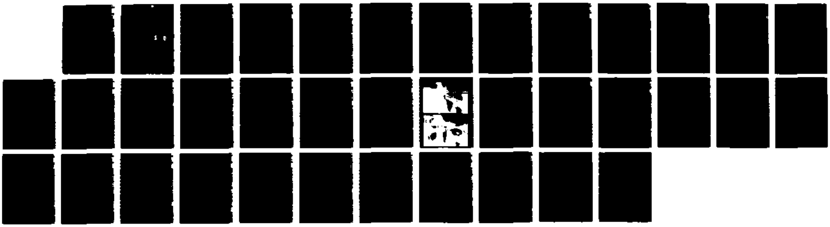
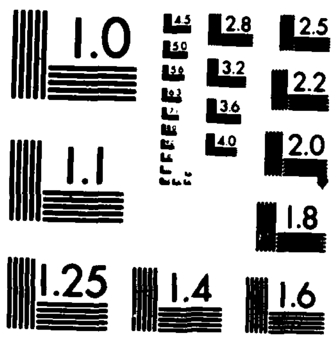
AD-A181 437 DEVELOPMENT OF HYMO FOR OPERATIONAL FORECASTING(U) 1/1
BRISTOL UNIV (ENGLAND) M G ANDERSON ET AL. MAY 87
R/D-4930-EN-01 DAJA45-85-C-0011

UNCLASSIFIED F/G 8/8 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

DTIC FILE COPY (12)

AD-A181 437

AD

DEVELOPMENT OF HYMO FOR OPERATIONAL FORECASTING

Final Technical Report

by

M.G.Anderson and L.Singleton

DTIC
ELECTE
JUN 1 1 1987
S D
D

May 1987

European Research Office

U.S. Corps of Engineers

London England

CONTRACT NUMBER DAJA 45-85-C-0011

Dr.M.G.Anderson

Approved for Public Release : Distribution Unlimited

6c. ADDRESS (*City, State, and ZIP Code*) University Road Bristol BS8 1SS, UK	7b. ADDRESS (*City, State, and ZIP Code*) Box 65 FPO NY 09510-1500

8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAE Waterways Experiment Station	8b. OFFICE SYMBOL (*If applicable*) WES	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAJA45-85-C-0011

8c. ADDRESS (*City, State, and ZIP Code*)
PO Box 631
Vicksburg, MS 39180-0631

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61102A	1L161102BH57	01	

11. TITLE (*Include Security Classification*)
(U) DEVELOPMENT OF HYMO FOR OPERATIONAL FORECASTING

12. PERSONAL AUTHOR(S)
Anderson, M.G. and Singleton, L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (*Year, Month, Day*)	15. PAGE COUNT
Final	FROM 3/85 TO 3/87		

16. SUPPLEMENTARY NOTATION

19. Abstract (cont.)

Tests for moving storm effects proved successful. They showed that we may reasonably conclude that a catchment of 145 km^2 may be regarded as the minimum for which high resolution (5 km grid square) precipitation data is required for low intensity storms (equivalent in character to European frontal conditions). For higher intense storms at 145 km^2 area, we may expect maximum differences of no greater than 5% in outflow hydrograph parameter attributable to moving storm conditions.

Contents

Accesion For
NTIS CRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution /
Availability Codes
Dist | Avail and / or Special
A-1

DTIC COPY INSPECTED 3

HYMO 1987 0005 REPORT

1. Introduction

This study relates to the further development of an operational model for ungauged catchment forecasting.

The work was begun under DAJA 45-83-C-0029 and continues under the present contract. Figure 1.1 shows the overall research design as viewed by the authors in January 1985. This research design has been modified to that shown in figure 1.2.

Prior to this report, validation and model configuration of Model 11 (figure 1.2) had been confined to the following conditions:

(i) single sub-basin areas
(ii) absence of channel routing therefore
(iii) single time base for precipitation events (i.e. no moving storm conditions had been evaluated).

This report details investigations that have been undertaken to extend the validation and, therefore, application of Model 11 into these areas.

Figure 1.1 MILHY MODELS: OVERALL RESEARCH DESIGN

1984	1985	1987	1988
MODEL I MILHY BASIC + SNOWMELT I	MODEL II INFILTRATION :FORTRAN ON HP9816	MODEL III INFILTRATION + SNOWMELT 2	MODEL IV RADAR DICTATING SUB CATCHMENT BOUNDARIES: DYNAMIC MODEL STRUCTURE

CONCEPTUAL →

CURRENT NEEDS IN RESEARCH

INCREASE VALIDATION DOCUMENTATION OF OPERATIONAL CONSTRAINTS. IDENTIFY STRATEGIC AREAS AND PRE-PROCESS MILHY RESULTS OR INPUT DATA	BENCH MARK TESTS ON COMPUTER SYSTEMS INCREASE VALIDATION	DEVELOPMENT OF MODEL CONFIGURATION ANDERSON/HOWES /PANGBURN	DECISION ON SUITABILITY/ APPLICATION IN LONG TERM

OPERATIONAL →

KEY:

☐ COMPLETED

[ ] PARTIALLY COMPLETED
TO BE INITIATED

MALCOLM G. ANDERSON
SALLY HOWES

12 JANUARY 1985

Figure 1.2 : Overall Research Design

/-----------DAJA45-85-C-0011---------/
Anderson and Singleton

	1984	1985	1986	1987
CONCEPTUAL	Model 1 BASIC	Model II INFILTRATION FORTRAN HP 9816	Model III INFILTRATION FORTRAN + ENHANCED ROUGHNESS/ ROUTING	Model IV As Model III with FLOOD INUNDATION ROUTINE
OPERATIONAL		Bench mark tests on computer systems	Establish catchments for moving storm effect Evaluate land-use input potential to Model III	Provide routines or selection of algorithm for moving st rm/ channel r uting/ channel r ugh-ness for specifie flood inundatio accuracy and operational needs

COMPLETED

PARTIALLY COMPLETED

TO BE INITIATED

Malcolm G. Anderson

Laura Singleton

17 March 1987

Figure 1.3 : Research Design Detail

1.	HYMO	Original USDA model
2.	MILHY	(Documentation - James August 1984)
		Validation/verification
3.	Infiltration Module	(Anderson - Documentation 1982 DAJA37-82-C-0092)
4.		Validation-subcatchment level (Anderson and Howes - Documentation 1984 DAJA37-81-C-0221)
5.		Presentation of Fortran code and documentation (Anderson and Howes - 1986 DAJA45-83-C-0029)
6.		Validation - catchment level moving storm and channel roughness - flood inundation - (Anderson and Singleton - DAJA45-85-C-0011 - current contract)
7.	Improved channel roughness/routing module	(Anderson and Singleton DAJA45-85-C-0011 - current contract)
8.	User development	

2. Objectives and Scope

Within the context of the background described in Section 1 and Figures 1.1 and 1.2, the following objectives were specified for work reported here:

(i) An evaluation of the current potential for the inclusion of land-use into Model 11.

