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Estimation of Sediment Yield and Discharge by Runoff Model

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1. INTRODUCTION

Williams (1978) derived the instantaneous unit sediment graph (*IUSG*) for determining sediment discharge from agricultural watersheds. The *IUSG* was defined as the distribution of sediment from an instantaneous burst of rainfall producing one unit of runoff. The *IUSG* is the product of the *IUH* and the sediment concentration distribution (*SCD*). The *SCD* was assumed to be an exponential function for each event and its parameters were correlated with the effective rainfall characteristics. A sediment routing function, using travel time and sediment particle size, was used to determine the *SCD*. The objective of this study was to develop a tank model for prediction of runoff and sediment yield, test it on an upland watershed in northwestern Mississippi, and compare it with the IUSG model.

2. THEORY

2.1. Tank model for sediment yield

For determining the sediment yield by the tank model, the sediment concentration distribution (*SCD*) of the first tank is produced by the incremental source runoff (or the effective rainfall) and sediment concentration of the next lower tank is computed from the sediment infiltration of the upper tank. The sediment concentration of the first tank is computed from its storage and the *SCD*; the sediment concentration of the next lower tank is obtained by its storage and the sediment infiltration of the upper tank; and so on. The sediment yield through the side outlet is obtained by multiplying the total sediment yield, obtained by the product of runoff and the sediment concentration in the tank, by the sediment yield coefficient. The sediment infiltration through the bottom outlet is obtained by multiplying the total sediment infiltration, obtained by the product of infiltration and the sediment concentration in the tank, by the sediment infiltration coefficient.

2.2. Sediment concentration distribution

The sediment concentration distribution (*SCD*) caused by rainfall was estimated by considering the sediment routing equation (Williams, 1975a):

$$Y = Y_0 \exp(-aTd^{0.5}) \tag{1}$$

The *SCD* used in the tank model and the *IUSG* model can be expressed as

$$C_{0i} = \frac{Yv_i}{\left[H\sum_{j=1}^{m} v_j^2 \right]} \tag{2}$$

To use (2) v_i, Y, H must be determined. Y was predicted using the modified universal soil loss equation, *MUSLE* (Williams, 1975b):

$$Y = 11.8(Vq_p)^{0.56} KCP(LS) \tag{3}$$

To determine H requires knowledge of a and $h(w)$. The routing coefficient a can be determined from (1) by replacing T by the time to peak T_p and predicting Y and Y_o with Using (3), (1) becomes

$$11.8(Vq_p)^{0.56} KCP(LS) = 11.8(VQ_p)^{0.56} KCP(LS) \exp(-aT_p d^{0.5}) \tag{4}$$

From (4), one gets

$$a = -\frac{\ln(q_p / Q_p)^{0.56}}{T_p d^{0.5}} \tag{5}$$

Thus, the sediment concentration distribution, C_{oi}, computed by (2) is used to compute the sediment yield in the tank model and the *IUSG* model.

3. RESULTS AND DISCUSSION

3.1. Study basin

A small upland watershed, W 5, a part of the Pigeon Roost basin located near Oxford in Marshall County, Mississippi, was selected for testing the tank model. The watershed has an area of approximately 4.04 km^2, is 1288 m long and 128.8 m wide. The average channel width depth ratio is approximately 2:1 at the gaging station.

3.2. Model parameters

The tank model parameters are the runoff and the sediment yield coefficients (*A1, A2, A3, B1, C1*), the infiltration and the sediment infiltration coefficients (*A0, B0, C0*) and the heights of the runoff orifices (*HA1, HA2, HA3, HA4, HA5*).

3.3. Sediment concentration distribution

The *SCD* was determined from (2) and the *IUH* used to obtain *IUSG* was determined by the Nash model for each event. The parameters for the sediment yield estimated by *MUSLE* in (3) for watershed W 5 are as follows: The soil factor, *K*, is 0.26, the crop management factor, *C*, is 0.07, the erosion control practice factor, *P*, is 0.47, and the slope length and gradient factor, *LS*, is 0.34.

3.4. Determination of Sediment yield

The sediment yield was computed for each event by the tank model and compared with the sediment yield computed by the IUSG (Lee and Singh, 1999). The observed and computed sediment yield graphs are illustrated in Figure 1. These error indices for the sediment yield by the tank model and *IUSG* are given in Table 1. The above results show that the tank model is a suitable model for computing sediment yield.

