WaterCress User Manual

January 2011

Contents

1.0 MODEL DESCRIPTION

1.1 Basic Functions - What WaterCress Does

WaterCress (Water Community Resource Evaluation and Simulation System) is a PC based, continuous time series, total water cycle model, which simulates the passage of flows through natural and constructed water systems. The model provides statistics on the flows and storages within the water system over the period of modelling, thus providing information on the performance of the system against desired outcomes or against alternative system layouts.

At its core is a model to convert catchment rainfall to runoff, but flows may also be introduced as flow records. The model then tracks flows through water systems established by the user at continuous equal time-steps of one day, 2hrs, 1hr or 30 mins. Thus the model may be used for both flood and water supply designs.

The model tracks salinity as a conservative parameter including changes as water of variable salinity is injected, stored and recovered from saline aquifers. The model also tracks water within broad quality categories so that different water paths can be reserved to supply different quality demands.

The central features of WaterCress are:

1. An assembly of icons representing specific components of a water system. These can be clicked and dragged onto the spatial layout page and joined by flow paths in order to simulate the water system to be trialled. These icons represent all conventional water supply and use components, such as catchments, dams, treatment plants, aquifers, in-house demands, irrigation areas, pumps, etc., but present them in a manner which allows trialling of non-conventional supply sources and management processes at a range of different scales.
2. A set of core mathematical relations and data bases which contain all variables and limits necessary to enable the quantities and qualities of water to be estimated and tracked through a specified water system. The water inputs to the model are generally derived from one or more sets of sequential rainfall data bases of adequate length suited to the trial area. Water is moved through the model to satisfy seasonally variable water demands, as modified by evaporation and direct rainfall. Secondary data sets define the sizes and rates of all components in the assembled water system as they pass the water through the system.
3. A series of tabular and graphical outputs which can be chosen and assembled from an output format menu. These provide the record of performance of any one, or group of components within the system. The performance will usually be assessed by the designer on the basis of the amount, reliability and quality of water supplied over the period of record and/or the size and frequency of peak flow rates, etc.

The model can represent the operation of 'total water cycle' systems with flows generated by rural or urban catchments, passing via natural or engineered drainage paths into and through water supply, sewerage and groundwater systems.

The layouts modelled may range from single on-site system scale to regional scale, including a mixture of different scales.

Water is moved through the system at a continuous sequence of fixed, selected time steps. The water balance is recalculated during each time step to account for all the activities performed in the nodes.

A group of components or nodes with their flow links is defined in WaterCress as a Project.

1.2 Typical Model Uses

The model is designed to meet the problems of exploring alternative system layouts at the feasibility stages. The model has been used successfully to investigate the performance of a new generation of water system layouts:

- involving multiple sources of water of different qualities (eg. traditional catchment sources, urban stormwater, groundwater, recycled wastewater, desalinated sea water and/or imported water), and

- designed to provide multiple objectives in water supply, flood mitigation and environmental enhancement.

The multiple sources include those generally available, but, using the WaterCress model, the user can explore the integration of less conventional sources into existing systems. This can often bring additional economic and environmental benefits. These benefits were not explored by previous generations of systems designers partly by virtue of the previous lack of design tools (such as WaterCress) able to i) examine opportunities offered by integration and ii) design systems providing multiple objectives.

WaterCress is particularly useful in situations where the designer wishes to explore a range of system layouts in which the economic value of many system benefits are hard to quantify. While, in theory, the choice of a "best" system design can be based on a set of pre-determined performance criteria, in most practical situations where multiple-objectives are involved, the wide range of trade-offs between competing objectives cannot be adequately expressed in mathematical terms. Moreover, it has been often found that the existence of certain trade-offs are not identified until well after the design process has been actually commenced.

In such cases `trial and error’ design approaches are far superior to approaches involving mathematical optimisation.

WaterCress can be used to demonstrate the performance and implications of alternative systems designs, in an easily understood manner, to both specialist and lay persons who may be affected by, and/or interested in the likely performance of the chosen system.

The use of trial and error models such as WaterCress will allow the nature of these trade-offs to emerge during the design stages and, by its ‘user friendly’ nature, a broader consensus can be reached on system selection.

By allowing the introduction of advanced treatment into the designed systems, the WaterCress model allows designers to link any source of water to any demand. Although default tables will indicate high cost penalties for treatment where the source quality requires considerable treatment to bring it to the demand standard, default data can be overwritten. The use of the model for exploration of unconventional systems therefore requires a high degree of responsibility to be shown by all parties involved in the designs, especially where they may start to involve financial commitments and/or implications for long term public health.

2.0 SYSTEM INSTALLATION AND CONTENTS

2.1 Computer Requirements

To use the 32 bit *WaterCress* program the following system configuration is required:

- A personal computer running under Windows.
- PC I or better video card.
- Monitor with at least 16 bit resolution. To set resolution, right click once on the desktop screen and select **Properties**. A window will appear, select the **Settings** tab at the top of the window. Under the **Colour Palette** box select **High Colour (16 bit)**. Then left click once on the Apply, the computer may require to be restarted.
- Display area must be set at 800 x 600 or greater. To set screen size, right click on the desktop screen and select **Properties**. A window will appear, select the settings tab at the top of the window. Under the **Desktop Area** box set the screen and the desktop to 800 x 600 by moving the button across. Left click once on **Apply** to accept the changes.

The program has been tested on a Pentium 166MHz with 32MB Ram, under Windows 95 through to XP, and worked successfully. For Vista and windows 7 the web provides a second loading file.

2.2 Install Information for WaterCress

To install *WaterCress* from a CD-ROM or from the web the user must follow the following instructions:

Select **Setup.exe.** This will take you into a standard install procedure. *WaterCress* can be loaded in any location, but as default it will load on c \Program Files\WC2000.

The user is now able to commence a project session using the *WaterCress* program. To open a new project see Section 5.2.1. To open an existing project refer to Section 5.2.3.

2.3 Software Package Contents

The WaterCress model package typically resides within the folder c:\wc2000 from here defined as **<program location>**. The actual name and even the drive name are up to the user and are set on installation.

The WaterCress package consists of:

- several text files (*.txt) containing default data for the 18 basic function nodes contained in the model,
- two data folders RAINDATA and FLOWDATA containing libraries of rainfall and flow data files into which the model user can accumulate his own files while working from one project to another,
- three main operating executables (watecress.exe, wcmain2h.exe and wcmain3h) and
- several executables which may be called on for assistance as tools in data input or output checking and formatting.

3. BASIC MODEL STRUCTURE AND OPERATION

3.1 Screen Structure

There are 3 basic screens in the WaterCress Program

Opening Screen where you select or create your project and define required project information.

Project Layout Screen for establishing the nodes and links making up the Project

Output Results Screen from where the project is run and the results are displayed.

3.2 Rainfall, Evaporation and/or Flow Data Input

Rainfall and evaporation are the usual prime drivers for the model and are converted to flow by a series of rainfall to runoff models. Recorded flow data (or data generated by other models) may be used instead (or in conjunction) as the flow driver, or to calibrate the flow predicted from the rainfall.

This data is input to the model through individual ASCI files. A project can access numerous rain and flow files. The modeller can often apply multipliers to factor the input values up or down to suit the requirements of the project.

3.3. Node and Link Structure

WaterCress allows the modeller to simulate the flows within a prototype water system by representing the system as a series of **nodes**, which represent the various functions or operations of water infrastructures/proceses (eg dams, weirs, usages, bores, treatments, etc), **linked** together by a series of 'free flow' gravity **drainage paths** and/or a series of fixed capacity **water supply** piped paths.

The nodes can be clicked and dragged onto a blank computer screen field and joined by flow paths in order to specify the water system to be trialled.

A group of components or nodes with their flow linkages is defined in **WaterCress** as a **Project**.

3.4 Nodes and Node data Entry

There is a menu of 18 basic node types that the modeller is able to use (as often as required) to make up a project. Each is described in detail in Sections 7 and 8.

Each node has an associated database which contains all variables necessary to enable the quantities and qualities of water to be added/ lost/ modified/ diverted etc. as the rainfall and water is passed through it.

The water inputs to the model are derived from one or more sets of sequential rainfall records of adequate length suited to the trial area. Water is moved through the model to satisfy seasonally variable water demands, as modified by evaporation and direct rainfall. Secondary data sets define the sizes and rates of all components in the assembled water system as they pass the water through the system.

The designer enters data where this is unique to the system being trialled (eg catchment areas) or can accept default data already entered into the database, where this is less critical or less variable (eg loss rates, evaporation pan factors). Time series inputs are most commonly rainfall and evaporation data.

Included is also a set of core mathematical relations which define the limits and calculate the operation of the components of the system according to the designer's selection of systems layout and sizing and operating data. Operating rules are also included which, for example, allow the designer to vary both the priorities and proportions of water supplied from the various sources, where more than one source has water available at any time.

3.5 Flow Links

3.5.1 Drainage

Drainage flows are normally unregulated in terms of flow rate or occurrence. No maximum rate is set for the movement of water down a drainage path. Drainage rates are usually dictated by rainfall rates, catchment areas and channel routing, but may also be determined by storage outflow formulae entered by the modeller.

In nodes where there are more than one drainage and diversion path allowed, drainage links at the sub-division level are colour coded so that the user can readily identify the different types/qualities:

Pink – diversion path from a diversion type weir, or separated groundwater flow from a catchment

Blue – normal rural or stormwater flows generated by rainfall on catchments,

Green – runoff from roofs from house and urban nodes,

Grey (thin black) – on-site greywater discharged from house and urban nodes,

Black – black sewage discharged from house and urban nodes.

There is no requirement to keep these paths separated and it is left to the user to define appropriate drainage connections once the flow in a flow path has drained from any node.

Once the colour coded drainage has been joined to the next node downstream (eg a tank) the colour code will change to that of the downstream node drainage. In the case of a tank this is the normal blue colour.

The majority of (blue) drainage originates at the most upstream catchment nodes. All nodes further downstream may receive drainage from upstream and all nodes can transmit drainage through them to further downstream.

Any node can have more than one drainage path directed to it, however, only one drainage path can normally be directed from any node (except where separate colour classes of water are involved, eg. an urban node may have 4 separate colour coded drainage lines coming from it, as above). If two drainage paths of the same type can actually exist (eg a reservoir with two spillways discharging to different downstream paths) it will be necessary to use an additional weir node to split the flow just downstream of the (single) outflow point provided by the model.

For storage type nodes, the downstream transmission of drainage often occurs as spill, after any inflows have caused the level of the storage to exceed its full capacity. Environmental flows may be discharged (drained) from storages at all times.

When a node exists at the furthest downstream location in the model, it will spill or drain beyond the notional boundary of the model. In this case a drainage path cannot be established. However, the water balance is calculated as though a drainage (spill) path exists.

Note: While drainage links can be directed to any type of node, including demand type nodes, **no demands can ever be supplied directly from the drainage link. Supplies must ALWAYS be taken from a storage type node via a water supply path**. If a drainage link is made to a demand node the drainage input will be transmitted through the node unchanged. If a drainage link is established downstream, the inflow will continue down this drainage path outlet, else the node will merely 'spill' the flow and the drainage inflow will 'disappear' from the model.

3.5.2. Water supply.

By comparison, water movement via a supply link is always regulated to a maximum flow rate. The rate may be changed according to season or some rule, however, **no hydraulics are involved** and the water will be supplied at the rate set, providing that that amount is available from the source and it is of suitable quality for acceptance by the receiving node.

In all cases, supplies are regulated in terms of flow rate and occurrence.

Multiple supply paths can be established between nodes, but only to nodes that have a capacity to demand water (eg. demand and storage nodes) and from nodes that have a storage capacity. Storage capacity is provided explicitly in the storage type nodes (eg reservoirs, tanks, etc), but also implicitly in several others node types (eg town, treatment plant). Nodes that do not contain storage capacity cannot be linked by supply paths (eg catchments).

A fundamental assumption made in the model is that water is drawn through the network of water supply links by a set of actual or notional demand nodes. Thus data entered into the model that controls the rate of water passing through a water supply path is generally entered via the receiving node, rather than the supplying node**.** Water is thus drawn through the supply network to meet the downstream demands, rather than being pushed through the supply network from upstream.

Since supplies may be drawn from one node to the next along a continuous supply pathway consisting of several storages, any nodes containing storage capacity that are not filled from a drainage path (mostly storage nodes, but also treatment plants) are programmed to be able to demand water to recharge themselves from upstream.

Water supplied to a demand node may then either be consumed at the demand node (eg evaporated, or 'lost'), or a fraction may be returned as wastewater (with an appropriate quality change) to the drainage system, thus allowing it to be potentially reused downstream.

When a supply path is established a priority and weight is user assigned to the path. Where several sources are connected to a single demand, these values may be altered by the modeller to achieve a choice in selection or shandying of the water supplied from the several sources (See 3.7 below).

3.6. Order of water balance calculation

The calculation of flow movements in each time step is performed in two stages with the transfers via the drainage paths being calculated first, followed by the calculation of the transfers via the supply paths second, as follows:

Stage 1 Drainage. At the statrt of the timestep, any rainfall or other input data for the time step are entered and runoff is calculated starting from each of the most upstream tributary nodes. All waters are moved from their sources via the drainage links in a downstream direction. Routing may be applied. Drainage flows from different tributaries are amalgamated. Each node in the drainage path performs its drainage related functions after input of the amalgamated drainage flows from upstream. If a storage receives drainage and supply inflows/outflows, the effects of supply flows are not taken into account in the Stage 1 calculations. Wastewaters generated from previous days activities are similarly transferred via drainage links Evaporation, seepages and leakages are removed and spills and diversions are transferred further through the system to complete an interim updated (end of time step) stage 1 water balance.

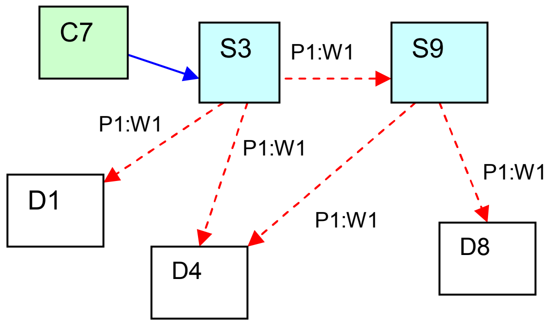
Stage 2. Water supplies. Supplies are then drawn from storages to satisfy demands. The sequence of calculation does not often matter, but where it does this is controlled as described in the next Section (3.7). After the supplies have been calculated the final end of timestep balance is given. The amounts of wastewater generated from the supplies are placed in temporary storages ready for release in the next time step.

The importance of the order of calculation of the supplies in reaching this final balance is addressed below.

3.7. Priorities and Weights and Supply Sequences,

As described, whereas only single drainage paths of a certain type can exist between any two nodes, multiple supply paths may exist between storages and demand nodes. This multiplicity requires that the order of supply can be controlled by the modeller in order to ensure that the flows occur in the manner and priority order intended. An example is provided below.

The diagram below shows a simple system comprising a single catchment (C), two storages (S) and three demands (D). The numbers shown on the nodes are the consecutive node numbers assigned to the nodes as the example layout was established. (Other nodes with missing numbers in the node number sequence are not shown).



Catchment C7 drains to a storage S3 which supplies a second storage S9. The three water demands are taking their supplies from the two storages as shown. All supply paths have their default priority and weights assigned as shown (see Section 6.9.5).

The stage 1 water balance calculation sequence (see section 3.6) will pass flow from C7 to S3. If this fills S3 beyond its maximum storage capacity S3 will spill and the amount will be accounted in the water balance, but drainage will progress no further (since no downstream drainage paths are shown). Once the drainage calculations have ceased with the status of the two storages determined, the sequence of calculation of supply commences.

Regardless of the values given by the priorities and weights (even if these are changed from the default values), the default sequence for calculation of the transfers of supplies from the upstream nodes to the downstream (receiving) nodes follows the node number order of the receiving nodes, as set by their order of establishment. If any node receives supply from more than one storage, the calculation (for that node only) will be in the order set by the priorities given to its supply paths. If these priorities are equal, the calculation for the supplies to that node will be in the node number order of the supplying nodes.

Thus, in the example, the supplies would be calculated in the path order:

- to (receiving node) **d1** from S3 first
- then, to **d4** from S3 and to d4 from S9 (with equal amounts from these two sources making up the total supply sought)
- then, to **d8** from S9 and
- lastly to **S9** from S3.

Thus, since the availability of water remaining in the storages will be reduced by the amounts of the preceding supply calculations, the demand d8 will always have the last (and possibly least reliable) supply, and d1 will have the most relaible supply since it receives first supply from the storage S3 which also gets first supply.

It can be seen from the above that the priorities and weights facility can only influence the priority of supply to a particular node and has no major influence on the order of supply calculation. In order to address this, the modeller is given an additional Supply Sequence mechanism.

The supply sequence is used less often, only when

a) a group of storages are in supply series (as for S3 and S9) and/or
b) the reliability of a particular demand is highly critical (say d8).

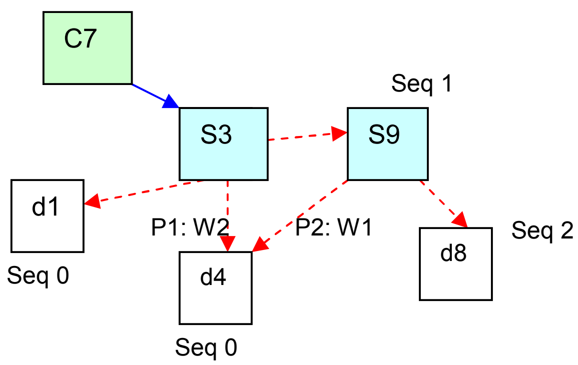
Using the same example, if supply to d8 is to be made most reliable, an arrangement can then be made using the supply sequence option as shown below.

Every node that can receive a supply is provided with a supply sequence number with the default supply sequence number zero. When all supply sequence numbers in a model remain at zero, the supplies continue to be calculated in the order of the receiving node numbers (as above). Otherwise the supplies are in supply sequence number order (ie 1, 2,..., etc. with 0 last).

Thus in the example below (with the Priorities and Weights allocated to the supply links for demand d4 changed for illustrative purposes only) and the Supply Sequences allocated to the receiving nodes with the objective of increasing the reliability of the supply to D8 as shown:

- S9 will be supplied from S3 first (as it has supply sequence number 1)
- D8 will then be supplied from S9 (as it has supply sequence number 2)
- D1 will then be supplied from remaining storage in S3 (since it has the default supply sequence zero, but has the lowest receiving node number)
- D4 will be supplied last, at first from S3 (as this has priority 1), or from S9 if S3 fails (as this has priority 2).

In this case, with different priorities, the weight values are irrelevant.



In most cases, when the storages are either large and/or are not linked by supply paths (and thus are only subject to rare failures), the order of supply makes little difference to the outcomes.

3.8. Water Quality

The WaterCress model currently tracks water quality in only 2 water quality categories, **salinity** and 'other'. The second category is a relative scale which ranks water quality according to a **quality code** number. Any parcel of water moving through the model is accompanied by its salinity and code number.

Salinity concentration is first estimated as a function of flow rate (see Section 7.4.2). This determines the mass of salt assumed to enter the flow. The salt is then assumed conserved at is travels downstream and through the system. Salt is only specifically removed by desalination (see Treatment node Section 8) and thus its concentration continually changes (and is tracked through the model) according to flow weighted merging and evaporation. HOWEVER**, if a storage evaporates to zero water holding, the salt load is removed** before the next inflow containing its own salinity concentration is added. (Deposited salt may be removed by wind). **Special care should be taken in modelling open storages in arid areas where salt build up occurs.**

The **quality codes** are a numerical index within the range 0-19 assigned by the modeller to flow generated within the model. A notional list of waters of different general quality is given below which is not comprehensive and is provided for indicative guidance only.

0	Advanced treated Disinfected	10	Stormwater wetland
1	Potable supply, filtered, disinfected	11	Resident greywater wetland filter, disinfect
2	Pristine catchment – Raintank (filtered)	12	Raw residential stormwater
3	Forested catchment - Raw roof runoff	13	Secondary treated disinfected effluent
4	Rural catchment – disinfected	14	Secondary treated effluent
5	Mixed agriculture catchment	15	Raw greywater or commercial stormwater
6	Tertiary treated effluent	16	Filtered primary and disinfected
7	Advanced reclaimed / Indirect use	17	Septic tank overflow
8	Stormwater following wetland and filter	18	Raw Black sewage
9	Secondary treated effluent	19	Toxic Industrial Effluents

Code 0 relates to the best quality water and subsequent increments indicate falling quality of water to a maximum value of 19. All nodes in the model have input boxes to set the quality code of water being generated by it and most nodes (demand nodes and storage nodes) that receive water via water supply paths have a quality code set to identify what quality water is acceptable by it.

Note: Quality codes and salinity ONLY control water movement via water supply paths. Water delivered by drainage paths is NEVER rejected on the basis of quality codes or salinity.

In many cases, where quality is not an issue, the modeller may simply wish to set all water generated as code 0 and all demands as code 19, thereby negating the impact of quality codes and allowing all water being modelled to be suitable for supply to all demands.

Otherwise, all demands are assigned a maximum salinity and code number. For potable demands these might be 500 mg/L amd code 1. Any water with values greater than either of these will NOT be then acceptable as a supply to this demand. Garden irrigation may accept 1000 mg/L and code 9, etc.

Although a simple concept, quality codes allow a user to control from what source water being modelled can be set up as a potential supply source to the different demands (or conversely not supplied). Therefore quality codes are used to track the general suitability of water for any particular purpose.

While water is given a code at its creation, the codes are similarly merged and flow weighted as the flows are mixed. For this reason it is best to keep codes simple, set within large numerical ranges, and for the modeller to be aware of what changes may be taking place. Codes and salinity may be output at all points within the model at any timestep (see below).

3.8.1 Constraints due to quality

For **drainage links** there are no quality constraints applied to the transfer of water from one node to the next. When two or more waters are mixed within a drainage stream the resulting quality code and salinity is averaged through flow weighting. This means that within the model raw sewage could be shandied down to an acceptable drinking quality, therefore the user must be aware of the drain mixing that is taking place to ensure the water supply is truely acceptable to the demand.

Demands can only be supplied via a **water supply link**. For all demands you must specify the quality of water that demand is willing to accept. Thus, supply can only be accepted by a demand node if the water at the storage node falls within limits pre-determined for the demand. For all demands you must specify the salinity and quality code of the water that demand is willing to accept.

A quality code mismatch is often the cause for the model failing to supply a particular node. Quality codes can also cause supplies to under-predict if set to apply constraints when none are intended by the system designer.

When it comes time for the model to work out whether it can use the water in a particular storage to satisfy a demand, it compares the salinity and quality code of the source with that demanded, and only if the demand quality constraint values are larger or equal to the source quality values will the demand accept that water.

In arid areas, where evaporation may increase the salinity of stored water above acceptable levels, salinity may be a limiting factor. Being a relatively conservative element salinity is calculated daily in the same manner as the water balance. Where water is mixed the mixture will assume the volume weighted average of the mixed volumes. Mixing in storage (with the exception of wetlands) is assumed to take place immediately and fully throughout the whole volume.

3.9 Zones

The model provides the facility for certain catchment and storage nodes to be grouped together within zones for the quick application of multipliers to some or all of their rainfall-runoff relations, storages, volumes or water diversions. It is very useful where a model may have many similar nodes within a zone, all of which need to have their input data changed on a trial basis to test what-if sceanrios. The application of the multipliers is described in Section 6.6.1 See Layout Screen Header 'Data Variation'. Zoning may be applied to:

- rural and urban catchments and text flow inputs, and
- reservoir, tank, offstream (farm) dams and routstore storages.

Catchment zones are used purely for identification of groups of catchment nodes for ease of application of modifiers to rainfall - runoff equations. These modifiers (refer section on **generic runoff modification** enable modification of runoff parameters over a group (or zone) of nodes.

Storage zones similarly enable multipliers to be applied to (for example) a all farm dam storages and diversions (to local use) within an identified grouping of dams within a zone. Refer Section 6.6.1.

3.10 Outputs

When the model is run, WaterCress offers the modeller a very wide range of outputs that can be selected and presented in tabular or graphical form. A Summary provides a simple average value for inflows, outflows, average supplies etc to each node within the model over the period for which the model has been run.

Details of the selectable outputs are given in Section 10.

Results can be displayed as time-series at the time-step for which the model is run (daily or hourly). The same results are also displayed as totals over daily (for hourly data), monthly and annual periods (for either calendar, financial or water years).

Because of its large extent, hourly data may be filtered so that only selected data is displayed (as shown adjacent).

These outputs provide the record of performance of any one, or group of components within the system. The performance will usually be assessed by the designer on the basis of:

- The amount and reliability of water supplied over the period of record
- Maximum and minimum flow rates, storages, etc
- The quality of water supplied and
- The average cost of operating the system components.

However, the range of outputs enables the system designer to assess the performance in terms of such things as the size and frequency of flows, storages and water levels for the maintenance of environments, etc. In addition, there is provision to convert the outputs to a comma separated variable (csv) file for further assessment in 3rd party programs such as Excel

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4. GETTING PREPARED

4.1 Data Required

Because the WaterCress model addresses all facets of water supply and demand within rural and urban water cycles, the amount of data to be gathered can be large and may include some or all of the following data and/or sources:

- Topographic Maps (for catchment areas, boundaries, etc.)
- System Maps (for identification of input/output processes, sequencing)
- Isohyets
- Data locations (rain gauges, flow gauges, dams)
- Rainfall, flow, evaporation time-series data
- Transfer rates into and out of facilities, including ASR rates
- Urban development zones, maps
- Identification of roof, paved, open areas
- Demands for different water quantities and qualities by different users and user groups
- Volume-Area-Depth-Outflow data for storages

It should be recognised that significantly greater time and effort is usually required for data identification, location, collation, checking, gap filling, error rectification etc. than in model running, calibration/recalibration and even output analysis.

4.2 Data Files Preparation

4.2.1 Introduction

WaterCress models consist of an assembly of nodes which represent specific water related processes occurring within the components of the system being modelled, plus a series of links between these nodes which represent the passage of water between them. The ‘upstream’ nodes generally represent sub-catchments and the model calculates a continuous time series of runoff from each sub-catchment according to the time series of rainfall over it. These flows are passed via the links to downstream nodes. These either

1) similarly calculate and merge the generation of runoff from additional tributary sub-catchments situated further downstream, or may
2) simulate any of the processes associated with the components of a water system, ie processes related to different varieties of storage, diversion via weirs, quality improvement in treatment plants, supply to demands and recycling of wastewater, etc.

Once the structure of the model has been established, its operation is governed by the values of the many items of data (ie coefficients, areas, volumes, flow rates, etc.) that are needed to describe and limit the many processes occurring within the model nodes.

This section describes the method of estimation of the areas of pervious and impervious surfaces within urban sub-catchments and the derivation of a set of standard models for different defined degrees of urban density. The implications and performance of the formulae adopted for calculation of runoff on impervious surfaces is then described.

4.2.2 Area Estimation

Particularly in low to medium rainfall areas (say <1000 mm/a), accurate estimation of the aggregate of the impervious areas within each catchment is a crucial requirement in order to make an accurate estimation of the total catchment runoff. The procedures described in the following sections were developed to provide a best estimate of the impervious and pervious areas based on the time and information resources available.

The total procedure for separation of sub-catchment, land uses, roof, paved and pervious areas for input to the WaterCress model is shown diagrammatically below.

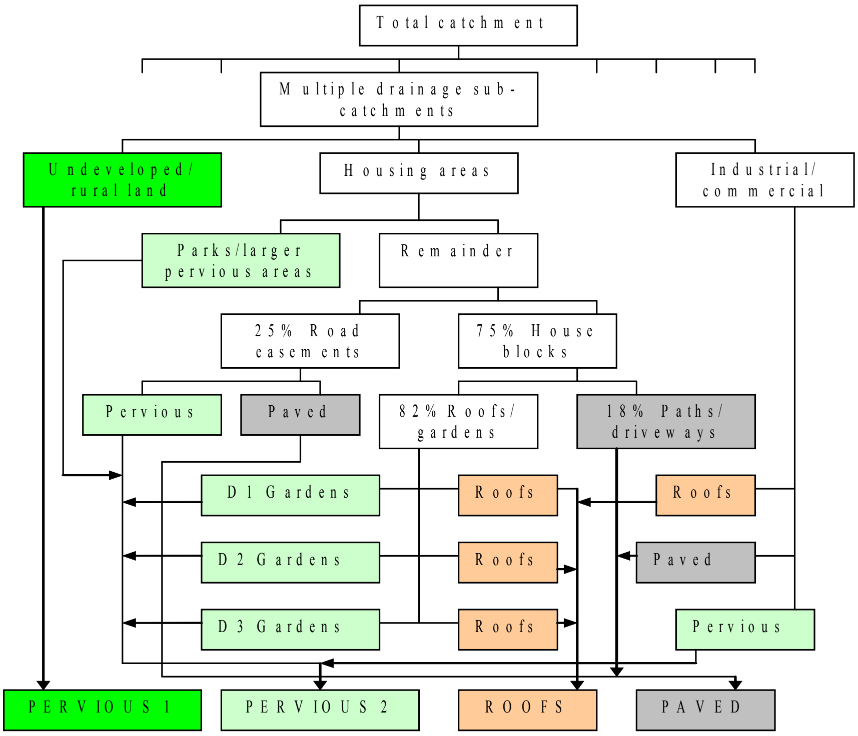


Figure 4.1 Decision tree for separation of impervious and pervious areas input to the WaterCress model (D1, D2.. are values for different development densities)

The separation can be undertaken in steps:

Step 1 - The total catchment area is firstly subdivided into approximately equal sub-areas, based on elevation contours, isohyets and drainage path mapped information. Boundaries of areas with high relief can be mapped accurately (eg. 49, 51 in Fig 4.2 below). Where there is little relief, the delineation becomes less accurate unless access can be arranged with detailed drainage maps. In all cases boundaries are selected in an attempt to have only one major drainage outlet where flow is passed to the next area.

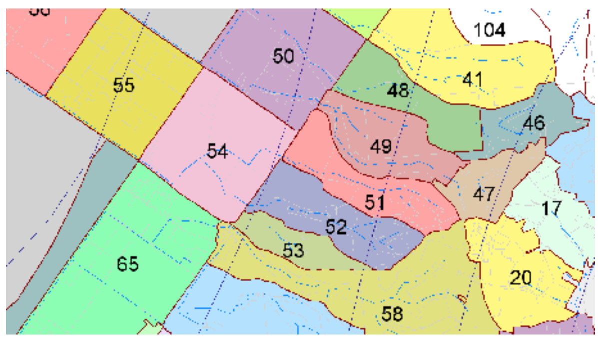
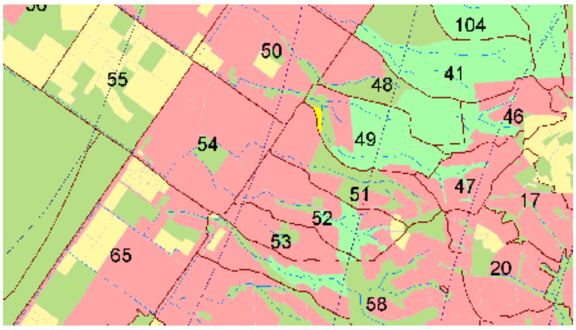


Figure 4.2 Definition of drainage paths and sub-areas.

Step 2 - Each sub-area has then been separated into 4 basic land use types:

1. Areas of relatively homogeneous housing, roads and gardens sub-categorized into one of three different dwelling densities and impervious proportions (shown in Figure 4.3 shaded red),
2. Industrial/Commercial areas with high impervious proportions (shown in Figure 4.3 shaded yellow),
3. Undeveloped hills face/rural catchments (shown in Figure 4.3 shaded light green), and

   Pervious urban parks and large open areas (shown in Figure 4.3 shaded darker green)



These are further described below, with the modelling for the pervious areas within the urban areas and the pervious areas in the last two dot points taken together under the 'Pervious Areas' heading in Section 4.2.5 below.

Figure 4.3 Basic landuse types identified and separated.

4.2.3 Housing (Domestic) Areas

Areas of housing comprise a relatively homogeneous assembly of houses, gardens, roads, verges and small open areas, including a few vacant blocks.

Step 3 - Significant pervious areas such as large parks, recreation areas, watercourse reserves, etc. within the housing area are identified and digitized as a separate land use and included separately under the 'pervious' classification.

Step 4 - All the remaining housing area is assumed to consist of 25% road easement and 75% housing blocks, each with a dwelling. Each housing block is assumed to include i) 10% of its area taken up by impervious paved paths, driveways, etc., ii) a dwelling with an impervious roof area, and iii) a pervious garden area which includes a small share of the aggregated areas of small communal parks.

Step 5 – In this example, the housing areas have been separated and classified into three densities, according to a visually assessment of aerial photos showing the relative proportions of impervious and pervious areas, as below:

Low Density – assumed roof area = 30% of 90% of the block area remaining after removal of 10% paved areas. (9.8 dwellings per ha.)

Mid density - assumed roof area = 45% of 90% of block area. These may be relatively new areas with smaller block areas or older areas with a lot of ancillary shedding or verandahs etc. (12.1 dwellings per ha.)

High Density – assumed roof area = 60% of 90% of block area. These tend to be the latest developments where block sizes are small and roof areas are large. (13.6 dwellings per ha.)

Several samples were taken from similar areas and the averages are shown in Table 4.1 below. The information on dwellings per hectare (and persons per dwelling, etc.) can be used if the model is later used for assessments of water supply and wastewater production.

Table 4.1 Fraction of impervious area with respect to total residential area

Housing Density	Assume roof %	Roof fraction	Pavement fraction	Garden fraction	House size m2	Block area m2
Low	30	0.23	0.07	0.45	230	766
Medium	45	0.34	0.07	0.34	280	622
High	60	0.45	0.07	0.23	330	550

Block sized are continuing to decrease and 300 m2 blocks are now common.

Step 6 - The 25% of assumed road easement area is assumed to be comprised of 15% of impervious paved area and 10% of pervious areas (ie verges and small areas of unpaved land).

Table 4.2 shows a summary of the assumptions made. A GIS was used to estimate the total of the impervious paved and roofed areas and pervious areas within the sub-areas designated as housing.

Table 4.2 Impervious area assumed with respect to total residential area.

	Low density	Mid density	High density
Impervious road	15%	15%	15%
Pervious road (verge)	10%	10%	10%
House roof area	23%	34%	45%
House Pavement	7%	7%	7%
Garden (pervious)	45%	34%	23%
Total Roof	23%	34%	45%
Total Pavement	22%	22%	22%
Total Pervious	55%	44%	23%

In addition to having an increased impervious fraction, the denser developments are also often assumed to be connected more directly to the drainage system. For example, while the front part of the roof may be connected by drain to the road (and hence the formal drainage system) the back roof often discharges to the backyard and garden or to rainwater tanks. Larger blocks with lower density clearly have more capacity to discharge water in this way. It is therefore assumed that as block sizes reduce a lesser proportion of impervious runoff will be lost on-site.

In this example it was assumed that the low density development had 50% of its roof connected to the stormwater system. The medium density and higher density developments were assumed to have 60% connected.

4.2.4 Industrial/Commercial Areas

The proportions of impervious and pervious areas within each of the sub-areas classified as Industrial/Commercial have been individually assessed using aerial photos (Google maps). Individual blocks were visually inspected and then aggregated to give total roof, paved and pervious areas.

Connection of the Industrial/commercial roof and pavement areas to the drainage system was assumed to be higher than domestic areas. Values of 80% connection for the roof area and 70% for paved area were adopted across all areas.

4.2.5 Modelling Runoff from Pervious Areas

Pervious areas by definition do not include any significant impervious areas. The following example describes the separation of the various separated pervious areas into two types, using different versions of the WaterCress pervious catchment rainfall to runoff model. The parameter values chosen for the versions of the model are adequate to account for different combinations of soils, slopes, degrees of vegetation, etc. and efficiency of inter-connection to the watercourses and drain systems.

Considerable experience has been gained with the prediction of runoff from rural catchments in the Mt Lofty ranges. These include runoff from some hills face catchments such as First, Third and Sixth creeks, but generally within the higher rainfall areas.

Very little direct data exists on runoff from aggregated garden areas and other pervious areas within urban areas such as parks, recreation areas and watercourse reserves on lower rainfall and the flatter land. However indirect experience with model calibration of urban area runoff shows that the proportion of runoff from their pervious areas is usually small to negligible in relation to runoff from their impervious areas. For aggregated house garden areas this is not surprising in view of the significant impedance and losses likely to be associated with their cultivation, landscaping and border fencing.

The model used for the within-urban pervious areas is therefore similar to that for the rural and hills face areas except that it has been modified by increasing the interception and soil moisture capacities to reduce the amount of runoff predicted (refer calibration later).

4.3 Accuracy of Key Data used in the Prediction of Flow.

When major discrepancies exist between flows predicted by a rainfall to runoff model and flows as measured by a gauging station, even after the model has been adjusted by calibration to the measured flows, the source of the discrepancies may be associated with any of the:

- inaccuracy of the rainfall measurements, and/or
- inaccuracy of the flow measurements, and/or
- inadequacy of the prediction model to take all conditions into account

4.3.1 Rainfall data errors

The accuracy of the rainfall records can be checked by comparing one record against the records of its neighbours, either directly, or as cumulated totals over several years. Most errors in recording via pluviometers are associated with power failures, in which case the record is missing all together. Errors in daily read rainfall records are harder to identify and usually involve non-attendance of the reader, failure to record readings or entering data on the wrong dates.

The moving of a gauge into a location having a different exposure, or the construction of a building nearby which changes the exposure, can give a long term change to the readings. The timing of such events can often be picked up by comparing double mass curves of the cumulated totals of rainfall recorded by the different raingauges within a local region.

The start of a period of systematic errors, or changed exposure, is revealed as a change in the relative slopes of the graphed cumulated rainfall totals. Otherwise errors are usually small and are made even less significant when several rainfall records are used to define the spatial variation of rainfall across the catchment. It would be very unusual for all gauges to be in error together, although high winds may cause a group of gauges to under-or over register together.

4.3.2 Flow data errors

By contrast, flow is much more difficult to measure and measurements are prone to many sources of error.

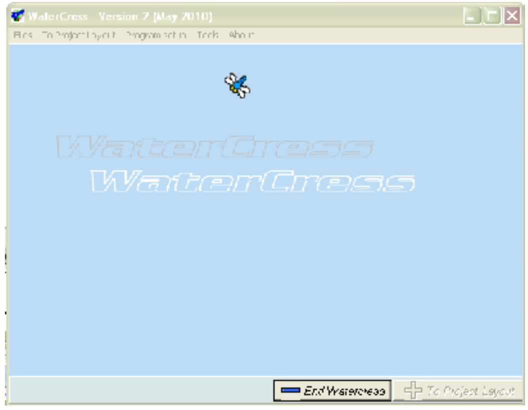
Most stream flows are estimated via separate measurements and calculations involving water depth, water velocity and cross section area. Under ideal conditions these measurements bear stable relations to each other which can be estimated by hydraulic calculation or field measurement. Ideal conditions are rarely met and accurate measurements can usually only be guaranteed if a standard measuring weir is constructed. These are expensive. Where measurements are taken in natural channels away from stable concreted sections, measurement conditions are often far from ideal. Logs, trash accumulations, bank erosion, sediment accumulations and seasonal vegetation growth substantially alter the relations, often from day to day or week to week. Since the calculations of flow are made on the basis of the most recent set of relations available, when any changes occur the calculated flow will be in error until the new set of relations has been established.

Because field measurements to check and/or re-establish the relations are i) often hazardous under high flow conditions, ii) require skilled operators, and iii) are expensive, they are usually infrequent and confined to low flows. Often they are not carried out at all. Under most circumstances high flow measurements are generally recognised as being estimates only.

Thus, unless measurements are carried out in a channel reach where the geometry and surface roughness are fixed (ie a concreted channel), the flow measurements should be regarded as a guide only. The measurements are liable to have large random errors due to i) random events, such as blockages by silt or debris, or ii) systematic errors due to incorrect assumptions made in developing the hydraulic relations, such as the incorrect estimation of roughness.

5. OPENING SCREEN

5.1 Header Bar

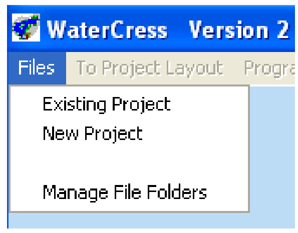


The printing on the header bar is greyed until the screen is activated. The functions of each of the headers are described below.

5.2 Files

Click on **Files** at the top LH to either create a new project or re-access an existing project. The window shown below RH will appear.

5.2.1. To create a new project



Select the **New Project** option. A window will appear into which you enter the name of the project you wish to create.

Give the project a name, preferably only 7 to 10 characters and don't include spaces. (Spaces will be automatically removed).

On clicking **Accept** this project name becomes an existing project and its folder name containing its initial default files will be entered into the list of other existing projects in the <program folder>. The next time you enter WaterCress and want to get to this project, you must follow the procedure for opening an existing project (see below).

Note. You can change the location of where this project is storedby selecting **Manage file folders.**

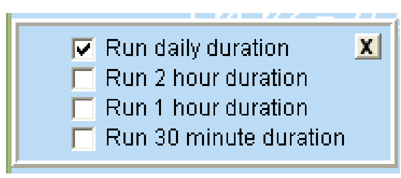
If you view the watercress program folder (<program_folder>) and open the folder created with the name of your project, you will see that a number of default files have been added. These files are ready to automatically receive the data and information you add as you continue to establish your WaterCress model.

IMPORTANT. These default files come from the folder <program folder>\new. The 'new' folder is listed with the folders for the existing projects and looks just like another project. NEVER DELETE 'NEW' or they will not be available for other projects.

Modification of these files (with caution) can be done to customise your data setup. If you suspect they have been corrupted then remove them and reload the program. All data transfer and storage in WaterCress is by ASCI files. Such files are easy to read, modify or recreate as required.

Clicking Accept also activates the previously greyed **To Project Layout** and **Program setup** menu tabs on the top header bar and the **time-step selection window** below. The time step must be selected before proceding further (see below).

5.2.2 Selecting the Time-step



The default time-step is daily as this is the time-step in which most readily available rainfall data exists. As at April 2010 time steps less than 30 minutes are not fully tested and have been omitted.

The time-step you choose will apply for all components and for the whole period of your model runs.

If you have some or all sub-daily data (eg 30 minute), but choose to run the model at a longer time-step (eg hourly or daily), the model will automatically sum your sub-daily data to the longer time-step and perform all calculations and presentations at that time step

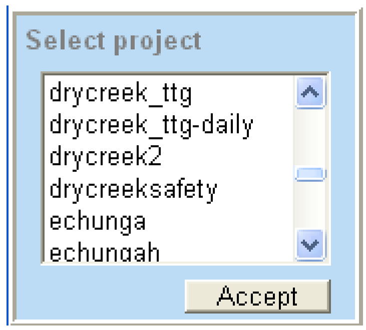
If you choose a sub-daily time step (eg hourly), but load (say) daily data, each daily data value will be divided into equal amounts according to the the proportion of the selected time-step to the daily time-step (eg each daily value will be divided into 24 equal amounts if the hourly time-step is selected). It is NOT recommended that the model be run at a time-step less than the time-step for which the majority of data is available to the model.

The time-step is automaytically saved once the tick appears in the window. Clicking on To Project layout will take you to the Layout Screen. However, before going there it is a good idea to set up the units that you wish the model to work in. This is accessed under Program Set-up (see below).

5.2.3 To Access an Existing Project

Click **Files** from the top menu bar of the opening screen (as shown 5.2.2) then **Existing Project**. The list of current projects will appear in alphabetical order. Scroll down and click on the project name you wish to open and then press "Accept" to open the project.

As before, clicking Accept activates the previously greyed **To Project Layout** and **Program setup** menu tabs on the top header bar and the time-step selection window below.



5.3 Other Headers

The functions of the other Headers on the Opening Screen are described below.

5.3.1 To Project Layout.

Clicking on this will take you to the next WaterCress model screen where either you can create your new model or your selected existing model will be displayed. You can perform the same actions by clicking on To Project Layout at the bottom RH corner of the screen.

5.3.2 Program Setup

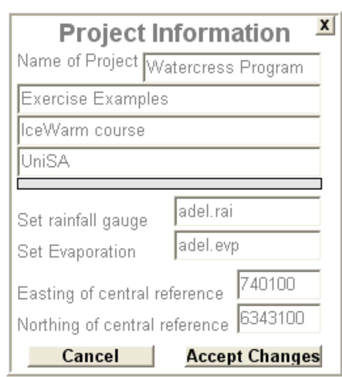
Two options are provided when selecting program setup

5.3.2.1 Project Information

Clicking on Project Information reveals a window for the selected project as displayed on the window to the right.

The top four edit windows in the panel can be used to record and details to assist in referencing or recording deatils pertaining to the model.

The four other edit windows can also be altered and these have specific uses as follows



Set rainfall gauges and evaporation enables the modeller to define the rainfall and evaporation files that will be assumed as the default files as nodes are later added to the project layout. This is an advantage when adding numerous nodes that will use the same rain and evaporation data, since this information will be automatically added to and used by all nodes as they are added to the model on the Layout Screen. The information is also automatically carried through to appear at the foot of the Layout Screen.

This information, as entered via the Project Information window has only limited relevance since once the modeller is actually in the process of creating the model layout on the Layout Screen, he is able to over-ride the information entered via the Project Information window for those nodes that require alternative rainfall or evaporation files for their operation in two ways. Either:

- for individual nodes (at any time) by entering the names of the alternative rainfall or evaporation files into the individual nodes when placed on the Layout Screen
- for groups of nodes (before they are placed on the Layout Screen) by over-riding the default names carried through from the Project Information window and entering the desired names of the alternative rainfall or evaporation files in the window at the foot of the Layout Screen. This will then be applied to all new nodes placed on the Layout Screen until altered again.

This is explained again in the description of the Layout Screen.

Easting and Northing define the spatial datum of the top LH corner of the Layout Screen. As components are added they take their coordinates from the distance they fall from this datum. The values can be redefined at any time by the user, however, these data are not used in the model calculations (nor do they change if the component is moved) hence this information is redundant and may be ignored.

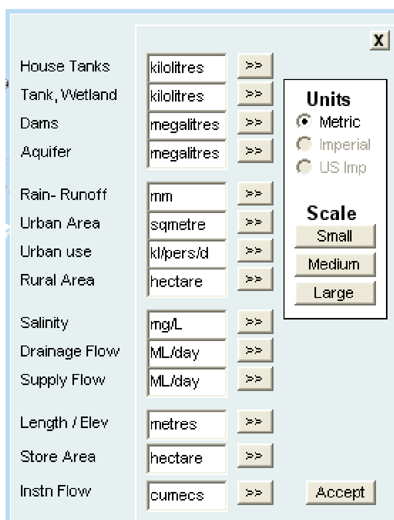
Project Information Storage Location

The above text data, including that entered into the top part of the Project Information window, is stored in the **<program_folder>\yourproject** in the file pbd.txt (project broad definition). Thus there is a **PBD** file for each project. While it is in ASCI format and can be read, it is recommended that you do not directly change the data in this file. If a PBD file is lost or corrupted, simply copy the file from **<program_folder>\new** into the project folder.

The Project Information window is rendered invisible by clicking "Accept changes" or "X". The window can be raised again by clicking Program setup.

5.3.2.2 Change Units

Clicking on Change Units will bring up the window shown below.



The program may be manipulated to accept sets of different default units by selecting from the **Units** and **Scale** buttons. Alternatively the scale of the units (eg L, kL, ML) may be set individually by toggling through the unit scales in the list of 14 categories on the LHS. Units are simply changed by clicking on the **>>** button to scroll you through the range available.

By clicking the **accept** button, your choice of units will be reflected in all the data entry and reporting locations throughout the whole model. The choice will also be retained if the model is closed down and later re-opened.

Alternatively, if not accepted, any changes will only remain valid for the present session, and will revert to their previous values after closing and re-opening. Clicking **X** will hide the window, but all units requested remain valid for the session.

If the units are changed at any subsequent time, all the data values already entered as inputs will automatically be re-scaled to reflect the changed selection you have made. However, for the outputs values to reflect the re-scaling changes, the program must be rerun.

The first 4 categories generally relate to the size of storages, ranging from the (usually) smallest to largest.

Rain-Runoff relates to any variable that relates to a depth averaged over an area such as rainfall, evaporation and catchment runoff (when expressed as a runoff volume averaged over the whole of the catchment area).

The next two relate to urban areas (often expressed as (say) roof area per dwelling) and water demands when expressed in per capita terms. The town and urban nodes use these units.

Rural Area usually relates to catchment or irrigation areas.

The next three relate to salinity concentration, unregulated flows in channels and bulk supply flows to meet demands when not expressed in per capita form.

Length provides the unit for all distance measurements. Elevation usually refers to depth of storages. Land or infrastructure elevation is not used in the model for any hydraulic calculations.

Store area provides the units for surface areas of storage.

Instantaneous flow is used to define peak rates of flow when the model is used to calculate maximum flow rates, usually in associated with the selection of sub-daily timesteps

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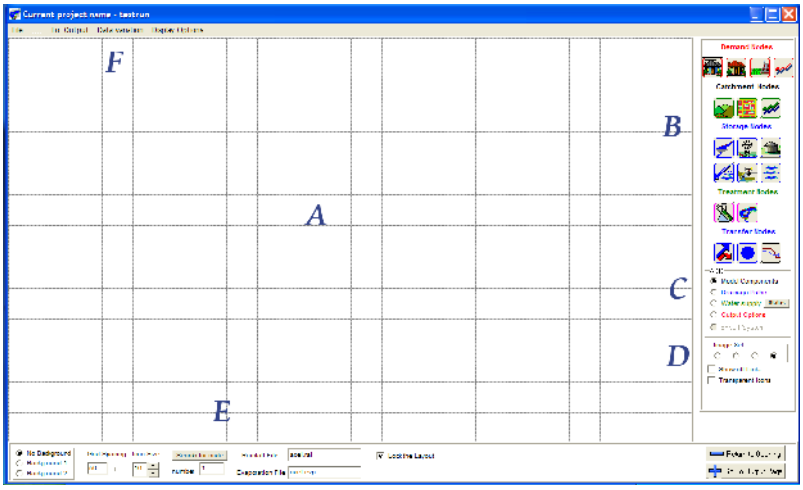
6. PROJECT LAYOUT SCREEN

Bring up the Project Layout screen by clicking on either 'Project Layout' on the top menu bar of the Opening Screen or the ' +To Project Layout' button on the lower right of the Opening Screen. You will be confronted by the screen below. The model operations accessed on this screen are grouped as shown and described below.

6.1 Area A – Project Layout Area



If you are starting a new project the large gridded part (Area A) will be blank. This is where you will lay out your new project. Otherwise the layout of the existing project you have chosen to re-open will be shown here. Large projects can overflow the screen area and can be accessed by right clicking onto the screen and dragging in the desired direction.

Various features of the grid are described under Area E, otherwise the grid only provides a passive visual role.

6.2 Area B – Component Menu

Contains a menu pallette of 18 possible components (each represented by a different icon and given a different name) that can be assembled in diagrammatic forms on Area A to represent a water system for which the performance is to be simulated. The component is selected by left clicking on the icon, releasing, and then left clicking again onto the layout screen at the desired location. Any component may be added to a layout (using a separate identifying name) as many times as required.

Once a component is placed onto the screen it becomes a node within the system connected to other nodes by flow paths. The same component (eg a reservoir) which appears several times in a project layout will be represented by a different numbered node within the system layout. Thus the term component and node are often used interchangeably, although strictly a component represents a specific water function while a node represents its function and location within the project layout.

The names of each component and a short description of its use is provided by hovering your computer pointer over each icon.

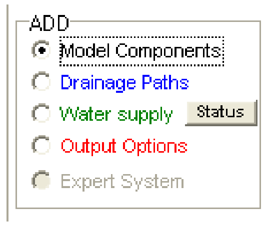
The components (also described as nodes, since this is how they appear when assembled and linked by flow paths on the layout diagram) are shown in six rows headed Demand Nodes, Catchment Nodes, Storage Nodes (making up 2 rows), Treatment Nodes and Transfer Nodes.

While all components perform the functions suggested by these classifications, many perform multiple functions which cross over to include functions of the other classifications. Thus the House (top LH) component also acts as a catchment and also contains on-site storage tanks.

The functions performed by each Component are described in Sections 7 & 8. The method of establishing a project layout is described in the later part of this Section.

6.3 Area C – Operation Mode Buttons

The top three rows of radio buttons are used when assembling or modifying a layout



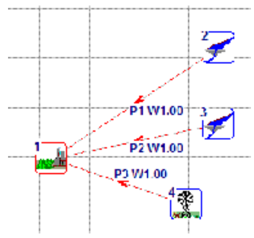
Model Components must be selected before placing components onto the layout screen.

Drainage paths must be selected when adding or deleting drainage paths.

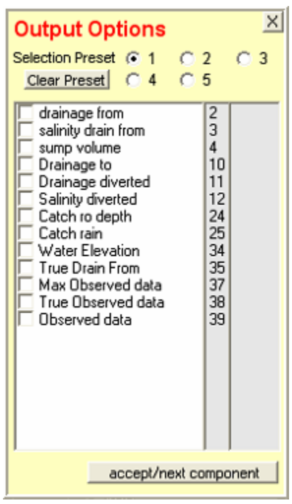
Water supply must be selected when adding or deleting supply paths.

More details on the use of these buttons are provided in 6.7 and 6.8 below.

Except when actually performing one of these actions, it does not matter which of these buttons has been activated. Thus, once established onto the screen, components may have data entered to them, be moved or be deleted while in any of these modes – except that deletion of components requires that the model layout is 'unlocked' (see the tick box at the base of the Screen under the description for Area E below).



Clicking on the **Status** tab will show the priority and weight associated with each of the water supply lines that have been established.