(ii) An evaluation of moving storm effects for subsequent identification of rainfall/radar input needs for given circumstances.

(iii) An evaluation of the method Model 11 currently adopts for estimation of the in and out of bank roughness

(iv) The specification of the broad research programme for the next six months in relation to the conceptual and operational needs shown in Figure 1.2

The basic model structure of Model 11 was established on the basis that the replacement of the Curve Number routine by the finite difference infiltration scheme offered higher resolution of model output with little change in data input needs. This has been broadly vindicated by the validation tests undertaken by Anderson and Howes (DAJA45-83-C-0029, 1986) at the sub-catchment level.

The development of Model 111 (Figure 1.2) now demands that other components of the model are examined and, if necessary, replaced and upgraded in a similar manner, consistent with operational demands and constraints. Figure 2.1 illustrates, in general terms, a selection of alternative approaches within each of the model components. It is clear from that figure that we are currently seeking to upgrade other modules, where appropriate, in the current contract.

Consistency of module compatibility in terms of parameterisation, computer time and output resolution is thus of major concern in the development of

Figure 2.1 Current capability in each model component

Precipitation →	Land use →	Infiltration →	Subcatchment identification →	Channel routing →	Hydrograph
4. Higher resolution radar	3. Change model to include vegetation	4. 3-D modelling	3. $n \sim 40$	4. 3-D Hydraulic out of channel models	
	2. K changes	3. 2-D Finite difference			
3. Radar 5 km grid	1. Organic matter-suction/moisture	2. 1-dimensional infiltration	2. $n \sim 8$ subcatchments	3. Stage-mannings n relationships	
2. 1 gauge per subcatchment		1. Green-Ampt style equation	1. Small computer: $n \sim 3$ subcatchments	2. Hysteresis in stage-discharge	
1. Single gauge				1. Fixed Mannings n in channel — Simple reduction out of channel	
See section 5	See section 3	See previous reports:		See section 6	
This report	This report	DAJA45-83-C-0029 DAJA37-81-C-0221		This report	

Model 111. (Given the basis of the development of Model 11 this was much less of a factor of course).

In particular, we see the need to examine the treatment of channel roughness currently employed in the model. Significant improvements we believe are possible in this module, and this report details initial approaches we are making.

A German watershed has been established as a validation base for much of the work currently being undertaken, and collaboration with USDA, Beltsville, Washington, has resulted in a potential data base for Oklahoma being identified for detailed moving storm/channel routing validation.

3. Evaluation of current potential for inclusion of land use

The current capability of HYMO 2 is limited with respect to vegetation/land use effects as follows:

(i) Limited to non-forested areas

(ii) Temporally fixed hydraulic conductivity conditions (e.g. no soil crusting development)

Given the present input parameters (Table 3.1) it is possible to envisage tackling this problem. To retain this limited data input, and simultaneously incorporate land use specification, three options are available:

(i) To modify the hydraulic conductivity for given land use conditions

(ii) To modify the detention capacity similarly, or

(iii) To modify the suction-moisture curves in accordance with land use.

In the context of (iii), this facility already exists through the inclusion of organic matter in the Brakenseik and Rawls scheme we have adapted for suction moisture curve generation (see report DAJA-37-81-C-0221).

No real equilibrium for (i) and (ii) is available at this stage. and so we have, in this report, explored the sensitivity of the output hydrograph to change in organic matter.

A hypothetical catchment, area 24 km^2, stream length 11.8 km, with no subcatchment subdivision, was established to test for sensitivity to organic content for each of the three soil classifications, clay, silt and sand. The catchment was assumed to be spatially homogeneous, with organic content varying from 0 to 10% for each class, in five increments, giving a total of 18 hypothetical situations.

The other variables required by the infiltration algorithm were kept constant wherever possible but some, like the saturated moisture content and saturated conductivity, vary with soil type. The initial soil moisture values, restricted by the algorithm to be less than the saturated value, were set at 0.04 less than the smallest saturated value in the profile for ten cells in all three layers. The last value in the soil moisture characteristic curves is the saturated moisture value, and this was matched with a corresponding suction value of -0.4 m, for all layers, and soil types. This value was set arbitrarily but is within the range of bubbling pressures (or soil air entry points), determined by Rawls et al. (1982). Detention capacity and evaporation were assumed to be zero for all soil types and storms. Three storms were used with cumulative rainfall totals ranging from 43 mm to 205 mm; all were given an identical duration of 9 hours.

Variability in hydraulic conductivity, initial moisture content, moisture content on the suction moisture curve and detention capacity were included.

Thus, for each organic content value, within each soil type and for each of the three storms, the model was run twenty times; some 360 times in total. From each run, the runoff volume, peak discharge and time to peak from commencement of storm, were taken as characteristics of the hydrograph. The twenty results were used to calculate the coefficient of variation for each of the soil/hydrograph characteristics/organic matter percentages shown in Table 3.2. From this table, the relative insensitivity of the hydrograph characteristics to organic matter change can be observed.

Thus, land use inclusion by this variable has a much lesser effect than, say, the hydrograph generation routine on the output hydrograph. To facilitate a full land-use incorporation into the current approach would thus necessitate the total restructuring of the current infiltration algorithm currently adopted to include a physically based component modelling vegetation and soil water interaction explicitly. In the context of mode component comparability (Figure 2.1), we feel that this cannot be justified. An additional element here is the substantially increased data that would be needed to drive such a scheme.

Table 3.1 **Data requirements of the soil water model**

Soil Profile Hydrologic Characteristics

For each layer:
- soil water content at saturation
- saturated hydraulic conductivity
- suction moisture curve (a maximum of 20 observations)

For each cell:
- initial soil water content

Soil Profile Dimensions

- total number of cells in column
- number of cells in layer 1
- number of cells in layer 2
- thickness of each cell

Surface Conditions

- detention capacity
- maximum evaporation during the day

Precipitation

- rainfall data time increment
- rainfall data for each time increment
- rainfall start time
- rainfall stop time

Program Controls

- iteration time for simulation
- simulation start time
- simulation stop time
- number of profiles for the catchment area

Note: no historical flow data is required.