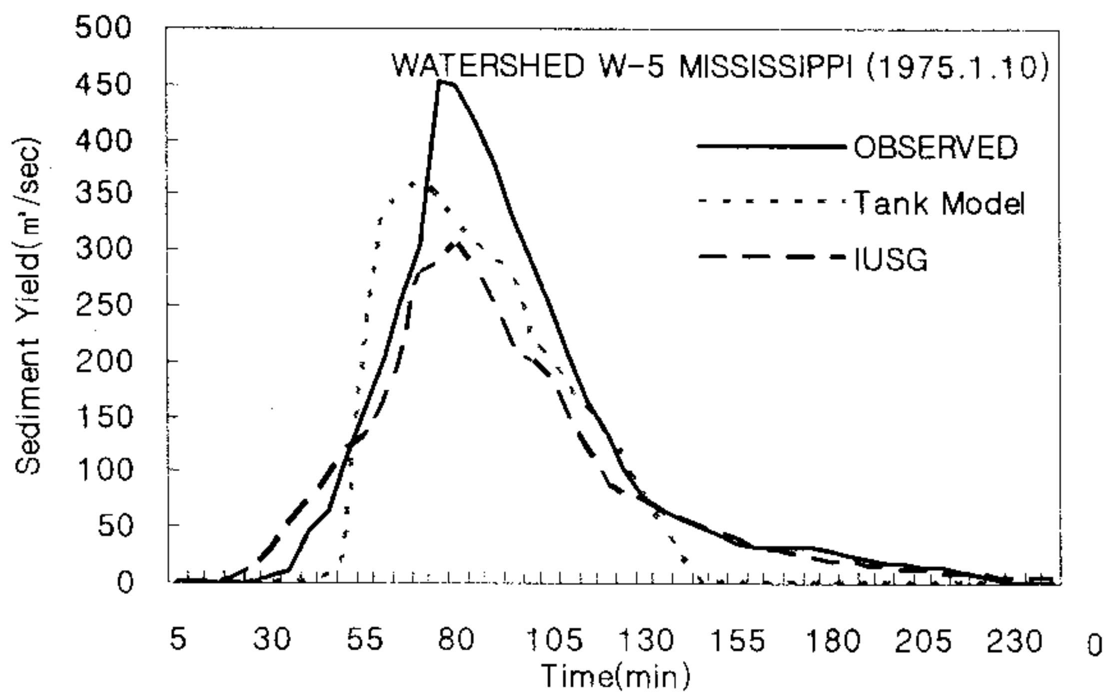

Fig. 1. Comparison of observed and computed sediment yield graphs

Table 1. Error indices for the sediment yield by the tank model and *IUSG*

Storm	*ME*		*MSE*		*Bias*		*VER(%)*		*PER(%)*		*TER(min)*	
	Tank	*IUSG*	*Tank*	*IUSG*	*Tank*	*IUSG*	*Tank*	*IUSG*	*Tank*	*IUSG*	*Tank*	*IUSG*
No.1	0.80	0.69	30.69	51.17	10.16	31.16	15.36	37.10	5.47	39.87	10	15
No.2	0.90	0.71	83.47	143.8	39.53	62.33	20.06	31.64	1.03	20.49	10	20
No.3	0.85	0.70	50.22	97.12	20.87	44.06	20.22	30.68	20.55	46.20	5	5
No.4	0.83	0.75	56.18	83.71	4.47	22.99	5.15	26.48	2.28	39.68	5	5

4. CONCLUSIONS

The following conclusions can be drawn from this study. (1) The *SCD*, obtained by incremental source runoff, is used equally in the tank model and the *IUSG* model. (2) The tank model satisfactorily simulated runoff and sediment yield. (3) The sediment yield computed by the tank model was in good agreement with the observed sediment yield and was more accurate than the sediment yield computed by the *IUSG* model. (4) The sediment yield graphs by the tank model have approximately the same shapes as do the runoff hydrographs by the tank model. (5) The values of the coefficients used to estimate runoff and sediment yield by the tank model are the same. These features enable this model to simultaneously compute runoff and sediment yield in river basin.

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