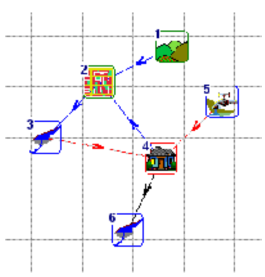
The **Output Options** button is used to select the set of time-series output record results (flow, storage, salinity, etc, etc) calculated by the model for any particular component or group of components.

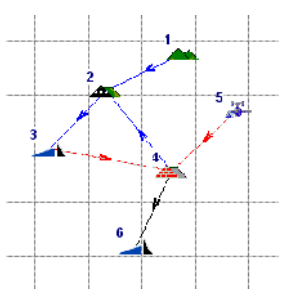
When the Output Options button is activated, and when any component on the screen is left clicked, a list of all the possible outputs that are calculated by the model for that components will be brought up on the example screen shown below for a weir component.

In total over 90 different types of time series are calculated by the model for the 18 component types. The means of selecting outputs are described in greater detail in Section x. A listing of all the options and their explanations in given in Section x.

6.4 Area D – Node Icon Styles and Links

Just below this panel is another where you can toggle between the style of icons you prefer. 2 options are shown below. Currently there are only two types. This will be developed further in later program development.



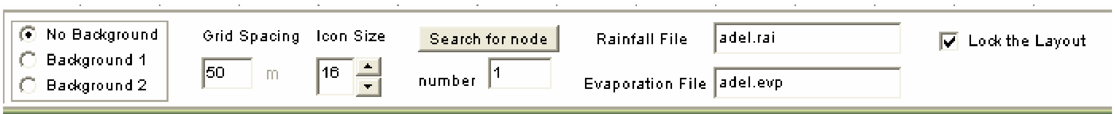


Clicking on **Show all links** shows all drainage and water supply links together. Note, under most circumstances, when assembling or modifying the layouts, only the link type which is being assembled/modified is shown. It is therefore wise to re-activate **show all links** periodically in order to confirm the totality of all links that have been established and are operating.

The size of all icons assembled on the screen may be increased or decreased via the **icon size** toggle in Area E.

6.5 Area E – Screen Base Area Controls

Across the bottom is a long panel containing several windows which provide (or enable the user to select) information or data common to the whole system.

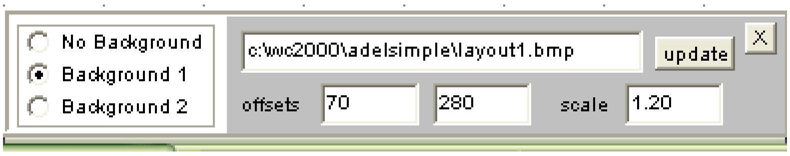


The features (from L to R) are associated with:

6.5.1 Backgrounds

A background image (usually a catchment map) is added by first creating a bitmap image of the background required (only works for bitmap at this stage). If the image is specific to the project, it is best to place it in the the project folder, ie <programfolder>\projectname\ imagename.bmp). Images of size 4 - 5 Mb are acceptable. Much larger (or more detailed) images may cause problems

The importation of an option for nil, or one of two of the pre-prepared **Background** maps (or spatial diagrams) to assist visualisation of the model layout is undertaken by clicking on either of the radio buttons at the LH side. Selecting one of the backgrounds will bring up the window shown (else if a background is already loaded it will bring up that background).



To set or change the image filename click on the edit box containing the file name, and follow the prompts. The file name can contain a path name, but the path name can be omitted if the image is placed in the project folder. The offsets and the scale are used to adjust the size of the image and its x and y position. Select “update“ to save the image with the project.

The usual procedure is to create a GIS image of the area to be modelled and then use this as the background for setting out the node icons in their right locations over the background. It is clearly easier to do it this way around, than the reverse.

When the image first appears on the screen it will be either larger or smaller than the screen. Use the scale factor to provide the size of the image on the screen. Remember, the screen can be scrolled to fit very large images and models, however, in general it is best to keep the the image to about the screen size. Scaling up or down too far leads to grainy images, and it is better to set the image close to its required size by using a 3rd party image editing package.

Offsets are best left at 0 and 0 when placing new images. They are mainly used to shift the image in the horizontal and vertical directions when you are trying to fit an existing component layout into a new background image. It is best to make small changes to the shift values to assess the movement they make to the image first. Beware, large shifts may send the image off the screen (where it can only be viewed by scrolling the screen).

6.5.2 Grid Spacing

Under most circumstances it is best to leave the **Grid Spacing** at the default of 50 m. The only use that the spacing value has is in determining link distances that influence costs. (See 6.6.3 for **Grid on/off**)

6.5.3 Icon Size

The font **Size of the icon** may be changed via the toggle. Reducing the icon size assists in reducing the spread of large projects outside the screen area.

6.5.4. Seach for Node Number

Is very useful when large projects with many nodes have been established. Entering the node number wanted, and clicking the search tab will shift the whole project layout to position the wanted node at the vertical centre of the screen vertically above the lock the layout tab.

6.5.5. Rainfall and evaporation file

The **Rainfall and Evaporation File** windows repeat the same information that has been enterred on the opening Screen. Changing the information in these windows will have no effect on the project already assembled on the screen. However, if you are to add many nodes with the same rainfall and evaporation – setting the file names in these boxes will set the requested rain and evap as the nodes are added.

6.5.6. Layout Lock.

With the **Lock the Layout** tab ticked on it is not possible to delete any of the nodes assembled on the screen. To delete nodes (see later) the lock must first be ticked off. Once a component is deleted it is not possible to recover it with its entered data intact.

6.6 Area F – Header Bar Functions

This area contains the following headings. The table refers to futher information on them.

Heading	Further Information
File	Provides access to Export/Import data manager
To Output	Click here to progress to Output Results Screen (Section 11)
Data variation	Enables quick change to certain input data within catchment zones
Display Options	Enables choices relating to the Layout Screen display.

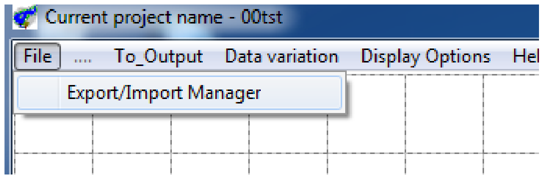
The three Headers requiring further detailing are addressed below:

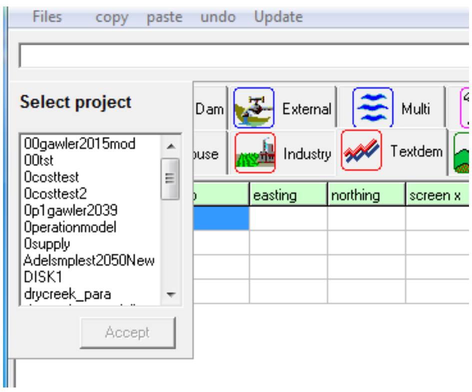
6.6.1 File/Export-Import Manager

The file tab contains the entrance to the **Export Import Manager**. This tool amalgamates all of thenode inputs (for all nodes) on to one spreadsheet page. This data can then be modified in a bulk lot rather than having to visit each node one by one.

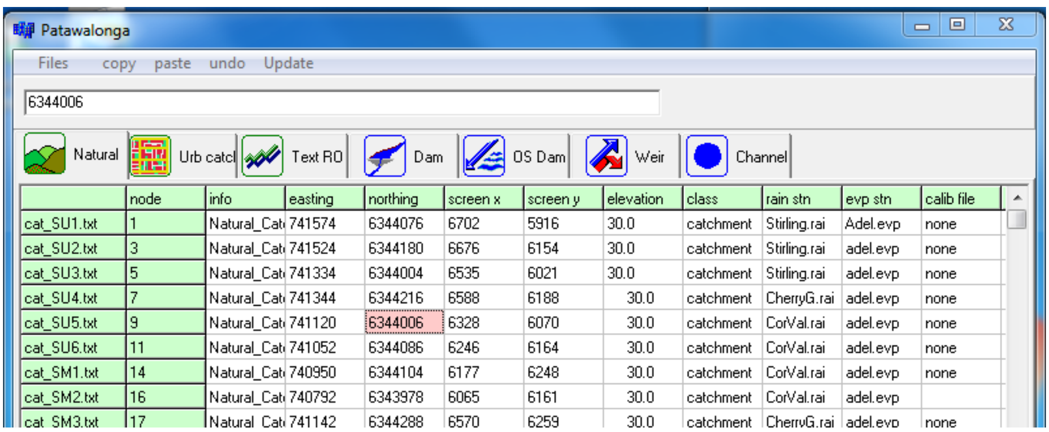
This program recently replaced the previously existing import/export manager. It has the advantage of not having to jump into Excel to make changes, and provides all project file information on one page. The program is still being developed and therefore only provides basic functions for file update, and further development is continuing.

The program (named fileupdate.exe) may be run external to watercress or is more typically initiated from the spatial layout page of the watercress model.





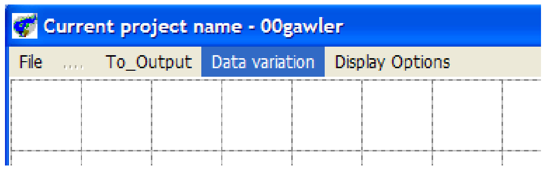
To commence you first identify the name of the project to be modified through the **files** option on the menu. This forces a drop down window identifying all projects available. Selection of the project then loads all the file information for the project



File information is displayed under the nodes “type“ category. Clicking on the **type** tabs provides access to all files within the requested project.

To save the changes back into the watercress project click **update**, and two options are provided. Curenly only **save current page** is working

6.6.2 Data variations

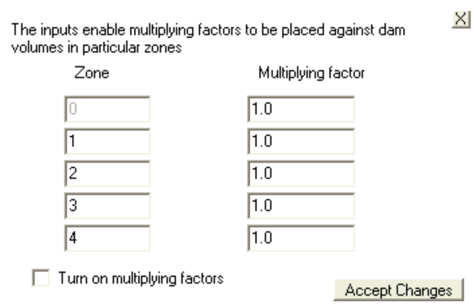


The input screen is reached through the Data variation tab on the top header bar. Four tabs are shown with the first tab explaining that the three tab options provided are for quick user comparison of 'what-if' scenarios.

The multipliers and changes identified in the three tab options refer to the nodes sharing the same zone numbers which have been assigned on the openning window of the node (eg zone 66 in the example shown at the RH (see also Section 7.1). Other froups of catchments or storages may share other common zone numbers. In most cases, however, the zone numbers are not assigned and no data variations are carried out.

It should be noted that any multipliers entered under the tab options (see below) are designed to reset to 'off' (ie multiplier = 1) each time the project is closed. Thus on re-entry to the project all multipliers will be reset to 1. This is done in order to avoid confusion for later users of the project when (without their knowledge/memory of these 'hidden' settings) the model would not generate previously published (or presently expected) results.

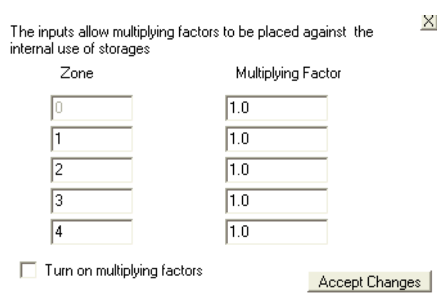
6.6.2.1 Tab 1. Increase Farm Dam Size



This option allows all the dam storages situated in up to 5 different identified zones (ie sharing the common zone numbers in the Zone data entry boxes) to be varied by making the single multiplier entries into the window revealed on clicking on this tab and shown on the RH. The option simply multiplies all the dam maximum volumes for all storages within that zone (ie sharing the same Zone number) by the multiplying factor provided by the user.

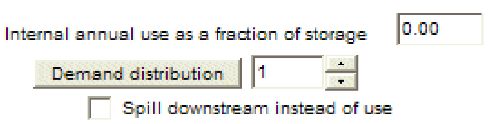
"Turn on the multiplying factors" will activate the multipliers selected. This box will not be 'ticked' when you enter (or re-enter) the program and thus the actual multipliers used by the model will revert to their default value of 1.

6.6.2.2 Tab 2. Increasing dam use



This option works in a similar manner to that above except that the multipliers apply to the internal dam uses set for all dams wthin 5 different zones. The option simply multiplies the selected dam internal uses by the multiplying factors provided by the user for each of the zones.

This option only operates on the internal use input for the dam.

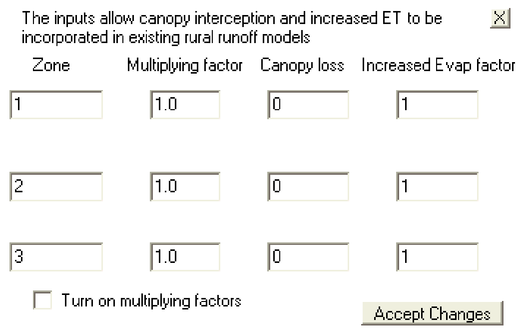


The "Spill downstream instead of use" facility enables environmental releases to be made from the storages which could be picked up by storage further downstream as a possible supply.

6.6.2.3 Tab 3. Forestry runoff estimation

This option works only all catchment nodes (using any of the rainfall to runoff models) and introduces an additional (variable) loss to simulate the effects of a changed land use which reduces runoff. The change is simulated by a set of 3 parameters which may be applied in up to 3 different zones.

The parameters can be rapidly turned on and off by checking or unchecking the “Turn on multiplying factors“ check box in the bottom left side of window.



Modification of the node output can be made by modification to one or a combination of the three parameters.

The **first is a multiplying factor** which simply multiplies the final value of runoff calculated by the model. If the other 2 optional parameters are applied, this multiplier comes in last after the other paramerts have made their changes.

The **second parameter introduces a notional canopy loss.** Canopy loss is typically 2 -3 mm, depending on the density of the canopy cover. The loss works an an initial loss and thus a value of 2 mm means the first 2 mm of rainfall in any day is lost and thus the rainfall input to the remainder of the rainfall to runoff model is reduced. Under South Australian conditions (rainfall 600-800 mm/a), forests with canopy closure will typically reduce the effective rainfall reaching the ground by 20%. Inspection of the rainfall depth v frequency relation can assist in setting the canopy loss to be applied.

When this parameter is switched on, the **Local rainfall** output in the results **Summary** for all catchment nodes in the respective zones will show their reported values of annual rainfall reduced by the application of their zone parameter. These can therefore be compared with the same Local rainfalls where the forestry variation is not applied.

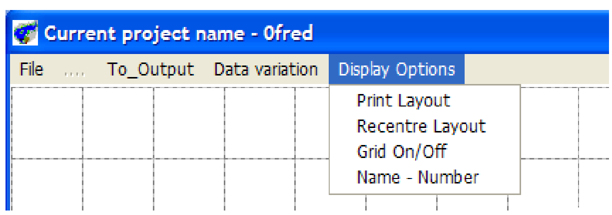
The third parameter is a multipier factor which acts on the evapotranspiration rate set within the model. Since forests have higher evapotranspiration rates, this factor may be set at 1.1 -1.2 and works directly on the evaporation calculations undertaken by the rainfall to runoff models.

Hence Final Runoff (mm) = (Original Runoff – effect due to (2nd) canopy loss parameter - reduction due to (3rd) higher ET parameter) * (1st) runoff multiplier parameter.

Note: Models containing i) permanent and unambiguous values of dam storage volumes and usages and ii) rainfall to runoff models calibrated for forest cover are best produced and fully tested before embarking on the use of these data variations.

6.6.3. Display Options

The **Display Options** tab at the top LH of the Header bar of the Project Layout Screen provides options related to the Screen layout presentation.



Print Layout creates a bitmap of the spatial layout of your project, including any background image shown on the screen at the time. The image is automatically scaled to the size of the project, even if it overflows the screen). A window requests the location and name of the image to be saved. The image can then be printed and be used to notate flows passing through the project links and/or make other notes.

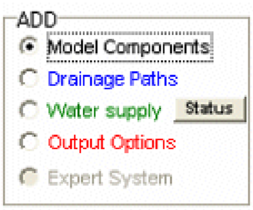
Re-centre layout returns the spatial layout of the project to the initial start-up location. (To move the whole layout relative to the screen right click on the screen and drag the project layout to the position you prefer).See also 6.5 for other screen controls.

Grid on/off is self-explanatory. See 6.5.2 for Grid spacing

Name/number toggles between the node name and the node number being displayed on each node component on the screen. (updated if necessary)

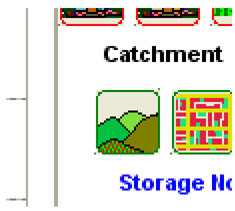
6.7 Establishing a Water System Layout

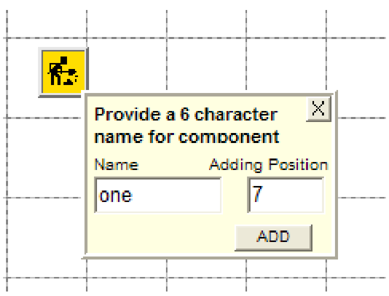
6.7.1 Adding Nodes



To commence adding nodes to a layout you must select **Model Components** on the ADD selection panel. Note*: Clicking on any component in the RH component menu display area will* <u>*automatically*</u> *switch to the ADD model component mode.*

Next, left click (and release) on the type of component you wish to add (example: Natural catchment icon in the second row of the component icon menu). Now move the cursor across to the layout area (A) and left click at the location you wish the icon to sit.





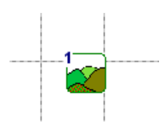
A prompt will now appear asking for the name of the node and giving an automatic sequential adding position within the project.

The name can be up to **6 characters** long and, along with the allocated number, becomes a unique identifier for this node. Use alpha numeric characters for the name but do not use spaces. A space will be automatically replaced with an underscore. It is preferable to choose a name for the node that will jog your memory of the actual part of the project it is representing and will distinguish it from other parts. The model program will not allow you to re-use the same name for any other Natural catchment, but you can re-use the name for any other type of component (but **once only** for any particular component type).

The number automatically allocated may be accepted, but, if you prefer, you may give it any number lower within the established sequence. This will automatically shift the numbers of all previously established nodes, with existing numbers equal or greater than the number you select, upwards by 1, thus retaining a unique number (and name) for each node. Existing drainage path and water supply links are also adjusted accordingly.

Other nodes established later will be given sequentially increasing numbers. There is thus some flexibility in allocating numbers to nodes other than in the strict sequence in which they were first created. However, experience shows that trying to be too clever with this becomes rapidly messy and confusing and it is often better to accept the automatic sequential numbers. Note: no gaps in the total number sequence is allowed.

Once **ADD** is clicked the node will appear on the spatial layout area.



6.7.2 Moving a Node

When building up a layout to be modelled you will often wish to reposition or even delete nodes. Moving a node is achieved by right clicking on the node and dragging and then releasing the mouse button.

Right clicking a node will also bring up the window into which all the data for that node is entered. If the window gets in the way of the move, drag and relocate the update window to a position that doesn't interfere. (Note: for any subsequent node selections, this data entry window will remain where you last placed it. It is best to place it in a location where it not going to interefere with building your project).

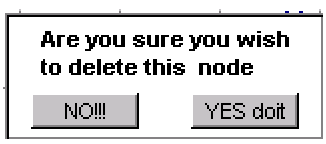
In most situations you will only want to move the node a small distance. However if the layout area becomes very congested, it is possible to drag the whole layout area (plus all the nodes already located on it) in any direction and by any amount. Thus system layouts may extend beyond the edges of the visible window.

Note. If you **right click on a node** and drag**, the node moves**. If **you right click off a node** and drag, the **entire spatial extent of the project moves**.

6.7.3 Deleting a Node

To delete a node, right click on the node in question. As before, the data entry window will appear. Click on the Delete Node button situated on the bottom LH corner of the window.

However, note that the **delete button will be deactivated if the Lock the Layout** checkbox is checked on. This is located in the lower Area D window of the screen. Therefore ensure this is checked off if you wish to continue.



When clicked an "are you sure?" window appears. Accepting the delete is permanent. Warning this has no "undo" method Deleting a node removes any attached water supply links or drains and changes the numbering of some components. Note the numbering system of remaining nodes with a higher number than the node deleted will be reduced by 1 after this operation.

Note: BEWARE The delete process does not automatically delete the copied number of the deleted node from the Output Options reporting list, if it has been previously selected for reporting via the Output Options process. If the deleted node had the highest sequential node number in the project, this number will remain on the selected Output Options list, but a node with this number will not exist in the current project. If the project is then re-run with the previous node number still being requested for output reporting the model will become unstable and may fail with an error message. Thus**, if you delete and do not replace a high numbered node, be safe and remove any reference to it from the Output Options listing.**

Further to the above, deleting and replacing nodes will often remove previous correspondence between node numbers on the screen layout and those listed in Output Options.

6.8 Linking Nodes – Drainage Paths

Flow paths between nodes are established as **either drains (Sect 6.8) or water supply links (Sect 6.9).**

6.8.1 Drainage paths

Drainage paths are usually established from catchments, towns, storages, treatment plants, etc. to represent unregulated natural gravity flows or spills from them to any linked downstream nodes. The operation of the drainage system is defined by the presence of the drainage links between nodes. These signify that any water generated at a node, subject to the internal rules of the node, is passed downstream. Storages receiving drainage inflows from upstream provide a locally available water source for supply.

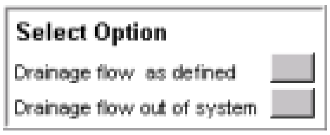
The established drainage paths are assumed to always have sufficient capacity to take the largest flows which could leave the upstream node. Thus the designer is not asked to nominate a capacity for a drainage path. At present, as far as drains are concerned, the model ignores any elevations set for the nodes and thus lower elevation nodes may drain into higher elevation nodes via the establishment of a drainage path. I.e. drainage paths are not presently elevation 'conscious'.

At present the type of conduit used to drain the system is not defined. Future costing options will require the type of drain established to be nominated. Similarly, future exceedence of the capacity of a stormwater drainage pipe (or sewer pipe) will not restrict the passage of larger flows along the same path, but will be counted as a 'failure' of the drain pipe. Linking stormwater components with natural creeks will initiate no capital cost (although a maintenance cost may be included).

NOTE: All icons which do not have an outward (downstream) drainage path are assumed to be spilling any water generated within them, or passing through them, 'out of the system'.

6.8.2 Adding a Drain Path

When drainage paths are to be established, deleted or modified the **Drainage Paths** button (located at the lower right hand of screen) must be selected. When this is done all existing paths become visible.



To establish a drainage path, click and hold down the left mouse button while pointing at the centre of the upstream node. Move the pointer to the centre of the receiving node and release the mouse button. The proposed drainage path is now displayed as a blue line and an input window becomes visible.

Drainage flow as defined is clicked if you wish to add the path as requested. Else, **drainage flow out of system** allows you to remove a drainage path if you have followed the above procedure over the alignment of an existing drain.

Note in some components there is more than one way that water may flow. A second window may appear asking you to specify which of the outflows should be connected. This is described below.

If the drainage connection is being made from a standard component (ie not containing a diversion option) a blue line and arrow signifying the link and direction will be displayed on the screen after drainage flow as defined has been clicked.

6.8.3 General Drainage and Diversions

Nodes generally have only one downstream drainage path. Any node, however may have an unrestricted number of upstream drainage paths delivering inflow to it. While this might sound restrictive, in practice there are few situations where this does not mirror normal river and drain systems, where tributaries converge and distributaries or anabranches are rare.

However, the splitting of drainage flows into two paths can be simulated by certain nodes (Weir, Natural catchment, House and Urban nodes). These can have subsidiary (diversion) drainage outlet paths in addition to the main drainage outlet path.

6.8.4 Drainage options for a Weir Node

The weir splits the streamflow in two directions. When the weir is connected to a downstream node the window shown will appear. Options are **main stream** which is selected to identify the continuation of the normal downstream path of a river or drain. If selected, this is shown on the layout as a **blue line and arrow** showing the direction of flow. If a diversion is desired, then a second connection must be made from the same node to another downstream node. The window will appear again and this time the Diversion option should be selected.

The proportion of the drainage flow that is diverted by the weir is defined via the diversion header on the weir node. This is described in Section 8. The diversion is directed along the diversion link which is signified on the screen by a dashed purple line and arrow.

6.8.5 Drainage options for a Natural Catchment Nodes

A **natural catchment** node enables the streamflow leaving it to be split into two directions. These are the normal flow path of overland flow and the groundwater path. One or both of these are selected when a drainage link is created or adjusted and requires the decision **main stream** or **groundwater**.

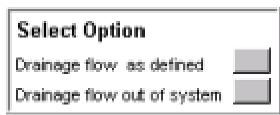
Main stream is selected for the continuation of the normal drainage flow downstream. In most cases this is used by itself. However, an option is provided to separate out the **groundwater** flow which has been generated on the catchment in question and to direct this further downstream. (This is particularly useful for modelling situations where the groundwater contribution from hilltop catchments remains underground until it intersects a groundwater table further downstream. The groundwater contribution will then by-pass any farm dams in the hilltop zone, but can be modelled to re-emerge further downstream.

The amount of groundwater is dictated by the water released from the groundwater store present in the rainfall to runoff model.

6.8.6 Drainage options for House and Urban Nodes

The House and Urban nodes can split the drainage flow into four directions. Options are **Grey sewage, Black sewage, Ground runoff and Roof runoff.** In this case Ground Runoff is equivalent to **Main stream** and the others are the diversions. These flows are all generated within the workings of the node in question. Stormwater flow and waste are generated within this node as well as the internal path of this water. A user may then specifically divert various qualities and quantities of water to one of four pre-defined outlets. The external expression (outside the node) of these outlets is then carried through with these outlet paths.

6.8.7 Removing a Drainage Path



To remove a drain you follow the same procedure used to create a drain between the two nodes in question.

The input window that appears requires you to specify whether:

- drainage is to the node specified
- drainage is to **out of system**

To remove the drain click drainage **out of system**

Alternatively, reselect a drainage path as defined above and if a connection already exists from the nodes you identified this will automatically be removed and the new connection as requested will be placed.

6.8.8 Drainage Out of System

Any drainage system has to have an end point and this is simulated in the program by a hidden node provided with a high component number (9999). This is added automatically at points where spill can occur. These are points where drainage may spill to "out of system". In the real world this out of system node would represent a discharge to the sea or to a river. Or it may be discharge of water outside your area of interest.

Thus it is possible to discard unwanted stormwater from the system if, for example, you wished to recycle sewage effluent but not stormwater from a town. In this case the black or grey wastewater is drained to a treatment plant and thence to its reuse point, the stormwater leaves the system.

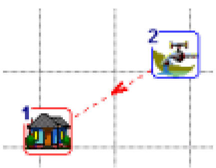
6.9 Watersupply Links

6.9.1 Supply and Demand Nodes

Water supply links enable water to be transferred (usually at a defined maximum rate) from one model node to another, which 'demands' the water. Most components within the model are capable of acting as both a supplier and a receiver of water transferred via a water supply link. Exceptions are:

Cannot Receive Supplies	Cannot Supply
	Demand
	Text Demand
Natural catchment	Natural catchment
Impervious catchment	Impervious catchment
Text flow	Text flow
External Supply	
Weir	
Channel	
Spring	

An error message will be displayed on the screen if a water supply is attempted between non-complying nodes.

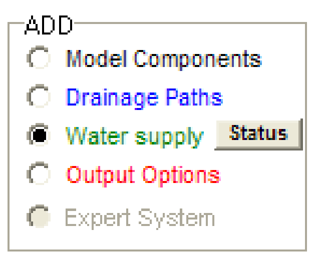


Water transfers take place wherever a water supply link is established between a node with supply capability (nodes containing an actual or notional storage) and a node with an actual or notional demand capability.

Whether/how a storage supplies water to a demand depends on its interaction with other storage nodes that are also connected to the same demand. This interaction is handled by the assigning priorities, weights abd supply sequences to all supply links

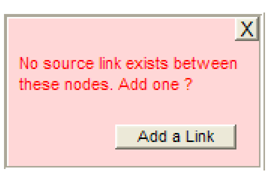
Priority gives the order of supply to a demand. A priority 1 link to the demand will supply before a priority 2 link, etc. A priority 0 link will not supply at all. Where two storages are connected to a demand and have the same priority, the proportion attempted to be taken from each is determined by the weighting. (see Sect 3.7 for a full description of priorities, weights and supply sequences).

6.9.2 Adding Supply Links

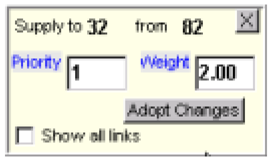


When supply links are to be established, deleted or modified the **Water Supply** button at the RH/centre base of the assembly field margin must be activated. When this is done existing supply links become visible.

Left click on the storage node, hold down the button, and drag and release over the demand node. Clicking from a non storage node will display the message" Source is only possible from a storage component". Click **X** to get out as no link can be made from here.



If there is no link existing at this requested location, a screen appears stating that there is no source link between the two nodes. To add a link click **Add a link.** Clicking across an existing link will provide you the opportunity to either change or remove the link.

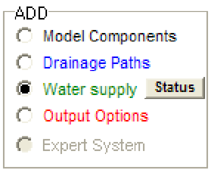


If adding or changing a link, a window identifying the the priority and weight will appear. Set a priority and weighting for the water supply by inserting the appropriate number in the edit boxes.

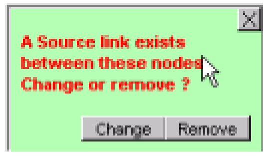
When happy with the values set, left click the **Adopt Changes** button in the lower window. If **show all links** is checked, a list will appear giving all the connections from sources to demands and the priorities and weights that have been assigned. Alternatively, clicking the **status** button in the ADD box will display the existing priorities and weights adjacent to the links.The proposed link is now displayed as a red dashed line and direction arrow. At any time (before adopt changes) the user may click **X** to leave without adding or changing a source link.

6.9.3. Removing a SupplyLink

The steps for the removal of a water supply leading from one component to another are as follows:

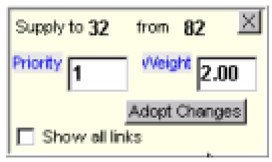


Select the **water supply** checkbox appearing in the ADD box at the bottom right of the screen.



To remove an existing water supply link, left click on the upstream (supplying) node, hold down the button and drag and release over the upstream (demand node). The window at RH will appear. Selecting **Remove** will remove the link.

6.9.4 Editing a Supply Link

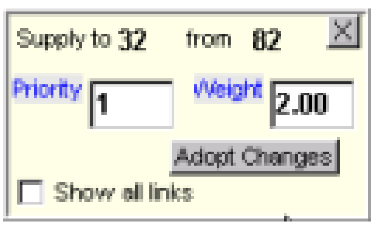


Follow the steps in 6.9.3 for removal. If there is already a supply link its priority and weight are displayed in the entry boxes. You may now change these. .When happy with the values set, left click the **Adopt Changes** button.

At any time the user may click **X** for cancel (top RH corner of window) to leave without adding or changing a source link.

6.9.5 Understanding Priorities and Weights

Priorities and weights are assigned to all water supply links and are only of significance when a receiving component gets its water supply from more than one other storage node. Ie the priorities and weights are assessed from the viewpoint of the water receiving component only.



The order in which the receiving (or demanding) node seeks to take the water from the storage nodes is determined by the assigned priorities. For example, it may be wished to supply a demand from a reservoir and an ASR bore and only when the reservoir is empty will water be taken from an ASR bore. In this case the reservoir will be given priority 1 and the ASR bore priority 2.

Priorities only have relative significance. I.e. if a node receives its water from only one other storage node but this is designated as priority two, this will be recognised as the highest priority and water will be taken regardless.

If the priority is set to 0, no water will flow.

If the receiving node seeks to get its supply from several sources at once and mix them in certain proportions, it can do so by assigning the same priority to each source and setting the proportions required through weighting. Thus, if three sources are given the same priority, and are given weights 1, 1 and 2, then all will supply simultaneously, but in the proportions of 1/4, 1/4 and 2/4. If the second of the sources was to run dry, then the weights will be re-allocated between the two remaining sources as 1/3 and 2/3.

Refer section 3.7 for a detailed example of use.

6.9.6 Supply Sequence

The Supply sequence is set in a data entry box generally located on the bottom of the demand window of all nodes that can receive supplies (see example Section 7.6).

The default value of 0 signifies that the supply sequence is in the normal order of calculation undertaken by the model (see Section 3.6) and that no particular change to that order is being sought by this node. In many projects the order of calculation (and hence supply) is not particularly important, however there are situations where supply to one component is necessary before supply to another is attempted.

Hence, when the Supply Sequence is set > 0, the value will define the sequence order that water is to be supplied to this component. For example a component with a sequence 1 will be supplied before one with a sequence of 2.

Note the supply sequence order is different from the priority order. **The supply sequence** defines the order in which one or all of the nodes will be supplied across the whole project . **The priority order** only relates to a particular demand node and defines the order in which that node will seek its supply wnen it can be supplied from more than one supply nodes.

Refer section 3.7 for a detailed example of the use of Supply Sequences and Priority Orders.

6.10. Node and File Naming Convention

User selected (variable) parameters for all nodes within a project are stored within the folder <program_folder>\your_project_name (eg. wc2000\onkaparinga) with the naming convention for the individual nodes being xxx_yyyyyyy.txt. The xxx is an identifier for the node type (eg cat for catchment, see table below) and yyyyyy is a six character name the user provides when a node is added to the project (eg hapval for happy valley).

There are currently 18 node types

Node Grouping	Type of Node	Identifier	Default file name
Demand Nodes	House Urban Demand Text Demand	twn twn ind fop	twn.base.txt twn2.base.txt ind.base.txt fop.base.txt
Catchment Nodes	Natural Impervious Text Flow	cat urb txt	cat.base.txt urb.base.txt txt.base.txt
Storage Nodes	Reservoir Aquifer Tank Offstream External supply Multi-store	dam asr tan int ext str	dam.base.txt asr.base.txt tan.base.txt int.base.txt ext.base.txt str.base.txt
Treatment Nodes	Treatment Wetland	stw wet	stw.base.txt wet.base.txt
Transfer Nodes	Weir Channel Spring	div env env	div.base.txt env.base.txt env2.base.txt

As each of these components are created in a new project a default file is drawn from the folder <program_folder>\files (ie wc2000\files). Reference to this folder will shows an instance of each of the default file name types with the component name "base" as default.

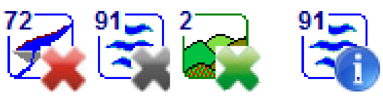
The user may personalise their program by saving their own base files in this directory. The best way to create a base file is to copy a file from an existing project which which has the base parameters required by the user, copy it to the <program_folder>\files directory, and rename it with the "base" identifier (ie discard the old base file). Any new node now added by the user will carry the parameters of this new base component.

Note. reloading the watercress program will override and replace these base files and therefore personalised files will be required to be backed up and replaced after a full program reload.

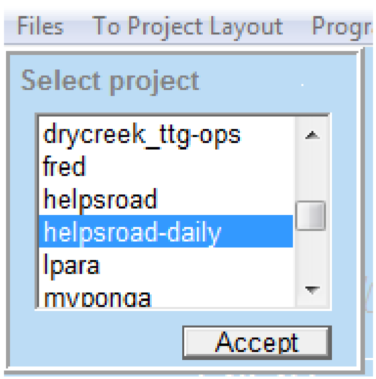
In addition, the house and urban nodes allow a range of setup options to be created which then can be accessed to modify nodes created. These type files as they are created take the format xxx_yyyyyy.txt and are also stored in the **\files** directory. As above the xxx is the identifier of the node and yyyyyy is the name provided by the user. For the house node the identifier is **twn** and for urban is **twn2.**

6.11. Checking file availability

When you select a project the program undertakes a simple data availability check. This, if a potential error is found, displays a colour coded “x” in the lower rh corner of the icon (as shown below). A “red x” identifies that the calibration file cannot be found and a “black x” indicates that a feva file cannot be found. Calibration and feva files have full path names and therefore can be easily moved or lost. Fixing requires that the missing file is located using the normal selection process.



A “green x” indicates a missing rainfall file. Rain files do not have path names and must be located in the project directory. Fixing requires either the missing file be returned to the required location or a name change rain file input window.



On making these changes the “X” will not automatically disappear as the checking process occurs when you select the project. Simply go back to the opening page and click on the “accept” button as shown. Now when you return to the node layout page the crosses should be gone. However, there may be more than on error and the display will only show one color cross. This process may require a couple of iterations before the layout is clean.

Note. Missing files most often occur when you import data from other computers.

The “i” information symbol shown above occurs on any node where a “feva” or calibration file is provided. This is to provide a visual guide to the user as to which nodes external files are linked. The “i” indicates that the data file has been found. Note. No “i” display is added for rainfall files

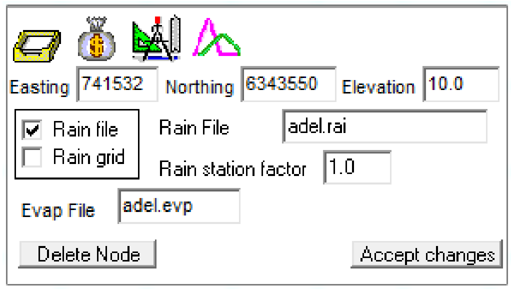
7. NODE COMMON DATA INPUTS And PROCESS CALCULATIONS

This Section describes how data is entered into, and the calculation methods used in operational processes which are common to several nodes (eg setting storage volumes, demands, seepage calculations etc.).

Where a node has a unique or more complex operation, data entry and calculations undertaken for that operation may be found in the descriptions of the individual nodes in Section 8.

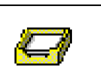
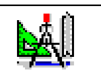
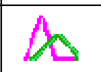
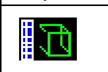
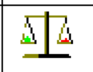
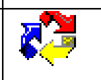
7.1 Initiating Data Entry – the Data Entry Icons and Initial Screen

The entry of data defining the operation of each of the nodes comprised within a project is initiated by **right clicking** on the node itself.



This will bring up a window similar to that shown at the RH. The range of icons that will be shown in the same location (as in the example above), for each of the 18 possible nodes are given in the table below and described in the following sections.

Table 7.1.1. Data Entry Icons present for each node type.

Node	File	Costs	Catch	Store	Demd	Rout	Prpties	Calib	Divert	Treat
										
House	Y	Y	Y			Y				
Urban	Y	Y	Y							
Demand	Y	Y			Y			Y		
TxtDemd	Y				Y					
Natural C	Y	Y	Y			Y		Y		
Urban C	Y	Y	Y			Y		Y		
Txt Flow	Y		Y							
Reservoir	Y	Y		Y	Y	Y	Y	Y		
Aquifer	Y	Y		Y	Y		Y	Y		
Tank	Y	Y		Y	Y	Y		Y		
O/s Dam	Y	Y		Y	Y		Y	Y	Y	
External	Y	Y		Y						
MltiStore	Y	Y		Y		Y	Y	Y		
Treatmnt	Y	Y						Y		Y
Wetland	Y	Y		Y	Y		Y	Y		Y
Weir	Y	Y						Y	Y	
Channel	Y		Y			Y		Y		
Spring	Y		Y					Y		

Before commencing the icon descriptions, data entered via the initial screen itself is described below.

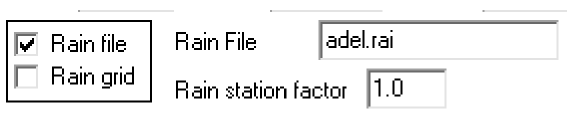
In the **top frame bar** is the **file name for the data file** containing all the data entered via all data entry methods for the node. The first part of the name (eg cat) defines a file for a natural catchment. The second part (eg two) is the name that the modeller has given to this particular natural catchment. The file cat_two.txt will be found in the <wcprogram_folder>\ project name under the same name, cat_two.txt.

The level below the top frame bar contains the set of **data entry file header icons** applicable to the functions covered by the node. There are a total of 10 icons in total (se sect 7.2), however, in general only 3 to 7 icons will be found for most components depending on the range and complexity of the functions they perform. **Left clicking** on any of the icons will bring up the data entry window applicable to the function(s) covered by the icon, as described in following sections.

Section 7.2 shows the relationship between the different components/node types and the range of data entry icons present in the header bar for each of them.

The next level down shows the **Easting, Northing and Elevation** values for the node. The first two are automatically calculated, based on the data entered into the Opening Screen for the top LH corner of the screen and the position that the node has been established on the screen. However, the present model does not take these values into account in its calculations and thus they **can be safely ignored**. An elevation may be entered for the node in the elevation window, and the value is used in some specialised applications involving storages and diversions. However, for most modelling applications the default **elevation** which appears in this window is not taken into account in the model calculations, and thus the values entered **may be safely ignored.**

The **Rain File and Evaporation File** are the rainfall and evaporation files being used by the node. The files can be changed in these windows if required.



Two options of file input are provided here. In most cases the **rain file** option will be used which identifies that the rain file name identified (in the example adel.rai) will exist as an individual file in the required format. When the model is run, these files will be first sought in the project file. These files have no path and must be located within the watercress folders in one of 3 locations. In order, the locations sought are

<wcprogram_folder>\your_project\raindata

<wcprogram_folder>\your_project

<wcprogram_folder>\raindata

Although poor practice, different versions of rainfall files may be in existence, even though they have the same name (eg. versions spanning different periods, or with gaps filled by different methods, etc.). It is therefore important to be certain that the rainfall data being accessed by the model is the intended version.

The **rain grid** option is primarily used when the rain input is provided as a grid of rainfall, in particular a grid based on local corrected radar records. Some version of the model do not have access to this option and it is greyed out. Selecting **rain grid** will provide the following options.

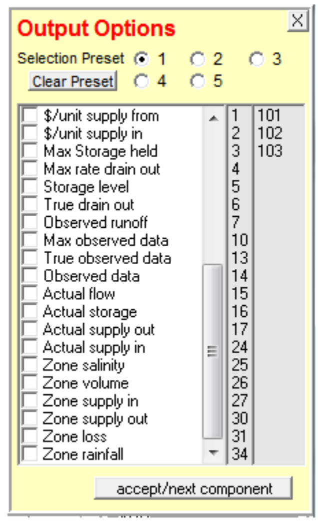
Inputs of this type are not input as individual files but as a single file. For this to occur the model must include an operation node. Unless you are running the model in operational mode you should only select the **rain file** input process

The **Rain Station factor** selected will multiply every rainfall reading contained in the rainfall file by this factor. The factor is used to adjust the rainfall measured at the location of the rainfall gauge (over the period of modelling) to the value estimated for the location of the node, or the estimated average rainfall over the catchment area represented by the node. Until more precise methods have been proven, the factor has been used to modify a historical rainfall record to represent the rainfall that might be experienced at the same location under the influence of **climate change**. Note the rain station factor is not used when the **rain grid** option is selected. It is assumed that as a grid of rainfall is input then the variation of rainfall across the area is adequately handled by the grid itself.

The Zone number. A group of similar nodes (eg catchment or storages) may be assigned a common zone number so that certain data common to all those included within the same zone may have some aspect of their data modified by a common factor. (Eg rainfall factors may be modified in steps of 2% or storages reduced by 5%, etc.). The application of the factors is described in section 6.6.2.

In addition certain output options allow for the accumulation of certain elements within an individual zone. The selection within output options shown to the right allows zone salinity, volume, supply in, supply out, loss and zone rainfall to be output.

To output the required parameter for a zone the user is required to select just one node that is included in the zone of question and select the zone output required.



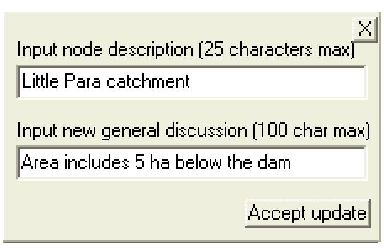
Accept Changes. The need to accept changes is common to all data entry windows. A common mistake is to forget to do this. It is particularly dangerous if more than one change has been made.

Data Entry for Individual Data Icons. Further details on data entry specific to certain components is given in Section 8 where the functions of the individual components are described. A general description of data entry via each of these icons is given below.

7.2 Filed Data/Memo

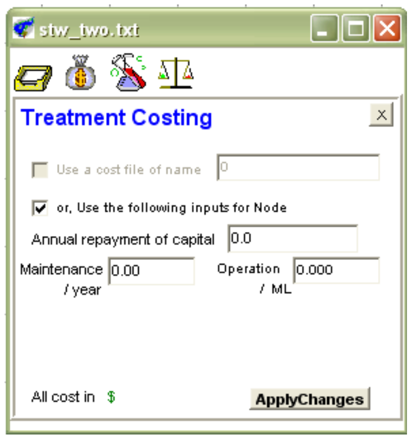
This is the only icon which appears on the data entry header bar for all components. It is also the one that is usually used least (or at all). Clicking on the icon brings up the window shown at the RH. This window provides two things:

Firstly, by clicking on **update memo,** the panel below will appear. The windows provide space for a very brief 'mind-jogger' in relation to an aspect of the node operation. This description can be updated by the user.



Second, the window below this description provides a long listing of all the data entered for that node via all its data entry icons and methods. It can be used to check the correctness of data entries, but only if you know the order of listing of the data. **It is not possible to alter data via this list**. If you wish to alter data it is necessary to re-enter the correct data value via the header icon.

7.3 Costs



Clicking on this icon reveals a window where capital and operational costs can be entered for the node in question**.** The format of each window will be tailored to the particular node.

While costs may be entered, the calculations have received very little checking to date.

Ultimately the costs will be able to be input in two forms.

Direct entry of estimates of the required annual repayment of capital, the maintenance per year and the operation cost per unit volume of water stored or passing, etc.

Indirect entry via a cost file. This is currently under development. This will allow the costs to be related to changes in operation scale, for example in optimisation runs.

Cost are tracked through the system, from upstream to downstream, following the flow paths, but the costs are trapped in storages (even if they spill). The build up of cost in the stores is then passed on to the demands drawing water from the storages via the supply links. This will result in a cost per unit volume of water supplied being calculated at each supply location.

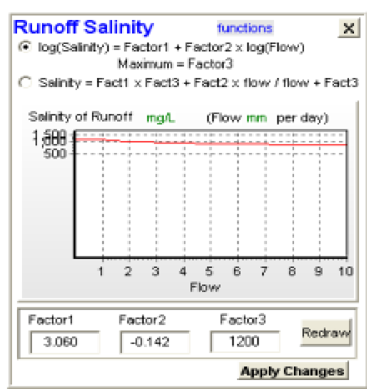
7.4 Catchment Data.

7.4.1 Main window

This icon appears for all components/nodes which are involved in the calculation or modification of runoff as given in Table 7.2.1. For the House and Urban nodes this icon leads to the full layout of the node, which includes runoff generation, but also provides data entry for internal storage, demands and recycling.

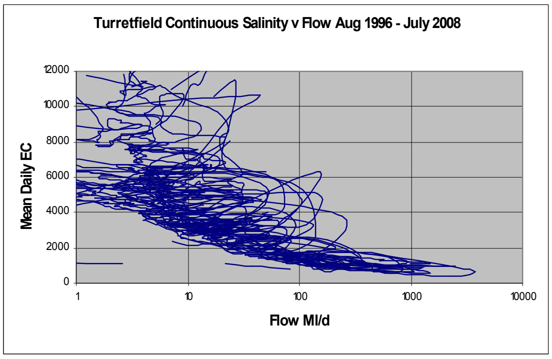
Data to be entered invariably includes the catchment area. For natural catchments a choice is provided for the rainfall to runoff model to be used. Because of differences between nodes, details for nodes carrying the Catchment Layout icon in the header bar are described in more detail in Section 8. However, one feature in common across all the nodes is the choice of a flow versus salinity model. This is described below

7.4.2 Salinity Model



One common input window is the salinity model. Clicking on Salinity model parameters will bring up the window shown to the RH. The window allows the modeller to input parameters to simulate the salinity of water leaving the catchment.

The relationship between mean daily flow and mean salinity is often very complex. The figure shows an example where continuous flow and salinity readings are plotted as mean daily flow(ML/d) and salinity (EC) with a line joining consecutive pairs over a 12 year period.The un-joined data is shown plotted on log-log scales below.



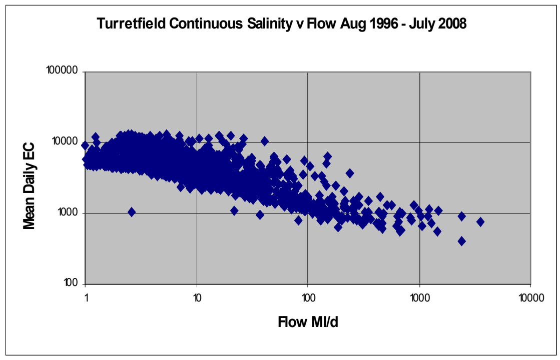


Figure 7.4.2 Recorded flow salinity relationship for the North Para River at Turretfield

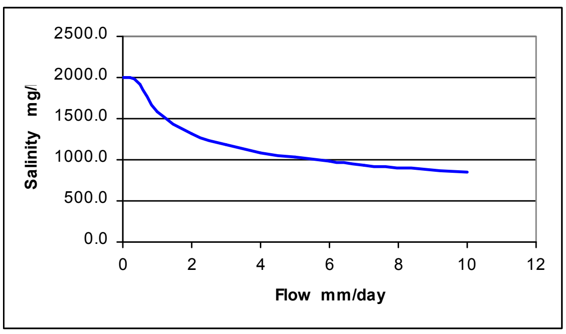
While complex models have been proposed, it is usually sufficient to represent the relationship by a simple mathematical relationship. Two are provided in the WaterCress mode

Equation 1 **- Log(salinity)=Factor1+Factor2xLog(flow)** and **Max salinity = Factor3.**

The graph on the window provides a graphical display of the flow salinity relationship chosen. Varying the parameters and selecting redraw provides a preview of the result before apply changes is selected.

In this equation **Factor1** is the log value of the salinity when flow = 1 (ie log (flow) = 0). In this example about 3. As flows increase a negative value for **Factor2** will reduce the salinity concentration at high flow levels**. Factor3** can be set at a maximum salinity that will not be exceeded at low flows. In the plot above, this might be set about 900 EC. The values obviously depend on the units for flow and salinity. If flow is expressed in mm/day and salinity in mg/L the values of the Factors remain relatively stable within regions with similar hydrology.

The graphs shown figure 7.4.2b are based on flows and salinity measured in mm/day and mg/L with Factor1 = 3.2, Factor2= - 0.27 and Factor3 = 2000 mg/L.



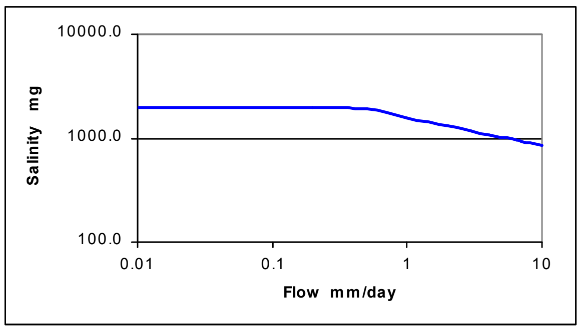


Figure 7.4.2b Modelled salinity using equation 1

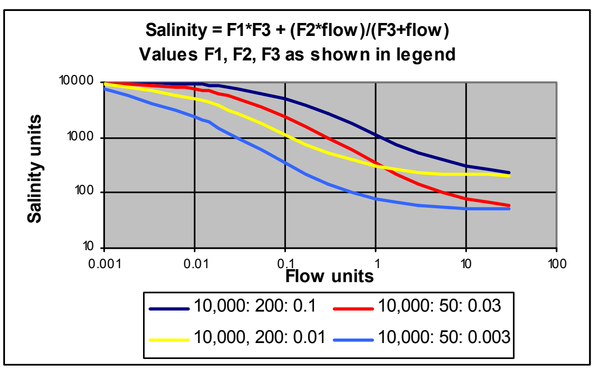


Figure 7.4.2c Impact of varying factors 1 -3 on equation 2

Equation 2 **Salinity = Factor1*Factor3 + (Factor2*flow)/(flow+Factor3)**

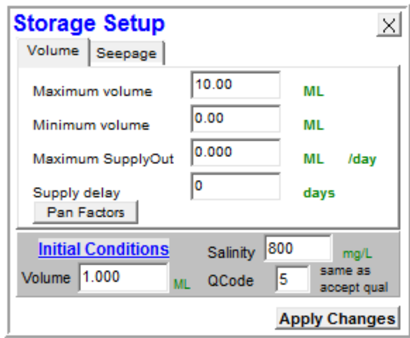
The formula asymptotes salinity between Factor1 as a maximum value at low flow and Factor2 as a minimum value at high flow. Factor 3 determines the slope and position of the relationship between the maximum and minimum values. Refer figure 7.4.2c.

With three factors to adjust both equations have similar flexibility in fitting to the data.

Beware: Changing the model selected will require a large change to the values of the Factors. If the Factors are not changed, a change in the model will give highly erroneous salinity values.

7.5 Storage Setup

Clicking on this Icon for the 7 components which display it in their header bars will reveal a similar window to that shown at RH, opened at the default Volume tab. For each of the 7 components, the window variously shows further tabs for data entry including Seepage, Pan Factors or Variation of Store across Year (see below).



All nodes (with a few omitting some elements) display the Volume tab under the Storage Setup window. It is therefore covered in detail here rather than in Section 8

7.5.1 Volume Tab

Maximum volume: defines the level at which spill occurs due to uncontrolled drainage inflows. Routing (refer later) may cause the volume in the store to exceed this value, but given no further inflow, the storage will continue to spill water down to this level. If no routing is included any inflows which exceed the maximum volume are immediately spilled downstream. Since the model calculates drainage from upstream to downstream, any spill occurring from any storage will be taken into account in the water balances further downstream on that same time-step.

Minimum volume: is the volume below which the storage will not supply water via any connected supply path to any demand component (including any internal demand set for the storage itself). Evaporation in excess of rainfall will continue to draw the level down below this minimum volume in the absence of other inflows.

The minimum storage is often referred to as "dead" storage. The lowest level a dam can fall to is zero storage, which is different from the minimum storage or volume.

Maximum supplyout: may be used to define the maximum rate that water can be supplied from this node. Normally maximum supply rates are set by the demand node NOT the supply node. The facility is used if a demand node wishes to set different supply rates from different storages to which it is linked by supply paths. Thus caution should be used in using this value as a similar constraint can be made on the demand side of the supply link.