Table 3.2 Coefficients of variation based on 20 runs for each organic matter/storm combination shown

	STORM	CLAYS						SILTS						SANDS					
		% Organic Matter						% Organic Matter						% Organic Matter					
		0	2	4	6	8	10	0	2	4	6	8	10	0	2	4	6	8	10
Runoff volume	I	2	2	2	3	2	2	15	15	13	16	13	15	-	-	-	-	-	-
	II	0.5	0.7	0.5	0.3.	0.5	0.7	8	8	7	9	8	7	82	125	97	69	119	62
	III	0.6	0.6	0.6..	0.5	0.7	0.4	3	5	4	4	5	4	139	126	157	103	103	308
Peak discharge	I	4	3	8	6	4	3	1	1	0.9	2	2	0.9	-	-	-	-	-	-
	II	0.4	0.6	0.4	0.8	0.5	0.6	8	8	7	8	8	6	81	125	99	68	119	61
	III	0.5	0.4	0.5	0.4	0.5	0.3	3	6	4	4	4	4	130	119	149	113	104	272
Time to peak	I	2	2	2	2	2	2	0.9	0	0	0.9	0	0	-	-	-	-	-	-
	II	0	0	0	0	0	0	1	2	1	2	2	2	67	93	93	60	113	43
	III	0	0	0	0	0	0	0	3	0.7	0.7	0	0.7	113	103	140	84	103	205

\- Indicates no runoff

4. Experimental catchments and related data sources

For the purposes of model development and for this report the identification of moving storm effects, test catchments in one area have been established, and a further set of catchments are to be incorporated into the study within the next six months.

4.1 West Germany : River Haune, Fulda

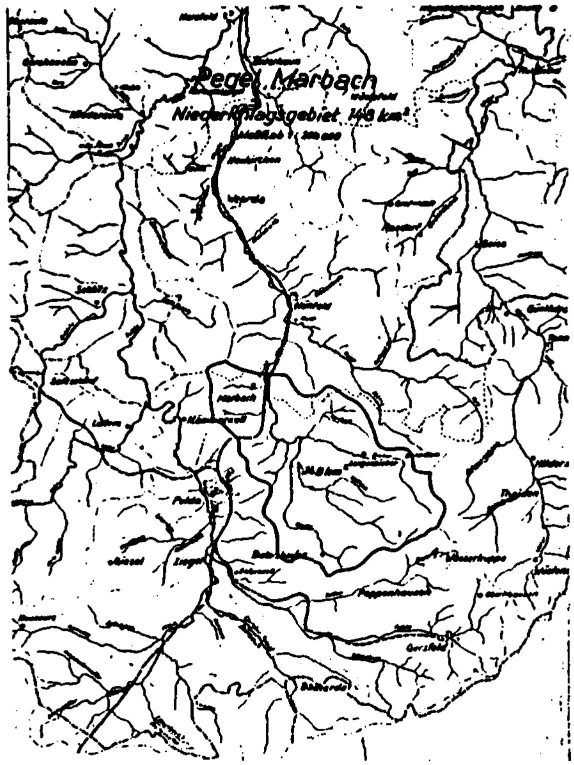
The initial travelling storm effects reported later were developed on the Haune catchment in West Germany (grid ref. 350 561). This is a catchment of 148 km, Figures 4.1 - 4.4, for which soil classification data, precipitation information, outflow hydrographs and rating curves are available.

Radar precipitation input, with a resolution of 5 km^2, has been anticipated, Figure 4.2, as a future development to replace raingauge data in suitable areas. The effects of radar uncertainty will be included stochastically at a later date.

Subdivision of the Haune catchment, carried out manually, is restricted to seven catchments. This limitation is imposed by the need to maintain a consistent level of resolution throughout the model (Figure 2.1), and by central processor, computing restrictions. Increasing the resolution of subcatchments in the Haune catchment, would extend the number of catchments from 7 to approximately 25. Sensitivity to subcatchment resolution will be examined in future work.

4.2 West Germany : River Fulda

It is hoped to expand the study site in West Germany to include the greater catchment of the Fulda river, of which the Haune is a tributary. The approximate area of this catchment is 2500 sq.km., about an order of magnitude greater than that of the Haune's catchment.



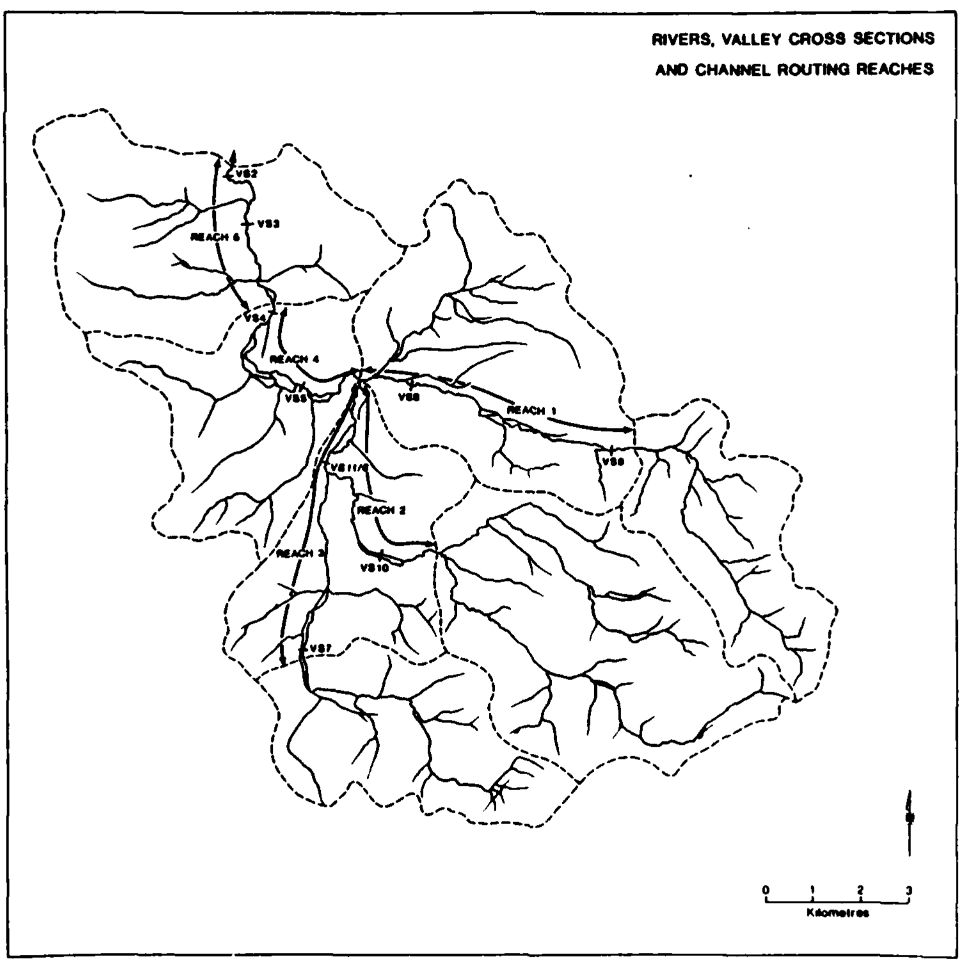


Figure 4.1 : Location and selected routing reaches of the River Haune used in the moving storm study - section 5.

