A STUDY OF RIVER MORPHOLOGICAL ANALYSIS OF BRAHMAPUTRA RIVER FROM DIBRUGARH TO MAJULI ISLAND

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled, **"A STUDY OF RIVER MORPHOLOGICAL ANALYSIS OF BRAHMAPUTRA RIVER FROM DIBRUGARH TO MAJULI ISLAND"**, in partial fulfilment of the requirements for the award of Degree of Master of Engineering WRD (Civil) submitted in the Water Resources Development Training Centre, University of Roorkee, Roorkee is an authentic record of my own work carried out since 16th July, 2000 till the date of submission under the supervision of Dr. Nayan Sharma, Associate Professor, WRDTC; Er. A.D. Pandey, Assistant Professor, Earthquake Engineering Department and Dr. S.K. Ghosh, Assistant Professor, Civil Engineering Department, University of Roorkee, Roorkee, India.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Dated: December 26th ,2000

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This is to certify that the above statement made by the candidate is correct to the best our knowledge.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOTATIONS

A	Cross-sectional area
B	Top width of river
x,y	Cartesion co-ordinates of cross-section
P_r	r^{th} order orthogonal polynomial
z_b	Bed level
$a_{r,n}$	Coefficients of cross-section
$A_{r,n}$	Coefficients of cross-section
ϕ	Function
{ }	A column vector
[ ]	A row vector, or rectangular or square matrix
$[\ ]^{-1}$	Inverse of square matrix
$[\ ]^T, \{\ \}^T$	Transpose of a matrix or a column vector
N	Shape function
ξ, η	Natural co-ordinate
l	Chainage along the river
t	Time in year
Q_T	Constant sediment load
d	Site of the material
Q	Water discharge
S	Longitudinal slope
P	Stream power
γ	unit weight of water

SYNOPSIS

The braided alluvial streams have a complex geometry posing difficulties in flow situation. This study has attempted to describe the braiding phenomenon, alluvial erosion and deposition of the Brahmaputra river. Plan Form Index reflects the fluvial land form deposition and its lower value indicates higher degree of braiding. Cross-section no. 44 processes 21 numbers of sub-channels for the year 1957 which is the highest among the all sections in the study reach, which has the minimum, plan Form Index.

Alluvial river bed profile does not follow any certain rule with respect to time and space. Modeling of river bed profile has always a challenge to the engineers and research workers in the field of river engineering. The river cross-section profiles are irregular in shape and size making it quite difficult to represent mathematically. The use of shape function has been tried in the model for interpolating cross-section profile and found better representation of the complex profiles.

INTRODUCTION

The Brahmaputra river with its tributaries is the largest river system of North Eastern region. Out of the total length of 2800 Km of the Brahmaputra from its source in China to its confluence with the Ganga in Bangladesh, 918 Km is in Indian territory.

The average annual rainfall figures in the Brahmaputra basin varies between 2130 mm in Kamrup district of Assam and 4140 mm in Arunachal Pradesh.

Brahmaputra has been responsible for enormous damages year after year causing human miseries and severe damage to land and property.

The Brahmaputra valley is a narrow elongated valley surrounded by hills on all sides except in the west. The valley is oriented in a East –West direction. More than 80% annual rainfall occur in a five month period of May to September.

Maximum water level recorded at Dibrugarh has been 107.95m on 29.7.1982 and minimum 100.13 m on 18.1.1973, while at Pandu the maximum has been 49.76 on 29.8.1988 and the minimum has been 40.19 m on 10.3.1978.

The highest floods recorded so far in the years 1987 and 1988. The flood of 1988 with the highest stages experienced so far corresponds approximately to a return period of 15 –20 years.

It has generally been observed in the Brahmaputra river that the maximum observed stages of different sites did not occur in the same year. Similarly, the maximum observed discharges of different sites were not in the same year. This variation indicates that,

a) The recorded floods at a particular site were caused by one or more flood producing tributaries above the particular site.

b) There was wide spread heavy rainfall in a year over a particular part of the catchment of the river without synchronization of peak runoff from other parts.

The floods in Brahmaputra are due to to two distinct hydrometeorological situations of Tibet and India and as such estimation of floods on a physical approach may be difficult. At each location, the better alternative will be statistical flood frequency approach.

The Brahmaputra, one of the largest rivers of the world, has been a problem river for long. Flowing through the Assam valley it has been causing great damage, year after year by eroding away valuable land besides spilling its bank on vast areas as well as creating drainage congestion.

Erosion along the course of the Brahmaputra on either side in the plains is a common phenomenon. It has braided channel at many reaches along its traverse through the plains of Assam. The constant shifting of the river course has been continuing through ages due to excessive sediment load, steep slope and high discharge. Again the causes of high sediment may be attributed to (i) fragile nature of Himalyas, (ii) high intensity of rainfall, (iii) major earthquake and (iv) frequent land slides.

The main causes of bank erosion in the Brahmaputra valley are attributable to (i) the instability of river, (ii) easily erodable nature of bank and (iii) concentration of the flow in the channel adjacement to the bank. Some of the bank tributaries also show the braiding pattern. Modelling of stream bed profile has always posed a challenge to the Engineers and the Research Workers in the field of River Engineering. Stream bed profiles modelling is helpful in the calibration of river models used subsequently for various purposes as

(a) Study of morphology

(b) Flood propagation

(c) Navigation etc.

A river profile model will help in supplementing the intermediate computation points. The will also be very much helpful to the planner in studying the river behaviour trend while planning for (i) road networks, (ii) bridge location and (iii) other river hydraulic structures such as high levee, barrages, sluices etc.

In most of the cases the stream bed profiles are irregular in shape and size making it quite difficult to represent them mathematically by means of simple functions. The complexity of the mathematical representation increases in the cases where the sections are moderately or heavily braided (alluvial river).

The present study attempts to provide means of computing of erosion, deposition, braiding indices, Thalweg changes, B/D ratio, average bed level, water ways, flow top-width. Cross-sectional profile of a river at any location within the reach in which past records of cross-sectional data are available and for any year within the period for which the measured data are available.

A lot of study is required to transform the Brahmaputra from the river of sorrow to river of prosperity.

REVIEW OF LITERATURE

2.1 GENERAL

The channel pattern of a reach of an alluvial river reflects the flow dynamics within the channel and the associated channel process of sediment transport and energy expenditures. Adjustments of equilibrium channel pattern may occur over a widely varying time scale. The study of river morphology attempts to describe and explain typical features of rivers. These features are formed by a three-dimensional time dependent water movement over a mobile bed and because of the complex phenomena involved, they can not usually be explained in detail; their treatment is mainly of descriptive nature.

2.2 REVIEW OF CHARACTERISTICS OF BRAIDED CHANNELS

Braided steams have the large and variable discharges, heavy sediment load, steeper gradients with erodible banks. Braided rivers characterized by wide and shallow cross- sectional widths. Braided channel pattern is optimal for the dissipation of excess energy in high energy streams.

Braided rivers are characterized by 'having a number of alluvial channels with bars and islands between meeting and dividing again'. Braided rivers may be invisaged as a series of channel segments, which divide and rejoin around bars in a regular or repeatable pattern. The term 'braiding' is generally taken to mean splitting of channel around bars (island). A different type of channel splitting has also been recognized and referred to as anastomosing (Lane,1957) or anabranching (Brice, 1964). Its definition is the union of one vessel with another or the rejoining of different branches which arising from a common trunk, from a networ. 'Successive division and rejoining with accompanying islands is the important characteristic denoted by the synonymous terms braided or anastomosing (anabranching) channel segments is that they are longer than a curved channel segment around a single braid or point bar and their flow pattern behave substantially of adjacent segments around bars. Nevertheless, many braided rivers appear to be both braided and anastomosing. Lepold and Wolman (1957) found that a bar of coarse sand diverts flow to cause erosion and positive feed back then accentnates bar development and widening.

Morphological studies focused on linking channel form and process. The hydraulic and sedimentary flow regime of the river was characterized using a dominant discharge analysis. This identified a dominant range of flows which were used as reference discharges and stages for the examination of the cross-sectional and plan form features of the channels.

Wolman & Gerson (1978) extended the arguments concerning the effectiveness of sediment transport in doing work on the channel to include the morphological changes caused by erosion and deposition. Hey(1975) demonstrated that in a degrading channel the flow doing most erosion (rather than sediment transport) would be dominant flow, while an aggrading channel would adjust to the flow doing most deposition. Hence in dominant discharge calculation it is appropriate to use the flow doing most sediment transport to define the dominant discharge.

Since the salient morphological features of the channel, the bars and the chars, are composed mostly of sand (Halcrow, 1991), it is the erosion, transport and deposition of sand which is fundamental to hydraulic shaping of the channel. The silt may then be viewed as 'Wash Load' passing through the channel without playing a significant role informing it dominant discharge is rather less than bankfull in the Brahmaputra.

In the case of the Brahmaputra, the data do not support the conclusion that great floods play the major role in transporting sediment over the medium to long term. The main morphological features are adjusted to the dominant range of flows.

The most prominent and important sedimentary features of the channel are the island chars and braid bars, which give it its characteristic, multi-channel cross-section, its braided planform, and its shifting nature.

There are always two and sometimes there distinct but closely related processes involved in surface erosion of the soil: i) tearing loss of soil material; ii) transport or removal of the eroded material by sheet flow; iii) deposition of the material in transport or sedimentation. If (iii) does not occur, the eroded material will be carried into a stream.

The spots most vulnerable to erosion are the steeper portion of the hill or valley slopes, neither at the crest nor at the bottom of the hill but intermediate. All soil possess a certain resistivity to erosion, and the resitivity may be increased greatly by a vegetation cover, especially a good grass sod. The underlying soil may have a much smaller resistivity to erosion, and if the surface conditions are changed by cultivation or otherwise so as to destroy the surface resistance, erosion will begin on land which has not hither to been subjected to it. Erosion by aquous agencies involves three processes:

(i) dislodgment of tearing loose of soil material and setting it in motion (this is called entrainment); (ii) transport of material by fluid motion; (iii) sedimentation or deposition of the transported material.

2.3 REVIEW OF LITERATURE ON RIVER BED PROFILE

A Summary of Some of the Literature Available in as follows:

i) CHEN [5]

Chen's work was primarily concerned with the mathematical modelling of water and sediment routing in natural channels. However the lateral section computations required that a polynomial be fitted to the cross-section of Lower Mississippi for computation of flow depth. A power series was adopted for the representation of the river bed profile.

In order to evaluate the best fit polynomial, the least square technique was adopted. The resulting polynomials were:

(1) $A = 0.00826657\, y^4 + 2.19563y^3 - 17.0103y^2 - 302.659y - 38.829$ to evaluate the cross-sectional area of representative cross-section.

(2) $B = 0.0192924y^4 + 1.04245y^3 - 10.7620y^2 + 69.8449y + 154.655$ to evaluate the top width of the representative cross-section.

2) JANSEN [12]

Jansen's morphological studies on non tidal rivers emphasize the need for improving the approximation of the river bed profile by the use of orthogonal polynomials rather than simple polynomials. In order to achieve this objective the legendre polynomials were used.

Each measured cross-section were matched with a liner series of orthogonal polynomials, Pr(y) through least square method. In this y is measured perpendicular to the river axis. Thus the bed leve Z_b (y) is expressed by:

$$Z_b(y) = a_0P_0(y) + a_1P_1(y) + a_2P_2(y) + \dots + a_rP_r(y) + \dots a_nP_n(y).$$

Legendre polynomials are suitable in this respect as they are defined on a restricted interval (-1 to +1 usually). If y values are normalized by means of the width B_s, their shapes are adequate to describe the river cross-sections. The parameters a_r for any cross-section n are linked with the curvature C in a cross-section P upstream of n. A linear relation was assumed:

$$a_{r,n} = A_{o,r} + \sum_{p=1}^{P_n} A_{p,r} C_{n-p+1}$$

where the co-efficient $a_{r,n}$ belong to a particular cross-section n, the co-efficient A apply to the whole river reach. Hence by determining the co-efficient A from the existing river geometry (Z_b and C), and by determining a with the help of these co-efficient, the value of Z_b can be obtained.

3) HARBHAJAN SINGH [13]

Subsequent to the earlier development in the direction of the riverbed profile modelling, Sri Harbhanjan Singh in his work examined the possibility of applying Fourier Approximation to the problem addressed. He examined the morphology of KOSI river bed.

The adopted section is heavily braided and therefore the approximation or the computed profile shows a poor agreement with the field measurement highlighting the fact that compromise has to be effected in numerical modeling with the order of acceptable error.

4) **TULUS PRIVADI [14]**

In his special problem titled "**Stream bed modeling using Legendre Polynomial**" he has tried to approximate the measured cross-sectional profile of the river Brahmaputra with the help of Legendre Polynomial. In his work he showed that approximately eleventh order Legendre polynomial gives satisfactory representation of the cross sectional profile.

4) **DAMBREAK MODEL[15]**

The DAM BREAK MODEL developed by U.S.Army Corps of Engineers which is comprehensive model for studying the effect of dam break in the down stream reach from the dam, still use linear interpolation for generating any intermediate cross section. The cross sectional interpolation procedure use by the model performs linear interpolation of elevation on width with distance between adjacent cross sections The manner of interpolation, while computationally simple may not give results close to the actual one due to the fact that the linear interpolation fails in providing smooth transition of section at measured location which is the case in the field.

6) G.P.SINGH [16]

In his M.E. Dissertation titled "**Spatio-Temporal Idealisation of Typical Cross Section of a Large Braided Alluvial River**", he has tried to approximate the measured cross-sectional profile of the river Brahmaputra with the help of shape functions.

METHODOLOGY

3.1 GENERAL

Deposition in the bed is accompanied by channel widening, while channel bed erosion is usually associated with a reduction in channel width. The amount of sediment deposition or removal along the banks directly affects the width change.

For a gradually varied flow, the total stream power or the rate of total energy expenditure of a stream reach is given by

$$P = \int_L \gamma Q \, S \, dx$$

The concept of minimum stream power criterion for a gradually varied flow, may be stated that the stream adjusts itself in such a way that its total stream power is minimised subject to certain physical constraints such as rigid banks, bed rock outcrops, sediment transport rate. In general braided streams are steeper, wider and shallower. An alluvial stream over a period of time attains an equilibrium condition, this is expressed as

$S = Q_T d/Q$ (Lanes balance analogy)

Where,

Q_T = constant sediment flow

d = size of the material

Q = water discharge

S = longitudinal slope

Q_T/Q can be considered as sediment concentration. In general, with increase in distance, this concentration decreases, also there is a decrease in sediment size d with distance as result of sorting and abrasion. Examination of stream profiles show that the slope is greatest near the source, decreasing more or less regularly as the river follows its course. Such reduction is slope corresponds to longitudinal profile which is concave upwards.

Braided pattern develops as a result of overloading of sediments. Consider a straight channel in which sediment load is increased for a given Q. As a result, slope and velocity will increase and depth will decrease. Increase in velocity will widen the channel which will further reduce the depth.

3.2 MORPHOLOGICAL STUDIES

From the available input data, the following parameters were evaluated for the concerned reach :

(i) Magnitude of Thalweg

(ii) Shifting of Thalweg

(iii) Change in cross-sectional area

(iv) Deposition / erosion

(v) Change in top width.

(vi) Average bed level

(vii) Width of water way

(viii) Longitudinal slope / Thalweg longitudinal slope.

(ix) Plan form Index

(x) B/D ratio.

COMPUTATION OF BRAID INDICATORS

The braiding indices proposed by Sharma (1995) provide a better logical and quantitative description of the braiding phenomenon and can be computed as below :

Plan Form Index (PFI)

$$\text{PFI} = \frac{\frac{T}{B} x100}{N}$$

Where,

T = flow top width

B = overall river width

N = Number of braided channels.

Plan Form Index represents the percentage of actual flow width over the overall river width per braid channel. Its lower value is indicative of higher degree of braiding.

