Wapug Autumn Meeting
Blackpool 1993

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Use of the Soil Conservation Service Model

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INTRODUCTION

This paper outlines the problems encounted in modelling a catchment with a substantial unpaved area upstream of the sewered area and the use of the SCS model to model this unpaved area. A description of the SCS model together with guidance on the use of the model within WALLRUS is included.

1. CASE STUDY

The study area is a normally dry, steep sided valley on the edge of a town in Southern England. The northern part of the catchment is urbanised with a surface water sewer system discharging to a series of deep bored soakaways.

The underlying geology of the catchment can be summarised as permeable sands and sandstones with some impermeable clay and ironstone outcrops.

Over half of the natural catchment is undeveloped farmland. This area naturally drains along the valley to the urban area although there are no drains or ditches within this part of the catchment.

Following flow and impermeable area surveys undertaken in early 1993 a WALLRUS model of the surface water sewer system was built and partially verified. It was found however that the flow volumes for the monitor downstream of the rural area and to the soakaways were under predicted for the most severe event.

Initial model runs with design storms with this (sewer system) model also predicted no flooding with a 1 in 20 year return period storm. However there have been a number of reports of extensive flooding in the last ten years. In addition substantial flows originating from the farmland have been observed.

As predicted by Leonard,[1] with a Soil Index of 1 for the majority of the catchment no runoff from the permeable areas was simulated by the WALLRUS model for design UCWI values. Therefore use of the alternative SCS runoff model was investigated.

The SCS model as discussed in more detail in Section 2 is a runoff model based on soil storage and antecedent rainfall.

The WALLRUS model was reverified using the SCS model for the extensive permeable area in the south of the catchment with a soil storage value of 520mm recommended for grassland on a permeable soil. A significant volume of runoff from the unpaved area was only predicted for one verification event (16.7mm of rainfall in 14 hours on a dry catchment). However for design storms substantial flow volumes were predicted as shown in Table 1 overleaf.

[1] The Calculation of contributing areas for Chalk Catchments, Leonard and Beale, WaPUG Autumn meeting, Blackpool 1990.

Table 1 Predicted runoff volumes from Pervious Area

Storm Return Period	Storm Duration (mins)	Wet Catchment	Dry Catchment
		Volume m^3	Volume m^3
1 in 2 years	60 120 180 240 300	337 601 787 922 1027	204 364 477 559 623
1 in 5 years	210 240 270	1298 1388 1467	789 844 892
1 in 10 years	210 240 270	1746 1862 1963	1063 1134 1196

These flow volumes ranged from 30 to 50% of the total runoff volumes and due to the limited capacity of the soakaways were highly significant.

Predicted flow hydrographs for the UK and SCS runoff models are shown plotted with the observed flows in Figure 1.

Frequent flooding (matching historical records) was also simulated with the revised model especially for wet catchment conditions. The permeable area included in the model did not cause an increase in peak flows but only in flow volumes.

2. THE SCS MODEL

This model is a procedure for estimating runoff volume for storm rainfall based on standardised infiltration rates, the available soil storage and the rainfall in the preceding five days.

The SCS equation which estimates the cumulative runoff from the cumulative rainfall is:

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

where

P = Total storm rainfall (mm)
Q = Total runoff volume (mm)
I_a = Initial losses including surface depression storage, interception and infiltration.
S = Storage depth or potential maximum retention of rainfall ranging from zero on an impermeable catchment to infinity on deep gravel.

The above equation can be used to calculate the cumulative runoff at each rainfall time step. Within the WALLRUS program this equation is transformed to give the percentage runoff within each time step.

The original SCS method[2] proposed that the initial losses (I_a) were set as 0.2 of the storage depth however further studies have indicated that lower values of initial loss ie 0.1 S or 0.05 S may be better estimates.

The Storage Depth (S) was originally related to a curve number (CN) which ranged from 0 to 100 corresponding to zero and 100% runoff. The relationship between soil storage depth and the curve number is given by the equation.

$$S=\frac{25{,}400}{CN}-254$$

Soil Storage Depth

The soil storage depth is related to both the soil type and vegetative cover. The soil types are defined within the WALLRUS User Manual but are not the same as the Soil Index in the Wallingford runoff model. However until more detailed guidance is available the following relationship is proposed.

Table 2 Soil Types

SCS Soil Type	Wallingford Procedure Soil Index	Description
A	1	Well drained permeable soils
B	2	Moderately permeable soils
C	2-3	Relatively impermeable soils and soils with a high water label
D	4-5	Clays or soils with an impermeable layer at shallow depth

The soil storage depth can then be estimated from either the table below or table 3.2 in the User Manual.

