SIMULATION OF HYDROLOGICAL FLOOD ROUTING ALONG SPILLWAY CHANNEL OF RIVER ASA IN ILORIN KWARA STATE.

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DEDICATION

This project report is dedicated to my wife Falilat Olaitan and Children Kafayat Adebanke, Habib Adedayo, and Afis Adeyinka.

ABSTRACT.

This report presents the hydrological flood routing along spillway channel of Asa dam. The storage constant K and a dimensionless weighting factor x were determined to be 0.92 and 0.2 respectively. Other constant Co, C1, C2 in Mukungum model are computed to be 0.2557, 0.5534 and 0.1909 respectively. To perform the analysis, the spillway channel was divided into 15 reaches, each reach is 1Km long. The inflow into the reach at the beginning of the catachment area is the discharge from the spilling at Asa dam. The runoff from the basin areas of the reaches is computed and added to the main stream inflow to obtain the total inflow before routing was done to get the outflow. The outflow of the first reach serve as the inflow to the second reach and the process continue in that order.

Also to depict the behaviour of the flowing water along the spillway channel, the outflow from each reach were plotted against the time (day), thus established the form or shape of flood hydrographs at different points on the river at the downstream reach. This enable the prediction of the possibility of flood at downstream reach of the spillway channel.

Based on this study, it was discovered that the construction of Asa dam across river Asa has changed the natural flood plains downstream to some extent because from the hydrograph it was observed that the effect of discharge from the dam was eminent at the upstream of the catchment area towards the city.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 General introduction

Flooding results primarily from excessive runoff from the watershed area and constrictions in the stream channel or valley that impede flow. Urban development is an important contributing factor to excessive runoff. Peak flows from a watershed can be two to six times greater after development than before, this is as a result of reduced infiltration over impervious areas and because improved drainage systems accelerate runoff.

Indiscriminate development through construction of bridges, culvert and refuse dumping near streams and rivers can contribute to the constrictions in the stream valley thereby causing flood and destruction, this is eminent in Lagos state and Ibadan.

Ilorin and it's environs is developing, hence there is a need for preventive hydrology, this prompted the studies and simulation of hydrological flood routing along River Asa "Spill way channel" , Since River Asa is the main river that flows through the city.

Flood routing is a process through which the variation of discharge with time (i.e hydrograph) at a point on a stream channel can be determined by consideration of discharge data at another point upstream. The storage along a reach of a channel (distance between any two points along the channel) is a fundamental concept in flood routing and this must be estimated.

1.2 Objectives of the project

To study and simulate the hydrological flood routing along spillway channel of Asa River, the following objectives need to be achieved;

(i) Carrying out a reconnaissance survey of the project area

(ii) Simulation of outflow at different points on the river at the down stream through computer programming.

(iii) Establishment of the form or shape of flood hydrographs at different points on the river at the downstream reach.

(iv) Predicting the possibility of flooding at downstream reach of the spillway channel.

1.3 Justification of the project

The establishment of the form or shape of flood hydrographs at different points on the river at the downstream reach, will enable the prediction of flooding and thus serve as a guide to the people residence at Ilorin.

The environmental protection agency at Ilorin will also benefit from the outcome of this study as regard the minimum flood plain to be maintained along the downstream channel of the River. Flood routing is very important for river managers concerned with forecasting floods in the lower parts of a river basin.

This project will enable the design engineers to route flood hydrographs in assessing the capacity of reservoir spillways, in designing flood protection schemes and evaluating the span and height of bridges or other hydraulic structures When there is the need to modify the channel of a river, it is necessary to know the likely effect on the shape of the flood hydrograph in addition to that on the peak stage.

1.4 SCOPE OF THE PROJECT

This project covered:-

(i) Collection of daily rainfall at Ilorin town

(ii) Collection of daily discharge at Asa dam spillway

(iii) Collection of map of river Asa catchment area (downstream of the dam)

(iv) Use of computer in estimating the outflow at different points on the river by adopting Muskingum flood routing model.

(v) Plotting of the flood hydrographs at different points on the river at the downstream reach.

1.5 River Asa

River Asa has it's source in Oyo state at Iwo North East and Ogbomosho South east, precisely at Lekewogbe and Babamogba areas. The River is about 82,300m long, it flows through Ilorin in kwara state before finally discharge into River Awun also in Ilorin Local Government area. Before it's termination it is joined by River Oyun to the east and River Imoru to the west. Among the earliest tributaries of River Asa are Rivers: Afidikodi, Ekoro, Alamula, Obe etc.

The uses of River Asa especially in kwara state can not be over emphasized; River Asa was dam and used for water supply to Ilorin metropolis, there are other water treatment stations along it's paths. Other uses of the River are irrigation, fishing etc.

The length of the River from the dam retaining wall to where the river ends is about 28,700m, this is the project site.

Flood - plain areas are rather evenly distributed among streams of different size, small streams are numerous and of great total length, but their flood plains are narrow, large streams are few but have wide flood plains. The construction of the dam across River Asa altered the natural flood plain downstream to some extent.

1.6 The dam and site description

Asa dam is at the Southern end of the city (see figure 1.1) and is basically a composite dam - a combination of earth dam and concrete dam. Dam location is at a point 5km south of Ilorin. The dam has a spillway to ensure safety against overtopping during flood. Over the weir is a bridge which has 4 piers and also the weir does not extend across the width of the channel, hence contraction of the nappe takes place.

1.6.1 Details of dam

Overall length	-	597 metres
Storage capacity	-	43,000,000 cubic metres
Extent of lake	-	18000 metres

1.6.2 Earth embarkment

Length	-	402 metres
Crest width	-	6 metres
Maximum height	-	27 metres
Upstream slope	-	1:3

Downstream slope	-	1:2:5
Earth fill	-	250,000 cubic metres

1.6.3 Overflow concrete gravity section

Length	-	130 metres
Crest width	-	6 metres
Maximum height	-	11 metres

1.6.4 Spillway

Length	-	65.532 metres
Height	-	14 metres
Maximum discharge	-	79,000 (m^3/s)

The density of drainage channels in the area is low, a fact reflected in the land surfaces with no visible drainage routes.

The soils in the catchment area are derived mainly from insite weathering of the parent rock, supporting low growing vegetation and occasional trees. The vegetation thickness thickens along the main water courses. The natural vegetal cover has been disturbed to some extent around the villages.

1.7 Climatic condition/vegetation

The city enjoys wet and dry seasons. The wet season starts towards the end of march and ends toward the end of October. Dry season begins in November and lasts till late February. December and January are usually cold dry months due to the influence of harmattan from the desert region in the north.

Rainfall begins usually by the end of march and lasts until October. The heaviest rainfall is recorded between June and early August. There is short spell of drought between August and September.

Vegetation consists of wooded savannah and grassland in this part of the state. Some of the notable trees include the locust bean, baobab, akeeaple and Shea-butter trees. The topography is plain lands in this part of the state.

CHAPTER TWO

2.O LITERATURE REVIEW

2.1 General review

Yung (1985), developed River flood routing by non linear Muskingum method. The linear form of the Muskingum model has been widely applied to River routing. However, a nonlinear relationship between storage and discharge exists in most actual River systems. In his paper, a nonlinear Muskingum model was solved using the state variable modelling technique. Various curve fitting techniques were employed for the calibration of model parameters and their performances within the model were compared.

Due to it's simplicity, among the many models used for flood routing in natural channels and Rivers, the Muskingum model has been one of the most frequently used tools. The most common form of the Muskingum model (herein referred to as the linear Muskingum model) is

$$S = K [xI + (1 - x) O] \text{--------------------} 2.1$$

The formulation of linear model can be modified to account for nonlinearity by writing

$$S = a [xI + (1 - x) O]^m \text{-------------------} 2.2$$

In which a and m are constants

x is a dimensionless weighting factor between

0 and 0.5 (but normally between 0.2 and 0.4

(Andrew chadwick et al 1993). X is also a constant expressing the relative contribution of inflow (I) and outflow (O) to storage (S) in the channel reach.

K is called the storage constant and has dimensions of time.

Comparing equations 2.1 and 2.2, one sees that equation (2.2) has more degrees of freedom, which presumably would yield a closer fit to the nonlinear relation between storage and discharge. However, because of the presence of nonlinearity in the equation, the calibration procedure becomes more complicated. Furthermore, the routing procedures for flood prediction will no longer be as straight forward as those for using the linear model.

State variable modelling concept is capable of describing systems which are linear or nonlinear, time variant or time invariant, deterministic or stochastic while having multiple inputs and outputs at the same time.

The derivation of the state variable formulation for nonlinear Muskingum model equation 2.2 is straight forward.

By rearranging and manipulating equation 2.2 output is then

$$Q[\frac{1}{1-a}][\frac{S}{a}]^{\frac{1}{m}}-[\frac{x}{1-x}]I \quad \text{-------------------2.3}$$

Combining equation (2.3) and continuity equation, the state equations can be expressed as

$$S = -[\frac{1}{1-x}][\frac{S}{a}]^{\frac{1}{m}} + [\frac{1}{1-x}]I \quad \text{----------------- (2.4)}$$

The solution procedure for the discrete time state variable nonlinear Muskingum model, thus, involves the following five steps:

Step 1: The inflow hydrograph to the channel reach is discretized into several time stages where time intervals need not be equal.

Step 2: From the initial state of system storage, S and initial inflow rate to the channel reach, I, the time rate of change of storage volume in the channel reach at the initial state, s_1, can be evaluated by the state equation (2.4)

Step 3: The state of the system, i.e, channel storage, at the next stage, S_2, is estimated or approximated as

$S_2 \approx S_1 + S_1 \blacktriangle t$

Step 4: The magnitude of the outflow rate at the current stage can then be calculated by solving the output equation, equation (2.3) using current values of inflow rate and channel storage at the same stage.

Step 5: Using current information on inflow and channel storage, steps 2-4 are repeated recursively until the last stage is reached.

Tingsandai and manandha (1985), developed an analytical diffusion model for flood routing which takes into account backwater effect and lateral flows. The model was applied to route the floods in a hypothetical rectangular channel with different upstream, downstream, and lateral boundary conditions. Different channel characteristics were assumed and the results obtained were found to check well with those obtained by the finite difference method of implicit scheme based on the complete St. Venant equations for unsteady open channel flow. The model shows good results when applied to simulate flood flow conditions on the lower Mun River, in North east Thailand. The model cannot be incorporated with detailed data of cross sections of River bed geometry but requires only their average values. The chezy's C and the diffusivity k due to channel irregularities were used in the model and were determined by trial and error during model calibration. The model provides an excellent means to analyse individual or overall effects of the boundary conditions and requires much less effort and time for computation at a particular station.

A pilot study in preventive hydrology on Cameron Run initiated by the water Resources Divisions of the US Geological survey in cooperation with Fairfax country and the city of Alexandria in norther Virginia in 1959 has been completed. A related cooperative project established in 1960 to delineate flood-hazard areas on important Fairfax country streams valleys in still underway.

Also a program which established a procedure by which the extent of flooding as a network of stream courses can be predicted for 25, 50 and 100 year flood recurrence intervals on the assumption of ultimate development in the watershed areas.

2.2 Data needed for the project

1. Daily rainfall in Ilorin
2. Daily discharges at Asa Dam Spillway
3. Map of River Asa catchment area (downstream of the dam).

2.3 Channel routing

This project is to establish the form or shape of flood hydrographs at different points on the River below the reservoir systems.

Hydrograph is the variation of discharge with time.

Once the inflow hydrograph relationships have been defined for the detention system a routing procedure is performed which can simulate the performance of the detention facility and produce an outflow hydrograph. Also local inflow which enters the reach between the inflow and outflow stations has to be treated.

If the local inflow enters mainly near the upstream end of the reach, it is usually added to the main-stream inflow to obtain total inflow before routing is done. If the local inflow occurs primarily near the downstream end of the reach, it may be subtracted from the outflow before storage is computed in this case, the main-stream flow is routed through the reach and the local inflow added after routing is complete.

Numerous flood - routing methods are applicable for routing an inflow hydrograph in channels.

General speaking, flood - routing methods can be classified as either hydraulic methods or hydrologic methods of initial importance prior to the selection of the routing methods is the selection of a proper routing time step. This time step being the time interval at which the ordinates of the inflow hydrograph are presented. The time step should be sufficiently short to define the inflow hydrographs within the model accuracy.

2.3.1 Muskingum analytical method

The stream is considered to have storage between the inlet and outlet structures and the MUSKINGUM is a common way of flood - routing.

Channel storage may be considered to consist of two parts, prism and wedge storage, as shown in figure 2.1. Assuming no sudden change of cross-section within the reach, then approximate expressions for inflow, outflow and storage are as follows:-

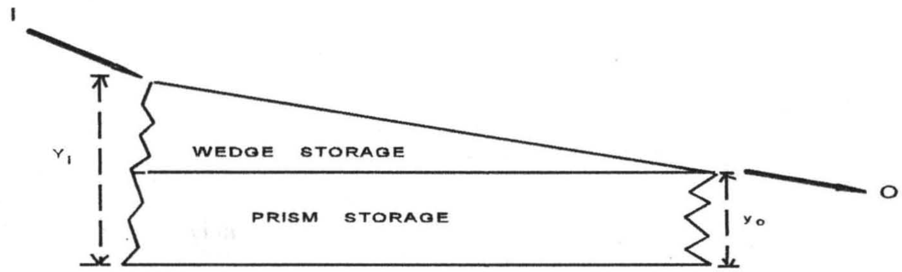


FIGURE 2.1 CHANNEL ROUTING

$I = ay_i^n$ $O = ay_o^n$ --------------- 2.5

Where a and n are constants.

Now

Prism storage = by_o^m

Wedge storage = $c[y_i^m - y_o^m]$ ----------------- ----- 2.6

Where b and c are constant.

Total storage S = prism storage + wedge storage

$= by_o^m - cy_o^m + cy_i^m$ ---------- 2.7

Substituting for y_i and y_o from (2.5) and assuming m = n (approximately correct for natural channel)

$$S=\frac{b}{a}O-\frac{c}{a}O+\frac{c}{a}I$$

$$S=\frac{b}{a}[\frac{c}{b}I+O-\frac{c}{b}O]$$

$$Taking\ \ k=\frac{b}{a} \qquad x=\frac{c}{b}$$

$$\therefore\ \ S=k[xI+O-xO]$$

$$S=k[xI+(1-x)O] \ \text{------------------} 2.8$$

K, is the travel time through the channel

X, a constant expressing the relative contribution of inflow (I) and outflow (O) to storage (S) in the channel reach.

To solve for K and X

(i) A plot of inflow and outflow hydrographs

(ii) A plot of different diagram of I-O against t.

(iii) But 0.5(I - O)t = mean storage

Hence plot $\sum S$ v_s t

(iv) Comparing y=mx+c with equation (2.8) K=m, which is the gradient.

(v) A plot of [XI + (1-X)0] v_s S for different values of X, say X=0.1, 0.2, 0.3 etc

(vi) The resulting plots from step (v) are called storage loops.

(vii) The storage loop that almost appropriate to a straight line can be used to determine X and K

i.e x is the value of x that gives the straight line and k is the gradient.

(viii) Also

$$\frac{I_1+I_2}{t}-\frac{O_1+O_2}{t}=S_2-S_1 \quad \text{---------------2.9}$$

Substituting S_2 ; S_1 *as* $S_2=K[XI_2+(1-X)O_2]$

$S_1=K[XI_1+(1-X)O_1]$ *respectively into equation (2.9) gives*

$$\frac{I_1+I_2}{t}-\frac{O_1+O_2}{t}= K[XI_2+(1-X)O_2]-K[XI_1+(1-X)O_1]$$

The only unknown is O_2 which can be expressed in terms of I_1 , I_2 and O_1 by collecting like terms as

$O_2 = C_oI_2 + C_1I_1 + C_2O_1$ ---------------------------2.10

Where

$C_o = (-kx + 0.5t)/(k - kx + 0.5t)$

$C_1 = (kx + 0.5t)/(k - kx + 0.5t)$

$C_2 = (k - kx - 0.5t)/(k - kx + 0.5t)$

$C_o + C_1 + C_2 = 1$

This is the analytical method.

2.3.2 Muskingum graphical method

If simultaneous inflow and outflow hydrographs are not available, graphical method which still employs Muskingum equation can be used to calculate K.

Recall Muskingum equation (2.8)

$S = K\,[xI-(I-x)O]$

If x = o, then S = KO

differentiating w.r.t time t

$$\frac{dS}{dt} = k\frac{dO}{dt}$$

$$\text{but} \quad I-O = \frac{ds}{dt} \quad \text{(storage equation)}$$

$$\therefore \quad I-O=k\frac{dO}{dt} \qquad \text{i.e} \qquad \frac{I-O}{k}=\frac{dO}{dt} \qquad \text{--------------2.11}$$

Equation (2.11) can be used to provide the graphical method of routing as follows:

(i) Plots of discrete values of the inflow hydrograph.

(ii) Measurement of storage constant K, horizontally from the position each hour is done.

(iii) A line from the end of k back to the previous discharge value O which is known or assumed is drawn.

(iv) A vertically downwards line from the next I value is drawn to intersect the line drawn in step (iii).

This intercept is the location of the next discharge of outflow, if joined to the previous discharge represents do/dt and may be used to form part of the outflow hydrograph.

(v) The procedure is repeated for other points of I to get a complete outflow hydrograph.

(vi) The outflow hydrograph of the reach will be used as the inflow hydrograph of the succeeding reach etc.

In this case, simultaneous inflow and outflow data are available. A value for x will be assumed in equation (2.8) and a plot of S derived from the known inflows and outflows is drawn against [xI+(1-x)O]. If the assumed value of x is correct, then a straight - line plot with gradient K should result. If this is not the case, a new value of x is chosen and the procedure repeated. Alternatively, regression analysis can be done to obtain a linear best fit line from which k is obtained.

This graphical technique is tedious. Cunge (1969) presented a simpler alternative to this approach, known as the Muskingum - Cunge method.

2.3.3 Muskingum - Cunge method

Cunge (1969) demonstrated that K is approximately equal to the time of travel of the flood wave, i.e

$$K \approx \Delta L/C \text{ -----------------(2.12)}$$

Where ΔL is the length of the river reach and

C is the flood wave celerity [$C \approx \sqrt{(gy)}$]

and

$$X \approx 0.5 - \frac{Q_p}{2S_o BC\nabla L} \quad \text{-------------2.13}$$

Where Qp is the mean flood peak

B is the channel surface width of the channel

S_o is the channel longitudinal bed slope

Using these equations allows rapid calculation of K and X, and the Muskingum - Cunge method may also be applied to rivers without recorded outflow hydrographs.

To determine the outflow hydrograph from the inflow hydrograph requires the application of the continuity equation in the form:

$$I - 0 = \frac{ds}{dt} \text{ --------------------(2.14)}$$

Where I is the inflow rate, O the outflow rate, S is the storage volume at t is time.

Equation (2.14) is written in a finite difference form to give

$$\frac{(I_t + I_{t+\nabla t})}{2}\nabla t - \frac{(O_t + O_{t+\nabla t})}{2}\nabla t = S_{t+\nabla t} - S_t$$

∴, *it can be represented as*

$$\frac{(I_1 + I_2)}{2}\nabla t - \frac{(O_1 + O_2)}{2}\nabla t = S_2 - S_1 \quad \text{----------------(2.15)}$$

CHAPTER THREE

3.0 SYSTEM ANALYSIS AND DESIGN

3.1 Collection and analysis of data

3.1.1 Rainfall

The daily rainfall data was collected at Ilorin International Airport since it is within the catchment area. The daily rainfall data was collected for a period of 10 years (1988 - 1997) and the mean presented in tables 3.1

3.1.2 Discharge measurement

River stage is the elevation of the water surface above some arbitrary zero datum. Primary field data gathered at Asa dam spillway shows daily river heights above the sill of the spillway which were measured by autographic Stage Recorder.

The water stage record was transformed into discharge

by using Francis formula:

$$Q = C\,[L - O.1nH]H^{m} \text{ ----------------(3.1)}$$

where C is coefficient of discharge = 2.1

L is length of weir = 65.532m

n is Number of end contractions = 10

H is stage height in metres above the weir

m is a constant = 1.4

Q is discharge (m^3/s)

This equation 3.1 can be written as

$$Q = 2.1\,[65.532 - H]H^{1.4} \text{ ------------3.2}$$

The mean heads of water above the sill and their corresponding discharge at Asa dam spillway for 1980 to 1997 are presented in table 3.2.

3.1.3 Statistical analysis of data

When data are collected and put in numerical form they do not seem to be meaningful until they are summarised in tables, charts, diagrams and some summary calculations are made. It is only in this form that they can be useful in aiding decision making.

Classification and tabulation of data forms the basis for reducing and simplifying the details given a mass of data into such a form that the assembled data can be easily understood. This is done in a statistical table where the data are arranged in columns and rows. The purpose of tabulation is to condense and thereby facilitate comparison of data. Tabulation is the first kind of statistical elementary summary made in statistical investigations.

Summarised calculations made are mean, mode, & standard deviation.

