THE NEW WALLINGFORD RUNOFF MODEL

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1 Limitations of the existing model

The runoff volume model in the Wallingford Procedure is used to calculate the proportion of rainfall which becomes runoff and enters the sewerage system. The existing runoff model has two components; an initial loss model and a continuing loss model.

The initial loss represents the rainfall which is lost at the start of the storm in wetting the catchment surface and in filling depressions and puddles on the catchment surface. The depth of rainfall which is lost depends on the characteristics of the surface; whether it is paved or roof for instance, and on the slope of the surface. Steeper sloping surfaces have less loss that flat surfaces. For typical paved surfaces the initial loss is about 0.5 mm for a surface which is initially dry.

Once the initial loss is used up runoff starts. However some proportion of the rest of the rainfall is also lost due to evaporation, infiltration, splashing onto permeable areas and areas which drain away from the gully inlets. This proportion is represented as being constant during a storm event and the proportion is calculated using a simple regression equation based on the amount of the surface which is impermeable, the soil characteristics and the catchment wetness.

There are several limitations to this existing model.

Assuming a constant proportion of loss is too simple for large, long duration storms. This is particularly so for catchments with significant permeable areas.

The calculation of catchment wetness depends on soil moisture deficit (SMD) values which are not immediately available. They have to be obtained from the Met Office and are only available as averages over large catchment areas.

The model requires rules on inclusion of permeable areas so as to keep within the validity of the regression equation.

There is considerable confusion over its use for partially separate systems.

2 The new model

2.1 Aims

A research project has therefore been carried out to develop a new runoff model. The aims of the new model are to overcome the limitations of the existing model. In particular:

To represent the runoff from paved and permeable areas separately rather than as one lumped value as given by the existing model.

To avoid the use of SMD in the definition of catchment wetness.

To continue to use the familiar soil classes to characterise soil conditions.

To show increased runoff from permeable areas in long duration storms.

To unify the urban runoff equations with the rural runoff equations given in the Flood Studies Reports.

To allow consideration of infiltration from the ground into permeable pavements and other structures, of infiltration from the ground into the sewerage system and of the limiting capacity of gullies and roof drainage system throttling the inflow.

2.2 Structure

The new model again is in two parts, an initial loss and a continuing loss.

The initial loss is exactly as before depending on surface type and surface slope.

The form of the continuing loss model is different for impermeable and permeable surfaces.

For impermeable surfaces

> A fixed proportion of the area is taken as being the effective area which contributes runoff.
> This proportion depends on the type and condition of the surface.
> The proportions range from 45% to 100% for paved and roof surfaces.
> The rest of the impermeable area is classed as non contributing and is treated as permeable surface.

For permeable areas

> The runoff varies with the catchment wetness. This is represented by an Antecedent precipitation index model.
> This index is calculated by summing rainfall and then applying a proportional loss of moisture each day

$$API_{i+1} = (API_i + P_i - e) * k$$

where

API_i	API value on the i'th day
P	rainfall depth
e	evaporation

The decay factor k depends on the soil class

Class	k
1	0.1
2	0.5
3	0.7
4	0.9

This means that light sandy soils dry out more quickly than heavy clay soils.

The soil has a characteristic soil moisture storage depth (S) assumed to be 200 mm

The runoff is then calculated based on the ratio of catchment wetness to the available soil moisture storage depth

$$\text{Runoff} = P * API / S$$

2.3 Use

The new model has been incorporated into WALLRUS and can be selected by using a special RUNOFF.PRM file which includes the parameters for the model.

Before using the model it is necessary to classify the paved surfaces into good, average, poor and bad surface condition. This obviously causes a difficulty for several reasons. Firstly it is additional work to classify the surfaces and enter the additional data into the SSD file. Secondly there are as yet no standard photographs or detailed descriptions of what makes up each surface type. Thirdly it is open to abuse to force fit a model by adjusting the surface classification until a good verification is achieved.

The API value is then calculated. On heavy clay soils which dry out very slowly this needs up to 30 days of rainfall data. For light sandy soils 5 days is adequate.