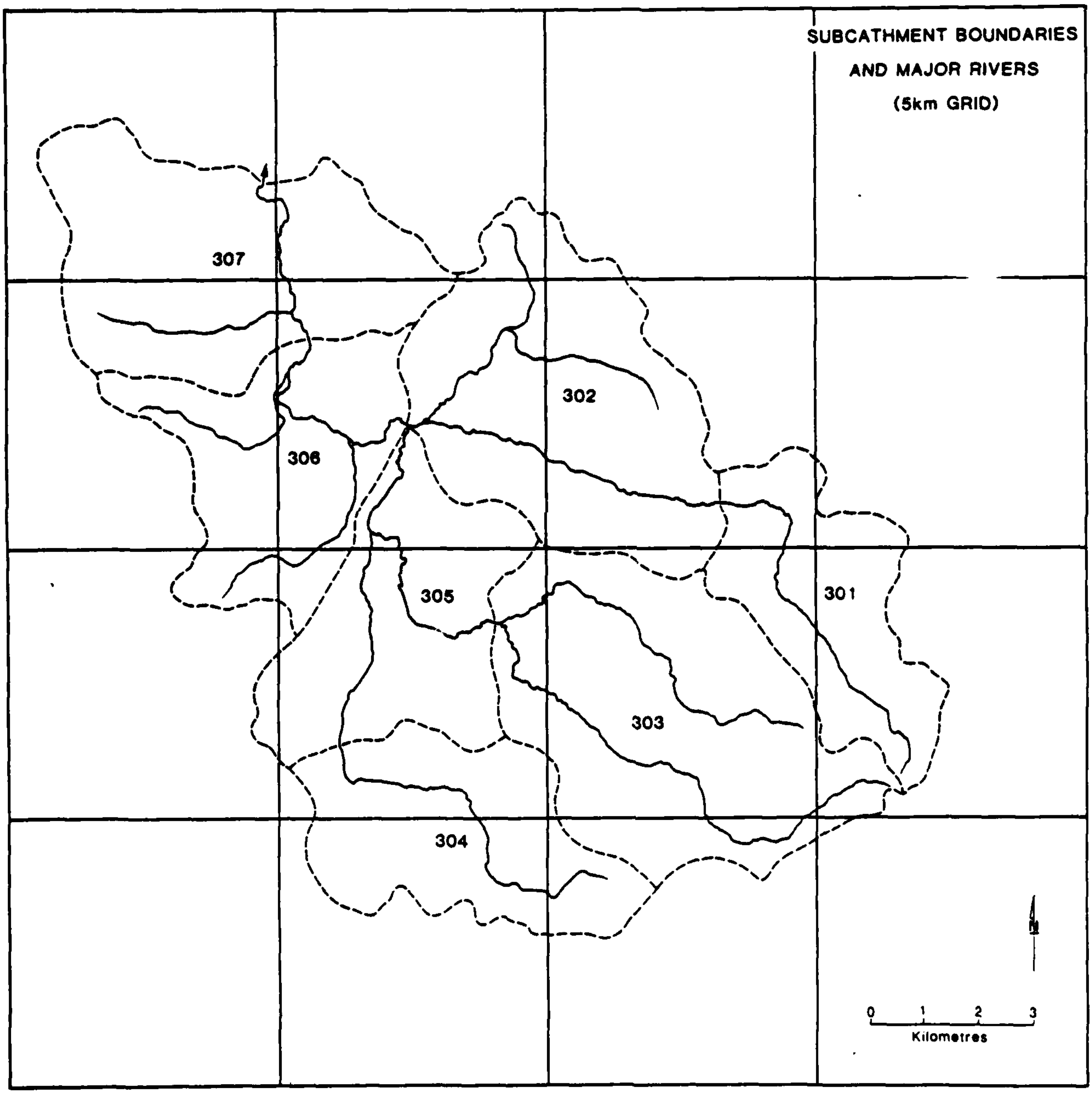


Figure 4.2 : Subcatchment boundaries and notional radar grid (5 km) used for precipitation inputs in the moving storm study - section 5.

