AD-A195 806 FOOD INUNDATION MODELLING USING MILHY(U) EUROPEAN RESEARCH OFFICE LONDON (ENGLAND) M G ANDERSON ET AL. MAY 88 DAJA45-87-C-0053 1/1

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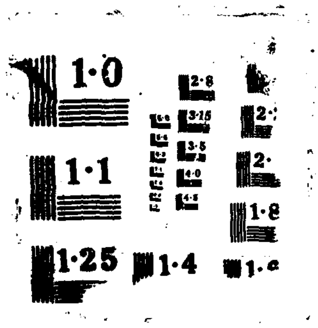
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The aim of this research is

I OBJECTIVES

The overall objective of the research can be seen by comparison of figure 1.1, the initial state of HYMO2 at commencement of this project, and figure 1.2 the foreseen final model structure. The aim is therefore to improve the operational predictive capabilities of HYMO2 by (Specifically) investigating specifically.-

1) the impact of spatial and temporally variable precipitation.

2) the channel conveyance scheme by incorporating appropriate hydraulic techniques which aim to improve the physical representation of out-of-bank conditions.

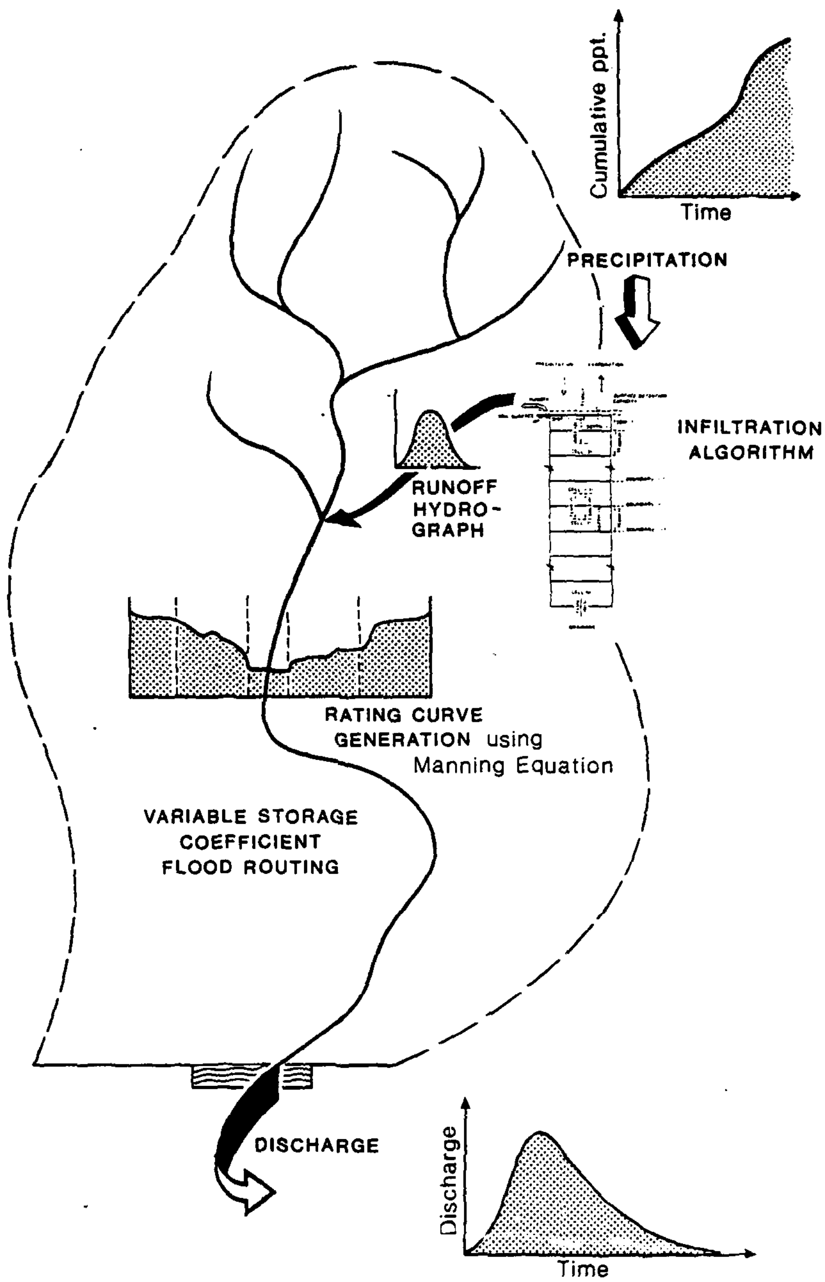

Fig 1.1 Initial model structure

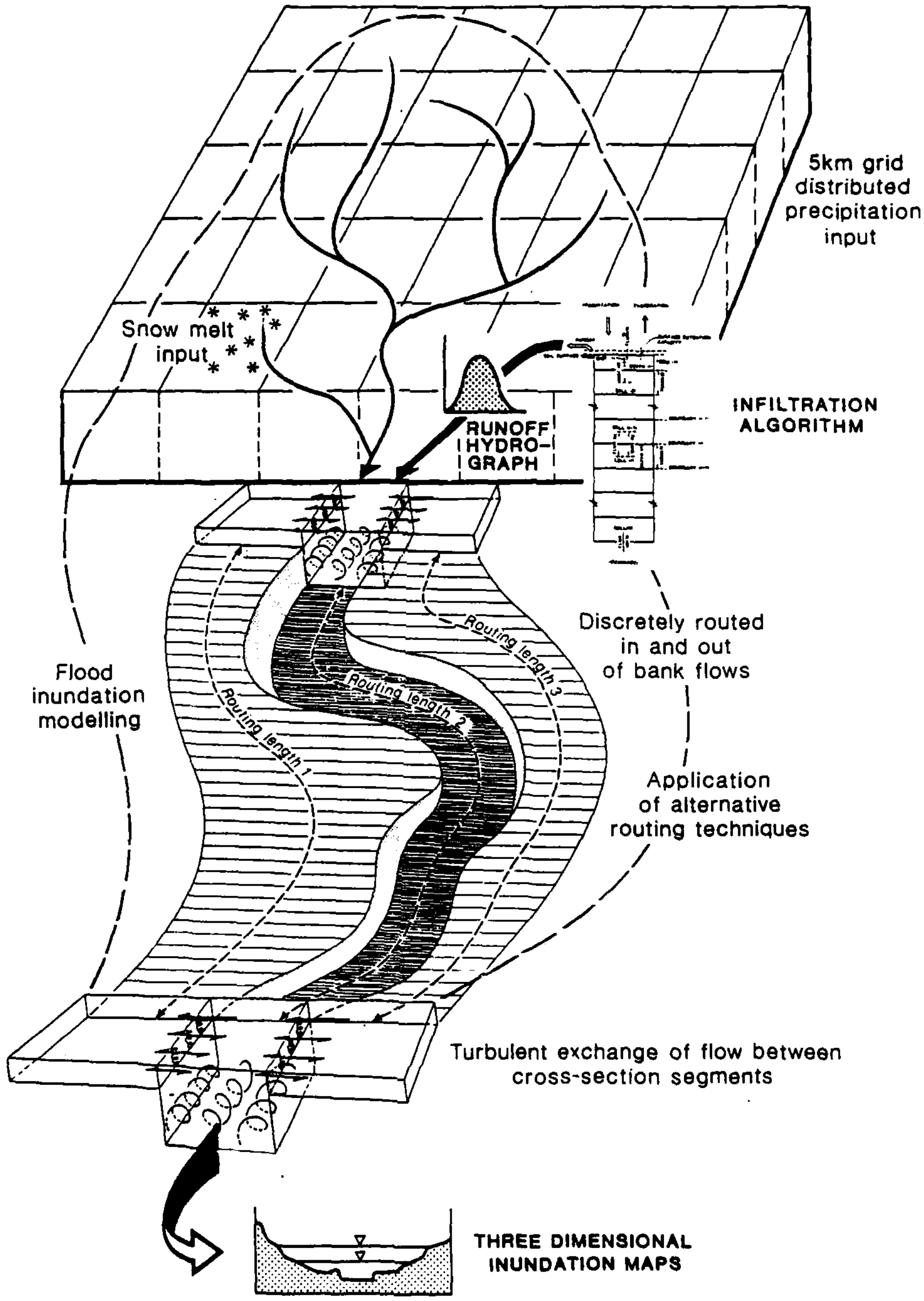

Fig 1.2 Foreseen final model structure

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Objectives For This Reporting Period include:

1) Further investigation of the downstream routing of channel and floodplain flow separately or jointly (section II).

2) Sensitivity analysis of a numerical model developed by Ervine and Ellis to predict channel and flood plain velocities from plan geometry (section III).

and 3) Development of a logical scheme for the incorporation of the upgraded channel conveyance scheme. (section III).

Keywords: Atmospheric properties, Drainage basins, Flooding, Mathematical prediction, Runoff, hydrology, Infiltration algorithms (edc)