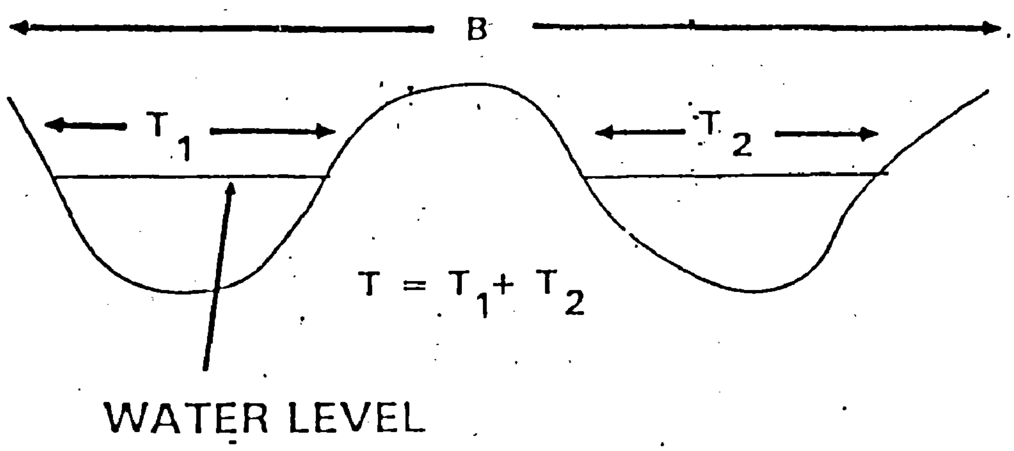

Fig. 3.1 : Schematic Diagram of Braided River for Computation of Plan Form Index

FLOW GEOMETRY INDEX (FGI)

Its higher value indicates higher degree of braiding

$$FGI = \frac{\sum d_i * X_i}{R * T} * N$$

Where d_i and X_i are depth and width of submerged sub-channel.

T = flow top width of stream = $\sum T_i$

R = hydraulic mean depth of the stream

N = Number of braided channels.

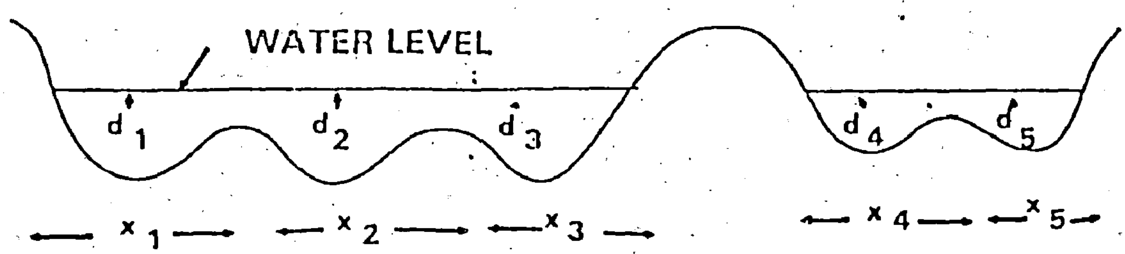

Fig. 3.2 : Schematic Diagram of Braided River for Flow Geometry Index

Cross Slope

Its higher value indicates higher braiding intensity

$$\text{Cross slope} = \frac{L/2}{\text{Average bank level} - \text{Average bed level}}$$

Where, L = the channel bank width.

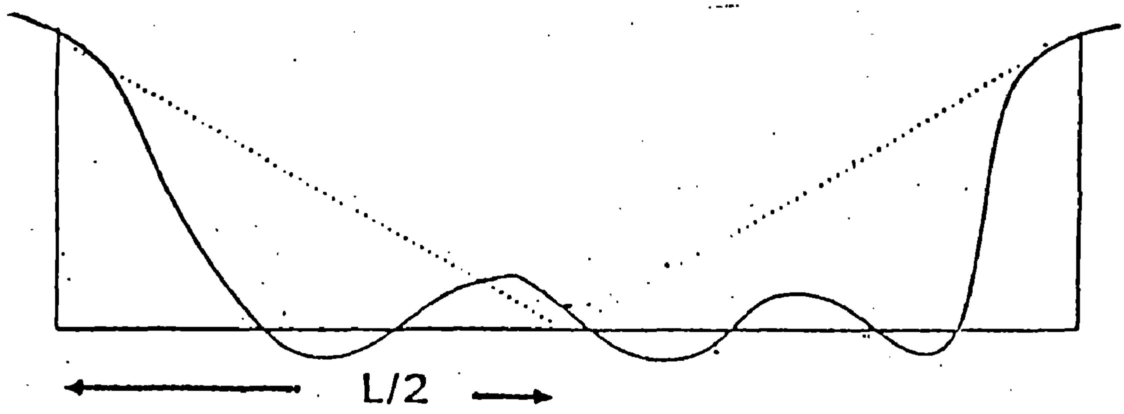

Fig. 3.3 : Schematic Diagram of Braided River for Cross Slope

B/D Ratio

Its higher value indicates higher degree of braiding

B = overall width

D = Average depth.

The following thresholds were identified by Sharma (1995) to provide a classification for Brahmaputra river.

Parameter	Range for Moderately Braided	Range for highly braided
B/D	$350 \leq B/D \leq 1000$	$B/D > 1000$
Plan Form Index	$4 \leq PFI \leq 19$	$PFI < 4$

COMPUTATION OF CROSS-SECTIONAL AREAS

The water level in the Brahmaputra river assumed at the lowest reduced level at the ends of the cross-sectional profile. The areas between the water level and the cross-sectional profile computed by the method of trapezoidal rule which has been shown in the shaded portion.

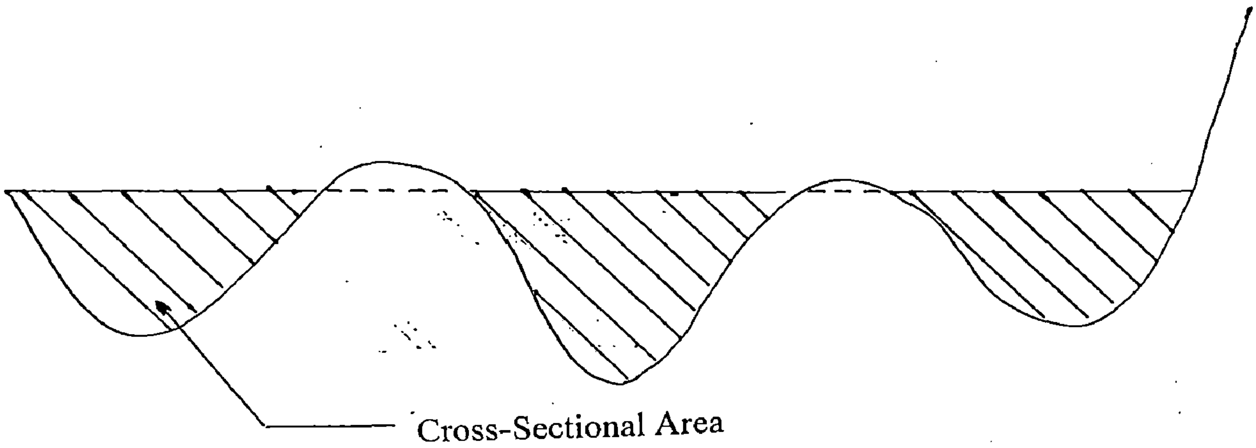

Fig. 3.4 : Schematic Diagram of Braided River for Cross-Sectional Area

THALWEG

The lowest reduced level of the cross-sectional profile gives the location of Thalweg and corresponding reduced level gives the reduced level of Thalweg.

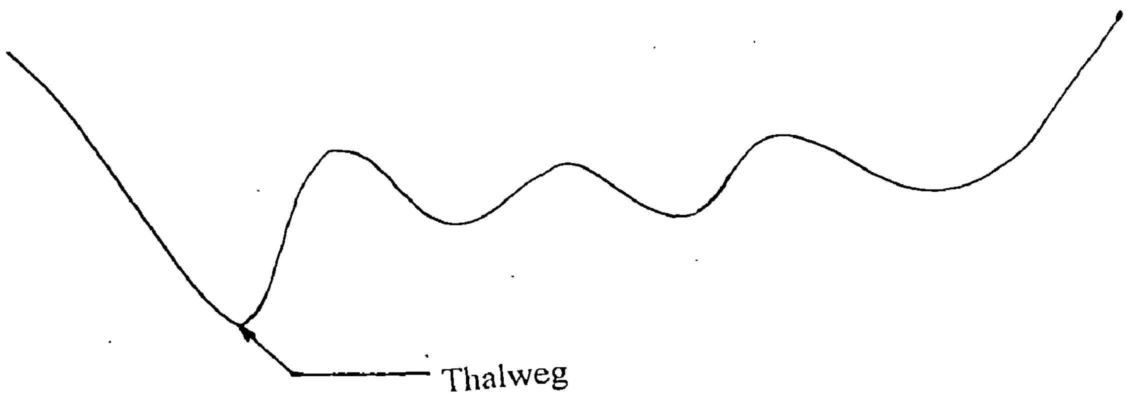

Fig. 3.5 : Schematic Diagram of Braided River for Thalweg

3.3 SHAPE FUNCTIONS IN RIVER BED PROFILE MODELLING

3.3.1 Isoparametric Approach

The term "isoparametric means, same parameter". Because either displacements or coordinates can be interpolated from nodal values.

The principle of the isoparameteric is to map a `parent' element in the ξ-η plane to the curvilinear element in x-y plane, the sides of which pass through the choosen nodes.

The popularity of isoparametric derives in part from the fact that, when one element has been thoroughly understood, it is not difficult to extend one's understanding to other isoparametric elements. Linear elements has straight sides but quadratic and higher order isoparametric elements may have either straight or curved sides which makes them very useful for modelling of curved structures.

Isoparametric co-ordinates are type of "intrinsic" or "natural" co-ordinate system.

ONE DIMENSIONAL ELEMENT

The simplest case is that of two noded element as shown in the fig. below

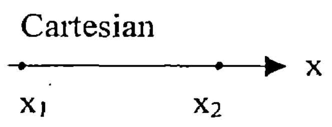

Fig. 3.6(a)

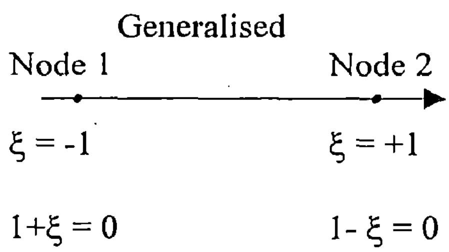

Fig. 3.6(b)

ξ = It is a natural or intrinsic coordinate. Ends of the line at $\xi = \pm 1$, regardless of the physical length L of the line.

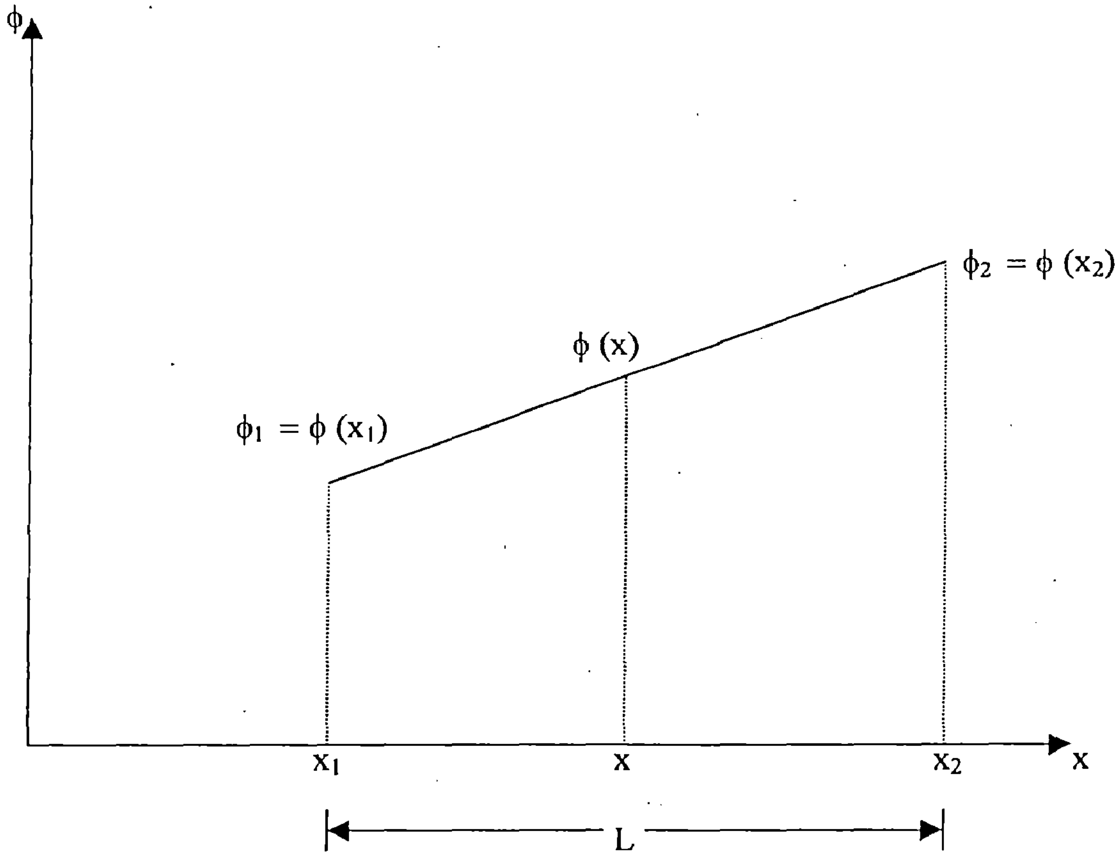

Figure 3.7

$$\phi(x) = \phi(x_1) + \frac{\phi(x_2) - \phi(x_1)}{x_2 - x_1}.x$$

$$= \phi(x_1) + \frac{\phi(x_2)}{L}x - \frac{\phi(x_2)}{L}x$$

$$= \left(1 - \frac{x}{L}\right)\phi(x_1) + \frac{x}{L}\phi(x_2)$$

$$= N_1\phi(x_1) + N_2\phi(x_2)$$

This satisfies the conditions: -

$$\Sigma\phi_i = 1$$

$$\phi_i\ (x_j) = 0$$

$$\phi_i(x_i) = 1$$

$$\therefore N_1(\xi) = \tfrac{1}{2}(1-\xi)$$

$$N_2(\xi) = \tfrac{1}{2}(1+\xi)$$

Where, N_1, N_2 are the shape functions. The function value ϕ^e is given by

$$\phi^e = \phi(\xi) = N_1(\xi)\,\phi_1 + N_2(\xi)\,\phi_2$$

Where ϕ_1 and ϕ_2 are functional values at nodes 1 and 2.

