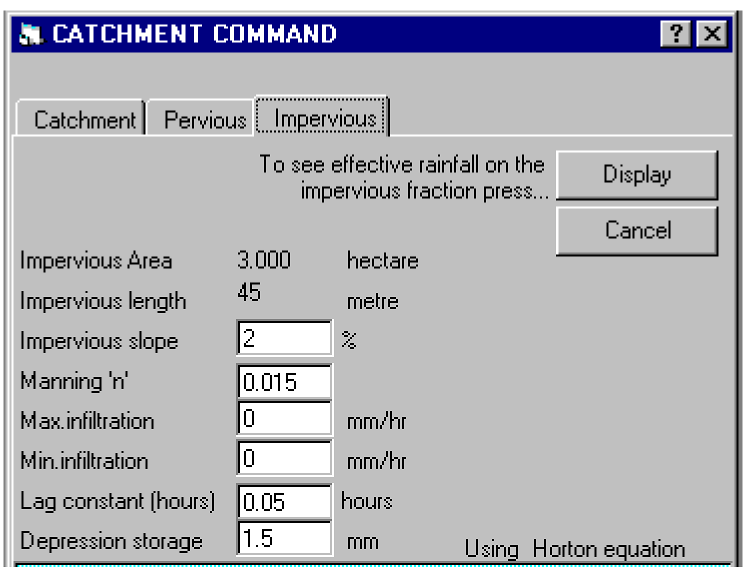


Figure 3-24 – Data required for impervious fraction (Horton method selected)

The Horton Infiltration option requires four parameters to compute the rainfall losses. These are:

The initial infiltration rate

The final infiltration rate

The exponential decay time constant

and The surface depression depth

For a more complete understanding of the method you should refer to the section in Chapter 7 *Hydrological Theory*; The Horton Equation.

Horton f_o for Impervious Areas

For impervious surfaces f_o is usually zero or a very small value such 2 mm/h (0.08 inch/h)

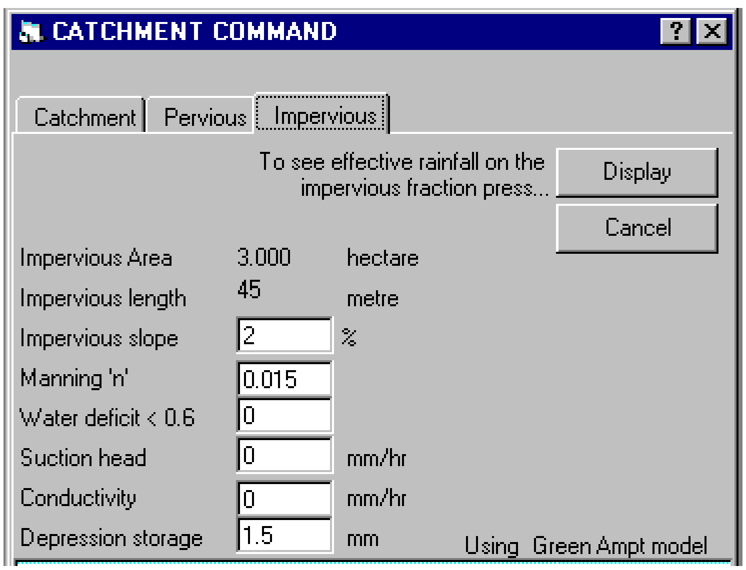
Horton f_c for Impervious Areas

For impervious surfaces the value of f_c should be zero.

Impervious Surface Depression Storage

See the general topic on Surface Depression Storage.

Impervious Data for Green & Ampt Method



`Figure 3-25 – Data required for the impervious fraction (Green and Ampt method selected)

The Green & Ampt Infiltration option requires four parameters to compute the rainfall losses. These are:

The initial soil moisture deficit

The suction head across the wetting front

The hydraulic conductivity in the soil

and The surface depression storage

For a more complete understanding of the method you should refer to the sections in Chapter 7 *Hydrological Theory* which deal with the Green and Ampt method and also the Green and Ampt Parameter Evaluation.

Impervious Water Deficit

For impervious surfaces the soil moisture deficit is normally equal to or very close to zero.

Impervious Suction Head

For impervious surfaces the suction head is zero.

Impervious Hydraulic Conductivity

For impervious surfaces the hydraulic conductivity is usually negligible.

Impervious Surface Depression Storage

See the general topic on Surface Depression Storage.

Lag and Route Command

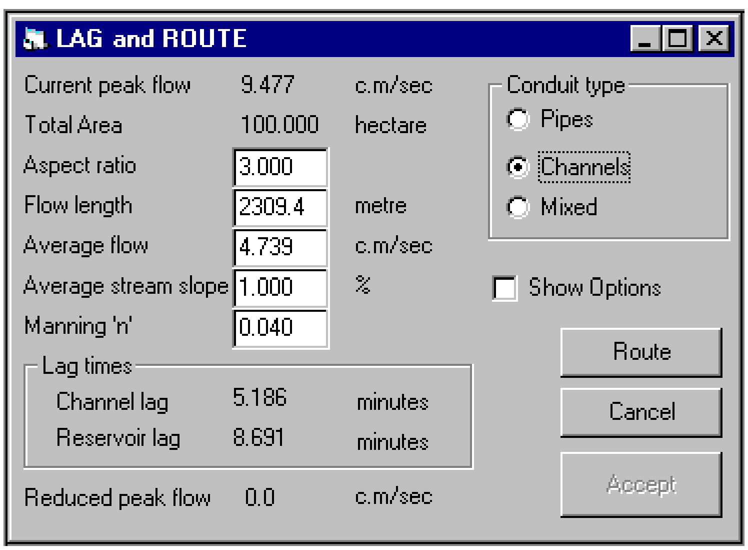


Figure 3-26 – Data entry for the Lag and Route command

The Lag and Route option of the Hydrology menu is enabled only after the Catchment command has been completed and the direct runoff hydrograph has been accepted by pressing the [Accept] button. It is likely that you may want to use this only if the catchment area is quite large - typically over 60 ha or 150 acres.

A typical sequence of steps is as follows:

Set the Catchment Aspect Ratio.

Adjust the estimate of longest drainage path if desired.

Adjust the average flow if desired.

Adjust the average slope if desired.

Adjust the conduit roughness if desired.

Select an option for Conduit Type - Pipes, Channels or Mixed

Change the Lag and Route Options

The Lag and Route Operation

This option lets you simulate a very large, reasonably homogeneous catchment as a single area while still using reasonable values for the overland flow length, slope and roughness. This is achieved by routing the direct runoff hydrograph (generated by the Catchment command) through a hypothetical linear channel and linear reservoir.

The method is largely undocumented and has been developed only for use within the MIDUSS 98 package. You are therefore advised to experiment with the method to satisfy yourself that it is possible to reproduce the results of a highly discretized catchment with reasonable accuracy. This should be done before applying it for the first time to a job of any importance.

The data required is used to estimate the total time of travel of a water particle from the most remote point on the catchment drainage network to the outflow point. This is done by approximating the longest path of pipes or channels as the sum of the two edges of an equivalent rectangular area and assigning a slope and roughness to it. More details are provided in the section on Chapter 7 *Hydrological Theory*; Large Catchment Simulation.

These values are clearly rather coarse approximations and are intended as guidelines. A better estimate of length should be available from mapping of the area.

In addition to the data entry boxes, the form also displays the current peak flow and the total area of the last catchment area defined. For the current default values the lag of the linear channel and linear reservoir are displayed in minutes.

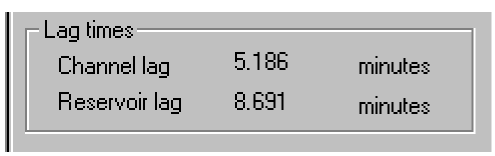


Figure 3-27 – The lag times are estimated from the approximate data provided.

These values are altered indirectly by changing any of the other parameters. However, if you wish to experiment by setting the lag times explicitly, you can select the ‘Show Options’ check box and click on the ‘Select lags explicitly’ check box. (See Figure 3-36). The default value used for the Manning's 'n' roughness depends on whether the drainage network is predominantly pipes or channels.

When the [Route] button is pressed the reduced peak flow is displayed on the form. Also shown is a graphical display of the initial direct runoff hydrograph and the modified runoff hydrograph. The modified runoff is also shown in a tabular display.

You can continue to change any of the parameters and see the effect on the graphical or numeric displays. When satisfied you can press the [Accept] button which causes the summary peak flows table to be updated and the other forms are closed.

Since acceptance of the Lag and Route results changes the Runoff hydrograph permanently, the menu item is disabled until another use of the Catchment command generates another direct runoff hydrograph.

Catchment Aspect Ratio

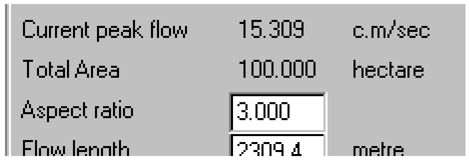


Fig 3_28 – The catchment aspect ratio is used to estimate the longest flow path

The total catchment area is copied from the last use of the Catchment command. The aspect ratio is used to compute the sum of the dimensions of an equivalent rectangle which is used as an approximate estimate of the longest drainage path in the network draining the catchment. By changing the aspect ratio you can indirectly modify the estimate of the longest flow length.

Next step - confirm or change the flow length.

Longest Flow Length

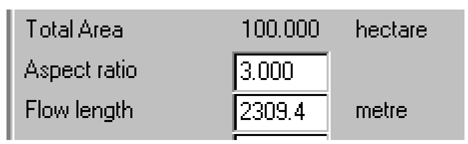


Fig 3-29 – The longest flow path can be edited if you have data.

This value is an estimate of the longest drainage path in the network draining the catchment and initially shows a value based on the total area and the aspect ratio of the catchment. You may change this if you can provide a better estimate.

Longer drainage paths result in longer times of concentration which in turn leads to increased lag times and increased attenuation of the flow peak.

Now confirm the time-averaged flow at the outlet.

Average Flow for Lag & Route

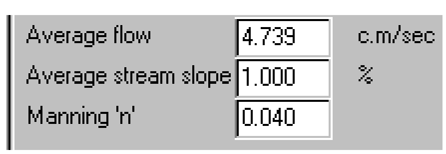


Figure 3-30 – Setting the time-averaged flow

The peak flow of the direct runoff hydrograph is known from the Catchment command. This parameter is intended to provide an estimate of the time-averaged flow at the outflow point from the catchment drainage network. The flow is assumed to vary linearly from this value at the outflow point to a negligible flow value at the furthest upstream point in the drainage network.

Next, set the average slope of the drainage path.

Average Conduit Slope for Lag & Route

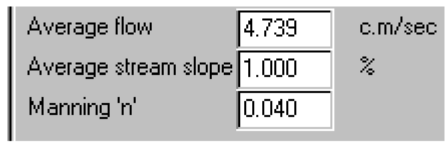


Figure 3-31 – Estimate the average conduit slope

You should provide an estimate of the average conduit slope in the longest drainage path. An initial default value of 1% is displayed but this may be too steep for a catchment which is drained predominantly by channels. Flatter slopes result in longer time of concentration which in turn leads to increased lag times and greater reduction of the flow peak.

Next, accept or modify the assumed conduit roughness.

Conduit Roughness for Lag & Route

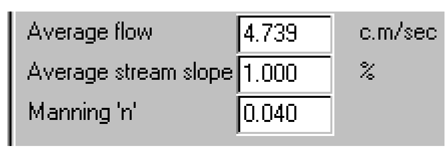


Figure 3-32 – Setting the conduit roughness

The default values for Manning's " *n* " are set as follows:

Pipes	*n* = 0.014
Channels	*n* = 0.04

The value displayed depends on whether the conduit type option is set as Pipes or Channels. If a mixed type is selected the value is "grayed out". You can change these by selecting either Pipes or Channels as the Conduit Type and then typing in a preferred value in the "Manning's 'n' " data entry box.

For suggested values refer to 'Manning Roughness for Pipes', or 'Channel Parameters' in Chapter 4 – *Design Options Available*.

The final step before pressing the [Route] button is to select the conduit type which best describes the drainage network.

Lag & Route through Pipes

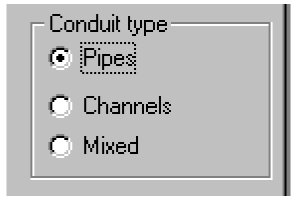


Figure 3-33 – Specifying the conduit type

The frame "Conduit Type" contains three option buttons. You can choose to model the catchment assuming the runoff is drained in pipe conduits which have a free surface. MIDUSS 98 assumes the pipes to be 75% full.

If the area is drained mainly through open channels select Channels as the conduit type.

Lag & Route through Channels

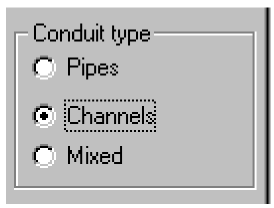


Figure 3-34 – Defining the drainage conduits as channels

The Frame "Conduit Type" contains three option buttons. You can choose to model the catchment assuming the runoff is drained in open channels. MIDUSS 98 assumes that the channel cross-section is triangular with a side-slope of 3H:1V. You can change the assumed side-slope by clicking on the 'Show Options' check box.

If the drainage network contains both pipes and channels select Mixed Conduits.

Lag & Route through Mixed Conduits

For a large catchment area , it is frequently not reasonable to assume that the entire area is drained with only pipes or channels. If you select the "Mixed" option, MIDUSS 98 assumes that the upstream (1-X)% of the drainage length is open channel and the downstream X% is in pipes. The value of " X " is initially set equal to the percentage of impervious area which was defined when the catchment was defined but you can of course change this.

Figure 3-35 – You can modify some of the option values

You can change these assumptions by clicking on the 'Show Options' check box.

The percentage of pipe length and whether it is upstream or downstream of the channel section of the flow length can be defined. If you want to refine the definition of "mixed conduits" adjust the Lag and Route Options.

Lag and Route Options

Clicking on the "Show Options" check box opens (or closes) several data entry objects that let you customize the default parameters used in the Lag and Route procedure. These are related mainly to conduit characteristics on which the time of concentration depends.

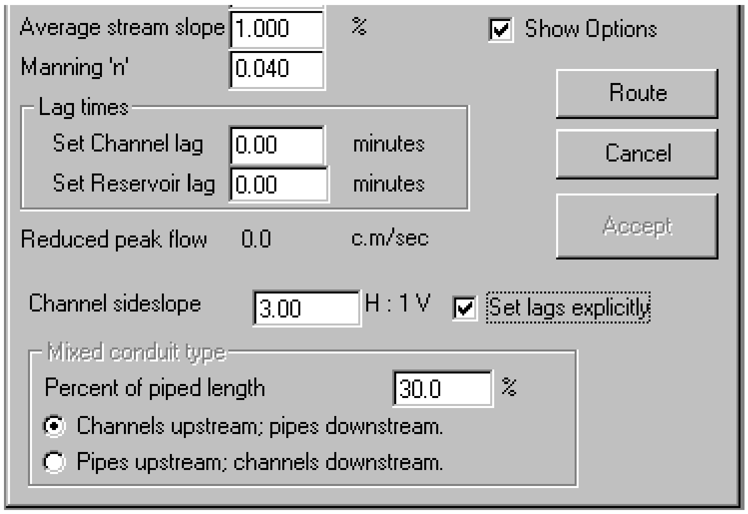


Figure 3-36 – Setting the Lag and Route options

You can change:

- The channel side slope
- The percentage of flow length in pipes (Initially set equal to the percent impervious of the catchment)
- The sequence of pipes and channels - e.g. pipes upstream or downstream

Note that the options related to the Mixed Conduit which are contained within the frame "Mixed Conduit Type" are enabled only when the "Mixed" Conduit Type option is selected.

At any time you can press the [Route] button to see the result of the Lag and Route operation.

The Lag and Route Operation

Figure 3-37 – Result of the Lag and Route operation

Pressing the [Route] button causes the reduced peak flow to be displayed as shown, a graphic display of the original Runoff and the modified Runoff is displayed and a tabular display of the modified hydrograph is shown.

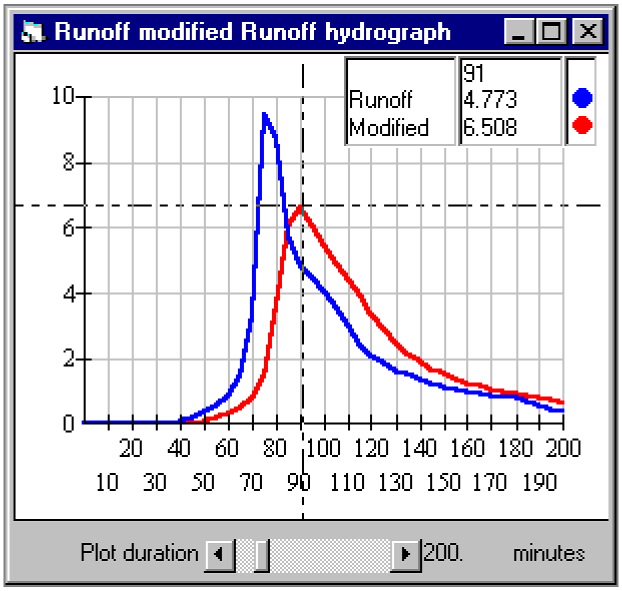


Figure 3-38 – Graphical comparison of the runoff hydrographs

You can experiment by changing some of the parameters to find the sensitivity of the result to the input data.

The Inflow hydrograph is stored in the Backup array to allow the modified Runoff hydrograph to be stored in the Inflow hydrograph array to allow graphical comparison.

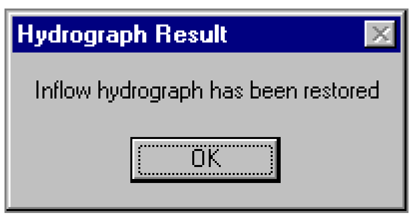


Figure 3-39 – The Inflow is restored when the operation is accepted

Thus when you are satisfied and press the [Accept] button the Runoff hydrograph will be overwritten and you will see the message shown in Figure 3-39 advising that the Inflow hydrograph has been restored.

If you press the [Cancel] button on the main form, both the Runoff and Inflow hydrographs are restored to their original values.

Baseflow Command

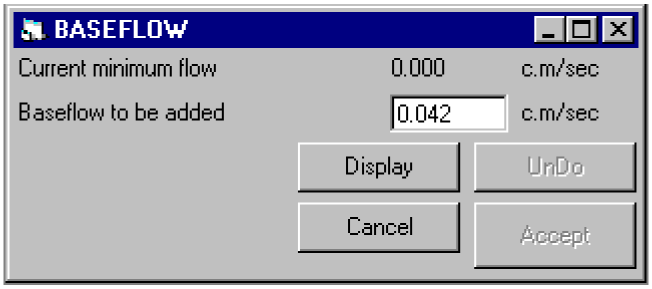


Figure 3-40 – Adding baseflow to the Inflow hydrograph

The direct runoff hydrograph generated by the Catchment command will normally start from zero even if the initial rainfall intensity is finite. This command allows you to add a constant baseflow amount to the inflow hydrograph.

The command is enabled only after the inflow hydrograph has been created by means of the **Hydrograph/Add Runoff** option of the hydrograph menu. The form is shown above and displays only two items of data.

The "Current minimum flow" is the smallest value in the Inflow hydrograph and is reported to indicate if baseflow has been added at a previous stage in the modelling.

You are prompted to enter a constant flow rate which is to be added to every ordinate in the Inflow hydrograph.

This is one of the few cases in MIDUSS 98 in which a negative quantity can be defined. This allows a previously applied baseflow to be removed. Obviously, if a negative value is used it cannot be arithmetically greater than the current minimum flow.

Chapter 4 - Design Options Available

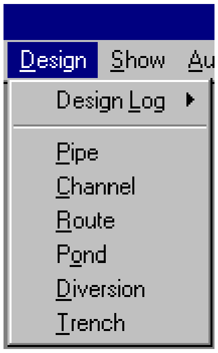


Figure 4-1 - The Design menu

Scope of Design

One of the most valuable features of MIDUSS 98 is the ability to design conveyance and storage elements in the drainage network. Design of these elements is facilitated by one of the commands Pipe, Channel, Pond, Trench or Diversion. In addition, a sixth command in the Design menu called Route carries out a flood routing analysis of the current inflow hydrograph through the most recently designed pipe or channel. Reservoir routing is an integral part of the Pond command.

Pipe Circular pipes running full (*i.e.* surcharged) or part full under conditions of uniform flow.

Channel Open channels of simple or complex cross-section under conditions of uniform flow. Simple cross-sections can be trapezoidal, triangular or rectangular. More complex, arbitrary cross-sections can be drawn as a series of straight lines joining points the coordinates of which can be edited during the design process.

Pond Detention ponds with arbitrary characteristics of discharge as a function of depth and storage volume as a function of depth. Outflow control characteristics can be described by a combination of weirs and orifices and stage-storage characteristics can be automatically generated for a number of special shapes such as multi-layer ponds, oversized sewers or "super-pipes" or, pyramidal shapes in the vicinity of catchbasins. Rooftop storage can also be simulated

Diversion Diversion structures which split the inflow hydrograph into outflow and diverted hydrographs.

Trench Exfiltration trenches of finite slope and general trapezoidal cross-section with one or more solid or perforated pipes can be designed for different soil and groundwater conditions.

Route The Route command carries out a flood routing operation of the current Inflow hydrograph in the most recently designed pipe or channel.

Pipe and channel flood routing is carried out by a kinematic wave method similar to the Muskingum-Cunge technique, involving the automatic calculation of the spatial weighting parameter by a procedure developed by Smith (1980). Reservoir routing is carried out by the Storage Indication method which is discussed in most hydrology texts but with an additional check for numerical stability in the neighbourhood of highly nonlinear storage - discharge relationships.

When the Diversion command is used, the diverted hydrograph is written to a file which can subsequently be read in to the inflow hydrograph array by means of the **Hydrograph/FileI_O** command to allow design of the diverted branch to be continued.

Further details of the design methods are presented in the individual discussions that follow. Some background theory on the hydraulics used in these design options is contained in Chapter 8 - *Theory of Hydraulics*

Before proceeding to the design options take a moment to review the procedure for updating the Inflow hydrograph

Updating the Inflow Hydrograph

MIDUSS 98 treats each pipe, channel, pond, diversion structure or trench as a link in the drainage system. These links form a tree-shaped network joining a set of nodes (points or junctions) at which overland flow may enter the drainage system.

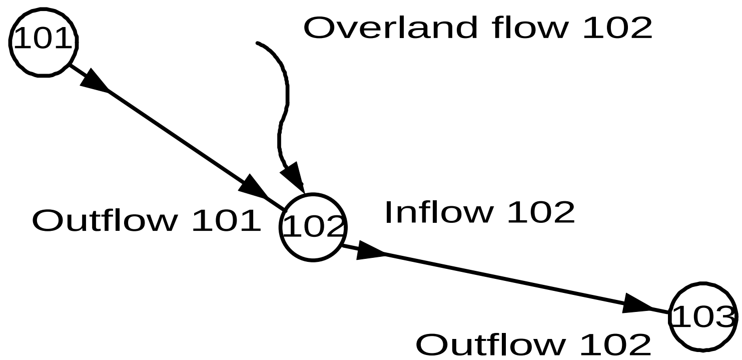


Figure 4-2 – A node and link numbering convention

Figure 4.2 illustrates a very simple system comprising 3 nodes and 2 links. MIDUSS 98 uses the convention that links are assigned the same number as the node at its upstream end. Thus, in the figure link #102 joins node 102 to node 103.

Before the link downstream of a node can be designed, any overland flow hydrograph entering at that point must be added to the current inflow. Again with reference to Figure 4.2, the hydrograph labelled 'Overland flow 102' must be added to 'Outflow 101' to make 'Inflow 102' before link #102 can be designed. This is done by means of the **Hydrograph/Add Runoff** command.

After completing the **Hydrology/Catchment** command described in Chapter 3 *Hydrology Used in MIDUSS*, the next logical step is the **Hydrograph/Add Runoff** command. If you use the **Options/Show Next logical menu item**, MIDUSS 98 opens up the **Hydrology** menu and places the mouse pointer at the **Add Runoff** command.

If you try to design a pipe, channel *etc* without using the **Add Runoff** command MIDUSS 98 will warn you that you may be making a mistake. However, this is only a warning and if you persist in trying to use one of the design options described in this chapter, MIDUSS 98 will bow to your superior knowledge and let you have your way.

Pipe Design

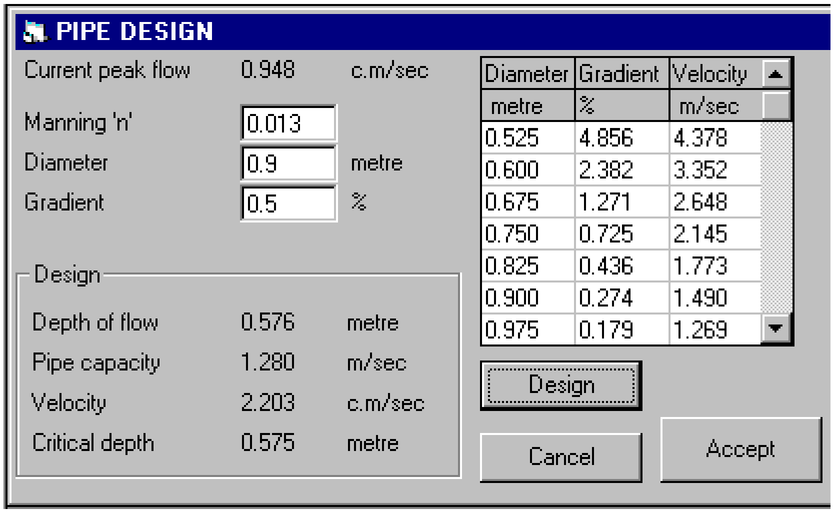


Figure 4-3 – The pipe design form

This is one of the five commands (Pipe, Channel, Pond, Trench and Diversion) used to design a link in the drainage network. It helps you to select the diameter (metres or feet) and gradient (%) of a circular pipe to carry the peak flow of the current inflow hydrograph. The command involves four steps.

- Choose a value for Manning's 'n' Accept or modify the current default values for Manning's 'n'.
- Review feasible diameter - gradient values Review a set of diameter-gradient values using a range of commercially available pipe diameters which will carry the peak flow with the pipe flowing full-bore.
- Specify diameter and gradient Select design values for the proposed pipe diameter and gradient and compute the depth and average velocity of part-full uniform flow in the designed pipe.
- Accept the design Accept the design or modify any one of the design parameters specified in step (1) or modify the design entered in step (3).

If a surcharged condition is found, MIDUSS 98 reports the slope of the hydraulic grade line instead of the free surface depth. See the item on Surcharged Pipe Design later in this chapter for more details. Refer also to the Pipe Design Log which may serve as a useful reminder if you are interrupted during the MIDUSS 98 session.

You can use the Pipe command to design a pipe even if an Inflow hydrograph has not been created. See Pipe Design for Steady Flow for details.

Manning roughness for Pipes

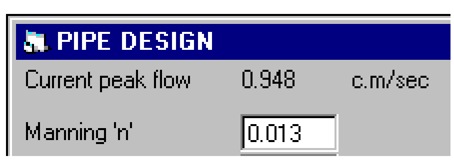


Figure 4-4 – Specifying the Manning 'n' roughness value.

MIDUSS 98 uses only the Manning "n" value to define roughness. Values depend on the type and condition of the pipe material and suggested values can be found in many texts. The table below provides a few typical values.

Description	**"n"**
Metal pipe - spun concrete lining	0.007
Wrought iron	0.008
Smooth pre-cast well jointed concrete	0.009
Uncoated cast iron; well-aligned glazed vitrified clay	0.01
Spun concrete	0.011
Monolithic concrete; rough pre-cast concrete; butt-jointed drain tile; slimed sewers	0.013
Pre-cast pipes with mortar squeeze at joints; well pointed brickwork	0.015
Old brickwork; foul sewers with grease, lime encrusted or sludge	0.019

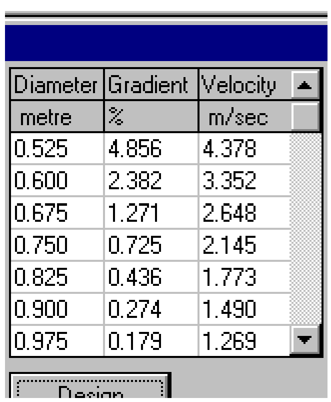
Manning "n" for corrugated pipes is dependent on diameter, especially for smaller diameters. A rough guide is given by:

$n = 0.014 + 0.02$ (D in metres) for $D < 0.4$ m

$n = 0.020 + 0.002$ (D in metres) for $D > 0.4$ m

Once the roughness is set you can review Possible Pipe Designs

Possible Pipe Designs



Diameter	Gradient	Velocity
metre	%	m/sec
0.525	4.856	4.378
0.600	2.382	3.352
0.675	1.271	2.648
0.750	0.725	2.145
0.825	0.436	1.773
0.900	0.274	1.490
0.975	0.179	1.269

Figure 4-5 – MIDUSS 98 displays a table of feasible designs.

For the currently defined peak flow and roughness MIDUSS 98 displays a small table showing feasible values of diameter, gradient (%) and average velocity. This provides a guide for a non-surcharged design which will produce an acceptable average velocity.

You can now enter a trial pipe design.

A Trial Pipe Design

You can enter trial values for diameter and gradient in two ways. You can type desired values in the appropriate text boxes as you did for Manning "n". Alternatively, if you double-click on one of the rows of the table the values will be copied but the gradient will be rounded up to the nearest 0.1%. In Figure 4-6 the gradient has been rounded up from 0.274% to 0.3%.

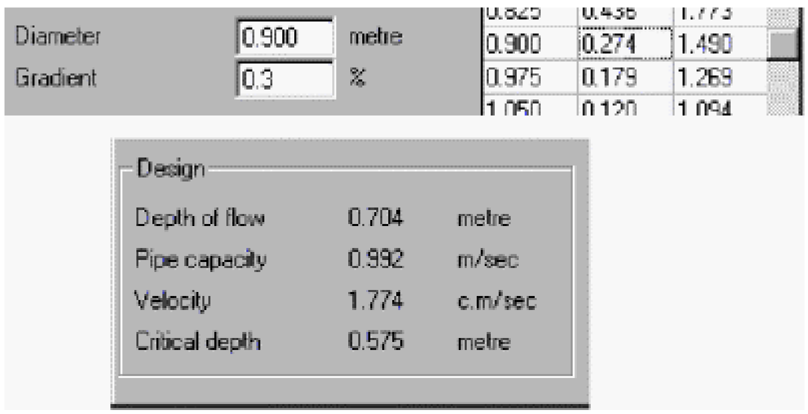


Figure 4-6 – Copying a trial design (top) and viewing the results

Once the diameter and gradient have been set, press the [Design] button to produce the results as shown in Figure 4-6. MIDUSS 98 reports the depth of uniform flow, the pipe-full capacity, the average velocity and the critical depth. The results in Figure 4-6 (bottom) show that the velocity is rather high. If the normal depth is less than critical the flow will be supercritical with the probable result of a hydraulic jump at some point downstream.

If the pipe is surcharged the design information reports the hydraulic gradient in place of the depth of uniform flow,

You can experiment with different values for diameter, gradient or roughness until you are satisfied with the design.

The final step is to Accept the Pipe Design

Accepting the Pipe Design

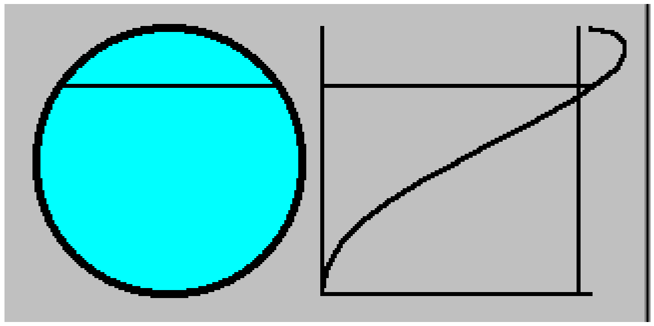


Figure 4-7 – A graphical depiction of the pipe design.

As well as numerical results, MIDUSS 98 displays a simple sketch showing the relative depth in the pipe and the corresponding curve of relative discharge (i.e. flow /full-pipe capacity). If you are satisfied with the design, press the [Accept] button to save the design and close the window.

Your design is saved and also your various trials are shown on the Pipe Design Log.

The Pipe Design Log

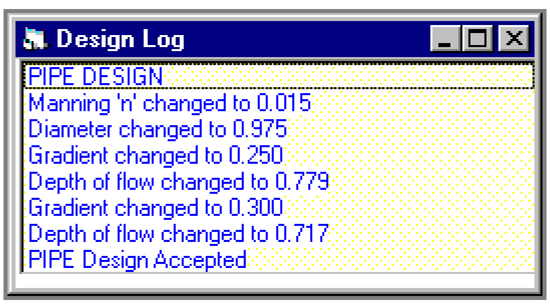


Figure 4-8 - A typical design log for a pipe design

If you experiment with a number of alternative designs you may find it useful to refer to a log which is maintained by MIDUSS 98. This log is usually located in the top right corner of the screen and appears for each of the design functions. A design log is of more value for facilities (such as the Pond design) in which many parameters are involved. However, it is included for Pipe design for completeness. The contents of the log file can be accumulated and saved or printed out at any time.

Surcharged Pipe Design

If the diameter or gradient is insufficient to convey the peak flow the pipe will be surcharged. In this case you will see the value of the pressurized hydraulic grade line instead of the uniform flow depth. Also the critical depth is not feasible and is shown as zero. The pipe capacity will be seen to be less than the peak inflow reported at the top of the window.

You will also see a warning message as shown in Figure 4-9 below. In some situations you may want to accept the surcharged condition. Such a case might be when the pipe is designed for a 5-year storm but you want to see the impact of a more severe (say 100-year) event. In this case you should press the [OK] button and then accept this design by pressing the [Accept] button. You can then use the Design/Diversion command to separate the minor and major flow. If surcharge is not acceptable press the [OK] button and then change the design until an acceptable design is obtained.

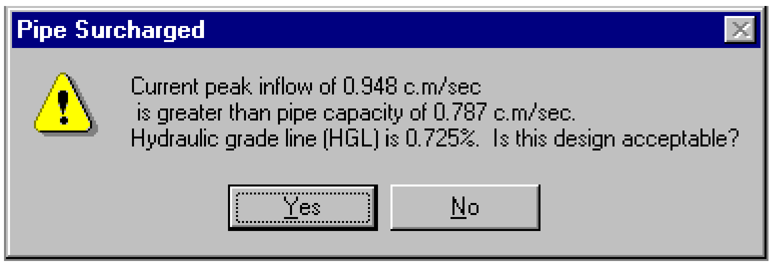


Figure 4-9 – Warning following a surcharged pipe design.

Pipe Design for Steady Flow

The **Design/Pipe** command is one of the few menu items which are enabled as soon as the system of units is defined. This lets you use the Pipe command to design a pipe for any flow that you specify.

If no Inflow hydrograph has been created the Pipe window opens with a text box against the "Current peak flow" which lets you specify a flow rate instead of simply displaying the current peak inflow. You can then design a pipe without having to do any hydrological simulation.

Figure 4-10 – If no inflow hydrograph exists you can specify the design flow.

The only difference is that a text box is opened against the prompt "Current peak flow". Type in a value and the table of feasible designs will be filled. You can then proceed as usual.

Channel Design

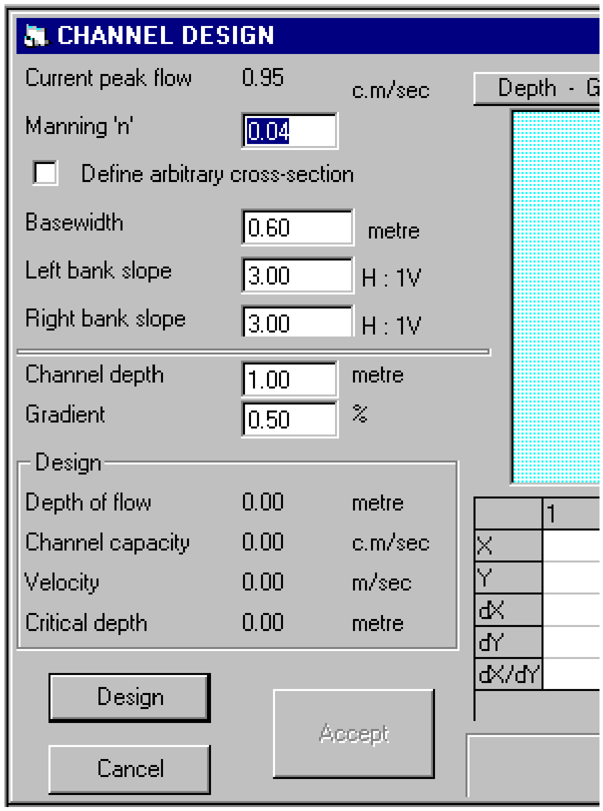


Figure 4-11 – Data required for a simple channel design

This is one of the five commands (Pipe, Channel, Pond, Trench and Diversion) used to design a link in the drainage network. The Channel design can be used to design two types of cross-section - a simple generalized trapezoidal shape, or a more complex, arbitrary cross-section.

Trapezoidal sections. In this mode the command is quite similar to the **Design/Pipe** command and involves four steps.

Set values for roughness, base width and side slope.

Review a table of Feasible Designs

Select values for the overall depth and gradient

Accept or Modify the design

Complex sections. The procedure is generally the same but the channel shape is defined by drawing a set of straight lines between points the coordinates of which can be edited to refine the design. Refer to the topic on Switching to a Complex Section for more details.

Set Parameters for the Trapezoidal Channel

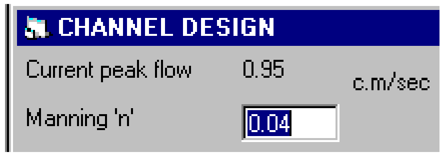


Figure 4-12 – Setting the Manning 'n' value for the channel

A value for Manning "n" must be entered in order for the table of feasible designs to be shown. The initial default value as shown here is 0.04. The table below shows some suggested values for different types and conditions of channel. Notice that the roughness for channel flow is very different from that for overland flow.

Description	"n"
Concrete lined, screeded and smoothed	0.014
Gunite concrete, not smoothed with sandy deposits	0.018
Irrigation canal in hard-packed smooth sand	0.020
Canal excavated in silty clay	0.024
Channel with cobble stone bottom	0.028
Natural channel with fairly regular cross-section	0.035
Natural channel, irregular section, grass slopes	0.040
Dredged channel, irregular side slopes, grass and weeds	0.050
Irregular channel with dense growth, little foliage	0.080
Irregular channel with dense growth, with much foliage and vegetation	0.110

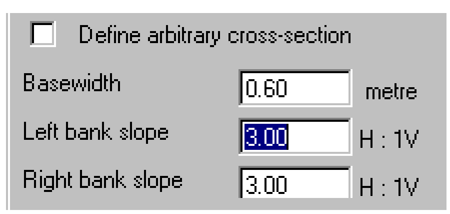


Figure 4_13 - Defining a trapezoidal cross-section.

The base width and side slopes are self-explanatory. By selecting appropriate values, trapezoidal, rectangular or triangular sections can be defined. You will find that a trapezoidal section can often be a good approximation for a natural channel. Negative (i.e. overhanging) sideslopes are not allowed with the trapezoidal cross-section.

With flow and roughness defined you can now Review the Feasible Designs

Review Feasible Depths and Gradients

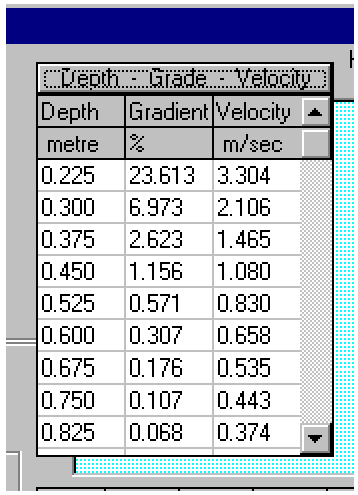


Figure 4-14 – MIDUSS98 displays a table of feasible designs

Pressing the large "Depth - Grade - Velocity" button causes a table of feasible designs to be displayed or hidden. The table depends on a flow rate and roughness being defined. By double clicking on a row of the table the depth and gradient are copied to the text boxes for channel depth and gradient. However, these designs do not provide much allowance for freeboard and you will usually need to either increase the overall depth and/or steepen the gradient.

The next step is to select a Channel Depth and Gradient

Select Channel Depth and Gradient

Figure 4-15 – Entering a trial design

Enter trial values for overall depth and invert gradient in the text boxes shown in Figure 4-15.

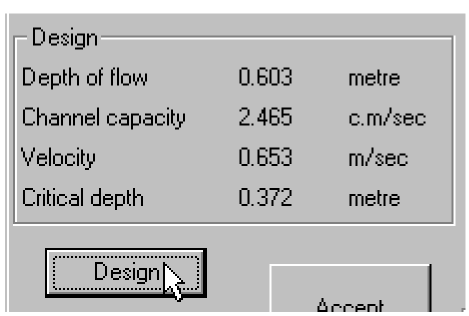


Figure 4-16 – Results of a trial design.

Then by clicking on the [Design] button as shown, the results of the uniform flow analysis are displayed. In addition to the normal depth and velocity, the channel capacity and the critical depth are displayed.

If you define a channel with insufficient capacity you will receive a warning as shown below. In such cases MIDUSS 98 completes the design by calculating the depth assuming that the sides are extended at the defined side slope. MIDUSS 98 will not let you "Accept" a design like this as the Route command cannot be used.

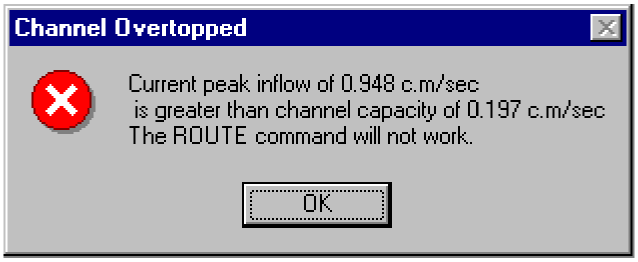


Figure 4-17 – Warning for an overtopped channel.

When satisfied you can Accept the Channel Design

Accept the Channel Design

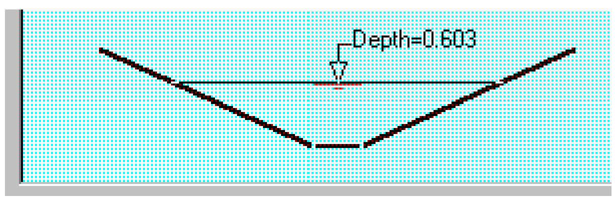


Figure 4-18 – Rsults of a trapezoidal channel design

In addition to the results displayed in the 'Design' frame', MIDUSS 98 plots the cross-section and computed water surface in the graph window on the right of the form. For a trapezoidal section the water surface elevation is plotted assuming the channel invert to be zero.

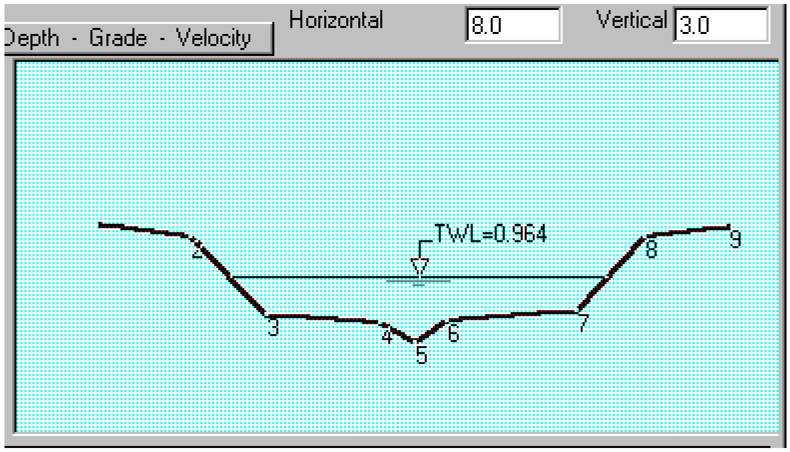


Figure 4-19 – Results of a complex cross-section channel design

For the complex section the water surface is plotted to the same vertical datum used by the coordinate system when you first sketched the cross-section.

If you want to switch to a complex cross-section click here.

Switching to Complex Section

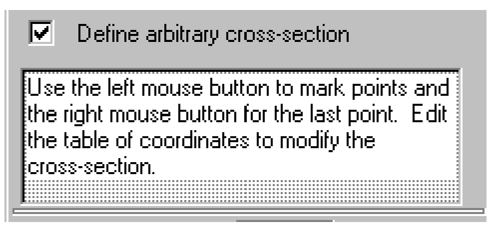
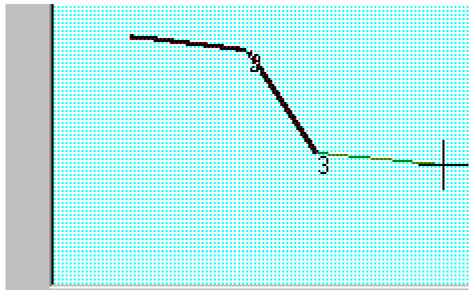


Figure 4-20 – Selecting the complex cross-section option

To design a complex channel cross-section the first step is to click on the check box labelled "Define arbitrary cross-section". The space previously used for the base width and side slopes of the trapezoidal section is covered by an information window reminding you how to draw the cross-section

Now you can start Drawing a Complex Cross-section.

Drawing a Complex Channel Section



	1	2	3	4	5	6
X	-0.01	1.47	2.33	3.96		
Y	2.00	1.86	0.90	0.79		
dX		1.48	0.87			
dY		-0.13	-0.96			
dX/dY		-11.14	-0.90			

Figure 4-21 – Drawing the channel cross-section

Once you have selected the "arbitrary cross-section" option the graph drawing window is enabled and you will see that the mouse pointer changes to a small cross-hair when it is over the window. The origin of the graph window is near the lower left corner with coordinates (0.0, 0.0). The window coordinates extend from –10% to +90% of the defined scale range. You can select a series of points by clicking with the primary (**left)** mouse button for all but the last point. The figure shows the first 3 points with the mouse pointer about to set point 4. The X and Y coordinates of the mouse pointer are shown in the table.

It is important that **you work from left to right**, although overhanging banks can be defined. With the second and subsequent clicks a straight line is plotted from the previous point. When you reach the last point click on the secondary (**right)** mouse button to signal the end of the section.

If the X and Y-scales are not correct for the size of channel you want to draw you can change these at any time (except while drawing the cross-section) by typing in the width and height you want the graph window to represent.

You may notice an initial line drawn from the origin to point 1. This will be removed in subsequent displays.

Once the section has been drawn you can examine the coordinates of the Complex section .

Coordinates of the Complex Section

	1	2	3	4	5	6	7	8	9	1
X	0.05	0.97	1.74	2.90	3.25	3.58	4.90	5.59	6.45	
Y	1.39	1.29	0.66	0.59	0.43	0.61	0.69	1.29	1.37	
dX		0.92	0.77	1.16	0.35	0.33	1.32	0.69	0.85	
dY		-0.10	-0.63	-0.06	-0.16	0.18	0.08	0.60	0.08	
dX/dY		-9.41	-1.22	-17.89	-2.13	1.83	16.32	1.15	10.54	

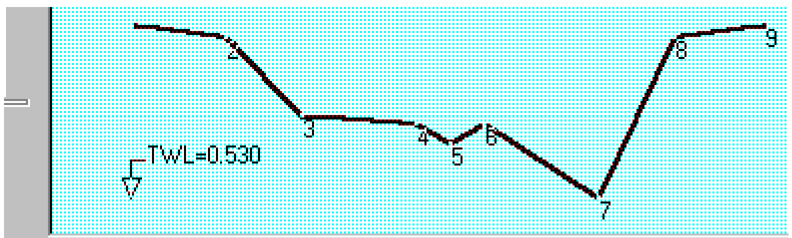
Figure 4-22 – The coordinates of a complex cross-section can be edited

As each point is defined the coordinates are displayed in the table below the graph window. As you move the mouse pointer the X and Y coordinates change to indicate the current position and are fixed when you press the mouse button.

For the second and subsequent points the X and Y coordinates are supplemented by the incremental change dX and dY for the preceding line segment and also the slope of the line dY/dX (i.e. dY/dX=0.0 means horizontal). These values can be used to adjust the shape of the section without having to work out specific X and Y values.

Unless you have been very careful, it is likely that the cross-section is not exactly what you want, or you may need to modify it for the purpose of your design. You therefore need to Edit the Coordinates.

Editing the Coordinates



	1	2	3	4	5	6	7	8	9	10
X	0.05	0.97	1.74	2.90	3.25	3.60	4.76	5.53	6.45	
Y	1.39	1.29	0.66	0.59	0.43	0.59	0.	1.29	1.39	
dX		0.92	0.77	1.16	0.35	0.35	1.16	0.77	0.92	
dY		-0.10	-0.63	-0.06	-0.16	0.16	-0.59	1.29	0.10	
dX/dY		-9.41	-1.22	-17.89	-2.13	2.19	-1.97	0.60	9.13	

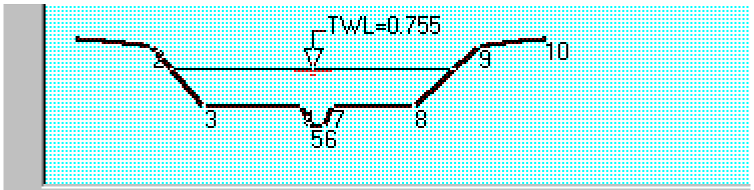
Figure 4-23 – Editing the elevation of point #7

Figure 4-23 shows the effect of editing the coordinates. Clicking on the cell for Y7 makes it the active cell. Alternatively, you can move around the grid by pressing the arrow keys. To change the value in the cell you can either re-type the value or position the cursor and use the Back Space key to delete and replace a character. In the figure, the user has deleted the '69' from the Y7 value making it zero. This is reflected in the plot of the section. Now by typing '66' the value of Y7 is made the same as that for Y3 and the plot of the section is restored..

You may need to increase the width of the channel and you can do this by changing the dX value for a point that is simply the width of the preceding line segment. If this makes the section too wide for the graph window you can fix this by adjusting the Graphic Scales.

This editing ability is particularly useful if you need to Widen a Channel cross-section.

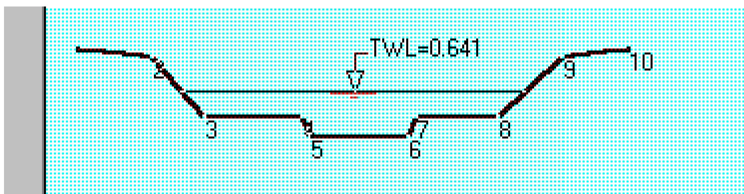
Widening the Channel



	1	2	3	4	5	6	7	8	9
X	-0.59	0.35	1.01	2.26	2.36	2.54	2.64	3.68	4.50
Y	1.03	0.96	0.39	0.39	0.20	0.20	0.39	0.39	0.96
dX		0.94	0.66	1.25	0.10	0.18	0.10	1.04	0.81
dY		-0.08	-0.57	0.00	-0.19	0.00	0.19	0.00	0.57

Figure 4-24 – Preparing to widen the low-flow channel

After defining a cross-section you may find you need to widen the low flow channel. You can do this easily by editing the 'dX' value for the appropriate line segment. The two figures show an increase in width of the line segment (5)-(6) from 0.18 to 1.25 as shown in the cell outlined in red. The 'X' values of all points to the right of point 5 are increased and the section is re-plotted.



	1	2	3	4	5	6	7	8	9
X	-0.59	0.35	1.01	2.26	2.36	3.61	3.71	4.75	5.57
Y	1.03	0.96	0.39	0.39	0.20	0.20	0.39	0.39	0.96
dX		0.94	0.66	1.25	0.10	1.25	0.10	1.04	0.81
dY		-0.07	-0.57	0.00	-0.19	0.00	0.19	0.00	0.57

Figure 4-25 – Changing dX between points #5 and #6 widens the entire channel

If you widen the channel you may find the plot is wider than the current window. This can be fixed easiy by Adjusting the Graphic Scales.

Adjusting the Graphic Scales

Figure 4-26 – The scale factors of the drawing window can be changed

The initial values of the scaling factors are X=10 m (30 ft) and Y=3.5 m.(10 ft) depending on the system of units selected. You can change these at any time, **except** when you are in the middle of drawing a cross-section.

Once you are satisfied with the design you can accept the Channel design.

Channel Design for Steady Flow

The **Design/Channel** command is one of the few menu items which are enabled as soon as the system of units is defined. This lets you use the Channel command to design a channel for a user specified flow.

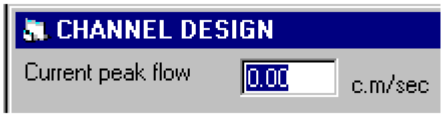


Figure 4-27 – The design flow can be entered if no Inflow hydrograph exists

If no Inflow hydrograph has been created the Channel window opens with a text box against the "Current peak flow" instead of simply displaying the current peak inflow. This lets you specify a flow rate and you can then design a channel without having to do any hydrological simulation. Type in a value and the table of feasible designs will be displayed. You can then proceed as usual.

Routing the Inflow Hydrograph

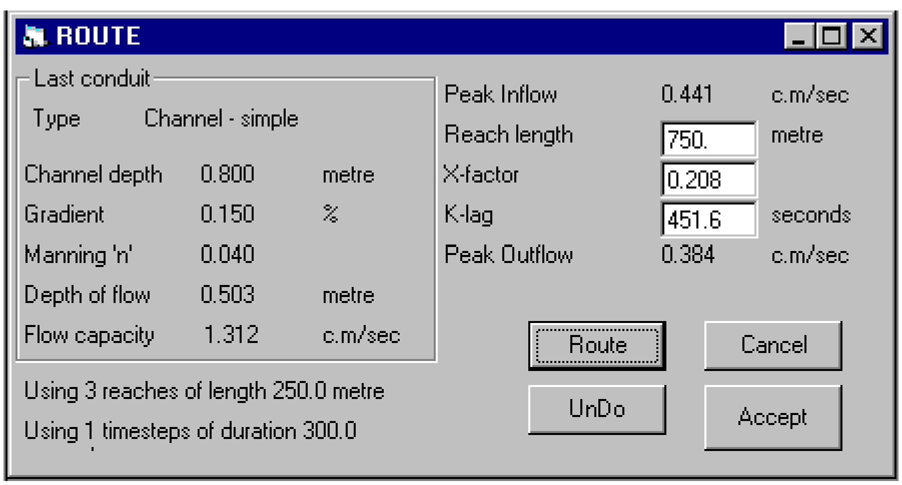


Figure 4-28 – Data required for the Route command

The **Route** command carries out a flood routing analysis of the current Inflow hydrograph through the most recently designed pipe or channel. The technique used is the Muskingum method with the modification that the weighting parameter X that defines the significance of the wedge-storage effect is computed by a method proposed separately by Cunge (1969) and Smith (1980). (Click to see References) The background theory of the Modified Muskingum method is described in Chapter 8

Theory of Hydraulics – Theory of Kinematic Flood Routing.

MIDUSS 98 remembers whether the last link designed was a pipe or a channel. If neither a pipe nor a channel has been designed the Design/Route menu item is disabled.

The command involves the following four steps.

Check Parameters of Last Conduit	The properties of the last pipe or channel are displayed along with the peak inflow and the flow capacity of the conduit.
Specify a Conduit Length	You are prompted to supply the length of the reach (metres or feet).
The Muskingum Routing parameters	K and X are estimated and displayed for you to either accept or modify.
Review and Accept the Results	The inflow hydrograph is routed through the reach and the peak outflow is displayed. You can review the results and accept them when satisfied.

If the reach length is zero the inflow hydrograph is copied to the outflow hydrograph. Very short but non-zero reach lengths may result in rather long execution times. For reaches of zero or negligible length you can use the **Hydrograph/Copy Inflow to Outflow** command.

Conduit Parameters for Route

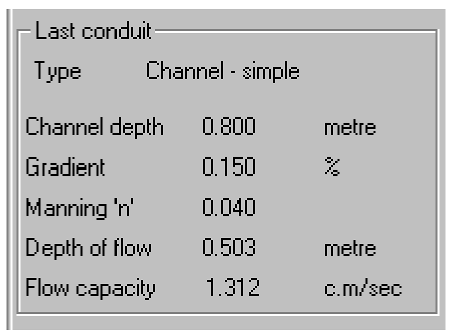


Figure 4-29 – Data for the last designed conduit is displayed.

The information displayed at the start comprises the pipe or channel geometry, roughness, gradient and uniform flow depth. The peak value of the inflow hydrograph and the pipe or channel capacity are also shown. If a pipe is surcharged, the inflow hydrograph is copied to the outflow hydrograph with no attenuation or lag. If a channel is overtopped, a warning message is displayed and the outflow hydrograph is left equal to the inflow hydrograph.

Sometimes you may define a pipe or channel cross-section which is to remain unchanged for several links. Over this length the discharge may increase quite significantly due to runoff from one or more sub-areas. If you cause the inflow to be increased by means of the **Hydrograph/Add Runoff** command and then proceed directly to the **Route** command MIDUSS 98 will continue to use the last-defined pipe or channel but will update the uniform flow analysis to obtain the correct depth and velocity. If this happens you will see the informative message shown in Figure 4-30 below and the new depth of flow will be shown in the 'Last Conduit' frame.

Figure 4-30 – Information message provided by the Route command.

However, if you increase the flow to a value in excess of the pipe or channel capacity the computed depth of uniform flow will exceed the specified overall depth and routing will be impossible. You will see a message advising you to re-design the pipe or channel with an increased flow capacity.

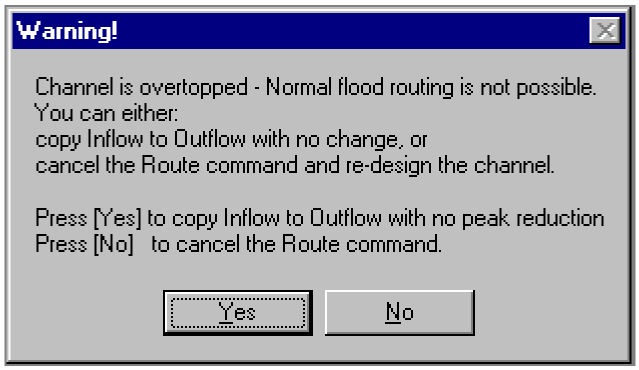


Figure 4-31 – A warning is displayed if the channel is overtopped.

Usually your next step will be to specify the Reach Length of the Conduit.

Conduit Length for Route

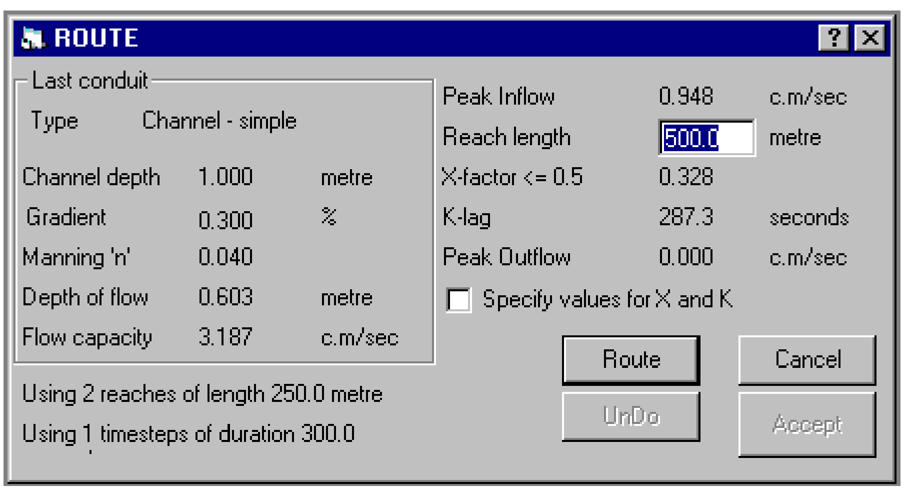


Figure 4-32 – Data used by the Route command

The reach length is specified simply by typing the value in the text box. When you do so the Muskingum routing parameters are computed and displayed as the values for 'X factor' and 'K-lag'. If you wish to specify your own values for these parameters you can check the box labelled 'Specify values for X and K' and the labels will be changed to text boxes so that you can modify them if you wish. However, it is not likely that you will be able to improve on the estimate made by MIDUSS 98.

If you enter a zero value for the reach length MIDUSS 98 ignores the rest of the calculation and simply copies the Inflow hydrograph to the Outflow. A message will be displayed and the [Accept] button will be enabled.

Before pressing the Route button it is probably wirth looking briefly at the Muskingum Routing Parameters which have been estimated.

The Muskingum Routing Parameters

For the specified reach length the lag K is computed using a celerity which is the average of the flow velocity and the kinematic wave velocity for the peak discharge.

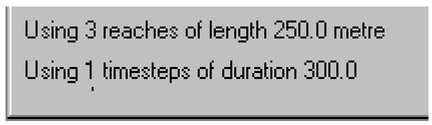


Figure 4-33 – Changes required for numerical stability are reported

When a finite reach length is specified MIDUSS 98 also checks on the numerical stability of the calculation and, if necessary, uses sub-multiples of the time step or the reach length to ensure stability. The result of this adjustment is displayed below the 'Last conduit' frame as illustrated in Figure 4-33.

It can be shown (see eq. [8.41] in Chapter 8) that numerical stability of the Muskingum method requires that the spatial weighting coefficient X must satisfy the condition $X <= \delta t/2K <= (1-X)$ where δt is the routing time-step. For very short reaches this criterion requires a routing time step δt which is a sub-multiple of the hydrograph time step Δt (*i.e.* $\delta t = \Delta t/n$). Similarly, very long reaches are divided into sub-multiple reaches and multiple Muskingum routing is used. If multiple reaches are used you are informed and the lag K is displayed with an appropriate multiplying factor. The routing time step δt is also displayed. These checks for numerical stability are performed automatically by MIDUSS 98 and you do not need to take any special action. Chapter 8 *Theory of Hydraulics* contains a full description of the method of calculating these parameters.

For the cases encountered in storm water drainage the values of X will usually be in the range 0.4 to 0.5. Lower values of X result in greater attenuation.of the peak discharge.

The estimated values of X and K are displayed and you have the opportunity to either accept these or modify one or both values. Once the values are accepted the routing operation is performed and the peak outflow is displayed. At this point you can either accept the results obtained or return to the previous step at which the Muskingum routing parameters can be further modified. .Assuming you wish to accept the values suggested by MIDUSS 98 all you need to do is press the [Route] button.

You can now review the results and decide if these are acceptable.

Review and Accept Routing Results

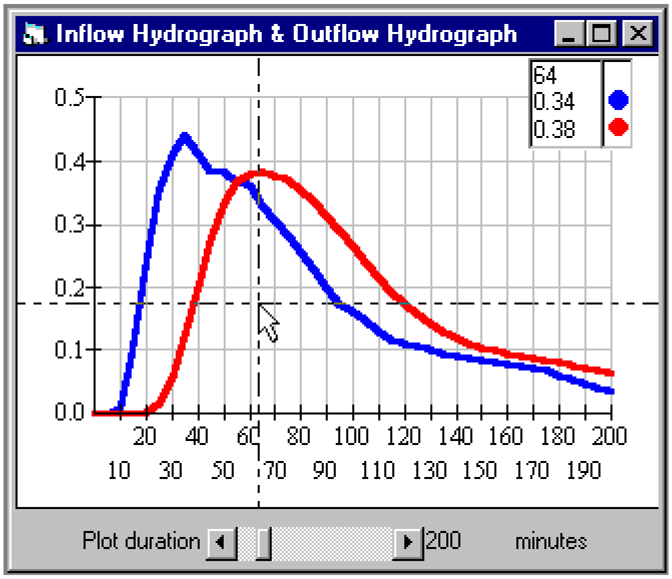


Figure 4-34 – Inflow and Outflow hydrographs following the Route command.

The best way to judge the result of the routing operation is from the graphical display as shown in Figure 4-34. The peak outflow is shown in the Route window and the modified Outflow hydrograph is displayed in a tabular form. However, the picture is what will provide a feeling of comfort or concern.

You can, of course, experiment with different values of the controllable variables and press [Route] again to see what difference this causes in the result. Once satisfied you can press the [Accept] key to save the design. The summary table of peak flows is updated to reflect the result.

Pond Design

In order to reduce the impact of urbanization it is common practice to provide storm water management in the form of a detention facility which reduces or 'shaves' the peak of the runoff hydrograph to an acceptable value. The actual facility may take a variety of forms such as:-

- an 'in-line' pond comprising a storage area with an outflow control device through which drainage occurs for all storm events.
- an 'off-line' storage chamber to which storm water is diverted when the water surface in a channel or the hydraulic grade line in a pipe rises above some elevation.
- roof-top storage on flat roof tops of industrial or commercial developments using flow control devices at the top of rainwater downpipes.
- parking lot storage on peripheral areas of large parking surfaces around shopping malls using inlet control devices in catchbasins.

The method is particularly effective in reducing the peak flow values of the 'peaky' hydrographs which result from large impervious areas.

In all of these facilities the principal of design is to provide a storage area which is normally dry and which fills rapidly when the runoff rate increases above a certain value. At any instant in time the rate of change of storage represents the difference between the inflow rate and the attenuated outflow.

Figure 4.35 illustrates a typical detention pond with an outflow control device comprising an open-topped box with an orifice in the upstream face. Floods of modest size are passed through the orifice but more extreme events cause overtopping of the weir around the upper edge of the box.

The inflow and outflow hydrographs for a typical event are also illustrated. The maximum storage volume is indicated by the shaded area between the two curves. Note also that the peak of the outflow hydrograph lies on the falling limb of the inflow hydrograph. At the instant when storage (and water level) reaches a maximum the inflow and outflow must be equal. Click Main Steps for more.

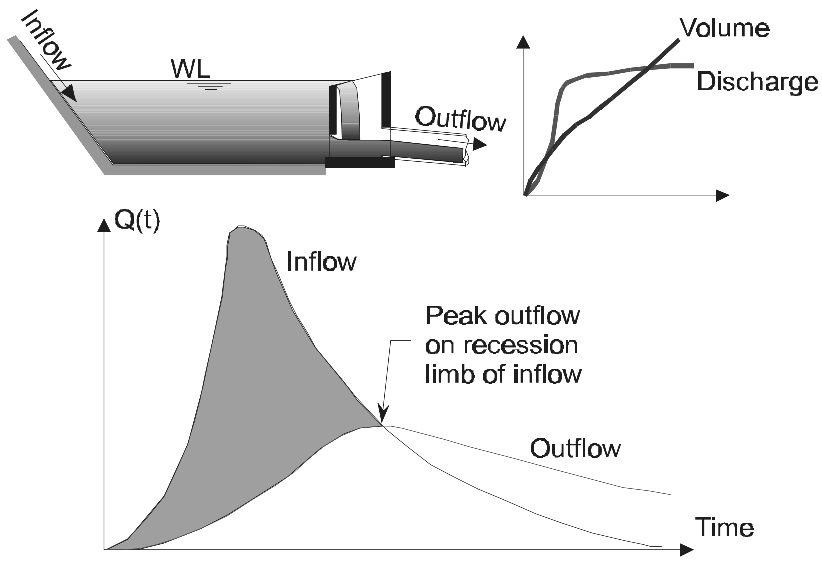


Figure 4-35 - An illustration of reservoir routing.

Pond Design - Main Steps

The POND command helps you to determine the proportions and discharge characteristics of a detention pond with the object of attenuating the peak flow in a link of a drainage network to an acceptable value. As with the other design commands in this chapter, the design comprises four steps.

- Specify the desired peak outflow and determine an approximate storage volume which might achieve this.
- Set up a table to define the Depth - Discharge and Depth -Storage volume relationships for the proposed pond. The discharge and storage functions must start from zero and increase monotonically. Miduss 98 contains a number of special commands to help you to define the Depth - Discharge - Storage values for a variety of standard outflow control devices and storage units of different geometry.
- Route the inflow hydrograph through the proposed pond and get peak values of outflow discharge, pond depth and storage volume.
- Accept or reject the design. If rejected, edit the Depth Discharge and Storage table or the associated control devices and repeat step (3) with the revised configuration until an acceptable design is achieved.

Many of the options available in the Pond command are accessed through a special menu which is enabled when the **Design/Pond** command is selected. Refer to the topic **The Pond Menu** later in this chapter to see a summary of the main features of this menu.

A logical series of steps is summarized in the following list of topics. You may use these in an order different than that shown but the sequence illustrated here is typical.

- Specify the target outflow
- Set the Number of Stages
- Minimum and Maximum Water Levels
- The Outflow Control Device
- Define an Orifice Control
- Define a Weir Control
- Plotting the H-Q Curve
- Defining Storage Devices
- A Single Stage Pond
- Describing a Pond with Multiple Stages
- Plotting Pond Storage
- Routing the Hydrograph
- Accepting the Pond Design

In addition to the general type of facility described in the above topics, the Pond command includes options for special types of stormwater management facility. You can review the main steps for these by referring to the topics below.

- Oversized Sewers (Super-Pipes)
- Parking Lot On-site Control
- Rooftop On-site Control

Oversized Sewers or Super-Pipes

Storage can sometimes be provided in the form of a reach of large diameter pipe, usually within a road allowance. The following sections describe the steps in designing this type of detention storage pond.

- Using a Super-Pipe for Storage
- Check the Storage Curve for the Super-Pipes
- View the Results of Super-Pipe Design

Some theoretical background is given in Chapter 8, *Theory of Hydraulics*; Super-pipes for Pond Storage

Parking Lot On-site Control

Commercial developments usually have a high percentage of impervious area (>75%) a large fraction of which is used for parking. Significant reduction in peak flows can be achieved by grading the parking area to form shallow storage areas around the catch-basins which drain the lot. The following steps describe how the pond command can be used to prepare a preliminary design for on-site control on parking areas.

Using Parking Lot Storage

Set linits on the Parking lot grading

Defining the Wedge Storage

Define the Parking lot Catchbasin Capacity

View the Results of parking lot Storage

Background theory on Wedges (or Inverted Cones) for Pond Storage is contained in Chapter 8 *Theory of Hydraulics*

Rooftop On-Site Control

The following steps describe how the Pond command can be used to design rooftop storage on large commercial buildings such as shopping malls and "big box stores".

Using Rooftop Storage

Generating the Rooftop Inflow

Target Outflow from the Roof

Desired Depth Range on the Roof

Parameters for the Rooftop System

Rooftop Discharge and Storage Characteristics

Rooftop Flow Routing

Graphing Rooftop Runoff

Design Tips for Rooftop Storage

Rooftop Error Messages

More detailed information can be fund in Chapter 8 *Theory of Hydraulics*; Rooftop Flow Control for Pond Storage

The Pond Menu

Figure 4-36 – A special menu is provided for the Pond design

When the Pond window is displayed (and has the focus as indicated by the coloured title bar) a special menu replaces the main MIDUSS 98 menu. It includes the following items most of which are discussed in more detail in the items which follow.

Main Menu Lets you return to the main MIDUSS 98 menu.

Storage Geometry displays items to compute storage volumes as a function of the stage H for various storage facilities such as a single or multi-stage pond, an oversized storm sewer (sometimes called a 'super-pipe') and wedge or pyramid shaped storage (such as a parking lot).

Outflow Control contains items to let you compute the stage-discharge values for one or more orifice controls and one or more weir controls.

Rooftops lets you define parameters relevant to rooftop storage

Plot lets you display various types of plot involving the depth (or stage), discharge and storage volume.

You can, of course, enter values directly into the grid of H, Q and V values in the Pond window. However, the tools provided will often provide a good estimate which you can refine if required.

Sometimes when the Pond window loses the focus to another window (such as a graph display or a data entry form) the main MIDUSS 98 menu is displayed in the menu bar. To see the Pond menu you need only click anywhere on the Pond window to restore it.

Specify the target outflow

MIDUSS 98 arbitrarily sets the target outflow to half the peak inflow. You will usually want to change this. Click on the text box at “Target outflow” to highlight the current value and type in the desired peak outflow that you would like to achieve for this hydrograph.

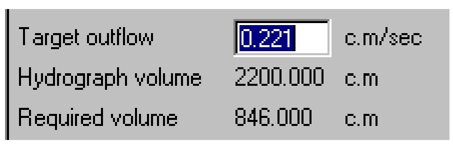


Figure 4-37 – Specify the target outflow to see an estimate of the required storage.

As shown in Figure 4-37, an approximate estimate of the required storage volume is displayed for information along with the total volume of the inflow hydrograph. The storage required will increase as the desired peak outflow is reduced.

The next step is to Select a Number of Stages or depths for the pond design.

Set the Number of Stages

The default number of stages or water levels used to describe the Depth - Discharge - Storage functions is set at 21. If you have changed this the latest value will be displayed.

Figure 4-38 – Up to 50 stages can be defined.

Click on the text box to highlight the current value. Type in a new value. The number of stages must be at least 3 and not more than 50. The default value of 20 depth increments will often be sufficient.

The next step is to set the Minimum and Maximum Water Elevations in the pond.

Minimum and Maximum Water Levels

The minimum and maximum water levels should be defined next.

Figure 4-39 – The range of depth is defined in terms of actual elevation.