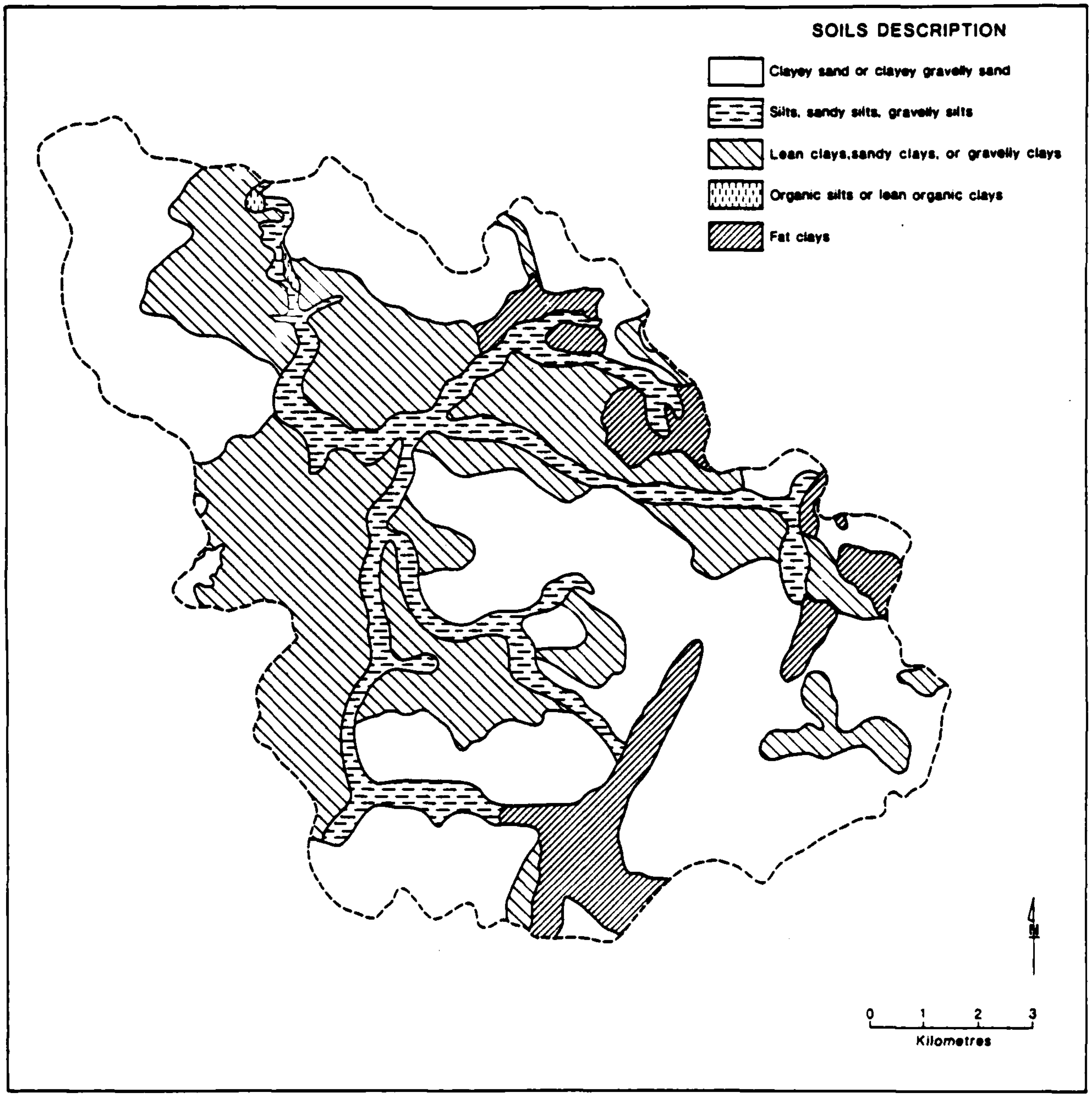


Figure 4.3 : Soils of the River Haune catchment

Figure 4.4 : River Haune

4.3 USA : Oklahoma

A further study site is being explored in Oklahoma, USA. This site includes some 175 raingauges in 2500 sq.km., with which it is hoped to investigate the modelling of severe convective storms, traversing the catchment. Collaboration with U.S.D.A. at Beltsville, Washington, is continuing with respect to data acquisition.

4.4 Hydraulic research : Hydraulics Research Ltd., England

Data from hardware models and study sites throughout the U.K. is at present being investigated, in order to include out of bank roughness effects in the model. This is discussed further in section 6.

5. Moving storm effects

The River Haune catchment was selected for running HYMO 2 with precipitation input assigned to correspond to 5 km grid squares (see Figure 4.2) to replicate moving storms, at variable speeds from four orthogonal directions. The basic purpose of this design is to be able to evaluate the space/time precipitation input data needs for HYMO 2 in the context of hydrograph predictions for particular applications.

The exact experimental design used was as follows:

3 storms	-	$^1/2$" in 24 hours
		1" in 6 hours
		2" in 30 minutes
2 storm speeds	-	5 km hr^{-1}
		10 km hr^{-1}
4 directions	-	N, S, E, W.

Hence, 24 experimental frames were undertaken in all. The operational rule of particular note in the design adopted relates to the fact that as soon as precipitation occurred in any part of a subcatchment, defined by the precipitation grid square, then the appropriate precipitation was apportioned to the whole subcatchment.

The results presented in this report relate principally to the $^1/2$" in 24 hour and 1" in 6 hour storms. Table 5.1 illustrates all eight experimental frames for the $^1/2$" storm, showing the time to peak and peak discharge values. Table 5.2 details the same parameter for the 1" storm. The principal points to note from the results are:

(i) For the $^1/2$" in 24 hour storm (being typical of a European frontal precipitation event) there is essentially no difference in either

Table 5.1 : Hydrograph results from running storm 1 ($^1/2$" in 24 hours)

	Time to peak (hours)							
	Speed : 10 km hr^{-1} Storm direction:				5 km hr^{-1}			
	N	S	E	W	N	S	E	W
301	24.5	8.5	24.75	24.0	25.0	24.5	26.0	22.5
302	25.0	24.5	24.25	24.25	26.0	24.35	24.25	25.0
303	23.75	25.0	23.75	23.75	23.25	26.75	25.5	22.5
305	24.5	24.25	24.5	24.5	24.75	24.75	25.0	26.0
304	24.0	25.0	24.5	24.75	24.0	26.0	24.75	24.5
306	24.75	24.25	24.0	22.25	25.25	25.0	24.0	26.0
307	25.0	24.0	24.0	25.0	26.0	24.0	24.0	26.0
Outflow hydrograph	25.2	24.3	24.1	24.8	25.4	24.4	24.2	23.9

Table 5.1

Storm 1 (0.5" in 24 hrs.)	Peak discharge M^3S^{-1}							
	10 km hr^{-1}				5 km hr^{-1}			
	N	S	E	W	N	S	E	W
301	1.14	1.25	1.13	1.13	1.11	1.13	1.13	1.12
302	1.95	1.94	1.93	1.95	1.96	1.92	1.92	1.94
303	2.31	2.32	2.30	2.31	2.29	2.33	2.31	2.28
305	1.37	1.37	1.38	1.38	1.37	1.36	1.38	1.38
304	1.35	1.35	1.34	1.33	1.33	1.34	1.33	1.33
306	1.21	1.21	1.21	1.32	1.20	1.22	1.21	1.22
307	1.89	1.90	1.91	1.90	1.90	1.90	1.90	1.89
Outflow hydrograph	11.04	10.97	10.99	11.14	10.99	10.90	10.93	10.79

Table 5.2 : Hydrograph results from running storm 2
(1" in 6 hours)

	Time to peak (hours)							
	10 km hr^{-1}				5 km hr^{-1}			
	N	S	E	W	N	S	E	W
301	6.5	6.3	6.5	6.0	7.0	7.0	7.0	6.0
302	7.0	6.5	7.0	7.5	8.0	7.0	7.5	7.5
303	6.5	7.0	7.0	6.5	6.5	7.5	8.0	6.5
[illegible]	7.0	7.0	6.5	7.6	7.5	7.5	7.0	8.0
304	6.0	7.0	6.5	7.0	6.0	8.0	7.0	8.0
306	7.5	7.0	6.5	7.5	8.5	8.5	7.0	9.0
307	7.5	6.5	6.5	7.5	8.5	6.5	6.5	9.0
Outflow hydrograph	7.4	7.4	7.4	7.6	8.2	8.0	8.0	8.0

Table 5.2

Storm 2 (1" in 6 hrs.)	Peak discharge (M^3S^{-1}) Speed: 10 km hr^{-1}				5 km hr^{-1}			
	N	S	E	W	N	S	E	W
301	14.81	24.61	14.71	14.71	14.85	14.51	14.22	14.66
302	22.72	22.76	22.81	20.94	22.72	22.66	22.30	22.36
303	29.64	29.72	29.77	29.73	29.56	29.63	29.41	29.62
305	15.18	15.24	15.36	15.18	14.97	14.97	15.30	15.36
304	15.99	16.11	16.08	16.15	15.86	15.79	16.08	16.00
306	11.58	11.55	11.58	11.52	11.42	11.42	11.35	11.37
307	20.02	20.05	20.07	20.26	19.49	19.50	19.57	19.58
Outflow hydrograph	123.00	118.84	120.87	120.01	120.86	114.19	114.38	117.25

time to peak or peak discharge for any of the conditions prescribed in terms of both speed and storm direction (see Figure 5.1). We may reasonably conclude therefore that a catchment area of 145 km^2 may be regarded as the minimum for which high resolution (5 km grid square) precipitation data is required for low intensity storms.