Table 3 Soil Storage Depths

Description	Soil Types			
	A	B	C	D
Cultivated	99	60	35	25
Wheat,Barley etc	137	80	48	35
Pasture/Playing Fields	397	162	89	64
Meadow	593	184	104	72
Wood (poor)	310	131	76	52
Wood (good)	762	208	109	76
Rural housing (35% Imp)	177	89	56	41

2 U.S. Soil Conservation Service, Engineering Field Manual for Conservation Practices. Washington D.C. S.C.S., 1979.

The Antecedent Moisture Condition

The antecedent moisture condition (AMC) modifies the soil storage within the program and is derived from the total rainfall in the preceding 5 days and the growing season. Assuming that the active and dormant growing seasons are Spring/Summer and Autumn/Winter respectively the AMC is given by:

Table 4 Antecedent Moisture Condition

	Total Rainfall in Preceding 5 days				
	0	12.5	28.0	35.5	53.5
Spring/Summer	Dry			Average	Wet
Autumn/Winter	Dry	Average	Wet		

The change in the soil storage made by using wet and dry AMC's compared to the average soil storage is shown on Figure 2 and is highly significant.

Runoffs

The rainfall required to produce runoff assuming initial losses of 0.2 times the soil storage is shown on Figure 3 for typical Soil Types and Land Uses and can be seen to be sensible. Wet cultivated land on a clay soil produces immediate runoff whereas dry woodland on a sandy soil requires over 300mm of rainfall before runoff occurs.

Figure 4 shows percentage runoff for typical Land Use and Soil Types as derived in the model. Again the results appear sensible.

CONCLUSIONS

Use of the SCS method provides a powerful tool for the WALLRUS modeller to include large unpaved areas within the model. The method allows the modeller to include areas which will only contribute during extreme events such as that discussed by Harding.[3]

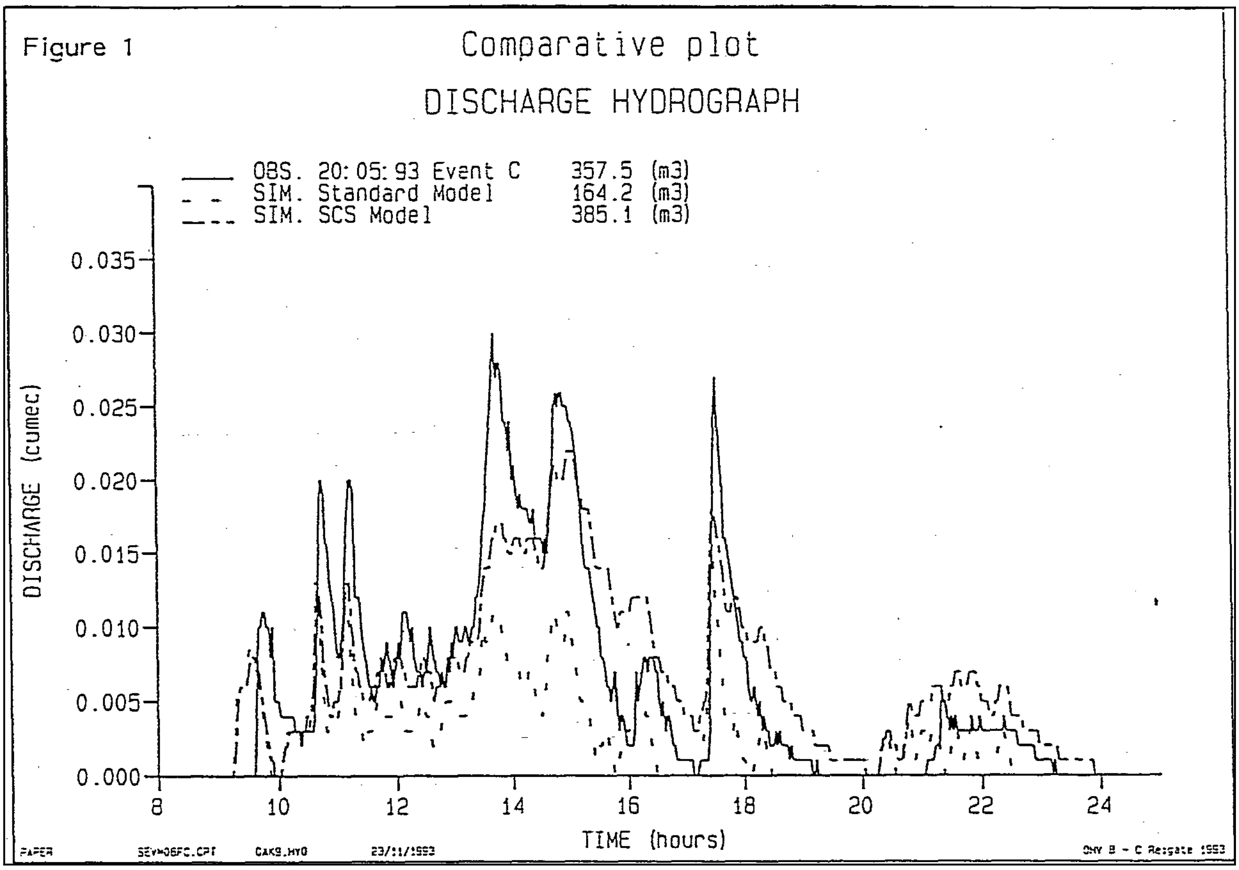
The omission of openspaces and playing fields from models as recommended in WaPUG User Note No.21,[4] must be carefully considered as the effects of large permeable areas can now be modelled satisfactorily.