If demands in your project are only linked to one storage supply source, or will require supply at equal rates from any connected storage (using the Priority and Weights facility) it is best to set **Maximum discharge = 0. This signifies no constraint will be set** and the supply though the link will only be controlled by the value set in the demand side (refer section 7.6 Demand).

Supply delay: The age of the water held in storage is calculated at each time step, assuming complete mixing of inflowing and previously stored water. The age of present inflow is assumed to be zero, hence the flow weighted age of inflow is also zero and its age does not enter into the equation below used for calculating the Age of the water in storage at time T:

VolAge(T) = {**Vol**(T-1)***VolAge**(T-1+ t)–**Spill**(T)***VolAge**(T-1)}/{**Vol**(T-1)+**Inflow**(T)–**Spill**(T)}.

Where T is time now, T-1 signifies the status at the end of the last time step and t is the time step.

The storage will not release water to supply unless the age of the water in storage is greater than the delay days.

Initial Conditions: The Volume, salinity and quality code relate to the starting volume and starting salinity of the storage. **Beware**: The Qcode set as the initial condition and the maximum Qcode of water set as being accepted by the storage when recharged via a supply path from another storage (see 7.6 Demand) are linked to always show the same value (ie the last value set in either the Storage or the Demand tabs). Therefore <u>always set the initial Qcode as the maximum Qcode that will be accepted if a supply is to be arranged into the storage from an external supply source.</u>

Pan factors: Clicking on the pan factors button reveals the window to the right

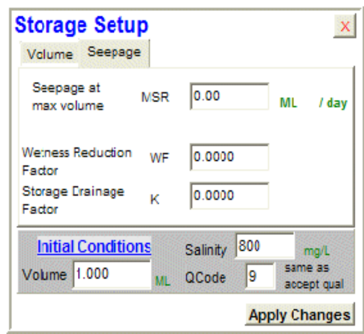
Water is also lost to the storage by evaporation, for which three parameters are to be defined:

The initial daily evaporation can be **either** equal to the mean monthly value (defined in the evapname.evp file – normally located in the raindata file) for each month, divided by the number of days in the month, **or** may be input as the actual data listed with the rainfall in the rainfall file.

Each (initial) daily evaporation value can be multiplied by the factors given in the window for the relevant month.

The surface area of the water body. This is set by the defined relationship of the volume to area relationship of the dam. For the calculation of surface area of a storage refer Section 7.8.

7.5.2 Seepage Tab



The storage may be subject to both evaporation and seepage losses (although these may be made to be zero if it is required to simulate the presence of roofs over the storage or liners beneath it).

Seepage is calculated via two optional formulae depending on the value set for **WF**.

For **WF**=0:

Seepage(t) = **MSR***(Storage volume(t)/(Max volume)

Where storage volume is calculated after all other inflows and outflows have been accounted for.

Under this formula the seepage rate falls at an exponentially decreasing rate from its maximum rate (given by **MSR**) as the volume in storage reduces.

For **WF**>0:

A two part formula similar to that for infiltration applies, in that a notional storage of water (Seepvol) is accumulated beneath the modelled storage as a result of previous seepage. This acts as a back pressure to further reduce the infiltration rate from the rate calculated by the simpler formula above. Ie:

Seepage(t) = **MSR***(Storage volume(t)/Max volume) - **WF***Seepvol(t-1)

And Seepvol(t) = SeepVol(t-1)*K+Seepage(t)

Again, the storage volume is that calculated after all other inflows and outflows have been accounted for.

WF and **K** must be set at less than 1.0. The size of Seepvol is self regulating.

Seepage is assumed to be totally lost from the system. It is not assumed to drain downstream.

Figure 7.5.2 shows a comparison between the two formulae. Both are for a storage staring full at 1 ML with a starting seepage rate of 10 kL/day. The graphs show the reduction in seepage rate over 50 days with no additional inflow. The top graph (with WF=0) shows the seepage rate retained at the highest rate over the longest period, but gradually reducing as the volume in the storage reduces. The lower graphs all show the seepage rate reduced via the build up of the underlying saturated groundwater. A higher K value increases the drainage from the groundwater mound, thus reducing its effect and retaining the seepage at a higher rate. A higher WF value reduces the seepage rate for a given K value as it multiplies the back pressure effect of the mound on the rate that the seepage can escape from the storage

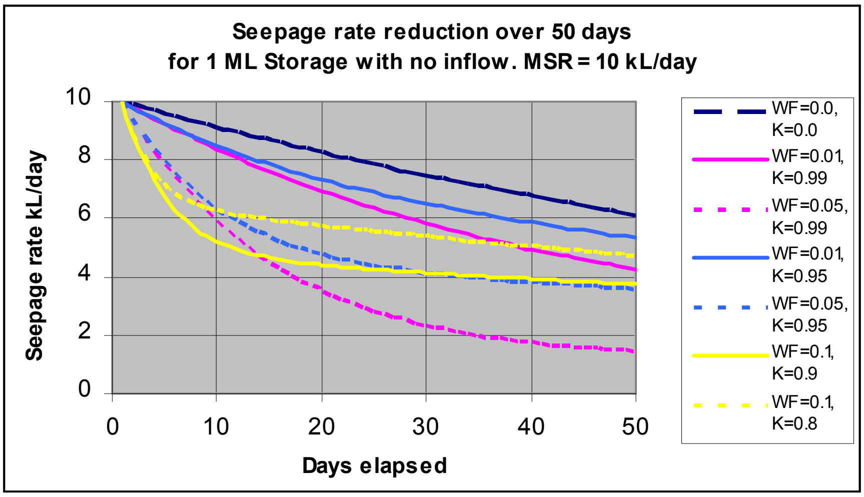
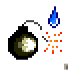


Figure 7.5.2 Effect of varying the seepage function parameters on modelled seepage rate

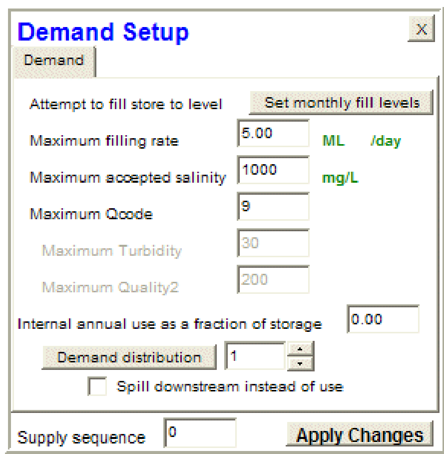
Unless high quality data is available to calibrate the formulae, only a notional seepage allowance can be set.

7.6 Demand.



While setting demands is a vital feature common to the House, Urban, Demand, Text Demand and all storage nodes, the House and Urban nodes do not carry the demand icon in their header. Demands for these are set via an internal tab accessed by clicking on the 'mini-nodes' established on the internal layout screens access via their header Catchment icons. These are described in Section 8. Also, while having the demand icons in their headers, the window layouts for the two demand nodes (Demand and Text Demand) are different and are thus also described in Section 8.

The following descriptions are for the storage nodes only, although aspects will be common to the other demand nodes..

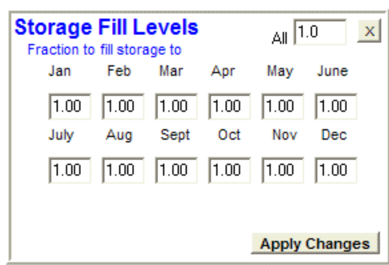


All storages (on-stream, off-stream, tanks, rainwater tanks, wetlands and treatment plants) can act as demand nodes when requesting that water be supplied to them via supply links to other storages. This demand is initiated if the water held in the receiving storage falls below a pre-determined value. When this occurs, the receiving storage will request to be filled to the pre-determined level from the other sources.

With minor variations, the window shown is common similar to all the **storage nodes carrying the Demand icon** in their header bars.

It is important to remember that the first 5 input boxes shown only apply when storages are being filled via water supply links. The constraints shown on this window do **NOT** apply when flows are linked via drainage paths.

7.6.1 Monthly Fill Levels and Maximum Filling Rate



Clicking the 'set monthly fill levels' tab provides a set of input windows which identify the level to which the storage requests to be filled, from any other connected storage, for each month of the year.

The values are input as a fraction of the maximum storage to be attained. **For example, setting a level of say 0.5 means that a transfer of water is sought from other connected storages (at the maximum filling rate, if possible) until the storage attains a volume equal to 0.5 x max storage volume.**

If the values are set to zero then the storage node will not demand water.

If the storage exceeds the fill level through drainage inflow, the demand switches off. The level will remain in excess until evaporation, seepage or supply from the storage reduce the storage level back to the fill level. Once back at the fill level, the storage will again seek to maintain this level by requesting supplies from other connected storages.

Given a supply is requested by the storage to maintain a certain fill level, the actual supplies received may be limited by a number of constraints:

First, the volume of transfer is limited by the **maximum filling rate**. This is defined as a volume per day. The sub-daily models divide this value in proportion to the timestep used. The water cannot be transferred to the storage at a rate greater than this amount. This can be assumed to equate to the capacity of the pipeline supplying the water.

Beware: Check that any discharge rates set for the transferring storages are compatible with the maximum filling rate set for the receiving storage.

The other constraints relate to the quality accepted. See below.

7.6.2 Supply Quality Constraints

Water will only be supplied when the quality of the source water meets the quality criteria set for the receiving storage node. These quality demands (salinity and quality code) are set on the Demand Setup window. Greyed out constraints (turbidity and a general user defined quality) are coming in future models versions. If the quality code or salinity of a transferring source exceeds the required maximum values entered, then no water will be accepted from that supply storage.

7.6.3 Internal Use

Internal use is a demand set up within the storage node with the main aim of reducing the number of nodes to be established, for example where multiple farm dams and associated demands are to be modelled within a single project. Combining the storage and the demand from that storage into one node simplifies the project layout.

The **internal use as a fraction of storage** allows a simple supply to be made from the storage to simulate (for example) the supply of water for irrigation from the storage. In this mode a defined fraction of the maximum storage of the dam is attempted to be supplied each year following a monthly demand pattern set within the **Demand distribution** tab. Demands for irrigation have often been set at 0.7 of the maximum storage volume per annum. Where the inflows to the storage cannot supply the demand in any part of the year, the storage simply empties and under supplies against the demand.

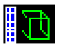
For example – Where the maximum storage volume is set at 20 ML, an internal use fraction set at 0.5 will attempt to supply 10 ML per year at the distribution pattern defined. Supply to meet an internal demand is given higher priority than for any other demand. As this is internal demand, the volume supplied may be tracked in the **'supplied from'** output option listing.

Toggling through the demand distributions will provide a choice of different patterns for the supply to be taken. The 12 monthly proportions making up the annual demand pattern are listed as sets with **wateruse.txt** within the project file. If a pattern cannot be found via toggling, one of these sets may be altered to define the desired pattern.

7.6.4 Spill downstream

Clicking on 'Spill downstream instead of use' will discharge the volume intended for daily supply to the internal demand downstream via the downstream link. This has limited application, but has been used to store winter runoff to be released in summer for environmental uses.

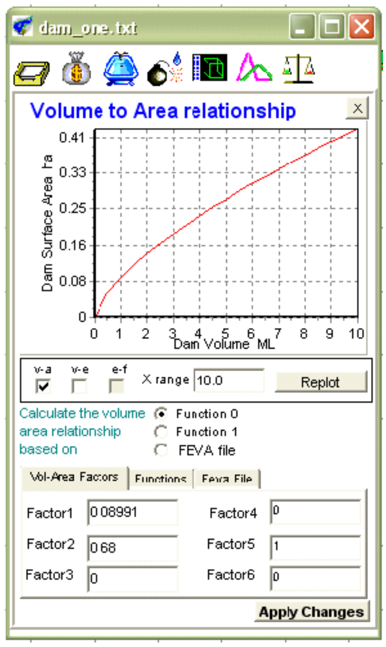
7.7 Storage Properties



The icon is only found on the headers for storage nodes. The properties addressed under the icon include the storage geometry and, via the use of the FEVA file, the determination of the outflow (spill) rate for storages held in excess of the maximum volume up to the spill level.

Clicking on the icon will bring up the window shown below at the RH.

7.7.1 Simple Volume-Area Options

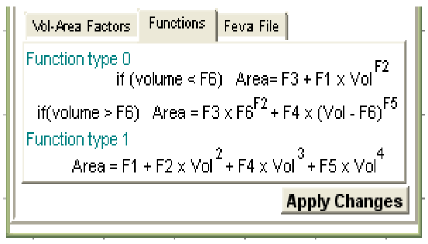


The relationship between the volume of water held within a storage and the water surface area at that volume is required for calculation of evaporation losses from the storage.

There are three options enabling the user to define the volume - area relationship, which when defined, is shown on the upper window as a graph.

The first two options are mathematical expressions and these can be selected via the radio buttons as **Function 0** or **Function 1** at the top of the lower half of the screen.

The Functions can be viewed by clicking on the Functions tab in the centre just below the radio buttons, as shown below



These relationships may use up to 6 parameters, input as Factors 1 through 6. The mathematical functions assuming V = Volume and A = surface area are

Function Type 0

If $V < F6$ then $A = F3 + F1 \times V^{F2}$

If $V > F6$ then $A = F3 + F1 \times F6^{F2} + F4 \times (V - F6)^{F5}$

Notes:

1) Note if F6 is set equal to zero the second part of the equation is not used.

2) F3 is a flat area at the base of the storage when V=0 which may be found in constructed dams and wetlands.

3) For V<F6, the first equation is a simple concave (F2>1) or convex (F2<1) relationship.

4) When the volume reaches F6 the second part of the relationship is activated and can introduce an additional convex or concave relationship up to the maximum volume. This allows a complex V-A relationship as might be found for a wetland.

5) The values of F change according to the units used for V and A. If the units are changed after the F values have been selected, the model will automatically readjust the F values to match the new units.

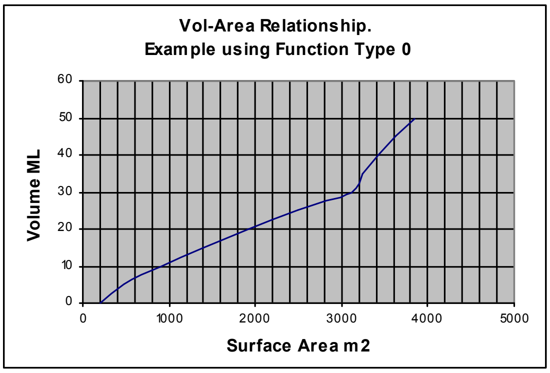


Figure 7.7.1 Example showing a volume to area relationship for a 50 ML capacity wetland with a top water surface area of 3850 m2

The values adopted for the example in figure 7.7.1 were:

F1	35	Multiplier for lower volume curve
F2	1.3	Exponent for lower volume curve
F3	200 m2	Flat area at bottom of wetland forming refuge
F4	20	Multiplier for upper volume curve
F5	1.2	Exonent for upper volume curve
F6	30 ML	Transition volume between lower and upper volume curves.

Function Type 1

$A = F1 + F2 \times V^2 + F3 \times V^3 + F4 \times V^4 + F5 \times V^5$

A fitting technique is desirable if this expression is to be used. The FEVA method (see below) is a simpler way of defining a complex V-A relationship which has been found by survey of a natural or as constructed storage geometry.

Clicking on **Replot** will show the graph of the relationship selected.

The third option for entering volume area data, but also including outflow hydraulic data, is a tabular input defined by requesting a **FEVA file** input. For this method the user must create an flow - elevation - volume - area file (FEVA file) which may be then used by the model.

7.7.2 FEVA – Flow Elevation Volume Area Option

A **FEVA** file is an flow-elevation-volume-area relationship. It can be used instead of the mathematical functions for volume-area given above, but it is also used to establish a relation between storage surchage depth (elevation) and outflow rate, particularly for sub-daily models involved in peak flow rate investigations.

The FEVA file must be created before you enter the WaterCress Program and must be constructed using the format shown below to ensure it is read correctly.

It is recommended that you **use the letters FEVA somewhere within the file name** to remind yourself of the file format a particular file is in. WaterCress uses a number of different file formats for different uses and they must not be mixed up.

Table 7.7.2 Example of a FEVA file

```
*FEVA
The Parks 300 ML storage
cumecs,m,ML,ha,
8
0,15.3,0,50,
0.02,15.4,50,50,
0.1,15.6,270,170,
0.3,15.7,440,250,
0.8,15.8,690,250,
2.5,15.9,940,280,
4.8,16.2,1804,304,
10.0,16.5,2716,304,
```

The format of the FEVA file is shown above and requires:

- The top line is a header which must commence *FEVA to define the type of file to the program
- The second line is a description of the storage to which the FEVA file relates eg The Parks 300 ML storage
- The third line are the units associated with the values in the listing below. See the unit options below. **Beware: Placing an unrecognised unit in this line will default the multiplying factor to 1. This means it will assume the file is in the base units which are sequentially cumecs, metres, kilolitres and square metres.**
- The fourth line provides the number of input lines provided, But this must be no greater than 20.
- The remaining lines are the raw data of elevation, volume and surface area placed in order of minimum volume to maximum volume. Note following " , " in list.

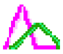
The listed **data must be in numerically increasing order** for the lookup tables to be read correctly. The data must be in the units and in the order specified above.

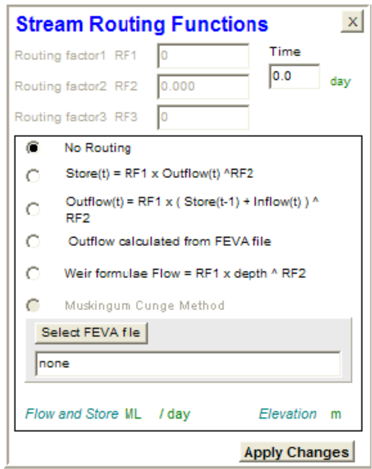
The third line above provides the units of the numerical table. There are only a certain number of accepted inputs. These are as shown by the bold alphanumerics as listed on the LH side of the descriptions in the boxes below.

Flow	Elevation	Volume	Area
cumecs (m3/s)	**m** (metres) **cm** (centimetres) **mm** (millimetres) **f** (feet) **ft** (feet) **in** (inch)	**kL** (kilolitres) **Ml** (Megalitres) **ML** (Megalitres)	**m2** (metres squared) **ha** (hectares) **ha** (hectares) **km2** (square kilometres)

The flow units are cumecs and describe the discharge volume from the storage at various elevations above the spillway elevation. If the tabular discharge and/or elevation are not required then enter zero into their list position.

7.8 Routing Functions





The routing icon appears on the header of nodes involved in flow generation, transmission or storage.

Clicking on the icon brings up the window at the RH. The upper part of the window allows the modeller to enter parameters (RF1, RF2, RF3, time delay) which are utilised in the choice of various routing formulae or methods given below.

The first choice given is to select ‘No Routing’. This is the default setting and is often selected for daily time-step modelling where timing of flow arrival does not matter.

7.8.1 Flow Storage relationships

If routing is to be selected, the radio buttons give a choice of 4 methods. The Muskingum Cunge method is currently unavailable and is greyed out.

Method 1. The method provides a simple linear or non-linear relationship:

Store(t) = RF1 x outflow(t)$^{\wedge RF2}$

Plus a calculation for continuity of volume:

Store(t) = Store(t-1) + inflow(t) - outflow(t)

Within the model the equations are solved iteratively by trial and error.

Method 2. The equation used by this method can be solved directly:

Outflow(t) = RF1 x (Store(t-1) + Inflow(t))$^{\wedge RF2}$

The volume of water retained in the store at the end of the last timestep is added to the current timestep inflow and outflow is calculated as per the equation. Continuity of volume is assumed, and therefore outflow(t) is limited by (store + inflow). **Care must be taken with the choice of RF1 and RF2 to ensure outflow does not exceed Store + Inflow**.

Method 3 - Weir formulae. Routing using depth rather than volume to calculate outflow.

Outflow(t) = RF1*depth(t)$^{\wedge RF2}$

If the spillway outflow versus depth relationship is known and is in the simple form shown above, the values for **RF1** and **RF2** will also be known and can be directly inserted into the formula. The depth is calculated by iteration from the Volume to Area relationship established via the Storage Properties icon. This may be in the form of the volume area functions or a FEVA file.

Note a FEVA file can also contain the flow/volume relationship but this will be ignored if method 4 is selected. In this case the model will use tabular data in the feva file to calculate depth from the volume and use this value in the weir formulae requested.

Method 4 – Feva File. Routing using a FEVA file

The establishment of a FEVA file is described in 7.7.2. The FEVA file allows the user to define in tabular form the outflow versus storage volume relationship. In this case the elevation (depth) and surface area parameters are not used, but they (or default values) must still be included in the file. The method works in a similar method to those above in that Store(t-1) + Inflow(t) are added to calculate Volume(t). This volume is converted directly to provide the outflow. Often in a storage a FEVA file is used for both the volume/area relationship and the flow/volume relationship.

Note. To avoid instability occurring in the solution of these equations, particularly in daily models when large changes in inflow can occur, all of the Methods 2 – 4 divide the inflow into ten equal parts and calculate the storages and outflows over the 10 sub steps per timestep.

7.9 Diversion Functions

The diversion icon only appears on the headers of the Diversion and the Offstream dam nodes. The diversion splits a single drainage flow path into two drainage paths. The mainstream continues as the remnant after the diversion has been calculated and extracted from it.

The amount of flow Diverted is determined by varying any of three parameters which are set in the first three tabs at the top of the window (RH) that appears when the icon is first clicked. The amount is then subject to the constraints set in the fourth tab.

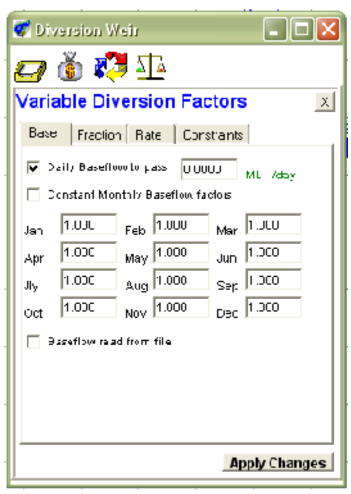
The three parameters define:

1) A base flow required to pass before any diversion is made.

2) A fraction of the flow in excess of the base flow that is diverted.

3) A maximum diversion rate. This in effect limits the maximum volume of diversion that can be made in the time step being used.

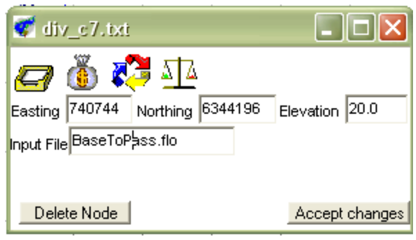
7.9.1 Baseflow tab window



The Base tab window is open as the default window. The baseflow is set by selecting either:

1) a constant daily baseflow volume to pass downstream. This amount does not vary throughout the year. All inflows less than this amount will continue down the mainstream. Only that part of any inflow greater than this may be subject to diversion (see next subsections). If a sub-daily model is being run this amount is divided by the timestep.

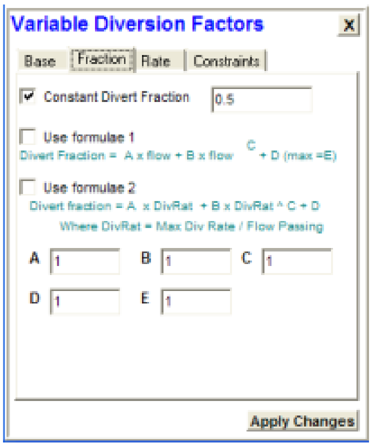
2) a tick in the Constant Monthly Baseflow factors box activates the 12 monthly boxes. The factors operate for the month shown on the baseflow value set in the ‘constant rate’ entry box above. Eg. 0.5*5ML/day for August.



3) a value read from a time series file. This option is NOT available for an offstream dam. Since the weir does not request a rainfall file, this file can be accessed from the 'vacant' location on the initial opening screen normally reserved for the rainfall file. The example above shows a file named BaseToPass.flo entered into this file location. The file must be located within the raindata folder for the project or the project folder under this same name. The data will follow the same format as a rainfall file but lists the daily flow to be released before diversion takes place rather than the daily rainfall. The data file header may commence *WeirEnvRelease daily ML/d

7.9.2. The Fraction Tab

This window sets the fraction of the inflow in excess of the baseflow that is to be diverted.



The fraction may be set by either:

A constant value less than 1.0

One of two different formulae. Up to 5 variables are available to define the fraction.

The first formula will require a good knowledge of the inflow variability and measurement units to arrange a sensible value for the diversion fraction.

The second formula:

DivFract = (DF1*K+DF2*flow)/(K+flow^C)

calculates a fraction which asymptotes between DF1 to DF2 as flow increases from low flow to high flow. The graph below shows the value of the Diversion Fraction for a range of inflows expressed as mm depth over the upstream catchment for a range of input parameters A-D where:

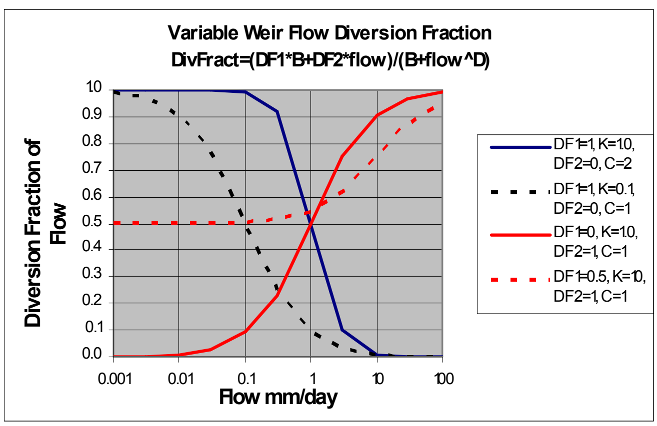
A=the diversion fraction when flow is just greater than baseflow

B=K

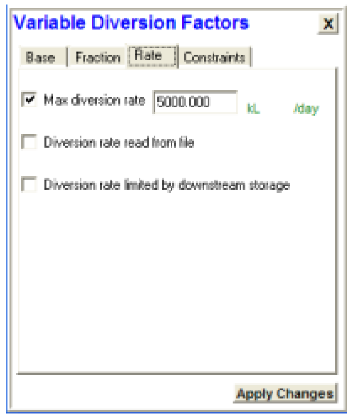
C=the diversion fraction at high values of (flow-baseflow) when converted to mm/day

D=exponent C

The value of K shifts the curve horizontally. The value of C alters the slope



7.9.3 The Rate Tab



This window sets the maximum flow rate that can be diverted. The example shows a rate of 5000 kL/day. If the diversion fraction has been set at 0.5 an inflow of 10,000 kL/day will be divided equally between diversion and mainstream. If an inflow of 12,000 kL/day occurs, only 5000 kL will be diverted, 7000 kL will continue in the mainstream.

The maximum rate may be set to:

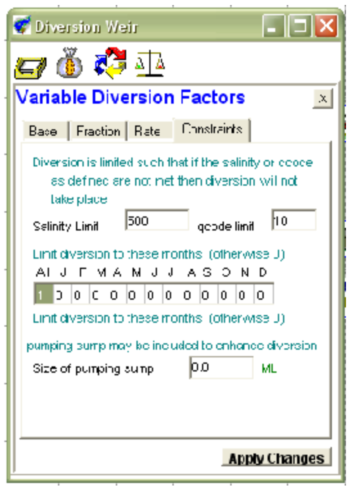
1) A constant amount (as shown), or

2) An amount set by a time series file. The naming and location of the file is as explained in 7.9.1 above. As above, this option is NOT available for an offstream dam.

As an additional feature to the above options, the diversion volume may be limited by the availability of storage space in a storage node immediately downstream (on the diversion path) of the weir. This option is not available from an off-stream dam since the diversion involved with the offstream dam diverts to the offstream dam itself. The option is redundant as diversion of this form is automatically limited to the capacity of the offstream dam (so that the dam does not overtop).

The 'rate limited' option only works when the diversion path from the weir is connected directly to an on-stream storage immediately downstream.

7.9.4 The Constraints tab



This window provides other options that may limit (or enhance) the diversions.

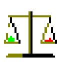
The diversion may be limited to inflows that reach minimum water quality standards in respect to salinity and Qcode. These are set in the entry boxes indicated.

In addition, the diversion rules set may be made to apply for all or just selected months of the year. Where a month is not requested (ie entry = 0) no diversion will occur. Particular months are set by clicking the required month box. A "1" indicates that diversion occurs, a "0" means no diversion will occur in this month.

Diversion depends on the flow passing the diversion point and this may be enhanced by a small instream storage which carries over flow from previous days. When a volume is set for the pumping sump the component will

- Divert the requested volume of water if possible.
- Any additional daily flow will remain in the pumping pool
- If no or limited flow the following day/s the pool will supplement the diversion until empty.

7.10 Calibration.

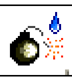
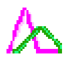
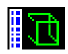
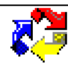

See Section 12.

7.11 Treatment

 This icon appears only in the Treatment and Wetland nodes and is different for each. See Section 8 for the description for each node.

7.12 Differences between Surface Storage Types

The model offers a selection of 5 different types of surface water storage. The relevant parts of Table 7.1.1 are reproduced below. Each of the storages is described in Section 8. It can be seen that most of the operations are similar. The major exceptions are marked in Bold type as Y or N, however some minor difference are not shown this way. The notes below offer a quick reference to identify the different operations offered by the stores.

Node	Store	Demd	Rout	Prpties	Divert	Treat
						
Reservoir	Y	Y	Y	Y		
Tank	Y	Y	Y	**N**		
O/s Dam	Y	Y	**N**	Y	**Y**	
MultiStore	Y	**N**	Y	Y		
Wetland	Y	Y	**N**	Y		**Y**

The Reservoir is generally used to represent a general purpose water authority or farm type dam located directly on a drainage path (ie. onstream). It has a fixed volume and spills when the max volume is exceeded. It can receive and supply water via water supply paths in addition to drainage inflows. Drainage path releases downstream can be arranged via the Demand icon window.

The Tank is generally used for small storages. It is assumed to be roofed and have vertical sides. It therefore does not evaporate and is not given any geometric properties relating depth to volume. However it can be used for flow routing and a FEVA file can be entered in relation to routing.

The Offstream dam is used in catchment studies where many farm dams exist. The node contains an in-built weir to divert flow into the dam and an in-built demand to provide local irrigation. The storage does not allow for routing.

The Multi-store is generally a large volume storage used for dual water harvesting and flood mitigation. It cannot receive inflow via a supply path, but can supply water to a demand (or second storage such as ASR storage). The water supply storage/harvesting level is set at different levels in different months so that the volume for flood storage above this level can be set according to the seasonal risk level of receiving flood inflow events.

The Wetland is used when inflows of poor quality code are to be delayed longer within the storage to allow natural time-dependant processes to improve water quality, before supplies are taken. The facility is particularly useful where different upstream inflows have different quality codes and thus different delay requirements.

Downstream releases can be arranged from all storages by arranging a water supply to a demand node, then releasing the supplied water as a wastewater stream via a drainage path. The Reservoir, Offstream dam and Tank provide a fixed supply delay for water quality improvement

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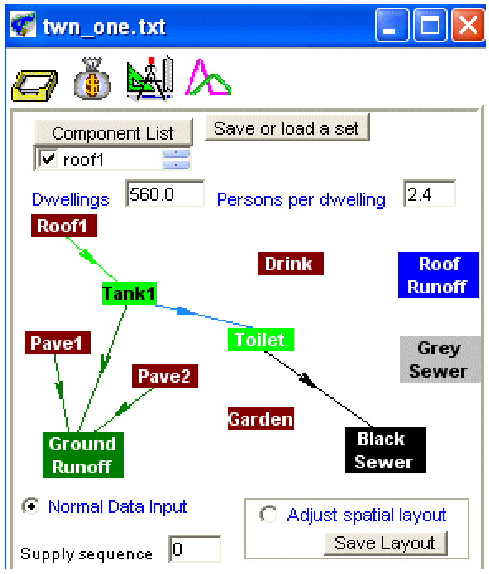
8.0 MODEL COMPONENT NODE DESCRIPTIONS

8.1. HOUSE Component

8.1.1 Introduction


The house component has been established to enable recycling to occur within a single node (involving runoff generation, supply, storages, treatment and their inter-linking in a simplified manner) thus saving space that would otherwise be required to accomodate all these functions in separate nodes on the larger layout screen.



The House component provides i) a mini-spatial system layout area in which the internal system layout is assembled and ii) a means for linking these to the larger ’outside’ layout screen, so that the house can be fully integrated into the larger scale system.

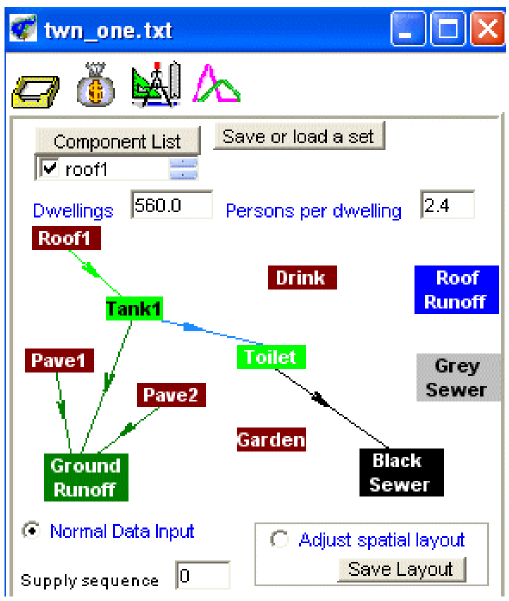
The House layout can represent the on-site water system for a single dwelling or a group of similar dwellings with similar on-site systems.

The House internal components may be interlinked to enable internally generated runoff and/or wastewater to be directed to meeting part or all of the internal water demand. As in the real world, any excess supplies and/or un-used flows are disposed back to the ’outside’ world.

The concept of quality coding is used to assist in ensuring only water of suitable quality is supplied to demands requiring different qualities.

8.1.2 Layout Window

The internal Layout area is accessed by clicking on the header **Catchment** icon. The Layout window provides access to numerous other sub-windows, as described below. The Layout window is divided into two main parts:



1. The top section provides an area on which i) on-site runoff surfaces, tanks, connections and demands can be arranged, and ii) a set of 4 connections points are provided for linking end-of-onsite-system drainages back to the ’outside world’ (ie other nodes on the main model Layout screen).

2. The lower section (not shown on the figure to right) provides the data input windows for each of the sub-components identified in the upper section area.

8.1.3 Saving and Loading House Setups

House setups may be saved and then reloaded into other existing house nodes. This enables on-site layouts to be saved for future use and thus the quick setup of previously established complex layouts.

Clicking the Catchment icon reveals the **save or load a set** button at the top of the layout window. Clicking on this button provides access to creating or using pre-set House setups.

If you are setting up a new project or a new node in an existing project, a default layout will already be shown on the layout window (along with default values already entered into all data entry locations for the House node). This layout and all associated data entries are taken from the twn_base file located in the <program_folder>\files folder.

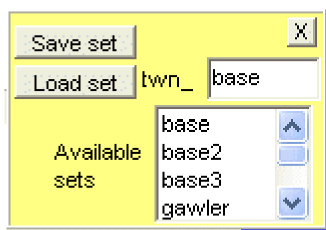
Loading alternative layouts. If you (or others) have previously saved alternative layouts with their sets of associated 'base' data for a House node, the names of these alternatives will appear listed in a window along with the base set (eg base2, base3...as shown in the example below). You may click on any of these and the layouts and associated data sets will populate your new node. This is very useful where you are creating a large model with many House nodes which are the same or similar in layout, but different to the default base layout.

Loading a alternative set can only be done once you open a House node and have accepted the default layout. You can then scroll down the list of alternative layouts (if any exist) and either type the selected layout name into the edit window, or click on the name in the list. Clicking **load set** will load the setup parameters and close the input window.

Note: The change process changes the layout and all assocaited data entered for the lau\yout. The **only data NOT changed when the new set is loaded are the number of dwellings and persons per dwelling which under most situations will always want to be reset to the particulars of the situation.**

Saving alternative layouts: In most cases you will wish to make changes to any of the 'pre-saved' layouts that you can load via this method. If you have re-arranged a layout (see below for how to do this) or changed any of the associated data (other than the no of dwellings and persons per dwelling – see below) and then wish to save your changes for transfer to another future model or to another future House node in the same model you can then save your layout. It will then appaer as a selection choice in the new House nodes as they are established.

Saving requires that first you set up the layout exactly how you want it to be saved. Then provide a reference name for your layout (other than 'base') and place this in the edit window. The characters twn_ are automatically appended to the front of the reference name and a default extension of txt is added automatically. Then click on "Save the set".



Note that the name 'base' is reserved for the set of default base files which must not be overwritten. If this is attempted by typing "base" in the exit box, an error message will appear. The name requested can only have a maximum length of 8 characters.

8.1.4 Number of Dwellings

The layout established on the Layout window is that of an on-site system suited to one ’dwelling’ or building. These units are assumed to be replicated and thus the water balance for the node involves all data for the single unit being multiplied by the **number of dwellings**, which is input by the user in the edit box in the upper right hand portion of the window. Similarly demands are input as use per person and the total demand is calculated by multiplying by the **persons per dwelling** input into the upper left hand portion of the layout window.

Changes to **number of dwellings** or **persons per dwelling** requires the **save layout** button to be clicked.

8.1.5 Adjusting Spatial layout

The **Adjust spatial layout** mode allows the position of the on-site components on the screen to be moved thus providing a more readable layout. Move the individual elements by left clicking and holding, then dragging the cursor to the new position and releasing.

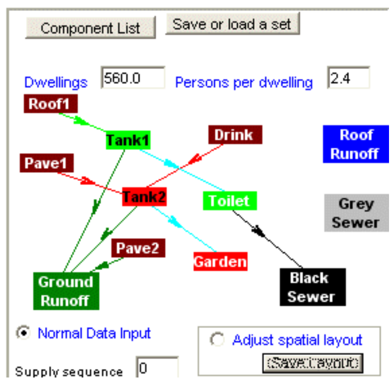
New components may be added in this mode by clicking on the **Component List** and then ticking the boxes for the components required**. Removing components** is the reverse of this procedure. Removal of a component will also remove all the connections to it. This is the only way of **removing a link** (see below). Caution, removal is permanent and can only be reversed by replacement.

When moving the components around you will note that the links are distorted. Don't worry about this, they will redraw themselves eventually.

Note. Adding and removing, components are not automatically saved,and any changes to the spatial layout require the clicking of the **Save Layout** button. Clicking the **save layout** will automatically return you to the **update information** mode.

Make sure you return to the **update information** mode once alterations are made

8.1.6 Selecting Components

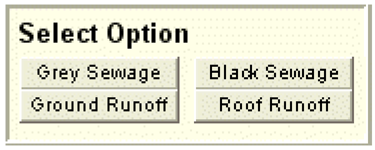


On the upper left hand corner of the Layout screen is a button “**Component List**“ which opens the list identifying the sub-components which can be used in the on-site layout. There are a total of 13 sub-components covering catchments, storages and demands. The drawbar will reveal those not shown at the top .

The catchments include 2 selectable roofs and 2 pavements, 3 storage tanks and 6 different qualities of water that may be demanded. These are identified as bathing, clothes washing, drinking, dish washing, toilet and garden. Wastewater is generated by all demands except garden watering.

The larger boxes shown on the Layout area (labelled Roof and Ground Runoffs and Grey and Black Sewers) enable off-site discharge connection points to the outside world. A House node can discharge up to 4 different qualities of water which can then be directed to any other node on the bigger ’off-site’ screen.

When placing a drain link from a town, the Select Option prompt as below will appear enabling you to select the correct connection (Note. If you connect any of these options to a node other than another House or Urban node, the flow will merge with any other catchment flow and the drainage path for the merged flows will appear as a blue line. Only when the discharges are linked to another House or Urban node will the drainage contents continue to be differentiated and be represented by drainage links of different colours).



Selecting the components in the listbox places them on the Layout area. Hide the open component list box by clicking on it again. Note: the checkbox doubles as the mechanism for removing unwanted links. By un-checking and rechecking a sub-component, all links to this component are removed. Note this is the only way to remove links.

To adjust the parameter values of the sub-components a series of input windows are provided in the lower half of the layout window. Left clicking on the sub-component raises the edit window for that component which is sub-divided into sections by the use of tabbed windows. There are essentially 3 different input types relating to the sub-component type of either Drainage, Storage or Demand.

The layout as provided typically might describe one dwelling and the total water balance for the component is multiplied by the number of **dwellings** input by the user in the edit box in the upper right hand portion of the window. Similarly demands are input as use per person and the total demand is calculated by multiplying by the **persons per dwelling** user input also in the upper right hand portion of the window.

The check buttons in the lower left hand corner indicate which mode you are in. Typically you will work within the **update information** mode. The **adjust spatial layout** allows you to change position of the sub-components to provide a more understandable descriptions of the model.

The **supply sequence** when set > 0 defines when the node will be attempted to be supplied. For example a component with a sequence 1 will be attempted to be supplied before one with a sequence 2. A value of 0 signifies no particular order is necessary (but 0 follows sequences 1 2 3 etc). In many layouts this order is not particularly important, however there are situations where supply to one component is necessary before supply to another is attempted.

On acceptance of the layout, **save layout** saves the information input in this upper component along with the spatial layout produced.

8.1.7 Creating Internal (Onsite) Links

Links are simply made by left clicking and holding the button down on the subcomponent from which the water flows, dragging across to the receiving sub-component and then releasing the button**. Note: there is no need to select either Drainage or Water Supply on the Mode button on the Main Layout screen.** Thus the type of link made is not defined by the modeller but is automatically identified by the program by reference to the component type at the “from” and “to” ends of the link. Despite this, the same two types of drainage and water supply links are still identified in the program.

Drainage links are established when catchment sub-components are linked to any tank or exit point to the outside world (i.e. ground, roof and sewage outfall). Drainage links are also made when a demand (e.g. wash) is linked to a tank. Here the water supplied the previous day is drained as wastewater to the tank. A tank can also drain to another tank as a spill, and/or to the outside world. Note, quality codes and salinity are accounted for in these processes.

Water supply links are made when a tank is linked to a demand. The tanks will attempt to supply water to meet the demands as a first priority, however, quality codes and salinity constraints still apply (see later).

In summary, the internal links are a greatly simplified and therefore must follow a strict set of rules:

1. Links between the roof or pave catchment to a tank or an exit point are drainage paths.
2. A demand (drink etc) cannot be supplied directly from the roof or pave catchments.
3. The demands must be supplied from tanks, therefore any link from a tank to a demand is assumed to be a water supply path.
4. Onsite recycling of water supplied from on-site or external sources can be undertaken by directing the (used) wastewater to an on-site tank. Excess wastewater overflowing the tank will then follow the drainage link from the tank to an exit point (or by default to the 'ground' exit point if a user defined link has not been not made).

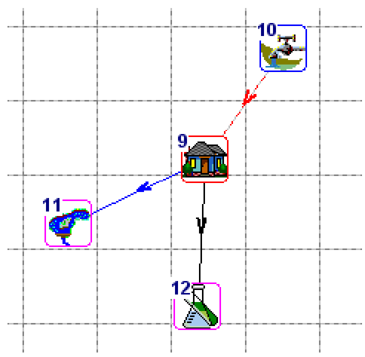
8.1.8 Removing Internal Links

Individual components and linkage are included and removed through the **component list** box. The checkbox doubles as the mechanism for removing unwanted links. By un-checking and rechecking a sub-component, all links to this component are removed. **Note this is the only way to remove links.**

8.1.9 Drainage and Supply Connections to the Outside World

Supply Connections

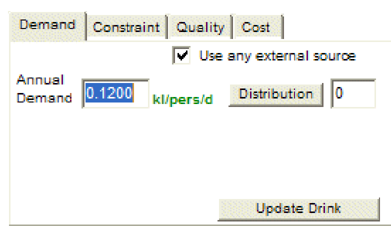
First priority for meeting demands is always given to water contained within on-site tanks, provided that the stored water meets the quality criteria set for the demand. In many cases it is known that the on-site systems will not be able to meet the on-site demands for significant proportions of the time, or at all, either in terms of this quantity or quality. For this reason, in most cases, **back-up supplies may also be drawn from external sources.**



The diagram at left shows a House node connected to an External supply node (node 10) as an external back-up source. It could have been connected to other sources (e.g reservoirs, aquifers, etc) with different reliabilities, qualities and/or priority settings.

A particular strength of the WaterCress model is the manner in which different waters may be arranged to supply different demands at different times of the year by setting quality constraints, priorities and weights, storage filling patterns and supply sequences. (see Section 3.7)

If a back-up supply is to be provided to any of the 6 on-site demands from any connected external source, that source must be connected to the node as shown above AND the **'Use any external source'** box must be clicked when entering the data for that demand as shown at the RH. (See also Section 8.1.11)



Note. No water supply paths are made to connect the internal demands to the external supplieson the internal layout screen. The connections are assumed (but are not shown) as soon as the 'Use any external source' box is clicked for that demand.

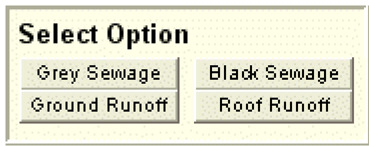
Drainage Connections

Drainage leaving the system is transferred to the "outside world" by linking catchments, tanks or demands (i.e wastewaters) to one of the 4 Ground runoff, Roof runoff, Grey sewer or Black sewer connection points.

A default exists such that any sub-component not having a drainage direction set for it will be directed in the following manner.

1. Roof and Pave goes to **Ground runoff**.
2. Tanks to **Ground runoff**.
3. Bath, Wash, Drink, Dish and Toilet to **Black sewer**.

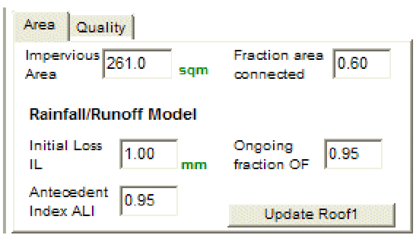
These links can be set by clicking on the sub-component and hold-drag- and releasing over the exit point of choice. Note paths from demand elements (drink, toilet etc) can only be to a tank (for internal recycling of water) or an exit point. Spill from tanks should be directed to the correct exit point (as all defaults are to Ground runoff).



When the drainage link from the House node to the next node downstream on the main Layout screen is finally made, a selection must be made on which of the 4 discharges are being linked. the choice will be link from the connection. The layout diagram above shows a Black sewage connection from the House node to a Treatment plant and a Ground runoff connection to a Wetland. All 4 of the internal House discharges may be connected to 4 different 'outside world' downstream nodes.

8.1.10 House Runoff Calculation

Only an initial loss/continuing loss model is available at the present time for calculation of runoff from the roof and pavement (impervious) catchments.



On a daily basis:

Runoff depth = (rainfall - initial loss) * **ongoing fraction**

Runoff volume is calculated from the impervious area and the fraction of this area that is connected to the drainage system. I.e.

Effective area = (**impervious area** * **fraction area connected**).

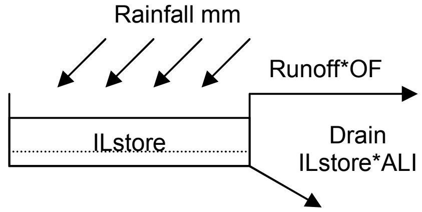
Runoff Volume per day is therefore **= Runoff depth * Effective area**.

All parameters used in these calculations are entered in the windows, as shown above.

On a sub-daily time step basis, the same formula applies, ie:

Runoff depth = (rainfall - calculated IL) * ongoing fraction

However, for the sub-daily model, the initial loss is continually calculated at each timestep by tracking the volume of initial loss accumulated within an **IL store,** the working of which is shown in figure 8.1.10.



IL is the depth of accumulated rainfall that must occur in the store before the store reaches its capacity of IL and runoff (ie spill) occurs.

The store is drained at each time step by an amount of ALI*ILstore. Larger values of ALI will drain the store more rapidly and thus increase the total amount of rainfall that is 'lost' and does not contribute to runoff.

Figure 8.1.10 Runoff calculation for impervious surfaces

For ILstore(t-1)*0.95+Raint(t) >I L:

Runoff(t) = (ILstore(t-1)*0.95+rain(t)-IL)*OF

For ILstore(t-1)*0.95+raint(t) < IL

Runoff(t) = 0

The form of calculation of ILstore for a 16 hour period is shown adjacent. ILstore is the store at the end of the hour shown. The Runoff depth must be reduced by the fraction OF and multiplied by the effective area to provide the volume of runoff for each time step.

The value of IL entered for the sub-daily timestep model is usually the initial loss entered for the daily time-step model (eg 1 mm/day shown in the table, a typical value for an iron roof/gutter in medium condition). Preliminary investigations for Adelaide rainfall has shown that in order to maintain the calculated runoff depth approximately equal when the same rainfall record is used but different timesteps are employed, different values of ALI must be used.

IL =	1 mm
ALI	0.950

Hr	Rainfall mm	ILstore mm	Runoff mm
1	0	0	0
2	0	0	0
3	0.2	0.20	0
4	2	1.00	1.19
5	0	0.95	0
6	0	0.90	0
7	0	0.86	0
8	0.2	1.00	0.01
9	0	0.95	0
10	0.4	1.00	0.30
11	2	1.00	1.95
12	0	0.95	0
13	0	0.90	0
14	0	0.86	0
15	0	0.81	0
16	0	0.77	0
total	**4.8 mm**		**3.5 mm**

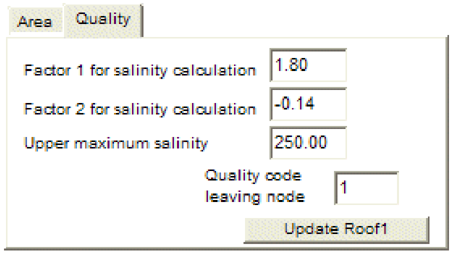
Timestep	6 mins	30 mins	1 Hour	6 hrs	1 day
ALI	0.995	0.978	0.957	0.746	0

If the daily value of IL is assumed to be X mm/day, the values shown above can be seen to fit the formula;

ALI for timestep T mins = (1 – T/1440), where 1440 is the number of mins in a day.

Remember, Click the update button on the window when all data has been input.

8.1.11 House Runoff Quality



The salinity of runoff water is calculated by a simple function

Salinity = 10 ^ (sal **Factor1** + sal **Factor2** * log10(runoff mm)).

Note, in this form, Factor1 and Factor 2 are fitted to the plot of Log10(salinity) versus Log10(Runoff mm/day).

Salinity is limited to **upper maximum salinity (Factor 3).**

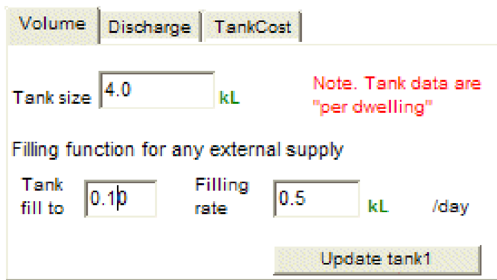
The quality code of the runoff water is set as the **quality code leaving**

Select the update button on the form when input complete

8.1.12 House Tanks

Node storage is controlled by selecting appropriate size tanks

Volume Tab



Storage is based on tanks with size defined as the individual house tank size. Total storage for the node is therefore **= tank size * number of dwellings**.

A tank may be set up to maintain a minimum water quantity using water drawn from an external source. This is done by setting the **tank fill to** parameter to the fraction of the tank size that you require the external source to fill the tank per timestep. An input of 1.0 would mean that the tank would be maintained full, however values of 0.1 to 0.5 would be more effective in utilising the on-site inputs while retaining the external supply as a back-up. For example, assuming a 10 kl tank, if tank 'fill to' is set to 0.2, then, when the water level in the tank falls below 10 x 0.2 (2 kL), water from any external source connected will attempt to re-fill the tank to this level.

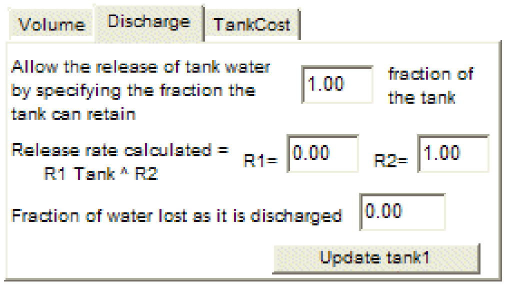
Set this value to zero if you do not want external water filling the tank. Where a trickle charge mechanism is required the **filling rate** may also be restricted.

Note that the internal tanks in the House and Urban nodes do not specify their own level of acceptance of qcode or salinity, but specify the 'highest' level of any of the demands which may be connected to them. (This is not so for the actual Tank node when operating on the main Layout screen). Thus, an internal tank which is connected to an internal demand for drinking quality (requiring a qcode of 1) is programmed to adopt this quality standard for its own filling. If a tank is connected to two demands it will only accept the standard of the highest quality water requested**. (Beware, if an internal tank is supplying demands requiring qcode 1 and 10, and is only connected to an external source with quality 10, the tank will not accept this water even though it could have supplied only the quality 10 demand).**

Discharge Tab

Peak flow rate attenuation. The tanks can also be used to attenuate flow from the node. The discharge tab enables the user to set aside some detention storage within the tank.

This is set by changing the value of "retain". A value of 0.4 means that the lower 40% of the tank will be retained, while the upper 60% is only detained temporarily and will be discharged at the user defined rate. Water is discharged from this detention storage at a rate based on the variables R1 and R2 where

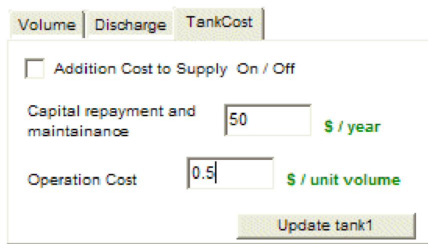


Release rate = **R1** * storedfraction ^ **R2**, where "storedfraction" is equal to the tank stored fraction ie. = volume stored/tank size

The **discharge loss fraction** determines the amount (fraction) of the discharge that does not make the outlet. In this case a zero means no loss and 1 means 100% loss.