Click on each of these data entry boxes and type in the desired value. The maximum level must be greater than the minimum water level. As you change these values the column of levels in the H-Q-V Table changes as long as the values are feasible (i.e. Maximum > Minimum)

After specifying the total depth the next step is to define an Outflow Control Device.

The Outflow Control Device

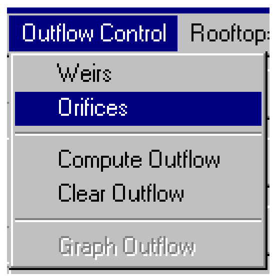


Figure 4-40 – The menu for the Outflow control

The outflow control device usually comprises a number of devices designed to control a wide range of outflow. By clicking on either of the first two items you can include as many as 10 orifices and 10 weirs. Usually only one or two of each is required.

It is normal to define the first orifice at the lowest level to control the low flows and then add another orifice or a weir at a higher level to handle the larger flows. Orifices require a much larger head to pass a significant discharge than with a weir. The result of combining an orifice and a weir is a very nonlinear stage-discharge curve.

Now you are ready to define a simple orifice control,

Define an Orifice Control

When you select the menu item **Outflow Control/Orifice** a grid table is displayed with four columns for Invert level, discharge coefficient, orifice diameter and the number of identical orifices. Initially no empty rows are displayed. Click on the 'Up-Arrow' of the Spin-Button to open up a row for the first orifice.

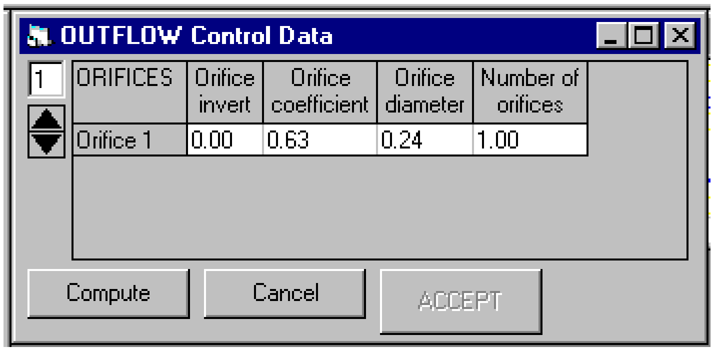


Figure 4-41 – Data required to define an orifice.

MIDUSS 98 displays suggested values showing the invert at the lowest water level, a coefficient of 0.63 and a diameter estimated to pass a reasonable fraction of the peak inflow. You can edit these values by selecting a cell by clicking the mouse pointer in it and then typing the desired value.

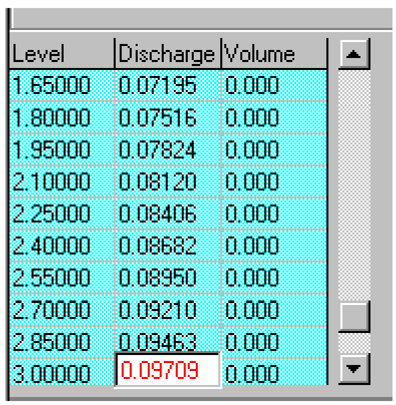


Figure 4-42 – Results after defining an orifice control.

When you are ready, press the [Compute] button. You will see the column of Discharge values fill up in the H-Q-V table. The maximum discharge corresponding to the maximum head or water level is highlighted as shown. You can edit the values in the Orifice data entry table and re-compute the discharge column until you are satisfied.

The [Accept] button is enabled when you press [Compute] and is disabled if you change the data. When ready, press the [Accept] button to accept this orifice design. This causes the highlighted cell to be restored to normal.

You can define other orifices at this stage but it is recommended that you start with one and then add other devices after you have seen the result of an initial Route operation.

You can see a plot of the stage discharge curve for the orifice you have just designed by using the Plot Command.

Normally to complete the outflow control device you need to define a Weir Control.

Plot the Orifice H-Q Curve

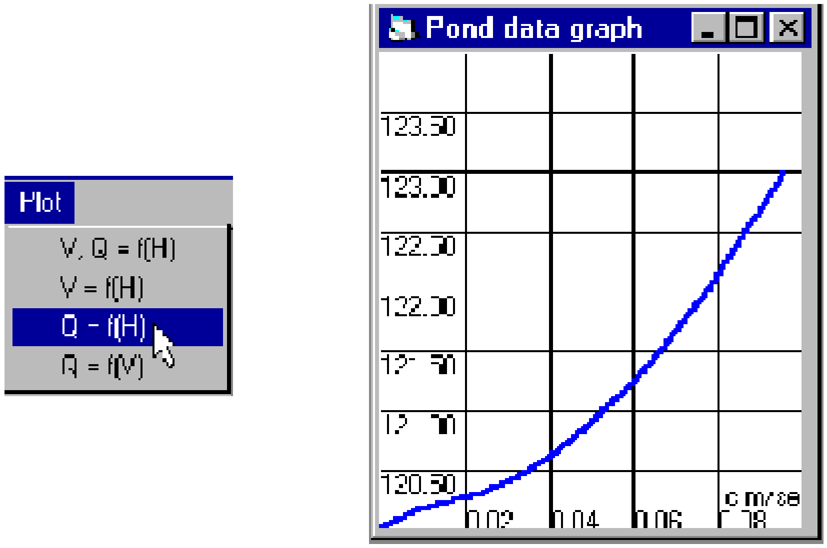


Figure 4-43 – Plotting the stage discharge curve for the orifice.

The plot menu offers several choices as shown. All but one of these plot one or more variables against elevation H. To see the stage-discharge curve for the current outflow control select the plot you require. If only an orifice has been defined so far, select the 'Q = f(H)' option.

A small graph is displayed as shown here for a single orifice located with its invert at the lowest water level. The slight change in curvature at the foot of the curve represents discharge when the water level is lower than the obvert or top of the orifice. This graph window can be re-sized as usual by dragging an edge or corner of the window.

This orifice will control low flows. To provide a control for more extreme events you should specify a weir control at a higher level. The next step is to define a Weir Control.

Define a Weir Control

When you select the menu item 'Outflow Control/Weir' the grid table displayed has five columns to let you specify the crest level, a discharge coefficient, the breadth of the horizontal crest and the left and right side slopes. Initially no empty rows are displayed. Click on the 'Up-Arrow' of the Spin-Button to open up a row for the first weir.

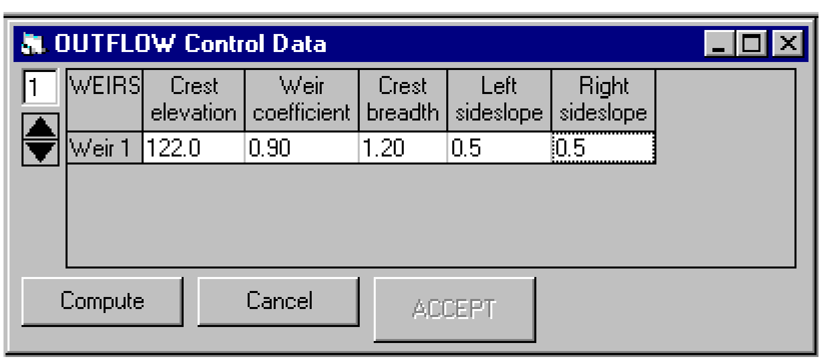


Figure 4-44 – Data required for a weir specification

MIDUSS 98 displays suggested values showing the crest elevation at roughly 75% of the total pond depth and a discharge coefficient of 0.9. The breadth is estimated to pass the peak discharge with a reasonable ratio of depth to breadth and the sideslopes are assumed to be vertical (i.e. 0.0). In Figure 4-44, the crest elevation has been changed from 122.4 to 122.0 m and the sides have been given a slope of 0.5 H:1V (or about 27 degrees from the vertical). These values can be edited by clicking the mouse pointer on the appropriate cell and then typing the desired value. You can move between cells using the left and right arrow keys.

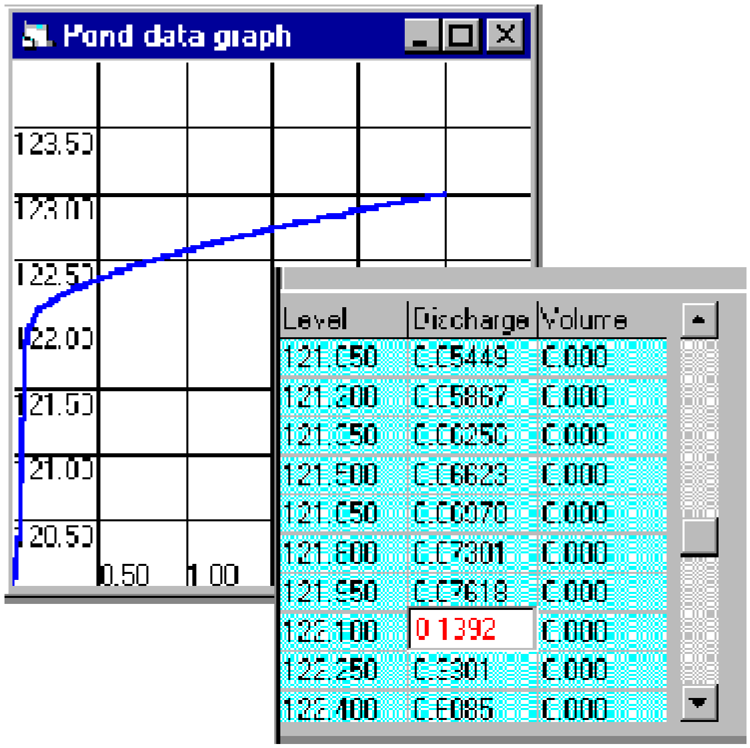


Figure 4-45 – Graphical and tabular results of adding a weir.

You can experiment by changing the parameters and pressing the [Compute] button with each change. With each trial you will note that in the HQV grid, the Discharge cell with a level above or equal to the crest elevation is highlighted and all discharges for levels above the crest will show an increased flow. Check to make sure that the maximum discharge (at the bottom of the grid) is close to or greater than the target outflow and not much less than the peak inflow otherwise you may get an error message when you attempt to Route the inflow through the pond.

If you have left the Plot window open, the graph of discharge is automatically updated with each change. The plot of Figure 4-45 shows the highly nonlinear relationship which results from the combination of orifice and weir.

Now that you have defined an outflow control device, the next step is to specify the storage characteristics of the pond. Click Defining a Storage Deviceto go to the next step or click here to return to the Main Steps of Pond Design

Defining Storage Devices

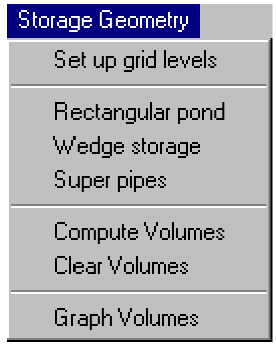


Figure 4-46 – The menu for the Storage Geometry command

Three types of storage device can be designed. These comprise:

- an idealized rectangular pond with any length to width aspect ratio and one or more stages or layers;
- storage in the form of an inverted cone which may form around a catch basin of a parking area, and
- storage in oversized storm sewers - sometimes called 'super-pipes'.

You can see further discussion and illustration of these various storage facilities in Chapter 8 *Theory of Hydraulics*; Typical Storage Components for Detention Ponds.

The most commonly used is a surface detention storage pond. The next step assumes that a Single Stage Pond is required (i.e. one with the same side slope over the full depth)..

A Single Stage Pond

When you select the menu item **Storage Geometry/Rectangular pond** the grid table displayed has five columns. These let you specify the base area, the length/width ratio at the base, the bottom and top elevations of the layer and the side slope which is assumed constant around the layer being defined. Initially no rows are displayed and you must click on the ‘Up-Arrow’ of the Spin-Button to open up a row for the first layer.

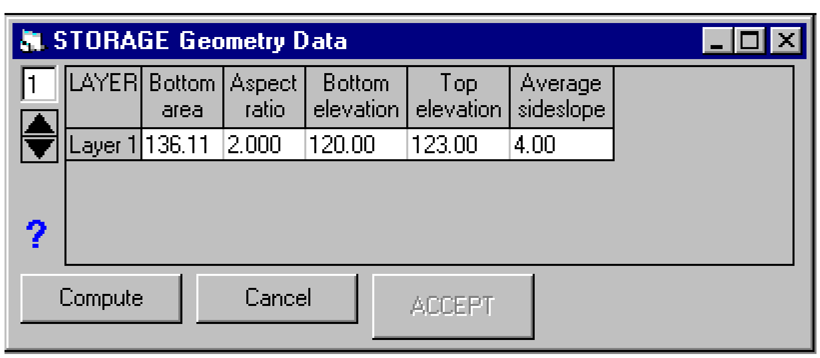


Figure 4-47 – Data required for a single layer rectangular pond.

MIDUSS 98 displays suggested values showing the rectangular area at the bottom of the pond. This is estimated from the target outflow to be achieved and is only approximate. The aspect ratio is set to 2.0. This will change for any upper layers depending on the side slope adopted. MIDUSS 98 assumes a single layer covering the total depth which you have specified and assumes also a bank side slope of 4H:1V for ease of maintenance or landscaping. All of these values can be edited by clicking the mouse pointer on the appropriate cell and then typing the desired value. You can move between cells using the left and right arrow keys.

Level	Discharge	Volume
1.65000	0.07195	589.929
1.80000	0.07516	690.159
1.95000	0.07824	800.028
2.10000	0.08120	919.968
2.25000	0.08406	1050.41
2.40000	0.08682	1191.79
2.55000	0.1965	1344.53
2.70000	0.3947	1509.08
2.85000	0.6505	1685.85
3.00000	0.9528	1875.29

Figure 4-48 – Result of defining a rectangular pond.

Press the [Compute] button to see the range of volumes which this design will produce. You can experiment by changing the parameters pressing the [Compute] button with each change. In the HQV grid, the Volume cell corresponding to the maximum depth is highlighted.

Frequently you may want to define a multi-layer pond which - for reasons of safety - has a much flatter bank slope for several metres above and below the normal water level. This is especially true if the pond is to have some permanent storage to provide some quality control. You can easily Define a Pond with Multiple Layers or Stages.

You can see a plot of storage as a function of depth by using the Plot Storage option in the **Pond/Plot** menu.

Describing a Pond with Multiple Stages

STORAGE Geometry Data

2

LAYER	Bottom area	Aspect ratio	Bottom elevation	Top elevation	Average sideslope
Layer 1	136.11	2.000	120.00	121.00	4.000
Layer 2	398.1	1.508	121.00	123.00	4.000

STORAGE Geometry Data

3

LAYER	Bottom area	Aspect ratio	Bottom elevation	Top elevation	Average sideslope
Layer 1	136.11	2.000	120.00	121.00	4.000
Layer 2	398.1	1.508	121.00	122.00	7.500
Layer 3	1234.3	1.264	122.00	123.00	4.000

Figure 4-49 – Adding extra layers to a rectangular pond.

To increase the number of layers defining a pond, click once more on the up arrow to reveal a second row in the table. As shown in Figure 4-49, the top of the first layer (circled in red) has been changed from 123.0 to 121.0. The bottom of the second layer is automatically adjusted to match the top of the layer below. In addition, the bottom area and the aspect ratio have been automatically re-calculated to match the corresponding values at the top of the first layer.

A third layer can be added in the same way. In the lower figure, the cells circled in red have been edited to set the depth of each of the three layers to 1.0 metre, and the bank slope of the second (middle) layer has been flattened to 7.5H:1V.

You can define up to 10 layers in this way. Often 3 or 4 are sufficient.

Plotting Pond Storage

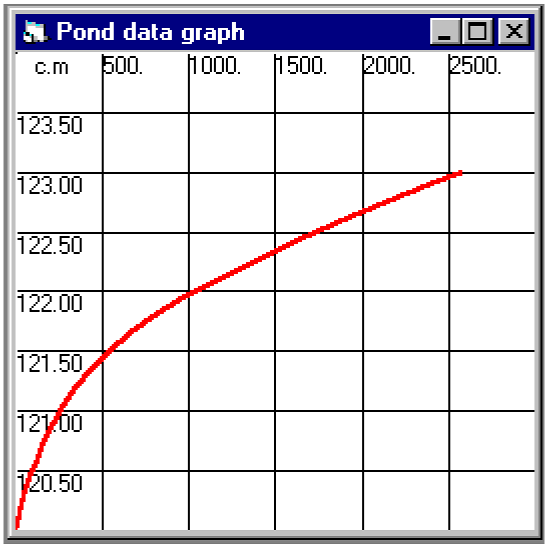


Figure 4-50 – A typical stage discharge curve for a rectangular pond

The **Pond/Plot** menu item lets you plot storage volume as a function of depth or - as illustrated in Figure 4-51 - you can plot both storage volume and discharge against depth or elevation on the same graph. If you are making changes to either the outflow control device or the storage facility the changes will be shown on the plot automatically as soon as you press the [Compute] button. Comparing the discharge and storage volume curves may be of interest if you plan to employ a flatter bank slope at or near the crest of the weir to reduce head over the weir for more extreme events.

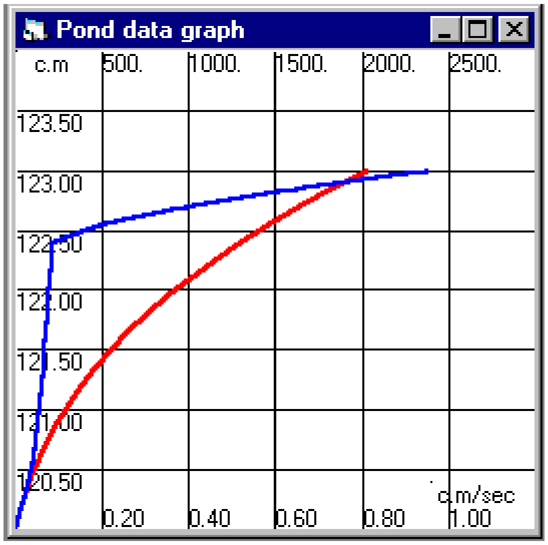


Figure 4-51 – Displaying a plot of discharge and storage

Although not shown here, you may also plot discharge Q as a function of the storage volume V. This will indicate the extent to which your design deviates from a linear reservoir. The estimates made in MIDUSS 98 for the required storage are calculated assuming a linear reservoir which accounts for differences between the initial approximate estimate and the results obtained from routing through the nonlinear reservoir.

Using a Super-Pipe for Storage

An alternative way to provide storage capacity to attenuate the peak flow of an inflow hydrograph is to use oversized storm sewers - sometimes referred to as "Super-Pipes". This is one of the options available in the **Pond/Storage Geometry** menu. A typical arrangement is shown in Chapter 8 *Theory of Hydraulics*; Super-Pipes for Pond Storage.

The data entry table shown in Figure 4-52 is similar to others used in the Pond command and contains columns for:

- the downstream invert level
- the length of the super-pipe
- the diameter of the pipe, and
- the gradient of the pipe.

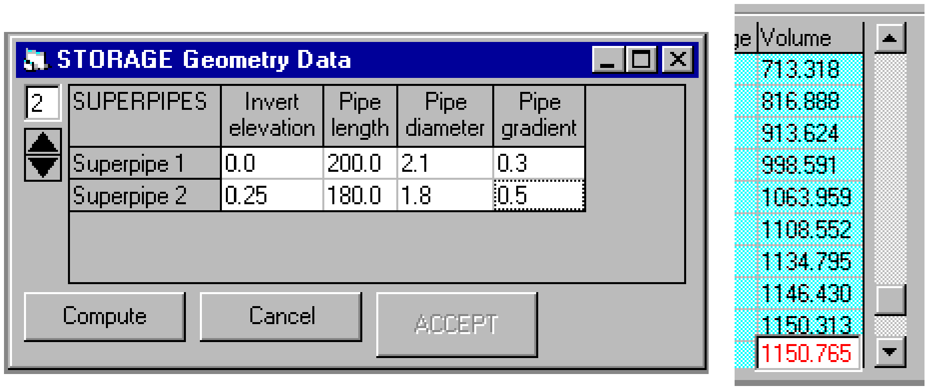


Figure 4-52 – Data required to define two superpipes and the resulting storage

Figure 4-52 shows two pipes presumably meeting at a junction manhole with diameters of 2.1 and 1.8 metres and slightly different values for invert level, length and gradient. It is important to install the pipes at a reasonably flat gradient in order to get maximum benefit from the potential storage.

On pressing the [Compute] button, the maximum potential storage (i.e. with a downstream water elevation of 3.0 m) is seen to be 1150 cub.m.

The use of Super-Pipes is described in the following topics.

Storage Curve for the Super-Pipes

Results of Super-Pipe Design

The first step is to define the outflow control device and then check a graphical display of the stage - discharge - storage characteristics of the system.

Storage Curve for the Super-Pipes

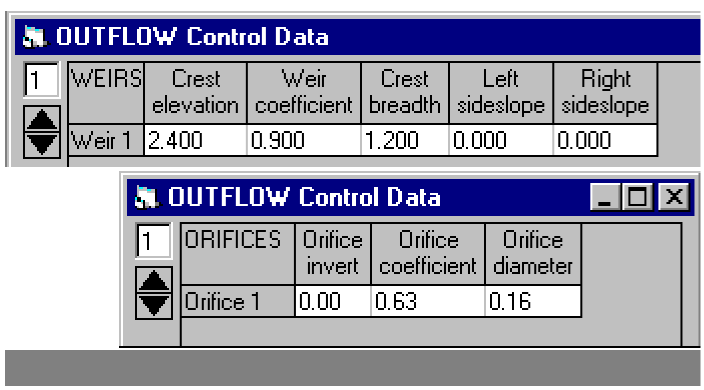


Figure 4-53 – Defining an outflow control for the superpipes

For simplicity, the outflow control device is assumed to comprise a single orifice and weir installed in the manhole chamber thus controlling the flow in both super-pipes. Note that the weir crest is above the obverts at the downstream end but below the obverts of both pipes at their upstream limits. If the weir is to be formed by a baffle at the downstream end of each pipe it will be necessary to consider the inflow in each branch of the system and design each super-pipe separately.

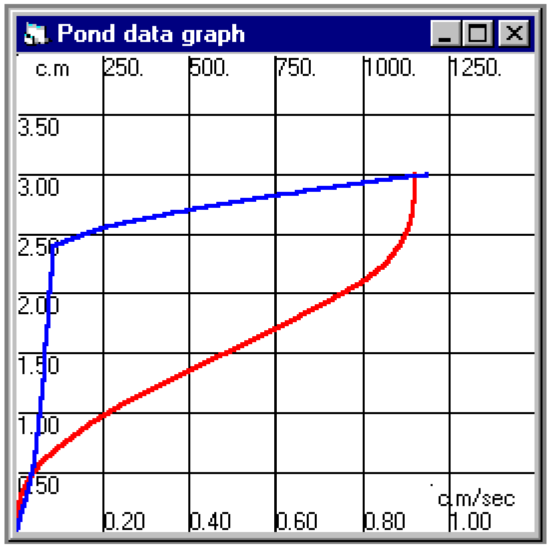


Figure 4-54 – Discharge and storage characteristics of the superpipe system

Using the **Plot/V,Q = f(H)** option the storage and discharge curves are displayed as shown in Figure 4-54. Notice the reversal of the storage curve due to the closed top of the pipe.

If the design appears reasonable, the final step is to press the [Route] button and see the results of the Super-Pipe design.

Results of Super-Pipe Design

Pressing the [Route] button produces the results shown below in Figure 4-55. The "Results" frame in the Pond window shows the peak outflow, maximum depth and storage in the facility. The estimate of required storage volume was in fact about 10% low but adequate for a preliminary design.

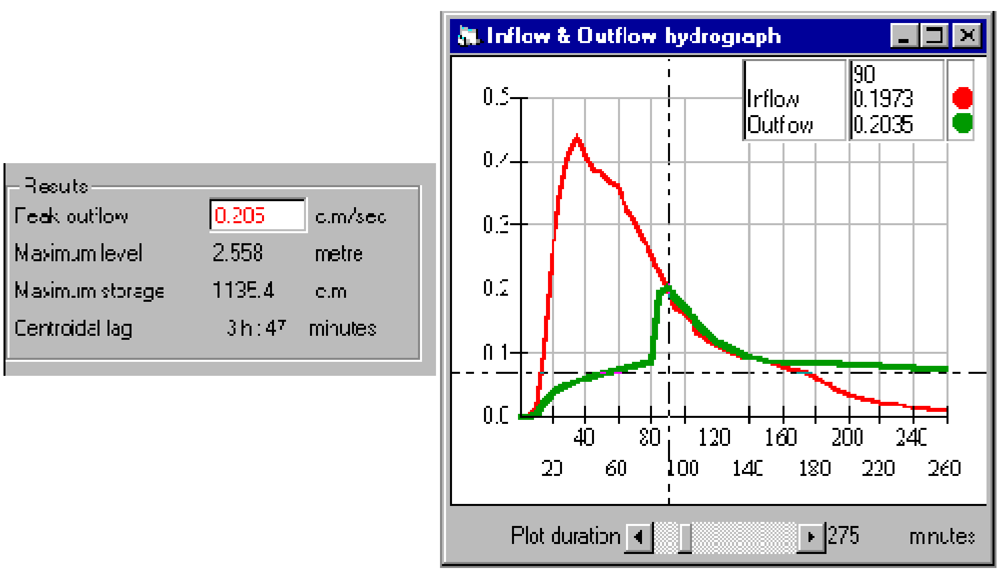


Figure 4-55 – Results of routing through the superpipe system

The graph of the inflow and outflow hydrographs is shown on the right. The "blip" on the outflow hydrograph indicates the point at which the weir is overtopped. In addition to the Results frame and the graph display, the outflow hydrograph is displayed in tabular form. If the super-pipe becomes almost full or surcharged there is no further volume available for storage and you will see that the outflow hydrograph will be identical to the inflow hydrograph along a part of the recession limb.

Thus a super-pipe will operate properly for the designed inflow but will pass higher peaks for more extreme events which cause surcharge upstream of the weir control. The solution in such cases may be to restrict the amount of flow which can be captured by the minor (piped) system. This can be done by limiting the number of catchbasins or installing flow restrictors (sometimes referred to as Inflow Control Devices or ICDs) in the tailpipes of the catchbasins thus forcing excess flow resulting from extreme storm events to be diverted to the major system.

Using Parking Lot Storage

Stormwater management on commercial developments often involves some measure of on-site control. A possible exception is when the development is immediately adjacent to a receiving watercourse with a large catchment area and with a time of concentration very much longer than that for the proposed development. In this case, the local runoff from a storm will be superimposed on the rising limb of the mainstream hydrograph resulting in zero or negligible increase in the mainstream peak flow.

When on-site control is required, storage on graded parking areas is commonly employed for this purpose. MIDUSS 98 provides the **Wedge storage** option to provide assistance in estimating the stage-storage values for the volumes around catchbasins draining the parking area. The procedures is described in the following topics.

Parking lot grading

Defining Wedge Storage

Parking lot Catchbasin Capacity

Results of parking lot Storage

Typically the grading of a parking area uses two grades draining towards the catchbasin which produces a ponded volume shaped like an inverted pyramid or cone. MIDUSS 98 assumes that the shape of the storage volume takes the form of an inverted cone the top surface of which is elliptical. The major radius and minor radius will equal the depth at the catchbasin multiplied by the grade in the relevant direction. A schematic of the arrangement is shown in Chapter 8 *Theory of Hydraulics*; Wedges (or inverted Cones) for Pond Storage.

Since the maximum depth of storage is likely to be quite small - much smaller than for a conventional detention pond - the first step is to set minimum and maximum elevations for the Parking Lot grading.

Parking lot grading

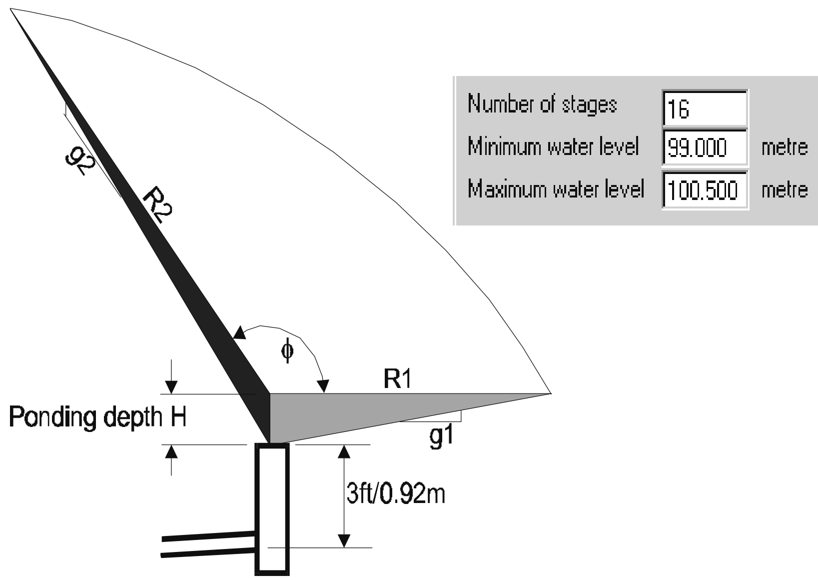


Figure 4-56 – A schematic for a catchbasin with a rim elevation of 99.92

Most authorities require parking lot storage to be not deeper than a specified maximum to prevent vehicles from being floated and to allow access for emergency vehicles. In the example of Figure 4-56, assume that the maximum depth above the catchbasin rim elevation will be about 0.5 m (or 1.5 ft). The values entered for water levels will usually be actual site elevations. Notice that the invert of the catchbasin tailpipe will be approximately 3ft or 0.92m below rim elevation, which in the illustration is 99.92 m. Using 15 depth increments (i.e. 16 depth values) provides values of discharge and volume at vertical intervals of 100 mm (or 4"). The storage volume will be zero for water levels below the rim elevation. For smaller depth increments you can use up to 50 water levels.

The next step is to describe the geometry of the inverted storage cones around the catchbasins by Defining the Wedge Storage.

Defining Wedge Storage

The wedge has the general shape of a wedge of pie or a segment of a circle or ellipse. The parameters required are:

- The invert level (or rim level) of the catchbasin
- The grade g1 expressed as g1 H:1 V along one edge of the segment
- The grade g2 expressed as g2 H:1 V along the other edge of the segment
- The angle in degrees subtended at the centre of the segment (i.e. the catchbasin) by the two edges.
- The total number of such wedges.

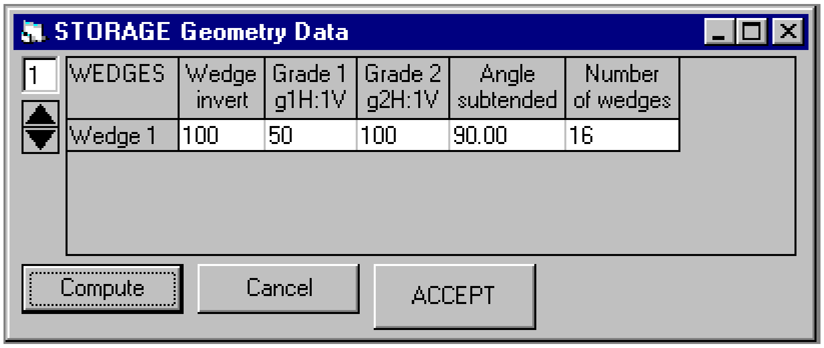


Figure 4-57 – Data required to define wedge storage

The example shown describes four complete elliptical cones, each of which can be defined in terms of four 90 degree segments. Thus there are a total of 16 quarter segments. The grades used are 2% or 50H:1V on the steepest edge and 1% or 100H:1V on the flattest edge. The catchbasin rim elevation is set as 100.00 m and the angle subtended by each quarter segment is 90 degrees.

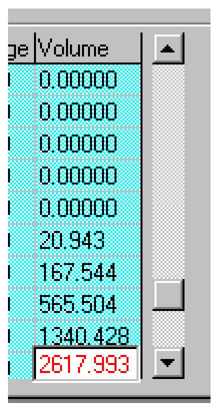


Figure 4-58 – Volume generated by the wedge storage

Pressing the [Compute] button causes the volume vector of the H-Q-V grid to be computed as shown in Figure 4-58. If the maximum depth is 0.5 m (which isprobably greater than is desirable) the total volume available would be 2618 cub.m

The next step is to define the discharge capacity of the four catchbasins draining these four elliptical areas.

Parking lot Catchbasin Capacity

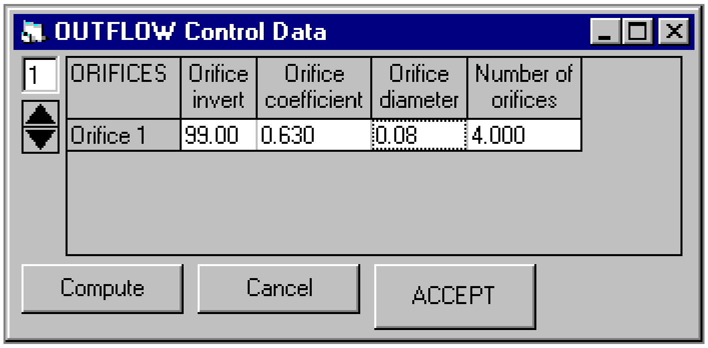


Figure 4-59a – An outflow control for four catchbasins

Four identical orifice controls are defined using the **Orifice** option of the **Outflow Control** menu. The invert of the tailpipe from the catchbasin is assumed to be 1.0 m (or 3.3 ft) below the rim level, that is 100.0 - 1.0 or 99.0 m elevation. A diameter of 80mm (3.25") is assumed here and a coefficient of discharge = 0.63 is used.

Pressing the [Compute] button generates a maximum discharge for the four catchbasins of 0.068 c.m/sec (or 2.4 cfs) when the depth over the catchbasin rim is 0.5 m. For extreme events you may wish to simulate the spill level from the parking area by defining one or more very flat, triangular weirs. This has not been done in this example.

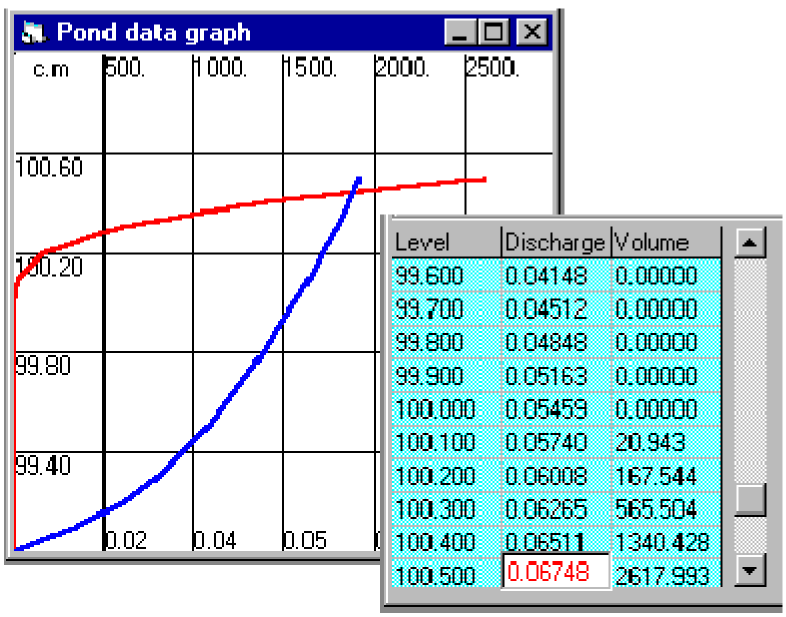


Figure 4-59b – Discharge and storage characteristics of the parking lot storage.

A plot of discharge and volume against the head H (or inspection of the H-Q-V table) shows that the volume is zero for values of H less than 100 m but discharge is finite over the full depth range. This special case can result in instability in the normal storage routing procedure and a special algorithm is used in MIDUSS 98 to ensure both stability and conservation of mass.

You can now test this trial design and see the results of the Parking lot storage by pressing the [Route] button.

Results of parking lot Storage

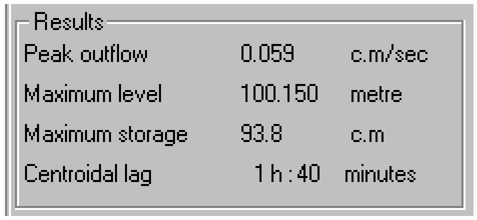


Figure 4-60 – Results of parking lot storage

The main results following the Route operation are shown in the "Results" frame in the Pond window. The maximum depth at the catchbasin is 0.015 m (6"). Peak flow has been reduced from 0.098 c.m/sec (3.5 cfs) to 0.059 c.m/sec (or 2.1 cfs) which is reasonable for four catchbasins under this modest level of surcharge.

From the depth and the defined grades the plan extent of the flooded elliptical areas will be close to 7.5m x 15m (24.5 ft x 49 ft) around each of the catchbasins. You can experiment by changing the grades or any of the discharge parameters until a satisfactory design is obtained.

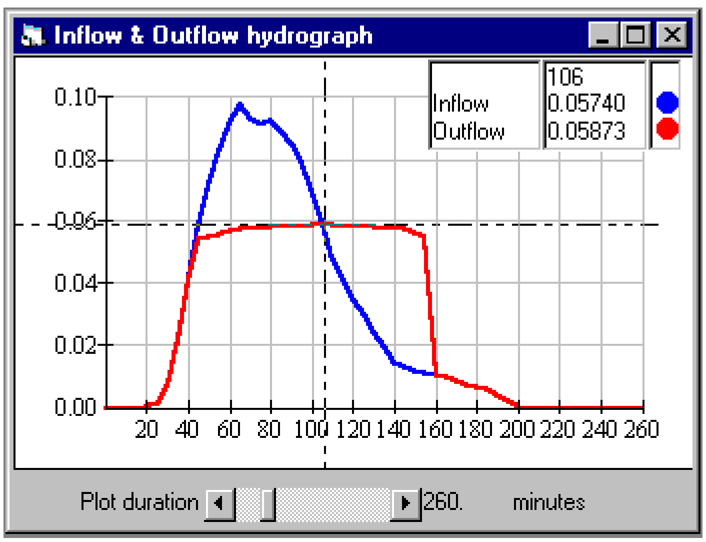


Figure 4-61 – Outflow hydrograph from the parking lot

The results are also indicated by a graph of the inflow and outflow hydrographs shown above and a table of the outflow hydrograph. The graph gives an indication of the duration of ponding on the parking surface - in this case less than four hours from start of rainfall.

Using Rooftop Storage

Large commercial buildings with flat roofs can provide an opportunity for on-site storage on the roof which can substantially reduce increased peak flow resulting from development. Flow from the roof is controlled by special devices which limit the outflow per roof drain to roughly 6 US gallons/minute for each inch of head (or 24 litres/minute for each 25mm of head).

Figure 4_62 – Selecting Rooftop storage from the Pond command menu

MIDUSS 98 offers a Rooftop Storage option within the Pond command. The procedure is described in the following steps or topics.

- Generating the Rooftop Inflow
- Target Outflow from the Roof
- Desired Depth Range on the Roof
- Parameters for the Rooftop System
- Rooftop Discharge and Storage Characteristics
- Rooftop Flow Routing
- Graphing Rooftop Runoff
- Design Tips for Rooftop Storage
- Rooftop Error Messages

The first step is to generate the flow on the rooftop. This must be done using the **Hydrology/Catchment** and **Hydrograph/Add Runoff** commands to generate the Rooftop Inflow before you invoke the Pond command.

Generating the Rooftop Inflow

To create the inflow hydrograph the total building roof area must be modelled using the **Hydrology/Catchment** command

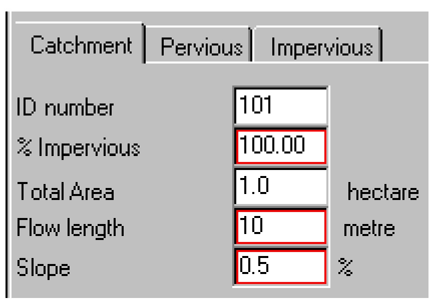


Figure 4-63 – Defining catchment data for rooftop runoff

The total area contributing to runoff on the roof will normally be equal to the building footprint. The example shows an area of 10,000 sq.m or about 108,000 sq.ft which is typical for a modest "big box" store or mall building.

Three parameters which you must set carefully are outlined in red. These are:

- The percent of impervious area which will normally be 100% (i.e. no roof gardens).
- The flow length which will be quite short and roughly equal to half the square root of the area tributary to each roof drain (e.g. 10 m for a 400 sq.m area).
- The gradient which typically should be less than 1%.

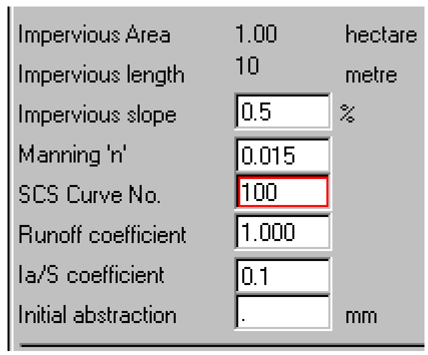


Figure 4-64 – Defining rainfall loss parameters for rooftop runoff

In addition, it is important to set the infiltration parameters for the impervious fraction to generate a runoff coefficient of 1.0. In the case illustrated in Figure 4-64, setting the SCS Curve Number to 100 automatically sets the initial abstraction to zero. For the Horton or Green and Ampt methods the surface depression storage can be explicitly set to zero or to some very small value.

After accepting the catchment results you must use the **Hydrograph/Add Runoff** command to move the runoff into the Inflow hydrograph. If you haven't already done so you should clear the Inflow hydrograph by means of the **Hydrograph/Start/New Tributary** command.

The next step may be to set a desired target for the peak outflow from the roof.

Target Outflow from the Roof

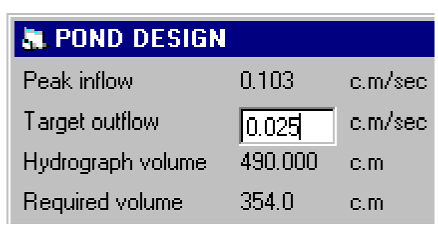


Figure 4-65 – If desired, you can set the target outflow from the roof.

You may specify a desired peak outflow from the roof and MIDUSS 98 will display an approximate estimate of the required volume. However, since both the area available for storage and the maximum depth is limited you will probably need to refine the design by trial and error.

Before generating the table of depth, discharge and storage you must next set the desired range of depths to be used.

Desired Depth Range on the Roof

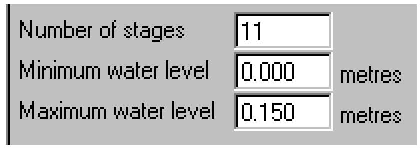


Figure 4-66 – MIDUSS98 estimates default values for the depth range.

MIDUSS 98 calculates a maximum depth which would provide storage equal to the total volume of the inflow hydrograph. This is rounded up to a multiple of a convenient depth increment such as 25mm or 1 inch. In Figure 4-16, the minimum depth is set at zero and 11 depths are defined to give 10 depth increments of 0.015m.

You can change these values if you wish. The computed defaults are provided as a guide.

Note that the suggested value of maximum depth takes into account the flow length and gradient used in the Catchment command.

You can now invoke the Rooftop option to set the necessary parameters for the Rooftop Storage system.

Parameters for the Rooftop System

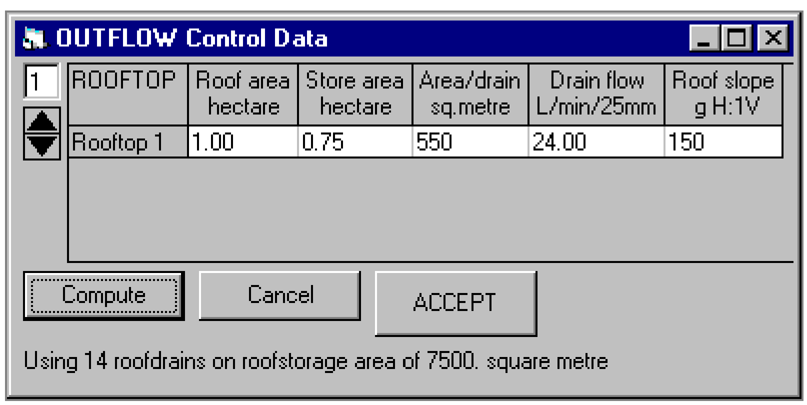


Figure 4-67 – Data required for rooftop storage (metric units)

As with the other Pond data entry forms, there is initially no row opened on the grid. You must press the 'Up' arrow on the spin button to display the default data. You can display more than one row but normally only one rooftop can designed at a time since the inflow to each roof must be generated by use of the Catchment command. However, if the roof drainage is complex with different sections having different densities of roof drain or roof slope you may want to use multiple roof sections.

Five values are displayed one of which cannot be varied.

Roof area is the total building footprint and is taken from the previous Catchment command. You cannot change this at this point.

Storage area is the roof area available for storage and is typically about 75% of the total area and this is shown as the default. However you can change this if you wish. In Figure 4-67 the value has been left at 75% of 1.0 ha.

Area per Drain is usually recommended by the manufacturer of the roof drain. A typical value is around 500 sq.m or 5000 sq.ft.

Drain flowrate. This is the flow capacity of the drain as a function of the head or depth at the drain inlet. This is also specified by the manufacturer and is often very close to a linear function of the depth. You should provide a value in litres per minute for each 25mm of depth. As shown in Figure 4-68, when using U.S. Customary units this will be measured in U.S. gallons per minute for each inch of depth.

Roof slope. Initially this is set to the gradient used in the Catchment command but expressed as a ratio xH:1V (e.g. 0.67% is shown as 150H:1V). You can change this value to see the sensitivity of the results to using a flatter or dead flat roof.

The line informing you of the number of roofdrains required is added only after you press the [Compute] button.

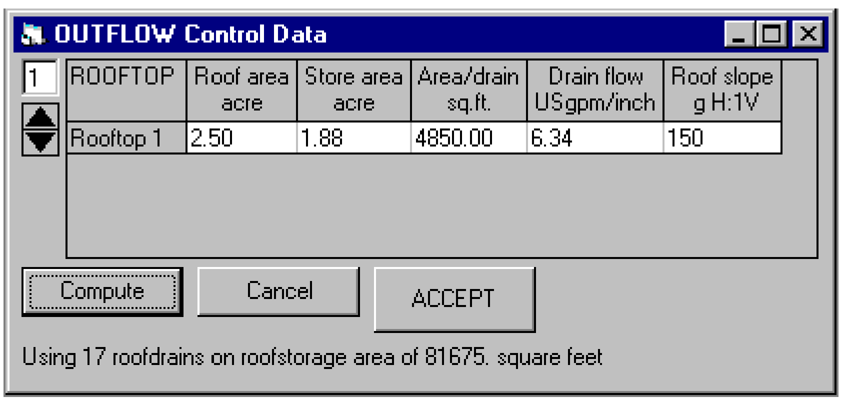
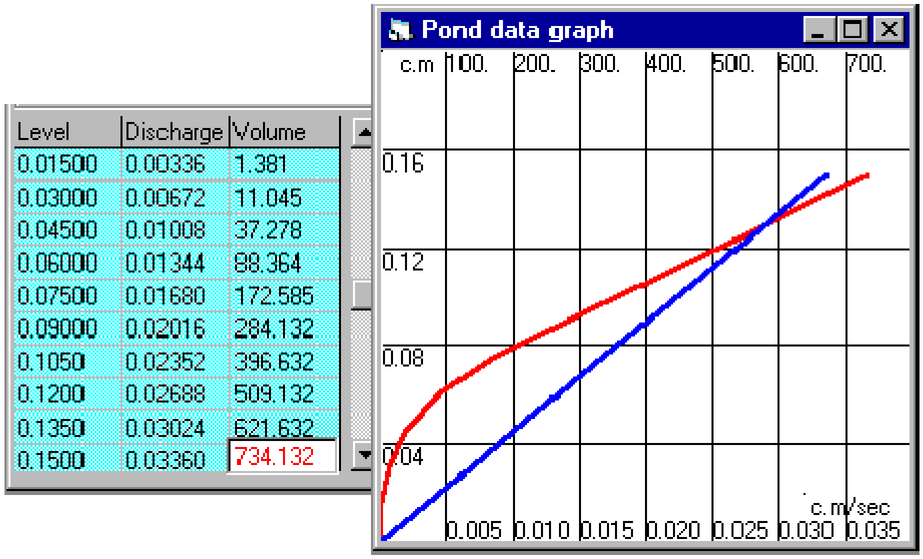


Figure 4-68 – Data required for rooftop storage (imperial units)

With this data you can now generate the discharge and storage characteristics of the rooftop.

Rooftop Discharge and Storage Characteristics



Level	Discharge	Volume
0.01500	0.00336	1.381
0.03000	0.00672	11.045
0.04500	0.01008	37.278
0.06000	0.01344	88.364
0.07500	0.01680	172.585
0.09000	0.02016	284.132
0.1050	0.02352	396.632
0.1200	0.02688	509.132
0.1350	0.03024	621.632
0.1500	0.03360	734.132

Figure 4-69 – Discharge and storage characteristics for rooftop storage.

Pressing the [Compute] button on the Rooftop data table causes the usual table of depth, discharge and storage volume values to be displayed as shown on the left of Figure 4-69. The method used by MIDUSS 98 to estimate the necessary maximum depth will usually provide an adequate margin of safety

The Plot option in the Pond menu will show that the discharge (in blue) is assumed to be a linear function of depth. The storage (in red) is nonlinear because the area tributary to each roof drain will normally be shaped like an inverted pyramid since a finite drainage slope must normally be provided.

You can experiment by changing the rooftop parameters. When you press the [Accept] button the highlight on the maximum volume is removed.

You can now press the [Route] button to complete the Rooftop flow routing operation.

Rooftop Flow Routing

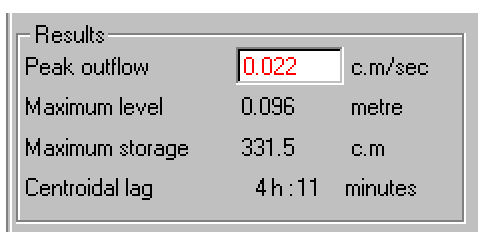


Figure 4-70 – Results of routing the rooftop runoff

The [Route] button is enabled after you accept the discharge and storage data generated in the previous step. The result of the flow routing is displayed:

In the "Results" frame of the Pond window,

As a graph of inflow and outflow, and

As a tabular display of the outflow hydrograph.

The results shown in Figure 4-70 give the peak outflow, the maximum depth, the maximum storage volume and the lag to the centroid of the outflow from the start of rainfall. Note that in Figure 4-70 the peak outflow value of 0.22 is highlighted and is not a text box which you can edit.

You can also see how quickly (or slowly) the roof storage drains by experimenting with the Graph of Inflow and Outflow.

Graphing Rooftop Runoff

The graph of inflow and outflow is displayed in the normal way and you can explore this with the mouse pointer as illustrated here. If you want to check the duration of ponding you can extend the time base of the graph by clicking on the slider control as shown below.

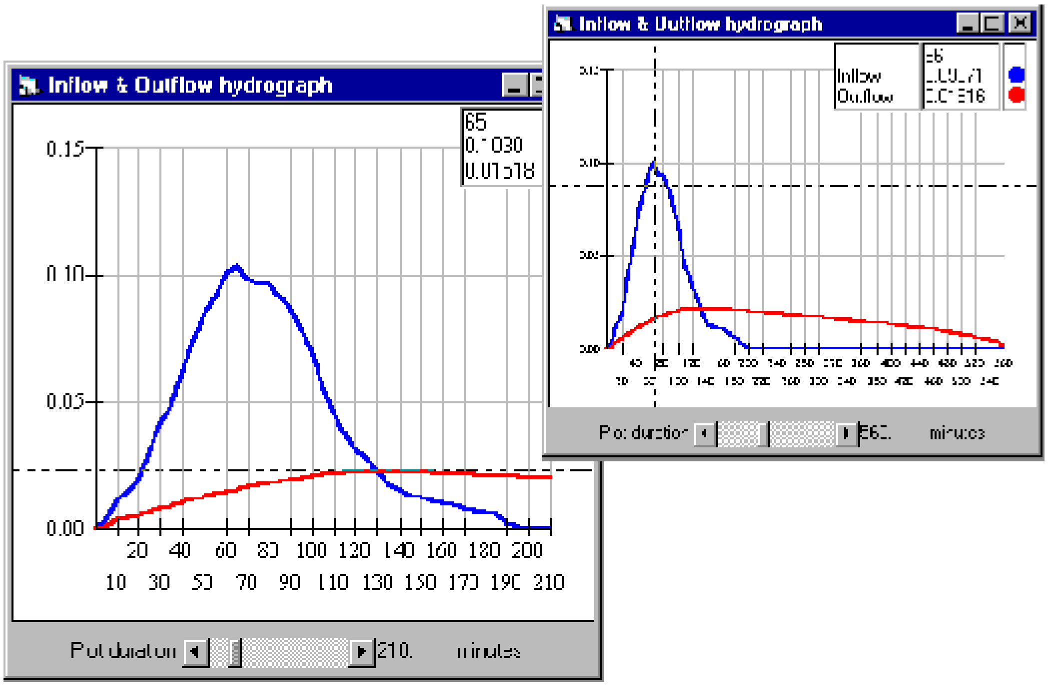


Figure 4-71 – You can experiment with the hydrograph plot to see the drainage time

Before concluding this section you may find it useful to review some design tips for using rooftop storage.

Design Tips for Rooftop Storage

- The structural integrity of the roof must be considered. In areas subject to potentially severe snowfall, the code requirements for carrying live load or snow load will provide load bearing capacity for up to 4 inches (100mm) of water or more. Some codes which limit maximum depth to this amount may allow an extra 25% to compensate for the grading of the roof around the roof drains.
- Building codes often require a drainage slope of 2% but this is excessive and severely limits the available storage. If rooftop storage is to be used it is often possible to relax this requirement to slopes not less than 0.5%.
- If the building is very wide it may be necessary to have roof drains remote from the perimeter of the building. This in turn requires provision of storm drains suspended below the roof (and above the suspended ceiling) which pick up one or more drains. It is very important that these drains be

properly designed to avoid surcharge in the pipe which could drown out the control at the drain inlet.

- Down-pipes from the roof drains will usually terminate in a 90 degree vertical bend at the bottom to connect with external services. Sometimes a maintenance access is provided inside the building to allow cleaning (e.g. rodding) of the drains. In such cases it is essential to secure the access cover to resist the high pressure which can develop in the down-pipe. Failure to do so can result in quite spectacular fountain displays to the severe displeasure of the tenant.

MIDUSS 97 does some basic error checking and the error messages you may see are described in the next topic.

Rooftop Error Messages

Design of a rooftop control system requires proper use of three commands - the Catchment command, the Add Runoff command and finally the Pond command. MIDUSS 98 performs some basic checks to warn you if there appears to be some inconsistency in the data. Three cases are described below.

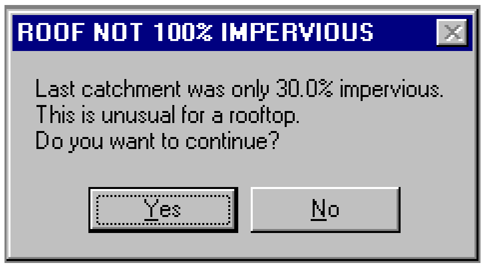


Figure 4-72 – Warning message for bad % impervious value

The percent of impervious area in the Catchment command will normally be 100%. If you have forgotten to set this properly the warning lets you cancel out of the Pond command and re-define the catchment. It is possible - although unlikely - that the roof may have a significant area of landscaping or roof-garden in which case you can bypass this warning and proceed with the design.

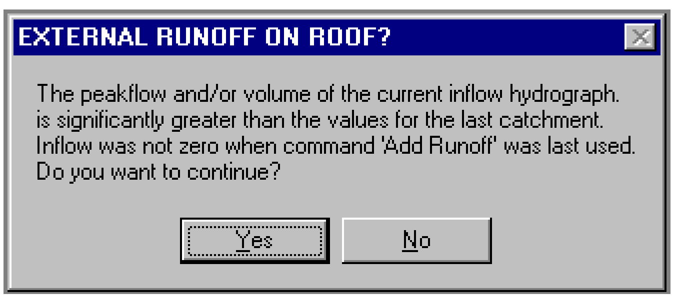


Figure 4-73 – Warning if Inflow has not been set to zero

The Catchment command must be used for each individual roof area and the Inflow hydrograph must be set to zero before using the Add Runoff command. MIDUSS 98 checks to ensure that this has been done and shows this warning if either the peak flow or volume is inconsistent. However, in unusual circumstances, it is possible that external runoff may be intentionally directed on to the roof in which case the warning can be ignored.

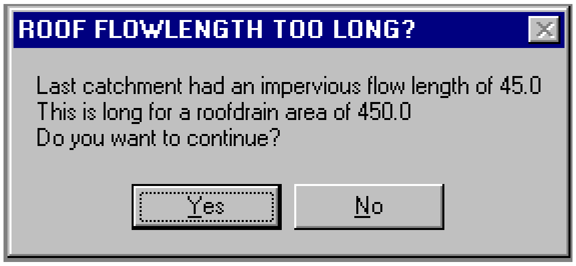


Figure 4-74 – Warning for bad flow length value.

The flow length on the impervious area should be relatively short and will normally be less than the square root of the area contributing to each roof drain. For example if the area per drain is 5000 sq.ft the length would normally be between 40 and 70 ft. The illustration shows an equivalent case in metric units.

Accepting the Pond Design

When you are satisfied with the design click on the [Accept] button on the Pond window. All currently open windows will be closed and the results will be copied to the current Output file.

You may find it useful to assemble a number of windows showing principle data, plots of storage and discharge, etc. and print a hardcopy of the results by use of the **Files/Print** command.

Diversion Structure Design

The purpose of this command is to split the inflow hydrograph into two components. The diversion structure is assumed to be similar to a side discharging weir or a catchbasin in a road.

In a **side-weir** there is a threshold flow below which all of the inflow is transmitted downstream as outflow. Once the inflow is greater than the specified threshold flow the excess flow (i.e. inflow - threshold) is divided to two parts. One fraction *F* is diverted to a different watercourse and the balance **(**$1-F$**)** is transmitted downstream as part of the outflow.

In the case of a **catchbasin** the inflow is the runoff in the gutter. At low inflow rates all of the inflow is captured by the catchbasin and is conveyed as outflow to the minor system. When the inflow reaches a certain threshold value some fraction *F* of the excess flow bypasses the catchbasin and is 'diverted' to the major system flow. The balance **(**$1-F$**)** is added to the outflow captured by the minor system.

The design process is described in the following steps.

- The Diversion Window
- Defining the Diversion Node Number
- Defining the Threshold Flow
- Designing for a Maximum Outflow from the Diversion
- The Diverted Fraction
- Results of the Diversion Design
- Graphing the Diversion Flows
- Accepting the Diversion Design

The first step is to open the Diversion window and review the current default data.

The Diversion Window

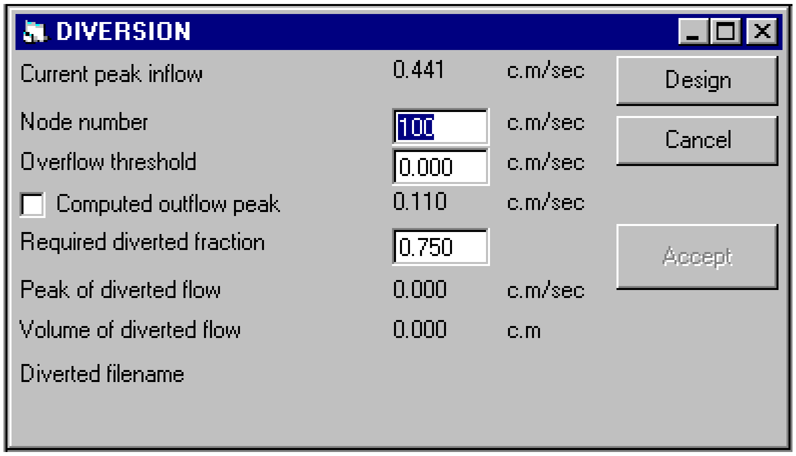


Figure 4-75 – Data required to define a diversion structure

When the Diversion window is displayed for the first time the initial display shows the current peak inflow, an initial threshold flow of zero and a diversion fraction of 0.75. In the illustration the peak inflow is 0.441. If the overflow threshold is zero then the diverted fraction *F* is applied to the total inflow so that the outflow is **(***1-F***)** x 0.441 which is approximately 0.110.

The next step is to define the Overflow Value or Threshold Flow.

Defining the Diversion Node Number

The node number serves to define the location of the diversion and is also embedded into the name of the file which will hold the diverted hydrograph. You can use any 5 digit integer "**nnnnn**" from which a filename of the form **DIVnnnnn.hyd is formed.**

Defining the Threshold Flow

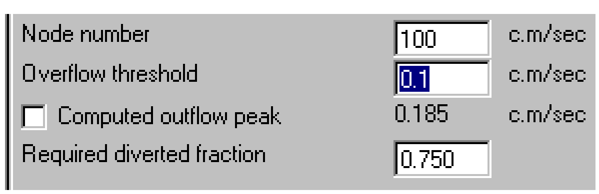


Figure 4-76 – The diverted fraction can be defined explicitly

When you enter a finite value for the threshold flow the Diverted Fraction is applied to the new excess flow and the peak outflow is recalculated and updated. In the sample shown here, a threshold flow of 0.1 reduces the excess flow to 0.341 of which 75% is diverted and 25% x 0.341 or 0.085 is added to the overflow of 0.1 to give a total outflow peak of 0.185.

You can of course change the value of the Diverted Fraction to any fraction in the interval 0.0 to 1.0.

At this point you should also define the node number where the diversion structure is located. This is used to construct a file name which will contain a record of the diverted hydrograph for future use or reference.

An alternative approach is to design the diversion structure for a desired maximum outflow which is described in the next topic.

Designing for a Maximum Outflow from the Diversion

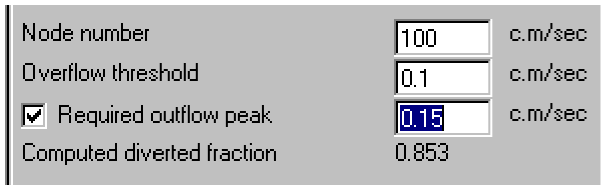


Figure 4-77 – You can specify the outflow to implicitly define the diverted fraction

If you click on the check box to the left of the label "Computed Outflow" several things happen. The label changes to "Required Outflow peak" and the value is displayed in a data entry box instead of a simple value. The label "Required diverted fraction" changes to "Computed diverted fraction", the value can no longer be edited in a data box and the computed value is displayed for information.

This lets you specify the maximum outflow that you would like to result from this design using the current inflow, threshold flow and diverted fraction value. When you enter the required outflow the value of the diverted fraction is adjusted to produce the required result with the current threshold flow. You can alter the threshold flow to see the effect of this on the computed diverted fraction.

When you are satisfied with this trial design you can press the [Design] button to see the results of the diversion design.

The Diverted Fraction

If the checkbox against "Computed outflow peak" is unchecked, the text-box for this data item is displayed and you can enter a fractional value in the range 0.0 to 1.0. This represents the fraction of the excess flow which is diverted where excess flow is (Inflow - Threshold flow).

The value is very dependent on the type of diversion. MIDUSS 98 uses an initial default of 0.75.

Note that if the checkbox is ticked, you will be prompted to define the peak outflow and the diverted fraction will be computed and displayed for information.

Results of the Diversion Design

The calculation applies a simple continuity rule to the design and computes the peak flow and volume of the diverted hydrograph. Also displayed is the name of the hydrograph file to which the diverted hydrograph will be written. However, this is not done until you press the [Accept] button and you can refine the design if desired.

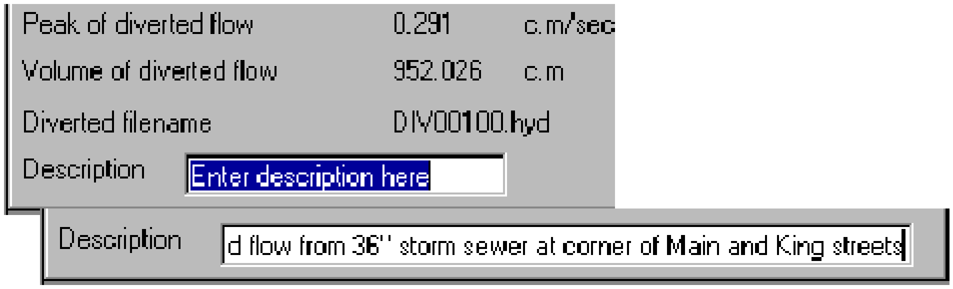


Figure 4-78 – Results of the Diversion command

Also shown in Figure 4-78 is a text entry box which prompts you to type in a brief description of the diverted hydrograph which will be incorporated in the header of the file containing the diverted hydrograph. As shown above, the text box expands and the text scrolls left to allow any reasonable length of description.

In addition to the results shown in the Diversion window, the diverted hydrograph is shown in tabular form and the Graph display shows the three hydrographs of interest as described in the next topic.

Graphing the Diversion Flows

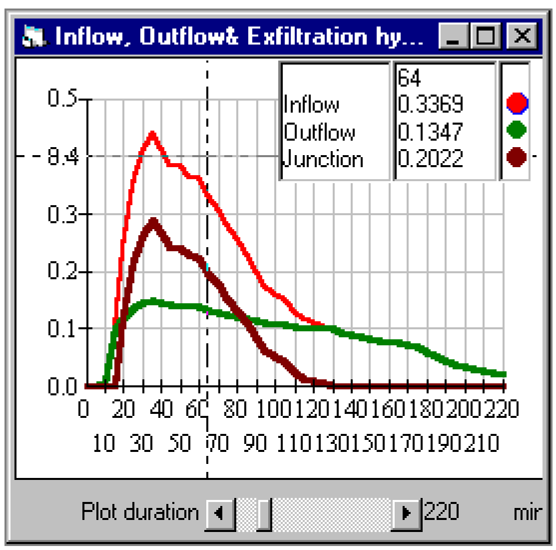


Figure 4-79 – Graphical result of the Diversion command.

The diverted hydrograph for the current trial design is written to the Temporary or junction hydrograph and this is displayed along with the inflow and outflow hydrographs. The illustration shows the cursor over the graph with the three numerical values displayed in the top right corner of the graph. The inflow can be seen to be equal to the sum of the outflow and the diverted flow within the accuracy of the display.

If you are satisfied with the design the final step is to accept the Diversion design by pressing the [Accept] button.

Accepting the Diversion Design

Before pressing the [Accept] button you should type in a brief description in the text box labelled "Description".. The text box will expand to hold a reasonable length of description which will be included in the header of the file holding the diverted hydrograph.

The diverted hydrograph is written to the file only after the [Accept] button is pressed, however, MIDUSS 98 checks to see if a file of the same name already exists in the current job directory. If it does you will see the warning shown below.

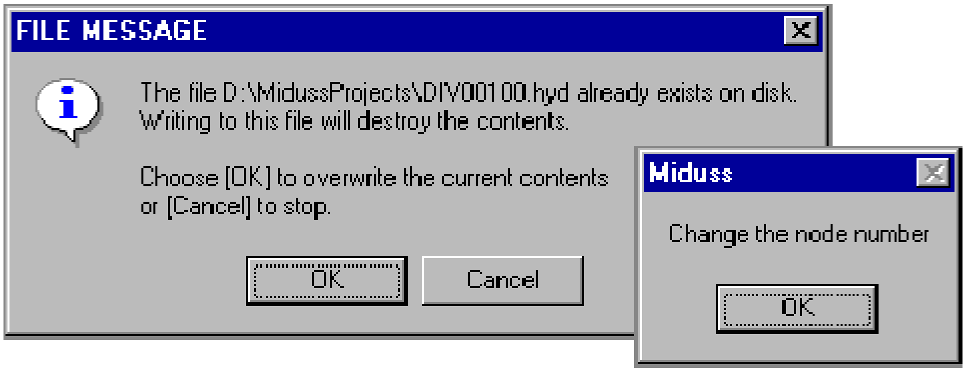


Figure 4-80 – MIDUSS98 protects you from overwriting a previous diversion hydrograph

If you don't want to overwrite the existing file you can press the [Cancel] button and the [Accept] command is aborted.

You will be prompted to change the node number which changes the file name and you can try again.

Exfiltration Trench Design

An exfiltration trench is a device which promotes the distribution and return of stormwater runoff into the soil and thus eventually to replenish the groundwater. It is common to see the term infiltration applied to facilities of this type. However, since inflow and infiltration (I & I) generally describes the increase of hydraulic load in a sanitary sewer system resulting from infiltration of water, the term ***exfiltration*** will be used in this section to describe the type of trench used for underground disposal of stormwater runoff.

In general, the trench causes an inflow hydrograph to be split into two components:

(1) an outflow hydrograph which continues down the storm sewer (if one exists), and

(2) the flow which is directed into the soil.

A comprehensive manual on the subject was published in 1980 by the U.S.Dept. of Transportation (see References) which describes devices such as porous pavement, basins, wells and trenches.

MIDUSS 98 assumes the exfiltration trench to comprise a trench of rectangular or trapezoidal cross-section containing one or more perforated pipes and possibly a conventional non-perforated storm sewer surrounded by clear stone fill with a relatively high voids ratio of around 40%. To increase exfiltration the system usually has some form of outflow control device to promote high water levels within the trench.

The device can be visualized as an underground detention pond from which lateral flow is possible in addition to the downstream outflow.

Overview of Trench Design

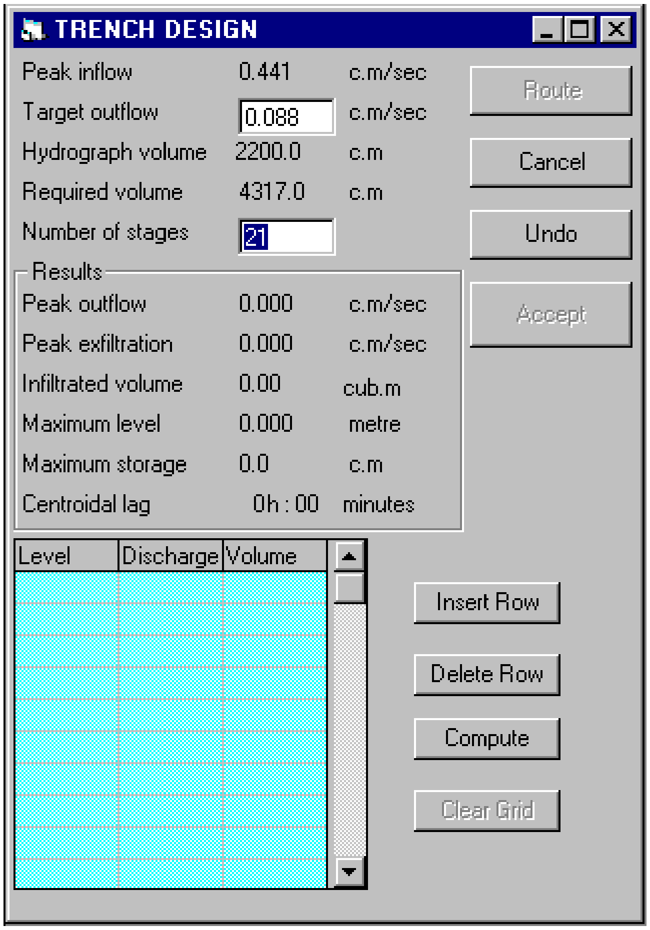


Figure 4_81 – The initial exfiltration Trench form

The **Design/Trench** command helps you to determine the proportions and discharge characteristics of an exfiltration trench with the object of attenuating the peak flow in a link of a drainage network to an acceptable value. As with the other design commands in this chapter, the design comprises four general steps.

- Specify the desired peak outflow and determine an approximate storage volume (including the stone fill) which might achieve this.
- Set up a table to define the Depth - Discharge and Depth -Storage volume relationships for the proposed trench. These functions must increase monotonically. MIDUSS 98 contains a number of special commands to help you to define the Depth - Discharge - Storage values for a variety of standard outflow control devices and a range of geometric and physical properties of the trench system.
- Route the inflow hydrograph through the proposed trench and get peak flow and volume of outflow and exfiltration to the soil as well as maximum depth in the trench.
- Accept or reject the design. If rejected, edit the Depth Discharge and Storage table and/or the physical characteristics of the trench and repeat step (3) until an acceptable design is achieved.

Many of the options available in the Trench command are accessed through a special menu which is enabled when the **Design/Trench** command is selected. Figure 4-82 in the topic The Trench Menu shows a summary of the main features of this menu in Figure 4-82 in the next topic.

A logical series of steps is summarized in the following list of topics. You may use these in an order different from that shown but the sequence illustrated here is typical.

- Set a Target Outflow for the Trench
- Set the Number of Stages in the Trench
- The Trench Geometry menu
- Trench Data
- More Trench Data
- Checking the Trench Volume
- Modifying the Trench Data
- The Trench Outflow Control
- Setting a Weir Control for the Trench
- Setting an Orifice Control for the Trench
- Defining a Pipe in the Trench
- Positioning the Trench Pipe
- Effect of a Pipe on Trench Storage
- Plotting the Trench Properties
- Routing Flow through the Trench
- Results of Trench Routing

The Trench Menu

Figure 4_82 – The Trench menu

When the **Trench** window is displayed (and has the focus as indicated by the coloured title bar) a special menu replaces the main MIDUSS 98 menu. It includes the following items most of which are discussed in more detail in the items which follow.