Table 3.1 <u>Mean daily rainfall (1988 - 1997)mm</u>

DAYS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP.	OCT	NOV	DEC
1	0.0	0.0	0.0	4.5	2.2	4.8	0.0	9.3	0.0	15.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	9.0	0.2	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.1	8.7	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.8	0.0	8.8	0.0
5	0.0	0.0	0.0	0.0	0.0	4.0	28.0	20.4	0.0	12.9	0.0	0.0
6	0.0	0.0	0.0	0.0	1.7	0.3	0.0	0.0	1.5	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	1.0	56.7	0.0	0.0
8	0.0	0.0	0.0	0.0	5.8	1.0	0.0	0.0	12.6	0.0	0.0	0.0
9	0.0	0.0	0.0	4.1	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	1.3	27.3	21.5	0.0	14.7	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	27.5	4.6	0.0	0.0	6.6	39.5	0.0	0.0
13	0.0	0.0	0.0	0.0	6.3	0.0	11.4	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.6	0.0	0.0
15	0.0	0.0	0.0	19.2	0.0	17.2	0.0	0.5	9.5	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	25.7	0.0	46.4	0.4	0.0	0.0	0.0	0.0
17	0.0	0.0	4.0	4.0	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0
18	0.0	0.0	0.0	0.0	0.6	0.0	1.8	17.5	6.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	17.8	6.4	4.6	10.8	0.0	0.0	0.0
20	0.0	0.0	0.0	15.1	0.7	0.0	8.0	18.5	0.0	0.0	0.0	0.0
21	0.0	0.0	13.4	0.0	6.2	0.0	0.0	0.1	7.6	22.5	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	1.9	38.6	1.1	23.3	0.0	0.0	0.0
23	0.0	0.0	73.0	0.0	0.0	0.4	5.5	2.7	1.1	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	14.3	0.0	1.0	0.0	9.3	0.0	0.0	0.0
25	0.0	0.0	0.0	16.4	0.0	0.0	0.2	0.0	11.1	8.8	0.0	0.0
26	0.0	0.0	0.3	1.7	2.5	0.0	4.7	0.2	9.3	0.0	0.0	0.0
27	0.0	0.0	0.0	0.2	0.0	1.0	0.0	44.5	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.2	16.5	0.0	1.7	12.3	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	10.0	0.0	0.0	35.4	78.7	0.9	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	23.9	19.7	1.9	0.0	1.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.1	0.0	0.0	1.4	0.0	0.2	0.0	0.0
Total	0.0	0.0	90.0	61.4	110.2	144.7	165.8	194.2	238.1	160.0	17.5	0.0

MIN = 0.0 MODE = 0.0 MEAN = 3.18 MAX = 78.7 S.D = 9.32

Table 3.2 Mean heads of water above the sill and their corresponding discharge at Asa dam spillway (1988 - 1997)

DAYS	AUG		SEPT		OCT	
	H(m)	Q(m^3/day)	H(m)	Qm(^{3}/day)	H(m)	Q(m^3/day)
1	0.08	345600	0.60	5762016	0.51	4596480
2	0.10	472608	0.56	5234976	0.52	4721760
3	0.12	604800	0.56	5234976	0.56	5234976
4	0.12	604800	0.57	5365440	0.55	5105376
5	0.10	681696	0.55	5105376	0.52	7421760
6	0.15	832896	0.52	4721760	0.50	4471200
7	0.16	911520	0.51	4596480	0.50	4471200
8	0.15	832896	0.59	5628960	0.60	5762016
9	0.14	756864	0.58	5496768	0.56	5234976
10	0.13	681696	0.54	4976640	0.50	4471200
11	0.13	681696	0.50	4471200	0.46	3981312
12	0.13	681696	0.48	4224096	0.42	3506976
13	0.12	609984	0.46	3981312	0.45	3861216
14	0.11	500000	0.43	3613616	0.45	3861216
15	0.10	472608	0.45	3861216	0.52	4721760
16	0.09	401803	0.43	3623616	0.63	6167232
17	0.08	345600	0.42	3506976	0.47	4102272
18	0.07	286848	0.40	3276288	0.40	3276288
19	0.09	407808	0.37	2939328	0.37	2939328
20	0.14	756864	0.21	1333152	0.34	2611872
21	0.20	1245024	0.34	2611872	0.31	2246512
22	0.23	1513728	0.35	2719872	0.30	2193696
23	0.23	1513728	0.38	3050784	0.27	1893888
24	0.23	1513728	0.50	4471200	0.24	1606176
25	0.26	1796256	0.47	4102272	0.23	1513728
26	0.29	2092608	0.47	4102272	0.24	1606176
27	0.30	2193696	0.46	3983112	0.24	1606176
28	0.32	2828736	0.42	3506976	0.22	1423008
29	0.27	1893888	0.46	3981312	0.20	1245024
30	0.21	1333152	0.63	6167232	0.20	1245024
31	0.21	1333152	0.63	6167232	0.20	1245024

The mean of a set of N numbers X_1, X_2, X_3 --------X_N

is denoted by X and is defined as:

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \text{----} X_N}{N}$$

$$= \frac{\sum_{j=1}^{N} x_j}{N} \qquad \text{-------------} (3.3)$$

It is a measure of the central tendency.

The mode of a set number is that value which occurs with the greatest frequency i.e it is the most common value. The set of data in the rainfall data is unimodal (i.e the set has only one mode).

The degree to which numerical data tend to spread about an average value is called the variation or dispersion of the data. The measure of dispersion used is standard deviation. The standard deviation of a set of N numbers X_1, X_2 -----X_N is denoted by S.D and is defined as

$$S.D = \sqrt{\frac{\sum (X-\overline{x})^2}{N}} \quad \text{-----------------(3.4)}$$

Where X represents each of the numbers

$\overline{x}$ represents the mean.

3.2 Catchment area of River Asa

As earlier mention the catchment area of a River is very important because in estimating future flows, predicting capacities of reservoirs and in-fact before any hydrological study could be done one has to know to which extend man-made changes has altered the catchment area.

The catchment area of River Asa downstream of the retaining structure (Asa dam) was traced out from the map obtained from Ministry of land and survey. The catchment area was divided into 15 reaches each 1 km length. The basin areas into the reaches were estimated using the planimeter and presented in table 3.3

Also attached in this chapter is the catchment area downstream of the dam, showing the reaches and the basin areas (figure 3.1).

Figure 3.2 shows the schematic outline of catchment area showing main River, Tributaries (A - O) and reaches (1 - 15).

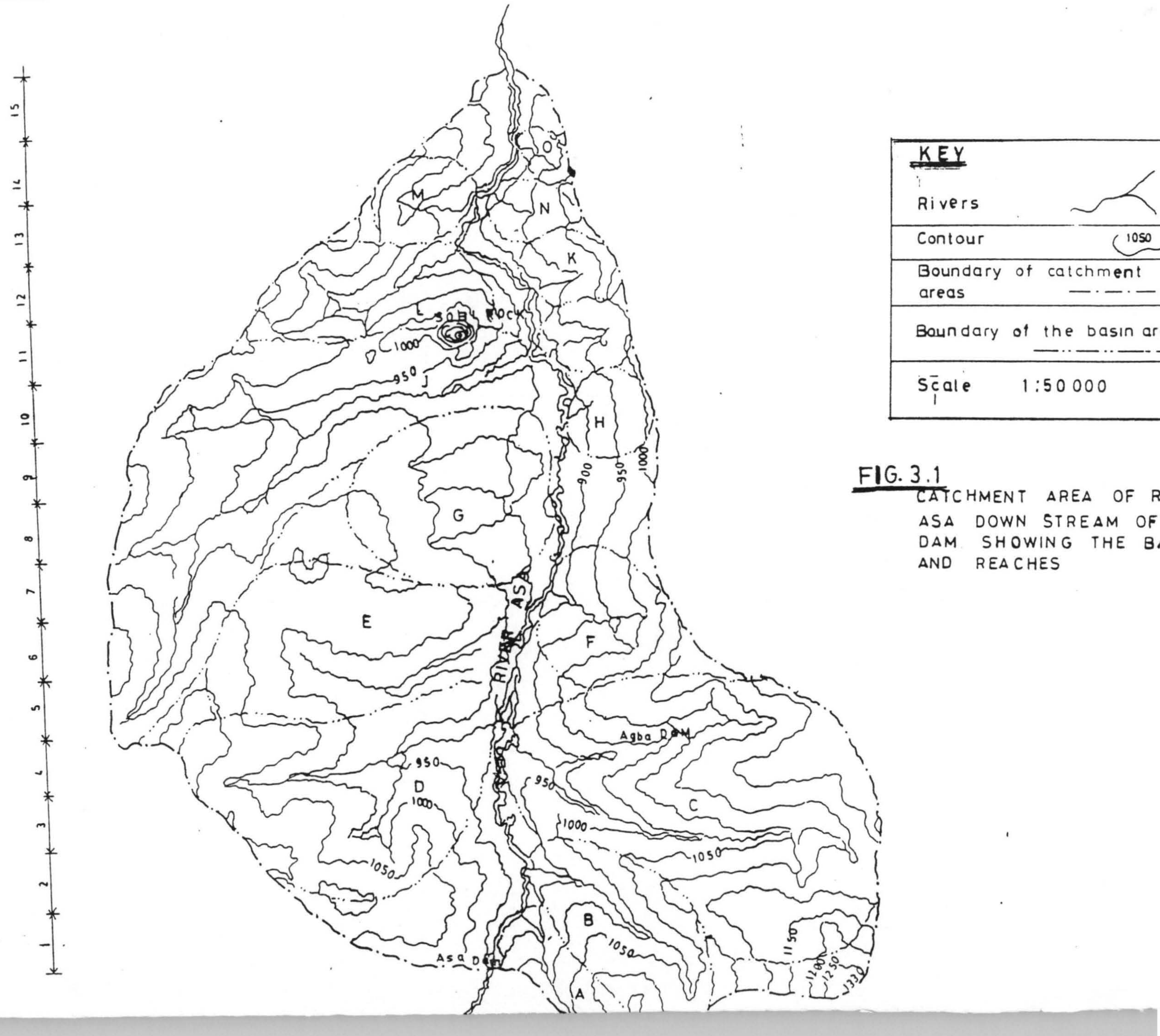


FIG. 3.1
CATCHMENT AREA OF R
ASA DOWN STREAM OF
DAM SHOWING THE B
AND REACHES

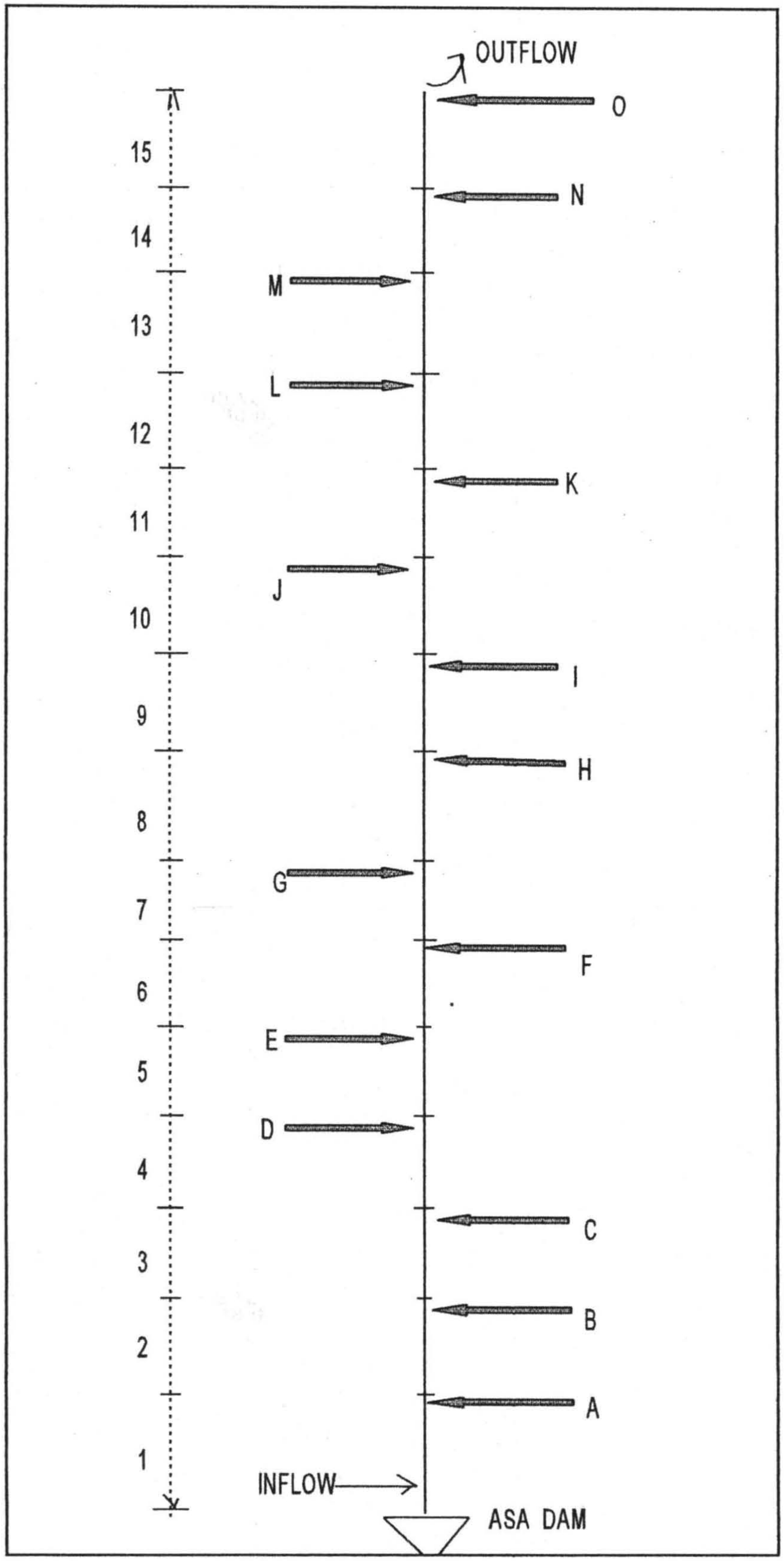


Fig 3.2 Schematic outline of catchment area showing main river tributary (A-0) and reaches (1-15)

Table 3.3 Catchment areas in M^2

REACH	BASIN	CATCHMENT AREA (m^2)	RUNOFF COEFFICIENT
1	A	2718750	0.40
2	B	643750	0.40
3	C	22062500	0.54
4	D	13687500	0.54
5	E	1062500	0.54
6	F	4437500	0.54
7	G	8437500	0.54
8	H	1875000	0.54
9	I	1593750	0.54
10	J	21875000	0.54
11	K	1687500	0.40
12	L	5656250	0.40
13	M	2062500	0.40
14	N	1156250	0.40
15	O	562500	0.40

3.3 Existing method of flood routing analysis

The existing method of flood routing analysis involved collection of inflow and outflow data. Determination of storage constant k and a dimension less weighting factor x. Other constants C_o, C_1 and C_2 in Mukungum model are computed.

With the obtained constants, continuity equation is then employed to develop the outflow hydrograph.

However, since the storage volume is not a simple function of stage, therefore solution of the continuity equation is more complex. The manual analysis is cumbersome and time consuming. Also, while performing the computation there may be error of judgement.

3.4 Proposed method of flood routing analysis

The proposed method involved the use of computer which is the best method of analysis. This relief the user the complexity involved in manual analysis and possibly eliminate the computational error once the program is correctly developed and the require data are supplied as appropriate.

3.5 Benefit of the propose method

The new method eliminate data redundancy. It makes changes easily and quickly. It improves accuracy and consistency. It provides data security from unauthorised use. The propose system will also have facilities of adding new data or easily run with current data obtain from the spillway.

The proposed system is designed so that a casual and novice user, also who has little prior knowledge of what is expected of them will be able to handle it.

CHAPTER FOUR

4.0 PROGRAM DEVELOPMENT

4.1 Determination of X and K

The constant X, expresses the relative contribution of inflow (I) and outflow (O) to storage (S) in the channel reach for a simple reservoir, x = 0 (inflow has no effect), while if inflow and outflows were equally effective, would be 0.5. For most streams, is between 0.2 to 0.4 (Andrew chadwick et al 1993).

The constant K, known as the storage constant is the ratio of storage to discharge and has the dimension of time. It is approximately equal to the travel time through the reach.

The K and X are determined by plotting storage volume (S) versus XI + (1 - X)O for various values of X. The best value of X is that which causes the data to plot most nearly as a single - valued curve. The Muskingum method assumes that this curve is a straight line with slope K. The unit of K depends on the units of flow and storage.

The flow data that are available for this purpose is presented in table 4.1. The change in storage was obtained by using equation (2.15) and presented in table 4.2.

Table 4.1 Flow data for determining X and K

S/No	Time(t) hr	Inflow(I) m^3/s	Outflow (O)m^3/s	S/No	Time(t) hr	Inflow(I) m^3/s	Outflow(O) m^3/s
1.	0.00	4.06	4.06	17	384.00	4.00	4.98
2.	24.00	4.40	4.15	18	408.00	3.32	4.32
3	48.00	7.00	5.30	19	432.00	4.72	4.17
4.	72.00	7.00	6.50	20	456.00	8.76	5.46
5.	96.00	7.89	6.80	21	480.00	14.41	8.52
6.	120.00	9.64	7.78	22	504.00	17.52	12.24
7.	144.00	10.55	8.94	23	528.00	17.52	14.88
8.	168.00	9.64	9.52	24	552.00	17.52	16.20
9.	192.00	8.76	9.36	25	576.00	20.79	17.68
10.	216.00	7.89	8.84	26	600.00	24.22	20.09
11.	240.00	7.89	8.37	27	624.00	25.39	22.45
12.	264.00	7.89	8.13	28	648.00	32.74	25.76
13.	288.00	7.06	7.80	29	672.00	21.92	26.54
14.	312.00	6.25	7.23	30	696.00	15.43	22.61
15.	336.00	4.89	6.40	31	720.00	15.43	19.02
16.	360.00	4.72	5.60				

Source: Kwara state Utility Board's Office, Ilorin.

from equation (2.15)

$$\frac{(I\text{-}1+I\text{-}2)}{2}\Delta t-(\frac{O_1+O_2}{2})=\frac{S_2-S_1}{\Delta s}$$

Sample solution

Data

$I_1 = 4.06\ m^3/s$ $\quad 0_1 = 4.06\ m^3/s$

$$[(\frac{4.06+4.40}{2})-(\frac{4.06+4.15}{2})]86400=S_2-S_1=\Delta S$$

$I_2 = 4.40\ m^3/s$ $\quad 0_2 = 4.15\ m^3/s$

$\Delta t = 24x60x60 = 86400$ secs.

$\Delta s = S_2 - S_1 = ?$

Solution

$$[(\frac{4.06+4.40}{2})-(\frac{4.06+4.15}{2})]86400=S_2-S_1=\Delta S$$

$[4.230 - 4.105]86400 = S_2 - S_1$

$\Delta S = 0.125x86400 = 10800m^3 = 10.8x10^3m^3$

The same procedure was follow to obtain to other change in storage and tabulated in table 4.2

The cumulative volume of reach storage (5) is found by summing the change in storage (ΔS).

Table 4.2

Analysis of flow data

Change in storage Δsm^3x10^3	Storage volume Sm^3x10^3	[XI+(1-X)O] X=0.2	X=0.25	X=0.3	X=0.35
	0.00	4.06	4.06	4.06	4.06
10.80					
	10.80	4.20	4.2125	4.2250	4.2375
84.24					
	95.04	5.64	5.7250	5.8100	5.8950
95.04					
	190.08	6.60	6.6250	6.6500	6.6750
68.69					
	258.77	7.0180	7.0725	7.1270	7.1815
127.44					
	386.21	8.1520	8.2450	8.3380	8.4310
149.90					
	536.11	9.2620	9.3425	9.423	9.5035
74.74					
	610.85	9.5440	9.5500	9.5560	9.5620
-20.74					
	590.11	9.2400	9.2100	9.1800	9.1500
-66.96					
	523.15	8.6500	8.6025	8.5550	8.5075
-61.78					
	461.38	8.2740	8.2500	8.2260	8.2020
-31.10					
	430.28	8.0820	8.0700	8.0580	8.0460
-42.34					
	387.95	7.6520	7.6150	7.5780	7.5410
-74.30					
	313.65	7.0340	6.9850	6.9360	6.8870
-107.57					
	206.08	6.0980	6.0225	5.9470	5.8715
-103.25					
	102.83	5.4240	5.3800	4.6860	5.2920
-80.35					
	22.48	4.7840	4.7350	4.6860	4.6370
-85.54					
	-63.06	4.1200	4.0700	4.0200	3.9700
-19.44					
	- 82.5	4.2800	4.3075	4.3350	4.3625
166.32					
	83.82	6.1200	6.2850	6.4500	6.6150
397.00					
	480.83	9.6980	9.9925	10.287	10.5815
482.54					
	963.38	13.2960	13.5600	13.8240	14.0880
342.14					
	1305.52	15.4080	15.5400	15.6720	15.8040
171.07					
	1476.59	16.4640	16.5300	16.5960	16.6620

Table 4.2 Continued

191.38					
	1667.97	18.3020	18.4575	18.6130	18.7685
312.768					
	1980.74	20.9160	21.1225	21.3290	21.5355
305.42					
	2286.16	23.0380	23.1850	23.3320	23.4790
428.54					
	3143.24	27.1560	27.5050	27.8540	28.2030
101.95					
	3245.19	25.6160	25.385	25.1540	24.9230
-509.76					
	2735.43	21.1740	20.8150	20.4560	20.0970
-465.26					
	2270.17	18.3020	18.1225	17.9430	17.7635

The plot of storage volume (M^3) versus [XI+(1-X)0] for various values of X ranging from 0.2, 0.25, 0.30, 0.35 and 0.4 are plotted.

The best result appears to be for X = 0.2, and K = 0.92 is estimated as shown in figure 4.1.