For three noded element as shown below:

Cartesian

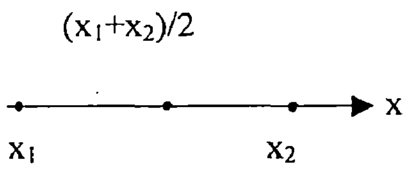

Fig. 3.8(a)

Generalised

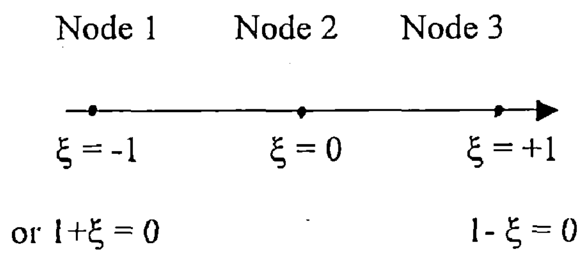

Fig. 3.8(b)

$$\phi(\xi) = N_1(\xi)\,\phi_1 + N_2(\xi)\,\phi_2 + N_3(\xi)\,\phi_3$$

ϕ_1, ϕ_2, ϕ_3 are functional values at nodes 1 and 2 and 3.

$$N_1(\xi) = \frac{\xi(1-\xi)}{-2}$$

$$N_2(\xi) = (1+\xi)(1-\xi)$$

$$N_3(\xi) = \frac{\xi(1+\xi)}{2}$$

For Four Noded Element as shown in the Fig below

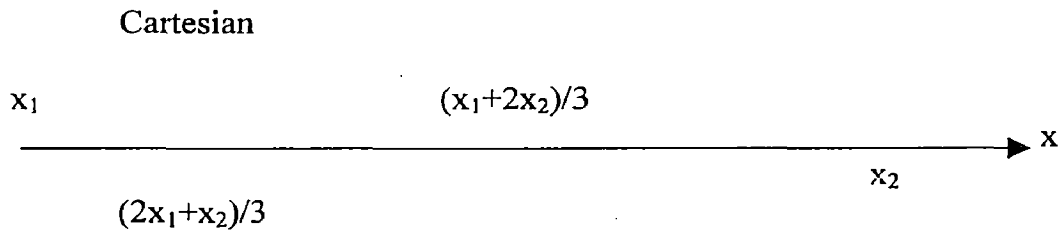

Fig. 3.9(a)

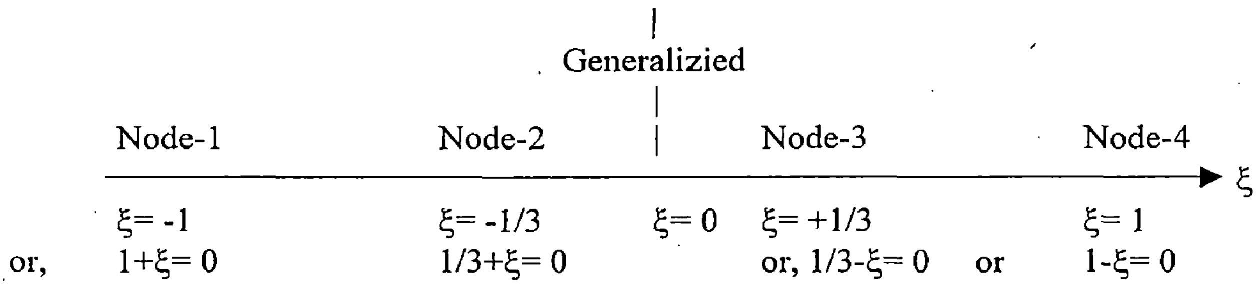

Fig. 3.9(b) :

The function $\phi^e = N_1(\xi)\,\phi_1 + N_2(\xi)\phi_2 + N_3(\xi)\phi_3 + N_4(\xi)\phi_4$

Where, ϕ_1, ϕ_2, ϕ_3 and ϕ_4 are function value at node 1, 2, 3, and 4.

$$N_1(\xi) = -\frac{9}{16}(1+\xi)(1/3-\xi)(1-\xi)$$

$$N_2(\xi) = \frac{27}{16}(1+\xi)(1/3-\xi)(1-\xi)$$

$$N_3(\xi) = \frac{27}{16}(1+\xi)(1/3+\xi)(1-\xi)$$

$$N_4(\xi) = \frac{(1+\xi(1+3\xi)(3\xi-1)}{16}$$

Two –Dimensional element or plane isoparametric element :

Consideran element of arbitrary shape as shown in Figure as below :

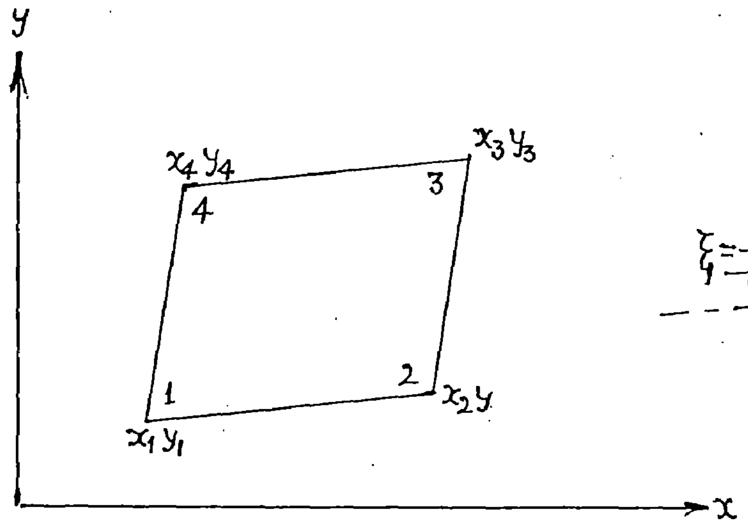

Fig. 3.10(a)

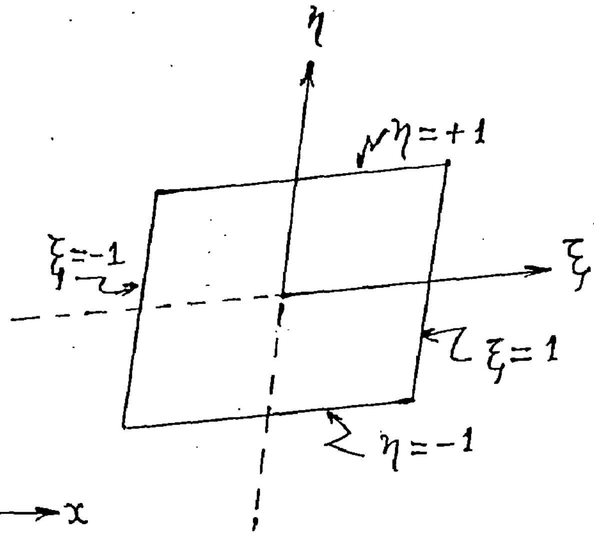

Fig. 3.10(b)

The element has a straight side but is otherwise of arbitrary shape and may be considered as a distortion of a parent rectangular element. Adopting mapping function as:

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} N_1 & 0 & N_2 & 0 & N_3 & 0 & N_4 & 0 \\ 0 & N_1 & 0 & N_2 & 0 & N_3 & 0 & N_4 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ x_2 \\ y_2 \\ . \\ . \\ x_4 \\ y_4 \end{bmatrix}$$

where,

$$N_1 (\xi, \eta) = \frac{(1+\xi)(1-\eta)}{4}$$

$$N_2(\xi,\eta) = \frac{(1+\xi)(1-\eta)}{4}$$

$$N_3(\xi,\eta) = \frac{(1+\xi)(1+\eta)}{4}$$

$$N_4(\xi,\eta) = \frac{(1-\xi)(1+\eta)}{4}$$

so that $N_i = 1$ for ξ_j, η_j $i = j$

$= 0$ for ξ_j, η_j $i \neq j$

3.3 MODIFIED SHAPE FUNCTION FOR UNEQUALLY SPACED SAMPLING POINTS

It is not necessary that to define a shape function the nodes should be equi-spaced. When the nodes are un-equally spaced then shape function gets slightly modified.

For example considering three unequally spaced nodes as shown in the fig. below.

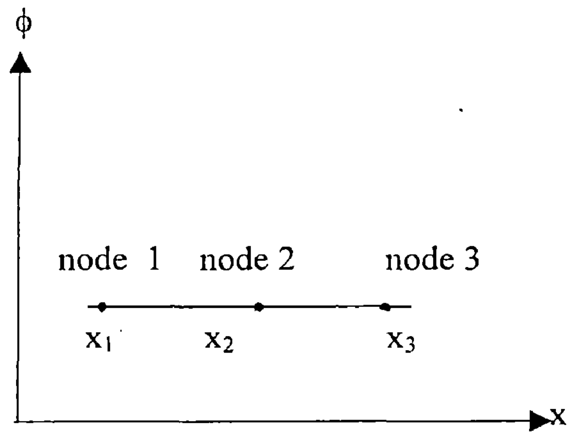

Fig. 3.11

If the functional value of function $\phi(x)$ at node 1 is ϕ_1, at node 2 is ϕ_2 and at node 3 is ϕ_3 then the functional value at any point x can be expressed as :

$$\phi(x) = N_1\,\phi_1 + N_2\,\phi_2 + N_3\,\phi_3$$

where N_1 N_2 and N_3 are the shape functions value at node 1, 2 and 3 corresponding to point x and are expressed as follows :

$$N_1(x) = \frac{(x - x_2)(x - x_3)}{(x_1 - x_2)(x_1 - x_3)}$$

$$N_2(x) = \frac{(x - x_1)(x - x_3)}{(x_2 - x_1)(x_2 - x_3)}$$

$$N_3(x) = \frac{(x - x_1)(x - x_2)}{(x_3 - x_1)(x_3 - x_2)}$$

Each of the N_i is polynomial of degree two. It is clear from above that

$N_i = 1$ for $x = x_i$

$= 0$ for $x = x_j$ where $i \neq j$

Taking n unequally spaced nodes :

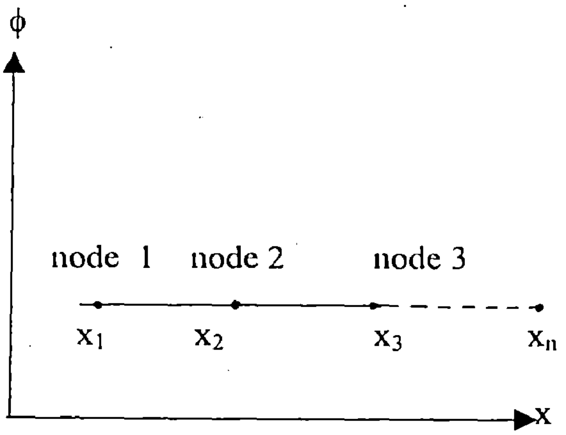

Fig. 3.12

Assuming that some function $\phi(x)$ has known values at points (ϕ_1, ϕ_2, ϕ_3 ..... ϕ_n). The points or nodes are not uniformly spaced. Then ϕ at any point x is given by :

$$\phi(x) = N_1 u_1 + N_2 u_2 + N_3 u_3 + \ldots\ldots\ldots\ldots + N_n u_n$$

where,

$$N_1(x) = \frac{(x - x_2)(x - x_3)\ldots\ldots\ldots(x - x_n)}{(x_1 - x_2)(x_1 - x_3)\ldots\ldots\ldots(x_1 - x_n)}$$

$$N_2(x) = \frac{(x - x_1)(x - x_3)\ldots\ldots\ldots(x - x_n)}{(x_2 - x_1)(x_2 - x_3)\ldots\ldots\ldots(x_2 - x_n)}$$

$$N_3(x) = \frac{(x - x_1)(x - x_2)\ldots\ldots\ldots(x - x_n)}{(x_3 - x_1)(x_3 - x_2)\ldots\ldots\ldots(x_3 - x_n)}$$

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$$N_n(x) = \frac{(x - x_1)(x - x_2)\ldots\ldots\ldots(x - x_{n-1})}{(x_n - x_1)(x_n - x_2)\ldots\ldots\ldots(x_n - x_{n-1})}$$

Each of the N_i is a polynomial of degree n – 1 and

$N_i = 1$ for $x = x_i$

$= 0$ for $x = x_j$ where $j \neq i$

3.5 USE OF SHAPE FUNCTION FOR SPATIAL AND TEMPORAL INTERPOLATION

3.5.1 Use of Shape Function for Spatial Interpolation

The river cross-sections are generally measured during a particular year is normalized to n nos. of data points i.e. (x_1, y_1), (x_2, y_2), ... (x_n, y_n), then for spatial interpolation of value of x_i and y_i for i = 1,2 .... n at any intermediate location can be determined by the use of shape functions.

The measured chainage can be expressed on one axis and x and y as function on another axis.

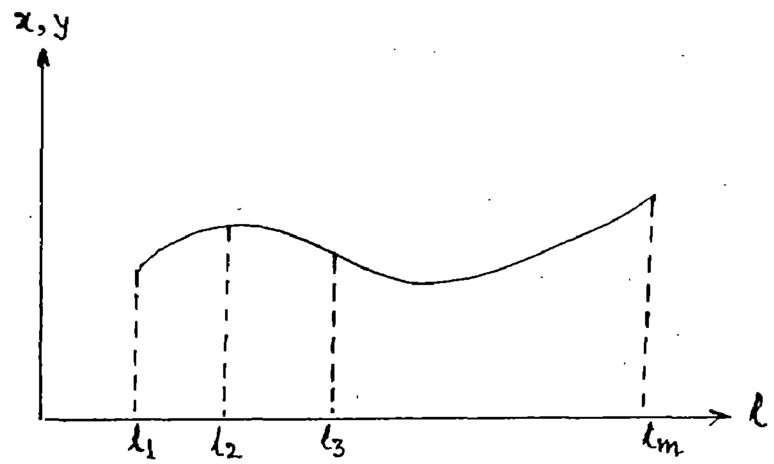

Fig. 3.13

The function x(l) and y(l) can be expressed in terms of shape function, as well as the known values of function x(l) and y(l) at l_1, l_2, l_3 ..... l_m as explained in para 3.2.

i.e. $x_1(l) = N_1x_{1,1} + N_2\, x_{1,2} + N_3x_{1,3} + \ldots\ldots\ldots + N_mx_{1,m}$

$y_1(l) = N_1y_{1,1} + N_2\, y_{1,2} + N_3y_{1,3} + \ldots\ldots\ldots + N_my_{1,m}$

$x_2(l) = N_1x_{2,1} + N_2\, x_{2,2} + N_3x_{2,3} + \ldots\ldots\ldots + N_mx_{2,m}$

$y_2(l) = N_1y_{2,1} + N_2\, y_{2,2} + N_3y_{2,3} + \ldots\ldots\ldots + N_my_{2,m}$

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$x_n(l) = N_1x_{n,1} + N_2\, x_{n,2} + N_3x_{n,3} + \ldots\ldots\ldots + N_mx_{n,m}$

$y_n(l) = N_1y_{n,1} + N_2\, y_{n,2} + N_3y_{n,3} + \ldots\ldots\ldots + N_my_{n,m}$

or,

$$x_i(l) = \sum_{j=1}^{m} N_j x_{i,j} \quad \& \quad y_i(l) = \sum_{j=1}^{m} N_j y_{i,j}$$

where; first subscript of x and y indicates the normalized coordinates point number and second subscript indicates the cross-section location number and $N_1, N_2 \ldots N_m$ are shape function given below :

$$N_1 = \frac{(l - l_2)(l - l_3)\ldots\ldots\ldots\ldots(l - l_m)}{(l_1 - l_2)(l_1 - l_3)\ldots\ldots\ldots\ldots(l_1 - l_m)}$$

$$N_2 = \frac{(l - l_1)(l - l_3)\ldots\ldots\ldots\ldots(l - l_m)}{(l_2 - l_1)(l_2 - l_3)\ldots\ldots\ldots(l_2 - l_m)}$$

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$$N_m = \frac{(l - l_1)(l - l_2)\ldots\ldots\ldots\ldots\ldots\ldots(l - l_{m-1})}{(l_m - l_1)(l_m - l_3)\ldots\ldots\ldots(l_m - l_{m-1})}$$

Thereby using the above shape functions, the value of (x_i, y_i) at given location can be interpolated knowing the value of corresponding (x_i, y_i) at given location can be interpolated knowing the value of corresponding (x_i, y_i) at known locations.

3.5.2 Use of Shape Function for Temporal Interpolation

The cross-section measured in different years at same location can be interpreted with use of time co-ordinate. The variation of x_i and y_i with respect to time at a particular location can be expressed as follows :

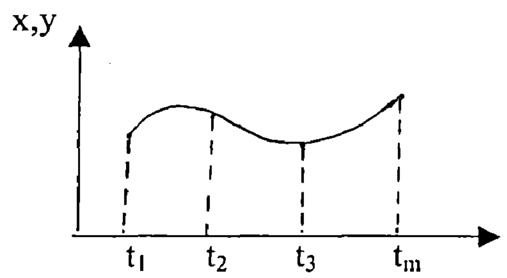

Fig. 3.14

Here t_1, t_2, t_3 ..... t_m are the years in which cross-sections have been measured in field.

If each cross-sectional data is noramlized into n number of data points i.e. (x_1,y_1), (x_2,y_2) ... (x_n, y_n) then for temporal interpolation of value of x_i and y_i in any year t ($t_1 \le t \le t_m$) can be determined by expressing time on one axis and x or y on the other as a function of time t.

The value of the function x(t) and y(t) can be interpolated at any time t (year) with the help of shape function as well as the known value of the section at time t_1, t_2, t_3.... t_m.