Main Menu lets you return to the main MIDUSS 98 menu.

Geometry displays items to define the geometry and other physical characteristics of the trench and also set the size, position and type of any pipes in the trench

Outflow Control contains items to let you compute the stage-discharge values for one or more orifice controls and one or more weir controls.

Plot lets you display various types of plot involving the depth (or stage), discharge, exfiltration flow and storage volume.

Sometimes when the Trench window loses the focus to another window (such as a graph display or a data entry form) the main MIDUSS 98 menu is displayed in the menu bar. To see the Trench menu you need only click anywhere on the Trench form to restore it.

Specify Target Outflow from Trench

MIDUSS 98 arbitrarily sets the target outflow to 20% of the peak inflow. You will usually want to change this. Click on the text box at “Target outflow” to highlight the current value and type in the desired peak outflow that you would like to achieve for this hydrograph.

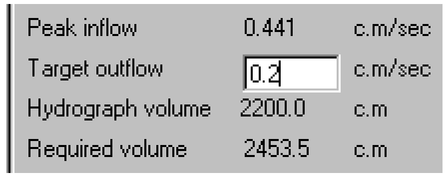


Figure 4-83 – Setting the target outflow.

As shown in Figure 4-83, an approximate estimate of the required trench storage (including the stone fill) is displayed for information along with the total volume of the inflow hydrograph. The storage required will increase as the desired peak outflow is reduced.

The next step is to set the Number of Stages for the Trench design.

Set Number of Stages for Trench

The default number of stages or water levels used to describe the Depth - Discharge - Storage functions is set at 21. If you have changed this at an earlier stage in the MIDUSS 98 session the latest value will be displayed.

Figure 4-84 – You can use up to 50 stages

If you want to change the current value, click on the text box to highlight the current value. Type in a new value. The number of stages must be at least 3 and not more than 50. The default value of 20 depth increments will normally be sufficient.

The next step is to select the Trench geometry option from the Trench/Geometry menu.

The Trench Geometry Menu

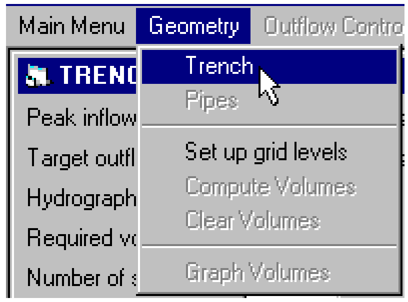


Figure 4-85 – The first step is to define the Trench geometry

You will use the Trench and Pipes options from this menu but only the former is enabled since it is not possible to define and locate a pipe until the containing trench has been described. Click on the Trench item as shown to open the Trench Data window.

Trench Data

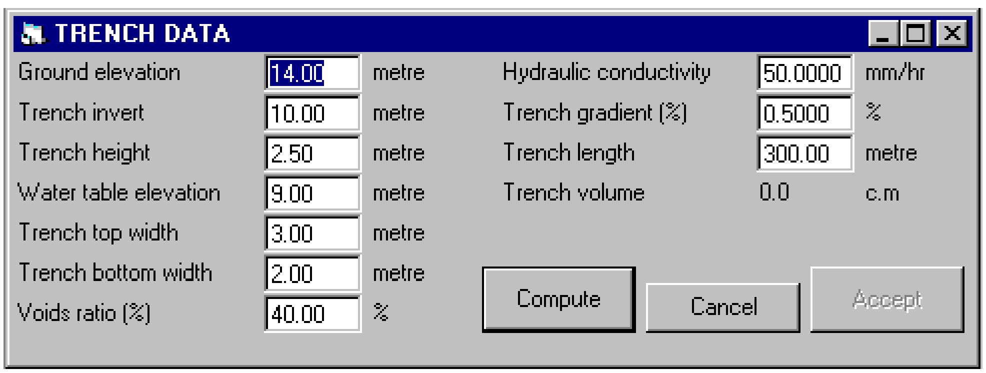


Figure 4-86 – Defining basic geometric and physical properties of the Trench

The Trench Data window contains data entry boxes for a number of geometric and physical properties of the trench that must be specified at the start of the design process. After you have completed a trial design you may return to this window to change one or more of these properties.

On the left side of the window the following quantities are shown with the current default values. Note that the 1st, 2nd and 4th items much be defined to the same datum. Also if the Top width and Bottom width are not the same the cross-section is assumed to be symmetrical.

- Ground elevation — Ground level at the downstream end of the trench
- Trench Invert — Invert level of the trench (not the pipe) at the downstream end.
- Trench Height — Total height of the stone filled trench at the downstream end
- Water table elevation — Ground water elevation
- Trench Top width — Top width - must be in the same units as the previous values
- Trench Bottom width — Bottom width must be in the same units as the previous values

- Voids Ratio — percentage of voids in the clear stone filling the trench.

The remaining data is defined in the next topic.

More Trench Data

- Hydraulic conductivity — the saturated hydraulic conductivity of the soil surrounding the trench.
- Trench gradient — the gradient of the trench invert
- Trench length — total length of the trench.
- Trench volume — Computed gross trench volume including the stone fill.

The trench volume and is computed when the [Compute] button is pressed to allow comparison with the "Required trench volume" estimated when the target outflow is specified. Note that MIDUSS 98 assumes the top water level in the stone fill to be horizontal. Thus a flatter trench gradient will provide more trench volume for storage in the voids.

When you have entered trial values for the trench data you can press the [Compute] button to check the Trench Volume.

Checking the Trench Volume

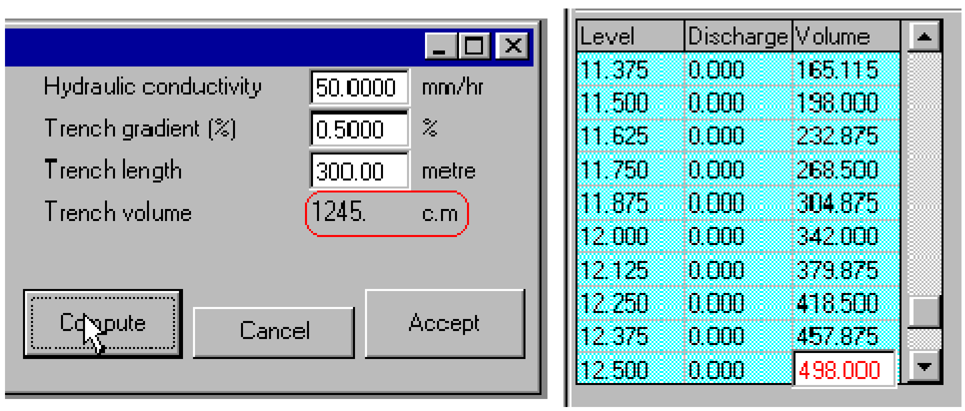


Figure 4-87 – The Trench volume includes the stone fill

The maximum available trench volume (including the stone fill) is displayed in the Trench Data window when you press the [Compute] button. Some preliminary adjustment of the trench dimensions can be made at this point to provide a trench volume roughly the same as predicted in the Trench window. The predicted estimate is very approximate and it is not worth trying to match the trench volume with any precision.

In addition to showing the computed trench volume, the Volume column of the grid will be updated with the maximum volume shown highlighted as shown. Note that the grid values indicate the net available storage in the voids of the clear stone fill. For example, the maximum available volume of 498 c.m is 40% of the trench volume of 1245 c.m.

You can modify the maximum available volume by modifying the Trench Data as follows.

Modifying the Trench Data

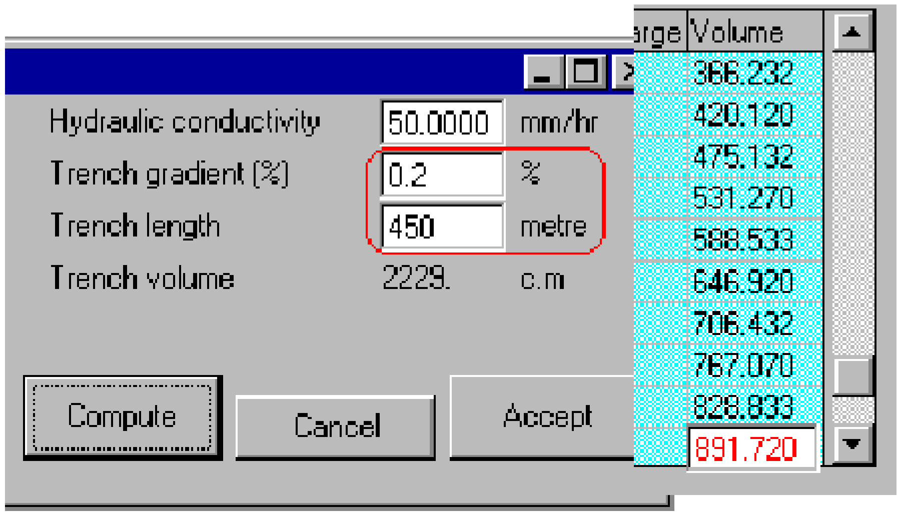


Figure 4-88 – Modifying the Trench geometry

The illustration shows changes to the two items circled in red. The gradient has been flattened from 0.5% to 0.2% and the length has been increased from 300 m to 450 m. Note that for any finite trench gradient, lengthening the trench may provide only a modest increase in maximum available volume since MIDUSS 98 assumes that the water level in the stone filled trench is horizontal.

Pressing the [Compute] button causes the available trench volume to be increased from 1245 c.m to 2229 c.m which is reasonably close to the predicted requirement of 2453 c.m. The grid of Depth, Discharge and Volume is also updated and shows the maximum available net volume has increased from 498 c.m to 892 c.m.

You can now proceed to designing an Outflow control device for the trench.

The Trench Outflow Control

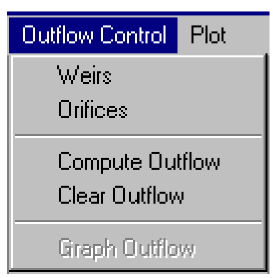


Figure 4-89 – The Trench Outflow control menu

The Outflow Control menu offers a number of options the most important of which allow you to design a weir or orifice which controls the stage-discharge characteristic of the device. Up to 10 such controls can be designed but normally only one or two will be required.

The next step is to set the crest level for a weir control.

Setting a Weir Control for the Trench

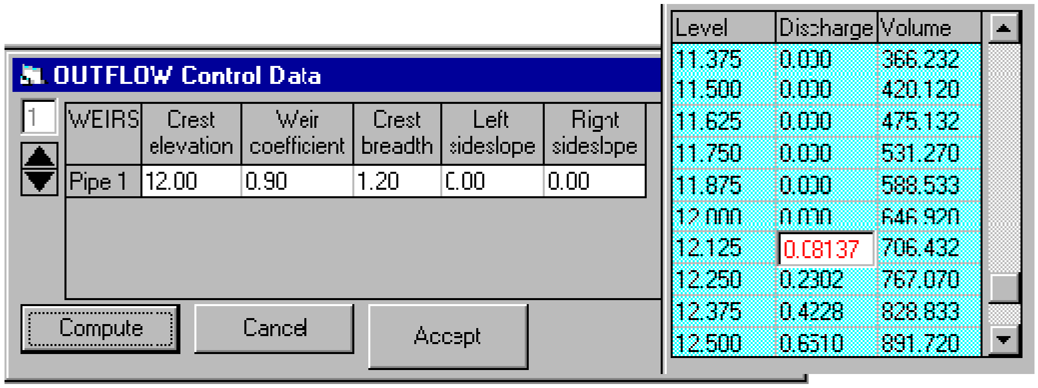


Figure 4-90 – Setting a weir for the Trench Outflow control

The table for specifying weirs or orifices is similar to that used for a regular detention pond. You must press the Up-arrow of the Spin button to open a row for the first weir. MIDUSS 98 sets initial default values for crest elevation, discharge coefficient, crest breadth and side slopes which will pass the target outflow with reasonable ease. These default values can be edited by clicking on the appropriate cell and typing the required value. In Figure 4-90 no changes have been made from the default values.

When the data have been entered press the [Compute] button to generate the Discharge column in the grid of Depth - Discharge - Volume data. Only the cells corresponding to a depth greater than the weir crest elevation will have a finite discharge value.

Cells below the weir crest will still have zero discharge. The next step will be to specify a small orifice near the bottom of the trench.

Setting an Orifice Control for the Trench

The default data provided by MIDUSS 98 assumes an invert level at the bottom of the trench and a discharge coefficient of 0.63. It is likely that you will want to reduce the orifice diameter. Here a small orifice of 75 mm (3") has been used.

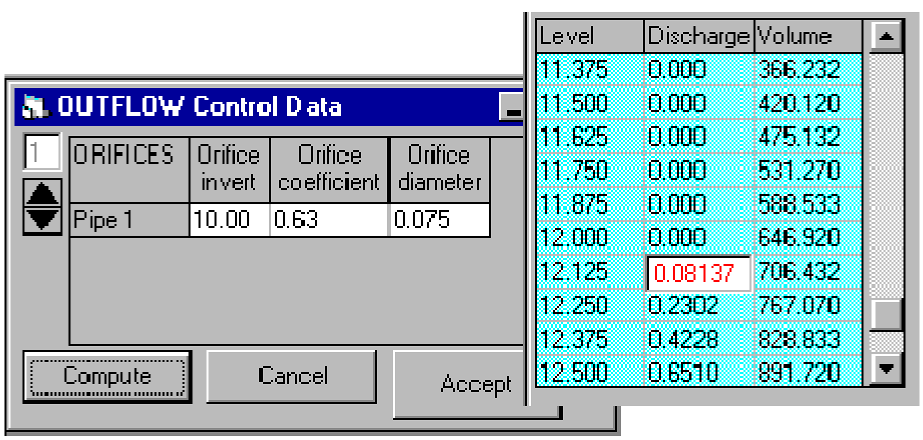


Figure 4-91 – Defining an Orifice in the Trench Outflow control

Pressing the [Compute] button causes the vector of discharges to be updated. The maximum available discharge is highlighted as shown here. You can, of course, try any number of data values. When you press the [Accept] button the highlighted cell is restored to its normal appearance.

Note that it is not necessary to define a pipe in order to carry out a flow routing operation through the trench. We will assume here that the final step in the design is to specify and position a single perforated pipe in the trench which will serve the dual purpose of distributing the inflow and conveying the outflow. For this to work effectively it is necessary for the pipe to be surcharged by the weir control at the downstream end of the trench. The next topic shows how to define a pipe in the trench.

Defining a Pipe in the Trench

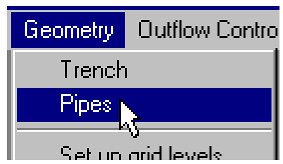


Figure 4-92 – One or more pipes can be defined in the Trench

Pipe geometry is defined using the second item in the Geometry menu. This item is enabled only after the general trench data has been specified.

Clicking on the **Geometry/Pipe** option opens a window which contains both a table for data entry and a graphic display of the trench cross-section on which pipes can be positioned. As with the other data tables you must click on the Up-arrow of the Spin Button to open a row for the first pipe. In addition, a perforated pipe with the default diameter is located on the centre line and at the bottom of the trench as shown below. The length and gradient of the pipe are initially set to the same values as specified for the trench. The default diameter is 150 mm or 6".

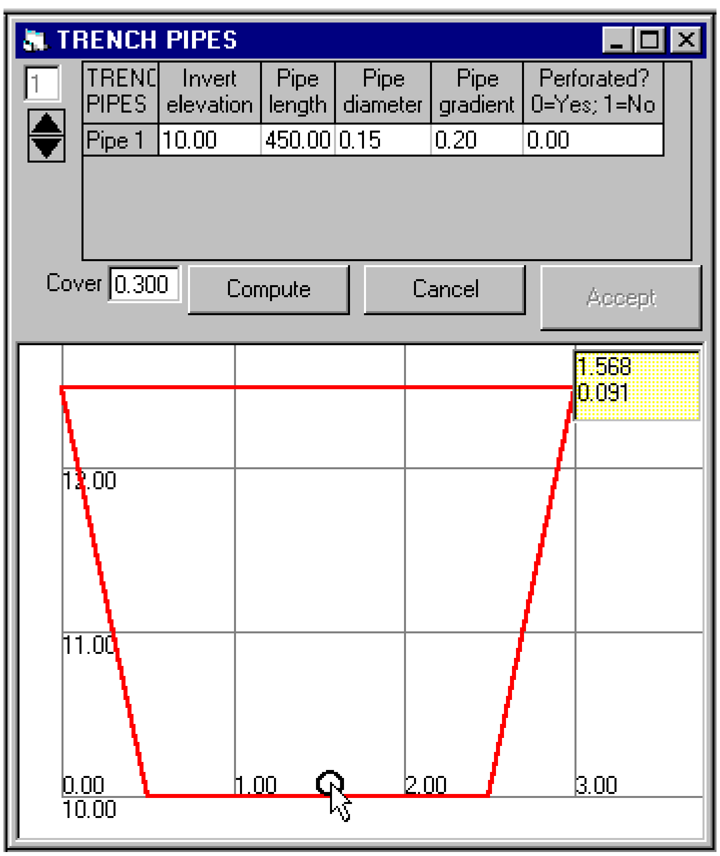


Figure 4-93 – The pipes can be defined graphically and fine-tuned numerically

The next step is to modify the position and size of the trench pipe.

Positioning the Trench Pipe

The first step is to click on the Pipe diameter cell and change this to a 375 mm (15") diameter. You will see the diameter of the plotted pipe increase appropriately.

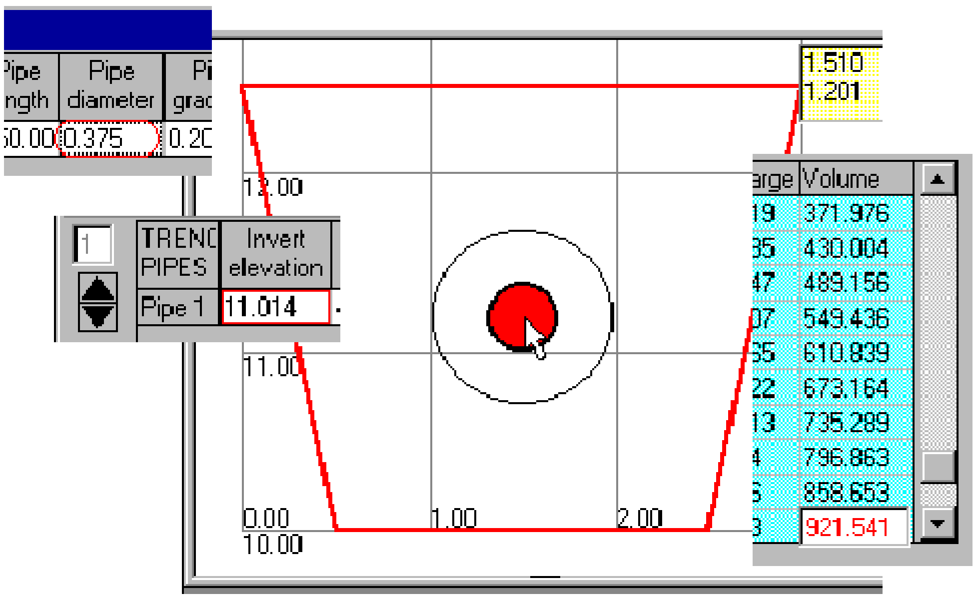


Figure 4-94 – Steps in editing the pipe data in the Trench

The next step is to move the pipe up and set it with an invert level of approximately 11.0 m. This is done by clicking on the pipe while holding down the left (primary) mouse button, and dragging the pipe up to the desired location. During the drag and drop operation the pipe is shown as a solid red circle surrounded by another circle which represents the cover specified in the data table beside the [Compute] button. This allows you to position multiple pipes to ensure adequate clearance. An initial clearance of 0.3 m (12") is set but you can change this in the usual way.

As you move the pipe, the Invert Elevation in the data table is updated allowing you to set the invert level with reasonable accuracy. (Probably at least as accurate as construction practice will allow!). If desired, you can type in an accurate value for the invert elevation at the downstream end of the pipe.

The final step is to see if the inclusion of a pipe makes a significant difference in the available net storage volume. Click on the [Compute] button to see the effect of the pipe on the trench storage.

Effect of a Pipe on Trench Storage

The effect of including a pipe on the available net storage volume depends on whether the pipe is perforated or non-perforated. If a perforated pipe is used to distribute the inflow along the length of the trench the effect will be to increase the available voids for storage and thus slightly reduce the outflow. If a non-perforated pipe is used - serving as a regular storm sewer - the result will be a net reduction in the available storage when the water level in the clear stone fill is above the invert level of the pipe.

If you refer back to the topic "Modifying the Trench Data" you will see that the net storage available when the trench is full has increased from 891.7 c.m to 921.5 c.m. - not a very dramatic difference.

You can also examine the properties of the trench system graphically by means of the various options in the Trench/Plot menu.

Plotting the Trench Properties

The Plot command is accessed from the special Trench menu. Options 2 and 3 which involve the exfiltration flow are not available until after the [Route] button has been pressed since exfiltration is computed as part of the routing operation.

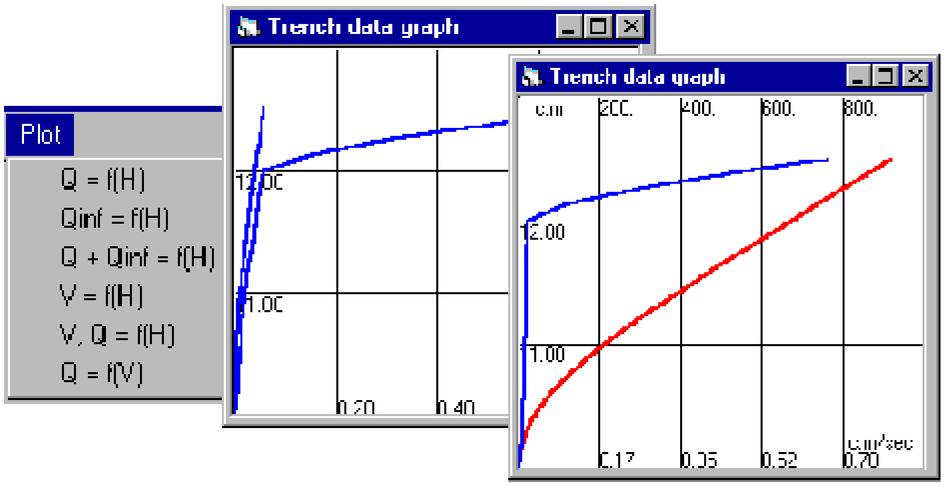


Figure 4-95 – Using the Plot menu to plot Trench properties

This plot shows the "V,Q = f(H)" option with storage volume in red and outflow in blue.

The "Q + Qinf = f(H)" option shows the exfiltration flow alone compared to the total outflow (i.e. weir, orifice and exfiltration). However, this is not available until the Inflow has been routed through the Trench which is the next step.

Routing the Inflow through the Trench

When you have completed the data entry you can test the effectiveness of the proposed design by clicking on the [Route] button. As with some other design commands information is presented in several ways.

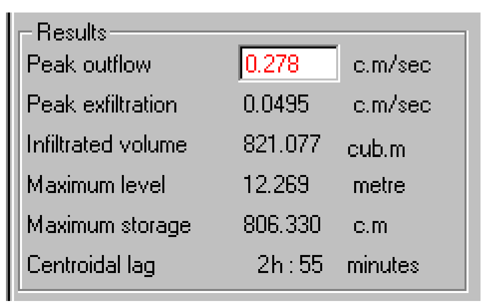


Figure 4-96 – The results of routing the Inflow through the Trench

The "Results" frame within the Trench window shows the maximum values for outflow, exfiltration, water level and net storage volume in the trench. If the length of the storage 'wedge' is less than the available trench length a message is displayed. This means that the trench could be made shorter with no change in its effectiveness – at least for this inflow hydrograph.

In addition, the total infiltrated volume is reported.

The outflow hydrograph is also displayed in tabular form from which the total outflow volume can be noted. You should be able to confirm that the sum of the outflow volume and the volume of exfiltration is reasonably close to the volume of the inflow hydrograph. Any error in continuity is usually due to the exfiltration or outflow hydrograph continuing beyond the maximum length of hydrograph specified in the **Time parameters** command.

Finally, the centroidal lag of the outflow hydrograph is reported.

The results are also displayed graphically as discussed in the next topic.

Results of Trench Routing

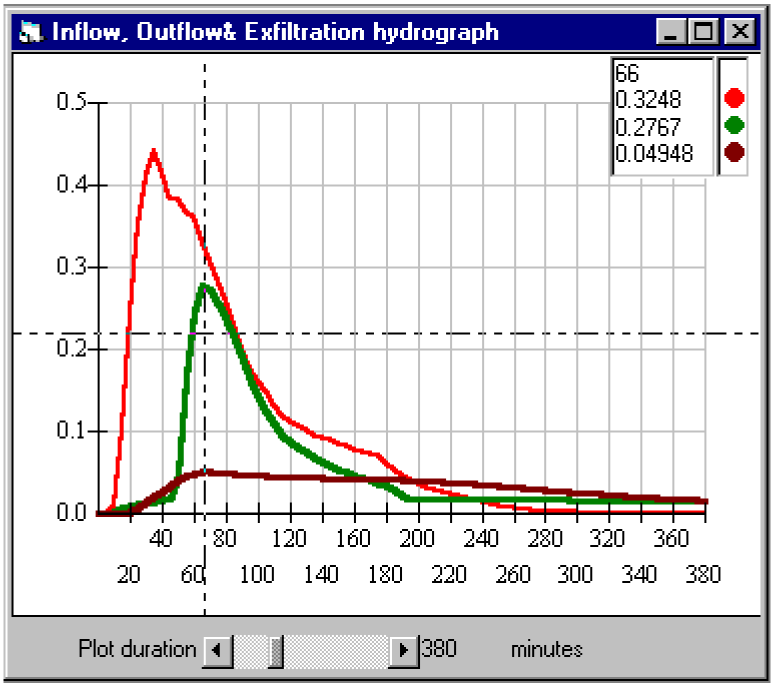


Figure 4-97 – A graph of Inflow, Outflow and Exfiltration

The graphical display shows three flow hydrographs for inflow, outflow and exfiltration. The time base of the displayed hydrographs can be changed by clicking on or moving the horizontal slider below the graph area. This may be useful if you want to see how long exfiltration persists.

As with other graphical displays, the graph window can be moved by dragging the title bar or resized by dragging an edge or a corner of the graph window.

Time in minutes and values of the flows at the vertical through the mouse pointer can be displayed in the small window in the top right corner of the graph area by moving the mouse pointer over the graph. Holding down the right (secondary) button on the mouse causes a pair of cross hairs to be displayed as illustrated.

The coloured dots against the flow values serve as a legend for the three hydrograph plots. You can display a set of written labels by clicking on the window containing the coloured dots to toggle this on and off.

Finally, the grid can be modified by clicking with the left (primary) mouse button in the window containing the flow values.

Should you wish to distinguish the hydrographs by line pattern instead of colour you can make use of the Show/Graph Style command in the Main Menu. You will have to set the thickness of all lines to one pixel in order to make line patterns visible since Windows does not support patterns with thick lines. You will have to repeat the [Route] command to display the new line properties.

Most of the windows displayed can be moved and re-sized and you may find it useful to construct a composite of the overall design and print a hardcopy for your file.

Chapter 5 - Hydrograph Manipulation

This chapter describes the various operations which can be used in MIDUSS 98 to manipulate the flow hydrographs which are generated during the hydrologic simulation. In addition, particular attention is given to the processes by which junction nodes are handled and some special considerations when dealing with relatively complex networks of nodes and links.

A brief description of the various commands is contained in Chapter 2 - *Structure and Scope of the Main Menu* under the heading The Hydrograph Menu. Some of the information in that section is duplicated here for convenience of reference.

The topics covered in this chapter are summarized below.

An Introduction to Networks

Drainage networks - whether they are natural drainage basins or man made stormwater systems - usually develop in the shape of a tree. Small tributaries join together to form larger tributaries leading eventually to a single, large channel or conduit at the outflow point of the watershed. A tree network can be visualized as a series of branches or links which connect a set of points with the minimum number of links. The points are referred to as nodes.

Notice that you will need to treat the major and minor drainage systems as separate networks connected at locations where there are diversion devices.

These nodes represent either:

(i) junctions where two or more links join,

or (ii) points in a single branch representing some discontinuity in conduit geometry or discharge.

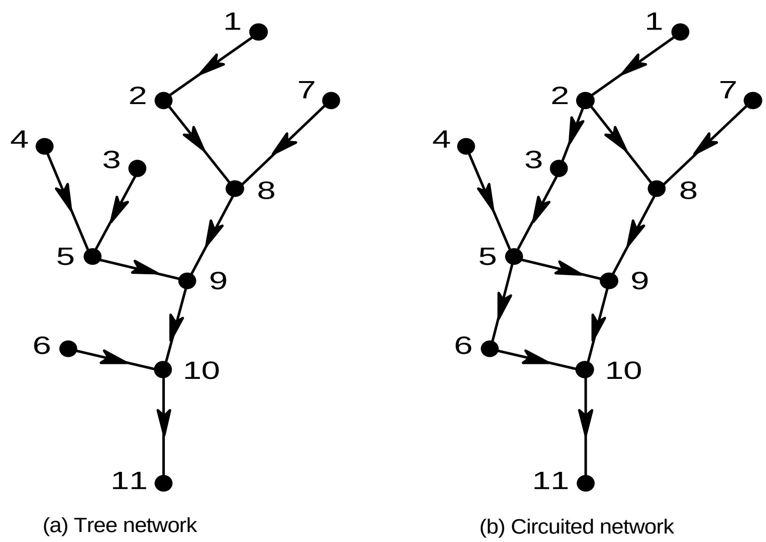


Figure 5.1 - (a) A Tree network and (b) A Circuited network.

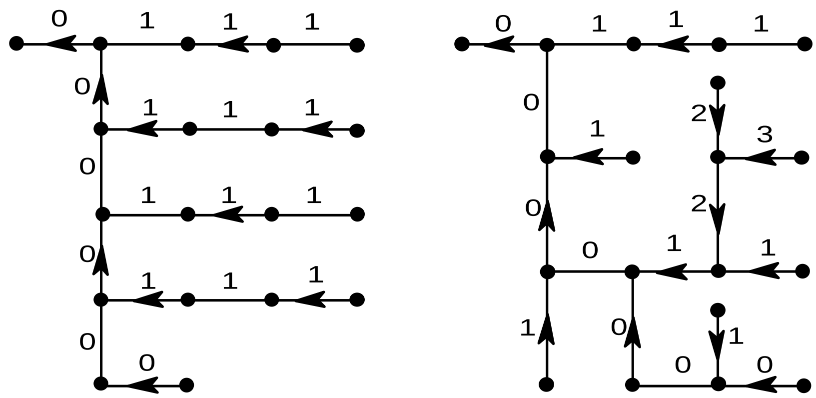
Figure 5.1(a) shows a simple tree network comprising 11 nodes and 10 links. In a tree network the number of links is always one less than the number of nodes. Another important characteristic of a tree network is that each internal node can have several inflow links but only one outflow link.

Figure 5.1(b) shows the same set of 11 nodes but with 12 connecting links. The two additional links form closed paths and the network is said to be circuited. In each of the two loops that are formed, there is one node that has two outflow links forming a bifurcation. Circuited networks are much loved by the water (or gas) supply engineer since the extra redundant links provide additional reliability of supply for certain demand points. In storm sewers, a circuited network may result if stormwater can be partially diverted by some control device such as a side-discharge weir or even a simple catchbasin. Devices of this type can be simulated by the **Design/Diversion** command (see Chapter 4 *Design Options Available* Diversion Structure Design).

Next, see Networks of Different Levels of Complexity.

Networks of Different Complexity

Figures 5.2(a) and (b) show two typical tree networks with different levels of complexity. The tree of Figure 5.2(a) is of first order complexity because every link is no more than one junction away from the main branch. The order of the branch is indicated by the number beside it in the figure.



(a) First Order Tree (b) Third Order Tree

Figure 5.2 - Tree networks of different order.

Figure 5.2(b) shows a tree with the same number of nodes (and therefore links) but with more complex connectivity. This tree is 3rd order, but depending on the choice of main branch, it may even appear to be 4th order.

The significance of the different orders of complexity is the number of junctions that you must keep track of at any one time in order to estimate the flow in every link of the tree. In Figure 5.2(a) only one junction node need be considered at any one time. In Figure 5.2(b) as many as three or four junctions may be required to process the flows through the network.

The purpose of this chapter is to describe how MIDUSS 98 can help you to manipulate and keep track of the flow hydrographs in each link of the drainage network. An important first step is to define a logical numbering convention for networks.

A Network Numbering Convention

MIDUSS 98 is intended for the analysis and design of drainage systems that are tree networks. This means that strictly speaking each node should have no more than a single outflow link. To avoid ambiguity the convention is adopted whereby each link is assigned the same number as the node at its upstream end. Despite this apparent restriction, it is possible to describe a looped or circuited network as noted below (see the section later in this chapter on Representing a Circuited Network).

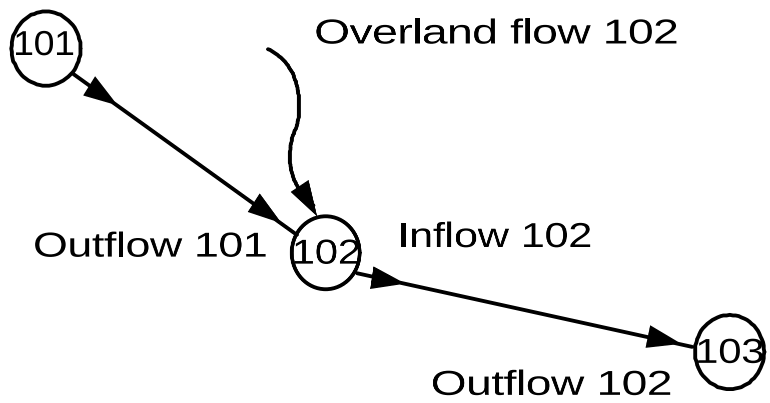


Figure 5-3 – A Network Numbering convention

As illustrated in Figure 5-3, each node is associated with a possible overland flow runoff hydrograph which is identified by using the same subscript number as the node where it enters the drainage system. Each link has associated with it an inflow and an outflow hydrograph which take the same subscript as the link (which is the same as the upstream node number). The node numbers used are quite arbitrary and used simply for reference purposes. Node numbers must be integers in the range 0 - 99999. It is usual but not required to use node numbers which increase in the downstream direction.

During analysis and design these hydrographs are stored in the three arrays for overland flow, inflow and outflow hydrographs. The nature of the design process is such that only one hydrograph of each type need be stored at any one time, so only one storage array of each type is required.

A fourth temporary hydrograph array is provided in order that an outflow hydrograph entering a junction node can be stored temporarily while other tributary branches which enter the same junction node are analyzed and designed. The special commands **Hydrograph/Combine** and **Hydrograph/Confluence** are provided to allow this type of manipulation. The peak flow values of these four hydrographs are displayed in the peak flow summary table and updated with the completion of each command - typically by pressing an [Accept] button.

In MIDUSS 98 an additional hydrograph storage array is defined to serve as a Backup Hydrograph so that an 'Undo' command can be implemented but the current value of the backup is not displayed. Usually the presence of a Backup hydrograph is indicated by the fact that the **Undo** menu item in the **Hydrograph** menu is enabled, otherwise it is 'grayed out'.

With this numbering convention established, we can now apply this to a simple tree network.

A Simple Tree Network

Figure 5.4 shows a simple 6 node network with 5 links. The figure also shows the various hydrographs associated with the system using the numbering convention just described. In this example, catchments contributing overland flow are located only at nodes (1), (3) and (5).

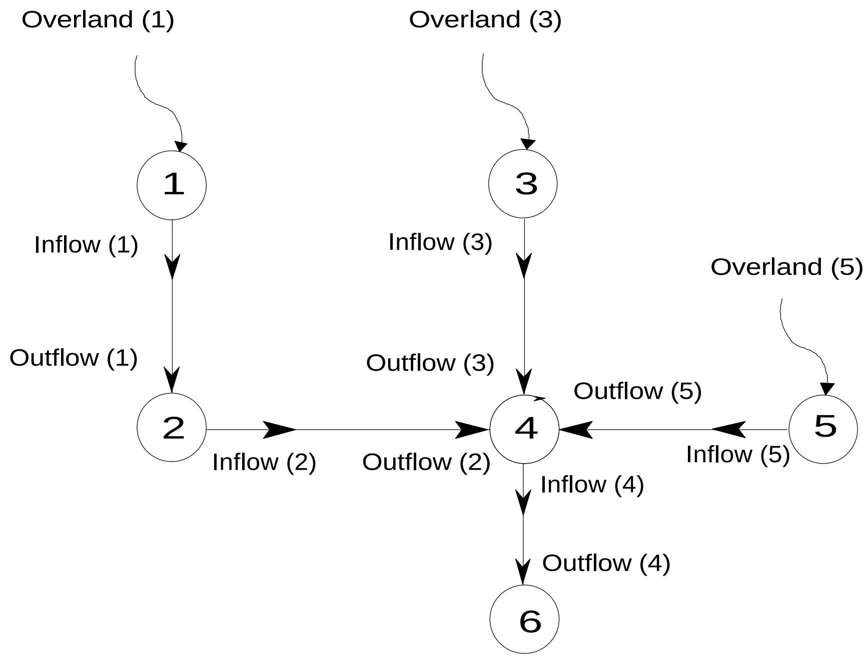


Figure 5.4 - Schematic diagram of a 6-node tree network.

The numbering convention used here can also be employed to describe a circuited network.

Representing a Circuited Network

Circuited networks may be represented by using the **Design/Diversion** command to define a structure or device which splits the inflow hydrograph into an outflow hydrograph and a diverted hydrograph. The latter is written to a file which can later be retrieved by means of the **Hydrograph/File I/O** command (see Chapter 6 *Working with Files*), to create a new 'tributary' to the tree network. The idea is illustrated in Figure 5.5.

It should be emphasized that this type of 'looped' network does not have to satisfy the requirement that the algebraic sum of the head losses around a loop must be zero (i.e. Kirschhoff's 2nd law). This is because the diversion structure at the branching node involves a control section at which the head loss is unknown.

For example, in Figure 5.5 node 6 is a branching node. The two branches join again at node 12. However, the total head loss along the two routes (6)-(7)-(9)-(12) and (6)-(10)-(11)-(12) will not be equal and one of the branches entering node (12) is likely to involve a control or section of critical flow..

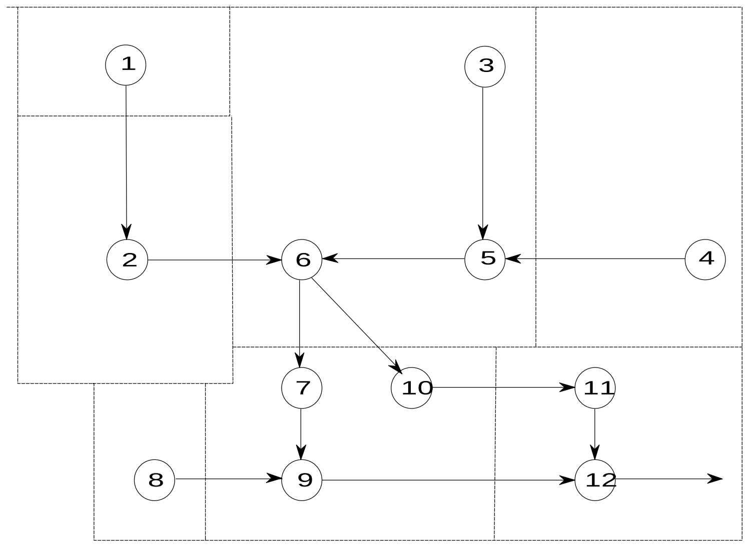


Figure 5.5 - Representing a circuited network as a tree.

Two simple examples are illustrated at the end of this chapter but before looking at these you should review the various commands available for manipulation of flow hydrographs.

Hydrograph Manipulation Commands

Figure 5-6 – The Hydrograph menu

As shown in this menu fragment, a number of commands are provided to let you manipulate hydrographs in various ways. These are described briefly in Chapter 2, *Structure and Scope of the Main Menu* and are summarized here as follows:

The START command allows you to either define the elements of the inflow hydrograph or set them all to zero. The zero option of this command should be used when starting a new tributary.

The ADD RUNOFF command adds the overland flow hydrograph to the current inflow hydrograph; the overland flow is unchanged. This causes the runoff from a catchment to be added to the main flow in the drainage network.

The NEXT LINK command sets the inflow hydrograph equal to the current outflow hydrograph. This command allows the design to proceed to the next downstream element of the drainage network.

The COMBINE command adds the outflow hydrograph to the current contents of the hydrograph at a specific junction node. If no junction hydrograph exists a new one is created. This enables the outflow from two or more branches flowing into a junction node to be accumulated. The resulting total hydrograph is stored in the temporary or junction hydrograph array.

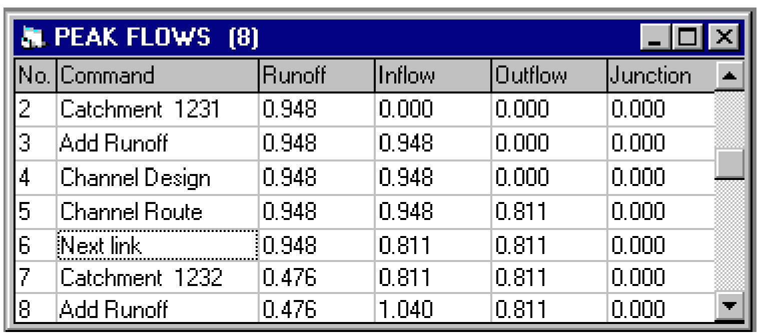
The CONFLUENCE command takes the accumulated hydrograph at a junction node and copies it into the inflow hydrograph array. The previous contents of the inflow hydrograph are overwritten. The temporary hydrograph is set equal to zero and the junction file is deleted.

The REFRESH command lets you review the junction files in the current job directory at any time. You can remove any files that are no longer required. It is invoked automatically the first time you use the Combine command in a design session.

All of the above commands cause a backup copy to be made of the hydrograph which is being changed. The **Hydrograph/Undo** menu item is enabled and you may reverse the process to restore the affected hydrograph to its previous value. Only one level of backup is provided.

The operations listed above are described in more detail in the sections which follow.

Each of the above commands is followed automatically with an update of the peak flow summary table that shows the new peak flow values in all four of the hydrograph arrays.


PEAK FLOWS (8)

No.	Command	Runoff	Inflow	Outflow	Junction
2	Catchment 1231	0.948	0.000	0.000	0.000
3	Add Runoff	0.948	0.948	0.000	0.000
4	Channel Design	0.948	0.948	0.000	0.000
5	Channel Route	0.948	0.948	0.811	0.000
6	Next link	0.948	0.811	0.811	0.000
7	Catchment 1232	0.476	0.811	0.811	0.000
8	Add Runoff	0.476	1.040	0.811	0.000

Figure 5-7 - A typical peak flow summary table.

The Start Command

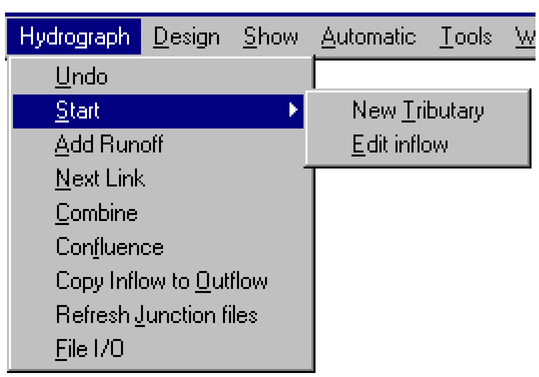


Figure 5-8 – Two options with the Hydrograph/Start command

As shown above, the **Hydrograph/Start** menu item can be used in two ways. You can either:

(a) set the Inflow hydrograph to zero

or (b) edit the current inflow hydrograph.

You should use the **Start/New Tributary** option after you have used the Combine command to store an outflow hydrograph at a junction node and wish to start a new tributary of the drainage network.

The **Start/Edit Inflow** option is less commonly used but may be useful to input a hydrograph which represents observed data for comparison with a simulated hydrograph. Alternatively, you may wish to input a hydrograph obtained by use of another model.

The Start / New Tributary Option

This option must be used when the design of a new tributary branch is started, so that when the furthest upstream overland flow hydrograph is generated it can be loaded into an empty inflow hydrograph by means of the **Hydrograph/Add Runoff** command.

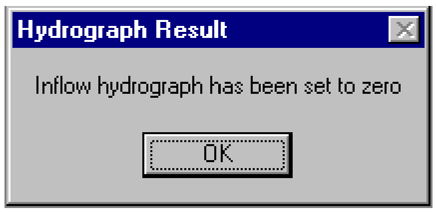


Figure 5-9 – The message following the Start/New tributary command

When you use the Start/New Tributary command the message shown in Figure 5-9 is displayed. You can continue either by clicking on the [OK] button or simply pressing the space bar. The summary table of peak flows is also updated to show the current inflow peak as zero.

The Start/Edit Inflow Option

You can use this option of the **Start** command to key in the flow values during a MIDUSS 98 design session. When you invoke the **Hydrograph/Start/Edit inflow** command the current Inflow hydrograph is displayed ib both graphical and tabular form. If the Inflow hydrograph is currently empty the graph will be a zero height, horizontal line and the table on the lower left corner will contain only zeros. The number of elements will equal the number of time steps in the maximum hydrograph duration specified at the start of the session.

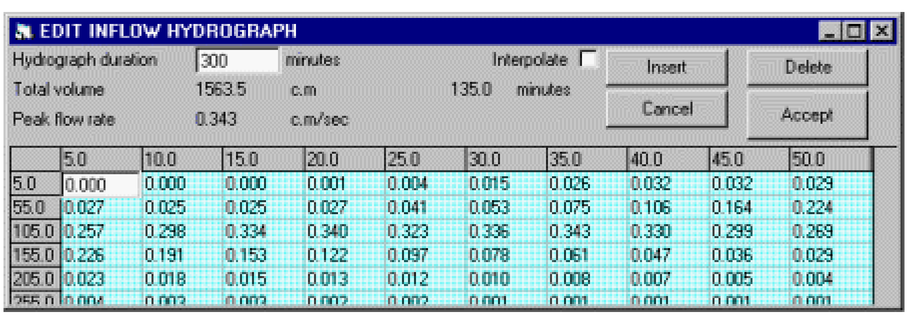


Figure 5-10 – The Inflow hydrograph editing window

If a finite Inflow hydrograph is displayed, it is likely that a large number of elements towards the end of the hydrograph will be zero and you can discard these by setting the duration to an appropriate value. In

Figure 5-10 a value of 300 minutes has been specified. On the graph you can move the time slider to show as little or as much of the hydrograph as you wish.

In the table, the time value (left of the [Cancel] button) is the time in minutes for the cell under the mouse pointer. The current cell for text entry is initially at the first cell in the top row and can be moved by means of the arrow keys. When the active cell is at the right end of a row, pressing the right arrow key will cause it to wrap around to the left cell of the next row.

The Inflow hydrograph can be edited as described in the next topic Editing an Existing Inflow Hydrograph

Editing an Existing Inflow Hydrograph

The tabular display shown in Figure 5-10 includes a number of command buttons with the following uses.

[Insert] causes a new cell to be inserted immediately prior to the current active cell and the new cell becomes the active cell. All the cells following the new cell are moved to the right (i.e. later) by one time step and the hydrograph duration is increased by one time step. The value entered in the new cell depends on whether or not the 'Interpolate' check box is checked or not.

- If 'Interpolate is left unchecked the value in the new cell is zero.
- If 'Interpolate is checked the value is a linear interpolation of the values in the two adjacent cells. If [Insert] is clicked when the first cell in the table is the active cell, the new cell becomes the first cell and the value is one half of the cell to the right (i.e. the previous first cell)

The statistics of total volume and peak flow are updated and the duration is increased by one time step.

[Delete] causes the currently active cell to be deleted and all cells after the deleted cell are moved one time step to the left (i.e. earlier). The duration of the hydrograph is reduced by one time step. If the [Insert] button was previously disabled it is re-enabled. The statistics of total volume and peak flow are updated.

[Cancel] causes the command to be aborted and the Inflow hydrograph is restored to its value prior to executing the **Hydrograph/Start/Edit inflow** command. The graph window is closed, the Inflow hydrograph is displayed in tabular form superimposed on the Edit Inflow table and a message is displayed to tell you that the Inflow hydrograph has been restored. A line showing the restored Inflow peak is entered in the peak flow summary table.

[Accept] causes the changes in the inflow hydrograph to be made permanent. The graph window and the Edit Inflow table are closed and a line showing the new peak value is added to the peak flow summary table. An important point to note is that the modified Inflow hydrograph is not copied to the current Output file as was the case with Miduss 4.72. If you want to use this hydrograph in future runs in Automatic mode you must save it as hydrograph file by using the **Hydrograph/FileI_O** command.

You can change the duration of the hydrograph by entering a desired duration in minutes in the text box. This must be not greater than the maximum hydrograph duration specified at the start of the session. If the specified duration is less than or greater than the current length the grid will be modified by truncating the trailing values or adding additional cells with zero values.

The duration can also be changed by using the [Insert] or [Delete] buttons.

To enter a new value or change an existing one make the cell to be edited the active cell either by moving to it with the arrow keys or by clicking on it with the mouse pointer. Then type the new value. As you enter values, you will see the total volume value in the table header being updated; the peak flow rate is also updated if you change the maximum value in the table. The changes you make to the data are also reflected in the graphical display.

When editing the data in this way, the Backspace key is active but the Delete key is not.

The Add Runoff Command

This command causes the Overland flow hydrograph to be added to the current Inflow hydrograph array. The contents of the overland flow array are left unaltered. If you use the option **Options/Other options/Show Next logical menu** item, the Add Runoff menu is automatically highlighted and the mouse pointer positioned after you have accepted the Catchment command. The command has the effect of accumulating the most recently generated runoff hydrograph into the drainage network.

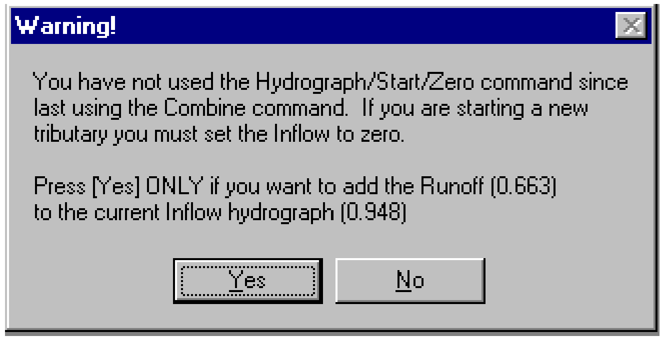


Figure 5-11 – MIDUSS98 warns you against possible 'double counting'

At the start of a new tributary or branch, the **Add Runoff** command should be preceded by the **Start/New Tributary** command to ensure that the inflow hydrograph array is empty. MIDUSS 98 detects if you have recently used the Combine command and then try to use the Add Runoff command without having set the Inflow hydrograph to zero. You will see a warning message as shown in Figure 5-11.

You will note that since the peak flows in the overland flow and inflow hydrographs are likely to occur at different times the peak flow of the sum of the hydrographs will usually be less than the sum of the peak flows of the individual hydrographs.

Figure 5-12 – Typical message following a hydrograph operation.

On successful completion of the **Add Runoff** command the message shown in Figure 5-12 is displayed. You can delete this and continue either by clicking on the [OK] button in the message box, or by pressing any key (e.g. the spacebar) on the keyboard

The Next Link Command

The **Hydrograph/Next Link** command causes the current Outflow hydrograph to be copied to the Inflow hydrograph array. The command will normally be used following any of the Design commands which cause a new Outflow hydrograph to be created (e.g. Route, Pond, Trench or Diversion). In order for the design to proceed to the next downstream element of the drainage network the outflow from the current element must become the inflow for the adjacent downstream link. Hence the need for the Next Link command.

After each of the Design commands which result in a new outflow you have two choices.

(i) The outflow may enter a junction node and thus require use of the **Hydrograph/Combine** command.

(ii) The outflow may simply pass to the next link downstream and thus require you to use the **Hydrograph/Next Link** command.

Working with Junction Nodes

The **Hydrograph/Combine** and **Hydrograph/Confluence** commands allow you to combine hydrographs at junction nodes in a network. They make use of the Junction or Temporary hydrograph array which serves as a storage buffer in which two or more outflow hydrographs can be accumulated.

As discussed in the section An Introduction to Networks at the beginning of this chapter, it may be necessary to store the accumulated flow hydrographs at more than one junction node at any one time. To illustrate this idea, Figure 5.13 shows the same 3rd order network as Figure 5.2(b) but with node numbers added for reference.

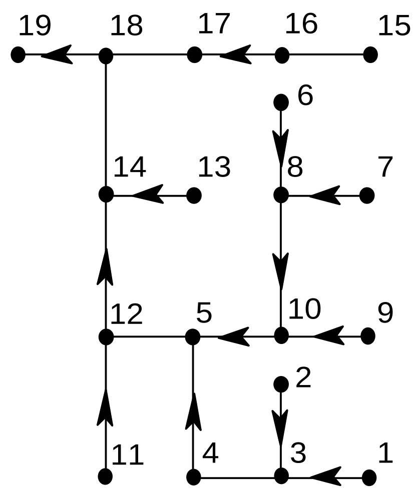


Figure 5.13 - A complex network

Assuming that modelling started with node #1 the sequence of operations might take the following form.

1 Generate flow at node 1.

2 Use Combine to create junction flow at node 3.

3 Generate flow at node 2.

4 Use Combine to add flow to junction node 3.

5 Get total flow at node 3 (using Confluence) and continue downstream.

6 Use Combine to create junction flow at node 5.

7 Generate flow at node 6.

8 Use Combine to create junction flow at node 8.

:

and so on.

In this case as many as three junctions may be 'active' at any one point in the modelling of the network. In order to do this, MIDUSS 98 creates a file which serves as a backup for the temporary storage array. Each time you use the **Combine** command to create a new junction node you are prompted to specify the number of the junction node. This should be a unique integer number in the range 1 to 99999 which is used to create a file name of the form Hydnnnnn.JNC which is stored in the current Job directory.

When a junction node is defined in this way it is added to the current list of junction nodes and a file with the appropriate name is created. The outflow hydrograph array is copied (not added) to the temporary storage array, the contents are then written to a newly created disk file.

If an existing junction node is used, MIDUSS 98 copies this hydrograph file to the temporary storage array, then adds the contents of the outflow hydrograph array to it and finally re-writes the updated contents of the temporary storage array to the same disk file. The original disk file is overwritten.

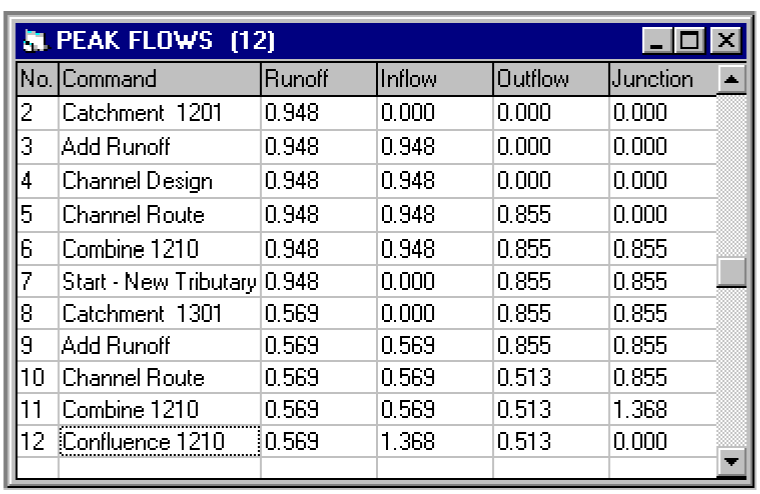
In both cases the updated contents of the temporary storage array are displayed in the table of peak flows. Refer to the topic on The Combine Command later in this chapter.

After using the **Hydrograph/Combine** command it is likely that you will want to define a new tributary. MIDUSS 98 detects if you have recently used the **Combine** command and then try to use the **Add Runoff** command without having set the Inflow hydrograph to zero.

A peak flow summary table which illustrates the use of the Combine and Confluence commands is shown in Figure 5-14 in the next topic.

For more details on using the **Combine** command or the **Confluence** command refer to the section later in this chapter.

An Example of Using a Junction


PEAK FLOWS (12)

No.	Command	Runoff	Inflow	Outflow	Junction
2	Catchment 1201	0.948	0.000	0.000	0.000
3	Add Runoff	0.948	0.948	0.000	0.000
4	Channel Design	0.948	0.948	0.000	0.000
5	Channel Route	0.948	0.948	0.855	0.000
6	Combine 1210	0.948	0.948	0.855	0.855
7	Start - New Tributary	0.948	0.000	0.855	0.855
8	Catchment 1301	0.569	0.000	0.855	0.855
9	Add Runoff	0.569	0.569	0.855	0.855
10	Channel Route	0.569	0.569	0.513	0.855
11	Combine 1210	0.569	0.569	0.513	1.368
12	Confluence 1210	0.569	1.368	0.513	0.000

Figure 5-14 – The peak flow summary table illustrates use of the Combine command.

This summary table shows the peak flows resulting from two catchments 1201 and 1301 the runoff from which is conveyed by channel to a junction node number 1210. Notice that for the second catchment the same channel cross-section is used. Finally, the total flow at junction 1210 is transferred to the Inflow hydrograph by the **Confluence** command to allow the design to continue downstream. If necessary, more than two tributaries can be combined at a junction node.

The Combine Command

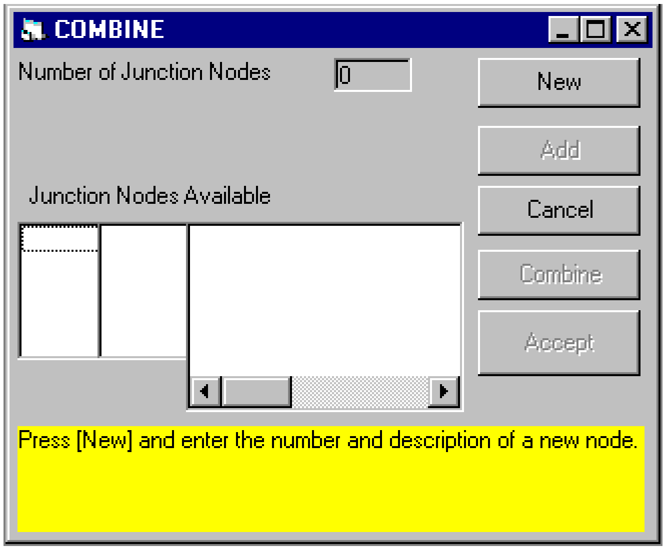


Figure 5-15 – The initial state of the Combine window

When the **Hydrograph/Combine** command is used the window shown in Figure 5-15 is displayed. If this is the first use of Combine, the list boxes will be empty and you must go through the following steps to define a junction node and add the Outflow hydrograph to it. The sequence of steps is as follows.

- Press [New] and enter a node number
- Enter a verbal description
- Press [Add] to copy this to the list box
- Select (i.e. highlight) the junction node by clicking on it in the list box
- Click [Combine] to add the current Outflow
- Click [Accept] to close the window

Define a Node number

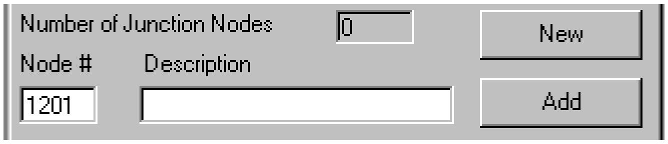


Figure 5-16 – Defining a new junction node number

The Combine window will initially show no existing junction files and you must define a new one by entering a node number and description. Press the [New] button to open the text box for a node number and type any positive integer in the range 1 to 99999.

This node number is used to create a Junction file name of the form **HYD??????.JNC**. Thus in the example shown a file with the name **HYD01201.JNC** will be created. MIDUSS 98 will not accept a node number less than 1.

Next, add a description.

Add a Description

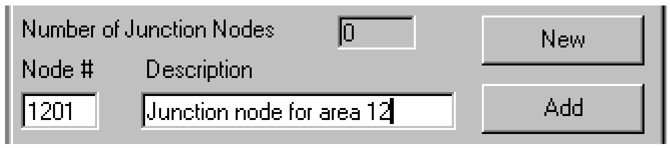


Figure 5-17 – Add a detailed description for future reference

The text box to contain the description is opened only after a node number has been entered. Click on the Description text box to set the focus and type in a verbal description. The length of the description can be much longer than the text box and can occupy several lines. These will be copied as a single record as part of the file header.

Next, add this file to the List of Junctions.

Add the Node to the List of junctions

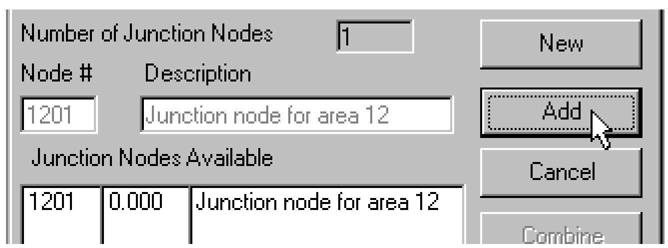


Figure 5-18 – Add the new node to the list of Junction Nodes Available

Once the node number and description of the new junction node have been defined you can click on the [Add] button. This will cause the file to appear in the 'Junction Nodes Available' list. In Figure 5-18, the new file is the only one in the list. If this was not the first junction node, it would be added at the foot of the list.

The list contains three sections defining:

- the node number,
- the peak flow of the accumulated hydrograph at the junction node. This is currently zero because nothing has been added yet, and
- the node description. If the description is longer than the width of this section a horizontal scroll bar will appear at the foot of this section of the list.

The next step is to select a junction file from the list.

Select a Junction Node

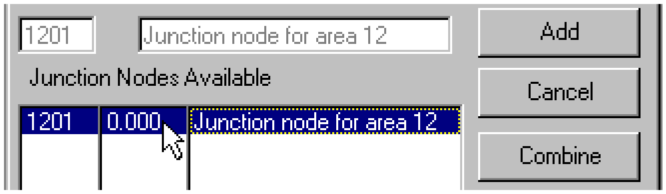


Figure 5-19 – Selecting a node enables the [Combine] button

To select a junction node from those shown in the list you must click on any part of the appropriate row with the mouse pointer. This will cause the junction file row to be highlighted as shown in Figure 5-19. Also, the [Combine] key will be enabled just to the right of the list.

Now you can add the current Outflow hydrograph to the selected junction file.

Add the Outflow

You can now click on the [Combine] button to add the current Outflow hydrograph to the accumulated flow at the selected junction node. If this is the first time this junction node has been used, selecting the file will cause a message (Figure 5-20) to be displayed advising you that the file does not exist and requesting confirmation to create the file.

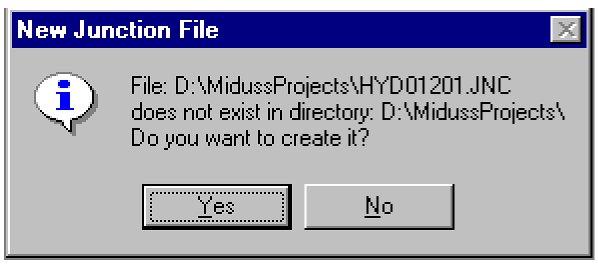


Figure 5-20 – Confirmation is required before a new file is created

The default button on the message box is [Yes] and you can accept this by clicking on the [Yes] button, or by pressing any key on the keyboard - e.g. the spacebar. Pressing [No] lets you choose another junction file.

When you press the [Yes] button, the new value of the peak flow at the selected Junction node is displayed in the middle section of the list box as shown in Figure 5-21. The [Combine] button is disabled to prevent accidental double use of the Outflow hydrograph.

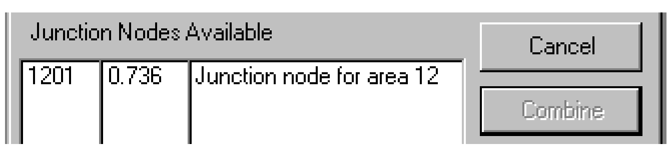


Figure 5-21 – Click [Combine] to update the peak flow at the selected junction

Finally, you are prompted to click on the [Accept] button, and a final message is displayed summarizing the updated peak flow and volume of the accumulated junction hydrograph. A typical message is shown in Figure 5-22.

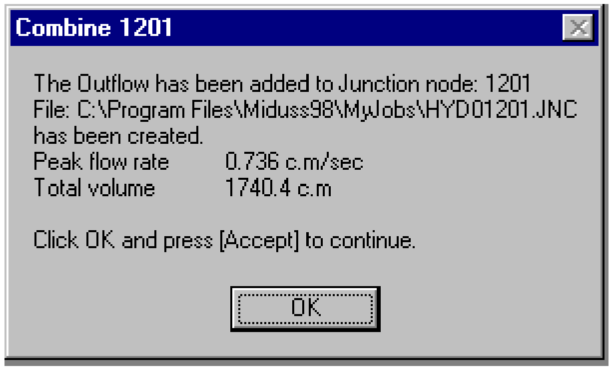


Figure 5-22 – MIDUSS98 describes the new junction hydrograph.

Now you can accept the result of the operation.

Accept the result

Adding the Outflow by pressing the [Combine] button enables the [Accept] button which has been "grayed out" up to now.

You will also have noticed helpful prompts displayed at the bottom of the Combine window. At this point you will be advised to press the [Accept] button to accept the result and close the Combine window.

When you do this you will see that the summary table of peak flows is updated with a new record noting the node number and the peak flow in the Junction or temporary hydrograph column.

The Confluence Command

This command is used when all the outflow hydrographs entering a junction node have been accumulated in the temporary storage array by means of two or more uses of the **Hydrograph/Combine** command. The **Hydrograph/Confluence** command causes the accumulated flow hydrograph at a particular node to be copied to the Inflow hydrograph. This enables you to continue with the design of the link (e.g. pipe or channel) immediately downstream of the junction node.

As described for the **Hydrograph/Combine** command, MIDUSS 98 uses disk files as a backup of the temporary storage array in order that any number of junction nodes may be active simultaneously. These backup files are given names of the form **HYDnnnnn.JNC** as defined in the **Combine** command.

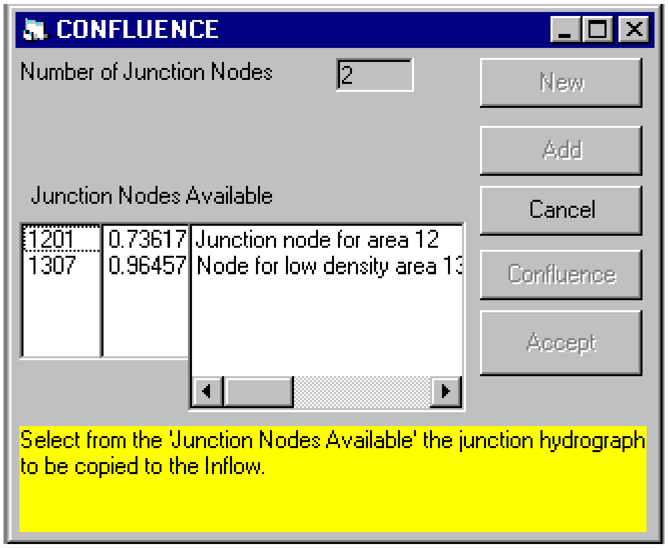


Figure 5-23 – The Confluence window will show at least one junction node

The window is basically the same as that used for the **Combine** command. Since the **Hydrograph/Confluence** command is enabled only after the **Combine** command has been used, there will be at least one Junction node shown in the list of Junction Nodes Available. Figure 5-23 shows two junction nodes from which we will choose the upper one for node 1201.

The procedure is outlined in the following steps.

- Select the Confluence node
- Copy the Junction hydrograph
- Accept the Confluence result.

A further safeguard is built into the **Confluence** command to reduce the potential for error in cases where the overland flow hydrograph from a sub-catchment enters the drainage network at a junction node. Because the confluence command causes the inflow hydrograph to be overwritten, it is important that the **Add Runoff** command be used after the **Confluence** command, otherwise the contribution of the local sub-catchment will be deleted. MIDUSS 98 can detect a situation in which you may have inadvertently used the commands in the wrong order (i.e. **Add Runoff** followed by **Confluence**) and warns you that the overland flow has been deleted. You then have the opportunity to use the **Add Runoff** command a second time (since the overland flow hydrograph is unchanged) and thus recover from the error.

Select the Confluence Node

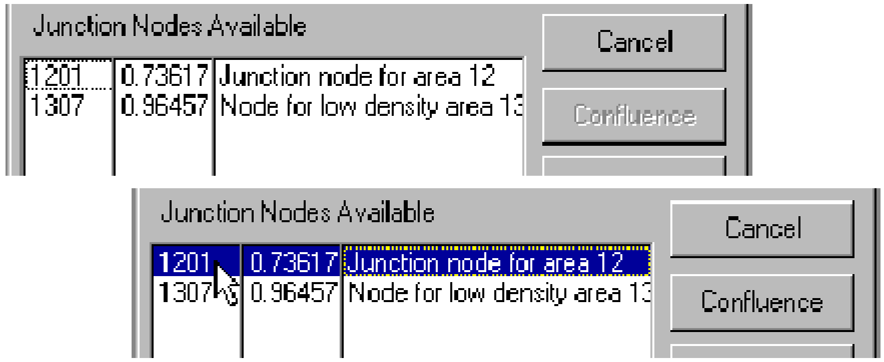


Figure 5-24 – Selecting a junction node enables the [Confluence] button

Figure 5-24 shows two fragments of the Confluence window containing the list of Junction Nodes Available. There are only two available in this example for junction nodes 1201 and 1307. Initially the [Confluence] button is disabled. By clicking with the mouse pointer on the row for node 1201 the row is highlighted as shown in the lower figure. The [Confluence] button is now enabled.

The next step is to copy the Junction hydrograph.

Copy the Junction Hydrograph

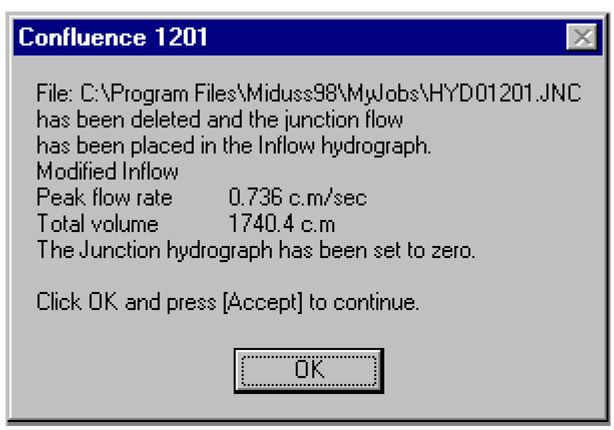


Figure 5-25 – The flow and volume of the new Inflow hydrograph are displayed

When you click on the [Confluence] button, a message is displayed telling you that the transfer of the Junction hydrograph to the Inflow hydrograph has been completed. Also, the associated file has been deleted and the Temporary or junction hydrograph array has been set to zero.

As shown in Figure 5-26, the list of Junction Nodes Available has been modified to show only the remaining node. The [Confluence] button is once again disabled.

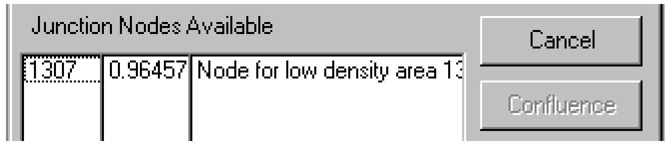


Figure 5-26 – The copied junction node is removed from the list

Now you should Accept the result of the Confluence operation.

Accept the Confluence Result

Pressing the [Confluence] button enables the [Accept] button which has been "grayed out" up to now.

You will also have noticed helpful prompts displayed at the bottom of the Combine window. At this point you will be advised to press the [Accept] button to accept the result and close the Confluence window.

When you do this you will see that the summary table of peak flows is updated with a new record noting the node number, the new peak flow in the Inflow hydrograph and a zero value in the Junction or Temporary hydrograph column.

Handling Old Junction Files

If a MIDUSS 98 design is completed in a single session, any junction files (i.e. files with a '.JNC' extension) created by the **Hydrograph/Combine** command should be automatically deleted with the corresponding **Hydrograph/Confluence** command. However if a design is carried out in two or more sessions, or if a design session is aborted for some reason, it is possible that some junction files may be left in the currently defined Job Directory. This is particularly true if you frequently neglect to specify a Job Directory with the result that all files created by MIDUSS 98 will accumulate in the MIDUSS 98 folder (typically C:\Program Files\Miduss98\ ).

In most cases junction files should be deleted since in repeating a run in automatic mode there is a danger that a flow hydrograph will be doubled if the **Hydrograph/Combine** command encounters an old file with the same node number.

To help you deal with this potential problem MIDUSS 98 makes a special check the first time the Combine command is used during a design session and detects all of the files in the current Job Directory which have an extension of *.JNC and gives you the chance to either remove them or retain them.

The procedure can be summarized in the following steps.