II DISCRETE ROUTING OF CHANNEL AND FLOODPLAIN FLOWS DOWNSTREAM

Following the November 1987 report, work on the comparision of outflow hydrographs from the separate routing of floodplain and channel flows and aggregate routing continued (Fig 2.1). In particular, the sensitivity of the hydrograph to the stage increment imposed by the rating curve generation routine, was investigated.

All the routines divide the vertical axis of the cross-section into twenty equal intervals, therefore during the discrete routing method, where individual rating curves are generated for each segment, the vertical intervals may vary, see Figure 2.2. Due to the generally greater elevation differences in the channel segment, the interval is larger here than in the floodplain segments ie $I_c \neq I_f$

Figure 2.3, shows the impact an increment difference of 0.4 ft can have on the outflow hydrograph. In curve 1, $I_c - I_f = 0.68$, whilst curve 2, $I_c - I_f = 0.2$ ft. Increment differences of 0.1 ft produced no significant deviation in outflow hydrographs. It is important to note from Figure 2.3, that such increment differences produce just as significant variation in the outflow hydrographs as the comparision between aggregate and discrete routing methods, see Figure 2.4.

In the November 1987 report, several errors in the discrete routing technique have been identified. The resultant hydrographs, Figs 2.5-2.8, in the Nov '87 report do not correctly identify the differences between aggregate routing of channel and floodplain flows together, and discrete routing (separating the flows for routing). This was due to an error in the allocation of storage arrays (ID numbers) in the source program. The