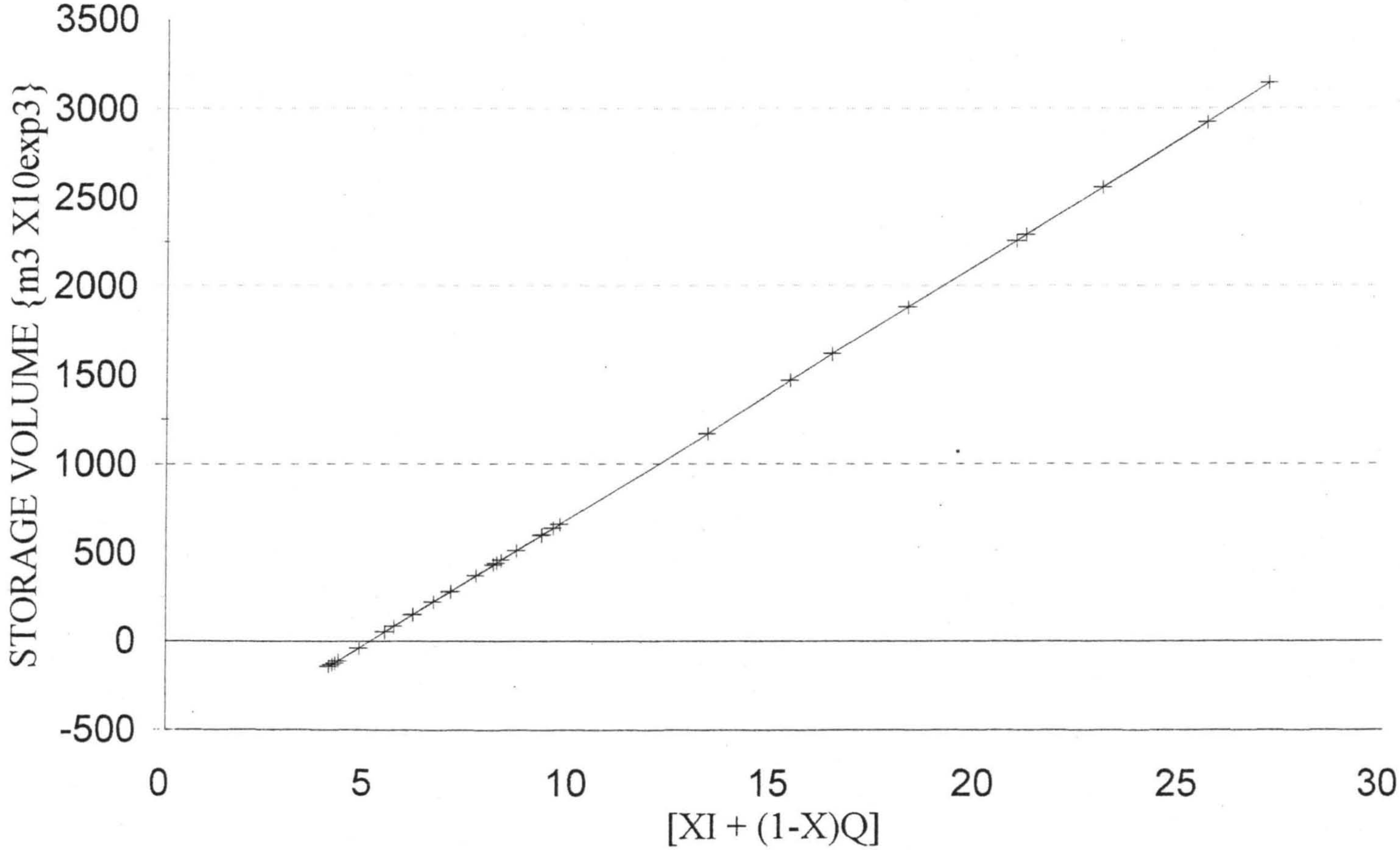
The line shows linear best fit line obtained from regression analysis and represented by the following equation

Storage volume = 142.01 [0.21+0.8Q]+(-715.272)

where I = inflow

Q = outflow

fig 4.1 **PLOT OF STORAGE VOLUME(m3) VERSUS [0.2I + 0.8Q]**



4.2 Computer programming

Routing procedure in channels using Muskingum method can be done using the computer, in order to process a particular set of data, the computer must be given an appropriate set of instruction called a programme. These instructions are entered into the computer and then stored in a portion of the computers memory.

A stored programme can be executed at any time. This causes the following things to happen.

1. A set of information called the input data, is entered into the computer and stored in another portion of the computer's memory.
2. The input data is then processed to produce certain desire results known as the output data.
3. The output data (and perhaps some of the input data) are printed into a sheet of paper or displayed on a monitor.

The computer programme used for the routing was done using the steps enumerated above and listed in Appendix 1.

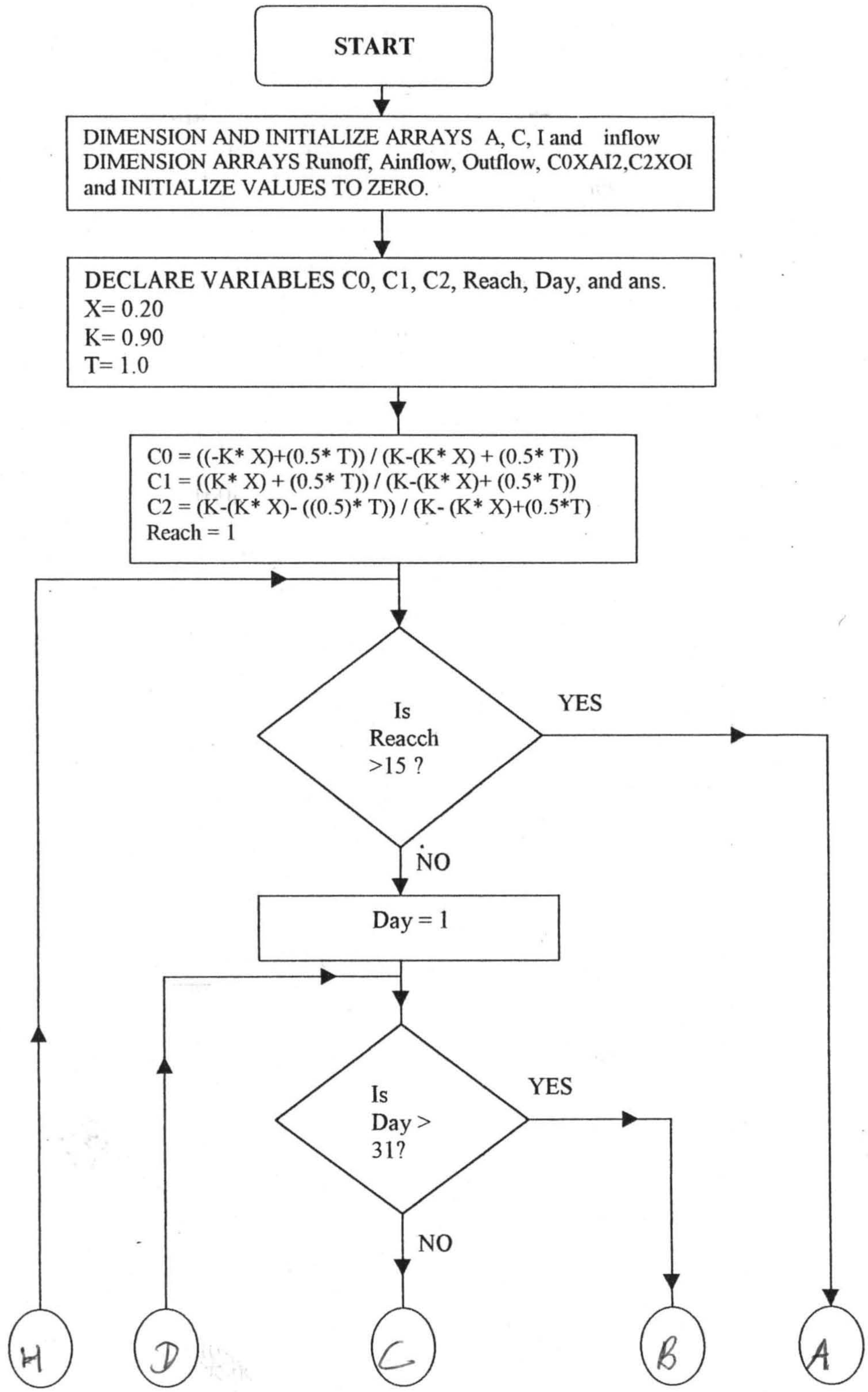
The entire procedure was represented pictorially by the flow chart in figure 4.2, this helps to visualize the flow of logic within a program.

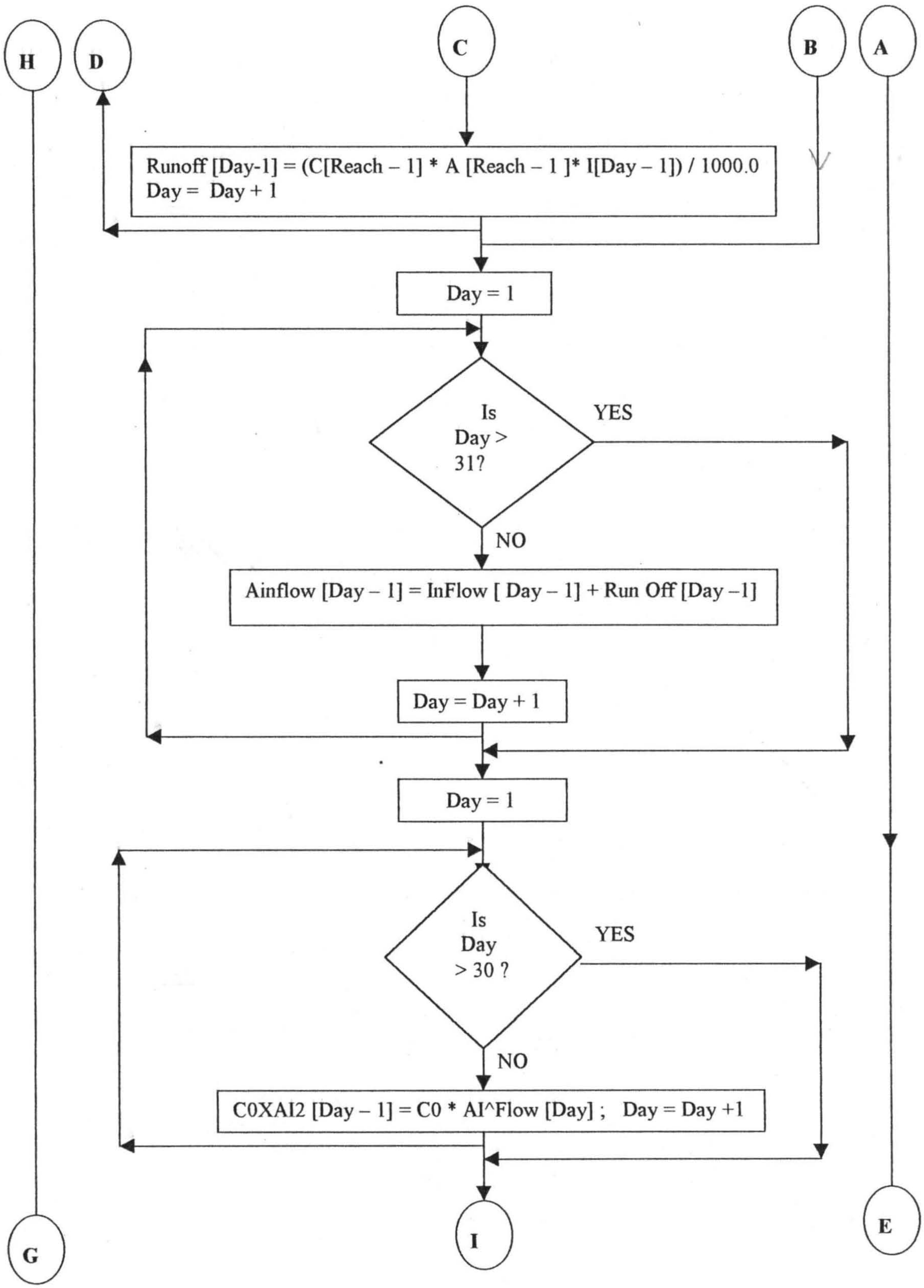
The catchment area was divided into fifteen reaches each of 1km length. The inflow into the reach at the beginning of the catchment area is the discharge from the spilling at Asa dam. Data for the discharge and rainfall at a particular month of the year were read in the programme. The runoff from the basin areas of the reaches into the main stream is computed thus:

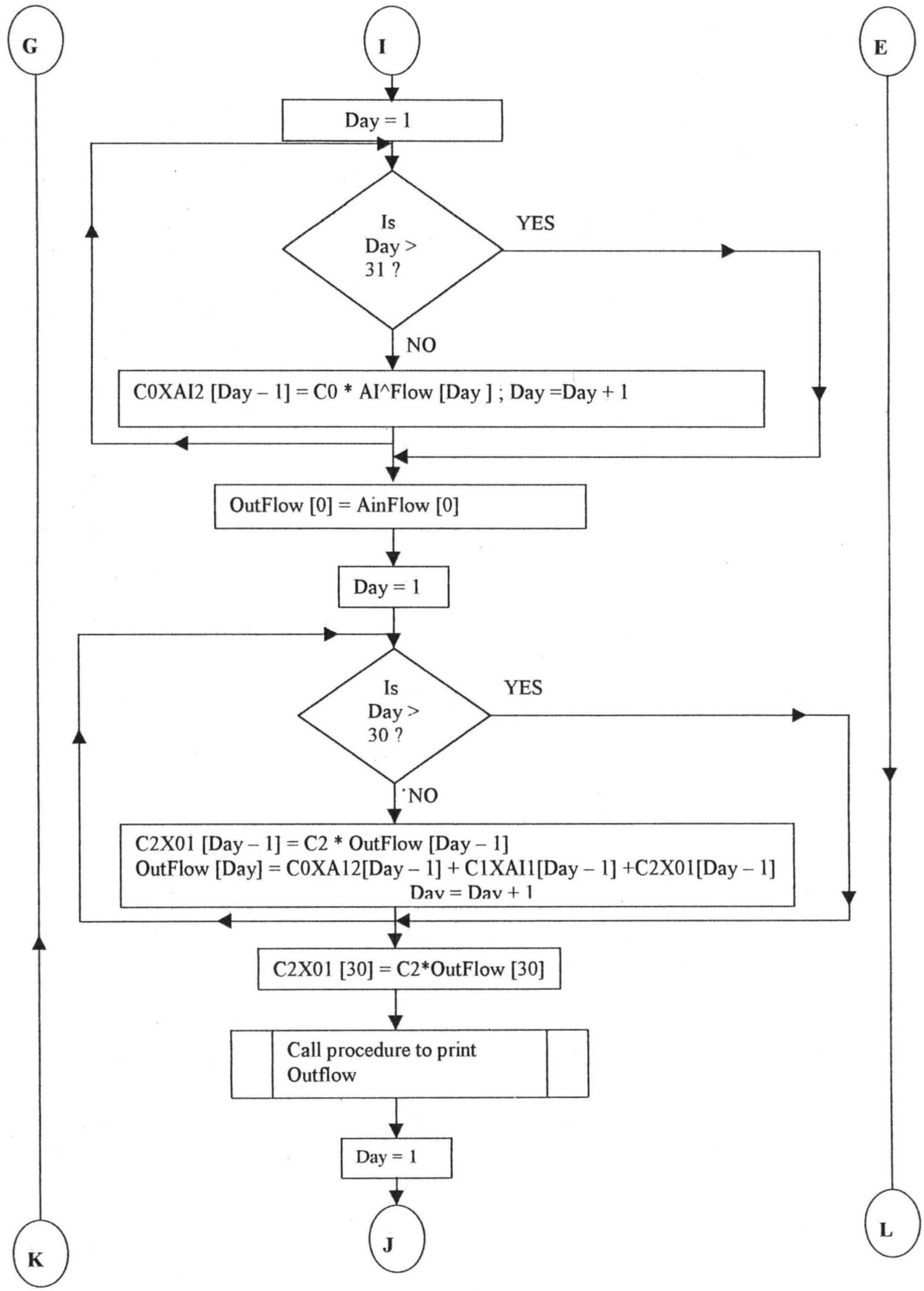
Runoff = catchment area of basin X rainfall X runoff coefficient.

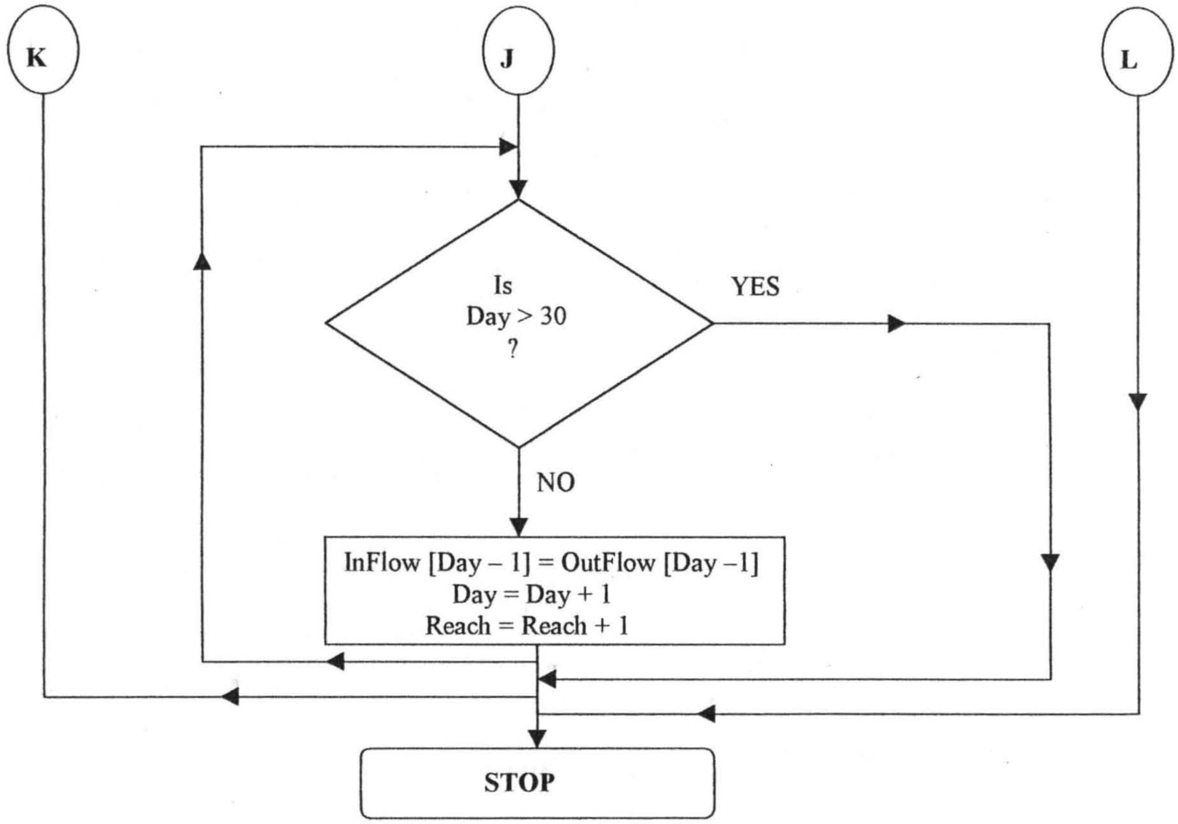
From Figure 3.2, the runoff entered near the upstream end of the reach, it was added to the main stream inflow to obtain the total inflow (A inflow) before routining was done to get the outflow.

Fig. 4.2 **FLOWCHART OF COMPUTER PROGRAMME FOR CHANNEL ROUTING.**




H
D
C
B
A
Runoff [Day-1] = (C[Reach – 1] * A [Reach – 1]* I[Day – 1]) / 1000.0
Day = Day + 1
Day = 1
Is Day > 31?
YES
NO
Ainflow [Day – 1] = InFlow [Day – 1] + Run Off [Day –1]
Day = Day + 1
Day = 1
Is Day > 30 ?
YES
NO
C0XAI2 [Day – 1] = C0 * AI^Flow [Day] ; Day = Day +1
G
I
E


G
I
E
Day = 1
Is
Day >
31 ?
YES
NO
C0XAI2 [Day – 1] = C0 * AI^Flow [Day] ; Day =Day + 1
OutFlow [0] = AinFlow [0]
Day = 1
Is
Day >
30 ?
YES
NO
C2X01 [Day – 1] = C2 * OutFlow [Day – 1]
OutFlow [Day] = C0XA12[Day – 1] + C1XAI1[Day – 1] +C2X01[Day – 1]
Day = Day + 1
C2X01 [30] = C2*OutFlow [30]
Call procedure to print
Outflow
Day = 1
K
J
L


K
J
L
Is
Day > 30
?
YES
NO
InFlow [Day – 1] = OutFlow [Day –1]
Day = Day + 1
Reach = Reach + 1
STOP

The routing procedure needs the input of k, the travel time through the reach and X, the proportion of inflow and output to storage for the computation of C_o, C_1 and C_2 as follows:

$$C_o = \frac{-kx + 0.5t}{k - kx + 0.5t}$$

$$C_1 = \frac{kx + 0.5t}{k - kx + 0.5t}$$

$$C_2 = \frac{k - kx - 0.5t}{k - kx + 0.5t}$$

t is the routing time step.

The first outflow is assumed to be equal to the first inflow. The values of C_oI_2, C_1I_1, C_20, are computed and $0_2 = C_oI_2 + C_1I_1 + C_20_1$.

The total outflow becomes the inflow of the succeeding reach and so on.

The mean discharge at Asa dam spillway and the mean rainfall for the August 1988 - 1997 were input in the programme.

The expected result is to show the various discharge at the end of the reaches for the entire fifteen reaches. The results for all the reaches were presented in tables 4.3 to 4.17 in Appendix 2.

Also to depict the behaviour of the flowing water along the spillway channel, the outflow from each reaches were plotted against the time (day). Thus, establishing the form or shape of flood hydrographs at different points on the river at the downstream reach. This enable the prediction of the possibility of flood at downstream reach of the spillway channel. The hydrographs were presented in figures 4.3 to 4.17 in Appendix 3

4.3 Running / Execution of the computer program

4.3.1 Running of the computer program

The program was written in Basic Language using Qbasic compiler (Microsoft Qbasic) as its translator. The Qbasic compiler can be found under Dos (disk operating system version 6.22) directory. The basic language was chosen because of its scientific facilities that it offers.

To run the program, one can take either of these two options:

(1) You can copy the program file name (Dam.bas) into Dos directory in drive c from drive A, by using this command after putting the program title disk in drive A:

C:\Dos>copy a: Dam.bas

Then you can run Qbasic under dos by typing:

C:\Dos>Qbasic.exe

The Qbasic working environment will now be provided on the screen for you. In the Qbasic working environment, we have a list of options called main menu. The options are FILE, RUN, OPTION, HELP. Under this option called submenu of each main menu option.