Tank Cost Tab

The cost of the rainwater tank can be added based on capital repayment (and maintenance) in $/year and an operational cost in $/kL.

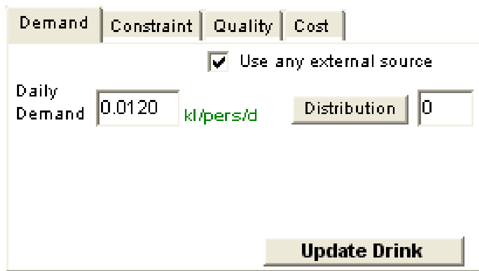


8.1.13 Setting Demands

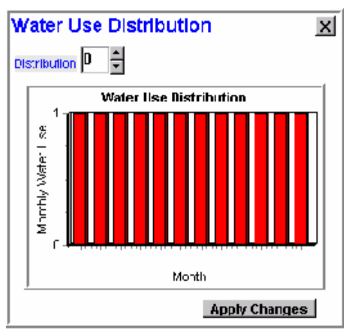
Demand Tab (for Garden Demand see next)

For all uses except gardens, Demand is set as an average volume per person per day. This is usually assumed to not change throughout the year for all in-House demands (eg drinking, toilet, laundry, etc.).

The kL/person/day value is multiplied by the numbers of dwellings and persons per dwelling and a distribution factor for each month, which is shown by clicking the distribution button.



The choice of distribution 0 will maintain the demand as seasonally unchanged. However, it is possible to introduce a seasonally variable monthly distribution (eg distribution 1) which may be regarded as varying either the demand per day, the numbers of persons and/or the persons per dwelling (say between summer and winter), by factors varying downwards from 1.0.



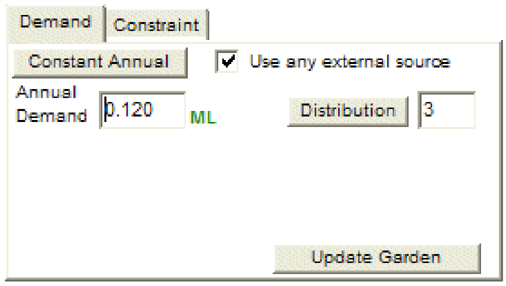
Twenty different sets of monthly water demand patterns are stored within the wateruse.txt file within the project folder. The first ten are used to proportion annual demand values across the year, with the total of the 12 monthly proportions summing to 1.0. The second ten can be applied directly to daily demand values (as in this situation) and have factors ranging from 1.0 downwards. Distributions 0 and 1 for the House and Urban nodes are listed as the 10th and 11th of the distributions in the project wateruse.txt file. The values may be changed via access to the wateruse.txt file.

The demands can be requested to be supplied entirely by internal sources or may allow a direct supply to demand shortfalls following internal supply has been attempted. To allow the external sources to be included the **use any external source** box needs to be checked. Where an external source is used, the node will first attempt to achieve all of its supply from its internal tanks. Only if this can't be done will it seek water from the external supply.

If the box is not checked the component will only attempt to supply all its water demand from the internal sources/tanks which may lead to supply shortfalls in low/medium rainfall areas.

Garden Demand

Demand for Garden is handled differently.

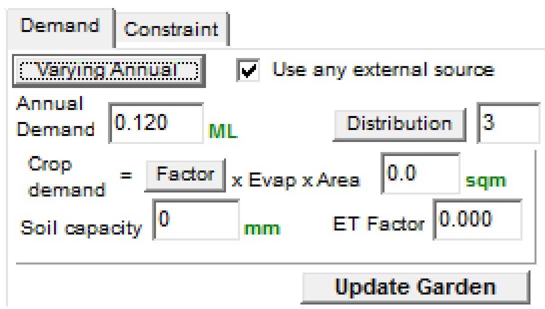


Two options for setting the daily irrigation demand for the Garden are found by toggling between the two alternatives of Constant Annual:Varying Annual which rotate when the top LH button is clicked.

For the **Constant annual** option an annual volume demand is set and this is then distributed across the year for each month by clicking on the distribution button. The demand for each day is then the (Annual demand * monthly distribution fraction)/(no. of days in the month).

The distribution is set in a similar manner (refer above). In this case the distribution number will relate to the position within the first 10 on the list.

If the button is clicked/rotated to the **Varying annual** option the upper part of the window remains the same, but the lower part contains information and formula which determine whether the daily crop use is supplied from a notional soil store or requires to be supplied from the irrigation source.

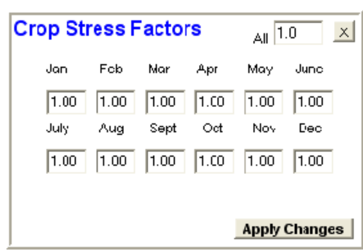


In this option the program calculates the volume demand based on evaporation and rainfall conditions.

The method then uses a simple soil moisture store with maximum capacity set by entering **Soil capacity.** The capacity of the store may be changed by the user. Its size will depend on the soil type and depth appropriate in the local situation. The store increases due to rainfall, but only up to the 'full' level which equals the soil capacity. When full it ceases to increase further.

The soil moisture is added to each day by any rainfall and reduced each day by the crop/soil evapotranspiration loss. The latter is calculated by two alternative ways described below (one of which is calculated via the values read in from the Evap File shown on the node openning window at RH), with the larger being adopted.

While the soil store contains some depth it provides an "internal" supply for the crop, thus reducing the need for a supply from any other source (ie. either from a tank supply internal to the node, or a source external to the node).



The **ET Factor** is a constant factor to adjust the daily evaporation rates calculated from the name.evp input file (ie. similar to a pan factor).

The **Factor** button when clicked reveals 12 values (Crop Stress Factors) as shown in the RH window.

The crop stress factor is used to determin the daily crop demand. This demand therefore varies depending on the season and the assumed crop demand factor. **Calculated demand(t) = ET factor x Evaporation(t) x Crop area**

While there is enough water in the soil store to meed the demand calculated then the node makes no external demand on the system. However when the soil store dries out (summer) the crop demand calculated is identified as the node demand.

Soilstore(t) = Soilstore(t-1) + rainfall(t) – calculated demand(t)

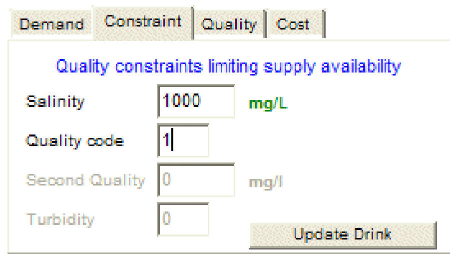
And:

Irrigation supply = 0   if (Soilstore > calculated demand) or

Irrigation supply = (calculated demand – soilstore) x area

Constraints Tab

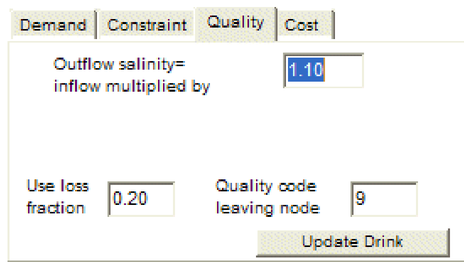
Quality constraints of the demanded water are set as a salinity and quality code. Exceedence of these values will result in no supply being made.



Quality Tab

Water supplied the previous day may be directed back into a tank for on-site recycling or into the sewer drainage system. In both cases a proportion of the supplied water is assumed to be lost in the use process. The volume loss is determined by the **loss fraction.**

This water has a defined salinity and quality code change. **Export salinity is multiplied by a value and export quality code is set.**



Cost Tab

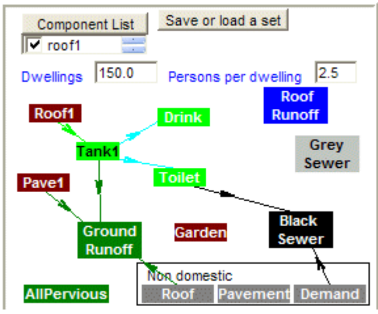
Cost is added in the same way as tanks sect 8.1.11.

8.2 URBAN Component

8.2.1 Introduction

The Urban component is essentially the same as the House component but contains details of runoff and demands for additional facilities likely to be co-located with the houses within larger urban areas.

Since the operations of the House and Urban component are identical for much of their operations, this section will only describe the additional functions and differences of the Urban component and the reader is directed to Section 8.1 for information on all other areas of common operation.



Differences

The Urban component has all the same functions for the on-site layout in the upper part of the screen **except** that it has only 3 domestic demands instead of the 6 for the House component. The 3 demands are labelled drink, toilet and garden. These relate to potable standard quality for (say) drinking and (possibly) non-potable qualities for inside-house (eg toilet) and an outside-house (eg garden) demands.

Additional Functions

The additions are the 4 function areas displayed across the bottom of the layout window ie, All Pervious and Non-domestic Roof, Pavement and Demand.

In this respect “Non domestic“ relates to industrial, commercial or municipal infrastructures associated with the urban area represented by the node.

The internal connections of the Additional Functions require explanation:

- AllPervious is shown as unconnected, however, the model assumes that AllPervious (runoff) is connected to the Ground runoff connection point. AllPervious has no demand and therefore does not require a supply link.
- Non-domestic Roof (runoff) is shown connected to the Ground runoff connection point. However,if a tank storage volume greater than 0 is provided under the demand input, this tank storage is placed in the “roof“ path and this may be used to supply part or all of the demands set in the Non-domestic Demand component. Any link to a non-domestic tank are not shown but are assumed by the model.
- Non-domestic Pavement runoff is assumed to flow with Roof runoff (ie after spill from any tanks) to any of the four outlets (as selected by the user). Selection of path is by left clicking over the non-domestic roof or pave buttons and moving the mouse and releasing over the outlet of choice. An arrow will indicate the path of water. In the example above the runoff is directed to the Ground runoff connection point. These flows cannot be picked up by any tank storage set in the upper domestic layout.
- Wastewater flow from the Non-domestic demand component is also able to be redirected by the user to any of the four outlets. Selection of path is by left clicking over the non-domestic demand button and moving the mouse and releasing over the outlet of choice. An arrow will indicate the path of water. The example shows connection to the Black sewer connection point. This wastewater is generated after supply from either the tanks fed from the Non-domestic area roofs (as first priority) or from any external sources attached to the node that have acceptable quality water, as second priority.

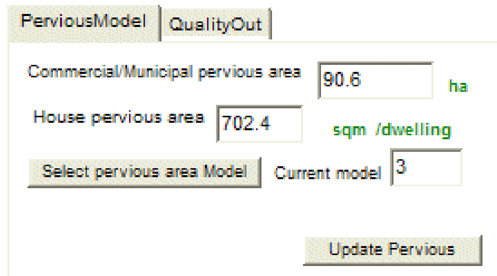
- Because the 4 Additional Functions cannot be deleted, their linkages are presently fixed. Other than the supply option from the notional tank storage assumed for the Non-domestic Roof/Demand function components, no internal arrangement can be made for on-site recycling for the Non-domestic addititions.

The 4 Additional Function components are described below.

8.2.2 The Pervious Subcomponent

The **All pervious** sub-component calculates runoff from all pervious areas, including the gardens in the domestic layout (which was missing from the House node) and parks, recreation areas, open spaces, undeveloped land, etc etc in the Non-domestic areas.

Clicking on AllPervious brings up the window at right.



The total of all pervious areas included in the enlarged node comprises the values entered into the top two entry boxes:

1) The total of all the pervious areas ncluded in the non-domestic industrial/ commercial/ municipal zone areas is input as (say) total hectares.

2) The house garden pervious areas, (plus any per dwelling allowance made for road verges, local parks, etc) are input (say) m2 per dwelling. This area is then multiplied by the number of dwellings entered at the top of the layout area to give the total of the pervious areas within the domestic part.

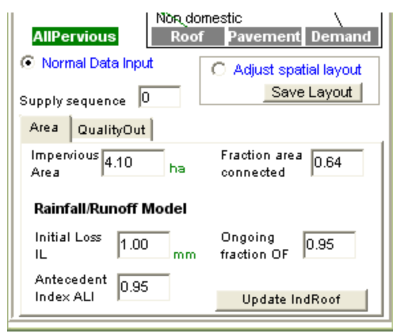
The two areas are then added and are assumed to have similar rainfall to runoff characteristics which are modelled via the choice of model selected when the **Select pervious area model** button is clicked. The pervious area rainfall/runoff models is chosen and set the same way as for the rural catchment component (see Section 9).

The drainage link from the All Pervious sub-component always goes to the Ground runoff connection point

8.2.3 Roof and Pavement Subcomponent

The Roof and Pavement sub-components calculate runoff generated from their impervious surfaces and these have similar inputs to the Domestic area house roofs and pavement. The only significant difference is that the areas are defined in total hectares (and not per dwelling as for the domestic area roofs and pavements).

The initial loss, ongoing fraction and antecedent index values assumed for the Domestic and Non-domestic roofs are assumed to be the same. Similarly for the inputs for the Pavements. Even though they are shown separately on the input sheets (see RH), changing them, on say, the Non-domestic input page will force the same change on the respective domestic housing input page.



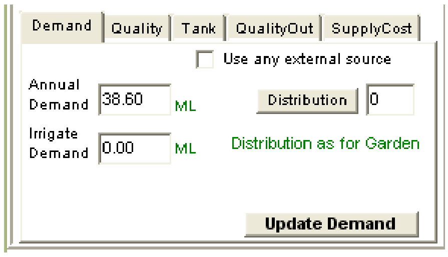
The Fraction area connected, however, may be **set different** for the respective impervious domestic and non-domestic surfaces.

The runoffs calculated on these surfaces are assumed to be combined and are usually directed as a single unit to the (default) Ground runoff connection point. They may, however, be directed to any of the 4 outlet connection points.

The **QualityOut** tabs provide the parameters for the flow versus salinity relations (see Catchments, Section 7) and the qcode.

8.2.4 Demand Subcomponent

Demand. Clicking on Demand reveals the window at RH with 5 tabs.



8.2.4.1 Demand Tab

The **Demand** window sets the demands for the activities involved in the Industrial/ Commercial/ Municipal zone. These demands are provided with two sets of seasonal distributions and quality constraints (see next).

Annual Demand relates to all non-irrigation type demand and is entered as a repeating annual volume. The demand is proportioned between the months in the normal way using the distribution button and selection of a seasonal pattern. Distributions may be modified by modifying the 12 listed values in one of the first 10 sets in the Project\wateruse.txt file.

Irrigate Demand is reserved for the irrigation of a defined part of the Commercial Municipal area entered under the AllPervious tab. The annual volume of demand must be calculated by reference to the part of this area to be irrigated and the average annual depth of irrigation to be applied. The distribution of this across the year is assumed to be the same as that set for the Constant Annual option set for the Domestic Garden sub-component.

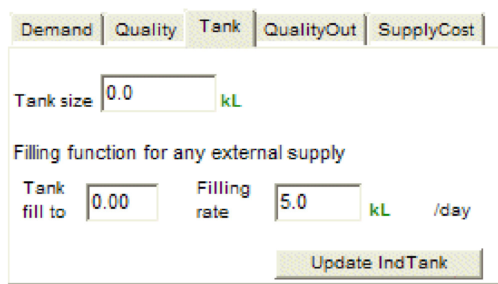
The demand identified here could be supplied internally from the non-domestic tank however typically this demand is supplied from external sources and therefore the **use an external source** box should be ticked.

8.2.4.2 Quality Tab

The Quality tab only has one set of quality constraints for both types of demand. Future versions will set the Irrigation demand constraints equal to those of the gardens. This would allow for two qualities to be demanded.

8.2.4.3 Tank Tab

The tank is fed from roof runoff. When the Tank size is set > 0, the demand will take storage from the tank as first priority. If the tank storage fails and an external source of acceptable quality is connected, this becomes the second priority back-up.



As for the tanks in the domestic layout, the tank can be trickle charged to a proportion of its full capacity from an external source using the **fill to** and the **filling rate** parameters

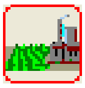
8.2.4.4 Quality Out Tab

The quantity and quality of the wastewater is set in the same manner as for other demands returning wastewater. The wastewater cannot be treated and recycled within the urban node.

8.2.4.5 Cost Tab

The operation of the cost data calculations is untested.

8.3. DEMAND Component



8.3.1 Introduction

Industry components represent traditional demands where supplies are provided from external sources and no explicit water recycling takes place. They are assumed to require a single quality standard of water and they may discharge a single quality of water to the drainage system. The node is designed to mimic either an irrigation or manufacturing industry demand.

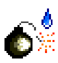
The component can estimate water demand in 3 ways

1. It can provide either a constant annual demand which may distributed in varying ways or,
2. May adjust the annual demand by suppressing the demand in response to local rainfall or,
3. May be a combination of the above

The component also provides for drainage (ie wastewater) to be released which represents either irrigation drainage or sewage outfall from a factory. This is expressed as a fraction of supply input and takes on an appropriate quality code for industrial drainage.

Clicking on the Demand node raises 4 data entry icons.

8.3.2 Demand Options

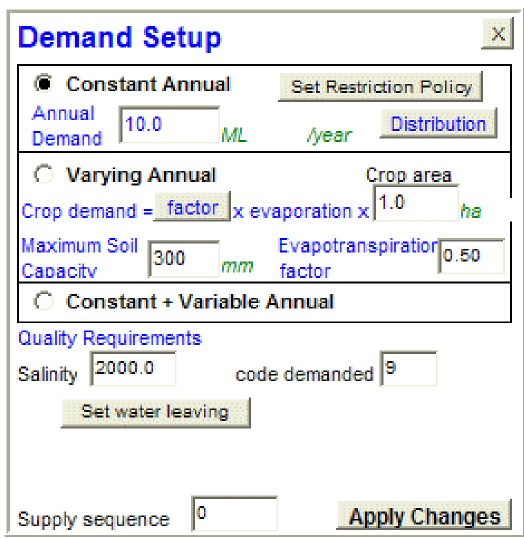

Three types of demand can be currently set

1) A constant annual demand, which is the simplest, and most often used.

2) A varying annual demand (rainfall suppression) method which adjusts demand in relation to rainfall.

3) A combination of (1) and (2)

In the screen Constant Annual, Variable Annual demand or a combination of the two is selected by checking the appropriate button.



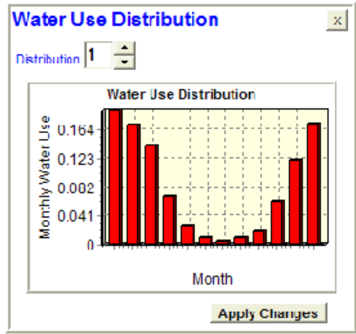
8.3.2.1 Constant Demand

The User sets the following parameters:

- The annual volume is the constant annual demand expected at a distribution that the user defines.
- The required quality code and salinity that must be met before supply is allowed.
- A discharge quality code which leaves the component.

The distribution of the demand can be set by clicking the required **distribution** button, which will display the following input window.

Monthly Distribution



The monthly distribution for a constant annual demand is requested within this window.

The distribution of the demand can be set by clicking the required distribution button. There are 10 pre-set distributions available and these may be different for each project.

The required distribution is set by clicking on the up/down toggle, and then Apply changes.

There are two forms of distribution used within the model

1. Domestic garden, irrigation and industrial distribution where the monthly factors relate to the fraction of the total annual that occur each month. (ie the sum of the monthly fractions add up to 1.0)
2. Domestic internal demand where the factor defines the proportion of the daily defined use assumed to be required. For example – A value of 1.0 indicates all of the user defined daily demand is required.

The reason for the different factors is due to the means by which demand is specified. For urban domestic use the demand is defined as a rate per day whereas industrial and garden demand is defined as an annual use.

At present the preset distributions may be changed from within the file wateruse.txt. Within this file you will see 20 sets of 12 numbers. This file can either be located in the program directory (<wcprogram folder>) or the project directory (<wcprogram folder>\my project). The program will search for it first in the project directory. Altering the wateruse.txt in the project directory allows distributions to be modified for individual projects. If wateruse.txt within the program location is altered this will affect all projects that are subsequently use wateruse.txt from that location.

The first 10 sets are used for the garden and industrial distributions, the second 10 are used for urban domestic distributions.

8.3.2.2 Varying Annual

This option will vary the amount of external demand depending on the amount of recent rainfall that has occurred. This is essentially an irrigation situation and requires as input the **area of crop** and the **crop use** for the crop. The method uses a simple soil moisture store (**soil capacity**) which it tracks the amount of moisture available to the plants. This soil moisture store provides an "internal" supply for the crop, thus reducing the external demand. The capacity of the store may be changed by the user. Its size depends on the likely carryover appropriate in the local conditions. The store collects rainfall until full, at which time excess water is spilled. Water is lost from the store at a rate equal to the larger of daily demand of the crop (**crop use** * evaporation) or a defined evaporation rate (**evap rate** * evaporation). A **Crop use factor** is input as a constant value for each month.

Where water is available in the soil store this will be used to meet all or part of the daily demand. Irrigation is deemed to be required when the soil water store drops to zero.

The order of calculations is:

1) Rainfall input
2) External demand calculated
3) Loss due to evaporation
4) Spill of excess water

This order ensures that any rainfall for the day is taken from the demand.

Crop Demand

Crop demand is calculated as a **crop use factor** x evaporation. The factor can be varied for each month.

Total demand is therefore **= crop demand * area of crop**

Soil Capacity

The method uses a simple soil moisture store (soil capacity) which it tracks the amount of moisture available to the plants. This soil moisture store provides an "internal" supply for the crop, thus reducing the external demand. The capacity of the store may be changed by the user. Its size depends on the likely carryover appropriate in the local conditions. The store collects rainfall until full, at which time excess water is spilled. Water is lost from the store at a rate equal to the larger of daily demand of the crop (crop use * evaporation) or a defined evaporation rate (evap rate * evaporation).

The evapotranspiration factor is the minimum evaporation factor that occurs for the day. The water lost equals the ET factor x daily evaporation. This means that although the crop may be set not to be use water say over winter, evaporation may still be removing water from the soil store.

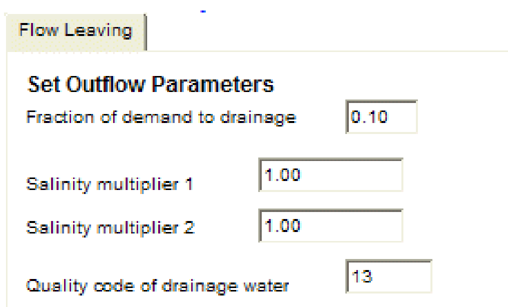
Water is lost from the store at a rate equal to the larger of daily demand of the crop (crop use * evaporation) or a defined evaporation rate (evap rate * evaporation).

Quality Requirements

The bottom 3 edit windows define the quality codes required for water transfer. Transfer will only be made if these quality requirements of the supply water are met.

8.3.3 Set water leaving

Water demanded by this node is either consumed by the node or passed downstream. The fraction of the demand not consumed (and therefore passed downstream) is set by **Fraction of demand to drainage**. The water passed to drainage also undergoes a quality change.



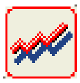
Salinity leaving = **Factor 1** + **Factor 2** x salinity supplied to the node.

The quality code leaving is set at the **Quality code of drainage water**.

8.3.4 Cost Functions


Clicking on the cost icon brings up the standard costing window, refer section 7.2.2

8.4. TEXT DEMAND Component



8.4.1 Introduction

Clicking on the Text Demand node raises 2 data entry icons and an openning window as shown below.

The text demand component allows the user to define a particular time series demand that requires to be supplied from source(s) established within the project layout. The file giving the time series demand is pre-established by the user. The demand may be an historic demand pattern derived from records. The component is useful if a demand is increasing over the duration of the model project, in which case a demand with a trend can be pre-prepared and introduced.

A part of the supply to the demand may be returned to the drainage system as a waste stream.

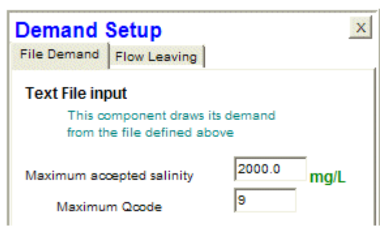
The text demand file defines the date/time and demand for each time step. For more information refer Section 13 on file formats

The file name is placed in the opening input screen, the **multiplier** is the amount you wish the demand (provided in the file) to be multiplied by. This is useful if you have a demand recorded for a small number of users which you wish to scale up to a larger number of users.

The file is required to be placed either in the raindata folder in the *WaterCress* directory (i.e. **<wcprogram_folder>\raindata**) or the project folder of the current project (i.e. **<wcprogram_folder>\myproject**).The program will search the project file first for the file and if not found will search in the raindata folder.

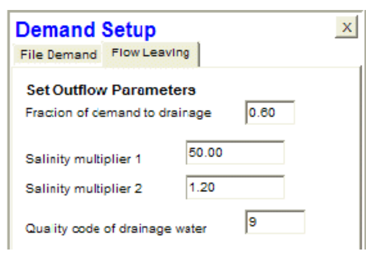
8.4.2 Demand Options

8.4.2.1 File Demand



Since the file input only defines the quantity demanded, the quality demanded must be set separately. The amount of water ultimately taken by the node depends on whether the quality constraints are met. In this case if the source had a salinity of 2100 mg/l or a Qcode of 10 the water will not be taken from the source.

8.4.2.2 Flow Leaving

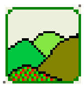


Defines the amount and quality of water that drains from the node. Water demanded by this node is either consumed by the node or passed downstream. The fraction of the demand not consumed (and therefore passed downstream) is set by Fraction of demand to drainage. The water passed to drainage also undergoes a quality change.

Salinity leaving = **Factor 1 + Factor 2** x salinity supplied to the node.

The quality code leaving is set at the **Quality code** of drainage water.

8.5. Natural Catchment Component



8.5.1 Introduction

The Natural (rural) Catchment component produces a time series of runoff using relatively complex rainfallto runoff conversion models and runoff to water quality relationships. A number of model options are provided to the user. These include an engineered (impervious) catchment which has an enhanced efficiency of surface runoff generation, thereby increasing the yield, particularly during drier seasons. The selection of the appropriate rainfall to runoff model and input of the appropriate parameters will allow a wide range of different catchment types to be simulated.

The natural catchment component calculates runoff from the natural or pervious surfaces (unless specifically identified by the specialist model) of a rural catchment applied with a single rainfall record. It is assumed that the surface component of runoff calculated reaches the catchment outlet in the same time-step as the rainfall unless a separate delay or routing procedure is adopted.

For large catchments which have several raingauges it is best to separate the catchment into a separate sub catchment for each raingauge and to link the sub-catchments by drainage lines according to their drainage pattern. A downstream catchment may receive runoff from an upstream catchment and will add the input flows to those calculated for the downstream catchment to give a total flow for all the upstream catchments.

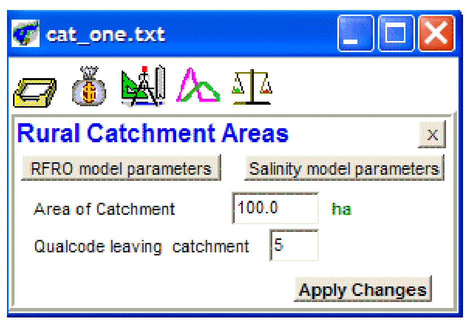
Inserting channel routing or storage routing (via wetlands or reservoirs, etc) between the upstream and downstream components will provide attenuation, losses and delay.

Selecting a natural catchment node raises 5 data entry icons.

8.5.2 Catchment Data Entry

Clicking on the catchment layout icon  will bring up the window below.

This window contains the **Area of the catchment** and the **Qcode of the water** draining from the catchment.

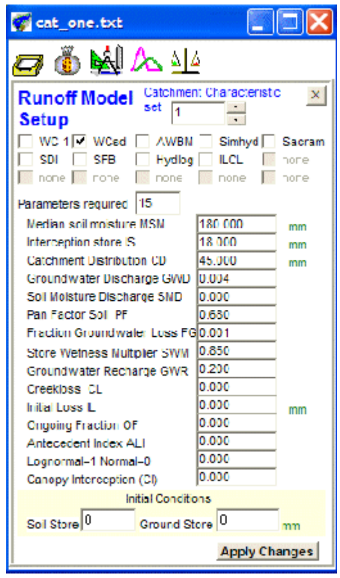


Models calculate runoff from the catchment as a proportion of the rainfall depth. The runoff depth is converted to a volumetric measurement by multiplication by the catchment area.

The **quality code** of the runoff may limit how this water can be used. Typically a rural catchment is assumed to produce water with a **quality code** of 5. For more detailed information on quality codes see Section 7.

8.5.3 Selecting the Rainfall to Runoff Model

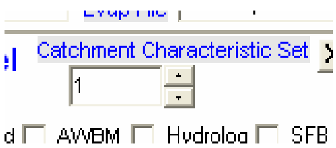
The catchment window provides two tabs **RFRO model parameters** and **Salinity model parameters**. For salinity models see below.



Clicking on **RFRO parameters** will bring up the window shown below. The window allows the modeller to select one of 9 rainfall to runoff models by clicking in the relevant boxes near the

top of the window. Descriptions of the models are given in Section 10.

When the model is selected the data entry boxes for each of the parameters contained in the model is displayed. The window shows the entry boxes for the WC-1 model.



At the top of the window is a box labeled **Catchment Characteristic Set.** The WaterCress model allows up to 15 different combinations of the model parameters to be stored and recalled for the RFRO model selected. Each combination forms a different characteristic set and each is selected and applied by toggling through the Set box.

A characteristic set contains both the model type and the parameters for that model. Therefore in any other rural catchment node you create, by setting its characteristic set, you also automatically set its parameters and model. Further if you change the parameters within a set at any node you change the parameters for any node with that set.

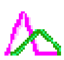
This allows quick calibration of complex models which are made up of a number of different catchment types. The list contains most common lumped parameter models used in Australia. Typically all of these models track soil wetness and groundwater storage. All models provide provision to input the initial values for **Soil store** and **ground store.** The value of initial Soil store may vary between 0 and MSM+. The value of initial Ground store is only 0 to 1 or 2 mms.

8.5.4 The water quality generating functions

For salinity refer to section 7.2.3

The **quality out** code of the runoff is the quality code for the flow leaving the catchment. This may limit how this water can be used further downstream. Typically a natural catchment is assumed to produce water with a **quality code** of 5. Refer section on **quality code.**

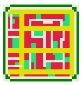
8.5.5 Routing Entry

Clicking on the routing icon  brings up the standard routing window. The inputs pertaining to this window are defined in detail in Section 7.

8.5.6 Cost Functions

Clicking on the cost icon  brings up the standard costing window. The capital cost of any construction or maintenance program within a catchment to enhance quantity or quality of runoff can be included here. This is more likely for roaded catchments where runoff is specifically enhanced requiring a significant capital and maintenance program. Cost input follows the standard cost window, refer 7.2.2

8.6 IMPERVIOUS Catchment Component

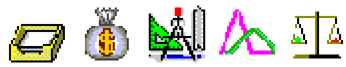


8.6.1 Introduction

This component, unlike the House or Urban nodes, only produces runoff from the impervious surfaces of an urban area, from which significant runoff can occur. Rainfall - Runoff models for this type of surface do not take soil moisture changes into account and the accuracy of runoff estimation is dependant on the correct estimate of the surface areas, the losses that take place during the runoff generation process and during the transfer of the runoff to the catchment outlet. A significant determinant in the latter is the efficiency of connection of the impervious areas to the drainage system.

This node does not include methods to estimate runoff from the associated areas of gardens, and open spaces. However, the runoff from these areas (in developed areas with medium density of development and rainfall 400-600 mm/a) is low compared to the impervious component. If runoff from the pervious areas is required, the runoff from these areas should be separately calculated using a Natural catchment rainfall to runoff model.

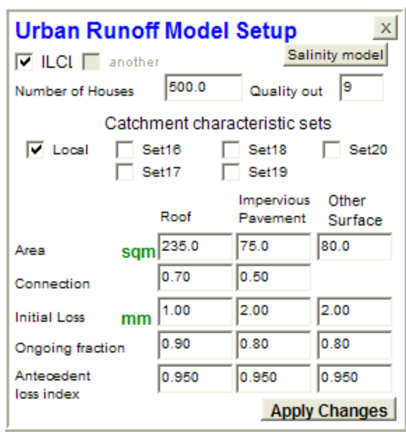
Selecting the impervious catchment node raises 5 data entry icons.



8.6.2 Catchment Layout

Clicking on the catchment layout icon  will bring up the window below.

The input window allows the setting the average area of **roof, impervious pavement** and **other surface** (typically a shared road pavement) of a typical developed lot. Since houses generally make up the majority of developed lots, the lots are referred to as houses. Total runoff from the node therefore requires the areas to be multiplied by the estimated total **number of houses** contained within the catchment area.



Three catchment areas are input on this page.

Domestic Roofs metres^2 per house

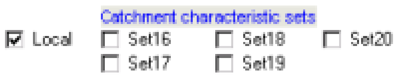
Domestic Pavement metres^2 per house

Other Surface metres^2 per house

Note that:

- The **other surface** is typically used to incorporate road pavement.
- the connection fraction is ONLY applied to the roof and pavement surfaces (the **other surface** connection is assumed to be equal to 1)
- the diversion losses may also be achieved by increasing the initial losses.
- The **roof area** should include all structures that potentially divert flow to the stormwater system.
- The area of **pavement** is that surrounding the dwelling which has some connection to the drainage system
- The area of **Road pavement** includes the impervious areas of the roads and footpaths. If footpaths can discharge onto grassed verge strips they can be added to Domestic Pavements so that diversion losses can be applied.

While the descriptions relate heavily to domestic situations the component is also often used to simulate runoff from commercial and industrial areas. Placing a value of 10,000 in the **number of houses** edit window then means that values placed in the **area** edit windows will relate to catchment areas in hectares.



The model allows 5 urban characteristic sets for each project. These are labeled set 16 to set 20.

They are labeled this way because they follow on from the 15 sets allocated for rural catchments.

A characteristic set contains both the model and the parameters for that model. Therefore in any other urban catchment node you create, by setting its characteristic set, you also automatically set its parameters. Further if you change the parameters within a set at any node you change the parameters for any node with that set.

The **local** option may be selected, allowing the user to specifically set parameters for this node only.

8.6.3 Selecting the Rainfall to Runoff Model

Currently only one mode is available with selection of ILCL (initial loss – continuing loss) checkbox in the top left hand corner. The formulae used in this method for the Impervious, House and Urban nodes to make continuous estimates of runoff from impervious areas is:

Runoff = **Area** * (Rainfall – **initial loss**) * **Con** * **ongoing fraction**   when Rainfall > IL, or

Runoff = 0 when Rainfall **< initial loss**, where:

- Runoff is a volume for the time-step
- Area is the total of all the individual (impervious) areas of roofs or paved surfaces within the sub-catchment for which runoff is being calculated,
- IL is the Initial Loss assumed for that surface type,
- Conn is the degree of connectivity for that surface to the main drainage system, and
- OF is the ongoing fraction of rainfall ‘lost’ after the initial loss had been extracted.

The formula can be applied for any time-step, but for time steps less than one day the **initial loss** must be adjusted to account for short term wetting and drying periods by introduction of the **antecedent Loss Index (ALI).** This is done by utilising the antecedent loss index which is a multiplier which adjusts the loss rate at each time step.

Daily values for IL can be estimated with some accuracy from plots of event rainfall v event runoff. A similar value will be obtained from plots of daily rainfall v daily runoff, except that the latter will have more scatter.

Typical values for IL, Conn and OF that have been found to give good calibrations between the predicted runoff and the measured runoff for the majority of gauged urban catchments in Adelaide (which were mainly residential) are:

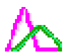
Parameter	Roofs	Paved Surfaces
IL	1.0 mm/day	2.0 mm/day
OF	0.9	0.8
Con	0.7	0.5

8.6.4 The water quality generating functions

For salinity refer to section 7.2.3

The quality out code of the runoff is the quality code you will set as what is leaving the catchment. This may limit how this water can be used. Typically an urban catchment is assumed to produce water with a quality code ranging from 9 to 12. Refer section on **quality code.**

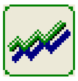
8.6.5 Routing Entry

Clicking on the routing icon  brings up the standard routing window. The inputs pertaining to this window are defined in detain in section 7.x

8.6.6 Cost Functions

Clicking on the cost icon  brings up the standard costing window. The capital cost of any construction or maintenance program within a catchment to enhance quantity or quality of runoff can be included here. This is more likely for roaded catchments where runoff is specifically enhanced requiring a significant capital and maintenance program. Cost input follows the standard cost window, refer 7.2.2

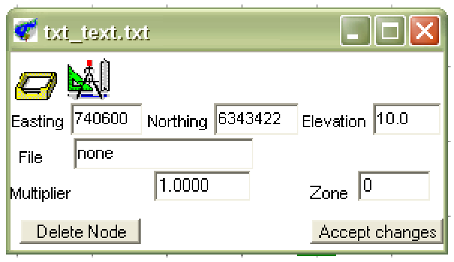
8.7. TEXT FLOW Component



8.7.1 Introduction

This component creates a drainage flow which is read in via a text file format which typically defines the date, flow and associated salinity.The flow is incorporated into the drainage system of the model. Typically this file may contain the flow in units of volume per time-step as either:

- A flow record from a gauging station
- A flow record created by a previous WaterCress (or other) model.
- A flow generated to contain a flood or drought sequence of calculated probability.

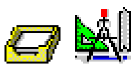


On clicking the node the window at RH appears. The file name is entered in the File data entry window. The file must be located in the project folder or else a path shown for its location.

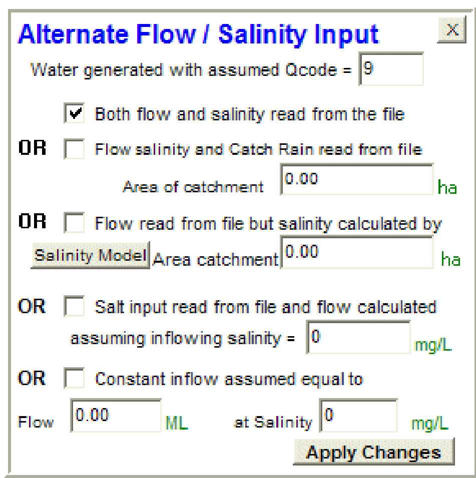
The data must be in the standard flow format **(see section X)**

The multiplier is used to factor the file information. For example, the flow may be derived from a gauging station on a catchment with a different upstream area. The multiplier can modify the record to represent the flow from the 'text flow' catchment area. A value of 1.0 is the default and ensures the flow entered = the file data.

The openning window contains two header data entry icons.



8.7.2 File Input Entry



Clicking on the layout icon  opens the window adjacent. There are 5 options for entering the data via the file:

Both flow and salinity read will mean that the program expects that the input file will contain two columns of data (in addition to the date/time). The Quality code of the flow is taken from the input window above.

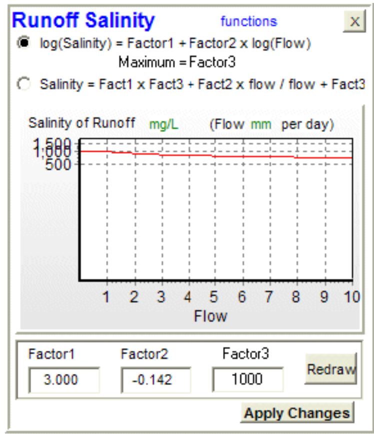
Flow, salinity and Catchment rain requires the three sets of values to be read from the file in the order shown.

The rainfall data and area of catchment are only required in order to enable the average area weighted rainfall is to be calculated for a project involving multiple sub-catchments, of which the text flow node represents one (or more).

Flow read – salinity calculated requires only the flow to be read from the file. The salinity is then calculated by a salinity function.

For the salinity calculations, “flow“ is required as units of average depth over the catchment (ie millimetres of flow). However, flow provided by the file is in volume units per timestep. To convert the file input to flow depth the area of the catchment must be provided. This is input in the adjacent catchment area window. Factors 1 , 2 and 3 are provided by the user enabling the salinity to be calculated as a function of flow. (see Section 7)

Salt input read from file and flow calculated enables a defined salt input (eg kgs/day) to be added to a stream flow as a time series and to be divided by a constant assumed value of salinity concentration (“assumed inflow salinity“) in order to calculate the corresponding flow rate associated with the salt load. The calculated flow and the assumed salinity are then passed into the project model. The “salt input“ is not used directly in the model. This method only applies for streams with a constant salinity concentration.



Constant inflow does not require any file input. A constant value of flow and salinity is input and no file name is required to be placed in the file input window.

8.8 RESERVOIR, TANK AND OFFSTREAM DAM Components

8.8.1 Introduction

Model calculations involving reservoirs , tanks and off-stream dams are essentially the same, but with some differences. As such they are lumped together under this heading. The WaterCress model requires storage to be available and to be drawn on for supplying water to satisfy demands. Water supplies are sourced from storage components such as these.

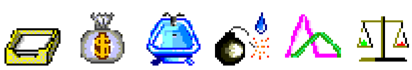
The differences are defined as follows

- A tank does not lose water to evaporation and therefore does not require a volume area relationship.
- An offstream dam does not influence downstream channel routing and therefore does not need the routing icon.
- The offstream dam involves diversing flow from the main stream and therefore requires a diversion icon.

Selecting a reservoir component raises the following icon options

The **Reservoir** (on-stream dam) component is a standard storage component enabling storage, rainfall and evaporation processes to occur. The reservoir is assumed to be on-stream which means all flow from the upstream catchments is directed into the reservoir, and the reservoir must be full before flow continues downstream. Volume/area functions are provided to enable rainfall and evaporation impacts to be calculated. The flows may be routed via the storage and records of reservoir inflow, outflow or storage may be used to calibrate simulation modelling.

Selecting a Tank component raises the following icon options

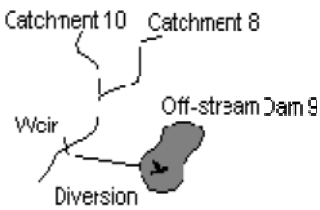


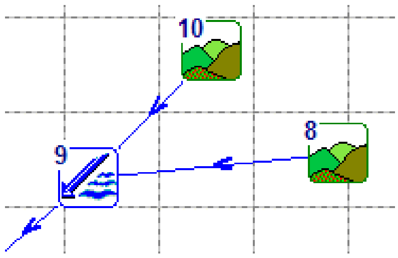
The **tank** component is a simplified reservoir component which is assumed to be roofed and therefore enables storage calculations to proceed without having to account for rainfall and evaporation from its water surface. The tank is located on-stream which means all flow from the upstream catchments is directed into it and it must be full before flow continues downstream. Typically the tank is used to hold wastewater or stormwater volumes.

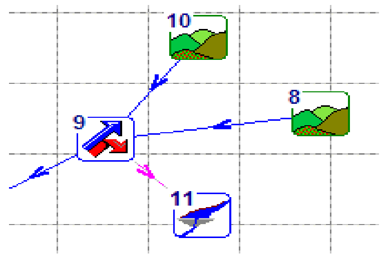
Selecting an off-stream dam component raises the following icon options

The **Off-stream dam** component is a special case combining the action of a weir diverting flow into an adjacent reservoir type storage. Diversion ceases when the storage is filled. The amount of diversion is controlled by rules input by the user.

Off-stream for the purpose of this node means the storage NEVER has a catchment of its own and is ONLY filled by diverting a proportion of the passing creek(s) flow.

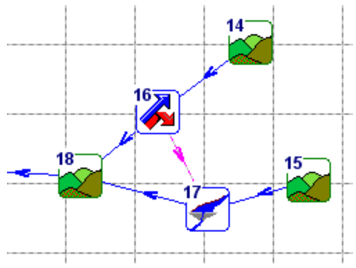






The two watercress model layouts above will both calculate the storages 9 and 11 as equivalent off stream dams.

If an off-stream dam receives diversions from a passing stream, but is also on-stream and receives inflow from its own (significant sized) catchment, the WaterCress model layout must adopt the reservoir node for the storage and NOT the off-stream dam as shown at the RH.



In general no spill will occur from the off-stream dam since the diversion to it is automatically limited so as not to overfill the dam. However rainfall falling on a full storage may overtop the storage and induce a small spill. This spill is passed down the same channel from which the diversions are taken.

Both the offsteam dam and the weir have the diversion input icon and both use the same functions for diversion. The diversion processes are described in detail in section 7.2.8.

The node is very useful in investigations of catchments with multiple farm dams where environmental flows are of concern and the calculation of diversion and use is similar regardless of whether the dams are on-stream or off-stream.

8.8.2 Storage Setup

 All of the node types use similar parameters and functions for storage. These are defined in section 7.2.4

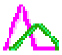
8.8.3 Demand Setup

 All of the node types use similar parameters and functions for demand. These are defined in section 7.2.5

8.8.4 Storage Geometry Setup

 The on-stream and offstream dam both use the same storage geometry options. These are defined in section 7.2.6

8.8.5 Routing Setup

 The on-stream dam and tank both use the same functions options. These are defined in section 7.2.7. The off stream dam does not use routing functions as it is assumed to be a storage off the main stream.

8.8.6 Diversion Functions

 The diversion functions for an offstream dam are identical to the functions for a weir. Refer section 7.2.8 for details .The off-stream dam diversion function differs from the weir functions in a few ways.

The storage cannot be overfilled. When the storage fills the diversion rate is automatically reduced to zero.

The offstream dam uses the rainfall file input for rainfall and evaporation and the FEVA file for dam volume area relationships. Therefore no file input is available to control the diversion rates. The options will be hidden when you open the diversion window.

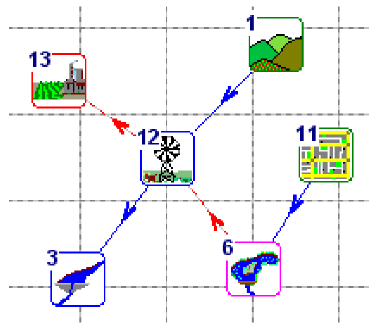
8.9 AQUIFER Component

8.9.1 Introduction

The aquifer acts as a water storage, but should only be used to supply water when natural or managed recharge to the aquifer will approximately balance the withdrawal from it, via a bore. If groundwater is to be included in a water system as a source of water, without recharge, such a supply should be modelled by using an External node as the source.

The main purpose of the aquifer node is to track salinity changes as lower salinity water is recharged and recovered from an aquifer, usually containing higher salinity water. The aquifer is normally recharged via a constructed recharge bore. A typical situation would be recharge using urban stormwater generated during the wet season and captured in a wetland, as represented by nodes 11 and 6 in the adjacent diagram. The water recharged to the aquifer from the wetland would be recovered during the dry season and delivered to a demand, as represented by node 13. Managed recharge and recovery at fixed injection and withdrawal rates are linked to the aquifer bore by water supply links. In this situation the aquifer is likely to be confined and the recharge and recovery rates will be limited by the bore testing information.

Other Recharge Combinations



Variable rate recharge can be simulated by placing the aquifer component into a drainage path. In the diagram catchment runoff generated by node 1 passes over the natural recharge area included in the aquifer facility. Infiltration takes place from the drainage channel and the infiltration directly recharges the aquifer. In the example, the remainder of the flow continues on to a downstream reservoir at node 3.

It should be noted that in the model, recharge via a drainage path may occur as:

- uncontrolled variable rate recharge to the aquifer (via channel or spreading basin infiltration), possibly at occasional large rates and possibly in addition to any recharge supplied to the aquifer via bore(s), or
- recharge from run-of-river flows but with the rate of recharge controlled by the capacity of the bore(s) and their acceptance limits on salinity and qcode.

The manner in which the aquifer node is attached and its options elected will alter the likely physical reality of the recharge situation being modelled, as indicated in the 3 examples following:

1. No drainage path exists, recharge is only via supply path(s): This is the normal situation for a typical aquifer storage and recovery situation, probably involving a confined aquifer. The maximum assigned recharge rate, salinity and q code assume a regulated situation in which the bore(s) have a maximum total injection rate and the salinity and qcode are set to bar unacceptable levels.

2. No supply paths exist, recharge is via a drainage path only: Situation a). The recharge to the aquifer is calculated by an infiltration equation. The recharge is not limited in its maximum rate, salinity or qcode. At the maximum, this could mimic recharge via onstream or offstream spreading ponds and similar. Situation b) The recharge from the drainage line is limited by the maximum assigned capacity of the bore(s) and their salinity and q code limits. The situation mimics a run-of river situation with recharge limited by the bore limits.

3. Both drainage and supply paths exist: In all cases, any recharge via the drainage path calculated for the time-step under consideration, will have precedence in occupying:

in Situation a) the capacity of the aquifer (only), or

in Situation b) the capacites of the both the recharge bore and the aquifer.

In situation b), only after the recharge via the drainage has been calculated can any spare capacity in the recharge rate via the bore be accomodated from the supply link(s). This situation could exist where a recharge bore exists adajacent to an ephemeral natural drainage channel. When the natural flows have ceased (along with any recharge from them), the stormwater flows from a nearby town can be recharged via the same bore.

If the recharge to the aquifer was via a large capacity infiltration type situation, it would be more likely (ie lower cost) that the wetland would be drained to (rather than supplied to) the same infiltration basin.

Under ALL situations the aquifer may be provided with a continuous natural recharge rate (as an internal feature of the aquifer node – ie not part of recharge from a drainage path) which is assumed to have the same salinity as the native salinity of the aquifer.

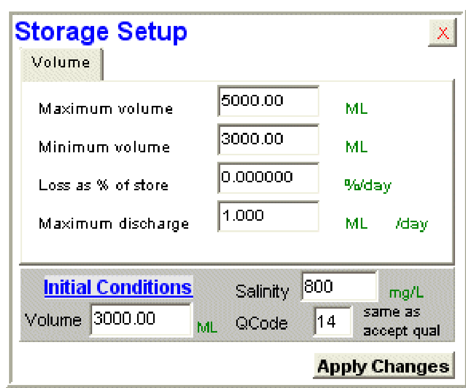
A percentage of all the recharges (other than the continuous natural recharge) may be assumed lost. This is a procedure to limit any excess build up of storage within the aquifer.

Selecting an aquifer component raises the following icon options

The node does not use rain or evaporation files and therefore these along with the rain station factor input are hidden on the aquifer screen

8.9.2 Storage Setup

Maximum Volume



The maximum volume is the volume at which no further recharge of any kind can occur. If the storage reaches this value no further recharge will occur until some withdrawal or loss takes place. In most cases the maximum is set at a value greater than is ever likely to be achieved during the model run. Thus, if the maximum storage is reached, any further natural recharge will cease, any recharge delivered by drainage links will be diverted past the aquifer (ie spilled from the aquifer or redirected into the downstream drainage path) and any supplies directed from external storages would not be accepted.

The maximum volume represents the level at which surface flooding via bores, seepage or springs might commence or aquicludes might be in danger of being ruptured.

Minimum Volume

The **minimum volume** is the lowest level to which the storage in the aquifer can fall. At this level withdrawal to supply will cease. The level will remain at this level until further recharge takes place. The minimum volume is often set at the initial level so that (with zero natural recharge) withdrawal cannot exceed the total recharge that has occurred since the start of the model run

Aquifer Loss

Aquifer loss is set at a percentage value that applies a loss to both the managed recharge (via supply link) and/or the variable recharge (via the drainage link). It is partly used as a mechanism to limit the build-up of storage in the aquifer or as a regulatory tool to assist in ensuring that withdrawal from the aquifer does not exceed the recharge to it in cases when there is natural recharge.

Maximum Discharge

The maximum discharge is the maximum volume (volume per day) that can be extracted from the aquifer (assumed via a bore – often the same bore used for injection). The model will not allow extraction to exceed this figure. Where bores have extraction rates which are less than the demand rates for which the recovered water is to be used, it may be necessary to duplicate bores. The maximum discharge rate will then be the total rate of the several bores wthdrawing water from the aquifer.

Initial Conditions

The initial conditions for both volume and salinity indicate the starting position of the aquifer. It is common to choose the initial condition at or just greater than the minimum storage. It will be necessary to build up storage in the aquifer in order to produce a workable volume of low salinity water if the native salinity is higher than that acceptable for use when recovered. Mixing and diffusion within the aquifer (see below) are working to constantly increase the level of any low salinity water already recharged, thus it is common that withdrawal does to exceed recharge and there will be a build up of storage within the aquifer over the modelling period. Where low salinity water is recharged (say stormwater at 100-200 mg/L), but the acceptable level of salinity of withdrawn water is higher (say 750 mg/L), there may be a corresponding reduction in the salt load within the aquifer.

The maximum, minimum and initial conditions are best chosen by trial and error. Calibration to recorded salinity data is highly desirable.

8.9.3 Demand Setup


All of the node types use similar parameters and functions for demand. These are defined in section 7.2.5

Note that the maximum filling rate applies only to the managed recharge deemed to be entering via a bore. This will include managed recharge from a drainage line at constant rate and/or recharge directed to the aquifer node via a supply link. The **maximum filling rate** is the operational injection rate set for the recharge bore(s) and is the total of these two recharges. Note that this rate does not apply to the variable stream recharge option via the drainage link which is deemed to recharge the aquifer unregulated and not via the bore (although at or close to the bore cell (see aquifer structure).

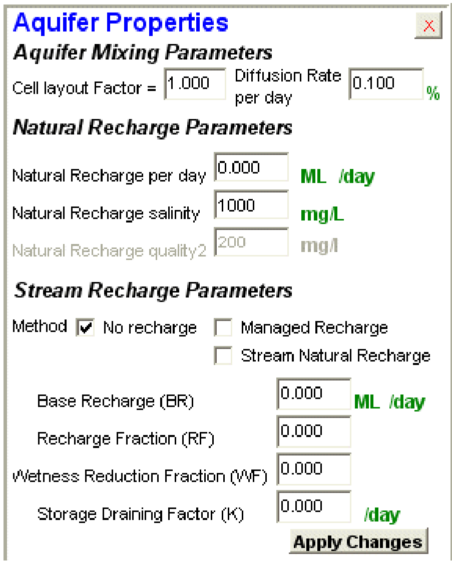
The **internal annual use** window should **normally be set at zero** since any use calculated would be over and above that occurring via the withdrawal process and would imply that the bore(s) would have to discharge both the maximum discharge (when operating) plus the internal use (since this latter could not be used within the aquifer itself).

