

Do Green Roofs Provide Storm Water Attenuation?

The benefits of green roofs are well documented and established, but uncertainty remains as to whether they can provide attenuation and storage for storm water.

Earlier research papers have claimed that with a green roof you can expect no runoff for over 80% of the rainfall events experienced during a year. This sounds very impressive, however it is the remaining 20% of the storms that can particularly affect the design and performance of a drainage network.

Micro Drainage worked with the University of Sheffield to pragmatically model the runoff from a green roof. The outcome now enables a green roof to be modelled as part of a Sustainable Drainage System (SUDS).

The research considered the implication of a roof being saturated. Antecedent conditions play a substantial role in the performance of any drainage network. For this reason the SUDS Manual (CIRIA C697) specifies that an infiltration structure should be designed to half drain within 24 hours. The importance of the antecedent ground condition was demonstrated during the 2007 floods, where the series of rainfall events leading up to the main storm were recognised as a key contributing factor.

It is only reasonable within drainage designs to test networks under the same conditions. High levels of antecedent rainfall can limit the potential of the green roof to provide attenuation and storage. However, during the design process a conventional storage tank is only tested under dry conditions. The volume of available storage in the tank would likely be substantially reduced if it had recently rained.

With this in mind it seemed unfair to simply ignore the potential benefits of green roofs for storm water attenuation by applying scenarios above and beyond the tests applied to conventional storm water systems. Nevertheless, a suitable value for the level of water already held within the roof before testing had to be calibrated.



Antecedent Conditions

The research set out to establish a reasonable set of antecedent conditions calibrated to the UK climate but with user definable parameters. The initial study covered data collected from the University of Sheffield's test rig plus third party research conducted at various sites globally. It was decided that a reasonably conservative perspective would be to consider the retention expected after a two day antecedent dry weather period (ADWP). That is, the available storage would be based on zero rain falling on the roof for two days prior to testing, with a user definable option to adjust.

The research focused on developing a method to calculate the flows from a green roof discharging into the drainage system. Conceptually, it is equivalent to a unit hydrograph for the vertical flow through a soil substrate with drainage layers. The University of Sheffield calibrated an algorithm to calculate these flows. To complete this work the following two key variables were required:

1. Depression Storage – the depth of water that falls on the roof but does not leave it.
2. Lag Time – the effect that the various components of the green roof will have on flows leaving the roof.

Depression Storage

Some of the contention surrounding the level of storage that can be expected from a green roof originates from earlier research which assumes that the porosity of the substrate, based on oven dry conditions, implies a certain level of retention. This methodology has limited regard for rainfall and the 'living' aspect of a green roof, resulting in scepticism. To address these issues the calculated retention was based on measurements of rainfall and runoff from real storm events on an actual green roof. The results were validated by comparing with global research on a variety of green roofs with varying soil substrate depths and a range of drainage layers. The data analysis resulted in a depression storage value between 3 to 5% of substrate depth, for an ADWP of 48 hours.

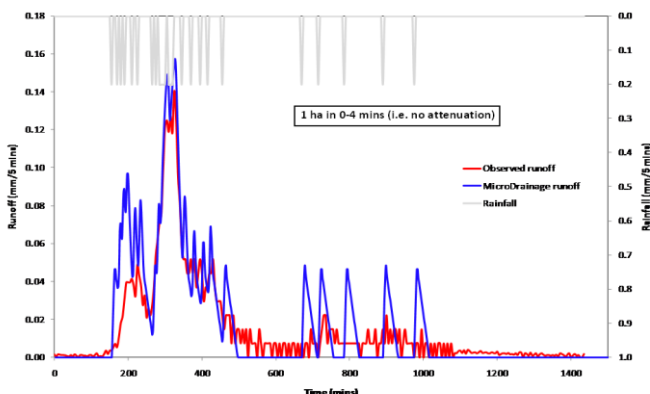
Lag Time

The most suitable modelling approach was selected after comparing model outputs from the WinDes Source Control module. Rainfall/runoff data was obtained from the green roof test rig situated at the University of Sheffield. Three Time Area Diagram (TAD) options were considered:

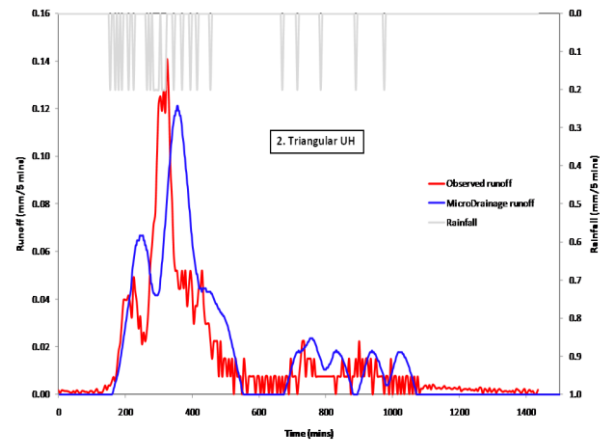
- ⊖ Instantaneous – 1 ha area in the 0-4 minute interval in the TAD.
- ⊖ A triangular “Unit Hydrograph” with a time to peak of 32 mins and a time base of 90 mins.
- ⊖ Exponential curve.