To run Dam.bas you pick FILE option, and under the FILE option we have drop menu that have the following option; NEW, OPEN, SAVE, EXIT.

Then you pick OPEN in Other to load program file. The dialogue box will be open for you to type name of the file that you want to open. You can then type Dam.bas

The program listing will appear on the screen and now you can use RUN option to run or execute it.

(2) On the other way you can run Dam.bas program directly from the operating system environment, by typing the following command at Dos directory prompt directly:

C:\Dos>Qbasic Dam.bas run

Immediately you press enter key the program will be executing automatically.

4.3.2 Program Execution

After the program has run, it make use of the data that has been supply automatically alongside the program coding, the data supply are for the following: daily rainfall for the month of August, Daily inflow, Catchment area for each fifteen reaches.

Two nested loop will be executed, the first one which is the outer one will be executed fifteen times, which represent each reach while the internal one will be executed thirty one times (31) which represent each day.

The output from the program execution will be displayed on the screen one after the other for the fifteen reaches. Between these, computer will be prompting the user to press any key to continue and this gives room for the outputs to be displayed page by page and reaches by reaches.

The outputs are display in seven columns as follows

DAY, INFLOW, AINFLOW, COXAI2, C1XAI1, C_2O_1, OUTFLOW.

4.4 Discussion of results

River Asa being the major river that flow through the city of Ilorin was analysed for possible flood discharges. The routing time step was chosen as one day i.e (t=1) so as to define the hydrographs within the model accuracy. The routing time step lead to the collection of the daily rainfall in Ilorin and the daily stage heights converted to their corresponding discharges.

For proper investigation the catchment area downstream of the dam was divided into fifteen reaches estimated using planimeter. These areas multiplied by the runoff coefficient and the rainfall gave the local inflow. The main stream inflow of the first reach were the discharges from the spillway of the dam. The local inflow entered at the upstream end of the reach, it was added to the main stream inflow to obtain total inflow (Ainflow) before routing was done.

Routing was done using the Muskingum method. The Muskingum analytical method was used for the routing procedure and the Muskingum graphical method was used to determine the dimensionless weighting constant x= 0.20 and the corresponding storage constant k= 0.92 days. The constants C_0, C_1 and C_2 were estimated to be 0.2557, 0.5534 and 0.1909 respectively.

The table of the results, table 4.1 to 4.15 are presented in Appendix 2, shows the routing procedure in tabular form for the reaches. The time (days) is presented in column 1. The inflow at the beginning of the reach is in column 2 for the different days of the month. Columns 3,4,5 shows the calculation of C_0 multiplied by succeeding day inflow, C_1 multiplied by the day inflow and C_2 multiplied by the day outflow respectively. The first day outflow is assumed to be equal to the first day inflow. The succeeding outflow is the summation of C_0 multiplied by succeeding day inflow, C_1 multiplied by the day inflow and C_2 multiplied by the day outflow of the proceeding row. This process is performed till the end of the month. The outflow from the previous reach become the initial inflow for the next reach and the runoff are then added to their corresponding outflows, to get the adjusted inflow (Ainflow) which then becomes the final inflow of the succeeding reach and so on and so forth.

The routing procedure could not have been done by a better method except with the use of computer. The computer programme was ran using the values of mean discharge from Asa dam spillway for the month of August 1988-1997 and rainfall also for the same month. Values of the catchment area of the basins and runoff coefficient for the reach being considered were also read.

Outflow - Inflow hydrograph (graphs of discharge against time) for the various reaches and the inflow at the beginning of the dam are shown in figures 4.3 to 4.17 appendix 3. The graphs shows that the effect of discharge from the dam was eminent at the upstream of the catchment towards the city, this shows fluctuating graph with peak values of discharge. The range of values is also very conspicuous. At the downstream end of the catchment area the discharge from the dam is less felt, peaks are rarely found and the range of value close.

The flows on the surrounding areas could be damaging because of unforseen sudden increase in the discharge within few days. The water reclaims large areas and farmland, during this period and houses along it's banks could be flooded because of increase flood plains.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The construction of Asa dam across River Asa has changed the natural flood plains downstream to some extent. The Muskingum method helped to determine the quantity of water at various times (daily) of a month along the downstream end.

From the analysis and results it was found that the effect of discharge from the dam was eminent at the upstream of the catchment area towards the city, but less effect at the downstream end. The large quantity of water needs a corresponding large area for it's flow, hence floods are bound to be prominent in the city.

5.2 RECOMMENDATION

It is recommended that the development of infrastructures along the banks of the river, be discouraged because it lead to narrower of the flood plains and the channel valley.

The indiscriminate dumping of refuse near the river should be discouraged because it lead to construction in the stream valley.

The above recommendation should be taken serious because in period of excessive flood, the land acquired due to human activities from the flood plain are reclaimed by water and the after effect may be disastrous.

Finally, it is recommended that further study should be carried out to cover environmental impact assessment of Asa dam on the Asa River basin.

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5. Yung T.K. (1985) "River flood Routing by Non-linear Musskingum method" Journal of hydraulic Engineering vol. III No 12

APPENDIX 1

PROGRAM LIST

```
MYINF(16, 32), NEXTINF(32)
 OUTFLOW(16, 32), AINFLOW(16, 32), COAI2(16, 32)
 C1AI1(16, 32), C2O1(16, 32)
1 II(32), AR(16), C(16)
= .2
= .92
= 1
. B = 1 TO 15
D AR(B)
T B
A 2718750,643750,22062500,13687500,10625000,4437500,8437500,1875000
A 1593750,21875000,1687500,5656250,2062500,1156250,562500
 B = 1 TO 15
D C(B)
T B
A 0.40,0.40,0.54,0.54,0.54,0.54,0.54,0.54,0.54,0.54,0.40,0.40,0.40,0.40,0.40
 B = 1 TO 32
D NEXTINF(B)
T B
A 345600,472608,604800,604800,681696,832896,911520,832896,756864,681696
A 681696,681696,609984,500000,472608,401803,345600,286848,407808,756864
A 1245024,1513728,1513728,1513728,1796256,2092608,2193696,2828736
A 1893888,1333152,1333152 ,0.0
 A = 1 TO 32
) II(A)
 A
. 9.3,5.7,0.0,3.2,20.4,0.0,0.0,0.0,0.0,0.0,27.1,0.0,0.0,0.0,0.5,0.4,0.0
. 17.5,4.6,18.5,0.1,1.1,2.7,0.0,0.0,0.2,44.5,1.7,35.4,1.9,1.4,0.0
 ((-KK * XX) + (.5 * TT)) / (KK - (KK * XX) + (.5 * TT))
 ((KK * XX) + (.5 * TT)) / (KK - (KK * XX) + (.5 * TT))
 (KK - (KK * XX) - (.5 * TT)) / (KK - (KK * XX) + (.5 * TT))
N = 1 TO 15
M = 1 TO 31
F = (C(N) * II(M) * AR(N)) / 1000
F(N, M) = NEXTINF(M)
LOW(N, M) = MYINF(N, M) + RUNOF
 M
R 2, 0

T "X = "; XX; "  K = "; KK; "REACH = "; N
T "CATCHMENT AREA = "; AR(N); "   RUNOFF COEFFICIENT = "; C(N)
T SPC(0); "DAY INFLOW"; SPC(2); "  AINFLOW"; SPC(2); "   CO*AI2";
T SPC(2); "      C1*AI1"; SPC(2); "    C2*O1"; SPC(2); "    OUTFLOW"
T "=== ======     ========     ======    =======    ========     ========"
R 7, 0
 1
 1



 = 1 TO 31
 > 17 THEN

 "PRESS ANY KEY TO CONTINUE.........", S$
 2, 0

 "X = "; XX; "  K = "; KK; "REACH = "; N
 "CATCHMENT AREA = "; AR(N); "   RUNOFF COEFFICIENT = "; C(N)
 SPC(0); "DAY INFLOW"; SPC(2); "  AINFLOW"; SPC(2); "   CO*AI2";
 SPC(2); "      C1*AI1"; SPC(2); "    C2*O1"; SPC(2); "    OUTFLOW"
 "=== ======     ========     ======    =======    ========     ========"
```

```
COLOR 7, 0
CC = 1
END IF
C0AI2(N, J) = C0 * AINFLOW(N, J + 1)
C1AI1(N, J) = C1 * AINFLOW(N, J)
IF J = 1 THEN OUTFLOW(N, J) = AINFLOW(N, J)
IF J > 1 THEN
OUTFLOW(N, J) = C0AI2(N, J - 1) + C1AI1(N, J - 1) + C2O1(N, J - 1)
END IF
C2O1(N, J) = C2 * OUTFLOW(N, J)
AA$ = "000" + STR$(AINFLOW(N, J))
PRINT SPC(0); STR$(J) + " " + STR$(MYINF(N, J));
PRINT SPC(2);
PRINT USING "#######.##"; AINFLOW(N, J);
PRINT ; SPC(2);
PRINT USING "#######.##"; C0AI2(N, J);
PRINT ; SPC(2);
PRINT USING "#######.##"; C1AI1(N, J);
PRINT SPC(2);
PRINT USING "#######.##"; C2O1(N, J);
PRINT SPC(2);
PRINT USING "#######.##"; OUTFLOW(N, J)
NEXTINF(J) = OUTFLOW(N, J)
CC = CC + 1
BB = BB + 1
NEXT J
INPUT "PRESS ANY KEY TO CONTINUE.........", S$
NEXT N
```

APPENDIX 2

RESULTS FOR ALL THE REACHES

X = .2 K = .92 REACH = 1
CATCHMENT AREA = 2718750 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	345600	355713.75	122413.38	196851.30	67919.45	355713.75
2	472608	478806.75	154625.23	264970.72	73928.36	387184.13
3	604800	604800.00	155514.95	334695.16	94232.80	493524.31
4	604800	608280.00	179956.63	336620.97	111592.66	584442.88
5	681696	703881.00	212941.05	389526.38	119941.90	628170.25
6	832896	832896.00	233042.33	460923.03	137935.77	722409.31
7	911520	911520.00	212941.05	504433.41	158841.97	831901.13
8	832896	832896.00	193502.44	460923.03	167303.47	876216.44
9	756864	756864.00	174284.73	418847.09	156899.70	821728.94
10	681696	681696.00	181819.45	377249.25	143209.91	750031.50
11	681696	711167.25	174284.73	393558.59	134092.05	702278.63
12	681696	681696.00	155950.59	377249.25	134026.50	701935.38
13	609984	609984.00	127831.71	337563.97	127399.22	667226.38
14	500000	500000.00	120967.59	276699.03	113187.38	592794.88
15	472608	473151.75	102837.55	261841.27	97541.70	510854.00
16	401803	402238.00	88357.28	222597.73	88255.70	462220.50
17	345600	345600.00	78202.13	191254.38	76224.70	399210.72
18	286848	305879.25	105540.55	169272.98	66003.86	345681.22
19	407808	412810.50	198646.08	228448.53	65075.16	340817.38
20	756864	776982.75	318334.91	429980.75	93974.17	492169.78
21	1245024	1245132.75	387310.72	689054.06	160825.56	842289.81
22	1513728	1514924.25	387755.56	838356.19	236227.30	1237190.38
23	1513728	1516664.25	387004.88	839319.06	279216.84	1462339.00
24	1513728	1513728.00	459236.97	837694.19	287465.72	1505540.75
25	1796256	1796256.00	535058.94	994044.63	302522.38	1584396.88
26	2092608	2092825.50	573220.38	1158165.63	349727.94	1831626.00
27	2193696	2242089.75	723677.00	1240768.13	397364.81	2081114.00
28	2828736	2830584.75	494040.28	1566440.13	450960.50	2361810.00
29	1893888	1932385.50	341366.47	1069378.38	479530.81	2511441.00
30	1333152	1335218.25	341227.47	738907.19	360926.44	1890275.63
31	1333152	1334674.50	0.00	738606.31	275154.06	1441061.13

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 2
CATCHMENT AREA = 643750 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	355713.8	358108.50	99364.07	198176.55	68376.70	358108.50
2	387184.1	388651.88	126176.12	215079.20	69867.71	365917.31
3	493524.3	493524.31	149631.33	273115.41	78499.22	411123.03
4	584442.9	585266.88	161943.16	323885.56	95707.16	501245.94
5	628170.3	633423.25	184693.64	350535.22	111037.60	581535.88
6	722409.3	722409.31	212686.69	399779.91	123397.16	646266.44
7	831901.1	831901.13	224016.50	460372.47	140504.73	735863.75
8	876216.4	876216.44	210086.03	484896.50	157503.98	824893.69
9	821728.9	821728.94	191755.63	454743.22	162772.52	852486.50
10	750031.5	750031.50	181331.05	415066.00	154521.08	809271.38
11	702278.6	709256.88	179459.20	392501.38	143379.19	750918.13
12	701935.4	701935.38	170585.38	388449.69	136585.91	715339.75
13	667226.4	667226.38	151555.97	369241.78	132820.84	695621.00
14	592794.9	592794.88	130639.60	328051.53	124800.97	653618.63
15	510854	510982.75	118199.21	282776.88	111411.13	583492.13
16	462220.5	462323.50	102063.58	255848.94	97834.45	512387.22
17	399210.7	399210.72	89530.13	220922.44	87019.65	455746.97
18	345681.2	350187.47	87437.37	193793.06	75892.76	397472.22
19	340817.4	342001.88	127047.73	189263.17	68188.57	357123.19
20	492169.8	496933.53	215349.28	275002.06	73415.76	384499.47
21	842289.8	842315.56	316376.75	466135.81	107644.86	563767.13
22	1237190	1237473.63	374044.34	684815.50	169965.34	890157.44
23	1462339	1463034.25	384911.72	809640.31	234630.08	1228825.25
24	1505541	1505540.75	405072.34	833163.38	272885.91	1429182.13
25	1584397	1584396.88	468292.94	876802.19	288531.31	1511121.63
26	1831626	1831677.50	534994.31	1013646.81	311922.22	1633626.50
27	2081114	2092572.75	603940.38	1158025.75	355253.22	1860563.38
28	2361810	2362247.75	644414.13	1307263.38	404258.72	2117219.25
29	2511441	2520556.50	483399.44	1394871.13	449838.97	2355936.25
30	1890276	1890764.88	368518.78	1046345.63	444525.78	2328109.50
31	1441061	1441421.63	0.00	797679.94	355029.22	1859390.25

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 2
CATCHMENT AREA = 643750 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	355713.8	358108.50	99364.07	198176.55	68376.70	358108.50
2	387184.1	388651.88	126176.12	215079.20	69867.71	365917.31
3	493524.3	493524.31	149631.33	273115.41	78499.22	411123.03
4	584442.9	585266.88	161943.16	323885.56	95707.16	501245.94
5	628170.3	633423.25	184693.64	350535.22	111037.60	581535.88
6	722409.3	722409.31	212686.69	399779.91	123397.16	646266.44
7	831901.1	831901.13	224016.50	460372.47	140504.73	735863.75
8	876216.4	876216.44	210086.03	484896.50	157503.98	824893.69
9	821728.9	821728.94	191755.63	454743.22	162772.52	852486.50
10	750031.5	750031.50	181331.05	415066.00	154521.08	809271.38
11	702278.6	709256.88	179459.20	392501.38	143379.19	750918.13
12	701935.4	701935.38	170585.38	388449.69	136585.91	715339.75
13	667226.4	667226.38	151555.97	369241.78	132820.84	695621.00
14	592794.9	592794.88	130639.60	328051.53	124800.97	653618.63
15	510854	510982.75	118199.21	282776.88	111411.13	583492.13
16	462220.5	462323.50	102063.58	255848.94	97834.45	512387.22
17	399210.7	399210.72	89530.13	220922.44	87019.65	455746.97
18	345681.2	350187.47	87437.37	193793.06	75892.76	397472.22
19	340817.4	342001.88	127047.73	189263.17	68188.57	357123.19
20	492169.8	496933.53	215349.28	275002.06	73415.76	384499.47
21	842289.8	842315.56	316376.75	466135.81	107644.86	563767.13
22	1237190	1237473.63	374044.34	684815.50	169965.34	890157.44
23	1462339	1463034.25	384911.72	809640.31	234630.08	1228825.25
24	1505541	1505540.75	405072.34	833163.38	272885.91	1429182.13
25	1584397	1584396.88	468292.94	876802.19	288531.31	1511121.63
26	1831626	1831677.50	534994.31	1013646.81	311922.22	1633626.50
27	2081114	2092572.75	603940.38	1158025.75	355253.22	1860563.38
28	2361810	2362247.75	644414.13	1307263.38	404258.72	2117219.25
29	2511441	2520556.50	483399.44	1394871.13	449838.97	2355936.25
30	1890276	1890764.88	368518.78	1046345.63	444525.78	2328109.50
31	1441061	1441421.63	0.00	797679.94	355029.22	1859390.25

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 3

CATCHMENT AREA = 2.20625E+07 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	358108.5	468906.38	110913.36	259491.89	89532.29	468906.38
2	365917.3	433825.69	105109.13	240078.30	87819.79	459937.53
3	411123	411123.03	137897.17	227514.69	82677.76	433007.22
4	501245.9	539369.94	210814.02	298486.28	85557.57	448089.63
5	581535.9	824576.38	165226.69	456318.97	113581.28	594857.88
6	646266.4	646266.44	188133.45	357642.59	140364.05	735126.94
7	735863.8	735863.75	210895.14	407225.59	131010.58	686140.13
8	824893.7	824893.69	217949.63	456494.56	143038.02	749131.31
9	852486.5	852486.50	206901.09	471764.38	156088.84	817482.19
10	809271.4	809271.38	274526.47	447849.22	159386.75	834754.31
11	750918.1	1073780.75	182886.20	594228.19	168362.41	881762.44
12	715339.8	715339.75	177844.84	395867.63	180527.94	945476.81
13	695621	695621.00	167106.38	384955.31	144013.53	754240.38
14	653618.6	653618.63	150700.55	361711.28	132907.58	696075.25
15	583492.1	589449.00	132217.03	326199.94	123216.33	645319.38
16	512387.2	517152.72	116517.83	286191.31	111056.20	581633.31
17	455747	455746.97	154922.55	252209.50	98097.59	513765.34
18	397472.2	605962.88	105314.52	335338.69	96467.80	505229.63
19	357123.2	411926.44	154651.80	227959.30	102557.09	537121.00
20	384499.5	604903.88	144439.22	334752.63	92637.30	485168.19
21	563767.1	564958.50	230931.20	312646.94	109184.20	571829.13
22	890157.4	903262.56	322389.63	499863.75	124637.48	652762.38
23	1228825	1260992.38	365389.59	697830.75	180797.94	946890.88
24	1429182	1429182.13	386338.53	790906.63	237531.00	1244018.25
25	1511122	1511121.63	418267.72	836251.81	270135.25	1414776.13
26	1633627	1636009.25	611221.00	905364.38	291115.31	1524654.75
27	1860563	2390725.25	546473.63	1323022.75	345159.69	1807700.75
28	2117219	2137472.75	710151.94	1182873.25	422863.13	2214656.00
29	2355936	2777683.00	600999.63	1537164.38	442192.28	2315888.25
30	2328110	2350745.50	479642.34	1300898.00	492689.41	2580356.25
31	1859390	1876069.50	0.00	1038213.25	434047.13	2273229.75

C0 = .2556634

C1 = .5533981

C2 = .1909385

X = .2 K = .92 REACH = 4
CATCHMENT AREA = 1.36875E+07 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	468906.4	537645.00	128360.34	297531.72	102657.14	537645.00
2	459937.5	502067.66	110704.11	277843.28	100920.40	528549.19
3	433007.2	433007.22	120607.08	239625.36	93458.25	489467.78
4	448089.6	471741.63	190632.72	261060.91	86627.02	453690.69
5	594857.9	745639.38	187945.08	412635.41	102786.14	538320.63
6	735126.9	735126.94	175420.94	406817.84	134299.78	703366.63
7	686140.1	686140.13	191525.48	379708.63	136814.81	716538.56
8	749131.3	749131.31	209000.30	414567.81	135193.81	708048.94
9	817482.2	817482.19	213416.14	452393.06	144876.88	758761.94
10	834754.3	834754.31	276644.53	461951.44	154791.19	810686.0
11	881762.4	1082065.38	241723.84	598812.88	170582.02	893387.1
12	945476.8	945476.81	192831.67	523225.03	193061.52	1011118.7
13	754240.4	754240.38	177960.98	417395.16	173585.69	909118.2
14	696075.3	696075.25	165929.39	385206.69	146820.61	768941.8
15	645319.4	649015.00	149458.23	359163.66	133266.81	697956.6
16	581633.3	584589.81	131351.00	323510.88	122561.27	641888.6
17	513765.3	513765.34	162238.00	284316.75	110252.31	577423.1
18	505229.6	634576.50	146014.69	351173.41	106315.91	556807.0
19	537121	571120.75	158998.70	316057.13	115232.16	603504.00
20	485168.2	621906.31	146384.77	344161.75	112708.72	590288.0
21	571829.1	572568.25	168966.11	316858.16	115184.66	603255.2
22	652762.4	660892.75	247187.48	365736.78	114755.76	601008.9
23	946890.9	966847.25	318049.97	535051.38	138942.14	727680.0
24	1244018	1244018.25	361706.50	688437.31	189419.31	992043.50
25	1414776	1414776.13	390176.38	782934.38	236680.34	1239563.13
26	1524655	1526133.00	546253.44	844559.06	269183.44	1409791.13
27	1807701	2136611.50	569419.00	1182396.63	316957.19	1659996.00
28	2214656	2227221.25	658982.31	1232540.00	395008.41	2068772.75
29	2315888	2577538.50	663293.06	1426404.88	436586.78	2286530.75
30	2580356	2594399.50	583827.25	1435735.63	482365.06	2526284.75
31	2273230	2283577.50	0.00	1263727.38	477714.44	2501928.00