8.9.4 Storage Geometry

Aquifer Mixing Parameters

The window contains values which relate to the manner in which the aquifer operates in mixing and difusing the salinity of water recharged into it with that already stored within it. The process is described in 3.12.4 below.

Natural Recharge Parameters



Natural recharge should only be used in situations where it is necessary to avoid the salinity in the outer parts of the aquifer from reducing too rapidly due to the action of mixing and difusion in situations where large volumes of low salinity recharge water are added. If/when used, in order to avoid overfilling the aquifer (reaching maximum volume), the **Natural recharge per day** should be kept small and the **Natural recharge salinity** could be artificially increased several times above the aquifer native salinity level. Note the native salinity is that set in the Storage window under Initial Conditions.

Stream Recharge Parameters

Three options are provided for calculating the amount of water infiltrated to the aquifer storage;

1) No recharge will provide zero stream recharge, regardless of any data entries to other windows. Natural recharge will continue (if data provided).

2) The Down Bore method will recharge flows to the aquifer up to the value of (MCR) -entered into the Minimum Constant Recharge window beneath - during the periods when the stream is flowing, but only up the maximum filling rate and at the acceptable levels of salinity and q code selected in Demand Setup. This form of recharge is suited to situations where MCR is assigned a value equal to or less than the capacity of a bore to accept inflows from the drainage path. If MCR is greater than the maximum recharge rate set in Demand Setup, only recharge up to the Demand Setup value will occur.

3) The Stream Natural Recharge method calculates the recharge that is derived from a stream channel containing variable flow passing over or adjacent to the aquifer. The method works on the concept of recharge to a unconfined aquifer, where, as more water flows past and recharges, the local water table rises so that it partially (and eventually fully) blocks the recharge process. The model simulates this by filling and emptying an imaginary storage, which, as it fills, increasingly constrains the recharge occurring. The potential recharge to the aquifer includes all flow up to a fixed flow rate plus a fixed proportion of the flow above that limit, however this is reduced according to the calculated storage status of the local water table. Note: The status of the main aquifer does not affect the recharge into it (except that it will not allow itself to be filled above maximum volume).

This situation mimics the operation of an infiltration from a spreader pond or 'losing' river reach. Parameter inputs to the model are provided in the 4 edit boxes provided. The parameters required are

The base recharge rate (**BR**) – is the maximum base rate at which all the flow is attempted to be recharged to the aquifer.

The recharge fraction (**RF**) – is the fraction of the flow above the base level which is additionally attempted to be recharged to the aquifer

The wetness reduction fraction (**WF**) – the factor reducing the entry of the recharge amounts calculated via BR and RF (according to the cumulated status of the local water table and represented by a 'wetness' storage operated as part of the model).

The factor governing the rate of draining of the 'wetness' storage (K).

If Q(t) is the flow rate for the day and WS(t-1) is the wetness storage cumulated up to the end of the previous day (representing the status of the local water table), the calculation of recharge to the underlying main aquifer is calculated as below:

Recharge to aquifer

R = BR + Q(t)*RF – WS(t-1)*WF

or **R = 0** if WS(t-1)*WF > BR + Q(t)*RF

Revised status of wetness storage for next day WS(t) = [WS(t-1) + R]*K

The initial value of WS is not selected by the modeller. It has no maximum value and will adjust its values to the scale of the flows passing over it according to the values selected for the 4 parameters. Note BR is a flow rate and RF, WF and K are all fractions between 0 and 1. The actual recharge will rise as BR and RF are increased. If WF and/or K are set to zero, all potential recharge will be recharged. It is the difference between WF and K that determine the delay in the time that it takes for the wetness store to build up and fall and the range of impact that the store has on the calculated recharge.

Aquifer Cell Structure and Operation

In order to model the mixing of the salinities of the recharged waters with the salinities of the native groundwater, a mixing model is employed which consists of a series of 10 notionally concentric cylindrical storage cells located radially as rings outwards about the recharge bore. The storage contained within each ring increases at a rate defined by the user (cell layout factor). A cell layout factor of 2 means the volume of each outward cell is 2 times that of its neighbouring inner cell.

Natural recharge is added to the outer edge of the aquifer. All other recharges (by supply or drainage paths and via a bore or as unregulated recharge) are added or withdrawn from the aquifer centre cell and the effects of the additions or withdrawals are transmitted across the cell boundaries with mixing taking place between the exchanged volumes and their salinities and the cell volumes and their salinities. Diffusion (set as a percentage of each cell volume diffused per day) also exchanges water across the boundaries. The water exchanges cause the salinity mixing.

The steps in calculation are:

Step 1. Set up initial cell structure

The innermost cell is the bore cell (cell 0) and has a volume v0. The outermost cell (cell 9) has volume v9. The cell volume proportions are calculated as f^n, where n is the number of the cell and f is the cell layout factor. Thus, for f = 2, cell 9 will have a volume 2^9 or 512 times larger than that of cell 0. The proportions are shown in the table below along with the cumulated proportions and the volumes of each cell and the cumulated volume for an aquifer with an assigned total water storage volume of 10,000 ML.

	Cell 0	1	2	3	4	5	6	7	8	9
ratio	1	2	4	8	16	32	64	128	256	512
sum	1	3	7	15	31	64	127	255	511	1023
cell vol	9.8	19.6	39.1	78.2	156.4	312.8	625.6	1251	2502	5006
sum	9.8	29.3	68.4	146.6	303.0	615.8	1241	2493	4995	10000

The cells are then filled from cell 0 outwards by an amount equal to the assigned initial volume. The salinity will be the assigned initial salinity value, equal to the salinity of the native salinity of the aquifer groundwater (sn).

The remainder of the cell(s) outwards are assumed empty. The diagram below is a not-to-scale representation of a half filled aquifer. In the example given above, cell 9 would occupy half of the aquifer storage and all cells to cell 8 would be filled.

Step 2. Re-calculate Cell Volumes and Salinities at each (daily) Time Step.

If the model is runing at a sub-daily time step any additions to the aquifer or withdrawals via either the water supply or drainage paths are summed to a daily total **and all water balance calculations for the aquifer are made at the daily time-step**.

Calculations for Recharge. In all situations

Any **constant rate stream recharge** via a drainage path with acceptable salinity and qcode is added to cell 0 at either the maximum filling rate, or at the stream flow rate, whichever is the **least (r1).**

If the constant rate stream recharge rate has not equalled the maximum filling rate, then any rate capacity remaining for the bore can be filled by any **managed recharge delivered to the aquifer via a supply path**. This is also added to cell 0 providing it also meets the acceptable salinity and qcode limits **(r2).**

Any **variable rate unregulated stream recharge** is also added to cell 0 regardless of its recharge rate, salinity level or qcode **(r3)**.

Any **constant rate natural recharge** (if any) is added to the furthest out cell containing storage.

Steps 1. The salinity of the cell 0 is recalculated as [(r1*s1) + (r2*s2) +(r3*s3)+(v0*s0)] = s0(1).

The excess volume in cell 0 (R) with its salinity s(0)1 is added to cell 1. The salinity of cell 1 is recalculated as [(R*s(0)1) +(v1*s1)] = s1(1).

The excess volume in cell 1 (R) with its salinity s(1)1 is similarly mixed with the contents of cell 2, and so on for all filled cells. The final cell will have its volume increased by R. If this exceeds its volume, the next cell will start to fill, but the mathematics is still the same for all filled (or partially filled) cells.

Step 2. Any natural recharge is added to the (partially filled) last cell and volume weighted mixed. If the cell 9 is filled all further recharges are ceased. Any recharge volumes that would have been recharged to the aquifer via the drainage lines will spill or continue downstream along the drainage path. **Any natural recharge selected occurs at every time step, regardless of whether recharge, or recovery, or neither is occurring**.

Since the cell volumes increase rapidly away from cell 0, the effects of mixing of the relatively small volume R has rapidly decreasing impact on the salinities re-calculated for the outer cells, which therefore remain relatively pristine for long periods. The greater that the initial and maximum volumes are set, the longer will be the time until any impact reaches the outer cells. However, the inner cells rapidly attain the avergae salinity of the recharged water.

Calculations for Recovery. Recovery from the aquifer will occur at the nominated daily recovery rate.

The recovery volume is withdrawn from cell 0 (with part, if necessary, drawn from neighbouring outward cells). If more than cell 0 is involved, the salinity of water withdrawn from the cells is averaged by volume weighting. Each cell is then refilled by drawing water from the outside cells, with salinity mixing being calculated as for recharging. Recovery ceases if the aquifer volume drops below the minimum volume assigned. However, if the salinity of the native groundwater is in excess of the maximum acceptable salinity of water recovered, it is more likely that recovery will cease due to the salinity of the recovered water rising above the acceptable level, rather than the minimum aquifer volume being reached.

It is possible that recharge and recovery may occur in the same time step. (In practice this may not happen due to time delays in reversing pump settings, etc,. However different agencies may have different priorities for recharge or recovery, hence the model performs both). The calculations performed are the same as above, but drainage calculations are always performed first and supply calculations after.

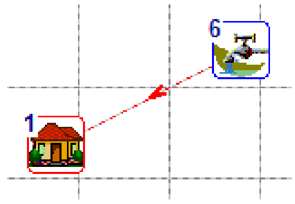
Calculations for the effects of Diffusion. The calculations for diffusion carry on every day regardless of whether there is recharge, recovery or nil exchange. The calculation is undertaken after any of the other calaculations are completed. The rate of diffusion is set as a % and this defines the volumes of water that are exchanged between adjacent cells on each day.

Diffusion occurs at each boundary between adjacent cells by the outwards exchange of a volume equal to (Diffusion%/100*Volume of inner cell). The effect of diffusion is to draw in the salinity of the outer cells and spread out the salinity of the inner cells. If low salinity is being recharged into a higher salinity aquifer, setting a too high value for diffusion will render any recharged water unacceptable due to mixing after only a short period, thus reducing the efficiency of the recharge and recovery process.

Diffusion is usually set at 0-1%.

8.10. EXTERNAL SUPPLY Component

8.10.1 Introduction



The external supply component can provide an unlimited supply of water at a user defined quality.

This node is useful in simulating a reticulated water supply or any other supply that involves the supply of a notionally unlimited supply of water. Most often it is assigned a low priority (high numerical value) and hence it is the last volume taken. In this way it is used to define how much an existing reticulated supply could be reduced by supplying water from local sources.

An external source may also represent an emergency pipeline or water carting. For water carting, the cost of water is generally high and imposes a cost penalty on the overall rate. Water from an external source may be invoked according to an operating rule in times of severe drought. The component may therefore be used to inflict a cost penalty for use within an objective function, ranking periods of failure of alternative systems.

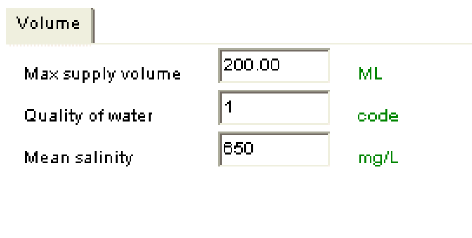
Selecting an **external** component raises the following icon options

8.10.2 Storage Setup

 The maximum volume which is able to be supplied in a day is set here. The value set is in volume units per day. Where the model is run sub-daily the maximum supply per timestep is calculated as a fraction of the daily value.

Supply Salinity and QCode

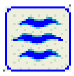
The external supply component is assumed to be able to provided and unlimited supply of water (nb. The user sets the upper limit) which has a constant salinity and quality code. These quality values are set by the user here.



8.10.3 Cost Functions

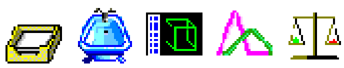
 Clicking on the cost icon brings up the standard costing window. The capital cost of any construction or maintenance program within a catchment to enhance quantity or quality of runoff can be included here. This is more likely for roaded catchments where runoff is specifically enhanced requiring a significant capital and maintenance program. Cost input follows the standard cost window, refer 7.2.2

8.11 MULTI-STORE Component



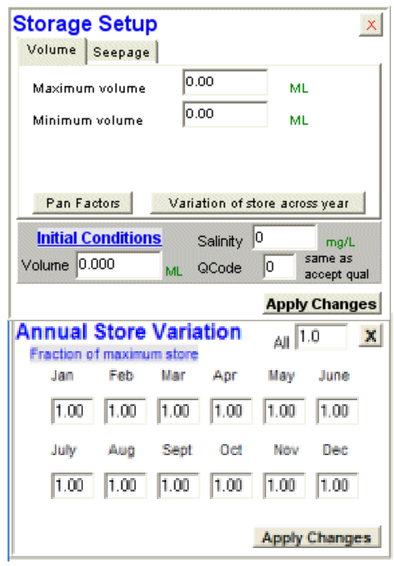
8.11.1 Introduction

The multi-store component allows both routing (flow attenuation and time delay) and storage for water supply and flood mitigation to be modelled. The component contains a storage component enabling storage, rainfall and evaporation processes to occur. In addition the node can act as a retention storage in which the volume retained can be altered month by month, and the routing capability allows a programmed release of water as required by such storages. **Selecting a multi-store** component raises the following icon options



8.11.2 Storage Setup

 The node uses similar parameters and functions for storage. These are defined in section 7.2.4. There is one additional input enabling the variation of the storage across the year.



8.11.2.1 Variation of store across the year

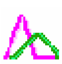
The maximum volume of the storage can be varied month to month by input, for each month, a fraction of the maximum store. The maximum volume for a particular month then becomes the maximum volume as set by the window above multiplied by the monthly factor set. At the change of month any water held above this volume will be released at a rate defined by the routing parameters.

For example - Setting the value in any month equal to one will set the storage equal to the maximum volume. Setting a value of 0.5 will set the storage to 0.5 x the maximum volume.

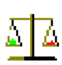
8.11.3 Storage Geometry

 These functions are the same as for the dam component and for details refer to section 7.2.6.

8.11.4 Routing Data Entry

Clicking on the routing icon brings up the standard routing window. The inputs pertaining to this window are defined in detain in section 7.2.7.

8.11.5 Calibration

 Clicking on the calibration icon brings up the standard calibration window. The inputs pertaining to this window are defined in detain in section 7.2.9

8.12. TREATMENT Component

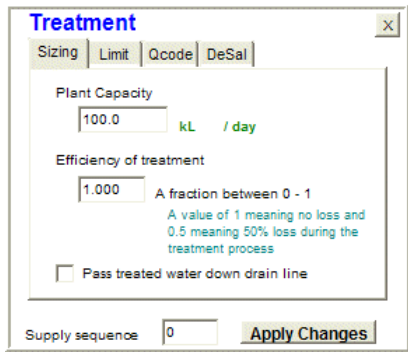
8.12.1 Introduction

The treatment process is very simple, initiating a net change in quality code, but at a price.

Selecting a treatment component raises the following icon options

8.12.2 Treatment Parameters

8.12.2.1 Sizing Tab



The **plant capacity** is the treatment capacity of the plant and has two influences on the process

1) The treatment process provides a storage to enable reuse of treated effluent directly from the treatment node.

2) The size of this storage is set equal to the plant capacity. Inflow of effluent in excess of the plant capacity will mean the excess untreated waste will be discharged down the drainage path.

The efficiency of the treatment determines how much of the sewage inflow becomes available for reuse. A cost function relates the plant capacity to cost of treatment.

The supply sequence number effects the computational sequence of components that are demanding a water supply. A treatment component may be connected in either of two ways.

1) On the path of a drainage line. Here it will treat all water up to the daily capacity of the treatment plant and retain this at the plant. Excess beyond plant capacity will spill downstream untreated. Sequence has no meaning under this layout.

2) Via a water supply path from another storage. Here raw effluent will be held within the other storage and is supplied to the treatment component for treatment. No excess to the treatment capacity occurs in this layout as the amount of raw effluent supplied cannot exceed the capacity of the treatment plant. Note however, the upstream raw effluent storage may overflow if the storage of effluent exceeds the capacity of the treatment plant to treat it.

8.12.2.2 Limit Tab

The water quality code is a very crude determinand which signifies the amount of treatment which the water would require before use. Qcodes lie between 0 and 19, the higher the number the worse the quality of water and the greater the amount (and cost) of treatment.

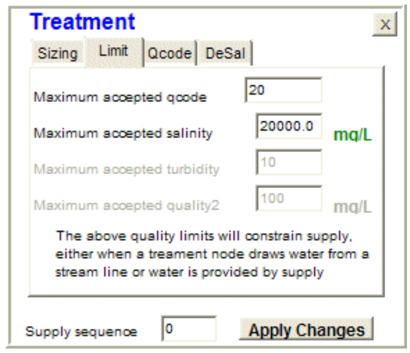
This section requires input to define the treatment process initiated. **Maximum accepted Qcode** is input as the upper limit quality of water to be treated. The treatment process will occur only on water with a code less than or equal to this code.

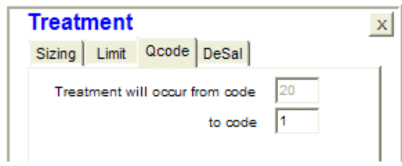
When desalination is selected, the **maximum accepted salinity** is the maixmum salinity that can be treated. Salinity in excess of this amount will pass untreated.

Treatment of turbidity and and a second general quality will be available in later versions.

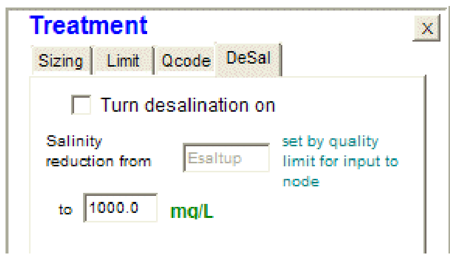
The qcode tab provides input defining the quality code the water will be reduced to.

Example: If **treatment will occur from** is set to 16 and **to Qcode** is set to 8, then water of quality codes 16 to 9 are reduced to qcode 8. Water of code 17 to19 entering the treatment plant will pass unchanged and no treated water will be drawn into the treatment storage.





8.12.2.3 Desalination Tab



If it is known that salinity is likely to exceed the upper limit of acceptability set for the demand the Treatment plant component may be used for salinity reduction. The salinity of the inflowing water will be reduced to the required limit at a cost. The input field gives an additional location you can input a cost per kilolitre of treatment. This input is different in that the cost can be defined as a proportion of the salinity reduction required. This means a reduction in salinity from 1500 to 1000 mg/l can be made cheaper than say a reduction from 2000 to 1000 mg/L. The function which may be input by the user is in the form of cost per kl = S1 + S2 * (salinity reduction) ^ S3 where S1, S2 and S3 are parameters supplied by the user. S3 raises the salinity reduction to the power.

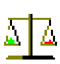
8.12.3 Treatment Costs

 Costs are passed down through the drainage paths until they reach a storage component. At storage, regardless of spill, the costs will be retained , only passed on to other components which are supplied water from this storage.

Technically a treatment component is not a storage but acts as one allowing supply to be made directly from the treatment plant. Unless supply is made directly from the plant it may not be appropriate to trap the cost of treatment in the treatment plant. This option gives the user the option of how the cost is transferred.

A tick in this box will spill the contents of the treatment store and the dollar cost down to the next node in the drainage sequence. No tick enables the component to operate as a storage.

8.12.4 Calibration

 Clicking on the calibration icon brings up the standard calibration window. The inputs pertaining to this window are defined in detain in section 7.2.9

8.13 WETLAND Component

8.13.1 Introduction

The wetland essentially operates in a similar way to an onstream reservoir. It has a volume area relationship, a maximum volume and has the capability of supplying a demand node.

However, the node differs from a reservoir in that it operates as a treatment node by decreasing the quality code number as the retention time increases. To do this the wetland storage is divided into 10 compartments and water volumes and quality are tracked between them with mixing and diffusion taking place and the age of the water in the compartments also being tracked. The quality improvement achieved by the time the water reaches the 10th compartment (from where it is assumed that any supply is taken) determines the amount and timing of the supply out.

Most input parameters are identical to onstream reservoirs. Those special parameters are detailed below

Selecting a wetland component raises the following icon options

8.13.2 Storage Setup


The node uses similar parameters and functions for storage. These are defined in Section 7.2.4

8.13.3 Demand Setup

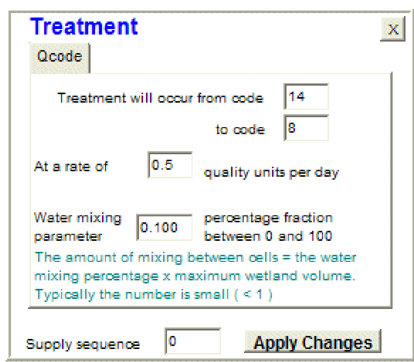

All of the node types use similar parameters and functions for demand. These are defined in section 7.2.5

8.13.4 Storage Geometry Setup

The on-stream and offstream dam both use the same volume - area options. These are defined in section 7.2.6. The wetland is usually assumed to be shallow, with maximum depth of the order of only 1 to 2 m. The surface area is therefore large in relation to the volume stored and evaporation losses may be proportionally higher than for deeper reservoirs.

8.13.5 Treatment Process


Clicking on the treatment icon brings up the window at the RH.



The treatment process (reducing quality code over time) is controlled with the first 3 input parameters which determine the basic range and rate of improvement. Both are subject to effects due to subsequent inflows and outflows and the mixing assumed.

The quality code will be reduced from the **from code** number entered to the **to code** number entered at a rate of quality code units entered per day.

In the example shown, if the quality code in any compartment was 12 one day, then the following day the parcel of water taht had occupied this compartment will fall 0.5 units to 11.5.

Similarly the qcodes of water in all compartments will fall by 0.5 units. However, inflowing water from the wetland’s catchment (which enters at compartment 1) and mixing will displace and mix the waters contained in the compartments to result in a ’re-mixed’ pattern of q codes within the compartments (and, in particular, the end compartment from where supplies are taken).

If the wetland receives flow with a quality code greater than 14 (in the example given above) reduction will not occur as the quality is beyond the specified range. It is important to ensure the higher value is above any likely inflow qcode value. Similarly the **to code** = 8 is the lowest that the wetland quality code will fall to and this must be lower than the maximum qcode that the supplies out will accept.

Water Mixing Parameters

As described above, water (of high quality code) inflowing to the wetland may raise the quality code at compartment 10 (the supply outlet point) making it unfit for immediate use. Inflow enters the first cell displacing the previous held water into the next cell(s) downstream. This way the salinity and quality code of the water varies from one end of the wetland to the other.

This means that medium to small inflows may not immediately affect the ability of the wetland to supply water. Given sufficient time the quality of this input water may improve to the required quality before it reaches the supply output point. Large inflows will displace all previous storage and (if the qcode is higher than the acceptable supply level) supply will cease until the qcodes again fall to acceptable levels.

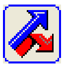
The water mixing parameter introduces mixing between the cells. The value is a number between 0 and 100 and relates to the percentage of the adjacent cell volumes that intermix. The intermix volume (per day) for adjacent cells equals the water mixing parameter multiplied by the maximum cell volume.The smaller the number the less mixing that occurs. A large number will mean that the wetland acts in a similar way to a normal storage (with total mixing each day).

Both quality codes and salinity are calculated by the same volume proportional mixing and displacement mechanisms. However, the salinity does not change with time in the wetland (other than by evaporation processes).

8.13.6 Cost Functions

Clicking on the cost icon brings up the standard costing window, refer section 7.2.2

8.14 WEIR Component



8.14.1 Introduction

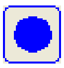
The Weir component can divide a drainage stream into two paths, utilising either a series of user defined functions or an input data file. The diversion mechanism and functions for this component are identical to those used within the off-stream storage node.

Selecting a weir component raises the following icon options

8.14.2 Diversion Functions

The diversion functions for a weir are defined in section 7.2.8.

8.15. CHANNEL Component

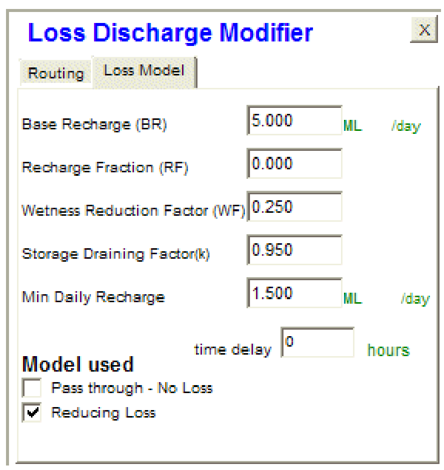


8.15.1 Introduction

Stream loss and routing can be simulated by placing the loss channel node in a drainage path. The node is also used in the model in a visual sence allowing the user to clearly identify the main channel of a watercourse with it being fed by adjacent nodes. As water passes through this path a proportion can be defined to be lost to the system. The remainder will continue downstream.

8.15.2 The Loss Method

The **Reducing Loss method** calculates the loss that is derived from a stream channel containing variable flow passing over pervious landscape. The method works on the concept of recharge to surrounding river banks, where, as more water flows past and recharges, the local water table rises so that it partially (and eventually fully) blocks the loss process. The model simulates this by filling and emptying an imaginary storage, which ,as it fills, increasingly constrains the loss occuring. The potential loss from the river includes all flow up to a fixed flow rate plus a fixed proportion of the flow above that limit, however this is reduced according to the calculated storage status of the local water table.



Note: The process is similar to that assumed for stream recharge to an aquifer, although in this case water is assued to be lost from the system and not accounted for further.

The amount of water lost to the drainage flow can be varied in a number of ways using the **Reducing Loss Method** provided as the loss option.

The first parameter **Base recharge (BR)** occurs while stream flow exists to support it.

The remaining parameters of the Reducing Loss Method determines how the Base recharge may be reduced as the channel and its surrounds wet up.

There are 5 input parameters required which are:

- Base Loss (Recharge to ground)
- Recharge Fraction
- Wetness reducing fraction
- Storage draining factor (k)
- Minimum daily loss (Recharge to ground)

Base recharge (BR) occurs while stream flow exists to support it. If the other parameters in the method are set to zero then a constant amount of the flow will be lost. The rate provided is in volume units per day. In sub-daily models the appropriate fraction of this value is assumed.

Recharge fraction (RF) is the value to simulate increased recharge that may occur if flow increases. The parameter is a fraction between 0 and 1 (usually very close to zero) which when multiplied by the flow gives an additional amount (in volume units) lost to flow.

Wetness reducing fraction (WF) The wetness reduction fraction **WF** is the factor to reduce the entry of the recharge amounts calculated via **BR** and **RF** according to the cumulated status of the local water table and represented by a 'wetness' storage operated as part of the model.

Storage draining factor (k) The factor governing the rate of draining of the 'wetness' storage (K).

Minimum daily recharge (k) This parameter allows a minimum rate of loss to occur, even during the wettest periods. In this case, the influence of **WF** and **K** can only reduce the base recharge down to this value.

Formulae for Operation of Reducing Loss Method

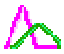
If Q(t) is the flow rate for the day and WS(t-1) is the wetness storage cumulated up to the end of the previous day (represeting the status of the local water table), the calculation of loss from the stream channel is calculated as below:

Loss = BR + Q(t)*RF – WS(t-1)*WF or R = 0 if WS(t-1)*WF > BR + Q(t)*RF

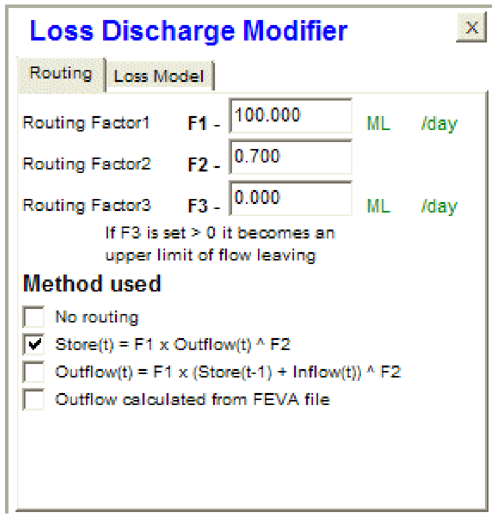
Revised status of wetness storage for next day **WS(t) = [WS(t-1) + R]*K**

The initial value of **WS** is not selected by the modeller. It has no maximum value and will adjust its values to the scale of the flows passing over it according to the values selected for the 4 parameters. Note **BR** is a flow rate and **RF**, **WF** and **K** are all fractions between 0 and 1. The actual recharge will rise as **BR** and **RF** are increased. If **WF** and/or **K** are set to zero, all potential recharge will be recharged. It is the difference between **WF** and **K** that determine the delay in the time that it takes for the wetness store to build up and fall and the range of impact that the store has on the calculated loss.

8.16 ROUTING Functions



Flow Storage relationship



The method allows a simple linear or non-linear routing relationship to be made assuming

Store(t) = F1 x outflow(t) ^{F2} and continuity of volume.

Therefore for the available volume

Store(t) = Store(t-1) + inflow(t) - outflow(t)

The equation S(t) = F1 x O(t)^{F2} is solved iteratively to ensure conservation of volume.

O(t) then becomes the outflow.

Simple Power Function

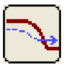
The equation used by this method, Outflow(t) = F1 x (Store(t-1) + Inflow(t))^{F2} does not require to be solved as such. The volume of water retained at the end of the last timestep (store) is added to the current time steps inflow and outflow is calculated as per the equation. Continuity of volume is assumed, and therefore outflow(t) is limited by (store + inflow).

Routing using a FEVA file

"FEVA" stands for flow elevation volume area. Therefore a feva file allows the user to define in tabular form the flow verses volume relationship. In this vase the elevation and area parameters are not used, but they (or default values) must still be included in the file. The method works in a similar method to those above in that store(t-1) + inflow(t) are added to calculate volume(t). Using this volume as the lookup variable in the feva lookup table the flow is extracted. The user should refer to the format required for the FEVA files in section13.4.1.

Note. To avoid sudden changes (and hence instability) particularly in daily models, the simple power function and the feva file methods calculate the storages and flows over 10 sub steps per timestep.

8.17 SPRING (Groundwater) Separation Component



8.17.1 Introduction

Natural (rural) catchment rainfall to runoff models incorporate notional groundwater stores which drain over a period of time and produce long periods of gradually diminishing base flows. Baseflows are often difficult to model as they depend on the complex hydrogeological processes in the area and on the pattern of rainfall sequences. Models rarely have very detailed baseflow distribution functions and typically resort to representing baseflow by the exponential release of flow from a single 'bucket' type storage.

In hilly regions and regions of complex hydrogelogy, groundwater flows may move via different paths to surface water flows. Baseflows may disappear in certain reaches and only appear again some distance downstream, or even as springs in adjacent surface catchments.

Since baseflows are very important to the preservation of water environments, the ability to model groundwater in a more flexible manner is often of advantage. The WaterCress model has two means for providing this flexibility. **The first means does not involve the Spring node and is described first.**

The Spring node allows a slightly more complex baseflow model to be established and is described second.

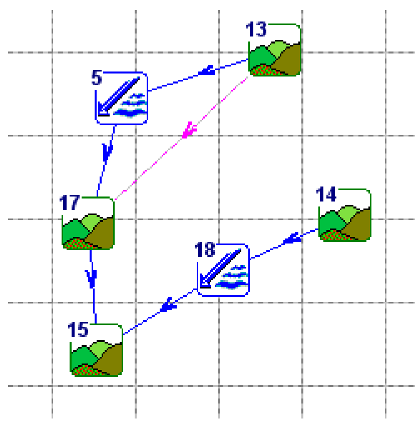
8.17.2 Simple Separated and Re-directed Baseflow

In most rainfall to runoff models the predicted surface flow consists of the sum of two or more flow processes, of which groundwater flow is one (eg. surface flow, interflow and groundwater flow). The groundwater flow in the WaterCress model may be kept separate from the other flows making up the surface flow and may be directed to other catchments or parts of the model.

(This facility has also now been programmed for the other rainfall to runoff models available through the WaterCress model).

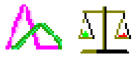
The separation of the groundwater discharge (baseflow) is effected when the drainage path from the natural catchments is linked to any other downstream node. As the link is made the window shown at RH appears. Clicking on Main Stream will keep the baseflow with the surface flows and connect both to the downstream node. Alternatively clicking Groundwater will only connect the baseflow component of the total flow.

If the 'Mainstream' has already been selected for connection from an upstream catchment node, a new connection from the same node to another downstream node will still bring up the same Select Option. If 'Groundwater' is then chosen, baseflow will be connected via the second path and the first path will revert to surface flow only (ie Mainstream – Groundwater).



The diagram at RH shows the groundwater (baseflow) component of the flow generated by the rainfall to runoff model contained in node 13 bypassing the offstream dam (node 5) and re-emerging to join the flow generated by the catchment node 17. The groundwater generated by catchment node 14 is kept with the surface flow and offstream dam node 18 receives the total of the generated flow.

8.17.3 Using the Spring Component

When the Spring component is clicked the header icons  appear

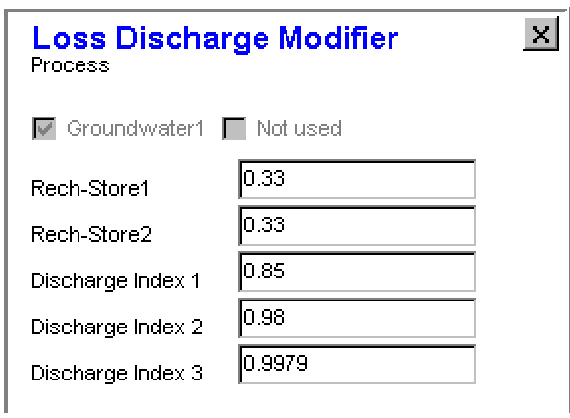
Clicking on the Routing icon reveals the data entry window shown below.

Any flow directed to the Spring node is divided into 3 parts in the proportions set in the data entry boxes adjacent to **Rech-Store1** and **Rech-Store2** with the proportion for Rech-Store 3 being the remainder ie **Rech-Store 3** = 1- Rech-Store1+Rech-Store2.

The inflow is usually the groundwater flow, but could be any flow that requires routing via the 3 parallel storages that the 3 different flow proportions are then directed into.

The 3 stores discharge a volume of water per time-step according to the Discharge Index set for each store. The indexes define what is retained in the store. For example a value of 0.85 means on each timestep 0.85 of the store is retained and therefore outflow(t) = 0.15 x store(t).

The outflow for next day (t+1) is then {store(t) * 0.85 + inflow(t+1)} * 0.15.



A value of 1.0 means all water is retained in the store and therefore there is no flow.

A value of 0 means that the flow passes through the store unchanged.

The outflow is comprised of the sum of the outflows from the three sets of outflows produced by the routing of the three proportioned inflows.

Note that the groundwater outflow from the natural catchment has usually already been routed through the groundwater store. Passing this flow through the Loss Discharge Modifier process will only attenuate it further. (The node cannot ''de-attenuate“ flows). To provide maximum flexibility of use of the Spring node it is best to remove the attenuation provided by the rainfall to runoff model by setting the groundwater store discharge factor = 1, in which case the groundwater store provides no attenuation and the inflow to the groundwater store is passed directly to the Spring node.

Alternatively, you may link the "main stream" drainage directly to the Spring node in which case the modifier process can redistribute the total hydrograph into fast, medium and slow recession flows. (This process can be repeated with a series of Spring nodes in series and/or parallel)

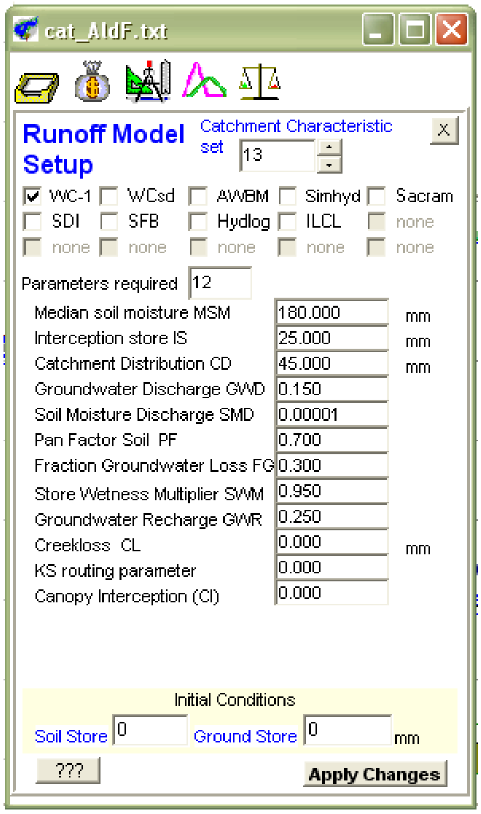
9. RAINFALL to RUNOFF MODELS Within WATERCRESS

9.1 Accessing, Selecting and Setting Up Runoff Models

There are numerous models currently available to calculate runoff from records of rainfall. The WaterCress model offers a choice of 8 models for natural catchments . Only the ILCL model is used for urban catchments.

The choice is provided after clicking the  catchment icon on the Header bar on any natural catchment node. After entering the catchment area and Qual code leaving the catchment. Clicking the **RFRO model parameters** tab on the screen will bring up the screen below.

The type of runoff model that will be applied to the rainfall record for the node may be chosen by ticking one of the windows:



WC-1	parameters (12
WCsd (sub daily)	(15)
ILCL	
AWBM	(15)
SimHyd	(8)
Sacram(ento)	(15)
SDI	(9)
SFB	(7)
Hydrolog	(10)

The ILCL model should not normally be selected for natural catchments but may be useful in particular circumstances. The ILCL model is automatically selected for the impervious parts of urban catchments.

These models were developed by many individuals for varying conditions across Australia. It is not the purpose of this manual to describe all of these in detail. Detailed discussion can be found on the web. Some models work better in particular environments than others. Familiarity with the model you select is highly desirable. It is also highly desirable that some runoff data is available to enable the parameters for the model selected to be adjusted to give a good calibration between modelled results and recorded results

The example above shows the 12 parameters required (with default values) for the WC-1 model. The number of parameters required for each model is shown at the LH in the list above. Models with less parameters are generally easier to use, but may be less versatile than those with a larger number of parameters.

In addition to the parameter list, the screen also shows **Catchment Characteristic Set** at the top and windows to enter initial conditions at the bottom.

9.1.1 Catchment Characteristic Set.

The toggle will bring up 15 sets of parameters previously entered into the model parameter windows and handed down from one model to the next as default values. Each set (ie Catchment Characteristic Set) may have been entered and accepted (ie saved) in respect of a different model, or more likely, many with have been entered and accepted as different versions of the parameter set for the same model.

The 15 sets, when altered, become project specific, and therefore different projects tend to have different parameter values saved against the Characteristic Set numbers. When a new project is created, the file "catch.txt" is transferred from the folder (eg. <program_location>\new) to the current project folder (eg. <program_location>\projectname) and will contain the default Characteristic Set of parameters. {You can make your own default Characteristic Set by copying catch.txt from another project folder (which has been altered to suit your needs) to <Program location>\new}.

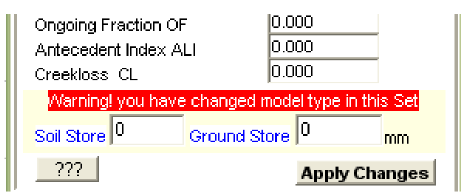
Within the “catch.txt” file, the 15 Catchment Characteristic Sets are stored as 15 sets of a sixteen number sequence in which the first number is the model type identifier, and the remainder being reserved for the model parameters for this model type. Thus each of the 15 sets contain both the model type identifier as well as the values of the parameters saved against that Set number.

Toggling through the 15 sets will therefore indicate for which model each set was saved by switching the tick to the respective model as each set number is brought up.

Being able to save different versions of the Sets has great advantage when setting up projects with multiple sub-catchments and/or calibrating models. Modelling results may be compared using different versions of the parameter sets, saved as different set numbers. After the comparisons have been made, the ‘best set’ of parameters may be recalled and re-installed without having to actually change all the parameters in the parameter set windows.

The same set of parameters may also be shared between different catchments within the same model, as the same Characteristic Sets will appear for each catchment node, and changing the Characteristic Sets for one node will automatically change the parameters for the same model when being used in other catchment nodes.

A danger exists however, if a different model is selected and the parameter set shown has been saved for another model. In this case the parameter set will be totally incompatible for the new model. Be aware that if you opt to change the model type you must change the parameter inputs to those required of the model chosen. For this reason, whenever the model selection changes, the **warning notice** shown below appears.



9.2 WC1 Model

This model, was developed for the SA Govt following experience with South Australian rainfall to run-off model calibration in the Mt Lofty Ranges, Barossa Valley and Mid North. The program was developed in 1988 to estimate the impact of farm dams in the Barossa Valley when it was found most of the existing models were not able to reproduce the recorded runoff of South Australia’s drier catchments with annual rainfall in the range 450 to 650mm.

9.2.1 Model Concept

The WC-1 model uses 3 storages, as shown in the below figure, to track the notional vertical passage of rainfall by gravity through interception, soil moisture and groundwater. The soil store is generally the main runoff producing component, requiring only changes to 4 of the parameters to produce reasonable model calibration.

Surface runoff is calculated with possible contributions generated via the calculations performed for the 3 layers of the model (as surface, interflow and groundwater contributions)

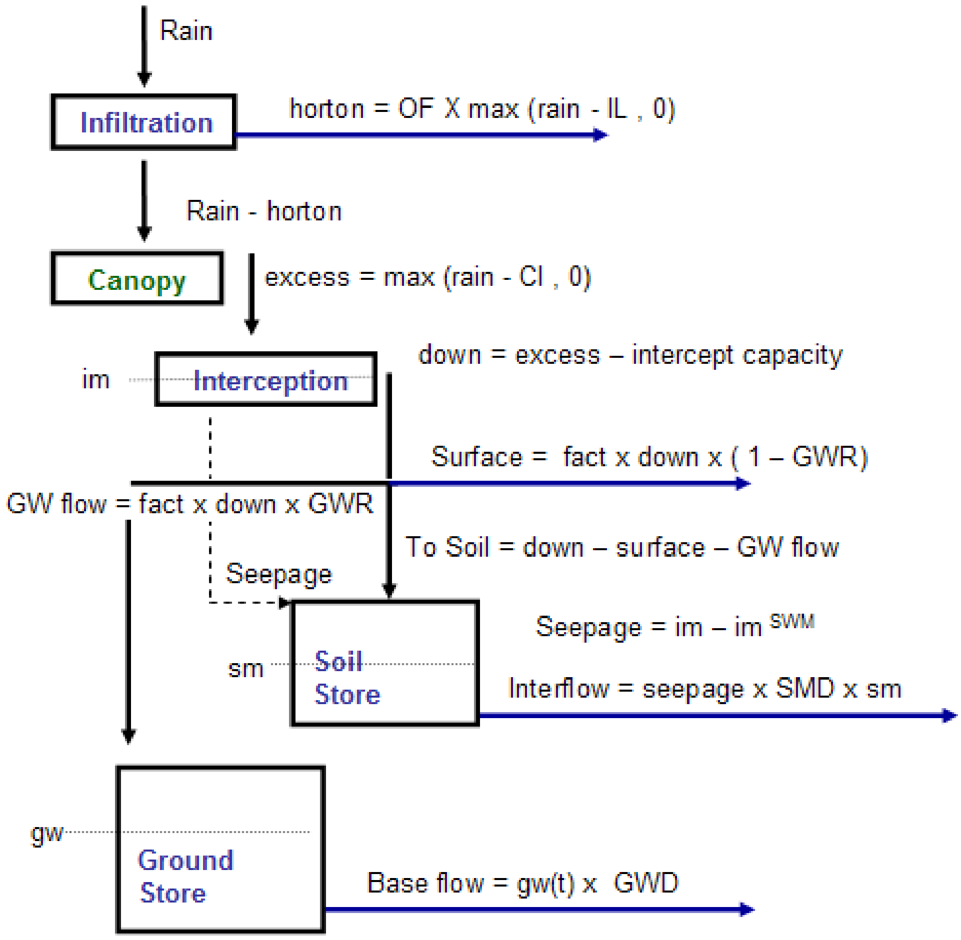


Figure 9.2.1 Layout of WC1 model

The greatest proportion of the flow is usually generated via calculations which notionally track the total of the saturated surface areas within the catchment. The total saturated area is assumed to be related to the accumulated soil moisture via a normal distribution equation as shown in the diagrams below. To calibrate such a model, two parameters are required, the median soil moisture of the catchment (MSM) and the catchment standard distribution (CD). Typically these values are found to lie between 150 to 250 mm (MSM) and 20 to 80 mm (CD). The selected value of CD should not be greater than 3 times that of the selected value of MSM.

The normal distribution curves (fig 9.2.2) indicate that the majority of the catchment area will share the MSM value selected above. Small proportions of the catchment area will have soil moisture capacities of the order of 3 standard deviations lower or higher than the median soil moisture value. To the LH of the normal diagrams the soil moisture capacity is low and thus the soils will saturate readily and commence to run off once rainfall commences. To the RH of the diagrams the soil moisture capacities are high and thus the soils will rarely saturate or run off.

As the rainfalls increase in frequency and amount, the model calculations accumulate the rising level of storage. The proportion of catchment assumed to be saturated is equal to the area under the normal distribution curve to the left of the accumulated soil moisture level.

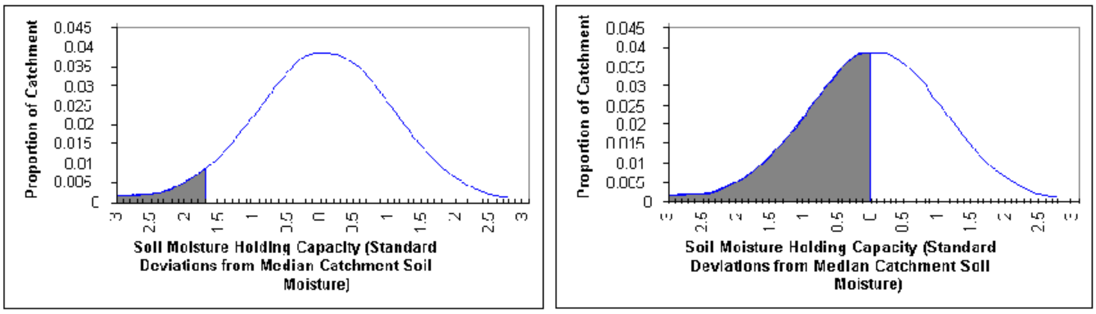
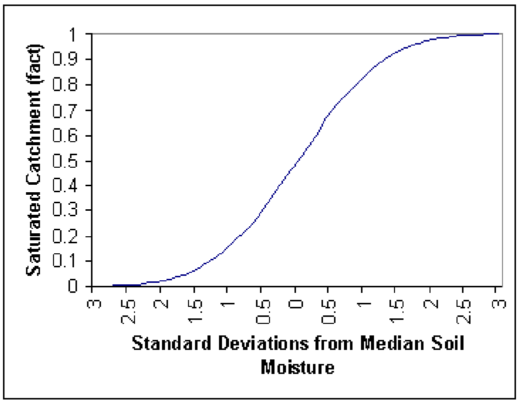


Figure 9.2.2 Distribution of catchment saturation



By integration of the equation for the normal distribution curve, the proportion of the total catchment area that is saturated can be related to the level of accumulated soil moisture fig 9.2.3. For example, when the moisture content of the soil store reaches (MSM - 1.6*CD) the saturated area (shaded in the LH diagram above) is is 5.5% of the catchment area . When the soil moisture reaches the median level (CD = 0), 50% of the catchment will be saturated.

Figure 9.2.3 Soil saturation fractions

This method of calculation avoids the need to identify upper and lower bounds and is compatible with soil and soil moisture distributions identified by catchment surveys. The volume of water running off the catchment is then the product of the contributing area and the effective rainfall.

The effective rainfall is defined as the volume of water spilling the interception store.

The maximum interception store (IS) may typically range from zero to 30 mm and is tracked continuously within the model as the varuable im(t). Water may leave the interception storage either by overtopping the storage thus becoming effective rainfall or it may percolate slowly into the soil store where it may contribute to an interflow component of flow. This percolation occurs at a rate calculated in a similar way to the Antecedent Precipitation Index (API).

The percolation rate is independent of season and is governed by the soil wetness multiplier (SWM), typically set at a value of 0.9. The value set is the proportion of the water held in the store (im(t)) which is retained to the next day. Percolation (or Seepage) is calculated as S = (1 - SWM) x im(t)

During the wet season the baseflow of the streams are seen to rise but the duration of such flow remains dependent on relatively continuous rainfall falling on the catchment. It is proposed that this baseflow return occurs due to the over saturated areas of the catchment returning a fraction of this moisture back to the streams. As the catchment dries or during long spells of no rain it is expected that this return will drop to zero.

This interflow is assumed in the model to equal **Ifl = s x SMD x sm(t)**

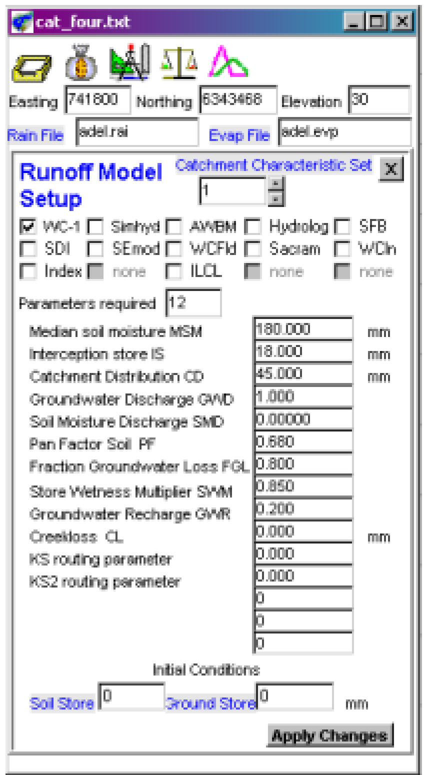
Where SMD is the parameter defining the proportion returned to the stream.

The catchment response is therefore defined by the six parameters mentioned above but evaporation can potentially override all of these. In semi-arid catchments choosing the correct evaporation rate is critical. Models use various formulas ranging from linear to power functions to estimate the moisture loss from soils. Experimentation with the linear model was not found to improve the estimate of runoff and was discarded for the simpler constant model. Here evapotranspiration is assumed to equal the pan factor times recorded daily evaporation. Typically a value of 0.6 to 0.7 is used for class A pan recordings.

Groundwater is simulated within the model using two parameters GWR (recharge) and GWD (discharge). Both operate in a simple linear fashion. Groundwater recharge is seen to have a greater relationship with streamflow than total rainfall. This suggests that groundwater recharge requires similar conditions to streamflow, hence the wetting up of the catchment, to occur. Tying recharge to streamflow simulates this, which assumes the greater saturated catchment-generated streamflow occurring the more recharge occurs from the soil to groundwater store. The parameter GWF is used to define the proportion passing to ground and often this may be up to 20 to 30 percent.

Baseflow discharging from the groundwater store is simply a linear relationship defined by parameter GWD. No loss is assumed to occur from the groundwater store to external basins.

9.2.2 Input Parameters



Medium soil moisture (MSM) - represents the median field capacity of the soil. Usually in the range 150-300 mm. Increasing this value delays the early season initiation of runoff, decreases surface runoff by providing greater opportunity for evapotranspiration, but assists (to a lesser extent) in maintaining late season groundwater flows.

Interception store (IS) - represents the maximum initial abstraction from rainfall before any runoff can occur. The normal range is 10-25 mm. A larger value will inhibit runoff after dry spells and reduce the total amount of runoff.

Catchment distribution (CD) - sets the range of soil moisture values about MSM. Usual values are 25-60 mm. A larger value will initiate runoff earlier and more often.

Ground Water Discharge (GWD) - is the proportion of the groundwater store that discharges as baseflow to the stream. This is a simple linear function ;

Baseflow = groundwater store x GWD. Usual values are small 0.001 to 0.0001

Soil moisture discharge (SMD) - As soil moisture increases there is a rise in the baseflow that occurs due to the saturation of the soil storage. Values are usually small 0.0001.

Pan factor for soil (PF) - This factor is applied to the daily evaporation calculated from the monthly pan evaporation data. The usual range is 0.6 to 1.0. The higher the value the less the runoff . The higher the value, the earlier runoff ceases after winter.

Fraction Groundwater Loss (FGL) - The removal of groundwater store due to irrigation (or just assumed loss) is a multiplying factor for all recharge. For example a value of 0.6 here means only 40% of the calculated recharge actuall occurs. The remainder is lost to the system.

Store Wetness multiplier (SWM) - This value determines the rate that water from the interception store moves to the soil store. The depletion of the interception store is calculated as the maximum of the loss based on the soil wetness multiplier and evaporation, whichever is the greater. The transfer rate can threfore be independent of season (if required) and ensures that the amount of water retained in the interception store follows a similar power recession curve of the API. Usual values are around 0.9. Making this value close to 1 means that depletion of the interception store is controlled by the evaporation rate (which follows a more seasonal pattern).

Groundwater Recharge (GWR) - is the proportion of rainfall that recharges the groundwater store. Usual values are 0.05 to 0.3 indicating that 5% to 30% of the flow running off the catchment is entering the groundwater system.

Creek Loss (CL) - is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates take up of water from riparian vegetation and the reduction of baseflow in summer months.

9.3 WC-sd Model

WCsd was developed as a version of WC-1 able to operate at time-steps less than daily. WC-1 was retained as an option within the WaterCress overall model package because of its past significant use in SA catchments.

