SIMULATION OF DRY WEATHER FLOWS IN WALLRUS

Richard Marshall

Sheffield City Council

Design & Building Services
Drainage & Bridges Division
2 - 10 Carbrook Hall Road
SHEFFIELD S9 2DB
Telephone (0742) 734459

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Introduction

Over the years, through Lloyd-Davies, TRRL, WaSSP and now Wallrus, the ways by which dry weather flows in sewers may be allowed for or simulated have become slightly more sophisticated and realistic. However, the current facility in Wallrus for modelling diurnal variations in dry weather flow is based on a somewhat different concept to those used previously.

This paper will describe a way in which base flows may be simulated with minimum input but with maximum benefit. (Please accept 'base flow' and 'dry weather flow' as synonymous for the remainder of this presentation.)

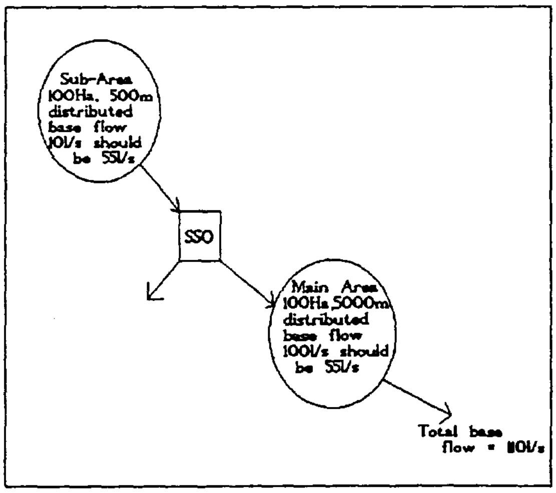
Dry Weather Flow in WaSSP

With WaSSP, the modeller may assign a base flow to any pipe length and may also specify a global base flow which is automatically distributed to all those pipes which do not have an individually allocated flow. This distribution is done on the basis of taking the sum of the individual flows away from the globally specified flow and distributing the remaining flow amongst those pipes with a zero allocation on a length pro-rata basis. (If required, entering a negative value will prevent any base flow being allocated to a pipe).

This method has two main short-comings. Firstly, the base flow in any pipe length is constant throughout the simulation period and secondly, considerable imbalances may occur when sewered sub-areas are used.

To expand on this second point;

Consider this layout. The sub-area is about the same size as the main area of interest but is modelled by only one tenth of the length of pipe network as the main area. The actual base flow contribution would be about the same from both the main area and the sub-area. The WaSSP modelled base flow from the sub-area would be only about half of the actual flow. Various problems could obviously arise when verifying such a system.



It is possible to get around this type of problem by carrying out a manual calculation and then attributing appropriate base flows to the pipes in the sub-area. There would still, however, be the drawback that the flows calculated would remain fixed for the duration of the simulation period. In reality, base flow can fluctuate considerably during the course of an event. If the rainfall intensity is on the low side or there is a significant degree of separated surface water drainage, then this fluctuation could have a noticeable effect and would have to be allowed for mentally when comparing observed with predicted flows.

Dry Weather Flow in Wallrus

Wallrus has tackled these two problems and far more realistic simulations are now possible. The fundamental differences are that a) the distributed flow is related to catchment area rather than length of sewer and b) one or more hydrographs may be designed to describe how the base flow fluctuates during the period of the simulation.

N.B. It is still possible to specify pipe length related dry weather flows as in WaSSP using Record 2, Item 9 and Record 18, Item 27. This could be useful to simulate constant inflows or infiltration into certain pipes, but it would be necessary to ensure that such inflow was allowed for when deciding the appropriate area based distributed flows. However, the author has generally found this to be an unnecessary complication when the process described below adopted.

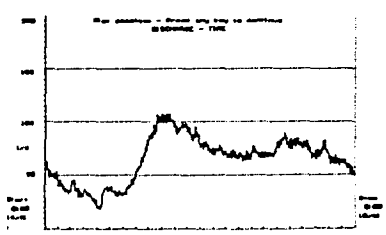
Dry Weather Flow Hydrographs

It is no secret that normal base flow is at a minimum during the night and has two distinct peaks during the daytime. There are, however, different ways of estimating the relationship between the peak and the average base flow (total number of litres passing a point in a 24 hour period with no precipitation divided by 86400).

