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SECONDARY CIRCULATION IN NATURAL STREAMS

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## SECONDARY CIRCULATION IN NATURAL STREAMS

### ABSTRACT

Secondary circulation which is sometimes referred to as secondary flow, secondary current or transverse current is an important phenomenon in natural streams and plays an important role in many natural processes in streams such as stream channel meander, bank erosion, bed scour, resuspension, and movement of sediment. Secondary circulation is that component of flow which is not in the main flow direction and is small as compared to the main flow velocity. A computerized data collection system for secondary circulation data acquisition in natural streams was developed and utilized in the field. The system includes an electromagnetic current meter, a micro-computer, an interface between the computer and the current meter, and a specially designed supporting structure. Secondary circulation data was collected in the Sangamon River near Mahomet, Illinois, utilizing the data collection system. A mathematical model for secondary circulation based on an existing model has been developed and tested against the data collected in the field. Model results generally reproduce similar secondary circulation patterns as observed from the field data but over-estimate the magnitudes of the velocities.

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KEYWORDS - computer; data acquisition; model; secondary circulation; secondary current; streams; transverse current; velocity

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## INTRODUCTION

The main component of flow in any stream, river, or canal might be expected to be parallel to the channel bed in the downstream direction. However, because of a variety of reasons including the resistance flow due to stream banks, a rotational or cellular movement of flow will occur in the main channel. This persistent flow component that is not in the main flow direction has been termed secondary circulation, secondary flow, secondary current, or transverse current. This type of flow, which is always present in any open channel flow, is completely different from induced flow circulations in some pockets found on the side of open channels.

The direction of secondary flow is strongly associated with the primary velocity distribution. Areas of high velocities near the bed or bank are associated with outward secondary flow, while areas of low velocities are associated with inward secondary flow. This phenomenon has significant implications with respect to bank erosion and bed scour, since areas of high velocities are much more susceptible to erosion and scour.

Considerable agreement exists among researchers that secondary circulation is an important phenomenon in natural rivers and is partially responsible for the development of meander patterns, bank erosion, bed scour, resuspension and movement of sediment, and an increase in boundary shear and flow resistance (24, 26, 29, 37, 38, 39, 41, 44, 45, 47, 53, 54). For example, the existence of strong secondary circulation near a certain region close to the bank with a component of velocity directed toward the bank will indicate the location of potential bank erosion areas.

### Objectives

The main objectives of this proposed research were:

- 1) To determine the magnitude and nature of secondary circulation in natural streams by direct measurement in the field.
- 2) To develop and verify a mathematical model for predicting secondary circulation in natural streams.
- 3) To determine the effects of secondary circulation on bank erosion by quantifying its effects on velocity and shear stress distribution, and on dispersion and transport of sediment in natural streams.

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## REVIEW OF LITERATURE

It is important to have a clear understanding of what the term secondary circulation means before proceeding further. When researchers talk about secondary flow, they are actually describing the three-dimensional nature of open channel flow. Ciray (18) defined the secondary velocity as follows:

When the magnitude of the vector composed by any two components of the local velocity vector in a three dimensional flow is small compared with the magnitude of the third component, the latter forms the main flow whereas the remaining two form the secondary.

Although this definition appears to be adequate to some extent, it lacks completeness. Perhaps more attention should be paid to the individual components of velocity than to the resultant of two vector quantities. In this line of thought, Chiu et al. (13) defined the secondary flow as the two components of flow which are in the transverse direction not coincident with the primary flow. Because of the presence of snags, obstructions, trees, etc., on the bed of a river, the velocity vector in a direction other than the

primary direction of the flow may be of greater magnitude than the primary velocity vector. Considering all these factors, Bhowmik (7) proposed the following definition:

In an open channel flow, any persistent component of velocity which is not parallel to or tangent to the center line of the channel and also not parallel to and in the same general downstream direction of the overall bed slope should be termed as secondary velocity.

Secondary current will be taken as the flow which is parallel to and also in the same direction as the secondary velocity. The definition stated above will ensure that the primary flow velocity is interpreted as the velocity in the downstream direction that coincides with the general direction of flow.

#### Historical Background

Historically, late nineteenth century hydraulic engineers, noting that the maximum velocity is below the water surface rather than at the water surface, offered the explanation that the frictional resistance at the air-water interface is responsible for this phenomenon. However, many researchers working at the time did not accept this idea, and they tried and were successful in correctly identifying the mechanisms of secondary circulation. They also indicated that these mechanisms might be responsible for the lower flow velocity at the air-water interface. These researchers did not identify secondary circulation by name, but they recognized its presence in concept. They include Bazin and Barcy in 1865, Gerrard in 1878, Francis in 1878, Wood in 1879, Stearns in 1883, and Cunningham in 1882 (7, 19).

In 1909 Gibson (30) analyzed the then-existing literature and offered his thoughts on why the filament of maximum velocity is below the water surface. He said that this phenomenon is "... due to the action of the sides of the channel in producing transverse currents inwards along the surface and outwards along the bed of the stream, thus distributing a layer of slowly moving water over the central part of the stream." He also indicated that the presence of curves in the stream's alignment can and will modify this phenomenon. He showed that the secondary flow velocity is about 5 percent of the main stream velocity.

It is noteworthy that almost 100 years after the initial postulations about the effect of wall roughness on the transverse flow phenomenon that were

made by Wood (59), Stearns (55), Francis (25), and others, Perkins (49) showed that the mean streamwise vorticity in turbulent flow arises both from mean flow skewing and from the inhomogeneity of anisotropic wall turbulence.

In the early twentieth century many others also worked on the transverse flow phenomenon. In 1917, Helstrom estimated the secondary flow velocity to be about 11 percent of the main stream velocity (32). In 1930 Nikuradse published results showing that secondary flow exists in noncircular conduits (27).

### Laboratory Measurements

Once the concept of secondary flow was recognized, researchers tried to measure the secondary circulation, especially in laboratory channels under ideal flow conditions. The simplest method is of course to use dye or neutrally buoyant particles to measure qualitatively the existence and the direction of secondary currents (3, 58). Another fairly sophisticated instrument used to measure secondary current in laboratory experiments is the hot-wire anemometer. Researchers such as Brundrett and Baines (8), Gessner and Jones (28), Hoagland (33), Tracy (57), and Liggett et al. (42) utilized hot wire anemometry systems to measure components of secondary currents. Launder and Ying (40) collected turbulence-induced secondary current data by using a DISA hot-wire probe. Muller (43) reported the results of laboratory experiments where a Laser Doppler Anemometer was used to measure the vertical and axial component of flow velocity. The presence and absence of secondary flow were interpolated on the basis of the increase or decrease of the turbulence and momentum exchange. All of Muller's experiments were conducted for supercritical flow ranges, i.e., the Froude number was more than unity. However, all these research projects were confined to laboratory experimentations.

### Field Measurements

While various researchers have measured secondary circulation in laboratory experiments, field instrumentations and measurements are rare. Only a very limited number of attempts have been made to measure secondary circulation in the field.

Kanwisher and Lawson (36) have described an electromagnetic flow sensor for measuring flow in natural open channels, which can be modified to measure



both the main stream and lateral flow velocities. This electromagnetic flow sensor has the potential of being used in the field to measure secondary flow velocities.

One of the most serious and comprehensive attempts that was made by any group of researchers to measure secondary currents in gravel bed rivers was that made by Bathurst et al. (4, 5). Their measurements were made at four bends on the River Severn in Wales, United Kingdom. Direct measurements of secondary velocities were made with an electromagnetic flow meter that had the capability of measuring two mutually perpendicular components of velocity simultaneously. The measuring head was 2 inches (50 mm) in diameter, and the instrument was accurate to within 0.33 fps (10 mm/s). All the measurements were confined to bends. The instrument worked out fairly well. The primary velocity data were collected with an Ott C-31 current meter. Isovels were developed, and their shapes were compared with the shape and pattern of secondary cells that could be sketched on the basis of the shape of the primary isovels. The data indicated that the peak values of shear stress were associated with the core of the maximum velocity.

Thorne et al. (56) conducted other detailed bend-flow hydraulics measurements on the Fall River, Rocky Mountain National Park, Wyoming. Primary and lateral velocity components were measured using a Marsh-McBirney Model 511 two-component electromagnetic current meter. The current meter simultaneously measures two mutually perpendicular velocity components with an accuracy of 0.01 ft/sec (3 mm/s). Much more accurate data were recorded, and secondary cells were often found to exist at outer and inner banks. The device used by Thorne et al. could not record the orientation of the sensor probe, which remained a difficulty in the data reduction. Demissie et al. (20, 21) developed a measuring system in which the current meter is supported by a self-standing system and data are transmitted to a computer on the stream bank for processing and storage. The flow velocity components are measured by a Marsh-McBirney current meter, Model 527, which can also measure the bearing of the sensor from the magnetic north in a clockwise direction.

#### Indirect Techniques

Field data collected by Bathurst et al. (4, 5) indicated that it is possible to draw secondary flow cells on the basis of the primary velocity isovels. Such an attempt was made by Bhowmik (7) for the field data collected

from the Kaskaskia River in Illinois. Fig. 1 shows the isovels at a section where the secondary flow cells were sketched. Data shown are from the same cross section but for two flow conditions: low and high flows. If it is assumed that the isovels are a set of flexible membranes held in place by fluids in between them, then a bulging or deformity in their shape indicates the presence of some force acting normal to the face of the membranes. Thus, if the membranes bulge inward, it indicates the presence of a force from the outside to the inside and vice versa. The approximate locations of the secondary cells in Fig. 1 were drawn on the basis of this technique. Data from any other isovels can similarly be used to draw the patterns of secondary cells. Brundrett and Baines (8) and Liggett et al. (42) expressed some doubt as to the validity of sketching secondary flow cells on the basis of primary velocity isovels. Their conclusions were based on laboratory experiments. However, even though it is not a precise technique, it provides a good qualitative picture of secondary circulation in natural channels.

Recently Ikeda (35) indicated a technique of sketching the patterns of secondary current cells in sand bed laboratory channels on the basis of the nature and existence of bed undulations or topography. In a deformable channel such as a sand bed channel, the bed profile in the lateral direction may partially reflect the magnitude and direction of the secondary current cells near the bed. Only qualitative information is obtained by using isovels or bed topography.

#### Mathematical Modeling

A few researchers have worked on the development of mathematical models related to secondary circulation in open channels. However, most of their work has been confined to cases with flow around bends. A strong secondary current is generated in a bend because of the imbalance of horizontal fluid forces; thus it is easier to quantify this current for flow around bends than for straight reaches.

Einstein and Li (23) have shown theoretically that uniform flow in straight channels can exist only in the case of laminar flow. For turbulent flow, they have shown that secondary currents will be generated and that the nonexistence of parallel isovels results from the presence of secondary flows, especially near the frictional boundary. Some other researchers who have

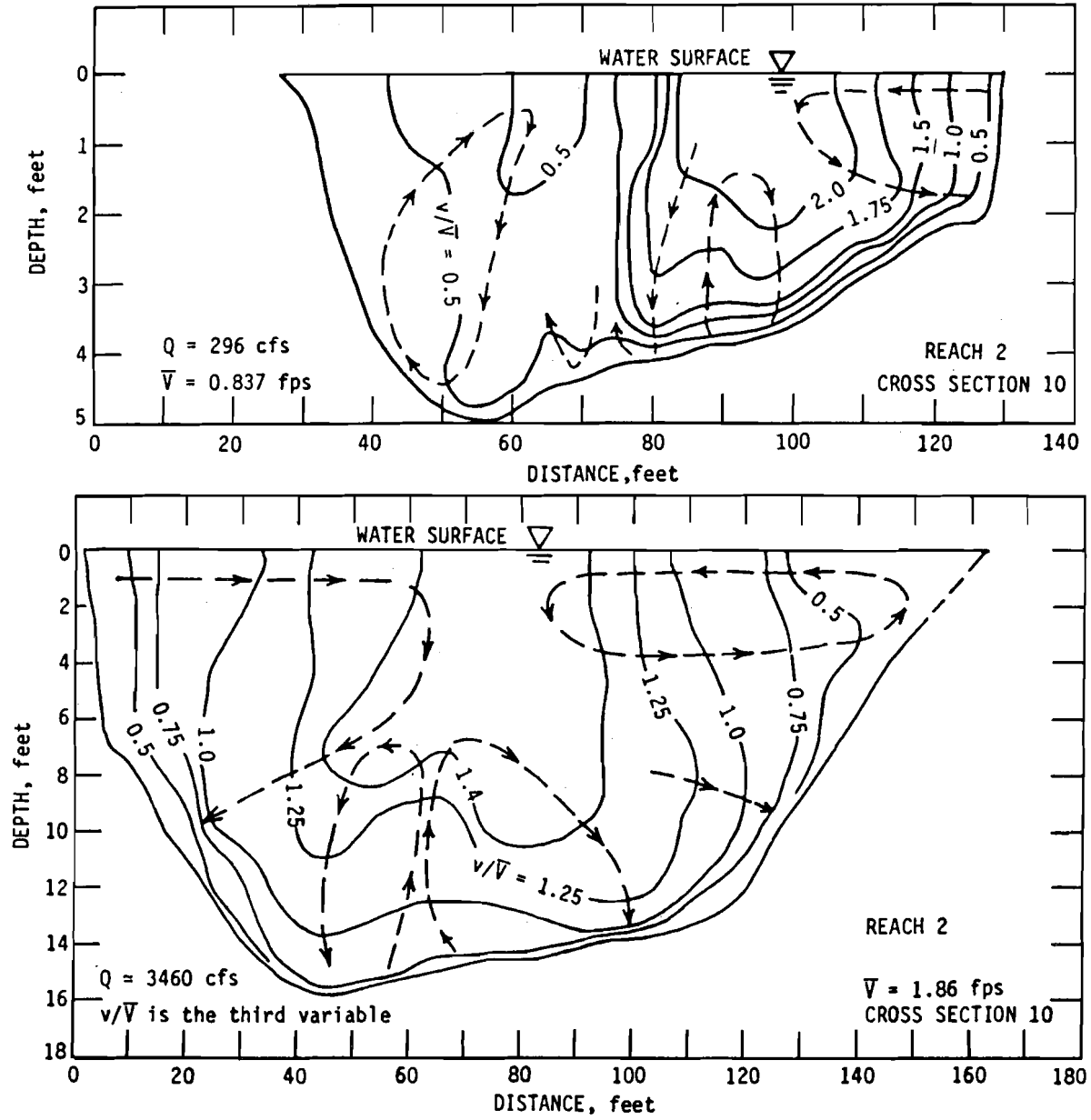


Figure 1. Isovets and secondary flow cells in a natural river (7)

worked on the mathematical formulation of secondary currents are Ibragimov et al. (34), Ananian (2), Ciray (18), Prasad (50), Tracy (57), Liggett et al. (42), and Odgaard (46).

One of the most significant contributions to the mathematical modeling of secondary circulation was made by Chiu and his associates (10-17). Much of Chiu's work related to secondary circulation around channel bends. He also worked in the analyses of secondary currents in straight open channels, and has indicated that whenever the three components of shearing force are not in equilibrium everywhere in a channel, the presence of secondary current is inevitable.

By introducing a coordinate transformation function, Chiu et al. (12) developed a model which appears to have considerable potential for application to natural open channel flow problems. A curvilinear orthogonal coordinate system which is constructed by computed isovels and their orthogonal trajectories forms the basis for the model. The model was used to compute secondary flows on the basis of some hydraulic data collected from the Rio Grande Canal (12, 13). Later, different functions for approximating isovels and shear stresses were used to improve the model (14-17). Comparisons of model results with measured data on the East Fork River (Wyoming) showed reasonable agreement. Field data such as cross-sectional area, discharge, depth, water surface profile, and primary velocity distribution patterns are needed to use the model.

## MATHEMATICAL MODEL

### Mathematical Derivations

This part of the report discusses the derivation of equations used in a new mathematical model for calculating secondary velocity components. The model is based primarily on Chiu's work (10-17). Detailed derivations for some functions are presented here so the mathematical model can be clearly understood.

In general, the model consists of the momentum and the continuity equations. Once the isovels for a cross section are approximated by mathematical functions, the momentum and the continuity equations are then transformed into a curvilinear coordinate system, which is based on the simulated isovels and their orthogonal trajectories. After the transformation

of these equations, one of the secondary velocity components is computed directly from the momentum equation, and the other component is derived by solving the continuity equation. Shear stresses are assumed to vary quadratically from the boundary line to the point of maximum velocity in the new coordinate system. Finally the secondary velocity components are transformed back to the cartesian coordinate system by following inverse transformation rules.

## Coordinate Transformation

### *Coordinate System*

The curvilinear coordinate system consists of two components  $\xi$  and  $\eta$  as shown in Fig. 2, where a constant value of  $\xi$  is an equal velocity line (isovel) and  $\eta$  is the coordinate perpendicular to the  $\xi$  lines. Assuming that the primary velocity distribution follows the logarithmic rule, which is reasonable for most natural channels, the velocity distribution can be represented by:

$$u = \frac{u_*}{k} \ln \frac{\xi}{\xi_0} \quad (1)$$

in which

$u$  = the primary velocity

$k$  = universal constant

$\xi$  = transformed coordinate

$\xi_0$  = coefficient characterizing the velocity distribution of the primary flow

$u_* = \sqrt{gRS_e}$  = mean shear velocity, where

$g$  = gravitational acceleration

$R$  = hydraulic radius

$S_e$  = energy slope

Eq. 1 defines the primary velocity distribution in a direction vertical to  $\xi$  curves in the channel cross section. Since  $u_*$  and  $k$  are constant at a given cross section, Eq. 1 states that for a given  $\xi$  all the velocities on this curve will have the same magnitude, i.e., a constant  $\xi$  is an isovel curve. The curve  $\xi = \xi_0$  is the line where primary velocities vanish. The coordinates of  $\xi$  and  $\eta$  in terms of  $Y$  and  $Z$  coordinates are given as (15):

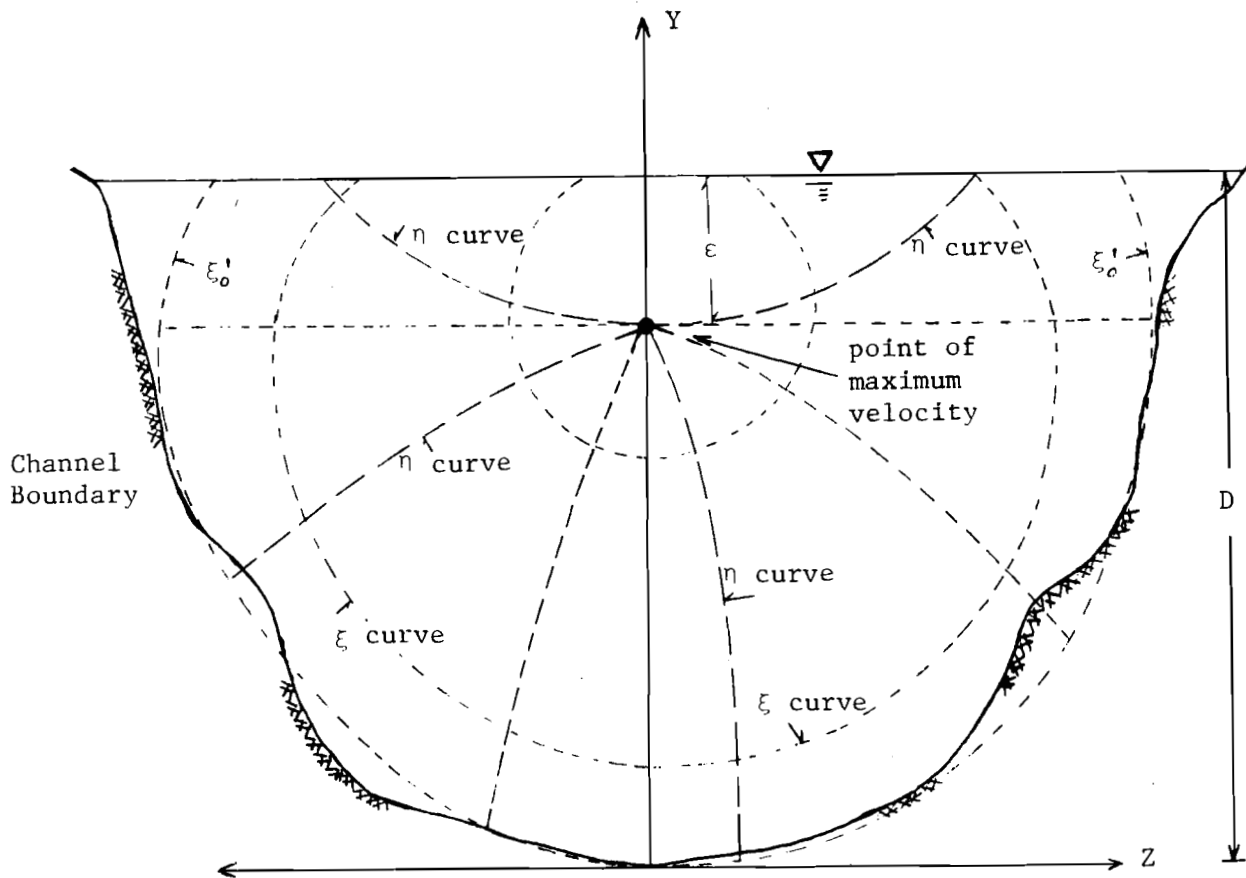


Figure 2. Curvilinear coordinate system

$$\xi = Y(1-Z)^{\beta_i} \exp(\beta_i Z - Y + 1) \quad (2)$$

$$\eta = \pm \frac{1}{Z} (|1-Y|)^{\beta_i \left[ \frac{D+\delta_y+\varepsilon}{B_i+\delta_i} \right]^2} \exp \left[ Z + \beta_i \left( \frac{D+\delta_y+\varepsilon}{B_i+\delta_i} \right) Y \right]^2 \quad (3)$$

in which

$$Y = \frac{y+\delta_y}{D+\delta_y+\varepsilon} \quad (4)$$

$$Z = \frac{|z|}{B_i+\delta_i} \quad (5)$$

$\beta_i$ ,  $\delta_i$ , and  $\delta_y$  are parameters determined from the distribution of the primary velocity;  $i = 1$  or  $2$  for either the left or right half of a cross section;  $\varepsilon$  = the distance from the water surface to the point of maximum velocity;  $B_i$  = the width of either the left or right half of a cross section; and  $D$  is the water depth (Fig. 2). The point of maximum velocity is assumed to be either below the water surface (as shown in Fig. 2 when  $\varepsilon > 0$ ), at the water surface (when  $\varepsilon = 0$ ), or above the water surface (when  $\varepsilon < 0$ ).

#### Scaling Factors

Eqs. 2 and 3 define a transformation relation between the new curvilinear coordinate system and the  $(Y, Z)$  coordinate system. The scaling factors are derived by referring to Fig. 3 and assuming that  $\vec{j}$  and  $\vec{k}$  are unit vectors in the  $Y$  and  $Z$  directions and tangent to  $\xi$  and  $\eta$  at point  $p$ ; the directions of  $\vec{j}$  and  $\vec{k}$  are in the increasing direction of  $\xi$ ,  $\eta$ ;  $\Delta S_\eta$  and  $\Delta S_\xi$  are the incremental distances along the positive  $\xi$  and  $\eta$  directions; and  $\vec{r}$  is the position vector to  $p$  from a fixed origin.

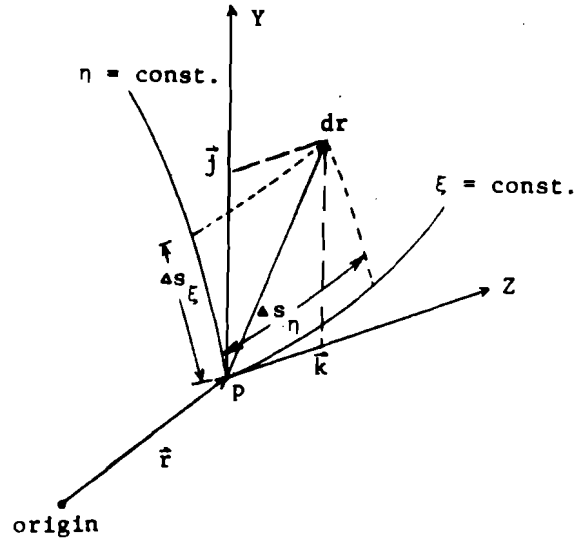


Figure 3. Relationship between the (Y-Z) coordinate system and the curvilinear coordinate system ( $\xi$ - $\eta$ ).

The derivatives of  $\vec{r}$  with respect to  $\xi$  and  $\eta$  are derived as follows:

$$\begin{aligned} \frac{\partial \vec{r}}{\partial \xi} &= \lim_{\Delta \xi \rightarrow 0} \left( \frac{\Delta \vec{r}}{\Delta \xi} \right)_{\eta=c} \\ &= \lim_{\Delta \xi \rightarrow 0} \left( \frac{\Delta \vec{r}}{\Delta s_\eta} \cdot \frac{\Delta s_\eta}{\Delta \xi} \right)_{\eta=c} \\ &= \left( \frac{\partial s_\eta}{\partial \xi} \right)_P \cdot \left( \frac{\partial \vec{r}}{\partial s_\eta} \right)_P \\ &= \left( \frac{\partial s_\eta}{\partial \xi} \right)_P \cdot \vec{k} \end{aligned}$$

Set  $h_\xi = \frac{\partial s_\eta}{\partial \xi}$

Then

$$h_\xi \cdot \vec{k} = \frac{\partial \vec{r}}{\partial \xi}$$

Similarly

$$h_\eta \cdot \vec{j} = \frac{\partial \vec{r}}{\partial \eta}$$



On the other hand, the derivations of  $\vec{r}$  with respect to  $\xi$  and  $\eta$  can be written in terms of Y and Z as:

$$\frac{\partial \vec{r}}{\partial \xi} + \frac{\partial \vec{r}}{\partial \eta} = \left( \frac{\partial Y}{\partial \xi} + \frac{\partial Y}{\partial \eta} \right) \vec{j} + \left( \frac{\partial Z}{\partial \xi} + \frac{\partial Z}{\partial \eta} \right) \vec{k}$$

By using the above relations the following equations are derived:

$$h_{\xi}^2 = \left( \frac{\partial Y}{\partial \xi} \right)^2 + \left( \frac{\partial Z}{\partial \xi} \right)^2 \quad (6)$$

and

$$h_{\eta}^2 = \left( \frac{\partial Y}{\partial \eta} \right)^2 + \left( \frac{\partial Z}{\partial \eta} \right)^2 \quad (7)$$

The differentials of  $\xi$  and  $\eta$  with respect to Y and Z can be obtained from Eqs. 2 and 3 directly. They are:

$$\frac{\partial \xi}{\partial Y} = (1-Y)(1-Z)^{\beta_i} \exp(\beta_i Z - Y + 1) \quad (8)$$

$$\frac{\partial \xi}{\partial Z} = \beta_i (1-Z)^{\beta_i} Y \exp(\beta_i Z - Y + 1) \left( -\frac{Z}{1-Z} \right) \quad (9)$$

$$\text{For } Y < 1 \quad \frac{\partial \eta}{\partial Y} = \frac{1}{Z} C_i (1-Y)^{C_i} \exp(Z + C_i Y) \left( \frac{-Y}{1-Y} \right) \quad (10)$$

$$\frac{\partial \eta}{\partial Z} = \frac{1}{Z} (1-Y)^{C_i} \exp(Z + C_i Y) \left( 1 - \frac{1}{Z} \right) \quad (11)$$

$$\text{For } Y > 1 \quad \frac{\partial \eta}{\partial Y} = \frac{1}{Z} C_i (Y-1)^{C_i} \exp(Z + C_i Y) \left( \frac{-Y}{Y-1} \right) \quad (12)$$

$$\frac{\partial \eta}{\partial Z} = \frac{1}{Z} (Y-1)^{C_i} \exp(Z + C_i Y) \left( \frac{1-Z}{Z} \right) \quad (13)$$

where

$$C_i = \beta_i \left[ \frac{D + \delta_y + \varepsilon}{B_i + \delta_i} \right]^2 \quad (14)$$

The differentials of Y and Z with respect to  $\xi$  and  $\eta$  can be obtained from equations 8 to 13 as follows:

$$\frac{\partial Y}{\partial \xi} = \frac{Y(1-Z)^2(1-Y)}{[(1-Y)^2(1-Z)^2 + \beta_i C_i Y^2 Z^2]} \cdot \frac{1}{\xi} \quad (15)$$

$$\frac{\partial Z}{\partial \xi} = \frac{-C_i Y^2 Z (1-Z)}{[(1-Y)^2 (1-Z)^2 + \beta_i C_i Y^2 Z^2]} \cdot \frac{1}{\xi} \quad (16)$$

$$\frac{\partial Y}{\partial \eta} = \frac{-\beta_i Y Z^2 (1-Y)}{[(1-Y)^2 (1-Z)^2 + \beta_i C_i Y^2 Z^2]} \cdot \frac{1}{\eta} \quad (17)$$

$$\frac{\partial Z}{\partial \eta} = \frac{-Z (1-Y)^2 (1-Z)}{[(1-Y)^2 (1-Z)^2 + \beta_i C_i Y^2 Z^2]} \cdot \frac{1}{\eta} \quad (18)$$

The scaling factors can now be derived from Eqs. 6 and 7, and Eqs. 15 to 18. As given by Chiu and Lin (16) the relations for  $h_\xi$  and  $h_\eta$  are:

$$h_\xi = \frac{(D + \delta_y + \varepsilon)(1-Z) Y}{\xi \sqrt{(1-Y)^2 (1-Z)^2 + C_i^2 Y^2 Z^2}} \quad (19)$$

$$h_\eta = \frac{(B_i + \delta_i)}{(D + \delta_y + \varepsilon)} \cdot \frac{\xi}{\eta} \cdot \frac{Z (1-Y)}{Y (1-Z)} h_\xi \quad (20)$$

#### Derivation of the Equation for the $V_\xi$ Velocity Component

The momentum equation in the curvilinear coordinate system is derived on the assumption that the control volume in Fig. 4 represents a volume of water in the curvilinear coordinate system.

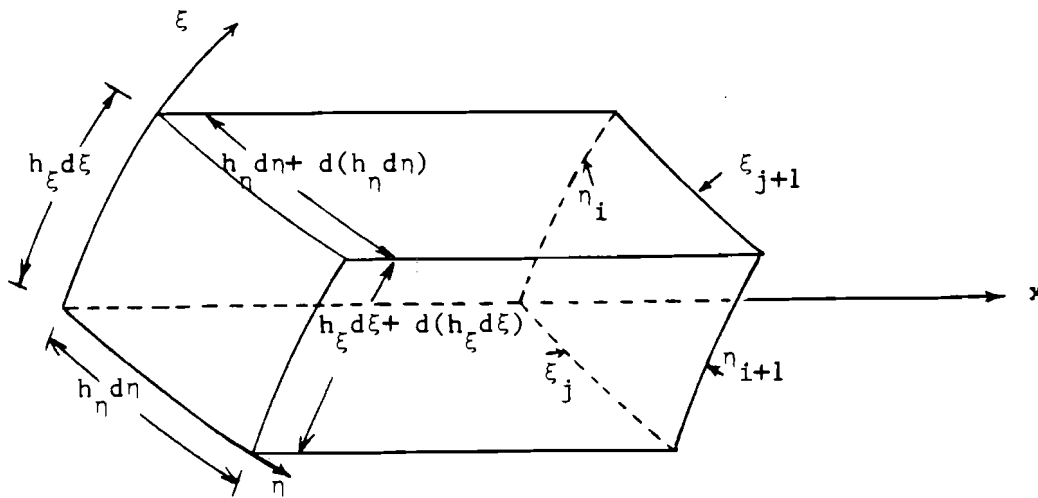


Figure 4. A control volume in the curvilinear coordinate system

Since each  $\xi = \xi_j$  line in Fig. 4 represents an equal primary velocity line, there is no change of primary velocity along this  $\xi$  line, i.e.,

$$\left. \frac{\partial u_j}{\partial \eta} \right|_{\xi=\xi_j} = 0$$

where  $u_j$  is the primary velocity on the  $j^{\text{th}}$  isovel. The longitudinal component of the momentum equation in cartesian coordinates is given as :

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} = -\frac{1}{\rho} \left[ \frac{\partial}{\partial x} (p + \rho g H) - \left( \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} \right) \right] \quad (21)$$

in which

$x, y, z$  are the coordinates

$t$  = the time

$u$  = the primary velocity in  $x$  direction

$v$  = the velocity components in  $y$  direction

$w$  = the velocity component in  $z$  direction

$\rho$  = the water density

$p$  = the hydrostatic pressure

$g$  = gravitational acceleration

$H$  = distance from the channel bottom to a datum

$\tau_{ix}$  = is the shear stress on the  $i^{\text{th}}$  face acting in the  $x$  direction in which  $i = x, y, \text{ or } z$ .

This equation can be written in  $x, Y, Z$  coordinates directly using the transformation equations given in Eqs. 4 and 5. Since the partial derivatives are as shown in the following equation:

$$\begin{aligned} \partial Y &= \partial y \\ \partial Z &= \begin{cases} \partial z & \text{if } z > 0 \\ -\partial z & \text{if } z < 0 \end{cases} \end{aligned} \quad (22)$$

Eq. 22 will change in sign only for  $z < 0$ .

The transformation relationship between  $Y, Z$  coordinates and  $\xi, \eta$  coordinates can be written in a general form as follows:

$$\begin{aligned} \vec{e}_\xi &= h_\xi \frac{\partial \xi}{\partial Y} \vec{j} + h_\xi \frac{\partial \xi}{\partial Z} \vec{k} \\ \vec{e}_\eta &= h_\eta \frac{\partial \eta}{\partial Y} \vec{j} + h_\eta \frac{\partial \eta}{\partial Z} \vec{k} \end{aligned} \quad (23)$$

in which  $\vec{e}_\xi$  and  $\vec{e}_\eta$  are unit vectors in the  $\xi$  and  $\eta$  directions, respectively, and  $\vec{j}$  and  $\vec{k}$  are unit vectors in the Y and Z directions, respectively.

Using Eq. 23, the transformation relationships for the velocity components between the two coordinate systems can be written as:

$$V_\xi = h_\xi \frac{\partial \xi}{\partial Y} v + h_\xi \frac{\partial \xi}{\partial Z} w \quad (24)$$

$$V_\eta = h_\eta \frac{\partial \eta}{\partial Y} v + h_\eta \frac{\partial \eta}{\partial Z} w$$

where  $V_\xi$  and  $V_\eta$  are velocity components in the  $\xi$  and  $\eta$  directions, respectively. Since  $\xi$  and  $\eta$  are orthogonal to each other as are the Y and Z coordinates, the following relations exist:

$$h_\eta \frac{\partial \eta}{\partial Y} = - h_\xi \frac{\partial \xi}{\partial Z} \quad (25)$$

$$h_\xi \frac{\partial \xi}{\partial Y} = h_\eta \frac{\partial \eta}{\partial Z}$$

These can be proved by referring to Fig. 5.

$$h_\eta \frac{\partial \eta}{\partial Y} = \cos (\eta, Y) = \sin (Y, \xi)$$

$$h_\xi \frac{\partial \xi}{\partial Z} = \cos (\xi, Z) = \cos (Z, \eta) = - \sin (Y, \xi)$$

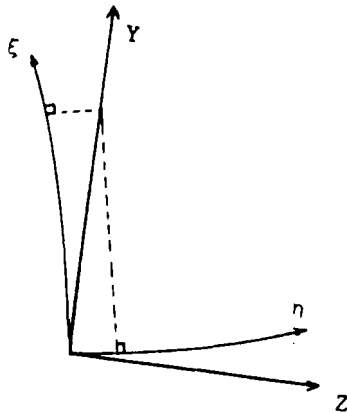


Figure 5. Definition sketch for derivatives between Y, Z and  $\xi$ ,  $\eta$

Therefore,

$$h_{\eta} \frac{\partial \eta}{\partial Y} = - h_{\xi} \frac{\partial \xi}{\partial Z}$$

By definition,

$$\text{angle}(Z, \eta) + \text{angle}(\eta, Y) = \text{angle}(\eta, Y) + \text{angle}(Y, \xi)$$

Thus,

$$\text{angle}(Z, \eta) = \text{angle}(Y, \xi).$$

Similarly,

$$h_{\xi} \frac{\partial \xi}{\partial Y} = \cos(\xi, Y)$$

$$h_{\eta} \frac{\partial \eta}{\partial Z} = \cos(\eta, Z)$$

Therefore

$$h_{\xi} \frac{\partial \xi}{\partial Y} = h_{\eta} \frac{\partial \eta}{\partial Z}$$

Now the left hand side (LHS) of the momentum equation (Eg. 21) can be rewritten as:

$$\begin{aligned} \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} &= \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + [v \left( \frac{\partial u}{\partial \xi} \frac{\partial \xi}{\partial Y} + \frac{\partial u}{\partial \eta} \frac{\partial \eta}{\partial Y} \right) + w \left( \frac{\partial u}{\partial \xi} \frac{\partial \xi}{\partial Z} + \frac{\partial u}{\partial \eta} \frac{\partial \eta}{\partial Z} \right)] \\ &= \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + [v \left( \frac{\partial u}{\partial \xi} \frac{\partial \xi}{\partial Y} \right) + w \left( \frac{\partial u}{\partial \xi} \frac{\partial \xi}{\partial Z} \right)] \\ &= \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + \left( v \frac{\partial \xi}{\partial Y} + w \frac{\partial \xi}{\partial Z} \right) \frac{\partial u}{\partial \xi} \\ &= \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + \frac{V_{\xi}}{h_{\xi}} \frac{\partial u}{\partial \xi} \end{aligned} \quad (26)$$

where only one velocity component,  $V_{\xi}$ , is retained.

The transformation of the right hand side (RHS) of the momentum equation into  $\xi$  and  $\eta$  coordinates can also proceed as follows:

The shear stresses in the x direction can be written as

$$\begin{aligned} \tau_{Yx} &= (\tau_{\xi x} \cdot \vec{e}_{\xi} + \tau_{\eta x} \cdot \vec{e}_{\eta}) \cdot \vec{j} \\ \tau_{Zx} &= (\tau_{\xi x} \cdot \vec{e}_{\xi} + \tau_{\eta x} \cdot \vec{e}_{\eta}) \cdot \vec{k} \end{aligned} \quad (27)$$

Since there is no velocity change in the  $\eta$  direction on each  $\xi$  curve,

$$\tau_{\eta x} = 0 \quad (28)$$

Substituting this equation, as well as Eq. 23, into Eq. 27 results in the following equations:

$$\tau_{Yx} = \tau_{\xi x} \cdot h_{\xi} \frac{\partial \xi}{\partial Y} \quad (29)$$

$$\tau_{Zx} = \tau_{\xi x} \cdot h_{\xi} \frac{\partial \xi}{\partial Z}$$

Using the chain rule for derivatives, the following relations can be derived.

$$\frac{\partial \tau_{Yx}}{\partial Y} = \frac{\partial \tau_{Yx}}{\partial \xi} \frac{\partial \xi}{\partial Y} + \frac{\partial \tau_{Yx}}{\partial \eta} \frac{\partial \eta}{\partial Y} \quad (30)$$

$$\frac{\partial \tau_{Zx}}{\partial Z} = \frac{\partial \tau_{Zx}}{\partial \xi} \frac{\partial \xi}{\partial Z} + \frac{\partial \tau_{Zx}}{\partial \eta} \frac{\partial \eta}{\partial Z}$$

Substituting Eq. 29 into Eq. 30 gives:

$$\frac{\partial \tau_{Yx}}{\partial Y} = \frac{\partial}{\partial \xi} (\tau_{\xi x} \cdot h_{\xi}) \left( \frac{\partial \xi}{\partial Y} \right)^2 + \frac{\partial}{\partial \eta} (\tau_{\xi x} \cdot h_{\xi}) \left( \frac{\partial \xi}{\partial Y} \cdot \frac{\partial \eta}{\partial Y} \right) \quad (31)$$

$$\frac{\partial \tau_{Zx}}{\partial Z} = \frac{\partial}{\partial \xi} (\tau_{\xi x} \cdot h_{\xi}) \cdot \left( \frac{\partial \xi}{\partial Z} \right)^2 + \frac{\partial}{\partial \eta} (\tau_{\xi x} \cdot h_{\xi}) \left( \frac{\partial \xi}{\partial Z} \cdot \frac{\partial \eta}{\partial Z} \right)$$

Summation of the two terms results in the following:

$$\frac{\partial \tau_{Zx}}{\partial Z} + \frac{\partial \tau_{Yx}}{\partial Y} = \frac{\partial}{\partial \xi} (\tau_{\xi x} \cdot h_{\xi}) \left[ \left( \frac{\partial \xi}{\partial Y} \right)^2 + \left( \frac{\partial \xi}{\partial Z} \right)^2 \right] + \frac{\partial}{\partial \eta} (\tau_{\xi x} \cdot h_{\xi}) \left[ \frac{\partial \xi}{\partial Y} \frac{\partial \eta}{\partial Y} + \frac{\partial \xi}{\partial Z} \frac{\partial \eta}{\partial Z} \right] \quad (32)$$

From Eq. 25 and the equations derived from Fig. 5, the following relations can be derived:

$$\left( \frac{\partial \xi}{\partial Y} \right)^2 + \left( \frac{\partial \xi}{\partial Z} \right)^2 = \left( \frac{1}{h_{\xi}} \right)^2$$

$$\frac{\partial \xi}{\partial Y} \frac{\partial \eta}{\partial Y} + \frac{\partial \xi}{\partial Z} \frac{\partial \eta}{\partial Z} = -\frac{1}{h_{\xi}} \frac{1}{h_{\eta}} \cos(\xi, Y) \sin(\xi, Y) + \frac{1}{h_{\xi}} \frac{1}{h_{\eta}} \cos(\eta, Z) \sin(\xi, Y) = 0$$

Substituting the above relations into Eq. 32 results in the following equation:

$$\begin{aligned}\frac{\partial \tau_{Yx}}{\partial Y} + \frac{\partial \tau_{Zx}}{\partial Z} &= \frac{1}{h_\xi^2} \frac{\partial}{\partial \xi} (\tau_{\xi x} h_\xi) \\ &= \frac{\tau_{\xi x}}{h_\xi^2} \frac{\partial}{\partial \xi} (h_\xi) + \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x})\end{aligned}$$

The RHS of the momentum equation can now be rewritten as:

$$\begin{aligned}& - \frac{1}{\rho} \left[ \frac{\partial}{\partial x} (p + \rho gH) - \left( \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{Yx}}{\partial Y} + \frac{\partial \tau_{Zx}}{\partial Z} \right) \right] \\ &= - \frac{1}{\rho} \left[ \frac{\partial}{\partial x} (p + \rho gH) - \frac{\partial}{\partial x} (\tau_{xx}) - \frac{\tau_{\xi x}}{h_\xi^2} \frac{\partial}{\partial \xi} h_\xi - \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x}) \right]\end{aligned}$$

An equation to further simplify the term involving  $h_\xi^2$  is derived as follows.