- Check for Junction Files
- Reviewing the Junction Files Available
- Selecting a File to Delete
- Continue to the Combine Command
- Confirming File Deletion on Exit

Check for Junction Files

The first time you use the **Hydrograph/Combine** command during a design session MIDUSS 98 detects any junction files in the current Job Directory. If one or more are found the message shown below is displayed.

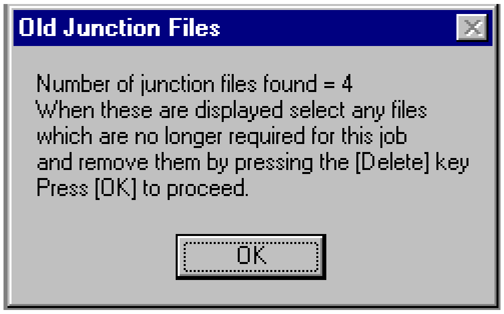


Figure 5_27 – MIDUSS98 checks for previously created junction files

Close the message box by clicking on the [OK] button or press the spacebar (or any key) on the keyboard.

MIDUSS 98 then displays the Junction Files Available.

Review the Junction Files Available

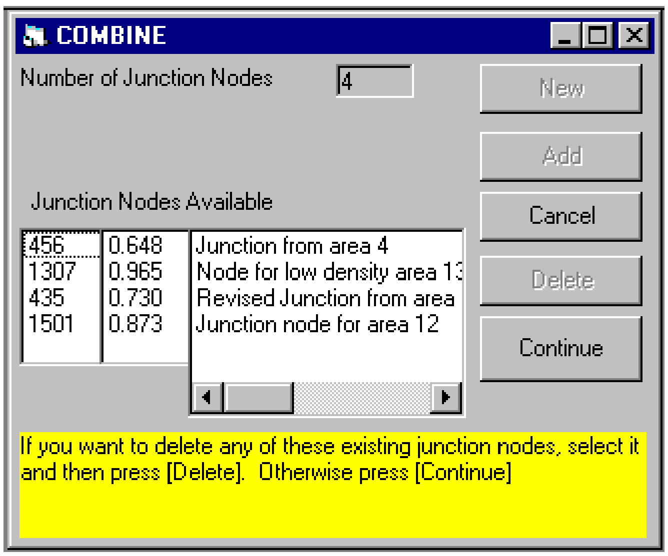


Figure 5-28 – All of the currently available junction nodes are displayed.

The **Hydrograph/Refresh Junction files** command uses the same window as is used for the **Combine** and **Confluence** commands as shown in Figure 5-28. In this example the 'Junction Nodes Available' list contains four files or nodes. In reviewing the files for possible deletion you will quickly learn the value of giving a full and meaningful description when junction files are first created.

Let's assume that only the bottom two (nodes 435 and 1501) are of use since they were created during a previous design session which was only partially completed and which is now being continued.

Now you can select a file to be deleted .

Select a File to Delete

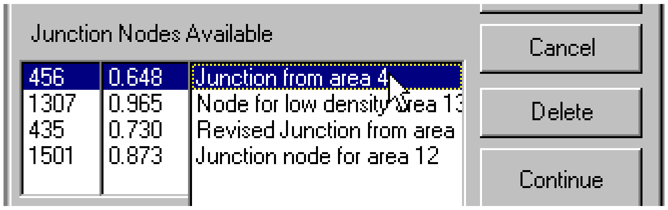


Figure 5-29 – Selecting an old junction node to be deleted.

Select the file for node 456 by clicking on it with the mouse pointer. As shown, the row is highlighted and the [Delete] button is enabled.

Now press the [Delete] button to remove the selected junction. MIDUSS 98 does not immediately delete the file **DIV00456.JNC** since it is possible that you may change your mind and recover the file. The file is therefore re-named by changing the extension to *.JNK . When the list is refreshed this file will no longer appear and the number of Junction Nodes will be reduced to three. This information is shown in a message box as follows.

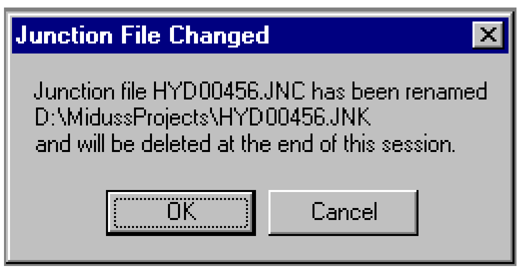


Figure 5-30 – MIDUSS98 advises you that the deleted file has only been re-named.

Should you change your mind at this point you can press the [Cancel] button and you will see a message that the junction file has been restored. When you close the message box the Combine window will be closed, but when you invoke the **Hydrograph/Combine** command again you will find the file appears once again in the list of Junction Nodes Available.

The process is repeated until only the junction files that you need for the current session are retained. Now you can finish with this house-keeping operation and continue to the Combine Command .

Continue to the Combine Command

Press the [Continue] button as suggested in the prompts shown at the bottom of the window. The window will be restored to the normal **Combine** format with the [New] and [Add] command buttons re-enabled. You can now proceed as described in the **Hydrograph/Combine** Command.

However, you will have one last chance to recover a junction file that was removed from the list at the end of the MIDUSS 98 session. See Confirm File Deletion on Exit.

Confirm File Deletion on Exit

As explained above, the "removed" junction files have merely been renamed and will not be physically erased from your hard disk until the end of the current session.

When you use the **Files/Exit** command to close MIDUSS 98 you will see a message box as shown in

Figure 5-31 for each of the removed junctions. If you press the [OK] button the file is erased but pressing [Cancel] will cause the file to be restored as a junction node by changing the extension back to ***.JNC**.

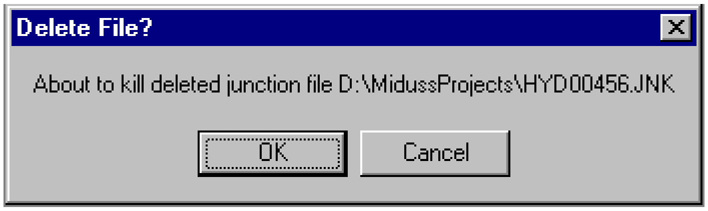


Figure 5-31 – When you finish the session you have a last chance to recover the 'deleted' file

The Copy Inflow to Outflow Command

This command causes the current Inflow hydrograph to be copied to the Outflow hydrograph overwriting the current contents. This may be useful if the current inflow is to be added to a new or existing junction node without the need to use a Design option such as the Pond command or the Pipe & Route commands. It is equivalent to using the **Design/Route** command with a pipe or channel of zero or negligible length.

The action can be reversed by means of the **Hydrograph/Undo** command.

Treatment of a Single Junction

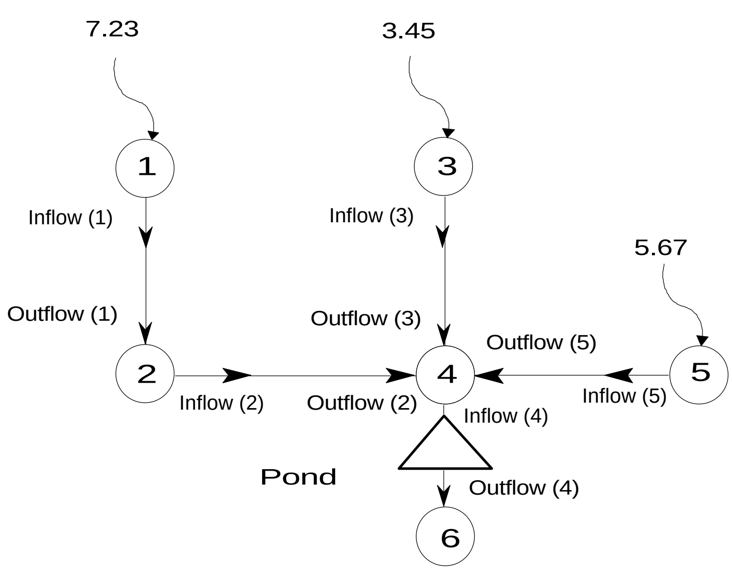


Figure 5.32 - A simple tree network with a single junction

Example 1: This example is for illustration and does not represent an actual MIDUSS 98 design session. Figure 5.32 shows a simple tree network comprising 6 nodes and 5 links. Three branches meet at a single junction node (4). The flows entering at nodes (1), (3) and (5) are assumed to have peak values as listed below and shown in the figure.

Node (1) - Peak flow = 7.23

Node (3) - Peak flow = 3.45

Node (5) - Peak flow = 5.67

The table below illustrates how the **Combine** and **Confluence** commands might be used to analyze this network. For brevity, the design of the links is represented by a combined Pipe/Route command resulting in some small and arbitrary attenuation. Each step in the design process will produce a complete hydrograph that is represented in the table by the peak flow. Note that in order to clarify the arithmetic it is assumed that the peaks are coincident in time. In an actual design the sum of two hydrographs would have a peak slightly less than the sum of the two respective peak flows.

Table 5.1 - Commands and peak flows for Example 1

Action	Runoff		Inflow		Outflow		Junction
Catchment 1	7.23		0.00		0.00		0.00
Add Runoff	7.23	- - - >	7.23		0.00		0.00
Pipe/Route	7.23		7.23	- - - >	7.10		0.00
Next Link	7.23		7.10	< - - -	7.10		0.00
Pipe/Route	7.23		7.10	- - - >	6.90		0.00
Combine at 4	7.23		7.10		6.90	- - - >	6.90
Start New tributary	7.23		0.00		6.90		6.90
Catchment 3	3.45		0.00		6.90		6.90
Add Runoff	3.45	- - - >	3.45		6.90		6.90
Pipe/Route	3.45		3.45	- - - >	3.20		6.90
Combine at 4	3.45		3.45		3.20	- - - >	10.10
Start New tributary	3.45		0.00		3.20		10.10
Catchment 5	5.67		0.00		3.20		10.10
Add Runoff	5.67	- - - >	5.67		3.20		10.10
Pipe/Route	5.67		5.67	- - - >	5.40		10.10
Combine at 4	5.67		5.67		5.40	- - - >	15.50
Confluence at 4	5.67		15.50	< - -	< - -	< - -	0.00
Pond	5.67		15.50	- - - >	10.35		0.00

The sequence of steps is straightforward and can be summarized as follows.

1. Runoff from sub-area 1 is generated and added to the Inflow
2. Pipe #1 is designed and flow routed to node (2)
3. The outflow from pipe #1 is made the Inflow for Pipe #2 by the Next Link command.
4. Pipe #2 is designed and flow is routed to node (4)
5. Outflow from pipe #2 is stored a junction node (4)
6. The Inflow is set to zero by the Start/New Tributary command
7. Runoff from sub-area 3 is generated and added to the Inflow.
8. Pipe #3 is designed and flow routed to node (4).
9. Outflow from pipe #3 is added to the flow at junction node (4).
10. The Inflow is set to zero by the Start/New Tributary command
11. Runoff from sub-area 5 is generated and added to the Inflow.
12. Pipe #5 is designed and flow is routed to node (4).
13. Outflow from pipe #5 is added to the flow at junction node (4).

14. The total flow at junction node (4) is placed in the Inflow hydrograph (overwriting the previous contents) by using the Confluence command. The junction file is deleted.
15. A detention pond downstream of node (4) is designed and the flow routed to node (6).

Treatment of a Circuited network

Example 2: Figure 5.33 illustrates a circuited network comprising 12 nodes and 11 links. The loop defined by nodes (6)-(7)-(9)-(12)-(11)- (10) is formed as a result of a Diversion structure at link #6 which produces a bifurcation of the flow to nodes (7) and (10).

Overland flow is assumed to enter the system at nodes (1), (2), (3), (4), (8),(9) and (11) with the following peak values.

Node (1) - Peak flow = 1.23

Node (2) - Peak flow = 0.63

Node (3) - Peak flow = 0.56

Node (4) - Peak flow = 2.34

Node (8) - Peak flow = 0.45

Node (9) - Peak flow = 0.75

Node (11) - Peak flow = 0.82

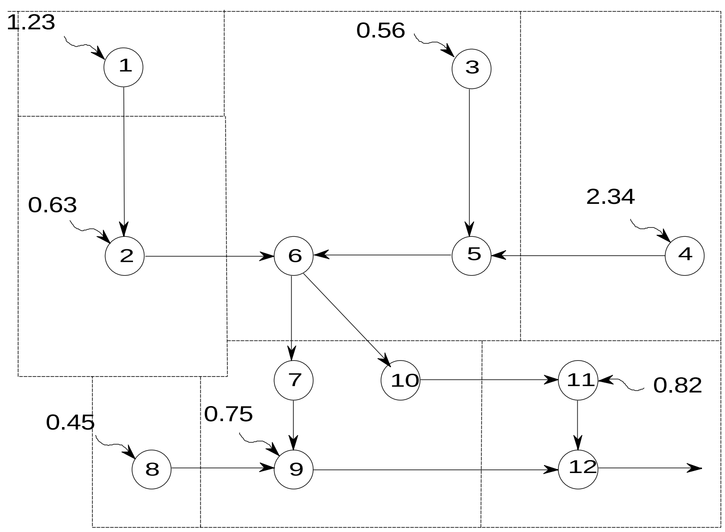


Figure 5.33 - A circuited network with a diversion structure

As in the previous example, all of the hydrographs are represented by their respective peak flow values. Also, the time to peak is assumed to be the same for all hydrographs in order to make the arithmetic more explicit. Refer to the table of commands shown below when reading the following explanation of the design procedure.

Table 5.2 - Commands and peak flows for Example 2

Action	Runoff		Inflow		Outflow		Junction
Catchment 1	1.23		0.00		0.00		0.00
Add Runoff	1.23	- - - >	1.23		0.00		0.00
Pipe 1/Route	1.23		1.23	- - - >	1.20		0.00
Next Link	1.23		1.20	< - - -	1.20		0.00
Catchment 2	0.63		1.20		1.20		0.00
Add Runoff	0.63	- - - >	1.83		1.20		0.00
Pipe 2/Route	0.63		1.83	- - - >	1.79		0.00
Combine at 6	0.63		1.83		1.79	- - - >	1.79
Start New tributary	0.63		0.00		1.79		1.79
Catchment 3	0.56		0.00		1.79		1.79
Add Runoff	0.56	- - - >	0.56		1.79		1.79
Pipe 3/Route	0.56		0.56	- - - >	0.52		1.79
Combine at 5	0.56		0.56		0.52	- - - >	0.52
Start New tributary	0.56		0.00		0.52		0.52
Catchment 4	2.34		0.00		0.52		0.52
Add Runoff	2.34	- - - >	2.34		0.52		0.52
Pipe 4/Route	2.34		2.34	- - - >	2.29		0.52
Combine at 5	2.34		2.34		2.29	- - - >	2.81
Confluence at 5	2.34		2.81	< - -	< - -	< - -	0.00
Pipe 5/Route	2.34		2.81	- - - >	2.76		0.00
Combine at 6	2.34		2.81		2.76	- - - >	4.55
Confluence at 6	2.34		4.55	< - -	< - -	< - -	0.00

The design starts with the design of links #1 and #2 (i.e. the links immediately downstream of nodes (1) and (2)) which, after routing through the pipes, produces a hydrograph with a peak flow of 1.79 entering the junction node (6).

This is stored in the Temporary or Junction hydrograph and also in a file called **`HYD00006.JNC`** - to allow links #3, #4 and #5 to be designed.

The hydrographs from links #3 and #4 meet at a second junction at node (5) which now occupies the Temporary or Junction hydrograph and causes a file **`HYD00005.JNC`** to be created.

After link #5 has been designed, the outflow hydrograph from this link can be added to the one already stored in file **`HYD00006.JNC`** by means of the **Combine** command.

The combined flow hydrograph entering link #6 is obtained by the **Confluence** command which sets the Junction hydrograph to zero and also deletes the file for this junction since it is no longer needed. Note that all the file manipulation is done automatically by MIDUSS 98 and that you need only use the **Combine** and **Confluence** commands consistently - i.e. with the correct junction nodes.

Table 5.2 - (Example 2 continued)

Action	**Runoff**	**Inflow**	**Outflow**	**Junction**
Diversion at 6	2.34	4.55 - - - >	1.15	0.00
(DIV00006.005)	< - - < - - < - -	3.40		
Next Link	2.34	1.15 < - - -	1.15	0.00
Pipe 7/Route	2.34	1.15 - - - >	1.09	0.00
Combine at 9	2.34	1.15	1.09 - - - >	1.09
Start New tributary	2.34	0.00	1.09	1.09
Catchment 8	0.45	0.00	1.09	1.09
Add Runoff	0.45 - - - >	0.45	1.09	1.09
Pipe 8/Route	0.45	0.45 - - - >	0.41	1.09
Combine at 9	0.45	0.45	0.41 - - - >	1.50
Confluence at 9	0.45	1.50 < - -	< - - < - -	0.00
Catchment 9	0.75	1.50	0.41	0.00
Add Runoff	0.75 - - - >	2.25	0.41	0.00
Pipe 9/Route	0.75	2.25 - - - >	2.21	0.00
Combine at 12	0.75	2.25	2.21 - - - >	2.21
FileI_O (DIV00006.005)	- - > - - >	3.40	2.21	2.21
Pipe 10/Route	0.75	3.40 - - - >	3.32	2.21
Next Link	0.75	3.32 < - - -	3.32	2.21
Catchment 11	0.82	3.32	3.32	2.21
Add Runoff	0.82 - - - >	4.14	3.32	2.21
Pipe 11/Route	0.82	4.14 - - - >	4.08	2.21
Combine at 12	0.82	4.14	4.08 - - - >	6.29
Confluence at 12	0.82	6.29 < - -	< - - < - -	0.00
Pipe 12/Route	0.82	6.29 - - - >	6.18	0.00

Link #6 is a diversion structure with a threshold flow of 0.55 and an overflow ratio of 0.85. Thus the peak outflow from the diversion structure is given by:

Qout = 0.55 + (1 - 0.85) x (4.55 - 0.55) = = 0.55 + 0.6 = 1.15

The discarded flow with a peak of 3.40 is stored in a file called **`DIV00006.xxx`** which is created by MIDUSS 98 to be recalled by the user at some future point in the design.

Design of link #7 proceeds as usual with the routed flow hydrograph (with a peak of 1.09) being stored at the junction node (9). A new tributary is started at node (8) and link #8 is designed and the outflow added to the hydrograph stored in junction node (9) by means of the **Combine** command.

The total flow entering node (9) (with a peak value of 1.50) is recalled by the **Confluence** command and used to design link #9. Notice that the **Catchment** command at node (9) could have been used before the **Confluence** command, as long as the **Add Runoff** command was used after it.

After generating and adding the overland flow from sub-area 9 and routing the flow through link #9, the outflow hydrograph (2.21 peak flow) is again stored at junction node (12) to allow links #10 and #11 to be designed.

The **Hydrograph/FileI_O** command is used to read the discarded hydrograph (from the diversion structure in link #6) and then places this in the Inflow hydrograph.

Links #10 and #11 are designed in the usual way, with sub-area 11 being added at node (12). The outflow link #11 is added to the hydrograph at node (12). Finally, the **Confluence** command copies the total flow hydrograph into the inflow array to allow design of link #12 to proceed.

This example demonstrates the importance of sketching the layout of the system and numbering the nodes before embarking on the design.

Chapter 6 - Working with Files

Programs and data normally reside in your computer's memory only as long as power is supplied. To keep a relatively permanent copy of computer-readable information, the programs, data etc. are stored in some form of physical medium. By far the commonest form is a surface covered with magnetic oxide in the form of permanently installed hard disks or exchangeable, floppy disks. Optical storage devices using recordable CDs are also becoming common. The notion of a file is a collection of information represented in some digital code and which can be read into the memory of the computer when it is needed. Most devices of this type are also capable of creating new files by outputting the information to the disk. The process of reading and writing files in a permanent form is fundamental to the storage, modification and distribution of packages of information.

Although you can use MIDUSS 98 without a detailed knowledge of computer operations, it is recommended that you becomes reasonably well informed with the way in which your computer manipulates files of information. Windows 95, Windows 98 and Windows NT offer some new features concerning the naming of files.

This chapter is concerned with the reading and writing of data files of various types and it is presumed that you have a basic understanding of the conventions for naming files and the folder or directory structure into which they are organized.

The following topics cover general information about file use in MIDUSS 98.

Types of Files and where they Reside

Commands that use Files

Storage Arrays that Interact with Files

File Names

File Formats

Most file operations which you will require can be done using the **Hydrograph/The File I/O Command**. Refer to this topic for complete details.

Types of Files and where they Reside

Two types of file are used by MIDUSS 98. These are MIDUSS 98 system files and job-specific files. MIDUSS 98 system files include the following:

default.out	a default output file used if you do not define a job-specific output file.
GrParams.dat	default options for line and fill patterns and colours in the Show/Graph window.
LagCurve.dat	an empirical curve used in the Lag & Route command
Miduss.log	a log of errors trapped during a MIDUSS 98 session.
Main.log	an optional log file created by the license manager
Qpeaks.txt	the data in the peak flows summary table for possible backup use.
*.mrd…..	a mass rainfall distribution such as Huff2.mrd or SCS_Type3_24hr.mrd
Miduss.Mdb…	the Input database for running in Automatic mode.

These files reside in the MIDUSS 98 folder i.e. C:\Program Files\Miduss98\ or an alternate location that you defined during installation.

Other files will reside in the current default job directory and will generally comprise either storm hyetographs or flow hydrographs. These will normally have the extension of *.stm or *.hyd for easy identification when using the File I/O command. Of course if you have not defined a job directory, any hydrograph files created will be stored in the Miduss98 folder. You should try to avoid this.

Two special types of hydrograph file should be mentioned. Files of the general form DIV *****.hyd are hydrograph files created by the Diversion command. Files with the extension *.JNC are junction files created by the Combine command.

After acceptance of the Storm command you are prompted to enter a descriptor that will be added to the name of any hydrograph file created to allow it to be associated with a specific storm event.

Commands that use Files

Almost all commands write information to the current Output file in order to allow creation of an Input database file for use in Automatic mode. Apart from this, only certain MIDUSS 98 commands make use of files. These are listed below for each of the commands which use them.

Menu Command	**Menu item**	**File name**
File	Open input Database	Miduss.Mdb
File	Output file…	*.out
File	Save Database As	*.Mdb, *.stm
Hydrology	Storm	*.mrd
Hydrograph	Combine	*.jnc
Hydrograph	Confluence	*.jnc
Hydrograph	File I/O	various
Design	Design/Log	Design.log
Design	Diversion	DIV?????.hyd
Show	Design Log	Design.log
Show	Output File	*.out
Show	Flow Peaks	Qpeaks.txt
Show	Graph	*.bmp
Automatic	Create Input Database	*.out, Miduss.Mdb
Automatic	Edit Input Database	Miduss.Mdb
Automatic	Save Database As	Miduss.Mdb
Automatic	Run input Database	Miduss.Mdb
Tools	Add Comment	*.out
Tools	Notepad	*.txt, *.*
Tools	Wordpad	*.doc, *.*
Help	Contents	*.hlp, *.cnt
Help	Tutorials	Tutorial*.exe

Note that Tutorial files on the MIDUSS 98 CD are read-only files.

Storage Arrays that Interact with Files

When you define the time parameters you set up the size of storage arrays to hold the hyetographs and hydrographs for the current MIDUSS 98 session. For example

Nstm = Maximum Storm Length / Time step

Nhyd = Maximum hydrograph / Time Step

The arrays used in MIDUSS 98 are then set up as follows.

Name	Size	Content
RainTemp()	Nstm	Temporary storm until accepted
Rain()	Nstm	Defined storm
RainEffI()	Nstm	Effective rain on Impervious fraction
RainEffP()	Nstm	Effective rain on Pervious fraction
OvHyd()	Nhyd	Total runoff
OvHydI()	Nhyd	Runoff from impervious area
OvHydP()	Nhyd	Runoff from Pervious area
Inflow()	Nhyd	Inflow to a facility
Outflow()	Nhyd	Outflow from a facility
TempHyd()	Nhyd	Temporary or Junction hydrograph
BkupHyd()	Nhyd	Backup to allow "Undo" recovery.

File Names

The Microsoft operating systems Windows 95, Windows 98 and Windows NT offer greatly increased flexibility in the way files can be named. File names have fewer "illegal" characters, can include spaces, can have more than one 'period' separator and can be longer than the 11 character "nnnnnnnn.eee" format used in Microsoft DOS.

The following characters are not allowed.

double quote	"
back slash	\
forward slash	/
colon	:
asterisk	*
question mark	?
less than	<
greater than	>
vertical/pipe		

See the Hydrology/Storm Descriptor topic in Chapter 2 for information on applying a special storm-specific tag to hydrograph names. This allows files in the same directory or folder to describe hydrographs at the same node but which result from different storm events.

Although it is tempting to use long and self-explanatory file names, try to make names reasonably unique in the first 8 characters. This will ensure that if the file names are displayed in an application which expects DOS names you do not get a list of files differentiated only by the "~1" or "~2" following of the first 6 characters of the original name.

File Formats

Storm hyetograph and flow hydrograph files are simple Ascii files that can be read, edited and created using a text editor such as Notepad. Each file contains a total of (N+6) records comprising 6 records of file header information followed by N records each of which holds a single value of rainfall intensity or hydrograph flow rate.

The file format is:

Record	Content	Example
1	Description	"Hydrograph #1"
2	File type	4
3	Peak value	"0.441"
4	Gravity	9.81
5	Time step	5
6	No. of values	36
7	Value 1	0
8	Value 2	3.970632E-03
:		
N+6	Value N	7.172227E-04

where

Description is an alphanumeric string enclosed in ".."

File Type is an integer value:

1 - 3	for	Storm, Impervious and Pervious effective rainfall hyetographs
4 - 7	for	Runoff, Inflow, Outflow and Temporary (or Junction) hydrograph

Peak value is the maximum ordinate expressed as a string

Gravity = 9.81 for metric or SI and 32.2 for imperial or U.S. Customary units

Time step is nominal time step in minutes

No. of values is the number of records following the header records.

Mass Rainfall Distribution files have only two header lines. The file format is:

Record	Content	Example
1	Description	"Hydrograph #1"
2	No. of values	21
3	Value 1	0.000
4	Value 2	0.063
:		
N+2	Value N	1.000

The first and last values of an **.mrd** file are always 0.000 and 1.000 respectively. Usually the numb er of values is odd defining an even number of increments. The files **`Huff.mrd`** have 21 values; the SCS storm files **`SCS_Type3_24hr.mrd`** have 97 values.

If you want to create a new file it is important that you follow the defined format. The simplest way is to make a copy of an existing file of the same type in Notepad and edit the values as required. You can quickly test the integrity of such a file by importing it into an appropriate array using the **Hydrograph/File I/O** command and then display it using either the **Show/QuickGraph** or **Show/Tabulate** commands.

(Hint: Notepad may add its default extension '.txt' to a file you have edited thus creating – for example – a file called PondInflow.005hyd.txt. Check the folder if in doubt.)

The File I/O Command

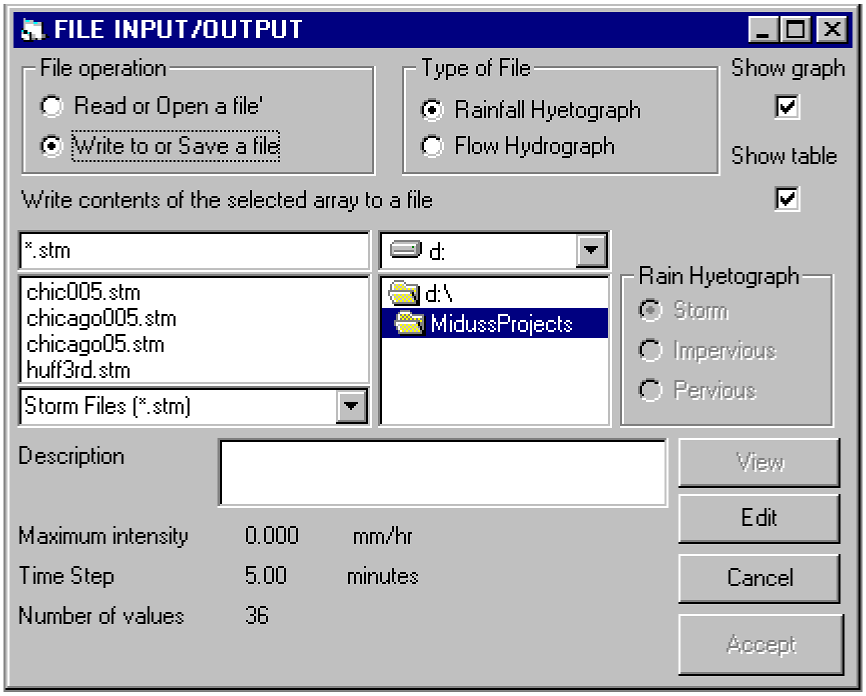


Figure 6-1 – The File Input-Output window.

This general command lets you read or write disk files from or to any of the three rainfall hyetograph arrays or the four hydrograph arrays. For any selected file the header information is displayed. If the file is not recognized by MIDUSS 98 you can use a text editor to view the file assuming it is in Ascii code. Options are available to let you display the contents of the file as a Graph or in Tabular form or in both modes.

The following topics describe specific parts of the File I/O window and provide a logical sequence of steps to use the command.

- The Hydrograph/File I/O menu
- The FileIO window
- The File Operation Options
- The File Type Options
- The Rainfall Hyetograph Options
- The Flow Hydrograph Options
- Choosing a Drive and Directory
- Setting the File Name Filter
- Selecting and Editing the File name
- Pre-viewing the File Header

The Hydrograph / File I/O menu

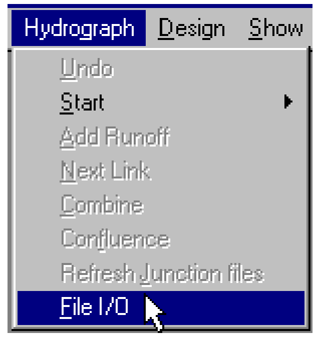


Figure 6-2 – The initial state of the Hydrograph menu

The Hydrograph menu, of which the File I/O command is one option, is not enabled until you have specified the system of units to be used and the time parameters. Even then, as shown here, only the Start and File I/O options are enabled. Other options are enabled as various hyetograph and hydrograph arrays are created during the design session.

Each time you attempt to load a file, MIDUSS 98 checks to make sure that the file contents are compatible with the current system parameters and it is for this reason that you are required to pre-define these values before attempting to import a file.

If you select a file which is recognized by MIDUSS 98 but which is not compatible with the current units or time step the information is displayed in the lower part of the window. The [View] button is enabled when you select a file but if you press the [View] button a warning message is displayed below the file header information. This is circled in red in Figure 6-3 below.

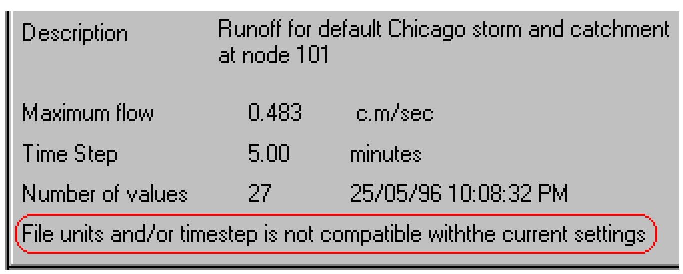


Figure 6-3 – MIDUSS98 checks that file characteristics are compatible.

The File I/O Window

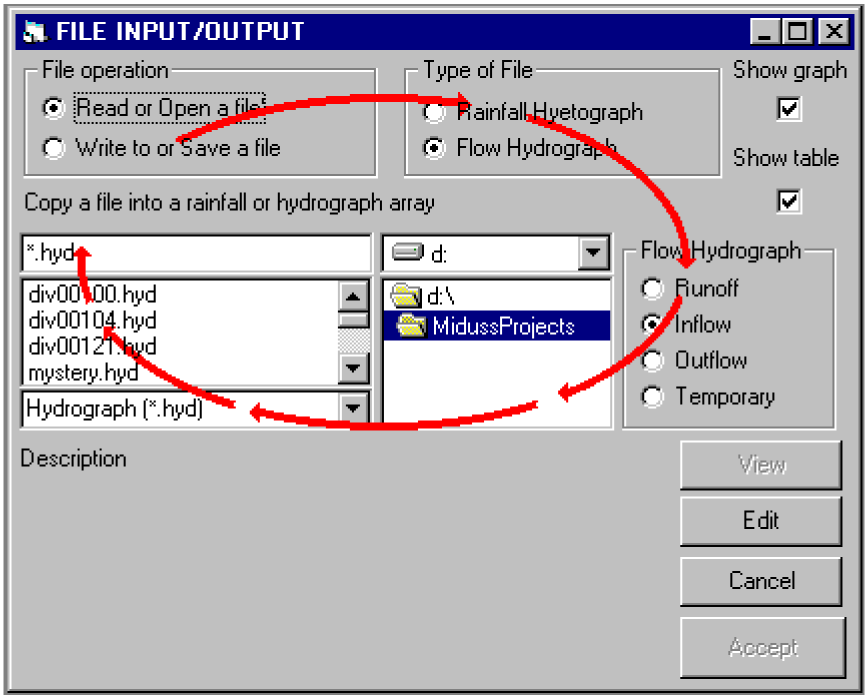


Figure 6-4 – The required steps proceed logically in a clockwise direction

The red arrows of Figure 6-4 suggest that you proceed through the various options on the File I/O window in a clockwise direction. First select the file operation required (input or output, read or write), then choose the file type (hyetograph or hydrograph). The latter choice will cause the appropriate set of options to be displayed from which you can select a hyetograph or hydrograph array. Next you accept or define the device and directory or folder in which the file exists or is to be stored. From here, proceed to the File filter to select the appropriate file extension that in turn will cause the appropriate files to be displayed. Finally you can define a filename - either that of an existing file, an edited version of an existing file or a completely new file name.

Each of these steps is discussed in the topics that follow. The first step is to decide on the File Operation option.

The File Operation Options

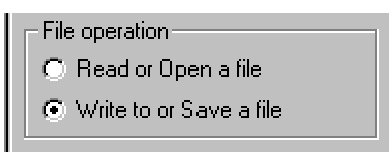


Figure 6-5 – The first step is to select a Read or Write operation

The initial default choice is to write a file to the disk. Click on the desired option. If you change this option the message displayed below the frame changes to confirm the type of operation.

The next step is to decide on the type of file.

The File Type Options

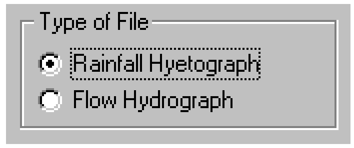


Figure 6-6 – Next, choose between hyetographs and hydrographs

The initial default option is for a rainfall hyetograph and the three arrays holding a hyetograph are displayed. Changing the choice causes the appropriate set of arrays to be displayed.

If the selected options are to write a rainfall hyetograph file to the Storm array and you have not yet defined a storm you will see the warning message shown below.

Figure 6-7 – The initial defaults may not be appropriate if no storm has been defined

This simply warns you that there is no information to write. The mouse pointer will be conveniently placed on the [OK] button and you can either click the primary (left) mouse button or press the space bar to close the message box.

The next step depends on the choice made here. You will see either a set of three options for Rainfall hyetographs or, if you have selected Flow hydrographs as the file type, you will see a set of four Flow hydrograph options.

The Rainfall Hyetograph Options

Figure 6-8 – Select which hyetograph to use.

The initial default option is for the Storm hyetograph. If you have selected to read a file into a rainfall array, all three of the options will be enabled. However, if you intend to write a rainfall hyetograph file only the options corresponding to arrays that have finite data will be enabled. If you have used the Hydrology/Storm command the Storm option will be enabled. If you have used the Hydrology/Catchment command the other two options will also be enabled.

If you want to review the Flow hydrograph options refer to the next topic, otherwise proceed to the next logical step which is to confirm or select the drive and directory to be used..

The Flow Hydrograph Options

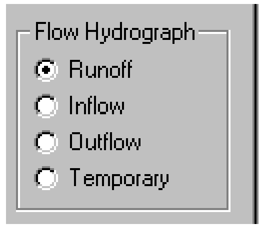


Figure 6-9 – All four hydrographs are available for a file Read operation.

The initial default option is for the Runoff hydrograph. If the File operation is set to read a file into one of these arrays, all four options will be enabled. However, if you want to write a hydrograph file only the options that correspond to an array containing finite data will be enabled. Clearly this depends on the previous actions taken during the design session.

Now proceed to the next logical step which is to confirm or select the drive and directory to be used..

Choosing a Drive and Directory

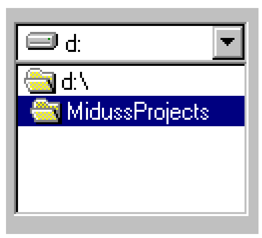


Figure 6-10 – The default drive and folder should be your Job directory

The drive selector and the default directory are set equal to the directory containing the current output file. If you have defined a job specific output file (which is recommended) it will be shown here. If you didn't have time to define a job directory and output file the output will be directed to a file called "default.out" which resides in the Miduss98 directory. During installation this will normally default to C:\Program Files\Miduss98\ unless you have elected to load MIDUSS 98 to another directory of your choice (for instance if your C: drive is getting really full.)

Selecting a drive and directory is done easily by first selecting the drive (i.e. device) and then navigating to the desired directory. The File I/O command presently does not support devices and directories (or folders) on a network.

The next step is to select an appropriate file name filter (or file extension) which will limit the number of files displayed in the file list box.

Setting the File Name Filter

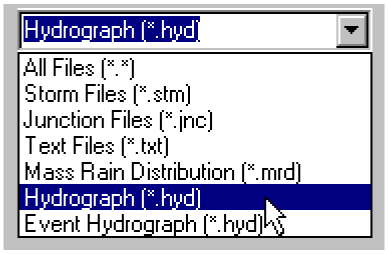


Figure 6-11 – Select the appropriate filter for the type of file being used.

If you have selected a file type of Rainfall hyetographs the default filter will be set to *stm. If the file type is a Flow hydrograph the default filter is *.hyd as shown in Figure 6-11. If a storm descriptor has been defined, it will be added to the Event Hydrograph filter and this will be the default for hydrograph operations.

To change the filter you should click on the down arrow at the right side of the Filter box to open the list. The available options are shown in Figure 6-11. Click the mouse pointer on the desired filter as shown here and it will be selected and the drop-down list box will be closed.

The final step is to select or edit or otherwise define the file name you want to use.

Selecting and Editing the File name

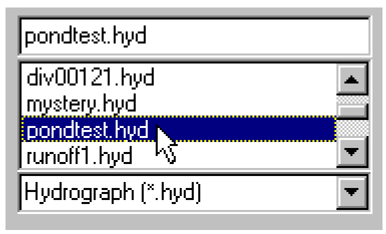


Figure 6-12 – You can select an existing hydrograph to read or over-write

Figure 6-12 illustrates a situation in which the user wants to read a flow hydrograph. Typically this is useful when a flow hydrograph has been created in a previous design session and you now want to refine the design of pond or other facility.

If you intend to write a file from an existing array of data you can either:

- Select an existing file which you want to overwrite,
- Select an existing file name and then edit it to create a new file, or
- Type in the name of the file you want to create.

  Hint: To add a filename to the default '*.hyd' do the following:

  - Click on the default name to highlight it
  - Press [Home] on the keyboard to move the text entry point to the left end of the text box
  - Press [Delete] on the keyboard to remove the asterisk '*'.
  - Type in the desired file name.

This completes the choices to read or write a file. The last step is to review the contents of the file header.

Pre-viewing the File Header

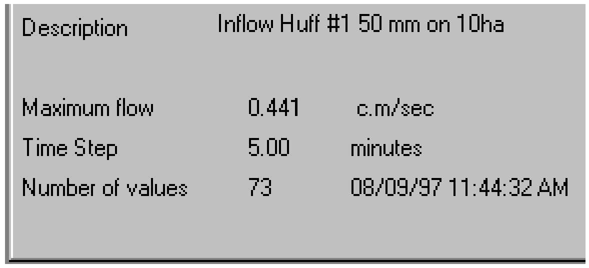


Figure 6-13 – Typical file header information.

This portion of the window will also vary depending on whether the file operation is to read or write a file. Figure 6-13 shows the situation when a hydrograph file is to be read in (i.e. imported) to an array. The main difference is in whether a description is already known for an existing file (as shown here) or, if a new file is to created, the description must be typed into a text box.

The other data show the maximum flow rate or rainfall intensity, the time step, the system of units employed (as indicated by the legend following the peak value - e.g. c.m/sec or c.ft/sec) and the number of values to be read or written. If the file already exists the date and time of its creation are also shown.

If you are creating a new file you are well advised to type in a meaningful description. Use two rows if you wish. The only restriction is that you cannot use the double quote character (") often used as the symbol for inch because this is used as the delimiter for the description. If you want to use a symbol for inch use two single quotes.

To see the properties of the file being read or written press the [View] command button.

Using the [View] Command

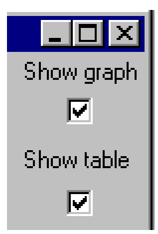


Figure 6-14 – You can choose to show or suppress the graph and table.

The actual file operation is carried out by pressing the [Accept] button but before this is enabled you must press the [View] button. If the appropriate check boxes are ticked MIDUSS 98 displays a graph and a tabular display of the hyetograph or flow hydrograph. If you are reading an existing file the properties are displayed prior to reading it into the requested array. If you are writing a new file from a selected array the graph and table show the array to be written. This can be an alternate way to view the properties of the current hyetographs and flow hydrographs generated during the design session. See the **Show/Quick Graph** and **Show/Tabulate** commands for other methods.

Note that whereas the title bar of the table corresponds to file type, the Title bar of the graph display shows "Backup" for a file being read in or imported. This is because the Backup array is used as temporary storage until you confirm that the file can be accepted.

If a file is being read in you may see a warning message advising you that the hyetograph or hydrograph will be "padded with zeros" or "will be truncated". These cases will occur if you are importing a file with fewer elements than can be stored in the current array sizes, or conversely, if the array size is not able to hold the total file size. In the latter case you can find out if this is significant by dragging up the top edge of the Table containing the file which is to be read.

When you are satisfied that all is well you can press the [Accept] button to accept the file Operation.

Accepting the File Operation

Before a new file is created you are prompted to enter a description of at least 20 characters.

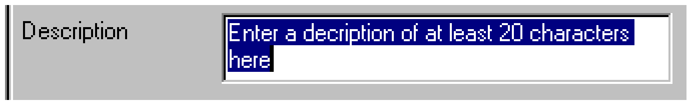


Figure 6-15 – It is worth while to provide a detailed description of the file

Use as much space as you need to provide a clear and unambiguous description as the data entry text box will support multiple lines (although you can see only two lines at a time.

When you press the [Accept] button you may see a warning message as shown below advising you that MIDUSS 98 has detected a file of the same name and directory as the one you are attempting to write.

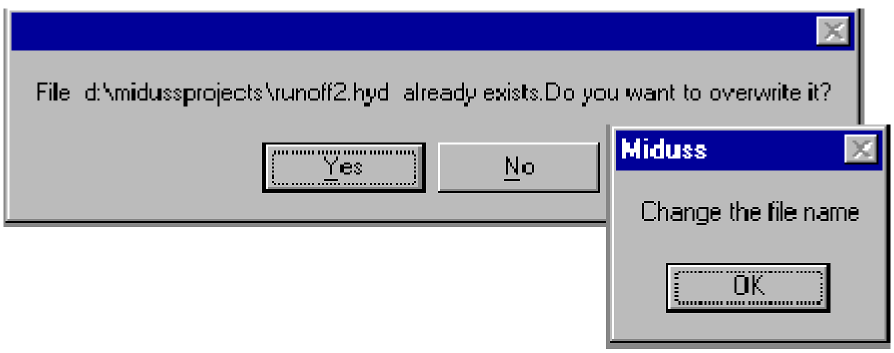


Figure 6-16 – MIDUSS98 protects you from accidental over-writes.

If you press the [Yes] button the operation will continue and the existing file will be overwritten. If you want to save the existing file press [No]. If you press [No] you will see the message box on the right of Figure 6-16 and on clicking on the [OK] button or pressing the space bar the File name data entry box will be re-activated and you can edit the name for the new file.

Chapter 7 - Hydrological Theory

The hydrology incorporated in MIDUSS 98 is based on relatively simple and generally accepted techniques. There are four commands to control the fundamental operations.

(1) STORM - This command allows you to define a rainfall hyetograph either of the synthetic, design type or a historic storm. It should be noted that as an alternative to using the STORM command, a previously defined rainfall hyetograph may be read in from a disk file, by means of the **Hydrograph/FileI_O** command.

(2) CATCHMENT - This command prompts you to define a single sub-catchment and computes the total overland flow hydrograph for the currently defined storm. The runoff hydrographs from the pervious and impervious areas are computed separately and summed. The roughness, degree of imperviousness and surface slope of both the pervious and impervious fraction are defined in this command. The effective rainfall on these two fractions is computed and stored for future use. The runoff hydrograph from the two fractions is computed separately and added to give the total runoff.

(3) LAG and ROUTE . This command is useful for modelling the runoff from very large sub-catchments without having to resort to specifying unrealistically long overland flow lengths. The command computes the lag time in minutes of a hypothetical linear channel and linear reservoir through which the runoff hydrograph is routed. Typically this results in a smaller, delayed runoff peak flow.

(4) BASE FLOW - This command lets you specify a constant value of base flow to be added to the current inflow hydrograph.

Some details of the hydrological techniques used in these commands are given in the detailed discussion which follows. If further information is required, reference should be made to any standard text on the subject. See the references for other suggested reading.

Theory of Design Storms

For those readers who wish a more detailed description of the methods used to define design storm hyetographs, this section contains a brief theoretical derivation of three of the methods described previously in the Hydrology/Storm menu command.

The following sections are provided:

- Derivation of the Chicago Storm
- Using a Mass Rainfall Distribution
    - Derivation of the Huff Storm
    - Derivation of the User Defined Storm
- Derivation of the Canadian 1-hour storm

Derivation Of The Chicago Storm

The synthetic hyetograph computed by the Chicago method is based on the parameters of an assumed Intensity-Duration-Frequency relationship, i.e.

[7.1] $$i = \frac{a}{(t_d + b)^c}$$

where i = average rainfall intensity (mm/hr or inch/hr)

t_d = storm duration (minutes)

a,b,c = constants dependent on the units employed and the return frequency of the storm.

The asymmetry of the hyetograph is described by a parameter r (where $0 < r < 1$) which defines that point within the storm duration td at which the rainfall intensity is a maximum.

Imagine a rainfall distribution (with respect to time) such as that shown by the dashed curve of Figure 7-1, *i.e.* with a maximum intensity *imax* at the start of rainfall at $t=0$, which then decreases monotonically with elapsed time *t,* according to some function *f(t)* which is, as yet, unknown. If the duration of such a storm is *td* then it is easy to see that the total volume of rainfall is represented by the area under the curve from $t=0$ to $t=td$. The average rainfall intensity for such an event could be estimated as *iave = Volume/td* as illustrated by the shaded rectangle of Figure 7-1.

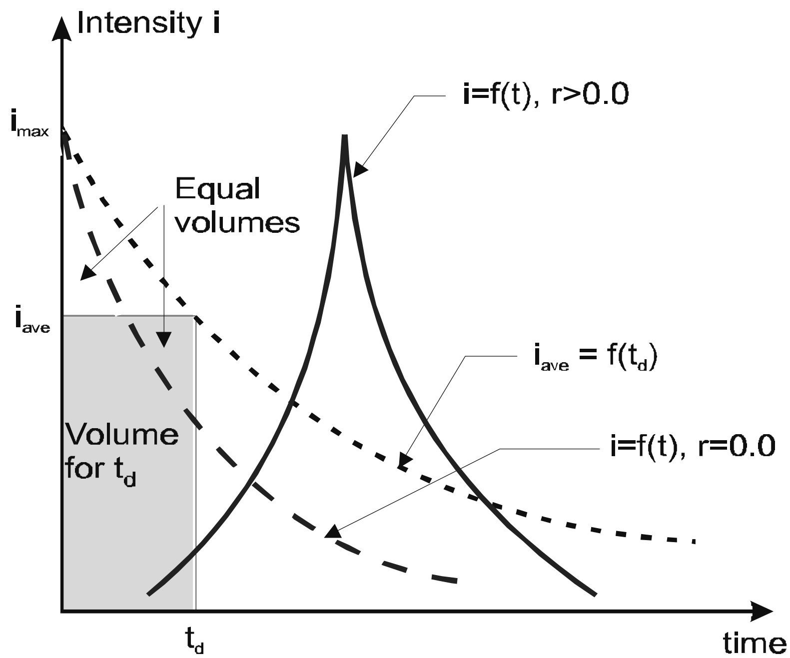


Figure 7-1 - Development of the Chicago storm

Several storms with different durations *td* but with the same time distribution of intensity would produce values of *iave* which decrease as *td* increases, leading to the dotted curve of Figure 7-1. Thus:-

[7.2] $$i_{ave} = \frac{Volume}{t_d} = \frac{1}{t_d}\int_0^{t_d} f(t)dt$$

If the average intensity $iave$ over an elapsed time t can be described by an empirical function such as equation [7-1], then by combining [7-1] and [7-2], the functional form of $f(t)$ can be obtained by differentiation, i.e.

[7.3] $$f(t) = \frac{d}{dt}\left[\frac{at_d}{(t_d + b)^c}\right]$$

or

[7.4] $$i = f(t) = \frac{a[(1-c)t_d + b]}{(t_d + b)^{1+c}}$$

Now if the value of r is in the range $0<r<1$ the time to peak intensity for a given duration is $t_p = r.t$ The time distribution of rainfall intensity can then be defined in terms of time after the peak $t_a = (1\text{-}r).t$ and time before the peak $t_b = r.t$ by the following two equations.

[7.5] $$i_a = \frac{a\left[\dfrac{(1-c)t_a}{(1-r)} + b\right]}{\left(\dfrac{t_a}{(1-r)} + b\right)^{1+c}}$$

[7.6] $$i_b = \frac{a\left[\dfrac{(1-c)t_b}{r} + b\right]}{\left(\dfrac{t_b}{r} + b\right)^{1+c}}$$

The solid curve of Figure 7-1 shows the time distribution of rainfall using a value of r greater than zero ($r = 0.4$ approximately).

Calculation of the discretized rainfall hyetograph is carried out by integrating these equations to obtain a curve of accumulated volume as illustrated in Figure 7-2 below. For convenience this curve is computed so that volume V is zero at $t=t_p$ and is defined in terms of the elapsed time after and before t_p. The expressions for volume after and before t_p are then given by equations [7-7] and [7-8] respectively.

[7.7] $$V_a(t_a) = \frac{a.t_a}{\left(\dfrac{t_a}{1-r} + b\right)^c} = \frac{a(t_a - t_p)}{\left(\dfrac{t_a - t_p}{1-r} + b\right)^c}$$

[7.8] $$V_b(t_b) = \frac{a.t_b}{\left(\dfrac{t_b}{1-r} + b\right)^c} = \frac{-a(t_p - t_b)}{\left(\dfrac{t_p - t_b}{1-r} + b\right)^c}$$

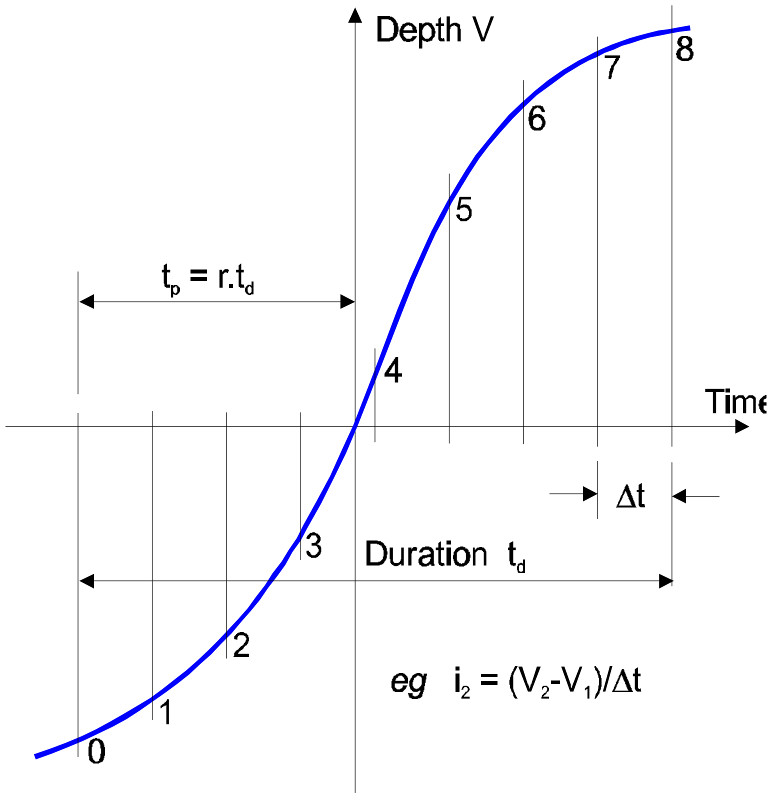


Figure 7-2 – Discretization of an integrated volume curve.

Discretized values of rainfall intensity can now be obtained by defining a series of 'slices' of equal timestep *Dt*. The time step at the peak intensity is positioned relative to the t_p position so that it is disposed about the peak in the ratio *r* to *(1-r)*. In general, this means that the commencement of the storm may not be precisely defined by $t = - r\ t_d$ and the storm duration is therefore not disposed about the peak exactly in the ratio *r* to *(1- r)*. However because the rainfall intensities at the extremities of the storm are generally very small this approximation is unlikely to lead to significant error.

Storm From A Mass Rainfall Distribution Curve

This method is used both for the four quartile Huff distributions and also for the user defined Mass Rainfall Distribution function. These are treated very similarly but are discussed separately in the two sections that follow.

Derivation of the Huff Storm

Based on data from watersheds in the mid-western USA, Huff (see References) suggested a family of non-dimensional, storm distribution patterns. The events were divided into four groups in which the peak rainfall intensity occurs in the first, second, third or fourth quarter of the storm duration. Within each group the distribution was plotted for different probabilities of occurrence. MIDUSS 98 uses the median curve for each of the four quartile distributions. The non-dimensional curves are illustrated in Figure 7-3 below and are tabulated in Table 7-1.

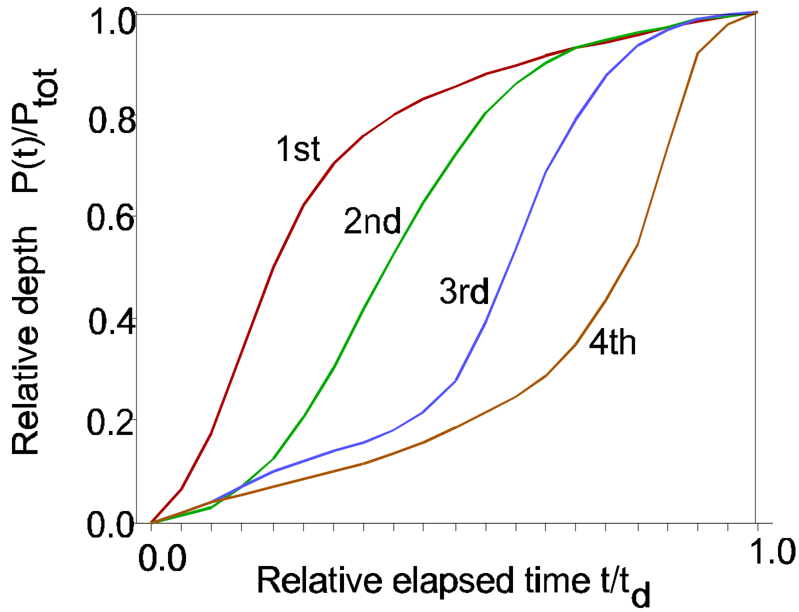


Figure 7-3 - Huff's four storm distributions.

To define a storm of this type you must provide values for the total depth of rainfall (in millimetres or inches), the duration of the storm (in minutes) and the quartile distribution required (i.e. 1, 2, 3 or 4). The duration must not exceed the maximum storm duration defined in the **Hydrology/Time parameters** menu command and, as with the Chicago storm option, an error message is displayed if this constraint is violated. Once the parameter values have been entered and confirmed by pressing the [Display] command button, the hyetograph is displayed in both graphical and tabular form. You can experiment by altering any of the data - even the type of storm - and re-using the [Display] button until you press the [Accept] button to save the storm and close the Storm command.

The four quartile Huff distributions are approximated by a series of chords joining points defined by the non-dimensional values in the table referenced below. Figure 7-4 shows a typical curve (not to scale) which for clarity uses only a very small number of steps. The time base for the NH dimensionless points defining the 'curve' is subdivided into dimensionless time steps defined by:

$$[7.8] \qquad \Delta t = \frac{(NH-1)}{NDT}$$

where NH = number of points defining the Huff curve (shown as NH = 7 but usually much more)

NDT = number of rainfall intensities required (shown as only 15 in Figure 7-4).

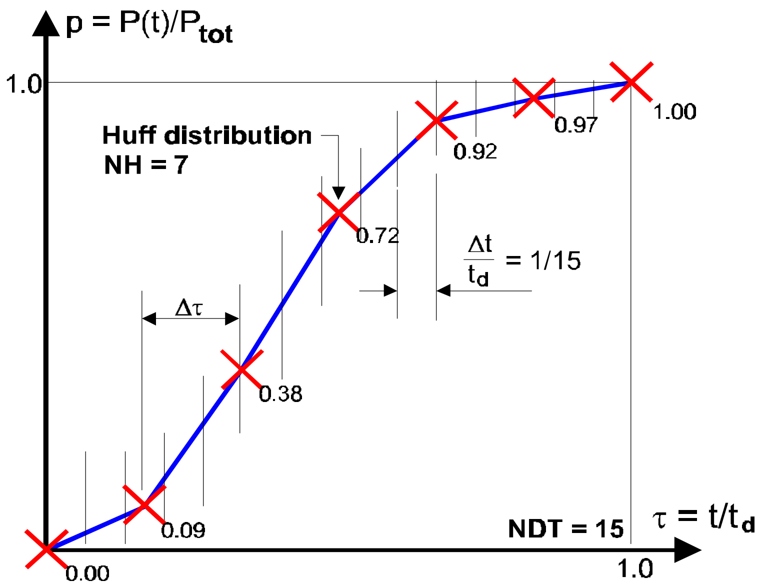


Figure 7-4 - Discretization of a Huff curve.

The values of the dimensionless fractions p_k and p_{k+1} at the start and finish of each time-step are obtained by linear interpolation and the corresponding rainfall intensity is then given as:

$$[7.10] \qquad i_j = \frac{(p_{k+1} - p_k)P_{tot}}{\Delta t}$$

where

$$p_{k+1} = p_m + (p_{m+1} - p_m)(h - m)$$

$$m = INT(h)$$

$$h = j.\Delta t + 1$$

For the example shown in Figure 7-4, the Huff 2nd quartile curve is approximated by NH=7 points with a storm duration which is divided into 15 time steps. Then Dt = (7-1)/15 = 0.4. The calculation of the rainfall fractions p_{k+1} required for eq. [7.10] is then carried out as shown in the table below.

j	1	2	3	4	5	…	12	13	14
$h=j\,Dt+1$	1.4	1.8	2.2	2.6	3.0		5.8	6.2	6.6
m	1	1	2	2	3		5	6	6
p_m	0.00	0.00	0.09	0.09	0.38		0.92	0.97	0.97
p_{k+1}	0.036	0.072	0.148	0.264	0.340		0.960	0.976	0.988

See the topic P(t)/Ptot for Four Huff Quartile data

Derivation of the user defined storm

The user defined Mass Rainfall Distribution function is defined in exactly the same way as for the Huff storm but with the difference that the number of points is not limited to 51 to define the curve. Since the initial and final points must have values of 0.00 and 1.00 respectively this means that there can be up to (Npts-1) equally spaced segments in the definition of the Mass Rainfall curve.

A number of popular rainfall distributions are described in *.mrd files which are included with MIDUSS 98. These include the various SCS 24-hour and 6-hour storms and regulatory storms such as Hurricane Hazel (Southern Ontario, Canada) and the Timmins storm for more northerly parts of Ontario. These files are simple text files and can be printed out to show the values used.

P(t)/Ptot for Four Huff Quartiles

t/td		**P(t)/Ptot for quartile**		
	1st	**2nd**	**3rd**	**4th**
0.00	0.000	0.000	0.000	0.000
0.05	0.063	0.015	0.020	0.020
0.10	0.178	0.031	0.040	0.040
0.15	0.333	0.070	0.072	0.055
0.20	0.500	0.125	0.100	0.070
0.25	0.620	0.208	0.122	0.085
0.30	0.705	0.305	0.140	0.100
0.35	0.760	0.420	0.155	0.115
0.40	0.798	0.525	0.180	0.135
0.45	0.830	0.630	0.215	0.155
0.50	0.855	0.725	0.280	0.185
0.55	0.880	0.805	0.395	0.215
0.60	0.898	0.860	0.535	0.245
0.65	0.915	0.900	0.690	0.290
0.70	0.930	0.930	0.790	0.350
0.75	0.944	0.948	0.875	0.435
0.80	0.958	0.962	0.935	0.545
0.85	0.971	0.974	0.965	0.740
0.90	0.983	0.985	0.985	0.920
0.95	0.994	0.993	0.995	0.975
1.00	1.000	1.000	1.000	1.000

Canadian 1-Hour Storm Derivation

Recent work by Watt *et al* (see references) has suggested a simple two parameter design storm which has a linear rising portion followed by an exponentially decreasing recession curve. Watt *et al* also suggest the possibility of reversing the linear and exponential segments but this option is not supported by MIDUSS 98. Figure 7-5 shows a definition sketch of this design hyetograph.

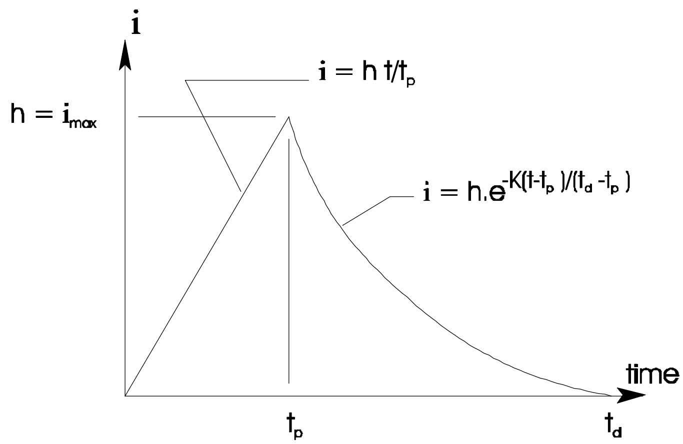


Figure 7-5 - The Canadian AES 1-hour design storm.

The parameter values which you are prompted to supply for this option are the total depth of rainfall (millimetres or inches), the duration in minutes, the time to peak intensity (minutes) *tp* and the decay coefficient K. The decay coefficient K is usually in the range 5 to 7. As with the other options, the maximum duration and the time step used are as defined in the **Hydrology/Time parameters** menu command.

It should be noted that the design storm as suggested by Watt *et al* is intended to be used for storms of 1 hour duration only, since the data used for the work was limited to this duration. However, MIDUSS 98 allows you to define other values of duration. Care should be taken if suggested values for the time to peak are taken from Watt *et al* as these are intended specifically for 60 minute storms.

The rising and falling limbs of the hyetograph suggested by Watt *et al* are defined by equations [7-11] and [7- 12] respectively.

[7.11] $$i = h\frac{t}{t_p}$$ for $t < tp$

[7.12] $$i = e^{-K\frac{(t-t_p)}{(t_d-t_p)}}$$ for $t > tp$

For specified values of the parameters t_d, t_p, K and the total depth of rainfall $Rtot$ the peak intensity h (see Fig. 7-5) can be obtained as follows.

[7.13] $$h = \frac{R_{tot}}{0.5t_a + \frac{1}{K}(t_d - t_p)(1 - e^{-K})}$$

The total depth for any time t can then be obtained by integration as shown in equations [7-14] for $t<t_p$ and [7-15] for $t>t_p$.

[7.14] $$Vol = \frac{h}{2}.\frac{t^2}{t_p}$$

[7.15] $$Vol = \frac{h}{2} t_p + \frac{1}{K} h(t_d - t_p)\left(1 - e^{-K\frac{(t-t_p)}{(t_d-t_p)}}\right)$$

By computing the volumes Vk and $Vk+1$ at the beginning and end of a time step, the intensity during the interval is then defined by equation [7-16].

[7.16] $$i_k = \frac{V_{k+1} - V_k}{\Delta t}$$

Suggested values for K and t_p are shown in two tables referenced below. These are based on data published by Watt *et al*. Values in minutes of the time to peak t_p are for 60 minute storms only and should not be used for storms of different duration. The time to peak as a proportion of duration is provided for guidance. See the topics listed below.

Suggested K values for Canadian Provinces. Suggested_K_values_for_Canadian_Provinces>widesec

Suggested tp values for locations in Canada. Suggested_tp_values_for_locations_in_Canada>widesec

Suggested K values for Canadian Provinces

Province	**K value**
B.C.(coastal region)	**5**
Yukon, New Brunswick, Nova Scotia, Newfoundland	**6**
B.C.(interior), Alberta, Saskatchewan, Manitoba, Ontario, Quebec	**7**

(from Watt *et al* - see References)

Suggested tp values for locations in Canada.

Location	**tp (minutes)**	**tp /Duration**
Yukon	20	0.33
B.C.(coast)	28	0.47
B.C.(interior), Prince George	13	0.22
Alberta	17-18	0.29
Saskatchewan	23-24	0.39
Manitoba (Brandon, Churchill)	31	0.52
Manitoba (Winnipeg)	25	0.42
Ontario (Timmins, Thunder Bay)	24-25	0.41
Ontario (Ottawa, Kingston, Windsor)	26-27	0.44
Ontario (Toronto, Sudbury)	21	0.35
Quebec (Montreal)	27	0.45
Quebec (Val D'Or, Quebec City)	23	0.38
New Brunswick (Fredericton)	17	0.28
Nova Scotia, Newfoundland	26-28	0.45

(from Watt *et al* - See References)

Note: These times to peak were obtained from 60 minute duration storms.

Calculating Effective Rainfall

Effective rainfall - sometimes called excess rainfall - is the component of the storm hyetograph which is neither retained on the land surface nor which infiltrates into the soil. The effective rainfall produces overland flow that results in the direct runoff hydrograph from a sub-area of a catchment. The difference between the storm and the effective rainfall hyetographs is termed the abstractions or rainfall losses. Abstractions are made up of one or more of the following three main components:-

- interception by vegetation or tree canopy
- infiltration into the soil
- storage in surface depressions and hollows

In the absence of field observations it is usually necessary to employ some form of mathematical model to represent the abstractions. This must be done for the pervious and the impervious fractions of the catchment.

MIDUSS 98 currently lets you choose from three methods to define the infiltration model.

(1) The Soil Conservation Service (SCS) infiltration method or the SCS Method

(2) The 'moving curve' Horton Equation for infiltration.

(3) The Green and Ampt Method

These options are available for both the pervious and impervious fractions of the catchment. However the choice of infiltration model must be made on the Pervious tab of the Catchment form. When the Impervious tab is displayed there is a note to remind you which option is in use. Refer to the Catchment command; Data for the Pervious Area for details and a view of the relevant forms.

The choice of infiltration method is made after the selection of the overland routing option. It is important to note that if you intend to use the SWMM/Runoff option for the generation of the overland flow hydrograph, the SCS infiltration option is not available and you must choose between the Horton equation and the Green & Ampt method.

The descriptions of the infiltration models given in the sections that follow apply equally to both impervious and pervious fractions of the catchment. Details are provided for:

The SCS Infiltration method

The Horton Infiltration equation

and The Green & Ampt algorithm.

The SCS Method

In 1972 the U.S. Soil Conservation Service suggested an empirical model for rainfall abstractions which is based on the potential for the soil to absorb a certain amount of moisture. On the basis of field observations, this potential storage S (millimetres or inches) was related to a 'curve number' CN which is a characteristic of the soil type, land use and the initial degree of saturation known as the antecedent moisture condition.

The value of S is defined by the empirical expression [7-17] or [7-18] depending on the units being used.

[7.17] $$S = \frac{1000}{CN} - 10$$ (inches)

[7.18] $$S = \frac{25400}{CN} - 254$$ (millimetres)

Typical values for the SCS Curve Number CN as a function of soil type, land use and degree of saturation can be found in most texts on hydrology (*e.g.* See references such as Viessman, 1977 or Kibler, 1982) or from the section on Pervious Data requirements. in Chapter 3 *Hydrology Used in MIDUSS 98.*

In some texts you may see values of CN quoted as a function of the percentage of impervious area. These are usually calculated as a weighted average assuming $CN_{impervious}$ = 98 and $CN_{pervious}$ equal to the value for 'Pasture in good condition' for the various soil types A, B, C or D. See Chapter 3 *Hydrology used in MIDUSS 98*, eq. [3.10].

Values of CN estimated in this way are intended to be applied to the **total** catchment assuming other parameters to be the same for both pervious and impervious areas. Many programs (including MIDUSS 98) compute the runoff from the pervious and impervious fractions separately and then add the two hydrographs. In such cases, it is most important that you **do not use** a composite value of CN since this would 'double count' the impervious fraction and greatly exaggerate the runoff prediction.

The effective rainfall is computed by the equation:

$$[7.19] \qquad Q(t) = \frac{\left(P(t) - I_a\right)^2}{\left(P(t) + S - I_a\right)}$$

where	$Q(t)$	=	accumulated depth of effective rainfall to time t
	$P(t)$	=	accumulated depth of rainfall to time t
	Ia	=	initial abstraction
	S	=	potential storage in the soil

All of the terms in equation [7-19] are in units of millimetres or inches. Note that the effective rainfall depth or runoff is zero until the accumulated precipitation depth P(t) exceeds the initial abstraction Ia.

The original SCS method assumed the value of the initial abstraction Ia to be equal to 20% of the storage potential S, but many engineers now regard this as unacceptably high for most stormwater management situations. MIDUSS 98 uses an initial default value of 10% but allows you to specify the ratio of $fa = Ia/S$ when you are entering the data for rainfall losses.

Alternatively, MIDUSS 98 lets you define the initial abstraction Ia explicitly as a depth. For suggested values, see the section on Pervious Data requirements in Chapter 3 *Hydrology Used in MIDUSS 98.*.

When you enter a value for the SCS Curve Number, MIDUSS 98 calculates the equivalent volumetric runoff coefficient (C) and displays this for information. You can also enter a value for the runoff coefficient and MIDUSS 98 will compute and display the corresponding value of CN. The SCS CN value is a function of runoff coefficient C, the total rainfall depth and the initial abstraction ratio $fa = Ia./S$. The relationship used is as follows.

$$[7.20] \qquad CN = \frac{1000}{10 + P_{tot}\left[\dfrac{1}{f_a} + \dfrac{1 - f_a}{2 f_a^2}.C\left[1 - \left(1 + \dfrac{4 f_a}{(1 - f_a)^2}\dfrac{1}{C}\right)^{1/2}\right]\right]}$$

Sometime this is a useful way to 'guesstimate' a value for CN in the absence of other information.

It is worth digressing a little at this point to explain a feature of MIDUSS 98 which you may notice when you are reviewing an output file. If you specify a runoff coefficient C for a particular sub-catchment, both the values of C and CN are copied to the output file. However, if you run the program in Automatic mode MIDUSS 98 uses the CN value as the basis for estimating rainfall losses. The reason for this is as follows. Typically, in designing a minor drainage system the engineer will use a relatively modest storm (say 5 year return interval) for which a reasonable estimate of C might be made based on records or previous experience with the rational method.

When the design is completed it is usual to subject the system to a more severe storm with a much larger depth of precipitation $Ptot$. For the same ground conditions, the severe storm will produce a much higher runoff coefficient than the 5- year storm. Now since the CN value is a measure of ground conditions it is preferable to use the CN value rather than the runoff coefficient C, which, if used with the severe storm, would greatly under-estimate the runoff. Of course, if the output file is used as input for a subsequent run in which the 5- year storm is used again, the result will be identical to that which would have been obtained using the runoff coefficient. After specifying values for Manning's 'n' and the SCS curve number CN (or runoff coefficient C) MIDUSS 98 displays the current value of the ratio $fa = Ia /S$ as well as the initial abstraction depth Ia in inches or millimetres. You have the option to accept the current values or alter the ratio Ia /S or the initial abstraction Ia by entering values in the appropriate text boxes.

If either the ratio $fa = Ia /S$ or the initial abstraction depth Ia is altered, the displayed values of both Ia /S and Ia are updated. These values become the default for future uses of the Catchment command but these are not retained for future design sessions with MIDUSS 98.. However, if the output file is later used as an input data file in Automatic mode the correct values will be used.

In both the Pervious and Impervious forms, pressing the [Display] button causes a tabular display of the effective rainfall to be displayed together with a graph showing the storm rainfall and one or both of the two effective rainfall hyetographs.

The Horton Equation

One of the first attempts to describe the process of infiltration was made by Horton in 1933. He observed that the infiltration capacity reduced in an exponential fashion from an initial, maximum rate $f0$ to a final constant rate fc.

The Horton equation for infiltration capacity $fcapac$ is given by equation [7-21] which shows the variation of the maximum infiltration capacity with time t.