In the design of Retention or Storage Systems it is especially important that the runoff from large pervious areas is included in the design even if these flows only occur in prolonged wet periods.

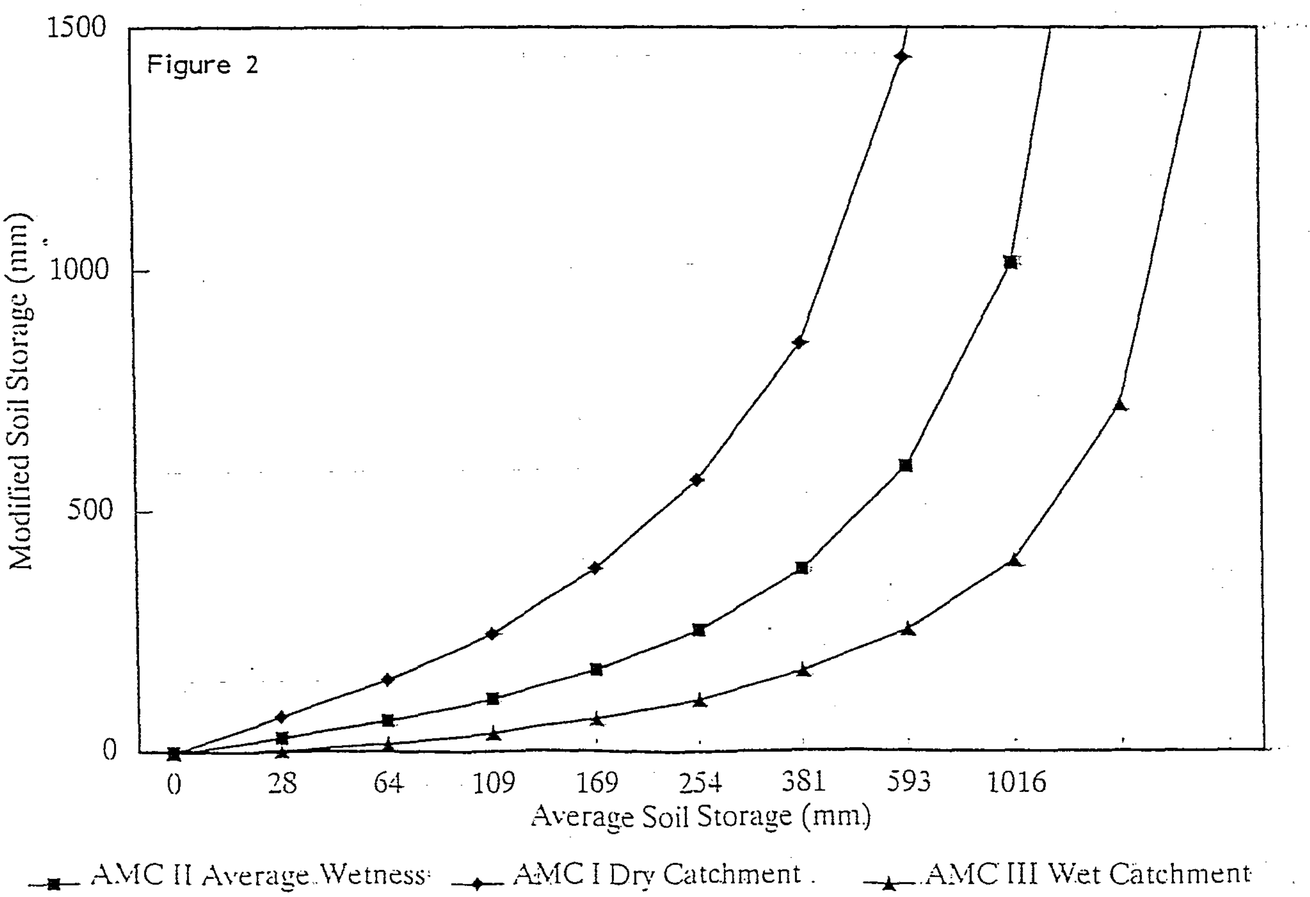
The industry has long awaited a means of modelling runoff from unpaved areas. The SCS model now available as an integral part of WALLRUS provides an opportunity which should be grasped by the industry to model these areas.