Since  $h_\xi \frac{\partial \xi}{\partial Y} = h_\eta \frac{\partial \eta}{\partial Z}$ , differentiating both sides by  $\xi$  and using the same relationship again results in

$$\frac{1}{h_\xi} \frac{\partial h_\xi}{\partial \xi} = \frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi}$$

This equation is substituted into the transformed RHS equation above; then

$$\text{RHS} = - \frac{1}{\rho} \left[ \frac{\partial}{\partial x} (p + \rho gH) - \frac{\partial}{\partial x} (\tau_{xx}) - \frac{\tau_{\xi x}}{h_\xi} \frac{h_\eta}{h_\eta} \frac{\partial}{\partial \xi} - \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x}) \right]$$

Equating the transformed LHS and RHS equations results in the following momentum equation.

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + \frac{v_\xi}{h_\xi} \frac{\partial u}{\partial \xi} = \frac{1}{\rho} \left[ \frac{\partial}{\partial x} (p + \rho gH) - \frac{\partial}{\partial x} (\tau_{xx}) - \frac{\tau_{\xi x}}{h_\xi h_\eta} \frac{\partial h_\eta}{\partial \xi} - \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x}) \right]$$

or

$$v_\xi \left( \frac{\rho}{h_\xi} \frac{\partial u}{\partial \xi} \right) = - \rho \frac{\partial u}{\partial t} - \rho u \frac{\partial u}{\partial x} - \frac{\partial}{\partial x} (p + \rho gH) + \frac{\partial}{\partial x} (\tau_{xx}) + \frac{\tau_{\xi x}}{h_\xi h_\eta} \frac{\partial h_\eta}{\partial \xi} + \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x})$$

or

$$v_\xi = \left( \frac{\rho}{h_\xi} \frac{\partial u}{\partial \xi} \right)^{-1} \left[ - \rho \frac{\partial u}{\partial t} - \rho u \frac{\partial u}{\partial x} - \frac{\partial}{\partial x} (p + \rho gH) + \frac{\partial}{\partial x} (\tau_{xx}) + \frac{\tau_{\xi x}}{h_\xi h_\eta} \frac{\partial h_\eta}{\partial \xi} + \frac{1}{h_\xi} \frac{\partial}{\partial \xi} (\tau_{\xi x}) \right] \quad (33)$$

where the velocity component in the  $\xi$  direction is isolated from the velocity component in the  $\eta$  direction.

### Derivation of the Equation for the $V_\eta$ Velocity Component

The continuity equation in the  $x, Y, Z$  coordinate system is

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial Y} + \frac{\partial w}{\partial Z} = 0$$

Applying the transformation rule between the two coordinate systems on  $\partial v/\partial Y$  and  $\partial w/\partial Z$  results in the following relation:

$$\frac{\partial v}{\partial Y} + \frac{\partial w}{\partial Z} = \frac{1}{h_\xi h_\eta} \left[ \frac{\partial}{\partial \xi} (h_\eta V_\xi) + \frac{\partial}{\partial \eta} (h_\xi V_\eta) \right]$$

The continuity equation in the curvilinear coordinate system is therefore:

$$\frac{\partial u}{\partial x} + \frac{1}{h_\xi h_\eta} \left[ \frac{\partial}{\partial \xi} (h_\eta V_\xi) + \frac{\partial}{\partial \eta} (h_\xi V_\eta) \right] = 0$$

or

$$\frac{\partial}{\partial \eta} (h_\xi V_\eta) = - h_\xi h_\eta \frac{\partial u}{\partial x} - \frac{\partial}{\partial \xi} (h_\eta V_\xi)$$

Integrating both sides of this equation results in:

$$h_\xi V_\eta = - \int_{\eta^*}^{\eta} \left[ (h_\xi h_\eta \frac{\partial u}{\partial x} + \frac{\partial}{\partial \xi} (h_\eta V_\xi)) \right] d\eta + C$$

in which

$\eta^*$  = the  $\eta$  value on the water surface

$C$  = an integration constant

The integration constant can be determined by using the boundary condition on the water surface. The continuity equation in the  $x, \xi, \eta$  coordinate system can finally be written as:

$$V_\eta = - \frac{1}{h_\xi} \int_{\eta^*}^{\eta} \left[ (h_\xi h_\eta \frac{\partial u}{\partial x} + \frac{\partial}{\partial \xi} (h_\eta V_\xi)) \right] d\eta + V_{\eta^*} \quad (34)$$

where  $V_{\eta^*}$  is the velocity  $V_\eta$  at point  $(\xi, \eta^*)$ . The velocity component in the  $\eta$  direction is therefore computed from Eq. 34.

### Approximation of Shear Stresses

To compute the velocity component  $V_\xi$  from Eq. 33, the shear stresses are needed. However, the shear stresses are also dependent on the velocity components. Therefore an additional equation is needed to solve the shear stresses and velocities. The additional equation is provided from the



distribution of shear stress in the new coordinate system. Chiu and Hsiung (14) assumed that the shear stress varies quadratically in the  $\xi$  direction as follows:

$$\tau_{\xi x}(\xi, \eta) = \alpha_0 + \alpha_1[\xi_{\max}(\eta) - \xi] + \alpha_2[\xi_{\max}(\eta) - \xi]^2 \quad (35)$$

in which  $\alpha_0$ ,  $\alpha_1$ , and  $\alpha_2$  are coefficients and  $\xi_{\max}(\eta)$  is the maximum  $\xi$  value on an  $\eta$  curve. The coefficients  $\alpha_0$ ,  $\alpha_1$ , and  $\alpha_2$  are determined from boundary conditions. As developed by Chiu, these are:

a)  $\varepsilon < 0$  (the point of maximum velocity is below the water surface)

$$\alpha_0 = 0 \quad (36)$$

$$\alpha_1 = f_1(\xi_0', \eta) \quad (37)$$

in which

$\xi_0' = \xi$  curve that approximates the channel boundary and

$$f_1(\xi, \eta) = \frac{-h_\xi F_0 - \alpha_2 \left(2 - \frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi} [\xi_{\max}(\eta) - \xi]\right) (\xi_{\max}(\eta) - \xi)}{1 - \frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi} [\xi_{\max}(\eta) - \xi]}$$

where

$$F_0 = \rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} \right) + \frac{\partial}{\partial x} (p + \rho g H) - \frac{\partial \tau_{xx}}{\partial x} \quad (38)$$

$\xi_{\max}(\eta) = 1$  for  $\eta$  curves that intersect with the stream banks or bed. For  $\eta$  curves that intersect with the water surface, it can be reasonably assumed that  $\tau_{\xi\eta} = 0$  if the wind effects are ignored; then

$$\alpha_1 = -\alpha_2 [1 - \xi_D(\eta)] \quad (39)$$

where  $\xi_D(\eta)$  is the  $\xi$  value of this  $\eta$  curve at the water surface.

$$\alpha_2 = \frac{-1}{[\xi_{\max}(\eta) - \xi_0' f_2(\eta)] [\rho g S_f + h_\xi F_0 f_2(\eta)]} \quad (40)$$

in which

$$f_2(\eta) = \frac{\xi_{\max}(\eta) - \xi_0'}{1 - \frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi} [\xi_{\max}(\eta) - \xi_0']} \quad (41)$$

and the overbar means the average value over the wetted perimeter, which is computed as

$$\bar{A} = \frac{1}{\text{W.P.}} \int_{\text{W.P.}}^A h_{\eta} (\xi_0', \eta) d\eta \quad (42)$$

and W.P. = total length of wetted perimeter.

b)  $\varepsilon = 0$  (the point of maximum velocity is on the water surface). For this case, Eqs. 36, 37, and 40 can still be used.

c)  $\varepsilon > 0$  (the point of maximum velocity is above the water surface). In this case the maximum value of  $\xi(\eta)$  at the water surface is

$$\xi_{\max}(\eta) = \xi_0(\eta)$$

and Eqs. 36, 37, and 40 are still valid.

#### Computer Model

The mathematical equations for computing the secondary velocities were presented in the preceding section. The equations, which were established in cartesian (x, y, z) coordinates, were first translated into the cross-section-wise (x, Y, Z) coordinates, and were then transformed into the curvilinear (x,  $\xi$ ,  $\eta$ ) coordinates. Several parameters were used in these translation and transformation processes. The functions of these parameters were to relate the channel geometry and primary velocity distribution pattern to the governing equations.

After the equations in the curvilinear coordinate system are established, the computations are carried out in a grid system constructed on the ( $\xi$ ,  $\eta$ ) coordinates. The secondary velocities in the (x, y, z) coordinate system are obtained by using inverse transformations.

The overall computational procedures are hence separated into two phases. Phase I determines the best fitted coefficients  $\xi_i$ ,  $\beta_i$ , k,  $\delta_y$ ,  $\xi_0'$ , and  $\xi_0$  for approximating the primary velocity distribution and the channel geometry. Phase II uses these parameters to construct a computational grid system and carries out the computations for secondary circulation. In order to make a clear presentation of the model, two flow charts, shown in Figs. 6 and 7, are used to illustrate the computational procedures.

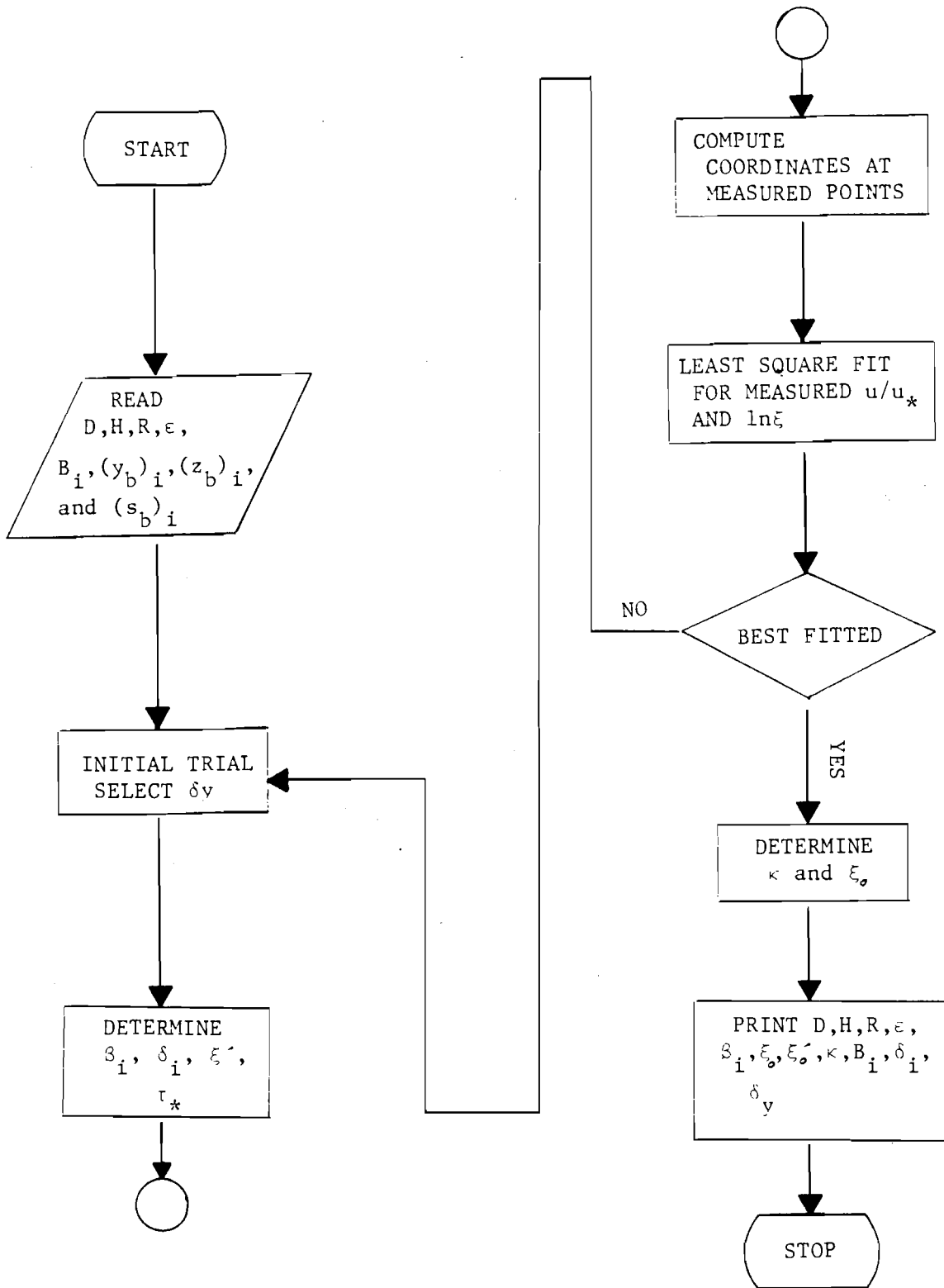


Figure 6. Flow chart of phase I analysis

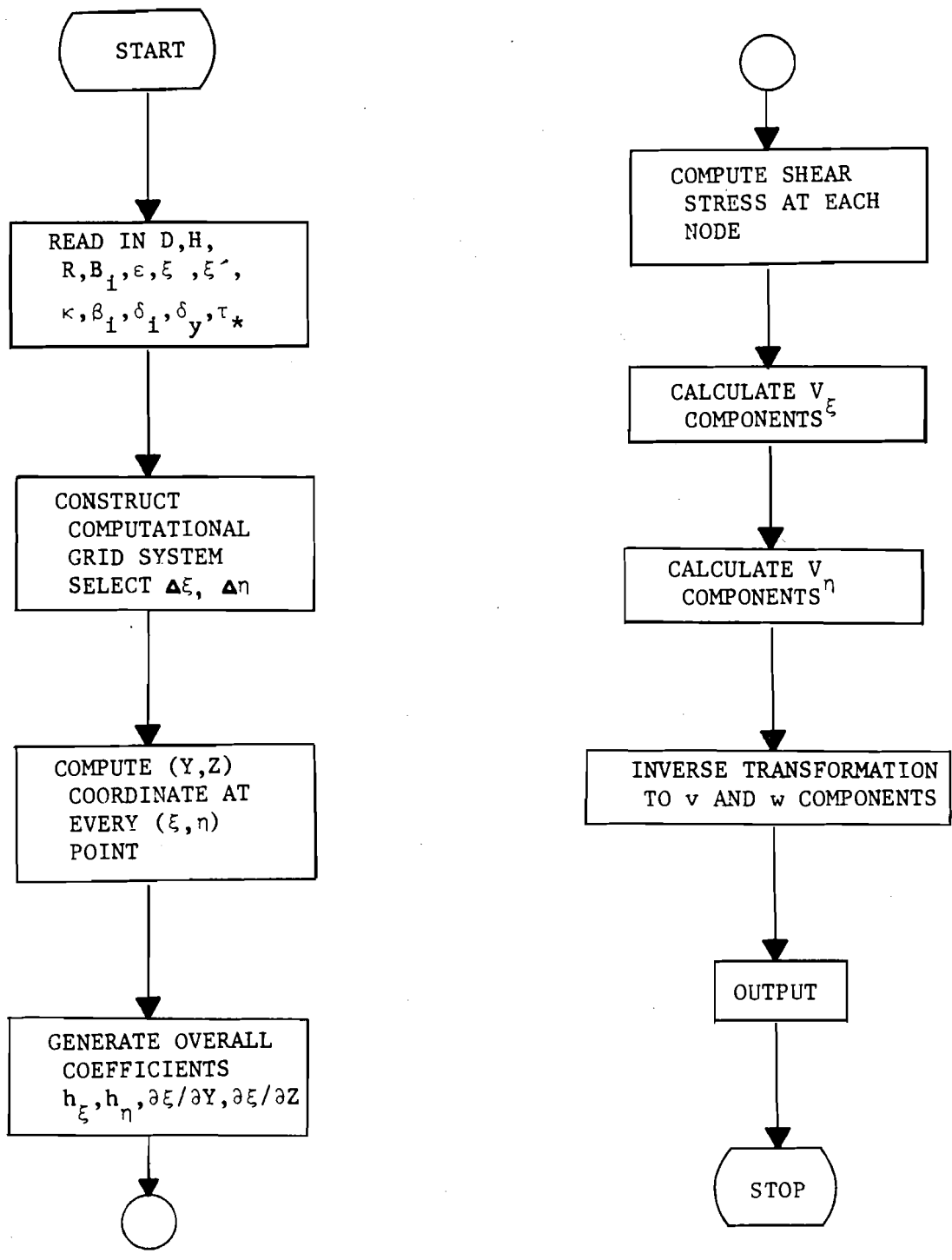


Figure 7. Flow chart of phase II analysis

### Phase I Analysis

The Phase I analysis performs the following functions: 1) analyzes field data and determines parameters; 2) derives parameters for Phase II computations.

The channel cross section and isovels of the measured primary velocities are plotted first. Then determinations are made of the mean elevation of the channel bottom,  $H$ ; the hydraulic radius,  $R$ ; and the distance from the water surface to the point of maximum velocity,  $\epsilon$  (Fig. 8). The axis which passes through the point of maximum velocity divides the channel cross section into two computational halves, as defined by subscripts  $i = 1$  or  $2$  previously. The water surface width of each half,  $B_i$ , and the water depth  $D$  are then determined. Before proceeding to the steps described in Fig. 6, additional data need to be determined. These include  $(y_b, z_b)_i$ , and the corresponding slopes  $S_i$  for each bank. This information is needed for the following computations.

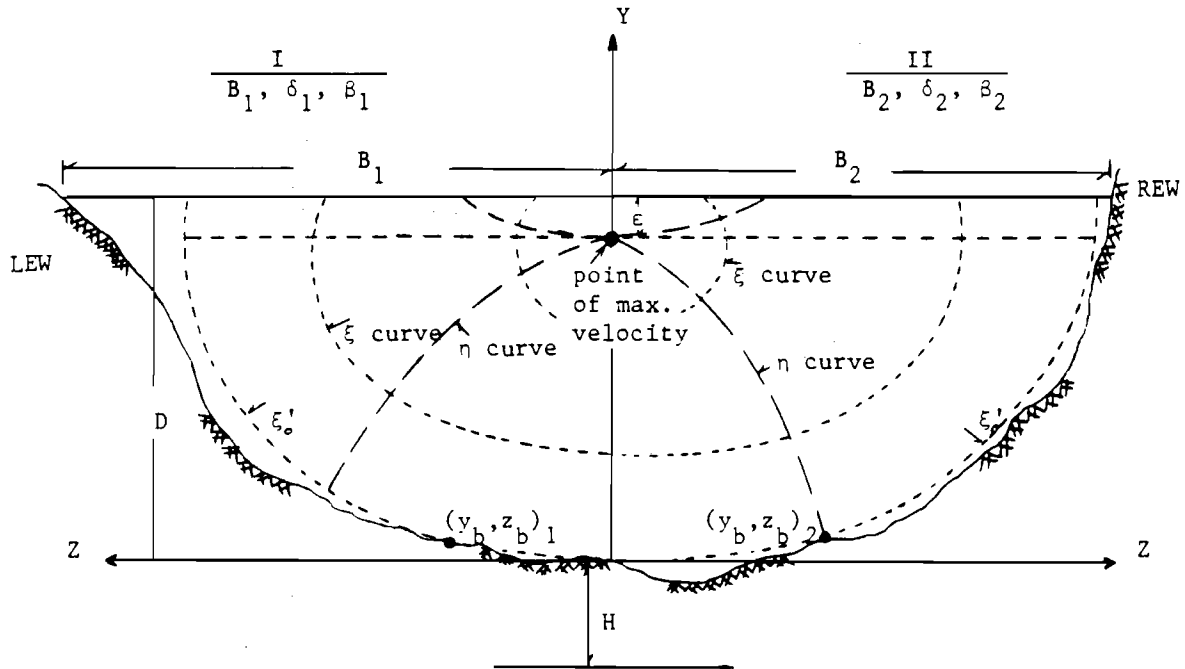


Figure. 8. Definition sketch for field parameters

On the assumption that the  $\xi_0'$  curve approximates the channel geometry, this curve should pass through  $(y_b, z_b)$ . At such a point, the slope of the  $\xi_0'$  curve (i.e. boundary) is

$$\begin{aligned} S_{\xi} &= \frac{\partial y}{\partial \xi} = \frac{\partial \xi}{\partial \xi / \partial y} = \frac{(\partial \xi / \partial z)(\partial z / \partial \xi)}{(\partial \xi / \partial Y)(\partial Y / \partial y)} \\ &= \beta_i \frac{D + \delta_y + \varepsilon}{B_i + \delta_i} \frac{Y \cdot Z}{(1-Z)(1-Y)} \end{aligned} \quad (43)$$

Equation 43 can be rewritten as

$$\beta_i = (S_{\xi}) \frac{B_i + \delta_i}{D + \delta_y + \varepsilon} \frac{(B_i + \delta_i - z_b)(D + \varepsilon - y_b)}{z_b(Y_b + \delta_y)} \quad (44)$$

On the other hand, the  $\xi_0'$  curve can also be described, by using Eq. 2, as

$$\xi_0' = \frac{y_b + \delta_y}{D + \delta_y + \varepsilon} \left(1 - \frac{|z_b|}{B_i + \delta_i}\right)^{\beta_i} \exp\left(\frac{\beta_i |z_b|}{B_i + \delta_i} - \frac{y_b + \delta_y}{D + \delta_y + \varepsilon} + 1\right) \quad (45)$$

or as

$$\beta_i = \frac{\ln(\delta_y) - \ln(y_b + \delta_y) + y_b / (D + \delta_y + \varepsilon)}{z_b / (B_i + \delta_i) + \ln(B_i + \delta_i - |z_b|) - \ln(B_i + \delta_i)} \quad (46)$$

This  $\beta_i$  value is the same  $\beta_i$  value described by Eq. 44. Moreover, the boundary condition at the origin gives the  $\xi_0'$  value as

$$\xi_0' = \frac{\delta_y}{D + \delta_y + \varepsilon} \exp\left(-\frac{\delta_y}{D + \delta_y + \varepsilon} + 1\right) \quad (47)$$

which is derived from Eq. 45 by setting  $y_b = z_b = 0$ . Equating Eqs. 44 and 46 gives an equation which contains two unknowns:  $\delta_i$  and  $\delta_y$ . By assuming a  $\delta_y$  value,  $\delta_i$  and  $\beta_i$  values can be computed. Therefore an iterative procedure to determine the  $\delta_i$  and  $\beta_i$  values is used to generate the closest computed velocity distribution to the measured primary velocities in a given channel.

Since the boundary curve  $\xi_0'$  and all the other  $\xi$  curves have to fit a logarithmic velocity distribution as described in Eq. 1, the following iterative steps depicted in Fig. 6 are used to determine the coefficients needed for Phase II.

- (1) assume trial  $\delta_y$  values
- (2) calculate  $\delta_i$  from Eq. 44 and Eq. 46
- (3) compute  $\beta_i$

- (4) compute  $\xi$  values at every data point where  $u$  is measured
- (5) perform linear regression on  $u/u_*$  and  $\ln \xi$
- (6) determine  $k$  and  $\xi_0$  from intercept and slopes of step (5)
- (7) repeat step (1) to step (6)

The  $\xi_0$  value obtained in step 6 is the line which defines zero velocity, while the  $\xi_0'$  line is the line which approximates the boundary. The best fitted coefficients are those coefficients which generate a primary velocity distribution that has the least standard deviation in comparison with the measured velocities.

The measured hydraulics parameters, i.e.,  $D$ ,  $B_1$ ,  $\varepsilon$ ,  $H$ ,  $R$ , and the derived parameters  $\delta_1$ ,  $\beta_1$ ,  $k$ ,  $\xi_0$ ,  $\xi_0'$ , and  $\tau_*$ , are then transmitted to Phase II for velocity and shear stress computations.

### Phase II Analysis

The Phase II analysis involves solving the equations discussed in the last section for field variables. The parameters, determined from field data in Phase I, relate these equations to local hydraulic conditions. The characteristics of these equations require building the computations on a grid system, similar to that of a finite difference method. Using the  $\xi$  and  $\eta$  curves to form the grid, field data parameters are calculated at the grid nodal points. Also many variables (e.g.,  $h_\xi$  and  $h_\eta$ ) require the corresponding  $Y$ ,  $Z$  coordinate values in their calculations. Consequently the  $Y$ ,  $Z$  coordinates at each grid point have to be retrieved.

### Grid System Construction

The grid system is constructed by drawing  $\xi$  curves and  $\eta$  curves with predetermined  $\Delta\xi$  and  $\Delta\eta$  intervals, between the maximum  $\xi$  and  $\eta$  values and the minimum  $\xi$  and  $\eta$  values. These maximum and minimum  $\xi$  and  $\eta$  values can be derived from Eqs. 2 and 3 once the parameters which depend on field data are determined through Phase I analysis, but the  $\Delta\xi$  and  $\Delta\eta$  values have to be determined by trial and error. The  $\Delta\xi$  and  $\Delta\eta$  values, once determined, are used in the numerical evaluation of the velocity components  $V_\xi$  and  $V_\eta$ , and significantly affect the accuracy and cost of computations. From Eq. 34 it can be seen that a smaller  $\Delta\eta$  value will give greater accuracy in the numerical integration. On the other hand, a larger  $\Delta\eta$  value will result in a shorter computation time. It is therefore desirable to have the  $\Delta\eta$  value as

large as possible and to keep the computational error within an allowable range.

The  $\Delta\eta$  values, however, depend on  $\Delta\xi$  (Eq. 34) values. The  $\Delta\xi$  value becomes available in the numerical evaluation of derivatives with respect to  $\xi$ . Finer  $\Delta\xi$  values are needed near the channel boundary areas, since the primary velocity gradient is the highest at this location. The derivatives with respect to  $\xi$ , when evaluated by a numerical method, produce error. This error is the sum of two errors, truncation and rounding off. The round-off error is negligible on a large machine such as the CDC-6400 that carries numbers to 5 digits beyond the decimal point; therefore the  $\Delta\xi$  value is selected to minimize the truncation error. The computation of  $\Delta h_{\xi}/h_{\eta}\xi$  (in Eq. 33) is used for checking this  $\Delta\xi$  selection. Two examples of a grid system generated using the procedures above are illustrated in Fig. 9.

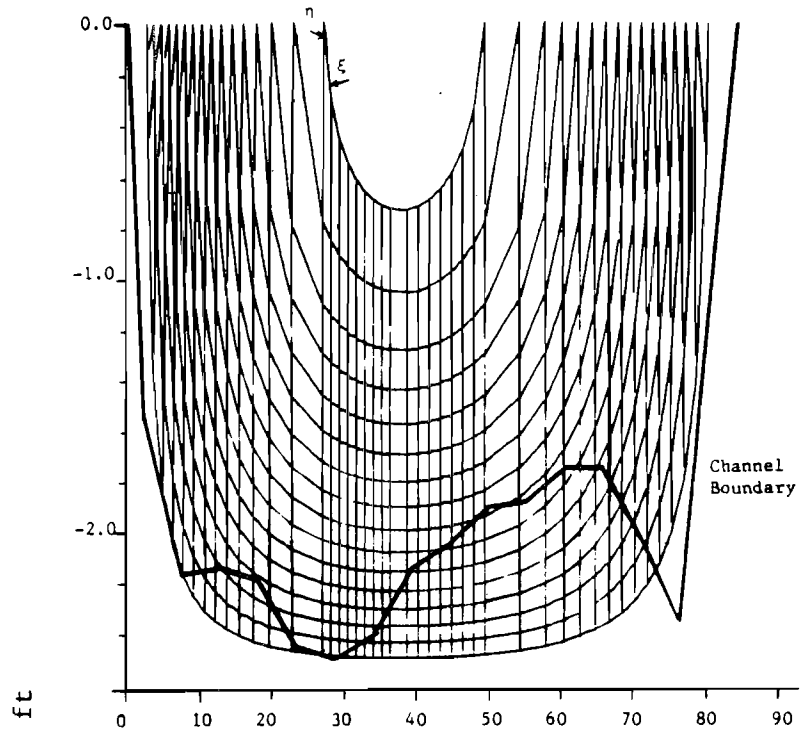
#### *Solving for (Y,Z) Given ( $\xi,\eta$ )*

The values of  $\xi$  and  $\eta$  can be computed directly from given Y, Z coordinates by using Eqs. 2 and 3. However, obtaining the values of Y and Z for given  $\xi$  and  $\eta$  coordinates requires solution of the two nonlinear equations. The "modified Regula Falsi" iteration method (51) is used to solve these non-linear equations. Since the variations of  $\xi$  and  $\eta$  curves are different in various regions, the following four algorithms are used to solve the equations:

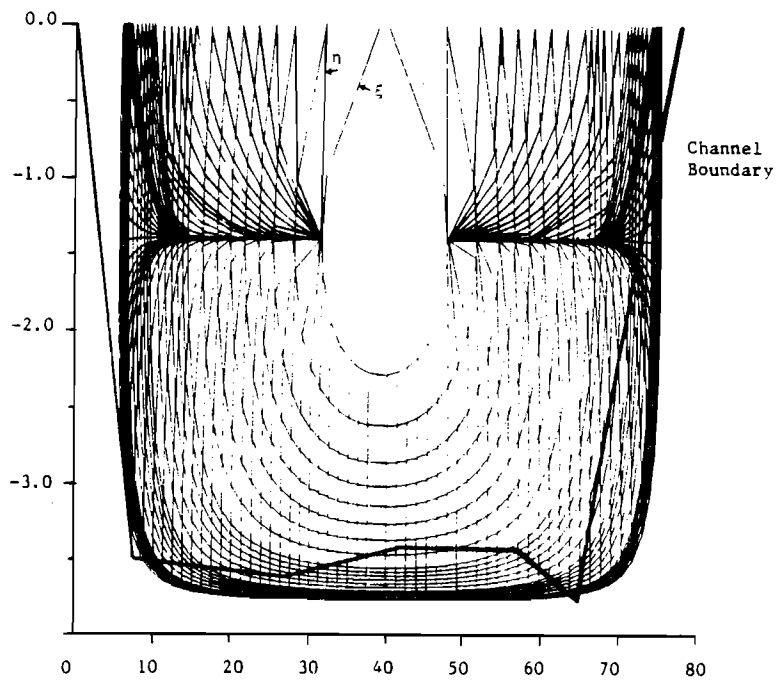
- (1) Solve Y for fixed Z from  $\xi$  curve
- (2) Solve Z for fixed Y from  $\xi$  curve
- (3) Solve Y for fixed Z from  $\eta$  curve
- (4) Solve Z for fixed Y from  $\eta$  curve

The algorithms are illustrated in Fig. 10. With these four algorithms, one can solve for Y (or Z) for an assumed value of Z (or Y) on a selected curve of  $\xi$  or  $\eta$ . The choice of the  $\xi$  (or  $\eta$ ) curve for solutions depends on the tangent values at two consecutive points on that curve. If the tangent values are very close to each other on one curve, then the other curve is selected. The algorithm converges quickly after the first (Y, Z) coordinate point is found, which then becomes the initial trial value for the next (Y, Z) point.





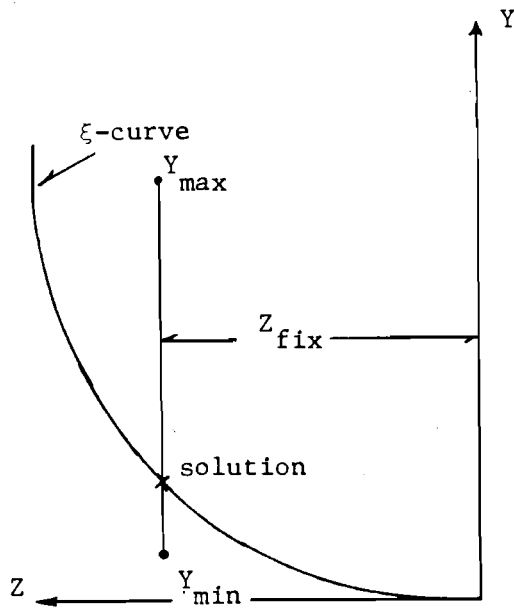
(a) Cross section 6, August 6, 1985



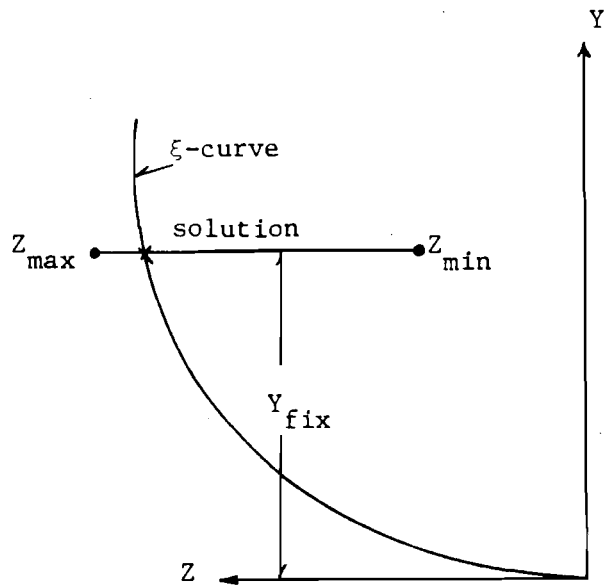
(b) Cross section 8, August 8, 1985

DISTANCE, ft

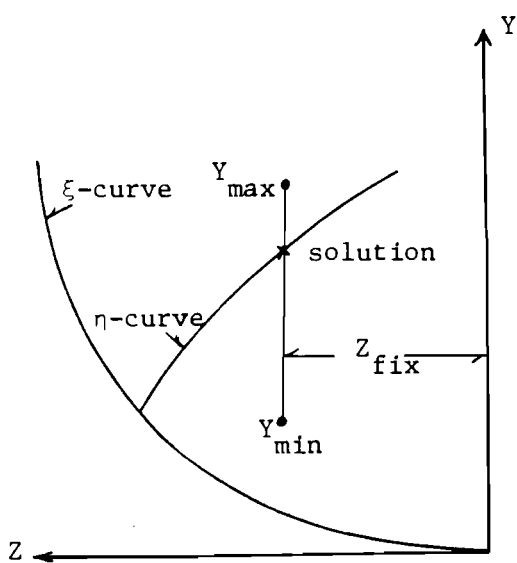
Figure 9. Grid systems for computational model



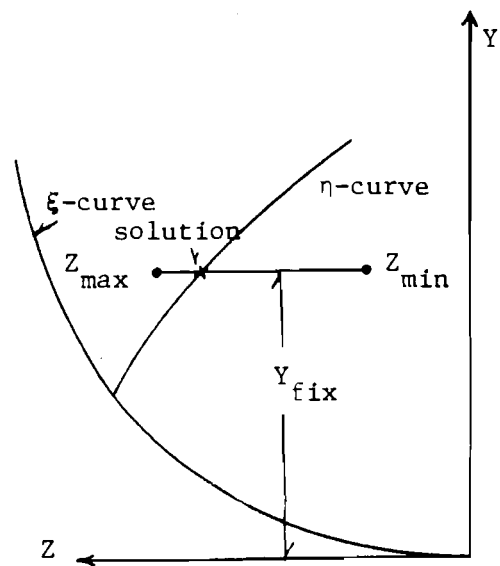
(1)



(2)



(3)



(4)

Figure 10. Algorithms for solving Y or Z from  $\xi$  and  $\eta$

Computation for  $V_\xi$

The  $V_\xi$  component is computed from Eq. 33 on every grid point. In general, the normal stress term  $\partial\tau_{xx}/\partial x$  is small and is included in the hydrostatic pressure variation term. If the flow is steady and uniform, then

$$\frac{\partial}{\partial x} (\rho g H) = \rho g S \quad (48)$$

where  $S$  is the slope of the channel bottom. Since the primary velocity is assumed to have a logarithmic distribution, and the shear stress a quadratic distribution, the velocity and shear stress derivatives can be written as:

$$\frac{\partial u}{\partial \xi} = \frac{\partial}{\partial \xi} \left( \frac{u_*}{k} \ln \frac{\xi}{\xi_0} \right) = \frac{u_*}{\xi k} \quad (49)$$

and

$$\frac{\partial \tau_{\xi x}}{\partial \xi} = -\alpha_1 - 2\alpha_2(\xi_{\max} - \xi) \quad (50)$$

The derivative of  $h_\eta$  with respect to  $\xi$  can be computed in  $Y$  and  $Z$  coordinates by using this relationship:

$$\frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi} = \frac{\partial}{\partial \xi} (\ln h_\eta)$$

Therefore

$$\frac{1}{h_\eta} \frac{\partial h_\eta}{\partial \xi} = - \frac{\beta_i C_i Y^2 Z^2 (1-Z)^2 + C_i Y^2 (1-Y)^2 (1-Z)^2}{\xi [(1-Y)^2 (1-Z)^2 + \beta_i C_i Y^2 Z^2]^2} \quad (51)$$

With these terms known and  $\partial u / \partial x$  determined from field measurement, the  $V_\xi$  component at each node is computed in a straightforward manner.

Computation for  $V_\eta$

Eq. 34 can be rewritten as:

$$V_\eta = - \frac{1}{h_\xi} \int_{\eta^*}^{\eta} [h_\xi h_\eta \frac{\partial u}{\partial x} + \frac{\partial}{\partial \xi} (h_\xi V_\xi)] + V_{\eta^*} \quad (52)$$

The following steps are needed to solve Eq. 52.

(1) Determine the boundary value  $V_{\eta^*}$

$$V_z = V_\xi (h_\xi \frac{\partial \xi}{\partial z})^{-1} \text{ or } V_z \text{ from field data}$$

$$V_{\eta^*} = h_\eta V_\xi \frac{\partial \eta}{\partial \xi} \quad (53)$$

(2) By using Leibnitz's rule, transform Eq. 52 as follows:

$$V_\eta = -\frac{1}{h_\xi} \int_{\eta^*}^{\eta} h_\xi h_\eta \frac{\partial u}{\partial x} d\eta - \frac{1}{h_\xi} \frac{\partial}{\partial \xi} \int_{\eta^*}^{\eta} (h_\eta V_\xi) d\eta + V_{\eta^*} \quad (54)$$

$$\text{or} = \sum \frac{-1}{h_\xi} \int_{\eta_i}^{\eta_{i+1}} h_\xi h_\eta \frac{\partial u}{\partial x} d\eta - \sum \frac{1}{h_\xi} \frac{\partial}{\partial \xi} \psi + V_{\eta^*} \quad (55)$$

$$\text{where } \psi = \int_{\eta^*}^{\eta} (h_\eta V_\xi) d\eta$$

(3) The numerical integration for each integral on the right-hand side is evaluated as:

$$\begin{aligned} \int_{\eta_i}^{\eta_{i+1}} A h_\eta d\eta &= \int_{-1}^{+1} (N_1 A_1 + N_2 A_2) (N_1 h_{\eta_1} + N_2 h_{\eta_2}) \left[ \frac{dN_1}{dr} \eta_1 + \frac{dN_2}{dr} \eta_2 \right] dr \\ &= \frac{1}{2} (\eta_2 - \eta_1) \sum_{m=1}^M (N_1 A_1 + N_2 A_2) (N_1 h_{\eta_1} + N_2 h_{\eta_2}) W_m \end{aligned} \quad (56)$$

where  $N_1 = \frac{1-r}{2}$ ,  $N_2 = \frac{1+r}{2}$ ,  $r$  is the reference parameter ranging from -1 to +1,  $M$  is the Gaussian point, and  $W_m$  is the weight coefficient.

(4) The derivative of  $\psi$  with respect to  $\xi$  is calculated by:

$$\frac{\partial}{\partial \xi} \psi_n = \frac{[\psi_n]_{i+1} - [\psi_n]_{i-1}}{2\Delta\xi} \quad (57)$$

which is the central difference approximation.

The whole computation is carried out on an  $\xi$  curve, and the values of  $\psi$  on neighboring  $\xi$  curves are also required.

A complete listing of the computer program for the model is provided in Appendix A.

## FIELD DATA COLLECTION

The field data collection component of the project consists of development of the instrumentation needed to measure secondary circulation in natural channels, and the actual data collection. A computerized field data collection system was developed for the project and used successfully in the field. In addition to the acquisition of secondary circulation data, other measurements and sampling for flow discharges, suspended sediment concentrations, bed loads, and bed material were performed during the field data collection periods. This section of the report describes the instruments used to collect the data and the data collection procedures, and presents a summary of the data collected.

### Field Data Collection Site

Three sets of field data were collected for the project. Data were collected in May and June 1984 and in August 1985. All the data were collected in the Sangamon River near Mahomet (near the junction of Sections 19, 20, 29, and 30, Township 20N., Range 7E.; river mile 180.6 above the Illinois River; and about 3.8 miles downstream of the Highway 47 bridge, Mahomet, IL). The Sangamon River near Mahomet, among other sites considered, was found to be the best site in terms of water depth requirements and site accessibility. The location of the study site is shown in Fig. 11. The stream channel at the study site is nearly a straight reach for about 500 feet, and then follows a gradual bend. At the upstream end of the site there is a bridge. The bridge piers did not obstruct the flow during the field trips; thus there were no eddies from the bridge piers. This was felt to be an important consideration in all secondary circulation measurements.

The channel width at this reach is almost constant (approximately 75 feet) and the cross section geometry is almost trapezoidal, which is an ideal case for the application of the mathematical model. Water depth at the study site varied from 2 to 4 feet, which made the data collection program relatively easy. The site is easily accessible by car, which facilitated the transport of equipment to the study site.