Interpolating expression will be as follows

$$x_1(t) = N_1x_{1,1} + N_2x_{1,2} + \ldots\ldots + N_m\, x_{1,m}$$

$$y_1(t) = N_1y_{1,1} + N_2y_{1,2} + \ldots\ldots + N_m\, y_{1,m}$$

$$x_2(t) = N_1x_{2,1} + N_2x_{2,2} + \ldots\ldots + N_m\, x_{2,m}$$

$$y_2(t) = N_1y_{2,1} + N_2y_{2,2} + \ldots\ldots + N_m\, y_{2,m}.$$

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$$x_n(t) = N_1x_{n,1} + N_2x_{n,2} + \ldots\ldots + N_m\, x_{n,m}$$

$$y_n(t) = N_1y_{n,1} + N_2y_{n,2} + \ldots\ldots + N_m\, y_{n,m}.$$

where, the first subscript is to indicate the ith point of the normalized data and second subscript is to indicate the time (year) in which cross-sections were measured.

N_1, N_2, N_3 .... N_m are expressed below.

$$N_1(t) = \frac{(t-t_2)(t-t_3)\ldots\ldots(t-t_m)}{(t_1-t_2)(t_1-t_3)\ldots\ldots(t_1-t_m)}$$

$$N_2(t) = \frac{(t - t_1)(t - t_3)............(t - t_m)}{(t_2 - t_1)(t_2 - t_3)........(t_2 - t_m)}$$

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$$N_m(t) = \frac{(t - t_1)(t - t_2)............(t - t_{m-1})}{(t_m - t_1)(t_m - t_2)........(t_m - t_{m-1})}$$

Therefore by using these shape function and knowing the value of x_i, y_i for known years, the values of x_i, and y_i for a given time t can be interpolated easily.

DEVELOPMENT OF SOFTWARE

4.1 DEVELOPMENT OF SOFTWARE

The software program NORMAL.FOR and PROFILE.FOR have been developed in FORTRAN programming language for the spatio-temporal simulation of cross section profile of river. The salient features of the program are discussed below :

NORMAL.FOR

NORMAL.FOR is the program which can be run on DOS and UNIX environments. This program reads the data from input file csm.dat and converts the data into desired number of equispaced data points. The output (results) from this program comes as nsm.dat. This program is used for computing the y co-ordinates corresponding to the normalized equispaced x co-ordinates. For finding value of y at any location other than the measured locations, it carries out Lagrangian interpolation.

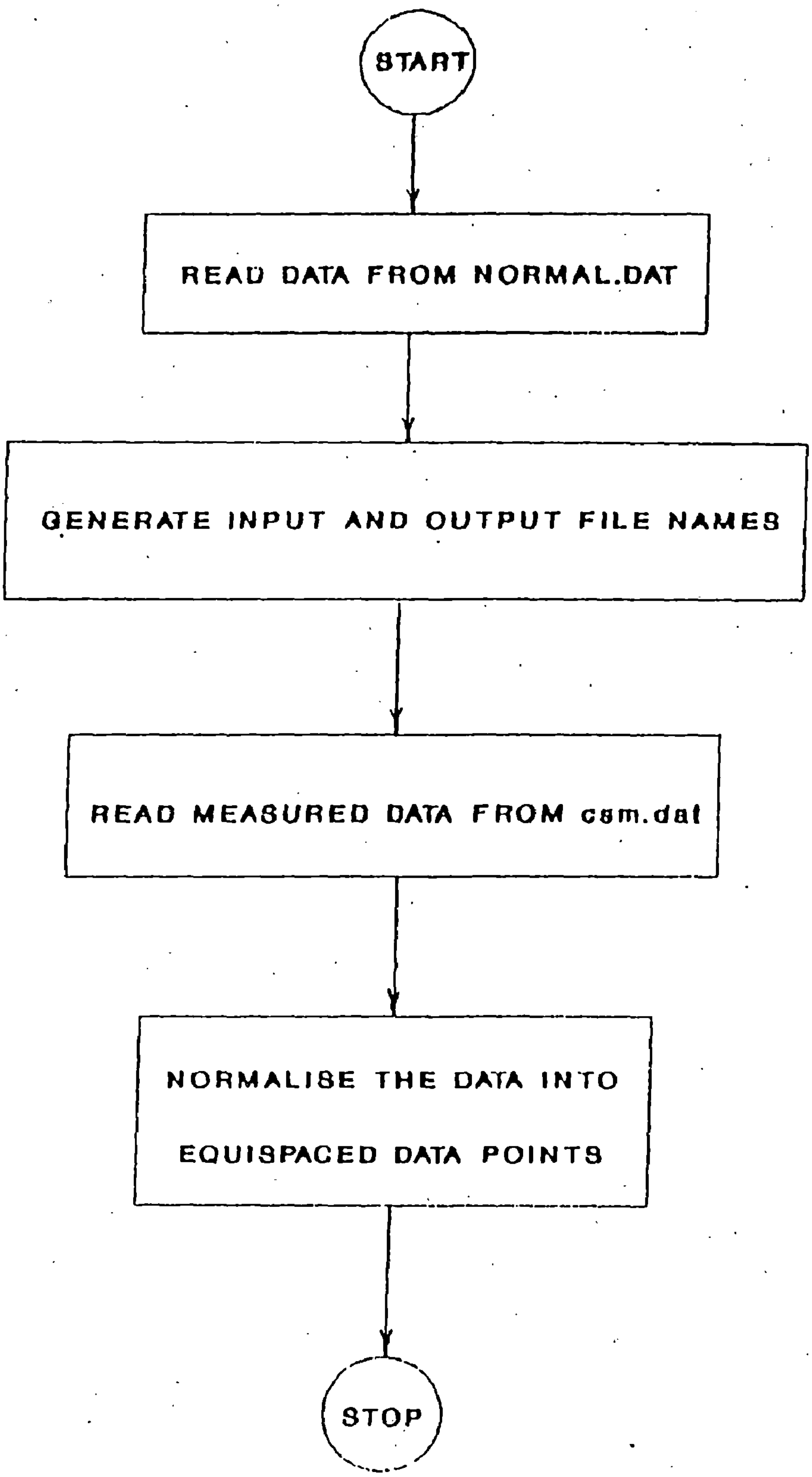
PROFIL.FOR

PROFILE.FOR is also developed in FORTRAN language and can be run on DOS and UNIX environments. This program uses normalized data of cross sections which are obtained as output from the program NORMAL.FOR for computing the intermediate cross section profile. The input data files are nsm.dat for this program and it gives output in file named cross.shape.

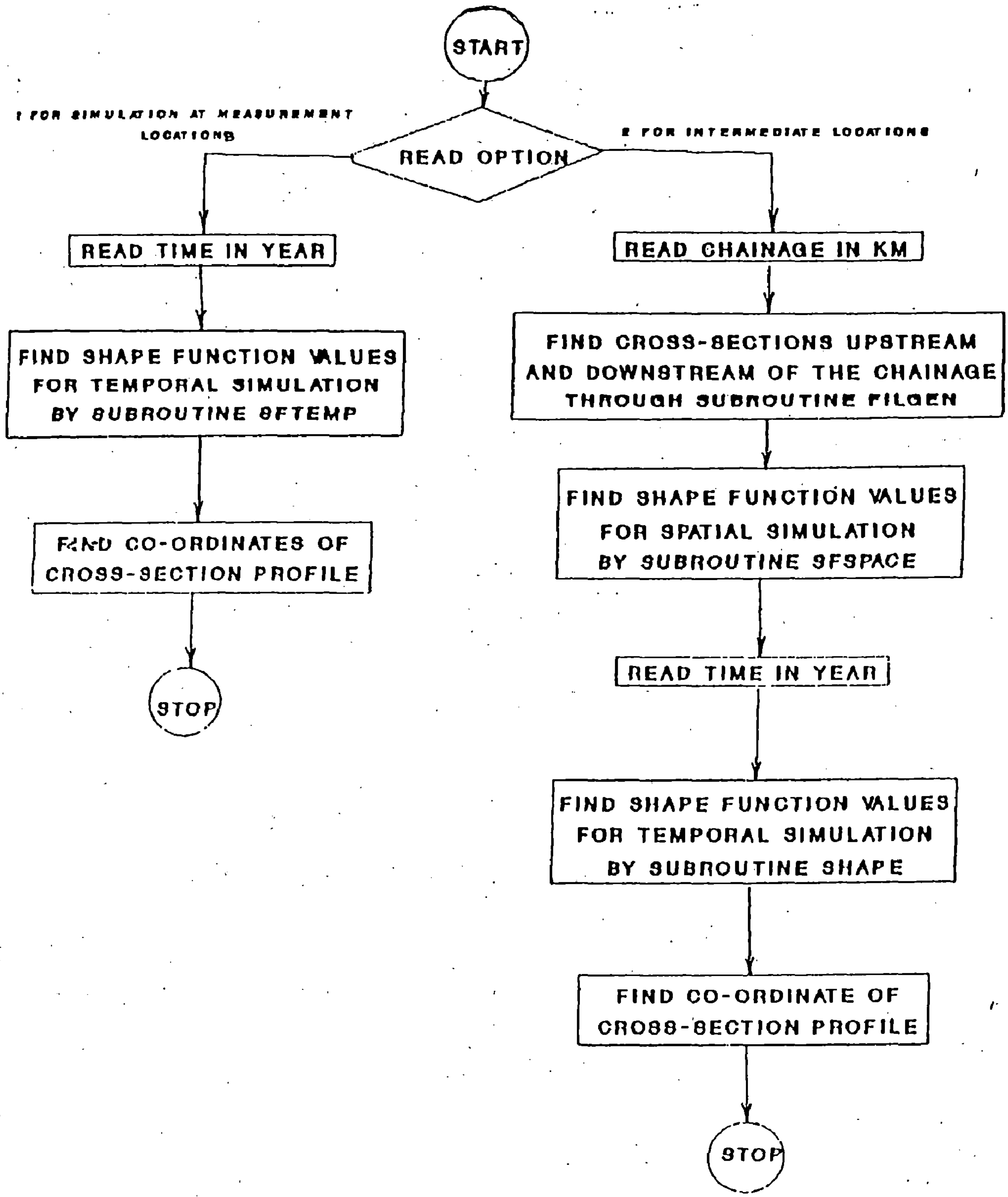
4.2 DATA AND RESULTS

The sample data is restricted so it has not been produced here. Result files are shown in Appendix – A.

FLOW CHART OF NORMAL.FOR



FLOW CHART OF PROFILE.FOR



SECTIONS ADOPTED FOR STUDIES

5.1 GENERAL

For the present studies and development of model the data of river Brahmaputra have been adopted. The Brahmaputra is one of the largest rivers in the world. It passes through Tibet, India and Bangladesh before its confluence with Bay of Bengal. The total watershed area is 5,80,000 sq.km of which 2,93,000 sq.km lies in Tibet (China), 2,40,000 sq.km in India and Bhutan and 47,000 sq.km in Bangladesh. Its total length is 2997 km out of which 1625 km is in Tibet, 918 km in India and 354 km in Bangladesh. Out of 918 km of its length in India, 640 km is in Assam.

The length of 640 km which lies in Assam begins at Dibrugarh and ends at Indo-Bangladesh Border. In this reach its width ranges from 3 km to 20 km. At most of the places it is highly braided. It will be highly expensive to measure the cross-section at close intervals. To avoid the foregoing difficulties, 64 typical locations were selected in the entire reach of 640 km based on the configuration and local peculiarity of the river. The distance between consecutive locations of cross-sections range from 5.5 km to 17 km. The detailed measurement of cross-section at these locations was done for the first time in 1957 followed by hydrographic surveys in 1971, 1977, 1981 and 1988. In an individual cross-section, the number of measurement points vary from 15 to 225. The zero chainage for all references to the sections lies in Bangladesh and all other chainage measurement have been done in the upstream direction from that point.

5.2 THE REACH OF THE RIVER UNDER STUDIES

The reach of the River for the model application lies between Dibrugarh to Majuli Island covering an distance of 216.76 km along the length of the river from cross-section no. 65 to 44. Mostly, the river flows in braided channels between alluvial banks. During floods, the river becomes one sheet of water form bank to bank.

5.3 DATA AVAILABLE FOR STUDY REACH

The data available in the form of chainage in m from the left bank of the Brahmaputra river and corresponding reduced level for the years 1957, 1971, 1977, 1981 and 1988. The distance between the cross-sections is also available. These data are restricted and obtained from Brahamaputra Board, Govt. of India for research purposes, therefore input data has not been produced here.

5.4 SECTIONS ADOPTED FOR DETAILED STUDIES

For the purpose of carrying out detailed studies of Majuli Island ranging from cross-sections 44 to 54 and cross-sections 57, 61 and 65 in the upstream of it for the years 1957, 1971, 1977, 1981 and 1988. Year 1957 was taken as base year.

DISCUSSION OF RESULTS

6.1 GENERAL

In order to carry out detailed analysis of river plan-form, the total length of the Brahmaputra from Dibrugarh to Majuli Island (216.76 km along river), has been considered. The Majuli Island is between the CS 44 and CS 54 which has been given the special attention for the analysis because it is under the constant attack of erosion and deposition by Brahmaputra river. Some lakhs of population are living on this island.

For the above defined reach, water level (Table 6.1), flow top-width (Table 6.2 and Fig. 6.1), average bed level (Table6.3 and Fig. 6.2); Thalweg (Table 6.4 and Fig. 6.3 and Fig. 6.4), water way (Table 6.5), cross-sectional area (Table 6.6), plan form index (Table 6.7 and Fig. 6.5), B/D Ratio (Table 6.8) and variation of PFI with B/D ratio have been studied for the years 1957, 1971, 1977, 1981 and 1988. Years 1957 taken as base year for comparison point of view.

In addition to the above study, shape function for the above reach has also been developed, through which we can predict the river bed profile within the reach for the years between 1957 and 1988.

6.2 MORPHOLOGICAL DISCUSSION

From Fig. 6.1, flow top-width of CS 44 increases by about 3 km in the year 1988 from the year 1981 (Table 6.2 and Fig. 6.1). At this point PFI is also very high with 21 nos. of channels which suggests greater braiding tendency. The abrupt variation of flow top width also observed for cross-section 45 between the years 1957 and 1971, for cross-section 53 between the years 1957 and 1971.

for cross-section 53 between the years 1957 and 1971.

Cross-section 54 also abruptly widened in the year 1977 from 1971

In the upstream of Majuli Island at cross-section 57, the flow top-width abruptly decreases from the year 1977 to 1981. At the cross-section 61 (near Dibrugarh), the flow top-width abruptly decreases from 1957 to 1971

From the Fig. 6.2, it is clear that average bed level is almost not varying.

From the Fig. 6.3 and Table 6.4, it is observed that there is lowering of Thalweg level from upstream to downstream as expected. It is also observed that Thalweg level is almost the same except at cross-section 54 for the year 1977 which is due to heavy erosion in 1977 which is also supported by the Table 6.3.

From the Fig. 6.4, it is found that at different cross-section, Thalweg location is continuously and slowly changing. It may be due to alternate effect of erosion and deposition, braiding character etc. At cross-section 61 there is abrupt thalweg shift for all years.

Form the Table 6.6. It is clear that cross-sections 53 and 54 are under erosion, cross-section 50 is under deposition and rest cross-sections are either under deposition or erosion with reference to the base year 1957.

From the Fig. 6.5, it is found that the PFI values are very large for the cross-section 45 in the years 1971, 1981; cross-section 46 in the year 1971; for cross-sections 52,53; for the year 1971 and hence these cross-sections do not posses braiding tendency in those years.

The plot also indicates that CS 44 for the year 1988; CS 45 for the year 1988; CS 47 for the years 1971, 1988; CS 48 for the year 1988; CS 49 for the year 1988; CS 53 for the year 1957 and CS 54 for 1957 are highly braided.

The graphical plot of plan Form Index with B/D ratio vide Fig. 6.6, which is exponential in nature for the Brahmaputra. With increasing width to depth ratio, plan Form Index displays a decreasing trend there by registering an increasing level of braiding.

The plot was prepared as show in the Fig. 6.6 and best fit line was drawn for obtaining the functional relationship as given below.

$$PFI = 5408.2\ (B/D)^{-0.6315}$$

Correlation coefficient = $\sqrt{0.4863} = 0.697$

Here, correlation coefficient is greater than 0.6, hence it indicates good relation.

PFI = plan Form Index

B/D = overall width / Av. Depth

Where,

It is an established fact that relatively steeper gradients are indicated in braided reaches and their magnitude registers increase with rise in intensity of braiding.