[3] "Switching-On" of Contributing Areas, WaPUG Autumn Meeting, Bournemouth, November 1988.

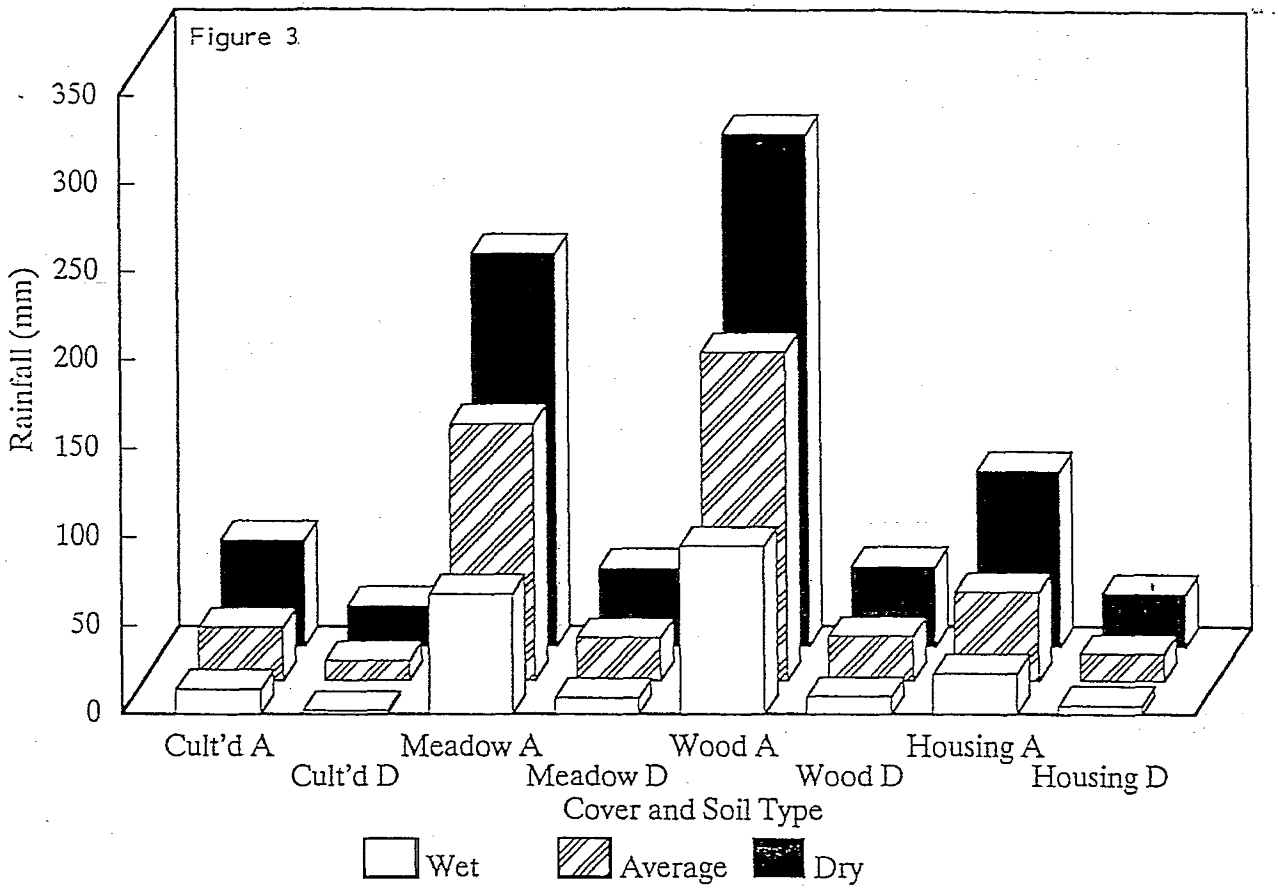
[4] Runoff Equations & Catchment Data, WaPUG User Note No.21, September 1989.