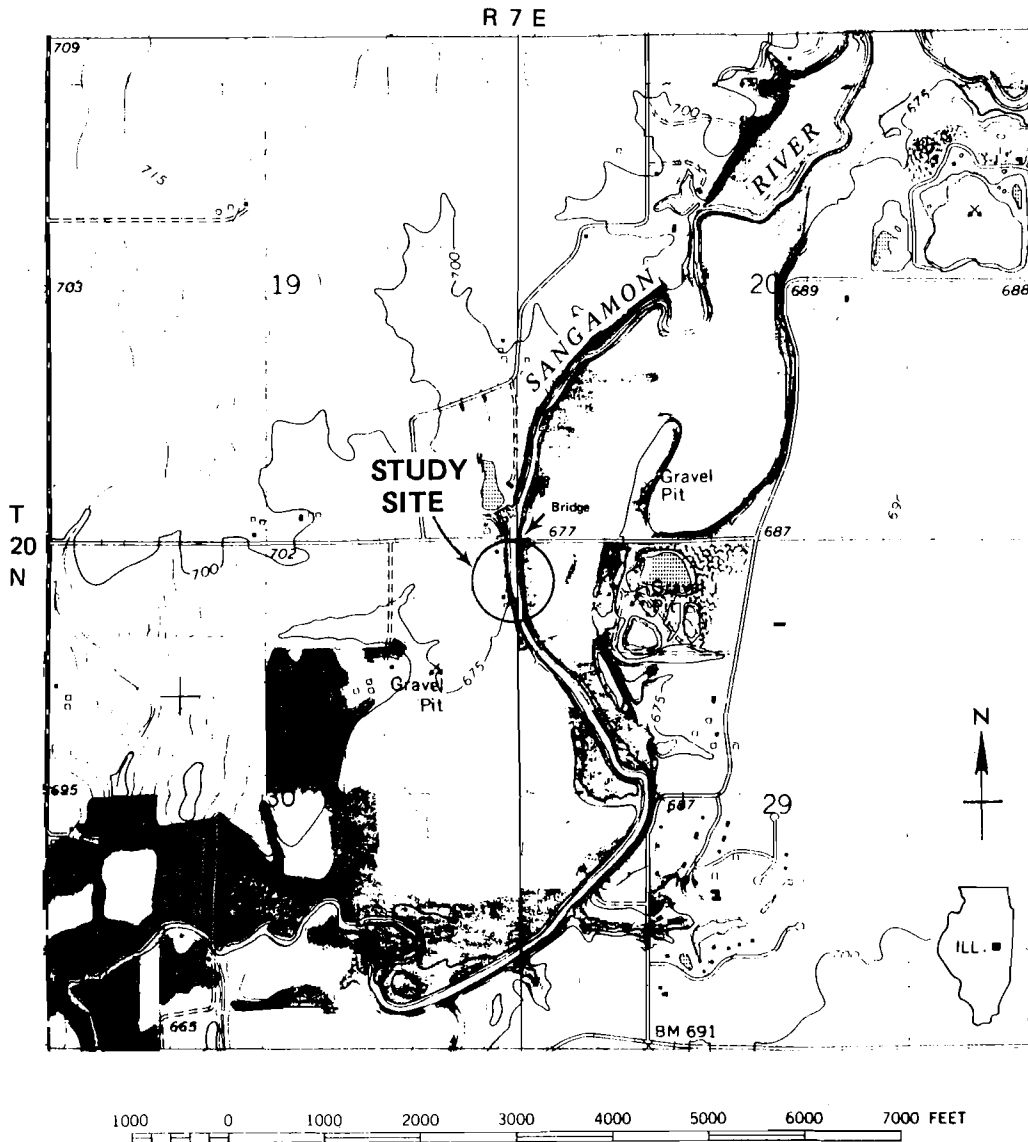


Figure 11. Location of study site

## Instrumentation

### Three-Dimensional Flow Measurement Setup

The instrumentation for measuring secondary circulation includes a Marsh-McBirney (Model 527) electromagnetic current meter, a Commodore (Model 8032) micro-computer with tape drive, an interface between the current meter and the computer, and a rigid support system for the current meter (Fig. 12). The support system includes a yoke which allows the current meter to be rotated 90 degrees so that both the lateral and vertical components of the secondary velocities may be measured.

Using the setup shown in Fig. 12, a continuous velocity reading from the current meter can be digitized and transmitted to the computer. Either the time history or an average and standard deviation of the velocity for a given period can be calculated and stored on cassette tapes.

### *Marsh-McBirney 527 Electromagnetic Current Meter*

The Marsh-McBirney 527 Electromagnetic Water Current Meter consists of a transducer probe with a geomagnetic compass, a cable, and a signal processor. The probe is a 4-inch-diameter sphere on a 1-inch-diameter rod. The current meter measures the flow of water in a plane normal to the longitudinal axis of the probe. The current meter operates on the Faraday Principle of Electromagnetic Induction, which, simply stated, says: "a conductor moving in a magnetic field (generated from within the probe) produces a voltage that is proportional to its velocity." The electrodes placed on the wall of the probe detect the voltages caused by water flowing past the probe in a plane normal to the probe's axes. The flow sensing volume around the probe is a sphere 12 inches in diameter (3 probe diameters).

The two components of velocity together with the compass reading can be directly monitored on the three panel meters on the signal processor. The panel meter has three selectable full-scale ranges of  $\pm 2$ ,  $\pm 5$ , and  $\pm 10$  ft/sec. The outputs are within 2% of full scale over the velocity range of the instrument, and the compass accuracy is  $\pm 10^\circ$  at tilt angles of up to  $25^\circ$ . Also provided on the signal processor is a voltage output jack, which makes the velocity and the compass readings available to external data logging equipment; i.e., computers or any other data logging devices.

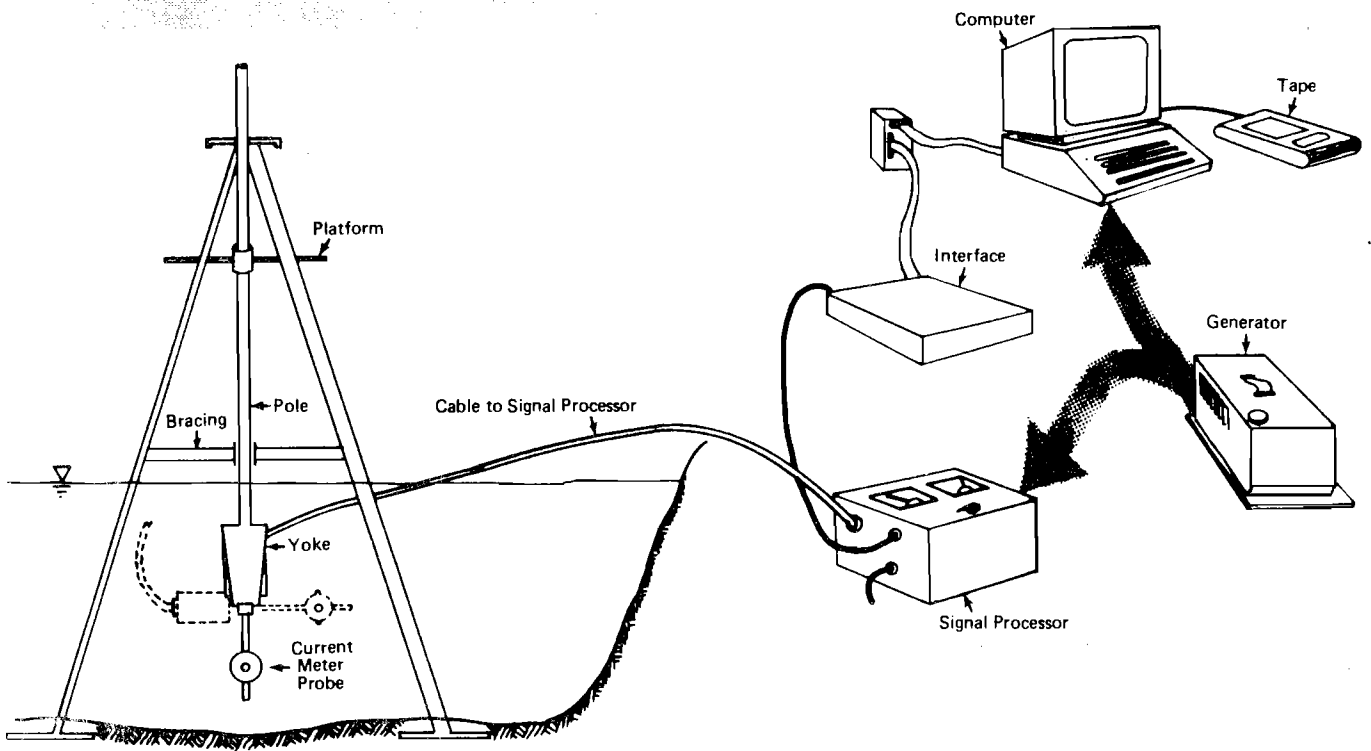
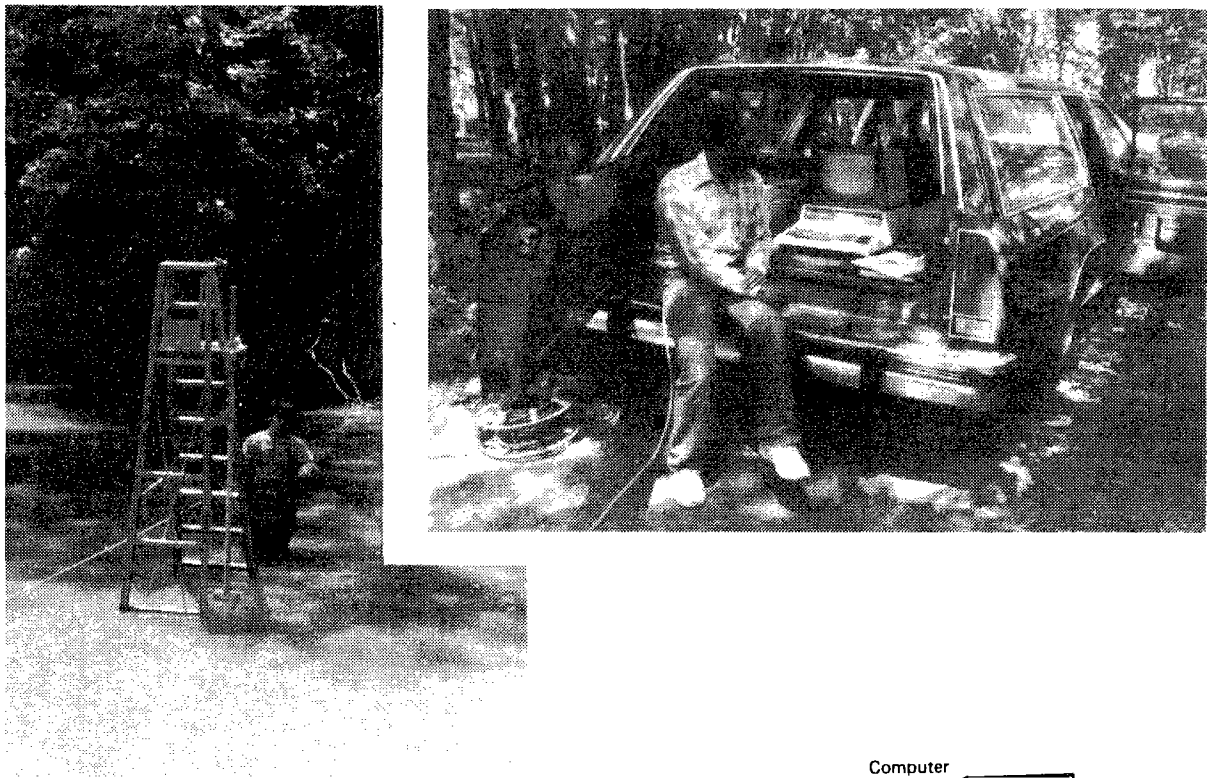


Figure 12. Field instrumentation setup



### *Interface and Computer*

Since the Marsh-McBirney electromagnetic current meter output is in an analog signal, and it is almost impossible to visually average the velocity readings from the panel meters, it was decided to construct a data logger system based on a micro-computer. The initial step is to build an interface between the current meter and the computer. An interface which can receive the current meter output at selected frequencies and average the values for specified time periods was built at the Illinois State Water Survey Electronic Shop. The interface transfers the voltage outputs to the computer as digital signals.

The computer used for this system is a Commodore micro-computer (Model 8032) with a cassette tape drive. A computer program was developed to control the sampling procedure; to calculate the means, standard deviations of the velocity components, and the angle; and to store the data on cassette tapes. Additional information such as on site descriptions, coordinates and rotation of the current meter, time, and the gain selected for amplification of the signal is entered into the computer before sampling is initiated. The data stored on the tapes include the descriptive information and the actual data.

Once in the office, the data stored in the tapes is transmitted from the micro-computer to a main-frame computer (CYBER) by using a communication program and a modem. Further analysis of the data is carried out on the CYBER computer.

### *Support System for the Current Meter*

The support system for the current meter was an important consideration in the development of the data acquisition system. The current meter has to be placed at a known depth in the stream, and the orientation of the current meter has to remain the same during the sampling period to obtain consistent data. To achieve these objectives, a rigid support system which could be moved from place to place had to be built. This was accomplished by modifying an aluminum stepladder and building a supporting platform, pole, and yoke as shown in Fig. 12. The yoke was designed to allow a 90° rotation of the current meter so that secondary currents both in the transverse and vertical directions could be measured. The yoke is supported by a pole which can be raised or lowered at regular intervals to change the depth of the measuring point. The pole is supported by the platform, which is attached to the

ladder. Additional bracings were used to reduce the vibration of the current meter generated by the stream current. A complete cross-sectional velocity distribution is measured by moving the whole support system along the channel width, lowering and raising the pole, and rotating the current meter.

#### Rotating Bucket Current Meter

This instrument, a standard Price-type meter, has a rotor with six cone-shaped cups mounted on a vertical stainless steel shaft. The meter has been calibrated by the manufacturer to a standard rating table where the number of rotations of the rotor over a specified time corresponds to a specific velocity.

The current meter is attached to a 30-lb weight to keep it from drifting in the current and is suspended into the stream from a bridge deck with a cable/winch/crane assembly. This meter was used to measure flow velocity in the Sangamon River at the bridge site shown in Fig. 11. These velocity data were used to determine the discharge at the test reach.

#### Suspended Sediment Samplers

Two types of suspended sediment samplers were used for this investigation: the US DH-59 and DH-48, which are standard samplers designed for the United States Geological Survey. These samplers are designed to accumulate a water-sediment sample from a stream vertical at such a rate that the velocity in the nozzle at the point of intake is as close as possible to the stream velocity. These types of samplers, properly used, will withdraw a sample of the sediment water mixture that represents an average of the sediment concentration through a stream vertical weighted for velocity so that proper sediment load calculations can be made.

Both samplers use standard 1-pint glass milk bottles to collect the sediment-water samples. The DH-59 sampler was designed to be suspended by a hand-held rope or a cable/winch/crane assembly. This sampler was used to determine sediment concentrations of the stream at the bridge site (Fig. 11). The DH-48 sampler was used to sample for sediment concentration at sites away from the bridge. It was designed to be suspended from a wading rod and lowered into the stream by hand.

### Bed Load Sampler

A Helley-Smith bed load sampler was used to measure the component of the total sediment load that moves in close proximity to the streambed. This sampler was designed for sampling coarse material where the diameter of the bed load material is above 0.25 mm. The sampler was designed to be lowered to the streambed, left in contact with the bed for a certain period of time, and then retrieved from the water. Samples are retained by a mesh bag (0.25-mm mesh openings) open to the flow through a 3-inch-square opening. The quantity of material trapped by the sampler over a certain period of time indicates the amount of bed load moving through the 3-inch-square area, and by extrapolation (to the total bed width of the stream) the total quantity of bed load carried by the stream can be calculated.

### Sonar Stage Meter

An electronic sonar distance meter was used to measure the stage or height of the stream. Readings were made throughout the data collection period in order to assess the changes over time in stage. The sonar meter is placed at a known datum on the bridge and transmits the sonar signal downward to the stream water surface. The water surface reflects the signal back to the meter and the distance is calculated on the basis of the lag time between transmission and return. The meter is calibrated for the effect of air temperature on the speed of sound. The instrument used was an Exact Technologies Corporation Dimensional Measurement Computer. It has a resolution of 1 inch over a range of up to 50 feet.

### Data Collection Procedures

#### Secondary Circulation

Secondary circulation data were collected from cross section to cross section within the study reach. Measurements are taken at several depths for each vertical. Normally ten or more verticals per cross section were selected for data collection. Generally data collection at one cross section lasted one full day.

The data collection procedure for secondary circulation is as follows: First the support platform and pole are moved into the stream and firmly set at the data collection site. Then the yoke with the current meter is securely attached to the pole on the platform. The cable from the current meter is

then connected to the signal processor, which is located on the stream bank. The output from the signal processor is first transferred to the interface and then to the computer by cables between the devices. After all the connections between the devices are completed, power is turned on to activate the system. The computer program which controls the data collection and storage is then loaded into the computer and run. The computer prompts with header lines for inputting general information such as location, date, and time. It then asks for coordinates and gain (or amplification) being used. Once the above procedures are completed, sampling is initiated and terminated by pressing designated keys on the computer keyboard. Finally, the data are displayed on the screen for inspection and then transferred to cassette tapes for further analysis.

#### *Data Reduction*

All the cross sections where measurements were taken were aligned to be normal to the stream banks. However, this selection does not guarantee that the cross sections are normal to the main flow direction. Furthermore, it is very difficult to keep the orientation of the current meter consistent for all measurements. Thus the measured values of secondary flows might not represent the true values. The measured velocities were adjusted to reflect the true longitudinal and secondary currents by using the orientation of the current meter with respect to the magnetic north, which is measured simultaneously with the velocities, and by using one of the following two criteria: 1) The discharges measured by the two current meters, the electromagnetic and the rotating bucket mechanical current meter, should be equal; and 2) the continuity of secondary flows must be satisfied between downstream and upstream cross sections.

The method employed to check the continuity of secondary discharge is that proposed by Dietrich and Smith (22), and also used by Thorne et al. (56). In this method, the net secondary discharge is determined by integrating the secondary velocity over the depth. The continuity of discharge requires that the net secondary discharge at a cross section be equal to that of the section immediately upstream or downstream. If the two differ, the section is reoriented to change the secondary velocities until an agreement is reached.

The measured velocity components  $V_x$  and  $V_y$ , shown in Fig. 13, are first converted to resultant velocities from which the downstream and cross-stream velocities are computed.

The magnitude of the resultant velocity =  $\sqrt{V_x^2 + V_y^2}$

The angle of the resultant velocity with respect to magnetic north ( $\theta$ ) is determined as:

$$\theta = \begin{cases} \tan^{-1}(V_x/V_y) & \text{if } V_y > 0 \\ \tan^{-1}(V_x/V_y) + \pi & \text{if } V_y < 0 \end{cases} \quad (58)$$

The angle of the main downstream velocity with respect to the magnetic north ( $\theta_N$ ) is given by:

$$\theta_N = \theta + \theta_c \quad (59)$$

in which

$V_y, V_x$  = measured velocity

$\theta_c$  = bearing of sensor with respect to magnetic north

$\theta_N$  = bearing of left bank with respect to magnetic north

$\theta$  = bearing of resultant flow with respect to magnetic north

The downstream and cross stream components of the velocity are then given by:

$$\begin{aligned} \text{downstream velocity} &= (\text{resultant}) (\cos \theta) \\ \text{cross stream velocity} &= (\text{resultant}) (\sin \theta) \end{aligned} \quad (60)$$

### *Sampling Period*

Two major factors are considered before selecting the sampling period: 1) the sampling period should be long enough that the velocity fluctuations will average out and a true mean velocity will be obtained; and 2) the sampling duration should be short enough that the measurements for at least one cross section can be completed within a day.

Theoretically the true mean velocity is the average of the velocity measurements for an infinite time period. In practice, however, a period of averaging time is determined which gives a mean velocity very close to the long-time average with specified tolerance limits.

One method of estimating the averaging period is to determine the mean velocities for several averaging periods and then select the averaging period which gives a mean within a specified range from the true mean. This will require taking long period samples for each of the sampling periods. However,

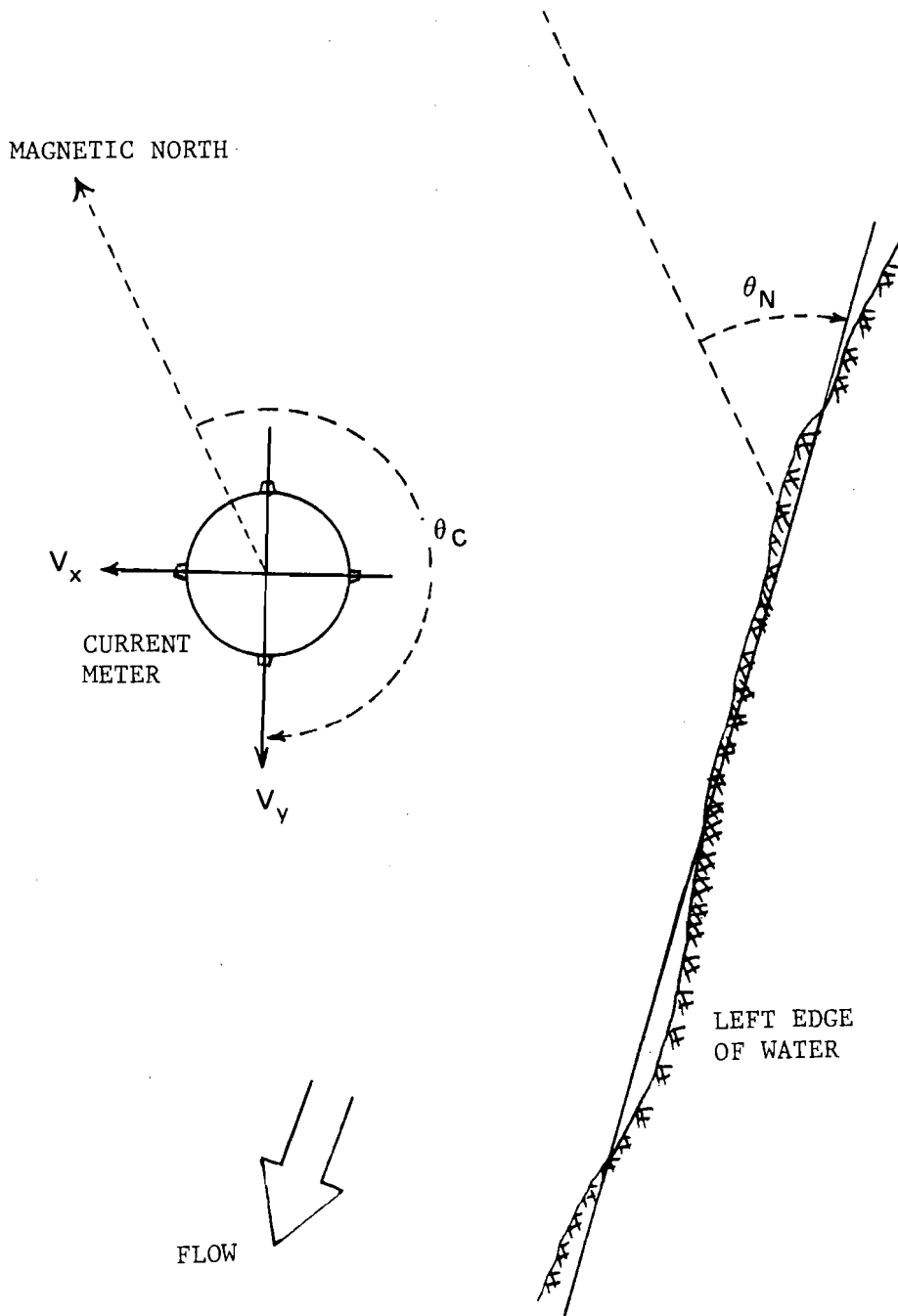


Figure 13. Orientation of measured velocities with respect to the main flow direction

an equivalent result is obtained from one long period sample as follows. A set of sampling periods  $\tau_i$ ,  $i = 1, 2, 3 \dots M$  are first selected. Then the sample is subdivided into blocks of  $N_i$  samples for each  $\tau_i$ . The mean,  $\bar{u}$ , and the standard error,  $S_{m_i}$ , which is the standard deviation in the mean, for each averaging period are then computed by the following equations (48)

$$\bar{u} = \frac{1}{T_m} \int_0^{T_m} u \, dt \quad (61)$$

$$S_{m_i} = \frac{\left[ \sum_{j=i}^{N_i} (v_j - \bar{u})^2 \right]^{1/2}}{N_i} \quad (62)$$

where  $v_j = \frac{1}{\tau_i} \int_0^{\tau_i} u_i \, dt =$  time average velocity for the period of  $\tau_i$

$N_i$  = the number of averages with an average period of  $\tau_i$

$T_m$  = the sampling period of the whole sample

$\bar{u}$  = the long-term average or the true mean

$u$  = velocity at time  $t$

To generalize the standard error for variable magnitudes of velocity, it is convenient to non-dimensionalize the standard error by the mean velocity. The normalized error,  $\bar{S}_{m_i}$ , is therefore given by:

$$\bar{S}_{m_i} = \frac{S_{m_i}}{\bar{u}} \quad (63)$$

Two sets of velocity measurements are shown in Fig. 14 to illustrate how the sampling periods were selected. The first measurement was taken near the center of the channel (42 feet from the left bank) and 1.25 feet from the water surface, while the second sample was taken close to the stream bank (26 feet from the left bank) and 1 foot from the water surface.

The total sampling time,  $T_m$ , for both samples was 5 minutes. The sampling periods,  $\tau_i$ , were 14, 27, 50, 99, and 150 seconds. The relationship between the sampling period and the normalized standard error for both samples is shown in Fig. 15. As shown in the figure the normalized standard error near the bank is greater than at the center of the channel. This is probably because of greater secondary currents and turbulence intensity near the banks

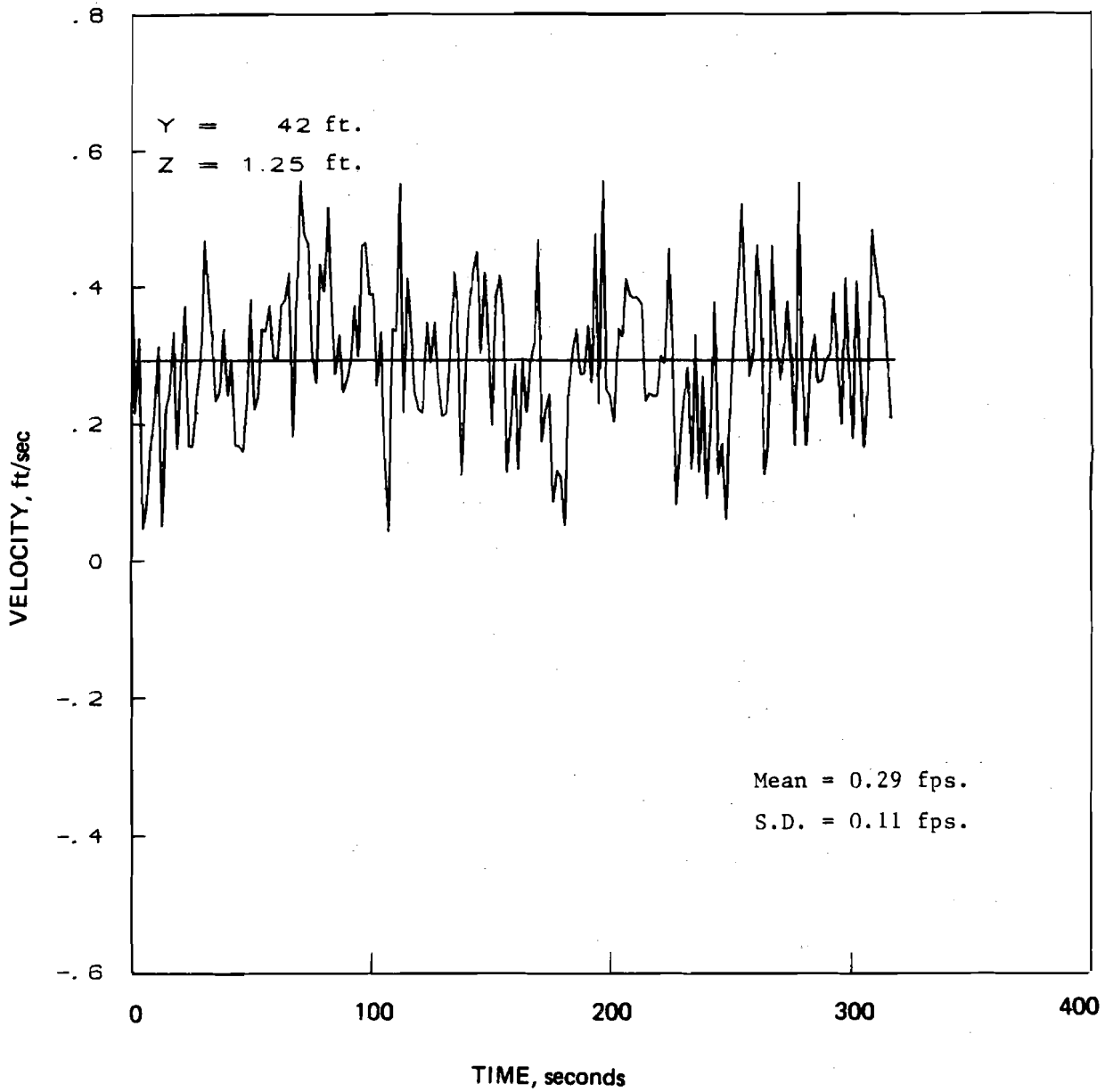


Figure 14a. Velocity fluctuations at a point (distance = 42 ft, depth = 1.25 ft), cross section 9, August 9, 1985



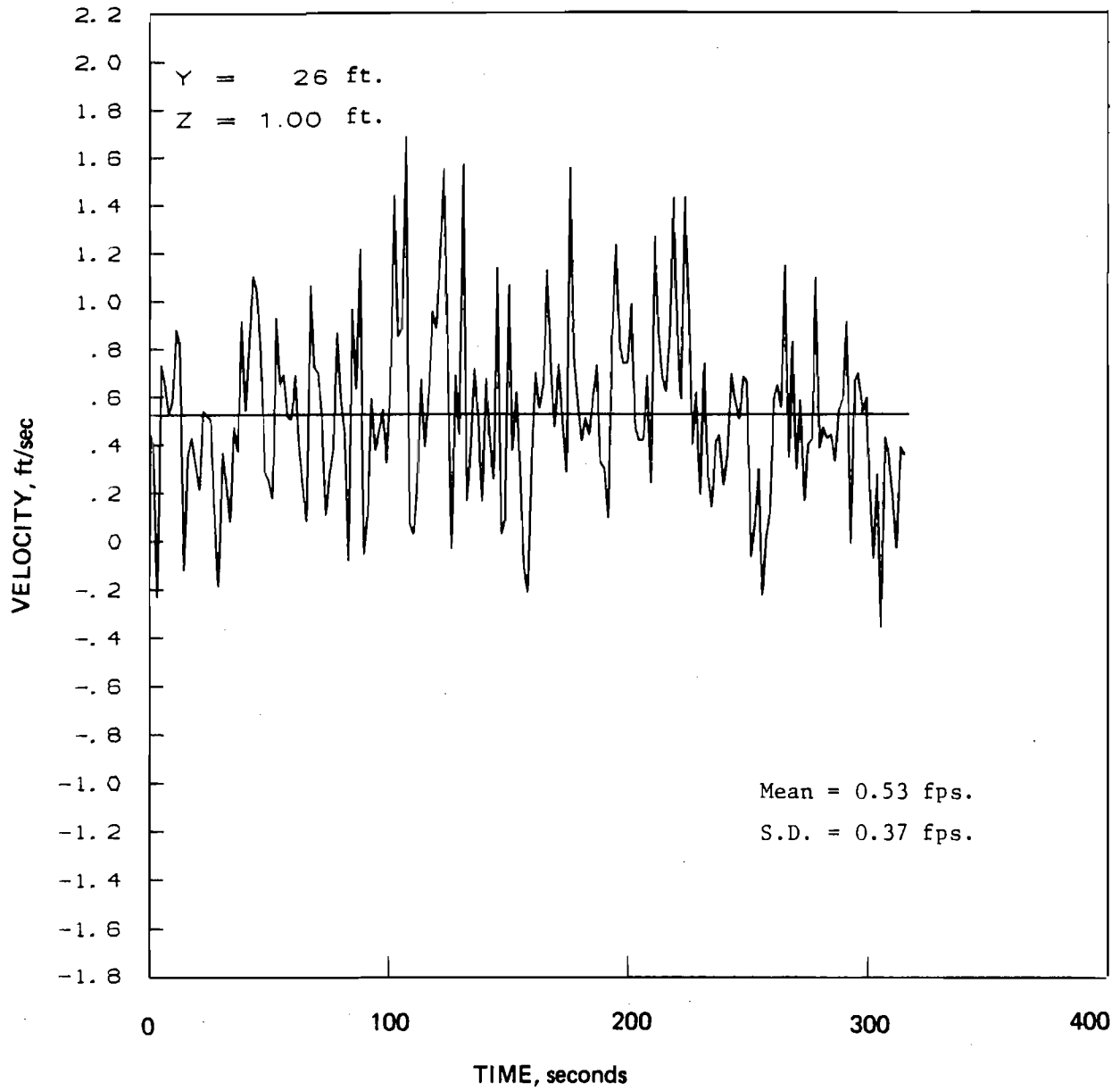


Figure 14b. Velocity fluctuations at a point (distance = 26 ft, depth = 1.00 ft), cross section 7, August 7, 1985

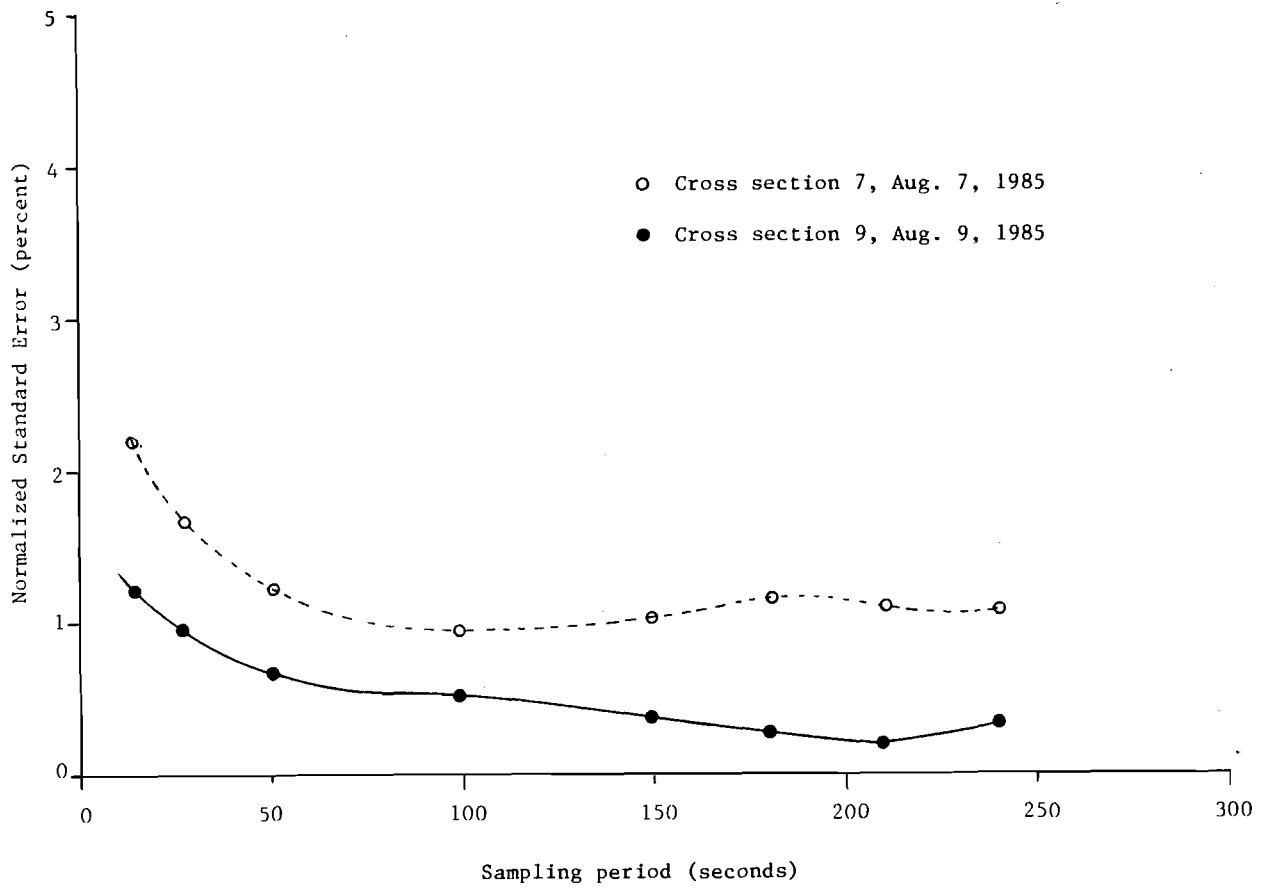


Figure 15. Relationship between sampling period and the normalized standard error for two sets of velocity measurements

than at the center of the channel. However, the normalized error for both samples decreases with increasing sampling period. The error decreases sharply for sampling periods more than 60 seconds and gradually thereafter. It was decided to use 60 seconds as the sampling period for an efficient and reliable data collection procedure.

#### Stream Discharge Measurement

The discharges of the Sangamon River at the study site were measured several times during each field trip. Two types of instrumentation were used to measure discharge of the Sangamon River: 1) the electromagnetic two-dimensional current meter, and 2) the rotating bucket mechanical current meter. The electromagnetic meter was employed primarily to measure secondary circulation. However, since the meter also measures the flow in the downstream direction, the data generated were used to compute the stream discharge. The rotating bucket mechanical meter was used to measure stream velocity and to compute stream discharge for a comparative analysis between results of the two methods.

The stream discharge measurement techniques used for the rotating bucket current meter were those recommended by the United States Geological Survey (9) and the American Society for Testing and Materials, Standard Practice for Open-Channel Flow Measurement of Water by Velocity-Area Method, Designation: D 3858-79 (1). Stream discharges are determined by subdividing a cross section of the stream into partial sections; the average velocity of the flow at each partial section is measured and multiplied by the flow area of the partial section. The sum of the individual partial section discharges equals the total stream discharge.

Discharge measurements performed at the bridge site used the rotating bucket current meter. The stream cross section under the bridge was divided into 7 partial sections, each approximately 10 feet wide. The velocity meter, suspended by a cable/winch/crane assembly, was lowered into the stream at the midpoint of each partial section. A depth gage built into the winch read the total depth of the stream at the midpoint of the partial section. This depth was recorded and later used to calculate the flow area of the partial section. Velocity measurements were then made at the vertical in the midpoint of the partial section. The meter was positioned below the water surface at 0.2 and 0.8 of the total depth (for total depths greater than 2.0 ft) or at 0.6 of the

total depth (for total depths less than 2.0 ft). The velocity of the stream at the measured points was recorded and used to calculate the average velocity of the partial section. Stream discharges were then calculated by multiplying the mean velocity for each partial section by the respective cross-sectional area. Total discharge for the section was obtained by summing all the individual partial discharges.

#### Suspended Sediment Concentrations and Particle Size Sampling

Sediment sampling was performed using the US DH-59 and US DH-48 samplers as described in "Instrumentation." The sediment sampling was performed to determine the concentration of suspended sediment and the total sediment load in the stream. The methods used were developed by the USGS (31) and are proposed practices of the American Society for Testing and Materials Committee D-19 (water) and Subcommittee D-19.07 (sediment) (1).

The sampling methodology employed the equal width increment method where the stream cross section is divided into three or four partial sections and the midpoint of each partial section is sampled. At each midpoint a clean sample bottle is inserted into the sampler and the sampler is carefully lowered from the stream surface to the bottom and raised back to the surface at a constant rate of 1 foot per second. The sample bottle is then capped, identified, and noted in the field book. This procedure is repeated at each partial section midpoint until the entire width is sampled. The purpose of using equal width increment and depth integrated techniques is to quantify the total amount of sediment carried in suspension by a stream where the concentration of sediment varies across the width and depth.

Suspended sediment concentration sampling was performed at the study site on most of the days of data collection. The sample bottles were identified and labeled in the field and then brought into the office for logging and preparation for delivery to the Inter-Survey Geotechnical Laboratory for analysis.

Suspended sediment particle size analysis was performed on three samples obtained by dip sampling. Dip sampling was used instead of the methods outlined above for suspended sediment concentration because of the low concentration of suspended sediment, which made it necessary to collect a large quantity of samples for the laboratory analysis.

### Bed Load Measurement

The coarse fraction of the sediment load ( $>0.25$  mm) moving in contact with or within 3 inches of the streambed was sampled using a Helley-Smith bed load sampler. This sampler was lowered to the streambed at the thalweg and left there for a period of five minutes. The sampler allows the streamflow near the bed to pass through the intake opening and into a fine mesh. The sample in the mesh bag at the time of retrieval was then examined for quantity and types of sediment (inorganic, wood, leaves, etc.). Field observations of the sample were then entered into the field notebook. Only one bed load measurement was collected as part of this investigation because of low flow conditions during sampling periods, at which time no appreciable bed load movement was observed.

### Bed Material Sampling

The streambed sediment was sampled in order to characterize the stream bed and to determine the distribution of sediment particle sizes that are available for transport as bed load and suspended load. The streambed was sampled across its width 100 ft downstream of the bridge sampling site. Three discrete samples were obtained from the bed at three locations: the midpoint, and the left and right quarter points. The bed samples were obtained using a shallow bucket 10 inches across and 3 inches deep. The bucket was lowered through the water column by hand and then tilted so that one edge could cut a sample from the top inch of the streambed. The bucket and sample were brought to the water surface carefully to avoid agitating or dispersing the material. The excess water was drained away from the sample and the sample was placed into whirl-pack sampling bags. The samples averaged approximately 500 grams each. All sample bags were labeled to identify date, time, and sampling location. The samples were then brought into the office for logging and preparation and delivered to the Inter-Survey Geotechnical Laboratory for analysis.

### Stage Measurement

The relative change in the stream surface elevation was monitored daily at the bridge site using a sonar distance meter. At a minimum, readings were made at the beginning and end of the work day. The sonar readings were

adjusted to reflect possible temperature effects on the speed of sound. Relevant data were recorded in the field notebook for later analysis.

### Summary of Field Data Collected

A summary of all the field data collected for the project is presented in this section. A complete list of all the data is included in Appendix B. All the cross sections where data were collected are shown in Fig. 16. Table 1 shows the dates when the data were collected at each cross section.

### **Secondary Circulation**

The velocity measurements used to construct secondary circulation were first processed separately to illustrate the distribution of each component in a cross section. Fig. 17 shows the distribution of the longitudinal, transverse, and vertical components of the velocity at cross section 7. It should be noted that different scales are used for the three components shown in the figure, so that the distributions of the lateral and vertical components, which are much smaller than the longitudinal component, can be shown effectively. The distribution of the longitudinal component (Fig. 17a) indicates that the higher velocities are located close to the center of the channel and the lower velocities are near the banks, as should be the case.