6.2 RESULTS OF SPATIO-TEMPORAL IDEALIZATION USING SHAPE FUNCTION

Spatio-temporal idealization is done to simulate a profile at any intermediate location and for any intermediate year between the years of survey. A few prifole have been simulated through this and have been plotted in Fig. 6.7 and 6.8 for the cross-section No. 50 for the years 1960, 1963, 1966, 1968, 1970, 1971 and we can see how the deposition is taking place at cross section 50 in the year 1971 with respect to year 1957. This result is also supported by Table 6.6.

The simulated profile shows a smooth transition between two section and it tries to capture all the local peculiarity and undulation of the natural profile. The simulated profile appears to be very close to the natural profile.

The model being data based and is developed utilizing shape functions, it has got a big advantage of reproducing exactly the same profile as measured one when the input data, the chainage and the year are specified same as that of measured location and year.

TABLE 6.1

WATER LEVEL

Cross sections	Water level (metre)				
	1957	1971	1977	1981	1988
44	76.26	74.355	73.455	77.06	76.68
45	77.357	81.485	81.025	81.1	78.62
46	80.223	85.3	82.65	82.4	82.2
47	83.698	79.8	83.05	84.61	81.15
48	85.65	82.6	82.6	82.6	83.25
49	83.79	86.35	83.65	86.25	83.21
50	86.11	87.31	84.15	84.6	84.25
51	87.11	90.57	87.23	88.34	56.79
52	90.62	90.315	90.31	90.31	88.71
53	84.94	93.75	94.18	88.8	90.4
54	90.625	92.31	94.6	96.6	94.1
57	99.66	98.06	96.55	97.2	101.4
61	107.8	107.86	109.8	110.2	109.8
65	118.95	122.14	122	122.37	114.65

TABLE 6.2

FLOW TOP-WIDTH

Cross – sections	Top Width (metre)				
	1957	1971	1977	1981	1988
44	10790	10140	10720	10300	13200
45	8704	6760	10000	9450	9688.5
46	12620.5	12400	12340	12270	12400
47	13205.6	13200	13300	13300	13425
48	7634	7600	8320	8260	10045
49	7659.6	7600	7655	7660	7760
50	6657	6640	6670	6670	6773
51	10628	10096	10980	10910	11270
52	9611	9690	12440	13010	12380
53	15244	11875	13800	15280	15470
54	9270	9520	11740	11610	11713
57	8820	10331.2	12850	10900	9500
61	11719	14926	14970	14480	13900
65	7949	8080	8084	8200	7200

TABLE 6.3

AVERAGE BED LEVEL

Cross – sections	Average Bed Level (metre)				
	1957	1971	1977	1981	1988
44	73.7	72.5	73.5	74.6	76.9
45	75.6	78.7	79.2	78.9	78.6
46	78.6	80.7	79.9	79.9	77.6
47	80.6	80.8	80.6	81.1	81.4
48	83.1	80.3	80.6	81.3	82.6
49	82.2	83.2	82.3	83.2	83.5
50	82.4	83.5	83.7	83.3	81.8
51	85.3	88.2	85.8	85.5	85.9
52	87.1	86.2	87.6	87.0	87.4
53	87.7	88.4	88.5	88.4	91.6
54	90.5	90.6	90.4	89.5	92.5
57	97	98.1	96.6	97.7	100
61	107.4	108.6	109.6	108.7	109
65	117.6	120.4	121	120.7	114.24

Table 6.4

THALWEG

BASE YEAR 1957

		THALWEG CHAINAGE (metre)/ RL (metre)					Change in Thalweg (metre) (-)ve: increase, (+)ve: decrease				Shifting of Thalweg (metre) (-)ve towards Right, (+)ve towards Left			
	Year	1957	1971	1977	1981	1988	1971	1977	1981	1988	1971	1977	1981	1988
CROSS-SECTIONS	44	6590/ 62.58	9500/ 60.75	5380/ 61.675	3700/ 62.35	2800/ 66.91	1.83	0.905	0.23	-4.33	-2910	1210	2890	3790
	45	7118/ 69.95	2560/ 7244	9415/ 68.795	8850/ 70.35	9288.5/72. 35	-2.49	1.155	-0.4	-2.4	4558	-2297	-1732	-2170.5
	46	8824.87/73. 15	8600/ 74.0	7400/ 73.0	8200/7 2.05	3900/ 69.51	-0.85	0.15	1.1	3.64	224.87	1424.87	624.87	4924.87
	47	9553.2/ 73	6740/ 74.8	13280/73.3	5800/7 3.5	8000/ 70.8	-1.8	-0.3	-0.5	2.2	2813.2	-3726.9	3753.2	1553.2
	48	914/ 73.64	7150/ 70.4	1600/ 70.6	4000/7 2.3	4000/ 70.05	3.24	3.04	1.34	3.59	-62.36	-686	-3086	-3086
	49	2702/ 73.52	4500/ 79.6	1800/ 74.2	1900/7 4.5	1200/ 73.37	-6.08	-0.68	-0.98	0.15	-1798	-902	-802	1502
	50	2834/ 74.95	4300/ 77.71	4740/ 75.09	5200/7 4.08	3700, 4900/ 73.55	-2.76	-0.14	0.87	1.4	-1466	-1906	-2366	-866/-2066
	51	8345/ 75.26	6740/ 78.56	9600/ 80.6	1100/7 6.5	4200, 4400/ 81.3	-3.3	-5.34	-1.24	-6.04	1605	-1255	7245	4145/ 3945
	52	4026/ 77.87	1036/ 79.25	12000/79.4	6100/7 9.18	5000/ 83.05	-1.38	-1.53	-1.31	-5.18	2990	-7974	-2074	-974
	53	2134/ 79.13	8080/ 79.3	10900,1190 0/81.2	8500/8 2.1	34/ 83.34	-0.17	-2.07	-2.97	-4.21	-5946	-8766/- 9766	-6366	2100
	54	2432/ 83.02	7200/ 87.47	1100/ 59.02	500/ 80.25	2250/ 86.76	-4.45	14	2.77	-3.74	-4768	1332	1932	182
	57	487/89.04	7237.2/94. 35	6000/89.3	3240/9 2.47	5200/95	-5.31	-0.26	-3.43	-5.96	-6750.2	-5513	-2753	-4713
	61	1054/102.5	13080/ 101.59	7554/ 102.39	2881/ 99.645	800/101.1	0.91	0.11	2.855	1.4	-12026	-6500	-1827	254
	65	3301/ 112.91	4165/ 114.873	6980/ 114.185	3840/ 116.1	1100/ 108	-1.963	-1.275	-3.19	4.91	-864	-3679	-539	2201

Table 6.5

WATERWAY BASE YEAR 1957

Cross-sections	LENGTH OF WATER WAY (METRE)					Change in length of water way (metre) (-)ve: increase, (+)ve: decrease			
Year	1957	1971	1977	1981	1988	1971	1977	1981	1988
44	6852	4355	3198	7858	4285	2497	3654	-1006	2567
45	7661	6314	7733	9138	5526	1347	-72	-1477	2135
46	10619	12189	10335	9902	12374	-1570	284	717	-1735
47	12830	1225	12660	13147	6064	11605	170	-317	6766
48	7050	7215	7630	7135	5660	-165	-580	-85	1390
49	4369	7386	3843	7499	2389	-3017	526	-3130	1980
50	6113	6640	2411	2750	5172	-527	3702	3363	941
51	9383	10091	9319	10502	8614	-708	64	-1119	769
52	9533	9643	11774	12719	10127	-110	-2241	-3186	-594
53	1162	11875	13800	8925	3680	-10713	-12638	-7763	-2518
54	2824	7936	11687	11584	10688	-5212	-8963	-8860	-7964
57	8321	3865	4256	2456	8369	4456	4065	5865	-48
61	5711	3263	5754	9254	7906	2448	-43	3543	-2195
65	6463	4396	4059	7137	1171	2067	2404	-674	5292

TABLE –6.6

CROSS-SECTIONAL AREAS

BASE YEAR 1957

	Cross-sectional areas (in metre^2)					Change in cross-sectional areas (sq.m) (-)ve Erosion, (+)ve Deposition			
CROSS-SECTION Year	1957	1971	1977	1981	1988	1971	1977	1981	1988
44	22053	16216	9273	28510	17131	5837	12780	-6457	4922
45	25331	2615	26157	23585	8437	22716	-826	1746	16894
46	22070	42686	86101	16469	29666	-20616	-64031	5601	-7596
47	39141	2545	17937	63610	13641	36596	21204	-24469	25500
48	17600	11544	20643	11653	9847	6056	-3043	5947	7753
49	17132	23405	14296	19046	6969	-6273	10099	6903	-3115
50	28548	23406	7033	10229	20247	5142	21515	18319	8301
51	16007	41429	18303	32618	13975	-25422	-2296	-16611	2032
52	30911	37025	38591	47525	21981	-6114	-7680	-16614	8930
53	1309	66157	80243	18058	4469	-64848	-78934	-16749	-3160
54	9709	16845	47594	84222	23701	-7136	-37885	-74513	-13992
57	19042	4713	8699	3525	13938	14329	10343	15517	5104
61	8394	7088	10738	25666	12041	1306	-2344	-17272	-3647
65	8915	12149	9132	13679	10838	-3234	-217	-4764	-1923

Table 6.7 : Plan Form Index

C/S Nos.	YEAR	B(metre)	T(metre)	N	PFI=(T/B)*1/N*100
44	1957	10790	6852	9	7.055915972
	1971	10140	4355	5	8.58974359
	1977	10720	3198	5	5.96641791
	1981	10300	7858	6	12.71521036
	1988	10200	4285	21	2.000466853
45	1957	8704	7661	5	17.60340074
	1971	6760	6314	1	93.40236686
	1977	10000	7733	3	25.77666667
	1981	9450	9138	1	96.6984127
	1988	9689	5526	11	5.184886328
46	1957	12621	10619	5	16.82750971
	1971	12400	12189	1	98.2983871
	1977	12340	10335	3	27.91734198
	1981	12270	9902	6	13.45014942
	1988	12400	12374	2	49.89516129
47	1957	13205	12830	2	48.5800833
	1971	13200	1225	2	4.640151515
	1977	13300	12660	5	19.03759398
	1981	13300	13147	3	32.94987469
	1988	13425	6064	7	6.452779995
48	1957	7634	7050	5	18.47000262
	1971	7600	7215	2	47.46710526
	1977	8320	7630	2	45.85336538
	1981	8260	7135	6	14.39669088
	1988	10045	5660	14	4.024745787
49	1957	7660	4369	4	14.25913838
	1971	7600	7386	3	32.39473684
	1977	7655	3843	6	8.36708034
	1981	7660	7499	2	48.94908616
	1988	7760	2389	7	4.398011782
50	1957	6657	6113	4	22.9570377
	1971	6640	6640	1	100
	1977	6670	2411	5	7.229385307
	1981	6670	2750	5	8.245877061
	1988	6773	5172	8	9.545253211
51	1957	10628	9383	5	17.6571321
	1971	10096	10091	1	99.95047544
	1977	10980	9319	4	21.21812386
	1981	10910	10502	2	48.13015582
	1988	13975	8614	5	12.32772809
52	1957	9611	9533	3	33.06280997
	1971	9690	9643	1	99.51496388
	1977	12440	11774	2	47.32315113
	1981	13010	12719	1	97.76325903
	1988	12380	10127	4	20.4503231

Contd/-- Table 6.7

Table 6.7 (Contd/-)

C/S Nos.	YEAR	B(metre)	T(metre)	N	PFI=(T/B)*1/N*100
53	1957	15244	1162	4	1.905667804
	1971	11875	11875	1	100
	1977	13800	13800	1	100
	1981	15280	8925	4	14.60242147
	1988	15470	3680	8	2.973497091
54	1957	9270	2824	5	6.092772384
	1971	9520	7936	4	20.84033613
	1977	11740	11687	2	49.77427598
	1981	11610	11584	1	99.77605512
	1988	11713	10688	3	30.41634651
57	1957	8820	8321	3	31.44746788
	1971	10331.2	3865	6	6.235158226
	1977	12850	4256	5	6.624124514
	1981	10900	2456	6	3.755351682
	1988	9500	8369	5	17.61894737
61	1957	11719	5711	9	5.414758559
	1971	14926	3263	6	3.643530305
	1977	14970	5754	9	4.27076375
	1981	14480	9254	6	10.6514733
	1988	13900	7906	11	5.170699804
65	1957	7949	6463	4	20.32645616
	1971	8080	4396	8	6.800742574
	1977	8084	4059	3	16.73676398
	1981	8200	7137	4	21.75914634
	1988	7200	1171	3	5.421296296

TABLE 6.8: CALCULATION OF B/D RATIO

CS	Chainage (k.m)	1957			1971			1977		
		B	D	B/D	B	D	B/D	B	D	B/D
44	423.31	10790	2.56	4214.8	10140	1.855	54663.3	10720	0	Infinity
45	439.63	8704	2.057	423.4	6760	2.785	2427.29	10000	1.825	5479.45
46	453.91	12620.5	1.623	7776.03	12400	4.6	2695.65	12340	2.75	4487.27
47	465.13	13205.16	3.098	4262.47	13200	0	Infinity	13300	2.45	5428.47
48	474.82	7634	2.55	2993.72	7600	2.3	3304.34	8320	2	4160
49	483.49	7659.6	1.59	4817.35	7600	3.15	2412.7	7655	1.35	5670.37
50	490.63	6657	3.71	1794.34	6640	3.81	1742.78	6670	0.45	14822.2
51	498.8	10628	1.81	5871.82	10096	4.37	2310.29	10980	1.43	7678.32
52	505.94	9611	3.52	2730.4	9690	4.115	2354.8	12440	2.71	4590.4
53	513.08	15244	0	Infinity	11875	5.35	2219.62	13800	5.68	2429.58
54	522.77	9270	0.125	74160	9520	1.71	5567.25	11740	4.2	2795.24
57	558.98	8820	2.66	3315.8	10321.2	0	Infinity	12850	0	Infinity
61	601.82	11719	0.4	29297.5	14926	0	Infinity	14970	0.2	74850
65	640.07	7949	1.35	5888.14	8080	1.74	4643.68	8084	1	8084

CS	Chainage (k.m)	1981			1988		
		B	D	B/D	B	D	B/D
44	423.31	10300	2.46	4186.99	13200	0	Infinity
45	439.63	9450	2.2	4295.45	9688.5	0.02	484425
46	453.91	12270	2.5	4908	12400	4.6	2695.65
47	465.13	13300	3.51	3789.17	13425	0	Infinity
48	474.82	8260	1.3	6353.85	10045	0.65	15453.8
49	483.49	7660	3.05	2511.48	7760	0	Infinity
50	490.63	6670	1.3	5130.77	6773	2.45	2764.5
51	498.8	10910	2.84	3841.55	11270	0.89	12662.9
52	505.94	13010	3.31	3930.51	12380	1.31	9450.4
53	513.08	15280	0.4	38200	15470	0	Infinity
54	522.77	11610	7.1	1635.21	11713	1.6	7320.6
57	558.98	10900	0	Infinity	9500	1.2	7916.7
61	601.82	14480	1.5	9653.3	13900	0.8	17375
65	640.07	8200	1.47	5578.23	7200	0.1	72000