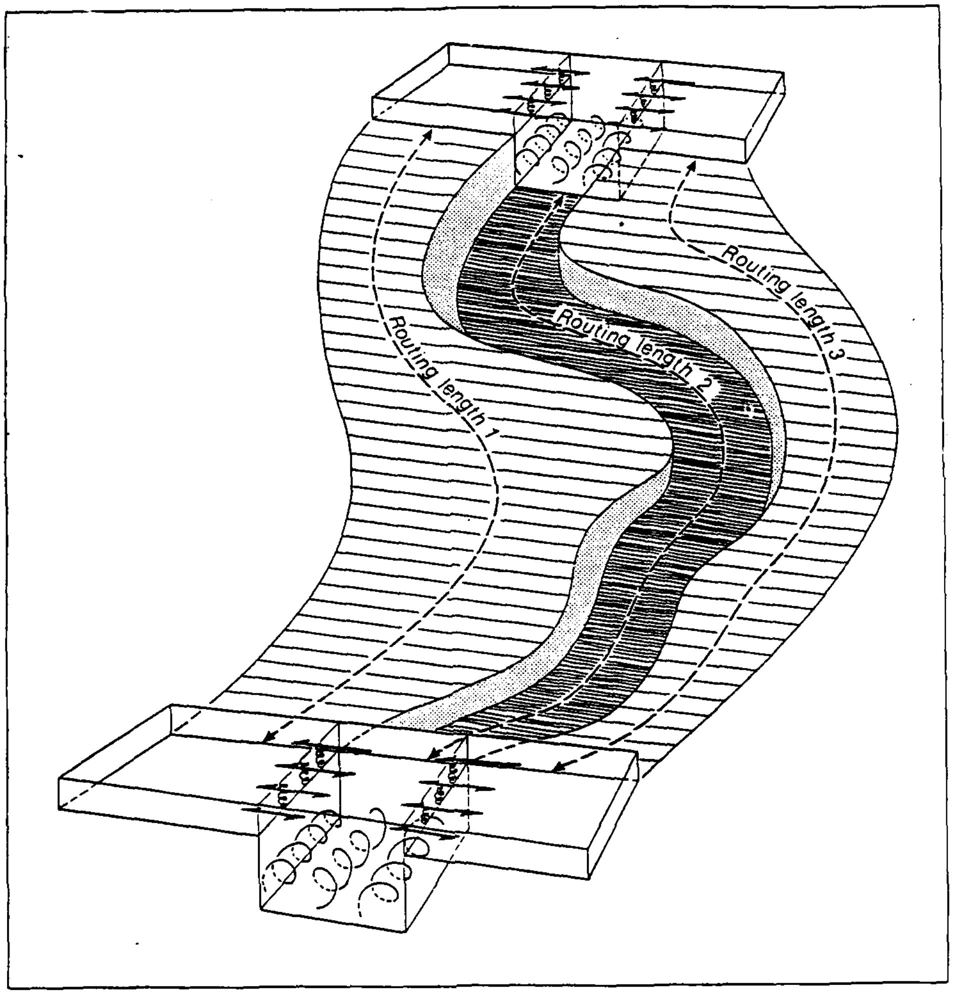

Fig 2.1 Diagram illustrating incorporation of turbulent exchange and separate routing pathways.

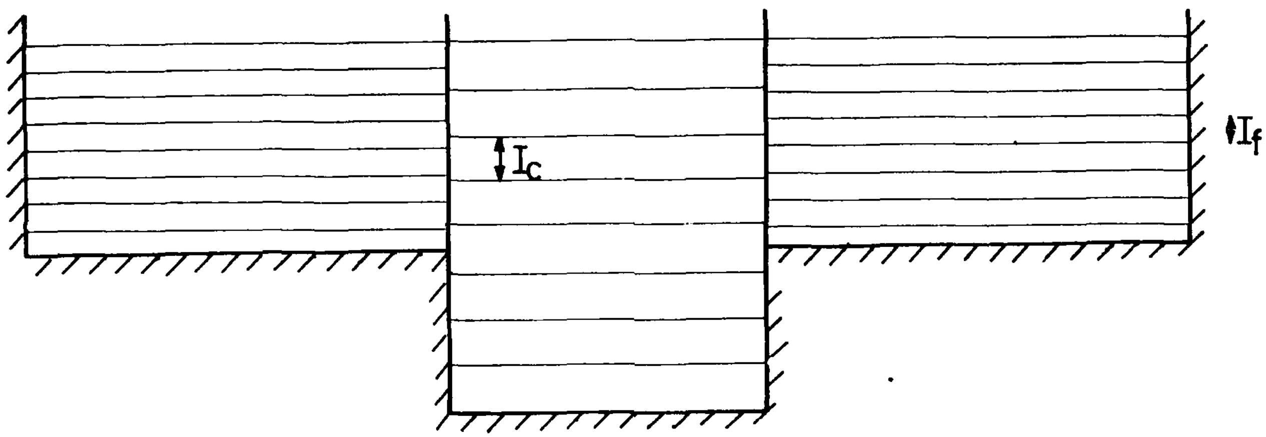

Fig 2.2 Illustrating the different vertical intervals generated by the Rating Curve routine. Note I_c is generally greator than I_f.