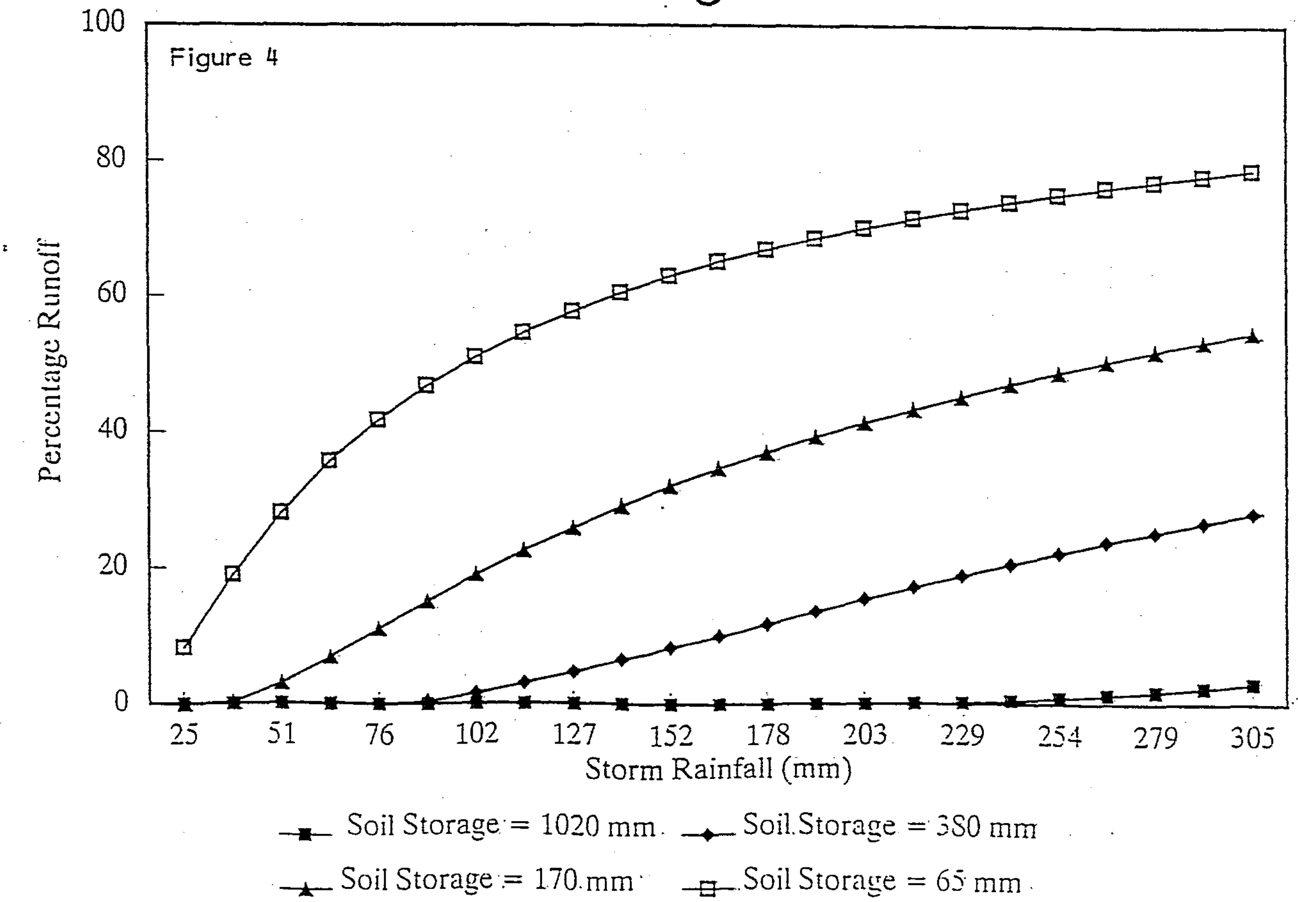
Effect of Catchment Wetness on Soil Storage values



Rainfall Required to Produce Runoff



Percentage Runoffs



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Written Comment John Packman Institute of Hydrology

I have a number of points to make on the SCS method

1. The method as programmed in WALLRUS is not quite the same as the original SCS method.(the basic equation $Q/P=P/(P+S)$ is for cumulative runoff and cumulative rainfall from the start of the storm, but WALLRUS uses the cumulative Q/P as an instantaneous PR value). The WALLRUS form is probably a better representation of runoff but would need slightly different values of S from the standard values quoted in the literature.
2. The SCS model is more sensitive to S than it might appear, so some care is necessary in choosing the correct value.
3. Unlike the SCS model the UK PR equation in WALLRUS is directly calibrated on urban catchment data in the UK, and is clearly the first choice method for most catchments.

Answer