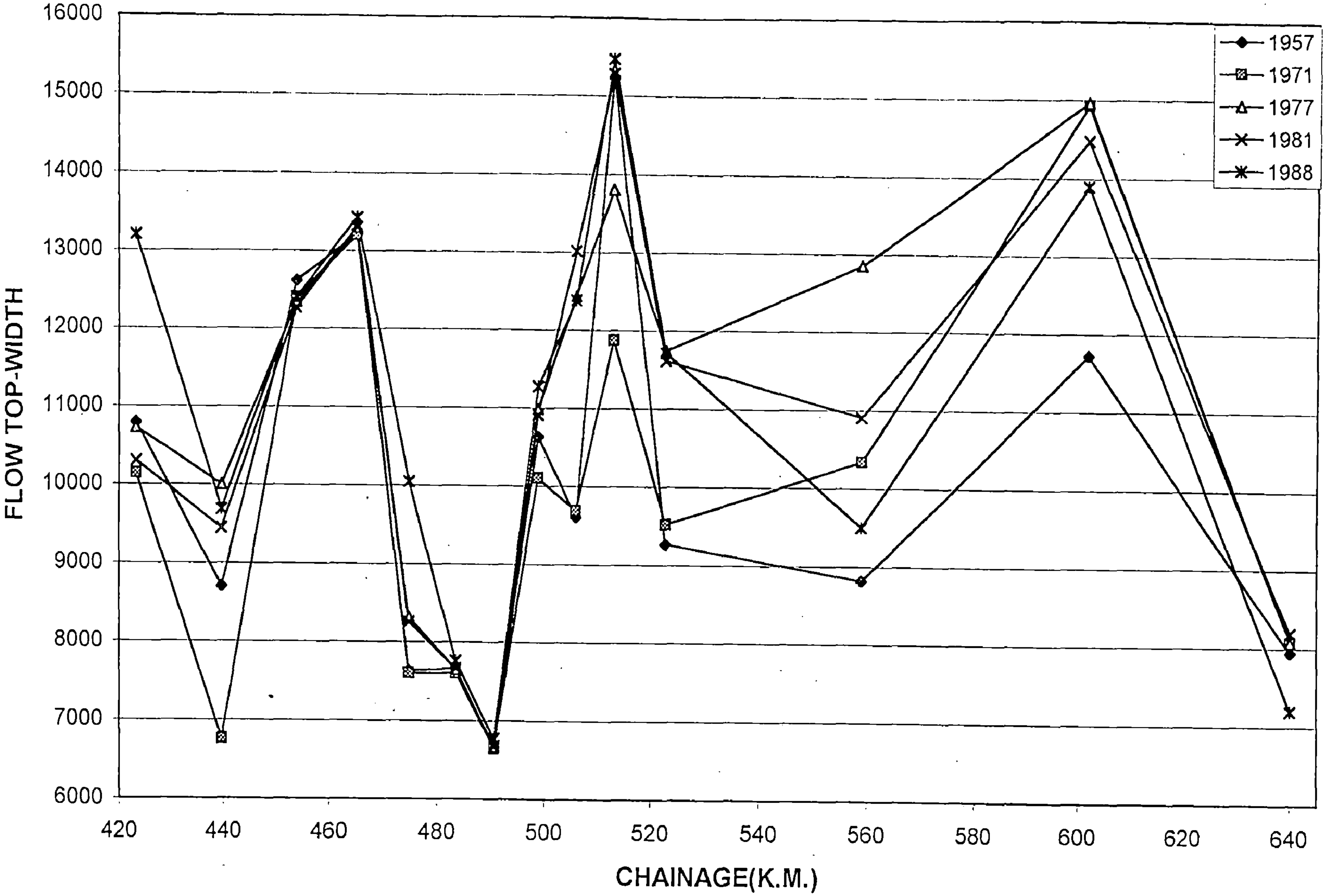


Fig. 6.1 **SPATIAL AND TEMPORAL CHANGES IN FLOW TOP-WIDTH FROM CS44 TO CS65**

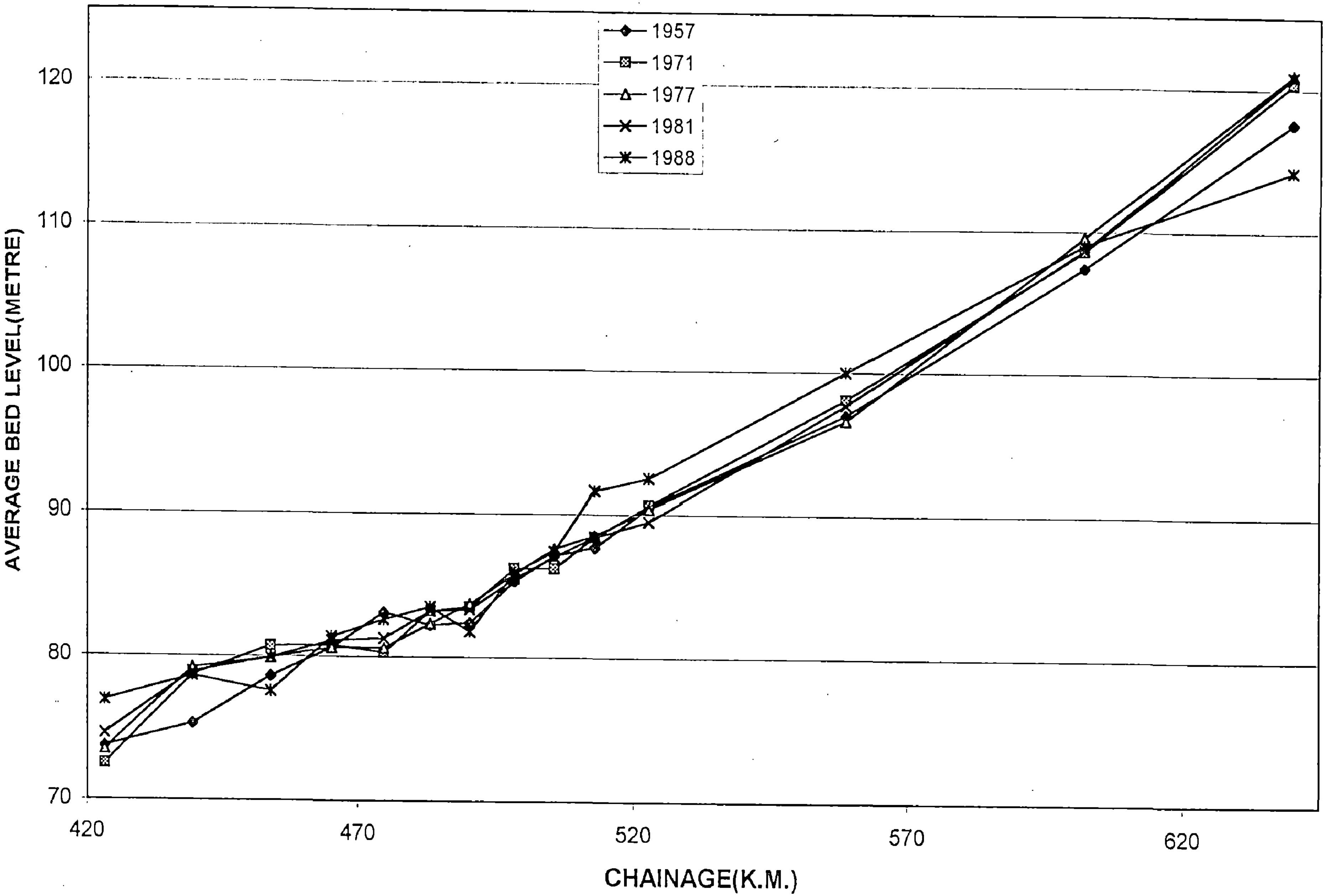


Fig. 6.2 **SPATIAL AND TEMPORAL CHANGES OF AV. BED LEVEL**

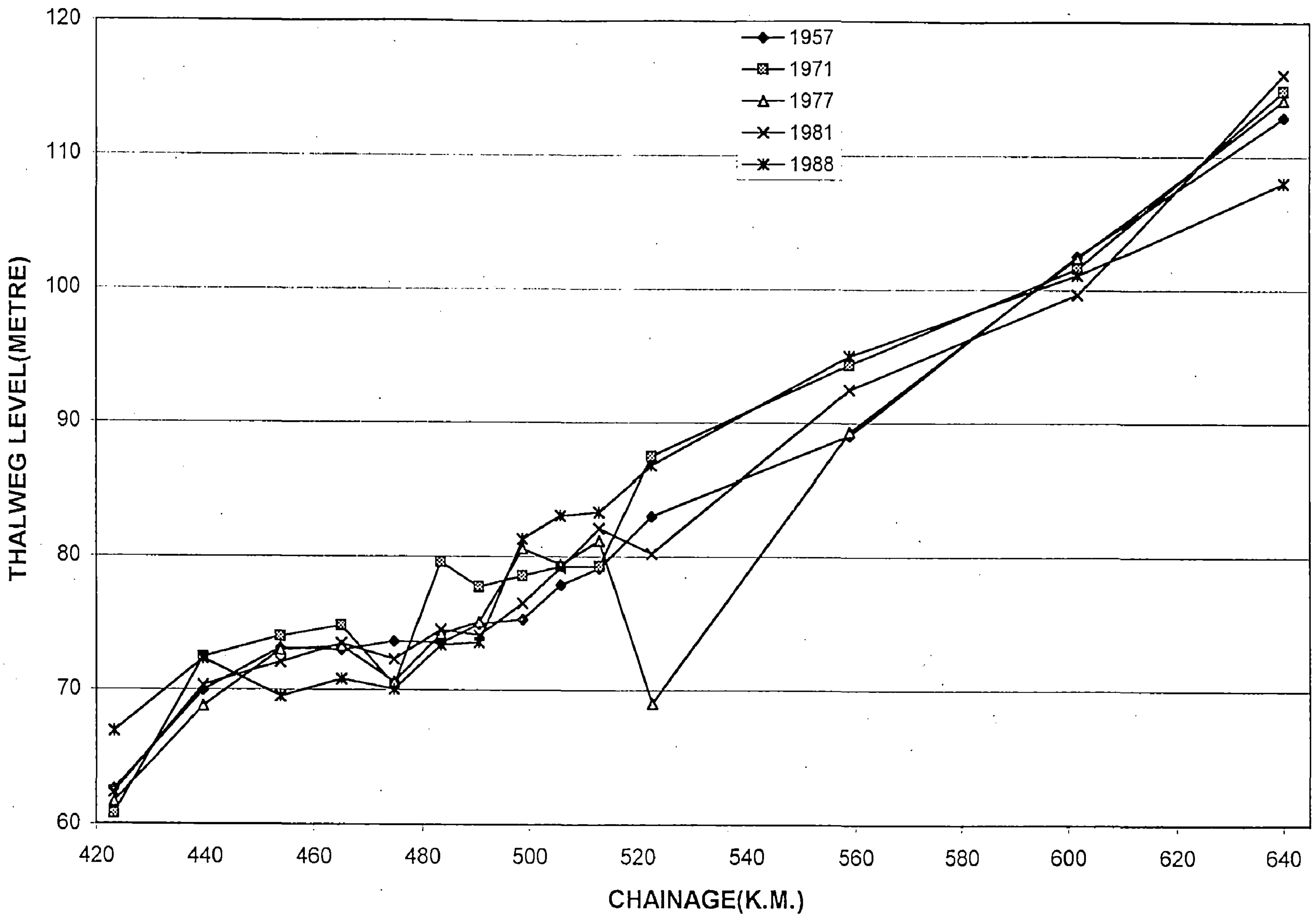


Fig. 6.3 ***VARIATIONS OF THALWEG LEVEL FROM CS44 TO CS65***

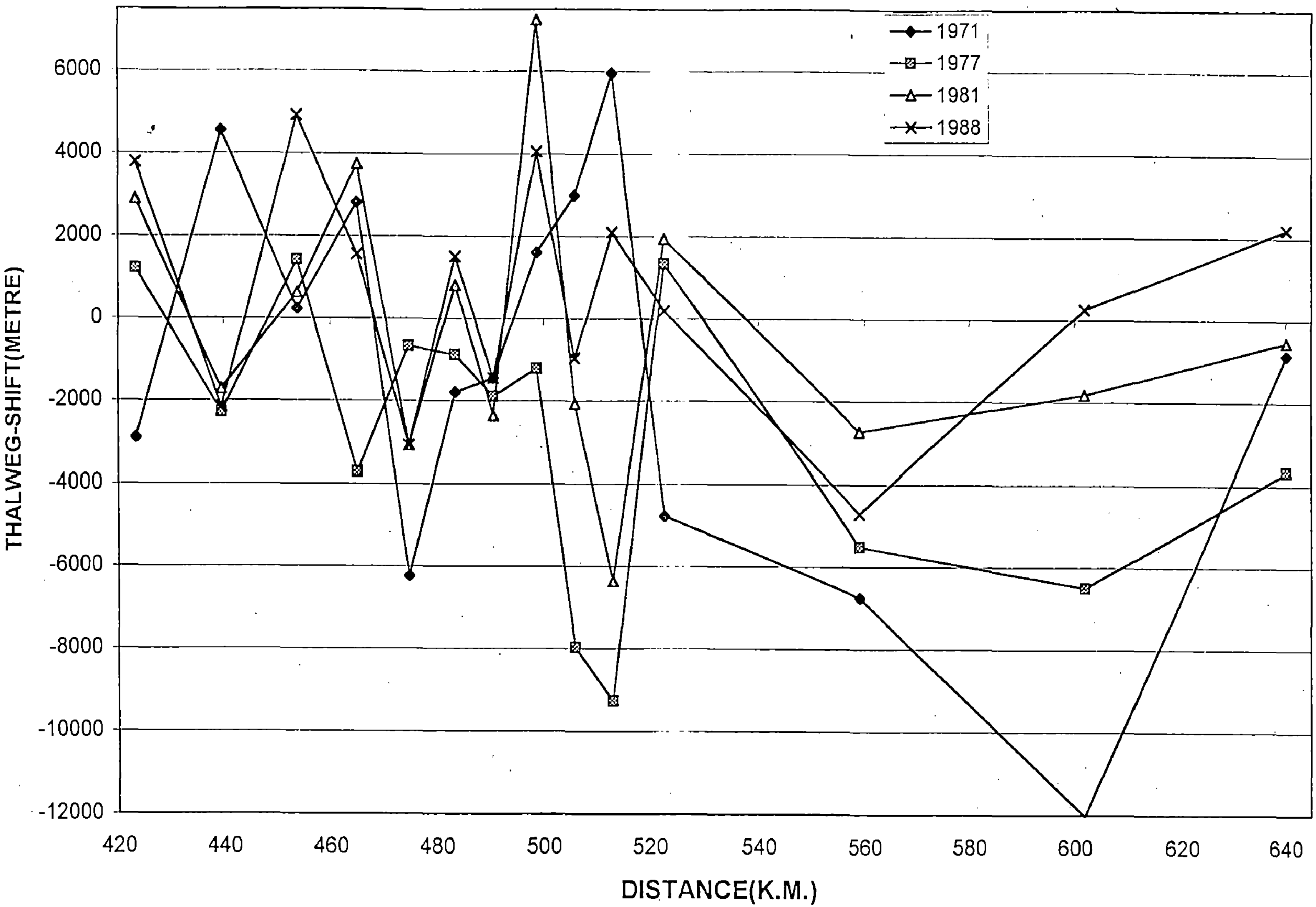


Fig. 6.4 ***SHIFTING OF THALWEG FROM CS44 TO CS54***

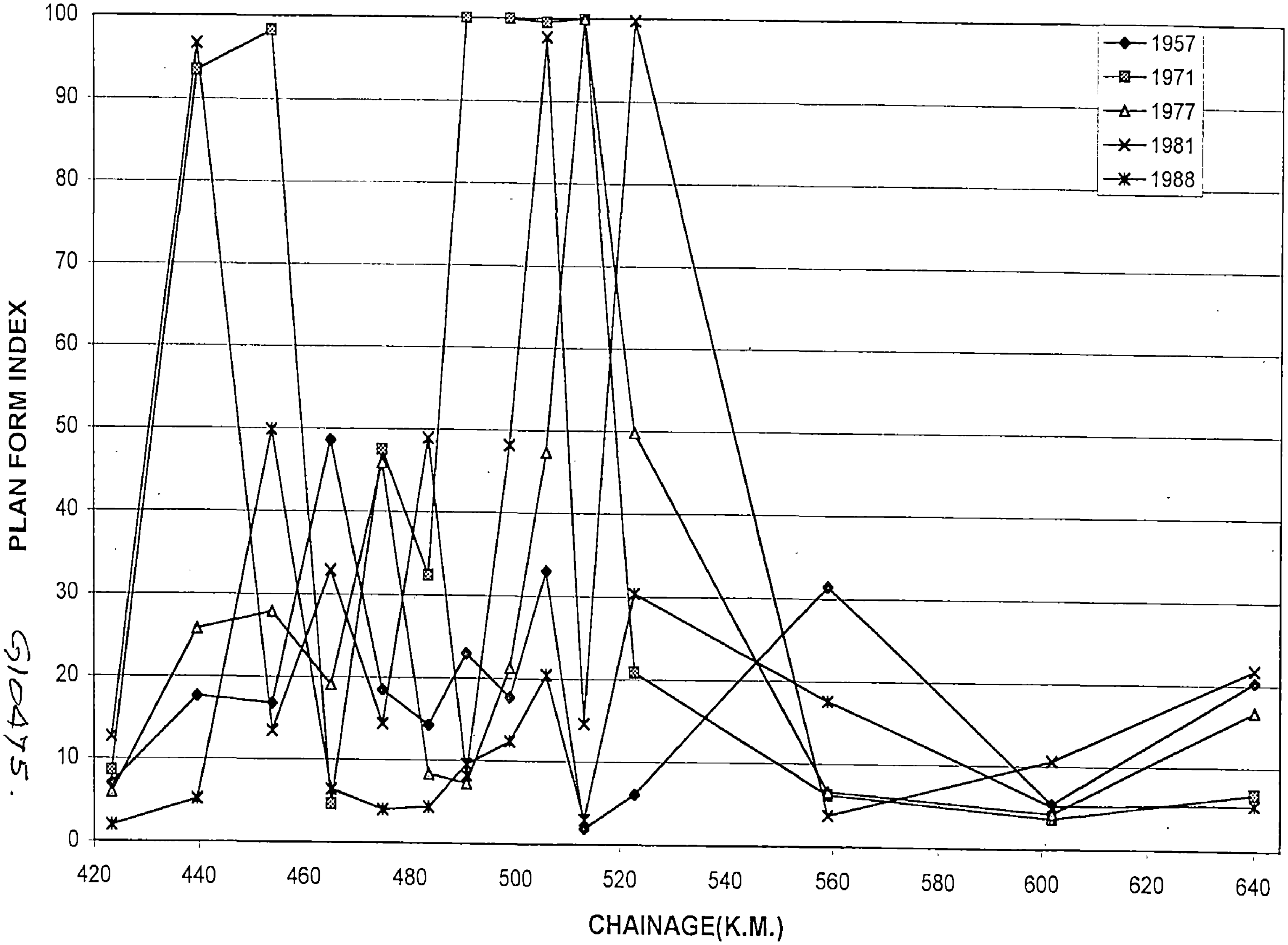


Fig. 6.5 ***EFFECT OF PLAN FORM CHARACTER FROM CS44 TO CS65***

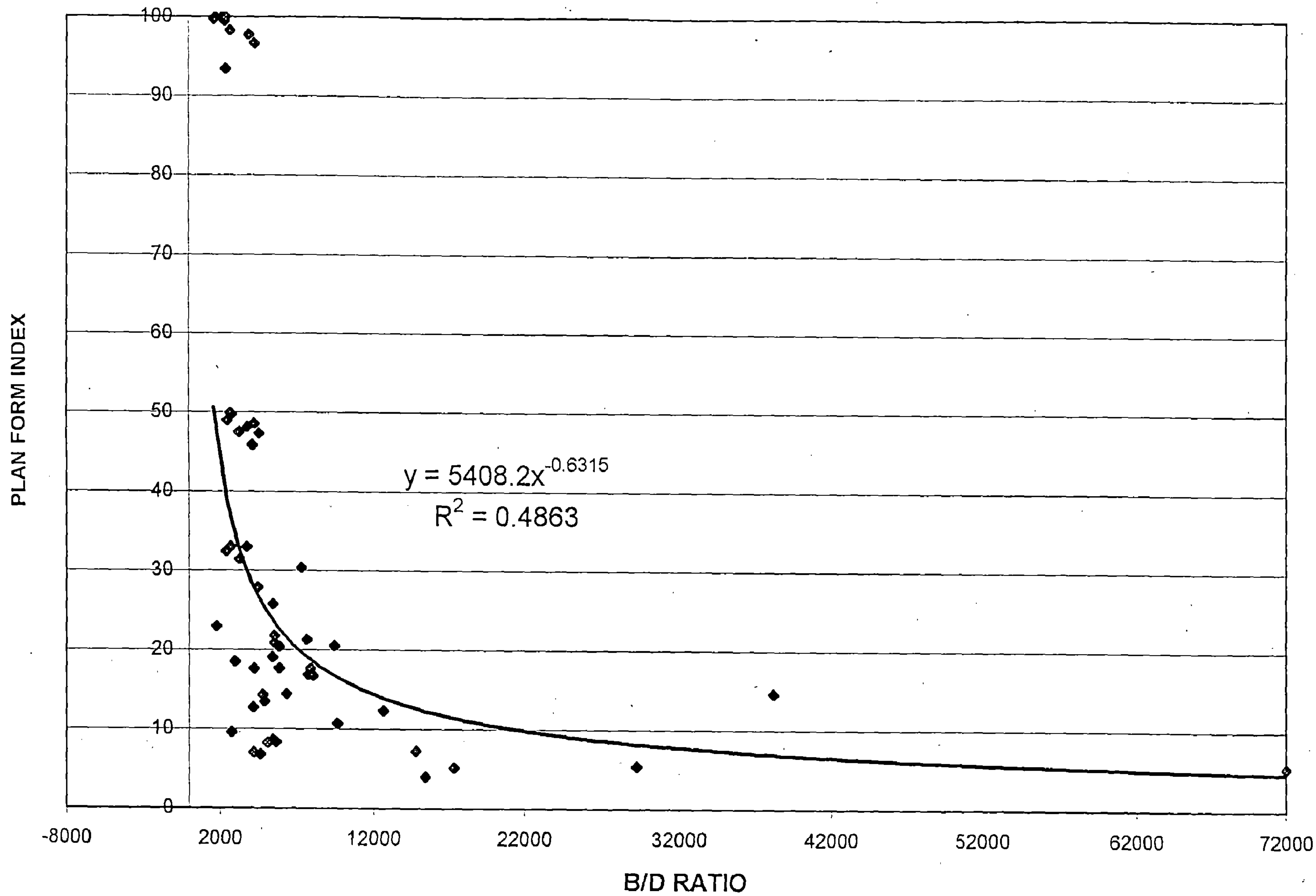


Fig. 6.6 ***B/D RATIO VS PFI FROM CS44 TO CS65***

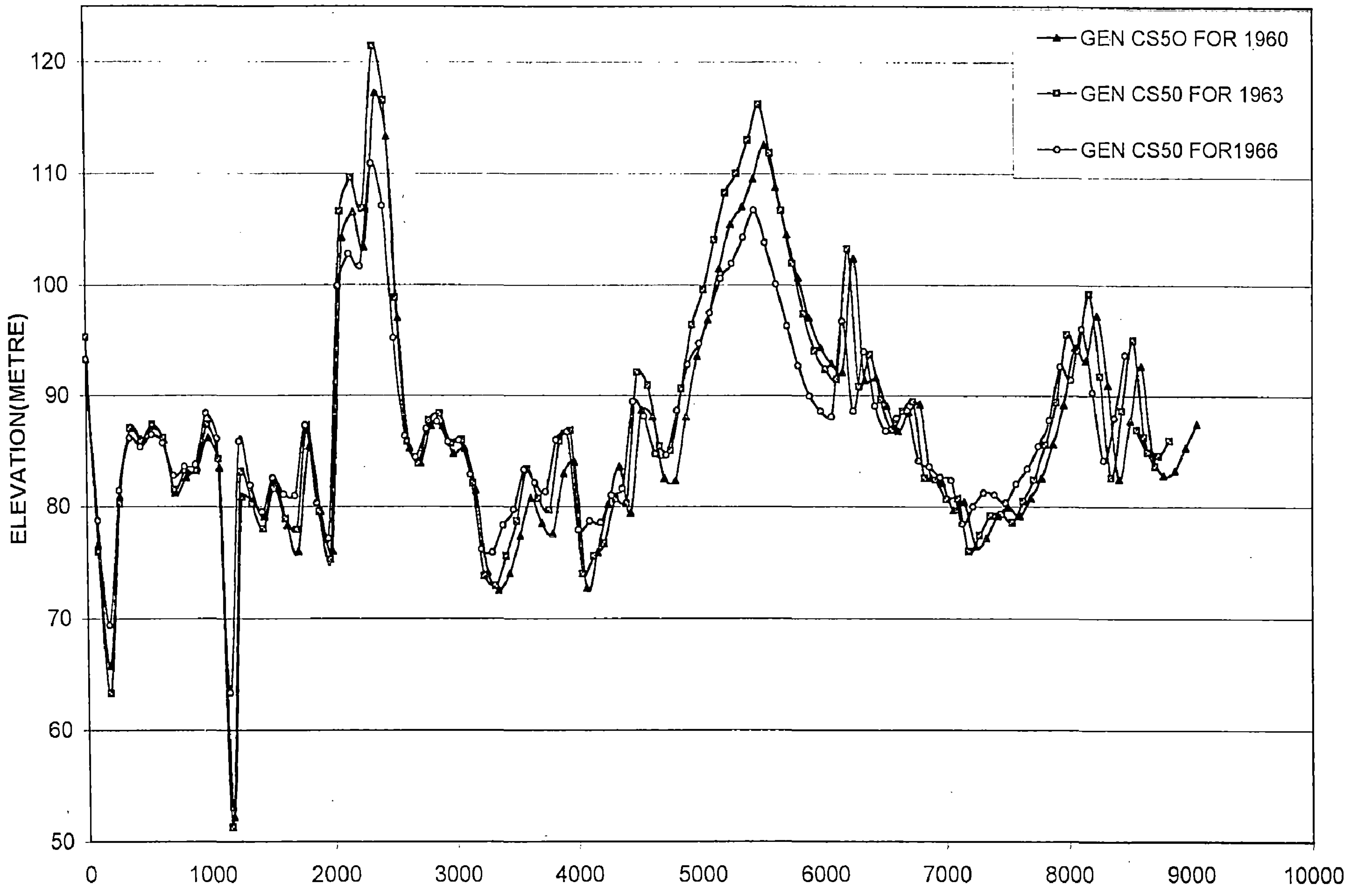


Fig 6.7 COMPARISION OF GEN. CS50 FOR YEARS 1960,1963 & 1966

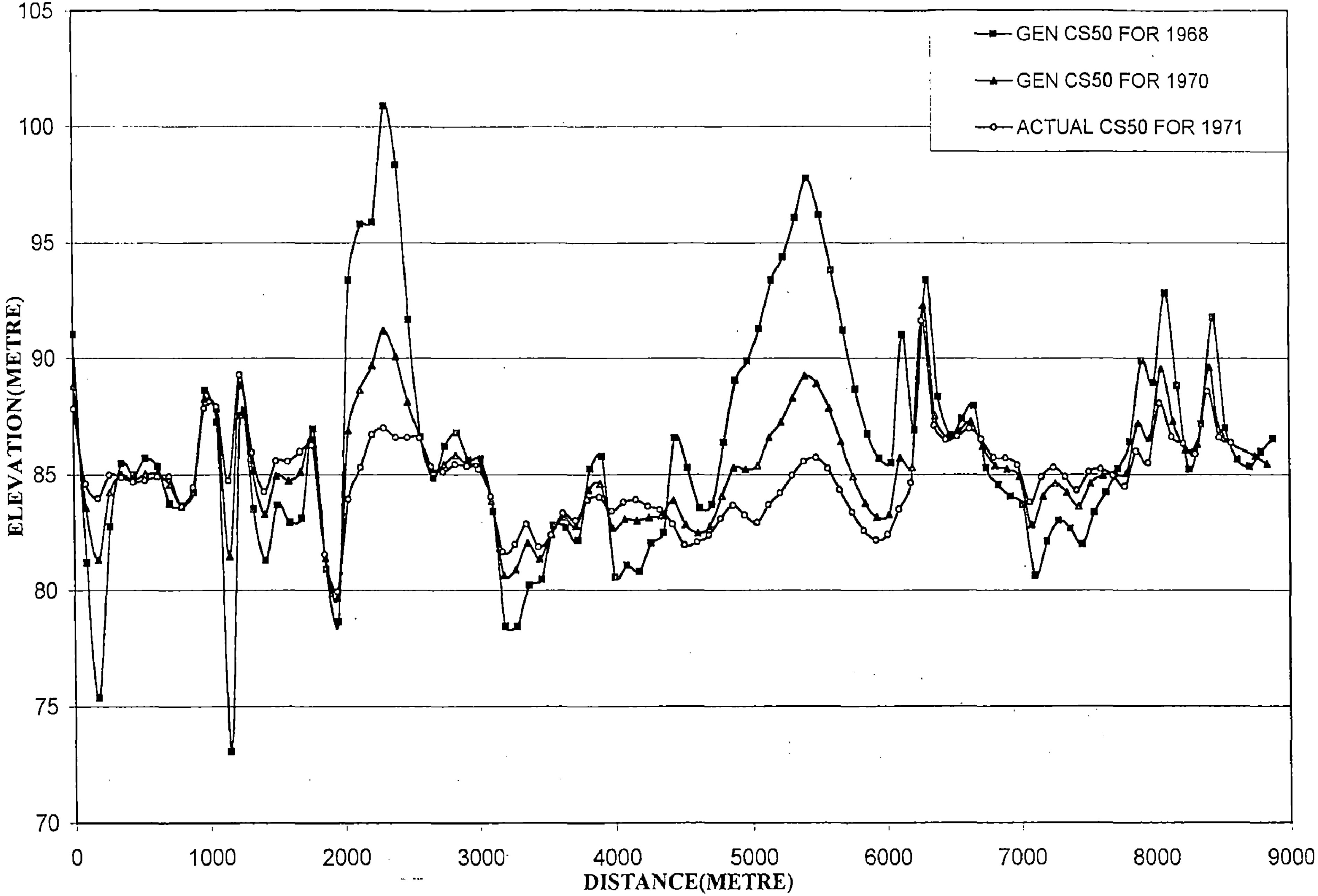


Fig 6.8 COMPARISION OF CS50 FOR THE YEARS 1968, 1970 & 1971

CONCLUSIONS AND SCOPE OF FUTURE WORK

7.1 CONCLUSIONS

The major conclusions that emerged from the present study are summarized below :

1. Majuli Island ranging from cross section 44 to 54 is under both the effect of erosion and depsoition.
2. The upstream reach of Majuli Island is also under the continuous effect of erosion and deposition.
3. Thalweg may shift its course and its levels are varying in nature mostly at cross-section 54.
4. PFI and B/D follow the equation $PFI = 5408\ (B/D)^{-0.6315}$. From this equation if two values are known, then third one can be calculated for rough prediction.
5. Average bed level is almost constant.
6. Flow top-width are varying in nature mostly at cross section 57.
7. River is under braiding from Dibrugarh to Majuli Island.
8. It is fairly established that the shape functions can be gainfully used to interpolate the braided channel geometry.