Table 1. Dates of Field Data Collection

<u>Date</u> <u>Month/day/year</u>	<u>Cross section number where</u> <u>data were collected</u>
06/27/84	7
06/28/84	6
06/29/84	5
07/09/84	3
07/10/84	4
07/12/84	2
07/13/84	1
08/05/85	5
08/06/85	6
08/07/85	7
08/08/85	8
08/09/85	9

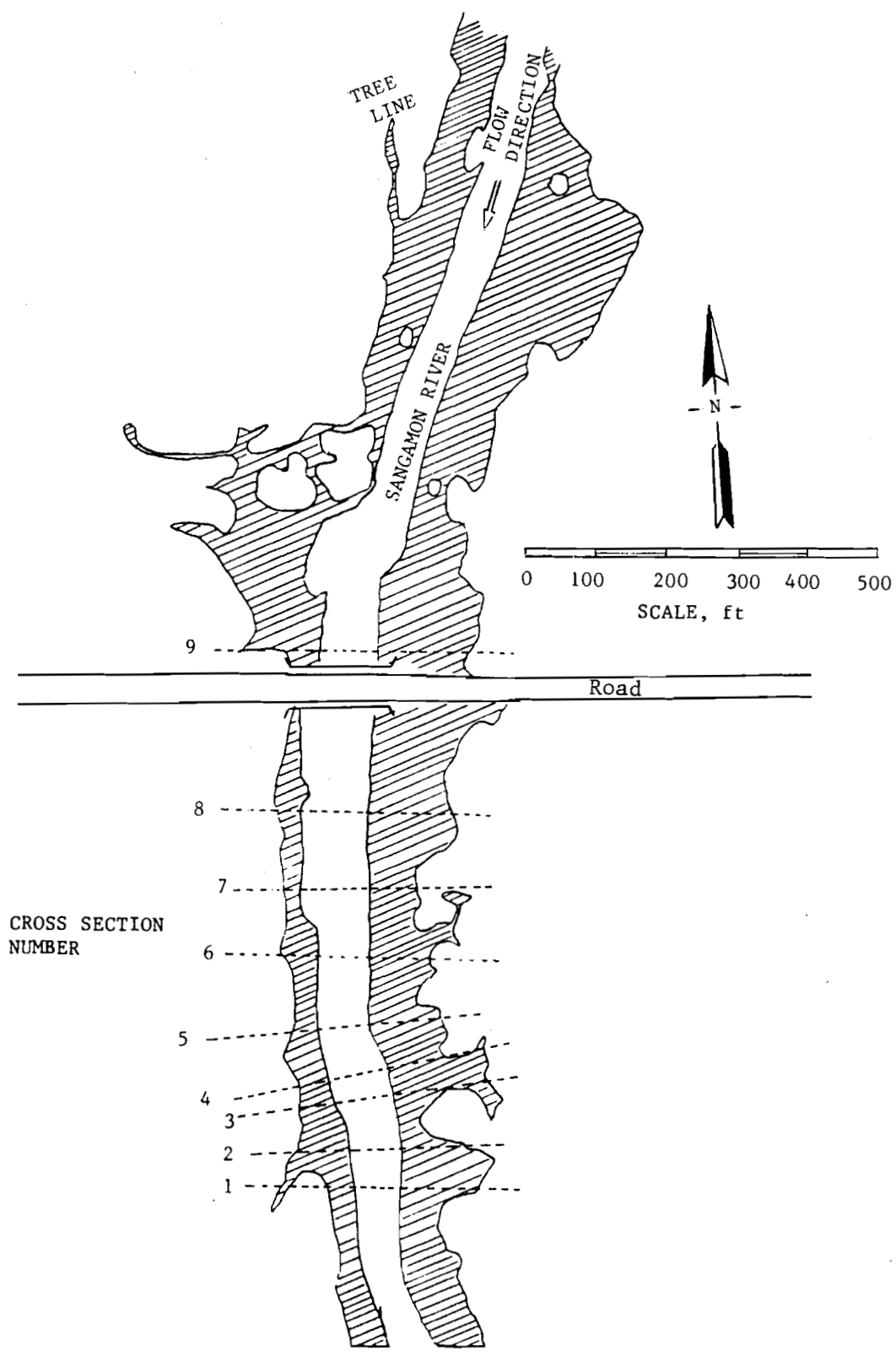


Figure 16. Location of cross sections at the study site

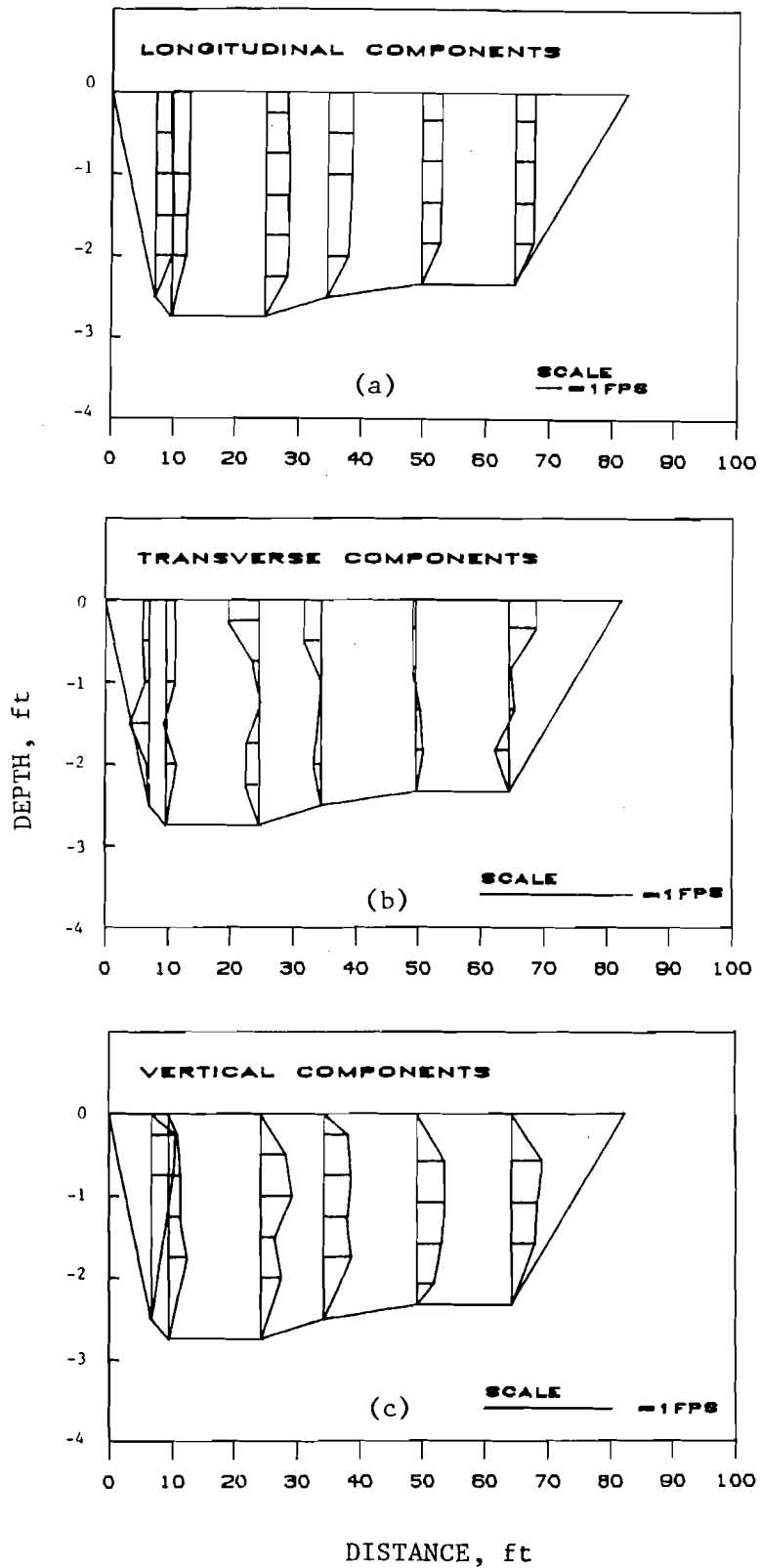


Figure 17. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 7, June 27, 1984



The distribution of the transverse component shown in Fig. 17b is, however, highly variable in magnitude and direction. The vertical components for this particular cross section (Fig. 17c) show some variation in magnitude but not as much as the lateral components. Fig. 17 is just an example to illustrate the type of data collected and how they were analyzed. Similar plots for all the data collected in the field are given in Appendix B.

The longitudinal velocity was further processed to generate isovels as shown in Fig. 18. Since the model used for this project utilizes the isovels as the basis for coordinate transformation, it was felt important to generate the isovels for measured data so that they could be compared with the model. Isovel plots for all the measurements are also shown in Appendix B.

The transverse and vertical components of the velocity were combined to generate the secondary current vectors as shown in Fig. 19. For this particular case, the measured values indicate primarily upward and lateral movements of the secondary currents. The downward currents were either missed in the measuring process or are located close to the banks. As with the previous plots, the rest of the secondary current plots are included in Appendix B.

### Stream Discharge

The discharge of the Sangamon River at the study site was measured at the bridge cross section using the rotating bucket current meter for the purposes of monitoring the changes in the daily streamflows. Stream discharges were also calculated on the basis of the secondary current measurements at the different cross sections. Table 2 presents a summary of the discharge measurements, as determined by both the rotating bucket and electromagnetic current meters. As shown in the table there are some differences in the stream discharges calculated from the two sets of measurements. Considering that the discharges were not measured at the same cross sections, and considering the errors in stream flow measurements, the agreement between the two sets of measurements was satisfactory for most cases.

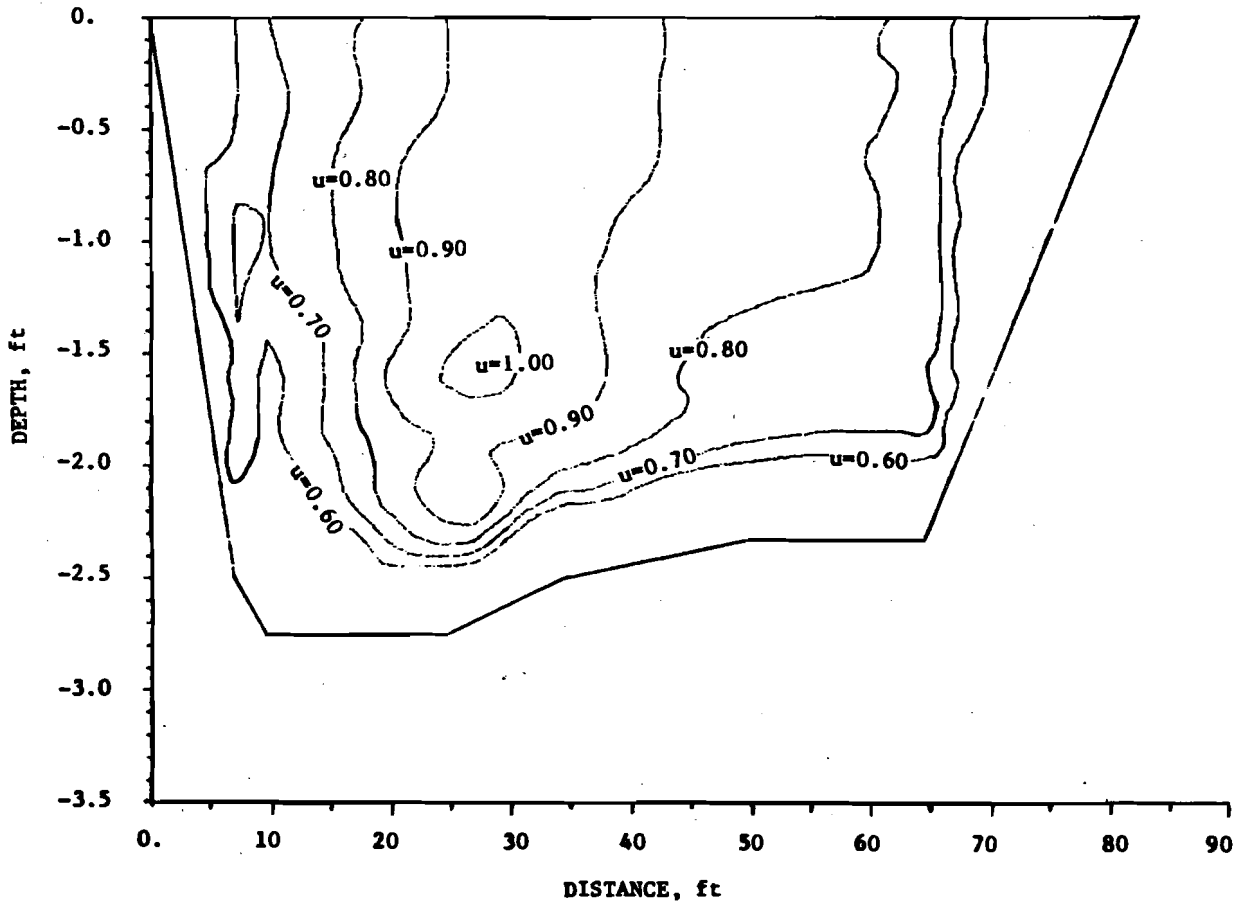


Figure 18. Isovells of the longitudinal velocity at cross section 7, June 27, 1984

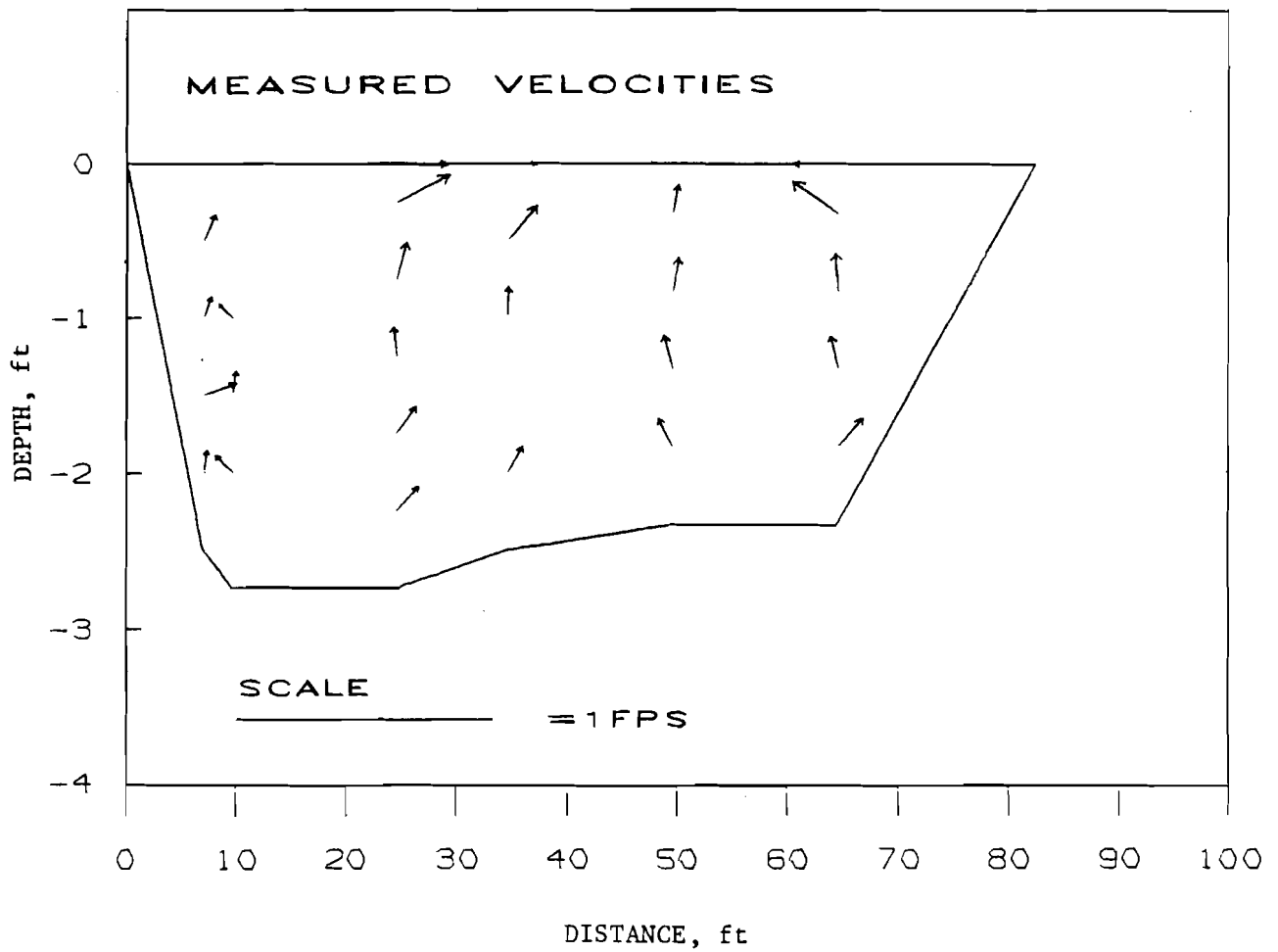


Figure 19. Measured secondary current vectors at cross section 7, June 27, 1984

Table 2. Water Discharge and Sediment Load Measurements During Data Collection Period

Date	<u>Water discharge (cfs)</u>		<u>Suspended sediment</u>	
	<u>Rotating bucket</u>	<u>Electromagnetic</u>	<u>Concentration (ppm)</u>	<u>Load (tons/day)</u>
6/27/84	--	139	--	--
6/28/84	--	140	205	77
6/29/84	--	119	--	--
7/09/84	71	48	--	--
7/10/84	65	58	114	20
7/12/84	36	--	--	--
8/05/85	126	75	85	29
8/06/85	100	115	94	25
8/07/85	73	66	48	10
8/08/85	--	115	--	--
8/09/85	80	59	52	11
8/14/85	70	--	103	20

The highest and lowest discharges measured in the 1984 data collection period were 140 cfs on June 28, and 36 cfs on July 12, respectively. For the 1985 data the highest discharge was 126 cfs on August 5 and the lowest was 59 cfs on August 9. The discharges measured during the field data collection periods are all below the mean streamflow and generally fall in the range of flows exceeded from 40 to 70 percent of the time as indicated in the flow duration curve shown in Fig. 20. The flow duration curve was developed from historical streamflow records of the Sangamon River gaging station at Mahomet, which is 4 miles upstream of the study site. Data collection was not conducted during higher flows because of logistic requirements of deep water measurements, which require using a boat to move the instrumentation from station to station. For water depths less than 4 feet the instrumentation is moved from station to station by wading in the stream channel and physically carrying the platform.

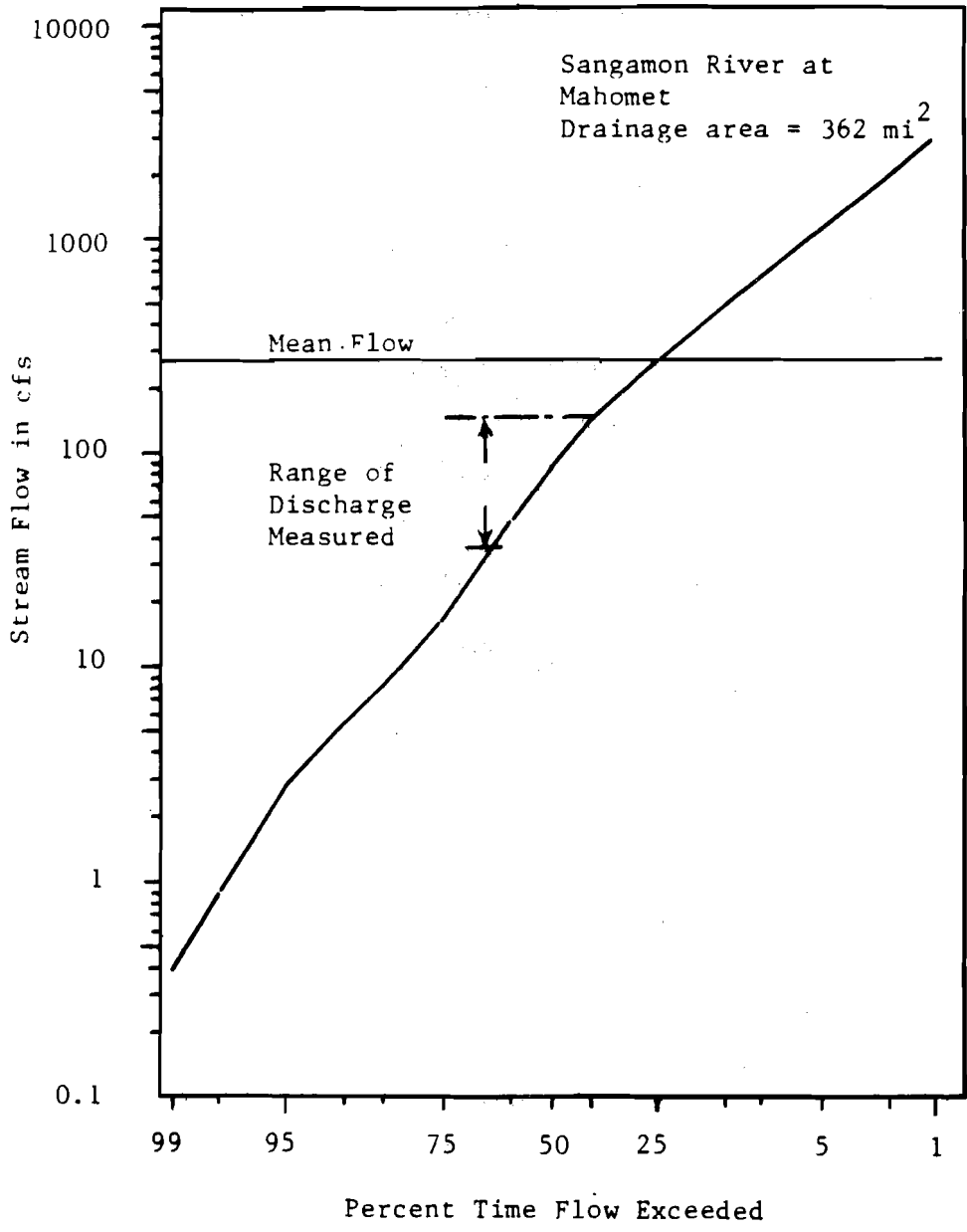


Figure 20. Flow duration curve for the Sangamon River at Mahomet, Illinois

### Suspended Sediment Concentration

A total of 48 suspended sediment concentration measurements were made during the data collection field trips. Several of the measurements were detailed cross-sectional measurements, while some were representative samples for calculating sediment load. The concentration measurements were averaged for the whole cross section and the suspended sediment loads were calculated from the average concentrations. These results are shown in Table 2. The suspended sediment concentrations during the 1984 data collection periods are generally higher than those in 1985. This is probably the influence of a major flood event in 1984 which preceded the data collection period. The suspended sediment load in the Sangamon River during the data collection period ranged from a low of 10 tons per day on August 7, 1985, to a high of 77 tons per day on June 28, 1984 (Table 2).

One detailed suspended sediment concentration measurement was performed on August 8, 1985, to investigate the distribution of sediment in the stream channel. A total of 21 point samples were collected at seven verticals. Fig. 21 shows the point concentration values and the equal concentration lines generated from the data. As can be seen in the figure, the suspended sediment concentration is higher towards the channel bottom and there are some regions of higher concentration which might be associated with secondary currents. However, there is no significant variation of concentration at that particular time of data collection, and more intensive data collection similar to that done here will be needed at different flows to conclusively associate concentration distribution with secondary currents.

### Bed Load

Only one bed load measurement was made at the study site. This measurement, which was made on August 6, 1985, yielded a bed load sample of 4.5 grams for a sampling period of five minutes. The sample consisted of inorganic fine gravel and coarse sand. The bed load flow area was estimated to be the central 50 feet of the stream channel, which had a total width of 69 feet. Bed load was calculated by multiplying the sampler intake width by the bed load flow area width and then extending the rate per unit time to a 24-hour period to determine total load per day. The bed load was estimated to be 0.3 tons per day. In comparison, the suspended load was 25 tons per day.

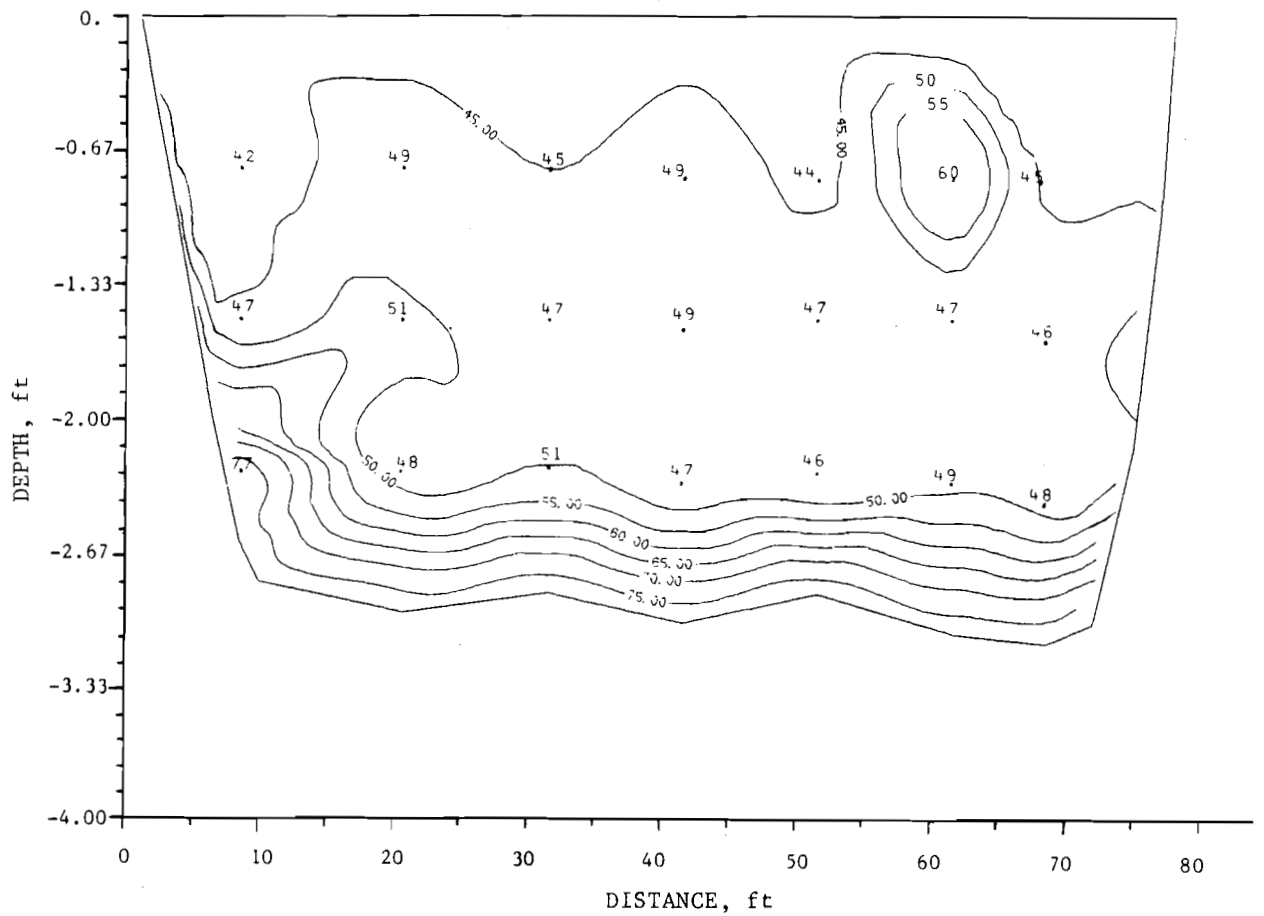


Figure 21. Distribution of suspended sediment concentration in parts per million, cross section 8, August 8, 1985

Therefore the bed load represents approximately 1.2 percent of the total sediment load (bed and suspended) on August 6, 1985, at this location.

### Bed Material Characteristics

The Sangamon River's bed is composed primarily of sand and some gravel. Sand and gravel bars are common in the river. Riffles in the river are composed of gravels up to 3 inches in diameter and coarse sand. Pools in the river occur between the riffles and are underlaid by sand and silt.

Table 3 summarizes the laboratory and statistical analyses of bed material samples obtained at the study site in 1984 and 1985. In 1984 two composite samples obtained by mixing four discrete samples taken at equal distances across the stream were collected at cross sections 2 and 4. In 1985 three separate samples were collected at cross section 8, one at mid-channel and one each at the one-fourth point of the stream width from the stream bank. In table 3 the individual sample results of the 1985 samples are averaged in order to provide a composite average for comparison with the 1984 samples. Sand predominates in the composite samples, and gravel makes up the bulk of the remaining sample with less than 5 percent silt and clay. All the composite samples are descriptively classified as "gravelly sand with silt."

The bed material varies in composition with respect to particle size distribution across the width and length of the river. The individual samples obtained on August 14, 1985, show a trend of increasing average particle size from the west to the east as shown in table 3. The longitudinal variation of particle sizes can also be seen in table 3 by comparing the composite samples obtained at the two cross sections in 1984. The gravel concentration was higher at cross section 2 than at cross section 4, and the sand concentrations were lower at cross section 2 than at cross section 4 (Fig. 16). The data provided here are intended to provide a general description of the channel bed material characteristics at the study site for use in comparing and contrasting different study sites. This was not a detailed channel morphologic investigation.

### Stage

The stage (height) of the river was measured during the 1985 data collection period to assess changes over time in the stage and water



Table 3. Characteristics of streambed material samples at the study site.

<u>Date**</u>	<u>Location</u>	<u>Mean</u>	<u>Median</u>	<u>Standard deviation</u>	<u>%Gravel</u>	<u>%Sand</u>	<u>Silt and clay</u>	<u>Description</u>
7/10/84	x-s #2*	1.41	1.02	.25	36.83	58.44	4.73	gravelly sand
7/12/84	x-s #4*	.86	.73	.41	16.95	81.19	1.86	gravelly sand
8/14/85	west 1/4	.50	.51	.53	2.99	93.40	3.61	silty sand
8/14/85	midpoint	.86	.68	.33	26.15	69.17	4.68	gravelly sand
8/14/85	east 1/4	2.06	2.85	.21	58.30	37.38	4.32	sandy gravel
8/14/85	composit	1.17	.31	.29	29.15	66.65	4.20	gravelly sand

\* x-s = cross section

west and east 1/4 refer to a point one-fourth of the stream width from the stream bank

\*\*All 1985 samples obtained from a cross section 100' downstream of the bridge site.

All 1984 samples were composited prior to laboratory analysis from 4 discrete samples obtained at equal distances across the stream width.

discharge. Figure 22 summarizes the stage measurements over the period August 5-14, 1985. The highest stage was recorded on August 5 and 8. The lowest stage occurred on August 14. The general trend was a gradual decrease in the stage from August 5 to 7 and from August 8 to 14, with some rise in between from the 7th to the 8th. The change in the stage is similar to that exhibited by the discharge in table 2.

## MODEL RESULTS

The mathematical model discussed earlier was used to generate secondary velocities corresponding to seven different measurements in the Sangamon River. In this section the results of the model are discussed and compared to the measured values. The comparisons between the computed and measured values are shown in two sets of figures for each cross section. In the first figure, computed and measured secondary velocity vectors generated from the lateral and vertical components are compared. In the second figure, the primary velocity isovels approximated by the model are compared to the actual isovels developed using the measured values. A table is also presented that summarizes the magnitudes of the computed and measured velocities for all the cases considered. Finally, a section on shear stress distribution is presented.

### Comparison of Computed and Measured Velocities

The comparisons for cross section 6 as measured on June 28, 1984, are shown in Figs. 23 and 24. Fig. 23a shows the secondary velocity vectors generated by the model, while Fig. 23b shows the vectors from the measured velocities. It should be mentioned here that the vectors for the measured velocities were obtained by interpolating the vertical components around the points where transverse velocities were measured. This was necessary because it was not possible to measure the vertical and transverse components at the same point simultaneously.

As shown in Fig. 23 the general pattern of secondary circulation generated by the model is similar to the measured one; however, the downward circulation indicated near both the right and left banks by the model (Fig. 23a) are not present in the measured velocities (Fig. 23b). Velocity measurements were not taken very close to the stream banks and the channel

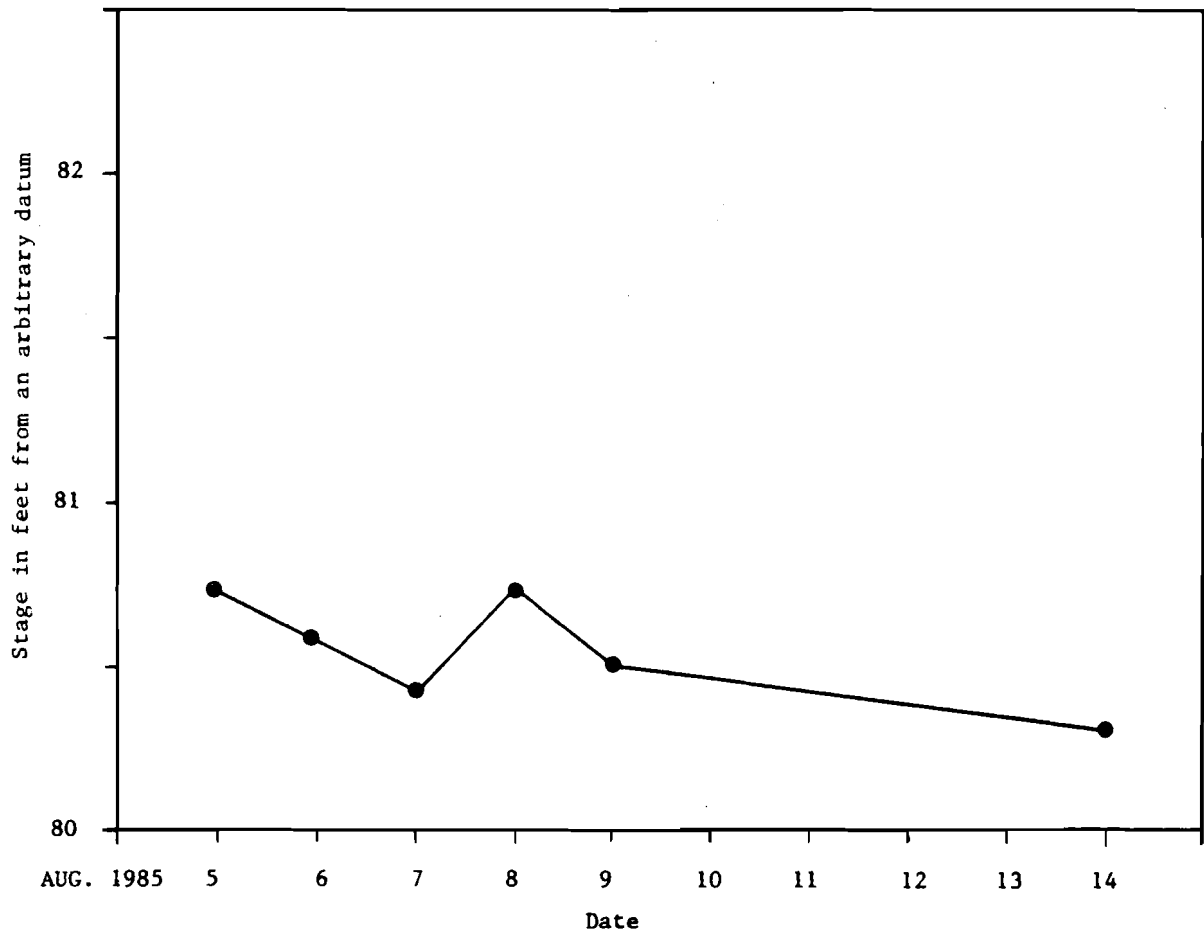


Figure 22. Variation of stream stages during field data collection

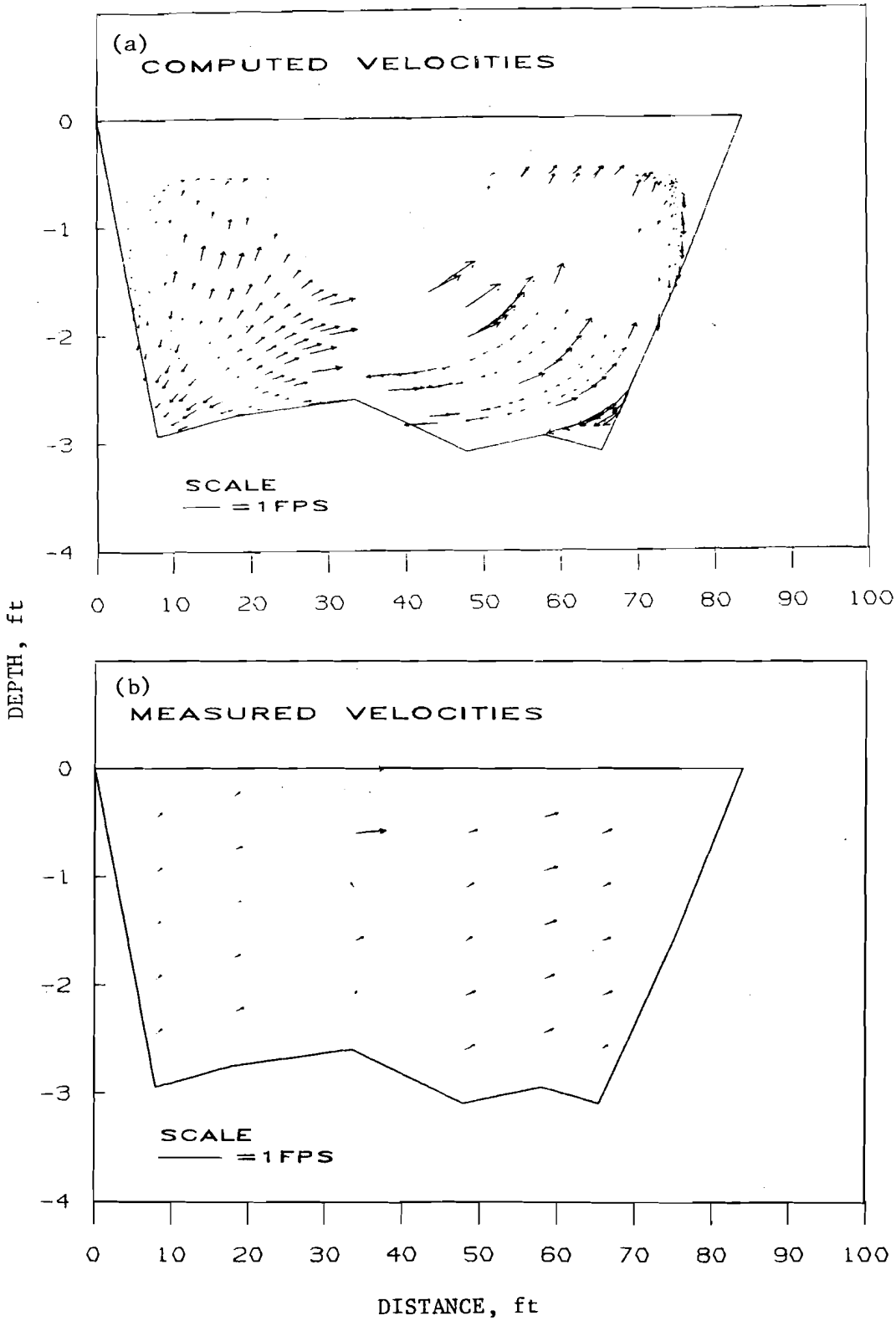


Figure 23. Comparison between computed and measured secondary velocities, cross section 6, June 28, 1984

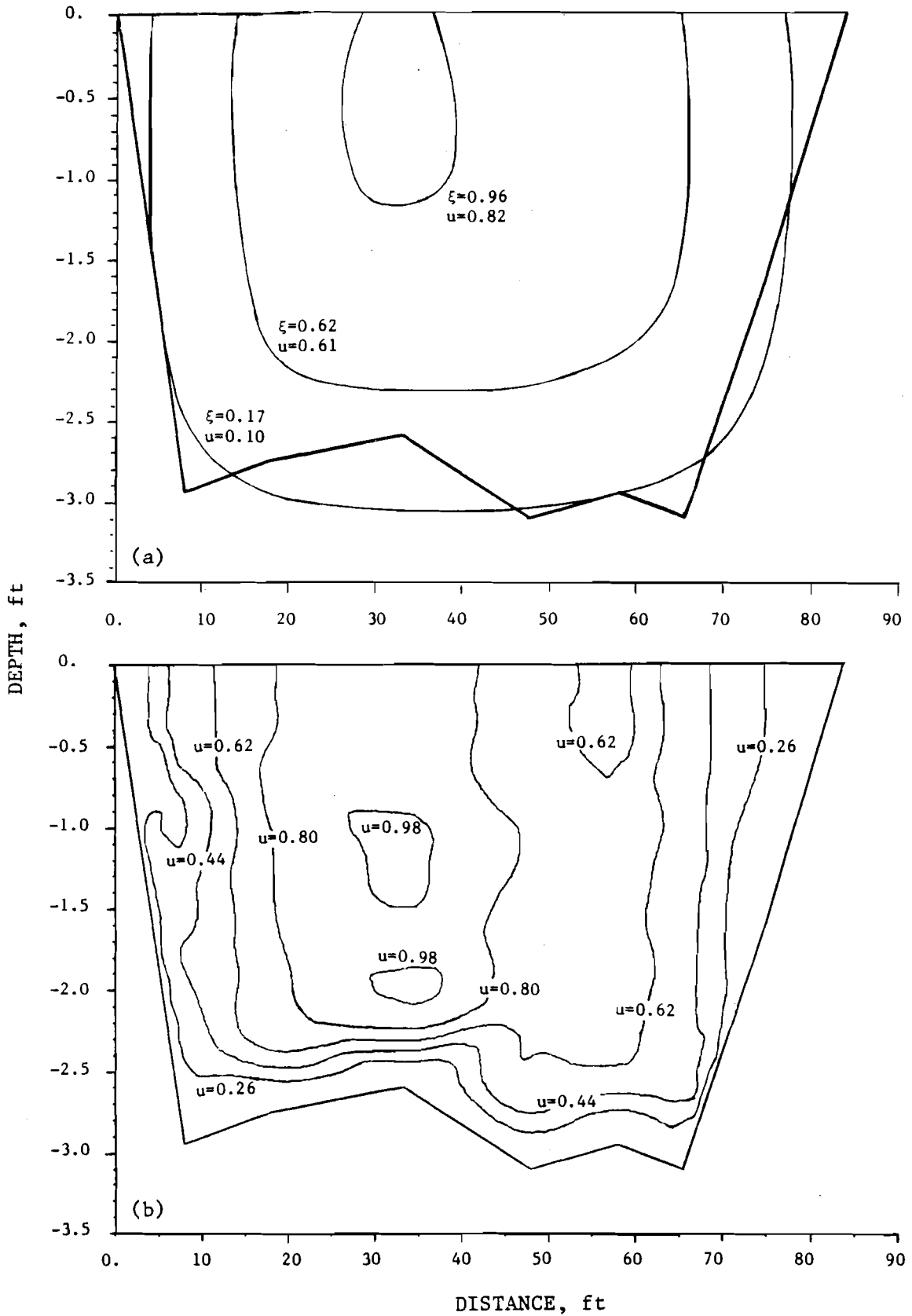


Figure 24. Comparison between isovels derived from computed and measured data, cross section 6, June 28, 1984

bottom because of the physical limitations of the equipment setup. The lack of these measurements makes it difficult to make conclusive remarks on the comparison of the model results with the measured values for areas close to the bank.

The measured secondary velocities are generally smaller than those generated by the model. This is true for all seven cross sections used for the model. The values of the primary, transverse, and vertical components of the velocity for all the cross sections are summarized in table 4. The percentages of the computed with respect to the measured transverse and vertical velocities are given in columns 9 and 11 in table 4. The percentages in both columns are all higher than 100 percent and in some cases extremely high. Because of the small magnitudes of the velocities, a very small error in velocity measurements or slight overestimation by the model results in very high percentages. However, further refinement of the model is needed and possible. Unfortunately this could not be accomplished within this project.

Table 4 also provides the relative magnitudes of the measured transverse and vertical velocity components with respect to the primary velocity component in columns 5 and 7, respectively. The transverse components range from 8 to 43.7 percent of the primary velocity, while the vertical components range from 4.1 to 40.4 percent. These values are in most cases higher than those reported in the literature, but might be because of the low flow conditions in the Sangamon River during data collection. Additional data during higher flows are required to more definitely define the relative magnitude of secondary velocity components as compared to the primary velocity.

Fig. 24 shows the primary velocity isovels generated by the model (Fig. 24a) and those developed from the measured velocities for cross section 6 discussed above. There is a clear similarity between these two plots; however, as can be seen in the figure, the isovels for the model are smooth curves, while the isovels from the measured velocities are irregular and show deformations at different places. This discrepancy was anticipated from the beginning since the model formulations assume smooth isovels which can be approximated by mathematical functions. The assumption of smooth isovels is the most limiting factor in secondary circulation models based on coordinate transformation.