[7.21] $$f_{capac} = f_c + \left(f_0 - f_c\right)e^{-t/K}$$

where	f_{capac}	=	maximum infiltration capacity of the soil
	f_0	=	initial infiltration capacity
	f_c	=	final (constant) infiltration capacity
	t	=	elapsed time from start of rainfall
	K	=	decay time constant

At any point in time during the storm, the actual infiltration rate must be equal to the smaller of the rainfall intensity $i(t)$ and the infiltration capacity $fcapac$. Thus the Horton model for abstractions is given by equations [7-22] and [7-23].

[7.22] $$f = f_{capac} \quad \text{for } i > fcapac$$

[7.23] $$f = i \quad \text{for } i <= fcapac$$

where	f	=	actual infiltration rate (mm/hr or inches/hr)
	i	=	rainfall intensity (mm/hr or inches/hr).

Figure 7-8 below shows a typical problem in which the average rainfall intensity in each time step is shown as a stepped function. It is clear that if the total volume of rain in time step 1 (say) is less than the total infiltration volume in that time step it is more reasonable to assume that the reduction in f is dependent on the infiltrated volume rather than on the elapsed time. It is therefore usual to use a 'moving curve' technique in which the ft curve is shifted by an elapsed time which would produce an infiltrated volume equal to the volume of rainfall.

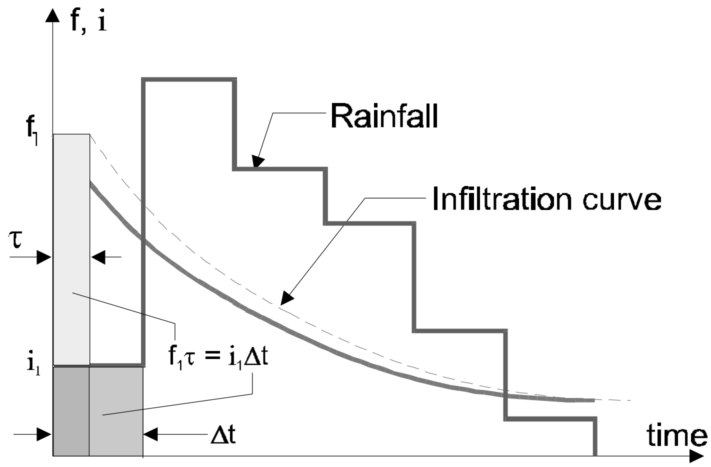


Figure 7-6: Representation of the moving curve Horton equation

Figure 7-6 shows a dashed infiltration curve shifted by a time t which is defined as follows. Let:

$$\Delta F = \int_{t}^{t+\Delta t} f_{capac} dt$$

If $i.dt \geq \Delta F$

then $t = \Delta t$ and

$$[7.24] \qquad f_0(new) = f_c + \left(f_0 - f_c\right)e^{-\frac{\Delta t}{K}}$$

If $i.dt < \Delta F$

then t is defined implicitly by the equation

$$\int_{t}^{t+t} f_{capac} dt = i.\Delta t$$

and

$$[7.25] \qquad f_0(new) = f_c + \left(f_0 - f_c\right)e^{-t/K}$$

Solving for t involves the implicit solution of equation [7-26]

$$[7.26] \qquad f_c t + K\left(f_0 - f_c\right)\left(1 - e^{-t/K}\right) = i.\Delta t$$

Application of equations [7-24] - [7-26] to every time step of the storm results in a hyetograph of effective rainfall intensity on either the impervious or pervious fraction. If the surface has zero surface depression storage, this is the net rainfall that will generate the overland flow. However, if the depression storage is finite, this is assumed to be a first demand on the effective rainfall and the depth must be filled before runoff can occur.

You are prompted to enter a total of five parameters comprising Manning's 'n', the initial and final infiltration rates f_0 and f_c (mm/h or inch/h), the decay time constant K (in hours, not 1/hrs) and the depression surface storage depth (millimetres or inches). For the impervious fraction you can enter either very small or zero values for all the parameters except the Manning roughness coefficient 'n'.

The Green and Ampt Method

The basic assumption behind the Green and Ampt equation is that water infiltrates into (relatively) dry soil as a sharp wetting front. Figure 7-7 below illustrates the variation in moisture content θ with depth z below the surface, at a point in time when the front has progressed a distance L.

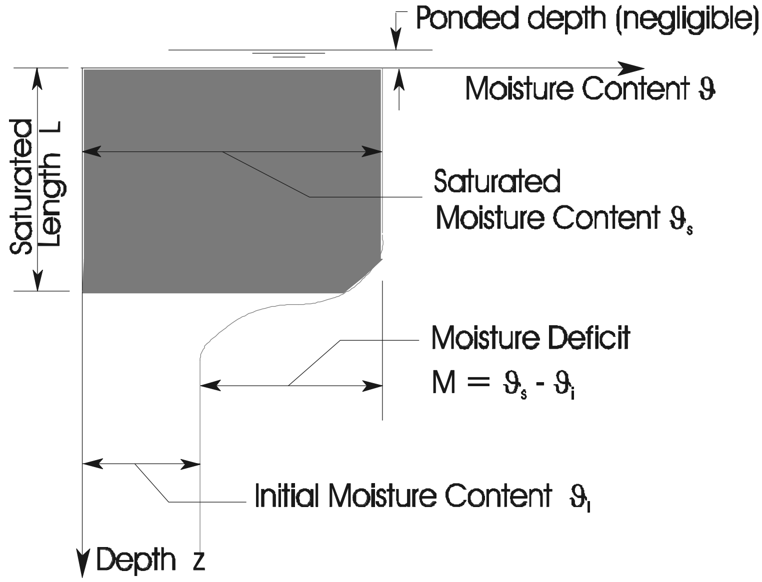


Figure 7-7 - Wetting front of the Green & Ampt model

The passage of this front causes the moisture content to increase from an initial value θi to a saturated value θs. This difference is defined as the moisture or water deficit M, *ie*

$$[7.27] \qquad M = q_s - q_i$$

Typically for dry soils M has a value in the range $0.2 < M < 0.5$ depending on the soil voids ratio, with lower values for pre-wetted soil.

If the hydraulic conductivity of the soil is K (mm/hour or inches/hr) then by Darcy's law,

$$[7.28] \qquad f = \frac{dL}{dt} = -K.\frac{\P h}{\partial z}$$

where $\P h / \P z$ represents the hydraulic gradient.

The head causing infiltration is given by equation [7-29].

$$[7.29] \qquad h = h_0 + L + S$$

where h_0 = depth of surface ponding (usually neglected)

L = depth of water already infiltrated

S = suction head at the wetting front.

The suction head S (millimetres or inches) is due to capillary attraction in the soil voids and is large for fine grained soils such as clays and small for sandy soils.

The total infiltrated volume between the surface of the soil and the wetting front is defined by equ. [7-30].

[7.30] $$F = L \times M$$

The infiltration rate $f = dF/dt$ is then given by [7-31].

[7.31] $$f = K\left(1 + \frac{MS}{F}\right)$$

In order to calculate the effective rainfall, this equation must be solved for each time step in the storm hyetograph. As illustrated in the Figure 7-8, three cases must be considered in which the infiltration rates at times t and $(t+Dt)$ are denoted by f_1 and f_2 respectively, and the rainfall intensity i is assumed to be constant during the time step. Each case is considered separately.

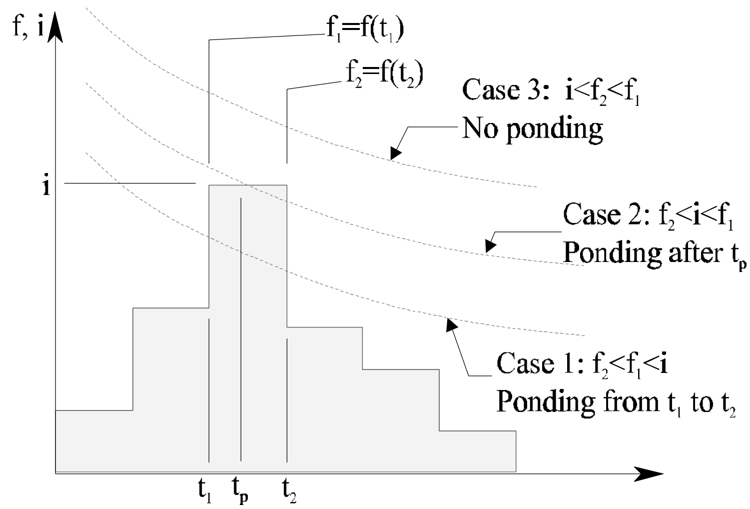


Figure 7-8 - Three cases of the Green & Ampt model.

Case (1) $f_2<f_1<i$

i.e. the rainfall intensity exceeds the infiltration capacity of the soil throughout the whole time step so that ponding must occur for the entire time Dt.

Case (2) $f_2<i<f_1$

i.e. at the beginning of the time step Dt the infiltration capacity f_1 exceeds the rainfall intensity but this changes before the time step is completed. Ponding will start during the time Dt..

Case (3) $i<f_2<f_1$

i.e. the rainfall infiltrates for the entire time step and no ponding occurs.

The solution algorithm used can be summarized as follows.

(i) If $i_j>f_j$ then case (1) holds and

[7.32] $$F_{j+1} = F_j + K\Delta t + MS\ln\left[\frac{\left(F_{j+1}+MS\right)}{\left(F_j+MS\right)}\right]$$

The effective rainfall is then given by [7.33].

[7.33] $$i_{eff} = i - \frac{\left(F_{j+1}-F_j\right)}{\Delta t}$$

(ii) If i_j £ f_j then either case (2) or case (3) applies. If we assume that case (3) applies - i.e. all the rainfall infiltrates during time Δt - then we can estimate:

$$[7.34] \qquad F_{J+1} = F_j + i\Delta t$$

and

$$[7.35] \qquad f_{j+1} = K\left(1 + \frac{MS}{F_{j+1}}\right)$$

(iii) Test if i_j £ f_{j+1} also. If so, then case (3) is true and:

$$[7.36] \qquad i_{eff} = 0$$

(iv) If $i_j > f_{j+1}$ as computed in step (ii) then case (2) holds. The volume required to cause surface ponding to occur is calculated as:

$$[7.37] \qquad F_p = \frac{KMS}{\left(i_j - K\right)}$$

The time to the start of ponding dt can then be found from equation [7-38].

$$[7.38] \qquad dt = \frac{\left(F_p - F_j\right)}{i}$$

Then:

$$[7.39] \qquad F_{j+1} = F_j + K\left(\Delta t - dt\right) + MS\ln\left[\frac{\left(F_{j+1} + MS\right)}{\left(F_j + MS\right)}\right]$$

and the effective rainfall can be estimated as:-

$$[7.40] \qquad i_{eff} = i - \frac{\left(F_{j+1} - F_j\right)}{\Delta t}$$

The application of this algorithm to each time step in the storm hyetograph produces an effective rainfall hyetograph for either the impervious or pervious surface. If the surface depression storage is finite this is subtracted from the initial elements of the hyetograph. The remaining effective rainfall produces the direct runoff hydrograph.

In the Green and Ampt method you are prompted to supply values for a total of five parameters. These are:

- Manning's '*n*' roughness coefficient
- Water (or Moisture) deficit M (say 0.0 to 0.6)
- Suction head S (mm or inches)
- Soil conductivity K (mm/hour or inches/hour)
- Surface depression storage depth (mm or inches)

Parameters for the Green & Ampt equation

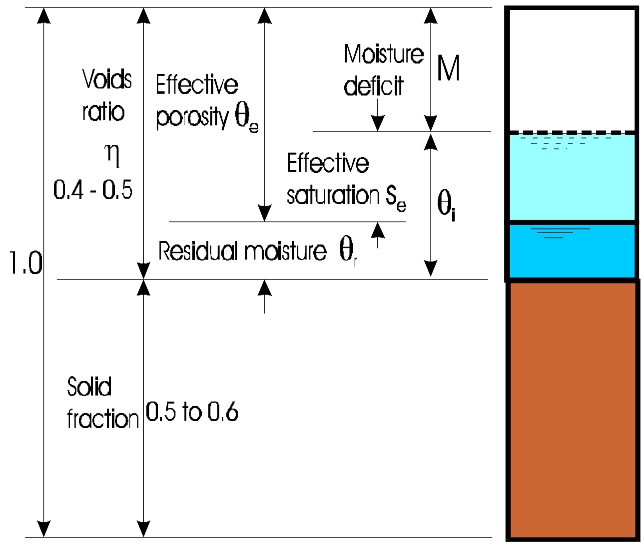


Figure 7-9 – Schematic representation of the Gree & Ampt parameters

The schematic of Figure 7-9 shows the fractions of solid material, moisture and air or vapour in the soil. The voids ratio of the soil *h* is typically between 0.4 to 0.5. Within the voids of a dried sample there is a certain volume of residual moisture *qr.* The remaining 'fillable' voids comprise the effective porosity *qe* = ***h*** - *qr* and typically varies from 0.31 to 0.48. Now if the initial moisture is denoted by *qi* the soil moisture deficit *M* = *qe* - *qi* .

The effective saturation is denoted by *Se* = *(q - qr)/ qe* and can be used to estimate the suction head at the wetting front as described by Brooks and Corey, 1964. - (see references)

Some typical values suggested by Rawls, Brakensiek and Miller (1983) (see references) are shown below.

Soil type	Porosity	Effective porosity	Suction head	Hydraulic conductivity
			mm	mm/h
sand	0.437	0.417	49.5	117.8
loamy sand	0.437	0.401	61.3	29.9
sandy loam	0.453	0.412	110.1	10.9
loam	0.463	0.434	88.9	3.4
silt loam	0.501	0.486	166.8	6.5
sandy clay loam	0.398	0.330	218.5	1.5
clay loam	0.464	0.309	208.8	1.0
silty clay loam	0.471	0.432	273.0	1.0
sandy clay	0.430	0.321	239.0	0.6
silty clay loam	0.479	0.423	292.2	0.5
clay	0.475	0.385	316.3	0.3

Calculating the Runoff

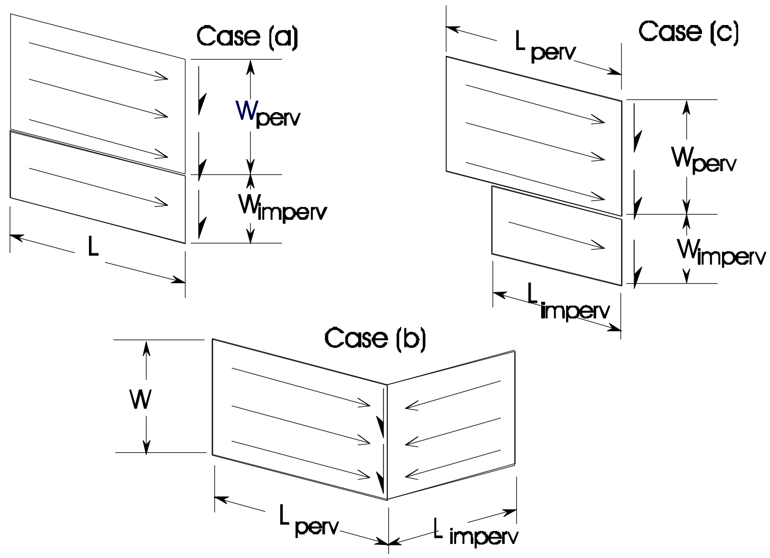


Figure 7-10 - Alternative definitions of catchment shape.

The catchment is assumed to be represented by two idealized, rectangular inclined planes - one for the pervious surface and the second for the impervious fraction. The two planes are commonly assumed to be inclined at the same gradient, but MIDUSS 98 lets you define this and all other characteristics to be different.

For each catchment you must first specify the total catchment area and the percentage of that area which is impervious. MIDUSS 98 then provides three options to define the shape of the two surfaces. Each of these is illustrated in a rather idealized way in Figure 7-10.

The default assumption is that the length of overland flow on the impervious surface is the same as that specified for the pervious fraction. This case is shown in Figure 7-10(a).

Alternatively, you may choose an option which assumes that the width of both rectangles is the same. This is equivalent to assuming that the overland flow lengths are in the same proportion as the areas of the two fractions, and is illustrated in Figure 7-10(b).

The third option allows you to define a specific length of overland flow for each of the two rectangles, so that neither length nor width need be the same. This case is shown in Figure 7-10(c).

From the sketches of Figure 7-10 it should be clear that the overland flow length is the distance from the boundary of the idealized rectangle to the drainage conduit (pipe or channel). It is along the overland flow length that the surface gradient should be estimated. The idealized catchments of Figure 7-10 are shown as non-symmetrical (i.e. with all the pervious or impervious area on one side of the drainage conduit) only to illustrate the concept.

In practice, it is usual for both pervious and impervious surfaces to be distributed more or less symmetrically about the drainage conduit.

Avoid the mistake of estimating overland flow length and slope between the outflow point and the point on the catchment boundary which is furthest from the outlet. This overestimates the time of concentration and underestimates the peak outflow.

If the catchment area is symmetrically distributed around the drainage network, an approximate value for the overland flow length can be found by dividing the area by twice the length of the drainage channel. If the catchment is unsymmetrical so that the drainage channel is along one edge of the catchment, the overland flow length can be approximated as (Area/Channel length). The two cases of symmetrical and one-sided catchments are illustrated in Figures 7-11(a) and (b) respectively. If neither of these cases applies then you must either make a subjective judgement or simulate the area as two separate sub-catchments.

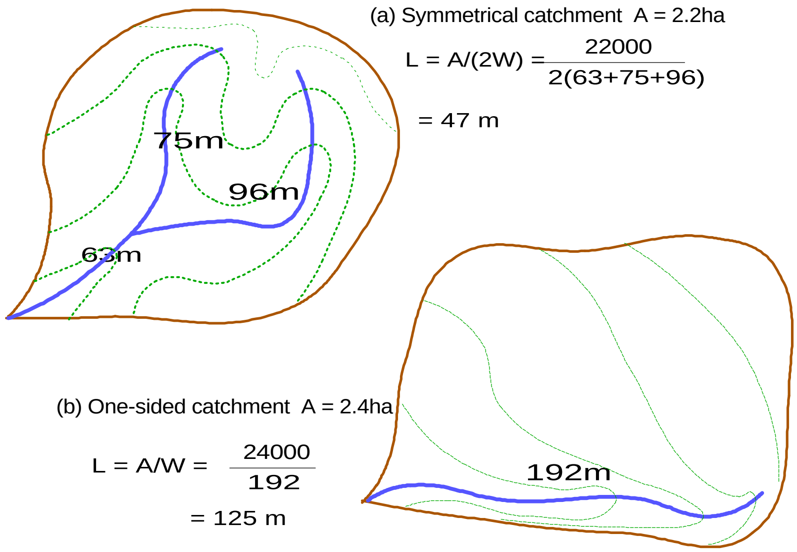


Figure 7-11 - Estimating overland flow length in symmetrical and one-sided catchments.

Another point to note is that in MIDUSS 98 the impervious fraction is assumed to be directly connected to the drainage network. This means that flow from the impervious areas does not pass over a pervious area before reaching the drainage channel. In some urban drainage models the impervious area is further subdivided into directly and indirectly connected fractions but these methods assume that runoff from the indirectly connected impervious area is uniformly distributed over the pervious fraction. In practice, such runoff is usually concentrated over a relatively small pervious area thus reducing the potential for infiltration. The assumption in MIDUSS 98 therefore leads to a conservative estimate of the total runoff from the catchment.

The Manning 'n' value is used to estimate the time of concentration (see equation [7.41]) for any specific intensity of effective rainfall. Typical values of ‘n’ for overland flow on pervious surfaces should be in the range 0.2 - 0.35 and do not represent realistic values of 'n' that might be used in channel flow calculations.

In addition to the above description, parameters must be defined which describe the infiltration process and rainfall abstractions on the pervious area. These will depend on the infiltration model selected and are as described in the section Calculating Effective Rainfall .

The Idealized Catchment

The catchment area is divided into various components as indicated in Figure 7.16. In MIDUSS 98 both the pervious and impervious areas are assumed to be directly connected and are further assumed to be described by lumped parameters - i.e. each fraction is assumed to be homogeneous.

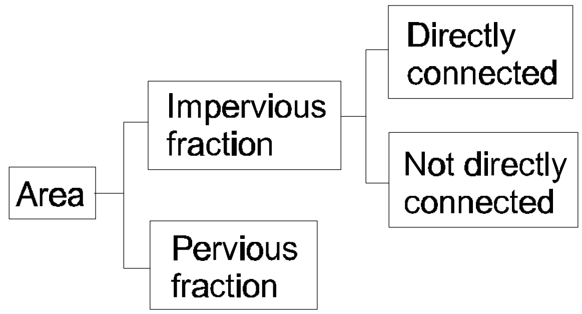


Figure 7-12 - Various components of an idealized catchment.

Conceptual Components of Rainfall

For each fraction of the catchment (pervious and impervious) the rainfall loss is the difference between the rainfall depth and the depth of runoff. This is made up of various components as illustrated in Figure 7-13. Not all methods of modelling rainfall losses use all of these components.

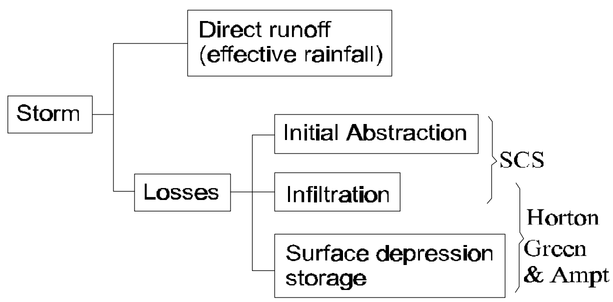


Figure 7-13 – Rainfall abstraction models use different components

The initial abstraction *Ia* may be defined explicitly as an average depth over the area (in mm or inches) or implicitly as a fraction of the potential storage depth in the soil (e.g. $Ia = 0.1\ S$). The notion of initial abstraction is used in the SCS infiltration method, but not by either the Horton equation or the Green & Ampt methods. The initial abstraction depth is treated as a first demand on the storm rainfall; surface depression storage is a first demand on the surface water excess leading to runoff.

The infiltration capacity is assumed to decrease continuously throughout the storm as the storage potential in the soil is progressively reduced by the volume of infiltration. The reduction in infiltration capacity is a function of the infiltrated volume and not of the elapsed time from the start of rainfall. In release 1 of MIDUSS 98 no provision is made for 'recovery' of infiltration potential during periods of zero or very low rainfall. For single event modelling this is not likely to be significant. MIDUSS 98 models the infiltration process by

- the SCS method,
- the 'moving curve' Horton equation or
- the Green & Ampt model.

Surface depression storage is represented by an average depth distributed uniformly over the surface area. The usual assumption made is that when rainfall intensity exceeds the infiltration capacity the depth of excess water on the surface must attain a value greater than the surface depression storage depth before runoff can occur. The concept of surface depression storage depth is not used in the SCS method but plays a significant role in the implementation of the Horton or Green & Ampt methods.

Processing the Storm Rainfall

The significance of the components of rainfall loss is illustrated in Figures 7-14 and 7-15. For this comparison the storm used is a 2nd quartile Huff distribution with a total depth of 50 mm over a period of 120 minutes. The rainfall abstractions have been modelled using the SCS Curve Number method with CN = 88.

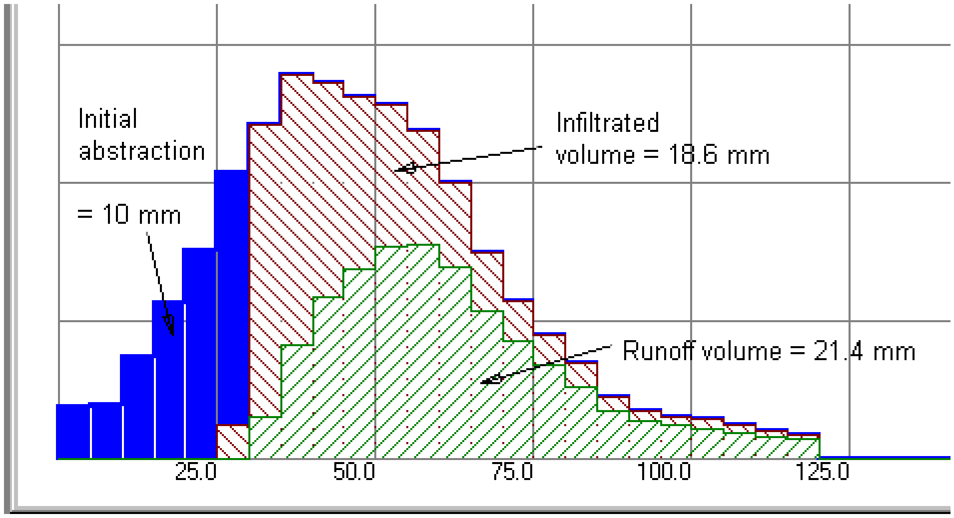


Figure 7-14 – Rainfall loss components with Ia = 10 mm, Yd = 0.0

Fig 7-14 above shows the normal application of the SCS method in which an initial abstraction Ia = 10 mm has been applied. It is clear that this is a first demand on the storm hyetograph. The remaining 40 mm of rainfall is split into an infiltrated volume of 18.6 mm leaving 21.4 mm of direct runoff.

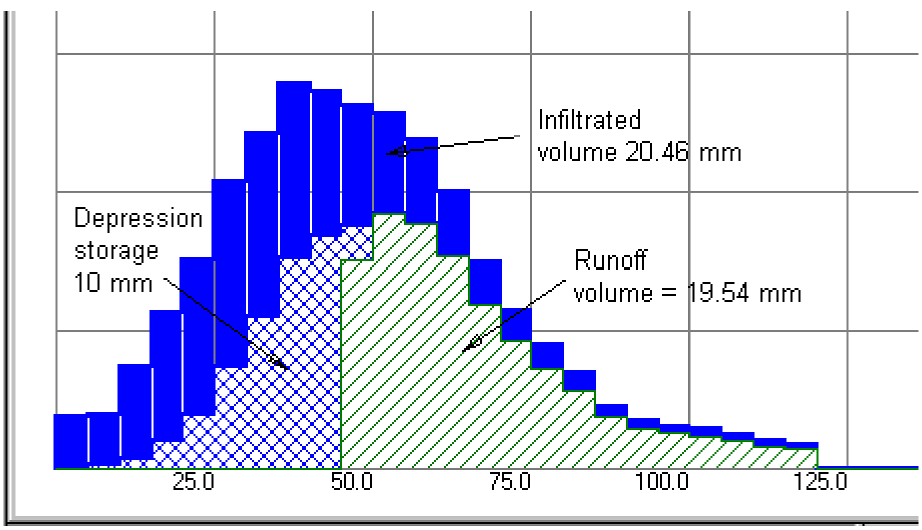


Figure 7-15 – Rainfall loss components with Ia = 0.0 and Yd = 10.0 mm.

Fig 7-15 shows an unusual application of the SCS method developed by means of some of the options in MIDUSS 98. In this case the initial abstraction is zero so that an infiltration volume of 20.46 mm is the first demand on the storm hyetograph. The remaining 29.54 mm of rainfall is divided between 19.54 mm of direct runoff and 10 mm which is detained as surface depression storage.

Note the difference in volume, peak intensity and shape of the direct runoff component. This would certainly be reflected in the resulting overland flow hydrograph. In this example the differences have been exaggerated by using a relatively large depth for Ia or yd. You will find it instructive to recreate this experiment using the Horton method to model the infiltration process or with smaller values of Ia and yd.

Rainfall Runoff Models

Rainfall runoff models may be grouped in two general classifications that are illustrated in Figures 7-16 and 7-17. The first approach uses the concept of effective rainfall in which a loss model is assumed which divides the rainfall intensity into losses and an effective rainfall hyetograph. The effective rainfall is then used as input to a catchment model to produce the runoff hydrograph. It follows from this approach that the infiltration process ceases at the end of the storm duration.

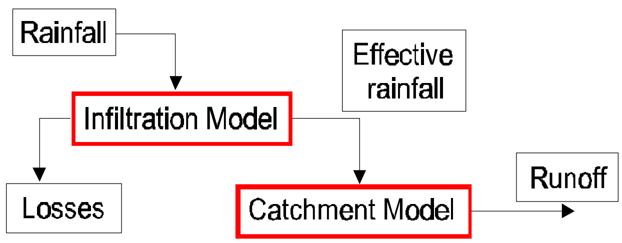


Figure 7-16 - A rainfall-runoff models using effective rainfall.

An alternative approach that might be termed a surface water budget model, incorporates the loss mechanism into the catchment model. In this way, the incident rainfall hyetograph is used as input and the estimation of infiltration and other losses is made as an integral part of the calculation of runoff. This approach implies that infiltration will continue to occur as long as the average depth of excess water on the surface is finite. Clearly, this may continue after the cessation of rainfall.

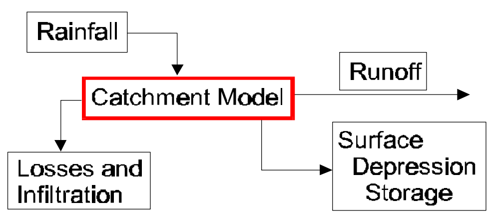


Figure 7-17 – A rainfall-runoff model using a surface water budget

MIDUSS 98 allows you the option to use particular implementations of both these techniques. The effective rainfall approach is employed in a convolution algorithm that uses response functions of different shape. For the case of triangular or rectangular response functions the time base is computed by a kinematic wave equation which involves the intensity of the effective rainfall.

The convolution process is therefore nonlinear in that the response function changes throughout the storm but the principle of superposition is retained. These two approaches are embodied in the 'Rectangular' and 'Triangular SCS' options of the **Hydrology/Catchment** command.

The third convolution option uses a response function which is obtained by routing a rectangular input of duration Dt and height A/Dt through a linear reservoir with a lag or storage coefficient $KL=tc/2$. For this case, the time of concentration tc is computed using the kinematic wave equation [7-41] but for the maximum value of effective rainfall intensity.

An example of a surface water budget model is also made available in the form of the SWMM/RUNOFF algorithm and can be implemented by using the 'SWMM method' option. It is important to note that if the 'SWMM method' option is to be employed it is necessary to use the Horton or Green and Ampt infiltration models to represent the rainfall losses. The four options are described in the sections that follow.

A Rectangular Response Function

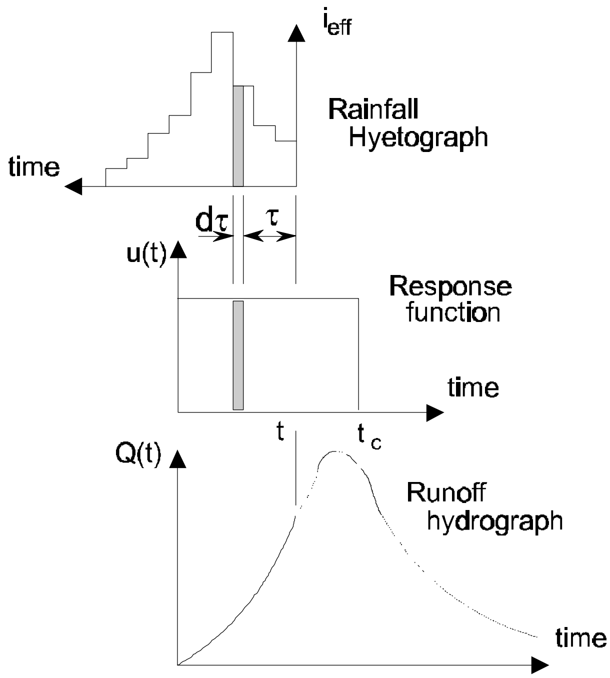


Figure 7-18 - Convolution using a rectangular response function.

Figure 7-18 illustrates a convolution process in which the response function is assumed to be rectangular with a dynamically varying time base equal to the time of concentration as defined by equation [7.41].

$$[7.41] \qquad t_c = k\left(\frac{L.n}{\sqrt{S}}\right)^{0.6} \frac{1}{i_{eff}^{0.4}}$$

where L = flow length (m or feet)

n = Manning's roughness coefficient

S = slope of overland flow (m/m or ft/ft)

i_{eff} = effective rainfall (mm/h or inch/h)

k = 6.989 for metric units

= 0.939 for Imperial or US customary units

The ordinate of the response function is given by $u_{max} = A/tc$ so that the evaluation of a discretized form of the convolution integral is relatively straightforward. If the effective rainfall is also a simple rectangular function the method reduces to the rational method. There is some evidence (Smith & Lee, 1984 see references) that this method is appropriate when the overland flow is dominated by runoff from relatively smooth, impervious surfaces.

In using the Rectangular Response option it is possible to define an artificially short flowlength (e.g. 1.0 m) thus making the time of concentration of negligible duration. This is equivalent to employing a Dirac d- function as the response function and may be of interest in simulating other models.

The SCS Triangular Response

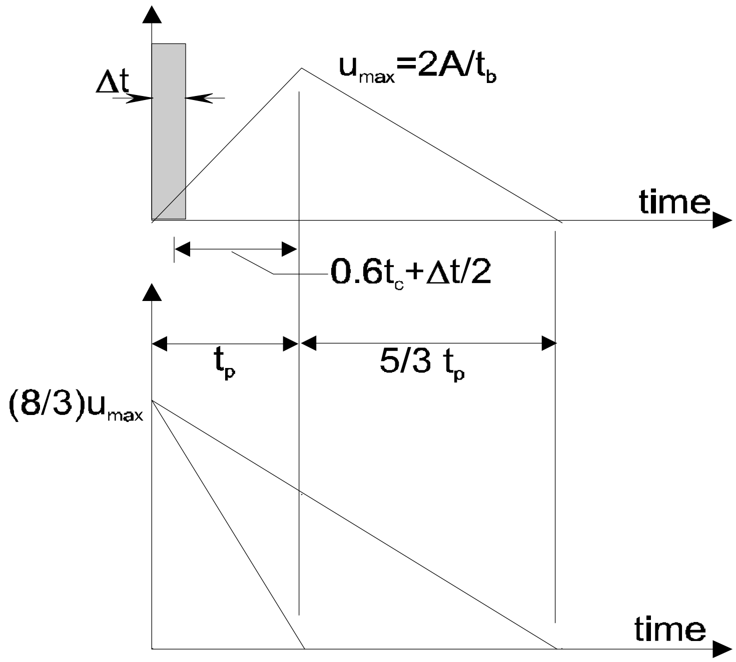


Figure 7-19 - Representation of the triangular response function.

A very common and popular technique proposed by the Soil Conservation Service uses a triangular response function as shown in the upper part of Figure 7-19 above. The time to peak t_p of the triangular IUH and the time base t_b are given by equations [7-42] and [7-43] respectively.

$$[7.42] \qquad t_p = 0.6t_c + \frac{\Delta t}{2}$$

$$[7.43] \qquad t_b = \left(\frac{8}{3}\right)t_p$$

The 'Triangular SCS' option in MIDUSS 98 represents a modification of this method in that the value of t_c is obtained by [7-41] and is assumed to vary in a nonlinear fashion in much the same way as for the rectangular response function. For each time step the effective rainfall intensity is known and the triangular response function for the corresponding time of concentration t_c is discretized and multiplied by the effective rainfall. The resulting contributions to the overland flow hydrograph are lagged and accumulated. The computation is made more efficient by representing the triangular response as the difference between two right- angled triangles as indicated in the lower part of Figure 7-19.

It will be found that with both the "Rectangular' and 'Triangular SCS' methods the time of concentration of the impervious fraction is much shorter than that for the pervious area due to smaller values of Manning's '*n*' and higher effective rainfall intensities. In cases where the contribution from each fraction is of the same order of magnitude the total runoff hydrograph exhibits a double peak because of this feature.

The Linear Reservoir Response

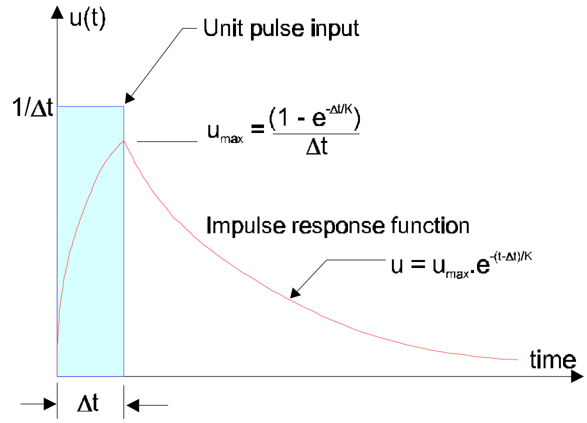


Figure 7-20 - The Single Linear Reservoir IUH

A more complex response function was suggested by Pederson (see references) and is currently in use in the URBHYD routine of the OTTHYMO model. The shape of the Instantaneous Unit Hydrograph (IUH) is obtained as the response of a single linear reservoir to a rectangular pulse of rainfall of unit volume and duration Dt. The storage coefficient K of the linear reservoir is taken to be $0.5\ t_c$ where t_c is computed by equation [7-41] in which the maximum rainfall intensity is used since this intensity tends to dominate the subsequent convolution process. The resulting IUH is illustrated in Figure 7-20 and comprises a steeply rising limb over the time step Dt followed by an exponential decay. Most applications of this method have used a procedure in which the IUH is discretized at intervals of Dt and then convoluted with the effective rainfall.

Because t_c is assumed to be constant in this method, both the response of the linear reservoir and the convolution are linear processes and it is therefore immaterial in what order they are carried out. The essential equivalence of the alternate methods is illustrated in Figure 7-21.

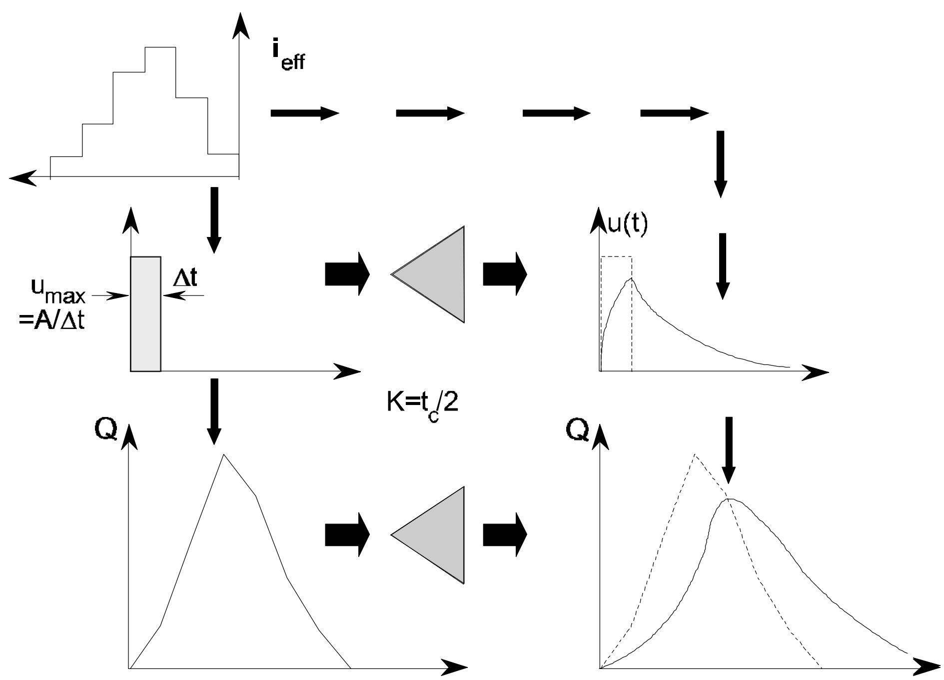


Figure 7-21 - Alternative implementations of a linear reservoir response.

MIDUSS 98 uses the alternate approach of convoluting the effective rainfall with a simple rectangular response of duration Dt and height $u_{max} = A/Dt$. The resulting 'instantaneous' runoff hydrograph is then routed through the linear reservoir. This approach reduces the computational time by at least an order of magnitude and improves the accuracy.

The routing process is carried out using a time step of $Dt/2$ in order to improve the accuracy in the vicinity of the peak runoff but the results are presented only at intervals of Dt.

The SWMM - RUNOFF Algorithm

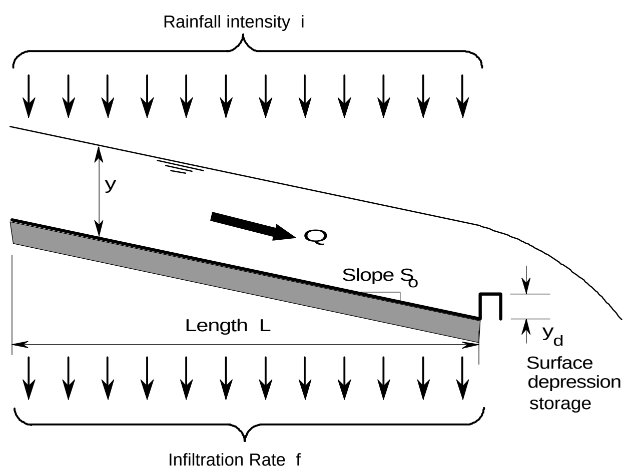


Figure 7-22 - Representation of the SWMM/RUNOFF algorithm.

The U.S. EPA SWMM model is made up of a number of large program modules. One of these - the RUNOFF block - is used to generate the runoff hydrograph from a sub-catchment. In MIDUSS 98, the 'SWMM Method' option uses a similar algorithm with the limitation that only the Horton or Green and Ampt infiltration equations are supported.

The method employs the surface water budget approach and may be visualized as shown in Figure 7-22. The incident rainfall intensity is the input to the control volume on the surface of the plane; the output is a combination of the runoff Q and the infiltration f. Considering a unit breadth of the catchment the continuity and dynamic equations which have to be solved are as shown in equations [7-44] and [7-45].

[7.44] $$iL = \left(fL + \frac{Q}{B} \right) + L\frac{\Delta y}{\Delta t}$$

[7.45] $$Q = B\frac{C_M}{n}S^{1/2}\left(y - y_d\right)^{5/3}$$

where L = overland flow length

B = catchment breadth

CM = 1.0 for metric units

1.49 for Imperial or US customary units

n = Manning roughness coefficient

y_d = surface depression storage depth

Rewriting [7-44] with $q = Q/B$ and then substituting for Q by means of [7-45] yields the single equation:

$$[7.46] \qquad \Delta y = \Delta t\left(i - f - \frac{q}{L}\right)$$

or

$$[7.46a] \qquad \Delta y = i \quad \Delta t - f \quad \Delta t - \Delta t \quad \frac{C_M}{n} S^{1/2} \frac{(y - y_d)^{5/3}}{L}$$

If the depth on the plane at the start and finish of the time step Dt is represented by $y1$ and $y2$ respectively an equation for $y2$ can be developed using the following approximations.

$$[7.47] \qquad \Delta y = y_2 - y_1$$

$$[7.48] \qquad (y - y_d)^{5/3} = \frac{(y_1 - y_d)^{5/3} + (y_2 - y_d)^{5/3}}{2}$$

$$[7.49] \qquad f \quad \Delta t = f_c \quad \Delta t + K \quad (f_0 - f_c)\left(1 - e^{-\Delta t/K}\right) \qquad \text{for } y>0$$

Equations [7-47] - [7-49] are solved using a Newton Raphson method to yield a solution for $y2$ which is then used to obtain a value for Q.

It can be shown (Smith, 1986a, see references) that the algorithm developed above is equivalent to convoluting the storm rainfall with a Dirac d–function and then routing the resulting 'instantaneous' runoff through a nonlinear reservoir with storage characteristics given by:

$$[7.50] \qquad S = C \quad Q^{0.6}$$

where

$$C = C_M{}^{0.6}\left(\frac{L\,n}{S^{0.5}}\right)^{0.6} A^{0.4}$$

In equation [7-50] 'A' is the catchment drainage area and other terms are as defined previously (see equations [7-41] and [7-45]).

Three points of some significance arise with respect to the ‘SWMM Method’ option.

(1) Considering the method to be equivalent to routing the instantaneous runoff through a nonlinear reservoir, it follows that the peak of the outflow must lie on the recession limb of the inflow. Consequently the time to peak for pervious and impervious fractions will not differ significantly and the total runoff will not exhibit the double peaked hydrographs which are sometimes encountered with the ‘Rectangular’ or ‘Triangular SCS’ options.

(2) The form of equations [7-44] and [7-45] implicitly assumes that the depth of flow over the plane is quasi-uniform. This over-estimates the volume on the plane and will usually result in over-attenuation of the peak runoff.

(3) Since infiltration is assumed to continue over the entire surface after cessation of rainfall as long as the average depth is finite, the recession limb of the runoff hydrograph will generally be much steeper than for the ‘Rectangular’ or ‘Triangular SCS’ options. In practice, after cessation of rainfall, the surface water tends to concentrate in pools and rivulets so that the area over which the infiltration continues is likely to be much less than the total area A. A more realistic representation of the infiltration after the storm is likely to be intermediate between the two extreme cases represented by the ‘SWMM Method’ method on one hand and the ‘Triangular SCS’ or ‘Rectangular’ method which employs the concept of effective rainfall. This feature is

sufficiently important that a detailed example is presented in the following section in order to illustrate the fundamental difference between the methods.

An Example of the SWMM Runoff Algorithm

The object of this example is to compare the overland flow that is generated by the 'SWMM Method' option with that which would be obtained using an effective rainfall approach. For simplicity we shall assume a catchment of 5.0 ha with no impervious area and no depression surface storage. The storm used is a 3rd quartile Huff storm with a total rainfall depth of 30 mm occurring in 60 minutes. Infiltration will be modelled by the Horton method with the following parameter values:

- n = 0.25
- f_0 = 40 mm/hour
- f_c = 20 mm/hour
- K = 0.25 hours
- y_d = 0

To simulate the SWMM algorithm using an effective rainfall approach we shall make use of equation [7.50] to define a nonlinear reservoir through which the instantaneous runoff is routed. This hydrograph can be created by convoluting the effective rainfall with an impulse (also known as a Dirac d-function) which can be simulated by specifying a very short overland flow length.

The steps are summarized as follows. You may find it instructive to run this example on your own computer as you read through the steps.

(1) In the Time Parameters use 2 minute timesteps and a storm duration of 60 minutes.

(2) Define the Huff storm; use 30 mm rainfall; 60 minutes duration; 3rd quartile.

(3) The impervious characteristics are not important but we must use the Horton method. Set n = 0.015 and the other parameters to zero.

(4) The first catchment 101 is used to represent the Dirac δ-function so use the following parameters.

Area	=	5.0 ha
Length	=	0.1 m
Slope	=	2.0 %
Percent impervious	=	0

For the infiltration parameters use the Horton method with:

fo	=	40 mm/hour
fc	=	20 mm/hour
K	=	0.25 hour
yd	=	0

The peak effective rainfall intensity is found to be 68.279 mm/h. Use the 'Rectangular' option since this most closely approximates an impulse. The peak runoff is 0.948 c.m/s. A few seconds with a calculator will confirm that for an area of 5 hectares this is equivalent to 68.279 mm/h.

Catchment 101	Pervious	Impervious	Total Area	
Surface Area	5.000	0.000	5.000	hectare
Time of concentration	0.456	0.075	0.456	minutes
Time to Centroid	38.140	34.039	38.140	minutes
Rainfall depth	30.000	30.000	30.000	mm
Rainfall volume	1500.00	0.00	1500.00	c.m
Rainfall losses	17.272	0.000	17.272	mm
Runoff depth	12.728	30.000	12.728	mm
Runoff volume	636.38	0.00	636.38	c.m
Maximum flow	0.948	0.000	0.948	c.m/sec

Figure 7-23 – Statistics of the Dirac-δ response hydrograph

(5) We shall want to route this runoff through an imaginary pond with stage discharge characteristics as given by [7- 50]. Use the **Hydrology/Add Runoff** command to define the inflow to the pond to be used in step (7).

(6) The final step to simulate the SWMM hydrograph is by routing the instantaneous runoff through a nonlinear reservoir. For the data used in this example, the value of C in equation [7-50] works out to be 1115.39. We now define a pond with discharges ranging from 0.0 to 0.25 in increments of 0.025 - i.e. 11 stages. Figure 7-25 shows the result of a pond design. The value of each storage volume is given by 1115.39 x $Q^{0.6}$. The peak outflow is found to 0.246 c.m/s In Figure 7-25, the hydrograph has been extended to 130 minutes.

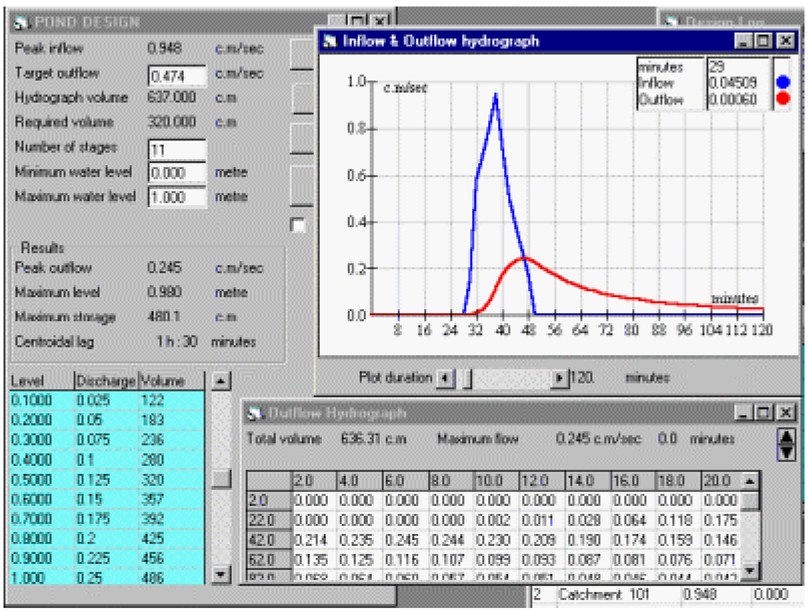


Figure 7-24 - Design of a hypothetical pond.

(7) The next step is to generate the 'SWMM method' hydrograph, so define another catchment with the same parameters as in step (4) but with a flow length of 50 m. The infiltration options are the same as before. The peak runoff is found to be 0.248 c.m/s.

The similarity in peak flows is promising, but the true test is to compare the plotted hydrographs. Figure 7-24 shows the 'SWMM Method' and simulated SWMM hydrographs

The rising limbs of the two hydrographs are in good agreement apart from a slight lag of about 2 minutes which is the shortest 'impulse' that MIDUSS can create when Dt is 2 minutes. However, immediately following the cessation of the effective rainfall the 'SWMM Method' recession limb drops more steeply. This is due to the fact that the surface water budget method assumes that infiltration continues as long as there is excess water on the pervious surface whereas the effective rainfall approach - which produced the longer curve in Figure 7-25 - assumes that infiltration stops at the end of the effective rainfall. The two recession limbs start to diverge at *t* = 50 min. which marks the end of the effective rainfall hyetograph.

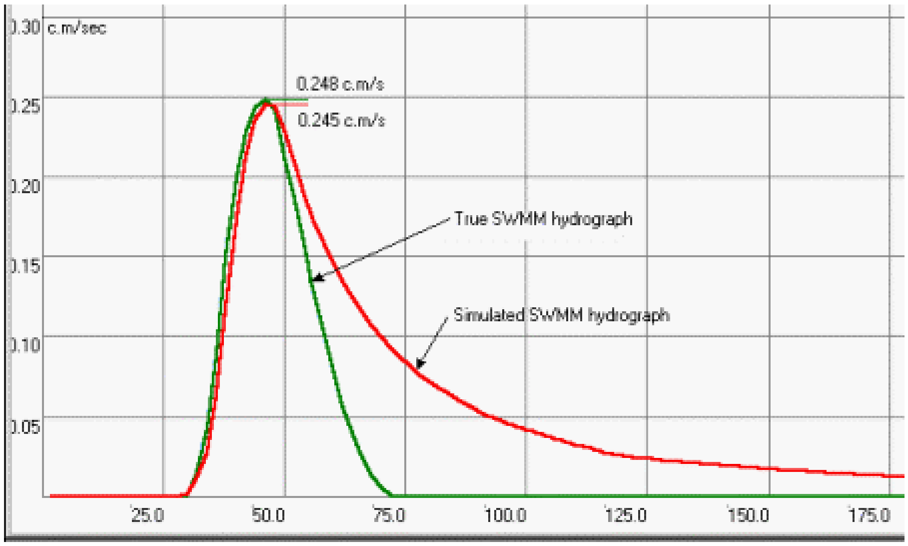


Figure 7-25 - Comparing the SWM HYD and simulated SWMM hydrographs.

Catchment 102	Pervious	Impervious	Total Area	
Surface Area	5.000	0.000	5.000	hectare
Time of concentration	16.783	3.103	16.783	minutes
Time to Centroid	47.830	37.373	47.830	minutes
Rainfall depth	30.000	30.000	30.000	mm
Rainfall volume	1500.00	0.00	1500.00	c.m
Rainfall losses	24.076	0.000	24.076	mm
Runoff depth	5.924	30.000	5.924	mm
Runoff volume	296.27	0.00	296.27	c.m
Maximum flow	0.248	0.000	0.248	c.m/sec

Figure 7-26 - Statistics of the 'SWMM Method' hydrograph.

This difference serves also to explain the anomaly that appears in the hydrograph statistics screen when using 'SWMM Method' option. Figure 7-26 shows the summary statistics obtained at the end of step (7) and you will note that the runoff volume (296.2 c.m) is much less than that for the effective rainfall volume of 636.38 c.m. (from Figure 7-23).

This may not always be the case and you should repeat this experiment with a finite value for depression surface storage - say 2 mm or 100 c.m over the 5 hectares of area. You will find that the effective rainfall volume is reduced by exactly 100 c.m. The infiltration and runoff volume are also reduced by amounts which add up to 100.0 c.m. less the volume still trapped in surface depressions when the calculation was ended. If continued long enough, this too would have infiltrated thus balancing the books properly. Hence the name 'surface water budget'.

To assist you in trying some experiments, a full listing of the output file is included in the Miduss98\Samples\ folder when you install MIDUSS 98..

Simulation of Large Catchments

Rainfall-runoff simulation requires certain assumptions with respect to the level of discretization to be employed and the parameter values to be used for the sub-areas. When modelling very large watersheds a compromise is necessary between using sub-areas that are too small or too large. Small sub-catchments impose cost penalties in data preparation and computation effort. Large areas present problems in assigning values to parameters – such as overland flow length - that are a reasonable representation of the physical system.

The ratio of channel travel time to sub-area response time varies widely for areas that are close to or distant from the outflow point. This variation results in a diffusion of the flow peaks from individual areas and accounts for a significant part of the basin lag. In large catchments this basin lag can equal or exceed the overland flow travel time and attempts to represent this by distorting overland flow parameters are subjective, unrealistic and storm specific. The process can be better represented by convoluting the overland flow response function with the derivative of the time-area diagram for the total watershed. The resulting modified response function can then be convoluted with the effective rainfall to yield a good approximation to the runoff hydrograph for the total area.

Numerical experiments suggest that the unwieldy process of double convolution can be approximated by using a single convolution of overland flow and rainfall and then routing the resulting hydrograph through a hypothetical linear channel and linear reservoir. The latter have lag times that are related to the maximum conduit travel time through the drainage network. MIDUSS 98 uses some preliminary guidelines to estimate the lags and partially automate the process.

This section describes the process used and compares a typical example with a fully discretized simulation. It must be emphasized that the suggested method is preliminary and would benefit from further testing of either real or idealized cases to verify or improve the guidelines.

Example of a Large Catchment

The process is described with reference to the catchment area in Figure 7-27. The runoff obtained from the discretized version will be compared to the approximate 'lumped-parameter' version. In Figure 7-27 the area in hectares of the sub-areas is shown in italics and in parenthesis in the lower-right corner of each rectangular area. The length between nodes is approximately to scale but can be found in file …\Miduss98\Samples\Large1.out.

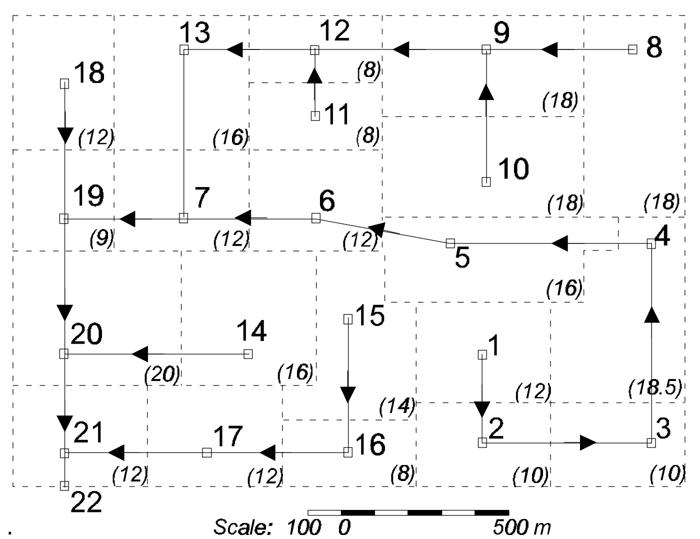


Figure 7-27 – Discretized version of a large catchment

(Areas shown in hectares as *(12)* in lower right corners)

The system is subjected to a 5-year storm represented by a 360 minute Chicago hyetograph with a total depth of 50.45 mm (the MIDUSS 98 default values). All the sub-areas are assumed to have the same overland flow characteristics with the exception of area, i.e.

Overland flow length	=	45 m
Overland slope	=	2.0 %
Percent impervious	=	30 %
Pervious roughness n	=	0.25
Impervious roughness n	=	0.013

With this simplifying assumption, the response functions of the sub-areas will have the same time parameters and vary only with respect to the area. Thus, for a triangular response function:

$$[7.51] \qquad t_c = k\left(\frac{L\,n}{\sqrt{S_0}}\right)^{0.6} i_{eff}^{\;-0.4}$$

$$[7.52] \qquad t_p = 0.6t_c + \Delta t/2$$

$$[7.53] \qquad t_b = \left(8/3\right)t_p$$

$$[7.54] \qquad u_{\max} = 2A/t_b$$

The drainage network is composed of pipes with a gradient of approximately 0.4%. The output file from the discretized simulation is called 'Large1.out' and can be found in the ..\Samples\ folder of the Miduss98 directory.

The distribution of areas relative to the outflow point can be represented by a time-area diagram as illustrated in Figure 7- 28. From Figure 7-27 you will note the rather circuitous (and unrealistic) drainage path of areas 1, 2 and 3. This gives rise to the late contribution of the furthest upstream 32 ha which in turn makes the Time-Area diagram depart from the reasonably linear shape which is apparent over the first 15 minutes. This feature makes the approximation more challenging.

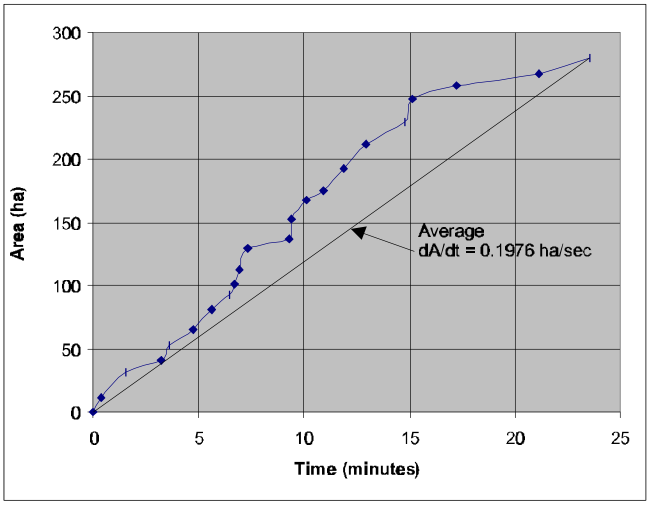


Figure 7-28 – Time-Area diagram for the catchment of Figure 7-27

The time to equilibrium Te is 23.21 minutes from node #1 to the outflow point at node #22. This is the time at which the entire catchment is contributing and is a function of the drainage network. The time of concentration tc and therefore the timebase tb of the response function, is a characteristic of the overland flow. Both quantities are also dependent on the magnitude of the storm.

The relative magnitude of Te and tc is an important parameter in determining the limit for lumped representation of a catchment. If $Te / tc << 1.0$ then it is likely that overland flow dominates the runoff process and thus the overland flow response function is a reasonable approximation for the entire catchment. In large catchments, Te / tc is larger (although still probably less than 1.0) and channel/pipe routing will play an important role in determining the shape and peak of the runoff hydrograph.

Combining Overland Flow and Drainage Network Routing

The combined effect of overland flow routing and drainage network routing can be obtained by convoluting one response function with the other. The right side of Figure 7-29 shows a triangular response function being convoluted with the derivative of the time-area diagram to produce a modified response function. This is then convoluted with the hyetograph of effective rainfall to produce the modified runoff hydrograph in the lower right corner of the figure.

The unwieldy process of double convolution can be approximated by the process shown on the left side of the Figure 7-29. The normal overland flow response function is convoluted with the effective rainfall to produce a 'lumped' runoff hydrograph. This assumes that all the sub-areas contribute to runoff simultaneously. This is then routed through a linear channel and linear reservoir. If appropriate values can be set for Kch and $Kres$ the resulting hydrograph should be a close approximation of the modified runoff hydrograph.

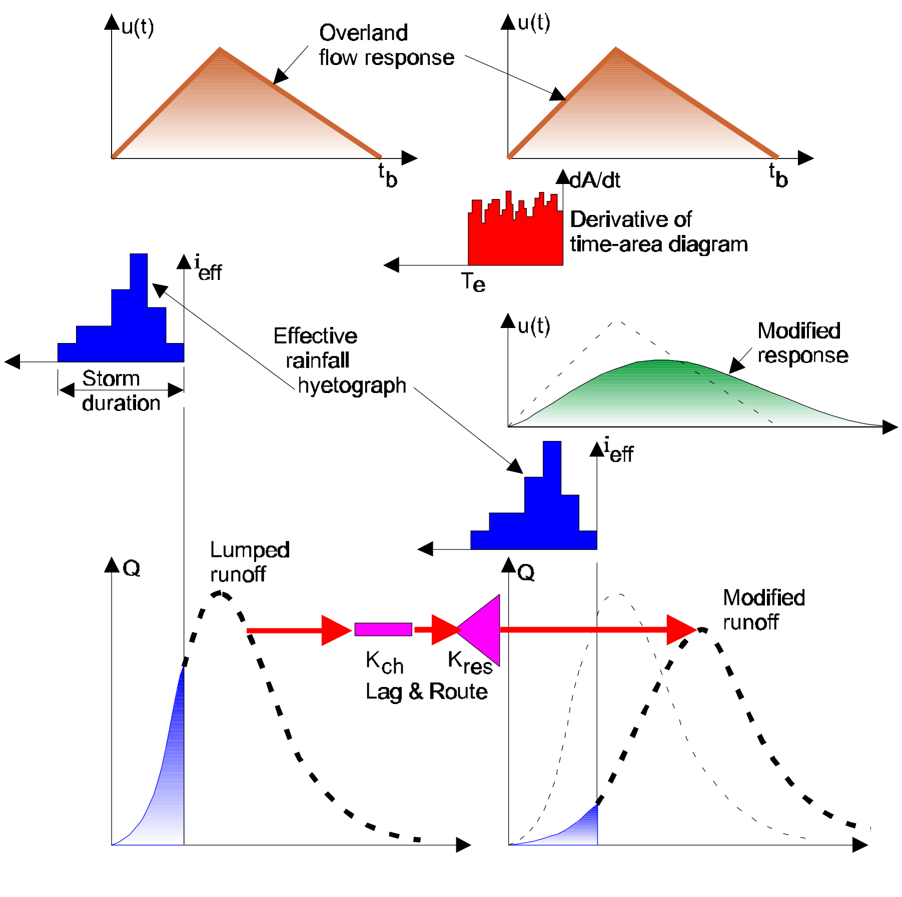


Figure 7-29 – Representation of the Lag and Route method

The total lag $Ktot$ is defined as the sum of the two components Kch and $Kres$, i.e.

[7.54] $$K_{tot} = K_{ch} + K_{res}$$

The distribution of the total lag between the two constituent parts is defined by a fraction r ($0.0 < r < 1.0$) as follows.

[7.55] $$K_{ch} = (1 - r)K_{tot}$$

and

[7.56] $$K_{res} = rK_{tot}$$

Estimating the Lag Values

Results from a limited number of numerical experiments suggest that some corelation exists between:

- The total lag $Ktot$ and the ratio of time to equilibrium to time of concentration (Te/tc), and
- The fraction $r = Kres/Ktot$ and the basin time to equilibrium Te

As preliminary guidelines the following relationships are used in MIDUSS 98.

[7.57] $$K_{tot} = T_e\left(0.4 + 0.005\frac{T_e}{t_c}\right)$$

Values for the fraction $r = Kres/Ktot$ are based on a curve which – for the data analyzed – approaches an asymptotic value of about 0.55 as shown in Figure 7-30.

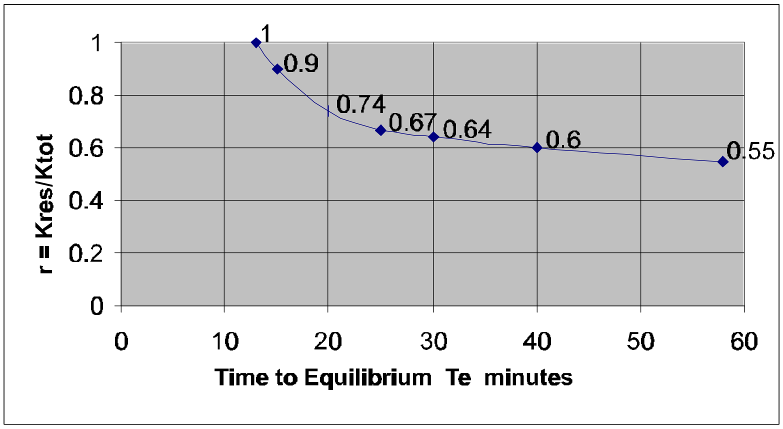


Figure 7-30 – Empirical curve defining r = Kres/Ktot = f(Te)

The data of Figure 7-30 is contained in a small data file called ‘LagRout1.dat’ which resides in the Miduss98 folder. This file can be edited or updated as and when further numerical experimental results are available. The trends suggested are interesting but inconclusive. More experiments are required to test the sensitivity of the identified parameters to factors such as:

- Shape and duration of storm
- Size and shape of the catchment
- Choice of overland routing model
- The rainfall loss model employed.

Until such time as further test results are available you should use this feature with caution. When possible, it is useful to carry out a comparison between the Lag and Route approximation and a typical discretized simulation to provide a measure of confidence in the method. The next section describes the results obtained for the catchment of Figure 7-27.

Comparison of Discretized and Approximate Results

Refer to the output file …\Miduss98\Samples\Large1.out for details of the test described here.

The fully discretized simulation produced a peak runoff of 19.136 c.m/s.

The lumped catchment runoff is found to have a peak of 26.488 c.m/s

The Lag and Route command is then used with MIDUSS 98 default values for all quantities with the exception of the catchment area aspect ratio which is set at 2000m/1400 m or 1.43 and the average pipe slope of 0.4%. The form is shown in Figure 7-31 below. The longest drainage path estimated by MIDUSS 98 is 3397 m whereas scaling the reach from node #1 the length is 3900 m. The underestimate is close to 13% and is due to the circuitous route from node #1 to node #5. The error will result in a slightly higher peak flow for the reduced peak flow that is shown as 20.217 c.m/s. A graphical comparison of the results is shown in Figure 7-32. Apart from the over-estimated peak flow the approximation is reasonable.

If the Stream length is entered as 3900 m as a result of scaling the drawing (Figure 7_27) the result is improved. The peak of the approximate runoff is reduced to 19.745 c.m/s with no measurable change in the general agreement between the discretized and approximate runoff hydrographs. The effect of the change in stream length is summarized in the Table below.

Stream length (m)	**Kch (min)**	**Kres (min)**	**Ktot (min)**	**r**	**Qpeak (c.m/s)**
3397	1.984	6.033	8.017	0.753	20.217
3900	2.725	6.508	9.233	0.705	19.745
		Discretized simulation			19.136

By checking the output file you will also see that continuity is respected and the total runoff volume is given as 6.2605 ha-m in all cases.

You can experiment with this example by running the file ‘Large1.out’ in automatic mode. After generating the database Miduss.Mdb, navigate to the **Hydrograph/Start new tributary** command following completion of the discretized simulation. Change the command from ‘40’ to ‘- 40’ and then use the [RUN] button in the Automatic Control Panel to run up to that point. You can then step through the ‘lumped’ runoff calculation and the Lag and Route approximation using the [EDIT] command button or in Manual mode

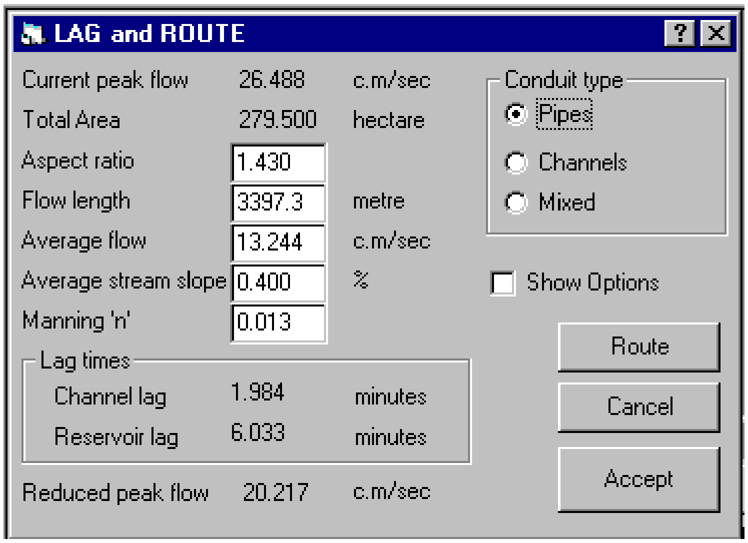


Figure 7-31 – Using the Lag and Route command

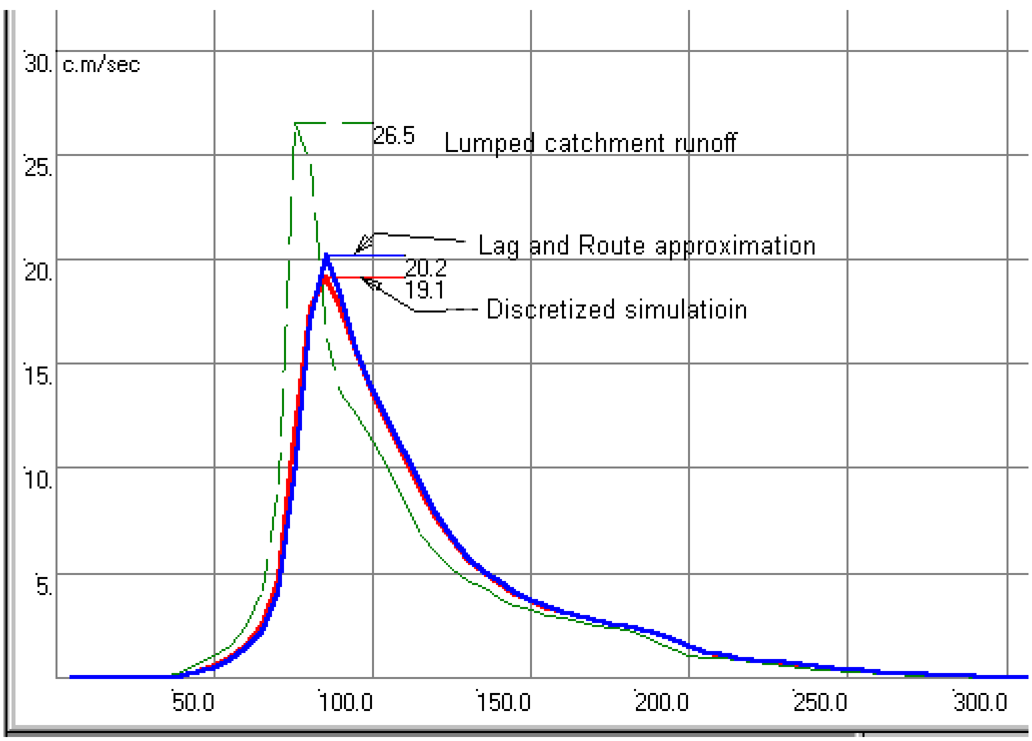


Figure 7-32 – Comparison of the Lag and Route approximation with the discretized runoff.

Chapter 8 - Theory of Hydraulics

This chapter explains some of the principles of hydraulics which are used in the Design commands available in MIDUSS 98. It is not intended to be a general treatment of hydraulics and you should use a standard text on the subject to obtain information not covered in this Help System.

The chapter is subdivided into six sections corresponding to the 6 commands available in the Design menu.

- Pipe design
- Channel design
- Flood Routing
- Detention Pond design
- Exfiltration Trench design
- Diversion Structure design

Theory of Pipe Design

This section summarizes the hydraulic principles which are used in MIDUSS 98 for the analysis and design of pipes. Flow is assumed to be uniform within each reach of pipe, so that the depth and other cross-sectional properties are constant along the length of the pipe. It follows that the bed slope S_0, the water surface and the slope of the energy line S_f are all parallel. The resistance is assumed to be represented by the Manning equation:

$$[8.1] \qquad Q = \frac{M}{n} A R^{2/3} S_0^{1/2}$$

where	Q	=	normal discharge (c.m/s or c.ft/s)
	M	=	1.0 for metric units
			1.49 for imperial or US customary units
	n	=	Manning's roughness coefficient
	A	=	cross-sectional area
	R	=	hydraulic radius = Area/Wetted perimeter
	S_0	=	bed slope (m/m or ft/ft)

No allowance is made for any apparent variation of 'n' with the relative depth of flow in the pipe.