9. The use of shape functions provide flexibility to start with a linear interpolation (two nodded shape function) to more complex non-linear forms afforded by higher order shape functions.

10. The data-base model with normalized data and use of shape functions, provides fairly accurate simulation even in the case of heavily braided rivers.

11. The data based package developed in capable of simulating profile of the Brahmaputra River at any points within the reach under consideration and for any year from 1957 to 1988.

12. For supplementing any missing data only temporal interpolation should be used as the spatial interpolation fails to produce the profile close enough to be accepted except for crude preliminary estimates.

7.2 SCOPE FOR FUTURE WORK

1. Study should be based on complete and latest data required for the purpose. Both the pre-monsoon and post-monsoon data for the same study year should be used identify seasonal and permanent variation.

2. Study of morphological behaviour of the Brahmaputra should be done with satellite and hydrographic data by developing mathematical model.

3. The present study has been restricted in scope to the goal of simulating the river cross-section profile through interpolation within the reach and the time for which measured data are available. Extrapolation beyond these limit will be desirable feature in forecasting the morphological pattern in future.

4. With the advent of "EXPERT SYSTEM, ARTIFICIAL INTELLIGENCE AND ARTIFICIAL NEURAL NETWORK", it becomes necessary to utilize the potential of these tools for providing interpolation and extrapolation.