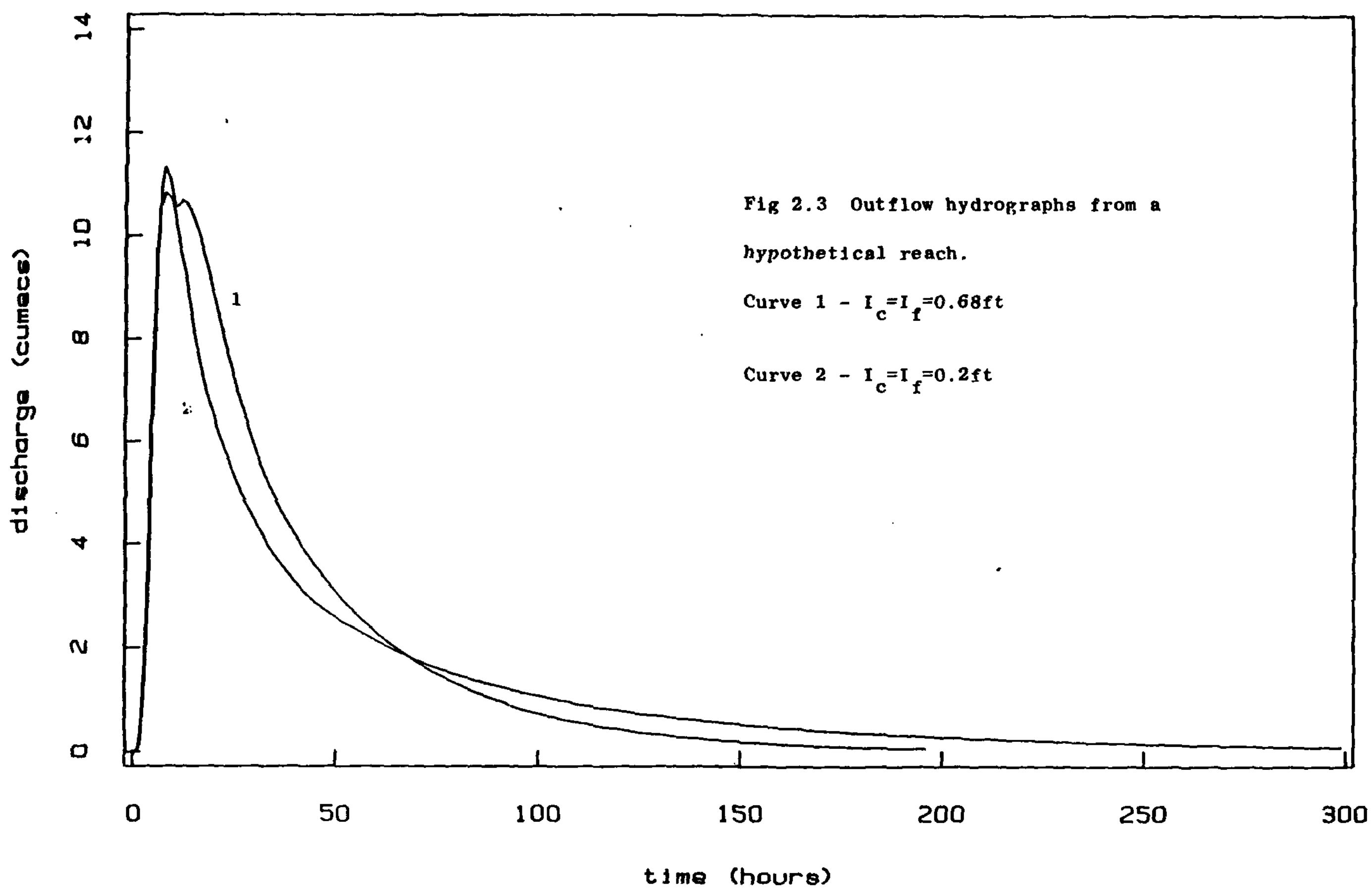

Fig 2.3 Outflow hydrographs from a hypothetical reach.

Curve 1 - $I_c = I_f = 0.68ft$

Curve 2 - $I_c = I_f = 0.2ft$

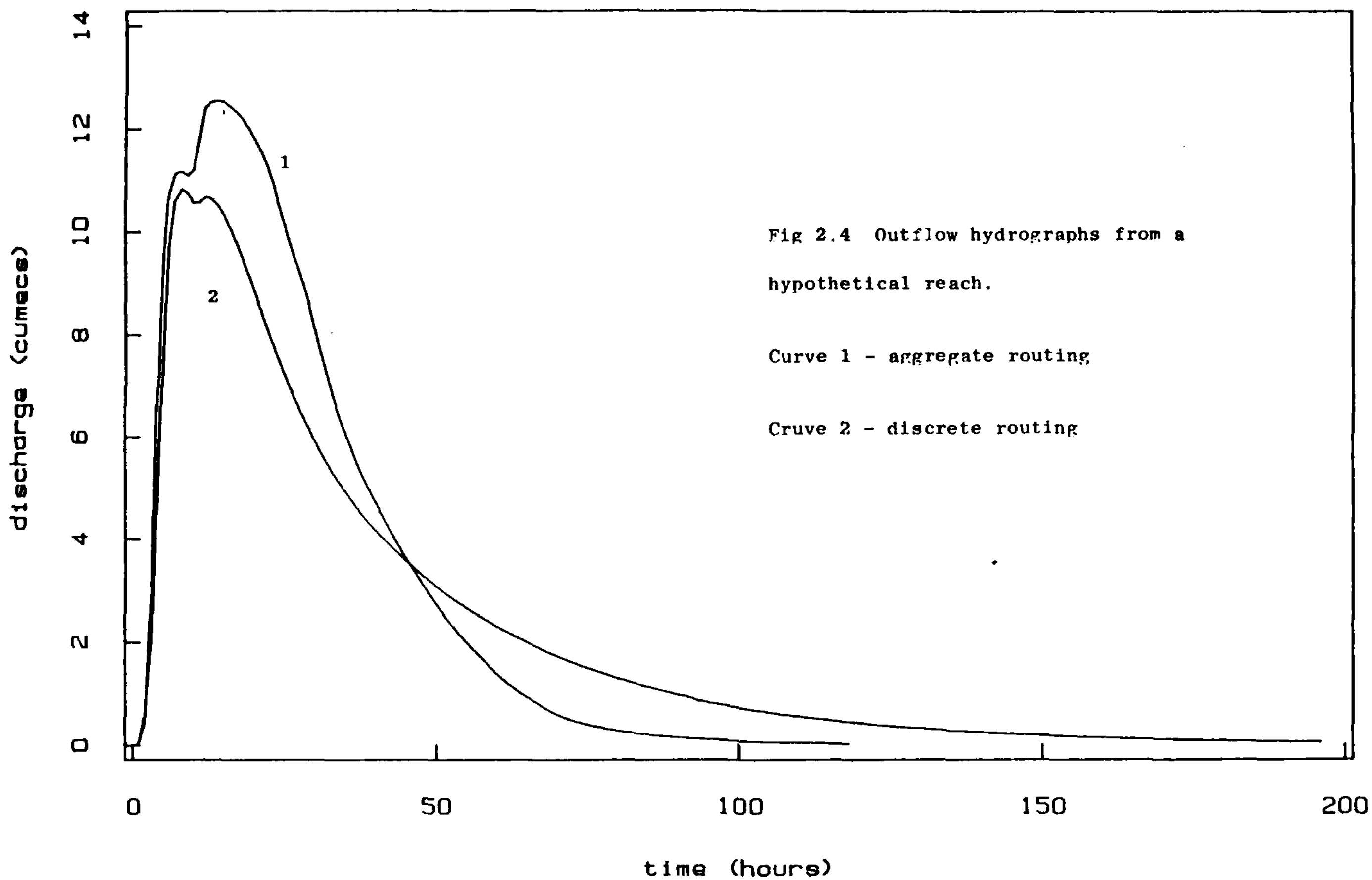

Fig 2.4 Outflow hydrographs from a hypothetical reach.