Next - Calculation of Normal Depth in Pipes

Normal Depth in Pipes

For a part-full circular section the cross-sectional properties are expressed in terms of the angle f subtended at the centre by the free surface as shown in Figure 8.1.

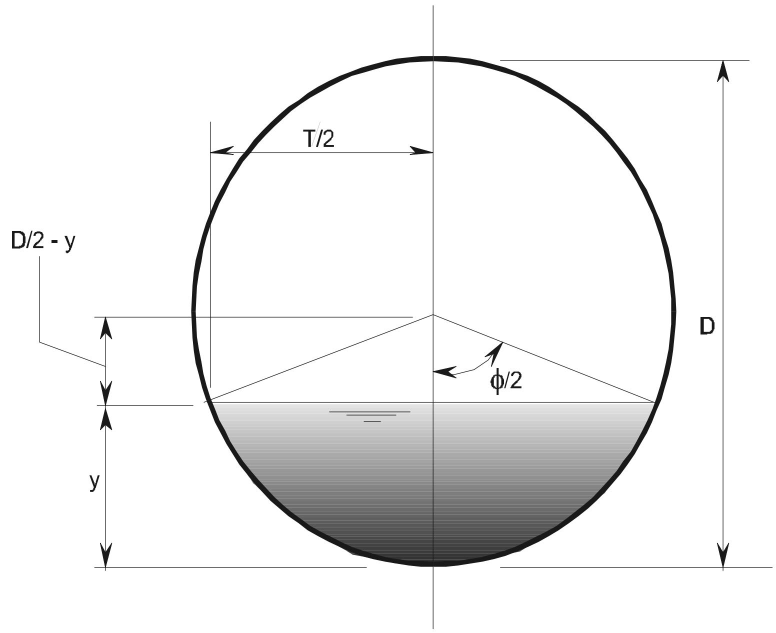


Figure 8.1 Definition sketch of a part-full pipe.

The following equations can be obtained by considering the geometry of the triangle subtending the half-angle $f/2$ at the centre of the pipe.

$$[8.2] \qquad y = \frac{D}{2}\left(1 - \cos\frac{f}{2}\right)$$

$$[8.3] \qquad A = \frac{D^2}{8}\left(f - \sin f\right)$$

$$[8.4] \qquad P = D\frac{f}{2}$$

The value of f can be found in terms of the ratio of the discharge Q to the full-bore pipe capacity Q_{full} by an iterative solution of the implicit equation [8.5].

$$[8.5] \qquad f(f) = f - \sin f - C_2 = 0$$

where

$$C_2 = C_1 f^{2/5} = \left(\frac{2pQ}{Q_{full}}\right)^{3/5} f^{2/5}$$

Equation [8.5] is solved by a Newton-Raphson procedure, thus:

$$[8.6] \qquad f_{k+1} = f_k - \Delta f_k = f_k - \frac{f(f_k)}{f'(f_k)}$$

where

$$f(f) = f - \sin(f) - C_2$$

and

$$f'(f) = 1 - \cos(f) - 0.4\frac{C_2}{f}$$

Equation [8.6] is applied until Df < 0.001 radians; the depth is then determined from equation [8.7].

[8.7] $$y = \frac{D}{2}\left(1 - \cos\frac{f}{2}\right)$$

For a cross-section with a closed top it is usual to find that maximum normal discharge occurs at a depth slightly below full-bore flow. For a circular pipe this occurs at a relative depth of y/D = 0.93818. It follows that there must be a smaller depth which produces a discharge equal to the full-bore flow. In a part-full pipe this occurs when y/D = 0.81963.

The root finding procedure in MIDUSS 98 will always find a solution within the relative depth range 0.0 < (y/D) < 0.81963 as long as the discharge is less than the full-bore flow. If the discharge is greater than this then MIDUSS 98 reports that the pipe will be surcharged and the slope of the hydraulic grade line is reported. (See Chapter 4 *Design Options Available,* Surcharged Pipe Design)

It is not possible, therefore, to take advantage of the slightly higher carrying capacity in the range 0.81963<(y/D)<1.0. It is not normally good practice to design pipes for uniform flow in this range of depth because the slightest surface disturbance will cause the free surface to 'snap through' abruptly to a condition of pressurized flow.

Next - Critical Depth in Pipes

Critical Depth in Pipes

When a pipe is designed it is often important to know if the normal flow depth y_0 is less than or greater than the critical depth y_{cr}. If $y_0 < y_{cr}$ then the flow is supercritical and there is a high probability that a hydraulic jump will occur at some point downstream. This is usually to be avoided.

The calculation of critical depth in a circular pipe is based on the critical flow condition of minimum specific energy which leads to the criterion of equation [8.8].

[8.8] $$\frac{Q^2 T}{g A^3} = 1$$

This is solved by an interval halving procedure using a function of the form:-

[8.9] $$f(y) = \frac{A^3}{T} - \frac{Q^2}{g} = 0$$

in which A is obtained by combining equation [8.3] with equations [8.10] and [8.11] below.

[8.10] $$T = 2\sqrt{\left(Dy - y^2\right)}$$

[8.11] $$f = 2\tan^{-1}\left(\frac{T/2}{\left(D/2 - y\right)}\right) = 2\tan^{-1}\left(\frac{T}{D - 2y}\right)$$

Convergence is assumed when $Dy/y < 0.00001$.

Equation [8.9] cannot be solved if the free-surface width T is zero. A test is therefore made to ensure that the specified discharge is not greater than the critical discharge corresponding to a depth of $ycr = 0.999\ D$. If this condition is violated MIDUSS 98 assumes the critical depth to be equal to the diameter. For further information on uniform or critical flow in pipes see a text on Open Channel Flow such as Henderson (References).

Theory of Channel Design

This section summarizes the methods used to analyze the channel for uniform and critical flow depth. As with the **Pipe** command, each reach of channel is assumed to be prismatic, that is, of constant cross-section and slope. As long as the channel flow has a free surface, the flow in each reach is assumed to be quasi-uniform, neglecting the variation of flow with time. For this condition the friction slope S_f and the water surface are assumed to be parallel to the bed slope S_0. The resistance is assumed to be represented by the Manning equation [8.12].

MIDUSS 98 lets you define the cross-sectional shape of the channel either as a trapezoidal shape as shown in Figure 8.2 or as an arbitrary cross-section defined by the coordinates of up to 50 points.

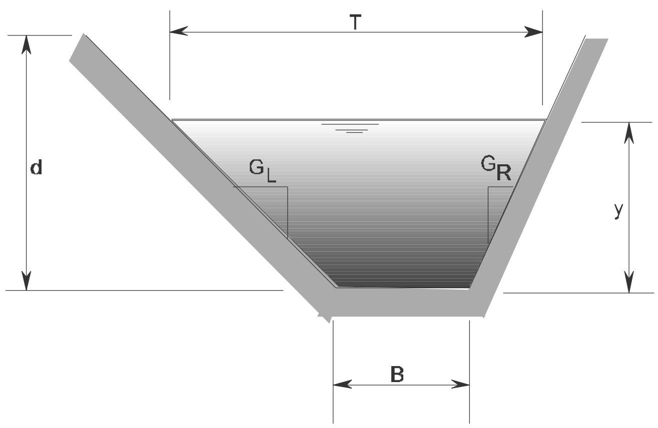


Figure 8.2 - Definition of a trapezoidal section.

Figure 8.3 shows a cross-section defined by 9 points. For the purpose of illustration, the remainder of this section assumes that the cross-section is trapezoidal in shape. MIDUSS 98 uses a simple routine to process the coordinates of a more complex section with a specified water surface elevation to yield the same cross-sectional properties.

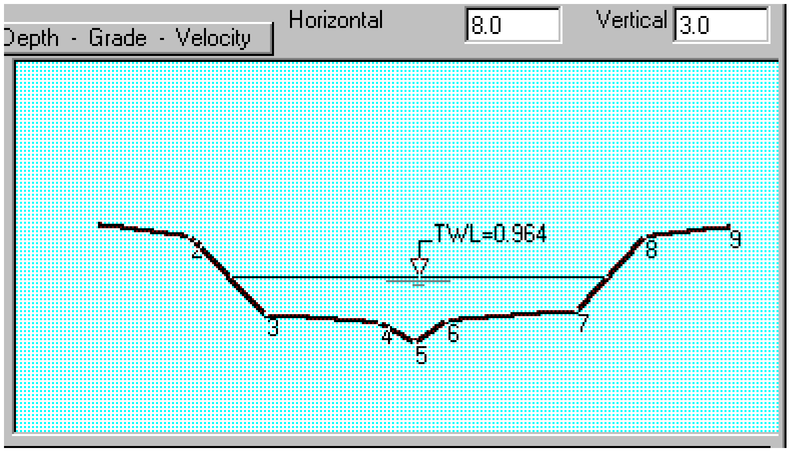


Figure 8.3 - An arbitrary cross-section using 9 points.

Next - Normal Depth in Channels

Normal Depth in Channels

Figure 8.2 shows a cross-section of arbitrary trapezoidal shape, of total depth d with a flow depth y. Using the Manning equation the normal discharge Q for any given depth y is given as follows.

$$[8.12] \qquad Q = \frac{M}{n} A R^{2/3} S_0^{1/2}$$

where	Q	=	normal discharge (c.m/s or c.ft/s)
	M	=	1.0 for metric units
			1.49 for imperial or US customary units (3.28 ft/m)^(1/3)
	n	=	Manning's roughness coefficient
	A	=	cross-sectional area
	R	=	hydraulic radius = Area/Wetted perimeter
	S_0	=	bed slope (m/m or ft/ft)

Evaluation of the cross-section properties depends on whether a simple trapezoidal cross-section or a more complex cross-section is defined. For a general trapezoidal shape the following equations are used.

$$[8.13a] \qquad T = B + (G_L + G_R) y$$

$$[8.13b] \qquad A = y\frac{(T+B)}{2} = \frac{y}{2}(2B + y(G_L + G_R))$$

$$[8.13c] \qquad P = B + y\left(\sqrt{1+G_L^2} + \sqrt{1+G_R^2}\right)$$

$$[8.13d] \qquad R = A/P$$

where B = base width

T	=	top width	
P	=	wetted perimeter	
y	=	depth of flow.	
G_L	=	slope of the left bank	(G_L horiz : 1 vert)
G_R	=	slope of the right bank	(G_R horiz : 1 vert)

and other terms are as previously defined.

The maximum carrying capacity Qfull for flow with a free surface is found from equation [8.12] setting $y = d$. If the peak discharge Q is less than Q_{full} the depth of uniform flow is found by an interval halving technique. Convergence is assumed when $Dy/y < 0.000001$.

The hydraulic gradient is then computed by equation [8.14].

$$[8.14] \qquad S_f = \left(\frac{Vn}{M}\right)^2 \frac{1}{R^{4/3}}$$

Next - Critical Depth in Channels

Critical Depth in Channels

The calculation of critical depth in a channel assumes that a free surface exists. MIDUSS 98 does not check to see if the critical depth is less than the specified total depth d.

If the base-width is finite but the sideslopes are vertical the cross-section is rectangular and the critical depth can be calculated explicitly by equation [8.15].

$$[8.15] \qquad y_{cr} = \left(\frac{Q^2}{gB^2}\right)^{1/3}$$

If the basewidth is zero and at least one of the sideslopes are finite the cross-section is triangular and again an explicit solution for ycr can be found from equation [8.16].

$$[8.16] \qquad y_{cr} = \left(\frac{8Q^2}{g(G_L + G_R)^2}\right)$$

For the case of a general trapezoidal cross-section an iterative solution is required to solve the critical flow criterion of equation [8.8]. This involves the application of the Newton-Raphson method (equation [8.6]) in which the function and its derivative are defined by equations [8.17] and [8.18] respectively.

$$[8.17] \qquad f(y) = \frac{A^3}{T} - \frac{Q^2}{g}$$

$$[8.18] \qquad f'(y) = \frac{3A^2}{T}\left(\frac{dA}{dy}\right) - \frac{A^3}{T^2}\left(\frac{dT}{dy}\right)$$

$$= 3A^2 - \frac{A^3}{T^2}(G_L + G_R)$$

Convergence is assumed when $Dy/y < 0.0001$. More information on the hydraulics of open channels can be found in many standard texts (See References)

Theory of Kinematic Flood Routing

Flood routing methods can be classified as hydraulic - in which both continuity and dynamic equations are used - or hydrologic, which generally uses the continuity equation alone. MIDUSS 98 uses a method based on a kinematic wave equation and therefore falls into the second category. For the type of conduits used in storm drainage systems, kinematic routing yields results of very acceptable accuracy.

The continuity equation is simply a statement that the difference between inflow and outflow must equal the rate of change of storage in the reach being considered. Equation [8.20] is a general continuity equation in which lateral inflow is ignored.

[8.20] $$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

If the flow in the channel can be assumed to be quasi-uniform then discharge is uniquely defined by the depth or stage, i.e.

[8.20] $$Q = f(WL)$$

so that

[8.21] $$\frac{\partial Q}{\partial A} = \frac{dQ}{dA}$$

Now separating variables in [8.20] yields:

[8.22] $$\frac{\partial Q}{\partial x} = -\frac{dA}{dQ}\left(\frac{\partial Q}{\partial t}\right) = -\frac{1}{c}\frac{\partial Q}{\partial t}$$

Equation [8.22] is seen to be a wave equation in which a function $Q(x)$ is propagated with a celerity c which is given by $c = dQ/dA$. The variation of Q with respect to both time t and space x can be best described using a space-time coordinate system which defines changes in discharge Q in an elementary reach Δx and over a timestep Δt.

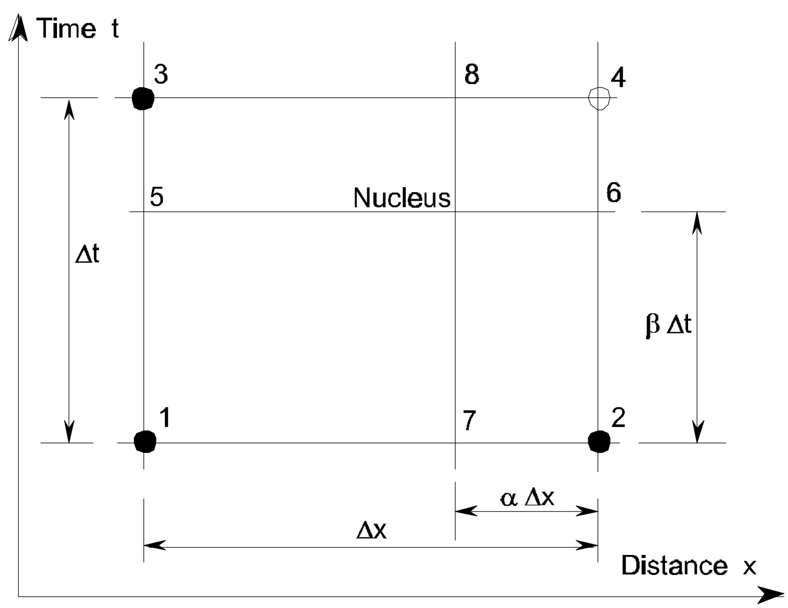


Figure 8.4 An element of a space-time coordinate system.

Figure 8.4 shows such a situation. For this element of the space-time system equation [8.22] can be expressed in terms of finite differences as follows.

$$[8.23] \qquad \frac{\Delta Q}{\Delta x} + \frac{1}{c}\frac{\Delta Q}{\Delta t}$$

This equation is applied around a 'nucleus' of the space-time element which is off-centre and defined by the weighting factors a and b which are applied to the x and t dimensions respectively as shown in Figure 8.4.

The finite difference quotients of equation [8.23] are expanded around the 'nucleus' point of Figure 8.4 in terms of the values of Q at points 5, 6, 7 & 8. These in turn can be expressed as weighted averages of the values at points 1, 2, 3 & 4 and the weighting coefficients a and b. Thus:

$$[8.24] \qquad \frac{\Delta Q}{\Delta x} = \frac{Q_6 - Q_5}{\Delta x} \quad \text{and} \quad \frac{\Delta Q}{\Delta t} = \frac{Q_8 - Q_7}{\Delta t}$$

where

$$Q_5 = b\,Q_3 + (1-b)Q_1$$

$$Q_6 = b\,Q_4 + (1-b)Q_2$$

$$Q_7 = a\,Q_1 + (1-a)Q_2$$

$$Q_8 = a\,Q_3 + (1-a)Q_4$$

Substituting equations [8.24] in [8.23] yields:

$$[8.25] \qquad \left(\frac{c \;\; \Delta t}{\Delta x}\right)(Q_6 - Q_5) + Q_8 - Q_7 = 0$$

The quantity ($c.Dt/Dx$) is a dimensionless time ratio which is equivalent to the Courant criterion for numerical stability. Denoting this by t and substituting for $Q5$ etc. results in equation [8.26].

$$[8.26] \qquad t b Q_4 + t(1-b)Q_2 - t b Q_3 - t(1-b)Q_1 + a Q_3 + (1-a)Q_4 - a Q_1 - (1-a)Q_2 = 0$$

Now the process of flood routing usually involves a 'marching' solution in which the initial conditions are known at time t and it is required to predict conditions at time ($t+Dt$). An upstream boundary condition is provided by the time-history of the inflow hydrograph at $x=0$. In the case of kinematic wave routing it is possible to advance the solution for all values of time t so that the solution advances over the whole time domain for each reach of channel.

In either case, the solution for the element of Figure 8.4 involves an estimate of $Q4$ in terms of the other three known values. Collecting terms and casting $Q4$ as the dependant variable yields:

$$[8.27] \qquad C_4 Q_4 = C_1 Q_1 + C_2 Q_2 + C_3 Q_3$$

where

$$C_1 = a + (1-b)t$$

$$C_2 = (1-a) - (1-b)t$$

$$C_3 = -a + bt$$

$$C_4 = (1 - a) + bt$$

Equation [8.27] is a generalized form of the Muskingum flood routing method but for the special case of b =0.5 this reduces to the more familiar form shown below.

$$C_1 = a + 0.5t = X + \frac{\Delta t}{2K}$$

[8.28] $$C_2 = (1 - a) - 0.5t = 1 - X - \frac{\Delta t}{2K}$$

$$C_3 = -a + 0.5t = -X + \frac{\Delta t}{2K}$$

$$C_4 = (1 - a) + 0.5t = 1 - X + \frac{\Delta t}{2K}$$

Before equation [8.27] can be applied two additional pieces of information are required:

(i) What values of a and b should be used to best represent the attenuation for a specific hydraulic condition?

(ii) What conditions must apply for the computation to be numerically stable?

Next see Evaluation of the Weighting Coefficients

Evaluation of the Weighting Coefficients

Convergence is the condition in which the solution of a finite-difference equation for a finite grid size approximates the true solution of the partial differential equation which it represents. It can be shown (Biesenthal (1975) and Smith (1980)) for the non-centred scheme of Figure 8.4 that as the coefficients a and b depart from a value of 0.5, truncation errors of the order of $O(Dx)$ and $O(Dt)$ increase respectively and independently. This property is fundamental to the use and apparent success of kinematic routing methods in modelling attenuation. It should be emphasized, however, that this attenuation results from truncation error and is a property of the numerical finite difference scheme and not of the physical system. The trick is to find a way to make the numerical truncation error a close approximation to the attenuation which the flood wave will experience.

For a non-centred finite-difference scheme the error may be included in the partial differential equation as e in equation [8.29].

[8.29] $$\frac{\P Q}{\P x} + \frac{1}{c}\frac{\P Q}{\P t} + e = 0$$

If only first order terms are included in the error term this becomes:

[8.30] $$\frac{\P Q}{\P x} + \frac{1}{c}\frac{\P Q}{\P t} - \frac{\Delta x}{2}\left((1 - 2a) + (2b - 1)t\right)\frac{\P^2 Q}{\P x^2} = 0$$

or

[8.31] $$\frac{\P Q}{\P x} + \frac{1}{c}\frac{\P Q}{\P t} = D\frac{\P^2 Q}{\P x^2}$$

Equation [8.31] is in the form of a diffusion equation where $\boldsymbol{D}$ is the coefficient of diffusion. In order to relate $\boldsymbol{D}$ to the physical characteristics of the channel an alternate diffusion equation can be developed using the continuity equation [8.20] with a simplified form of momentum equation in which the convective and temporal accelerative terms are assumed to be negligible, i.e.

$$[8.32] \qquad \frac{\partial h}{\partial x} = S_f$$

where h = water surface elevation

S_f = friction gradient

This can be developed (Smith(1980)) to yield the diffusion equation of [8.33].

$$[8.33] \qquad \frac{\partial Q}{\partial x} + \frac{1}{c}\frac{\partial Q}{\partial t} = \left(\frac{K^3}{2Q^2\, dK/dh} \right) \frac{\partial^2 Q}{\partial x^2}$$

where K = channel conveyance defined by $S_f = Q^2/K^2$

Now from the definition of the conveyance K the total derivative is obtained as:

$$[8.34] \qquad \frac{dK}{dh} = \frac{dQ}{dh}\frac{1}{S_f^{1/2}}$$

Comparison of the terms in equations [8.31] and [8.33] provides a means of evaluating the diffusion coefficient $\boldsymbol{D}$ and thus the weighting coefficients α and β in terms of the hydraulic characteristics of the channel. Thus:

$$[8.35] \qquad D = \frac{Q}{2S_f\, dQ/dh} = \frac{\Delta x}{2}\left((1-2\alpha) + (2\beta - 1)\tau\right)$$

$$[8.36] \qquad (1-2\alpha) + (2\beta - 1)\tau = \frac{Q}{h_f\, dQ/dh}$$

where the friction head loss over the reach being considered is given by

$$h_f = S_f\,\Delta x$$

Equation [8.36] can be simplified by assuming an initial value of β = 0.5 so that:-

$$[8.37] \qquad \alpha = 1 - \frac{Q}{2h_f\, dQ/dh}$$

If equation [8.37] yields a value for α which is less than zero, MIDUSS 98 sets $\alpha = 0.0$ and solves for β from [8.36]. This value will generally be in the range $0.5 \le \beta \le 1.0$. The generalized Muskingum coefficients of equation [8.27] can then be evaluated and a solution obtained for $Q4$.

In MIDUSS 98, evaluation of the diffusion coefficient differs depending on whether the conduit is a pipe or channel. The Manning equation [8.12] can be differentiated to obtain an expression for dQ/dy as follows:

[8.38] $$\frac{dQ}{dy}=\left(\frac{M}{n}S_0^{1/2}\right)\left(\frac{5}{3}TR^{2/3}-\frac{2}{3}R^{5/3}\frac{dP}{dy}\right)$$

Substituting in the 2nd part of [8.35] yields an expression for D which can be evaluated in terms of the channel cross-section parameters and the channel gradient, thus:

[8.39] $$D=\frac{1.5A}{S_0\left(5T-2R\frac{dP}{dy}\right)}$$

For pipes, an alternative procedure is used in which a fitted polynomial represents the ratio $Q/(dQ/dyr)$ as a function of the proportional discharge Qr which is the ratio of actual discharge to full pipe capacity. With very acceptable accuracy this can be represented as follows:

[8.40] $$\frac{Q}{dQ/dy_r}=((1.06Q_r-1.16)Q_r+0.8336)Q_r+0.034743$$

from which the diffusion coefficient D can be found using equation [8.35].

Next: Criteria for Numerical Stability in Flood Routing

Criteria for Numerical Stability in Flood Routing

Once values have been determined for the weighting coefficients a and b it is possible to carry out a check on the numerical stability of the process. This involves the calculation of limiting values for the grid dimensions Dx and Dt.

Biesenthal (1975) obtained the following condition for numerical stability.

[8.41] $$\frac{a}{b}\leq\left(\frac{c\ \Delta t}{\Delta x}\right)\leq\frac{1-a}{1-b}$$

In general, this means that the nucleus of Figure 8.4 must lie above and to the right of a diagonal through the centre of the space-time element which has a slope of $-(1/c)$.

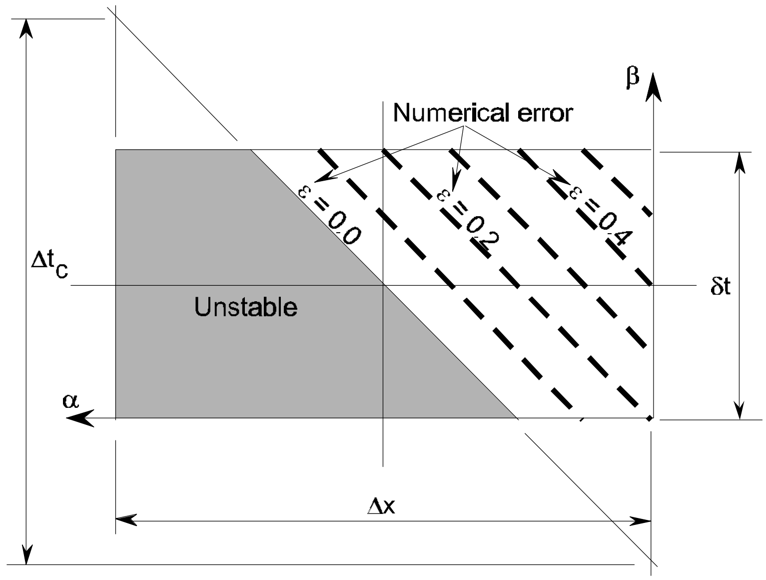


Figure 8.5 Stability and numerical error characteristics of a space-time element.

Figure 8.5 shows a typical case in which the time step dt is approximately half of the Courant time step given by $Dtc = Dx/c$. The heavy dashed lines parallel to the main diagonal form a family of lines each of which comprises the locus of points for which the nucleus will generate a numerical error e of a specific value. It is significant that the same numerical attenuation can be produced by a set of (a, b) coordinates and MIDUSS 98 makes use of this feature.

The shaded area of Figure 8.5 indicates locations of the nucleus which are numerically unstable. Because the values of a and b are constrained to provide a required numerical error, the criterion for stability given by equation [8.38] must be satisfied by manipulating either the routing timestep dt or the reach length Dx. The greater the coarseness of the space-time grid the greater the chance of numerical instability. Thus we need to determine upper limits for both Dx and the routing time-step dt

Equation [8.35] shows a relationship between the diffusion coefficient D and the weighting coefficients a and b. If we assume initially that $b = 0.5$ this reduces to:

$$[8.42] \qquad 2a = 1 - \frac{2D}{\Delta x}$$

Similarly if $b = 0.5$ the inequality [8.41] becomes:

$$[8.43] \qquad 2a \le \frac{c\Delta t}{\Delta x} \le 2(1 - a)$$

Taking the 1st and 2nd parts of [8.43] and substituting for a from [8.42] we obtain:

$$[8.44] \qquad 1 - \frac{2D}{\Delta x} \le \frac{c\Delta t}{\Delta x}$$

or

$$\Delta x \le 2D + c\Delta t$$

To get an upper bound for the routing time-step we use the 2nd and 3rd parts of [8.43] and obtain:

$$[8.45] \qquad \frac{c\Delta t}{\Delta x} \leq 2 - 1 + \frac{2D}{\Delta x}$$

or

$$\Delta t \leq \frac{\Delta x + 2\,D}{c}$$

MIDUSS 98 uses the limiting criteria of [8.44] and [8.45] to divide either the reach length L or the hydrograph time-step *?t* into sub-multiples which satisfy the conditions for stability.

In the case of very long reaches the time step remains unchanged but routing is carried out over two or more subreaches. The final outflow hydrograph is the only one presented to the user.

In the case of very short reaches only a single reach length is used but the routing time-step is set at *d t = Dt/n (n = 2,3,4...).* Only flow values at intervals of *Dt* are presented in the final outflow hydrograph.

Theory of Reservoir Routing

Reservoir routing involves the application of the continuity equation to a storage facility in which the storage volume for a particular geometry is a dependant only on the outflow. This can be viewed as a special case of the more general kinematic wave routing procedure described in section 8.3 *Kinematic Flood Routing* in which the weighting coefficients are assigned values of *a* = 0.0 and *b* = 0.5 (see Figure 8.5).

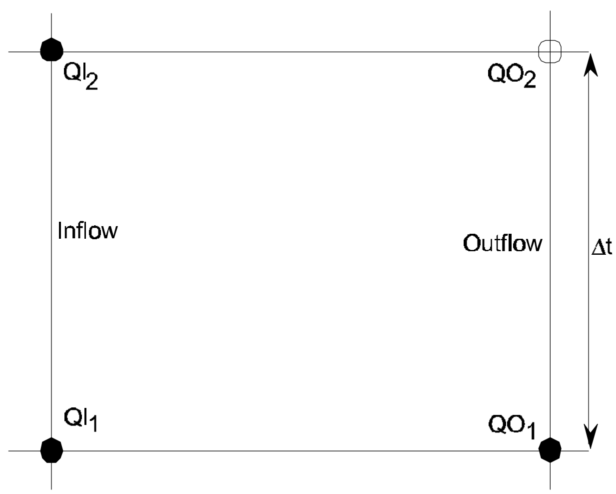


Figure 8.6 A space-time element for reservoir routing.

With reference to Figure 8.6 the continuity equation can be averaged over a time-step *Dt* as follows.

$$[8.46] \qquad \frac{QI_1 + QI_2}{2} = \frac{QO_1 + QO_2}{2} + \frac{S_2 - S_1}{\Delta t}$$

where QI = time series of inflow values

QO = time series of outflow values

S	=	storage volume
$1,2$	=	subscripts corresponding to times t and $t + Dt$ respectively.

Equation [8.46] can be expanded as follows to yield an indirect solution for the outflow $QO2$.

$$QI_1 + QI_2 = \left(\frac{2S_2}{\Delta t} + QO_2\right) - \left(\frac{2S_1}{\Delta t} + QO_1\right) + 2 \quad QO_1 \qquad [8.47]$$

or

$$f(QO_2) = f(QO_1) + QI_1 + QI_2 - 2QO_1 \qquad [8.48]$$

where

$$f(QO) = \frac{2S}{\Delta t} + QO$$

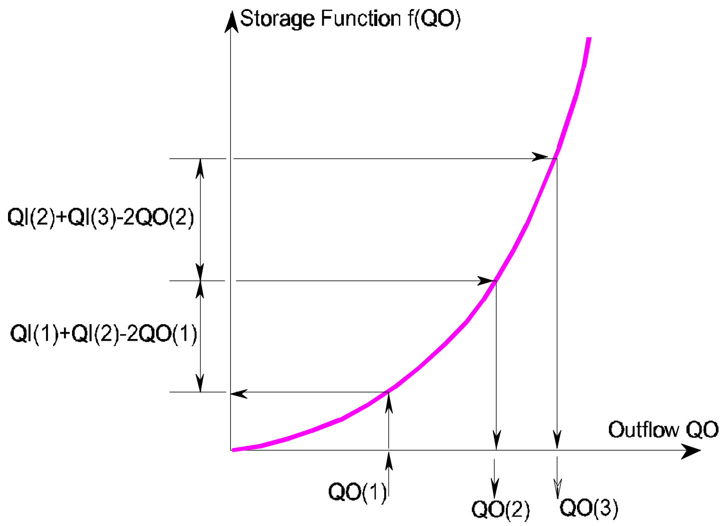


Figure 8.7 Graphical illustration of equation [8.48]

The application of equation [8.48] is illustrated graphically in Figure 8.7. Starting with some initial, known value of $QO_1 = QI_1$ the corresponding value of $f(QO_1)$ is found by interpolation or otherwise. The inflow hydrograph $QI(t)$ provides an upstream boundary condition from which QI_2 can be found. Then from equation [8.48] a value is obtained for $f(QO_2)$ and finally by back interpolation QO_2 is calculated and the process continues for other time increments.

Next - Estimating the required Pond Storage

Estimating the Required Pond Storage

At the start of the **Pond** command MIDUSS 98 estimates the required volume by making the assumption that the reservoir is linear. This means that the storage volume S is a linear function of the outflow QO and defined in terms of a lag coefficient K. Thus:

$$S = KQO \qquad [8.49]$$

For this special case the storage terms can be eliminated from equation [8.47] and an explicit solution is obtained for $QO2$ as follows.

$$QI_1 + QI_2 = \left(\frac{2K}{\Delta t} + 1\right)QO_2 - \left(\frac{2K}{\Delta t} + 1\right)QO_1 + 2QO_1 \qquad [8.50]$$

$$QO_2 = QO_1 + \frac{QI_1 + QI_2 - 2QO_1}{\left(\frac{2K}{\Delta t} + 1\right)} \qquad [8.51]$$

With reference to Figure 8.8, MIDUSS 98 initially assumes that the lag coefficient K_2 has a value of $0.2t_b$ (where t_b is the time base of the inflow hydrograph) and the corresponding peak outflow QO_2 is obtained by applying equation [8.51] to the inflow hydrograph. Arbitrary assumptions are also made for the lag which will attenuate the peak outflow to 1/100th of the peak inflow. Using a secant method as illustrated in Figure 8.8 the estimate of K is successively improved. The relation is shown in equation [8.52].

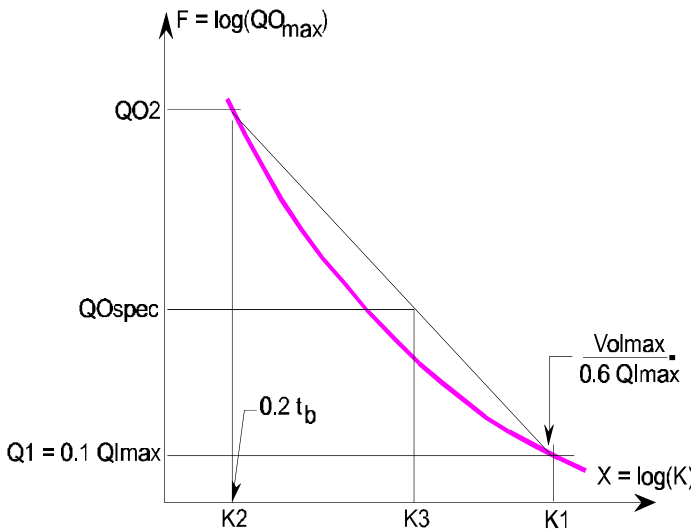


Figure 8.8 An iterative solution for K.

$$X_3 = X_2 - \left(\frac{F_2 - F_{spec}}{F_2 - F_1}\right)(X_2 - X_1) \qquad [8.52]$$

where X = log(K)

F = log($QOmax$)

This procedure converges very rapidly on the necessary lag K_{opt} to produce the desired peak outflow

QO_{spec}. The corresponding storage volume is given as $S_{opt} = K_{opt}$ x QO_{spec}.

Next - Numerical Stability in Reservoir Routing

Numerical Stability in Reservoir Routing

The storage indication method is traditionally assumed to be inherently stable. However, this complacency is not justified in situations where the hydrograph is sharply peaked and the discharge-volume functions are poorly conditioned or exhibit pronounced discontinuities or points of contraflexure. In such circumstances, use of an arbitrary time-step can result in a computed outflow peak that is larger than the peak inflow - a condition that is physically impossible.

The search for a criterion to avoid this anomaly can start with the assumption that:

[8.54] $$QO_2 = QO_{\max} = QI_2 - e \quad \text{where } e > 0$$

Now by substituting [8.54], equation [8.49] can be written as:

[8.55] $$QI_1 + QI_2 = QO_1 + QI_2 - e + \frac{2}{\Delta t}(S_2 - S_1)$$

or

[8.56] $$(QI_1 - QO_1) < \frac{2}{\Delta t}(S_2 - S_1)$$

This provides an upper limit on the routing time-step to be used which is shown in equation [8.57].

[8.57] $$\Delta t \leq \left(\frac{2(S_2 - S_1)}{QI_1 - QO_1} \right)$$

The peak outflow must lie on the recession limb of the inflow hydrograph, so that:

[8.58] $$QI_1 = QI_2 - \Delta QI = QO_2 + e - \Delta QI \approx QO_2$$

The routing time-step is then defined approximately as:

[8.59] $$\Delta t \leq 2\left(\frac{\Delta S}{\Delta QO} \right)_{\min}$$

To implement this check, MIDUSS 98 scans the storage-discharge function to determine the flattest part of the curve and uses this to determine an appropriate sub-multiple of the time-step to be used. Figure 8.9 shows a typical situation which can give rise to problems of this type.

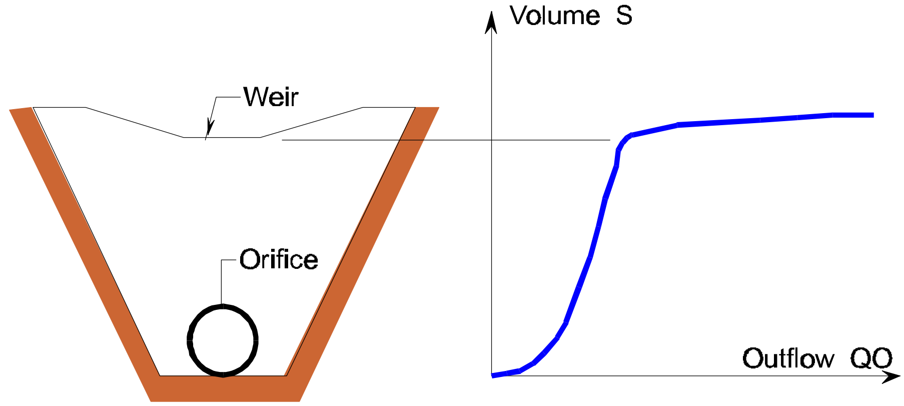


Figure 8.9 Storage-discharge function for a typical outlet control device.

Next - Outflow Control Devices for Ponds

Outflow Control Devices in Ponds

MIDUSS 98 provides a number of tools to assist in the creation of the necessary table of stage, discharge and storage values which form the basis for evaluating the function *f(QO)* of [8.48]. This section describes how these flow estimates are made for two basic types of outflow control device.

- Orifices and
- Weirs

Figure 8.9 shows a simple but typical device which incorporates an orifice for low flow control and a weir for less frequent flood events. Up to 10 weirs and 10 orifices can be defined. In addition, MIDUSS 98 has a special tool to assist in the design of Rooftop Flow Control and Storage for on-site control.

Next - Storage Components for Detention Ponds

Orifice Flow for Pond Control

The stage discharge equation for the orifice is calculated for two cases which depend on the relative value of the specific energy H relative to the invert of the orifice and the diameter of the orifice D.

In Case 1, $H > D$ and the orifice is fully submerged.

[8.60] $$Q = C_c \frac{\pi}{4} D^2 \sqrt{2g(H - \frac{2}{3}D)}$$

where H = head relative to the invert of the orifice

D = orifice diameter

g = gravitational acceleration

C_c = coefficient of contraction

In Case 2, $H \leq D$ and the orifice acts as a broad-crested weir of circular shape. The critical discharge can be approximated by equation [8.61]

[8.61] $$Q = f\left(\frac{H}{D}\right)C_c\sqrt{g}D^{5/2}$$

where

$$f\left(\frac{H}{D}\right) = 0.494\left(\frac{H}{D}\right)^{1.57} - 0.04\left(\frac{H}{D}\right)^{0.5}$$

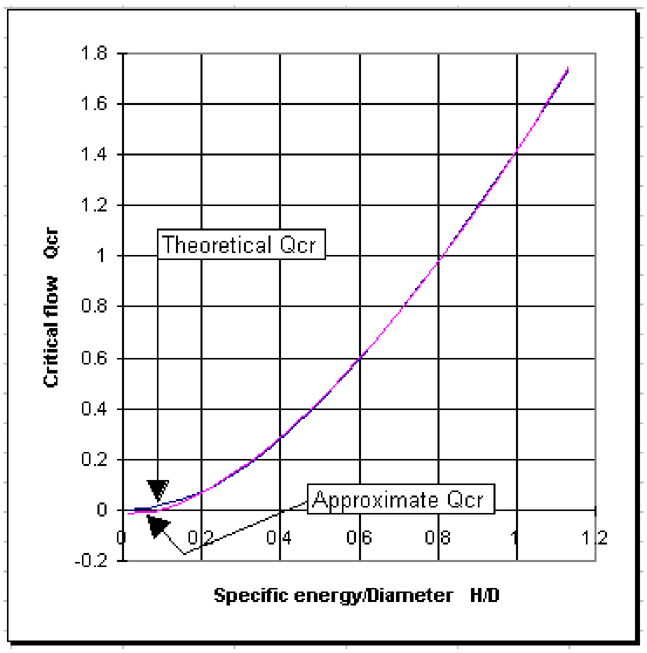


Figure 8.10 Critical flow through a segment of a circle.

As shown by the comparative plot of Figure 8-10, equation [8.61] is a very reasonable approximation to the critical discharge through a segment of a circle.

Next, Using a Weir for Outflow Control

Weir Flow for Pond Control

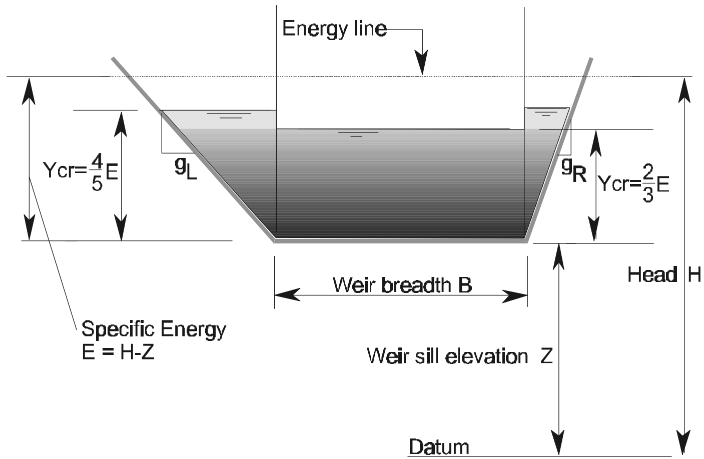


Figure 8.11 Definition sketch of a trapezoidal weir.

The weir control is assumed to have a general trapezoidal shape as illustrated above. The critical discharge is calculated for the central rectangular section and two triangular sections. For any value of head H greater than the weir sill elevation Z the critical discharge can be calculated using the general criterion for critical flow of equation [8.8]

$$\frac{Q^2T}{gA^3} = 1 \qquad [8.8]$$

and calculating the cross-section properties A and T in terms of the parameters shown in Figure 8.11.

For a rectangular section:

$$Q_{cr} = B\sqrt{g}\, y_{cr}^{3/2} \qquad [8.62]$$

where

$$y_{cr} = \frac{2}{3}(H - Z)$$

For a triangular section:

$$Q_{cr} = \sqrt{g/2}\,\frac{(S_L + S_R)}{2}\, y_{cr}^{5/2} \qquad [8.63]$$

where

$$y_{cr} = \frac{4}{5}(H - Z)$$

Next, Using an Orifice for Outflow Control

Typical Storage Components for Detention Ponds

In addition to control flow estimation tools, MIDUSS 98 provides a few methods for estimating the available volume in various standard storage facilities. These assist you in setting up the stage, discharge and storage values which form the basis for evaluating the function $f(QO)$ of [8.48]. This section describes how these storage estimates are made for three basic types of storage facility.

- Rectangular ponds
- Super Pipes
- Wedge (or Inverted Cone) ponding

In addition, MIDUSS 98 has a special tool to assist in the design of Rooftop Flow Control and Storage for on-site control.

Rectangular Pond Storage

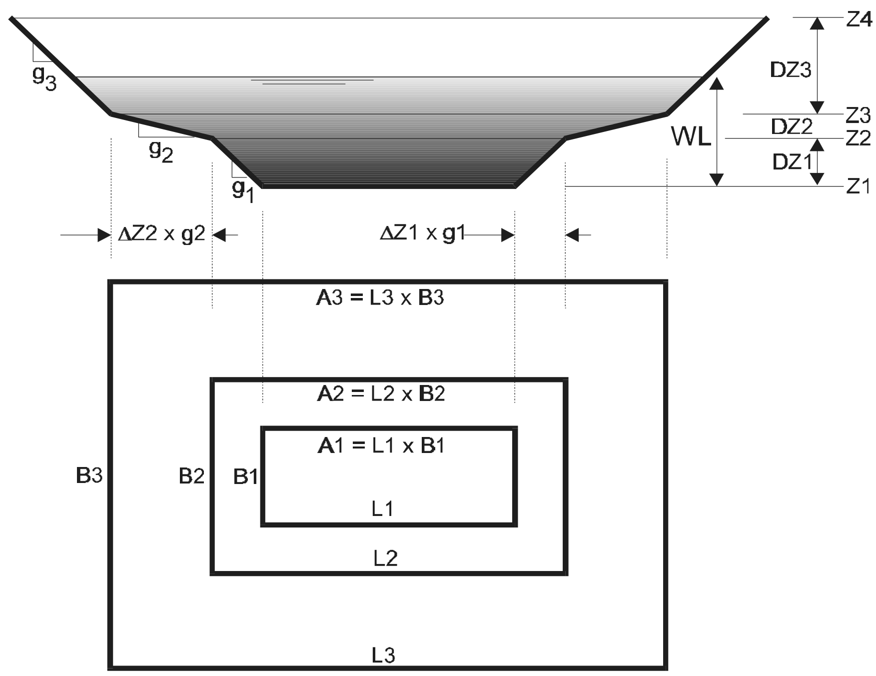


Figure 8.12 Schematic of a 3-stage rectangular pond

Detention ponds are usually constructed with sideslopes which are dictated by consideration of maintenance (e.g. grass cutting) and safety. It is common for the side slope to be different at different water surface elevations. If the pond has a permanent storage component (e.g. for quality) it may be desirable to maintain a flat slope of 4:1 or 5:1 for 3m/10ft both below and above the permanent water surface elevation. Even if the pond is a "dry" pond it may be necessary to have a flatter slope at higher depths in order to get a suitably nonlinear stage-storage curve.

Figure 8.12 shows an idealized pond with three stages. The shape in plan is approximated by a series of rectangles corresponding to different elevations and which have an aspect ratio L/B which reduces with increasing height.

In practice it is most unlikely that the pond geometry correspond closely to this idealized shape but the rectangular pond method provides a useful design tool to estimate the general dimensions (volumes, land area etc.) required to achieve a required level of flow peak reduction.

The volume is calculated using Simpson's rule so that;

$$V = \frac{H}{6}\left(A_1 + 4A_m + A_2\right) \qquad [8.64]$$

where

$$A_1 = B_1 L_1$$
$$A_m = \left(B_1 + g_1 H\right)\left(L_1 + g_1 H\right)$$
$$A_2 = \left(B_1 + 2g_1 H\right)\left(L_1 + 2g_1 H\right)$$
$$H = Min(WL, Z_2) - Z_1$$

MIDUSS 98 provides an approximate estimate for the base area $A1$. This is calculated from the estimate of required storage volume and assumes that only a single stage is used and that the depth is 2/3 of the depth range specified, the base aspect ratio is 2:1 and the side slope is 4H:1V.

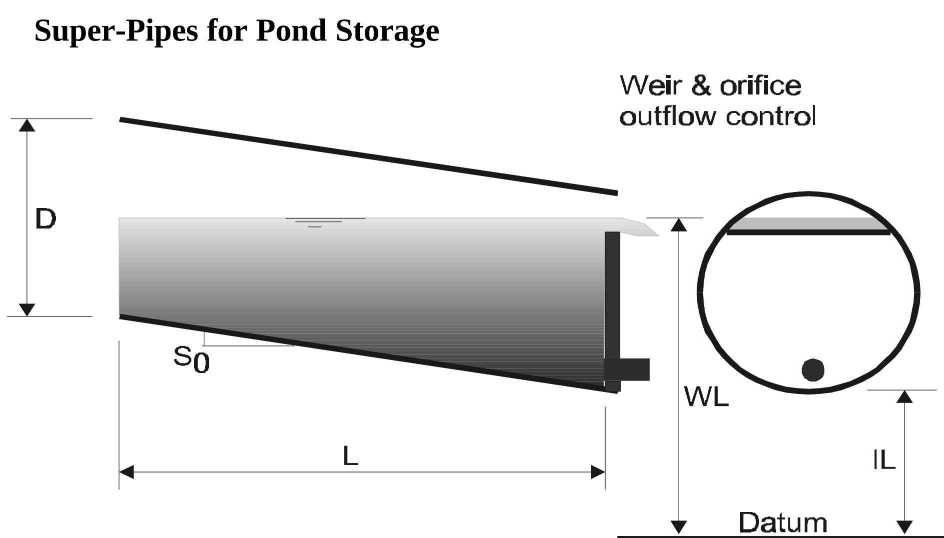


Figure 8.13 Schematic of SuperPipe Storage

Figure 8.13 shows a typical arrangement of a single super-pipe with a simple outflow control device installed at the downstream end. The control can be installed either in the pipe barrel or in a manhole structure. The latter is convenient if more than one super pipe converges at a junction node.

You should remember to avoid using too steep a gradient as this can seriously limit the available storage volume since the water surface is likely to be nearly horizontal.

In MIDUSS 98 the volume is obtained by calculating the cross-section of the storage at 21 equally spaced sections along the length L and then using Simpson's Rule. The section area is given as a function of the relative depth y/D from the following equations.

[8.3] $$A = \frac{D^2}{8}\left(f - \sin f\right)$$

in which f is obtained by [8.11]

[8.11] $$f = 2\tan^{-1}\left(\frac{T/2}{\left(D/2 - y\right)}\right) = 2\tan^{-1}\left(\frac{T}{D - 2y}\right)$$

where

[8.10] $$T = 2\sqrt{\left(Dy - y^2\right)}$$

The volume is then obtained as:

[8.65] $$V = \frac{L}{20}\left(A_1 + 4A_2 + 2A_3 + \cdots + 2A_{19} + 4A_{20} + A_{21}\right)$$

MIDUSS 98 provides an initial default length for a single super pipe assuming that (1) the diameter is approximately half the depth range, (2) the slope is zero (3) the pipe is full and the volume is equal to the estimated required storage.

Wedges (or inverted Cones) for Pond Storage

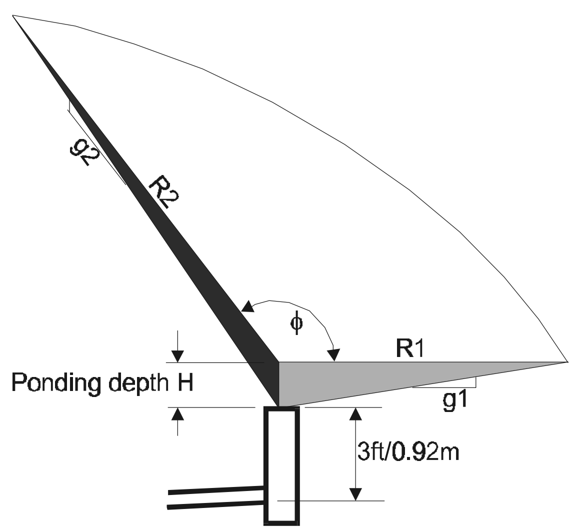


Figure 8.14 Schematic of wedge storage

To assist in estimating the available storage on parking lots, MIDUSS 98 provides a wedge storage procedure that calculates the volume of a sector of a flat, inverted cone as illustrated in Figure 8.14. The angle subtended by the segment is defined as an angle f (in radians) for generality. In practice, this will often be 90 degrees with four such segments describing the storage around a catchbasin draining the parking lot with grades $g1$ and $g2$ mutually at right angles.

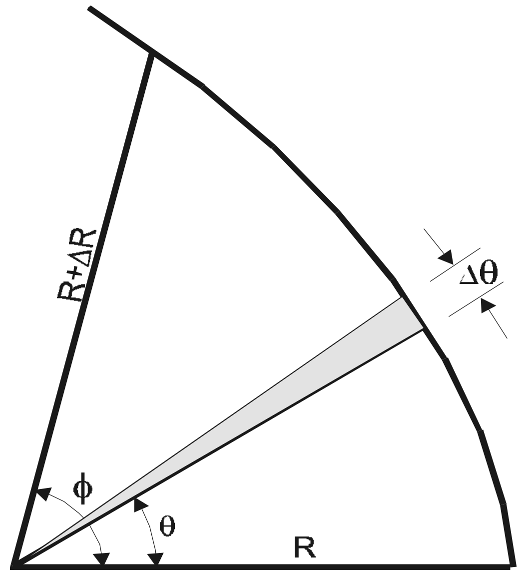


Figure 8.15 Calculation of surface area of a segment of inverted, ovoid cone.

The radius R and grade g are assumed to vary linearly with the angle as shown in Figure 8.15. Then a small element of the surface area is described as:

$$[8.66] \qquad dA = \frac{1}{2}\left(R_1 + \frac{\Delta R}{f}q\right)^2 dq$$:

Integrating between the limits 0 and f gives the surface area as

$$[8.67] \qquad A = \frac{f}{6}\left(R_1^2 + R_1 R_2 + R_2^2\right)$$

The volume V is then calculated as:

$$[8.68] \qquad V = A\frac{H}{3} = \frac{f}{18}\left(g_1^2 + g_1 g_2 + g_2^2\right)H^3$$

MIDUSS 98 assumes that the invert of the tail pipe or the Inflow Control Device (ICD) in the catch basin is approximately 3 ft (0.92 m) below the rim elevation and that the maximum depth of ponding will probably be less than 1 ft (0.3m) above rim elevation as illustrated in Figure 8.14. To provide an initial estimate for design purposes MIDUSS 98 assumes that the last defined impervious area has a catch basin density of 1 per 2500 sq.m or 2989 sq.yd. It is further assumed that each catch basin has a drainage area with orthogonal grades in a ratio of 2:1 (e.g. 40H:1V in one direction and 80H:1V at right angles). Based on a depth of 1 ft (0.3m) above rim elevation, the necessary grades to provide the estimated required volume are calculated and displayed together with the total number of elliptical quadrants (four such quadrants per catch basin).

In setting up parking lot storage the depth range should be slightly more than 4 ft (1.22m) to comply with the assumptions made above.

Rooftop Flow Control for Pond Storage

For developments involving large commercial buildings with flat roofs, on-site storage can be provided by installing roof drain controls. Typically these devices contain one or more "notches" which take the form of a linear proportional weir in which discharge is directly proportional to the head or depth of storage, for example 24 litres per minute per 25 mm of head or 6 US gallons per minute per inch of head. The actual value is defined along with other relevant parameters.

If the roof is dead level then the volume of storage is calculated simply as roof area times head where the roof area available for storage is smaller (e.g. 75%) than the building footprint to allow for service structures (access, elevator, HVAC) on the roof.

When a finite grade is used to promote drainage the calculation of available storage depends on whether the head H is less than or greater than the fall or difference in elevation between ridge and valley in the roof profile.

[8.69] $$V = A\left(\frac{H}{\Delta Z}\right)^2 \frac{H}{3} \quad \text{for} \quad H < \Delta Z$$

[8.70] $$V = A\left(H - \frac{2\Delta Z}{3}\right) \quad \text{for} \quad H \geq \Delta Z$$

where

$$\Delta Z = L\,S_0$$

and L = flow length from ridge to drain

S_0 = roof grade

Theory of Exfiltration Trench Design

An exfiltration trench is a facility that encourages the return of runoff to the ground water. It may be a very simple "soak-away" and comprise only a trench filled with clear stone (i.e. single sized gravel) into which runoff is directed. A more complex facility might be incorporated in-line with a conventional storm sewer and include one or more perforated pipes along the length of the trench to provide more uniform distribution of the inflow over the length of the trench. It is this latter type of facility which is described in the MIDUSS 98 **Trench** command.

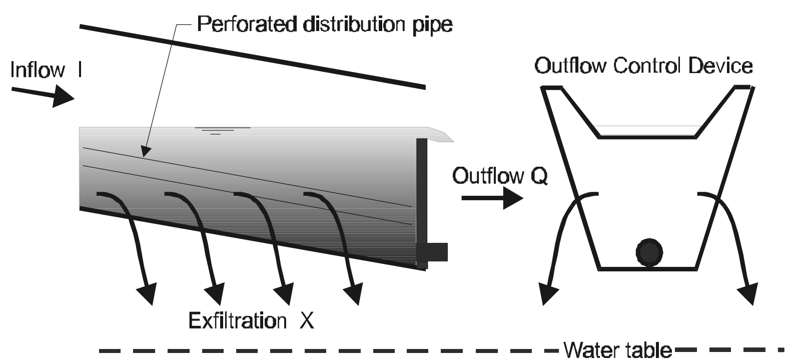


Figure 8.16 A typical exfiltration trench.

Figure 8.16 illustrates a typical arrangement of an exfiltration trench which splits the inflow hydrograph into two components. One fraction is transmitted downstream as an outflow hydrograph that is attenuated by the storage within the voids of the clear stone fill. The balance of the flow is transmitted to the ground water through the pervious walls of the trench. The Trench form has an option to include or exclude the base of the trench in estimating the area contributing to exfiltration.

It is usual to provide some form of outflow control device at the downstream end of the trench to force the free surface in the trench to rise. This causes (1) the volume of voids available for storage to be increased and (2) the surface area along the walls of the trench is increased to allow increased exfiltration. Figure 8.16 shows a typical outflow control device with a small orifice at or near the downstream invert of the trench to allow drainage of accumulated flow in the trench plus an overflow weir to produce high water levels during the maximum inflow rate. The trench may be thought of as a variation of the "super-pipe" facility with a permeable pipe wall.

Analysis of the facility is based on a form of the continuity equation which takes account of the outflow control, the rate of exfiltration and the rate of change of storage within the trench. Thus

Inflow = Outflow + Exfiltration + Rate of change of Storage

or

$$[8.71] \qquad \frac{I_1 + I_2}{2} = \frac{Q_1 + Q_2}{2} + \frac{X_1 + X_2}{2} + \frac{V_2 - V_1}{\Delta t}$$

where I = Inflow rate

Q = Outflow rate

X = Exfiltration rate

V = Volume stored

and the subscripts 1 and 2 define values at times t and $(t+Dt)$ respectively.

Equation [8.71] can be expanded as:

$$[8.72] \qquad I_1 + I_2 = \left(\frac{2V_2}{\Delta t} + Q_2 + X_2\right) - \left(\frac{2V_1}{\Delta t} + Q_1 + X_1\right) + 2Q_1 + 2X_1$$

or

$$[8.73] \qquad I_1 + I_2 = f(V_2, Q_2, X_2) - f(V_1, Q_1, X_1) + 2Q_1 + 2X_1$$

For any specified outflow control device, the water surface elevation in the trench is dependent on the outflow Q. Both storage volume V and exfiltration X are therefore dependent on Q and a solution for the unknown outflow at time $(t+Dt)$ can be obtained from:

$$[8.74] \qquad f(Q_2) = f(Q_1) - 2Q_1 - 2X_1 + I_1 + I_2$$

The method is similar to the graphical solution described in Figure 8.7 *Graphical illustration of equation [8.48]* in topic Theory of Reservoir Routing. One difference is that it is convenient to construct curves (or tables) of both $f(V,Q,X)$ and X as functions of the water surface elevation. In order to do this we must first provide a method of predicting the rate of exfiltration from the trench.

Next - estimating the Trench Exfiltration Rate

Trench Exfiltration Rate

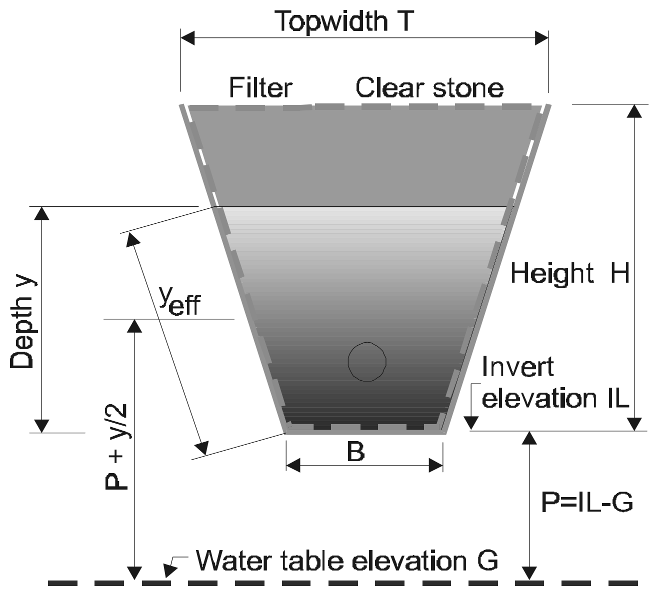


Figure 8.17 Exfiltration Trench Cross-section

Figure 8.17 shows the cross-section assumed in MIDUSS 98. The shape is a trapezium of height H and top width T tapering symmetrically to a bottom width B. The water table is assumed to be horizontal and located at a depth P=(IL-G) below the downstream invert level of the trench. If the depth of water in the trench voids is y the wetted surface of the trench wall has a length αy where α is given by:

$$[8.75] \qquad a = \sqrt{1 + \left(\frac{T-B}{2y}\right)^2}$$

Flow through the porous soil is assumed to be laminar and can be estimated using Darcy's Law

$$[8.76] \qquad \frac{Q}{A} = q = KS_f$$

where K = hydraulic conductivity of the soil

Sf = friction gradient

Q/A = volumetric flux.

Note that the volumetric flux is much smaller than the actual velocity through the voids since only a fraction of area A is available for flow.

The average driving head between the water in the trench and the water table is P + y/2 and the path length is P so that the available gradient is given by [8.77].

$$[8.77] \qquad S_f = \frac{IL - G + H/2}{IL - G} = 1 + \frac{H/2}{IL - G}$$

The exfiltration flow through a unit length of trench can then be estimated as:

[8.78] $$dX = (2ay + bB)KS_f$$

where b=1 or 0 depending on whether the 'Include base width' check box is checked or unchecked. Checked is the default condition.

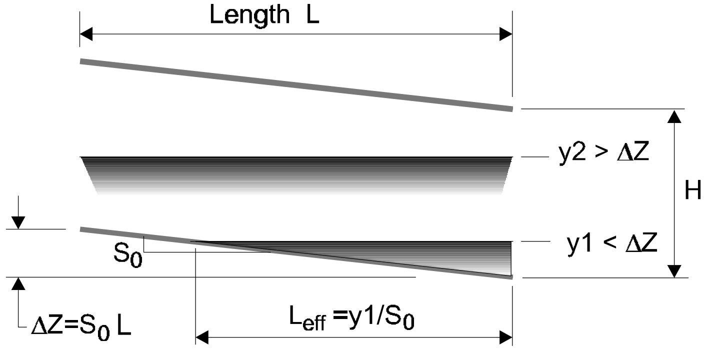


Figure 8.18 Idealized Longitudinal section on an Exfiltration Trench.

If the trench invert has a finite slope it is possible that for low flows which can be transmitted by the orifice in the outflow control device, the horizontal free surface does not extend over the full length of the trench. Figure 8.18 shows this situation. Even if the downstream depth is greater than the invert drop DZ the available surface for exfiltration must be corrected to allow for the reduced depth at the upstream end. This assumes that the hydraulic gradient along the trench is negligible and that the surface is essentially horizontal. The available wall surface through which exfiltration can occur is therefore given by [8.79] and [8.80].

[8.79] $$A_X = a\left(y - \frac{\Delta Z}{2}\right)L \qquad \text{for} \qquad y^3DZ$$

[8.80] $$A_X = a\frac{y^2}{2S_f} \qquad \text{for} \qquad y<DZ$$

Next - Estimating the Required Trench Volume

Estimating the Required Trench Volume

When the Trench command is invoked MIDUSS 98 tries to estimate the required trench volume (i.e. voids plus stone) which is required to achieve the currently defined target peak outflow. The process is similar to that described in the topic Theory of Reservoir Routing; Estimating the Required Pond Storage. However, an additional level of iteration is required because for each estimate of storage volume the corresponding exfiltration must be computed and the target outflow reduced by this amount.

As with the Pond procedure, the iteration uses the secant method to solve a relationship between Q and K to yield the required value of Q and thus estimate the storage from the corresponding lag K.

The algorithm is summarized as follows.

1. Assume maximum exfiltration rate Xmax = 0
2. Set desired Qout = TargetQout - Xmax
3. Initialize values of K and Q for two points on the curve, i.e.

   K1 = Hydrograph Volume/(0.6*Imax)

   K2 = 0.2 Inflow hydrograph timebase

   Q1 = 0.1 Imax
4. Route inflow through a linear reservoir of lag K2 to get maximum outflow Q2
5. Interpolate between points (K1,Q1) and (K2,Q2) to get K3 for required Qout
6. For next iteration set K1 = K2

   K2 = K3

   Q1 = Q2
7. If change in Q2 > ε go to step 4.
8. Solution found for Q2. Estimate storage S = K2.Q2 and convert to trench volume.
9. From trench volume estimate maximum water level Wlmax.
10. For WL calculate exfiltration Xmax.
11. For 5 iterations go to step 2.

Because of the many other quantities which can affect the routing operation the estimate is only an approximate guide and trial and error is normally required.

Chapter 9 - Displaying your Results

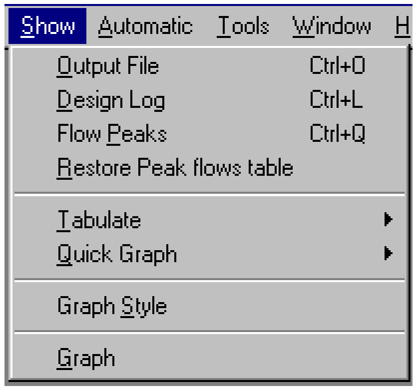


Figure 9-1 – The Show menu lets you display results in various ways

This chapter describes the commands available to show you the results of your MIDUSS 98 session. As indicated in the menu shown in Figure 9-1, the main topics are as follows:

Output File	Show the current content of the Output File
Design Log	Show the current contents of the Design Log
Flow Peaks	Show the summary of Peak Flows
Restore peak flows table	Restore the Peak Flows Summary table
Tabulate	Display a table of Hyetograph or Hydrograph values
Quick Graph	Display a graph of a Hyetograph or Hydrograph
Graph Styles	Review or alter currently selected Colors, Patterns and Line properties
Graph	Draw and store a customized graph containing hydrographs and/or hyetographs

Each of these topics is discussed in the sections which follow.

The Show Menu

Each use of this command causes an instance of a standard Windows editor to be created with the current Output file as the subject of the command line. If the current output is less than 50,000 bytes in size MIDUSS 98 tries to use the Microsoft Notepad text editor. If the output file is larger than 50,000 bytes the Microsoft Wordpad editor is used.

After reviewing the output file you should close the editor explicitly either by using the File/Exit command in the Notepad or Wordpad menu or by clicking on the Close Window icon **[x]** in the top-right corner of the window. If you simply click in the MIDUSS 98 window, the editor window will disappear behind the MIDUSS 98 window and the next time you use the Show/Output file command you will create a second instance of the editor.

Showing the Design Log

This command opens the Notepad text editor and displays the current contents of the Design log. This contains the accumulated files created during each of the Design functions which generate a log of changes and results.

The file can be saved under another name or printed at any point during the MIDUSS 98 session.

Showing the Flow Peaks File

The Peak flows summary table is represented by a grid linked to a small database Qpeaks.Mdb which resides in the MIDUSS 98 directory. To allow you to save, print or otherwise manipulate this information the database is also saved as a simple text file Qpeaks.txt which also resides in the MIDUSS 98 directory. Both the database and text files are re-newed at the start of each MIDUSS 98 session.

The **Show/Flow Peaks** command opens an instance of the Notepad editor and displays the current contents of the Qpeaks.txt file which can be saved under another name or in another directory or printed.

Restore peak flows table

Should the Peak flows summary window be closed it can be restored and updated with this command.

The Show/Tabulate command

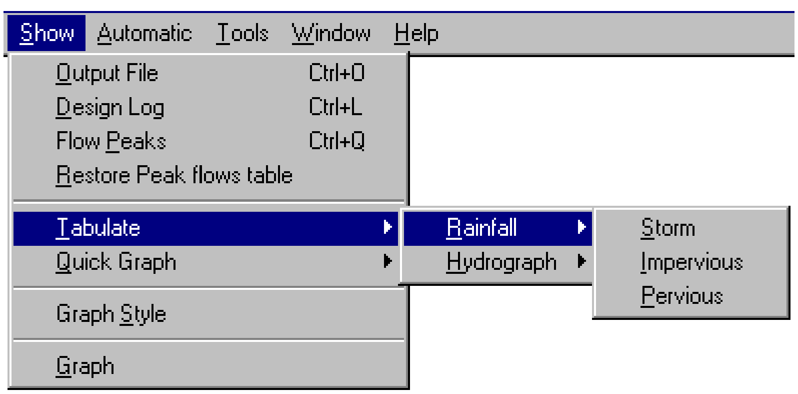


Figure 9-2 – You can display a table of hyetograph or hydrograph at any time

With all of the Hydrology or Design commands a table is displayed showing the affected rainfall hyetograph or flow hydrograph. This command causes a similar tabular display to be opened showing the current contents of any user selected hyetograph or hydrograph.

The menu fragment shown above indicates the available selection from the three rainfall or effective rainfall hyetographs. A similar display is shown for available hydrographs. In both cases any array which is not currently available is shown in gray and cannot be selected.

Only one array can be tabulated at a time.

The Show/Quick Graph command

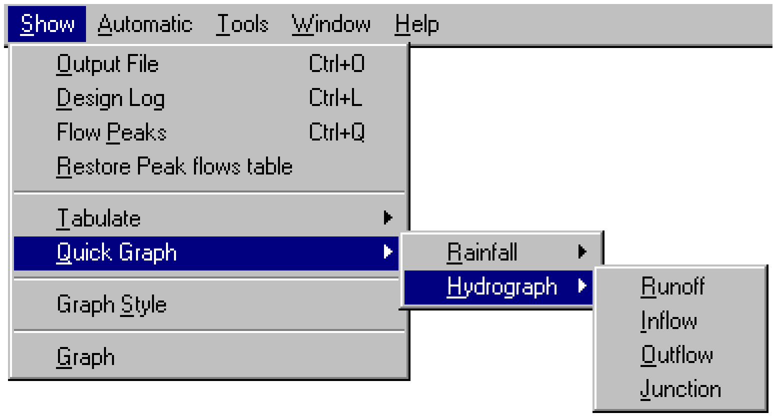


Figure 9-3 – Quick Graph shows a plot of any hyetograph or hydrograph

This command causes a graph to be displayed of any one of the currently available hyetographs or hydrographs as indicated in the menu fragment shown above. Arrays which are not currently available are shown in gray and cannot be selected.

Only one array hydrograph or hyetograph can be displayed at any one time. An option to allow two or more hydrograph files to be shown on the same graph will be made available in the near future.

If you want to combine several arrays on a single graph you should use the **Show/Graph** command.

Show Graph

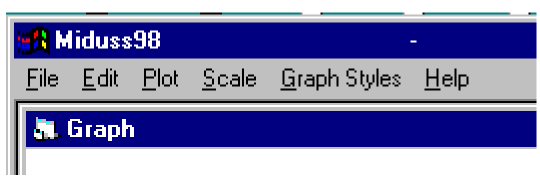


Figure 9-4 – The Show/Graph command has a special menu

The purpose of this command is to let you build a composite graph containing one or more hydrographs and hyetographs together with custom annotations and simple graphic shapes. As illustrated above, the Main Menu bar is replaced with a customized Graph Menu.

The options displayed on the Graph Menu are summarized below and are discussed in more detail in the sections which follow.

Graph/File	Lets you save and load graph bitmap files, print hardcopy, minimize the Graph form or exit the Graph command
Graph/Edit	Contains options to enter text with different fonts and colours, draw simple graphical shapes such as lines, arrows, rectangles and circles and selectively erase reactangular areas of the graph
Graph/Plot	Select the rainfall hyetograph or flow hydrograph to be added to the graph, preview the graph and then add it to the current graph.

Graph/Scale Allows vertical and horizontal scales to be set, select whether hyetographs are on the top or bottom edge, set the fraction of the plot height for hydrographs and hyetographs and toggle the grid and crosshairs off and on.

Graph/Graph Styles Define or change the colours, patterns and line thickness to be used for different hyetographs and hydrographs.

Graph/Help Opens the normal MIDUSS 98 Help System.

Show/Graph/File Menu Options

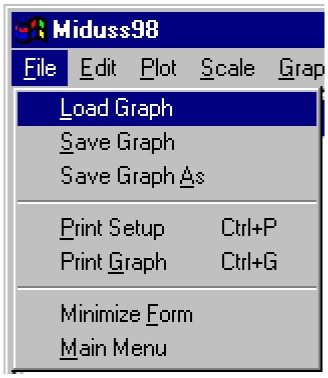


Figure 9-5 – Options available in the Graph/Files menu

The Graph menu shown in Figure 9-5 offers the following options:

Load Graph Load a previously saved bitmap file (*.bmp) into the Graph window

Save Graph Save the current contents of the Graph window as a bitmap file. The default file is called DefaultGraphFile.bmp and is stored in the Miduss98 folder. It is approximately 0.5 MB in size.

Save Graph As Save the current contents of the Graph window with a special name in the currently defined job folder.