Table 4. Mean Measured and Computed Velocities

Cross Section	Date	Measured		Measured		Measured		Component		Computed	
		longitudinal component (fps)	transverse component (fps)	col (4) col (3) (%)	vertical component (fps)	col (6) col (3) (%)	transverse component (fps)	col (8) col (4) (%)	vertical component (fps)	col (10) col (6) (%)	
7	6/27/84	.599	.048	8.0	.138	23.0	--	--	--	--	
6	6/28/84	.535	.118	22.1	.022	4.1	.22	186	.27	1227	
5	6/29/84	.465	.060	12.9	.137	29.5	.19	317	.15	109	
3	7/09/84	.352	.054	15.3	.115	32.7	.16	296	.12	104	
4	7/10/84	.302	.055	18.2	.122	40.4	.28	509	.38	311	
2	7/12/84	1.0009	.064	6.3	.088	8.7	--	--	--	--	
1	7/13/84	.744	.172	23.1	.067	9.0	--	--	--	--	
5	8/05/85	.444	.081	18.2	.072	16.2	.13	160	.16	222	
6	8/06/85	.627	.274	43.7	.211	33.6	.40	146	.51	242	
7	8/07/85	.316	.068	21.5	.101	31.9	--	--	--	--	
8	8/08/85	.373	.091	24.4	.073	19.6	.30	330	.39	534	
9	8/09/85	.251	.105	41.8	.069	27.5	--	--	--	--	

The comparisons of the model results with the measured values for the remaining six measurements are shown in Figs. 25 to 36. In general, the preceding discussion for cross section 6 (June 28, 1984) is applicable for all the comparisons. Some of the comparisons indicate a better correlation between measured and computed velocities and some are worse than the ones shown for cross section 6, as summarized in Table 4. A complete listing of the velocities generated by the model is included in Appendix C. Additional work both in data collection and in refinement of the model is definitely needed before the model adapted for this project can be applied to flow conditions in natural streams.

#### Shear Stress Distribution

As discussed in the section on approximation of shear stresses, the shear stresses were assumed to vary quadratically in the  $\xi$  direction according to Eq. 35. The coefficients for Eq. 35 are derived from boundary conditions, which depend on the flow conditions and the channel boundary. The shear stress distributions generated by the model for two sets of measurements at cross section 6 are shown in Figs. 37 and 38.  $\tau/\tau_0$  is the ratio of the shear stress at any point ( $\tau$ ) to that at the channel bottom ( $\tau_0$ ). The figures clearly show higher shear stresses around the junctions of the stream bank with the stream bed, which might indicate areas of higher erosion rates as compared to the whole channel cross section.



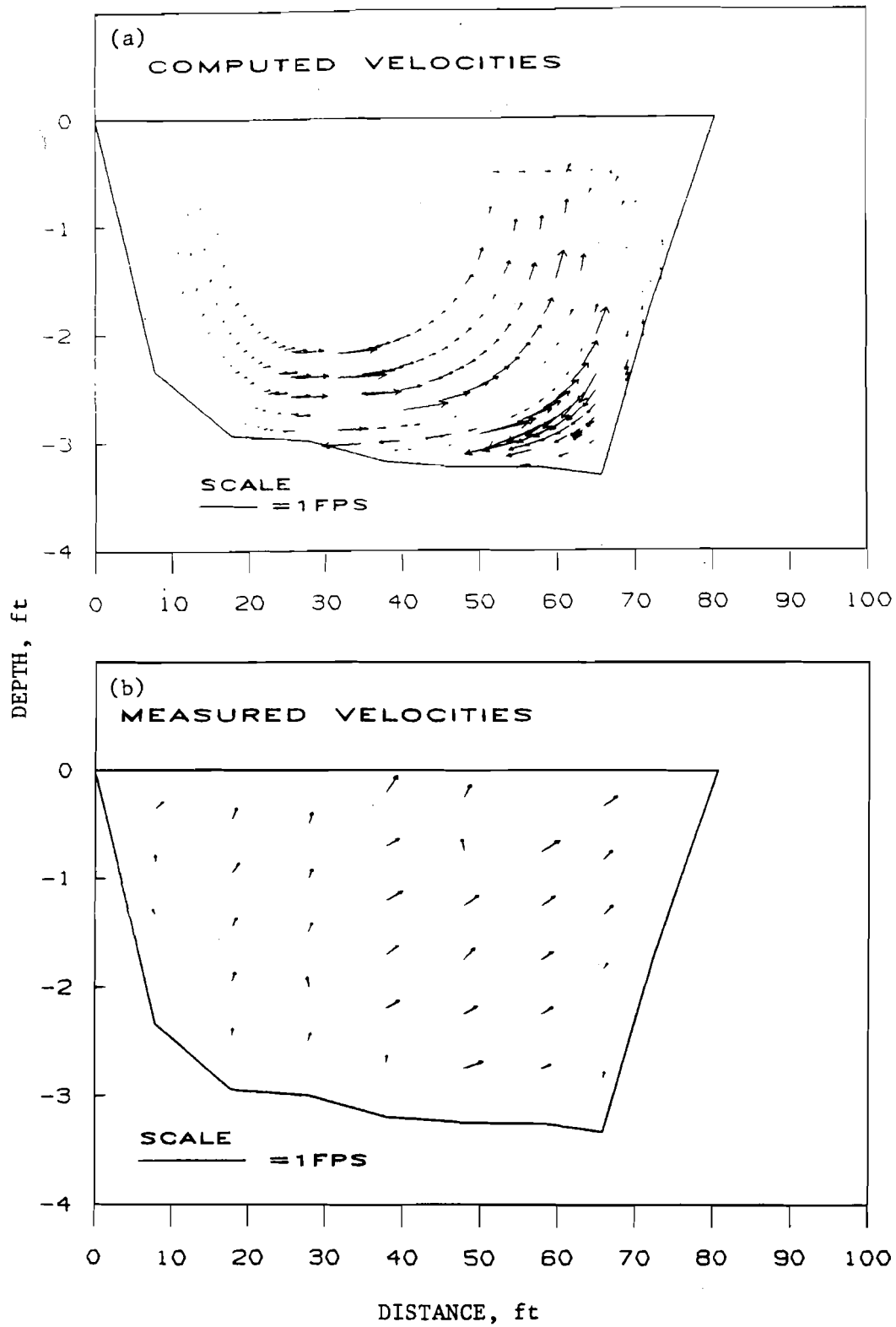


Figure 25. Comparison between computed and measured secondary velocities, cross section 5, June 29, 1984

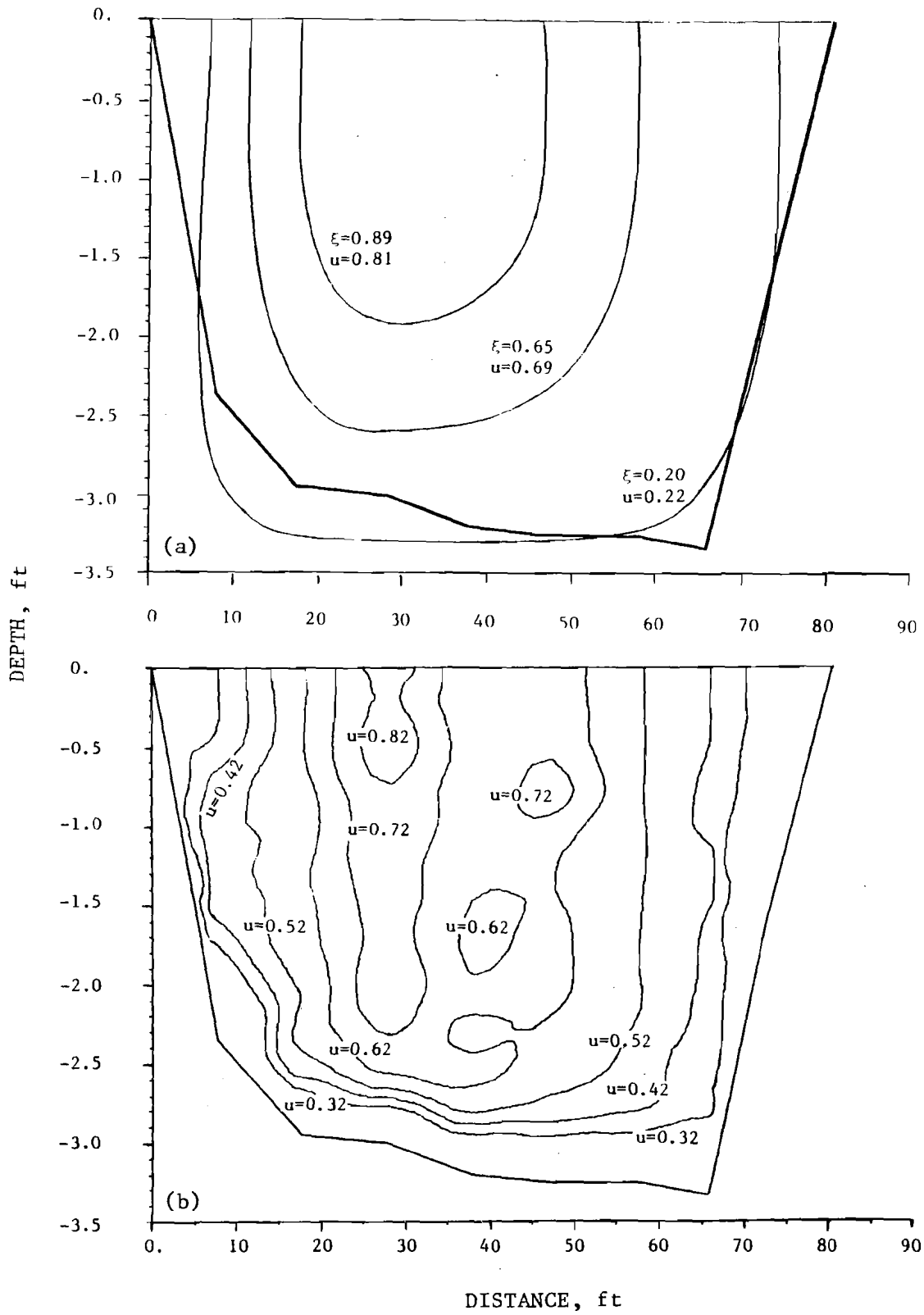


Figure 26. Comparison of isovels derived from computed and measured data, cross section 5, June 29, 1984

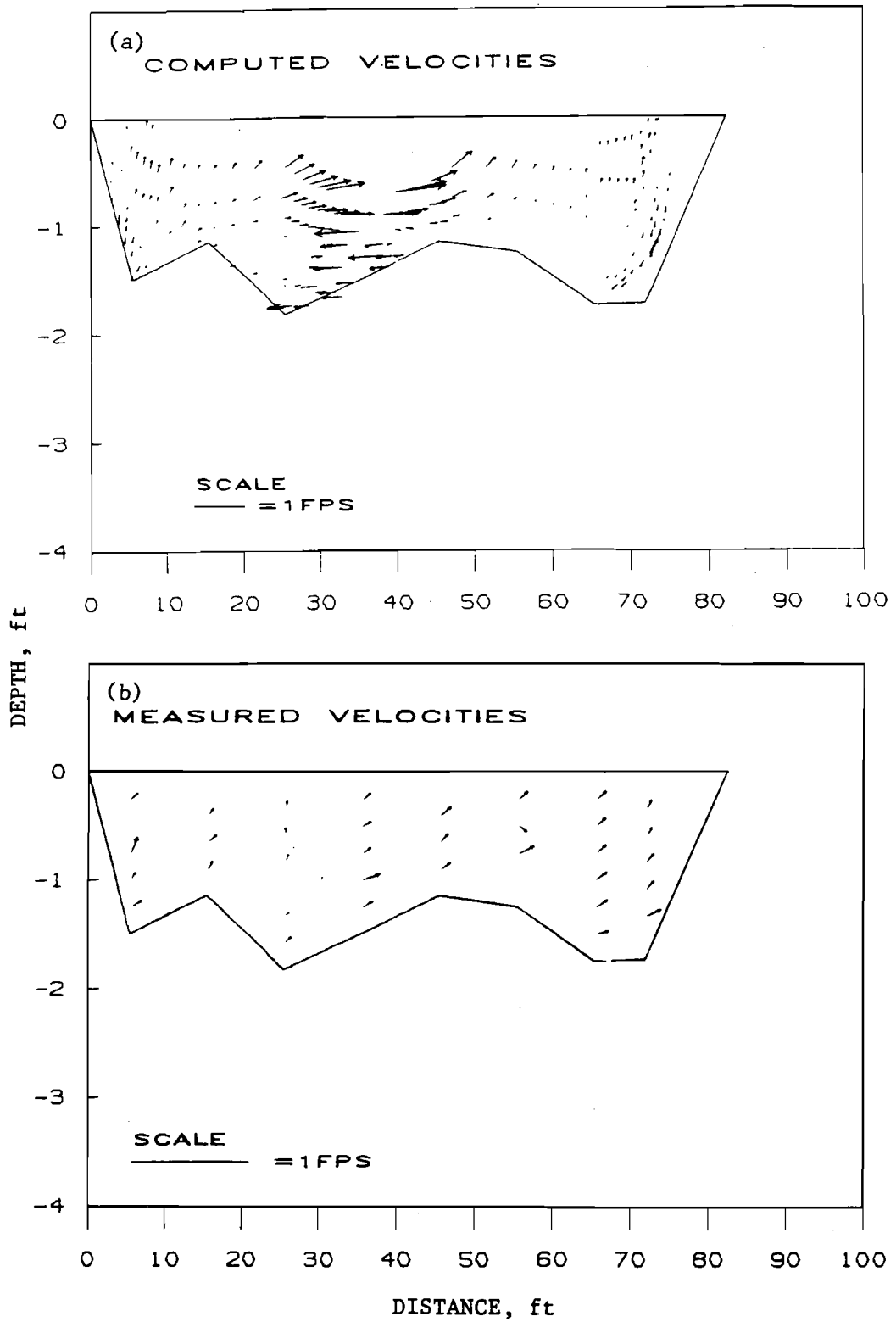


Figure 27. Comparison between computed and measured secondary velocities, cross section 3, July 9, 1984

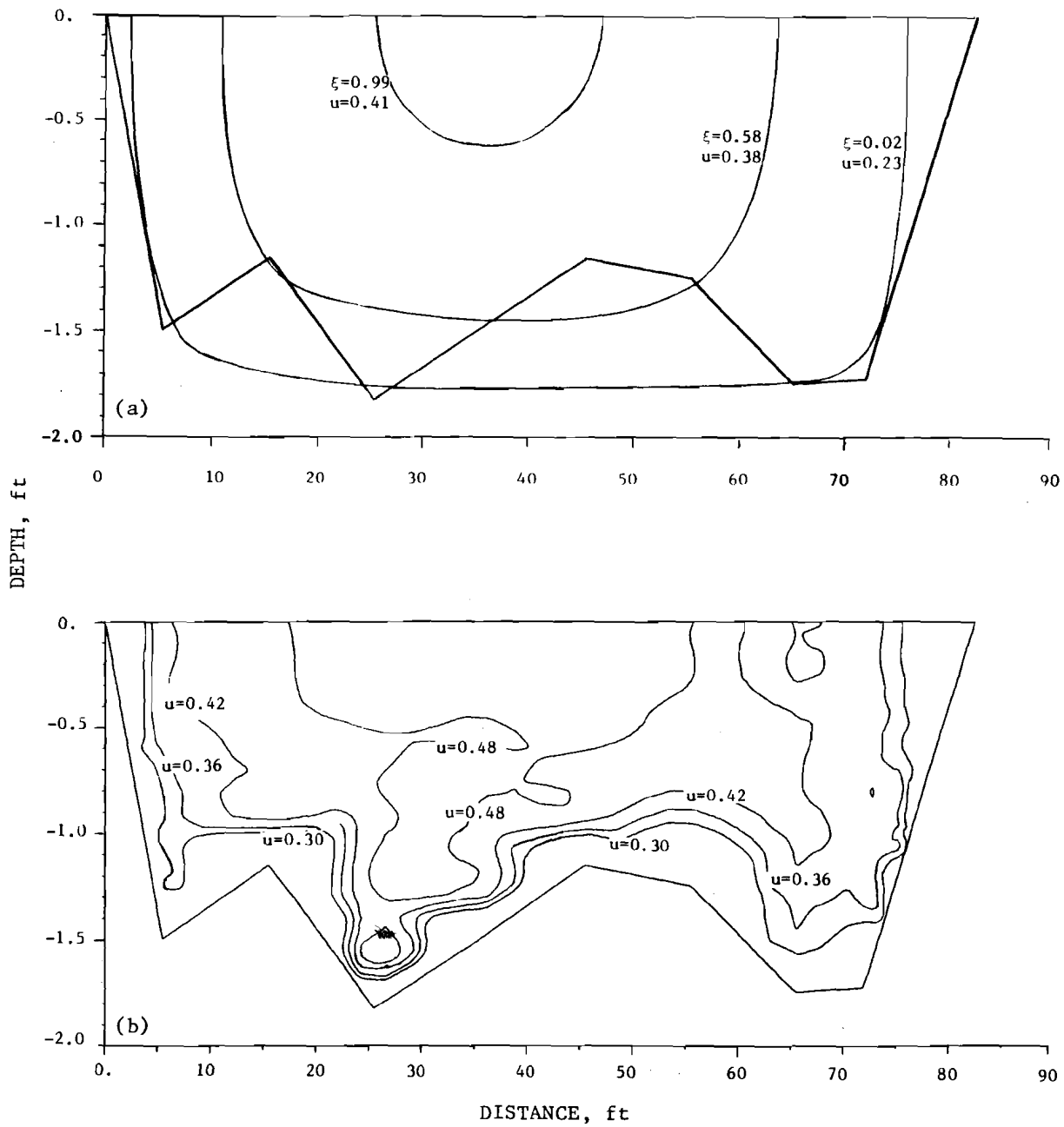


Figure 28. Comparison of isovels derived from computed and measured data, cross section 3, July 9, 1984

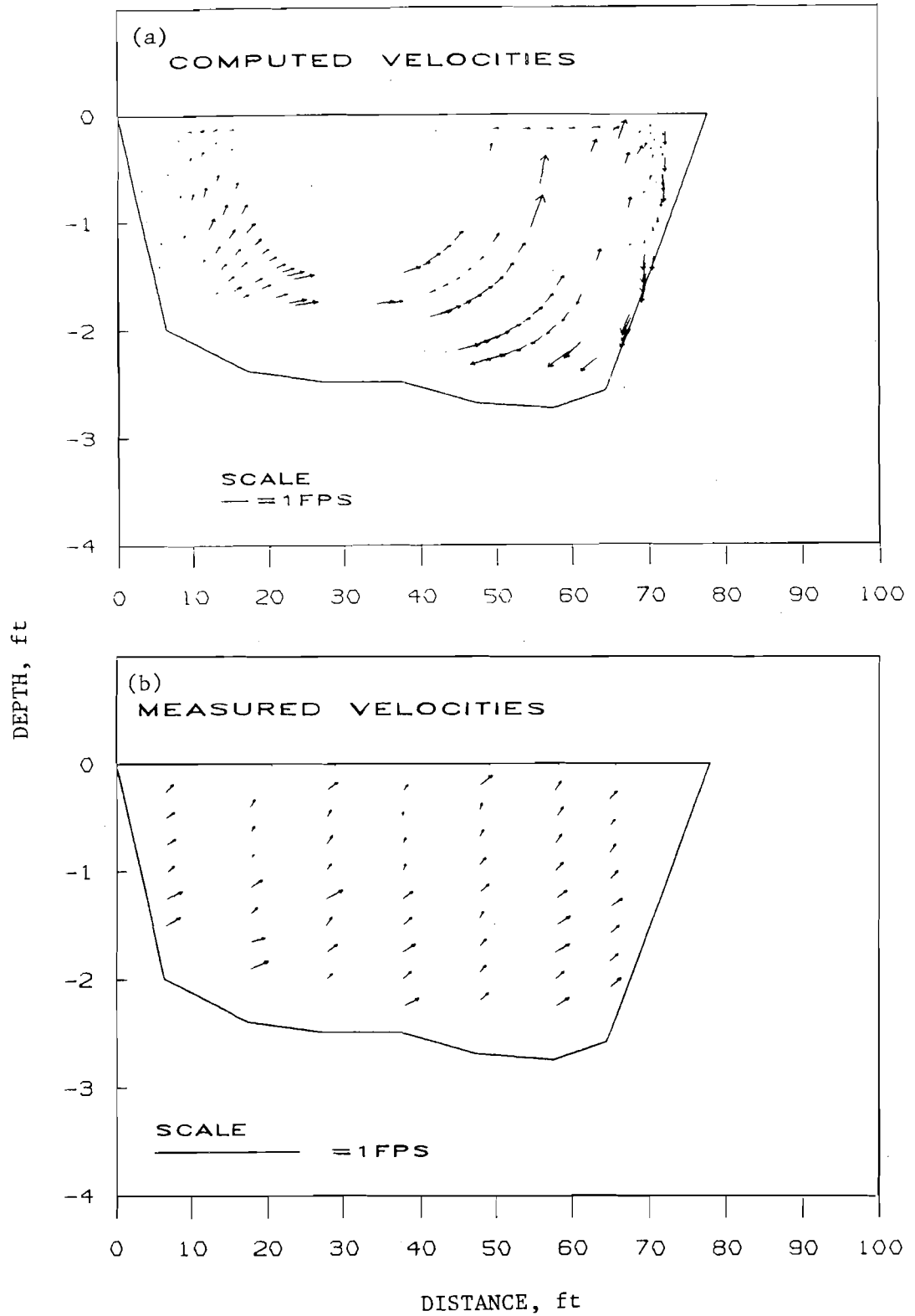


Figure 29. Comparison between computed and measured secondary velocities, cross section 4 July 10, 1984

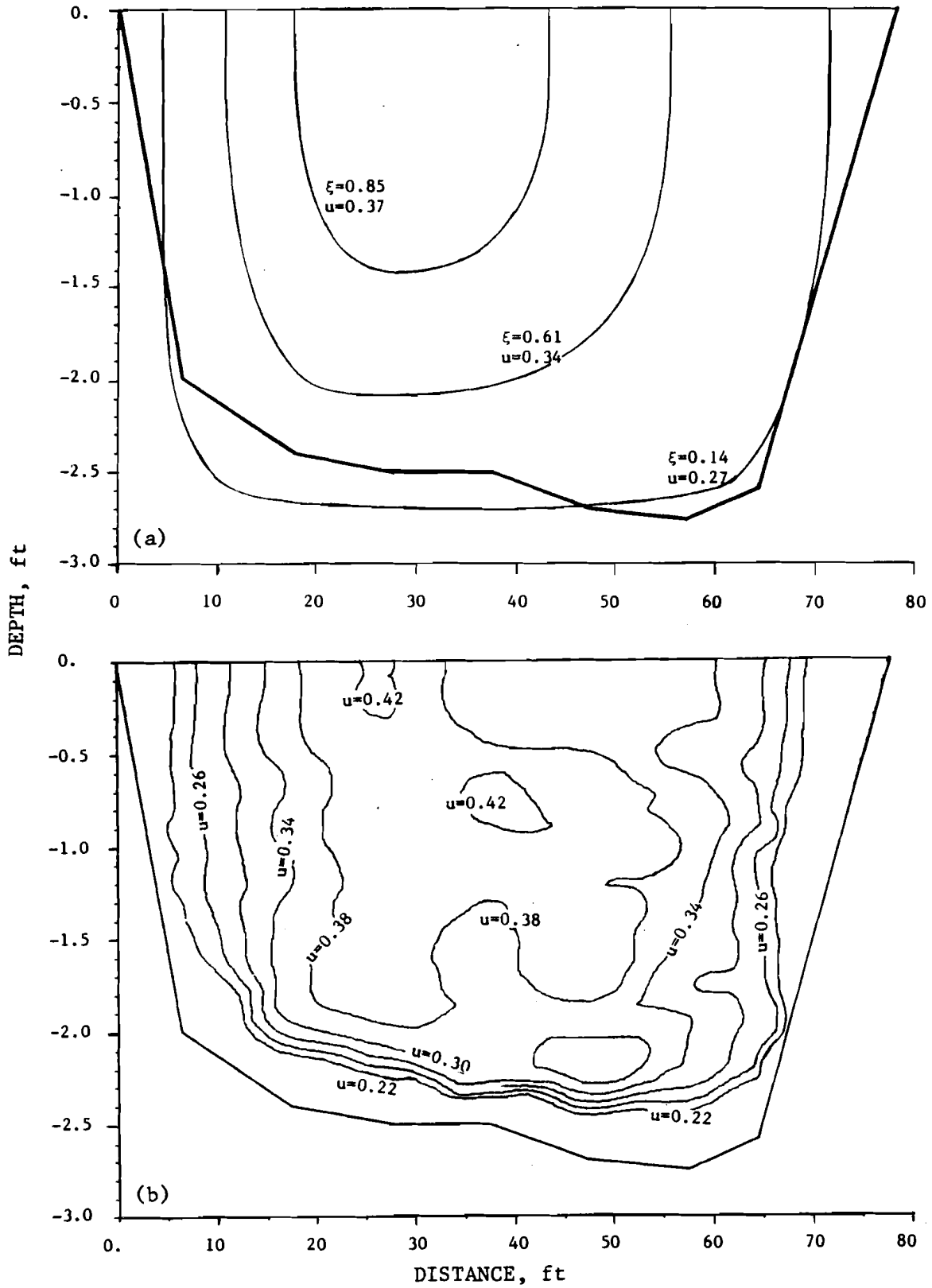


Figure 30. Comparison of isovels derived from computed and measured data, cross section 4, July 10, 1984

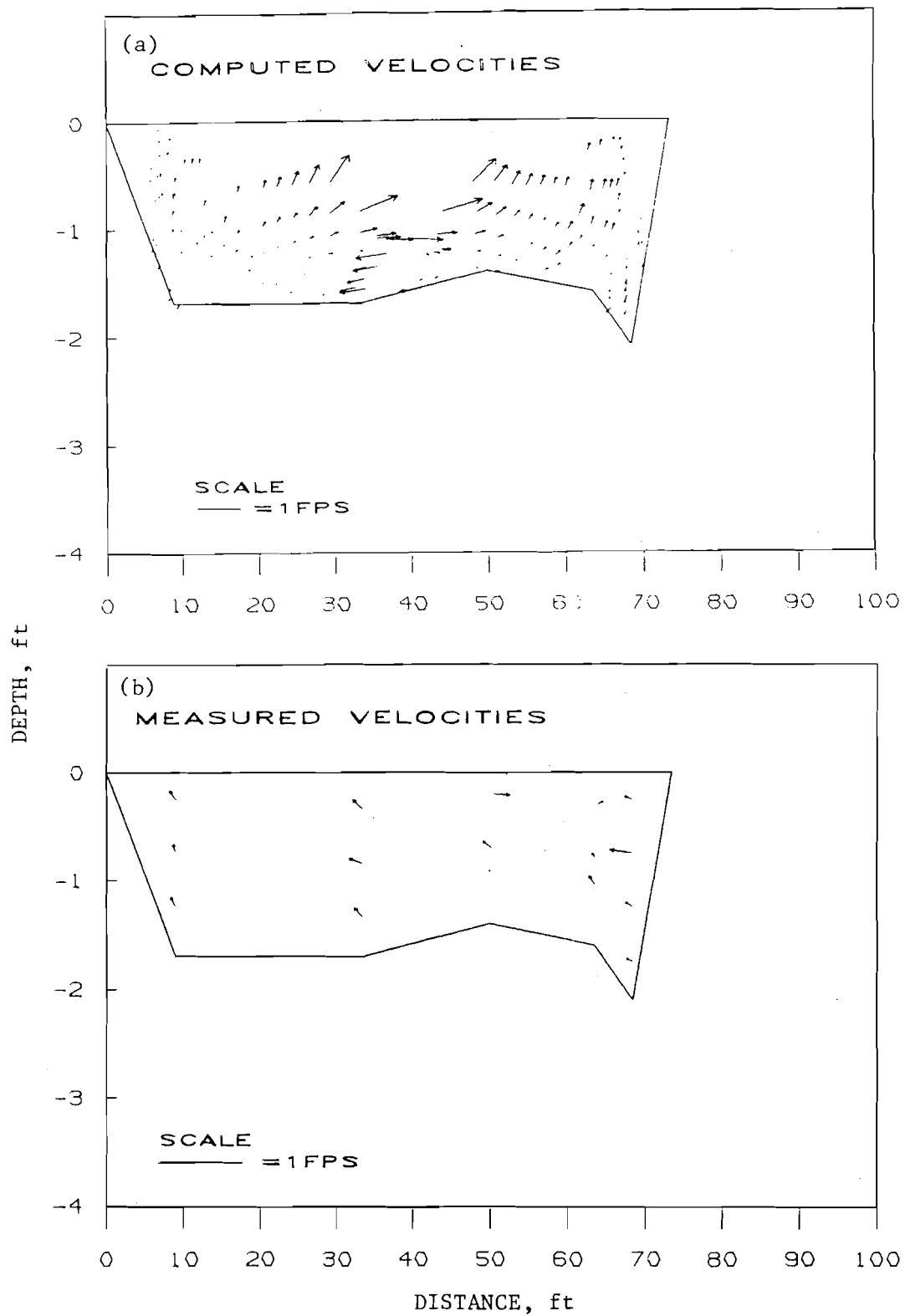


Figure 31. Comparison between computed and measured secondary velocities, cross section 5, August 5, 1985

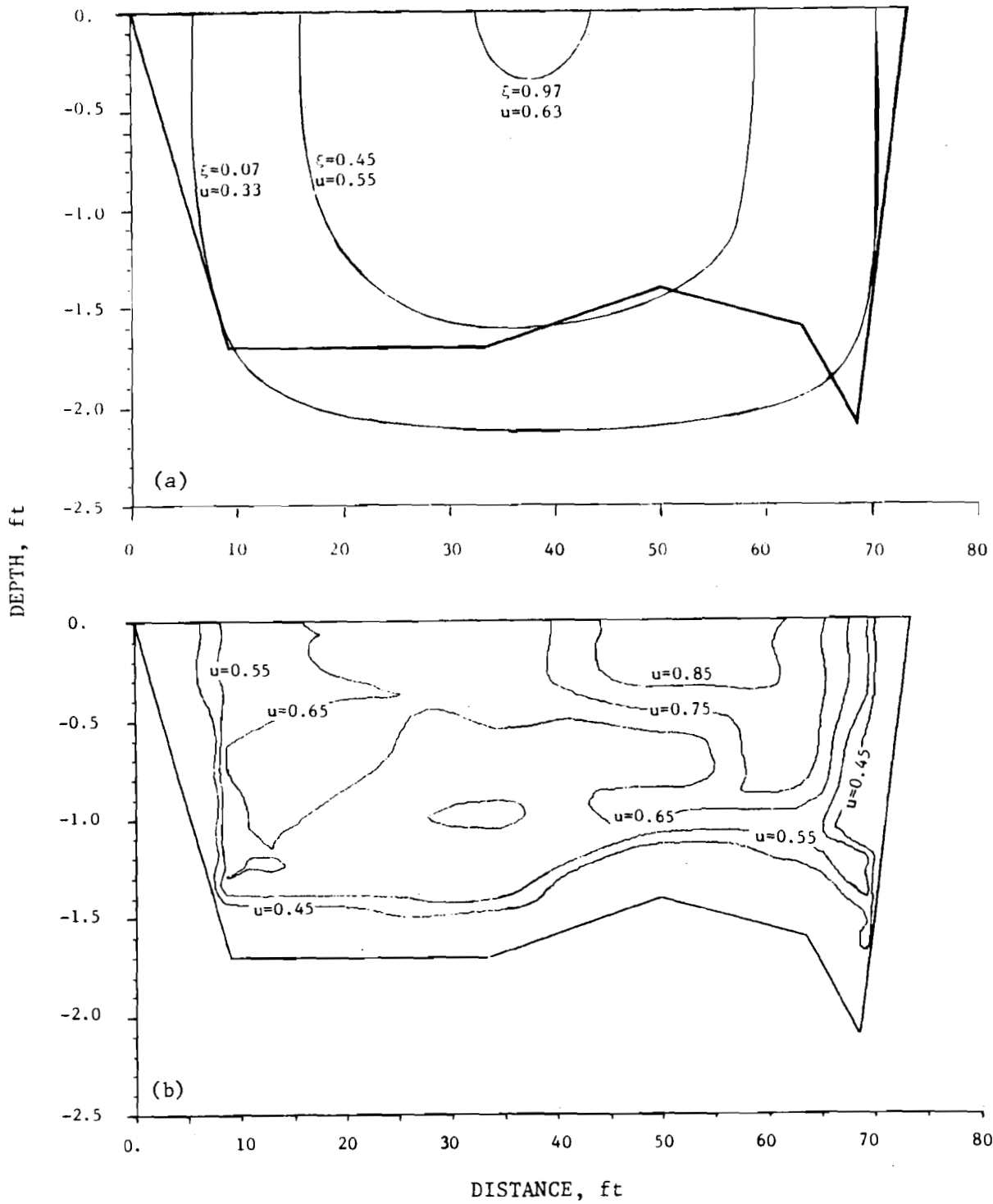


Figure 32. Comparison between isovels derived from computed and measured data, cross section 5, August 5, 1985



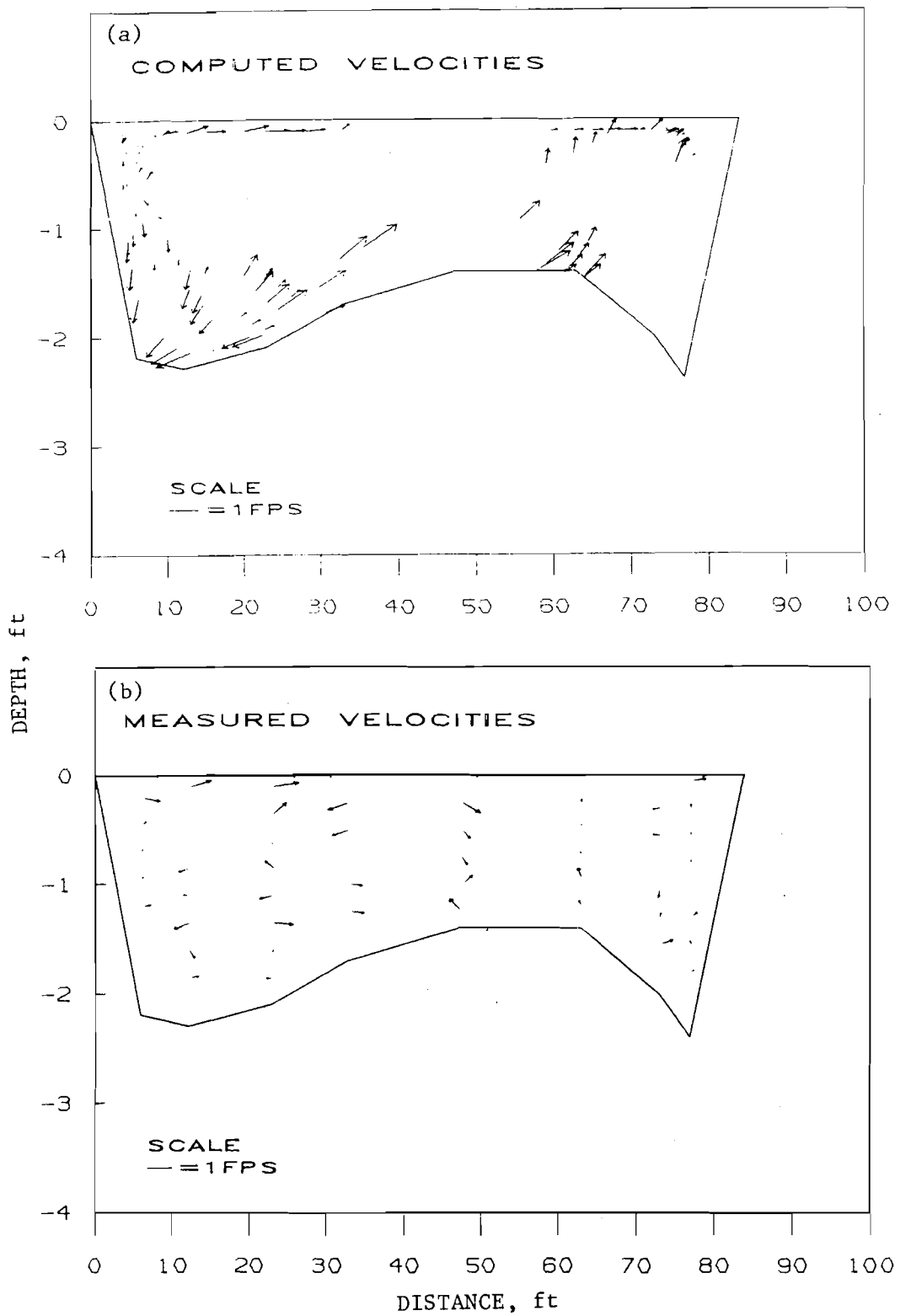


Figure 33. Comparison between computed and measured secondary velocities, cross section 6, August 6, 1985

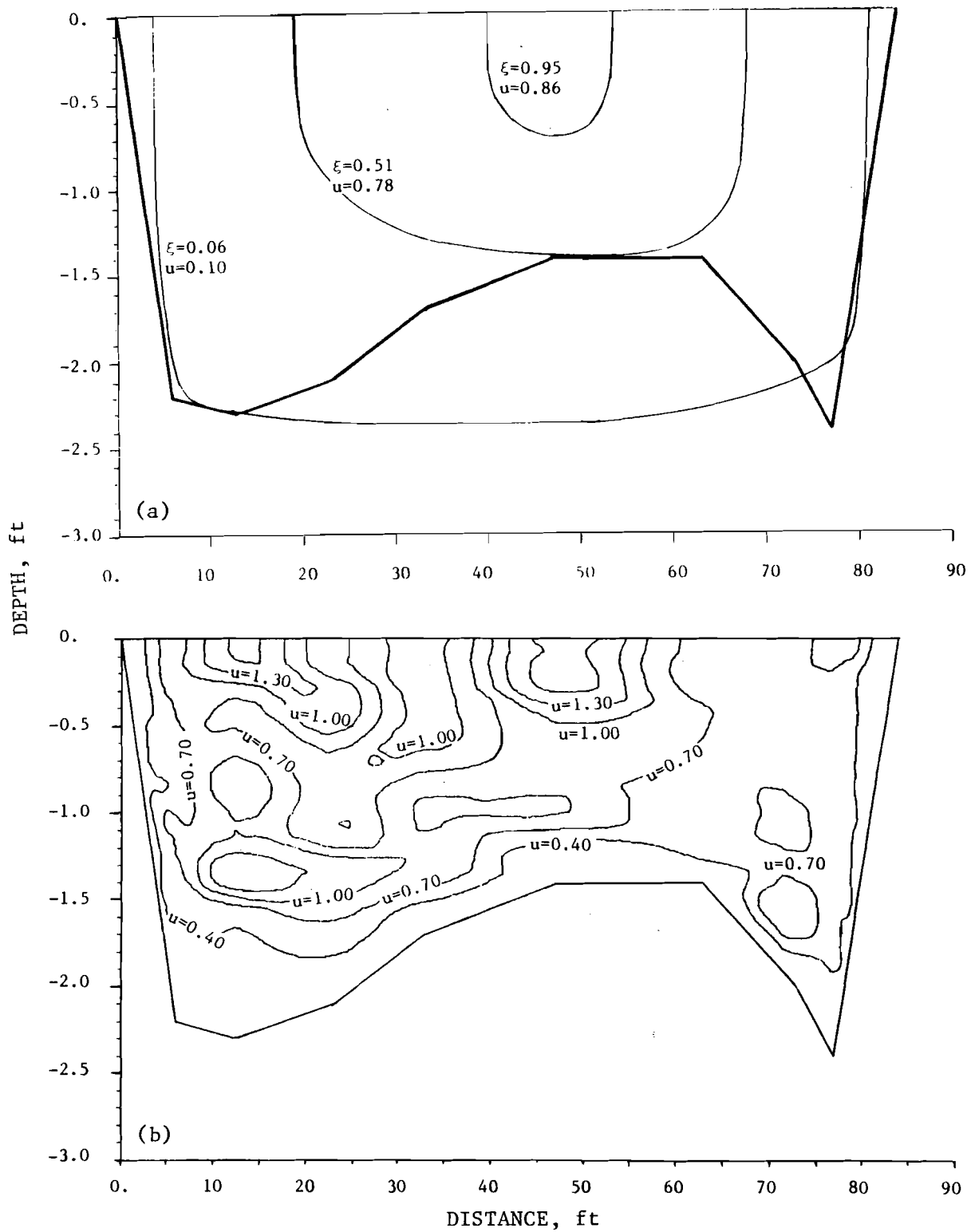


Figure 34. Comparison of isovels derived from computed and measured data, cross section 6, August 6, 1985

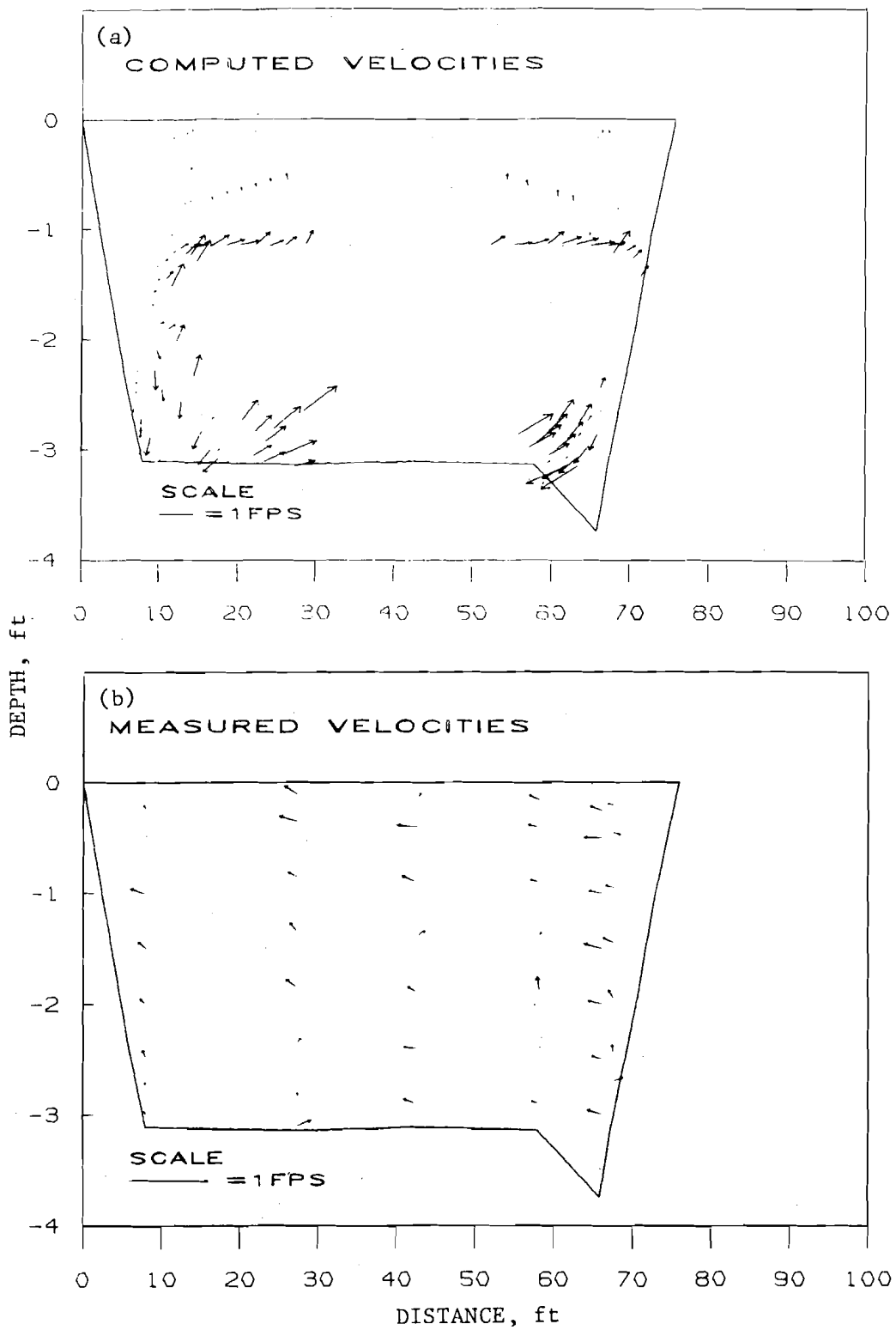


Figure 35. Comparison between computed and measured secondary velocities, cross section 8, August 8, 1985