(ii) For the 1" in 6 hour event, by contrast, certain differences are apparent in the context of both time to peak and peak discharge. However, these differences are not large - see Figures 5.2 and 5.3. Amongst the largest difference is to be found in the 10 km hr^{-1}, northerly moving storm compared with the 5 km hr^{-1} southerly moving storm. In this case. the peak discharges are respectively 123 m^3S^{-1}, and 114.19 m^3S^{-1}. The respective time to peak differs by some 30 minutes - see Figure 5.2.

For higher intense storms at 145 km^2 area then we may expect maximum differences of perhaps no greater than 5% in outflow hydrograph parameters attributable to moving storm conditions.

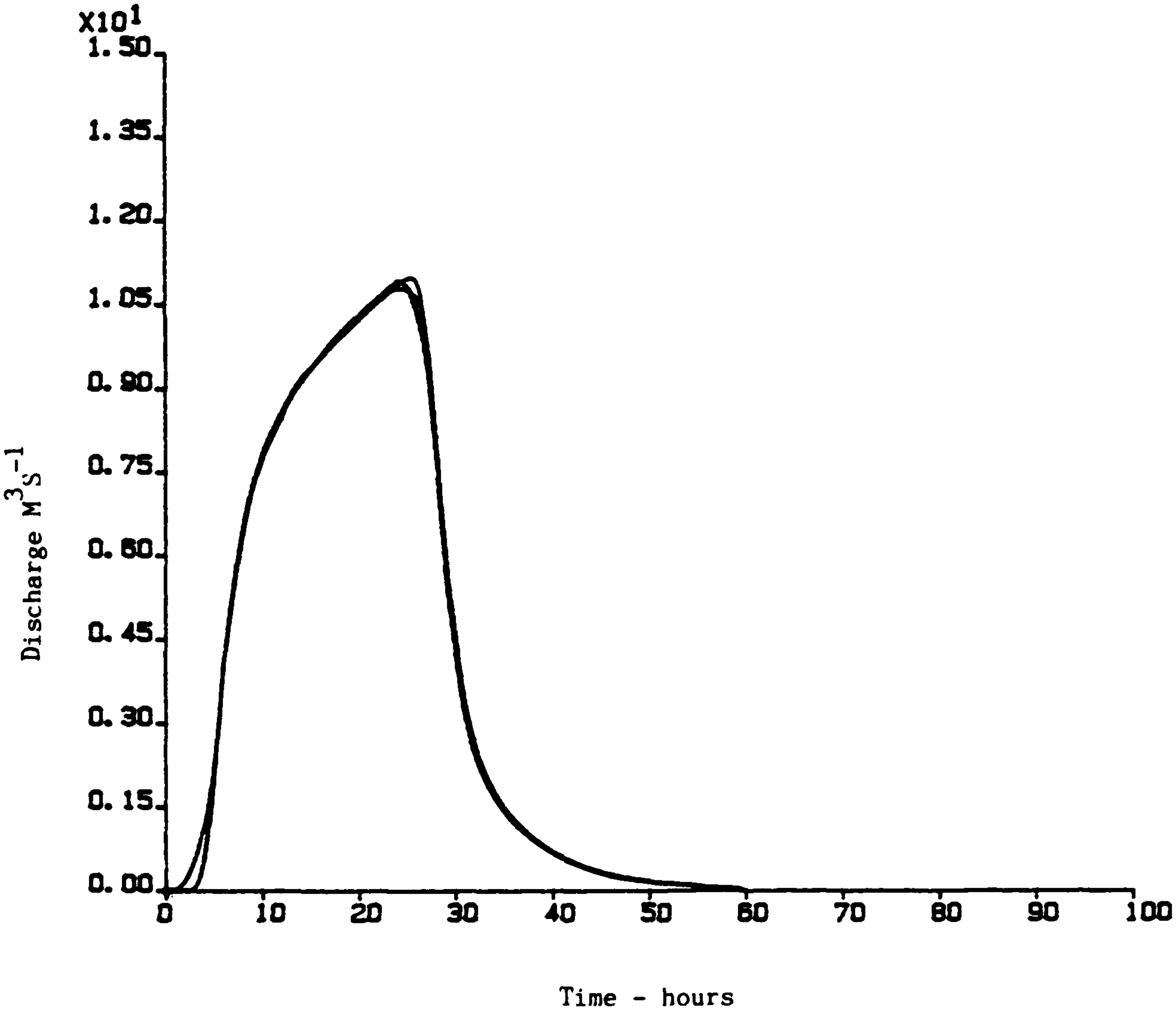


Figure 5.1 ; Hydrographs for the ½" in 24 hour storm (5 km hr^{-1}) generated by storm movements in four orthogonal directions, Note similarity of hydrograph responses