WCsd introduces an additional parameter **ALI** to cater for the effects of high intensity rainfall on dry catchments (when calculated at sub-daily time-steps) and a choice between either a normal or log normal distribution of soil water holding capacity. However, the log normal option has not been found to produce any consistently better results and is thus not recommended for general use

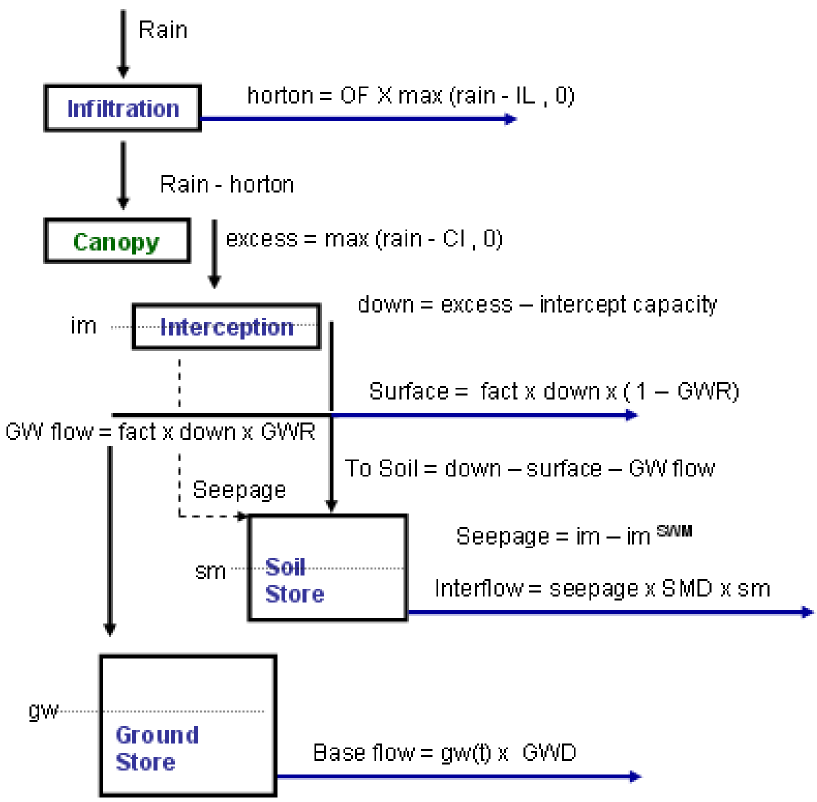


Figure 9.3.1 Layout of the WCsd model

The calculation of runoff due to high intensity rainfall on dry catchments is assumed to take place only relatively rarely. The calculation is undertaken on a continuous basis using an additional simple soil storage capacity IL located in the upper layer of the model. The model works in exactly the same way as the sub-daily version of the ILCL model explained in 9.4 and below, except that, in this case, the value of IL is chosen at a much higher value than is normal, in order to reduce the frequency at which runoff via this high rainfall intensity mechanism is produced. (NB. In this case, the runoff from the more frequent low intensity rainfalls is calculated by the remainder of the WCsd model via the conceptual storages in its subsequent lower layers.).

As a first approximation, the value of IL should be selected to be equal to the depth of rainfall that is estimated as required to initiate significant runoff from a dry (summer) catchment within the time-step chosen for the model.

Table 9.3.1 below gives summer rainfall intensity figures for Adelaide for time-steps of 30 mins to 1 day and ARIs from 2 to 10 years. If a value of IL was chosen at 21.8 mm., and the model run at 1 hr time-steps, runoff would only be initiated by a 1 hour storm burst by this mechanism about once every 5 years.

The storage mechanism caters for rain bursts of longer than 1 hour by allowing the loss mechanism to accumulate successive rainfalls into the storage, while allow enabling the infiltration capacity to recover during each successive time-step.

Table 9.3.1

ARI (years)	Model Time-step		
	30 mins	1 hr	1 day
	Values of IL mm		
2	12.3	16.1	48.4
5	16.7	21.8	63.0
10	20.0	25.8	72.0

The calculation of runoff due to high intensity rainfall is thus undertaken on a continuous basis using a simple fixed storage capacity of IL mm to act as a cumulative loss and recovery mechanism. During dry periods the moisture depth contained in the storage is near zero. Rainfall increases the capacity to a maximum value equal to IL mm and the capacity is diminished at each time by the ALI multiplier.

Assume the storage at the end of the last time step is S(t-1). Assume rainfall this time step is Rf(t). Thus runoff takes place if S(t-1)*ALI+Rf(t) > IL.mm

If runoff takes place: then runoff(t) = {S(t-1)*ALI+Rf(t) – IL}*OF where OF is the fraction of the runoff generated that reaches the catchment outlet.

The storage at the start of the next time-step will then be = IL*ALI

If no runoff takes place: If S(t-1)*ALI+Rf(t) < IL, no runoff will take place and the storage at the start of the next time step will = {S(t-1)*ALI+Rf(t)}*ALI.

During dry spells with no rainfall, the storage converges to zero by successive applications of the factor ALI, which is less than 1. (NB the storage is calculated in the same manner as the standard Antecedent Precipitation Index – hence the use of the term Antecedent Loss Index).

Because WCsd can be run at different time-steps, the values of both IL and ALI require to be adjusted if the model time step is changed. The aim of the adjustment will be to ensure that the total flow calculated at the different time-steps are approximately equal. However, If the model is being used to calculate peak flow rates, the choice of a too long time step will inevitably compromise the accuracy of estimation of peak flows, even if the total or average flows are retained equal.

The relative values of IL at different time-steps is shown in table 9.3.1. A formula established for SA relates ALI to the chosen time-step as:

ALI = 1- {(timestep in hrs)/24}.

Insertion of the selected time-step into this formula provides ALI values as below.

Table 9.3.2

Time-step	6mins	30mins	1hr	6hrs	1day
ALI	0.995	0.975	0.955	0.755	0.0

Thus at the daily time step ALI becomes redundant and thus does not appear oin the daily time step version of the models.

The value of OF is selected at the maximum proportion of rainfall that is likely to runoff in the most intense and largest storm. A value of 1.0 could be assumed as the maximum, but more conservative values have normally been adopted at about 0.75 to 0.85.

If no runoff is generated all rainfall that has taken place is fed into the lower canopy and interception stores of the model. If surface runoff has been generated, the rainfall fed into these stores is reduced by the runoff. It should therefore be noted that infiltration loss by this mechanism is not double accounted since all the non-runoff-producing rainfall is still assumed to pass into the lower storage layers of the WC model. By setting the appropriate parameters, the 'lower' part of WC model will then work normally.

The normal - log normal switch requires a 0 or 1 to be selected. As stated earlier the normal model is recommended for general applications.

The remainder of the WCsd model structure and calculations remain the same as described for WC-1

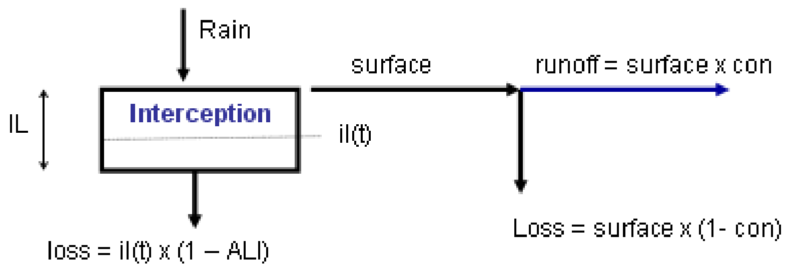
9.4 ILCL model (Impervious Model)

The initial loss continuing loss model (ILCL) uses a simple formulae to make continuous estimates of runoff from impervious areas from continuous records of daily rainfall. It is essentially the same as that described in Sect 9.3 for the estimation of runoff from high intensity rainfall used as part of the WCsd model except that the value of IL is chosen as the minimum amount of rainfall that is required to produce runoff under average circumstances. Since the ILCL model is used almost exclusively for runoff estimation from impervious areas, the value of IL is usually of the order of only 0.5 to 2.0 mm.

Since the ILCL model can be used at the sub-daily time-step the antecedent loss index ALI is employed to track the time based recovery of the loss mechanism as described for the WCsd model..

The loss mechanism is shown in Figure 9.4.1 below. In this representation the amount of storage capacity available for take up of further loss is identified as 'space' and can be seen as the depth between the present storage level il(t) and the maximum capacity IL of the store. Ie the current space available for interception loss = IL-il(t-1) where t-1 denotes the end of the last time step of calculation.

When the rainfall exceeds the interception storage space, runoff is generated, but the amount of runoff is reduced by the factor OF (where OF is equal to (1-CL) and OF and CL are the ongoing fraction and continuing loss respectively). 'Surface' in the diagram is therefore already multiplied by OF as shown in the formulae below the diagram. The amount of surface runoff is finally reduced by Con which is the fraction of surface runoff that reaches the catchment outlet via the varying connectivity of the drainage paths within the catchment.



space = IL-il(t-1)

If rain > space(t-1) Surface = (rain-space) x OF

If rain <= space(t-1) Surface = 0

Figure 9.4.1 Layout of the ILCL model

For a daily model

- Daily runoff = Area * (Daily rainfall – IL) * Con * OF   when rainfall > IL, or
- Daily runoff = 0 when rainfall <IL

For a sub daily model

- Daily runoff = Area * (Daily rainfall – space) * Con * OF   when rainfall > space, or
- Daily runoff = 0 when rainfall <space

Where:

Area is the total of all the individual (impervious) areas of roofs or paved surfaces within the sub-catchment for which runoff is being calculated,

IL is the Initial Loss assumed for that surface type,

Con is the degree of connectivity for that surface to the main drainage system, and

OF is the ongoing fraction of rainfall 'lost' after the initial loss had been extracted.

IL can be estimated with some accuracy from plots of event rainfall v event runoff. A similar value will be obtained from plots of daily rainfall v daily runoff, except that the latter will have more scatter.

Con*OF together equal the efficiency of runoff, after the effects of the IL abstractions have been taken into account.

Typical values for IL, Con and OF that have been found to give good calibrations between the predicted runoff and the measured runoff for the majority of gauged urban catchments in Adelaide (which were mainly residential) are shown in table 9.4.

OF and Con are assumed as constants for any catchment, regardless of the time-step used. Although IL should strictly depend on the time-step selected, it has been found that using the values of IL given in Table 9.4 for all time-steps in conjunction with the values of ALI given in Table 9.5 for the time-step chosen makes very little difference to the calculation of runoff

Table 9.4 Parameters for ILCL model

Parameter	Roofs	Paved Surfaces
IL	1.0 mm/day	2.0 mm/day
OF	0.9	0.8
Con	0.5 - 0.8	0.0 - 0.8

The formula established for SA which relates ALI to the chosen time-step is:

ALI = 1- {(timestep in hrs)/24}.

Insertion of the selected time-step into this formula provides ALI values as below.

Table 9.5

Time-step	6mins	30mins	1hr	6hrs	1day
ALI	0.995	0.975	0.955	0.755	0.0

Thus at the daily time step ALI becomes redundant and thus does not appear in the daily time step version of the models.

9.4.1 Experience with ILCL Modelling of Urban Runoff in Adelaide

In calculating total runoff using continuous modelling in a location like Adelaide where there are many days with only a small rainfall, the influence of IL on the proportion of annual rainfall that is converted to annual runoff is quite large, as shown in figure 9.4.1

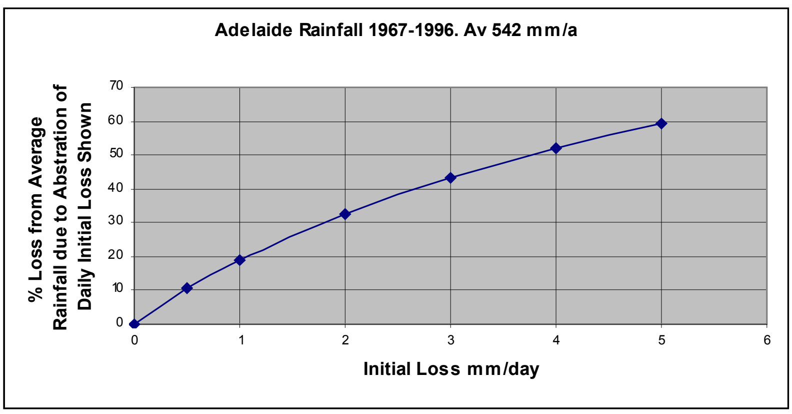


Figure 9.4.1. Reduction in Effective Rainfall due to Abstraction of Initial Losses

Figure 9.4.1 shows the average annual reduction in rainfall due to the abstraction of Initial Losses in the range 0.5 to 5 mm/day from the 30 year Adelaide rainfall (1967-1996). Ie. the abstraction of 1 mm/day from all daily rainfalls in Adelaide over the period 1967 to 1996 would reduce the average effective rainfall from 542 mm/a by 19.5%. A 2 mm/day abstraction reduces the average by 32.5%, etc. Similar reductions would apply to all locations within the Adelaide region with rainfall in the range 450-650 mm. This curve can therefore be used to identify the effect of the (Daily rainfall-IL) part of the above formula on the prediction of annual runoff.

By inserting the values of IL, OF and Con as given in Table 1 into the WaterCress runoff formula, the average annual runoff depth per unit area of roof and paved areas as a % of the annual rainfall would be (1.0-0.195)*0.5*0.9 = 36% and (1.0-0.325)*0.8*0.85 = 46% respectively (where 1-0.195 is the long term reduction in effective rainfall due to the abstraction of an IL of 1 mm/day, etc.). If (as stated) the roofed and paved areas are assumed to occupy equal areas, the average runoff coefficient for the total of the impervious areas would be 41%. If the pervious part of the catchment is assumed to occupy 50% of the total catchment area, but to generate little runoff, then the runoff coefficient for the whole catchment would be 20.5%.

By assuming different values for IL, Con, OF and different proportions of roofed, paved and pervious areas, different average runoff coefficients for the total catchment can be calculated.

Figure 9.4.2 shows a theoretical indicative range of runoff coefficients calculated for catchments with different proportions of impervious and pervious areas. Obviously, by including pervious areas into the calculations, which are assumed to have zero runoff, the overall catchment runoff coefficients will be reduced in direct proportion to the proportion of pervious area. Thus while (from Figure 1) an 80% runoff coefficient might apply to a ‘stand-alone’ roof with an initial loss of 0.5 mm/day and when connected directly to the drainage system (ie Con = 1.0) and having an ongoing loss (OF) of 10%, if the roof was surrounded by an equal area of pervious catchment with zero runoff, the overall runoff coefficient for the total area would drop to 40%.

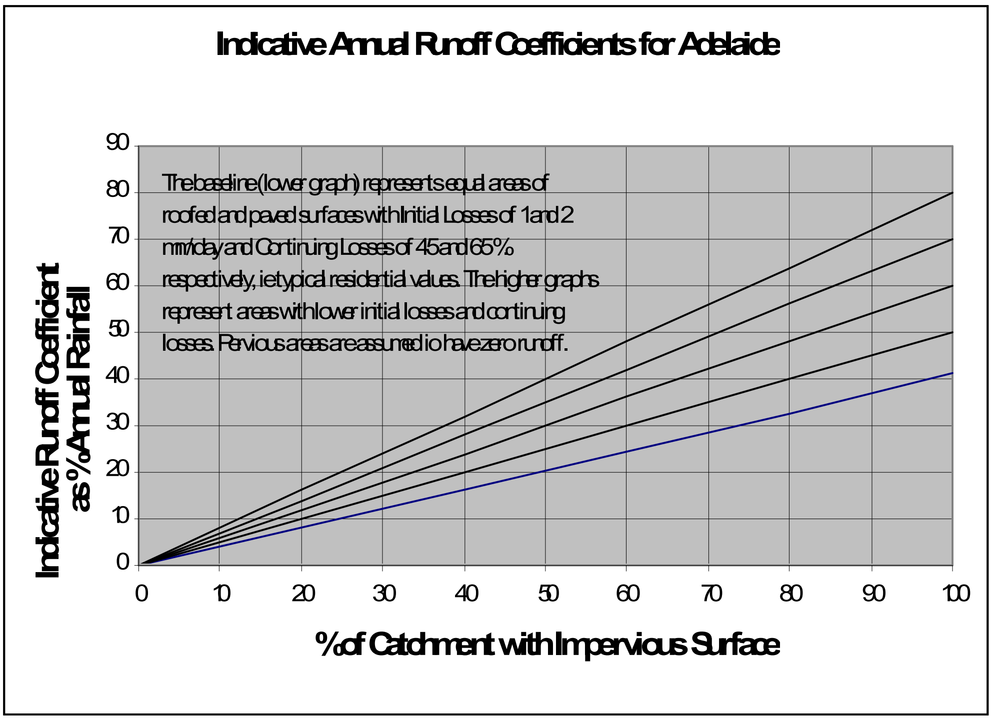


Figure 9.4.2 Indicative Runoff Coefficients for Urban catchments with Different proportions of Impervious and Pervious Areas.

The lower line in Figure 9.4.2 is compatible with the runoff coefficients calculated for a range of gauged catchments in Adelaide. For example, the Paddocks residential catchment with about 50% of its area pervious (ie parks and gardens) has a runoff coefficient of 18%. The Parafield catchment which contains some industrial areas, but also a large area of open escarpment area in addition to the normal parks and gardens within its residential areas has a coefficient of 16%. The Adelaide Terrace catchment which contains mainly industrial areas adjacent to South Road with little pervious area has a runoff coefficient of 40%. Since they can all be represented by the lower line relation, by inference they must share compatible values of IL, Con and OF. The family of higher lines then represent the relations for situations having lower values of IL or higher values of Con and OF.

With the exception of Adelaide Terrace, very little data on runoff from industrial areas in South Australia has been recorded to date. General experience shows that runoff efficiency increases as the individual sizes of contiguous impervious areas increase, due to the decreasing ratio of edge length (where infiltration losses may occur) to contributing area. In industrial areas more care is also usually taken in the designed connection of the impervious areas to collector networks and in the sizing of the discharge pipes. However, these effects may be counter-balanced if unlined detention/retention storages are included in future industrial areas.

Runoff from the pervious parts of the catchment is calculated in the WaterCress model via a far more complicated set of equations which simulate the storage and progressive movement of water through three layers of the catchment – i) the surface layer, ii) the unsaturated layer of soil beneath the surface and above the groundwater table and, iii) the groundwater layer.

The addition of the pervious part of the runoff equation is shown in figure 9.4.3. In most cases the influence of the pervious catchment is small when compared to the urban component.

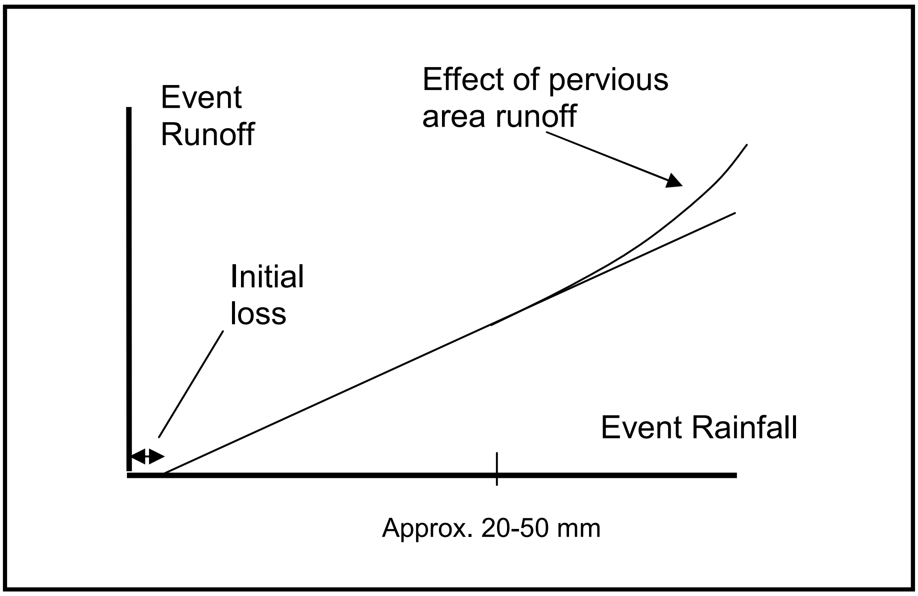


Figure 9.4.3 Typical form of relation between event rainfall and event runoff for an urban catchment.

The extent if the pervious runoff influence can be assessed by looking at actual catchment data. Figure 9.4.4 shows the results for a relatively homogeneous small residential catchment of 70 ha in Adelaide (the catchment of the Paddocks wetland). Over the period 1992-2002 event rainfall was measured at two locations within the catchment. The catchment is small and has a stable standard weir for flow measurement. The weir has been calibrated by field measurement during low and medium to high flows. The quality of data should therefore be good.

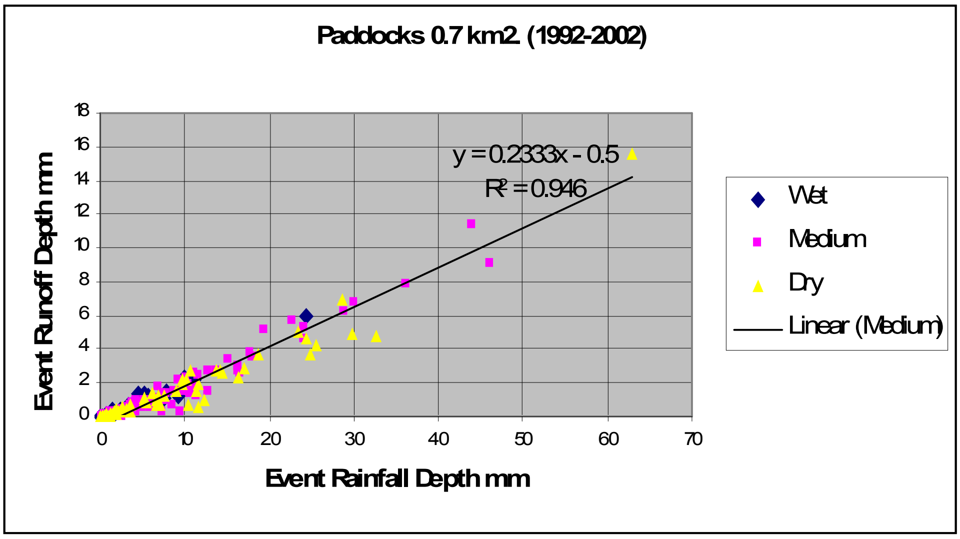


Figure 9.4.4. Example pervious runoff influence using Paddocks catchment rainfall event data.

The equation runoff/(catchment area) = 0.23 * rainfall -0.5 is shown as the least squares linear fit to the data in which the initial loss IL is 0.5 mm and the coefficient of efficiency of runoff (Con * OF) is 0.233 (or approx. 23%). The correlation coefficient shows a good fit at R squared = 0.946.

The linear nature and lack of major scatter shown on Figure 4 confirms that a relatively stable linear relation exists between rainfall and runoff in urban catchments in Adelaide. While the data is plotted for events, a similar graph (but with greater scatter) would be obtained using daily data. Calibration between the model and accurately measured flows can be used to determine the size of the initial losses on the impervious surfaces, the efficiency of subsequent runoff on the impervious surfaces, the point of initiation of runoff from the pervious surfaces (not apparent on Fig 9.4.4). If the pervious areas appear to contribute, the relative proportions of runoff generated on the impervious and pervious surfaces can be assessed.

The corollary of the above is that any model which has been developed to estimate runoff from rainfall in urban catchments and which uses this simple form of calculation of runoff should be able to predict the runoff with a good degree of accuracy, particularly at lower flows. By extension, any measured flows that do not conform to this general form of relationship (once established by analysis of the bulk of the rainfall and runoff events) should be regarded as being likely inaccurate in respect to either its measured rainfall or runoff.

The line shown on Figure 9.4.4 has been fitted to the data falling into the ‘medium’ wet conditions (defined as having an antecedent precipitation, or wetness index of 10-30 mm). It would be expected that i) the wetter condition data (API > 30 mm) would lie above the line (ie. greater runoff would be expected for the same amount of rainfall) and ii) the drier conditions data (API < 10 mm) would lie below the line (less runoff would be expected for the same amount of rainfall). This tendency can be seen, particularly if the linear relation was re-drawn curving upwards above about 40 mm of rainfall. Unfortunately there were not many high rainfall events during this time and none under wetter conditions to investigate the runoff from impervious parts of the catchment.

It is probable that the accuracy of estimation of urban runoff would be marginally improved if catchment wetness was included in the prediction equation.

Figure 9.4.5 shows the same relation between rainfall and runoff depth, except that the rainfall and runoff have been cumulated to monthly totals. Because the monthly total is the addition of several events, the variability is reduced and the R squared value rises to 0.96. Because monthly rainfall totals contain several events for which rainfall is insufficient to overcome the initial loss, the % of rainfall that becomes runoff is reduced to about 20%. The upward curvature of the relationship is still indicated weakly, but few data points are available and a greater variability is evident for the higher rainfall months.

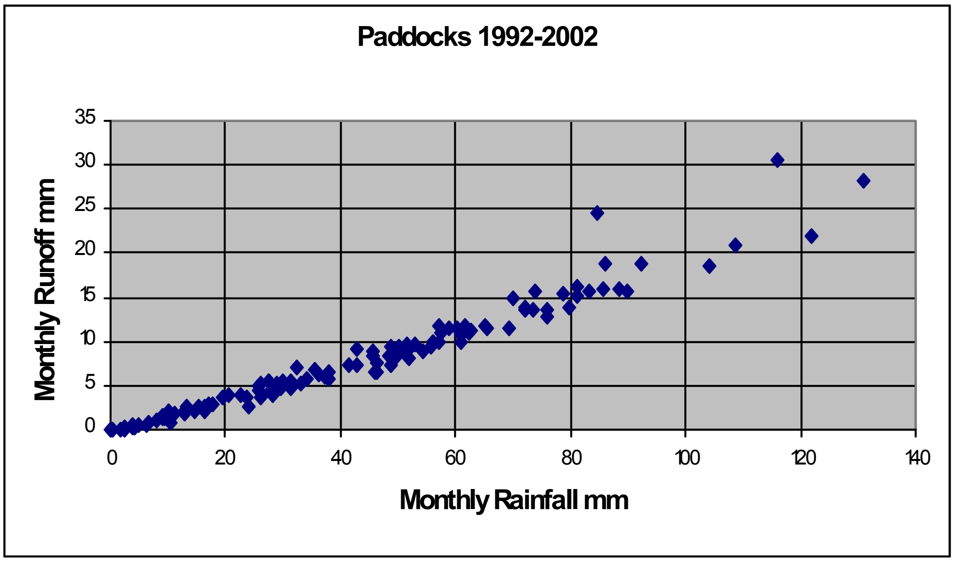


Figure 9.4.5. Monthly rainfall v monthly runoff depth for the Paddocks catchment.

Confirmation that models can predict runoff for urban catchments with a good degree of accuracy is shown in Figure 9.4.6 which shows the comparison between monthly flows estimated by the WaterCress model using the runoff to rainfall equations as described above to the flows actually measured at the gauging station. Since most rainfall stations measure rainfall at the daily time interval, the model is usually set up to perform its calculations of runoff at the daily time step, using long sequences of daily rainfall records. The model has recently been extended to calculate runoff from rainfall at time-steps down to 6 minutes. Where rainfall data is available at these shorter time intervals greater accuracy in prediction is expected to be achieved.

The model has been calibrated to achieve the best fit by ‘trial and error’ adjustments to the initial loss and efficiency of runoff coefficients contained in Equation 1 and the 10 different coefficients required for the pervious area Equation 2. The R squared fit between the recorded v modelled monthly estimates is 0.82.

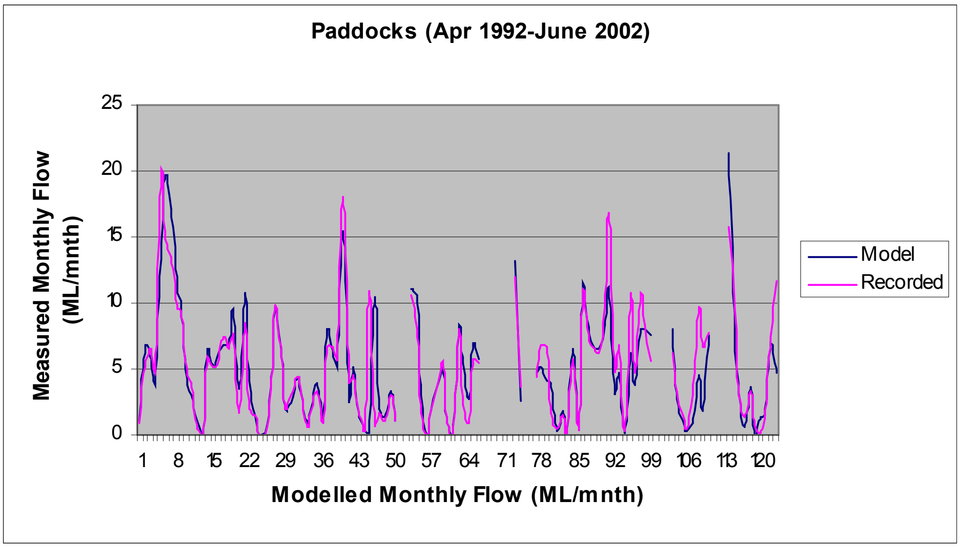


Figure 9.4.6 Comparison between monthly flow estimated using the ILCL rainfall to runoff model and as measured at the gauging station.

A relatively simple and stable relationship generally exists between rainfall and runoff for the impervious areas of urban catchments. Such a simple relationship does not exist for the pervious areas. Under most situations in low rainfall areas (rainfall < 600 mm/a) the pervious areas only contribute small depths of runoff. Hence, as the proportion of impervious area within any catchment increases and the pervious proportion decreases, the rainfall to runoff relationship generally becomes more linear and precise. A rainfall to runoff model will therefore be able to provide an accurate estimate of the runoff from the catchment provided that:

- the total area of impervious surfaces within a catchment is known and this forms a relatively high percentage of the total area (say > 30%), and
- the rainfall is measured accurately at sufficient locations to give an accurate representation of the rainfall over the whole catchment.

9.5 AWBM Model

This model concept was developed by W Boughton and sections of this text are taken from the AWBM manual version 2.0 January 1996.

The original AWBM model was established as a daily rainfall runoff model only. The model uses 5 surface stores: 3 to simulate partial areas of runoff, 1 to simulate groundwater and 1 for routing.

Runoff occurs if any of the 3 partial area stores exceeds their capacity. The sizes of the stores are selected to best simulate the catchments non-linear response to rainfall as its wetness increases. (The WC models also adopt this concept of variable storage across the catchment but handle it in a different way to AWBM. The two models each offer advantages and disadvantages which are discussed below and it is considered that the concepts utilised by AWBM and WC-1 are likely to produce the best results for semi-arid catchments).

This layout is shown on the structure diagram of the model, figure 9.5.1.

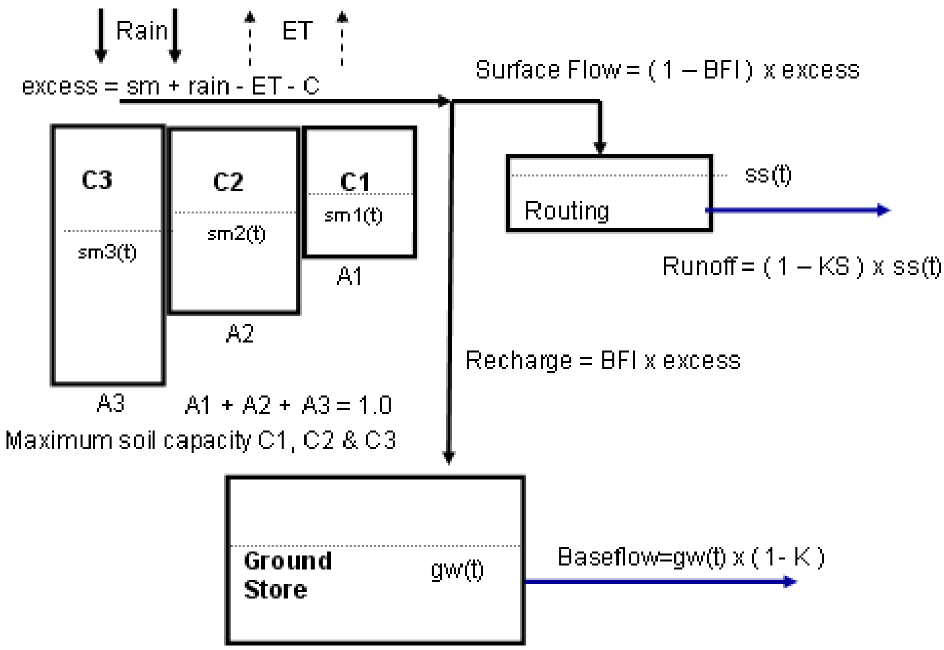


Figure 9.5.1 Layout of AWBM model

9.5.1 Model Concept

The model is a 10 parameter model using 5 storages as shown above to track interception, soil moisture and groundwater. The 3 soil stores are generally the main runoff producing component requiring 5 parameters for calibration.

The soil store requires 3 storage parameters C1, C2 and C3 which are the soil moisture holding capacities of each storage. Two further parameters A1 and A2 are fractions of the catchment which define the partial area contributed by each of the stores C1 and C2. In the original model, the area fraction A3 for C3 was calculated as = 1.0 - (A1 + A2). In this localised model version, to add greater flexibility, a value A3 is able to be set as the area fraction for C3 (less than 1.0 – (A1+A2)) so that the model may include an area fraction (1.0 – (A1+A2+A3)) that will not contribute runoff at all.

The water balance of each store is calculated independently on a daily time step. At each day, the evapotranspiration is removed from each store and then the rainfall is added. As these stores are overtopped the spillage potentially becomes the runoff depth.

When runoff occurs, part of this is directed as recharge to the baseflow store. The amount recharging the baseflow store is calculated as a constant fraction of the streamflow. This fraction is set by the parameter BFI. For example a BFI = 0.3 means that the recharge to groundwater will be 30% of the runoff generated from the soil stores.

A baseflow recession constant (K) controls the amount of discharge that occurs from the baseflow store (BS). To simulate baseflow, the baseflow store is depleted at the rate of (1-K) x the volume of water held in the store. For example a value of K = 0.9 will mean baseflow BF = (1 - K) x storage in ground store.

The volume of surface water running off the catchment (quick flow) is then the product of (1 - BFI) and the contributing area. Ie:

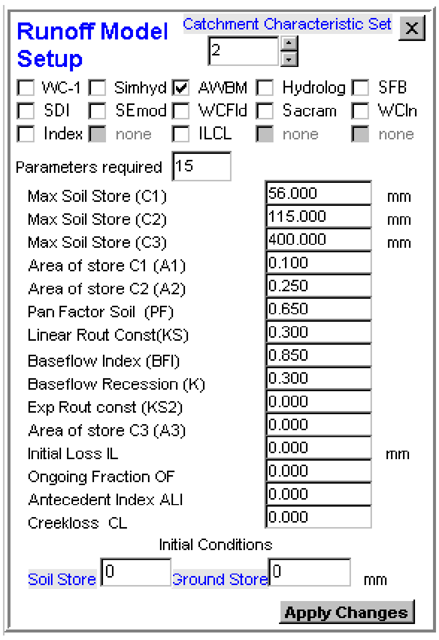
Runoff (RO) = (Ro1 x A1 + Ro2 x A2 + Ro3 x A3) x catchment area x (1 - BFI)

Various simplifications are suggested by Broughton to enable quick calibration of the model. The original AWBM model has built-in default values which may be used as a starting point for calibration, however, it is usual that these will require some modification to suit the individual catchment. The default soil stores and partial areas are based on the equivalent average soil storage capacity SSC as

C1 = 0.5 x SSC @ A1 = 0.2

C2 = 0.75 x SSC @ A2 = 0.4

C3 = 1.5 x SSC @ A3 = 0.4



On the basis of local South Australian experience, and to convert the model to work at the sub-daily time-step, a set of additional parameters have been added to the model and are described in 10.3.3. By choosing appropriate values, the user may choose to override these parameters thereby providing a standard Boughton AWBM model working at the daily time-step.

9.5.2 Input Parameters (Standard Model)

C1 - C3 are soil store capacities measured in depth units

A1 – A3 are the proportions of area for each of the soil stores C1, C2 and C3. Note A3 is not a standard input for AWBM. It is included here (when set less than 1-(A1+A2)) to allow a fraction of the catchment that does not runoff. If you set A3=0, this value will be ignored and A3 will be calculated as 1-(A1+A2), as per the standard AWBM model.

Pan Factor PF multiplied by the evaporation rate gives the evapo-transpiration rate from the soil structure.

The linear Routing Coefficient KS determines how much water is retained in a routing store each day. Note this should be set = 0 if you use other nodes in the project to perform system routing.

The Baseflow Index determines how much water is directed to the groundwater store. In the case shown, a BFI of 0.85 means after runoff is calculated 85% will pass into the groundwater store.

Baseflow recession K defines the rate that the groundwater is redirected back to the surface. In the case shown a K = 0.3 means baseflow is calculated to be (1-0.3) * baseflow store.

9.5.3 Non-standard Additions

The above parameters comprise the basic daily time-step AWBM model provided all data entries below K are set to zero.

Six additional parameters have been added to the basic AWBM model. The minor modification involving **A3** has been described. Three additional parameters are related to sub-daily flow estimation to take account of high intensity rainfall on dry catchments **IL, OF** and **ALI**. The others are a creekloss factor **CL** and a canopy interception **CI**.

Creek Loss **CL** - is a reduction factor used to decrease runoff and introduces a loss of CL x evaporation. This simulates rapid (non-exponential) reduction in baseflow due to infltration or riparian vegetation and will reduce the baseflow, particularly in summer months.

Canopy interception which enables a loss of water in a forest canopy to be accounted for, is described in the WC-sd model (section 9.3)

The **IL,OF, ALI** model sits above and is separate from the main AWBM model in exactly the same way as for the WC-sd model. Although not recommended, the AWBM model may be run with sub-daily time-step rainfall data in its standard form by setting IL at a very high value and ALI and OF at zero.

The operation of the IL, OF, ALI model is described in the WC-sd model in 9.3

9.5.4 Comparison of WC and AWBM Models

The AWBM model adopts a similar concept of variable storage across the catchment as WC1, but handles it in a different way. It is considered that the concept used by AWBM and WC-1 are likely to produce the best results for semi-arid catchments, where rainfall ranges from 400 to 700 mm.

The two models utilise the principles in different ways and each offer advantages and disadvantages

The WC-1 model with its smooth relationship between rainfall and runoff produces more continuous runoff events than the 3 step function of AWBM. For example no runoff will occur in AWBM until the smallest soil store is filled, where as WC-1 will potentially provide runoff at low moisture stores. Different catchments may behave differently in this respect (eg runoff may be generated, even in summer, from relatively impervious areas close to a catchment outlet). In WC-1 this effect has to be overcome by introducing an interception store and/or Creek Loss.

Of interest is the similar way that the baseflow store is recharged, by taking a constant proportion of streamflow. Examination of streamflow in the Barossa Valley and the Wakefield River has indicated that recharge (reflected as baseflow) is closely related to streamflow of the previous winter season. It appears in semi-arid catchments that the rainfall conditions that provide for streamflow also provide for recharge. This being said, the constant discharge rate adopted by both models is used by many others and is more an issue of simplicity rather than being the best function.

9.6 Simhyd Model

9.6.1 The model concept

The Simhyd model was created from the hydrolog model which has been in use since the 1970's. The model uses 3 stores to simulate fast, interflow and baseflow components of runoff. Various routing functions are also available but these are not included in this basic model provided.

The layout is shown on the structure diagram of the model below.

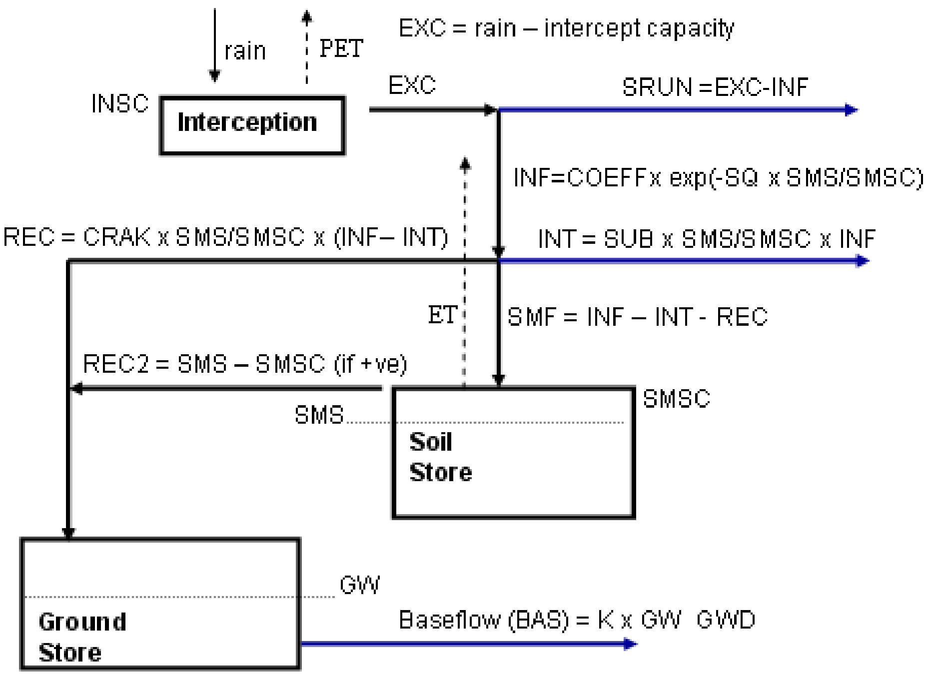
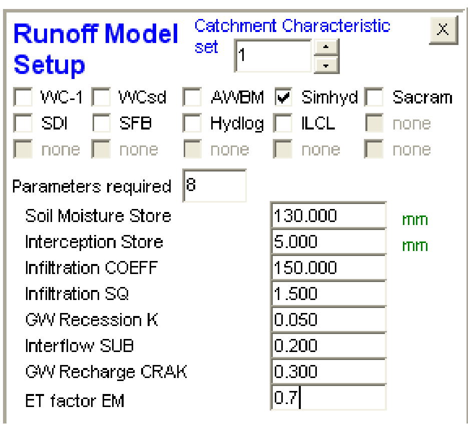


Figure 9.6.1 Layout of the Simhyd model

9.6.2 Data Input



Rain falling is initially intercepted by a store which spills an excess **EXC** when its volume exceeds **INSC** mm. Water is lost from this interception store at the potential evapotranspiration rate **PET**, which is the evaporation provided in input files by the user.

Infiltration coefficients **COEFF** and **SQ** are input by the user and define the amount of excess that is able to be infiltrated, and therefore the amount of water that will runoff (infiltration excess). The potential infiltration at any time will be equal to

INF =COEFF x exp(-SQ x SMS/SMSC).

If this value is less than excess then excess runoff will occur.

The amount of infiltration is then split into 3 portions using the parameters SUB and CRAK.

Firstly interflow INT is calculated being equal to

INT = SUB x SMS / SMSC x INF

Then groundwater recharge REC is calculated being equal to

REC = CRAK x SMS / SMSC x (INF - INT)

The remainder = INF - INT - REC is assumed to fill the soil store. However if the soil store volume SMS becomes greater than its maximum SMSC then this excess will be added to REC which is then passed to the groundwater store.

The soil store is subject to evaporation loss which is calculated to be

ET = lesser of {EM x SMS/SMSC or PET).

EM is understood to be a user input parameter. However in Simhyd it appears to be set at a constant value of 10. For the WaterCress version of this model an extra parameter for EM is provided for the user.

Baseflow BAS is calculated = K x GW. Where GW is the amount held in the groundwater store.

Total runoff becomes equal to SRUN + INT + BAS

9.6.3 Discussion

Hydrolog was used widely in SA in the early 1980's to estimate flow from South Australian catchments with annual rainfall of 500 to 700 mm. However it was found at the time that the model did not reproduce the RF/RO relationships faithfully and this led to the development of WC1 and the consideration of other models such as AWBM.

The problems found centered around the calculation of the infiltration function which was a far too blunt instrument to explain runoff effectively. It was found in most instances to be calibrated out of operation in all but extreme rainfall conditions. Without this function this just left a linear interflow function to explain variances in runoff. In low rainfall areas this was found wanting.

However, it is recognised that the infiltration function could potentially be of value when a sub-daily timestep is used.

9.7 SFB Model

9.7.1 The model

The SFB model was produced by Broughton in an attempt to simplify the rainfall to runoff modeling to absolute basics. This was designed as a 3 parameter model (S, F and B) and in this form simply assumes constant values for the other required variables.

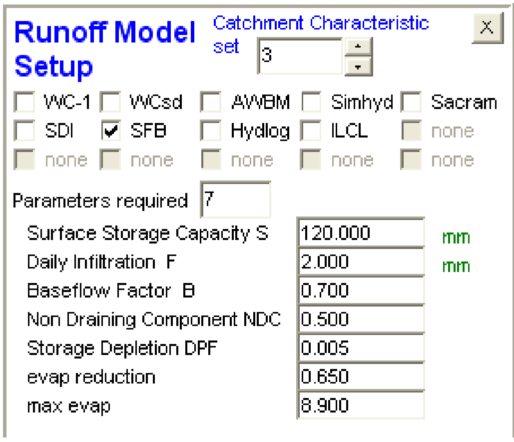


Figure 9.7.1 The watercress input window

This version provides for 7 parameters enabling the non draining components and the groundwater discharge to be varied.

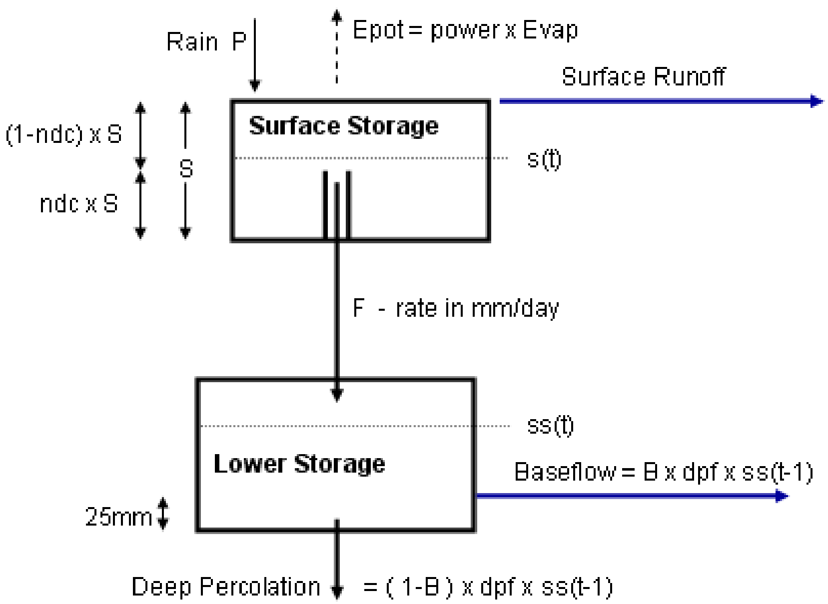


Figure 9.7.2 Layout of the SFB model

9.8 SDI Model (Soil Dryness Index)

This description of the model has been taken from a paper from G Kuczera, "The Soil Dryness Index Streamflow Model: An overview of its capabilities" 1988.

A. B. Mount originally developed the Soil Dryness Index (SDI) model in 1972 to calculate fire potential of the forest fuels as the vegetation dried. Langford et al (in 1978) selected the SDI model to simulate the land hydrologic cycle on Melbourne's water supply catchments.

Most applications have involved predominately forested water supply catchments in South-Eastern Australia. It is operated on a daily basis using daily rainfall and daily evaporation. An alternative has been to use constant monthly evaporation data instead of daily data.

9.8.1 Model Concept

The SDI is a lumped conceptual model of catchment hillslope processes, its structure is shown in figure 9.8.1.

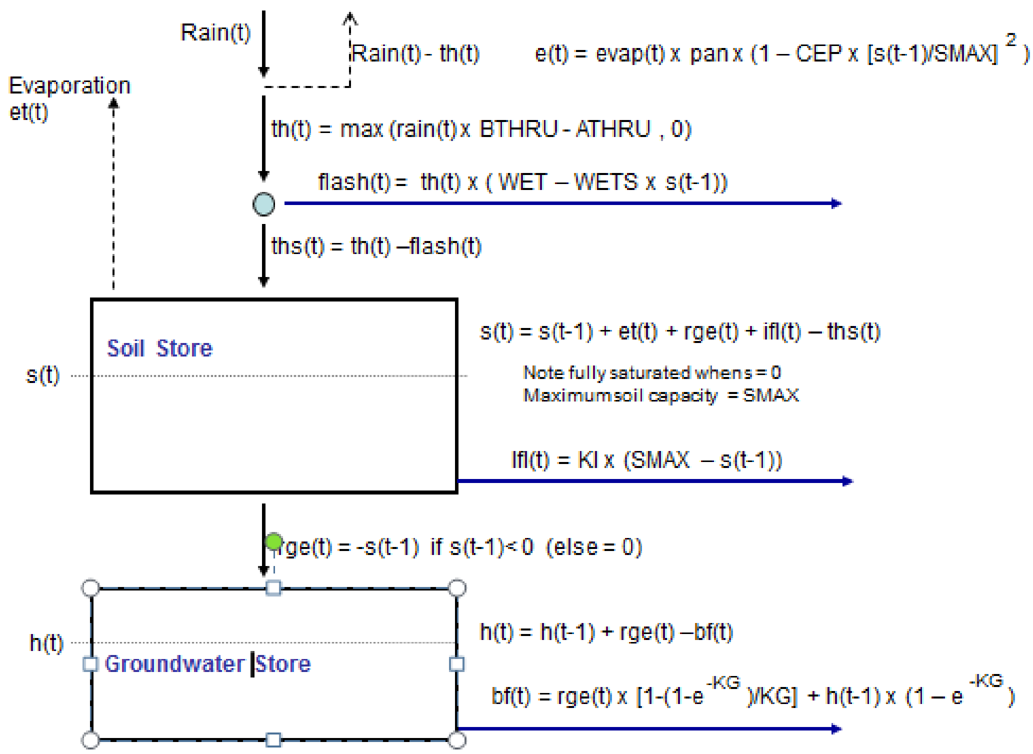


Figure 9.8.1 Layout of the SDI model

The model is a 9 parameter model using 2 storages (as shown) to track soil moisture and groundwater. The soil store is generally the main runoff producing component creating 'flash' and interflow runoff. Baseflow is also generated from the groundwater store.

The model requires two time series inputs

- rf(t) which equals the rainfall depth (in mm) for current day
- pe(t) which equals the pan evaporation (in mm) for current day.

The daily rainfall is firstly partially intercepted using an initial loss, continuing loss process. The initial loss is set by the parameter **ATHRU**, and the continuing loss by (1 - **BTHRU**). The effective rainfall passing this interception is termed throughfall **th**.

The function therefore can provide a non-linear runoff response to rainfall determined by the soil moisture store.

Hortonian Runoff is calculated as the value **flash** where:

Flash = th(t) x **WETFRAC**

WETFRAC = **WET** - WETS x s(t-1)

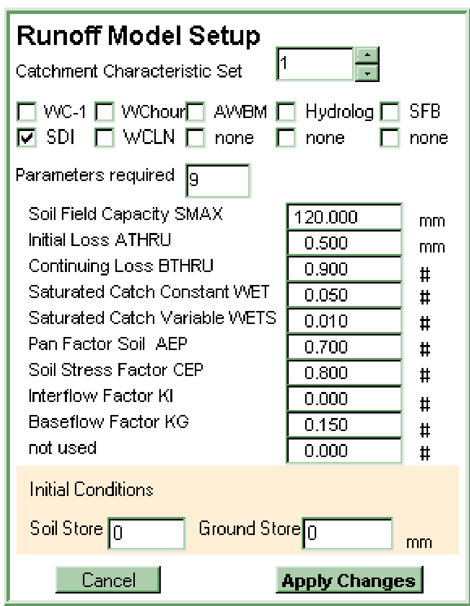
where th(t) is the current days throughfall and s(t-1) is the previous days soil store

Note the soil moisture store in the SDI model works in the opposite way to most other models. The soil store is reduced as water is added, hence the reason for the ' - **WETS** x s(t-1)' in the above equation. A soil moisture of zero indicates a fully saturated catchment and a value approaching **SMAX**, which is the maximum soil store, is dry.

Interflow is calculated as:
Interflow = **KI** x (SMAX - s(t-1)). It is based on the previous days soil moisture
KI is a model parameter
Recharge to the groundwater store is assumed to occur when the field capacity is exceeded
rge(t) = -s(t-1)   for s(t-1)<0, else rge = 0.
Evapotranspiration is taken from the soil store where:
evp(t) = AEP * PE(t) * ESW * EVPD   PE(t) is the recorded evaporation for day
AEP is a model parameter relating to pan evap
ESW = 1-CEP*(s(t-1)/smax)**2 ifs(t-1)>0 (else =1)
EVPD = 1 - BEP * PE(t)
ESW and EVPD must lie between 0 and 1
The soil store balance is then carried out as:
s(t) = s(t-1) - throughflow + interflow + flash + recharge + evp
Baseflow is calculated as an exponential decay of the groundwater store based on a relationship using the coefficient kg as:
bf(t) = ground(t-1)*(1 - exp(-kg)) + rge(t)*(1-(1-exp(-kg))/kg)
ground(t) = ground(t-1) + rge(t) - bf(t)
Runoff is therefore calculated as:
Runoff (depth) = flash(t) + ifl(t) +bf(t)

9.6.2 Input Parameters

SMAX = 50 - 120mm
ATHRU = 0.5 - 3 mm   BTHRU = 0.9 - 1
catchments in semi arid areas require ATHRU high
WET = 0.03 - 0.06   WETS = 0 - 0.01   WETS usually set to 0
KI = 0.00002   interflow component usually small
KG = 0.15
AEP = 0.0.7 - 1.0   CEP = 0.60 - 1.0



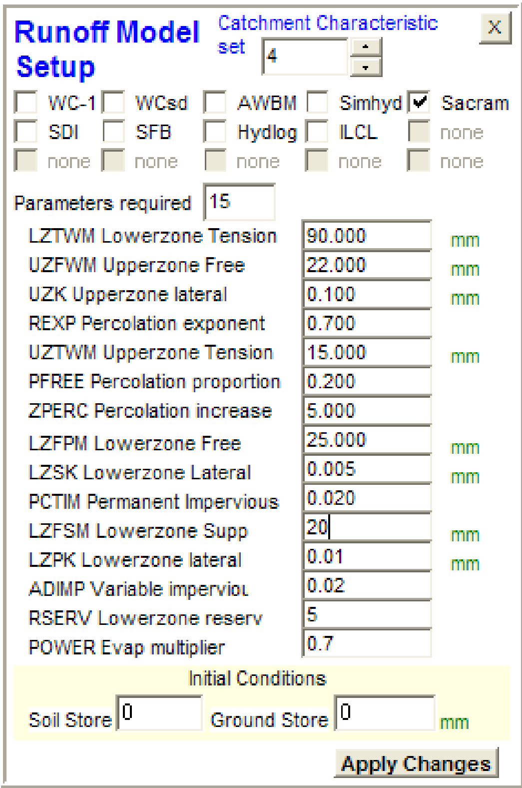
9.9 Sacramento model

9.9.1 Model Inputs

Sacramento is a more complex model requiring in its original form 16 parameters. In this version this has been reduced to 14 parameters plus one additional to adjust the evaporation (POWER)

Much of the complexity is related to the groundwater modelling and therefore it could be expected that the model is most suitable for systems with a high baseflow component.