An estimate must be made of the evaporation rate. In the absence of any better information standard values of 1 mm/day in winter and 3 mm/day in summer can be used.

The WALLRUS model is then run in exactly the same way as for the old runoff model.

3 Experience to date

The new runoff model has been tested on data from three catchments with long observations of rainfall and flow.

Unfortunately most of the testing was on short storms, where the model was found to be not much different from the existing model

There has not yet been much experience of the effect of the model on large storms which may show significant differences, and significant improvements, from the old model.

4 Design conditions

The model can be used as it stands for verification of models using measured rainfall and flow data. However, design values of API are needed to use the model for prediction of flow from design storms. The design values depend on the soil index and so have to be derived for each area of the country and for each soil type. We have derived values for one site for a range of soil types and compared the differences in values which are obtained.

It is expected that the new design values will give different results to the old runoff model with the old design values. This is because of what we have called, "The London bus effect".

The "Average summer UCWI" which is used with the old model represents the average for all days in summer. Values are quite low. However summer storms come in groups spread over a few days with long dry periods in between. (Like London buses.) The average catchment wetness for days on which it then rains is much higher than the average for all days. Some work on this considering UCWI values for the old runoff model have shown that the true summer values are closer to those for average winter conditions.

5 Future developments

We wish to continue on with research work on this model to make it more useable. This will look at three topics.

Continue testing work with particular emphasis on large storms.

Develop design values of catchment wetness for all soil types for the entire country.

Produce guidelines on classifying paved surfaces, if possible including photographs of typical surfaces.

WaPUG Blackpool

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1.1 New Run off Model **M Osborne (HRL)**

Question

Dave Walters M.W Barber & Company

DW liked the concept of being able to verify the end of a long storm. Does the new model deal with the immediate surface wetting caused by very high intensity rainfall (greater than 30mm/hr) which can cause very high runoff ?

Answer

Yes this has been considered. This fast response is particularly a problem in Southern Europe where the ground is baked hard and you get very high intensity rainfall and is being addressed at the moment.

Question

Rob Henderson Wessex Water

There is a big jump in factor between soil Class 1 and 2, how sensitive is the new model to soil class ?

Answer

This has not been investigated to date, but this is an equal problem with the existing runoff model. The existing data set has very little information from Soil class 1 areas. The new model gives more runoff from paved areas and less from pervious.

Question

David Wright Consultant

What is the likelihood of getting good data ?

Answer

Obtaining good data is a problem because most of the long term data collection was stopped in the 1970's. The model is being checked against verification data, although that data is not thought to be reliable enough to use for calibrating the model. There is some long term data collection continuing and it is hoped that in a couple of years there will be enough new data to make a re-calibration worthwhile.

Question

Bob Armstrong Watson Hawksley

In a recent verification three storms occurred in quick succession causing the UCWI to change from 5 for the first storm to 120 for the last storm and this had caused problems with the verification. Discussions with John Packman of the Institute of Hydrology had confirmed that in deriving the UCWI equation storms occurring in quick succession had not been given detailed considerations. There was therefore a possibility that it may give erroneous values for the later storms.

Answer

In the old model the changes in UCWI would be the same whether it was a sandy or a clayey soil. In the new runoff equation SMD is no longer used and the model depends on the long term API. The value of this now depends on the soil type, so a sandy soil will show less change than a clay soil. However as this example is a clay soil that does not help us much.In the old model the change in wetness would also cause a difference in the runoff from the paved surface which would not happen with the new model. It may therefore be the case that the new model would improve the situation, but it would be necessary to try and see.

Comments from John Packman Institute of Hydrology on the design value of UCWI.

The "London Bus" effect does mean that typical UCWI values before summer storms (in particular) are rather larger than the design value, but this does not necessarily mean the design values of UCWI we use are wrong. The design values were defined in order to estimate T-year peak flows not reproduce specific (verification) events. They do not necessarily have to represent average UCWI values as they were chosen such that when used with the 50% summer profile (symmetrical) they gave a good match to data T-year peak flows in the catchment (defined from long flow records).