Print Setup Select a printer or printer parameters

Print Graph Produce a hardcopy of the Graph window

Minimize Form Minimize the Graph form to an icon. The Graph window can be restored by re-invoking the **Show/Graph** command.

Main Menu Close the graph form (erasing the contents) and return to Main Menu

Show/Graph/Edit Menu Options

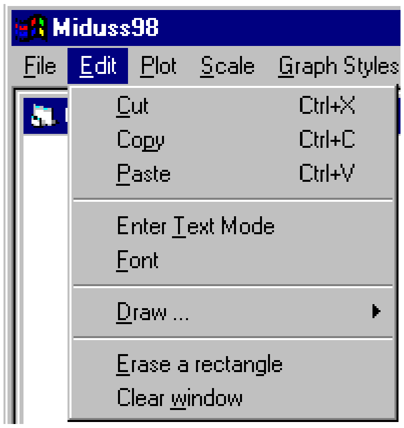


Figure 9-6 – Choices in the Graph/Edit menu let you annotate the plot.

This Graph menu item offers the options listed below. Most of these are sufficiently complex that more detail is provided in the appropriate sub-sections which follow.

Enter Text Mode	Prepare to enter text on the Graph window
Font	Select a font (style, size, weight and colour) for text entry
Draw	Draw one of a number of simple shapes
Erase a Rectangle	Define a rectangle to be blanked out
Clear Window	Clear the entire Graph window and all Scale settings

Show/Graph/Edit/Enter Text Mode

Selecting this menu item changes the mouse pointer to a 'writing hand' and disables all of the other items in this menu with the exception of Font.

Click the primary (left) mouse button to change the ‘hand’ to a cross. Position the cross at the top left corner of the intended location of the text and click the primary (left) button to ‘set’ the starting point for the text.

Text can be entered from the keyboard but editing by means of the Backspace, Arrow and Delete keys is not available. The Enter key causes a new line to be started aligned with the previous one.

Click the cross cursor at a new location to enter text with same attributes at a new location.

Pressing the Escape key or the End key restores the 'writing hand' pointer and you can move to another position to enter text.

If you wish, you can access the Font item in the Show/Graph/Edit menu and select size, font, colour and attributes from a standard dialogue box.

When you have finished entering text, click the menu item 'Text Entry mode' to de-select it (i.e. remove the check mark). The other Graph menu items will be enabled and the default mouse pointer will be restored.

Show/Graph/Edit/Font

This option lets you select the Font (e.g. Times Roman), Font Style (e.g. Bold), Point size and Font Colour from a Font dialogue box.

When you are in the process of entering text (i.e. when the 'writing hand' icon is displayed) this Graph menu item is the only one which is not disabled so that you can enter text items in a variety of styles.

Show Graph/Edit/Draw

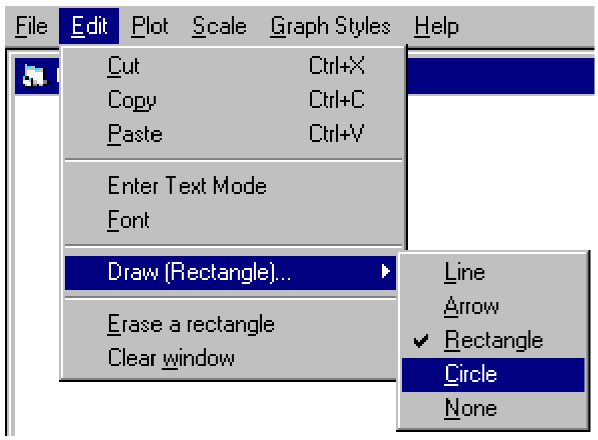


Figure 9-7 – Several simple shapes can be added to the graph

The menu item in Figure 9-7 shows the simple shapes that can be added to the Graph window by using the **Show/Graph/Edit/Draw** command. Shapes are drawn by clicking and holding down the primary (left) mouse button and dragging the pointer to the final position. A dynamic grayed image is displayed to let you decide on the desired size and shape of the object. When drawing an arrow the 'arrow-point' is at the start of the 'drag' operation, i.e. the arrow direction is the reverse of the drawing direction.

Once a shape is selected it is shown against the 'Draw' item as a reminder.

The 'None' option should be used to avoid drawing unwanted shapes accidentally.

Show/Graph/Edit/Erase a Rectangle

This option lets you erase a rectangular area from the current graph either to create a space for text entry or to correct a previous mistake.

To define the rectangle, click and hold down the primary mouse button and drag out the dotted rectangular frame.

Show/Graph/Plot Menu Items

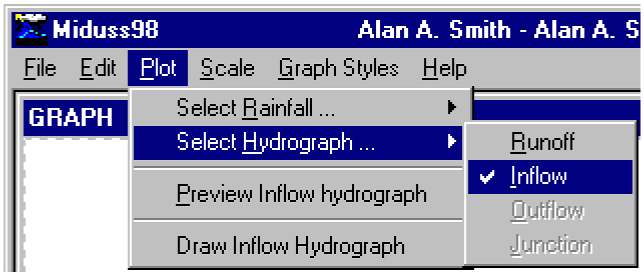


Figure 9-8 – The Graph/Plot menu lets you select, preview and draw flow data

These four menu items let you select, preview and add a hydrograph or hyetograph to the current contents of the Graph window. The list opened by either of the **Select…** items will allow you to select only from hydrographs and hyetographs which contain significant data.

The checkmark against a list item indicates the last selected item. The **Preview…** and **Draw…** menu items are modified to show the last selected item.

Select Rainfall	Select one of the three rainfall hyetographs to plot
Select Hydrograph	Select one of the four flow hydrographs to plot
Preview Selection	Display a 'Quick Graph' of the selected hyetograph or hydrograph
Draw Selection	Add the selected item to the current contents of the Graph window

Show/Graph/Scale Menu Items

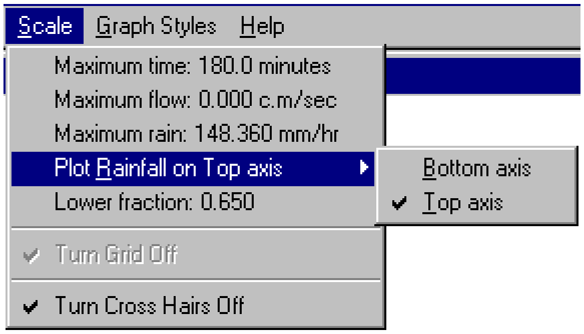


Figure 9-9 – The hyetographs can be added at top or bottom of the graph

These menu items allow you to control the limits for scaling the graph. In many cases, these values must be set before the first hyetograph or hydrograph is plotted since subsequent objects must use the same scales to be consistent.

The graph window can be split horizontally to avoid hyetographs plotted on the top edge from overlapping with hydrographs on the bottom axis.

A brief description of each of the options is given below.

Maximum time Set the time scale on the X-axis. Once the first item has been plotted the time scale cannot be changed.

Maximum flow Set the highest hydrograph flow value which sets the scale for the lower fraction of the window which is used for hydrographs. Use this if you want to make room for a subsequent hydrograph which is larger than the first one plotted. Once this has been set by plotting the first hydrograph it cannot be changed.

Maximum rain Set the maximum intensity with which a rainfall hyetograph can be plotted. Once a hyetograph has been plotted this value cannot be changed. If the first hyetograph is the total storm this will accommodate the effective rainfall on both pervious and impervious surfaces.

Plot Rainfall On … Lets you choose whether to plot the rainfall hyetographs on the bottom or top axis. Once this has been set it cannot be changed without clearing the window.

Lower Fraction Allows you to split the window into upper and lower fractions to hold rainfall and hydrograph plots respectively. Once an object has been plotted, you cannot change this except by clearing the window. The default fraction is 0.65.

Turn Grid Off/On Toggles the grid off or on.

Turn Cross Hairs Off/On Toggles the cross-hairs which move with the mouse pointer when the primary mouse button is held down. This is useful for drawing simple shapes with reasonable precision. When the cross-hairs are enabled the X and Y coordinates are also displayed at the left end of the Title bar

The Show/Graph Styles Command

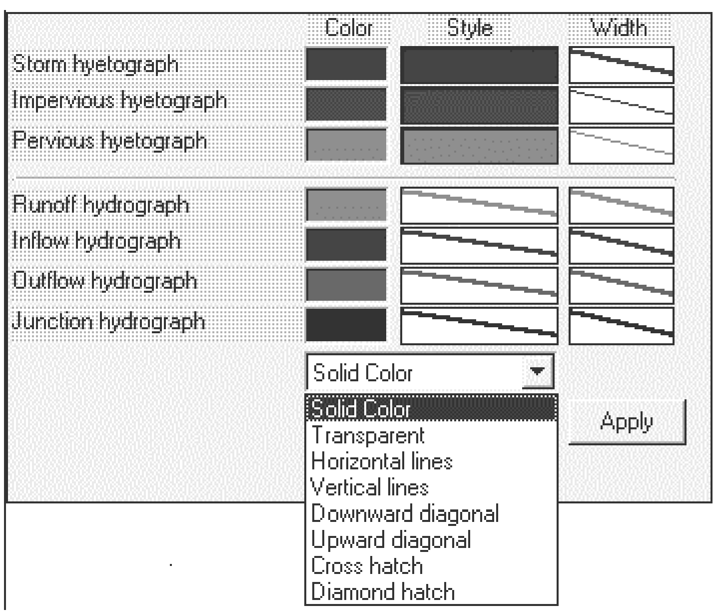


Figure 9-10 – You can customize the colour and fill attributes of the graph

This command lets you customize the colours, patterns and line styles used in all of the graphic displays of hyetographs and hydrographs including the **Show/Graph** command. As shown, three columns let you select Colour, Style or Width to be used when graphing any of the three hyetographs and four hydrographs.

By clicking on a Colour choice a dialogue box is opened to reveal the choices available. However, if your screen display can show only a limited number of colours your choice may not always be displayed as expected. Some experimentation may be necessary.

For the three hyetographs, Style means a fill pattern. By clicking on one of the three boxes a drop down list is opened (as illustrated in Figure 9-10) which lets you choose from a small number of options.

Style for the four hydrographs means line pattern - continuous, dashed etc. This choice is also offered from a list box which is shown when you click on any of the Hydrograph/Style boxes. However, note that a line pattern other than continuous is available only if the line width is 1 pixel.

Width describes the thickness of the line in pixels. A restriction of Windows is that widths of more than 1 pixel will automatically default to a continuous line pattern. For the 3 hyetographs, the line width is used for the line enclosing the bar graph.

Chapter 10 - Running MIDUSS 98 in Automatic Mode

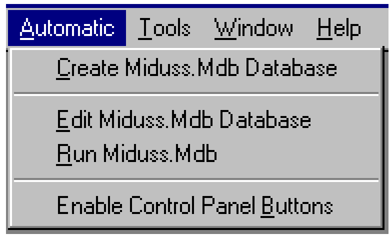


Figure 10-1 – The Automatic Menu

This chapter describes the commands that let you use MIDUSS 98 in automatic mode. This is a rather unique feature of MIDUSS 98 and it is worth learning these time-saving operations if you are (or plan to be) a regular user of MIDUSS 98.

The chapter begins with a number of general topics listed below.

- Reasons for Using Automatic Mode
- Files Used in Automatic Mode
- Structure of the Database File
- Advantages of Using a Database.

Following this general introduction a detailed description is given of the three steps available in the menu commands and the commands available within each step. The steps illustrated in the Automatic menu are introduced in the topic Steps to Run MIDUSS 98 in Automatic Mode. More detail is given in the following sections.

- Create the Miduss.Mdb Database
- Edit the Miduss.Mdb Database
- Using the Automatic Control Panel

Reasons for Using Automatic Mode.

While MIDUSS 98 is being run in manual mode, all commands and all relevant data are input from the keyboard and the results are displayed on the screen. If you have defined an output file a log is maintained on this file of all commands, input data and some of the results. The file contains all of the data necessary to duplicate the MIDUSS 98 session. This file not only serves as a detailed record of the session but can be used to create an input file for use during a subsequent MIDUSS 98 session, allowing all the recorded commands and data to be read in automatic mode, thus relieving you of the need to re-enter this information. This form of automatic processing will be found useful in a number of situations of which the ones described below are typical.

(a) A design session can be completed in several runs. The commands, data and design decisions of the first session are recorded and used during the second session to quickly get to the point where the previous session stopped. The design can then be continued in manual mode. The output file will then contain the commands and data for both sessions.

(b) A design may be completed using a storm hyetograph with (say) a five- year return period. Later, it may be desired to test the design under a more severe storm. Using the output file created in the previous session, this can be done by running through the previous design in automatic mode and redefining a new storm at the appropriate point.. An example is described in Chapter 11

A Detailed Example. – An Automatic Design for a Historic Storm.

(c) You may wish to revise one or more components in a previously completed design. This can be done by running the design in automatic mode and revising the design of the specific component(s). After a design decision is read from the input file - e.g. the diameter and gradient of a pipe - you can either accept or revise the design. The output file then contains any altered design parameters.

(d) You may want to add one or more commands in manual mode to those already captured in the output file. These commands may represent a change in the hydrologic modelling, the design of a new component in the drainage network or simply an opportunity to generate and print graphics for use in a final report.

The output file is a sequential, formatted file and can be displayed on the screen using a text editor such as Notepad or Wordpad or copied to your printer.

If you have used an earlier version of MIDUSS you will notice that there are very many differences between the method used in MIDUSS 98 and that used previously. However, the general principle remains the same - that output from a manual session can be used to provide input for a subsequent run in Automatic mode. There is no currently available program to convert an output file created with an earlier DOS version of MIDUSS for use with MIDUSS 98.

Next topic: the Files Used in Automatic Mode

File Structure Used for Automatic Mode

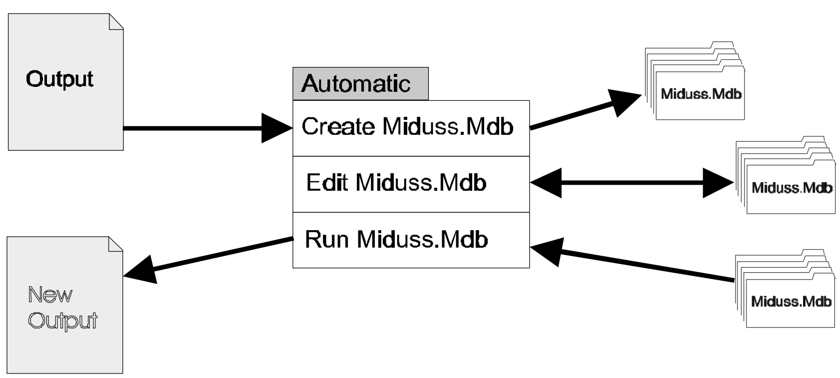


Figure 10-2 - Schematic of Automatic File Operations

Figure 10.2 above illustrates the three operations which are available under the **Automatic** command in the Main Menu. These commands operate on two types of file.

Output The Output file is an ASCII text file which has been produced by MIDUSS 98 and which contains lines of text containing commands, data and results. The Output file can be read using any text editor such as Notepad or Wordpad. These are included with your Windows 95/98/NT operating system.

The icon labelled 'New Output' represents a file which contains the results of a Run in Automatic mode and includes any changes (such as a larger storm event) made during the run.

Miduss.Mdb This is a database file comprising a number of records (rows) each of which corresponds to a line in the Output file. The contents of the database can be viewed only with special software designed to handle databases such as Microsoft Access ®, dBASE® or Paradox ®. MIDUSS 98 contains procedures for viewing, editing and reading the contents of Miduss.Mdb. The default file extension for a database file is 'Mdb' and you should not change this.

It is important to note that in order to be available as an input source, Miduss.Mdb must reside in the MIDUSS 98 directory (e.g. C:\Program Files\Miduss98\ ). Obviously only one copy of Miduss.Mdb can exist in this directory. However, you can create a copy of the file in another directory should you wish to save it for future use. The four commands in the Automatic menu do the following.

Create Miduss.Mdb	Reads the contents of your Output file line by line and creates corresponding rows in the database Miduss.Mdb. The same operation is carried out automatically when you use the **Files/Open Input File** command in the **Files** menu.
Edit Miduss.Mdb	Displays the current contents of the database Miduss.Mdb and allows you to edit the data in any of the fields of any row. The Edit process cannot be used to insert new records (rows) into the database. You can do this by entering additional commands in Manual mode while running in Automatic mode.
Run Miduss.Mdb	Start reading and executing the commands in Miduss.Mdb. There are three modes in which you can run Miduss.Mdb which are controlled by the command buttons on the Control Panel.
Enable Control Panel Buttons	Sometimes you may find that the command button on the Control Panel that you want to use has been disabled. This command is designed for these situations and enables all of the command buttons.

Next topic: the Structure of the Miduss.Mdb Database

Structure of the Database File

The database file can be visualized as a table made up of many rows and several columns. The rows are referred to as **Records**. Each record contains a number of **Fields** that correspond to the cell at the intersection of a row and column. The number of Fields or Columns is fixed and cannot be changed by the user.

The database file used by MIDUSS 98 is always called Miduss.Mdb and it always resides in the MIDUSS 98 folder. Miduss.Mdb contains 4 columns; it follows that every Record has four Fields. These Fields contain the following data:

1) An index counter starting from 1 to the maximum number of lines in the Output file which was used to create Miduss.Mdb.

2) An integer which is either zero or an integer corresponding to one of the commands in the MIDUSS 98 Main Menu. For example, the Hydrology/Time Parameters command is command 31 since it is in the third column of the Main Menu and is the first item in the Hydrology menu.

3) A value of a parameter required for input, such as a maximum storm duration, catchment area or pipe roughness.

4) A text or string variable which may contain a command name (e.g. STORM), descriptive text, a series of required numerical values such as historical rainfall or channel cross-section coordinates, or results for information.

The illustration below shows the top of a typical database.

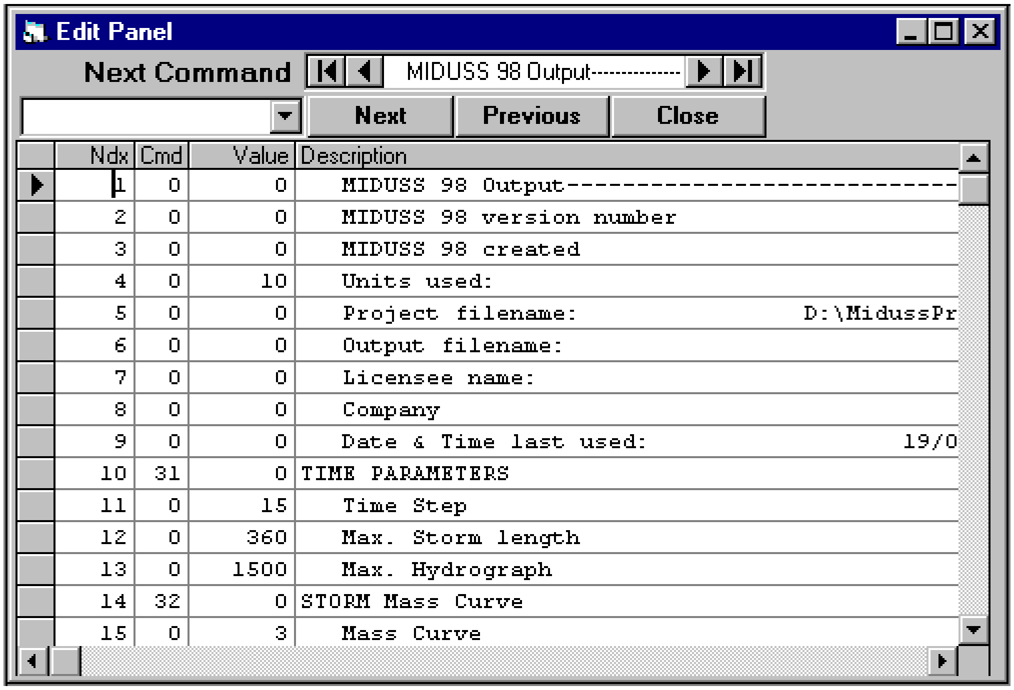


Figure 10-3 - Layout of Miduss.Mdb in the Edit Panel

Next topic: the Advantages of Using a Database

Advantages of Using a Database File

Previous versions of MIDUSS used a simple ASCII text file for both Input and Output. Using a database instead of a text file for input has a number of advantages.

1) The database is structured so that any record can be accessed directly instead of having to read records sequentially from the beginning of the file. This is much more efficient and allows large database files to be manipulated very rapidly.

2) Due to the direct access described above it is possible to link or 'bind' the database to a number of different controls or objects on the screen. The most convenient is a grid which can have rows and columns corresponding to the records and fields of the database. This is the grid that you see in the Edit Panel (Figure 10-3) and in the Control Panel which is displayed when running MIDUSS 98 in automatic mode.

3) Linking the database to a visible grid allows the database file to be used as an input source for MIDUSS 98 while still making it visible to the user.

4) The visible records allow you to keep track of the progress of the run and anticipate commands where you may wish to take some special action.

5) The grid displayed allows you to make changes to the data during the run and any changes entered into the grid are immediately reflected in the Input database.

6) MIDUSS 98 has a special data editing feature which lets you change a command number to the equivalent negative value. This causes a continuous run to stop and revert to the step-by-step Edit mode. This lets you run at speed up to a point in the input data where you want to take control or perhaps revert to Manual mode.

Steps to Run MIDUSS98 in Automatic Mode

There are three steps in using an existing Output file to run MIDUSS 98 in Automatic mode

(1) Create the Input database Miduss.Mdb

(2) Review and/or Edit the Input Database Miduss.Mdb

(3) Use Miduss.Mdb to run MIDUSS 98 in Automatic mode

These steps are described in more detail in the sections which follow.

Creating the Input Database Miduss.Mdb

This first step assumes that you have already completed a session of MIDUSS 98 in manual mode and can access the output file. If you didn't explicitly name an Output file, the output will be contained in the file DEFAULT.OUT which can be found in the MIDUSS 98 directory (typically C:\Program Files\Miduss98\).

If this is the case it is probably wise to make a copy of DEFAULT.OUT under a different name and preferably in a different Job Directory. It's also a good idea to look at the output using Notepad or Wordpad to re-assure yourself that you are working with the correct file.

You may also find it useful to have a printout of the file for your first use of Automatic mode or for a long and complex file.

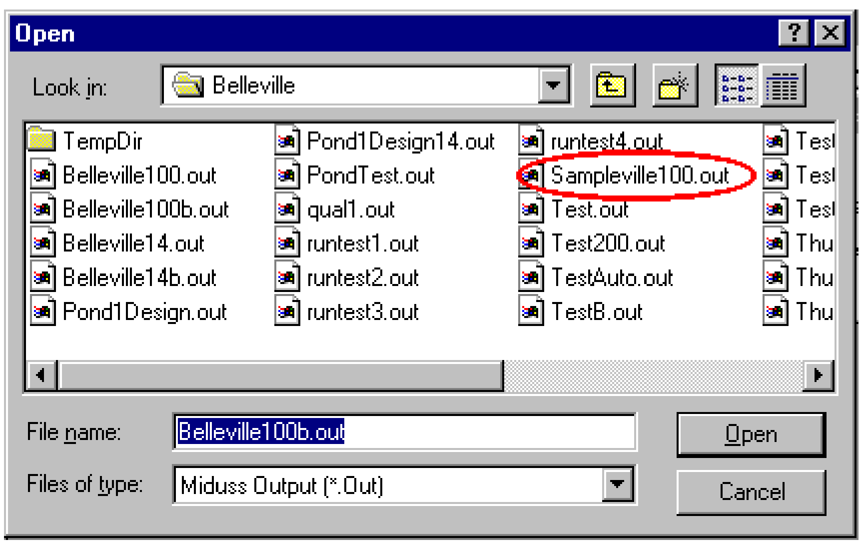


Figure 10-4 - Selecting an Output file from a Dialog Box

When you select the **Automatic/Create Miduss.Mdb** command a dialog box is opened as shown above and you can navigate to your Job directory and select an existing output file as shown circled in red. Pressing the [Open] button causes the dialog box to close and a small progress form with the title 'Create Miduss.Mdb' is opened displaying the number of commands and the total number of records converted from the output file to the database Miduss.Mdb.

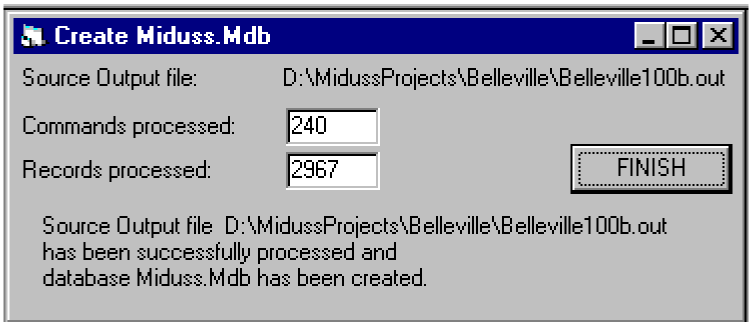


Figure 10-5 - The Create Miduss.Mdb window.

When the process is complete the command button [Finish] is enabled and you can click on this to close the window. The command will create a database file with the name Miduss.Mdb which resides in the Miduss98 folder.

The same procedure is automatically carried out when you select the **Files/Open Input File** command from the **Files** menu.

Once you have created Miduss.Mdb the next step is often to review or edit the Miduss.Mdb Database

Edit the Input Database Miduss.Mdb

The next step is to review the database either to ensure that the correct file has been created, or to make some change to the data. The diagram below shows the top portion of a typical database contained in the Edit Panel window.

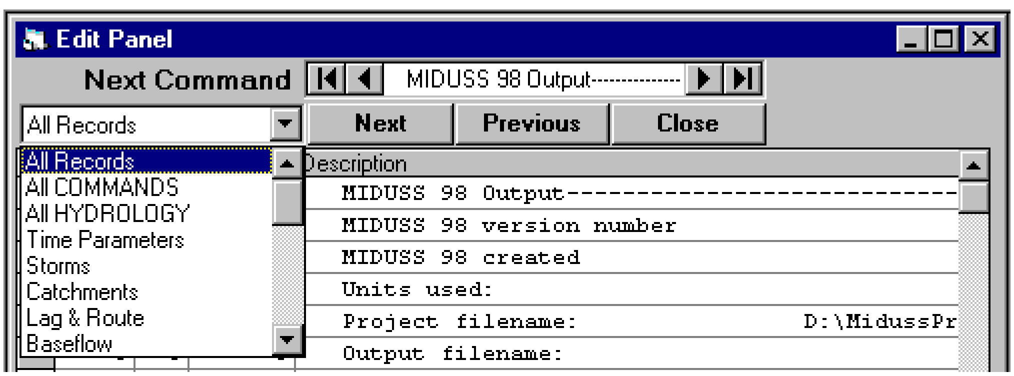
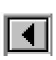
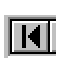
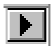


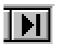
Figure 10-6 - The header of the Edit Miduss.Mdb window

The rectangle above the three command buttons is called the Data Control. The arrow symbols at the left and right ends of the Data Control allow you to move forward or backward through the file.

 Backwards one record at a time, or

 Move directly to the beginning of the file.

 Forward one record at a time, or

 Move directly to the end of the file.

The three command buttons let you do the following.

1) [**Next**] Move the current record to the record containing the next command

2) [**Previous**] Move the current record to the record containing the previous command

3) [**Close**] Close the Edit Panel window.

When you use the [Next] and [Previous] command buttons the pointer is located on the record containing the next or previous command and the name of the command is displayed in the text section of the Data Control. Pressing [Next] at the end of the file moves the pointer (i.e. the current record) to the start of the file. Similarly, pressing [Previous] near the top of the file moves the pointer to the last command of the database - normally the EXIT command.

The 'Drop-down' List box lets you select from various types of record such as 'All HYDROLOGY', or 'Catchment'. Selecting one of these causes the full database to be replaced with a list of records corresponding to your choice. This is a useful way to review (say) all of the Catchment commands used. The description will also show the Catchment ID number and you can quickly find the Index number corresponding to a particular Catchment. Selecting 'All Records' from the Drop-down List box causes the full data base to be restored and you can navigate to the desired record.

Now that the input database is ready you can run it using the automatic Control Panel. However, it is important that the units used are consistent. MIDUSS 98 takes care of this for you.

Using Consistent Units

When you start a new session of MIDUSS 98 one of the things you are required to specify is the system of units to be used. If you now start to run the current Miduss.Mdb in automatic mode it is essential that the units being used for the session must match the units in the input database.

In case you have made an error, MIDUSS 98 compares the units used in Miduss.Mdb with your current selection. If these are not the same MIDUSS 98 changes the selection of units for the session to match the units in the input file. A warning message similar to that shown below is displayed and the current output file is re-written with the modified Units parameter.

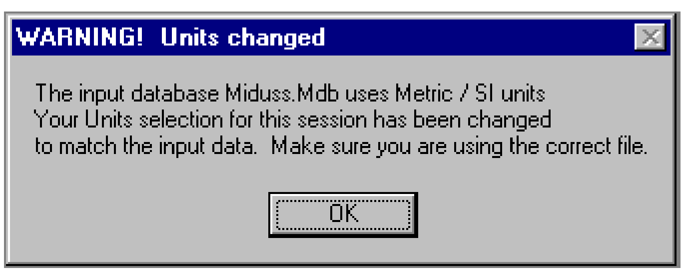


Figure 10-7 – MIDUSS 98 checks to make sure the units are consistent

The error may have been due to either

- selecting the wrong units from the Options/Units menu, or
- using the wrong input file.

If the wrong file has been used you will need to either Exit from and re-run MIDUSS 98 or use the Files/Quit and Start Over command. Although MIDUSS 98 protects you from this type of error it is always advisable to use the Edit panel to review the contents of Miduss.Mdb before starting the run.

Now that the input database is ready you can run it using the Automatic Control Panel.

Using the Automatic Control Panel

When you are ready for the run use the **Automatic/Run Miduss.Mdb** command. The Automatic Mode Control Panel is displayed. This contains a grid which is linked to the database Miduss.Mdb and a number of control buttons.

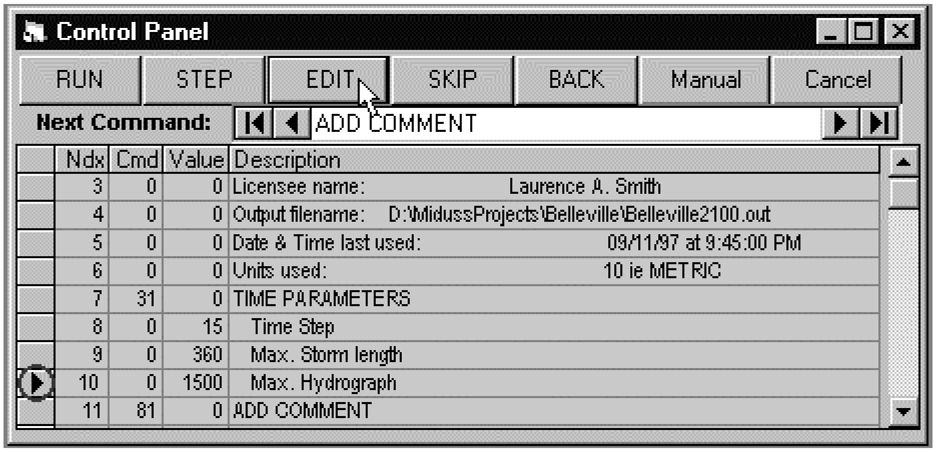


Figure 10-8 - The Automatic Mode Control Panel

The Control Panel is usually positioned in the lower, right corner of the MIDUSS 98 window, immediately above the Peak flow summary table and normally displays only the section of the database which contains the current record. The current record is indicated by the arrow-head in the left column (circled in red in Figure 10-8 above). You can increase the number of records displayed by dragging the top edge of the Control Panel upwards and you can use the vertical scroll-bar to move through the database either to see commands still to be executed or to edit data which is yet to be read and used.

However, be careful if you manually change the current record by clicking on a row to edit some data. Processing of the database will continue ***from that record*** and you should re-set the current record before continuing unless you deliberately want to skip to the edited record to ignore or repeat a section of the database.

Figure 10-9 – An Automatic run can use three modes

The first three command buttons let you control the manner in which the automatic run is made. These are:

- The [RUN] Command button
- The [STEP] Command button
- The [EDIT] Command button

The next two buttons let you move forward or backward through the database by skipping from one command to another. There is a minor difference in the manner in which you navigate through the database in the Edit Panel and in the Control Panel.

The two buttons are:

- The [SKIP] Command button
- The [BACK] Command button

In the Edit Panel pressing [Next] or [Previous] positions the pointer on a command line.

In the Control Panel the Current Record (as indicated by the pointer in the extreme left column) is positioned 1 record before the actual command line.

Finally, the last two buttons let you terminate the automatic session.

- The [MANUAL] Command button
- The [CANCEL] Command button

The MANUAL command closes the Control Panel but creates a 'bookmark' at the record where this was done. Then, if you use the **Automatic/Run Miduss.Mdb** command again, processing will start from this bookmark.

The Control Panel RUN command

[RUN] This causes commands to be executed consecutively and continuously until one of three things occur.

- The end-of-file is reached as signified by the EXIT command (Command #19).
- You press either the [EDIT] or [STEP] or [MANUAL] command.s
- A negative command number is encountered. Changing a command number to be negative in the Edit Panel is a convenient way of causing an automatic run to stop at a pre-determined point.

In this mode you will not be able to see much detail and the only indication of progress is from the current record displayed in the Control Panel or by the summary of peak flows which is continuously updated.

The Control Panel STEP command

[STEP] This mode executes and closes commands one at a time, one command being completed for each mouse click on the [STEP] button. As with the [RUN] command, this mode also provides little opportunity to see the results of the command and progress can be monitored by watching the Control Panel or the Peak Flows summary table. However, between commands you can always open the current (new) output file using the **Show/Output File** menu command which will contain a record of the run up to this point.

The Control Panel EDIT Command

[EDIT] This mode provides the greatest control on the automatic execution of the commands in the input database. With each click on the [EDIT] command the next command is executed but the final result is displayed on the screen and remains there until you press the [Accept] button on the appropriate form. The mouse pointer is automatically located over the [Accept] button on the just completed command and the [EDIT] button on the Control Panel is Disabled. When you click on [Accept] the [EDIT] button is enabled and the mouse pointer is located over it to let you quickly proceed to the next command

The [EDIT] mode lets you change any of the data on the form from that which was read from the input database. Typical uses of this feature might be to change the magnitude of the storm event at the beginning of the session in order to test a design under the impact of a more severe event, or increase the base width of a channel.

The Control Panel SKIP Command

[SKIP] This command moves the pointer (which indicates the current record) from the current position immediately before a command to the record immediately before the next command. The text display on the Data Control displays the name of the next command. In some commands, an additional parameter is shown (such as a catchment ID number) to help you judge where you are in the file. When the EXIT command is encountered the pointer moves to the beginning of the file (BOF) and points to the record before the first command.

You can also navigate forward through the file by pressing the forward arrow at the right hand end of the Data Control or simply by using the vertical scroll bar of the grid and clicking the mouse on the left column of any record. Note, however, that if you position the pointer exactly on a command line, pressing [EDIT] will NOT execute that command but the next one. Position the pointer on the record immediately prior to the next command to be executed.

The Control Panel BACK Command

[BACK] This button performs the reverse of the [SKIP] command. The current record and its pointer move back towards the Beginning Of File (BOF) stopping at the record immediately before the previous command. At the BOF or the first command pressing [BACK] moves the pointer to the last command in the database which should be the EXIT command.

You can also move backwards through the database by clicking on the back arrow at the left end of the Data Control. You can also position the pointer (and therefore the current record) by clicking on the left (grayed) column in any record. Note, however, that if you position the pointer exactly on a command line, pressing [EDIT] will NOT execute that command but the next one.

The Control Panel MANUAL Command

[MANUAL] When running in automatic mode pressing this button causes execution to stop and MIDUSS 98 reverts to manual mode. The Control Panel is closed but a 'bookmark' is stored to identify the point at which Automatic processing was stopped. If you re-start Automatic processing by using the **Automatic/Run Miduss.Mdb** command processing will start from where you left off.

The Control Panel CANCEL Command

[CANCEL] This button stops any automatic processing and closes the Control Panel.

Chapter 11 - A Detailed Example

This chapter presents a simple example that makes use of many of the commands presented in earlier chapters. For brevity, the size of network is very small but the techniques illustrated will be found adequate for the design of drainage systems of significant size. You may find it useful to work through this example on your computer while reading this chapter.

Two design sessions will be described. The first is in manual mode and will design the system for a 5-year storm. The second session in automatic mode will test the design under the action of a more severe storm. A final section describes how to use the **Show/Graph** command to plot 2 or more hyetographs and/or hydrographs.

The MIDUSS 98 CD contains a folder called 'Tutorials' which holds a number of audio-visual lessons on the basic operations in MIDUSS 98. Most of these lessons have been based on the examples presented in this chapter. If you have a sound card on your computer you will find it useful to view these lessons while you are reviewing this chapter. The lessons can be run directly from the CD or they can be invoked from the **Help/Tutorials** menu item.

A Manual Design for the 5-year Storm

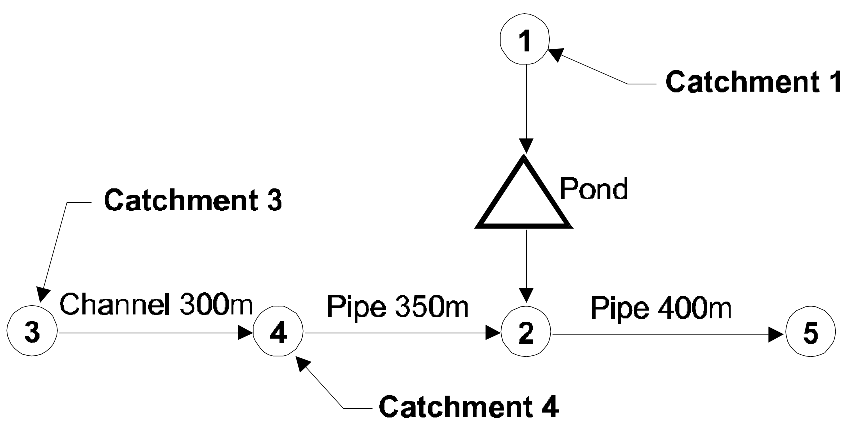


Figure 11-1 – A four-link drainage network

Figure 11.1 shows a network comprising 5 nodes and 4 links. Link #3 is intended to be an open channel, links #4 and #2 are to be pipes and link #1 is to be a detention storage pond. The sub-catchments which generate overland flow enter the system at nodes (1), (3) and (4) and have the characteristics summarized in Table 11.1.

Table 11.1

Catchment data for the network of Figure 11.1

Catchment number	1	3	4
Percent impervious	65	20	30
Area (ha)	5.0	3.5	2.5
Overland flow length (m)	85	125	90
Surface gradient (%)	2.0	1.5	2.5
Manning 'n'	0.20	0.25	0.25
SCS Curve Number CN	84	76	76
Initial abstraction (mm)	5.0	7.5	7.5

The impervious fractions in the three contributing sub- catchments are assumed to have roughness and imperviousness values as indicated in Table 11.2. The runoff from these catchment areas is to be computed using the SCS infiltration method and the triangular unit hydrograph method for overland flow.

Table 11.2

Characteristics of impervious areas

Catchment number	1	3	4
Manning 'n'	0.015	0.020	0.020
SCS CN or Runoff coeff. C	0.95	98	98
Initial abstraction Ia – (mm)	1.5	2.0	2.0

Design Storms

The drainage system is to be designed for a 5-year design storm of the Chicago hyetograph type and tested under a more severe historic storm. The 5-year synthetic storm is to be based on the intensity-duration-frequency relation shown in equation [11.1], with a value or $r = 0.35$ and a storm duration of 2 hours.

$$[11.1] \qquad i = \frac{a}{(t_d + b)^c} = \frac{1140}{(t_d + 6)^{0.84}}$$

The historic storm is defined by the table of rainfall intensities in mm/hour at 5 minute intervals as shown in Table 11.3. The total duration is 3 hours.

Table 11.3

Historic storm hyetograph in mm/hour for 5 minute intervals.

12	12	14	15	21	19
18	15	14	12	11	10
12	16	20	24	38	42
75	77	96	105	102	89
65	56	54	38	35	20
17	13	9	6	4	3

Setting the Initial Parameters

Three steps are required at the start of a MIDUSS 98 design session. These define:

- The system of units to be used
- The name of an output file to be used, and
- The time step parameters for modelling.

These are detailed in the steps which follow and are also described in Chapter 2 – Structure and Scope of the Main Menu.

Selecting the Units

When you launch MIDUSS 98 the Options/Units menu item is opened automatically and the mouse pointer is moved over the Metric or Imperial choices. This is to force you to select from either Metric (S.I.) or Imperial (U.S. Customary) units. In this example metric units are used. Note that your choice can be changed up to the point where the time parameters are selected. After that, you cannot alter the selection for the session.

When you click on your choice, MIDUSS 98 displays a prompt suggesting that the next step should be define an output file for the session. For your convenience, the directory and name of the last used output file is displayed. You can close these message boxes either by clicking with the mouse pointer on the [OK] button or simply by tapping the space bar or any other printing key on the keyboard.

Specifying an Output File

When you accept the units, the menu item **File/Output file/Create New file** is opened automatically and the mouse pointer is positioned over this item. A job specific output file is not a requirement but it is strongly recommended. If you don't specify one, all output will be written to a default file in the Miduss98 directory.

This is a good point at which to specify a special sub-directory for the project that will contain all of the relevant files. When you click on the **Create New file** or **Open existing file** menu items, a file dialogue box is displayed. If you want to create a new directory for this project, click on the 'Create New Folder' icon. A new directory with the temporary name 'New Folder' is displayed ready for editing. Type in an appropriate name; for this example use a directory called 'MyJobs' in drive 'C:\'. (Hint: You may have to click anywhere on the 'white space' of the dialogue box to get Windows95 to recognize your new folder name.)

Double click on the new directory or folder to open it. You can then type the name of the required output file in the File name text box. For this example, use a filename ‘Chap11.out’ or another of your choice.

When you click on the [Open] command button, the file dialogue box closes and a message is displayed. Typically, if a new file has been specified, MIDUSS 98 will ask you to confirm that you want to create this file. If you select an existing file as the output file, the message will warn you that if you continue, the existing contents of the file will be lost. Close the message box by clicking either [Yes] or [No]. If you press [No] the Open file dialogue box is re-opened until an acceptable output filename has been selected or defined.

The name of the output file will be displayed at the right-hand end of the status bar. If you want this display to include the full path of the file, you can do this by selecting the **Options/Other Options** item from the menu and click on the item **Include Path on Status Bar**. If you have used the suggested name, you should see the path ‘C:\MyJobs\Chap11.out’ at the right end of the status bar..

Define the Time Parameters

The third required step is to define the time parameters. Click on the **Hydrology** item in the main menu. Only the **Time parameters** item is enabled at this stage. Click on the command to open the Time Parameters dialogue box. The three items to be defined and their default values are:

Time Step	5	minutes
Maximum Storm length	180	minutes
Maximum Hydrograph	1500	minutes

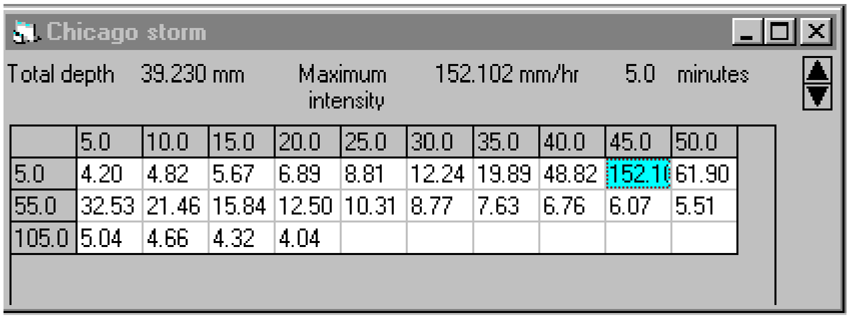
These are acceptable for the current example although you may prefer to reduce the hydrograph length to (say) 1000 minutes. However, too short a hydrograph length may result in truncation of a long outflow hydrograph from a detention pond that will result in continuity errors in hydrograph volume. For other projects you can change these default values easily by clicking on a value to highlight it and then type in the desired value.

Specifying the Design Storm

In the **Hydrology** menu the **Hydrology/Storm** item is enabled only after the time parameters have been defined and accepted. On accepting the time parameters you may see a prompt that you can now define a storm and on closing the message box the Storm command is opened automatically and the mouse pointer is moved over it.

These two prompting features can be toggled off or on in the **Options/Other Options** menu. If you open this menu you can see whether or not the options **Show Prompt messages after each step** and **Show Next logical menu item** are checked. For the first few design sessions, you may find it useful to use both options. After some experience with the program you may decide to omit the Prompt messages.

Click the **Storm** command to open the Storm window. Using the Chicago tab of the form, enter the parameters given in equation [11.1] above and press [Display]. The hyetograph is displayed in graphical and tabular form.



	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
5.0	4.20	4.82	5.67	6.89	8.81	12.24	19.89	48.82	152.1	61.90
55.0	32.53	21.46	15.84	12.50	10.31	8.77	7.63	6.76	6.07	5.51
105.0	5.04	4.66	4.32	4.04						

Figure 11-2 – Table of the Chicago rainfall hyetograph

The resulting hyetograph is shown Figure 11-2. The peak intensity is 152.1 mm/hour at 45 minutes. After you press the [Accept] button the storm descriptor window is opened as shown in Figure 11-3. The default string of '005' is for a 5-year storm. This is acceptable for the design storm so click on [Accept]. This means that any hydrograph files saved during the session will have a default extension of '005hyd'.

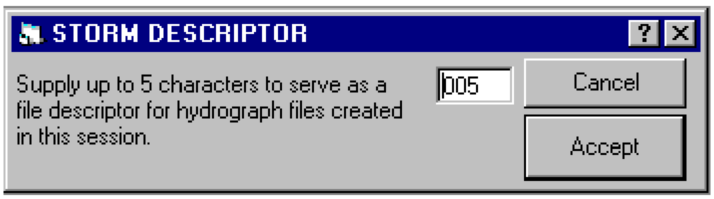


Figure 11-3 – Defining the storm descriptor

Runoff Analysis

The simulation and design does not need to follow the sequence of node numbers. You should first design the channel and pipe conveying the runoff from areas 3 and 4 to the junction node 2.

Now that a design storm has been defined the **Catchment** command is enabled in the **Hydrology** menu. Click the **Hydrology/Catchment** command to open the 3-tab Catchment form. On the Catchment tab, enter the first 5 items of data given in Table 11.1 for area 3. On the same part of the form select the Triangular SCS response as the routing method and select the Equal Lengths option which assumes that the overland flow lengths on the pervious and impervious fractions are equal.

Select the Pervious tab. The area and flow length are shown and cannot be changed but the slope of 1.5% could be changed if necessary. For this example leave it at 1.5%.

Select the SCS method as the infiltration method and fill in the remaining three parameters from Table 9.1 to define the Manning 'n', SCS Curve Number and Initial Abstraction depth Ia. As you enter a CN of 76 you will see the runoff coefficient increase to 0.223 and the initial abstraction reduce to just over 8 mm. These changes are consistent with a less pervious soil type. When the initial abstraction is reduced still further to 7.5 mm, the only change you will see is a slight reduction of the ratio Ia/S from the default of 0.1 to 0.0935.

Now select the Impervious tab; note the area and flow length and leave the slope at 1.5%. Enter the three parameters from Table 11.2. As with the Pervious parameters, you will see the ratio Ia/S increase when you type in an initial abstraction of 2.0 mm.

Runoff Hydrograph

Total volume 479.30 c.m Maximum flow 0.189 c.m/sec 50.0 minutes

	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
5.0	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.014	0.099	0.189
55.0	0.153	0.081	0.070	0.064	0.064	0.065	0.062	0.060	0.057	0.054
105.0	0.051	0.048	0.044	0.041	0.037	0.033	0.028	0.025	0.022	0.019
155.0	0.018	0.016	0.015	0.014	0.013	0.012	0.012	0.011	0.010	0.009
205.0	0.009	0.008	0.007	0.007	0.006	0.005	0.005	0.005	0.004	0.004
255.0	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.001	0.001

Figure 11-4 – Table of the Runoff hydrograph for Area 3

Finally, select the Catchment tab again and press the [Display] button. The rainfall hyetographs are displayed briefly followed by the graphs of runoff from the pervious, impervious and total areas. The peak flow of 0.189 c.m/s is mainly from the impervious fraction. Press the [Show Details] button to display the table shown in Figure 11-5. The pervious fraction contributes more than half the volume of runoff. The table of runoff flows (Figure 11-4) shows zero runoff for the first 30 minutes; this is due to the relatively high initial abstraction of 7.5 mm which is apparent if you click on the Pervious tab and press [Display].

Catchment 3	Pervious	Impervious	Total Area	
Surface Area	2.800	0.700	3.500	hectare
Time of concentration	52.770	5.930	30.537	minutes
Time to Centroid	125.636	64.281	96.513	minutes
Rainfall depth	39.230	39.230	39.230	mm
Rainfall volume	1098.45	274.61	1373.06	c.m
Rainfall losses	30.236	6.550	25.499	mm
Runoff depth	8.994	32.680	13.731	mm
Runoff volume	251.80	227.51	479.30	c.m
Maximum flow	0.044	0.184	0.189	c.m/sec

Figure 11-5 – Details of the Runoff from Area 3.

The contribution of area 3 to the drainage network is completed by pressing the [Accept] button to end the Catchment command. Then use the **Hydrograph/Add Runoff** command which causes the summary peak flow table to show a peak of 0.189 c.m/s in the Inflow (see Figure 11-10).

Designing the Channel

When you click on the **Design/Channel** command the form opens with the default trapezoidal parameters of 3H:1V side-slopes, a base-width of 0.6 m and a roughness of n = 0.04. With the default design of 1.0m depth with a slope of 0.5%, clicking on the [Design] button shows a depth of 0.262 m. If you want to review alternate designs you can click on the [Depth Grade Velocity] button to display a table of feasible values of depth and gradient. Velocity is also shown for information. You can 'import' any of these designs by double clicking on the appropriate row of the grid. The gradient is rounded up to the nearest 0.05%.

Flatten the channel grade to 0.25%. Notice that any change to the design parameters causes the plot of water surface to be deleted and the [Accept] button is disabled until the [Design] button is pressed again. The depth is increased to 0.308 m and the critical depth is just over half that, so the flow is tranquil or sub-critical. Figure 11-6 shows a fragment of the Channel Design window. Press the [Accept] button to close the form. The peak flows in the summary table are unchanged but another record is added for information.

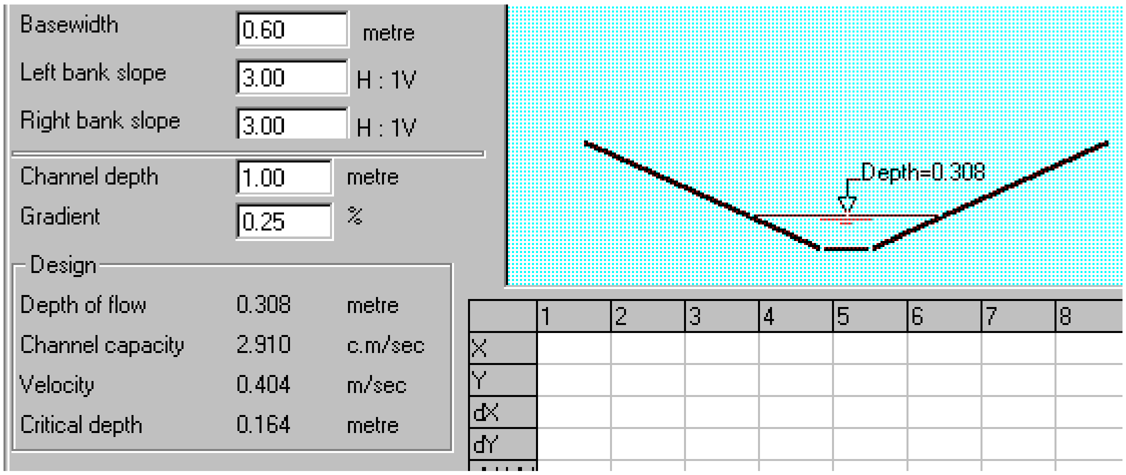


Figure 11-6 – A fragment of the Channel Design form.

If you have enabled the **Options/Other Options/Show Next logical menu item**, the mouse pointer will automatically point to the **Design/Route** command. Click on this to open the Route window. The default length (initially 500 m) is highlighted and you can type in the actual reach length of 300 m. This will cause the values of the X-factor and K-lag to be reduced which means reduced attenuation of the outflow hydrograph.

Press the [Route] button to show the graphical comparison of the inflow and outflow and also the tabular display of the outflow hydrograph. The peak is reduced from 0.189 c.m/s to 0.160 c.m/s and lagged by 5 minutes. Since the hydrographs are plotted at 5 minute increments, very 'peaky' hydrographs may sometimes show some truncation of the outflow. Press [Accept] to close the form. Another record is added to the peak flow summary table showing the peak inflow and outflow.

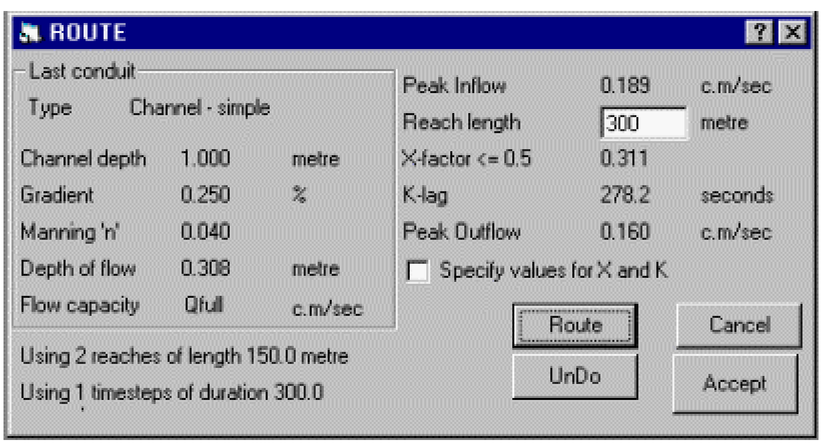


Figure 11-7 – Final result of the Route command

Moving Downstream

When an outflow hydrograph is computed you can do one of two things:

1. If this is the last link on a tributary you should probably use the **Hydrograph/Combine** command to store the outflow at the junction node, adding it to any previous outflows which may have been accumulated previously.
2. If this is not the last link in the tributary, you should use the **Hydrograph/Next Link** command to convert the computed outflow from the present link into the inflow to the next node and link downstream.

In this example, the second case is true and we want to add the runoff from area 4 and design the pipe to carry the total flow to the junction at node 2. Press the **Hydrograph/Next Link** menu item and note the change in the peak flow summary table. With most of the **Hydrograph/…** commands a brief explanatory message is displayed along with a table of the modified hydrograph.

Adding the Next Catchment

When you select the **Hydrology/Catchment** command to generate the runoff from area 4, the default values reflect the values entered for the previous catchment area. From the data in Tables 11.1 and 11.2 the parameters for the pervious and impervious fractions are unchanged and only the first 5 parameters on the Catchment tab need to be changed. You may find it convenient to enter the top item first (the ID number) and then press the Tab key on the keyboard to move down and highlight the next item.

The increased impervious fraction and steeper slope more than compensates for the smaller area and peak runoff is 0.216 c.m/s. Pressing [Show Details] reveals that the volume is just under 400 c.m and that more than 60% of this is generated from the impervious fraction. You should also notice from the graph and from the time of concentration shown in the details, that the time to peak is different for the pervious and impervious fractions. As a result, the total flow peak of 0.216 is significantly less than the sum of the two individual peaks (0.037 + 0.209 = 0.246).

Press [Accept] to close the Catchment form and select the **Hydrograph/Add Runoff** command to add the runoff to the current inflow. A total peak flow of 0.256 c.m/s is shown in the peak flow summary grid (see Figure 11-10). You may also note from the table of the new inflow hydrograph that the total volume of 878.46 c.m is equal to the sum of the runoff volumes from the two catchment areas. You can confirm this by using the **Show/Output File** command (or by pressing Ctrl+O) which lets you browse through the output file to recall the details from each of the two Catchment commands. You can also see that the time of concentration of the impervious runoff differs by almost 2 minutes. Because the hydrographs are very ‘peaky’ this causes the total peak (0.256) to be over 35% smaller than the sum of the two constituent runoff hydrographs (0.189 + 0.216 = 0.405 c.m/s).

Designing a Pipe

You can now use the **Design/Pipe** command to size the pipe leading to junction node 2. The Pipe window shows the peak inflow and a table of diameter-gradient pairs that would carry this flow when running full. Double click on the row containing the 525 mm diameter. The gradient is rounded up to 0.4% and pressing [Design] shows that this design will run just over ¾ full with an average velocity of 1.43 m/s. Figure 11-8 shows this result. You can, of course, experiment with different designs or different roughness values until you have an acceptable design. Press [Accept] to close the window.

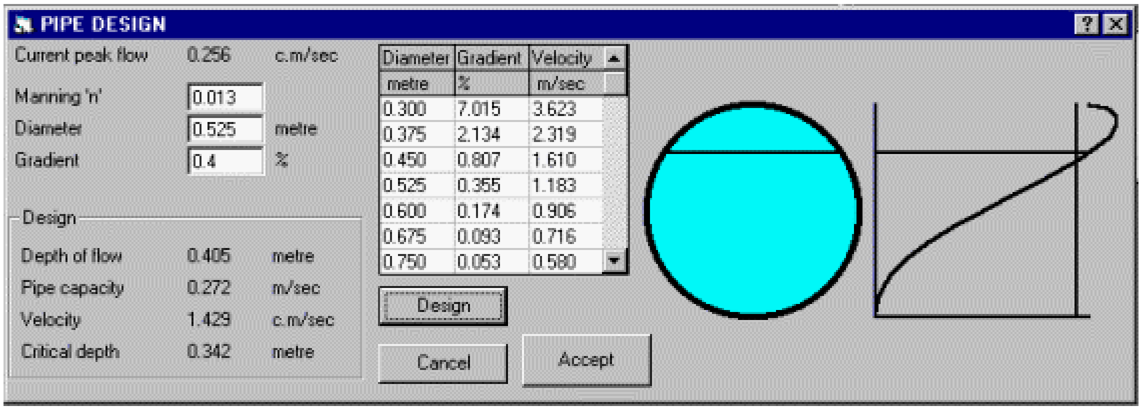


Figure 11-8 – Final result of the Pipe Design command

When you press the **Design/Route** command, the form opens with the length of 300 m previously used for the channel. Change the highlighted value to 350 m and click on the [Route] button. The outflow hydrograph table reports a peak flow of 0.242 c.m/s which represents 5% attenuation. This is a little high for a pipe, and the reason is apparent if you look at the graph. Click on the horizontal scroll bar to reduce the plotted time base to about 120 minutes. The inflow hydrograph has a double peak – due to the difference in time to peak from areas 3 and 4 – and the outflow hydrograph tends to average out these peaks despite the fact that the routing time step was only 2.5 minutes. However, the volume of outflow is still correct.

Defining a Junction Node

You must now store this outflow hydrograph at junction node 2 while you design the highly impervious area 1 and a detention pond. Use the **Hydrograph/Combine** command to open the Combine dialogue window. Since this is the first use of the command the form contains no data. The procedure can be followed fairly easily by responding to the prompts in the yellow box. Thus:

- ***Press [New] and enter the number and description of a new node.*** When you press the [New] button a text box is opened to define the Junction node number. Type '2'. As soon as a node number is entered, another text box opens for a description. Type a brief description such as "Node 2 – junction of links 1 and 4". The textbox will expand to accommodate a second line.
- ***After entering a description, press [Add] to add this to the List of Junction Nodes.*** The [Add] button has been enabled. Click on it to cause the node number and description to appear in columns 1 and 3 of the multiple list box. The middle column shows a value of 0.000. This will be updated to hold the current peak value of the accumulated flows at the junction. If the description is longer that the width of the descriptor column, a horizontal scroll bar is added to column 3 of the list box.
- ***Click on a node in 'Junction Nodes Available' to highlight the node to which the current Outflow will be added.*** When you click anywhere on the desired row, the entire row is highlighted and the [Combine] button is enabled.

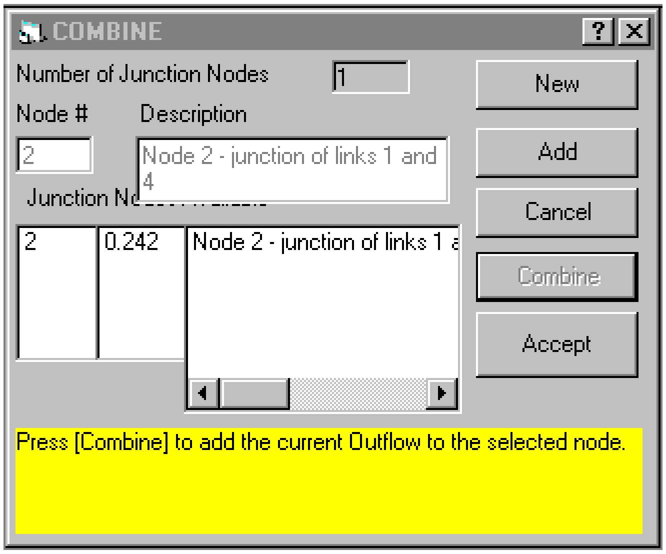
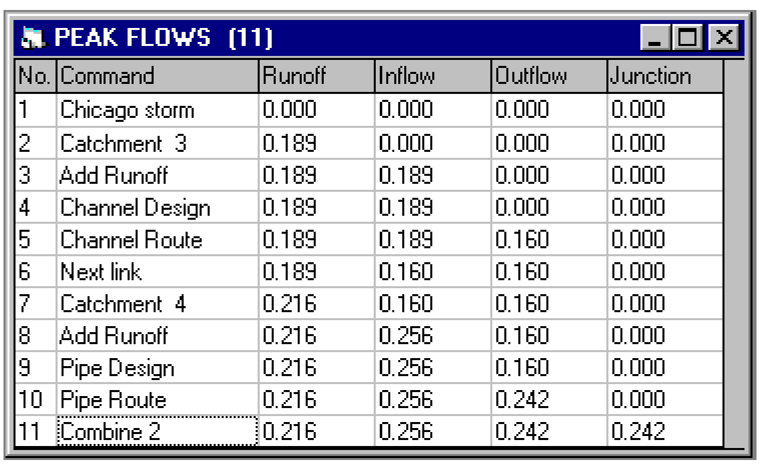


Figure 11-9 – Final display of the Combine dialogue form.

- ***Press [Combine] to add the current Outflow to the selected node.*** Click on the [Combine] button. MIDUSS 98 shows a warning message to advise you that a new file HYD00002.JNC will be created in the currently defined Job directory. Press the [Yes] button to confirm this. The [No] option is provided in case you have made an error. When you press [Yes] the value of 0.242 is entered in the middle column of the list box as shown in Figure 11-9. Also, another message is displayed showing the operation and the node number in the title bar, the name of the file created and the peak flow and volume of the accumulated hydrograph. This is a modal form and you must click on the [OK] button to continue.
- ***Click [OK] and press [Accept] to finish the Combine operation***. Press the [Accept] button that is now enabled. The Combine form is closed and the peak flow summary table is updated with another record showing the Combine operation, the node number and the updated peak flow of the Junction hydrograph as shown in Figure 11-10 below. Note that the height of the Peak Flows table has been increased by dragging the top edge of the window upwards.


PEAK FLOWS (11)

No.	Command	Runoff	Inflow	Outflow	Junction
1	Chicago storm	0.000	0.000	0.000	0.000
2	Catchment 3	0.189	0.000	0.000	0.000
3	Add Runoff	0.189	0.189	0.000	0.000
4	Channel Design	0.189	0.189	0.000	0.000
5	Channel Route	0.189	0.189	0.160	0.000
6	Next link	0.189	0.160	0.160	0.000
7	Catchment 4	0.216	0.160	0.160	0.000
8	Add Runoff	0.216	0.256	0.160	0.000
9	Pipe Design	0.216	0.256	0.160	0.000
10	Pipe Route	0.216	0.256	0.242	0.000
11	Combine 2	0.216	0.256	0.242	0.242

Figure 11-10 – Peak flow summary for branch (3)-(4)-(2)

Adding Catchment Area 1

Before the new tributary branch from node 1 to junction node 2 can be designed, you must clear out the Inflow hydrograph left over from the analysis of the previous branch. You can do this by clicking on the **Hydrograph/Start/New Tributary** menu item. You can use this command either before or after generating the runoff from catchment area 1.

The next logical command is the **Hydrology/Catchment** command, Because the parameter values are different for both the pervious and impervious fractions you will have to edit the data on all three tabs of the Catchment form. The impervious fraction is defined in terms of a runoff coefficient of 0.95 which, for the currently defined storm, is equivalent to a Curve Number of 99.43.

The resulting peak runoff is 0.990 c.m/s with the peak occurring 50 minutes after the start of rainfall. This peak flow will be routed through a detention pond before adding the runoff to Junction node 2. After pressing the [Accept] key, use the **Hydrograph/Add Runoff** command to add it to the Inflow hydrograph. If you have forgotten to set the Inflow to zero, MIDUSS 98 warns you that you may be double counting the inflow hydrograph from the previous branch. However, there may be situations where a new tributary runoff should be added to the previous inflow, so you must make the decision as to whether the warning is legitimate or not.

Design the Pond

For this example assume that the following criteria will guide the design of the pond.

- The pond will be a dry pond with no permanent storage.
- The outflow peak should be approximately 0.3 c.m/s for the 5-year storm.
- The maximum depth should be 2.0 m. with a top water elevation of 102.0 m.
- Outflow control will comprise an orifice and an overflow, broad-crested weir with a trapezoidal shape.
- The ground available is roughly rectangular in plan with an aspect ratio of 2:1.

Click on the **Design/Pond** command to open the Pond form. The form shows the current peak inflow and the hydrograph volume of 1410 c.m. The default peak outflow is 0.495 c.m/s and for this a storage volume of approximately 439 c.m is required. Edit the Target outflow by typing a value of 0.3 c.m/s. The required volume is increased to 590 c.m.

Enter the minimum and maximum levels as 100.0 and 102.0 m; leave the number of stages as 21 which implies 20 depth increments. This will cause the Level – Discharge – Volume table to show levels increasing by 0.1 m. Before you can route the inflow hydrograph through the pond, you must define two characteristics of the proposed pond:

The storage geometry, and

The outflow control device.

Defining the Pond Storage Geometry

Select the **Storage Geometry/Rectangular pond** menu. This causes the Storage Geometry Data window to be opened . Click once on the up-arrow of the spin button to open up a single row in the table. This shows default data which will generate the required volume in a depth of roughly 2/3 of the maximum depth of 2.0 m. You can test this by pressing the [Compute] button on the Geometry Data form. The column of volumes is computed with a maximum value of almost 1150 c.m.

To check the size and shape of the surface area at elevation 102.0 open another row in the data table by clicking again on the up-arrow of the spin-button. The computed area is just over 1000 sq.m but the aspect ratio is only 1.4. To get the aspect ratio at elevation 102.0 to be 2:1 you must increase the aspect ratio at elevation 100.0. To do this click on the cell containing the aspect ratio of 2.0 in the first row. The outline of the cell is slightly thicker when it is selected. Type in a value – say 3.5. The effect is not shown until you select another cell either by clicking on one or by using one of the arrow keys on the keyboard. With 3.5 at the bottom elevation, the aspect ratio at level 102.0 is 1.84.

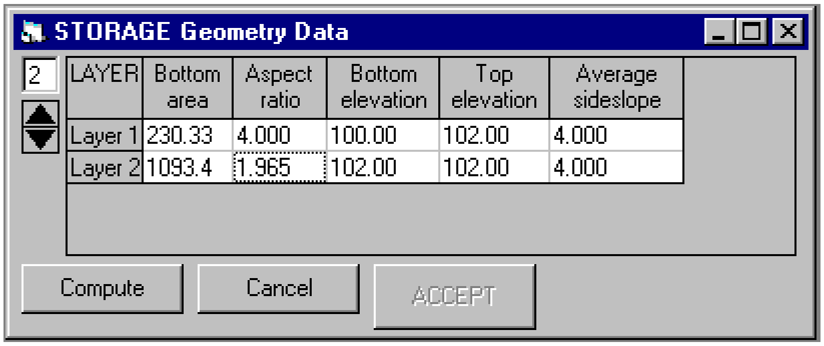


Figure 11-11 – Defining the pond geometry as a single layer.

By trial you will find that an aspect ratio of 4:1 at the pond bottom will yield a ratio of just under 2:1 at the top. The surface area at level 102.0 is 1093 sq.m. This design is shown in Figure 11-11. Press the [Compute] button again to refresh the column of volumes and enable the [Accept] button on the data form. Click the [Accept] button to close the data form. It can be re-opened and edited later if you wish. Note that it is more usual to have a number of 'layers' with different side-slopes but only one layer is used at this stage for simplicity. MIDUSS 98 lets you define up to 10 layers.

Defining the Outflow Control Device.

To define the outflow control device select the menu item **Outflow Control/Orifices**. A similar data entry form is displayed. Click on the spin-button to open a row to define an orifice. The default values suggested by MIDUSS 98 are based on the following assumptions:

The invert of the orifice will be at the bottom of the pond,

The coefficient of discharge is 0.63, and

The suggested diameter is sized to discharge 25% of the target outflow with a head equal to 1/3 of the maximum depth.

The suggested values for the orifice are shown in Figure 11-12, Press the [Compute] button to fill in the column of discharge as a function of water elevation, and then press [Accept] to close the data form.

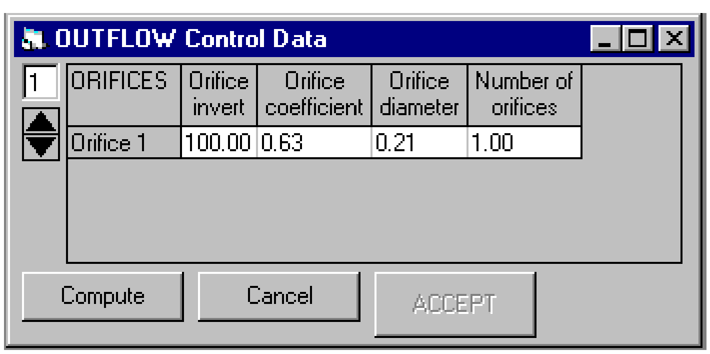


Figure 11-12 – Defining an Orifice for the Outflow Control

The outflow control should have a weir to pass the higher flows – particularly for the more severe historic storm. Select the **Outflow Control/Weirs** menu item to open a data form for the weir specification. When you open a data row by clicking on the spin-button, the default data is displayed. These data are based on certain simple assumptions:

The crest elevation corresponds to 80% of the maximum depth.

The coefficient of discharge is 0.9.

The weir breadth is estimated to pass the peak inflow with a (critical depth/ breadth) ratio of 0.2.

The side-slopes are vertical.

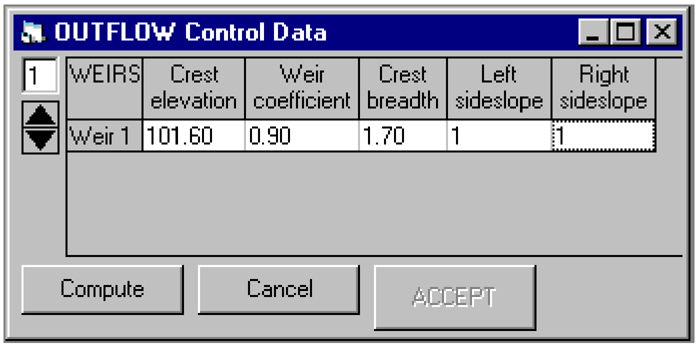


Figure 11-13 – Defining a Weir for the Outflow Control

Change the side-slopes to 1H:1V (i.e. 45°) but leave the other parameters unchanged in the meantime as shown in Figure 11-13. Press the [Compute] button. As shown in Figure 11-14, the column of discharges is updated for elevations above 101.6. Press [Accept] to close the data form.

Level	Discharge	Volume
101.100	0.09470	465.386
101.200	0.09951	531.793
101.300	0.1041	602.776
101.400	0.1085	678.454
101.500	0.1127	758.958
101.600	0.1168	844.418
101.700	0.2068	934.960
101.800	0.3783	1030.722
101.900	0.6131	1131.815
102.000	0.9072	1238.375

Figure 11-14 – The H-Q-V grid after defining a Weir.

You can plot a graph of the storage and/or discharge characteristics by selecting the **Plot/V, Q = f(H)** menu item. You can enlarge the plot (Figure 11-15) by dragging the corners of the graph window. The highly non-linear nature of the blue, stage-discharge curve is clear. You may notice a small convex segment of the orifice discharge curve below an elevation of 100.2 which is caused by the orifice operating as a circular weir.