During 1990, staff at Sheffield have been undertaking an in-house verification of a WaSSP/Wallrus model of the remaining section of the Don Valley Intercepting Sewer (DVIS). It was decided that the dry weather flow hydrograph facility should be used although this is not quite as simple as it would first appear. The dry weather flow hydrograph is in fact a series of dimensionless values which are used to vary a global base flow expressed in cubic metres per second per square kilometre and obviously there would need to be a considerable amount of manual taking off to produce a reasonable representation of the measured base flow.

Close inspection of the dry weather flows for this catchment at all of the appropriate monitor sites showed a close correlation in fundamental shape, whether the upstream catchment was mainly domestic or mixed domestic and industrial or whether the pipe was small diameter on a steep slope or a large rubble egg-shaped sewer next to a river. It was felt that, if this fundamental shape could be described in a computer, then it should be possible to produce a suitable set of hydrograph values to suit any location within the catchment and for any time period.

The Spreadsheet Solution



A monitor site which was fairly central to the survey and which had produced excellent results, including a good tight scattergraph, was selected and a 24 hour plot was smoothed by hand and 48 half hour values were estimated visually. These values ranged from approximately 10 l/s at 04.30 to a maximum of about 110 l/s between 08.30 and 09.00. There was a secondary peak of about 90 l/s around 19.30 and a small but consistent peak of about 35 l/s between 05.00 and 05.30. The timing of these peaks and troughs appeared to be consistent throughout the drainage area.

These values were entered into a spreadsheet and interpolated to produce 720 'basic' values at 2 minute intervals. In order to produce a complete set of values for any location, it is only necessary to give the maximum and minimum flows for that point. The value for each time increment is calculated from the formula:

$$Q_{rt} = (a - b) / (c - d) * (Q_{rb} - d) + b \qquad \text{where:-}$$

Q_{rt} = Required value at time t
a = Maximum diurnal base flow at required location
b = Minimum diurnal base flow at required location
c = Maximum 'basic' diurnal base flow
d = Minimum 'basic' diurnal base flow
Q_{rb} = 'Basic' value at time t

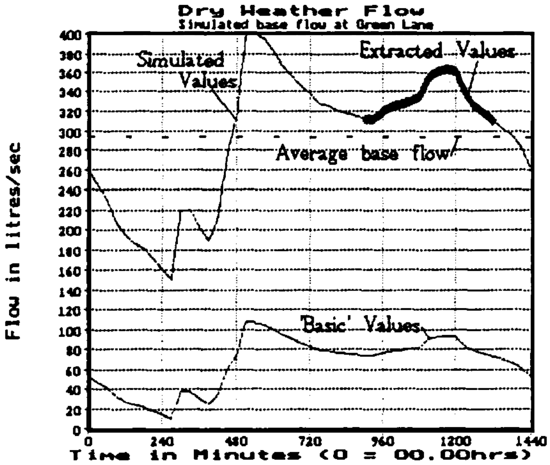
A simple graph was set up to display these basic and derived flows and a 24 hour set of derived values were checked against the monitored dry weather flows at each relevant location. The degree of correlation was remarkable.

If the start and finish times are given, the spreadsheet can extract the set of values required to simulate base flow for any period to a 2 minute increment. This graph shows:

☼ The lower trace is the 'basic' values.

☼ The upper trace is the simulated base flow at the outfall to the system being modelled, with the period of a particular event (15.00 to 22.00) highlighted.

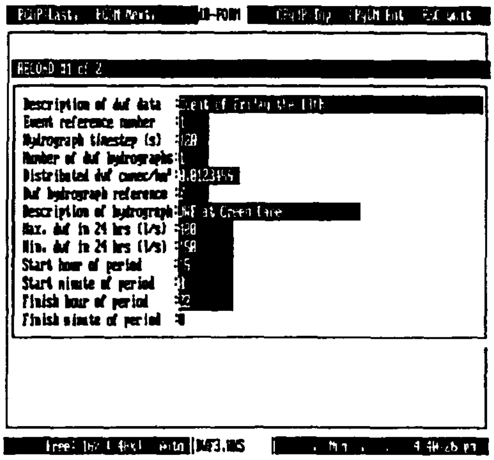
☼ The average simulated base flow is indicated by the broken line.