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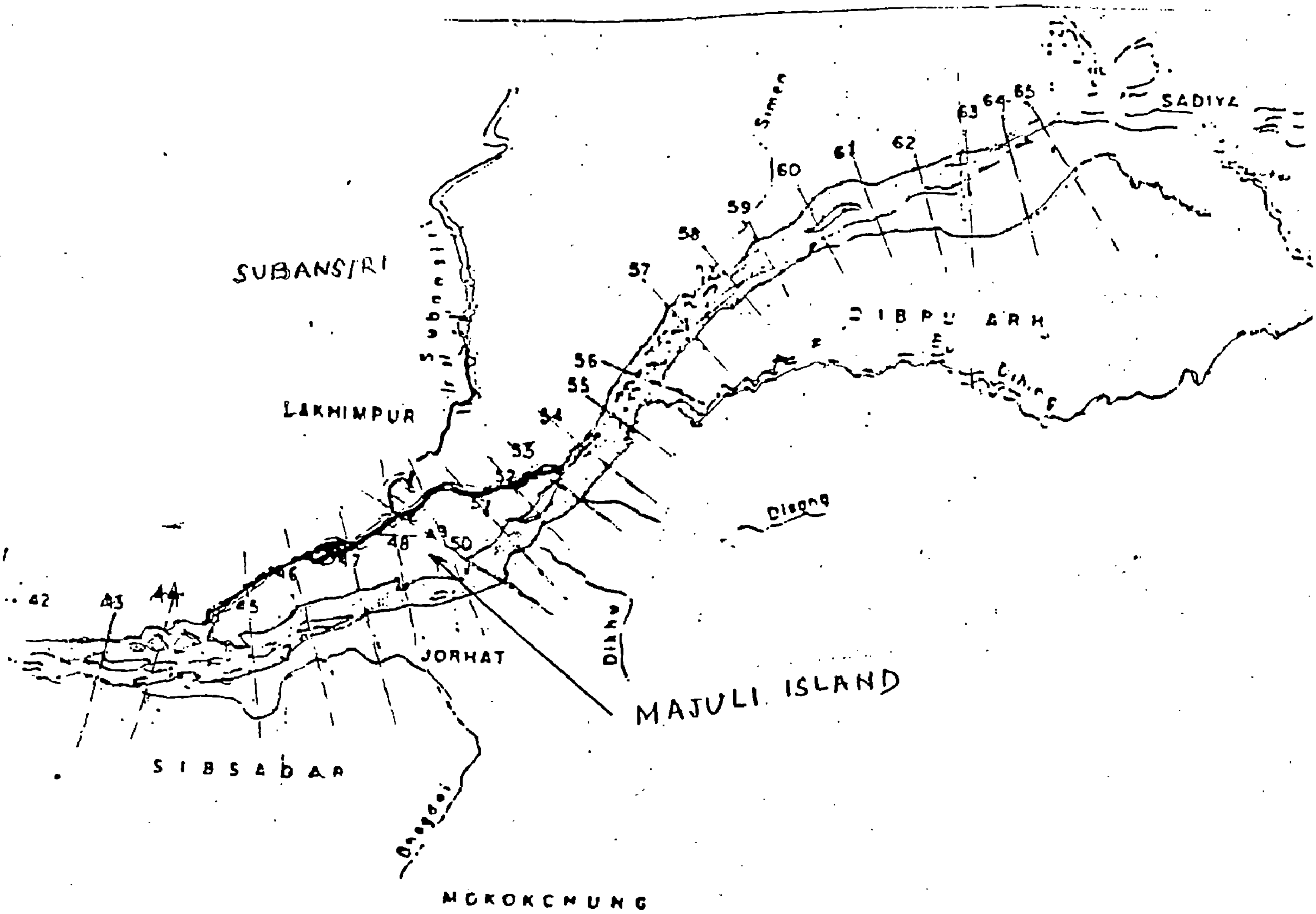
MAP FROM DIBRUGARH TO MAJULI ISLAND



APPENDIX – A

NORMALISED SECTION
CROSS SECTION NO 50
CHAINAGE 490.630

57		71		77		81		88	
0	84.89	0	84.31	0	84.15	0	84.6	0	87.75
65	84.62	65.7	84.47	66	84.52	66	84.92	67.1	86.03
130	84.45	131.5	84.64	132.1	84.74	132.1	84.99	134.1	82.5
195	84.4	197.2	84.8	198.1	84.82	198.1	84.81	201.2	85.22
260	84.45	263	84.93	264.2	84.92	264.2	84.88	268.2	84.2
325	83.71	328.7	85.02	330.2	82.98	330.2	82.23	335.3	82.85
390	81	394.5	82.93	396.2	79.88	396.2	78.84	402.4	83.45
455	85.1	460.2	82.97	462.3	81.87	462.3	81.22	469.4	83.22
520	93.67	525.9	85.42	528.3	85.17	528.3	85.17	536.5	83.08
585	90.29	591.7	85.2	594.4	84.87	594.4	84.96	603.5	83.89
650	85.92	657.4	85.1	660.4	84.85	660.4	84.75	670.6	78.48
715	85.54	723.2	85.14	726.4	84.96	726.4	84.62	737.7	83.42
780	85.05	788.9	85.12	792.5	84.91	792.5	84.73	804.7	85.41
845	84.97	854.7	85.1	858.5	84.92	858.5	84.82	871.8	84.08
910	85.05	920.4	85.08	924.6	85.04	924.6	84.94	938.8	81.72
975	85.45	986.1	85.06	990.6	85.43	990.6	85.33	1005.9	85.15
1040	86.13	1051.9	85.01	1056.6	85.21	1056.6	85.4	1073	85.28
1105	86.45	1117.6	84.92	1122.7	84.7	1122.7	85.22	1140	84.74
1170	86.08	1183.4	84.91	1188.7	85.08	1188.7	85.12	1207.1	84.7
1235	85.55	1249.1	84.9	1254.8	85.37	1254.8	84.87	1274.1	84.72
1300	85.91	1314.9	84.83	1320.8	85.41	1320.8	84.57	1341.2	84.68
1365	86.68	1380.6	84.32	1386.8	85.1	1386.8	84.66	1408.2	84.49
1430	86.67	1446.3	84.26	1452.9	84.84	1452.9	84.78	1475.3	84.41
1495	86.19	1512.1	84.89	1518.9	84.7	1518.9	84.85	1542.4	84.3
1560	85.65	1577.8	84.88	1585	84.54	1585	84.8	1609.4	84.08
1625	85.28	1643.6	84.79	1651	84.55	1651	84.73	1676.5	84.01
1690	84.95	1709.3	84.77	1717	84.67	1717	84.69	1743.5	83.93
1755	84.78	1775	84.47	1783.1	84.37	1783.1	84.8	1810.6	83.77
1820	84.7	1840.8	84.38	1849.1	84.78	1849.1	84.88	1877.7	83.51
1885	84.83	1906.5	84.77	1915.1	85.9	1915.1	84.89	1944.7	83.54
1950	85.13	1972.3	84.79	1981.2	85.57	1981.2	84.91	2011.8	84.07
2015	85.45	2038	84.74	2047.2	85.13	2047.2	84.92	2078.8	84.47
2080	85.64	2103.8	84.73	2113.3	84.97	2113.3	84.89	2145.9	84.69
2145	85.79	2169.5	84.72	2179.3	84.83	2179.3	84.8	2213	84.66
2210	85.88	2235.2	84.73	2245.3	84.64	2245.3	84.77	2280	84.73
2275	85.92	2301	84.75	2311.4	84.4	2311.4	84.85	2347.1	84.75
2340	85.98	2366.7	84.76	2377.4	84.61	2377.4	84.75	2414.1	84.69
2405	86.07	2432.5	84.76	2443.5	84.76	2443.5	84.67	2481.2	84.67
2470	86.08	2498.2	84.71	2509.5	84.64	2509.5	84.65	2548.3	84.43
2535	85.98	2564	84.47	2575.5	84.61	2575.5	84.71	2615.3	84.04
2600	85.77	2629.7	84.21	2641.6	84.49	2641.6	84.74	2682.4	84.63
2665	85.41	2695.4	84.21	2707.6	84.26	2707.6	84.68	2749.4	85.09
2730	84.91	2761.2	84.35	2773.7	84.54	2773.7	84.69	2816.5	85.25
2795	85.11	2826.9	84.47	2839.7	84.77	2839.7	84.71	2883.6	85.83
2860	85.75	2892.7	84.26	2905.7	84.58	2905.7	84.68	2950.6	84.93
2925	86.19	2958.4	83.95	2971.8	84.21	2971.8	84.66	3017.7	82.69
2990	86.13	3024.2	83.56	3037.8	83.99	3037.8	84.65	3084.7	80.94
3055	85.91	3089.9	83.16	3103.9	84.24	3103.9	84.66	3151.8	80.03
3120	85.86	3155.6	83.24	3169.9	83.71	3169.9	84.61	3218.9	79.84
3185	85.83	3221.4	83.69	3235.9	83.3	3235.9	84.55	3285.9	78.82
3250	85.96	3287.1	83.95	3302	83.76	3302	84.5	3353	77.35
3315	86.23	3352.9	84.05	3368	84.08	3368	84.46	3420	75.73

57		71		77		81		88	
3380	86.23	3418.6	83.99	3434.1	84.33	3434.1	84.44	3487.1	75.09
3445	85.35	3484.4	83.92	3500.1	84.35	3500.1	84.42	3554.1	74.72
3510	83.9	3550.1	83.79	3566.1	84.14	3566.1	83.94	3621.2	74.38
3575	81.71	3615.8	83.62	3632.2	83.61	3632.2	83.58	3688.3	73.69
3640	80.47	3681.6	83.49	3698.2	82.58	3698.2	84.06	3755.3	74.07
3705	80.3	3747.3	83.6	3764.3	82.15	3764.3	84.23	3822.4	75.04
3770	81.61	3813.1	83.96	3830.3	81.84	3830.3	84.03	3889.4	74.27
3835	79.21	3878.8	83.89	3896.3	81.66	3896.3	82.75	3956.5	74.15
3900	76.8	3944.6	83.56	3962.4	82.14	3962.4	82.13	4023.6	74.67
3965	78.06	4010.3	82.93	4028.4	82.83	4028.4	81.8	4090.6	75
4030	80.21	4076	81.17	4094.5	83.08	4094.5	81.07	4157.7	76.02
4095	80.46	4141.8	79.11	4160.5	83.22	4160.5	80.95	4224.7	77.54
4160	80.04	4207.5	77.91	4226.5	83.23	4226.5	80.93	4291.8	78.89
4225	79.38	4273.3	77.64	4292.6	83.08	4292.6	79.93	4358.9	79.53
4290	80.63	4339	77.67	4358.6	82.96	4358.6	79.8	4425.9	79.35
4355	82.42	4404.8	79.4	4424.7	82.52	4424.7	80.2	4493	78.22
4420	83.49	4470.5	80.09	4490.7	80.85	4490.7	80.11	4560	78.35
4485	83.11	4536.2	80.09	4556.7	78.73	4556.7	79.36	4627.1	78.89
4550	82.37	4602	78.66	4622.8	76.86	4622.8	78.3	4694.2	77.71
4615	82.39	4667.7	78.26	4688.8	75.66	4688.8	78.15	4761.2	76.38
4680	82.47	4733.5	78.39	4754.9	75	4754.9	78.31	4828.3	74.98
4745	82.43	4799.2	78.99	4820.9	75	4820.9	78.68	4895.3	73.64
4810	82.34	4865	80.13	4886.9	75.6	4886.9	79.01	4962.4	75.34
4875	82.5	4930.7	80.83	4953	76.83	4953	77.4	5029.5	77.3
4940	82.9	4996.4	80.82	5019	78.43	5019	74.56	5096.5	74.3
5005	82.69	5062.2	83.82	5085	79.34	5085	75.27	5163.6	74.94
5070	81.35	5127.9	86.16	5151.1	79.7	5151.1	75.23	5230.6	76.62
5135	80.4	5193.7	85.76	5217.1	79.71	5217.1	74.13	5297.7	75.61
5200	78.87	5259.4	85.33	5283.2	80.44	5283.2	75.26	5364.8	76.24
5265	67.08	5325.1	84.95	5349.2	81.6	5349.2	76.47	5431.8	78.06
5330	75.1	5390.9	84.98	5415.2	83.16	5415.2	77.64	5498.9	85.74
5395	77.65	5456.6	85.03	5481.3	84.94	5481.3	81.17	5565.9	87.31
5460	79.2	5522.4	85.06	5547.3	85.73	5547.3	84.21	5633	84.64
5525	79.12	5588.1	85.07	5613.4	85.2	5613.4	85.61	5700	84.65
5590	78.91	5653.9	85.01	5679.4	85.32	5679.4	85.45	5767.1	84.33
5655	78.88	5719.6	84.92	5745.4	85.34	5745.4	84.96	5834.2	84.03
5720	78.93	5785.3	84.91	5811.5	85.11	5811.5	84.81	5901.2	84.05
5785	78.93	5851.1	84.88	5877.5	84.85	5877.5	84.84	5968.3	83.9
5850	78.9	5916.8	84.82	5943.6	84.72	5943.6	84.92	6035.3	83.68
5915	78.86	5982.6	84.78	6009.6	84.8	6009.6	84.95	6102.4	83.39
5980	78.87	6048.3	84.76	6075.6	84.74	6075.6	84.92	6169.5	83.33
6045	78.93	6114.1	84.76	6141.7	84.67	6141.7	84.87	6236.5	83.31
6110	79.01	6179.8	84.86	6207.7	84.65	6207.7	84.79	6303.6	83.19
6175	79.11	6245.5	84.76	6273.8	84.68	6273.8	84.6	6370.6	83.09
6240	79.23	6311.3	84.58	6339.8	84.65	6339.8	84.51	6437.7	83.02
6305	79.13	6377	84.53	6405.8	84.5	6405.8	84.68	6504.8	83.01
6370	78.95	6442.8	84.54	6471.9	84.57	6471.9	84.54	6571.8	83.24
6435	78.83	6508.5	84.55	6537.9	84.64	6537.9	84.37	6638.9	83.36
6500	78.71	6574.3	84.58	6604	84.52	6604	84.47	6705.9	82.87

Program : Profile.for
Output file: Cross.Shape
GENERATED CROSS SECTION
CHAINAGE= 490.630
YEAR 1983
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.00	88.208
86.24	87.150
172.63	84.098
258.97	88.459
345.31	87.830
431.54	86.560
517.80	86.454
604.20	86.323
690.52	84.404
776.94	82.267
863.19	79.331
949.54	80.418
1035.76	81.539
1122.06	86.799
1208.44	82.672
1294.72	83.565
1381.10	83.748
1467.34	83.919
1553.66	83.551
1640.06	83.353
1726.34	84.260
1812.71	78.976
1898.94	72.590
1985.38	82.167
2071.60	81.946
2157.86	78.209
2244.29	90.272
2330.53	92.240
2416.92	86.743
2503.17	84.240
2589.40	84.961
2675.84	86.367
2762.11	86.811
2848.56	86.454
2934.80	85.943
3021.15	85.021
3107.37	83.098
3193.67	82.043
3280.11	83.543
3366.35	87.121
3452.70	89.391
3538.95	86.058
3625.19	84.845
3711.66	85.821
3797.92	84.349

3884.31	78.220
3970.57	78.335
4056.92	79.305
4143.29	81.909
4229.52	82.895
4315.90	90.640
4402.11	91.495
4488.49	88.252
4574.71	86.180
4661.08	86.085
4747.44	86.463
4833.70	87.135
4920.09	88.441
5006.35	89.469
5092.81	90.169
5179.06	90.496
5265.31	90.693
5351.66	89.607
5437.90	88.521
5524.33	87.891
5610.63	87.011
5696.85	87.022
5783.21	87.067
5869.45	86.822
5955.90	87.879
6042.17	85.222
6128.61	83.949
6214.83	84.862
6301.09	84.260
6387.48	84.262
6473.72	84.793
6560.15	86.534
6646.40	85.452
6732.63	85.142
6819.07	85.175
6905.30	84.793
6991.67	84.535
7077.95	84.296
7164.35	84.293
7250.67	84.268
7336.91	84.107
7423.29	83.967
7509.57	84.902
7595.94	85.744
7682.24	86.548
7768.47	86.821
7854.82	87.135
7941.07	86.356
8027.48	82.006
8113.81	84.350
8200.21	83.774

8286.47	83.446
8372.70	83.084
8459.04	83.385
8545.38	83.933
8631.76	84.031

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