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 5
CATCHMENT AREA = 1.0625E+07 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	537645	591003.75	143491.84	327060.34	112845.38	591003.75
2	528549.2	561252.94	125139.01	310596.28	111393.06	583397.56
3	489467.8	489467.78	120686.09	270870.53	104467.88	547128.38
4	453690.7	472050.69	167553.02	261231.94	94710.18	496024.50
5	538320.6	655365.63	179825.13	362678.06	99955.38	523495.13
6	703366.6	703366.63	183192.70	389241.75	122670.09	642458.56
7	716538.6	716538.56	181022.22	396531.06	132722.23	695104.56
8	708048.9	708048.94	193987.67	391832.91	135618.95	710275.50
9	758761.9	758761.94	207262.78	419897.41	137750.59	721439.50
10	810686.1	810686.06	268158.56	448632.09	146050.92	764910.75
11	893387.1	1048873.38	258506.08	580444.50	164749.69	862841.56
12	1011119	1011118.75	232428.28	559551.19	191645.03	1003700.25
13	909118.3	909118.25	196590.30	503104.28	187811.80	983624.50
14	768941.8	768941.81	179175.44	425530.91	169459.16	887506.38
15	697956.7	700825.44	164694.20	387835.44	147818.02	774165.50
16	641888.7	644183.69	147625.97	356490.00	133723.34	700347.63
17	577423.1	577423.13	168025.41	319544.84	121788.09	637839.31
18	556807.1	657213.31	161041.50	363700.59	116349.98	609358.38
19	603504	629896.50	178052.13	348583.50	122409.16	641092.06
20	590288	696431.75	154376.98	385404.00	123927.66	649044.81
21	603255.3	603829.00	155269.56	334157.81	126727.54	663708.63
22	601008.9	607320.19	190001.70	336089.81	117647.71	616154.94
23	727680	743171.25	253629.23	411269.53	122914.62	643739.25
24	992043.5	992043.50	316910.97	548994.94	150423.92	787813.38
25	1239563	1239563.13	360725.41	685971.88	194056.50	1016329.81
26	1409791	1410938.63	489675.94	780810.69	236907.69	1240753.75
27	1659996	1915314.75	531403.19	1059931.50	287819.63	1507394.25
28	2068773	2078526.50	636509.44	1150252.50	358802.94	1879154.25
29	2286531	2489638.25	648665.69	1377761.00	409671.00	2145565.00
30	2526285	2537186.00	641705.13	1404073.88	465144.91	2436097.75
31	2501928	2509960.50	0.00	1389007.25	479432.09	2510924.00

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 6
CATCHMENT AREA = 4437500 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	591003.8	613288.88	152645.42	339392.88	117100.47	613288.88
2	583397.6	597056.19	139880.72	330409.75	116308.05	609138.75
3	547128.4	547128.38	128775.75	302779.78	112004.25	586598.50
4	496024.5	503692.50	146336.28	278742.47	103786.49	543559.75
5	523495.1	572378.63	164253.16	316753.22	100980.75	528865.25
6	642458.6	642458.56	177712.81	355535.34	111123.76	581987.13
7	695104.6	695104.56	181591.47	384669.53	123035.42	644371.94
8	710275.5	710275.50	184445.69	393065.09	131613.23	689296.44
9	721439.5	721439.50	195559.70	399243.22	135399.08	709124.00
10	764910.8	764910.75	237199.39	423300.13	139423.69	730202.00
11	862841.6	927779.94	256609.44	513431.63	152736.14	799923.19
12	1003700	1003700.25	251476.81	555445.81	176193.70	922777.19
13	983624.5	983624.50	226902.92	544335.88	187714.77	983116.31
14	887506.4	887506.38	198232.13	491144.31	183101.17	958953.56
15	774165.5	775363.63	179298.33	429084.75	166589.58	872477.63
16	700347.6	701306.13	163072.19	388101.47	147972.13	774972.63
17	637839.3	637839.31	166511.73	352979.03	133493.86	699145.75
18	609358.4	651292.75	166721.91	360424.16	124679.91	652984.63
19	641092.1	652114.81	177270.73	360879.09	124458.69	651826.00
20	649044.8	693375.44	169747.28	383712.63	126517.48	662608.50
21	663708.6	663948.25	158202.17	367427.69	129833.88	679977.38
22	616154.9	618790.81	166234.69	342437.66	125153.27	655463.75
23	643739.3	650209.13	201415.06	359824.47	121021.73	633825.63
24	787813.4	787813.38	259838.36	435974.41	130269.95	682261.25
25	1016330	1016329.81	317337.88	562434.94	157731.02	826082.75
26	1240754	1241233.00	412647.78	686895.94	198099.44	1037503.81
27	1507394	1614027.38	481472.50	893199.63	247770.05	1297643.13
28	1879154	1883227.88	570229.75	1042174.69	309786.69	1622442.13
29	2145565	2230392.25	623985.06	1234294.75	367020.31	1922191.13
30	2436098	2440650.50	642809.13	1350651.25	424895.47	2225300.00
31	2510924	2514278.75	0.00	1391397.00	461757.25	2418355.75

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 7
CATCHMENT AREA = 8437500 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	613288.9	655662.00	162374.23	362842.09	125191.13	655662.00
2	609138.8	635109.38	149971.78	351468.31	124187.83	650407.44
3	586598.5	586598.50	142695.92	324622.47	119456.47	625627.94
4	543559.8	558139.75	158974.78	308873.47	112037.92	586774.88
5	528865.3	621812.75	148792.83	344109.97	110722.61	579886.19
6	581987.1	581987.13	164742.34	322070.56	115255.34	603625.38
7	644371.9	644371.94	176227.89	356594.19	114958.02	602068.25
8	689296.4	689296.44	181297.08	381455.31	123686.18	647780.13
9	709124	709124.00	186685.94	392427.84	131067.56	686438.56
10	730202	730202.00	236078.98	404092.38	135600.98	710181.38
11	799923.2	923397.56	235920.38	511006.44	148124.83	775772.38
12	922777.2	922777.19	251346.89	510663.13	170899.83	895051.63
13	983116.3	983116.31	245169.36	544054.69	178128.42	932909.88
14	958953.6	958953.56	223643.05	530683.06	184704.86	967352.50
15	872477.6	874755.75	198598.11	484088.16	179297.19	939031.00
16	774972.6	776795.13	178746.00	429876.94	164585.84	861983.44
17	699145.8	699145.75	187329.45	386905.91	147635.33	773208.75
18	652984.6	732719.00	172006.45	405485.28	137832.92	721870.69
19	651826	672784.75	190954.78	372317.78	136583.02	715324.63
20	662608.5	746899.13	173961.83	413332.53	133629.39	699855.56
21	679977.4	680433.00	168859.45	376550.31	137652.11	720923.75
22	655463.8	660475.63	165191.17	365505.94	130422.82	683061.88
23	633825.6	646127.50	174429.25	357565.72	126233.26	661119.94
24	682261.3	682261.25	211199.14	377562.06	125681.13	658228.25
25	826082.8	826082.75	265484.75	457152.59	136414.56	714442.31
26	1037504	1038415.06	383596.44	574656.88	164026.09	859051.88
27	1297643	1500396.25	416779.38	830316.38	214286.36	1122279.38
28	1622442	1630187.75	532670.25	902142.75	279034.13	1461382.13
29	1922191	2083482.38	571141.13	1152995.13	327239.44	1713847.13
30	2225300	2233957.00	619915.94	1236267.50	391686.66	2051375.75
31	2418356	2424734.50	0.00	1341843.38	429204.97	2247870.00

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 8
CATCHMENT AREA = 1875000 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	655662	665078.25	167760.89	368053.03	126989.05	665078.25
2	650407.4	656178.69	159950.19	363128.03	126554.63	662803.00
3	625627.9	625627.94	150845.22	346221.28	124039.94	649632.88
4	586774.9	590014.88	153536.42	326513.09	118593.14	621106.44
5	579886.2	600541.19	154324.94	332338.34	114303.94	598642.63
6	603625.4	603625.38	153926.83	334045.13	114747.80	600967.25
7	602068.3	602068.25	165613.69	333183.41	115082.41	602719.75
8	647780.1	647780.13	175497.23	358480.28	117213.24	613879.50
9	686438.6	686438.56	181567.41	379873.78	124337.40	651190.75
10	710181.4	710181.38	205351.70	393013.00	130941.54	685778.56
11	775772.4	803211.13	228831.97	444495.50	139252.66	729306.25
12	895051.6	895051.63	238510.94	495319.84	155152.84	812580.13
13	932909.9	932909.88	247316.66	516270.53	169741.22	888983.63
14	967352.5	967352.50	240205.31	535331.00	178208.34	933328.38
15	939031	939537.25	220481.19	519938.09	182106.58	953744.63
16	861983.4	862388.44	197681.20	477244.09	176145.72	922525.88
17	773208.8	773208.75	189085.97	427892.22	162502.23	851071.00
18	721870.7	739589.44	184073.09	409287.38	148832.84	779480.44
19	715324.6	719982.13	183716.36	398436.72	141713.30	742193.31
20	699855.6	718586.81	184339.72	397664.56	138213.97	723866.38
21	720923.8	721025.00	174918.69	399013.84	137517.41	720218.25
22	683061.9	684175.63	169723.11	378621.47	135843.20	711449.94
23	661119.9	663853.69	168284.89	367375.34	130637.80	684187.75
24	658228.3	658228.25	182656.77	364262.25	127221.95	666298.00
25	714442.3	714442.31	219679.92	395371.00	128719.48	674141.00
26	859051.9	859254.38	298445.03	475509.72	142014.41	743770.38
27	1122279	1167335.63	374062.03	646001.31	174893.78	915969.13
28	1461382	1463103.38	447331.66	809678.56	228163.34	1194957.13
29	1713847	1749689.63	524953.56	968274.88	283576.81	1485173.50
30	2051376	2053299.50	575060.56	1136292.00	339260.56	1776805.25
31	2247870	2249287.50	0.00	1244751.38	391541.03	2050613.13

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 9
CATCHMENT AREA = 1593750 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	665078.3	673082.06	170708.66	372482.31	128517.29	673082.06
2	662803	667708.56	166087.36	369508.63	128254.98	671708.25
3	649632.9	649632.88	159498.30	359505.59	126754.71	663850.94
4	621106.4	623860.44	157539.64	345243.16	123300.20	645758.63
5	598642.6	616199.38	153645.34	341003.53	119543.36	626083.00
6	600967.3	600967.25	154093.39	332574.13	117272.96	614192.25
7	602719.8	602719.75	156946.53	333543.94	115315.50	603940.50
8	613879.5	613879.50	166485.66	339719.72	115671.70	605806.00
9	651190.8	651190.75	175328.50	360367.72	118740.28	621877.06
10	685778.6	685778.56	192419.75	379508.53	124957.13	654436.50
11	729306.3	752629.19	207747.02	416503.53	133062.27	696885.44
12	812580.1	812580.13	227280.59	449680.28	144600.19	757312.81
13	888983.6	888983.63	238617.92	491961.81	156867.66	821561.06
14	933328.4	933328.38	243947.63	516502.13	169447.89	887447.38
15	953744.6	954174.94	235944.14	528038.56	177553.28	929897.63
16	922525.9	922870.13	217587.72	510714.56	179775.48	941536.00
17	851071	851071.00	203135.17	470981.06	173387.02	908077.75
18	779480.4	794541.38	190763.83	439697.66	161821.02	847503.25
19	742193.3	746152.19	189136.72	412919.19	151277.25	792282.50
20	723866.4	739787.94	184155.47	409397.22	143840.31	753333.13
21	720218.3	720304.31	182133.77	398615.03	140796.72	737393.00
22	711449.9	712396.63	175515.86	394238.91	137770.83	721545.50
23	684187.8	686511.44	170348.03	379914.09	135093.89	707525.63
24	666298	666298.00	172353.20	368728.03	130860.86	685356.00
25	674141	674141.00	190198.89	373068.34	128299.63	671942.13
26	743770.4	743942.50	243971.16	411696.34	132046.75	691566.88
27	915969.1	954266.94	305880.91	528089.50	150404.98	787714.25
28	1194957	1196420.25	387493.63	662096.69	187955.17	984375.38
29	1485174	1515639.63	454682.19	838752.06	236295.11	1237545.50
30	1776805	1778440.50	524574.81	984185.56	292084.25	1529729.38
31	2050613	2051818.00	0.00	1135472.13	343850.59	1800844.63

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 10

CATCHMENT AREA = 2.1875E+07 RUNOFF COEFFICIENT = .54

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	673082.1	782938.31	188945.38	433276.56	149493.08	782938.31
2	671708.3	739039.50	169722.41	408983.03	147350.13	771715.00
3	663850.9	663850.94	174760.94	367373.84	138631.97	726055.56
4	645758.6	683558.63	221675.02	378280.03	129984.59	680766.75
5	626083	867058.00	157026.50	479828.22	139373.59	729939.63
6	614192.3	614192.25	154405.50	339892.81	148211.89	776228.31
7	603940.5	603940.50	154882.44	334219.50	122679.95	642510.19
8	605806	605806.00	158991.22	335251.88	116812.73	611781.88
9	621877.1	621877.06	167315.48	344145.56	116674.09	611055.81
10	654436.5	654436.50	260010.80	362163.91	119935.19	628135.13
11	696885.4	1017004.25	193617.19	562808.19	141697.36	742109.88
12	757312.8	757312.81	210043.11	419095.44	171486.22	898122.75
13	821561.1	821561.06	226887.83	454650.31	152870.11	800624.75
14	887447.4	887447.38	239250.83	491111.66	159320.67	834408.25
15	929897.6	935803.88	241924.33	517872.06	169874.78	889683.13
16	941536	946261.00	232162.27	523659.00	177510.03	929671.19
17	908077.8	908077.75	269526.00	502528.47	178208.89	933331.31
18	847503.3	1054222.00	216449.77	583404.44	181441.88	950263.38
19	792282.5	846620.00	248470.17	468517.88	187367.22	981296.06
20	753333.1	971864.38	188826.42	537827.88	172676.25	904355.25
21	737393	738574.25	187794.81	408725.56	171716.84	899330.56
22	721545.5	734539.25	189042.48	406492.59	146686.08	768237.25
23	707525.6	739419.38	175220.47	409193.25	141718.59	742221.13
24	685356	685356.00	171791.03	379274.69	138646.63	726132.31
25	671942.1	671942.13	177412.36	371851.47	131692.66	689712.38
26	691566.9	693929.38	335780.81	384019.19	130020.83	680956.50
27	787714.3	1313370.50	256802.83	726816.69	162263.53	849820.81
28	984375.4	1004456.63	423303.97	555864.38	218793.20	1145883.00
29	1237546	1655708.00	396833.91	916265.63	228737.00	1197961.50
30	1529729	1552173.13	464638.13	858969.63	294395.97	1541836.50
31	1800845	1817382.13	0.00	1005735.75	308939.25	1618003.75

C0 = .2556634

C1 = .5533981

C2 = .1909385

X = .2 K = .92 REACH = 11
CATCHMENT AREA = 1687500 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	782938.3	789215.81	198282.97	436750.50	150691.70	789215.81
2	771715	775562.50	185625.86	429194.78	150025.20	785725.19
3	726055.6	726055.56	174599.39	401797.75	146038.53	764845.88
4	680766.8	682926.75	190139.34	377930.34	137940.80	722435.69
5	729939.6	743709.63	198453.19	411567.47	134804.59	706010.50
6	776228.3	776228.31	164266.36	429563.25	142215.83	744825.25
7	642510.2	642510.19	156410.25	355563.91	140539.42	736045.44
8	611781.9	611781.88	156224.63	338558.91	124589.97	652513.56
9	611055.8	611055.81	160591.17	338157.09	118262.26	619373.50
10	628135.1	628135.13	194407.08	347608.78	117811.07	617010.50
11	742109.9	760402.38	229617.14	420805.22	125986.38	659826.94
12	898122.8	898122.75	204690.47	497019.41	148246.33	776408.75
13	800624.8	800624.75	213327.67	443064.19	162289.38	849956.19
14	834408.3	834408.25	227545.72	461759.91	156317.78	818681.25
15	889683.1	890020.63	237751.95	492535.69	161462.08	845623.38
16	929671.2	929941.19	238618.69	514627.66	170269.38	891749.75
17	933331.3	933331.31	245967.61	516503.75	176334.73	923515.75
18	950263.4	962075.88	251675.34	532410.94	179254.25	938806.13
19	981296.1	984401.06	234403.16	544765.63	183938.81	963340.50
20	904355.3	916842.75	229943.19	507379.00	183894.34	963107.63
21	899330.6	899398.06	196600.00	497725.16	175895.72	921216.50
22	768237.3	768979.75	190224.73	425551.91	166158.69	870220.88
23	742221.1	744043.63	185645.47	411752.31	149301.56	781935.31
24	726132.3	726132.31	176334.23	401840.22	142573.67	746699.38
25	689712.4	689712.38	174130.19	381685.50	137618.58	720748.13
26	680956.5	681091.50	224947.59	376914.72	132403.31	693434.25
27	849820.8	879858.31	293253.75	486911.91	140199.59	734265.63
28	1145883	1147030.50	312384.03	634764.44	175733.17	920365.25
29	1197962	1221856.50	394519.09	676173.06	214401.36	1122881.63
30	1541837	1543119.00	413905.97	853959.06	245373.84	1285093.50
31	1618004	1618948.75	0.00	895923.13	288935.59	1513238.88

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 12
CATCHMENT AREA = 5656250 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
===	======	========	======	=======	========	========
1	789215.8	810257.06	204178.30	448394.69	154709.28	810257.06
2	785725.2	798621.44	195543.11	441955.56	154141.28	807282.25
3	764845.9	764845.88	186551.39	423264.22	151154.56	791639.94
4	722435.7	729675.69	192301.20	403801.13	145298.52	760970.19
5	706010.5	752165.50	190424.58	416246.94	141561.98	741400.88
6	744825.3	744825.25	188179.89	412184.84	142866.59	748233.50
7	736045.4	736045.44	166823.86	407326.13	141911.48	743231.31
8	652513.6	652513.56	158351.16	361099.75	136723.72	716061.50
9	619373.5	619373.50	157747.02	342760.09	125289.01	656174.63
10	617010.5	617010.50	184369.30	341452.41	119488.59	625796.13
11	659826.9	721140.69	198499.31	399077.88	123214.59	645310.31
12	776408.8	776408.75	217302.70	429663.09	137626.91	720791.75
13	849956.2	849956.19	209306.86	470364.13	149808.97	784592.69
14	818681.3	818681.25	216484.19	453056.63	158379.67	829479.94
15	845623.4	846754.63	228219.17	468592.38	158081.91	827920.50
16	891749.8	892654.75	236109.20	493993.41	163232.08	854893.44
17	923515.8	923515.75	250141.06	511071.84	170572.00	893334.69
18	938806.1	978399.88	248951.75	541444.63	177913.63	931784.88
19	963340.5	973748.00	256932.50	538870.25	184887.67	968310.00
20	963107.6	1004963.88	235579.20	556145.06	187251.58	980690.44
21	921216.5	921442.75	223119.94	509924.66	186924.20	978975.88
22	870220.9	872709.63	201474.05	482955.81	175657.48	919968.81
23	781935.3	788044.06	190903.72	436102.06	164223.81	860087.38
24	746699.4	746699.38	184268.94	413222.00	151076.22	791229.63
25	720748.1	720748.13	177401.47	398860.63	142930.30	748567.13
26	693434.3	693886.75	213465.38	383995.59	137321.53	719192.38
27	734265.6	834946.88	236287.08	462058.00	140298.28	734782.50
28	920365.3	924211.50	307556.50	511456.88	160129.33	838643.38
29	1122882	1202974.13	329650.44	665723.56	186956.05	979142.69
30	1285094	1289392.25	387689.66	713547.19	225752.34	1182330.00
31	1513239	1516406.38	0.00	839176.38	253373.36	1326989.25

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 13
CATCHMENT AREA = 2062500 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	810257.1	817929.56	207594.80	452640.66	156174.27	817929.56
2	807282.3	811984.75	202393.38	449350.78	155884.06	816409.75
3	791639.9	791639.94	195227.20	438092.03	154207.34	807628.25
4	760970.2	763610.19	193851.91	422580.41	150369.16	787526.56
5	741400.9	758230.88	191295.94	419603.50	146411.94	766801.50
6	748233.5	748233.50	190017.06	414070.97	144599.91	757311.38
7	743231.3	743231.31	183070.73	411302.78	142953.36	748687.94
8	716061.5	716061.50	167759.86	396267.06	140784.09	737326.88
9	656174.6	656174.63	159993.19	363125.78	134575.56	704811.00
10	625796.1	625796.13	170698.23	346314.38	125579.21	657694.50
11	645310.3	667667.81	184280.09	369486.09	122695.53	642591.81
12	720791.8	720791.75	200591.66	398884.75	129162.60	676461.75
13	784592.7	784592.69	212067.69	434192.09	139125.25	728639.00
14	829479.9	829479.94	211774.45	459032.59	149960.25	785385.00
15	827920.5	828333.00	218649.36	458397.88	156716.09	820767.31
16	854893.4	855223.44	228393.00	473279.00	159197.53	833763.31
17	893334.7	893334.69	241914.45	494369.69	164373.14	860869.50
18	931784.9	946222.38	248531.69	523637.63	171970.16	900657.25
19	968310	972105.00	254628.73	537961.06	180272.59	944139.50
20	980690.4	995952.94	250309.42	551158.44	185756.91	972862.38
21	978975.9	979058.38	235434.39	541809.00	188499.23	987224.75
22	919968.8	920876.31	220462.38	509611.19	184397.47	965742.63
23	860087.4	862314.88	202288.47	477203.38	174607.73	914471.00
24	791229.6	791229.63	191381.23	437864.94	163080.50	854099.56
25	748567.1	748567.13	183913.38	414255.59	151285.69	792326.69
26	719192.4	719357.38	197243.05	398091.00	143099.75	749454.63
27	734782.5	771495.00	214769.00	426943.84	140995.45	738433.81
28	838643.4	840045.88	257797.63	464879.78	149449.17	782708.31
29	979142.7	1008347.69	302679.28	558017.69	166522.55	872126.56
30	1182330	1183897.50	339557.91	655166.63	196135.77	1027219.50
31	1326989	1328144.25	0.00	734992.44	227381.09	1190860.25