Curve 1 - aggregate routing

Cruve 2 - discrete routing

application of HYMO to multi-routing generated this difficulty which is easily avoided if different identification numbers (ID's) are given to the inflow and outflow hydrographys in the ROUTE command. Great care must be taken in these applications that ID numbers are correctly allocated. Figure 2.4 illustrates the correct difference between aggregate routing (curve 1) and discrete routing (curve 2).

III IDENTIFICATION OF THE PARAMETERS WHICH SIGNIFICANTLY AFFECT DISCHARGE PREDICTIONS

The objective of this investigation was to apply a numerical solution of discharge computation, developed by Ervine and Ellis (1987), to identify the most important determining parameters and dictate the priority areas for further investigation.

Ervine and Ellis' Scheme

Erine and Ellis appreciated the complexity of flow in meandering channels especially where flows breached the channels. They developed a model predicting velocity and hence discharge from the energy losses in three separate cross-sectional segments which they identified as:-

i) channel, in channel flow

ii) floodplain (area 1) - including flood plain flows inside the meander belt width.

iii) flood plain (area 2) - outside the meander belt (see definition figures 3.1 and 3.2 and symbols appendix)

1) Main Channel Energy Losses

There are four main sources of energy loss.

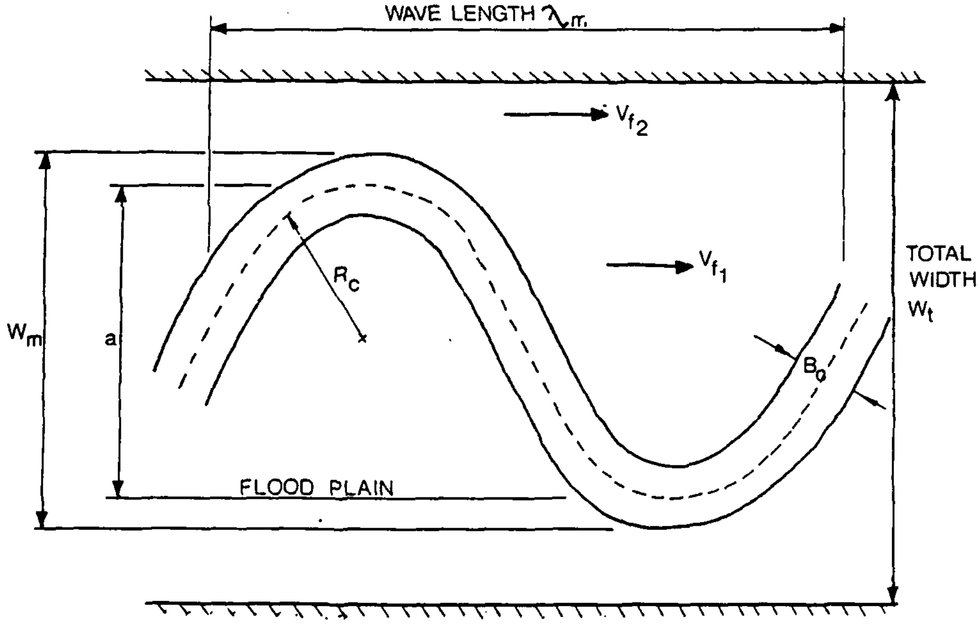

Fig 3.1 Definition diagram for Ervine and Ellis' numerical solution

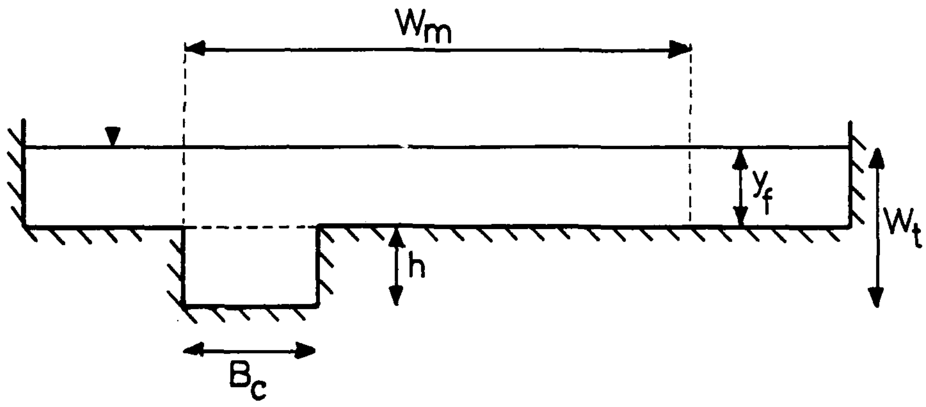

Fig 3.2 Definition diagram for Ervine and Ellis' numerical solution

a) frictional losses around the wetted perimeter. From the bed material size (K_c), the Colebrook-White and Darcy-Weisbach equations are applied to determine mean depth velocity Quantified, along a complete meander as:

$$h_f = \frac{f_c}{4} \cdot \frac{r\lambda}{R} \cdot \frac{V_c^2}{2g} \qquad 3.1$$

b) traverse currents generate at meander bends where there is shear due to centrifugal forces affecting surface waters specifically.

Chang (1983) quantified these losses as:

$$h_t = \left(\frac{2.86\sqrt{f} + 2.07f}{0.565+\sqrt{f}}\right)\left(\frac{y_c}{R_c}\right)^2 \left(\frac{r\lambda}{y_c}\right)\left(\frac{V_c^2}{2g}\right) \qquad 3.2$$

c) turbulent shear stress generated by velocity differences between main channel (V_c) and the component of flood plain flow parallel to the channel ($V_{f1}\cos\theta$). Depending on which velocity is greatest the flux in head can operate in either direction. However, due to the difficulty in determining this apparent shear stress, Ervine and Ellis ommitted turbulent shear stresses from their analysis.

d) Pool and riffle sequences, can give rise to head loss but only at low flows, but flooded out during overbankflow, therefore is ignored here.