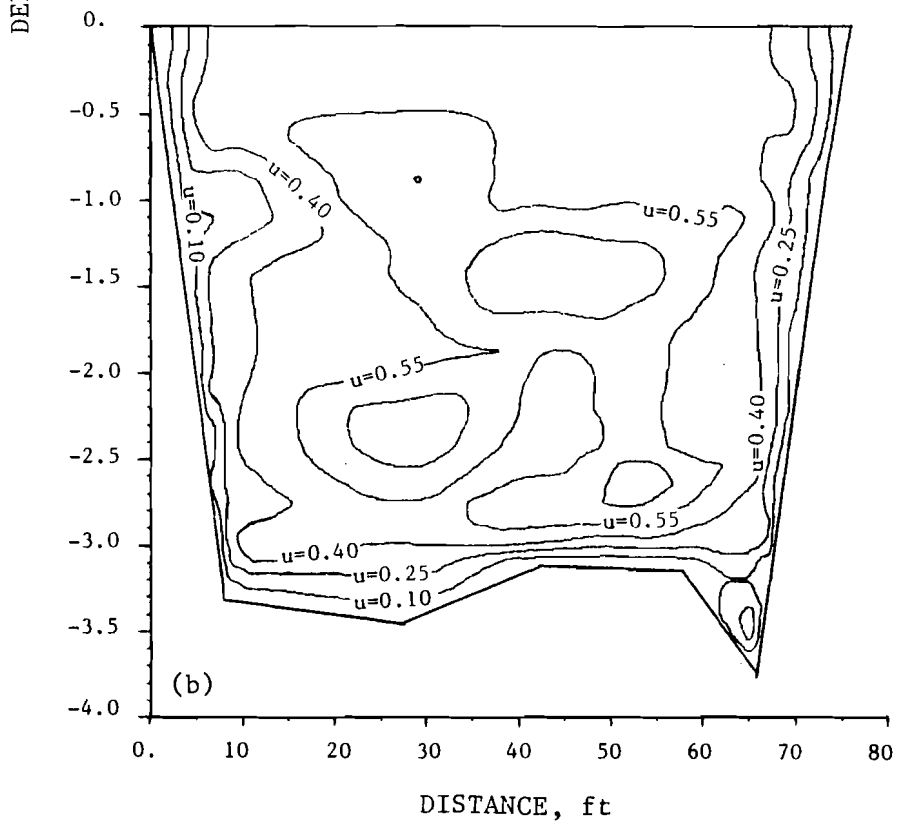
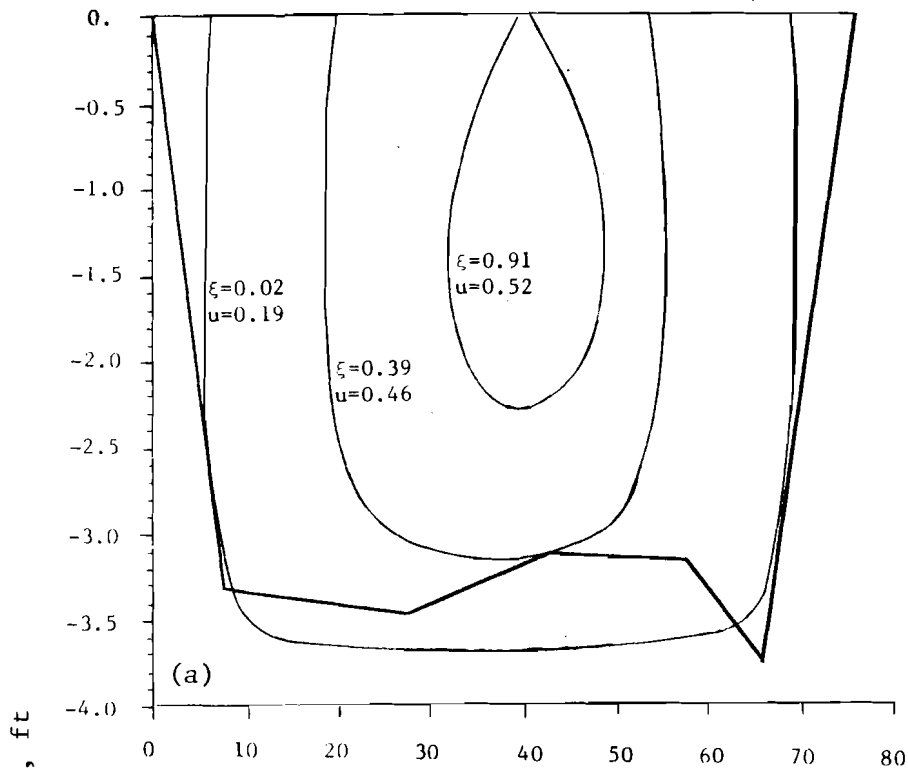


Figure 36. Comparison of isovels derived from computed and measured data, cross section 8, August 8, 1985

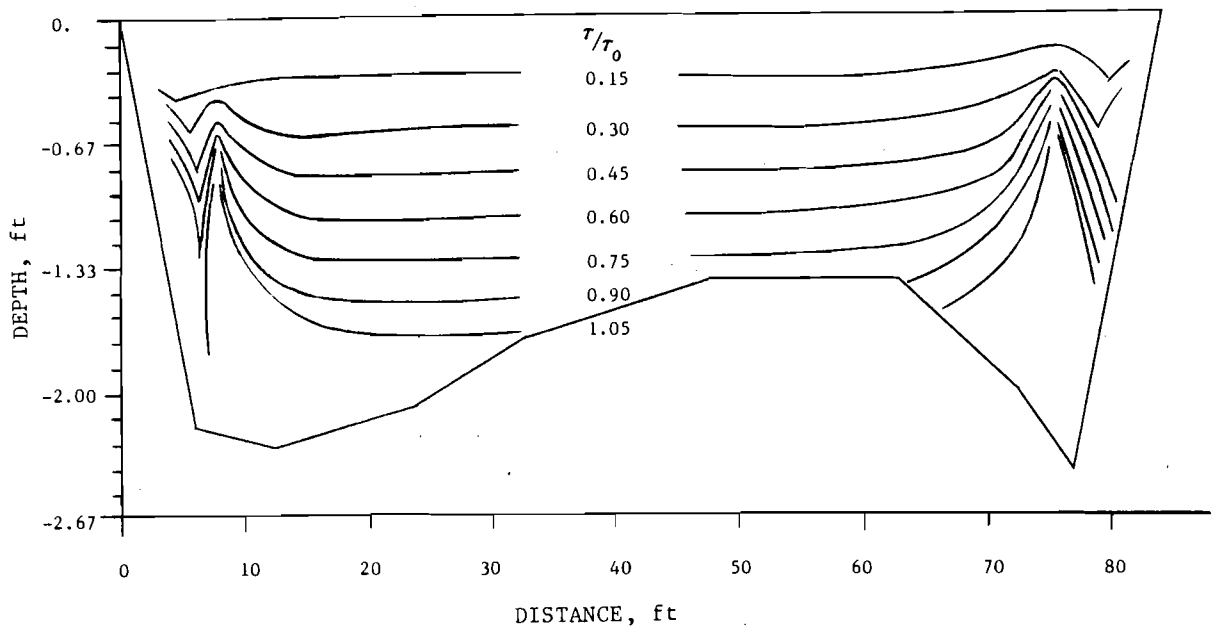


Figure 37. Shear stress distribution, cross section 6, June 28, 1985

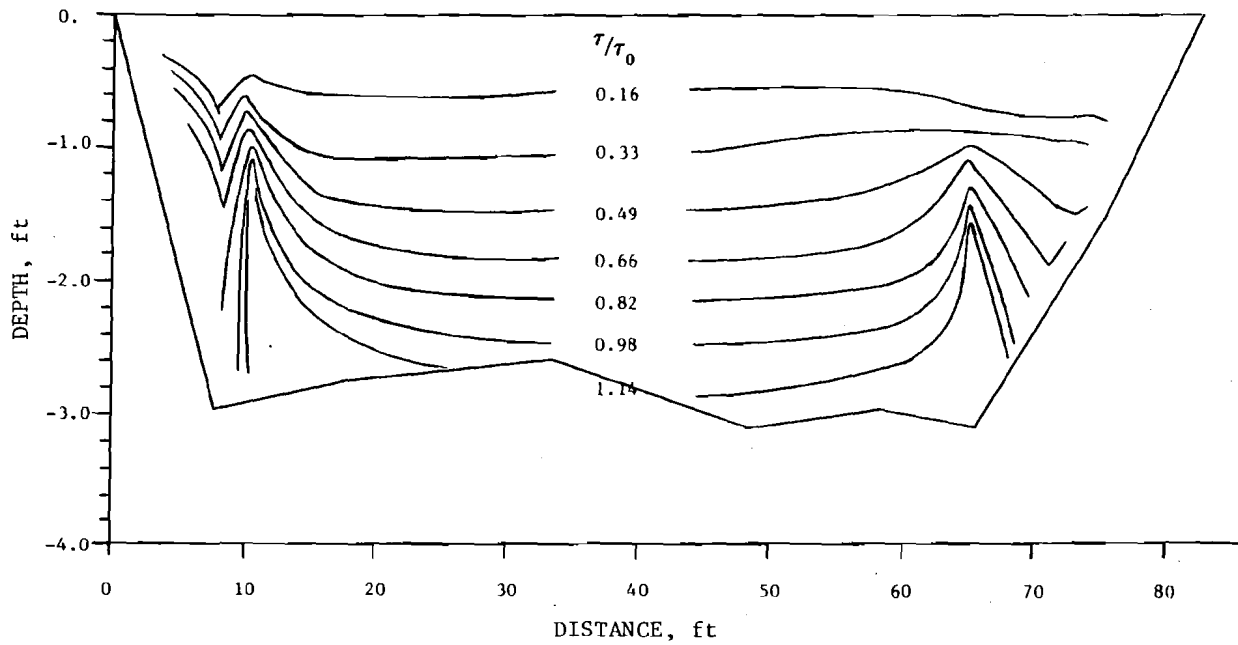


Figure 38. Shear stress distribution, cross section 6, August 6, 1985

## SUMMARY AND CONCLUSIONS

Secondary circulation is an important hydraulic phenomenon in natural streams. However, studies in the field have been limited, and in particular actual measurements of secondary circulation have been very few. This is because of the difficulty in measuring very small velocities under natural conditions. The development of mathematical models has also been limited, primarily because of the lack of reliable field data for calibration and verification.

This project is one of the few research projects in the United States that has attempted to measure secondary circulation in natural streams. As a result of this project, a reliable field data collection technique has been developed. The data collection system is computerized to reduce the time required in field data recording and reduction. The system has been used successfully several times to measure secondary circulation data in the Sangamon River near Mahomet, Illinois. All the data collected for the project are included in Appendix B. The data are also analyzed and presented graphically to simplify comparison of data with model results.

At the beginning of this project it was anticipated that an existing model would be available for calibration and verification. However, attempts to obtain existing models were not successful because of the early stages of model development by other researchers. Instead of delaying or dropping the task of calibration and verification of existing models, it was decided to develop a model based on information available in the literature. At that time, the model being developed by Chiu and his associates at the University of Pittsburgh was the best documented model available.

A mathematical model based on Chiu's methods has been developed and was used to compare measured secondary velocities with computed velocities. A complete listing of the computer program for the model is included in Appendix A. The mathematical derivations and the equations used in the model are thoroughly discussed in the report. The model has been used to simulate field conditions for all the cases where field data were collected, and the results are included in the report.

Comparisons of field data and model results show mixed results. In some cases the results are satisfactory while in others they are not. In general, the model is capable of generating similar secondary circulation patterns to those indicated by the field data. However, the magnitudes of the secondary

currents generated by the model are greater than those measured in the field. Comparison of model results with measured values was further hampered by the lack of data points very close to the banks, where the model indicates the existence of consistently downward velocity components. Because of the limitations of the physical setup for collecting field data, secondary circulation data very close to the stream banks could not be collected.

The overall results of the research can be summarized by the following statements:

- 1) A reliable state-of-the-art secondary circulation data collection system has been developed and used successfully in the field. This will significantly increase the productivity of future research in the area.
- 2) A mathematical model for secondary circulation has been developed and compared with field measurements. The results of the comparison are not totally satisfactory, and further research is needed to improve the application of the model to flow conditions in natural streams.



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APPENDICES

(SECONDARY CIRCULATION IN NATURAL STREAMS)

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Appendix A

List of Computer Program



PROGRAM GIO(TAPE1, TAPE2, TAPE3, TAPE4, INPUT, OUTPUT, TAPE62,  
 TAPES=INPUT, TAPE6=OUTPUT)

\*\*\*\*\*  
 DEFINITION OF VARIABLES  
 \*\*\*\*\*

ALPHA1(N,KPART) : COEFFICIENTS 1 IN SHEAR STRESS APPROXIMATION  
 ALPHA2 : COEFFICIENT 2 IN SHEAR STRESS APPROXIMATION  
 BETA(KPART) : GEOMETRY CORRECTION FACTORS  
 B1(KPART) : WIDTH OF THE RIVER SURFACE ON EACH COMPUTING SIDE  
 CETA(K) : GEOMETRIC CORRECTION FACTORS  
 DELY : DEPTH ADJUSTING COEFFICIENT  
 DUDX : INCREASMENT OF VELOCITY U IN X DIRECTION  
 DUDT : U INCREMENT OF TIME  
 DEPTH : DEPTH AT THE Y-AXIS  
 DHETA(N,K,KPART) : FNC8 K - SI INCREMENTS, N - ETA INCREMENT  
 EPSILON : LOCATION OF THE POINT OF MAXIMUM VELOCITY  
 DELTA(KPART) : WIDTH ADJUSTING FACTORS  
 DENSITY : DENSITY OF FLUID  
 DS1(S) : INCREMENTS OF SI VALUE  
 DELTA : INCREMENTS OF ETA VALUE  
 DETADZ(N,K,KPART) : DERIVATIVE OF ETA W.R.T. Z  
 DS1DZ(N,K,KPART) : DERIVATIVE OF XI W.R.T. Z  
 ETAMIN : LOWER BOUND OF ETA AT TIME OF COMPUTATION  
 ETAMAX : UPPER BOUND OF ETA AT TIME OF COMPUTATION  
 MANY FUNCTIONS WHICH ARE USED FREQUENTLY ARE DEFINED  
 IN THE FNC CATEGORY  
 .FNC1 : FNC1 = DEPTH+DELTA+EPSILON  
 .FNC2 : FNC2 = B1(K)+DELTA(K)  
 .FNC3 : FNC3 = COMPUTE THE SI VALUE  
 .FNC3DY : FNC3DY = DERIVATIVE OF FNC3 W.R.T. YC  
 .FNC3DZ : FNC3DZ = DERIVATIVE OF FNC3 W.R.T. ZC  
 .FNC4 : FNC4 = COMPUTE THE ETA VALUE  
 .FNC4DY : FNC4DY = DERIVATIVE OF FNC4 W.R.T. YC  
 .FNC4DZ : FNC4DZ = DERIVATIVE OF FNC4 W.R.T. ZC  
 .FNC5 : FNC5 = S1MAX(ETA) - S1  
 .FNC6 : FNC6 = COMPUTE THE HSI VALUE  
 .FNC7 : FNC7 = COMPUTE THE HETA VALUE  
 .FNC8 : FNC8 = (1./HETA)\*(D(HETA)/D(S1))  
 .FNC9 : FNC9 = COMPUTE FO VALUE  
 .FNC10 : FNC10 = THE VALUE OF SI AT GIVEN ETA CURVE WHICH  
 INTERSECTS WITH WATER SURFACE  
 .G : GRAVITATIONAL ACCELERATION  
 .HR : HYDRAULIC RADIUS  
 .HETA(N,K,KPART) : TRANSFORMATION FACTOR IN ETA DIRECTION  
 .HSI(N,K,KPART) : TRANSFORMATION FACTOR IN SI DIRECTION  
 .ISTOP : TESTER. ISTOP .LE. 1 ACCEPTABLE, REJECT OTHERWISE  
 .JBEG(2,40) : THE BEGINING NUMBER FOR ETA CURVE ON EACH XI LINE  
 .KPART : KPART = 1 OR 2  
 .NAME : NAME OF THE CROSS SECTION  
 .NDIVIDE(2) : INTERVALS FOR VELOCITIES PLOTTER  
 : 1 = 1, SI INTERVALS  
 : 1 = 2, ETA INTERVALS  
 .KTOTAL : KTOTAL = TOTAL ETA CURVES USED ON EACH SIDE  
 .NECHO : NECHO = 0, PRINT OUT MRF ERROR MESSAGES  
 : NECHO = 1, NO PRINT OUT FOR MRF ERRORS  
 .OPTION : OPTION = 1, NUMERICAL ACCURACY TEST ONLY  
 : OPTION = 2, PLOT ISOVELS AND GRADIENT LINES  
 : OPTION = 3, COMPUTE TOCOEFFICIENTS CHECK INTERV.  
 : OPTION = 4, CARRY OUT WHOLE COMPUTATIONS  
 .PLOT1 : PLOT = 1, PLOT ISOVELS AND TRAJECTORS  
 : PLOT = 2, PLOT NO GRAPHS  
 .PLOT2 : PLOT = 1, PLOT SHEAR STRESSES DISTRIBUTION  
 : PLOT = 2, PLOT NO GRAPHS  
 .PLOT3 : PLOT = 1, PLOT Y COMPONENTS OF VELOCITIES  
 : PLOT = 2, PLOT NO GRAPHS  
 .PLOT4 : PLOT = 1, PLOT Z COMPONENTS OF VELOCITIES  
 : PLOT = 2, PLOT NO GRAPHS  
 .PLOTS : PLOT = 1, PLOT SECONDARY VELOCITIES  
 : PLOT = 2, PLOT NO GRAPHS  
 .PETA(2) : CURVELINEAR COORDINATE EDGES ON EACH SIDE  
 .PHI(N,K,KPART) : STREAM FUNCTION  
 .PRESURE : HYDROSTATIC PRESSURE  
 .SE : THE ENERGE SLOPE  
 .SHEAR(N,K,KPART) : SHEAR STRESSES  
 .SHEARD : DERIVATIVE OF SHEAR STRESS W.R.T. SI CORDINATE  
 .SHVELO : SHEAR VELOCITY OF THE CROSSECTION = SQRT(G+R\*SE)  
 .VSI(N,K,KPART) : VELOCITY COMPONENT IN SI DIRECTION  
 .SIDIFF(N,K,KPART) : FNC5  
 .SINUT : SI VALUE THAT APPROXIMATE THE CHANNEL GEOMETRY  
 .SIMIN : LOWER BOUND OF SI AT TIME OF COMPUTATION  
 .S1MAX : UPPER BOUND OF SI AT TIME OF COMPUTATION  
 .S1ZERO : XI ZERO FOR VELOCITY DISTRIBUTION  
 .VETA(N,K,KPART) : VELOCITY COMPONENT IN ETA DIRECTION  
 .VY(N,K,KPART) : COMPUTED VELOCITY COMPONENT IN Y DIRECTION  
 .VMY(N,K,KPART) : MEASURED VELOCITY COMPONENT IN Y DIRECTION  
 .VZ(N,K,KPART) : COMPUTED VELOCITY COMPONENT IN Z DIRECTION  
 .VMZ(L,K,KPART) : MEASURED VELOCITY COMPONENT IN Z DIRECTION  
 .WP : WETTED PERIMETER  
 .XI(N,K,KPART) : XI(N,K,KPART) = SI COORDINATES  
 .X1MAX(N,KPART) : MAX SI VALUE ALONG A ETA CURVE  
 .ETA(N,K,KPART) : ETA COORDINATES  
 .Y(N,K,KPART) : Y COORDINATES AT COMPUTED POINT  
 .YC : MODIFIED Y COORDINATE  
 .YMAX : FULL DEPTH CONVERTED INTO Y  
 .YMEAN : DISTANCE FROM ORIGIN TO PT. OF MAX. VEL. CONVERTED INTO Y  
 .YMIN : SMALLEST COMPUTATION VALUE  
 .UNIVK : UNIVERSAL CONSTANT K  
 .Z(N,K,KPART) : Z COORDINATES AT COMPUTED POINT

```

C      .ZC          : MODIFIED Z COORDINATE
C      .ZMAX        : MAX. ZC POSSIBLE IN THE COMPUTATION
C      .ZMIN        : MIN. ZC POSSIBLE IN THE COMPUTATION

```

```

-----
C
C      MAIN PROGRAM
C

```

```

-----
C      INTEGER NA, OPTION, PLOT1, PLOT2, PLOT3, PLOT4, PLOTS
C      DIMENSION ALPHA1(50,2), VSI(50,40,2), VETA(50,40,2)
C      DIMENSION VY(50,40,2), VZ(50,40,2), ETAMAX(2), FNINE(40)
C      DIMENSION DSIDZ(50,40,2), ETAMIN(2), DSI(5)
C      DIMENSION DETADZ(50,40,2), PHI(50,40,2)
C      DIMENSION XI(50,40,2), DHETA(50,40,2), SHEAR(50,40,2), DUDX(40)
C      DIMENSION, XIMAX(50,2), PETA(2)
C      DIMENSION Y(50,40,2), Z(50,40,2), DELTA(2), NDIVIDE(2)
C      DIMENSION JBEG(2,40), NB(2), B1(2), ZBOUND(20), YBOUND(20)
C      COMMON /R1/ FNC1
C      COMMON /R2/ WP
C      COMMON /R3/ SIDIFF(50,40,2)
C      COMMON /R4/ F2(50,2)
C      COMMON /R5/ BETA(2), CETA(2)
C      COMMON /R6/ ETA(50,40,2)
C      COMMON /R10/ HSI(50,40,2), HETA(50,40,2)
C      COMMON /R7/ DEPTH, DELY, EPSILON
C      COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
C      CHARACTER*28 NAME

```

```

-----
C1
C      INPUT PHASE
C

```

```

-----
C      --- CHANNEL GEOMETRY DATA
C      READ(1,10)DEPTH, YMEAN, HR, WP, B1(1), B1(2), AVGVEL, SE
C      --- GENERATED COORDINATES DATA
C      READ(1,11)EPSILON, DELY, SINUT, BETA(1), BETA(2),
C      1 DELTA(1), DELTA(2), UNIVK, SIZERO
C      --- MAXIMUM NUMBER OF DUDX, AND PLOTTING SELECTIONS
C      READ(1,13) NLINES, NDIVIDE(1), NDIVIDE(2)
C      --- VELOCITY GRADIENT IN X DIRECTION
C      READ(1,12)(DUDX(I), I=1, NLINES)
C      --- READ IN RANGE OF SPECIFICATION
C      READ(1,14)SCALE, SIMAX, ETAMIN(1), ETAMIN(2), ETAMAX(1), ETAMAX(2)
C      DSI VALUES FOR 5 ZONES
C      READ(1,14)DSI(1), DSI(2), DSI(3), DSI(4), DSI(5)
C      --- OPTIONS
C      READ(1,16)OPTION, PLOT1, PLOT2, PLOT3, PLOT4, PLOTS
C      --- CHANNEL BOUNDARIES
C      READ(1,13)MCBPTS
C
C      READ(1,15)(ZBOUND(I), I=1, MCBPTS)
C      READ(1,15)(YBOUND(I), I=1, MCBPTS)
C      --- CROSSSECTION NAME
C      READ(1,303)NAME
C
C      KPART = 2
C      DENSITY = 1.94
C      G = 32.174
C      DUOT = 0.
C      AVGSHEA = DENSITY*G*HR*SE
C      FNC1 = DEPTH + EPSILON + DELY
C      SHVELO = SORT(G*HR*SE)
C      ISTOP = MONG = NECHO = 0
C      WRITE(4,303)NAME
C      WRITE(4,224)DEPTH, (B1(I), I=1,2), YMEAN
C      WRITE(4,225)HR, SE, WP, OPTION
C      WRITE(4,231)
C      WRITE(4,232) (ZBOUND(I), I=1, MCBPTS)
C      WRITE(4,232) (YBOUND(I), I=1, MCBPTS)
C      WRITE(4,226)EPSILON, DELY, (BETA(I), I=1,2), (DELTA(I), I=1,2)
C      WRITE(4,233) DSI(1), DSI(2), DSI(3), DSI(4), DSI(5)
C      WRITE(4,205)AVGSHEA, AVGVEL

```

```

-----
C2
C      GENERATING OVERALL COEFFICIENTS FOR EACH HALF
C

```

```

-----
C2
C      YMAX = ((YMEAN-EPSILON)+DELY)/FNC1
C      YONE = (YMEAN + DELY)/FNC1
C      IF(EPSILON .GT. 0.) YONE = YMAX
C      YMIN = DELY/FNC1
C      DO 20 K = 1, KPART
C      FNC2 = B1(K) + DELTA(K)
C      ZMAX = B1(K)/FNC2
C      CETA(K) = BETA(K)*(FNC1/FNC2)**2
C      DEFINE A LOWER BOUND FOR ETA VALUE
C      TOL = .1E-07
C      YA = 0.999999
C      IF(YA .GT. YMAX) YA = YMAX
C      CALL MRF4(YA, ZA, TOL, BETA(K), SINUT, MONG, NECHO)
C      ETALOW = FNC4(YA, ZA, CETA(K))

```

```

C      PETA(K) = ETALOW
C
C      *****
C      --- DEFINITION BLOCK; CHANNEL BOUNDARIES ---
C      I = 3
C      FLG = 1.
C      MP = 1
C      MPI = 5

```

```

130  ZA = 0.5/FNC2
      S11 = FNC3(YMAX, ZA, BETA(K))
      ETA1 = FNC4(YMAX, ZA, CETA(K))
      IF (FLG.EQ.1.) ETAMIN(K) = ETA1
      S12 = FNC3(YMIN, ZA, BETA(K))
      ETA2 = FNC4(YMIN, ZA, CETA(K))
      IF (FLG.EQ.1.) ETAMAX(K) = ETA2
      IF (OPTION.NE.1) GOTO 122
      WRITE(4,229)
      WRITE(4,230)MP,S11,ETA1,MP1,S12,ETA2
      IF (MP.EQ.2) GOTO 20
      WRITE(4,228)I,PETA(K)
122  IF (MP.EQ.2) GOTO 121
      FLG = 10.
      MP = MP + 1
      MP1 = 4.
      GOTO 130
C
C *****
121  WRITE(4,199)K
      WRITE(4,200)FNC1,FNC2,ETALOW
      WRITE(4,220)
C
      IF (OPTION.EQ.4) THEN
        IF (K.EQ.1) REWIND 3
        READ(3)NA,NB(1),NB(2)
        DO 100 I = 1, NA
          READ(3)JBEG(K,I)
          NC = JBEG(K,I)
          DO 110 J = NC, NB(K)
            READ(3)XI(J,I,K),ETA(J,I,K),Y(J,I,K),Z(J,I,K)
            YTURE = Y(J,I,K)+FNC1-DELY
            ZTURE = Z(J,I,K) + FNC2
            WRITE(4,201)J,I,XI(J,I,K),ETA(J,I,K),Y(J,I,K),Z(J,I,K),
          + YTURE,ZTURE
110    CONTINUE
          WRITE(4,215)
100    CONTINUE
          GOTO 137
        END IF
C --- ASSIGN XI CURVE VALUES (NA = NUMBER OF ISOVELS)
        NATIME = 1
        TEST = SINUT
C
        DO 149 I = 1,40
          IF (I.EQ.10) NATIME = 2
          IF (I.EQ.18) NATIME = 3
          IF (I.EQ.26) NATIME = 4
          IF (I.EQ.32) NATIME = 5
C
          IF (I.NE.1) TEST = TEST + DSI(NATIME)
          IF (TEST.GT.SIMAX) GOTO 148
          NA = I
149    CONTINUE
C
148    NATIME = 1
          IF (EPSILON.LT.0.0) THEN
            XI(NA,1,K) = SINUT
            DO 150 I = 2, NA
              IF (I.EQ.10) NATIME = 2
              IF (I.EQ.18) NATIME = 3
              IF (I.EQ.26) NATIME = 4
              IF (I.EQ.32) NATIME = 5
              I1 = I - 1
              I2 = NA - I1
              I3 = I2 + 1
              XI(I2,I,K) = XI(I3,I1,K) + DSI(NATIME)
150    CONTINUE
          ELSE
            XI(1,1,K) = SINUT
            DO 159 I = 2,NA
              IF (I.EQ.10) NATIME = 2
              IF (I.EQ.18) NATIME = 3
              IF (I.EQ.26) NATIME = 4
              IF (I.EQ.32) NATIME = 5
              I1 = I - 1
              IF (EPSILON.EQ.0.0) XI(1,I,K) = XI(1,I1,K) + DSI(NATIME)
              IF (EPSILON.GT.0.0) XI(1,I,K) = XI(1,I1,K) + DSI(NATIME)
159    CONTINUE
          END IF
C --- DETERMIN ETAMIN ON EACH SI CURVE IF EPSILON IS LE 0
          IF (EPSILON.GE.0.0) GOTO 152
          I = J = 0
165    I1 = NA - I
          J = J + 1
          Y(J,I1,K) = Z(J,I1,K) = 0.0
          J1 = J + 1
          CALL HRF4(YMAX,ZA,TOL,BETA(K),XI(J,I1,K),MONO,NECHO)
          ETAMINI = FNC4(YMAX,ZA,CETA(K))
          IF (I1.EQ.NA) THEN
            IF (ETAMINI.LT.ETAMIN(K)) STOP
            ETA(J,I1,K) = ETAMINI
            Y(J,I1,K) = YMAX
            Z(J,I1,K) = ZA
            DO 158 M = J1,NA
              Y(M,I1,K) = Z(M,I1,K) = 0.0
158    XI(M,I1,K) = XI(J,I1,K)
          ELSE
            ETA(J,I1,K) = ETAMINI
            Y(J,I1,K) = YMAX

```

```

Z(J,I,K) = ZA
I2 = I1 + 1
DO 157 M = J1,NA
Y(J,M,K) = Z(J,M,K) = 0.0
157 XI(M,I1,K) = XI(J,I1,K)
160 DO 158 M = 12,NA
158 ETA(J,M,K) = ETA(J,I1,K)
END IF
I = I + 1
IF(I.LT.NA) GOTO 155
C ---- DO A BOUNDARY LINE ----
J = J + 1
XI(J,I,K) = SINUT
ETA(J,I,K) = PETA(K)
NATIME = 1
DO 151 M = 2,NA
IF(M.EQ.10) NATIME = 2
IF(M.EQ.18) NATIME = 3
IF(M.EQ.26) NATIME = 4
IF(M.EQ.32) NATIME = 5
Y(J,M,K) = Z(J,M,K) = 0.0
ETA(J,M,K) = ETA(J,I,K)
M1 = M - 1
151 XI(J,M,K) = XI(J,M1,K) + DSI(NATIME)
C
JBASE = J + 1
GOTO 161
C
C --- EPSILON .GT. 0.0 ---
C
152 J = 1
ETA(1,1,K) = PETA(K)
Y(1,1,K) = Z(1,1,K) = 0.0
JBASE = 1
I = 1
IF(EPSILON .GT. 0.0) THEN
169 JBEG(K,I) = J
J = J + 1
I = I + 1
J1 = J - 1
I1 = I - 1
IF(I .GT. NA) GOTO 170
JBEG(K,I) = J
Y(J,I,K) = Z(J,I,K) = 0.0
C --- DETERINE ETA ON WATER SURFACE ---
CALL MRF4(YMAX,ZA,TOL,BETA(K),XI(J,I,K),MONO,NECHG)
ETA(J,I,K) = FNC4(YMAX,ZA,CETA(K))
Y(J,I,K) = YMAX
Z(J,I,K) = ZA
DO 168 M = 1,J1
Y(J,M,K) = Z(J,M,K) = 0.0
168 XI(J,M,K) = XI(J1,M,K)
ETA(J,M,K) = ETA(J,I,K)
GOTO 169
170 I = 1
J = J1
C
C DERIVE DISTRIBUTION GRID SYSTEM,
C SOLVE THE Y Z COORDINATE FOR THE LAST POINT
C
Y1 = YMAX
Z1 = ZMAX
DUMY = 1.0
CALL CORDTF(CETA(K),BETA(K),XI(J,I,K),ETA(J,I,K),
* BI(K),DELTA(K),Y1,Z1,YA,ZA,ISTOP,DUMY)
Y(J,I,K) = YA
Z(J,I,K) = ZA
C
174 J1 = J + 1
IF(J1 .GT. 50) THEN
NB(K) = J
GOTO 172
END IF
IF(YA .GT. 0.25) THEN
YA = YA - 0.1
CALL MRF4(YA,ZA,TOL,BETA(K),SINUT,MONO,NECHG)
ETA(J1,I,K) = FNC4(YA,ZA,CETA(K))
Y(J1,I,K) = YA
Z(J1,I,K) = ZA
XI(J1,I,K) = XI(J,I,K)
ELSE
ZA = ZA - 0.03
IF(ZA .LE. 0.0) THEN
NB(K) = J
GOTO 172
END IF
CALL MRF1(YA,ZA,TOL,BETA(K),SINUT,ETA(J,I,K),MONO,NECHG)
ETA(J1,I,K) = FNC4(YA,ZA,CETA(K))
IF(ETA(J1,I,K) .GT. ETAMAX(K)) THEN
NB(K) = J
GOTO 172
END IF
XI(J1,I,K) = XI(J,I,K)
Y(J1,I,K) = YA
Z(J1,I,K) = ZA
END IF
DO 173 M = 2,NA
Y(J1,M,K) = Z(J1,M,K) = 0.0
XI(J1,M,K) = XI(J,M,K)

```

```

170   ETA(J,M,K) = ETA(J,I,K)
      J = J + 1
      GOTO 174
END IF
C
C -- DEFINE DELTA VALUES IN THE LOWER PORTION
C   DERIVE DISTRIBUTION ON ETA,
C   SET DYC = 0.1 MANUALLY FOR 10 INTERVALS (YA = .999999 INITIALLY)
C
161   I = 1
153   JI = J + 1
      IF(JI .GT. 50) GOTO 154
      IF(YA .GT. 0.25) THEN
        YA = YA - 0.1
        CALL MRF4(YA, ZA, TOL, BETA(K), SINUT, MONG, NECHO)
        ETA(JI, I, K) = FNC4(YA, ZA, CETA(K))
        XI(JI, I, K) = XI(J, I, K)
        Y(JI, I, K) = YA
        Z(JI, I, K) = ZA
      ELSE
        ZA = ZA - 0.03
        IF(ZA .LE. 0.0) GOTO 154
        CALL MRF1(YA, ZA, TOL, BETA(K), SINUT, ETA(J, I, K), MONG, NECHO)
        ETA(JI, I, K) = FNC4(YA, ZA, CETA(K))
        IF(ETA(JI, I, K) .GT. ETAMAX(K)) GOTO 154
        XI(JI, I, K) = XI(J, I, K)
        Y(JI, I, K) = YA
        Z(JI, I, K) = ZA
      END IF
      J = J + 1
      GOTO 153
154   NB(K) = J
      J = JBASE
167   NATIME = 1
      DO 165 M = 2, NA
        IF(M .EQ. 10) NATIME = 2
        IF(M .EQ. 16) NATIME = 3
        IF(M .EQ. 26) NATIME = 4
        IF(M .EQ. 32) NATIME = 5
        ETA(J, M, K) = ETA(J, I, K)
        M1 = M - 1
        XI(J, M, K) = XI(J, M1, K) + DS1(NATIME)
        Y(J, M, K) = Z(J, M, K) + 0.0
165   CONTINUE
      J = J + 1
      IF(J .GT. NB(K)) GOTO 166
      GOTO 167
166   DO 301 I = 1, NA
        IM = NA - I + 1
        IF(EPSILON .EQ. 0.0) IM = 1
        JBEG(K, I) = IM
301   CONTINUE
172   CONTINUE
C
      IF(OPTION.EQ.2 .OR. OPTION.EQ.3) WRITE(2) NA, NB(1), NB(2)
C
C -- DEFINE INITIAL GUESSES FOR SUBROUTINE CORDT
C
      YOPER = YMIN
      ZOPER = 0.00001
      DYY = 1.0
      DO 132 I = 1, NA
        IF(OPTION.EQ.2 .OR. OPTION.EQ.3) WRITE(2) JBEG(K, I)
        NCHECK = JBEG(K, I)
        DO 133 J = NCHECK, NB(K)
          J1 = J - 1
          ISTOP = 0
          ... DEFINE UPPER (LOWER) LIMITS FOR Y AND Z
          IF(J .EQ. NCHECK) THEN
            WRITE(4, 215)
            IF(Y(J, I, K) .NE. 0.0 .AND. Z(J, I, K) .NE. 0.0) THEN
              YC = Y(J, I, K)
              ZC = Z(J, I, K)
              GOTO 136
            END IF
            IF(ETA(J, I, K) .GE. 0.) THEN
              Z1 = ZMAX
              ZC = Z1 - 0.1
              Y1 = YONE
              YC = Y1 - 0.1
            ELSE
              Z1 = 0.00001
              ZC = Z1 + 0.1
              Y1 = YMAX
              YC = Y1 - 0.1
            END IF
          ELSE
            IF(Y(J, I, K) .NE. 0.0 .AND. Z(J, I, K) .NE. 0.0) THEN
              YC = Y(J, I, K)
              ZC = Z(J, I, K)
              GOTO 136
            END IF
            IF(ETA(J, I, K) .GE. 0.) THEN
              IF(ETA(JI, I, K) .LT. 0.) THEN
                Z1 = ZMAX
                Y1 = YONE
              END IF
              YC = (Y1 + YOPER)/2.
              ZC = (Z1 + ZOPER)/2.
            ELSE