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 14
CATCHMENT AREA = 1156250 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	817929.6	822230.81	209400.11	455020.94	156995.53	822230.81
2	816409.8	819046.00	206481.00	453258.47	156840.06	821416.56
3	807628.3	807628.25	201720.13	446939.91	155916.48	816579.50
4	787526.6	789006.56	198455.28	436634.72	153624.64	804576.50
5	766801.5	776236.50	193616.81	429567.78	150596.00	788714.63
6	757311.4	757311.38	191412.13	419094.66	147744.53	773780.63
7	748687.9	748687.94	188507.52	414322.47	144779.38	758251.31
8	737326.9	737326.88	180194.39	408035.28	142747.42	747609.38
9	704811	704811.00	168148.42	390041.06	139571.69	730977.13
10	657694.5	657694.50	167491.64	363966.88	133229.48	697761.19
11	642591.8	655125.56	172946.53	362545.22	126914.54	664688.00
12	676461.8	676461.75	186286.34	374352.63	126478.88	662406.31
13	728639	728639.00	200794.22	403227.41	131197.27	687117.88
14	785385	785385.00	209899.30	434630.53	140381.61	735218.88
15	820767.3	820998.56	213210.08	454339.03	149869.83	784911.44
16	833763.3	833948.31	220092.84	461505.38	156076.77	817418.94
17	860869.5	860869.50	232334.39	476403.53	159944.42	837675.00
18	900657.3	908751.00	241925.86	502901.06	165864.92	868682.38
19	944139.5	946267.00	250912.84	523662.34	173886.16	910691.88
20	972862.4	981418.63	252409.08	543115.19	181097.81	948461.38
21	987224.8	987271.00	247035.14	546353.88	186474.77	976622.06
22	965742.6	966251.38	234116.05	534721.63	187093.73	979863.75
23	914471	915719.75	218362.02	506757.53	182524.13	955931.38
24	854099.6	854099.56	202568.95	472657.06	173304.14	907643.69
25	792326.7	792326.69	191631.78	438472.06	162017.08	848530.13
26	749454.6	749547.13	194052.39	414797.94	151246.39	792120.94
27	738433.8	759015.06	200310.91	420037.47	145131.75	760096.75
28	782708.3	783494.56	227156.72	433584.38	146159.64	765480.13
29	872126.6	888499.06	262847.13	491693.66	154068.44	806900.75
30	1027220	1028098.25	304624.94	568947.56	173488.50	908609.25
31	1190860	1191507.75	0.00	659378.06	199924.28	1047061.00

C0 = .2556634
C1 = .5533981
C2 = .1909385

X = .2 K = .92 REACH = 15
CATCHMENT AREA = 562500 RUNOFF COEFFICIENT = .4

TABLE OF RESULTS

DAY	INFLOW	AINFLOW	C0*AI2	C1*AI1	C2*O1	OUTFLOW
1	822230.8	824323.31	210334.06	456178.94	157395.08	824323.31
2	821416.6	822699.06	208769.52	455280.06	157315.78	823908.06
3	816579.5	816579.50	205884.86	451893.53	156830.28	821365.38
4	804576.5	805296.50	202818.98	445649.53	155540.17	814608.69
5	788714.6	793304.63	197827.41	439013.25	153516.23	804008.69
6	773780.6	773780.63	193857.13	428208.72	150909.56	790356.88
7	758251.3	758251.31	191136.38	419614.81	147590.77	772975.38
8	747609.4	747609.38	186884.11	413725.59	144796.69	758341.94
9	730977.1	730977.13	178392.02	404521.34	142326.78	745406.38
10	697761.2	697761.19	171495.31	386139.69	138476.28	725240.13
11	664688	670785.50	169353.06	371211.41	132914.45	696111.25
12	662406.3	662406.31	175670.91	366574.38	128593.07	673478.94
13	687117.9	687117.88	187968.58	380249.72	128088.88	670838.38
14	735218.9	735218.88	200701.91	406868.72	132951.86	696307.19
15	784911.4	785023.94	209007.14	434430.72	141394.27	740522.50
16	817418.9	817508.94	214162.86	452407.88	149854.69	784832.13
17	837675	837675.00	223096.98	463567.72	155887.06	816425.44
18	868682.4	872619.88	233095.22	482906.16	160875.58	842551.75
19	910691.9	911726.88	243551.08	504547.91	167429.58	876876.94
20	948461.4	952623.88	249692.30	527180.19	174809.67	915528.56
21	976622.1	976644.56	250578.59	540473.19	181712.78	951682.13
22	979863.8	980111.25	244552.00	542391.69	185738.22	972764.56
23	955931.4	956538.88	232051.30	529346.75	185722.44	972681.88
24	907643.7	907643.69	216938.13	502288.28	180841.78	947120.50
25	848530.1	848530.13	202527.86	469574.94	171857.69	900068.19
26	792120.9	792165.94	196888.77	438383.09	161144.56	843960.50
27	760096.8	770109.25	195803.06	426176.97	152066.58	796416.44
28	765480.1	765862.63	208331.38	423826.91	147795.31	774046.63
29	806900.8	814865.75	232407.45	450945.13	148923.19	779953.63
30	908609.3	909036.75	267775.75	503059.19	158913.50	832275.75
31	1047061	1047376.00	0.00	579615.88	177524.78	929748.44

C0 = .2556634
C1 = .5533981
C2 = .1909385

APPENDIX 3

FLOOD HYDROGRAPHS

fig 4.3 HYDROGRAPH FOR REACH 1

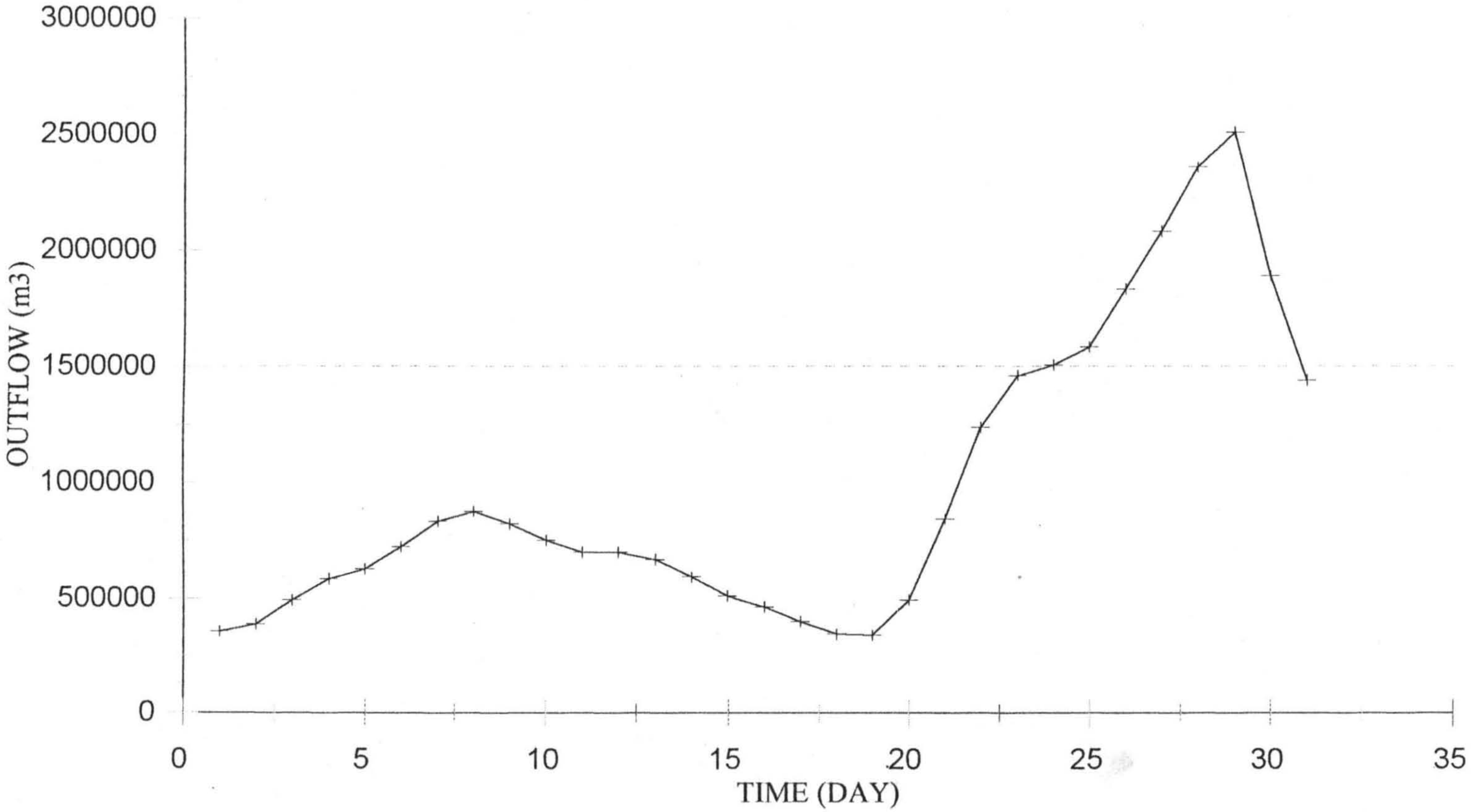


fig 4.3 HYDROGRAPH FOR REACH 1

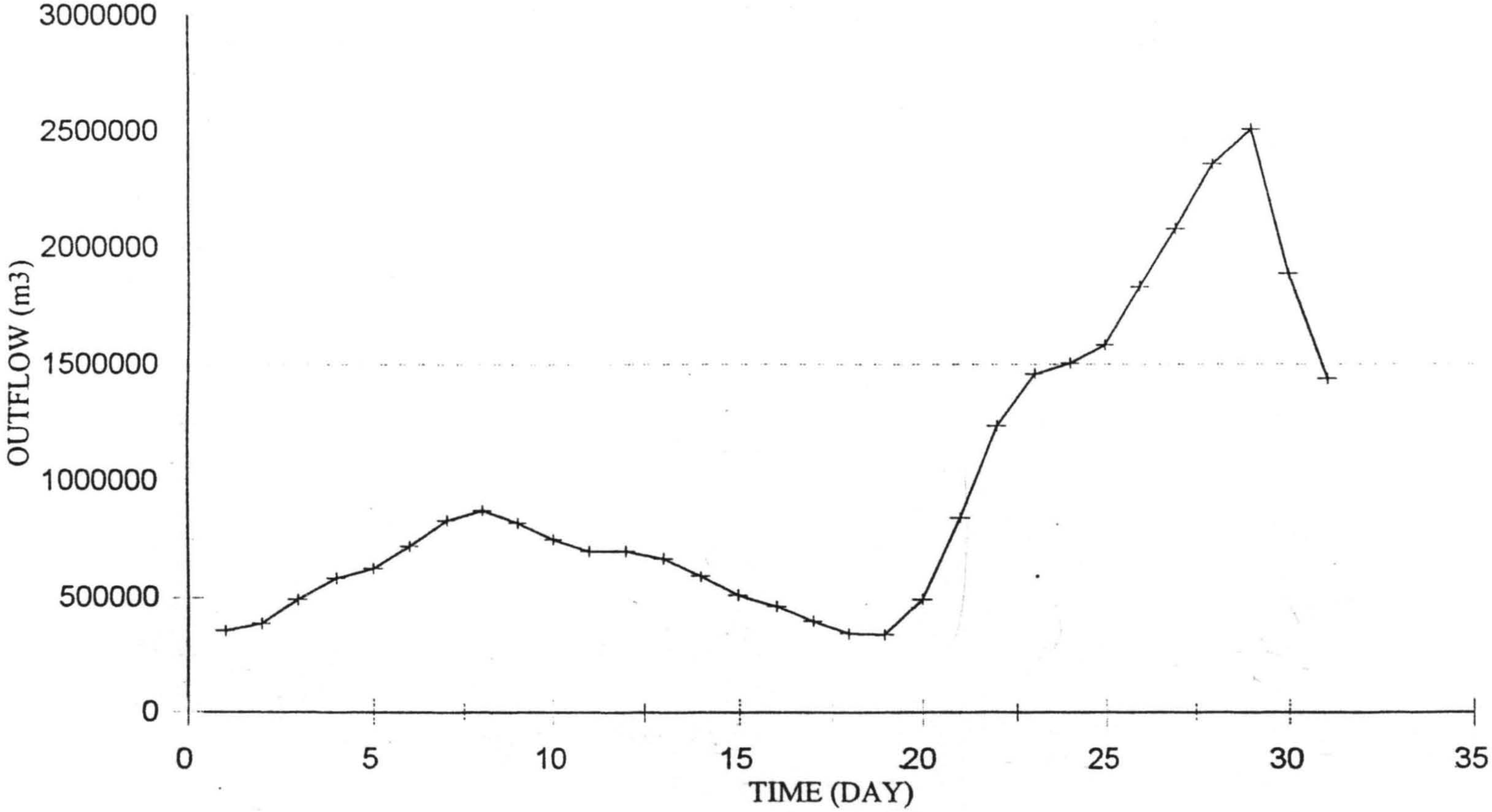


fig 4.4 HYDROGRAPH FOR REACH 2

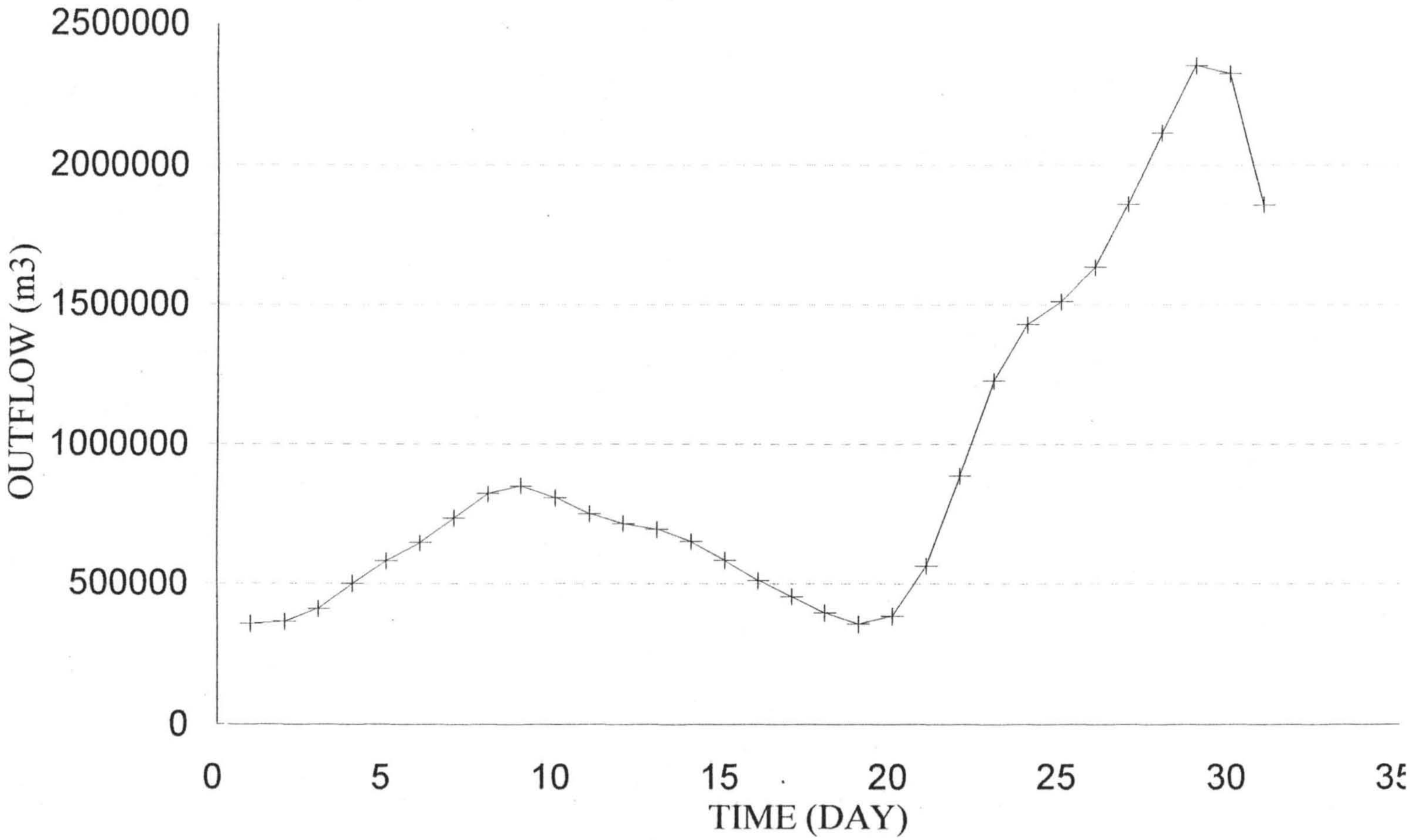
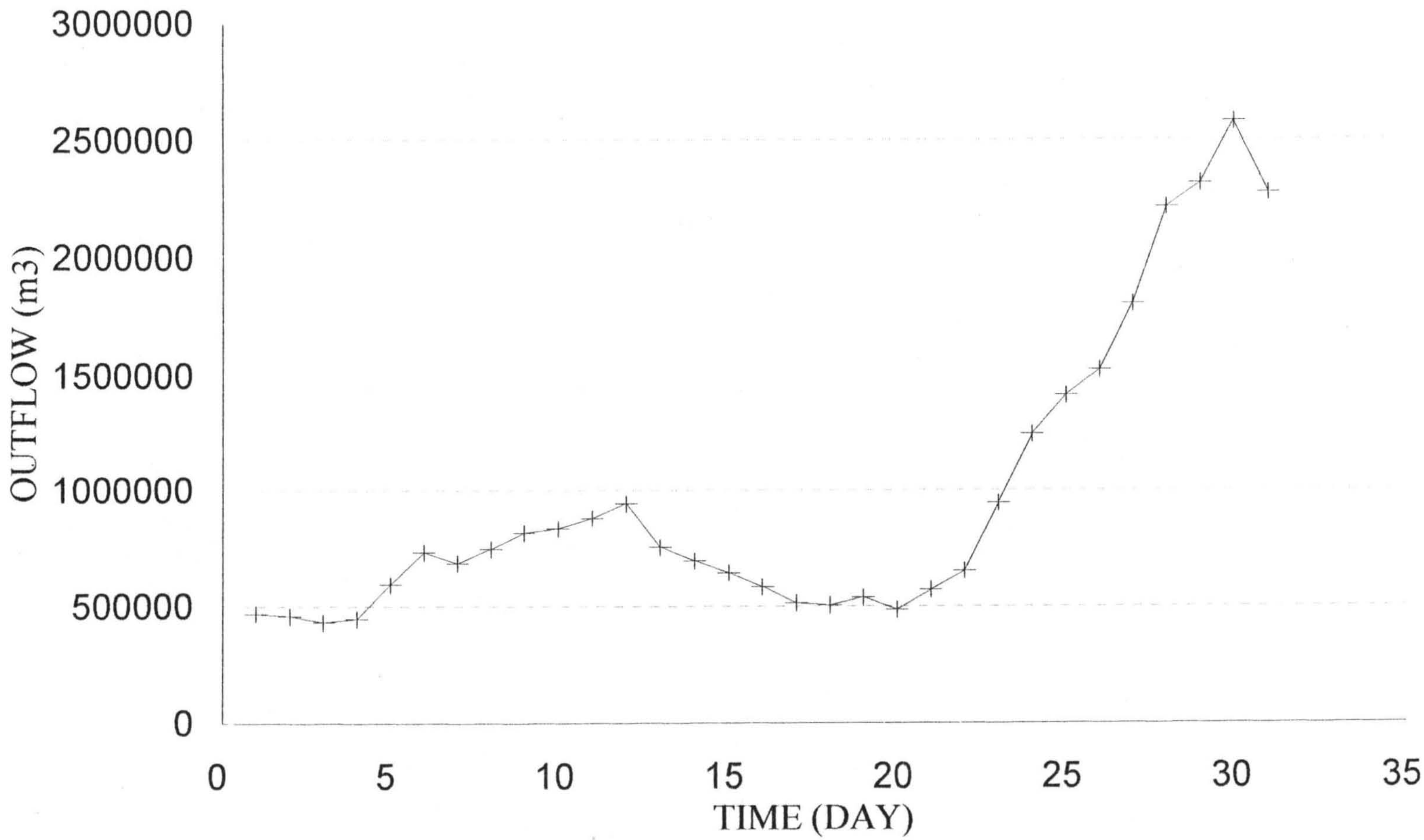