2. Flood Plain Flow Losses

Within the meander belt, energy losses can be attributed to:

a) friction losses over the wetted area

$$h_f = \left(\frac{f}{4}\right)\left(\frac{1}{y_f}\right)\left(\frac{V_{f1}}{2g}\right)(W_m\lambda - r\ B_c) \qquad 3.3$$

b) expansion and contraction losses, where flow normal to the channel encounters a sudden drop (expansion) at the entrance to the channel and contraction where it leaves the main channel.

$$\text{expansion losses} = r\lambda\left(\frac{1-y_f}{y_c}\right)^2 \frac{V_{f1}^{\ 2}}{2g}.\sin^2\theta \qquad 3.4$$

$$\text{contraction losses} = C_L.\frac{V_{f1}^{\ 2}}{2g}.\sin^2\theta.\ (r\lambda) \qquad 3.5$$

where C_L is contraction loss coefficient, determined by Yen and Yen (1983), based on the ratio of depth of flood plain flow to channel flow.

Flood plain head losses outside the meander belt are attributable to <u>friction losses</u>

$$S_o = \frac{f}{4} \cdot \frac{1}{y_f} \cdot \frac{V_{f2}^{2}}{2g} \qquad 3.6$$

<u>Application of Ervine and Ellis' Solution</u>

From Ervin and Ellis' solution, the velocity for each of the three segments was generated separately from equations 3.1 to 3.6 giving:

<u>Main channel velocity</u>

$$V_c^{2} = \frac{2gSR}{r} \Bigg/ \left(\frac{f_c}{4} + \left(\frac{R}{R_c}\right)^{2} \cdot \frac{2.86\sqrt{f_c} + 2.07f_c}{0.565 + f_c} \right) \qquad 3.7$$

<u>Flood plain (area 1)</u>

$$V_{f1}^{2} = 2gSW_m \Bigg/ \left(\frac{f_{f1}}{4y_f} \cdot (W_m - B_c r) + r\sin^{2}\theta \cdot \left(1 - \frac{y_f}{y_c}\right)^{2} + C_L \right) \qquad 3.8$$

Flood plain (area 2)

$$V_{f2}^{2} = \frac{8gSy_f}{f_{f2}} \qquad 3.9$$

From the continuity equation the total discharge from the three segments is given by

$$Q = V_c(B_c h)+V_{f1}(y_f W_m)+V_{f2}y_f(W_t-W_m) \qquad 3.10$$

A hypothetical reach was set up with a cross-sectional geometry mimicking those of the Fulda catchment, West Germany (table 3.1). The sensitivity of the velocity and discharge predictions, (Equations 3.7-3.10) was then tested by consistently varying the following parameters:-

- slope

- geometry
  (Channel width, flood plain meander belt width, radius of curvature and hydraulic radius were varied together).

- Manning n friction factor
  (To be consistant with previous work the sensitivity of Ervine and Ellis' solutions, were checked against Mannings 'n', converted to Darcy-Weisback friction factors using

$$f = \frac{8gn^2}{R^{1/3}}$$

The ratio of flood plain to channel frictions were investigated as well as simple increases and decreases in friction.

- flood plain and channel flow depths

- angle of flood plain to channel water.

Results

Tables 3.2 to 3.6 show the percentage deviation in the resultant velocities and discharges from those computed in Table 3.1.

Table 3.1

Parameter specification for hypothetical reach

	SI units
Bed slope	0.0007
Sinuosity	1.3
Hydraulic radius	2.5
Radius of curvature	125.0
Width of meander belt	175.0
Channel width	30.0
Friction channel (f)	0.071
Friction flood plain 1	0.356
Friction flood plain 2	0.356
Depth channel	0.5
Depth flood plain	3.5
Angle of flood plain flow to channel (radians)	0.785
Contraction loss coefficient	0.47

Results

Main channel velocity	1.205
Flood plain, area 1 velocity	0.360
Flood plain, area 2 velocity	0.278
Discharge	157.2

Table 3.2

<u>Channel Velocity Results</u> (% deviation from origin velocity)

% Change in variable	increase 5%	increase 30%	decrease 5%	decrease 30%
Slope	+ 3	+13	-2	-19
Channel Friction	- 4	-24	+5	+50
Geometry	+ 1	+ 3	-0.5	- 5

Table 3.3

Flood plain (area 1) Velocity Results (% deviation from origin velocity)

% change in variable	increase 5%	increase 30%	decrease 5%	decrease 30%
Slope	+ 3	+13	-2	-19
Friction	- 4	-27	+5	+23
Geometry	+ 1	+ 2	-0.5	- 4
Flow depth	-15	- 5	-20	-33
Flood plain Flow depth	+ 2	+15	- 2	-18
Angle of flood plain flow to channel	0.0	- 1	0.0	+ 1

Table 3.4

Flood plain (area 2) Velocity Results (% deviation from origin velocity)

% change in variable	increase 5%	increase 30%	decrease 5%	decrease 30%
Slope	+ 3	+13	- 2	-19
Friction	- 5	-28	+ 5	+25
Depth	-16	- 5	-20	-23
Flood plain flow depth	+ 3	+15	- 2	-19

Table 3.5

Discharge Results (% deviation from origin discharge)

% change in variable	increase 5%	increase 30%	decrease 5%	decrease 30%
Slope	+ 3	+13	- 2	-19
Channel friction	- 3	-17	+ 4	+35
Flood plain friction	- 1	- 9	+ 2	+15
Geometry	+ 4	+27	- 4	-28
Flow Depth	-16	- 4	-19	-29
Angle of flood	0.0	0.0	0.0	0.0

Table 3.6

Friction Effects On Velocity And Discharge (% deviation from origin)