The following three graphs show the results. The red line indicates the measured runoff from the test rig and the blue is the simulated runoff. The rainfall peaks are shown in grey across the top of the graphs and correspond to the runoff peaks.

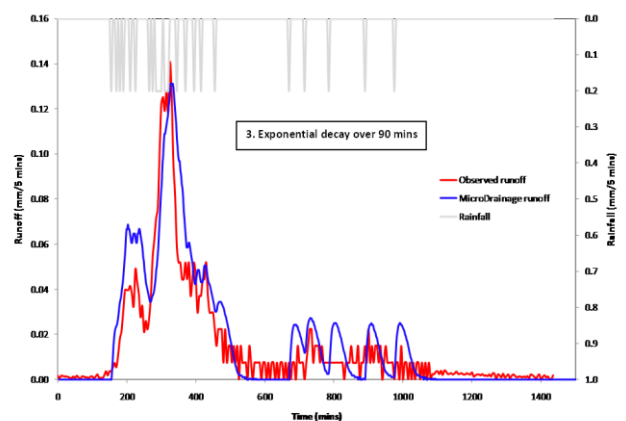
Graph 1. Instantaneous – 1 ha area in the 0-4 minute interval in the TAD.



Graph 2. A triangular “Unit Hydrograph” with a time to peak of 32 mins and a time base of 90 mins.



Graph 3. Exponential curve.



The standard TAD direct runoff in 0-4 mins approach followed the rainfall profile too closely and over estimated the peaks. It also failed to recognise the lag effect of the soil substrate on the flows.

The triangular Unit Hydrograph approach over estimated the lag effect of the soil which resulted in both over and under estimation of peaks.

The Exponential model approach displayed the greatest accuracy between observed and modelled flows, closely replicating the peaks and lag effect.

The Exponential method uses the following formula;

$$A_t = e^{-kt}$$

Lag Time (continued)

Where:

A = a factor required to scale the curve to provide the correct total catchment area (area under the graph)

e = exponential

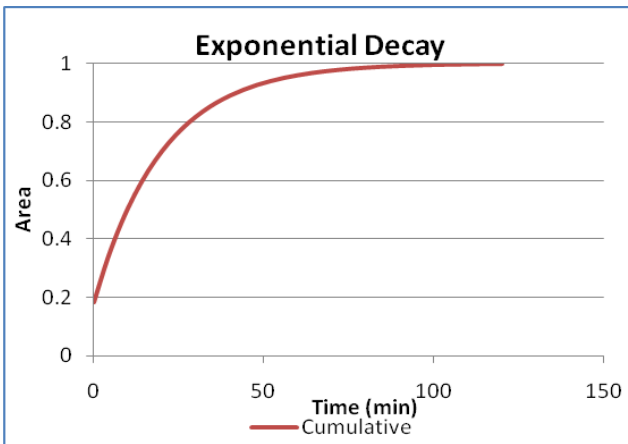
k = decay coefficient

t = time in minutes

The t time is 120 minutes. The rig and third party data suggested that the runoff from the roof becomes instantaneous after 120 minutes. If the engineer wishes to adjust this and increase the draindown they may adjust the k value which dictates the lag and draindown times.

The figure below shows how the area of the green roof is accumulatively added into the drainage network over a 120 minute period.

Graph 4. Exponential Decay applied as a cumulative graph.



Continuous Analysis

The green roof calculator in the Source Control and Simulation modules of WinDes also has the ability to run continuous analysis. The Pluvius module uses 700 years worth of UK rainfall records to generate rainfall data that can be run continually in WinDes. The green roof method can 'recharge' the depression storage by specifying an evapo-transpiration rate that is applied between storms during continuous analysis. If the designer is still concerned about how a roof will perform during wet conditions, editing the k decay coefficient and running continuous analysis will provide a comprehensive test of the storm water handling capabilities of the green roof.

The results can be quite striking. For example, the volume stored within a 10m long storage pipe with a 0.1m diameter orifice outlet conveying runoff from 0.1ha impermeable area can be reduced by 70% if a green roof is specified.



Conclusion

The research carried out at the University of Sheffield has enabled Micro Drainage to provide the capability to model green roofs in the industry standard WinDes software, calibrated and validated with UK data meeting SUDS requirements and making drainage design more accurate. This aids the end users in meeting the growing SUDS requirements through improved design and simulation.

Contact Details

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