fig 4.5 HYDROGRAPH FOR REACH 3



63

fig 4.5 HYDROGRAPH FOR REACH 2

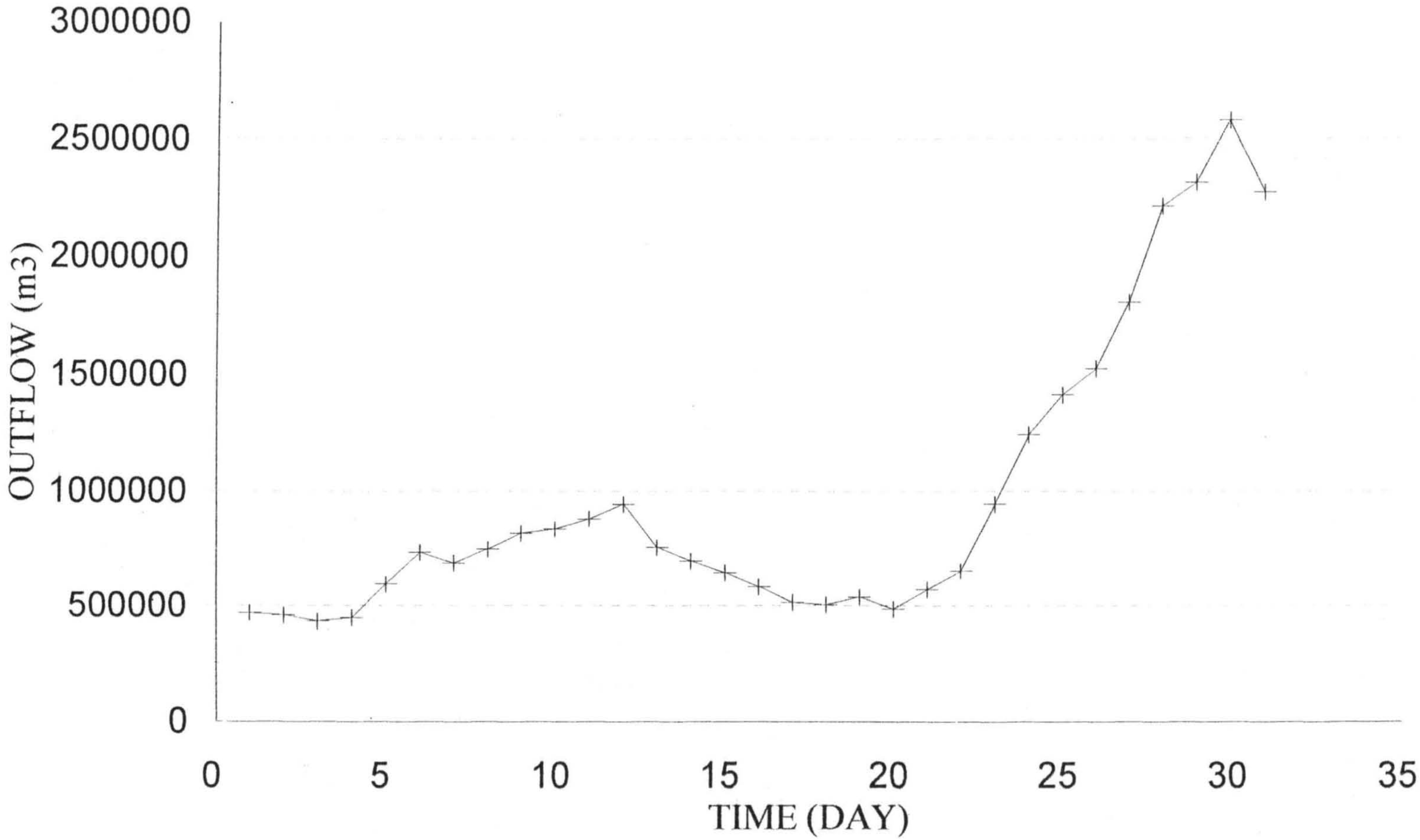


fig 4.5 HYDROGRAPH FOR REACH 3

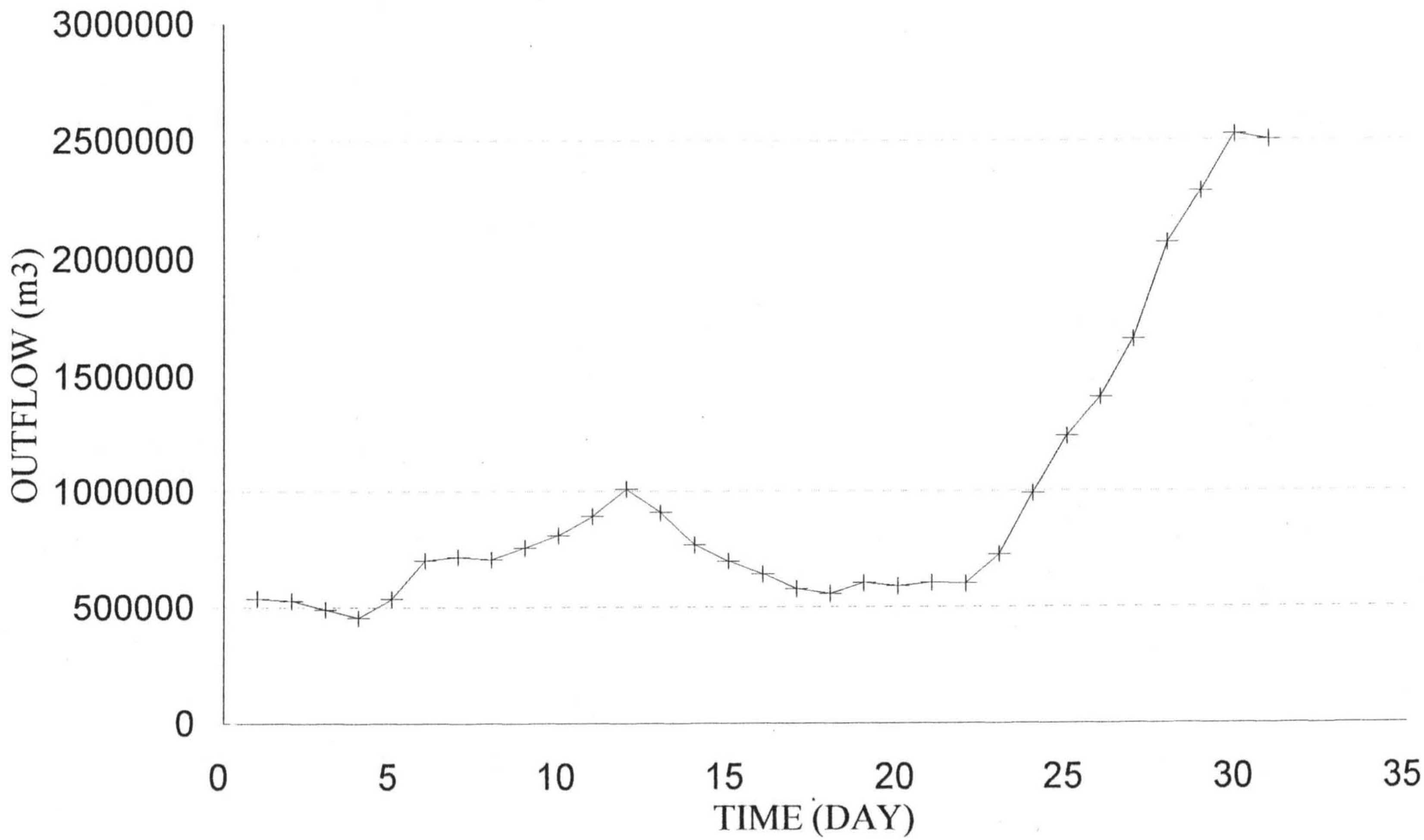


fig 4.7 HYDROGRAPH FOR REACH 5

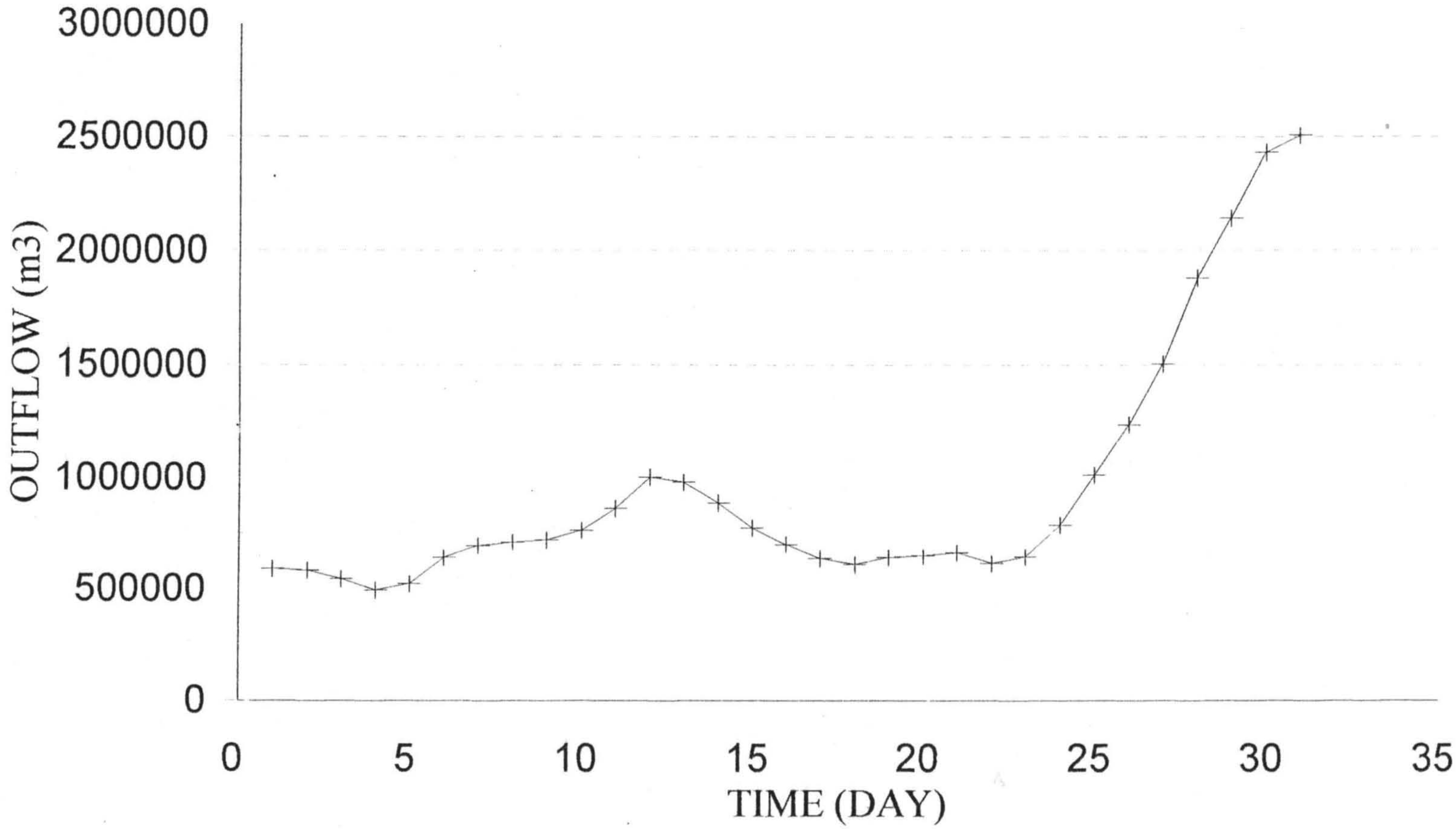


fig 4.8 HYDROGRAPH FOR REACH 6

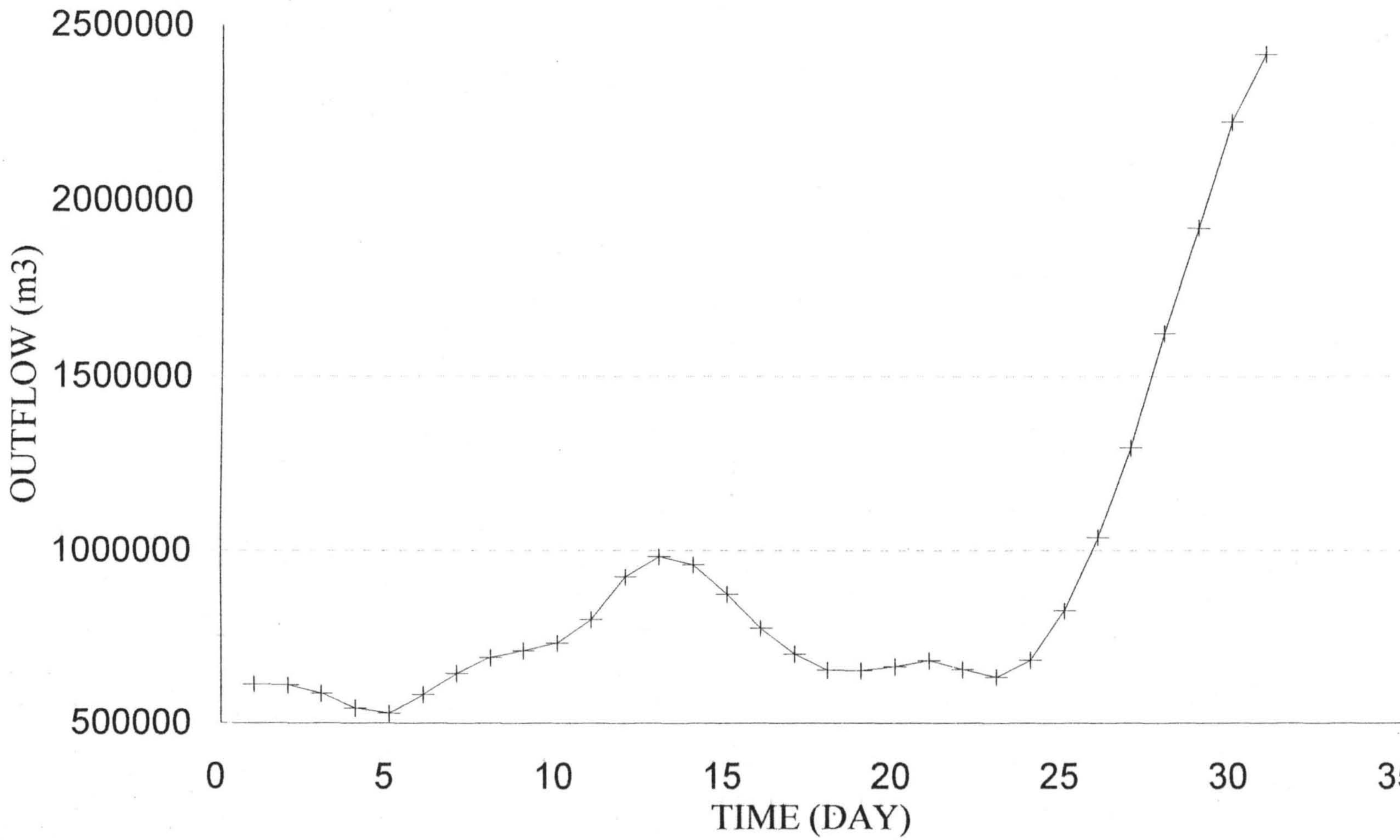


fig 4.9 HYDROGRAPH FOR REACH 7

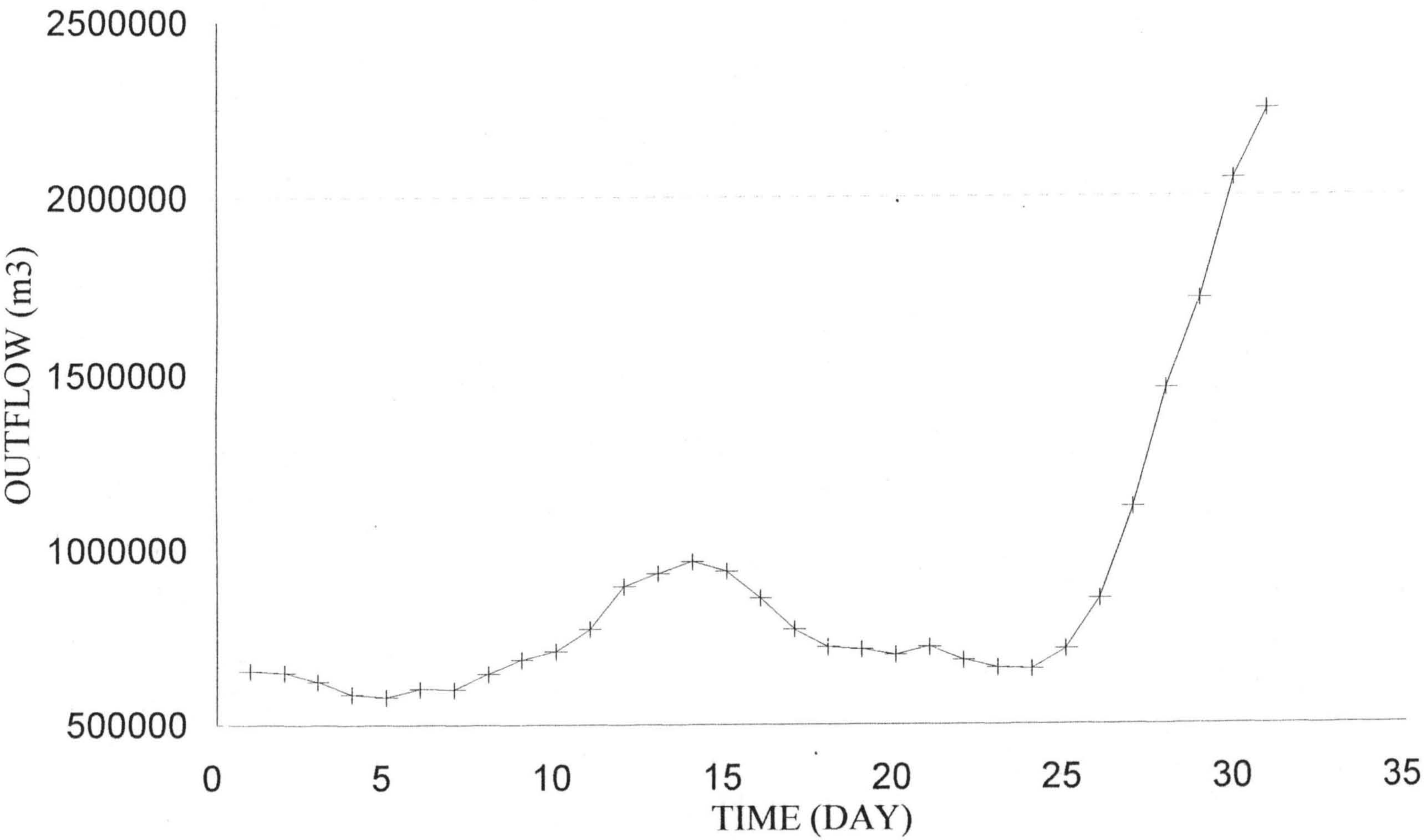


fig 4.10 HYDROGRAPH FOR REACH 8

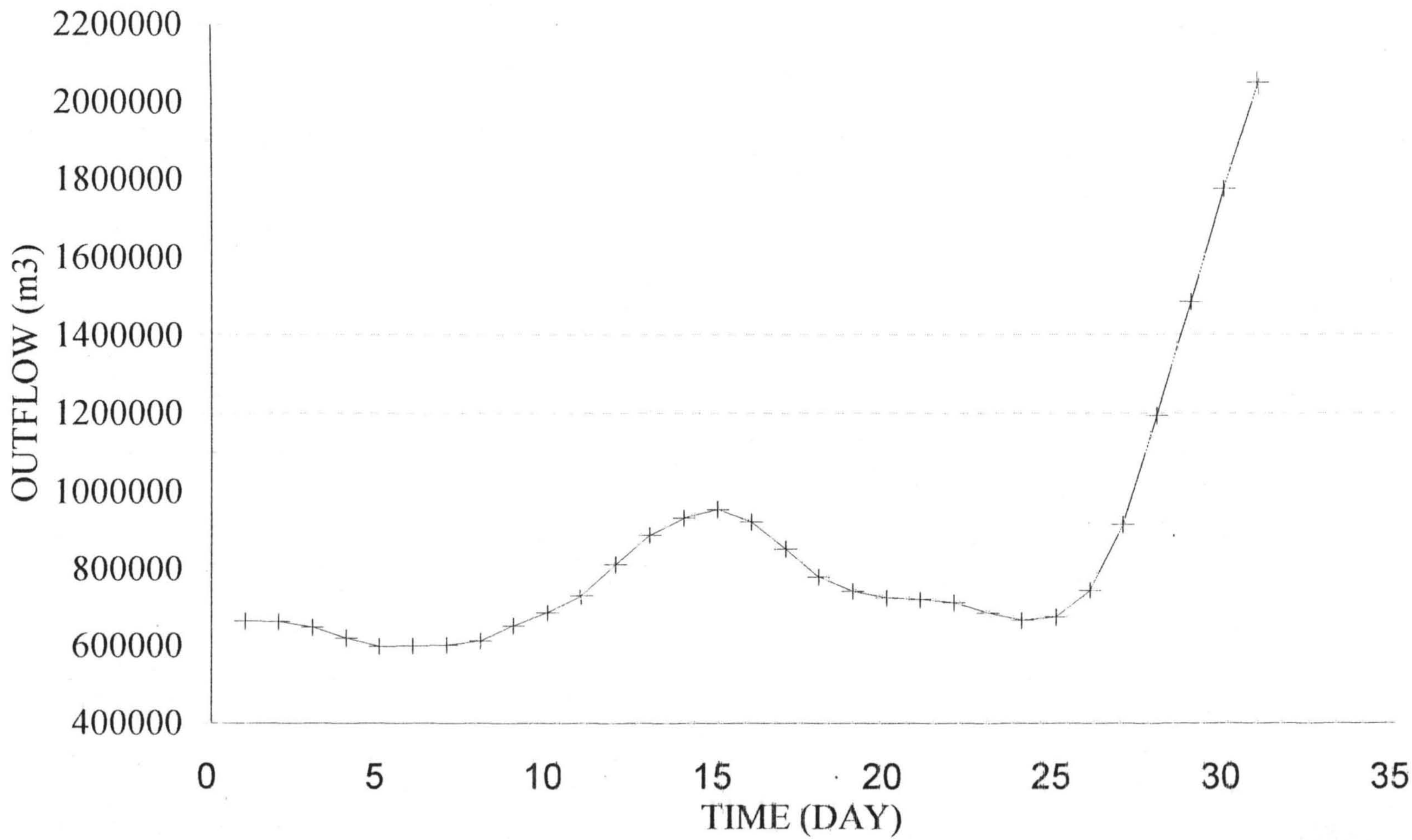