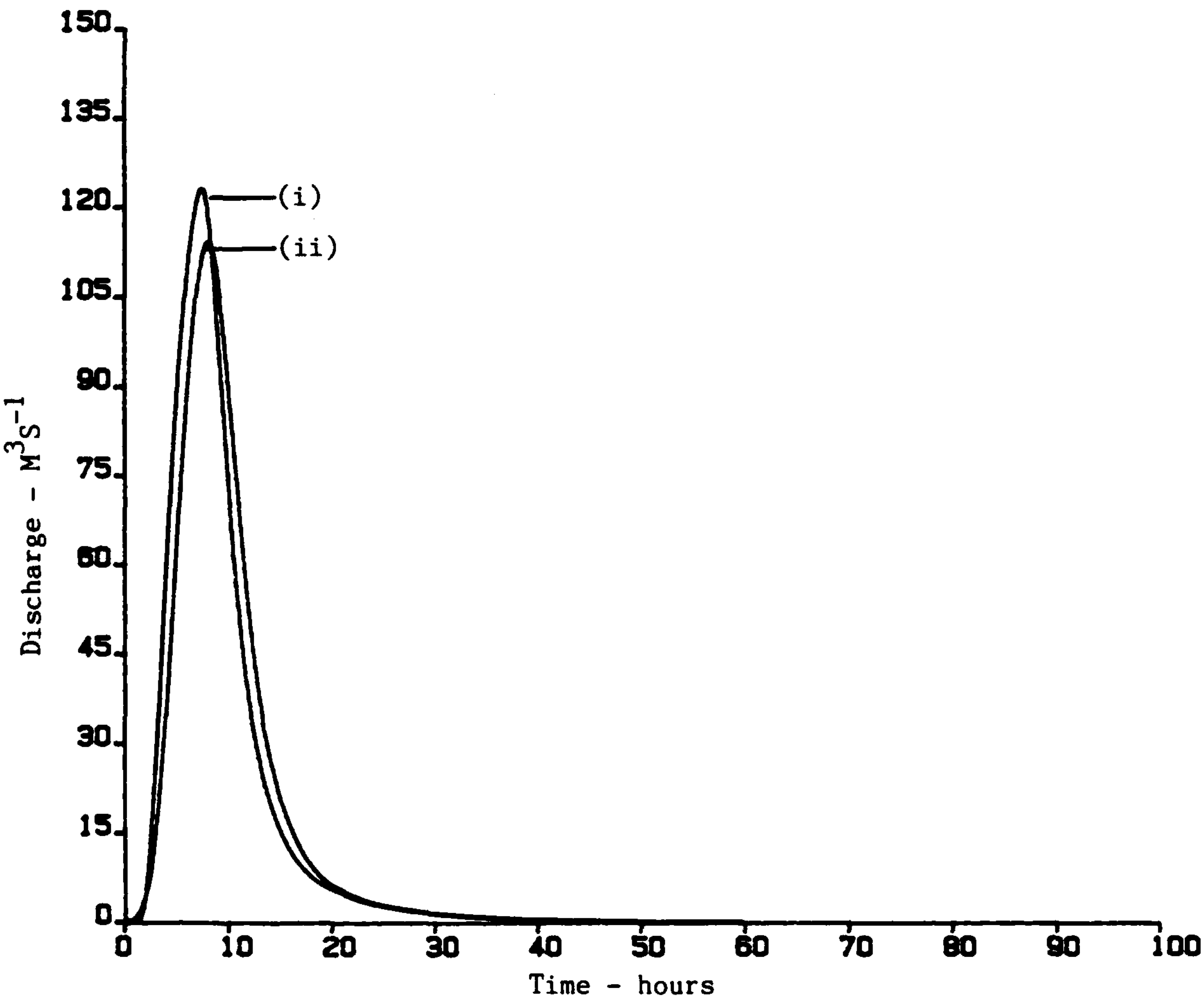


Figure 5.2 : Hydrographs for the 1" in 6 hour storm showing
(i) northerly storm track at 10 km hr^{-1}, and
(ii) southerly storm track at 5 km hr^{-1}

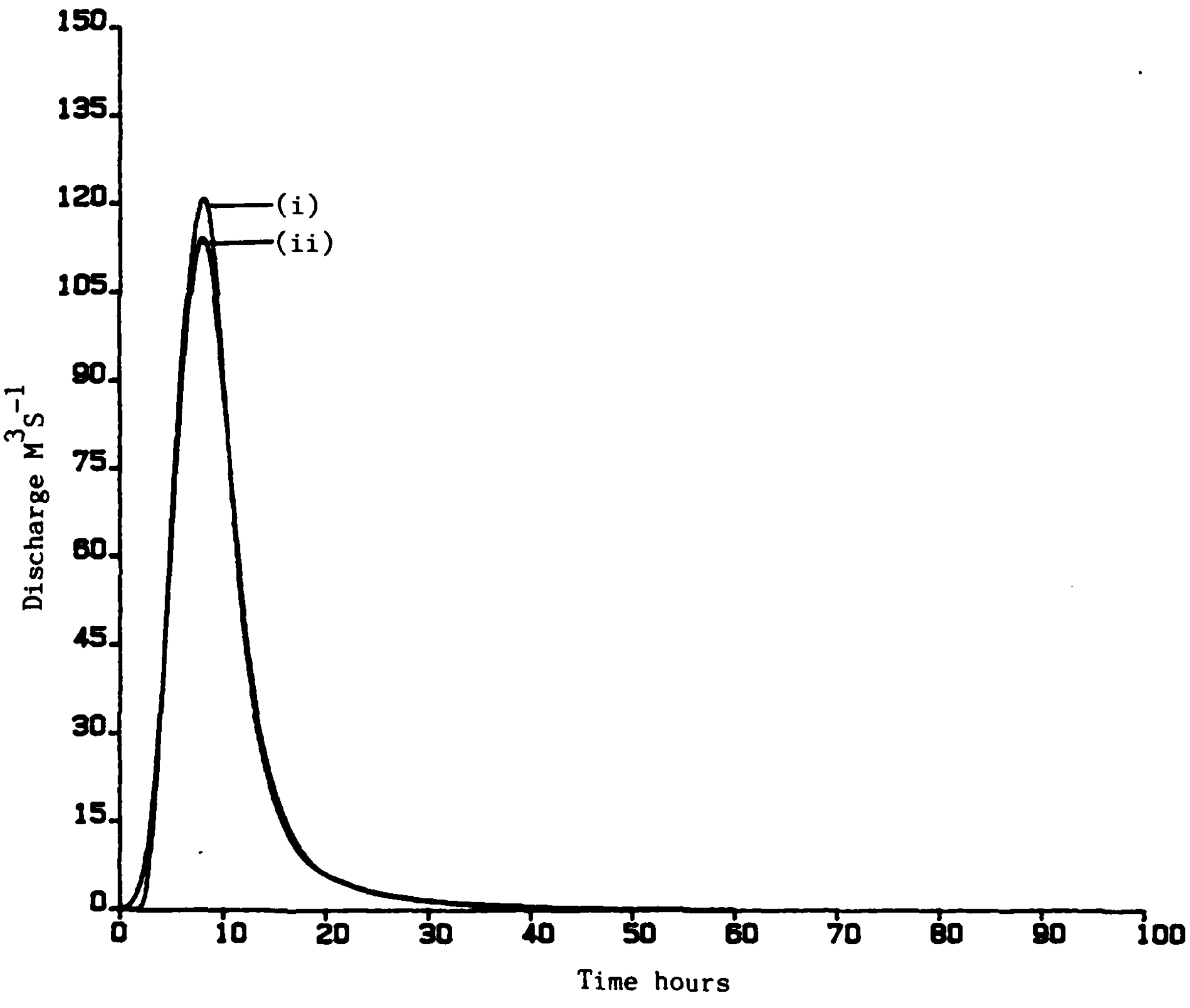


Figure 5.3 : Hydrographs for the 1" in 6 hour storm showing for the 5 km hr^{-1} speed
i) northerly storm track
ii) southerly storm track

6. Revision of out-of-bank roughness and stage-discharge calculations

HYMO 2 accepts that friction varies with stage and includes a function to reduce Manning's n with rising stage.

$$n' = n - 0.0025 \frac{\text{Area}}{\text{Wetted perimeter}} \qquad 6.1$$

There seems no physical basis for this equation and with a large hydraulic radius, n' may assume a negative value, resulting in a negative discharge.

In the flow-rating curves generated by Manning's equation (in cases where they are unknown), there is no provision for any interaction between computations undertaken in the specified channel sections; i.e. the channel cross sectional sub-areas are assumed independent in terms of the hydraulic calculations.

There are thus two areas of potential research here:

(i) the assignment of roughness to channel sub-areas, and

(ii) the revision of the Manning equation for discharge calculations in compound (out-of-bank) channel conditions

Evidence is available to show that significant errors can occur in discharge estimation in compound channels using the Manning equation. As we have noted above, this is due to the in-channel and out-of-bank interaction. Certain workers (e.g. Chow) have suggested that a redefinition of the area and wetted perimeter terms may be undertaken to provide an improved discharge estimate based on the Manning formula. Figure 6.1 illustrates the condition. Figure 6.1a shows the full interaction between in-channel and out-of-channel flow. Figure 6.1b defines the channel morphometry terms that are then used to define the area (A) and wetted perimeter (P) for both the flood plain (Fp) and main channel (Mc).