% deviation		CHANNEL VELOCITY	FLOOD PLAIN VELOCITY area 1	FLOOD PLAIN VELOCITY area 2	DISCHARGE
f_c	f_1 & f_2				
0.078	0.356	- 4	-	-	- 3
0.125	0.356	-24	-	-	-17
0.064	0.356	+ 5	-	-	+ 4
0.031	0.356	+50	-	-	+35
0.071	0.392	-	- 4	- 5	- 1
0.071	0.629	-	-27	-28	- 9
0.071	0.321	-	+ 5	+ 5	+ 2
0.071	0.155	-	+23	+25	+15
0.071	0.071	-	+103	+124	+35
0.125	0.125	-24	+63	+69	+ 3
0.031	0.031	+50	+183	+239	+98
0.356	0.071	+55	+107	+124	- 3

Table 3.7

Flow Depth effects on Velocity and Discharge (% deviation from origin)

% deviation		FLOOD PLAIN VELOCITY area 1	FLOOD PLAIN VELOCITY area 2	DISCHARGE
Y_f	Y_c			
0.525	3.675	-15	- 6	-16
0.665	4.655	- 5	- 5	- 4
0.475	3.325	-20	-20	-19
0.33	2.31	-33	-23	-29
0.525	3.5	+ 2	+ 3	+ 2
0.665	3.5	+15	+15	+16
0.475	3.5	- 2	- 2	- 2
0.33	3.5	-18	-19	-14

If the 30% variable increases and decreases are examined the rank order of deviation in results is as follows:

Channel	Rank	variable
	1	friction factor
	2	friction factor
	3	slope
	4	slope

Flood plain	Rank	variable
area 1	1	flow depth
	2	friction factor
	3	friction factor
	4	slope

Flood plain	Rank	variable
	1	friction factor
	2	friction factor
	3	depth
	4	slope

Discharge	Rank	variable
	1	friction factor
	2	flow depth
	3	geometry
	4	geometry

From these results it is possible to identify as the key parameters:-

1. <u>Friction factor</u> - including the ratio of flood plain to channel frictions

2. <u>Flow Depth</u> of water on the flood plain

IV LOGICAL SCHEME FOR RESEARCH

An objective of the last six months work has been to establish a logical program for the development and incorporation of an improved channel conveyance scheme.

This program is seen as having four stages:-

4.1 Establishment of A Potential Model Structure

Work over the last year has been the development of more physically and hydraulically based channel conveyance schemes. These have been incorporated in a model structure (Fig 4.1), giving not a single model but approximately 80 individual module combinations (The figure of 80 potential models is arrived at by multiplying the 2 precipitation inputs by 2 runoff generation schemes by 5 turbulent cross-sections by 2 routing lengths by 2 routing techniques). The division of turbulence between segments and multiple routing lengths is now complete and alternative routing techniques are now being investigated.

The establishment of the final model structure is therefore now considered to be complete.

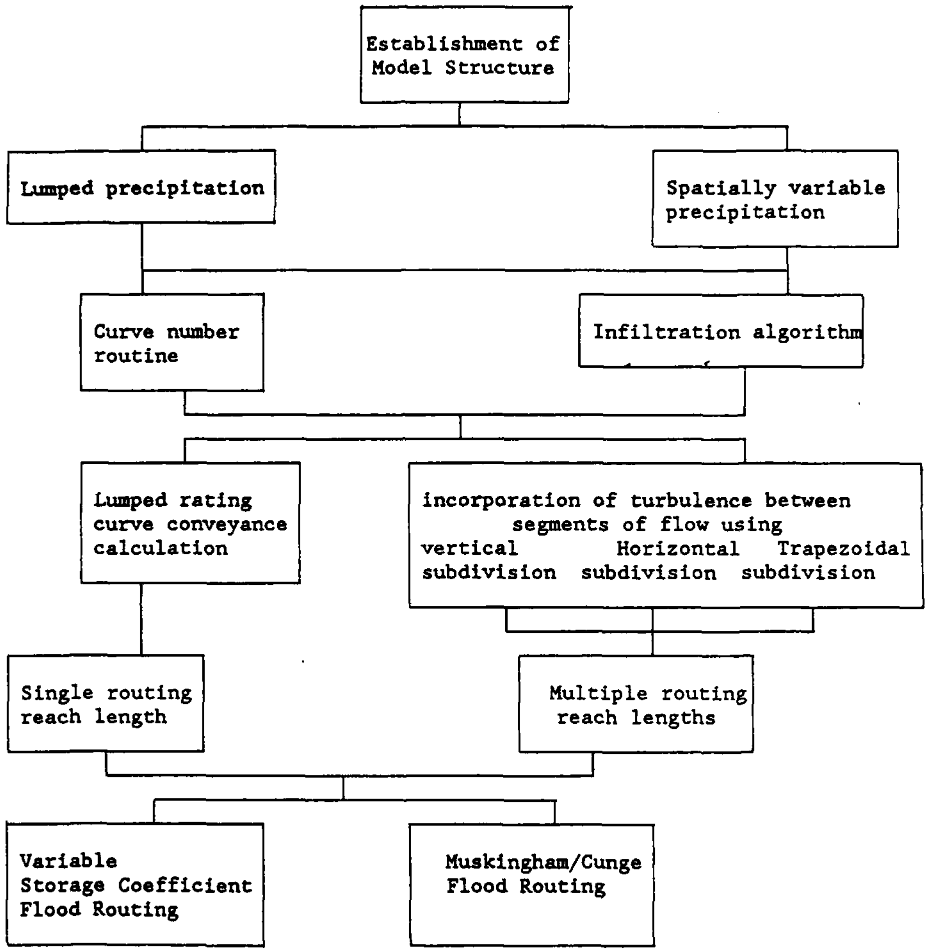

Fig 4.1 Potential model structure

4.2 Development of A Key To Model Selection

Given a potential 80 models it is important that guidelines can be given so that the most appropriate model can be selected for individual situations.