The watercress input window is shown below and typical values for each parameter is shown adjacent



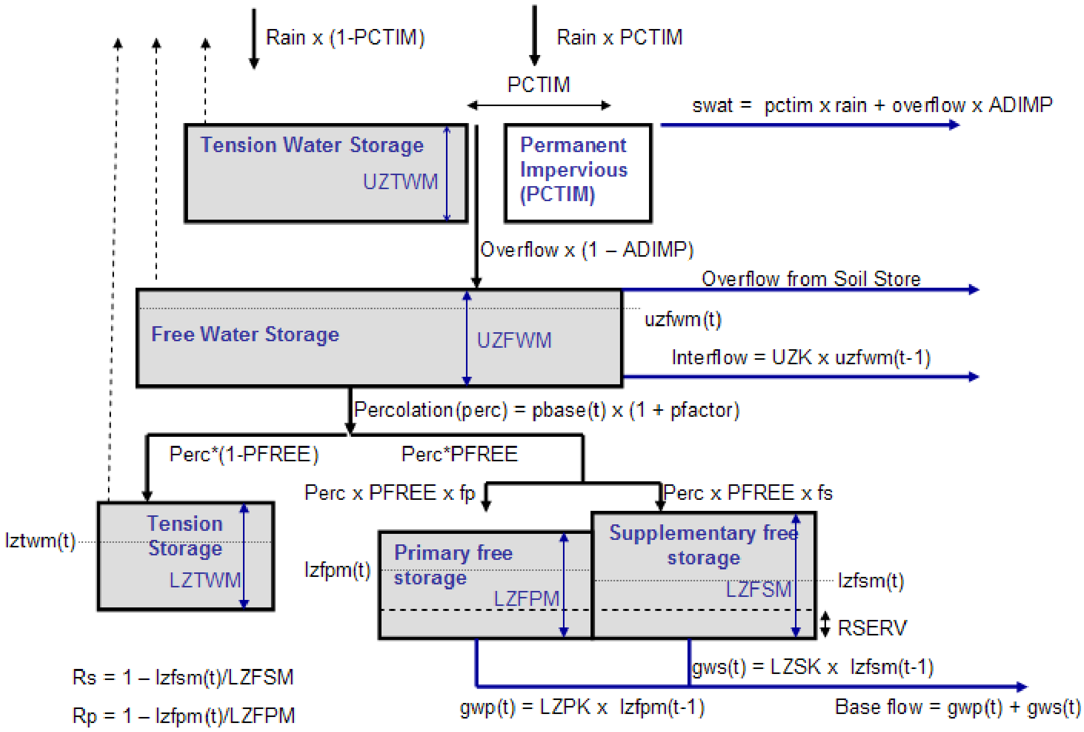
Parameter	Typical Range
LZTWM	90 - 400
UZFWM	10 - 80
UZK	0.09 - 0.5
REXP	0.5 - 3
UZTWM	10 - 100
PFREE	0.005 - 0.45
ZPERC	1 - 80
LZFPM	5 - 50
LZSK	0.002 - 0.3
PCTIM	0 - 0.03
LZFSM	5 - 50
LZPK	0.0001 - 0.3
ADIMP	0 - 0.03
RSERV	0 - 20
POWER	0.5 - 1.0

9.9.2 Model Concept

The model utilises 5 stores, two upper and 3 lower (groundwater). These stores separate storage of two types, tension and free water. Tension stores are those which retain the water only losing it to evapotranspiration. The free storage only temporarily detains water which in time will be mobilised into stream flow.

Rainfall on the upper storages models direct runoff from impervious surfaces, saturated surface runoff and interflow. The majority of the runoff, generated from the upper store, is interflow, and is based on linear relationship between soil moisture. This would provide a flow relationship with rainfall which is averaged over time. Because of this the model is likely designed to model monthly flows.

The complexity of the 3 store groundwater model will likely to be difficult to calibrate but it could also provide a better flow calibration as it can provide two different stores and rates of groundwater discharge. However, the equalising of soil moisture across these stores (as required by the model) will reduce the value of the two stores.



Rs = 1 – lzfsm(t)/LZFSM

Rp = 1 – lzfpm(t)/LZFPM

fs = Rs / (Rp + Rs)

fp = Rp / (Rp + Rs)

pfactor = ZPERC x (LZfillfrac ^ REXP) x uzfwm(t-1) / UZFWM

where LZfillfrac = space in lower stores / (LZFPM + LZFSM + LZTWM)

10. OUTPUT OPTIONS: SELECTION AND DEFINITIONS

When a project is run, the model calculates drainage and water supply flows into and out of each node, plus storage, salinity and Qcodes levels, etc,etc and placing these into memory as averages over all time steps from hourly, daily, monthly, annual, to project total duration. This quantity of data is far too large to all be output together so, except for a general Summary providing average flows over the total project duration, all other outputs are only shown when specifically selected by the modeller.

In Sections 10.2 onwards, the range of ouput options, the manner in which the outputs are selected and the definitions of the terms used are described.

10.1 Model Run without Output Options (Summary Only)

The WaterCress model may be run at any time that you have a project assembled and some valid time-series input data (ie rainfall or flow data) on which the model can operate. However, if you have not selected any Output Options for your project, the only output results that you can access following the model run will be located in the Summary table (see Section 12).

The Summary, as its name suggests, provides a very useful overview of the performance of the project over the modelling period. In many cases, particularly at the setting up stages of a project, the Summary output may be completely adequate to check that the model is working, and working in the manner intended.

However, if you wish to examine the performance of various aspects of the performance in greater detail, in particular by investigating the time-series variations of the various parts of the model during the period of the model run, you must identify the particular aspects in the list of options offered in Output Options and make your selection as described below.

10.2 Scope of Output Options

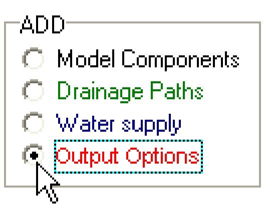
The model provides more than 90 output options across the 18 node types available in the model. The number of options available depends on the complexity of processes occurring within the component. Thus the more complex components (eg the House and Urban components) have of the order of 30 output options available. Simpler components (eg External) only have a few output options.

The outputs provide valuable information on the performance of individual nodes and provide confidence that the layout of the model is working in the manner expected and/or intended by the modeller.

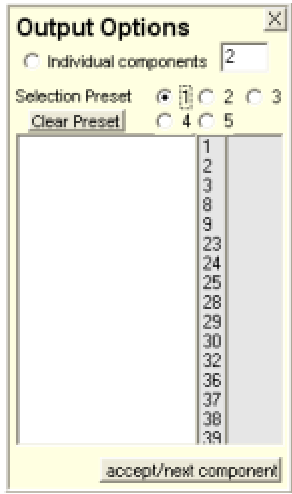
10.3 Selecting Output Variables

10.3.1 Adding Outputs

If you require to output data from the Output Options menu, you must make your selection before you enter the output screen (from where you run the model).



On the Area C of the Project Layout screen (see Section 6) click the **Output Options** button to raise the Output Options panel.

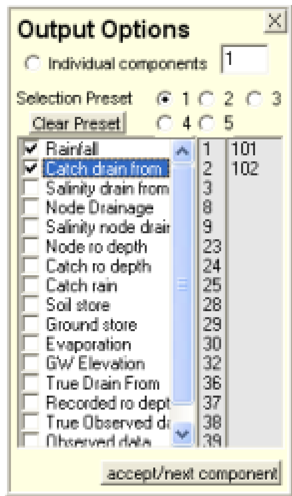


For a new project, the panel will be empty. This is where you enter your selection(s) of which outputs you wish to be able to examine in greater detail for particular nodes (eg, inflows, storage levels, spills, salinity variations, etc) . The outputs will be in the form of a time-series for these variables.

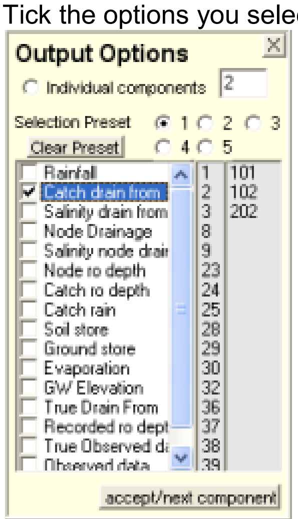
Before making your selection, you must nominate which Preset Selection group you are establishing. The default is shown as 1on the row of buttons at the top of the panel and this is the obvious group number under which to establish your first selection. However, on subsequent runs you may wish to set up other groupings of outputs, while not wishing to remove your original grouping, in which case you can retain up to 5 selection groups as choices for further runs. When you run the model you will be asked to nominate which Preset Selection group you wish to run.

To establish/update Selection Preset number 1, click **Selection Preset " 1 "** as shown. If this selection is already populated (the selections will appear in the panel below) click **Clear Preset** to blank the sheet. You should now have an empty output option window similar to the one to the left above.

To add output variables to the panel list **left** click onto the node you want to select output data from. The whole range of available output options for that node will appear in two columns on the LH of the panel, giving the names of the options, a tick box for making a selection and an index number for that particular selection. A draw bar will enable you to scrll down if the selection is longer that the panel.



Tick the options you select, say the top two in the example shown



ie."Rainfall and "Catch drain from" (the modelled outflow from the catchment). When you have made your selection Click **accept/next catchment.** Two numbers will appear in the RH part of the panel. The first part of each number is the number of the node for which you are making the selection (1 in this example). The second part of the number is the two digit record of the index number of the selection (ie 01 to 99). This second part may be common to several nodes. The names and index numbers and listing of nodes for which each applies is given below. This code enables you to see at a glance what outputs you alteady have in the preset.

To add more outputs to your selection, **left click** on another node and the range of available output options for this component now appears. If you wish to have this output for inspection along with your previous selection, retain the same Selection Present as before. Otherwise set up a new Selection Present group.

In the example "Catch drain from" is selected again. Click **accept/next component** and this selection will be added to the previous selections in the RH panel.

Note. It is recommended that you limit your number of selections under any Preset grouping to about 10-15. While more may be displayed and/or exported to file (eg Excel spreadsheet), for a normal trial and error method of investigation/design, reviewing more than about 12 time-series results at any time becomes counter-productive. If more are to be recorded, it is best to assembled them progressively via several runs onto a spreadsheet.

10.3.2 Removing and Re-Ordering Outputs

To remove any of the selections previously made, simply reclick onto the node in question and then click the ticked box to turn it off. Click **accept/next component** and the selection will disappear from the list.

The order that the selection is made in the RH list is the same order as which the results will appear in the output listing on the Results Screen. Occasionally, it is useful to have outputs which need to be compared to each other next to, or near to each other. Thus arranging, or changing the order in which the selections appear in the RH listing is desirable.

The position that any selection appears in the RH list can be ordered by highlighting the number of the selection in the list just above the point where you wish your next selection to be placed. Your new selection will then appear just below this number and above the one below.

Thus to change the order of an existing list, all you have to do is to re-click on the node of the selection that you wish to move, tick it off from the existing list, highlight the new position that you wish it to take, and then tick it back on. You may have to revisit several nodes in making your changes.

Remenber to click **accept/next component** to **save** your new ordered selection**.**

10.3.3 Identification/Definition of options provided

The selections that appear when you left click a node will vary depending on the type of node. The following is a description of the options that may be made available.

The abreviated name is the name that will appear at the head of the column in which the output values appear. 10.4 List and Descriptions of Output Options

Certain performance values may not appear in the listing below. It is very rare that these cannot be calculated by summation or differencing of those that do appear. It is always important to have a diagram of the layout of the project before you and to understand the model operation in order to assist in obtaining the performance values of interest, either directly via the output options listed, or indirectly by reference and calculation involving two or more of the output options.

Option 1

Node Rainfall (NodeRain) - This is the rainfall depth on the node (as per the node rainfall file, modified by the multiplier selected). Spatiallly averaged rainfall on the upstream catchment is available as CatchRain (see Option 25).

Option 2

Drainage Out (DrainOut) - This is the sum of all drainage paths leaving the node, except when drainage is also identified as leaving the node via the Diversion path. Diversions are identified and accounted for in Option 11. If optional drainage diversions are not separated in the Summary listing, they will be included in DrainOut.

Option 3

Salinity Drain Out (SalDrnOut) - This is the average flow weighted salinity of the option 2 drainage.

Option 4

Storage Held/Channel Storage (Store) - Relates only to nodes containing a storage, including those with a channel store involved in routing. The output values are the storage volume held at the end of the time-step.

For Natural catchments Store is not available, but soil and groundwater storage are separately accounted and output via options 28 and 29.

For House and Urban nodes Store is the total storage volume held in the three onsite tanks.

For the Weir node it is the water retained in the diversion sump.

Option 5

Salinity of Storage (SalStore) - This is the salinity associated with the Option 4 storage. It is not available for the (small) routing storages.

Option 6

Supply Out (SupOut) – Supply out is the total of all water supplied via water supply links discharging from this node. For House and Urban nodes that have an internal demand for water that is supplied from the internal sources and storages, and provide no supply out from the node, the term Internal Supply is used for that part of the internal demand that is satisfied from internal sources within the node (see GenWat, Option 8). For these nodes, more detailed time-series of supplies provided from internal and external sources to different demand types are given in Options 70-79 and 81-85.

For Offstream dams, any internal supplies are included as Supply Out.

Option 7

Salinity Supply Out (SalSupOut/IntSalSup) - This is the average flow weighted salinity of the water supplied in Option 6.

Option 8

Water Generated in Node (WatGain) – This is the drainage water generated in the node itself. It does not include any water inflowing to the node from upstream. This option is only available for nodes which generate drainage ie Natural, Impervious, House and Urban nodes and the net effect of rainfall on open storage surface areas (see Option 15). For storages, It is also calculated before losses to seepage are extracted. See also Gen RO

Option 9

Salinity of Drainage Generated (SalGen) - This is the salinity of the water generated in option 8 within the node.

Option 10

Drainage In (DrainIn) - This is the total of all water entering the node via drainage paths from upstream nodes, including diversions from Weirs, baseflows via Springs and runoff and wastewater from upstream House or Urban nodes. (However, note: If the receiving node is a House or Urban node, any separated sewer inflows (while still included in DrainIn) will be kept separately accounted so that they can be accumulated with similar flows generated within the node in question (if such flows exist). <u>These inflows may not be used as supplies within these nodes</u>, therefore if these paths are input to the node (in the desire to keep them separately accounted), it will be necessary to ensure that similar separate outlet paths are created for them (or they will disappear 'out of model').

Option 11

Drainage Diverted (Divert) or Water Treated (Treat) – This is always drainage diverted from the 'main stream'. The composition of the flow diverted may be different:

- for a Weir this is the proportion of the mainstream that is calculated via the formula entered.
- for an Offstream dam this is the drainage diverted from the mainstream into the dam.
- For a Treatment plant it will be proportion of the mainstream that has been diverted to the

plant to be traated and will be output under the heading Treat

Option 12

Salinity Diverted (Sal Dvt) - This is the salinity of the drainage water diverted in Option 11

Option 13

Supply In (Sup In) - This is the volume of water supplied through all water supply links to this node.

- For Demand nodes it relates to the amount of water supplied to meet the demand
- For storages it relates to the amount of water drawn into the storage as 'requested' by its set-up.
- For House and Urban nodes it does not include supplies provided internally from the on-site systems. These are defined as IntSup (see Option 6).

Option 14

Salinity Supply In (SalSupIn) - This is the average flow weighted salinity of the water supplied to the node as per Option13.

Option 15

Water Loss (WatLoss) - This is the total loss of water from storages or channels including seepage, evaporation from open storage surface areas, and water lost internally between supply and wastewater production or treated water output (for a treatment plant).

Option 16

$ held in Storage ($inStore) – The costs involved in construction or maintaining upstream works all flow down the stream paths to be trapped in storages. $ costs build up in a storage before being transfered to a 'customer' via a supply path. Unlike water, the $ held in storage are not removed by spill events.. The cost of supplied water is calculated as the proportion of the stored water removed to supply, multiplied by the dollars held in storage. Used only for storage.

Option 17

QCode of Storage (Qc Store) - The average volume weighted Quality Code of the water held in the storage. This will usually be the same as for Option 18, but covers periods of storage when no supply out is taking place.

Option 18

QCode of Drainage in (QcDrnIn) - The flow average Qc of all drainage in

Option 19

Water Recycled (Recycle) – The amount of wastewater that has already passed through supply, has been reduced by any associated losses and is re-supplied to assist in satisfying internal demands.

Option 20

Blank

Option 21

Blank

Option 22

Blank

Option 23

Runoff Generated depth (GenRO) - This is the spatially averaged depth of runoff (typically expressed in mm) generated from rainfall on Natural and Urban catchment nodes only. It excludes any inflows from upstream.

Option 24

Catchment Runoff depth (CatchRO) - This is the spatially averaged depth of runoff (typically expressed in mm) from the entire catchment above and including the node in question. This can be adjusted to accumulate rainfall for selected month periods only (eg wet season Mar-Oct etc) or the entire year. It is expressed as node *DrainOut/(total area of all upstream runoff generating areas)*. The total area excludes surface areas of any upstream open storages, although these may add to (or detract from) the drainage leaving the downstream node in question

Option 25

Catch Rain (CatchRain) - This is the area weighted rainfall of all catchment nodes that make up the entire catchment above and including this node. This can be adjusted to accumulate rainfall for selected month periods only (eg wet season Mar-Oct etc) or the entire year. Typically NodeRain (Option 1) and CatchRain (this Option) may be plotted against NodeRO (Option 23) and CatchRO (Option 24), respectively, to provide rainfall runoff relationships.

Option 26

$ Supplied In ($SupIn) – flow weighted average cost per unit volume of water supplied to demand and storage nodes from all supply sources.

Option 27

$ Supplied Out or $ Supplied Internally ($SupOut or $IntSup) – cost per unit volume of water supplied from a node. Corresponds to Option 6 with respect to internal supplies to the House and Urban nodes.

Option 28

Modelled Soil Store (SoilStore) - The total amount of storage currently held within the soil moisture stores of the Natural catchment as calculated by the rainfall to runoff models. Commonly expressed in depth (mm).

or Demand (Demand) – The time-series pattern of demand for water set for the demand node in question.

Option 29

Modelled Groundwater Store (GwStore) - The amount of storage currently held within the groundwater stores of the Natural catchment as calculated by the rainfall to runoff models. Commonly expressed in depth (mm).

or Demand Not Met (DemGap) – The time-series of the gap between demand and supply for the demand node in question. Will be zero for all times when the demand is being met. Used to define the time, amount and duration of failure events in conjunction with Option 28.

Option 30

Node Evaporation (NodeEvap) - The amount of water being lost to evaporation within the Natural catchment models (mm) as modified by any pan factor applied.

Maximum Storage Held (MxStore) – Will extract and record the maximum storage value calculated when the project is run at a short time step, when the results are reported at a longer time step. Eg when the results are aggregated over the daily, monthly or annual periods will record the maximum storage that has occurred during those periods.

Option 31

Maximum Rate of Drainage Out (MxDrnOut) - Will extract and record the maximum rate of mainstream drainage outflow calculated when the project is run at a short time step, when the results are reported at a longer time step. Eg when the results are aggregated over the daily, monthly or annual periods will record the maximum rate of mainstream drainage outflow that has occurred during those periods. Used for flood peak analysis.

Option 32

Blank

Option 33

Blank

Option 34

Storage Level (StorElev) - This is the elevation (from the adopted datum) of the water in a storage as calculated from the storage v depth (elevation) relationship entered for the node.

Option 35

True Drain Out - This is the time-series for the modelled drainage out with periods of unreliable accuracy data omitted. This time-series is used in the model calibration process for comparison with observed flow data recorded at the same location over the same time period. The periods of unreliable data for both modelled and observed data are set by the data quality code selector for the observed data entered under the **Run** then **Alternative Run** then **Quality Code** headings on the **Results Screen**. See Section 13 for information on model calibration.

Option 36

Observed Flow Depth (Obs RO) – This is the complete record of observed flow, expressed as an average depth over the upstream catchment. It contains both reliable and any less reliable flow data as described under Option 35. (The same record with the unrelaible data omitted is TruObsRO see Option 38.

Option 37

Maximum Observed Data (Mx Obs) - This can be used to output the time-series for any observed data record identified within the node calibration file. Because the time-series is assumed to contain maximum values, the highest value within each output period is reported rather than the aggregate value as for other Output Options.

Option 38

True Observed Data (Tru Obs) - Refer Options 36 and 39. This is the same as the Observed data time-series (option 39) except that poor quality data has been omitted, as per the notes described for Option 36 above. The Observed data used in this situation is invariable flow data which is accompanied by the quality code indices used to differentiate the 'true' (and poor quality) data.

Option 39

Recoded (observed) Data (ObsData) – Observed data can be any time-series data measuring an aspect of the performance of the project being modelled. For the purposes of calibration, the Observed data will be entered as a file via the calibration icon of the node that is calculating the corresponding aspect (See Section 13). To enable calibration to be undertaken, the time-series of the corresponding aspect as simulated by the model (eg storage, flow salinity, water level, etc), must also be selected in the same output option group.

Option 40-49

Blank

Options 50

Wetland Qcode Cell [0] (Qc(0)Wet) - A wetland is divided into 10 segments (cells) and the water entering is passed through each cell by mixing, displacement and diffusion. The quality code is assumed to gradually reduce depending on the cumulated duration of time the water remains within the cells. Supply out is not taken until the Qcode has reduced to a selected level. To enable inspection of the working of the Qcode change Options 50-54 are available for outputing the time-series changes to the Qcode for cells 0 to 4.

or Aquifer Salinity Cell[0] (Sal(0)Aq) - An aquifer is divided into ten cells each holding salinity and volume information. Water injected into the aquifer enters the first cell (0) and moves out via displacement and diffusion to the other cells. The reverse occurs on recovery. This process allows the simulation of fresh water injection into, and recovery from saline aquifers. The time-series changes to the salinity in the 10 cells (cell 0 to cell 9) is available for output via Output Options 50 to 59.

Options 51 to 54

As above for Wetland cells 1 to 4 ie. **Qc(1)Wet to Qc(4)Wet**.

or, as above for Aquifer cells 1 to 4 ie. **(Sal(1)Aqui) to (Sal(4)Aqui)**

Option 55

Wetland Volume Cell(0) (Vol(0)Wet) – As above, a wetland is divided into 10 segments (cells). The WaterCress model calculates the mixing and age of water by calculations which involve the cell volumes varying. To enable inspection of the working of the Qcode changes, Options 55-59 are available for outputing the time-series changes to the wetland cell volumes.

or Aquifer Salinity Cell [5] (Sal(5)Aqui) – continuation of options 50 to 54.

Options 56 to 59

As for Option 55 for Wetland cells 1 to 4 ie. **Vol(1)Wet to Vol(4)Wet.**

Or, as above for Aquifer cells 6 to 10 ie. **(Sal(6)Aqui) to (Sal(9)Aqui)**

Options 60 to 69 for House and Urban Nodes only

Note: many of the Option numbers relate to different outputs for the two nodes.

Option 60

BOTH Sewer Drain Out (Sewer) – This is the sum of the black and grey sewer drainage paths leaving the House or Urban nodes. It may also include the sewer flows coming from upstream nodes, if these are separately connected to the node.

Option 61

BOTH Salinity of Sewer Drain Out (SalSwOut) - This is the salinity of the water leaving (as defined in option 60) the node.

Option 62

BOTH External Supply (Ext Sup) – this is the total of the supply provided from outside the House and Urban nodes to augment any internal (onsite) supplies in satisfying the total of all the demands within the nodes.

Option 63

BOTH Drink External Supply (ExtDrink)- this is the total of the supply provided from outside the House and Urban nodes to augment any internal (onsite) supplies in satisfying the demands within the nodes entered via the 'Drinking' demand window (only).

Option 64

HOUSE - Dish External Supply (ExtDish) – this is the total of the supply provided from outside the House node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Dish' demand window (only).

URBAN – Toilet External Supply (ExtToilt) - this is the total of the supply provided from outside the Urban node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Toilet' demand window (only).

Option 65

HOUSE Bath External Supply (ExtBath) - this is the total of the supply provided from outside the House node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Bath' demand window (only).

URBAN Garden External Supply (ExtGard) - this is the total of the supply provided from outside the Urban node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Garden' demand window (only).

Option 66

HOUSE Wash External Supply (Extwash) - this is the total of the supply provided from outside the House node to augment any internal (onsite) supplies in satisfying the demands within the nodes entered via the 'Washing' demand window (only).

URBAN Industry External Supply (Ext Ind) - this is the total of the supply provided from outside the Urban node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Industry' demand window (only).

Option 67

HOUSE Toilet External Supply (ExtToilt) - this is the total of the supply provided from outside the House node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Toilet' demand window (only).

Option 68

HOUSE Garden External Supply (ExtGard) - this is the total of the supply provided from outside the House node to augment any internal (onsite) supplies in satisfying the demands within the node entered via the 'Garden' demand window (only).

Option 69

BOTH $ External Supply ($ExtSup) - This is to overall cost of external water supplied to the House and Urban nodes in units $ per unit volume. It is the average cost across all water qualities of water being supplies (as outputs in options 63 - 68)

Option 70

BOTH Internal Supply (Int Sup) – this is the total of the supply provided from internal (onsite) water sources inside the House and Urban nodes in attempting to satisfying the total of all the demands within the nodes.

Option 71

BOTH Drink Internal Supply (IntDrink) - this is the total of the supply provided from internal (onsite) water sources inside the House and Urban nodes in attempting to satisfying the demands within the nodes entered via the 'Drinking' demand window (only).

Option 72

HOUSE Dish Internal Supply (IntDish) –this is the total of the supply provided from internal (onsite) water sources inside the House node in attempting to satisfying the demands within the node entered via the 'Dish' demand window (only).

URBAN Toilet Internal Supply (IntToilt) - this is the total of the supply provided from internal (onsite) water sources inside the Urban node in attempting to satisfying the demands within the node entered via the 'Toilet' demand window (only).

Option 73

HOUSE Bath Internal Supply (IntBath) - this is the total of the supply provided from internal (onsite) water sources inside the House node in attempting to satisfying the demands within the node entered via the 'Bath' demand window (only).

URBAN Garden External Supply (IntGard) - this is the total of the supply provided from internal (onsite) water sources inside the Urban node in attempting to satisfying the demands within the node entered via the 'Garden' demand window (only).

Option 74

HOUSE Wash Internal Supply (IntWash) - this is the total of the supply provided from internal (onsite) water sources inside the House node in attempting to satisfying the demands within the node entered via the 'Washing' demand window (only).

URBAN Industry Internal Supply (Int Ind) - this is the total of the supply provided from internal (onsite) water sources inside the Urban node in attempting to satisfying the demands within the node entered via the 'Industry' demand window (only).

Option 75

HOUSE Toilet Internal Supply (IntToilt) - this is the total of the supply provided from internal (onsite) water sources inside the House node in attempting to satisfying the demands within the node entered via the 'Toilet' demand window (only).

Option 76

HOUSE Garden Internal Supply (IntGard) - this is the total of the supply provided from internal (onsite) water sources inside the House node in attempting to satisfying the demands within the node entered via the 'Garden' demand window (only)..

Option 77

Tank1supply (Tnk1Sup) - This is the Water supply that is able to be supplied internally within the town from tank 1.

Option 78

Tank2 supply - town node - This is the Water supply that is able to be supplied internally within the town from tank 2.

Option 79

tank3 supply - town node - This is the Water supply that is able to be supplied internally within the town from tank 3.

Option 80

Cost of Internal Supply ($IntSup) - town node - This is the cost of supplying water from internally within the node. This is by rainwater tanks and effluent reuse.

Option 81

Tank 1 Volume (Tnk1Vol) - **town node** - This is the volume of tank 1 in the internal town node water supply.

Option 82

Tank 2 Volume - town node - This is the volume of tank 2 in the internal town node water supply.

Option 83

Tank 3 volume - town node - This is the volume of tank 3 in the internal town node water supply.

Option 84

Tank 4 Volume – Urban node - This is the amount of runoff created from the roof area provided into the town node.

Option 85

Roof OutPavement runoff created - town node - This is the amount of runoff created from the roof area provided into the town node.

Option 86

Grey Out

87-93

Blank

Option 94

Zone Storage Salinity (ZnSal) Average salinity of all storages of the component type in the zone.

Option 95

Zone Volume – (ZnVol) - Total volume of water stored in all of the storage components of this type in the zone.

Option 96

Zone Supply In (ZnSupIn) – total of all water supplied out y Use - store node - This is the total use of the water used from all of the storages in the zone.

Option 97

Zone Supply Out – (ZnSupOut) This is the total volume of all water supplied to storages in the zone. Supplied to means water transferred to the storages from external storages by means of water supply links. It does not include water passed through drainage paths.

Option 98

Zone Loss (ZnLoss)- This is the total loss of the water stored in all of the storages in the zone caused by evaporation and seepage.

Option 99

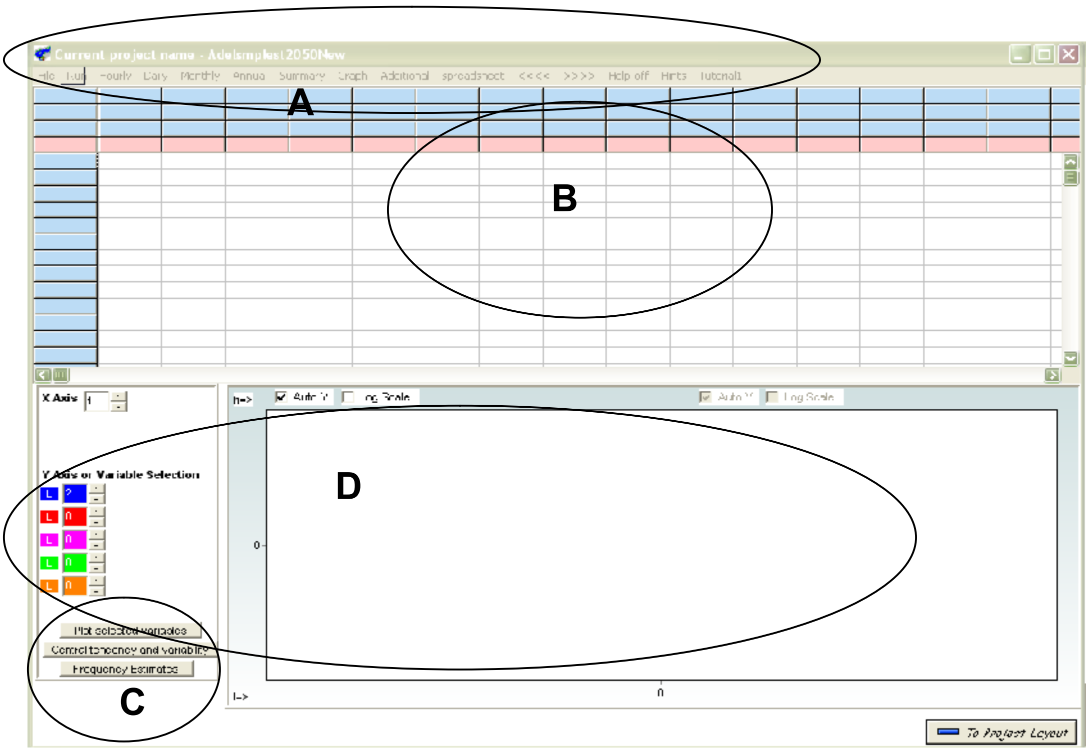
Zone Rainfall (ZnRain) - This is the average rainfall in the zone.

11. OUTPUT RESULTS SCREEN

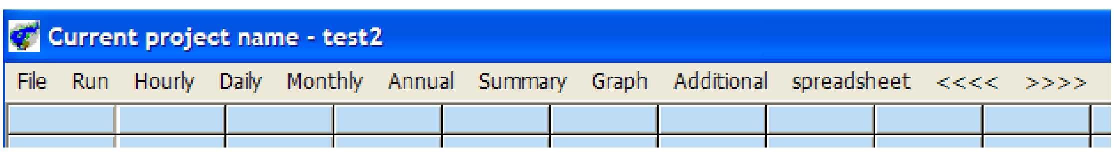
11.1 Screen Layout

After completing all project layout, data entry and output selection tasks on the Project Layout Screen, the Output Screen is brought up by either clicking on **To Output** on the Header bar of the Project Layout Screen or **Go to Output Page** at its bottom RH corner. The Output Screen is where you will run your project and view the results.

If you have not run your project, the Output Screen will look as shown below, else the upper part of the Screen **(Area B)** will be populated by results.



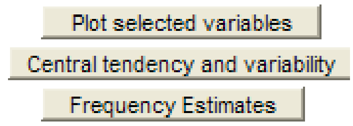
Area A is the Header Bar which provides the initiation of model running, access to different displays of the results and other operations and aids.



The second header in Area A is **Run**. This is where you make your final selections before running your model, and then run it (Section 11.2). After running the model the headers **Hourly, Daily, Monthly, Annual and Summary** dictate how the immediate results are displayed, and thus these areas are all described first (Section 11.3).

Area B (Sections 11.3 and 11.4) enables listing of the time-series results for the Output Options selected on the Project Layout Screen. The default listing is of monthly values, but hourly (if the model was run at this time step), daily, annual and long term Summary listings can be displayed by toggling these Headers on the Header bar.

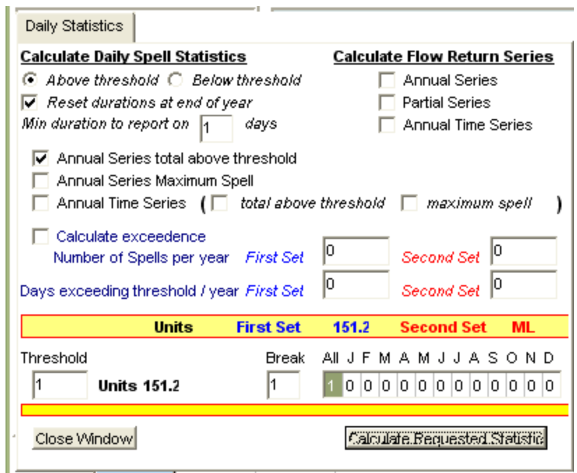
Area C (Section 11.5)provides means for plotting the time series outputs and selecting different statistical analyses of the results:



Plot selected variables enables the listed time series to be plotted as as time series or as X-Y plots.

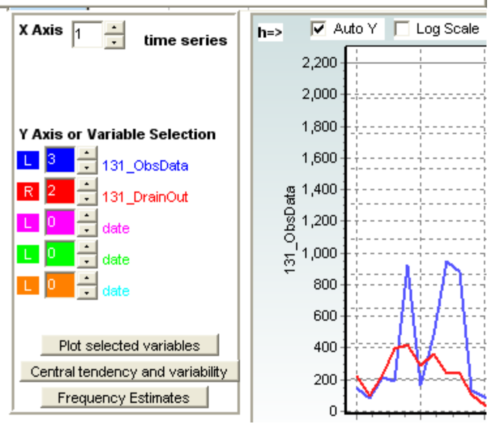
Central tendency and variability provides statistical information such as averages, skews, standard deviations and graphs of seasonal (monthly averages) patterns and exceedences for individual listed outputs or correlation statistics for the calibration between two sets of listed outputs.

Frequency Estimates provides a range of statistics on annual and Partial series and different forms of spell analyses as per the figure on the RH..

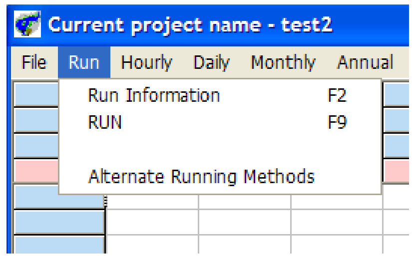


Area D is the area where the time-series or X-Y graphs are plotted.

The area to the far LH enables up to 5 of the listed outputs to be selected for plotting (via the 5 coloured selector boxes) and/or for analysis via the 3 selector buttons immediately below in Area C.



11.2 Area A. Run. Running Your Project

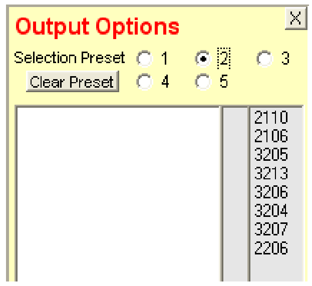


Clicking on **Run** on the Header Bar will bring up the window shown.

11.2.1 Run Information.

Clicking on **Run Information (or F2)** brings up the window shown below. The window functions are set out in 3 parts.

Selection Preset. The row of 5 radio buttons enable the modeller to toggle between 5 sets of output options to be displayed in the results tables in Area B. These sets are the same as those at the top of the Output Options window on the Project Layout Screen refer section 10.3. The example shows Selection Present 2 selected.



Note 1. The two selection numbers need not be the same at the time of running. The Preset number selected under Run Information will show the results for whatever options have been previously entered under that Preset number on the Output Options window.

Note 2. If output options have been previously selected for nodes on a project layout which have been subsequently deleted and the program cannot locate an output to match to that deleted node, the run will be terminated withg an error message. **It is important to check that output options entered under all Presets are valid and in particular do not call for nodes which have been subsequently deleted.**

Start run at / over. Enter the starting month and year for any common period for which your project data has data for all the time-series sets required for all nodes in the project. Also enter the number of years over which the run is to be made. If the model is to be run over the longest period for which time seies data is common to all the nodes in the project, the starting data may be set earlier than the start of any data. Similarly the period over which the model is to be run may be enterred as being longer than the period of common data. However, the model will ONLY run over a common period for which ALL time-series data is present and correct. The model will not commence calculation until it has located data for all nodes in the project. Similarly, as soon as any data series ends, for any node in the project, the model will cease calculation.

If you have short periods of calibration data, ensure the calibration button is ticked off, if you wish the model to run (in non-calibration mode) over a longer period than that covered by the calibration data.

Assess Data from. The dates and period enterred here define the start and duration of results recorded by the model. The main purpose of setting different Assess dates to Start dates is to:

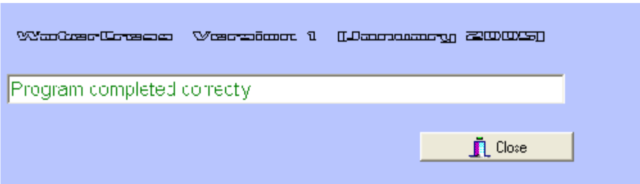
enable the model to get through any initialisation period (if needed), and/or

report annual values for the month commencing the assess data month (ie set month to 1 or 7 to give annual data for **calendar (Jan-Dec) or financial (Jul-June) years.**

These dates are remembered for each project and may be reset by clicking the **update** button.

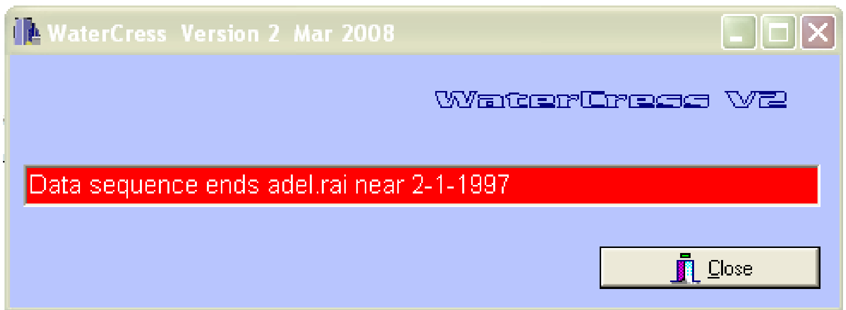
11.2.2. Running the model

Clicking on this (or **F9**) initiates the model calculation. The model run is completed within seconds for most normal projects. Very large projects run over a long period with short time-steps may take of the order of 30 secs. Some projects using multiple runs with short time-steps (eg using data generation) may take several minutes to complete.



When completed normally the message “Program Completed Correctly’ appears on the screen. The message window must be closed to proceed. ’Normal’ completion means the model has not run out of data before reaching the end of the period for which it was requested to run.

Alternatively, a message similar to below will be shown. This is also perfectly acceptable, but means that the model ceased its calculations when it reached the end of the shortest input time-series data set entered into the project, thus marking the end of the input data common period. Ie the model was asked to run over a period longer than the input data covered. The results should be perfectly acceptable up to the date shown on the message.

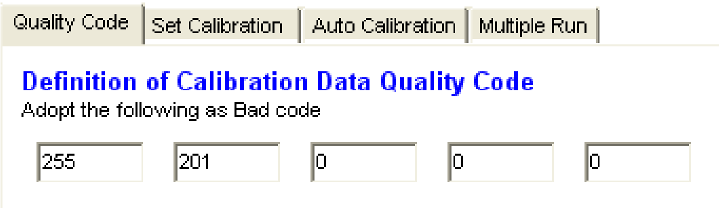


On occasions error messages may be displayed, in which case the run has failed. The likely errors are described in Section 16.0 “Potential Errors“.

Once run, clicking the **Close** button on the "program complete" window will load the results from the completed run and display them onto the Output Screen (or make then available for display). The initial form of the results displayed will depend on the last selection made for the presentation of the results.

11.2.3 Alternative Run Information

Clicking this reveals 4 optional tabs as shown, with the Quality Code option defaulted



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11.2.3.1 Quality Code

The windows allow the model use to enter data quality codes (codes that accompany listed data to signify the relative level of accuracy of the data) in order to define poor quality (ie Bad code) data that may then be excluded from consideration when comparing model results with recorded data. (see Section 12, calibration).

It is common for each recorded data value in a continuous time series to be accompanied by a numerical number code which signifies its assessed quality (ie. accuracy) and the confidence that can be placed in this assessment. For example it is normal for good quality data to be given a low number (eg. 1). Code number 2 may signify good quality, but slightly less confidence. Data that looks strange, but no particular reason can be found for definitely assessing it to be incorrect may have a code number 70. Estimated data may have code 150. Missing data may have code 200, etc. Each data authority usually have their own set of quality codes, which may vary significantly.

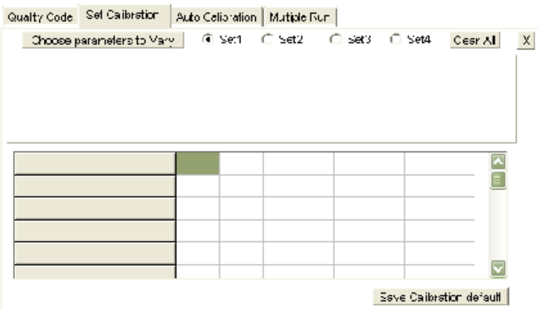
In the Quality Code window the WaterCress model enables you to enter the code numbers of all quality codes for data that you may wish to ignore when you compare the model predictions of (say) runoff measured at a gauging station against the runoff predicted by the model for the same location. Data which is deemed to be of acceptable accuracy is defined as “good“ (or “true“), that which is not, is defined as “bad“.

When selecting model data outputs to be displayed (see Section 10.3) for which calibration data is also available (ie. against which the model predictions can be compared), 4 versions of the same output data can be selected. For flow records (the most likely form of calibration data) these are:

- Option 2. Drain Out (the time-series of flow leaving the node as predicted by the model.
- Option 35. True Drain Out (as above, but omitting the predicted data for those time steps for which the comparitive observed data has received a “bad’ data classification, as described above).
- Option 39. Observed Data (the time-series of observed flow (including any bad data).
- Option 38. True Observed Data (as above, but omitting the observed data for those time steps which have received a “bad’ data classification).

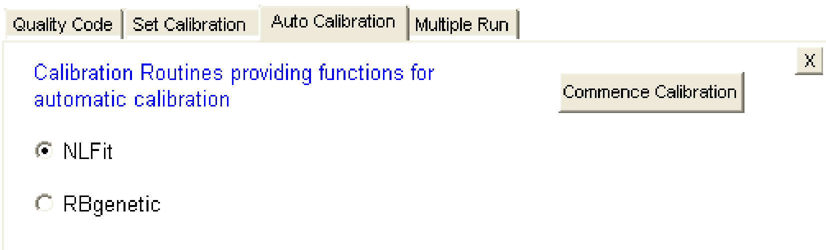
Up to 5 “bad“ data values can be set, and these are remembered when you leave and re-enter the program.

11.2.3.2 Set Calibration



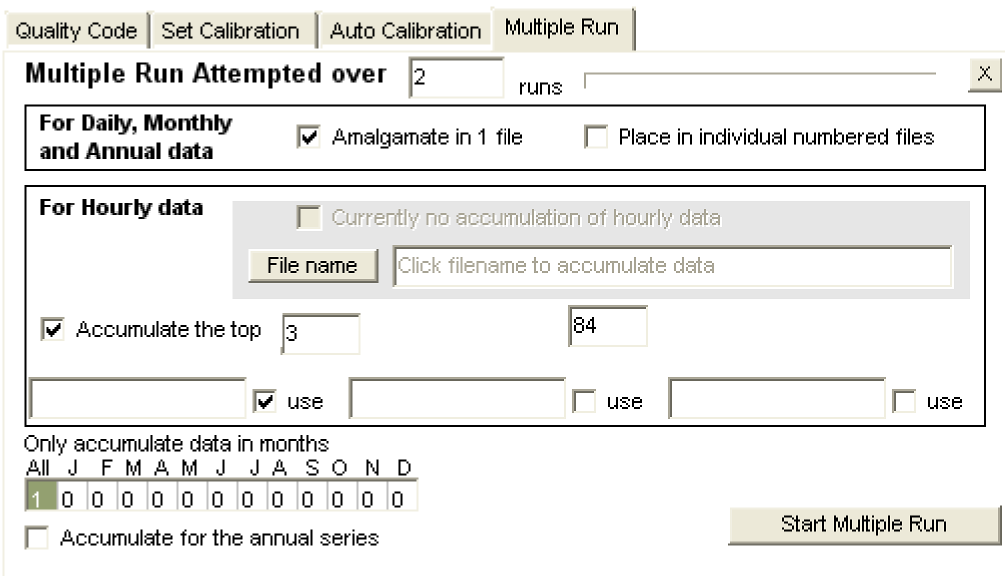
This operation is described in detail in the Tools manual

11.2.3.3 Auto Calibration



This operation is described in detail in the Tools manual

11.6.1.4 Multiple Run



Multiple run is set up to perform multiple runs with sets of generated rainfall data. The usual purpose is to provide better definition of extreme events. The model may be run with daily or sub-daily time-steps

The program is designed to run only up to 200 years in one run. Generated data is therefore best bundled into lots of 100 years. Each bundle of 100 years uses rainfall data with file names incremented for every run step.

For example, if you are using two rainfall stations called adel.rai and belair.rai the rainfall file names required for multiple runs will be

adel1.rai, adel2.rai, adel3.rai, ...>

belair1.rai, belair2.rai, belair3.rai................>

The rainfall data must be stored in the same locations as you would store single file runs. However, as the multiple rainfall data is often used for many different projects it is probably best stored in the "raindata" folder where it is accessible to all projects.

To initiate the multiple set run, you must first complete a single set run, as you would do normally, through clicking Run/RUN via the Header Bar menu. In this first run use the normal rain file names (eg adel.rai, belair.rai with no increment numbers), set the run duration (eg. to 100 years) and select the required output options for the subsequent runs. This single run therefore sets up of the output formats ready for a multiple run.

Under **Multiple Run attempted over** set the number of runs.

The entry boxes below determine the manner in which the output is to be presented, depending on whether the time-step is daily or sub-daily. 100 runs of 100 years creates 10,000 years of potential output data, ie 3650,000 potential daily values or 24 times this for hourly values. Because of these large numbers of potential outputs, the presentation of output data for daily and sub-daily time series data is handled in a different manner.

For **daily time-step data**. During a WaterCress project run, output data is accumulated as daily, hourly and annual totals which are listed in the project folder in the adaily.csv, amonthly.csv and aannual.csv files. For the multiple run, options are provided to either i) list all the outputs into one long file for each accumulation, hence all the output will be placed in single adaily.csv, amonthly.csv and aannual.csv files or ii) output data for each run will be placed in individual files adaily1.csv, adaily2.csv ....>, amonthly1.csv... > aannual1.csv...> files will be created.

For **hourly time-step** data

For hourly then the accumulation method allows for significant filtering before data is saved thereby reducing storage space

If you are running an hourly model, and you wish to store hourly data, firstly you need to set a file in which to store the output data.

The options to filter data are limited at this stage as this section , particularly hourly modelling, is under development. The option provided allows you to record the top "n" hourly values of a particular variable for each year. This enables you to search out the peak events.

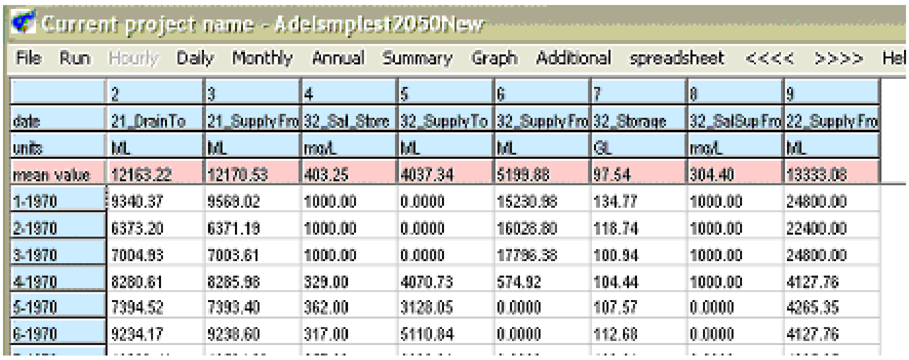
11.3 Area B and Area A, Headers Hourly… to Summary.

11.3.1 Initial Results Listing.

As soon as the "program complete" window is clicked 2 sets of results data become immediately available these are:

1. the time-series results for the output option set established under the Preset selected, These are listed under their Option abbreviated names in Area B, and
2. the summary data covering the water balance for each of the nodes in the project layout over the modelling period for which the model has been run. These are hidden until Summary on the Header bar is selected. The Summary is described in Section 11.3.3 below

The time-series of calculated results for the output option example shown above (Selection Preset 2) will be automatically displayed in the tabular Area B of the Output Screen, as shown below. The **Monthly values** are initially displayed. The results can be scrolled down on the RH scroll bar and will cover the selected period of the run (as set in **Run Information**). The results will be listed in the same order as they were selected in the **Output Options** window on the Project layout Screen.



	2	3	4	5	6	7	8	9
date	21_DrainTo	21_SupplyFro	32_Sal_Store	32_SupplyTo	32_SupplyFro	32_Storage	32_SalSupFro	22_SupplyFro
units	ML	ML	mg/L	ML	ML	GL	mg/L	ML
mean value	12163.22	12170.53	403.25	4037.34	5199.88	97.54	304.40	13333.08
1-1970	9340.37	9568.02	1000.00	0.0000	15230.98	134.77	1000.00	24800.00
2-1970	6373.20	6371.19	1000.00	0.0000	16028.80	118.74	1000.00	22400.00
3-1970	7004.93	7003.61	1000.00	0.0000	17796.38	100.94	1000.00	24800.00
4-1970	8280.61	8285.98	329.00	4070.73	574.92	104.44	1000.00	4127.76
5-1970	7394.52	7393.40	362.00	3128.05	0.0000	107.57	0.0000	4265.35
6-1970	9234.17	9238.60	317.00	5110.84	0.0000	112.68	0.0000	4127.76

The example shows the monthly time-series values listed for the 8 options selected for output via the Output Options window The selections covered selected outputs from node nos 21, 22 and 32 (ie. 2110..3205...2206). The headings of each column of results show the Node number (ie 21..32..and 22) and the abridged names of the output option and the units. The results will be shown initially by default at the monthly time-step. The whole list of monthly totals (or values at the end of each month) are displayed for each month listed at the LH.

Viewing the data at other time-steps, or in summary form, is described below.

The list can be scrolled down using the RH draw bar. The first and last entry will be those selected in the Runoff Information window.

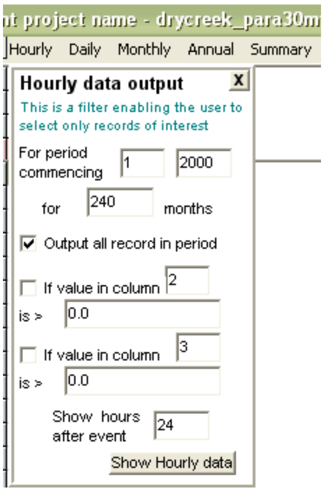
If the Preset contains more columns than can be shown oin the computer screen, the overflow can be displayed by using the horizontal scroll bar.

The average value of each time-series over the whole period is listed in the pink row near the top of each column.

11.3.2 Viewing the Results at other time Steps

By Clicking on Daily, Monthly or Annual in the Header Bar, the same data can be viewed at these time-steps. Beware, the daily listed data may take some time to be displayed if the data occupies a large number of columns over a long period of run time. Allow plenty of time for the daily results to be displayed. Occasionally it is best to display the annual results before displaying the daily results. The Annual listed results will be totalled for each year, with each year commencing at the month number entered into the month box at the Assess data from tab on the Run Information window). Note: The annual listed results for storages, water levels, etc. are the values at the end of the year.