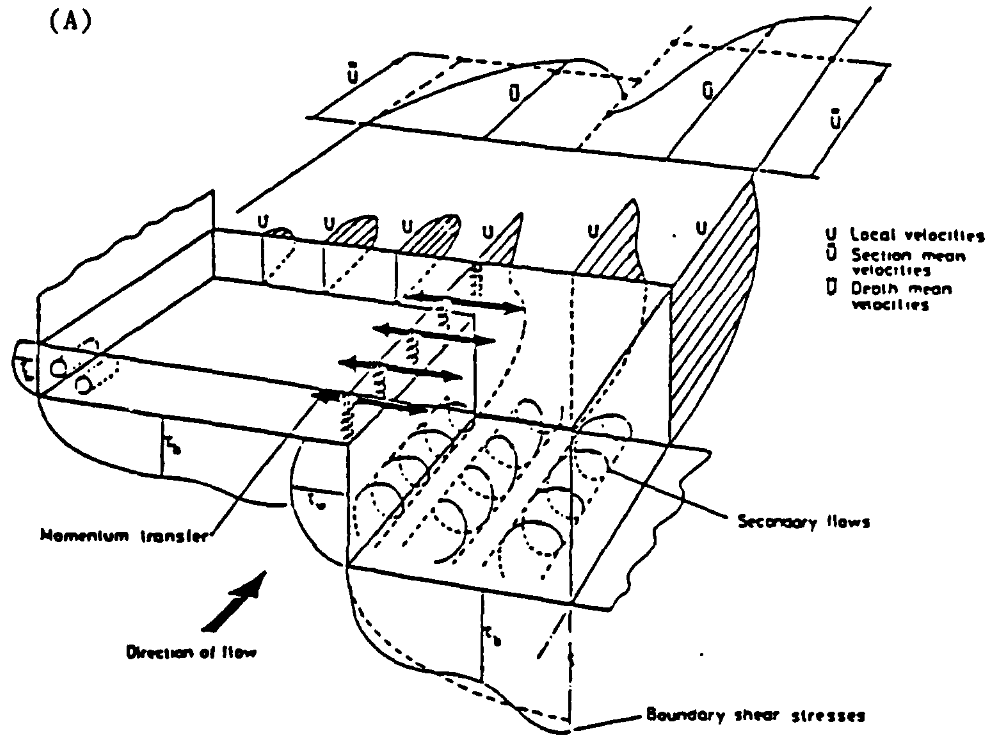
From Manning's equation:

$$Q_i = (A_i \quad S^f \quad) \; . \; (P_i \quad n_i)^{-1} \qquad 6.2$$

where Q_i is the flow through each sub area A_i. Table 6.1 provides four different methods used to determine A_i and P_i, based upon momentum transfer between sub areas (Figure 6.1a). Knight (1984) has shown that whilst certain of these methods provide differences in discharge estimates by up to as much as +25% of measured flow, method 3 was significantly more accurate in the flume trials undertaken.

We will be evaluating the effect of including these alternative procedures in the estimation of the rating curves for HYMO 2 in the next six month period.

Evidence from flume studies conducted at Hydraulics Research shows that a pronounced hysteresis can occur in the stage-discharge relationship for compound channels. Potentially, this can be thought to have a major effect upon flood inundation levels, and is currently not included in the HYMO 2 computation procedure. When the full effects of equation 6.2 and Table 6.1 have been evaluated, this aspect will be examined.



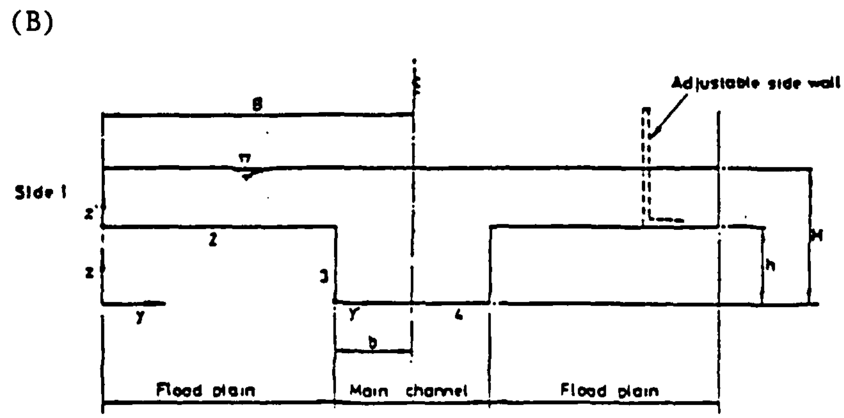


Figure 6.1 : Definitions of channel cross sectional sub areas in a compound channel (see Table 6.1)

Table 6.1 : **Design Methods for Compound Channels**

Method (1)	A_{fp} (2)	P_{fp} (3)	A_{mc} (4)	P_{mc} (5)
1	$(H-h)(B-b)$	$B-b+H-h$	$2bH$	$2b+2h$
2	$(H-h)(B-b)$	$B-b+2(H-h)$	$2bH$	$2b+2H$
3	$(H-h)(B-b/2)$	$B-b+H-h$	$b(H+h)$	$2b+2h$
4	$(H-h)(B-b/2)$	$B-b+H-h$	$b(H+h)$	$2b+2h+2\sqrt{[(H-h)^2+b^2]}$

7. Discussion

The following progress has been made in this reporting period:

(i) A West German catchment (the River Haune, ~~Figure~~ 4.1) has been established as a validation base for HYMO 2.

(ii) On this catchment, an initial study has been completed of the relative effects of many storms on resultant catchment outflow hydrographs (~~section~~ 5). This study is an essential element of the model/data development programme. We aim to specify the precipitation input needs (in time and space) for selected applications of HYMO 2 within the next twelve months.

(iii) An initial study of an approach to land use incorporation into the infiltration algorithm using organic matter change has revealed a relative insensitivity to this parameter (~~Table 3.1~~). To apply HYMO 2 to forested conditions may necessitate further exploration - most probably in the modification of the hydraulic conductivity under such conditions. It is to be noted that validation of our scheme so far has been confined to non-forested areas (see report DAJA-45-83-C-0029). We plan to rectify this within the next twelve months.

(iv) The current treatment in HYMO 2 of rating-curve generation using the standard Manning equation has been examined. It is considered that the current approach (equation 6.1) may lead to errors in both peak flow and flood inundation estimates. An examination of alternative methods of estimating area and wetted perimeters in compound channels (see Table 6.1) will be examined in the context of the Fulda catchment in the next reporting period.

END

7-87

DTIC

END

7-87

DTIC