The next stage was to produce the required dimensionless hydrograph values which will be applied to the distributed dry weather flow for the period being simulated. The question is, what is the distributed dry weather flow to be fixed at? We know that it must be expressed in $m^3/s/km^2$, but it could be the base flow at time zero (midnight), the minimum at that location, the maximum at that location, the flow at the start of the simulation period etc.. In fact it does not matter as there is no restriction on the range that the dimensionless hydrograph must fall within. However the convention that has been adopted is that the maximum rate of diurnal base flow at the location in question is used; i.e. 400 l/s in the example above. This results in all of the hydrograph values being between 0 and 1.

Each of the extracted simulated values is divided by the entered maximum diurnal flow. The result is placed in a column in a part of the spreadsheet which has been specially adjusted so that a range may be printed to an

ASCII file complete with all of the other information required to make up a .DWF file.

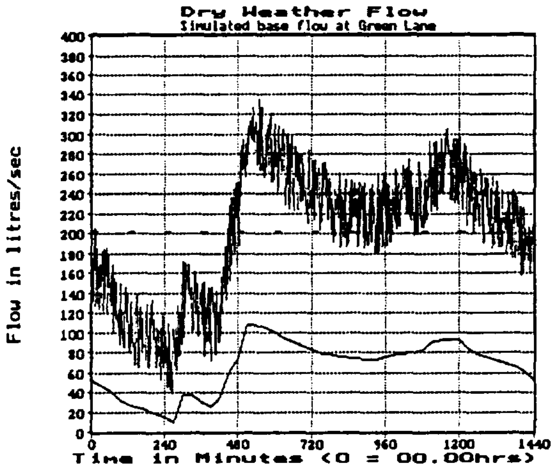


The simple database facility within the spreadsheet has been used to devise a screen which prompts the user for all of the required input. Also, a customised menu allows for viewing and plotting the graph, modifying the input, saving the file etc.

An important item which must not be overlooked is the derivation of the distributed base flow. It has been established that it is to be the peak flow during a 24 hour period at the outfall to the simulated system, but the area must be obtained from the .PRN file produced by Simulation Method Part 1 before this file is overwritten by the .PRN file from Simulation Method Part 2.

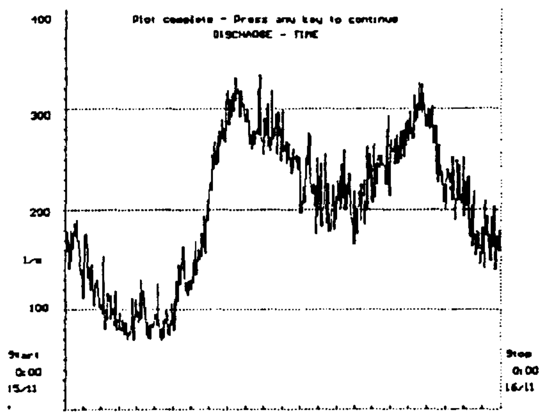
Conclusion

The technique described in this presentation has proved to be very useful in producing realistic simulations of base flows with very little effort and .DWF files are now used in Wallrus simulations in Sheffield as a matter of routine.



The spreadsheet approach was adopted as it provides an easy method of visualising results during the development process. However, having established that the method is valid, at least within Sheffield, there seems to be no reason why the production of .DWF files, using the theory outlined above, should not be available within Wallrus, in a similar manner to that in which .RED files are generated.

Finally, it is possible to add a further degree of realism by adjusting each simulated value of the base flow by a randomly generated chaos factor. The degree of randomness could be user specified to reflect the location within the sewer network. The example here (above) was generated by adding to each of the simulated values, for a particular time and location, a random factor of between -40 l/s and +40 l/s. The result now bears an uncanny resemblance to a typical monitored diurnal pattern (below).



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