Results for projects that have been run at time-steps less than **hourly** can be similarly viewed at the Hourly time-step by clicking the Hourly tab on the Header bar. However, since the hourly data is so extensive it can only be displayed in parts. Thus a window appears as shown at the LH which requires you to enter the period which you wish to view.



In the upper part of the window you are provided with a default choice of viewing all the data in all the tabled columns within a selected period of months. Alternatively, by entering values in the boxes in the lower part of the window, the tabled data can be filtered to only show that part of the data where values for selected data columns are greater than a selected level. This is particularly useful in windowing in on events which result in peak levels of flow rate, storage level, salinity etc.

The box at the bottom, enable a recession from the peak levels to be displayed over the number of hours selected.

Note that data run at time-steps less than hourly cannot be displayed at time viewed

11.3 3 Viewing the Results in Summary

Run Hourly Daily Monthly Annual Summary Graph Additional spreadsheet <<<< >>>> Help-off Hints Tutorial1

	1996-2008	DrainIn	WaterGain	WaterReuse	SupplyIn	SupplyReturn	WaterLoss	SupplyOut	DrainOut	Divert/Sewer	StoreChange	RainVo
	over 12 yrs	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML
1	c1-RuralCatch	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	1207
2	c1-City	292.89	53.05	0.00	172.56	73.52	0.00	0.00	345.94	73.54	0.00	0.0
3	c1new-City	0.00	292.40	0.00	930.71	434.24	0.00	0.00	292.40	434.35	0.00	0.0
4	c1-FlowModification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
5	c2-RuralCatch	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	1975
6	c2-City	45.77	98.35	0.00	378.74	135.44	0.00	0.00	144.12	135.48	0.00	0.0
7	c2new-City	0.00	44.98	0.00	149.90	66.53	0.00	0.00	44.98	66.54	0.00	0.0
8	c3-RuralCatch	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	126.
9	c3-City	68.20	180.10	0.00	688.51	249.50	0.00	0.00	248.30	249.56	0.00	0.0
10	c3new-City	0.00	68.15	0.00	227.50	101.01	0.00	0.00	68.15	101.03	0.00	0.0
11	c2-FlowModification	12882.34	0.00	0.00	0.00	0.00	544.81	0.00	12337.52	0.00	24.85	0.0
12	c4-RuralCatch	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	407.
13	c4a-RuralCatch	0.00	1.03	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	2567
14	c4-City	200.06	171.69	0.00	650.82	232.15	0.00	0.00	371.75	232.20	0.00	0.0
15	c4new-City	0.16	101.22	0.00	338.27	150.17	0.00	0.00	101.39	150.21	0.00	0.0

Change	RainVolIn	EvapLoss	CostSupFrom	CostSupTo	LocalRain	CatchRain	CatchR-off	R-offCoeff	CatchArea
	ML	ML	$/ML	$/ML	mm	mm	mm	%	ha
00	1746.19	0.00	0.00	0.00	654.00	527.30	152.10	28.84	267.00
00	1747.30	0.00	0.00	0.00	592.30	500.80	142.00	28.35	624.00
00	1894.29	1878.06	0.00	0.00	505.10	475.40	60.90	12.81	3228.00
00	148.51	51.10	0.00	0.00	495.00	474.70	61.40	12.93	3258.00
00	382.53	133.35	0.00	0.00	617.00	497.50	250.90	50.43	62.00
00	3529.16	0.00	0.00	0.00	641.70	517.40	144.00	27.84	550.00
00	1581.46	1542.77	0.00	0.00	592.30	504.40	101.60	20.15	817.00
00	3587.32	3533.73	0.00	0.00	540.50	432.90	8.10	1.87	663.70
00	806.11	240.69	0.00	0.00	510.20	408.60	225.10	55.10	158.00
00	0.00	0.00	0.00	0.00	0.00	505.10	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	505.10	463.10	41.20	8.90	4272.70
00	1478.05	0.00	0.00	0.00	671.80	538.10	164.50	30.56	220.00
00	1549.07	1520.04	0.00	0.00	575.90	495.80	79.70	16.08	489.00
00	72.89	25.46	0.00	0.00	560.70	501.70	95.40	19.02	812.00
00	162.61	56.41	0.00	0.00	560.70	449.10	240.60	53.57	29.00

Clicking on **Summary** in the Header bar brings up the window shown in the two half figures above (they are continuous across the Output Screen and the window has to be scrolled horizontally and/or vertically to reveal its full extent.

Basic information on the water balance and costs, averaged over the total period of the run, is displayed for each node present within the project, as listed in node numerical order on the LH column. The summary information for each node is presented on one line per node within the 4 colur coded columns.

The first (red) set of 9 data columns defines the balance for flows passing through each of the nodes. The basic balance for most nodes is simply:

DrainIn + WaterGain +SupplyIn – WaterLoss = DrainOut + SupplyOut +/- StoreChange

Where:

DrainIn is the sum of all inflows via drainage paths from upstream nodes

WaterGain is the runoff generated by rainfall on the node itself (inc rainfall on storage surfaces)

SupplyIn is the sum of all inflows via water supply paths from upstream nodes

Waterloss is the loss from surface water flows or storages in the node itself (inc evap and seepage losses from storages)

SupplyOut is the sum of all outflows via supply paths to downstream nodes

DrainOut is the drainage out via the mainstream drainage path (which for most nodes and/or in most circumstances will be the only outflow drainage path)

StoreChnge is the change in any storage contained within the node over the total period of model run

WaterReuse, SupplyReturn and Divert/Sewer are used in situations where recycling and/or diversions are involved:

The diagram below shows a hypothetical node containing flows relating to all the column headings and their relationship (with example flows). The sum of the Node Inputs plus the Net Gain from the processes within the Node equals the sum of the Node Outputs as given by the equation at the top of the following diagram showing which Summary Outputs are relevant to each of the project node components.

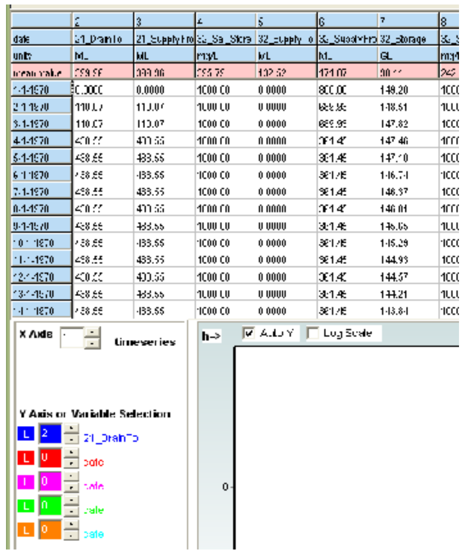
The 2 columns in yellow contain the estimation of the total rainfall volume falling onto the node and the total loss by evaporation from the node surface.

The section in green will provide the cost of water supplied to and from the node per unit of supply. This information should be ignored until adequately verified.

The section in blue at the RH end shows basic information about the catchment rainfall and runoff, both with respect to the node itself and to the catchment upstream of the node.

The Summary provides a very quick overview means of assessing the performance of a project and its individual components. Further detail on the performance of all aspects of each node is provided via time-series contained in the Hourly,..Annual listings (described above) and via the other facilities for exporting, graphing and statistical analysis (described below).

11.4 Area B. Time-Series Graphs



Area B is reserved for displaying time-series graphs of the data tabled in Area A or X-Y graphs where one set of tabled values are plotted against another.

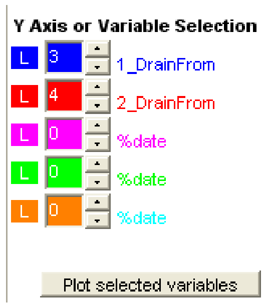
Both sets of graphing are selected by using the set of 6 toggle buttons at the LH side of the graphing area.

Each of the toggle buttons may be set at one of the number of the columns in the table above. In the example shown 7 whole columns are shown. Up to 18 columns may be displayed.

The top X-Axis toggle button is defaulted to 1. This refers to the column number in the tables in Area A above. It can be seen that Column 1 contains the time steps and thus when displaying its default value of 1, then the graph becomes a time-series plot. Alternatively where a value other than one is placed in this window an X-Y plot is produced between the X column specified and Y values for the first and second y columns specified (The red and the blue traces).

11.4.1 Plotting Outputs

11.4.1.1 Time Series Plots



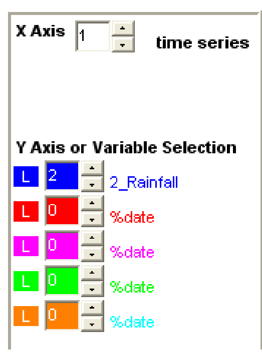
The columns in the spreadsheet are numbered and plotting the times series is simply a process of placing the appropriate number in the variable selection box. For example if you wish to plot column 3 and column 7 then, on the blue Graph Window click the up/down arrows to make it read column 3 and on the red Graph Window click the up/down arrows to make it read column 7, then click **Plot selected variables**.

The “L” to the left of the graph number indicates left axis. Clicking on this toggles the axis between left and right. (L or R)

Scrolling through the graph is either by the arrows on the top menu, or better, by clicking on the spreadsheet and using page up and page down (or arrow up and down) on the keyboard. The point highlighted on the spreadsheet (unless the end of the data is reached) is the left most point on the graph

Graphing can be made for hourly, daily, monthly and annual by selecting the appropriate summary step from the top menu bar.

11.4.1.2 X-Y Plots



The input boxes to the left-hand side of the graph sheet provide inputs to the graph. The 5 coloured windows identify up to 5 traces that will appear on the graph. Selection of the required spreadsheet column will plot that variable in time series. Values of "0" will not plot a trace. The white window defines an X axis variable, which should be set equal to one for a time-series plot, but can be reset to allow X-Y plotting.

An X-Y plot of the spreadsheet can be made by changing the X axis input box to identify a column in the spreadsheet greater than 1. Currently only two Y axis variables can be selected for this option, these being the top two (blue and red) edit windows. Once the inputs are set, click on the **Plot Data** button to view the graph.

A separate graph is displayed (banded in green) which may be relocated to enable the viewing of both the x-y plot and time series simultaneously.

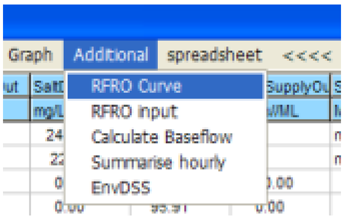
To relocate this graph and/or adjust the axis "right" click on the colour band surrounding the graph to raise the graph setup window. Click on one of large, standard, medium or small options. The range and form of the graph can also be adjusted from this window.

To go back to a time series plot simply return the x axis edit box to 1.

11.4.1.3 Annual rainfall-runoff relationship

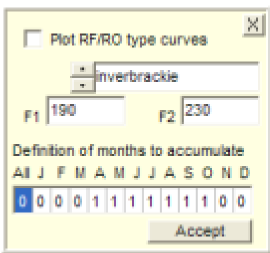
Capacity is available to accumulate the catchment rainfall throughout the year and compare it to either recorded or modelled runoff results. The results can then also be compared to a tanh curve allowing the tanh parameters to be adjusted to fit the modelled or recorded data.

Access to this facility is from the "**Output Page**" through the menu item **Additional/RFRO** curve.



Clicking here provides a dropdown menu which allows you to toggle whether you want the tanh curves plotted. Choose tanh parameters calibrated for other catchments or provide your own parameters F1 and F2

Define the period of the year that you want rainfall accumulated.



The third option here allows you to plot winter vs annual runoff plots, often which give better a better fit in some climates.

To accumulate all months either click on the All box or select "**1**" in every box of the selector. To choose winter months or any months click to ensure that there is a "**1**" only on the months you want accumulated.

Once you have set the months required you must run the program again, then you are able to graph the tanh curves.

Catchment rainfall is accessed from the the standard output provided in the **output options** selector seen in this list as **Catch Rain** in most components (refer section 6.1). Catch rain is the area weighted rainfall of the catchment based on the rainfall stations and rainfall station factors you have used and the areas of each individual catchment node. **Catch rain** as described above is affected by your request of which months you wish to be included. ie it is the rainfall accumulated for the year for only those months you have requested.

If you are only using a single rainfall file, you may use the simple rainfall output (output variable 1 refer section 6.1) as the x axis value. This ofcourse can only be the annual value, ie specific months cannot be chosen.

Also on the "output options" selector you would select **Catch ro depth** (runoff depth) and possibly (if a calibration file is provided) **observed ro depth**. The former being the amount the model thinks occurred the latter is the value from a recorded data input file.

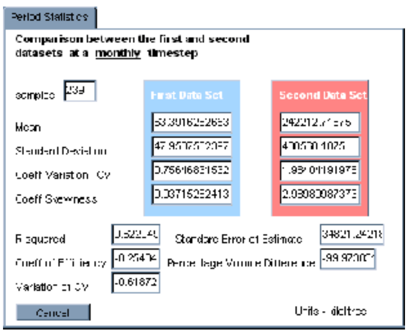
To plot these three values once the program is run:

- select annual on the top menu item. As it is annual you wish to plot.
- place the column number of the rainfall in the **X axis** box (see information on graphing XY curves)
- place the numbers of the runoff columns in the blue and red positions of the **Y axis variables**
- Click "plot selected variables" and a green XY graph will appear.
- If you have also ticked **Plot RF/RO type Curves** a line trace of the tanh curve based on your requested curve parameters will also appear.

The tanh curve can be fitted by changing the values of **F1** and **F2** and clicking **plot selected variables** again.

11.5 Area C Central Tendency

When monthly or annual is selected, statistics are completed over the total period of record requested. For daily, statistics are completed over the total daily record requested.

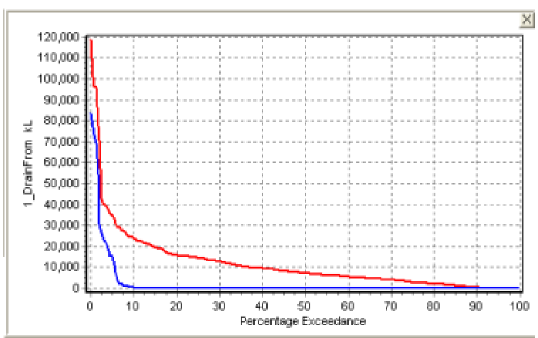


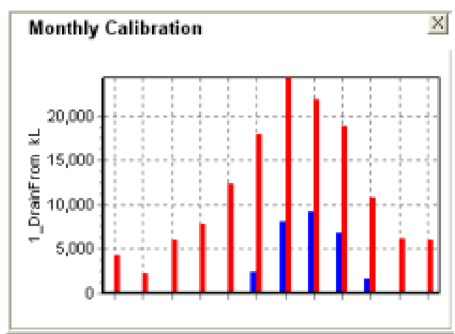
The statistics are calculated when the **Central tendency and Variability** button (lower LH corner of the screen) is pressed, and three windows (two are graphical) are displayed.

This statistical output is often used to calibrate a rainfall runoff model, hence a range of comparison statistics are also provided comparing the first data set to the second. (see also Section 12). These access how the first data set is related to the second providing the

- R^2
- Coefficient of Efficiency
- Coefficient of Variation
- Standard Error of Estimate
- Percentage Volume Difference

A flow distribution curve is included which shows the percentage of the time certain flows are in exceeded. This provides a direct visual comparison of the two variables chosen, and as for statistics, only includes the data deemed "good".





A monthly comparison is provided to enable an assessment of the comparable timing of the comparison variables. This output only occurs when monthly output is selected.

11.6 Area A. Remaining Headers

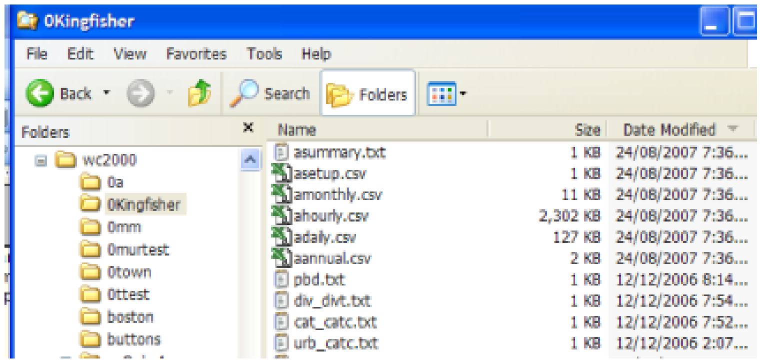
The remaining Headers are File, Graph, Additional, Spreadsheet and <<< >>>. These are described below.

11.6.1 File

The options available under File are shown in the window at RH. Each are described below.

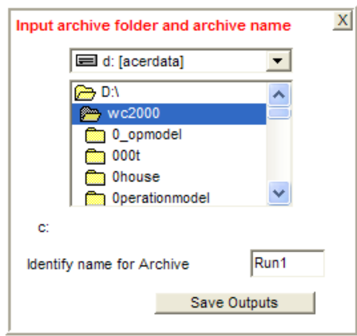
11.6.1.1 Save Current Run

When you run a WaterCress project, 5 files containing the annual, monthly, daily, hourly timeseries and summary results of the last run are automatically updated as aannual.csv, amonthly.csv, adaily.csv, ahourly.csv and asummary.csv as csv files within the project folder. (See centre top RH).



If you wish to save the contents of these files for a particular run before they get updated by the results of the next run, you must save them under a new name and place them in an archive of your choice.

When you select **Save current run** the directory selector appears allowing you to select the name and location of where the archive files are to be placed. Double click within the selector to navigate through and select the archive folder. The path selected is displayed below the directory selector.



When saving an archive these names have the archive name appended to the front. For example "aannual.csv" is renamed "Run1_aannual.csv". The archive name appended can be 6 characters max. Note the "_" is added automatically and is not included in the archive name.

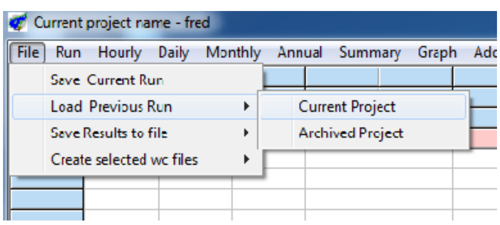
Click "save" to save the archive file .

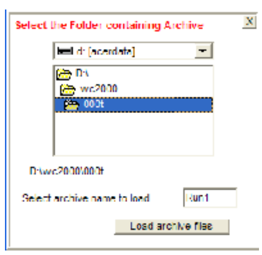
11.6.1.2 Load Previous Run. Accessing the last run or a saved run

If you have used **Save Current Run** previously to save the results of any particular runs, you may restore them back for display on the output results screen by going back into the archive and selecting the run name of the run you wish to display. This gives a quick way of comparing aspects of different results.

The user selects either

- Current Project – to load the last run stored in the project
- Archived Project – to specify the archive to load. This option will lead you to a second screen to define the location of the archive and archive name.





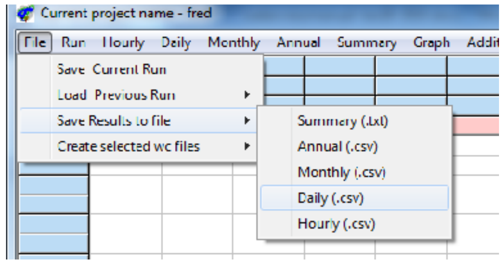
The directory selector allows the directory containing the archive files to be identified. Double click within the selector to navigate through and select the archive folder. The path selected is displayed below the directory selector.

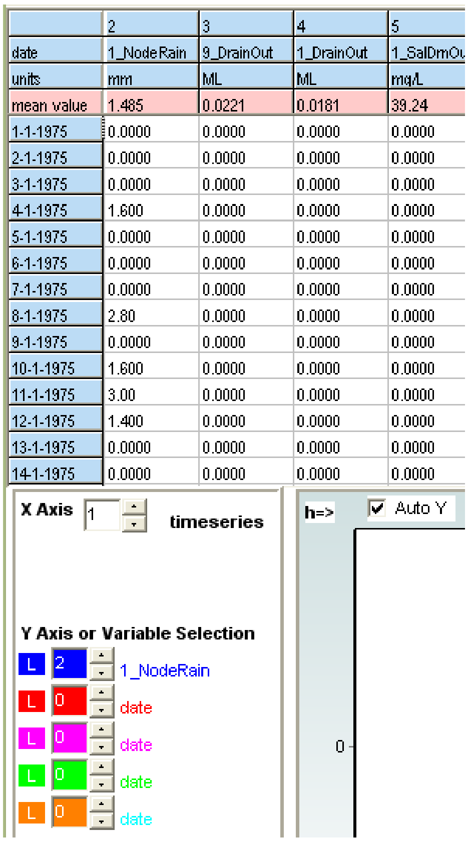
The current run files are named "aannual.csv" etc., and the archived files are renamed "Run1_aannual.csv", etc. The archive name appended can be 6 characters max. Note the "_" is added automatically and is not included in the archive name.

Clicking "Load archive files" will load and display the 5 time series files.

11.6.1.3 Save Results to File. (One at a time)

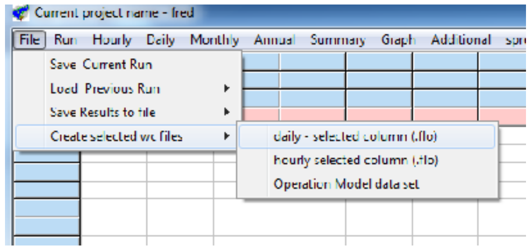
An alternate to **save current run** that saves only one results output at a time. Often a more polished output display or complex computations/analysis of the results is required which is not readily available in the *WaterCress* output. The program therefore provides the facility to export any of the results listed above (one at a time) to an external spreadsheet such as Excel.





When "Save results to file" is clicked a window appears in which you select the which of the results you wish to save. If you wish to save more than one of the listed options, each has to be separately saved and (if required) merged in (say) Excel. The results are saved as csv files. The program will lead you through naming the file and selecting a location for the file to be saved.

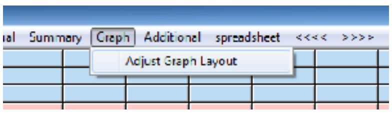
11.6.1.5 Create Selected WC files



Any one of the listed time-series results given in the results table as shown at RH can be selected and reformatted with its individual time/date information in order to be suitable as a WaterCress input time-series data file for future model runs.

The method of selection of the results column to be turned into the file is by noting its column header number and then selecting this number on the top (blue) Variable Selector toggle buttons below (Screen Area D). Clicking on the respective 'daily or houly selected column (flo)' (depending on whether the time-series is daily or sub-daily) will bring up a "Save As" windows where the name and location of the file is to be saved.

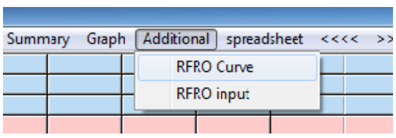
11.6.3 Graph



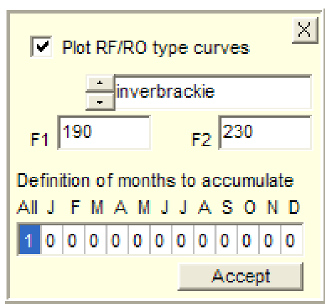
Allows the formatting of the graphs provided on the screen. This can also be accessed by right clicking on the graph in question.

11.6.4 Additional

11.6.4.1 RFRO curve



When plotting annual rainfall runoff relationships this option allows a tanh curve to be automatically plotted for comparison purposes. This is only available when the X axis graphical input is set to a value other than 1



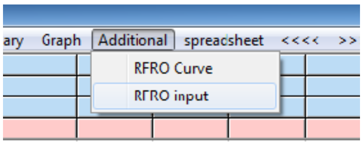
Typically the X axis would be set to the column number holding the rainfall information and the Y axis could then display up to 2 columns (flow usually in depth units) defined by the user by placing their column numbers in the blue and red traces.

When plot graph is pressed a X Y plot of the rain runoff relationship is displayed plus (if requested by the user via the tick box) a tanh curve (of user requested shape set by F1 and F2).

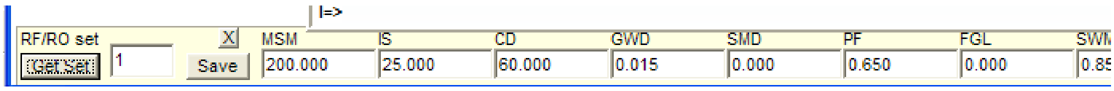
Often a plot comparing winter (or other) rainfall and annual runoff provides a better correlation, and by selecting which months to accumulate the user can customise their assessment.

The definition of months to accumulate determines which months are accumulated in the catchment rainfall output parameter. Note it does not affect the node rainfall output parameter.

11.6.4.2 RFRO input



This option places the parameters used for the rural rainfall runoff model on the output screen. This is simply for ease of calibration allowing the used to remain on the output page while running various runoff options.



Choose the set you wish to modify and change and save as required.

11.6.5 Spreadsheet

Simply adjusts the number of columns being displayed (hence adjusts the column width).

11.6.6 <<< >>>

Used to toggle through the data thereby scrolling the graphs across the data. This is also obtained by clicking on the spreadsheet being plotted which will toggle the graph displayed to commence at this point. Clicking the up and down arrows or the page up and page down keys on the keyboard will also scroll both the spreadsheet of data and the graphs.

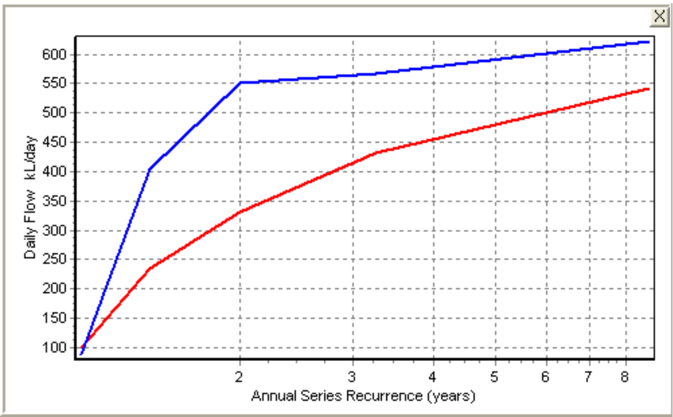
11.7 AREA B Statistical Output

11.7.1 Flow Return and Spell Statistics

11.7.1.1 Flow: Annual Series

The annual series is calculated by finding the maximum daily flow event within the series for each year, and then ranking these to determine their return period.

Run the option by selecting annual series and clicking "**Calculate Requested Statistic**" to produce graphical output:



11.7.1.2 Flow: Partial Series

The partial series is calculated by identifying all of the flow peaks in the record (perhaps many each year) and then ranking these to determine their return period. To do this you must define where one flow period ends and another begins. In this model you may define the break between the events by meeting 2 requirements of flow. These are input as **Threshold** and **Break** and their input is made in the two edit boxes between the two yellow bands.

A flow sequence is considered completed (or broken) when the flow falls below the threshold flow for a period of sequential days defined in the edit window break (in the units shown).

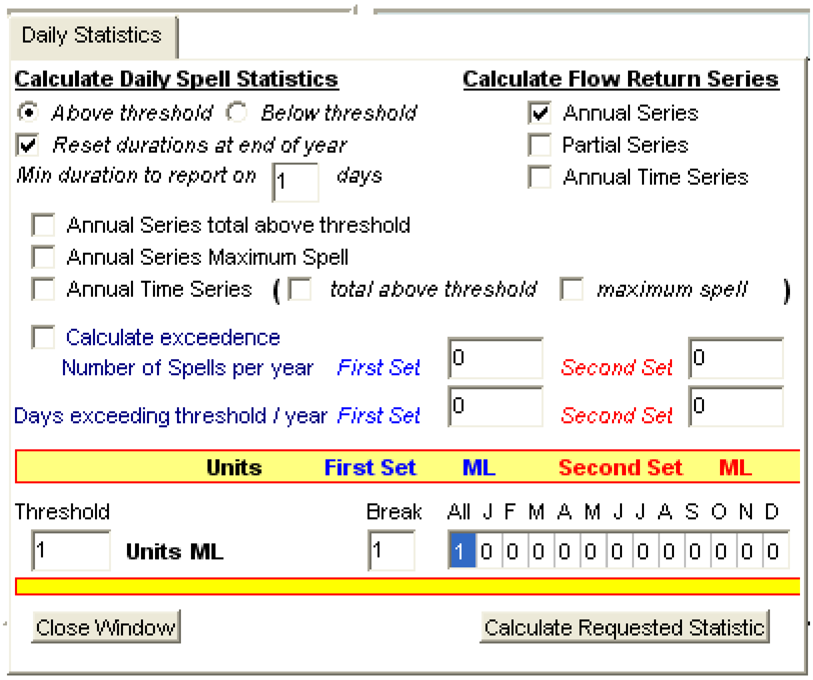
If this criteria is not met the program assumes that the flow record is continuous even over yearly breaks. Selection of these breaking criteria is critical to ensure a reasonable result is obtained.

Rather than there being only one record per year, as for the annual series, there may be numerous events, which are then plotted against their return period. The calculation of partial series return period is therefore not as obvious as for the annual series. For this program the return period is calculated as per rules defined in Australian Rainfall and Runoff (see reference).

Run the option by clicking "**Calculate Requested Statistic**" to produce the graphical output:

11.7.2 Spell Statistics

Spells are defined as the number of sequential days that the flow lies either above or below a specified threshold value. This is an important issue in calculating environmental flows where usage may affect how often certain areas of a river are wetted or inundated.



Here you may select either an above or below threshold calculation. **Above threshold** tracks the duration of time the flow lies above the threshold flow i.e. the duration of high flow events. **Below threshold** tracks the duration of drought or low flow periods. A spell is defined as broken, using a similar procedure to partial series assessment, when it meets 2 requirements of flow. These are input as Threshold and Break, and their input is made in the two edit boxes between the two yellow bands.

A spell is considered broken if the flow falls either above or below the threshold flow for a period of sequential days defined as break.

When tracking spells they may extend over one year into the next, or you may elect to reset the duration to zero at the beginning of the year. It is certainly possible that the spell of low flow events may exceed 365 days. This is done by checking the **resel durations at end of year** check box in the window, which if checked, will zero the spell at the start of the year.

The report displays all spells from 'n' to 'maximum' days, the value of n may be changed to a number > 1 in the "minimum duration to report on" edit box.

11.7.2.1 Spell: Annual Series - Total above Threshold

The Annual series will report and plot the total number of days that the flow exceeds the threshold each year against its return period (for calculation of return period refer annual series for flows above).

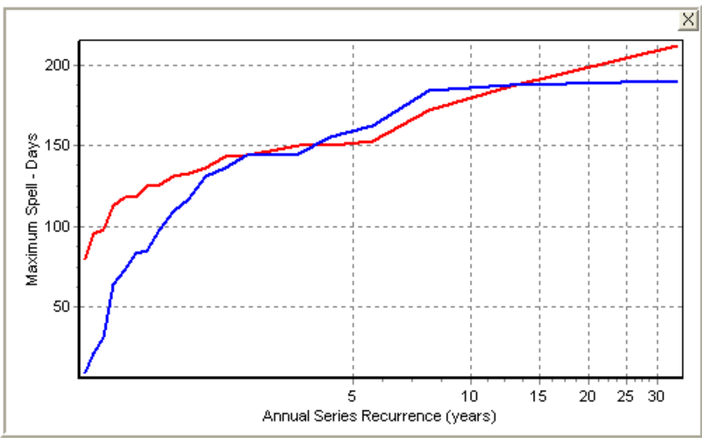
Run the option by clicking **Calculate Requested Statistic** to produce graphical output.

11.7.2.2 Spell: Annual Series - Maximum Spell

The Annual series will report and plot maximum duration unbroken spell (either above or below the threshold, as requested) occurring each year against its return period (for calculation of return period refer annual series for flows above).

Run the option by clicking "**Calculate Requested Statistic**" to produce graphical output.

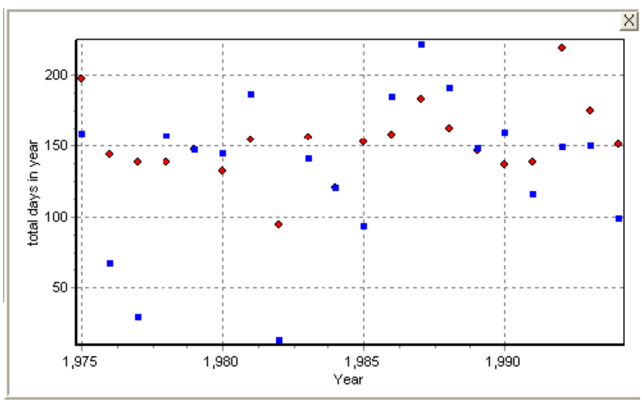
Both Annual Series Graphs look like:



11.7.2.3 Spell: Annual Time Series

A time series plot of the spells is available in two forms:

1. An annual time series plot of the total number of days that flow is either above or below (as requested) the threshold each year
2. An annual time series plot of the maximum spell period for each year. This is the longest spell in the year which meets the specified break requirements.



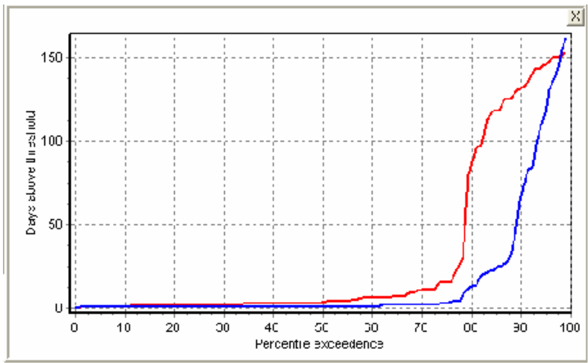
The required option is specified by ticking the annual time series and the required option. Run the option by clicking **Calculate Requested Statistic**

11.7.2.4 Spell: Calculate Exceedence

When running the percentage exceedence option all of the lengths of spells found in the record are ranked from shortest to longest. The resulting exceedence probability plot indicates the frequency that a spell of a particular length may occur. This may be used when examining streamflow requirements to meet a particular environmental need which requires a specific duration (such as fish breeding). Direct comparison of a landuse impact can be made between the records.

Run the option by clicking "Calculate Requested Statistic" to produce output as:

1. A graphical output displayed on the green bordered graph.
2. The mean number of spells per year.
3. The mean number of days per year that the flow exceeds the specified threshold.
4. From these the mean and median spell length can be found



12. MODEL CALIBRATION

12.1 Steps in Calibration

Calibration is most often carried out in order to compare the modelled flow results with those measured at a gauging station and to make adjustments to the rainfall-runoff model to reduce the differences as much as possible.

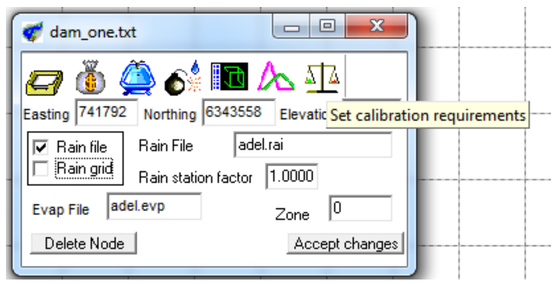
The fundamentals in performing calibrations are:

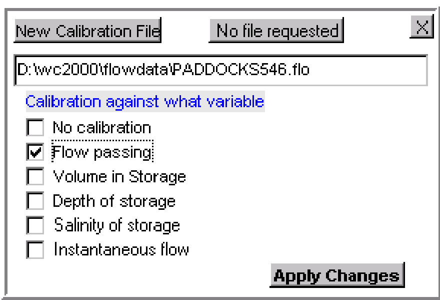
- to enter a file into the model at the appropriate location providing a record of the flow at the gauging station (observed data) over a sufficient period to allow a meaningful comparison with the modelled flow (modelled data).
- to identify and omit from the comparisons any periods of poor quality data in the observed data so that the model will only be calibrated against good quality data.
- to recognise the many statistical means for comparing the two records and to select those that are most pertinent to the purpose of the project modelling (ie long term average yields, seasonal yields, peak flow rates, base flow recessions, etc.).

Each of these steps are described below.

12.2 Entering the Calibration Data

The path to a calibration file is via the Balances icon in the data entry header of most nodes. This is found by right clicking on the node in question then selecting the balances calibration tag shown at the RH figure. This will raise the calibration input window shown below.





A calibration file can be entered by clicking on "New Calibration File" and following the file location prompts. For this example, folder D:\wc2000\flowdata contains the file PADDOCKS546.flo file. Note the full path name is used for calibration files.

As the file contains flow information tick the box "Flow Passing" to identify this. If the calibration is to be done using some other measure, and the loaded file contains this type of data, then the appropriate box relevant to this type of data must be ticked.

Flow passing is an accumulating variable. Ie input is daily and flowsare accumulated for monthly and annual results.

Volume in Storage, Depth of storage and Salinity of storage are non accumulating, and daily, monthly and annual results are taken as the end of period (month or year) values.

Instantaneous flow is a special case used in calibration of sub-daily data and is the maximum value in the period. For example for an hourly timestep, the values in the day month and year will be the peak flow recorded in that period.

Make sure you click **Apply Changes** to save the data to the node.

Only one calibration file can be input to each node. If more are selected via the Output Options selection window, only the first in the list will be processed. However, since the calibration file entered into one node may refer to the output of another node, if you wish to be able to compare to more calibration files than just the one, you can enter these into other nodes.

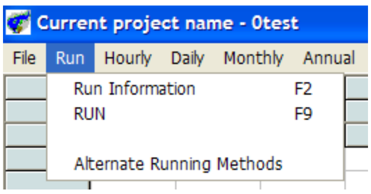
Note: the calibration files are accessed whenever they are ticked on. The model will then only run over the common period for which all calibration data is available. Calibration data can be switched off by clicking on the No Calibration box. The model will then run over the common period for which all other input data is available.

Reference to Section 10.4 shows that one or more of Output Options 36 to 39 must be selected for the node(s) in question that contains the calibration file name(s) and pathway(s). By including these selections in the output list, the data from the file(s) will become available for comparison with any other time-series calculated by the model and selected via other relevant Output Option numbers (eg Option 2, Drain Out).

Note: A calibration run need not necessarily be one where you compare a modelled output against a measured one. Often one model may be compared against another and an option is available to save a particular time series variable output as a file to calibrate (more correctly compare) against. Also provision is made to calibrate volume of storage in reservoirs, water level in reservoirs and salinity of flow.

12.3 Defining Good and Bad Data for Calibration

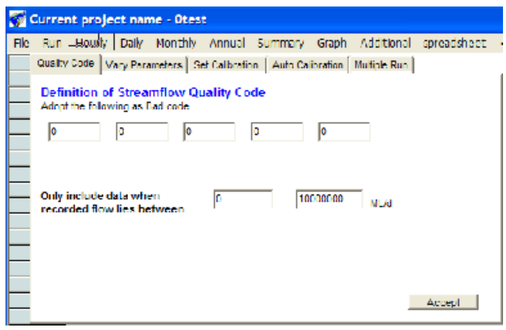
When a file containing recorded data is used (such as streamflow) it may contain periods of good and bad quality data. These types data are identified by quality codes and watercress allows you to complete comparisons on only the parts of the data you wish.



To do this it requires you to input what you identify as bad data. Up to 5 „bad data“ variables can be set, and these are remembered when you leave and re-enter the program.

To input this information select run|alternate running methods from the top menu. This opens a tabbed input window. Select the **Quality code** tab

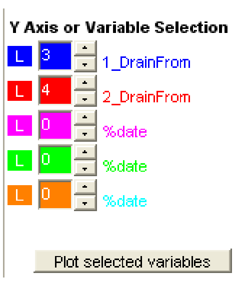
In one or all of the 5 edit boxes identify the quality code number that represents bad data, and click **Accept**.



Now when you request output data of type 36 and type 38 (True drain from and True observed data) only the good data will have values placed against it. The remainder will be zeroed.

12.4 Visual Assessment of Calibration Time-series Data

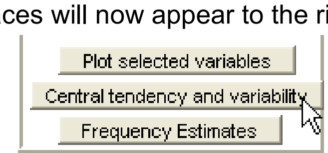
12.4.1 Time Series



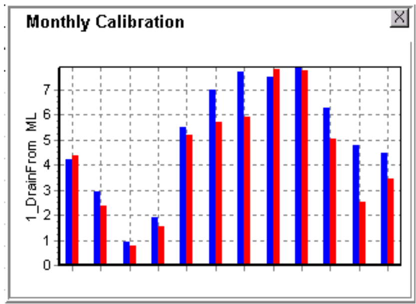
These comparisons can be plotted by selecting the appropriate columns in the graph variable selection window. While 5 columns can be plotted, direct comparisons are only made in the first two, the red and the blue traces.

In the example provided this would be column 3 and 4

Click **Plot selected variables** and Graph traces will now appear to the right. This graph shows a direct comparison between actual and modelled data. **Similar graphing can be made for daily and annual by selecting the appropriate summary step from the top menu bar and replotting the trace**.

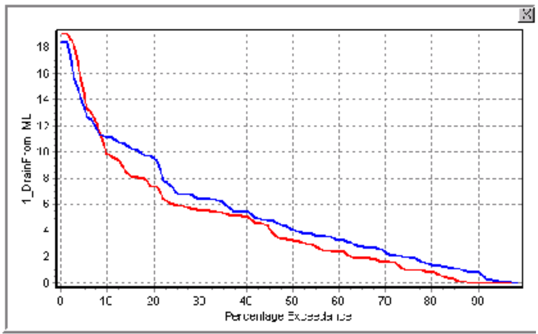


12.4.2 Seasonal (monthly) averages



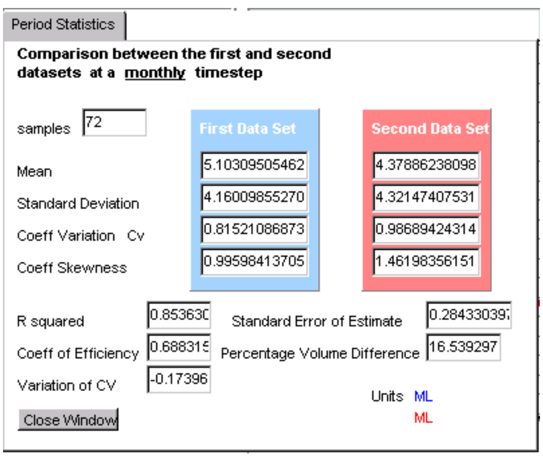
A monthly comparison is provided to enable an assessment of the comparable timing of the comparison variables. This output only occurs when monthly output is selected

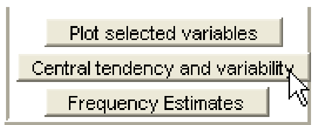
12.4.3 Flow Duration



A flow distribution curve is included which shows the percentage of the time certain flows are in exceeded. This provides a direct visual comparison of the two variables chosen, and as for statistics, only includes the data deemed "good".

12.5 Statistical Comparison of Actual and Modelled





Comparison statistics of the output data can be made by clicking the central tendency and variability button.

For the columns identified in the blue and red traces of the graph, summary statistics and comparison statistics are calculated.

When monthly or annual is selected, statistics are completed over the total period of record requested. For daily, statistics are completed over the total daily record requested.

This statistical output is often used to calibrate a rainfall runoff model, hence a range of comparison statistics are also provided comparing the first data set to the second. These access how the first data set is related to the second providing the

- R^2
- Coefficient of Efficiency
- Coefficient of Variation
- Standard Error of Estimate
- Percentage Volume Difference

The statistics are calculated when the **Central tendency and Variability** button (lower LH corner of the screen) is pressed, and three windows (two are graphical) are displayed.

13. FILE NAMES, LOCATIONS AND FORMATS

13.1 File Names and Extensions

All data files must be identifiable in text file format (ie. name123.rai or name1999to2007.flo). The "rai" or "flo" extension types are not mandatory, although they are useful for identifying the contents of the file. No spaces are allowed in the file name.

13.2 Expected File Locations

The wc2000 program is usually located on the main C or D drive. If you are using a model project already set up by a person who has set the program directory that is located in the different drive to your own, the locations of some files required by the model refer to that drive (ie D:/wc2000/myproject/filename) the model will not find that file and will not run, but will report which file it could not find, allowing you to go back and change the file path to suit your open drive layout (ie C/wc2000/myproject/filename).

The model program, when run, will generally always require access to a set of rainfall time-series files in order to initiate the flow contained within the water system being modelled. However there may be several other data files required to make the necessary calculations. These include calibration time-series files (eg flow data) and tabular type files (eg FEVA files) which must be i) located where the program expects to find them and ii) be in an acceptable format.

The locations (and means for the program to identify the locations) of all data files generally fall into two categories:

- the files are located in one of three nominated folders which are included in the model structure and are called automatically by the model program, or
- the files may be located elsewhere, in which case their location must be identified by their full path which must be enterred by the model user.

13.2.1 Rain time series data files

These files fall into the first category and are called automatically when located in one of three nominated locations, the first two of which must be contained in folders named raindata. The file will have the same name and extension as the name enterred into the rainfall window on the node.

- In the general data folder eg **<program_folder>\raindata\name.rai**. This raindata folder is a general repository for all data files used by the modeller for all his/her projects. It normally also contains evaporation and may contain flow data files)
- In a specially established additional **raindata** file established by the modeller in the project folder, eg **<program_folder>\myproject\raindata\name.rai** or name.evp, etc. This project folder will then only contain data specific to the project and avoids having all other non-project specific data also contained within the same folder).
- The rainfall file (name.rai) may also be located in the project folder (ie not in the raindata folder. Eg **<program_folder>\myproject\name.rai**. However, located here, the files may be visually difficult to spot amongst all the other files.

The order that the WaterCress program searches for the data within the 3 possible ’automatic’ locations is actually 3, 2, 1 as listed above.

Where no rainfall file is required for a node operation (eg for a tank) simply input “none”in the rainfall window on first node data entry window.

The **<program_folder>\raindata** folder is provided on installation of the model and is designed to be used as a central repository for the storage of rainfall data (and other time-series data) for all projects undertaken by the modeller. However, storing the data within the project folder offers some advantages if, for example, the project including all of its input data needs to be transported to another computer. This can then be easily done by just grabbing the whole project folder, which will contain all the necessary project folders and files in one ’grab’. The downside of storing the data files in the project folder is that it is not available for other projects.

13.2.2 Evaporation Files.

The evaporation file usually consists of the 12 average monthly pan evaporation values and may be similarly located with the same three options as the rainfall file. When actual evaporation data is available as a time series the evaporation values are listed as a second data series with the rainfall within the rainfall file. The evaporation is then recognised via the information entered into the file header (see 13.3 below). If actual evaporation data is used, the evaporation and rainfall data lists must start and finish together.

13.2.3 Time-series data files for Text Demand, Text Flow, Weir, etc.

These components do not require a rainfall file for their operation and use the rainfall data entry window to define the name of the text file containing the demand, flow or diversion data on which the node will be operating. These components therefore require that the files on which they operate are located according to the same rules as for rainfall data, as above.

13.2.4. Flow and Calibration files.

These files are provided with a full path name and therefore fall into the category of files that can be located anywhere and the information on their location is requested automatically when the window into which the data is entered is activated. It would be unusual to locate the files outside the wc2000 structure and thus the pathway to the file location may be entered by using the program navigator routine commencing with **<program_folder>** and following the pathway to the file. The pathway will then appear in the entry window.

13.2.5. FEVA, Image files.

These files also have a full path name provided and therefore may be located anywhere.

13.3 Time-Series Files Header Information

The header is the information that must be placed in the first line of the file immediately before the data list commences. The header identifies the locations and nature of the following data.

13.3.1 Rainfall/evaporation Files .

As a throwback to earlier versions a rainfall file does not necessarily need a header, but without it there are a number of limitations being:

- rainfall is assumed to be in mm
- the file only allows input of 1 variable following the date, **dd mm yyyy vvvvv.vv**
- the file can only consist of daily time-step data.
- no identification is provided on the data that follows.

For models using sub-daily data it is therefore mandatory that a header is included, and this is recommended for all files. The use of a header will also allow the inclusion of evaporation as well as rainfall.

The header must contain at least three word sets separated by spaces or commas. The example below shows five, which is also the maximum for a rainfall type file:

***comment, time-step, rainfallunits,qualitycode,units where**

***comment** (or more specifically the *) allows entry of any text up to 20 characters which helps identify the file and its content. Make sure no spaces are placed in this sequence, ie *LocationXrainfallwithgapsfilled NOT * Location X with.....

time-step defines the time step of the following data (see following list for acceptable definitions)

units must be the units of the rainfall (as above)

qualitycode (code) indicates that a numerical code is attached to each rainfall data entry to identify its quality or reliability. Different data collection authorities use different sets of indicators. In the case of rainfall data (unlike flow data) the quality code actually plays no part in the program logic and therefore both the qualitycode header and the quality codes in the data list may be omitted, BUT only if no evaporation data follows. If evaporation data is included, both the qualitycode header (code) and default numerical values for the rainfall qualitycode (eg. 1, or any other number) must be included for each of the rainfall entries in the list, else the program will get out of sequence in reading its data inputs.

evaporationunits (eg. mm) signifies that evaporation data (in the units indicated) must be read. An evaporation entry must then be included for each rainfall data entry. No qualitycode is provided for the evaporation data.

The header information and the data listing may be comma delimited instead of space delimited. Whichever method is used, both the header and data listing must employ the same method.

Examples of 3 and 5 word set headers will then look like:

***gawlerrainfallgapsfilled hourly mm**

***adelrainfall daily mm code mm**

***adelrainfall,daily,mm,code,mm**

In the second example above, the file will be providing both daily rainfall and evaporation data in mm. The actual quality code values in the data list will not be used, but the list must contain an integer number in this column. The data list must always contain the equal number of data column sets as are given in the header. Examples are given in 13.6.

13.3.2 Flow and Calibration Files.

The most common use of a time series file of flow data is to provide a comparison between flow recorded at a particular location with the flow generated by the model for the same location within the model, and to use this comparison to adjust (or calibrate) the model to give, as close as possible, a match between the two data sets. While flow is most often used for calibration, the Calibration file may contain any other recorded data which can be matched by the model operation, eg storage water levels, water supplied, etc. In the example below the calibration is assumed to be a flow file.

The calibration file header includes only the first four word sets listed for the rainfall file, but all four sets must be present.

A typical Calibration File containing flow data will have a header similar to the example below:

***StnNoXYZflow , daily , kL/day , qcode**

The file may also be comma delimited instead of space delimited. It is important that the qcode is present as this is used to identify good and bad data in the calibration process. (see 12.3)

13.3.3 Text Flow, Text Demand and Weir files

These time series data file inputs require information describing the units for the input data. Text flow may contain only flow or it may contain flow and salinity. If it contains only a flow column the header may look like:

***MannumAdelPumpRecords , daily , ML/d**

If the file contains salinity also then it would look like:

***MannumAdelPumpRecords , daily , ML/d , mg/L**

13.4 Other Files

13.4.1 FEVA files

Flow elevation volume area file (FEVA) contain 4 lines of header text and the remainder of the file is the feva data. A feva file is essentially a lookup table and can be used for numerous operations, for example the volume area relationship and the volume to flow relationship. These lines are identified as:

***feva -** The „*feva“ identifies to the program that this is a feva file and that it should follow the format identified for this file type.

The second line is simply a description of the file and is only for the authors benefit. It is not used by the program.

The third line provides the units for each of the columns of data that are provided in the file. See section 13.5 for recognised values

The fourth line provides the number of rows of provided data. The number of columns is always 4.

The remaining lines provide the input data with data values sprarated by a comma. For example a typical FEVA file will look like:

```
*feva  flow elevation volume area file
Kaurna Park - Helps Road drain
cumecs,m,ML,ha,
12
 0.0,  0.0,  0.0, 0.0
 0.0, 0.50,  3.0, 4.2
 0.0, 0.70,  7.0, 6.2
 0.0, 0.80, 15.0, 8.2
 0.0, 0.90, 30.0, 12.2
 0.0,  1.0, 40.0, 16.5
0.05,  1.05, 45.0, 16.5
0.5,  1.1, 70.0, 17
40.0, 1.15, 90.0, 17.1
50.0,  1.5, 489.0, 40.4
63.1,  2.0, 699.0, 42.1
92.9,  2.3, 843.0, 47.8
```

13.5 Recognised Header Time-step and Unit Definitions

The word sets used in the header to indicate the time-step and units of the data containbed in the following listing must be in a form recognisable by the program. The different word sets recognised by the program are listed below:

timesteps	Length or depth	Flow	Salinity
Daily Hourly 30min	m metre mm inch in	kL KL kL/day ML ML/day ML/hour GL GL/day cumecs cusecs	EC mg/l ppm grains

Inputting an unknown definition will cause the program to assume the units are in their base program units. These are daily, metres, kL/day, mg/l. If the program appears to be reading the wrong units, first check the header.

13.6 Time Series Data listing formats

This format can be either space or comma delimited, and no data can be missing otherwise the program will identify a data sequence error at the point of miss match. Time series data always commences with the time and date values and ends with the data values for that time.

The time and date data follows the format

day:hour:min,mm,year,data1,data2 (DD:hh:mm,MM,YY,xxx.xx,yyy.yy)

For daily data the format does not include a time value. It provides simply the day, month and year separated vy commas. For example a daily file will look like

11,3,2005,xxx.xx
12,3,2005,zzz.zz

For hourly data the format includes an hourly value appended to the day value and separated by a colon. For example an hourly files looks like

11:01,3,2005,xxx.xx
11:02,3,2005,zzz.zz

For sub hourly data the format also includes a minute value appended to the day and hour value and separated by a colon. For example a 30 minute timestep file looks like

*summerrd,30min,ML
11:01:00,3,2005,xxx.xx
11:01:30,3,2005,zzz.zz
11:02:00,3,2005,vvv.vv

or

*calibrate,30min,ML,code
11:01:00,3,2005,xxx.xx ,1
11:01:30,3,2005,zzz.zz ,1
11:02:00,3,2005,vvv.vv,99

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