fig 4.11 HYDROGRAPH FOR REACH 9

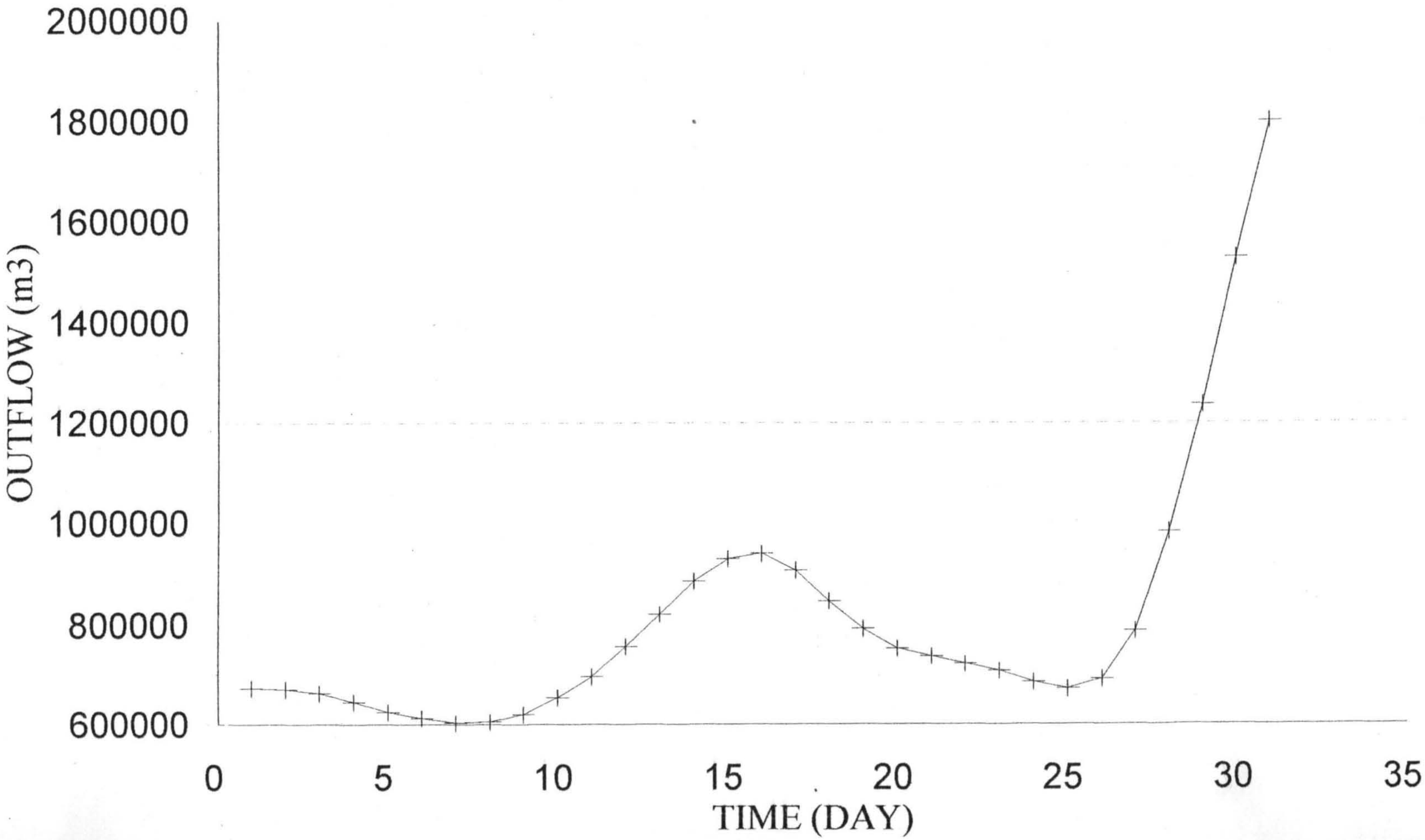


fig 4.12 HYDROGRAPH FOR REACH 10

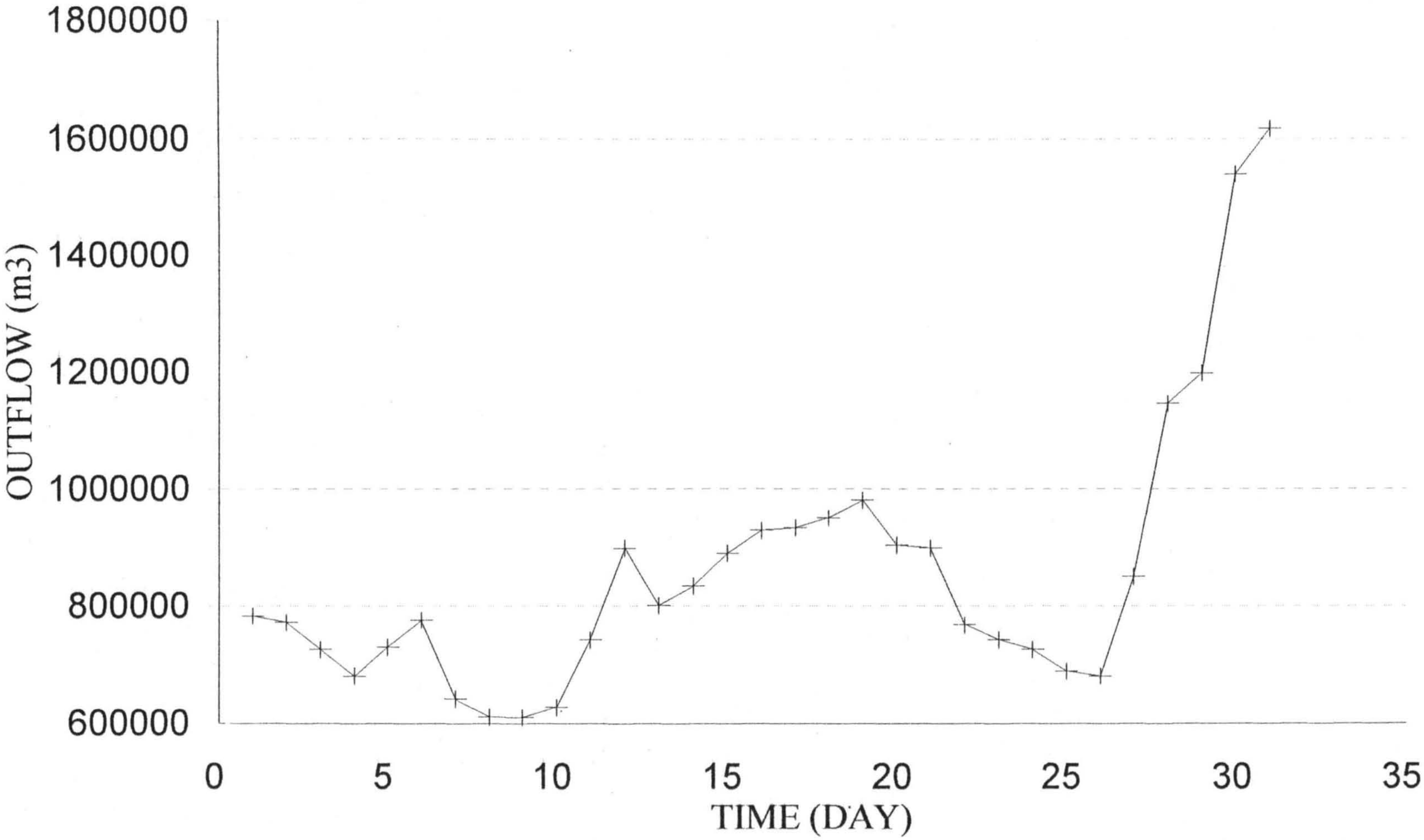


fig 4.13 HYDROGRAPH FOR REACH 11

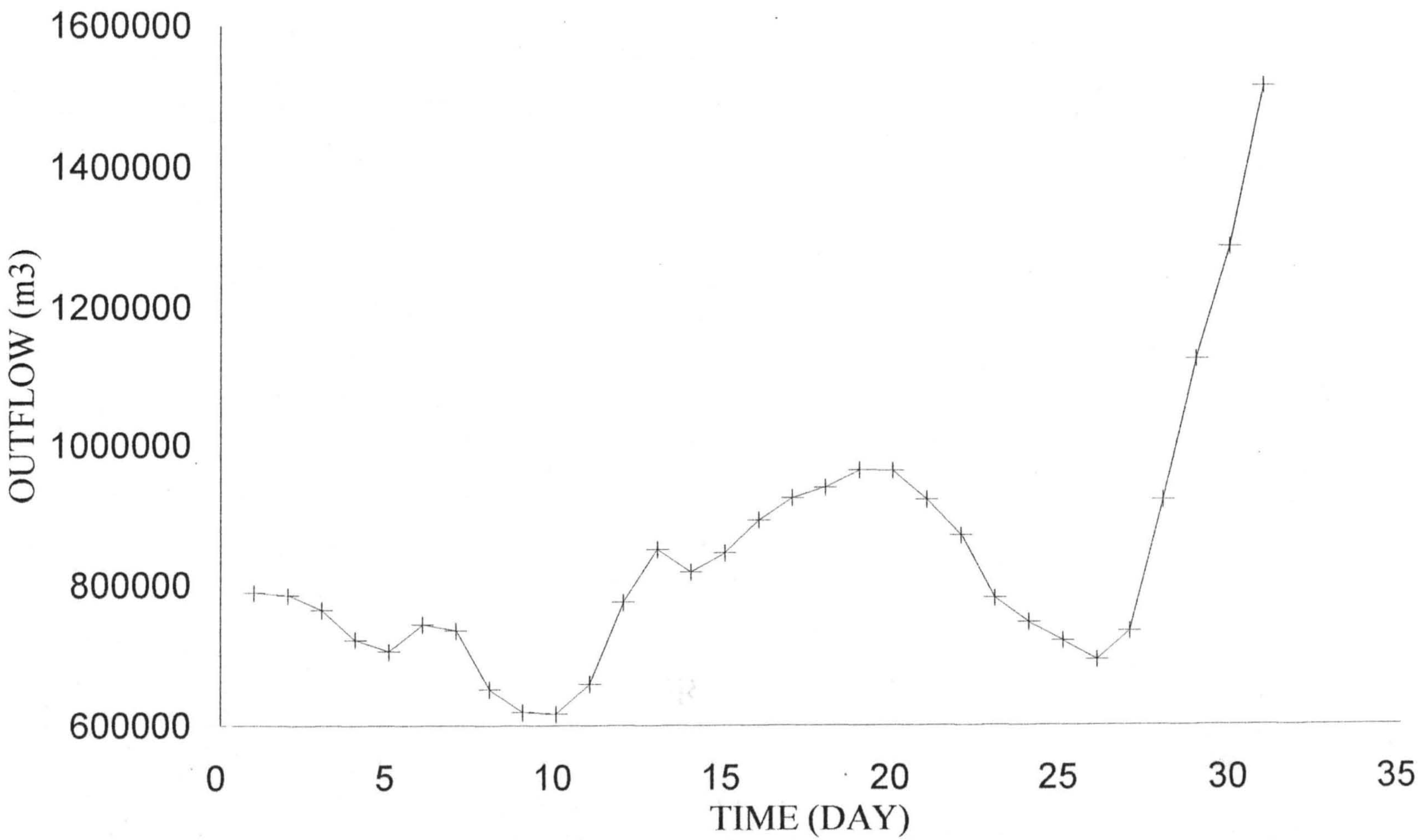


fig 4.14 HYDROGRAPH FOR REACH 12

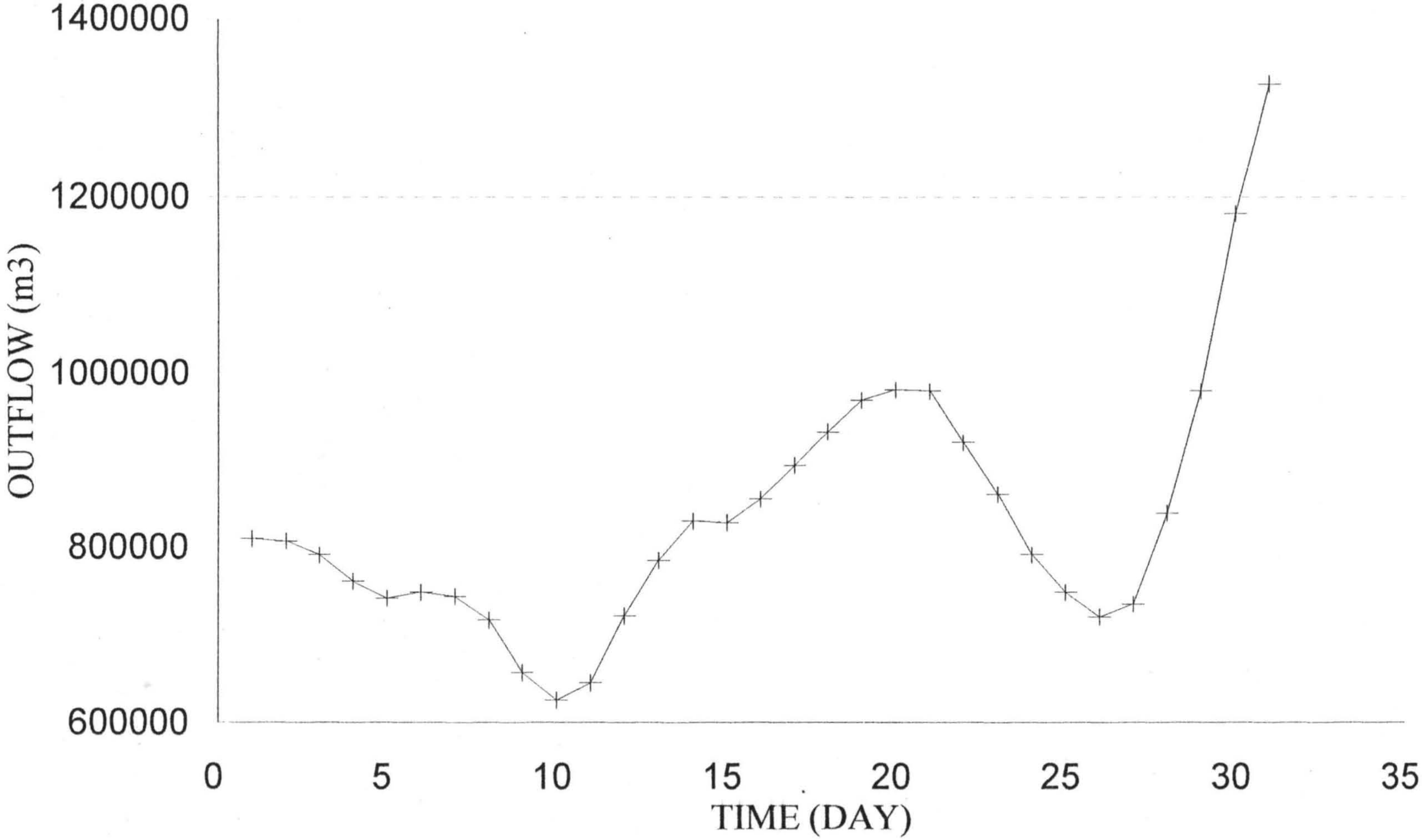


fig 4.15 HYDROGRAPH FOR REACH 13

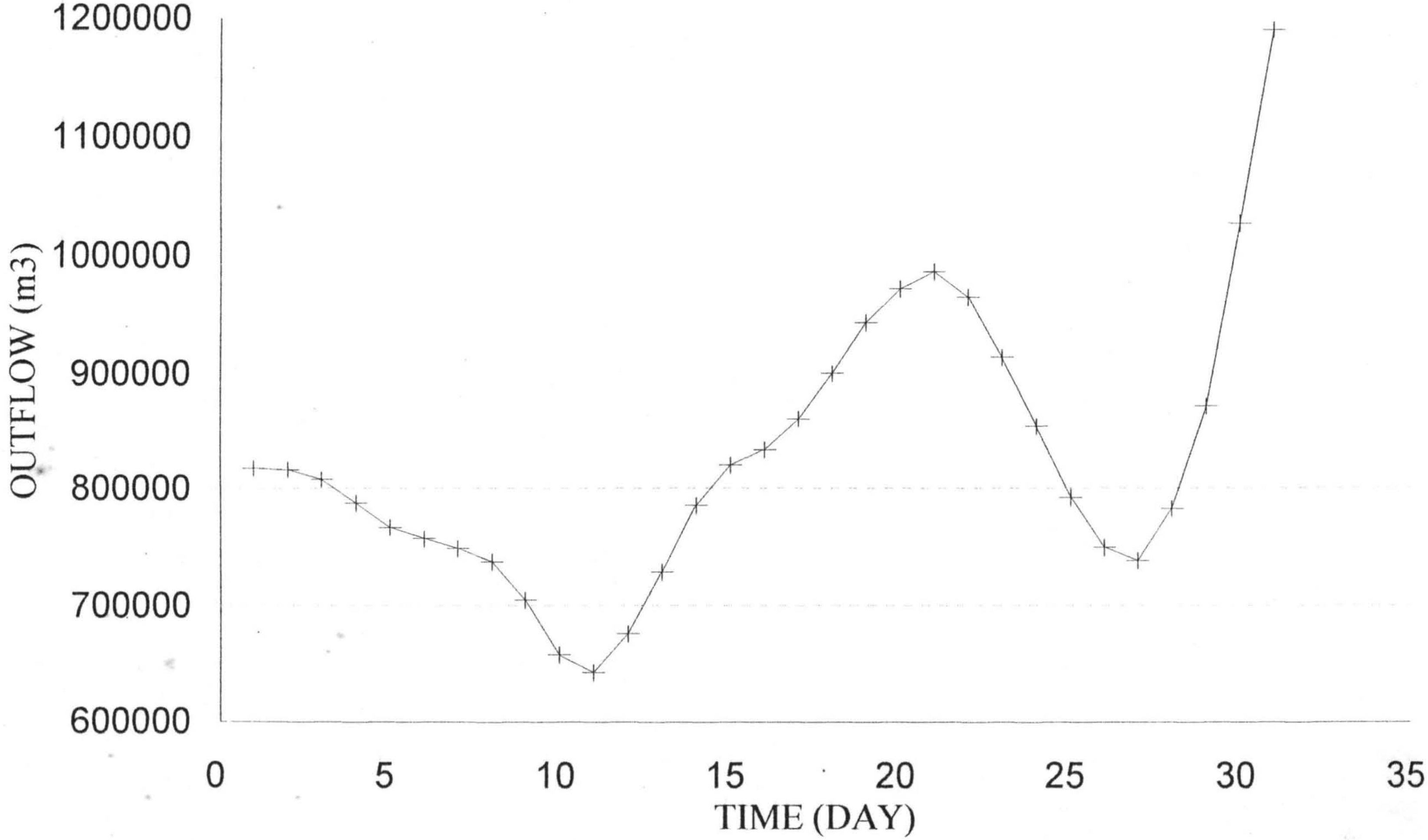


fig 4.16 HYDROGRAPH FOR REACH 14

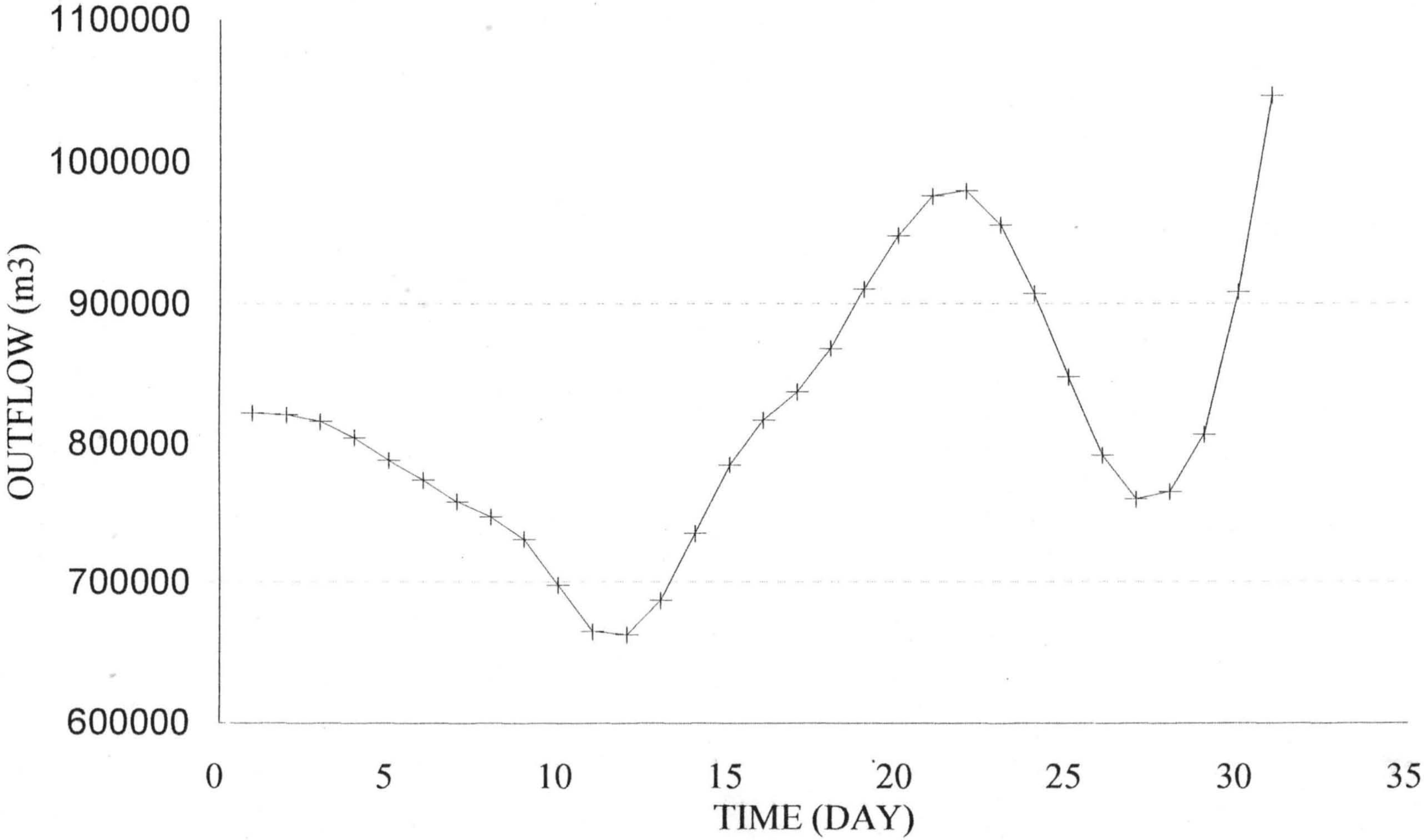


fig 4.17 HHYDROGRAPH FOR REACH 15