The numerical model developed by Ervine and Ellis (1987) (Section III) is seen as an appropriate method of identifying appropriate modules to use, and hence (figure 4.1) to define the most appropriate model structures.

4.3 Validation of Individual Model Structures

Validation of every combination of model formulation is seen as an unrealistic task for this research project. Therefore, the best formulation is for a single small scale reach to be investigated by fitting observed hydrographs from the Fulda catchment. This scheme will then be applied to the whole Fulda catchment and the model fit checked again against observed hydrographs. At each scale the sensitivity of the scheme to individual model components and parameters will be investigated, directed by the results of the sensitivity analysis of Ervine and Ellis' (1987) numerical model (section III)

4.4 Establish the best geometric representation for flood inundation

In order to maximise the accuracy of flood inundation predictions, a state-of-the art, two dimensional hydrodynamic model (TABS2) is being applied to a single reach in the Fulda catchment. It is hoped this will provide a base prediction of inundation against which HYMO can be tested, widening applications beyond those available from field data alone. TABS2 should provide an indication of the dominant factors controlling the inundation extent.

V RESEARCH PLAN FOR THE NEXT SIX MONTHS

1. Establishment and preparation of reach, Bad Hersfeld to Rotenburg for TABS2 application (Fig 5.1)

2. Trip to HEC Davis to apply TABS2 and investigate flood inundation prediction

3. Incorporation of TABS2 results into operational HYMO

4. Sensitivity analysis on small scale catchment (Marbach to Hermannspiegal) and large scale (Fulda catchment)

5. Bench test Muskingum/Cunge flood routing technique package against existing Variable Storage Coefficient Method

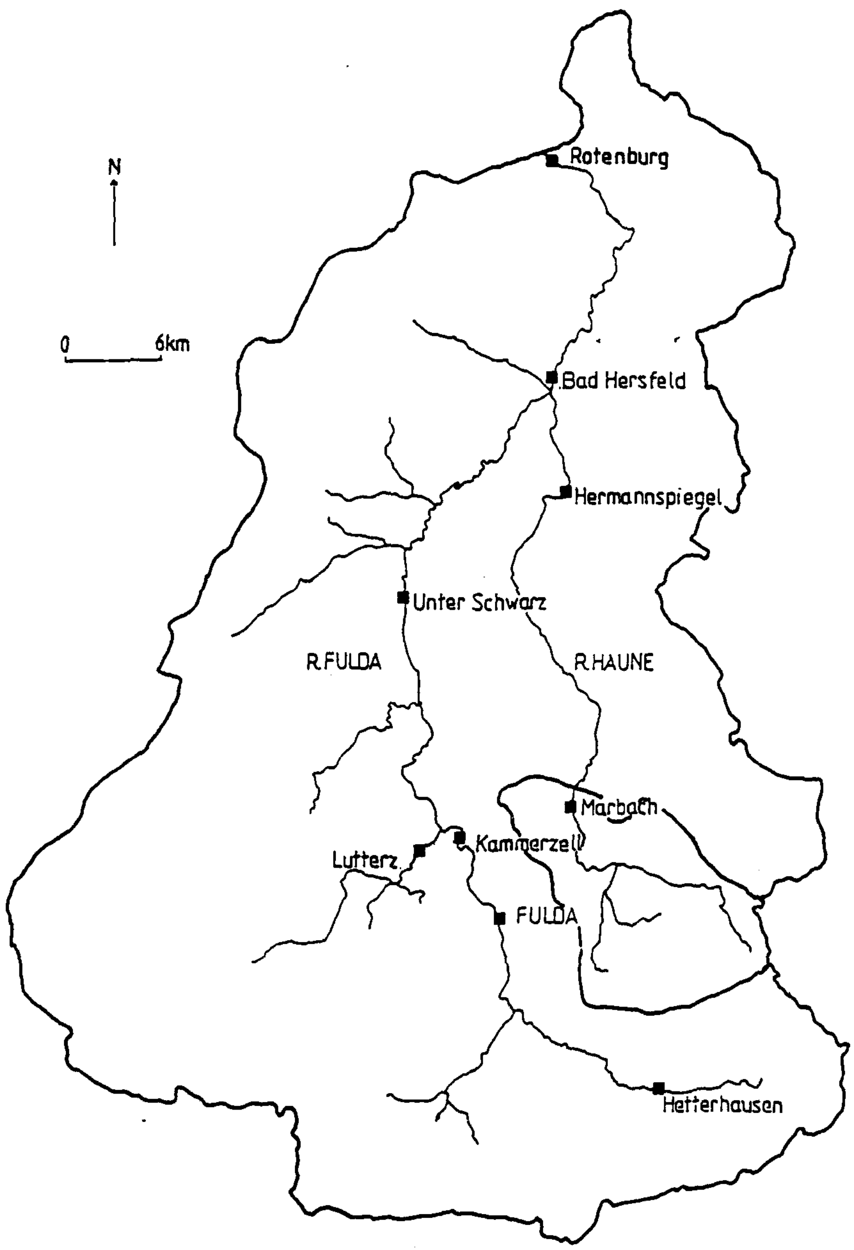

Fig 5.1 Fulda Catchment

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VII Symbols

a	Colebrook White constant, dependant on hydraulic radius/max flow depth
B_c	Channel width
C_L	Contraction loss coefficient
f	Colebrook-White friction factor
g	gravitational acceleration
h	bankfull depth
K_c	bed material size
n	Manning friction coefficient
Q	discharge rate
r	sinuosity of channel meander (curved channel length/straight valley length)
R	hydraulic radius of channel
R_c	radius of curvature of meander belt
S	longitudinal bed slope
V	velocity
W_m	width of meander belt
W_t	total floodway width
y	depth of flow
	meander wavelength
θ	angle of meandering channel to streamwise direction

Subscripts

c	main channel
f	flood plain
f_1	flood plain within meander belt
f_2	flood plain outside meander belt

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