```

```

      YC = (Y1 + YONE)/2.
      ZC = (Z1 + ZMAX)/2.
    END IF
  END IF
C
C --- --CORDTF FIND CORRESPONDING Y Z COORDINATES
C - Y1 Z1 ARE THE GUESSED VALUES AND YC ZC ARE SOLUTIONS
C
      CALL CORDTF(CETA(K), BETA(K), XI(J, I, K), ETA(J, I, K),
+ BI(K), DELTA(K), Y1, Z1, YC, ZC, ISTOP, DYY)
C ---NOW Y1 DEFINES THE UPPER LIMITS FOR SEARCHE,
C Z1 DEFINES THE UPPER LIMITS FOR LOWER REGION AND LOWER
C LIMITS FOR UPPER REGION FOR SEARCH.
C YC AND ZC ARE THE SOLUTIONS.
C ---IF ISTOP = 0 SOLVED THIS GIVEN PAIR (X1, ETA)
C --- ISTOP = 1 THESE TWO COORDINATES DO NOT REPRESENT A POINT
C --- ISTOP = 2 THIS PAIR DOES NOT EXIST IN CHANNEL CROSSSECTION
C IF (ISTOP .EQ. 1) THEN
      WRITE(4, 219) (ISTOP, XI(J, I, K), ETA(J, I, K))
      GOTO 999
    END IF
    IF (ISTOP .EQ. 2) THEN
      WRITE(4, 227) (ISTOP, XI(J, I, K), ETA(J, I, K), Y1, Z1, YC, ZC)
      GOTO 999
    END IF
28 Y(J, I, K) = YC
   Z(J, I, K) = ZC
138 YTRUE = YC - FNC1 - DELY
    ZTRUE = ZC - FNC2
    WRITE(4, 201) J, I, XI(J, I, K), ETA(J, I, K), YC, ZC, YTRUE, ZTRUE
    IF (OPTION .EQ. 2 .OR. OPTION .EQ. 3) WRITE(2) XI(J, I, K), ETA(J, I, K),
+ Y(J, I, K), Z(J, I, K)
134 Y1 = YC
    Z1 = ZC
    IF (J1 .GE. NCHECK) DYY = Y(J1, I, K) - Y1
133 CONTINUE
C
C FOR ALL ETA .GE. 0.0, DETERMINE THE MIN Y FOR
C THE NEXT SI CURVE BY USING CURRENT Z AS Z UPPER
C
      JNOW = NB(K)
      IF (ETA(JNOW, I, K) .GE. 0.0) THEN
        IPLUS = I + 1
        IF (IPLUS .GT. NA) GOTO 132
        IF (Y(JNOW, IPLUS, K) .NE. 0.0 .AND. Z(JNOW, IPLUS, K) .NE. 0.0) GOTO 132
        Z2 = Z(JNOW, I, K)
        DUMY = 0.00001
        CALL CORDTF(CETA(K), BETA(K), XI(JNOW, IPLUS, K), ETA(JNOW, I, K),
+ BI(K), DELTA(K), Y1, Z2, YOPER, ZOPER, HONO, DUMY)
        END IF
132 CONTINUE
C
      IF (OPTION .EQ. 2) GOTO 20
C
137 CONTINUE
C -- COMPUTE OVERALL COEFFICIENTS
C
      XITERM = SHVELO / UNIVK
      DO 26 I = 1, NA
        WRITE(4, 215)
        NC = JBEG(K, I)
        XIVELO = XITERM * ALOG(XI(NC, I, K) / SIZERO)
        FNINE(I) = FNC9(DENSITY, DUDT, DUDX(I), XIVELO, HR, AVGSHEA)
18 DO 21 J = NC, NB(K)
        HSI(J, I, K) = FNC6(K, FNC2, XI(J, I, K), Y(J, I, K), Z(J, I, K))
        HETA(J, I, K) = FNC7(K, FNC2, XI(J, I, K),
1 ETA(J, I, K), Y(J, I, K), Z(J, I, K), HSI(J, I, K))
C
C DETERMINE SIMAX - SI VALUES
C
      IF (EPSILON .LE. 0.0) THEN
        XIMAX(J, K) = 1.0
        SIDIFF(J, I, K) = FNC5(XIMAX(J, K), XI(J, I, K))
      ELSE
        IF (I .EQ. 1) THEN
          XIMAX(J, K) = FNC10(ETA(J, I, K), CETA(K), BETA(K))
        END IF
        SIDIFF(J, I, K) = FNC5(XIMAX(J, K), XI(J, I, K))
      END IF
      DHETA(J, I, K) = FNC8(K, XI(J, I, K), Y(J, I, K), Z(J, I, K))
      DSIDZ(J, I, K) = FNC3DZ(Y(J, I, K), Z(J, I, K), BETA(K))
      DETADZ(J, I, K) = FNC4DZ(Y(J, I, K), Z(J, I, K), CETA(K))
21 CONTINUE
26 CONTINUE
C
      WRITE(4, 207)
      WRITE(4, 203) (FNINE(I0), I0=1, NA)
      WRITE(4, 202)
      DO 22 I = 1, NA
        WRITE(4, 215)
        NC = JBEG(K, I)
        DO 23 J = NC, NB(K)
          WRITE(4, 201) J, I, HSI(J, I, K), HETA(J, I, K), SIDIFF(J, I, K),
+ DHETA(J, I, K), DSIDZ(J, I, K), DETADZ(J, I, K)
23 CONTINUE
22 CONTINUE
20 CONTINUE
C
      IF (OPTION .EQ. 1) GOTO 999
      IF (OPTION .EQ. 3) GOTO 998

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IF(OPTION .EQ. 2) THEN
  CALL D130150(NA,MCBPTS,DEPTH,EPSILON,Y,Z,JBEG,
+           NB,B1,ZBOUND,YBOUND,FNC1,DELTA,DELY)
END IF

C
C3-----3
C
C  COMPUTATION ALONG BOUNDARY LINE.  DETERMINE SHEAR COEFFICIENTS
C
C3-----3
C
C      ALPHA2 IS COMPUTED FOR EAT CURVES ON BANKS AND BED ONLY
ALPHA2 = 0.
DO 30 K = 1,KPART
  I = J1 = 1
  IF(EPSILON .LT. 0.0) J1 = NA
  DO 31 J = J1,NB(K)
    F2(J,K) =
  1  SIDIFF(J,I,K)/(1.-DHETA(J,I,K)*SIDIFF(J,I,K))
  31 CONTINUE
  CALL SHEAR2(K,J1,NB(K),AVGSHEA, FNINE(1),ALPHA2,T1,T2)
  WRITE(4,206) K, J1
  WRITE(4,203)(F2(J,K),J=J1,NB(K))
  30 CONTINUE
  WRITE(4,208)ALPHA2

C4-----4
C
C  COMPUTE SHEAR STRESS AND SECONDARY FLOW COMPONENTS VSI, AND THE
C  STREAM FUNCTION FOR EACH HALF OF THE CROSS-SECTION
C
C4-----4
C
C  DO 40 K = 1,KPART
C  COMPUTE ALPHA1 COEFFICIENT FOR EACH ETA CURVE
  I = J = 1
  IF(EPSILON .LT. 0.0) THEN
    I = NA
    J1 = NA - 1
    DO 44 J = 1,J1
      ALPHA1(J,K) = -ALPHA2*SIDIFF(J,I,K)
      I = I - 1
    44 CONTINUE
    I = NA
  END IF
  DO 45 J = 1,NB(K)
    CALL SHEAR1(K,J, FNINE(1),ALPHA2,ALPHA1(J,K))
  45 CONTINUE
C
C  DO 41 I = 1,NA
C  NC = JBEG(K,I)
C  DO 42 J = NC,NB(K)

C  ... COMPUTE SHEAR STRESS AND VSI ALONG EACH ETA LINE
SHEAR(J,I,K) = ALPHA1(J,K)*SIDIFF(J,I,K)+
1  -ALPHA2*SIDIFF(J,I,K)*SIDIFF(J,I,K)
SHEAR2 = -ALPHA1(J,K)-2.*ALPHA2*SIDIFF(J,I,K)

C
C  ... COMPUTE VSI (AS U FOLLOWS LOGRITHMIC DISTRIBUTION)
C
C  RODUOS1 = (DENSITY*SHVELO)/(XI(J,I,K)*UNIVK)
TERM1 = DHETA(J,I,K)*SHEAR(J,I,K)
TERM2 = SHEAR - HETA(J,I,K)*FNINE(1)
VSI(J,I,K) = (TERM1 + TERM2)/RODUOS1

C
C  ... COMPUTE STREAM FUNCTION ALONG EACH SI LINE, NAMELY SUM(VSI*HETA)
C  ... ALSO COMPUTE SUM(HETA*HSI) AND TEMPORARY STORE INTO VETA
C
C  J1 = J - 1
IF(J .EQ. NC) THEN
  PHI(J,I,K) = 0.
  VETA(J,I,K) = 0.
ELSE
  TVX11 = VSI(J1,I,K)
  TVX12 = VSI(J,I,K)
  THETA1 = HETA(J1,I,K)
  THETA2 = HETA(J,I,K)
  DETA = ETA(J,I,K) - ETA(J1,I,K)
  CALL INTPHI(TVX11,TVX12,THETA1,THETA2,PG,DETA)
  PHI(J,I,K) = PHI(J1,I,K) + PG
  TVX11 = HSI(J1,I,K)
  TVX12 = HSI(J,I,K)
  CALL INTPHI(TVX11,TVX12,THETA1,THETA2,PG,DETA)
  VETA(J,I,K) = VETA(J1,I,K) + PG
END IF
42 CONTINUE
41 CONTINUE
40 CONTINUE

C5-----5
C
C  COMPUTE VETA'S
C
C5-----5
C
C  DO 50 K = 1,KPART
  WRITE(4,199)K
  NA1 = NA - 1
  DO 51 I = 2,NA1
    NC = JBEG(K,I)

C
C  ... COMPUTE VETA AT WATER SURFACE
C
TX = HSI(NC,I,K)*OS1DZ(NC,I,K)
VZ(NC,I,K) = VSI(NC,I,K)/TX

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VETA(NC,I,K) = HETA(NC,I,K) = DETADZ(NC,I,K) = VZ(NC,I,K)
C
NCCA = NB(K)
I1 = I - 1
I2 = I + 1
DSI1 = X1(NCCA,I2,K) - X1(NCCA,I1,K)
ND = NC + 1
DO 52 J = ND, NB(K)
TERM = (-PHI(J,I1,K) + PHI(J,I2,K))/DSI1
TERM = TERM/HSI(J,I,K)
VETA(J,I,K) = VETA(NC,I,K) - DUDX(I) * VETA(J,I,K) / HSI(J,I,K) -
* TERM
52 CONTINUE
51 CONTINUE
C
WRITE(4,220)
WRITE(4,209)
WRITE(4,203)(ALPHA1(L1,K),L1=1,NB(K))
WRITE(4,215)
WRITE(4,211)
DO 53 IP = 1, NA
MNC = JBEG(K,IP)
DO 54 IQ = MNC, NB(K)
IF(IP.EQ.1 .OR. IP.EQ.NA) THEN
WRITE(4,201) IQ, IP, SHEAR(IQ,IP,K)
ELSE
WRITE(4,201) IQ, IP, SHEAR(IQ,IP,K), VSI(IQ,IP,K), VETA(IQ,IP,K)
END IF
54 CONTINUE
WRITE(4,215)
53 CONTINUE
50 CONTINUE
-----6
C
C
C
C
C
C
COMPUTE VY AND VZ AT COORDINATE (SI, ETA)
-----6
C
DO 60 K = 1, KPART
FNC2 = B1(K) + DELTA(K)
WRITE(4,199) K
WRITE(4,222)
WRITE(4,217)
DO 62 I = 2, NA1
WRITE(4,215)
NC = JBEG(K,I)
DO 61 J = NC, NB(K)
YTEMP = Y(J,I,K)
ZTEMP = Z(J,I,K)
YTR = YTEMP * FNC1 - DELY
ZTR = ZTEMP * FNC2
IF(K.EQ.1) ZTR = B1(I) - ZTR
IF(K.EQ.2) ZTR = ZTR + B1(I)
DXIDY = FNC3DY(YTEMP,ZTEMP,BETA(K))
DXIDZ = DSIDZ(J,I,K)
PETAPY = FNC4DY(YTEMP,ZTEMP,CETA(K))
PETAPZ = DETADZ(J,I,K)
IF(J.EQ.NC) THEN
VY(J,I,K) = 0.
ELSE
DO = HSI(J,I,K) * HETA(J,I,K) = (DXIDY * PETAPZ - DXIDZ * PETAPY)
D1 = VSI(J,I,K) * HETA(J,I,K) = PETAPZ -
* VETA(J,I,K) = HSI(J,I,K) * DXIDZ
D2 = -VSI(J,I,K) * HETA(J,I,K) = PETAPY +
* VETA(J,I,K) = HSI(J,I,K) * DXIDY
VY(J,I,K) = D1 / DO
VZ(J,I,K) = D2 / DO
END IF
WRITE(4,218) I, J, YTR, ZTR, VY(J,I,K), VZ(J,I,K)
61 CONTINUE
62 CONTINUE
60 CONTINUE
C
C
C
DRAW SHEAR STRESSES AND VELOCITY COMPONENTS
C
CALL D130SV(NA,MCBPTS,DEPTH,EPSILON,Y,Z,JBEG,
+ NB,B1,ZBOUND,YBOUND,FNC1,DELTA,DELY,SHEAR,VY,VZ,
+ PLOT2,PLOT3,PLOT4,PLOTS,AVGSHEA,NDIVIDE,
+ AVGVEL,SCALE,NAME)
C
GOTO 999
C
998 DO 63 K = 1, 2
WRITE(4,199) K
WRITE(4,300)
C
NA1 = NA - 1
DO 64 I = 2, NA1
C
ADD 1 TO NC1 SO THAT IT START AT CORRECT POINT (I+1) WILL
C
HAVE CORRESPONDING NUMBERS
NC1 = JBEG(K,I) + 1
DO 65 J = NC1, NB(K)
DSITEMP = X1(J,I+1,K) - X1(J,I-1,K)
A1 = ALOG(HETA(J,I-1,K))
A2 = ALOG(HETA(J,I+1,K))
A3 = (A2-A1)/DSITEMP
WRITE(4,302) J,I,HETA(J,I,K),DSITEMP,DHETA(J,I,K),A3
65 CONTINUE
64 CONTINUE
63 CONTINUE
C

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10  FORMAT(/7F8.2,F9.6)
11  FORMAT(/2F6.2,7F8.4)
12  FORMAT(/10F6.3)
13  FORMAT(/3I5)
14  FORMAT(/6F6.3)
15  FORMAT(/0F6.2)
16  FORMAT(/6I5)
199 FORMAT(IH1,///15X,'CROSS-SECTION PART',I3)
200 FORMAT(/15X,'FNC1',E10.4,3X,'FNC2',E10.4//,
+ 15X,'ETALOW',E10.4//)
201 FORMAT(2I5,6(5X,E12.5))
202 FORMAT(/4X,'J',4X,'I',
+ 7X,'HSI',14X,'HETA',13X,'SIDIFF',11X,'DHETA',12X,
+ 'DSIDZ',12X,'DETADZ'/113(1H-))
203 FORMAT(8(2X,E10.4))
205 FORMAT(/10X,'CHANNEL INFORMATION',5X,'AVERAGE SHEAR STRESS',
+ 10X,'MEAN VELOCITY',
+ /35X,F10.6,10X,F10.4//)
206 FORMAT(/9X,'F2',3X,'PART',I3,' **** ETA SEQ.',I3//)
207 FORMAT(/9X,'INTERMEDIATE COEFFICIENTS'//10X,'FNINE'//)
208 FORMAT(/----- ALPHA2 = ',E12.5)
209 FORMAT(/9X,'ALPHA1'//)
211 FORMAT(/4X,'J',4X,'I',7X,'SHEAR',12X,'VSI',14X,'VETA',
+ /96(1H-//)
215 FORMAT(/)
217 FORMAT(/12X,'I',4X,'J',7X,'Y TRUE',11X,'Z TRUE',11X,'VY',
+ 15X,'VZ'//)
218 FORMAT(8X,2I5,4(5X,E12.5))
219 FORMAT('I STOP', 15,2X,'XI = ',E11.5,' ETA = ',E11.5,' NO ?')
220 FORMAT(9X,'GEOMETRY'//,4X,'J',4X,'I',7X,'SI',15X,'ETA',14X,
+ 'YC',15X,'ZC',15X,'Y TRUE',11X,'Z TRUE'/113(1H-))
222 FORMAT(/9X,'COMPUTED VELOCITIES'//)
223 FORMAT(/9X,'SHEAR STRESSES, VELOCITY COMPONENTS IN CURVILINEAR',
+ ' COORDINATES'//)
224 FORMAT(/,10X,'CHANNEL GEOMETRY DATA'//15X,'DEPTH = ',F6.2,
+ 2X,'WIDTH (1)',F10.2,2X,'WIDTH (2)',F10.2,2X,'DEPTH TO ',
+ 'POINT OF MAX. VEL.',F10.2//)
225 FORMAT(15X,'HYDRAULIC RADIUS ',F10.2,2X,'ENERGY SLOPE',E11.4,2X,
+ 'WETTED PARAMETER',F10.2,2X,'THIS OPTION IS',15//)
226 FORMAT(/10X,'SECONDARY VELOCITY PARAMETERS'//15X,
+ 'EPSILON',F6.2,2X,'DELY',F7.2,/,
+ /15X,'BETA 1',E11.5,2X,'BETA 2',E11.5,//15X,'DELTA 1',E11.5,2X,
+ 'DELTA 2',E11.5//)
228 FORMAT(/20X,'POINT',I3,4X,E10.4)
229 FORMAT(15X,'BOUNDARY POINTS'//)
230 FORMAT(/15X,2(5X,'POINT',I3,3X,
+ 2(1X,E10.4)))
227 FORMAT(15,6(1X,E10.4))
231 FORMAT(/10X,'MEASURED CHANNEL BOUNDRIES'//)

232 FORMAT(/10X,10F6.2)
233 FORMAT(/10X,'ZONE INTERVALS (DSI VALUES)',/10X,5F6.4//)
300 FORMAT(/,15X,'PERFORM NUMERICAL INTERVAL CHECK',//)
302 FORMAT(20X,2I5,3X,4E10.4)
303 FORMAT(A28)
999 STOP
END

C-----FUNCTION FNC3
FUNCTION FNC3(Y,Z,BA)
A0 = 1. - Z
A1 = A0**BA
A2 = EXP(BA*Z-Y+1.)
FNC3 = Y*A1*A2
8  RETURN
END

C-----FUNCTION FNC4
FUNCTION FNC4(Y,Z,CETA)
A2 = EXP(Z*CETA*Y)
A0 = 1. - Y
IF(A0.LT.D.)GOTO7
A1 = A0**CETA
FNC4 = (1./Z)*A1*A2
RETURN
7  A1 = (-A0)**CETA
FNC4 = - A1*A2/Z
RETURN
END

C-----FUNCTION FNC3DY
FUNCTION FNC3DY(Y,Z,BA)
A1 = (1.-Z)**BA
A2 = EXP(BA*Z-Y+1.)
FNC3DY = A1*A2*(1.-Y)
RETURN
END

C-----FUNCTION FNC3DZ
FUNCTION FNC3DZ(Y,Z,BA)
A1 = 1.-Z
A2 = A1**BA
A3 = EXP(BA*Z-Y+1.)
FNC3DZ = BA*A2*Y*A3*(-Z)/A1
RETURN
END

C-----FUNCTION FNC4DZ
FUNCTION FNC4DZ(Y,Z,CETA)
A2 = EXP(Z*CETA*Y)
IF(Y.GE.1.) THEN
A0 = Y - 1.
A3 = (1. - Z) / Z
ELSE
A0 = 1. - Y

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      A3 = (Z - 1.) / Z
END IF
A4 = (A0**CETA) / Z
FNC4DZ = A0 * A2 * A3
RETURN
END
-----FUNCTION FNC40Y
FUNCTION FNC40Y(Y, Z, CETA)
C
C IF Y = 1. ASYMTOTICALLY VALUES ARE CONVERGED
C THEREFORE IT SET Y = 0.99999
C
IF(Y .EQ. 1.) Y = 0.99999
A2 = EXP(Z+CETA*Y)
A0 = 1. - Y
IF(Y .GT. 1.) A0 = Y - 1.
A1 = A0 ** (CETA - 1.)
FNC4DY = (CETA/Z) * A1 * A2 * (-Y)
RETURN
END
-----FUNCTION FNC5
30 FUNCTION FNC5(V51, V52)
FNC5 = V51 - V52
RETURN
END
-----FUNCTION FNC6
FUNCTION FNC6(K, FNC2, AS15, AY5, AZ5)
COMMON /R1/ FNC1
COMMON /R5/ BETA(2), CETA(2)
AA51 = FNC1*AY5*(1. -AZ5)
AA53 = (1. -AY5)*(1. -AZ5)
AA54 = AA53*AA53
AA55 = BETA(K)*(FNC1/FNC2)*AY5*AZ5
AA56 = AA55*AA55
AA52 = AS15*SQRT(AA54+AA56)
FNC6 = AA51/AA52
RETURN
END
-----FUNCTION FNC7
FUNCTION FNC7(K, FNC2, AS17, AETA7, AY7, AZ7, HFNC6)
COMMON /R1/ FNC1
COMMON /R5/ BETA(2), CETA(2)
AA71 = FNC2/FNC1
AA72 = AS17/AETA7
AA73 = AZ7*(1. -AY7)
AA74 = AY7*(1. -AZ7)
FNC7 = AA71*AA72*(AA73/AA74)*HFNC6
RETURN
END
-----FUNCTION FNC8
FUNCTION FNC8 (K, AS18, AY8, AZ8)
COMMON /R5/ BETA(2), CETA(2)
AA81 = (1. -AY8)*(1. -AZ8)*(1. -AZ8)*(1. -AZ8)
AA82 = AY8*AY8*AZ8*AZ8
C
AA83 = AA81*CETA(K)*AY8*AY8
AA84 = CETA(K)*BETA(K)*AA82*(1. -AZ8)*(1. -AZ8)
AA85 = AS18*((AA81*CETA(K)*BETA(K)*AA82)*
+ (AA81*CETA(K)*BETA(K)*AA82))
C
FNC8 = -(AA83+AA84)/AA85
RETURN
END
-----FUNCTION FNC9
C FUNCTION FNC9 COMPUTES FO OR F VALUES ACCORDING TO THE
C MOMENTUM EQUATION. ALL INPUT VALUES ARE PRECALCULATED
C FROM FIELD MEASURED DATA.
FUNCTION FNC9(DENSITY, DELUT, DELUX, XITERM, HR, SHEAR)
AMT = DELUT + XITERM * DELUX
AMS = DENSITY*AMT
FNC9 = AMS-SHEAR/HR
RETURN
END
-----FUNCTION FNC10
FUNCTION FNC10(V12, V15, V16)
COMMON /R7/ DEPTH, DELY, EPSILON
COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
EXTERNAL FNC3
TOL = .1E-07
C... ON THE WATER SURFACE, Y1 = (DEPTH+DELY)/(OEP+DELY*EPI). THEREFORE
C... WE HAVE ETA AND Y1 SPECIFIED.
Z = 0.
NECHO = 0
CALL MRF2(YMAX, Z, TOL, V15, V12, 1STOP, NECHO)
FNC10 = FNC3(YMAX, Z, V16)
99 RETURN
END
-----SUBROUTINE CORDTF
SUBROUTINE CORDTF(CETA, BETA, S1, ETA, B1, DELI, YU, ZU, Y1, Z1, MONO, DYY)
C THIS SUBROUTINE IS THE COMBINATION OF NONLIN1 AND
C NONLIN2, I.E. IT USES MODIFIED REGULA FALSI METHOD
C TO FIND Y OR Z, THEN USE BISECTION METHOD ON THE
C OTHER DIRECTION.
C MONO = 0 COMPLETES THE LOOP
C MONO = 1 NO SOLUTION FROM MRF4 - MRF1
C MONO = 2 THIS ETA VALUE DOES NOT EXIST (FAIL IN 'CIRCL')
COMMON /R7/ DEPTH, DELY, EPSILON
COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
COMMON /CIR/ PASI, PAETA
COMMON /LL/ TOL, TOLETA

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PASI = S1
PAETA = ETA
TOL = .1E-07
TOLETA = .1E-3
MONO = ITER = 114 = NECHO = 0
C ..... START SEEKING SEQUENCE; DETERMINE UPPER AND LOWER
C ..... BOUNDS BEFORE CALL SUBROUTINE CIRCLES
C ..... DEFINE UPPER OR LOWER REGION
IF(PAETA.LT.0.)GOTO70
O .....
C ..... LOWER REGION
C .....
Y = YU
Z = ZU
IF(DYY.LT. 0.01 .AND. Y.LT. 0.9) GOTO 24
CALL MRF4(Y,Z,TOL,BEDA,PASI,MONO,NECHO)
IF(MONO.NE.1)GOTO 23
23 YU = Y
ZU = Z
C BANK AND UPPER BOTTOM REGION COMPUTATION
I14 = 4
C CHECK A LOWER BOUND BEFORE CALL CIRCLL
NECHO = 1
26 CALL MRF4(Y1,Z,TOL,BEDA,PASI,MONO,NECHO)
ITER = ITER + 1
IF(ITER.EQ. 1) DY = (YU - Y1)/6.
IF(ITER.GT. 6) THEN
WRITE(4,52)
GOTO 50
END IF
Y1 = Y1 + DY
GOTO 26
25 FIE1 = FNC4(Y1,Z,CETA) - PAETA
IF(ABS(FIE1).LT.TOLETA) THEN
Y1 = Y1
Z1 = Z
RETURN
END IF
IF(FIE1)11,12,13
C LOWER BOTTOM REGION
C CHECK LOWER BOUND BEFORE CALL CIRCLL
24 YU = Y
ZU = Z
I14 = 1
NECHO = 0
CALL MRF1(Y,Z1,TOL,BEDA,PASI,PAETA,MONO,NECHO)
IF(MONO.NE.1) GOTO 27
WRITE(4,55)
GOTO 50
C CHECK IF THIS IS LOWER BOUND
27 FIE1 = FNC4(Y,Z1,CETA) - PAETA
IF(ABS(FIE1).LT.TOLETA) THEN
Y1 = Y
Z1 = Z1
RETURN
END IF
IF(FIE1)20,12,21
C .....
C ..... UPPER REGION
C .....
70 FIE1 = FNC4(YU,ZU,CETA) - PAETA
IF(ABS(FIE1).LT. TOLETA) GOTO 12
CALL MRF4(Y1,Z,TOL,BEDA,PASI,MONO,NECHO)
IF(MONO.NE.1) GOTO 40
40 FIE2 = FNC4(Y1,Z,CETA) - PAETA
IF(ABS(FIE2).LT. TOLETA) GOTO 12
IF(FIE1=FIE2) 18,12,18
18 YU = Y1
ZL = Z
ZU = ZMAX
YL = YONE
GOTO 77
18 YL = Y1
ZU = Z
GOTO 77
20 YU = Y
ZU = Z1
YL = YMIN
ZL = 0.00001
GOTO 60
21 YL = Y
ZL = Z1
GOTO 60
11 ZU = Z
YU = Y1
YL = YMIN
ZL = 0.00001
GOTO 60
13 ZL = Z
YL = Y1
60 CALL CIRCLL(BEDA,CETA,YU,YL,ZU,ZL,Y,Z,I14)
IF(I14.EQ. 100) THEN
MONO = 2
WRITE(4,56)BEDA,CETA,YU,YL,ZU,ZL,Y,Z
GOTO 12
ELSE
GOTO 12
END IF
77 CALL CIRCLU(BEDA,CETA,YU,YL,ZU,ZL,Y,Z,I14)
IF(I14.EQ. 100) THEN

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      MONO = 2
C     WRITE(4,56)BEDA,CETA,YU,YL,ZU,ZL,Y,Z
      GOTO 12
      ELSE
      GOTO 12
      END IF
12    Y1 = Y
      Z1 = Z
      RETURN
50    WRITE(4,201)ITER,YU,YL,ZU,ZL
59    WRITE(4,238)Y,Z
201   FORMAT(5X,'ITER',10X,'YU',10X,'YL',10X,'ZU',10X,'ZL'//
1    3X,14,12X,4(3X,F8.5))
51    FORMAT(5X,'UPPER REGION FAILED - FROM MRF4'//,5X,
+ 'CHECK INPUT DATA'//)
56    FORMAT(8(1X,E10.4))
53    FORMAT(5X,'UPPER REGION FAILED - FROM MRF2'//5X,
+ 'NO SOLUTION FOR THIS ETA VALUE...'//)
55    FORMAT(5X,'LOWER BOTTOM REGION FAILED - FROM MRF1'//5X,
+ 'SHOULD NOT HAPPEN'//)
54    FORMAT(5X,'UPPER REGION FAILED - FROM MRF2'//,
+ 5X,'THIS IS IMPOSSIBLE, Z1 .LE. ZL')
52    FORMAT(5X,'LOWER REGION FAILED - FROM MRF1'//)
      RETURN
238   FORMAT(2(2X,E11.5),'DIVERGE? --BAD ETA VALUE')
      END
C-----CIRCLL
SUBROUTINE CIRCLL(BEDA,CETA,YU,YL,ZU,ZL,Y,Z,I14)
COMMON /CIR/ PASI,PAETA
COMMON /LL/ TOL,TOLETA
COMMON /MRF/ YMAX,ZMAX,YONE,YMIN
      ID = INO = 0
      NECHO = 1
      A = A1 = 0.
100   ID = ID + 1
C     WRITE(4,140)ID,YU,YL,ZU,ZL,Y,Z,I14
      IF(ID .GT. 10) THEN
      ID = 0
      INO = INO + 1
      IF(I14 .EQ. 4) THEN
      IF(ABS(YU-YL) .LT. .1E-01) THEN
      IF(ABS(A) .LE. ABS(A1)) THEN
      IF(ABS(A) .LT. .1E-01) GOTO 110
      A1 = A
      IF(INO .LT. 6) GOTO 150
      IF(ABS(A) .LT. .1) GOTO 110
      GOTO 101
      ELSE
      MAN = 0
15    Y = (YU + YL)/2.
      MAN = MAN + 1
      IF(MAN .GT. 10) GOTO 110
      A = FNC4(Y,Z,CETA) - PAETA
      IF(ABS(A) .LT. .1) GOTO 110
      IF(A) 11,110,13
11    YU = Y
      GOTO 15
13    YL = Y
      GO TO 15
      END IF
      END IF
      END IF
C     IF(I14 .EQ. 1) THEN
      IF(ABS(ZU-ZL) .LT. .1E-01) THEN
      IF(ABS(A) .LE. ABS(A1)) THEN
      IF(ABS(A) .LT. .1E-01) GOTO 110
      A1 = A
      IF(INO .LT. 6) GOTO 150
      IF(ABS(A) .LT. .1) GOTO 110
      END IF
      END IF
      END IF
      END IF
150   IF(I14 .EQ. 1) Z = (ZU + ZL)/2.
      IF(I14 .EQ. 4) Y = (YU + YL)/2.
      IF(I14 .EQ. 1) THEN
      CALL MRF1(Y,Z,TOL,BEDA,PASI,PAETA,MONO,NECHO)
      IF(MONO .EQ. 1) THEN
      ZU = Z
      GOTO 100
      END IF
      ELSE
      CALL MRF4(Y,Z,TOL,BEDA,PASI,MONO,NECHO)
      IF(MONO .EQ. 1) THEN
      YL = Y
      GOTO 100
      END IF
      END IF
114   A = FNC4(Y,Z,CETA) - PAETA
      IF(A1 .EQ. 0.0) A1 = A
      IF(ABS(A) .LT. TOLETA) GOTO 110
      IF(A) 120,110,130
110   RETURN
120   YU = Y
      ZU = Z
      GOTO 100
130   YL = Y
      ZL = Z
      GOTO 100

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140 FORMAT(5X, I3, 6(1X, E10.4), I4)
101 I14 = 100
RETURN
END
-----CIRCLU
SUBROUTINE CIRCLU(BEDA, CETA, YU, YL, ZU, ZL, Y, Z, I14)
COMMON /CIR/ PASI, PAETA
COMMON /LL/ TOL, TOLETA
COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
ID = I14 = INO = 0
NECHO = 1
A = A1 = 0.
100 ID = ID + 1
IF(ID .GT. 10) THEN
  ID = 0
  INO = INO + 1
  IF(ABS(YU-YL) .LE. .1E-2) THEN
    IF(ABS(A) .LE. ABS(A1)) THEN
      IF(ABS(A) .LT. .1E-01) GOTO 110
      A1 = A
      IF(INO .LT. 6) GOTO 150
      IF(ABS(A) .LT. 1.0) GOTO 110
      GOTO 101
    ELSE
      DIVERGED COMPUTATION
      IF(INO .GT. 6) GOTO 101
      END IF
  END IF
150 Y = (YU + YL)/2.
CALL MRF4(Y, Z, TOL, BEDA, PASI, MONO, NECHO)
IF(MONO .EQ. 1) GOTO 101
A = FNC4(Y, Z, CETA) - PAETA
IF(A1 .EQ. 0.0) A1 = A
IF(ABS(A) .LT. TOLETA) GOTO 110
C
C NEED TO CKECK WHEN Y IS VERY CLOSE TO 1
C
TESTA = ABS(A - A1)
IF((Y-1.) .LT. .1E-05 .AND. TESTA .LE. .1E-02) GOTO 110
C
IF(A) 120, 110, 130
110 RETURN
130 YL = Y
ZU = Z
GOTO 100
120 YU = Y
ZL = Z
GOTO 100
C101 WRITE(4, 140) ID, Y, Z, A, YL, ZL
C140 FORMAT(5X, 'SUBROUTINE CIRCLU FAIL', 3X, 'ID = ', I4, 3X,
C 1 'Y = ', E12.5, 'Z = ', E12.5, /12X, 'FIE = ', E12.5, 3X,
C 1 'ZLOWER = ', E12.5, 3X, 'ZLOWER = ', E12.5)
101 I14 = 100
RETURN
END
-----SUBROUTINE SHEAR2
SUBROUTINE SHEAR2(KN, KJ, KF, S1, S9, COEFSHE, SUM1, SUM2)
C THIS SUBROUTINE CALCULATES THE ALPHA2 COEFFICIENT IN
C THE SHEAR STRESS DISTRIBUTION APPROXIMATION ACCORDING
C TO CHIU'S ASSUMPTION. THIS COEFFICIENT IS A CONSTANT,
C AND THE COMPUTATION IS CARRIED ALONG THE CHANNEL BED & BANKS.
COMMON /R2/ WP
COMMON /R3/ SIDIFF(50, 40, 2)
COMMON /R4/ F2(50, 2)
COMMON /R6/ ETA(50, 40, 2)
COMMON /R10/ HSI(50, 40, 2), HETA(50, 40, 2)
-----SUM ALONG WETTED PARAMETERS-----
IF(KN .EQ. 2) GOTO 30
SUM1 = SUM2 = 0.
30 TINEW = T2NEW = 0.
KJ1 = KJ + 1
DO 100 I = KJ1, KF
  I1 = I - 1
  THETA1 = HETA(I1, 1, KN)
  THETA2 = HETA(I, 1, KN)
  TVX11 = SIDIFF(I1, 1, KN) = F2(I1, KN)
  TVX12 = SIDIFF(I, 1, KN) = F2(I, KN)
  DETA = ETA(I1, 1, KN) - ETA(I, 1, KN)
  CALL INTPHI(TVX11, TVX12, THETA1, THETA2, PQ, DETA)
  SUM1 = SUM1 + PQ
  TVX11 = HSI(I1, 1, KN) = S9 = F2(I1, KN)
  TVX12 = HSI(I, 1, KN) = S9 = F2(I, KN)
  CALL INTPHI(TVX11, TVX12, THETA1, THETA2, PQ, DETA)
  SUM2 = SUM2 + PQ
100 CONTINUE
IF(KN .EQ. 1) RETURN
TENT1 = SUM1/WP
TENT2 = SUM2/WP
COEFSHE = (-1./TENT1)*(S1+TENT2)
RETURN
END
-----SUBROUTINE MRF1
SUBROUTINE MRF1(Y1, Z1, TOL, BETA, PASI, PAETA, ISTOP, NECHO)
C THE SUBROUTINE IS THE MODIFIED REGULA FALSI ALGORITHM
C FOR FUNCTION 3
C Z IS FIXED VALUE AND Y IS THE INTERATIVE VALUE.
C
DIMENSION A(300), B(300), P(300)

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COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
EXTERNAL FNC3
C
C C INITIAL VLAUE TO ZEROS
C
DO 10 IM = 1,300
A(IM) = 0.
B(IM) = 0.
P(IM) = 0.
10 ISTOP = 0
C
C C GIVE EITHER 0.01 OR 0.99 FOR + OR - TEST
C THE A IS ALWAYS SEATS AT THE LEFT OF B
IN = 1
IF(PAETA .GE. 0.) THEN
B(IN) = YONE
A(IN) = YMIN
ELSE
B(IN) = YMAX
A(IN) = YONE
END IF
TL = FNC3(A(IN), Z1, BETA) - PASI
TR = FNC3(B(IN), Z1, BETA) - PASI
IF(TL+TR)11, 12, 13
11 P(IN) = A(IN)
DO 20 IN = 1,999
P(IN+1) = (A(IN)+TR-B(IN)*TL)/(TR-TL)
CHECK = FNC3(P(IN+1), Z1, BETA) - PASI
IF(ABS(CHECK).GT.TOL)GOTO98
Y1 = P(IN)
GOTO99
98 IF(TL+CHECK)14, 99, 16
14 A(IN+1) = A(IN)
B(IN+1) = P(IN+1)
TR = CHECK
CHK = FNC3(P(IN), Z1, BETA) - PASI
IF(CHK+TR.GT.0.)TL = TL/2.
GOTO20
16 A(IN+1) = P(IN+1)
B(IN+1) = B(IN)
TL = CHECK
CHK = FNC3(P(IN), Z1, BETA) - PASI
IF(TL+CHK.GT.0.)TR = TR/2.
GOTO20
12 IF(TL.EQ.0.)GOTO15
Y1 = B(IN)
GOTO99
15 Y1 = A(IN)
GOTO99
20 CONTINUE
13 ISTOP = 1
IF(NECHO .EQ. 0) WRITE(4,77)A(IN),B(IN),TL,TR
77 FORMAT(/5X,'MRF1 ', 'YL ',E10.4, ' YU ',E10.4, ' TL ',E10.4,
* ' TR ',E10.4/)
99 RETURN
END
C-----SUBROUTINE MRF2
SUBROUTINE MRF2(Y1, Z1, TOL, CETA, PAETA, ISTOP, NECHO)
C
C C THE SUBROUTINE IS THE MODIFIED REGULA FALSI ALGORITHM
C FOR FUNCTION 4
C
C C Y IS FIXED VALUE AND Z IS THE INTERATIVE VALUE.
C
DIMENSION A(300),B(300),P(300)
COMMON /MRF/ YMAX, ZMAX, YONE, YMIN
EXTERNAL FNC4
C
C C INITIAL VLAUE TO ZEROS
C
DO 10 IM = 1,300
A(IM) = 0.
B(IM) = 0.
P(IM) = 0.
10 ISTOP = 0
C
C C GIVE EITHER 0.0001 OR 0.9999 FOR + OR - TEST
C THE A IS ALWAYS SEATS AT THE LEFT OF B
IN = 1
B(IN) = ZMAX
A(IN) = 0.00001
TL = FNC4(Y1, A(IN), CETA) - PAETA
TR = FNC4(Y1, B(IN), CETA) - PAETA
IF(TL+TR)11, 12, 13
11 P(IN) = A(IN)
DO 20 IN = 1,999
P(IN+1) = (A(IN)+TR-B(IN)*TL)/(TR-TL)
CHECK = FNC4(Y1, P(IN+1), CETA) - PAETA
IF(ABS(CHECK).GT.TOL)GOTO98
Z1 = P(IN)
GOTO99
98 IF(TL+CHECK)14, 99, 16
14 A(IN+1) = A(IN)
B(IN+1) = P(IN+1)
TR = CHECK
CHK = FNC4(Y1, P(IN), CETA) - PAETA
IF(CHK+TR.GT.0.)TL = TL/2.
GOTO20
16 A(IN+1) = P(IN+1)
B(IN+1) = B(IN)

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```

      TL = CHECK
      CHK = FNC4(Y1,P(IN),CETA) - PAETA
      IF(TL=CHK.GT.O.)TR = TR/2.
      GOTO20
12  IF(TL.EQ.O.)GOTO15
      Z1 = B(IN)
      GOTO99
15  Z1 = A(IN)
      GOTO99
20  CONTINUE
13  ISTOP = 1
      IF(NECHO.EQ.O)WRITE(4,77)A(IN),B(IN),TL,TR
77  FORMAT(/5X,'MRF2 ','ZL ',E10.4,' ZU ',E10.4,' TL ',E10.4,
+       ' TR ',E10.4/)
99  RETURN
      END
C-----SUBROUTINE MRF3
SUBROUTINE MRF3(Y1,Z1,TOL,CETA,PAETA,ISTOP,NECHO)
C     THE SUBROUTINE IS THE MODIFIED REGULA FALSI ALGORITHM
C     FOR FUNCTION 4
C     Z IS FIXED VALUE AND Y IS THE INTERATIVE VALUE.
C
      DIMENSION A(300),B(300),P(300)
      COMMON /MRF/ YMAX,ZMAX,YONE,YMIN
      EXTERNAL FNC4
C
      INITIAL VLAUE TO ZEROS
C
      DO 10 IM = 1,300
      A(IM) = 0.
      B(IM) = 0.
10  P(IM) = 0.
      ISTOP = 0
C
      GIVE EITHER 0.01 OR 0.99 FOR + OR - TEST
      THE A IS ALWAYS SEATS AT THE LEFT OF B
C
      IN = 1
      IF(PAETA.GE.O.)THEN
          B(IN) = YONE
          A(IN) = YMIN
      ELSE
          B(IN) = YMAX
          A(IN) = YONE
      END IF
      TL = FNC4(A(IN),Z1,CETA) - PAETA
      TR = FNC4(B(IN),Z1,CETA) - PAETA
      IF(TL=TR)11,12,13
11  P(IN) = A(IN)
      DO 20 IN = 1,999
          P(IN+1) = (A(IN)+IR-B(IN)+TL/(1R-1L)/
CHECK = FNC4(P(IN+1),Z1,CETA) - PAETA
      IF(ABS(CHECK).GT.TOL)GOTO98
          Y1 = P(IN)
          GOTO99
98  IF(TL=CHECK)14,99,16
14  A(IN+1) = A(IN)
          B(IN+1) = P(IN+1)
          TR = CHECK
          CHK = FNC4(P(IN),Z1,CETA) - PAETA
          IF(CHK=TR.GT.O.)TL = TL/2.
          GOTO20
16  A(IN+1) = P(IN+1)
          B(IN+1) = B(IN)
          TL = CHECK
          CHK = FNC4(P(IN),Z1,CETA) - PAETA
          IF(TL=CHK.GT.O.)TR = TR/2.
          GOTO20
12  IF(TL.EQ.O.)GOTO15
          Y1 = B(IN)
          GOTO99
15  Y1 = A(IN)
          GOTO99
20  CONTINUE
13  ISTOP = 1
      IF(NECHO.EQ.O)WRITE(4,77)A(IN),B(IN),TL,TR
77  FORMAT(/5X,'MRF3 ','YL ',E10.4,' YU ',E10.4,' TL ',E10.4,
+       ' TR ',E10.4/)
99  RETURN
      END
C-----SUBROUTINE MRF4
SUBROUTINE MRF4(Y1,Z1,TOL,BETA,PASI,ISTOP,NECHO)
C     THE SUBROUTINE IS THE MODIFIED REGULA FALSI ALGORITHM
C     FOR FUNCTION 3
C     Y IS FIXED VALUE AND Z IS THE INTERATIVE VALUE.
C
      DIMENSION A(300),B(300),P(300)
      COMMON /MRF/ YMAX,ZMAX,YONE,YMIN
      EXTERNAL FNC3
C
      INITIAL VLAUE TO ZEROS
C
      DO 10 IM = 1,300
      A(IM) = 0.
      B(IM) = 0.
10  P(IM) = 0.
      ISTOP = 0
C

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C          GIVE EITHER 0.0001 OR 0.9999 FOR + OR - TEST
C          THE A IS ALWAYS SEATS AT THE LEFT OF B
      IN = 1
      B(IN) = ZMAX
      A(IN) = 0.0001
      TL = FNC3(Y1,A(IN),BETA) - PASI
      TR = FNC3(Y1,B(IN),BETA) - PASI
      IF(TL=TR)11,12,13
11      P(IN) = A(IN)
      DO 20 IN = 1,999
      P(IN+1) = (A(IN)+TR-B(IN)+TL)/(TR-TL)
      CHECK = FNC3(Y1,P(IN+1),BETA) - PASI
      IF(ABS(CHECK).GT.TOL)GOTO98
      Z1 = P(IN)
      GOTO99
98      IF(TL=CHECK)14,99,16
14      A(IN+1) = A(IN)
      B(IN+1) = P(IN+1)
      TR = CHECK
      CHK = FNC3(Y1,P(IN),BETA) - PASI
      IF(CHK+TR.GT.O.)TL = TL/2.
      GOTO20
16      A(IN+1) = P(IN+1)
      B(IN+1) = B(IN)
      TL = CHECK
      CHK = FNC3(Y1,P(IN),BETA) - PASI
      IF(TL=CHK.GT.O.)TR = TR/2.
      GOTO20
12      IF(TL.EQ.O.)GOTO15
      Z1 = B(IN)
      GOTO99
15      Z1 = A(IN)
      GOTO99
20      CONTINUE
13      ISTOP = 1
      IF(NECHO.EQ.O) WRITE(4,77)A(IN),B(IN),TL,TR
77      FORMAT(/5X,'MRF4 ',ZL',E10.4,' ZU ',E10.4,' TL ',E10.4,
+          ' TR ',E10.4/)
99      RETURN
      END
-----SUBROUTINE SHEAR1
SUBROUTINE SHEAR1(K1,K2, FNINE, ALPHA2, ALPHA)
COMMON /R3/ SIDIFF(50,40,2)
COMMON /R4/ F2(50,2)
COMMON /R10/ HSI(50,40,2),HETA(50,40,2)
      I = 1
      XBON = SIDIFF(K2,I,K1)/F2(K2,K1)
      T1 = -HETA(K2,I,K1)*FNINE
      T2 = -ALPHA2*(1.+XBON)*SIDIFF(K2,I,K1)
      ALPHA = (T1 + T2)/XBON
      RETURN
      END
-----SUBROUTINE INTPHI
SUBROUTINE INTPHI(A1,A2,B1,B2,C,D)
---GAUSSINA INTEGRATION FOR PHI
DIMENSION SHAPE(2),W(3),PT(3)
DATA PT/-0.77459667,0.000000,0.77459667/
DATA W/O.5555555,0.8888888,0.5555555/
      C = 0.
      D1 = D/2.
      DO 100 I = 1,3
      SHAPE(1) = (1. - PT(I))/2.
      SHAPE(2) = (1. + PT(I))/2.
      C=C+W(I)*(SHAPE(1)*A1+SHAPE(2)*A2)*(SHAPE(1)*B1+SHAPE(2)*B2)*D1
100      CONTINUE
      RETURN
      END
-----D13000 ROUTINE
SUBROUTINE D1300V(NA,MCBPTS,DEPTH,EPSILON,Y,Z,JBEG,
+ NB,BI,ZBOUND,YBOUND,FNC1,DELTA,DELY,SHEAR,VY,VZ,
+ PPL0T2,PPL0T3,PPL0T4,PPL0T5,AVGSHEA,NDIVIDE,
+ AVGVEL,SCALE,STATION)
INTEGER PPL0T2,PPL0T3,PPL0T4,PPL0T5
DIMENSION Y(50,40,2),Z(50,40,2),DELTA(2),NDIVIDE(2)
DIMENSION JBEG(2,40),NB(2),BI(2),ZBOUND(20),YBOUND(20)
DIMENSION SHEAR(50,40,2),VY(50,40,2),VZ(50,40,2),XYL(4)
C
C          INITIAL D13000 PLOT ROUTINE
C
C          CHARACTER=28 STATION
C          CHARACTER=21 NOTATU(3)
C
C          DATA NOTATU/'VERTICAL COMPONENTS ', 'TRANSVERSE COMPONENTS'
+          'SECONDARY VELOCITIES '/
C          DATA PIE/3.14159265/
C
C          CALL UINI(1)
C
C          XYL(1) = 0.0
C          XYL(2) = 100.
C          XYL(3) = 0.0
C          XYL(4) = 5.00
C          VMAX = 0.0
C          CALL JWIND0(XYL(1),XYL(2),XYL(3),XYL(4))
C          CALL JVPORT(-1.0,1.0,-0.7,0.7)
C
C          RATIO = XYL(2)/XYL(4)
C
C          AXES ATTRIBUTES