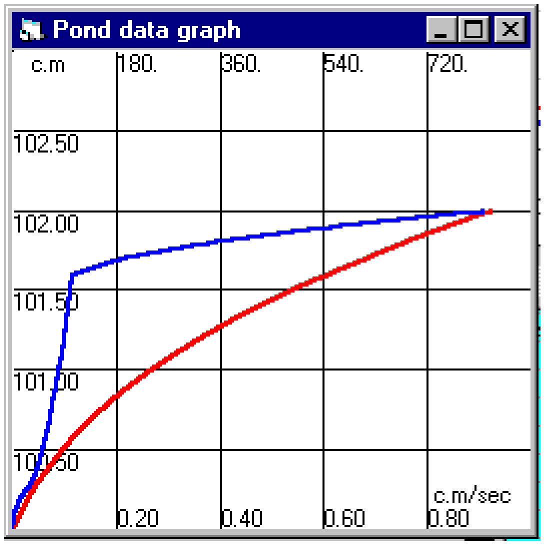


Figure 11-15 – Plot of the functions V, Q = f(H).

Refining the Pond Design

You can now press the [Route] button to see how the pond performs. From the Pond Design form it is clear that the design is very conservative. The peak outflow is only 0.129 c.m/s – well below the target outflow of 0.3 c.m/s and the storage volume is too large at 857 c.m. The weir is overtopped by only a very small head (101.614 – 101.6 or 14 mm) and only for about 15 minutes.

Of the various ways in which the outflow could be increased, reducing the land area required for the pond will probably yield the greatest cost saving. Select the **Storage Geometry/Rectangular pond** menu item to re-open the Storage Geometry Data form again. Reduce the base area to 150 sq.m and click on another cell to see the result. The surface area is reduced to under 900 sq.m. Press [Compute] to update the 'Volumes' column and then press [Route] again. The peak outflow increases to 0.233 c.m/s, the volume is reduced to 725 c.m. and the head over the weir increases to 0.115 m.

Try reducing the base area still further – say to 115 sq.m. The surface area is reduced to 800 sq.m., the maximum storage is 647 c.m. (which is within 10% of the initial estimate) and the peak outflow is still just under 0.3 c.m/s. A fragment of the Pond Design form is shown in Figure 11-15. From the Outflow hydrograph Table, you may notice a small error in the volume continuity as the pond outflow hydrograph is longer than the maximum hydrograph length so that the tail of the recession limb is truncated. The graph of the Inflow and Outflow hydrographs is shown in Figure 11-16.

Results

Peak outflow	0.298	c.m/sec
Maximum level	101.753	metre
Maximum storage	646.8	c.m
Centroidal lag	1 h : 56	minutes

Figure 11-16 – Results of the Pond Route operation.

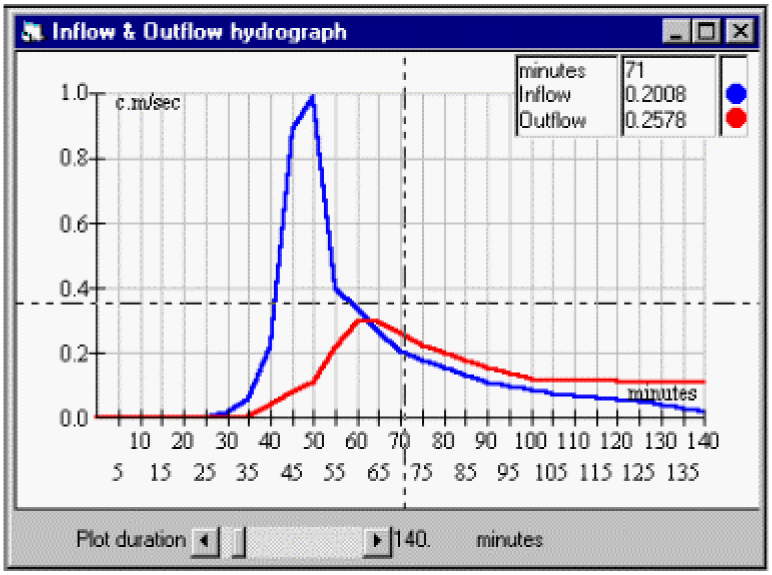


Figure 11-17 – Graphical display of Pond Inflow and Outflow

Press the [Accept] button to close the Pond Design forms. Since this is the only Pond design in this project, you can leave unchecked the box labelled 'Keep all Design Data'. You can review the iterations during this design in the Design log. If you want to keep a record of this you can use the **Design/Design Log/Print/Total Log File** or **Design…Current Design Log** menu items to print a hardcopy of the Design Log.

Saving the Inflow Hydrograph File.

As it is possible that you may want to revise the pond design when you subject it to the historic storm, it might be useful to save the pond inflow file before continuing. Select the **Hydrograph/File I/O** command to open the File Input/Output dialogue window. Perform the following steps, working in a clockwise fashion around the form.

Confirm the File Operation as 'Write to' or 'Save a file' by selecting the lower radio button.

Set the Type of File as a Flow Hydrograph by selecting the lower radio button. This causes the Flow Hydrograph frame to be displayed.

Select the desired Flow Hydrograph by clicking on the 'Inflow' radio button.

In the Drive and Directory list boxes, navigate to your Job directory

In the Hydrograph type drop-down list box, select the 'Event Hydrograph (*.005hyd)'

The file-name box shows the default '*.005hyd'. Edit this to (say) 'PondInflow.005hyd'. (Hint: click on the default name to highlight it, press the 'Home' key on the keyboard to position the text entry marker in front of the asterisk, type the desired name and finally delete the asterisk.)

Press the [View] command button to display the Graph and/or the table. This is necessary to enable the [Accept] button.

Press [Accept]. Some default text "Enter a description…" is highlighted. Type in a description of at least 20 characters (about half the width of the text box) e.g. "Inflow to pond from area #1".

Press [Accept] again to close the form.

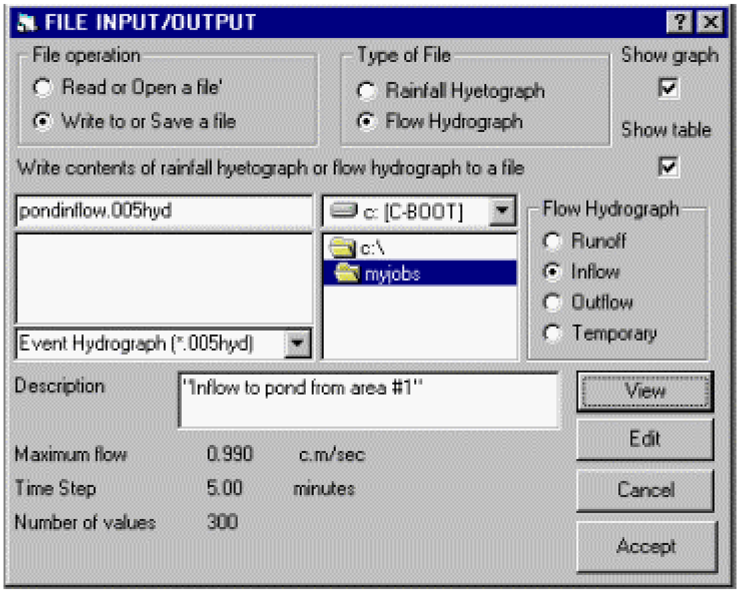


Figure 11-18 – The File I/O form is used to save the Pond inflow.

Adding Flow from the Two Branches.

When the Pond Design form was closed, the peak flows summary table was updated with a new record showing the value of 0.298 in the Outflow column. If you assume that the outflow from the pond is close to the junction node 2, you can add the pond outflow to the junction by using the **Hydrograph/Combine** command again.

The process is simpler this time as the junction node has been created. Follow the directions in the yellow box as before to:

Click on the row describing Node 2 to highlight it, This enables the [Combine] button.

Click the [Combine] button to update the peak of the total junction hydrograph to 0.534 c.m/s. MIDUSS 98 displays a message to confirm the junction file name, the peak flow and the total volume.

Click [OK] and then [Accept] to close the form.

Designing the Last Pipe

The final step in the design is to recover the accumulated flow from the Junction node 2 and design a pipe to carry this flow over the last 400 m reach.

To recover the hydrograph at Junction node 2 select the **Hydrograph/Confluence** command. Notice that in the **Hydrograph** menu, the **Hydrograph/Combine** command is disabled because a new Outflow hydrograph has not been created since the last use of Combine. This is to protect you from making the error of combining the same outflow twice.

The Confluence dialogue form in Figure 11-19 is similar in appearance to the Combine form. The [New] and [Add] buttons are disabled as they have no relevance for the Confluence operation. The 3-column list box shows the currently active junction nodes.

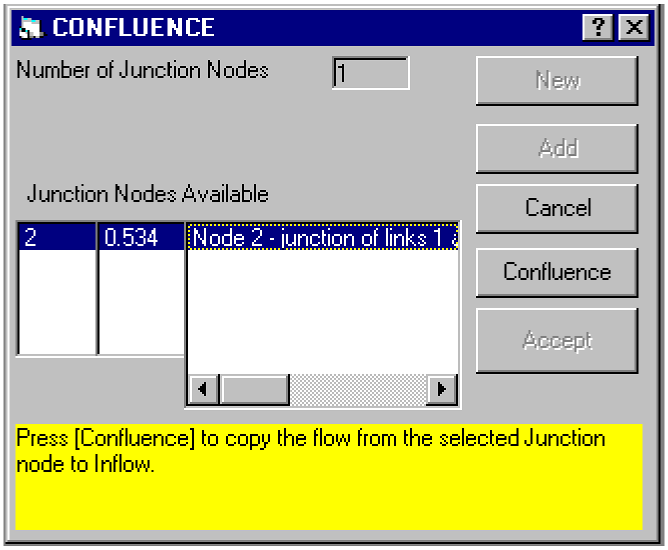


Figure 11-19 – Recovering the hydrograph at Junction node 2.

Click on the row describing Node 2 to highlight it. This enables the [Confluence] button. Pressing [Confluence] causes a message box to be displayed as shown in Figure 11-20. This reports the file that has been deleted. In fact, the file is not deleted but is renamed with the extension *.JNK. You may therefore recover the file by renaming it prior to the end of the session at which point it will be erased. Also reported is the peak flow and volume of the new Inflow hydrograph. Notice that if the current Inflow hydrograph has not been used, MIDUSS98 will provide a warning message that you will lose some data if you continue with the Confluence command.

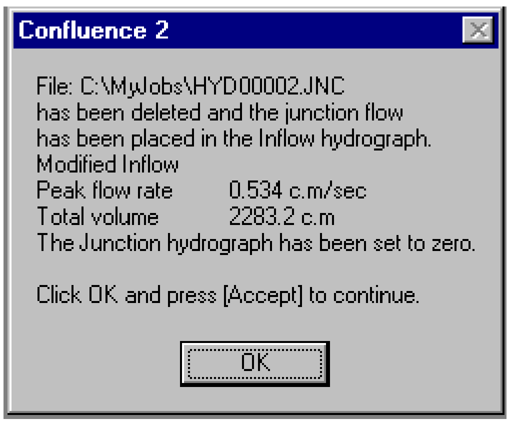


Figure 11-20 – The information message following use of the Confluence command.

The Final Pipe Design

You can now select the Design/Pipe command and design a pipe to carry the peak flow of 0.534 c.m/s. Assuming the default value of n = 0.013, a 675 mm diameter at 0.5% will carry the peak flow with a depth of 0.5 m. Note, however, that the critical depth is only slightly less than the uniform flow depth. This implies a Froude number close to 1.0 which is close to the condition of easy wave formation. You may prefer to flatten the slope slightly to (say) 0.45%.

Finally, using the Route command again yields an Outflow peak flow of 0.530 c.m/s with almost negligible attenuation and lag.

This finishes the design for the 5-year storm. You can now end the session by selecting the **File/Exit** command. Before closing down MIDUSS 98 reminds you of the name of the output file. A copy of the file 'Chap11.out' is provided for your information in sub-directory C:\…\Miduss98\Samples\.

An Automatic Design for a Historic Storm

When the design for the 5-year storm has been completed, you can check how this drainage system will respond to the more extreme event described by the historic storm defined in Table 11-3. You can use the Automatic mode to do this without having to re-enter all of the commands and data from the keyboard.

The procedure is described in the topics that follow in the remainder of this chapter and can be summarized as follows.

- Run MIDUSS 98 and define a new output file.
- Use the previous output file to create an Input Database called Miduss.Mdb that resides in the MIDUSS 98 directory.
- Run MIDUSS 98 in Automatic mode using the database as input.
- Step through the database in EDIT mode to allow you to modify the design parameters as desired.
- When the previous Chicago hyetograph is displayed, reject this and replace it with a historic storm.
- Continue with the design, making any adjustments that you may feel are appropriate. These may include some refinement of the Pond design and separation of major and minor flow components if a pipe is surcharged under the more severe storm.
- Complete the run and compare peak outflows for the two events.

First Steps

When you launch MIDUSS 98 and define the units, you will see a message prompting you to define an output file and reminding you of the last output file used. When the **File/Output file/Create New file** opens, reject this and move the mouse pointer to select instead the **File/Open Input File** command.

Two windows will open. One window titled 'Create Miduss.Mdb' is immediately overlain in part by an 'Open' file dialogue window that will show the previously selected Job Directory and the previous output file as the defaults. You can select any output files available but in this case you will convert the contents of the previous output file 'Chap11.out' to a database file called Miduss.Mdb which will be the Input for this second run.

When you click on the [Open] command button the dialogue box closes and you will probably see a standard warning message advising you that a file called Miduss.Mdb already exists in the Miduss98 folder. Click on the [Yes] button to proceed. After a few seconds processing the 'Create Miduss.Mdb' window (see Figure 11-21) will show the source data file, the number of commands processed and the number of records in the data file. If the path of the source file is too long for the form you can re-size it by dragging on the right edge. Close the form by clicking on the [FINISH] button that is now enabled.

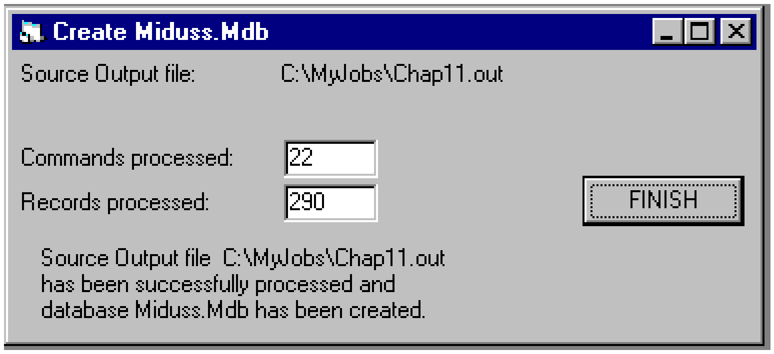


Figure 11-21 – Creating an Input Database from an Output file.

Finally, in order to enable items on the main menu, you must use the **File/Output file/Create New file** command once again to specify a new filename. If you are quite certain that you will not need the old output file you can use the same filename again and ignore the warning that the current contents will be lost. For this example, use a different filename such as ‘C:\MyJobs\Chap11B.out’.

Reviewing the Input Database

Before running the Input Database, it is worth taking a moment to review the file Miduss.Mdb. Obviously, this is an essential first step if you want to edit any of the command parameters or even just make one of the commands negative to force a continuous run to stop and revert to manual mode. Select the **Automatic/Edit Miduss.Mdb Database** command. The window shown in Figure 11-22 Is displayed. The Edit Panel controls let you navigate through the file to verify or change data.

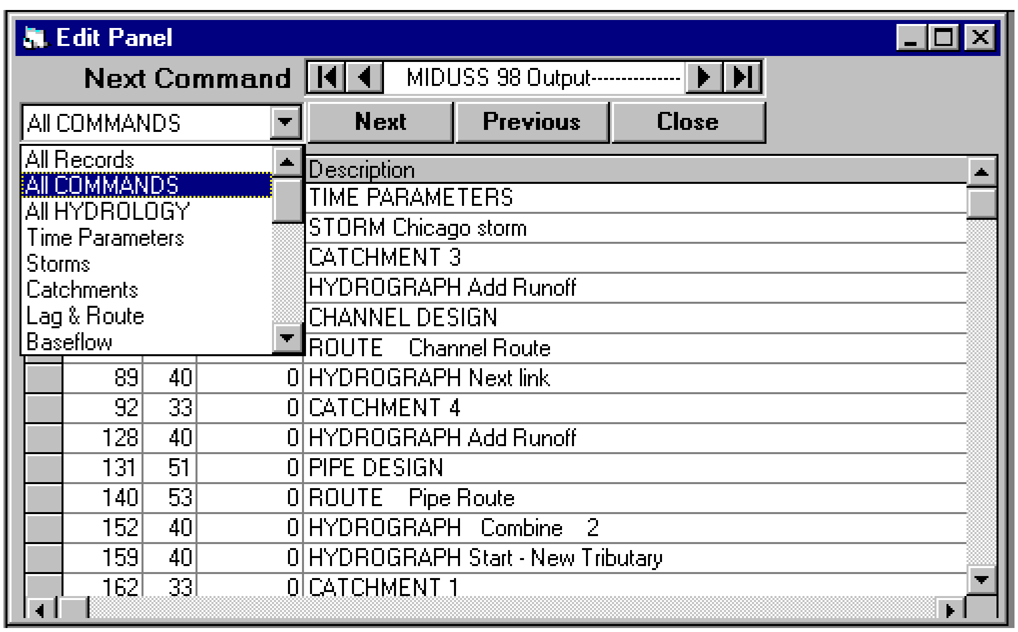


Figure 11-22 – Reviewing the Input Database.

To provide an overview of the session, you can also review a subset of the records by clicking on the down arrow and selecting a particular type of command. Figure 11-23 shows only the command lines for the total database. This was done by clicking on ‘All COMMANDS’ on the drop down list.

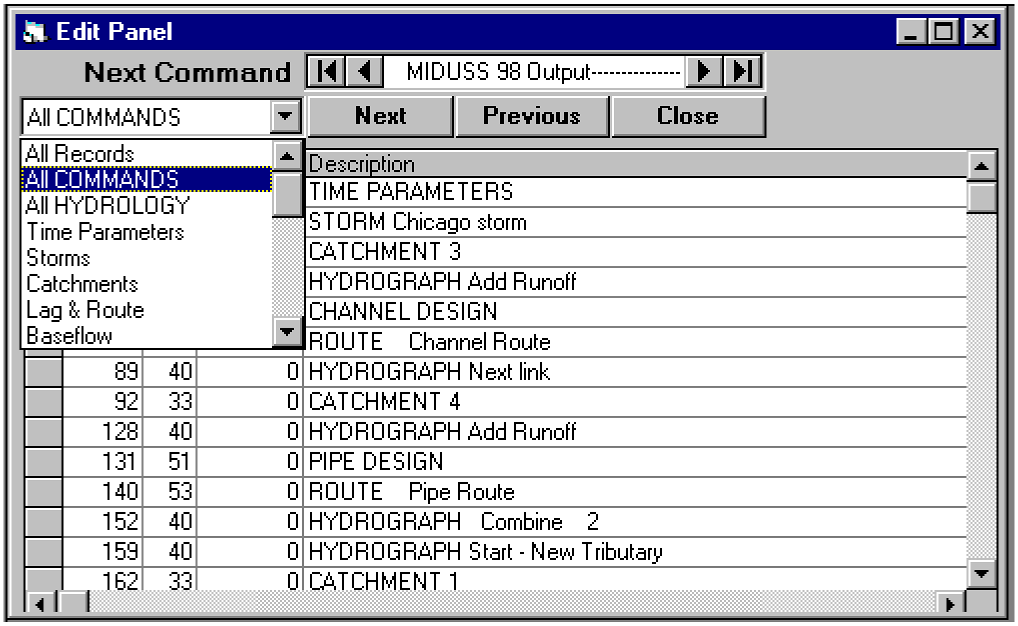


Figure 11-23 – Displaying a sub-set of the Database in the Edit Panel

Starting the Automatic Run

Select and click on the **Automatic/Run Miduss.Mdb** menu item to start the run. The Control Panel shown in Figure 11-24 Is displayed in the lower right of the screen. In its default size it displays only 9 records at a time but you can increase the height of the window by dragging on the top or bottom edge of the form.

When initially displayed, only the first 3 records have been read and the current record – indicated by the right arrow in the left margin of the grid – is about to read the units used. Note that if you have specified the wrong type of units for this input file, MIDUSS 98 will change the units for this design session to match these used when the previous run was made.

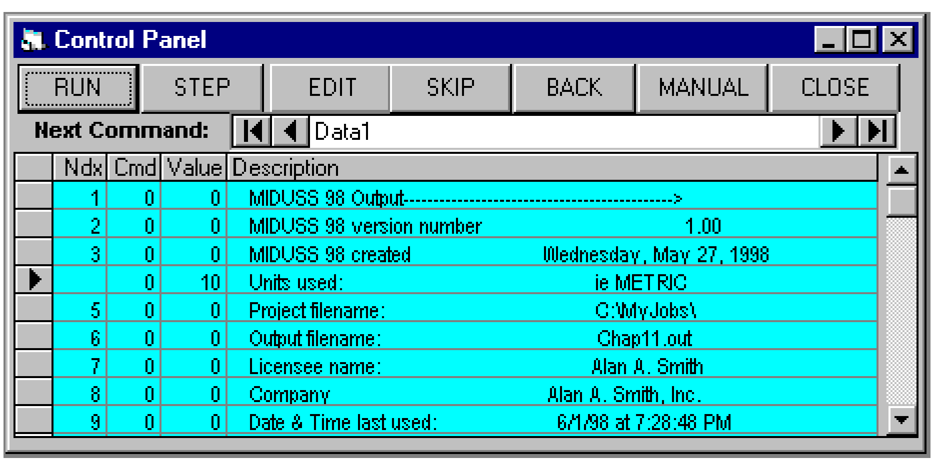


Figure 11-24 – The Control Panel for using Automatic Mode.

The default command button is [RUN] which processes the commands sequentially and continuously without giving you a chance to change or even monitor the results. In this automatic run you will use the [EDIT] button to pause after each command to display the result and give you a chance to modify the parameters.

Click on [EDIT]. MIDUSS 98 displays the Time Parameters and the mouse pointer is automatically positioned on the [Accept] button of the form. The maximum storm duration is 180 minutes, which is enough for the historic storm. Click [Accept] to close the form.

Change the Storm Event

After you have accepted the time parameters, the mouse pointer is relocated over the [EDIT] button on the Control Panel and the next record (number 14) is seen to be the Storm command. Click on [EDIT] to show the Storm window with the 2-hour Chicago hyetograph.

To change the storm the first step is to click on the Historic tab on the Storms form to display the data for the Historic storm. You should:

- Check the box labelled ‘Check to set rainfall to zero’, and
- Increase the duration from 120 to 180 minutes
- Click on the [Display] command button.

The Historic tab should be similar to Figure 11-25 below, with the exception that the Rainfall depth will be zero. The Graph window will be empty and the tabular form will have an extra row added with all the 36 cells having a value of ‘0.00’.

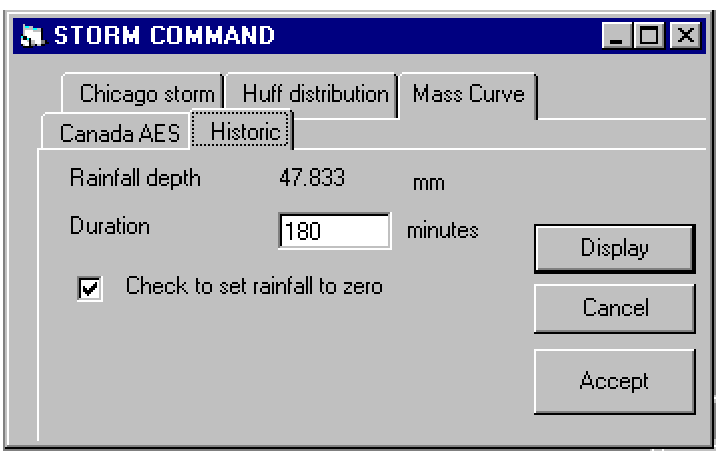


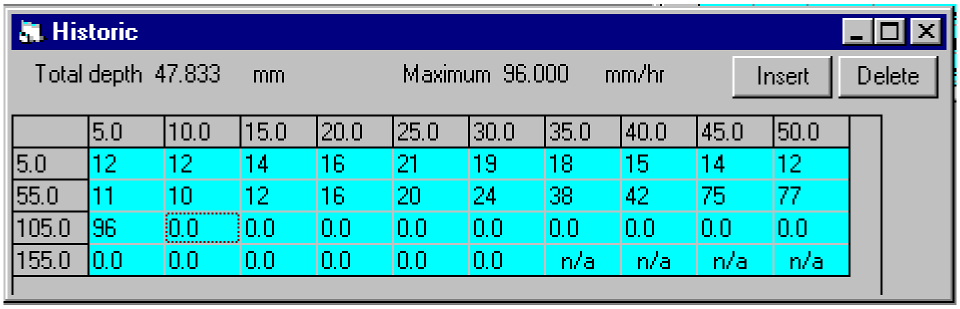
Figure 11-25 – The Historic tab of the Storms window with 21 values entered.

Defining the Historic Storm.

The Historic table is initially blank (unless you deliberately wanted to copy the previous storm intensities) and the first cell should have a slightly heavier gray outline. If it does not show this, click on it with the mouse ponter.

You can now start typing in the intensities shown in Table 11-3. As soon as you type a number (even the first ‘1’) you will notice that the first bar of the storm hyetograph is plotted and the Rainfall depth in the Storm window is updated. As each cell value is entered, use the Right-arrow key on the keyboard to advance the active cell. When you are at the right end of a row, pressing the Right-arrow will 'wrap' around to the first cell of the next row.

Figures 11-26 And 11-27 show the Table and Graph respectively at a point where 21 values have been entered. At this point the total rainfall depth is 47.833 mm as shown in Figures 11-25 and 11-26.



	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
5.0	12	12	14	16	21	19	18	15	14	12
55.0	11	10	12	16	20	24	38	42	75	77
105.0	96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
155.0	0.0	0.0	0.0	0.0	0.0	0.0	n/a	n/a	n/a	n/a

Figure 11-26 – The Historic Storm table after 21 intensities have been entered.

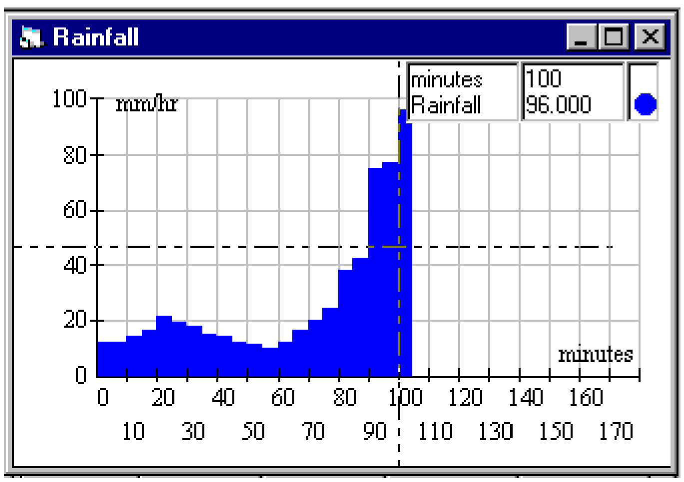


Figure 11-27 – The Rainfall Graph after 21 intensities have been entered.

After entry of the Historic storm is complete, the total rainfall depth should be 99.167 mm. Press [Accept] to close all three forms. The Storm Descriptor window is opened and contains the value of '005' used for the minor storm. If not already highlighted, click on this text box to highlight the value and replace it with '100'. When you press the [Accept] key, MIDUSS 98 displays the message shown in Figure 11-28.

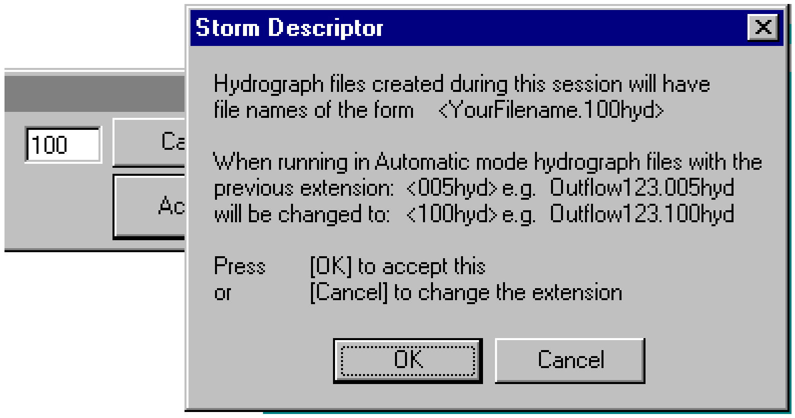


Figure 11-28 – The result of changing the Storm Descriptor.

The change in file extension means that if any hydrograph files are created they may have the same name and share the same directory as previous hydrograph files but are distinguished by a unique file extension. Click on the [OK] button to accept the default action of replacing the previous extension '.005hyd' with the new file extension '.100hyd'.

Continuing with the New Storm

The Control Panel should now show the next record (#25) as the start of the Catchment command for area 3. Click on the [EDIT] button to cause the results of this command to be displayed. The peak flow is now 0.46 c.m/s. Click on [Accept] and then on [EDIT] to execute the Add Runoff command. Click on the [OK] button and again on [EDIT] to run the Channel Design command. The depth in the channel has increased from 0.308 m to 0.458 m.

Continue in this way to Route the flow through the channel, add the runoff from area 4 and check the design of the pipe from node 4 to Junction node 2. When the Pipe Design form is displayed a message is also shown warning you that the pipe is surcharged (see Figure 11-29). Click on the [Yes] button to accept this design and return to the Pipe Design window. Then use the [Accept] command button to close the form.

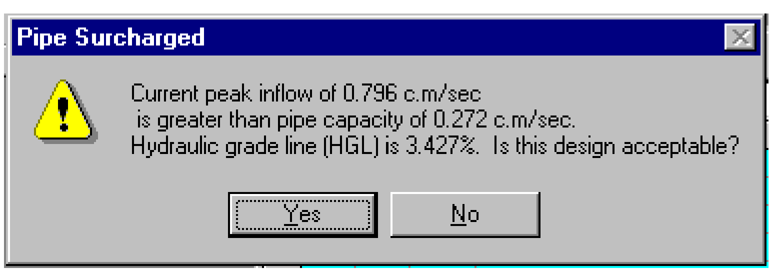


Figure 11-29 – A Warning of surcharge in Pipe 4-2.

Separating the Major System Flow

At this point you must split the Inflow hydrograph into two components:

- A minor system fraction which does not exceed the capture capacity of the pipe, and
- A major system fraction that is rejected by the minor system and which will flow on the surface – typically on the street.

You can do this by introducing a diversion device that simulates one or more catchbasins at the upstream end of the pipe. The following steps summarize the process.

(1) Revert into Manual mode for steps (2) and (3) noted below. You may find this is not always necessary but it is included here for completeness.

(2) Design a diversion structure that will split the inflow hydrograph into two components. The outflow should have a peak equal to the capacity of the pipe and the remainder will flow on the major system – typically the street.

(3) Make the Outflow from the diversion the Inflow to the pipe.

(4) Return to Automatic mode and execute the next command that will Route the captured flow through the pipe to node 2.

(5) Continue in Automatic mode.

Figure 11_30 illustrates the technique of substituting a diversion structure plus a pipe when the pipe is surcharged. At a later stage you can recover the diverted hydrograph and check the capacity of the road system to convey this flow. The procedure is described in more detail in the topics which follow.

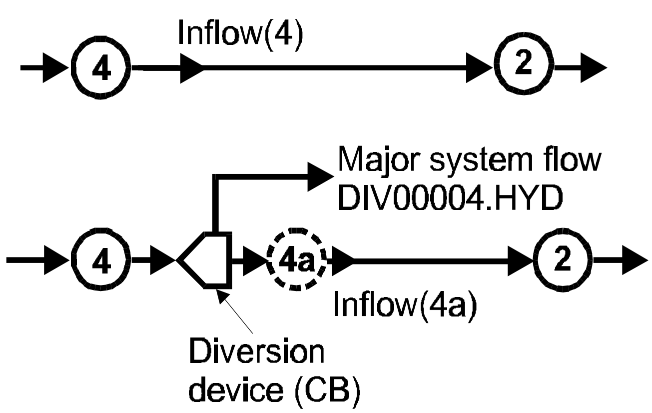


Figure 11_30 – Separating major and minor flow at a surcharged pipe.

Design of a Diversion Device.

After you have accepted the surcharged pipe design the next two commands should be executed in Manual mode. Click on the [MANUAL] command on the Control Panel to close it and revert to Manual mode.

Click on the **Design/Diversion** command. In the top two rows, the form displays the peak flow of the current Inflow hydrograph and the type and capacity of the last conduit. The node number is copied from the last Catchment area. This may not always be appropriate and you may want to edit this. In this example it is correct because the runoff from area 4 enters at node 4. When used following the design of a surcharged pipe, the Diversion sets the threshold flow equal to the pipe capacity and assumes that the diverted fraction is 1.0 – i.e. 100% of the excess flow is diverted to the hydrograph file DIV00004.HYD.

You may prefer to set the diverted fraction to a value less than 1.0 to allow for the increased carrying capacity of the pipe under surcharged conditions, i.e. when the hydraulic grade line is steeper than the pipe gradient. Also, if the catchbasins are fitted with inflow control devices (ICDs) you may set the threshold to a value less than the pipe capacity.

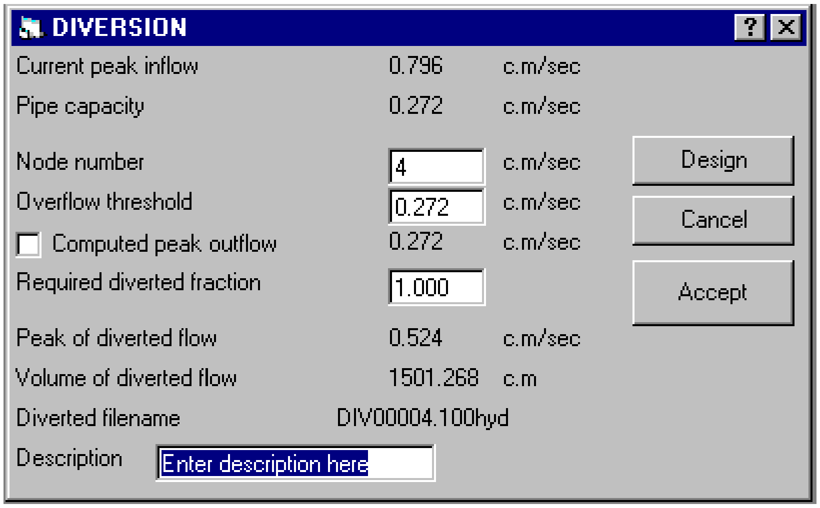


Figure 11_31 - The initial state of the Diversion Command window.

Figures 11-31 and 11-32 show the result of the Diversion operation. Before closing the form with the [Accept] button you should enter a description such as “Major flow hydrograph at Node 4”. In Figure 11-32 the Outflow hydrograph exhibits a plateau or constant value because 100% of the excess inflow is diverted. If the diverted fraction is less than 1.0 the ‘plateau’ will show some increase above the threshold flow rate.

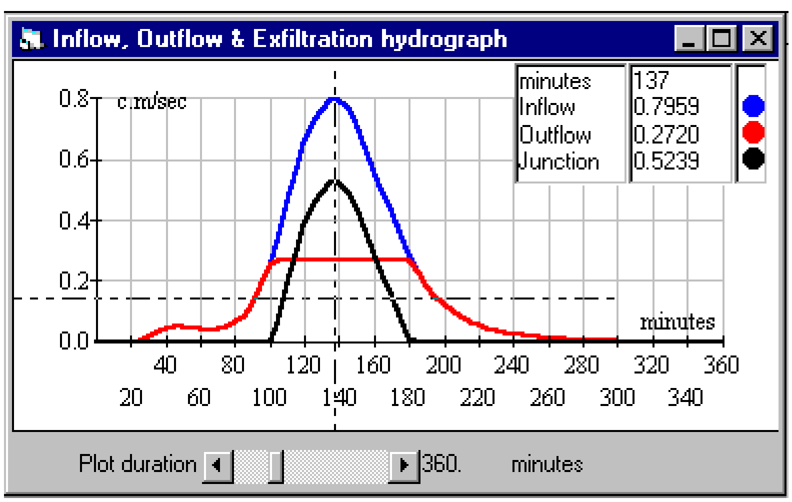


Figure 11-32 – Graphical display of the Diversion operation.

The outflow from the diversion can now be converted to the inflow to the pipe by using the Hydrograph/Next Link command. The result is seen in the Peak flow summary table of Figure 11-33.

PEAK FLOWS (11)

No.	Command	Runoff	Inflow	Outflow	Junction
7	Catchment 4	0.399	0.452	0.452	0.000
8	Add Runoff	0.399	0.796	0.452	0.000
9	Pipe Design	0.399	0.796	0.452	0.000
10	Diversion 4	0.399	0.796	0.272	0.000
11	Next link	0.399	0.272	0.272	0.000

Figure 11-33 – Peak flows summary after the Diversion

Continuing in Automatic Mode

You can now resume the automatic processing of the commands in the Input database file. Select the **Automatic/Run Miduss.Mdb** command. The Control Panel will re-open at the point where it was interrupted. Although the pipe-flow has been reduced to the full-pipe capacity, flood routing is not physically possible. MIDUSS 98 displays a warning message that gives you the choice to simply copy the Inflow to the Outflow (i.e. with neither attenuation nor lag) or cancel the route operation to re-design the pipe. Click on the [Yes] button to choose the first option.

You can continue with the automatic processing (using the [EDIT] command to store the outflow from the pipe at junction node 2, start the new tributary at node 1 and compute the runoff from area 1. The flow entering the pond now has a peak of 1.154 c.m/sec. The peak flow is 16% greater than previously but, at 4176 c.m the volume is almost three times larger. It is likely, therefore, that the outflow control can be left unchanged but the storage will have to be increased by using more area.

Refining the pond Design.

When the Pond design is executed in automatic mode the concern expressed in the previous topic is confirmed by MIDUSS 98 with a warning message in the Pond window to the effect that the upper limit of either the discharge or storage is too small to route the increased hydrograph. The storage routing function $(Q + 2S/Dt)$ involves both discharge and storage volume and the design could be adjusted by either increasing one or the other or both. Assume that you will provide more storage since the Pond Design form shows that a required volume of over 2000 c.m. is necessary to reduce the outflow to less than 0.6 c.m/sec.

Click on the **Storage Geometry/Rectangular pond** menu item to re-open the data table. Previously, only one layer covering the total depth of 2.0 m was used. Make the changes shown in Figure 11-34. This introduces a 15 m wide step in the side-slope at a level of 101.2. This greatly increases the land area required (from 1094 to 2745 sq.m) but more than doubles the maximum volume from 1238 c.m. to 2516 c.m.

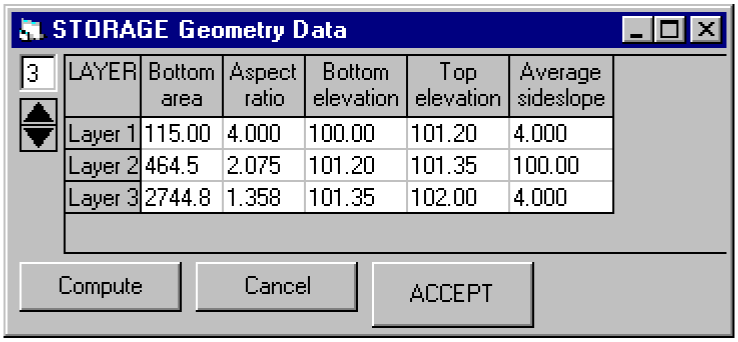


Figure 11-34 – Providing extra storage capacity in the pond.

The stage-discharge curve remains unchanged but the increase in storage is sufficient to enable routing to be completed with a peak outflow of 0.623 c.m/sec and maximum storage of almost 2200 c.m. You can experiment further with changes to both geometry and discharge control, but for this example you should accept this design and continue with the automatic design session.

Completing the Automatic Design Session

If you check the next record in the Control Panel you will see that this was the point at which the 5-year Inflow to the pond was saved as a file. You may wish to refine the design of the pond still further in a separate design session, so it would be useful to save the Inflow for the historic storm as well. Should this not be required you could easily avoid processing this command by pressing the [SKIP] button. However, assume that this is not the case.

When the **Hydrograph/FileI/O** command is executed from the Input database, a message is displayed as shown in Figure 11-35.

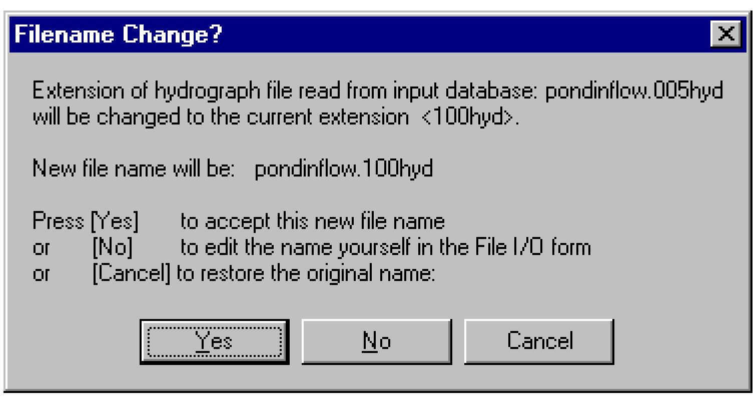


Figure 11-35 – MIDUSS 98 automatically changes the file extension.

MIDUSS 98 recognizes that the hydrograph file extension has been changed for the historic storm and gives you the choice to accept the modified filename, keep the original name (most unlikely!) or enter a special filename.

Click on the [Yes] button to accept the change in the file extension. The File Input/Output window remains open to allow you to edit the description should you wish to do so. Add to the previous description so that it now reads “Inflow to Pond from area #1 *for the Historic storm*”. Finally, press the [Accept] button to close the form.

Designing the Final Pipe.

Continue with the automatic processing to use the **Combine** and **Confluence** commands. This yields an inflow to Pipe (2) - (5) with a peak of 0.895 c.m/sec. You can see from record 276 in the Control Panel that the pipe capacity is 0.564 c.m/sec, so this pipe is surcharged as well. If the capacity had been greater than the inflow from Junction node 2 you would have had to check if any fraction of the major system flow from reach (4)-(2) could have been captured by the minor system at this point.

The process of separating the major and minor flow hydrographs is repeated here. You should do the following.

- Run the Pipe command from the input database and accept the surcharged design
- Revert to Manual mode by pressing the [MANUAL] command button in the Control Panel..
- Use the Diversion design to generate the hydrograph file DIV00002.HYD with a peak of 0.331 c.m/sec. Note that you will need to specify a node number of ‘2’ instead of accepting the default of ‘1’.
- Select the **Hydrograph/Next Link** command to make the inflow to the pipe equal to the pipe capacity of 0.564 c.m/sec.
- Use the **Automatic/Run Miduss.Mdb** command to resume automatic processing.
- Run the Route command and when prompted to do so, press the [Yes] button to copy the Inflow to the Outflow at node 5. The peak outflow is equal to the pipe capacity of 0.564 c.m/sec.
- Complete the automatic processing by pressing the [EDIT] button to execute the ‘EXIT’ command This closes the Input database.
- Click on the [CLOSE] button to close the Control Panel.

Checking the Major System Flow.

The remainder of the design can be completed in Manual mode. This involves the following steps.

(1) Save the pipe outflow at node (5) with the Combine command.

(2) Recover the major system flow in the surface link from node (4) to (2).

(3) Check the capacity of a typical road profile assuming a road grade of 0.5%.

(4) Route this over some fraction of the reach length – say half of the length of 350 m .

(5) Add the routed flow to the surface flow from file DIV00002.HYD

(6) Check the total major system flow on the road cross-section from the junction node (2) to the Outlet node (5).

(7) Add the minor and major flows at node (5).

Before starting on the major system analysis, select the **Hydrograph/Combine** command and accumulate the outflow from the pipe at node (5). The total volume of the minor flow is 5494 c.m. with a peak of 0.564 c.m/sec.

Defining the Road Cross-Section

Select the Hydrograph/FileI/O command and in the 'File Operation' frame click on the 'Read or open a File' radio button. Next, navigate to your job directory by double clicking on Drive C: and then double click on directory 'MyJobs'. Select the File type of 'Event Hydrograph (*.100hyd)'. You should see the File Input/Output window as shown in Figure 11-36.

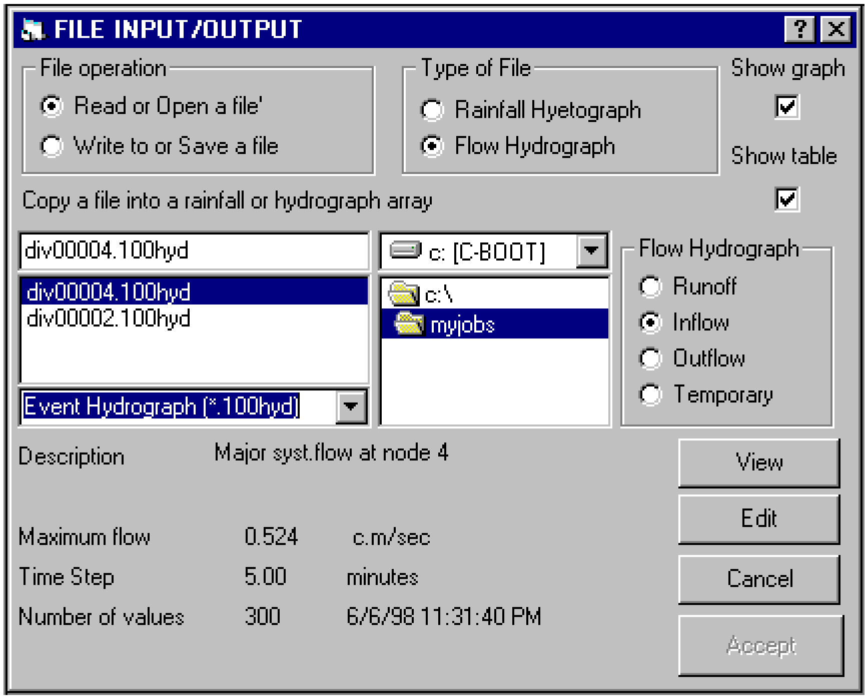


Figure 11-36 – Use the File Input/Output command to recover the Diverted flow hydrograph

Click on the 'Inflow' Flow hydrograph radio button to import the hydrograph in file 'div00004.100hyd' into the Inflow. The hydrograph has a peak of 0.524 c.m/sec, a volume of 1501 c.m and an effective duration of only 85 minutes.

Defining a Road Cross-section as a Channel

You can check the capacity of the major system by defining a channel cross-section which approximates a typical urban road cross-section.

Select the Design/Channel command to open the Channel Design window. Before sketching the cross-section, set the horizontal and vertical scales (in the top right corner of the form) to contain a width of 20 m and a depth of 1.0 m.

You can sketch the shape approximately by watching the coordinates of the mouse pointer. Use 7 or 8 points to define boulevard slopes of around 2.5%, curb heights of 0.15 m and a road crossfall of 2% over a road-width of 10 m between curbs. Remember to use the secondary mouse button to define the last point.

You can refine the coordinates by clicking on one of the X or Y coordinate cells and typing an accurate value. You can move the active cell by means of the left and right arrow keys. A trial section is shown in Figure 11-37. Note that the [Design] command is not enabled until you press the [OK] button to indicate that editing of the cross-section coordinates has been completed.

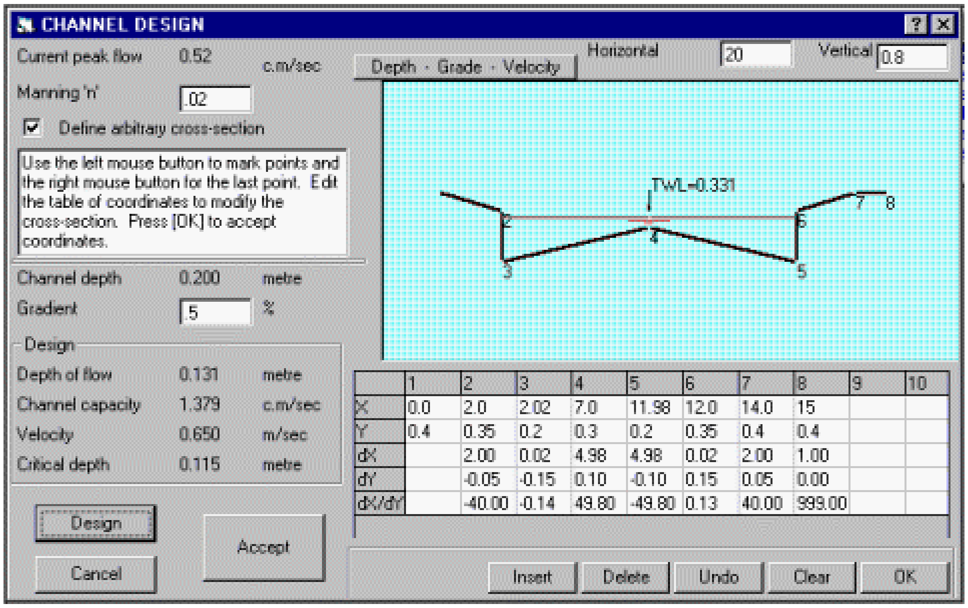


Figure 11-37 – Sketching the road cross-section for the major flow.

To complete the design you must specify a value for Manning's 'n' and a longitudinal road gradient. Try n = 0.02 and a grade of 0.5%. The final design is shown in the figure.

You can use the **Design/Route** command to get the Outflow from the major system at node (2). An average reach length of (say) 175 m would be reasonable but in practice, the attenuation is negligible.

At junction node (2) the added contribution to the major flow can be obtained by using the **Hydrograph/Next Link** command and then importing the file 'div00002,100hyd' into the Runoff flow hydrograph.

To add the two hydrographs you can use the **Hydrograph/Add Runoff** command. This is one of the situation in which MIDUSS 98 will issue a warning that perhaps you should have used the **Hydrograph/Start/New Tributary** command. However, you can press [Yes] to force the addition in this case.

The total major system flow is 0.845 c.m/sec with a volume of 2230 c.m.

A Second Channel Command

When you use the **Design/Channel** command to check the road section capacity from node (2) to the outlet, it appears as though the previous cross-section has been lost. However, when you check the 'Define arbitrary cross-section' box, the data is restored. Pressing the [Design] button shows that for the same roughness and gradient, the maximum depth is increased only slightly from 0.131 m to 0.161 m.

As with the previous routing operation, no significant attenuation occurs between node (2) and the outlet at node (5). Then, using the **Hydrograph/Combine** command to add the outflow of the major system to the minor flow, you will obtain a total outflow peak of 1.414 c.m/sec with a volume of 7724 c.m.

This concludes the design session. A copy of the output file 'Chap11B.out' is provided in the …\Samples\ sub-directory.

Generating a Custom Plot

Once the design has been completed you may want to generate one or more figures for inclusion in the report. During both the manual and automatic design sessions you have the opportunity to use the **File/Print/Miduss Window** menu command to make a hard copy of any of the screens. However, you will quite likely require a customized plot of one or more hydrographs, together with a storm hyetograph. In addition, you may need to compare data from different design sessions – such as pre- and post-development hydrographs – or add information to illustrate a point. This section will illustrate how you can do this for the design which you have just completed using the **Show/Graph** menu command.

To do this you will run MIDUSS 98 a third time using the second output file in automatic mode. The object is to produce a diagram to show the three runoff hydrographs from areas 1, 3 and 4 together with hyetographs of storm rainfall and effective rainfall on the impervious and pervious fractions respectively..

This design session will use the previous output file to generate an input database and write the results to a temporary file in the same Job directory. The procedure is described in the topics that follow. These can be summarized as follows.

- Run MIDUSS 98 and define a new output file. Use the previous output file to create an Input Database called Miduss.Mdb that resides in the Miduss98 directory.
- Run MIDUSS 98 in Automatic mode using the database as input.
- Set one or more points in the input database where you want to carry out some manual operations.
- Run MIDUSS 98 in automatic mode using the [RUN] command button in the Control Panel,
- Use the **Show/Graph** command to create one or more graphs to print out.

Setting up the Necessary Files

After MIDUSS 98 has started and you have selected Metric units, you should define a new output file called 'C:\MyJobs\Temp.out'. Next, generate a new input data base 'Miduss.Mdb' by selecting the **File/Open Input File** command using the previous output file 'C:\MyJobs\Chap11B.out'.

Once the database has been created, use the **Automatic/Edit Miduss.Mdb Database** to review the commands. Assume that you want to display a figure showing all three runoff hydrographs from areas 1, 3 and 4 together with a plot of the historic storm hyetograph.

- Using the [Next] command button on the Edit Panel, move the arrow indicating the active record to record #65, immediately after the Catchment 3 command. Using the mouse pointer, click with the primary mouse button on or in front of the Command 40 in column 2. If the '40' is highlighted, type in '-40' in column 2 of the 'HYDROGRAPH Add Runoff' command. If the value is not highlighted simply type '-' (negative) in front of the '40',
- Repeat the process at record #132, immediately after the 'Catchment 4' command.
- Repeat the process again at record #214, after the 'Catchment 1' command. Note that this is the largest of the three runoff peaks with a value of 1.154 c.m/sec.

You can now close the Edit Panel by clicking the [Close] command button. You are now ready to start the second run in automatic mode.

A Second Automatic Run

Select the **Automatic/Run Miduss.Mdb** menu command to open the Control Panel. This time, instead of using the [EDIT] button, click on the [RUN] command button. Depending on the speed of the computer, you may see some of the detail as the commands are processed in sequence. When MIDUSS 98 encounters the negative command number it does three things:

- The negative command number is restored to the same positive value.
- The automatic mode reverts to the [EDIT] mode instead of the continuous [RUN] mode.
- MIDUSS 98 displays a message advising you what has been done as shown in Figure 11-38.

Figure 11-38 – Message displayed when MIDUSS 98 encounters a negative command number.

Plotting a Hyetograph and Hydrograph

You may prefer to revert to Manual mode by clicking on the [MANUAL] button on the Control Panel but this is not necessary.

Select the Show/Graph menu command. A blank plotting form is displayed (approximately full screen size for 640 x 480 screen resolution) together with a special menu. Assume that you want to plot the hydrograph on the bottom edge and the inverted storm hyetograph on the top edge of the form. Remember that you will want to plot two other hydrographs on this diagram so the vertical scaling should be adjusted to suit the maximum flow rate which was 1.154 c.m/sec for catchment #1.

- Select the menu item **Scale/Plot Rainfall on…** and click on **Top Axis** if this is not already the default.
- Select **Scale/Lower fraction 0.650** . A small window opens prompting you to enter the desired lower fraction of the plotting area on which the hydrographs will be plotted. Change the default of 0.65 by typing in 0.75.
- Select **Scale/Maximum flow 0.500 c.m/sec** and type in a peak flow rate of 1.2 in the text box.

When you have set the Scale factors the Scale menu should be as shown in Figure 11-39

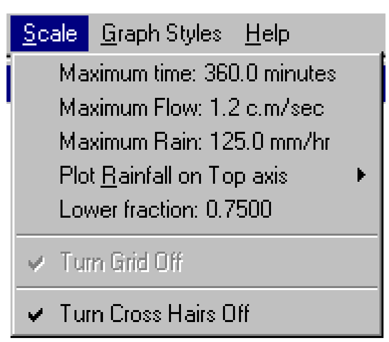


Figure 11-39 – Setting the Scale factors

Select and click on the menu command **Plot/Select Hydrograph…/Runoff**. The menu items **Plot/View Selected Item** and **Plot/Draw Selected Item** are enabled and modified to read **Plot/View Runoff hydrograph** and **Plot/Display Runoff Hydrograph** respectively and the mouse pointer is positioned between them. Move the mouse pointer down to highlight the **Display Runoff Hydrograph** item. Click on it to draw the first hydrograph with a small text legend to show the peak value of 0.460.

Adding the Rainfall Hyetographs

To add the storm hyetograph, select the menu command **Plot/Select Rainfall…/Storm** and click on it. The bottom item on the **Plot** menu changes to **Draw Storm Hyetograph**. Click on it to draw the storm rainfall inverted on the top edge of the window, with values of intensity shown on the right-hand vertical axis. If you want to estimate the value of intensity at any point with greater accuracy, you can move the mouse pointer with the primary button held down to display the cross-hairs. In this mode the title bar of the GRAPH window displays the coordinates of the mouse pointer expressed in the units of the most recently plotted object. Figure 11-40 shows a fragment of the window with this feature after plotting the storm hyetograph. In the title bar, X is the time in minutes and Y is the intensity in mm/hr.

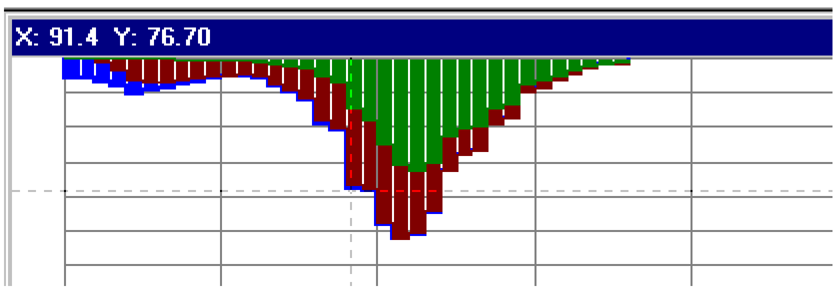


Figure 11-40 – Using the cross-hairs to interrogate the storm hyetograph.

If you want to add the effective rainfall hyetographs for the impervious and pervious fractions you can do this easily by repeating the process for these items. Note that since each plotted item overlays the previous one(s) you must draw the filled bar graphs in this order in order to see all of them.

In order to continue with the automatic run, you should use the **File/Minimize Form** command to reduce the window to an icon. Later, you can use the **Show/Graph** menu command to restore it without loss of data. Note that you cannot return to the main menu (with the **File/Main Menu** command) without losing all of the data that has been plotted so far. Should you try to do this – either intentionally or in error – a warning message is displayed.

Adding the Other Hydrographs to the Plot

Once the Graph window has been iconized you can press [RUN] on the Control Panel once again. There are a few steps associated with the surcharged pipe which require you to confirm the action but processing is otherwise automatic until the runoff from area #4 has been calculated.

Use the Show/Graph command to re-open the Graph window. From the graph menu select the Runoff hydrograph with the **Plot/Select Hydrograph/Runoff** command and add it to the plot with the **Plot/Draw Runoff Hydrograph** command.

You can repeat the process to:

- Iconize the Graph window
- Run the input database to compute the runoff from area #1
- Re-open the Graph window
- Select the third runoff hydrograph, and
- Add it to the plot.

You should now have a plot showing three hydrographs and three hyetographs.

Adding Explanatory Text

Before printing it you should add some text to identify the area from which each hydrograph is generated. The following steps describe the process.

(1) Use the **Edit/Erase a rectangle** command to draw a space (i.e. erasing a portion of a grid line) to the right of (say) the value of 1.154 on the hydrograph from area #1. You may clear similar rectangles to the right of the other two values.

(2) Select the **Edit/Enter Text Mode** command. The mouse pointer changes to a 'writing hand' as a reminder. Click the primary mouse button at a location where you want to enter text. The mouse pointer changes to a cross and any character you enter from the keyboard will be in the lower right quadrant of this cross. You can position the cross and click again to adjust the location.

(3) Type 'Runoff from Area #1'. Be careful because errors can be corrected only by using the **Erase a rectangle** tool.

(4) You may relocate the cross pointer and enter other items of text.

(5) Press either the Escape or End key to restore the 'writing hand' mouse pointer. At this stage, only the **Enter Text Mode** and the **Font items** are enabled in the **Edit** menu. This allows you to alter the style and colour of text.

(6) To finish entering text, click on the checked menu item **Enter Text Mode** to return to the normal mouse icon and re-enable the menu items.

Appendix A

References

The following references may be found useful for further information on modeling of hydrology and storm water management. Several of these relate to specific topics covered in this help file while others are of more general application to hydrology and stormwater management. Of the latter, a number of titles have been suggested by contributors to the SWMM-Users Internet List Server operated at the University of Guelph, Ontario by Dr. William James.

To subscribe to the SWMM-Users List send email to:

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RIVERNET-INFO@IGC.APC.ORG

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SWMM-USERS@LISTSERV.UOGUELPH.CA

URBAN-DRAINAGE@MAILBASE.AC.UK

WASP-USERS@LISTSERV.UOGUELPH.CA

WATER-L@LISTPROC.WSU.EDU

WATER-DISTRIB-SYSTEMS@MAILBASE.AC.UK

WATER-ED@LISTSERV.UOGUELPH.CA

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Appendix B

Transferring a MIDUSS 98 License

This appendix describes the procedure for transferring a MIDUSS 98 license from one computer to another. One machine is called the Source computer and has an authorized license with 1 or more copies shown in the Authorization Information window. The other machine is called the Target computer on which the MIDUSS 98 software has been installed but not authorized.

The transfer of the license is done using a floppy disk (3.5" or 5.25"). Both computers must have the same type of floppy disk drive designated as Drive "A" on both machines. In summary the process is as follows:

Identify the Target machine that is to receive a new or updated license. Insert a diskette on which a 'fingerprint' of the Target computer is written.

Copy the license information from the Source machine on to the diskette containing the fingerprint of the Target computer.

Copy the license authorization from the diskette to the Target machine.

On the Target machine a current copy of MIDUSS 98 is installed. This MIDUSS 98 installation may be in any of these states.

- It may have a few days of a trial period left.
- It may be authorized but require updating to a new level or version
- The trial period may have been exhausted.

The three steps are described in the following topics.:

Step 1 Register the Target computer

Step 2 Copy a License to the Diskette

Step 3 Transfer the License

Step 1 Register the Target computer

1.1 Insert a diskette into the Target computer.

1.2 Run MIDUSS98. Two displays are possible.

1.3 If MIDUSS98 is still authorized the screen of Figure B-1 will be displayed showing the current authorization. Press [Change Authorization].

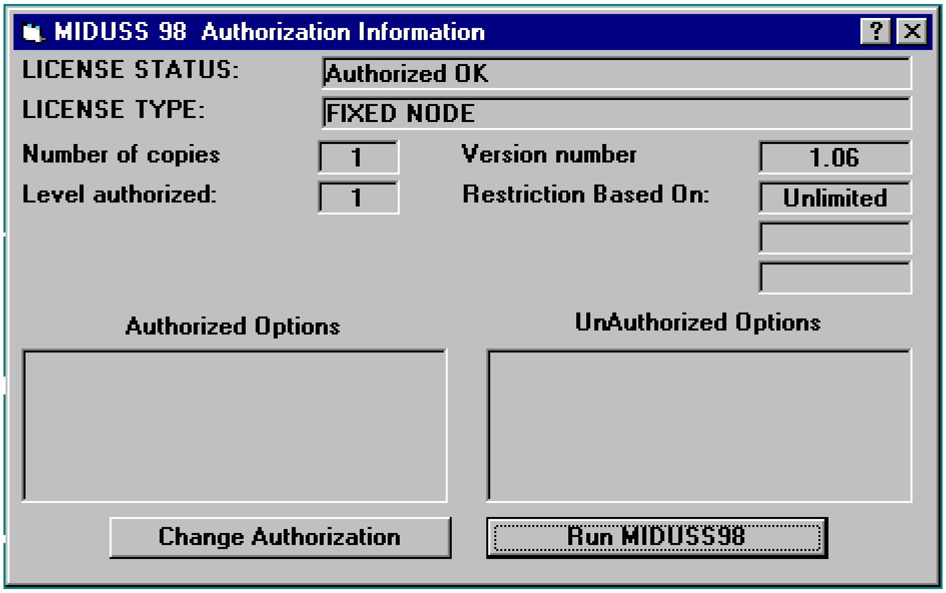

Figure B-.1 - Miduss98 Authorization Information

1.4 If no authorization is present the warning message of Figure B-2 is displayed. Press the [Yes] button to proceed with License upgrade or [No] to cancel the operation.

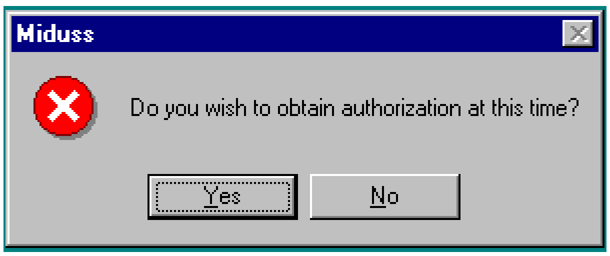

Figure B-2 - Do you wish to obtain authorization at this time?

1.5 The Authorization window is displayed as shown in Figure B-3. The process of transferring license uses only the command buttons at the bottom of the form. Press the [Register] button.

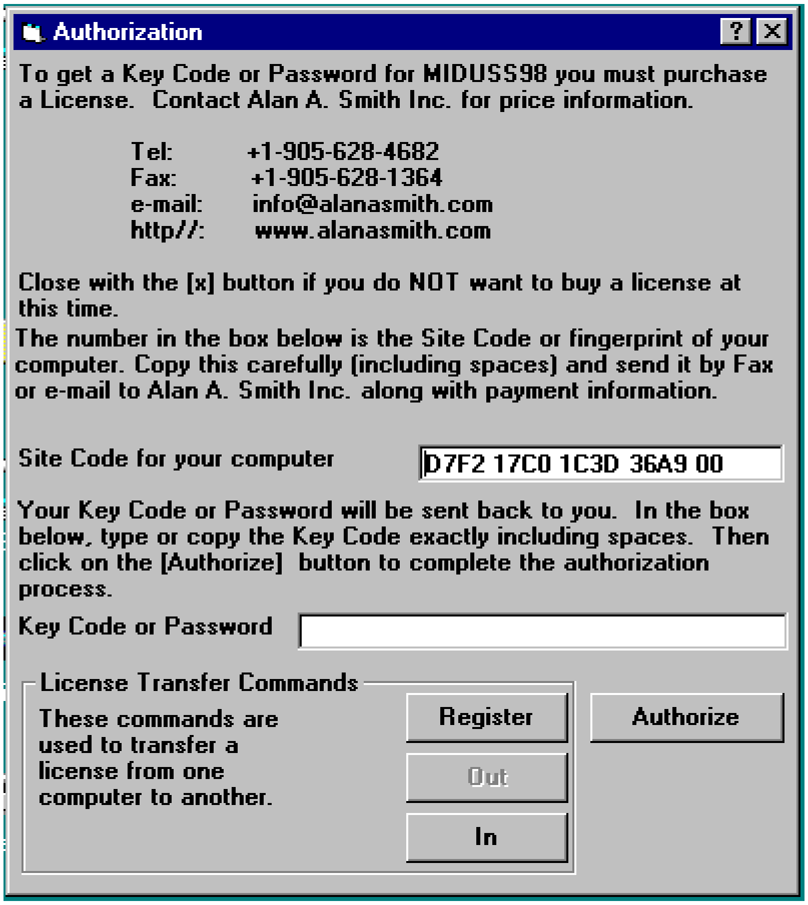

Figure B-3 - Authorization or MIDUSS98 Authorization

1.6 The activity light on the disk drive indicates that a file is being written on the diskette. When finished, the message box of Figure B-4 is displayed.

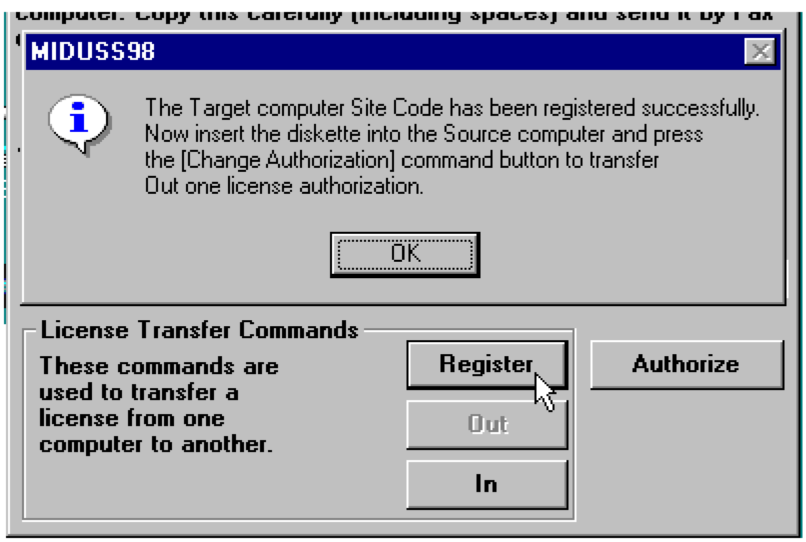

Figure B-4 Successful completion of registering the Target computer.

Because no transfser of authorization has yet occurred, you will see a message as shown in Figure B5 saying that authorization has not been enabled. This is normal and will be corrected in Step 3.

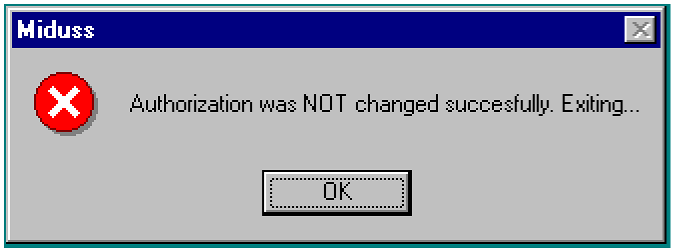

Figure B-5 – Registering the Target computer has not transferred Authorization

Step 2 Copy a License to the Diskette

2.1 Remove the diskette from the Target computer and insert it in the drive of the Source computer.

2.2 Run MIDUSS 98 on the Source computer. An Authorization Information window similar to Figure B-1 is displayed but showing the status of the authorization on the Source computer. There must be at least one copy available on the Source computer.

2.3 The [Out] button is enabled. When you press this the activity light of the diskette drive indicates that the registration information on the diskette is being read and license information is being written on to the diskette.

2.4 When the process is completed the message box of Figure B-5 is displayed. Press the [OK] button and remove the diskette from the Source computer.

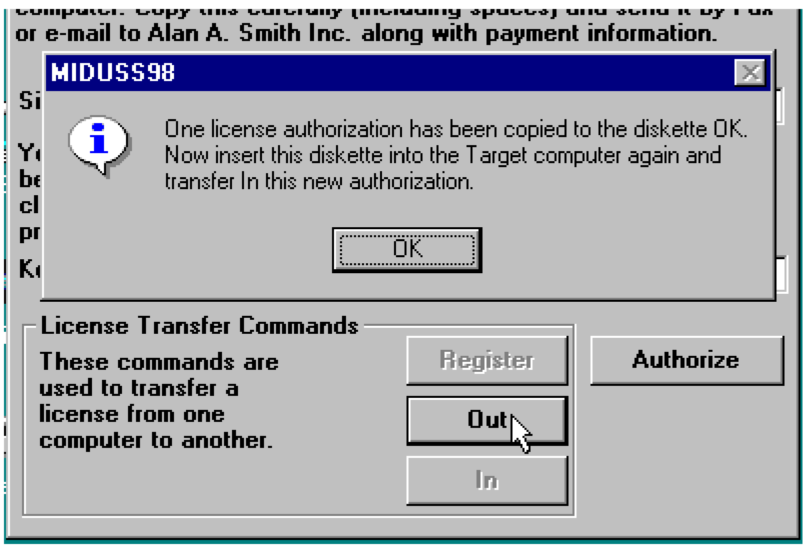

Figure B-6 - License from Source computer successfully written on the diskette.

Step 3 Transfer the Authorization to the Target computer

3.1 Insert the diskette into the drive of the Target machine

3.2 If the Authorization window is no longer visible, run MIDUSS 98 again and repeat steps 1.2 and 1.3 to display the Authorization window. The [In] button is now enabled.

3.3 Press the [In] button.

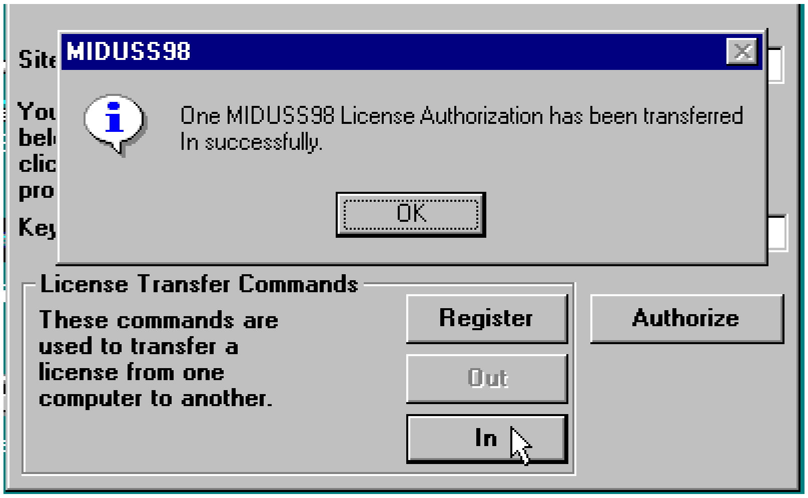

Figure B-7 - Successful transfer of authorization to the Target computer.

3.4 Click on [OK]. You should now see the Authorization Information form showing the new license. Typically, this will have unrestricted access.

MIDUSS 98

MICROCOMPUTER
INTERACTIVE
DESIGN OF
URBAN
STORMWATER
SYSTEMS

MIDUSS 98

USER MANUAL

and

HELP SYSTEM

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