```



```

CALL UUSTI('ALL.EXIST',1)
CALL UUSTI('TOP.LABEL.TYPE',0)
CALL UUSTI('RIGHT.LABEL.TYPE',0)
CALL UUSTI('TOP.TITLE.FONT',5)
CALL UUSTI('TOP.TITLE.HORIZONTAL',1)
CALL UUSTI('ALL.TITLE.QUALITY',3)
CALL UUSTI('TOP.MAJOR.INWARD',0.0)
CALL UUSTI('TOP.TITLE.POSITION',0.1)
CALL UUSTI('TOP.TITLE.DISTANCE',0.2)
CALL UUSTI('TOP.TITLE.STRING',STATION)
CALL UUSTI('LEFT.MAJOR.INWARD',0.01)
CALL UUSTI('LEFT.SCALE.INTERVAL',1.0)
C   DRAW LEFT AXIS FOR DEPTH
CALL UUSTI('LEFT.TITLE.STRING','DEPTH, FT. ')
CALL UUSTI('LEFT.SCALE.MAXIMUM',XYL(4))
CALL UUSTI('LEFT.LABEL.HSIZE',0.015)
CALL UUSTI('LEFT.LABEL.VSIZE',0.015)
CALL UUSTI('ALL.LABEL.QUALITY',3)
CALL UUSTI('LEFT.TITLE.FONT',11)
CALL UUSTI('LEFT.LABEL.FONT',9)
C
C   DRAW BOTTOM AXIS FOR CROSS SECTION WIDTH
CALL UUSTI('BOTTOM.SCALE.INTERVAL',10.)
CALL UUSTI('BOTTOM.TITLE.STRING','DISTANCE FROM LEFT BANK OF
+RIVER, FT. ')
CALL UUSTI('BOTTOM.LABEL.HSIZE',0.015)
CALL UUSTI('BOTTOM.LABEL.VSIZE',0.015)
CALL UUSTI('BOTTOM.TITLE.HSIZE',0.020)
CALL UUSTI('BOTTOM.TITLE.VSIZE',0.020)
CALL UUSTI('BOTTOM.LABEL.QUALITY',3)
CALL UUSTI('BOTTOM.MAJOR.OUTWARD',0.02)
CALL UUSTI('BOTTOM.MAJOR.INWARD',0.0)
CALL UUSTI('BOTTOM.TITLE.DISTANCE',0.09)
CALL UUSTI('BOTTOM.TITLE.FONT',11)
CALL UUSTI('BOTTOM.TITLE.QUALITY',3)
CALL UUSTI('BOTTOM.LABEL.FONT',9)
C
C   TRANSFER COORDINATES
C
C   DEFINE UNIT IN PLOTS
UNIT = (XYL(2) - XYL(1)) / 15.
RATIO = (XYL(4)-XYL(3))/(XYL(2)-XYL(1))
C
C   NA1 = NA - 1
C
C   ADJUST COORDINATES
C
DO 100 K = 1,2
FNC2 = B1(K) + DELTA(K)
C
DO 110 I = 1,NA
NC = JBEG(K,I)
DO 120 J = NC,NB(K)
Y(J,I,K) = -DEPTH*(Y(J,I,K) = FNC1 - DELY) + 4.0
IF(K.EQ.1) Z(J,I,K) = B1(I) - Z(J,I,K)*FNC2
IF(K.EQ.2) Z(J,I,K) = Z(J,I,K)*FNC2 + B1(I)
IF(I.GE.2.AND.I.LE.NA1) THEN
IF(K.EQ.1) VZ(J,I,K) = -VZ(J,I,K)
IF(VMAX.LT.ABS(VZ(J,I,K))) VMAX = ABS(VZ(J,I,K))
IF(VMAX.LT.ABS(VY(J,I,K))) VMAX = ABS(VY(J,I,K))
END IF
120 CONTINUE
110 CONTINUE
100 CONTINUE
C
DO 111 I = 1,MCBPTS
YBOUND(I) = -DEPTH*YBOUND(I) + 4.0
111 CONTINUE
RAT = UNIT / VMAX
C
C   DRAW SHEAR STRESSES ALONG BOUNDARY
C
IF(PLOT2.EQ.1) THEN
I = 1
CALL UOAXIS(XYL(1),XYL(2),XYL(3),XYL(4))
C
C   DRAW BOUNDARY
C
CALL JOPEN
CALL JLWIDE(16383)
CALL JMOVE(ZBOUND(1),YBOUND(1))
CALL JPOLY(ZBOUND,YBOUND,MCBPTS)
CALL JDRAW(ZBOUND(1),YBOUND(1))
CALL JCLOSE
C
DO 150 K = 1,2
DO 160 J = 1,NB(K)
SHEAR(J,I,K) = SHEAR(J,I,K) / AVGSHEA
170 DO 180 I = MK,NA
180 CONTINUE
160 CONTINUE
150 CONTINUE
C
C   LABLES
C
WRITE(6,77)
CALL JPAUSE(1)
END IF
C

```

```

C
C
C      DRAW VELOCITIES COMPONENTS
C
C      IF(PPLOT3.EQ.1 .OR. PPLOT4.EQ.1 .OR. PPLOT5.EQ.1) THEN
C      ANG = 30./180.*3.14159265
C      IF(PPLOT3.EQ.1) THEN
C
C          CALL JFRAME
C          CALL UUAXIS(XYL(1),XYL(2),XYL(3),XYL(4))
C
C      DRAW BOUNDARY
C
C      CALL JOPEN
C      CALL JLWIDE(16383)
C      CALL JMOVE(ZBOUND(1),YBOUND(1))
C      CALL JPOLY(ZBOUND,YBOUND,MCBPTS)
C      CALL JDRAW(ZBOUND(1),YBOUND(1))
C      CALL JCLOSE
C
C          THETA = 3.14159265 / 2.
C
C      CALL JOPEN
C      CALL JLWIDE(8000)
C
C      DO 200 K = 1,2
C      DO 210 I = 2,NA1,NDIVIDE(1)
C      NC = JBEG(K,I)
C      DO 220 J = NC,NB(K),NDIVIDE(2)
C      CALL JMOVE(Z(J,I,K),Y(J,I,K))
C      PVY = VY(J,I,K) * RAT = RATIO + Y(J,I,K)
C      PVZ = Z(J,I,K)
C      CALL JDRAW(PVZ,PVY)
C
C      RT = SORT(VY(J,I,K)*VY(J,I,K)+0.0*0.0)/8.0
C
C      DX = RT * COS(THETA) = RAT
C      DY = RT * SIN(THETA) = RAT * RATIO
C      IF(VY(J,I,K) .LT. 0.0) DY = - DY
C      TY = PVY - DY
C      TZ = PVZ - DX
C      DX = RT * SIN(ANG) = COS((PIE/2.-ANG)+THETA) = RAT
C      DY = RT * SIN(ANG) = SIN((PIE/2.-ANG)+THETA) = RAT*RATIO
C      DX1 = RT * SIN(ANG) = COS(THETA-(PIE/2.-ANG)) = RAT
C      DY1 = RT * SIN(ANG) = SIN(THETA-(PIE/2.-ANG)) = RAT*RATIO
C      YA = TY + DY
C      ZA = TZ + DX
C      YB = TY + DY1
C      ZB = TZ + DX1
C
C      CALL JMOVE(PVZ,PVY)
C      CALL JDRAW(ZA,YA)
C      CALL JMOVE(PVZ,PVY)
C      CALL JDRAW(ZB,YB)
C
C      220 CONTINUE
C      210 CONTINUE
C      200 CONTINUE
C
C      CALL JCLOSE
C
C      WRITE IDENTIFICATION
C
C      XPOST = XYL(1) + UNIT
C      YPOST = XYL(4) - 0.5
C      CALL JOPEN
C      CALL JJUST(1,2)
C      CALL JFONT(3)
C      CALL JMOVE(XPOST,YPOST)
C      CALL JSIZE(3,3,3=RATIO)
C      CALL JHSTRG(NGTATU(1))
C      CALL JCLOSE
C
C      DRAW AN UNIT LENGTH TO EXPRESS SCALE
C
C      XPOST = XYL(1) + 2. * UNIT
C      YPOST = XYL(3) + .60
C      CALL JOPEN
C      CALL JMOVE(XPOST,YPOST)
C      CALL JJUST(1,2)
C      CALL JFONT(3)
C      CALL JSIZE(2,8,3.0=RATIO)
C      CALL JHSTRG('SCALE')
C      CALL JMOVE(XPOST,YPOST-.2)
C      CALL JDRAW(XPOST+1.0=RAT,YPOST-.2)
C      CALL JMOVE(XPOST+1.2=RAT,YPOST-.2)
C      CALL JHSTRG('1FPS')
C      CALL JCLOSE
C
C      CALL JPAUSE(1)
C      END IF
C
C      IF(PPLOT4.EQ.1) THEN
C
C          CALL JFRAME
C          CALL UUAXIS(XYL(1),XYL(2),XYL(3),XYL(4))
C
C      DRAW BOUNDARY
C
C      CALL JOPEN
C      CALL JLWIDE(16383)

```

```

CALL JMOVE(ZBOUND(1),YBOUND(1))
CALL JPOLY(ZBOUND,YBOUND,MCBPTS)
CALL JDRAW(ZBOUND(1),YBOUND(1))
CALL JCLOSE

C
  THETA = 0.0
C
  CALL JOPEN
  CALL JLWIDE(8000)
C
  DO 300 K = 1,2
  DO 310 J = 2,NA1,NDIVIDE(1)
  NC = JBEG(K,1)
  DO 320 I = NC,NB(K),NDIVIDE(2)
  CALL JMOVE(Z(J,I,K),Y(J,I,K))
  PVY = Y(J,I,K)
  PVZ = Z(J,I,K) + VZ(J,I,K) * RAT
  CALL JDRAW(PVZ,PVY)
C
  RT = SORT(VZ(J,I,K)*VZ(J,I,K)+0.0*0.0)/8.0
C
  DX = RT * COS(THETA) * RAT
  IF(VZ(J,I,K) .LT. 0.0) DX = -DX
  DY = RT * SIN(THETA) * RAT * RATIO
  TY = PVY - DY
  TZ = PVZ - DX
  DX1 = RT * SIN(ANG) * COS((PIE/2.-ANG)+THETA) * RAT
  DY = RT * SIN(ANG) * SIN((PIE/2.-ANG)+THETA) * RAT * RATIO
  DX1 = RT * SIN(ANG) * COS(THETA-(PIE/2.-ANG)) * RAT
  DY1 = RT * SIN(ANG) * SIN(THETA-(PIE/2.-ANG)) * RAT * RATIO
  YA = TY + DY
  ZA = TZ + DX
  YB = TY + DY1
  ZB = TZ + DX1
C
  CALL JMOVE(PVZ,PVY)
  CALL JDRAW(ZA,YA)
  CALL JMOVE(PVZ,PVY)
  CALL JDRAW(ZB,YB)
C
  320   CONTINUE
  310   CONTINUE
  300   CONTINUE
C
  CALL JCLOSE
C
  WRITE IDENTIFICATION
C
  XPOST = XYL(1) + UNIT
  YPOST = XYL(4) - 0.5
  CALL JOPEN
  CALL JJUST(1,2)
  CALL JFONT(3)
  CALL JMOVE(XPOST,YPOST)
  CALL JSIZE(3.3,3.3*RATIO)
  CALL JHSTRG(NOTATU(2))
  CALL JCLOSE
C
  DRAW AN UNIT LENGTH TO EXPRESS SCALE
C
  XPOST = XYL(1) + 2. * UNIT
  YPOST = XYL(3) + .60
  CALL JOPEN
  CALL JMOVE(XPOST,YPOST)
  CALL JJUST(1,2)
  CALL JFONT(3)
  CALL JSIZE(2.8,3.0*RATIO)
  CALL JHSTRG('SCALE')
  CALL JMOVE(XPOST,YPOST-.2)
  CALL JDRAW(XPOST+1.0*RAT,YPOST-.2)
  CALL JMOVE(XPOST+1.2*RAT,YPOST-.2)
  CALL JHSTRG('=1FPS')
  CALL JCLOSE
C
  CALL JPAUSE(1)
  END IF
C
  IF(PPLOTS .EQ. 1) THEN
C
    CALL JFRAME
    CALL UAXIS(XYL(1),XYL(2),XYL(3),XYL(4))
C
    DRAW BOUNDARY
C
    CALL JOPEN
    CALL JLWIDE(16383)
    CALL JMOVE(ZBOUND(1),YBOUND(1))
    CALL JPOLY(ZBOUND,YBOUND,MCBPTS)
    CALL JDRAW(ZBOUND(1),YBOUND(1))
    CALL JCLOSE
C
    CALL JOPEN
    CALL JLWIDE(8000)
C
    DO 400 K = 1,2
    DO 410 J = 2,NA1,NDIVIDE(1)
    NC = JBEG(K,1)
    DO 420 I = NC,NB(K),NDIVIDE(2)
    CALL JMOVE(Z(J,I,K),Y(J,I,K))
    PVY = VY(J,I,K) * RAT * RATIO + Y(J,I,K)

```

```

PVZ = Z(J,I,K) + VZ(J,I,K) = RAT
CALL JDRAW(PVZ,PVY)
C
RT = SORT(VY(J,I,K)=VY(J,I,K)+VZ(J,I,K)+VZ(J,I,K))/8.0
THETA = ATAN(VY(J,I,K)/VZ(J,I,K))
C
DX = RT * COS(THETA) = RAT
DY = RT * SIN(THETA) = RAT = RATIO
IF(VY(J,I,K) .LT. 0.0) DY = -DY
IF(VZ(J,I,K) .LT. 0.0) DX = -DX
TY = PVY - DY
TZ = PVZ - DX
DX = RT * SIN(ANG) = COS((PIE/2.-ANG)+THETA) = RAT
DY = RT * SIN(ANG) = SIN((PIE/2.-ANG)+THETA) = RAT=RATIO
DX1 = RT * SIN(ANG) = COS(THETA-(PIE/2.-ANG)) = RAT
DY1 = RT * SIN(ANG) = SIN(THETA-(PIE/2.-ANG)) = RAT=RATIO
YA = TY + DY
ZA = TZ + DX
YB = TY + DY1
ZB = TZ + DX1
C
CALL JMOVE(PVZ,PVY)
CALL JDRAW(ZA,YA)
CALL JMOVE(PVZ,PVY)
CALL JDRAW(ZB,YB)
C
420 CONTINUE
410 CONTINUE
400 CONTINUE
C
CALL JCLOSE
C
WRITE,IDENTIFICATION
C
XPOST = XYL(1) + UNIT
YPOST = XYL(4) - 0.5
CALL JOPEN
CALL JJUST(1,2)
CALL JFONT(3)
CALL JMOVE(XPOST,YPOST)
CALL JSIZE(3.3,3.3=RATIO)
CALL JHSTRG(NOTATU(3))
CALL JCLOSE
C
DRAW AN UNIT LENGTH TO EXPRESS SCALE
C
XPOST = XYL(1) + 2. = UNIT
YPOST = XYL(3) + .60
CALL JOPEN
CALL JMOVE(XPOST,YPOST)
CALL JJUST(1,2)
CALL JFONT(3)
CALL JSIZE(2.8,3.0=RATIO)
CALL JHSTRG('SCALE')
CALL JMOVE(XPOST,YPOST-.2)
CALL JDRAW(XPOST+1.0=RAT,YPOST-.2)
CALL JMOVE(XPOST+1.2=RAT,YPOST-.2)
CALL JHSTRG('IFPS')
CALL JCLOSE
C
CALL JPAUSE(1)
C
END IF
END IF
C
CALL JEND
C
77 FORMAT(12X,'CHANGE PAPER ON PLOTTER. ENTER STOP TO STOP RUNS')
STOP
END
C -----D13000 ROUTINE
SUBROUTINE D13010(NA,MCBPTS,DEPTH,EPSILON,Y,Z,JBEG,
+ NB,BI,ZBOUND,YBOUND,FNC1,DELTA,DELY)
DIMENSION ZP(50),YP(50)
DIMENSION Y(50,40,2),Z(50,40,2),DELTA(2)
DIMENSION JBEG(2,40),NB(2),BI(2),ZBOUND(20),YBOUND(20)
C
INITIAL D13000 PLOT ROUTINE
C
CALL UUINI(1)
YMIN = XMIN = 0.0
YMAX = DEPTH = 1.2
XMAX = (BI(1) + BI(2)) = 1.1
C
CALL JWINDO(XMIN,XMAX,YMIN,YMAX)
CALL JVPOR(-1.0,1.0,-1.0,1.0)
CALL UUSTI('ALL.EXIST',0)
CALL UUAXIS(XMIN,XMAX,YMIN,YMAX)
C
DRAW BOUNDARY
C
CALL UUCURV(ZBOUND,YBOUND,MCBPTS)
C
DRAW XI CURVES
DO 100 K = 1,2
FNC2 = BI(K) + DELTA(K)
DO 110 I = 1,NA
NC = JBEG(K,I)

```

```

ND = 1
DO 120 J = NC, NB(K)
YP(ND) = Y(J, I, K) * FNC1 - DELY
IF(K.EQ.1) ZP(ND) = B1(1) - Z(J, I, K) * FNC2
IF(K.EQ.2) ZP(ND) = Z(J, I, K) * FNC2 + B1(1)
ND = ND + 1
120 CONTINUE
C
ND = ND - 1
CALL UUCURV(ZP, YP, ND)
110 CONTINUE
100 CONTINUE
C
CALL JPAUSE(1)
C
DRAW ETA CURVES
C
DO 150 K = 1, 2
FNC2 = B1(K) * DELTA(K)
MK = NA
MP = 1
DO 160 J = 2, NB(K)
IF(J.LE.NA) THEN
IF(EPSILON.GT.0.0) MK = J
IF(EPSILON.LT.0.0) MP = NA - J + 1
END IF
ND = 1
170 DO 180 I = MP, MK
YP(ND) = Y(J, I, K) * FNC1 - DELY
IF(K.EQ.1) ZP(ND) = B1(1) - Z(J, I, K) * FNC2
IF(K.EQ.2) ZP(ND) = Z(J, I, K) * FNC2 + B1(1)
ND = ND + 1
180 CONTINUE
C
ND = ND - 1
CALL UUCURV(ZP, YP, ND)
160 CONTINUE
150 CONTINUE
C
LABELS
C
CALL JPAUSE(1)
CALL JEND
C
STOP
END

```

Appendix B

Measured Velocities

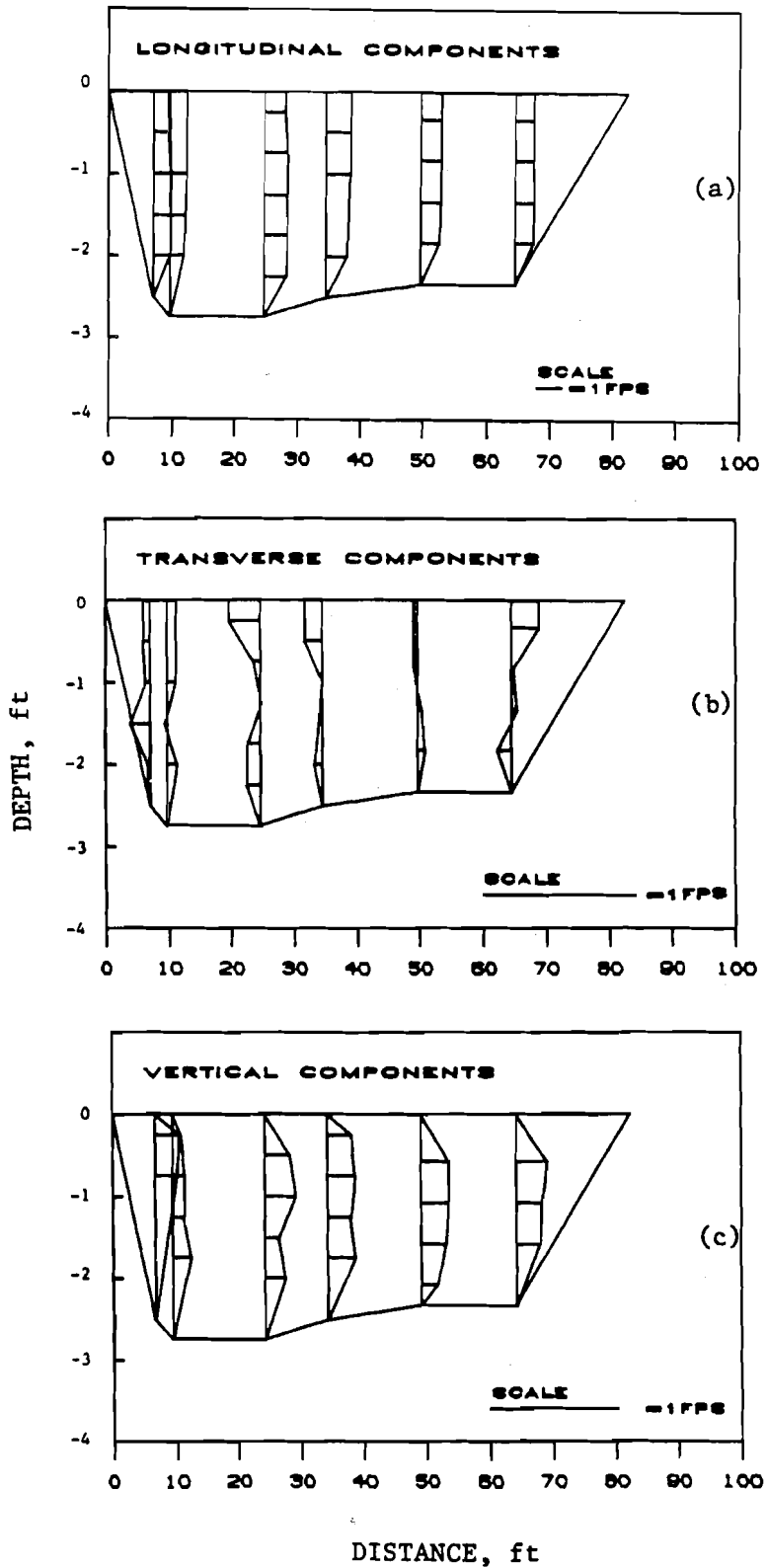


Figure B-1. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 7, June 27, 1984

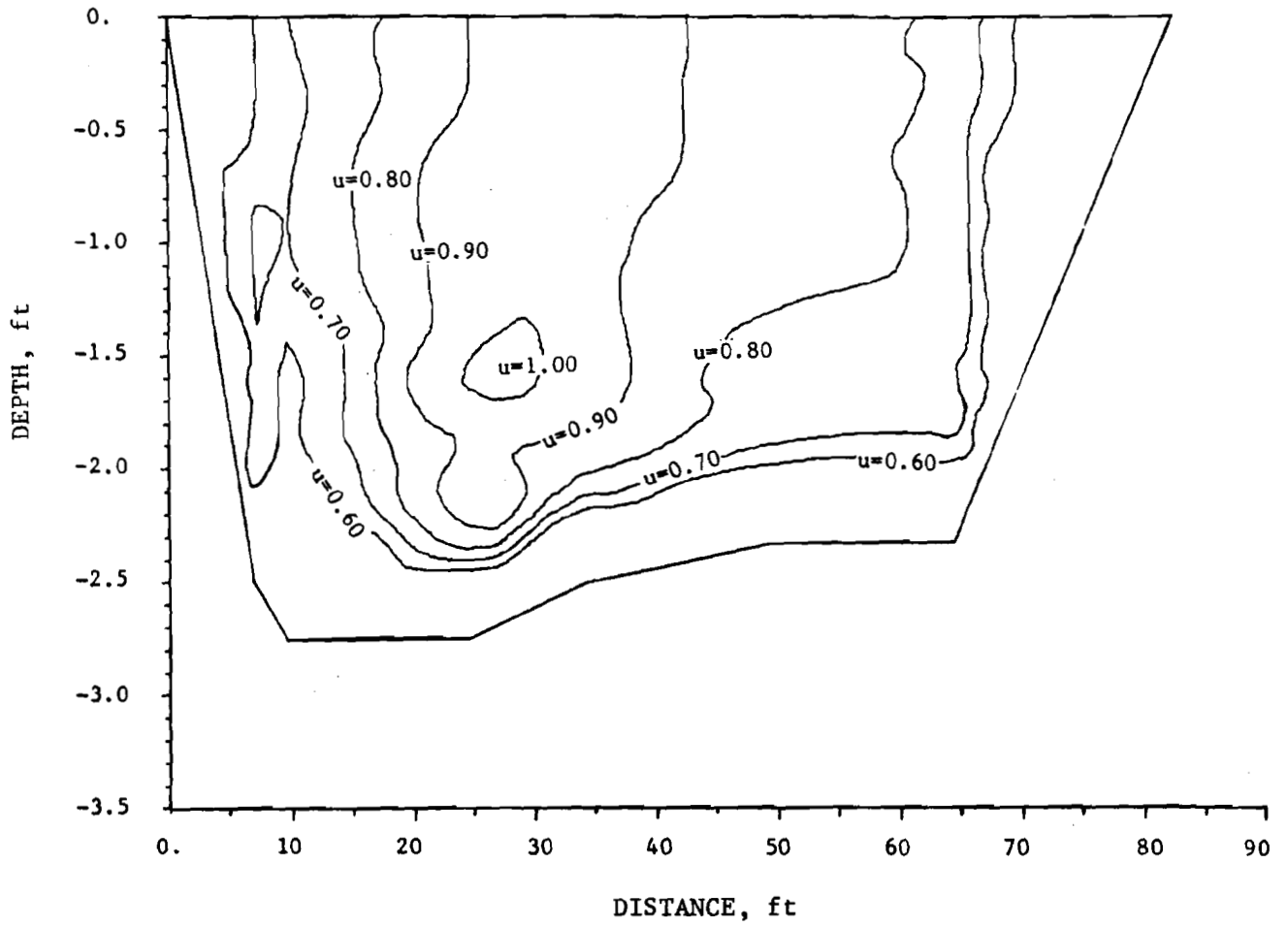


Figure B-2. Isovels of longitudinal velocity at cross section 7, June 27, 1984



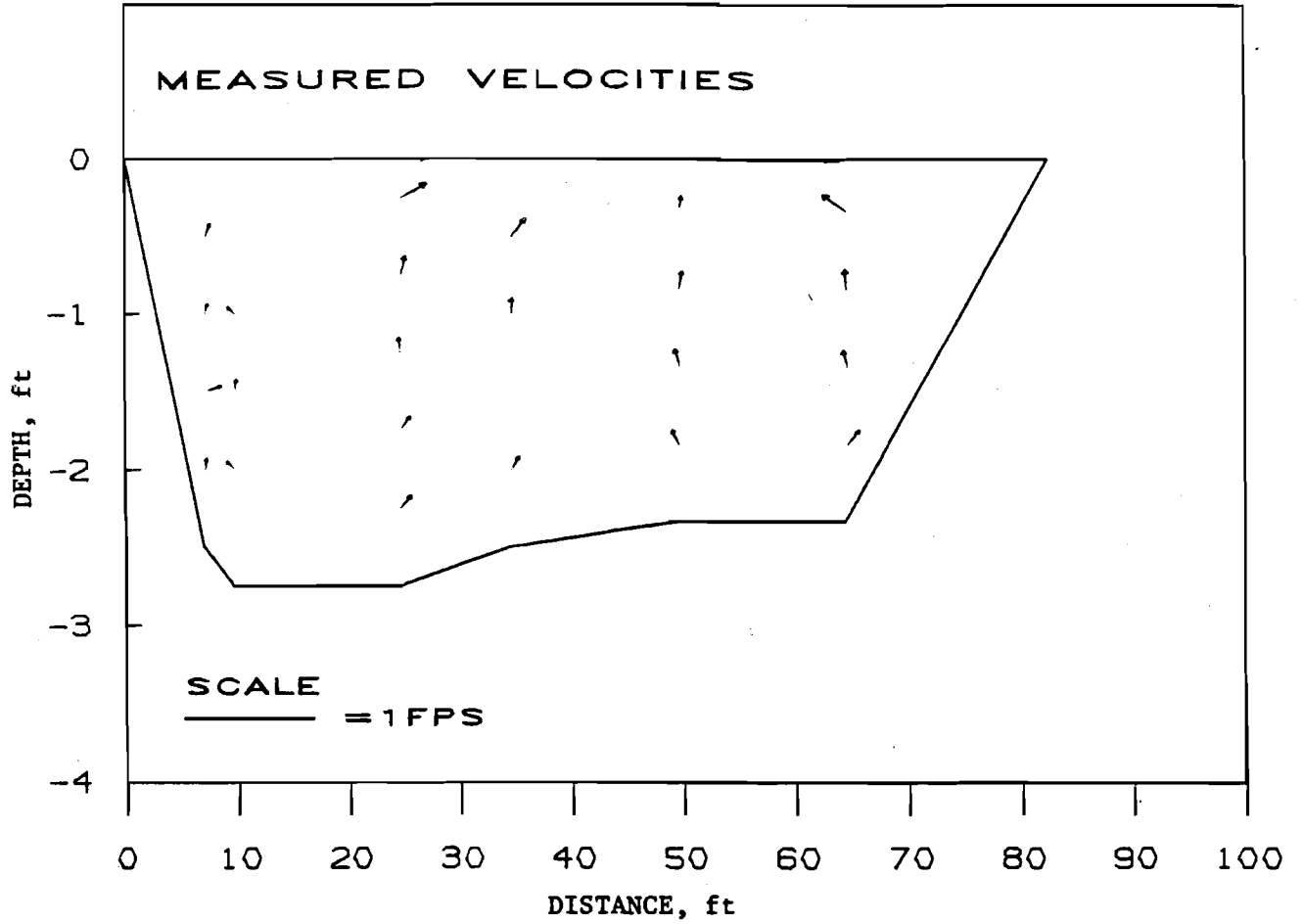


Figure B-3. Measured secondary current vectors at cross section 7, June 27, 1984

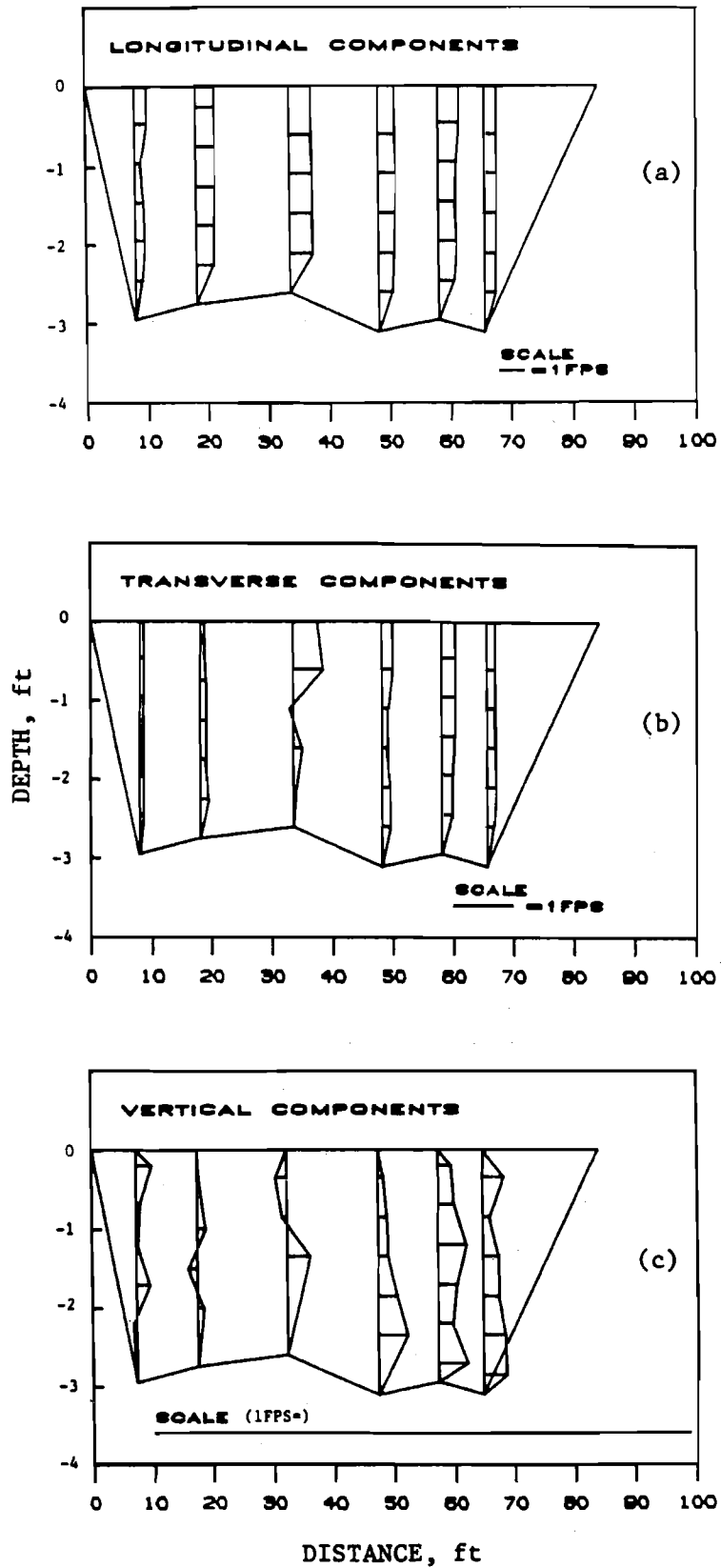


Figure B-4. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 6, June 28, 1984

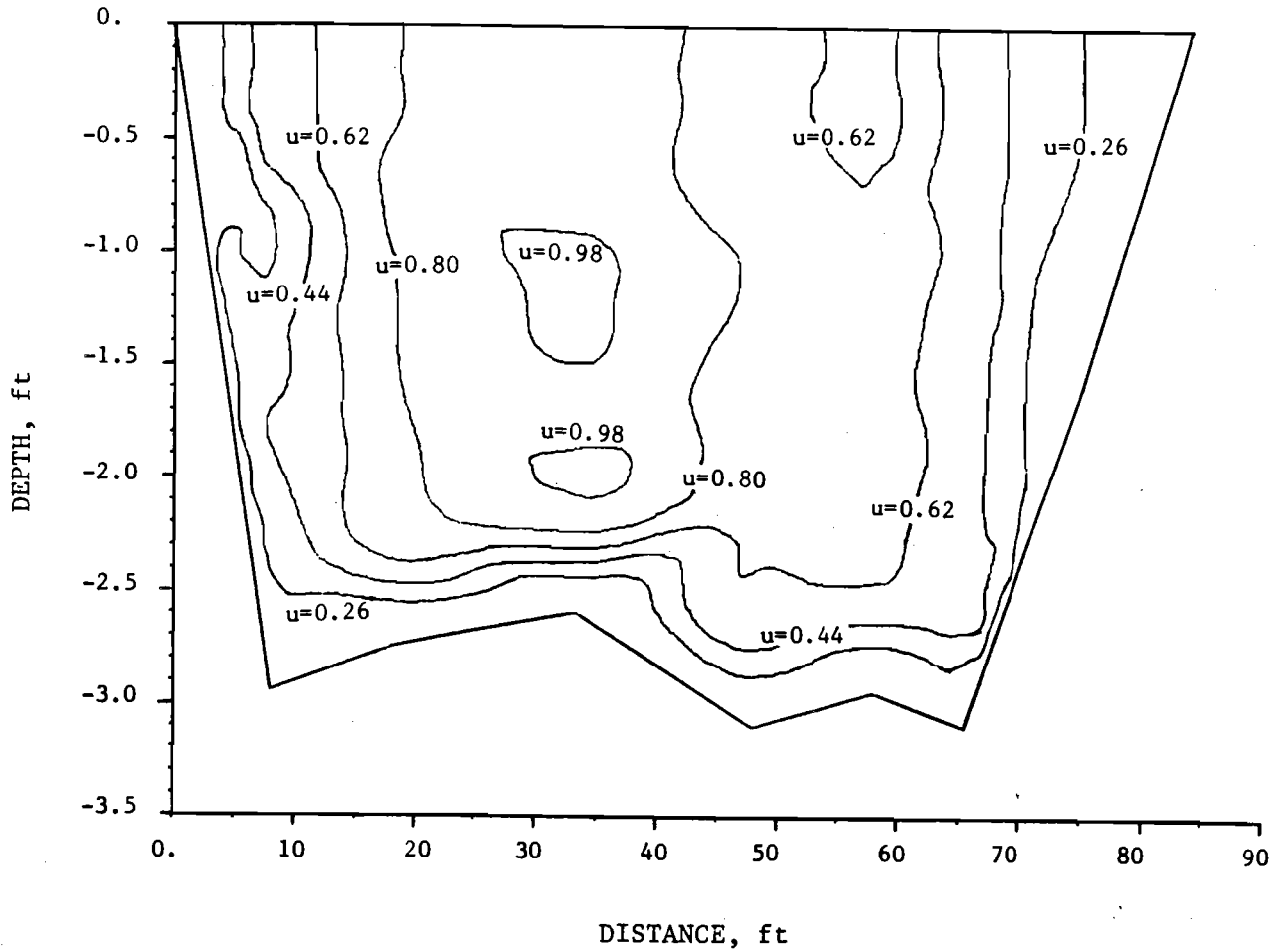


Figure B-5. Isovells of longitudinal velocity at cross section 6, June 28, 1984

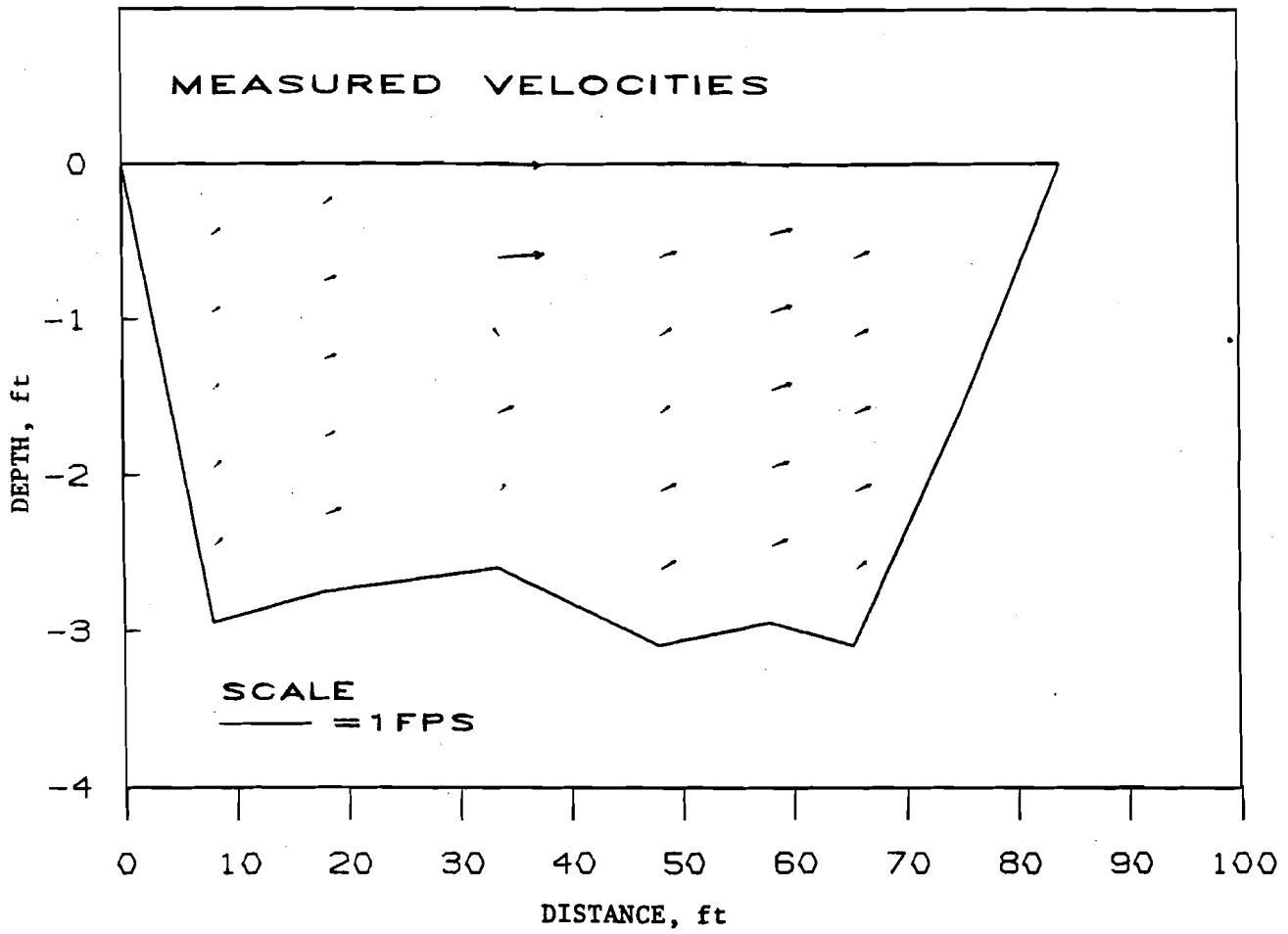


Figure B-6. Measured secondary current vectors at cross section 6, June 28, 1984

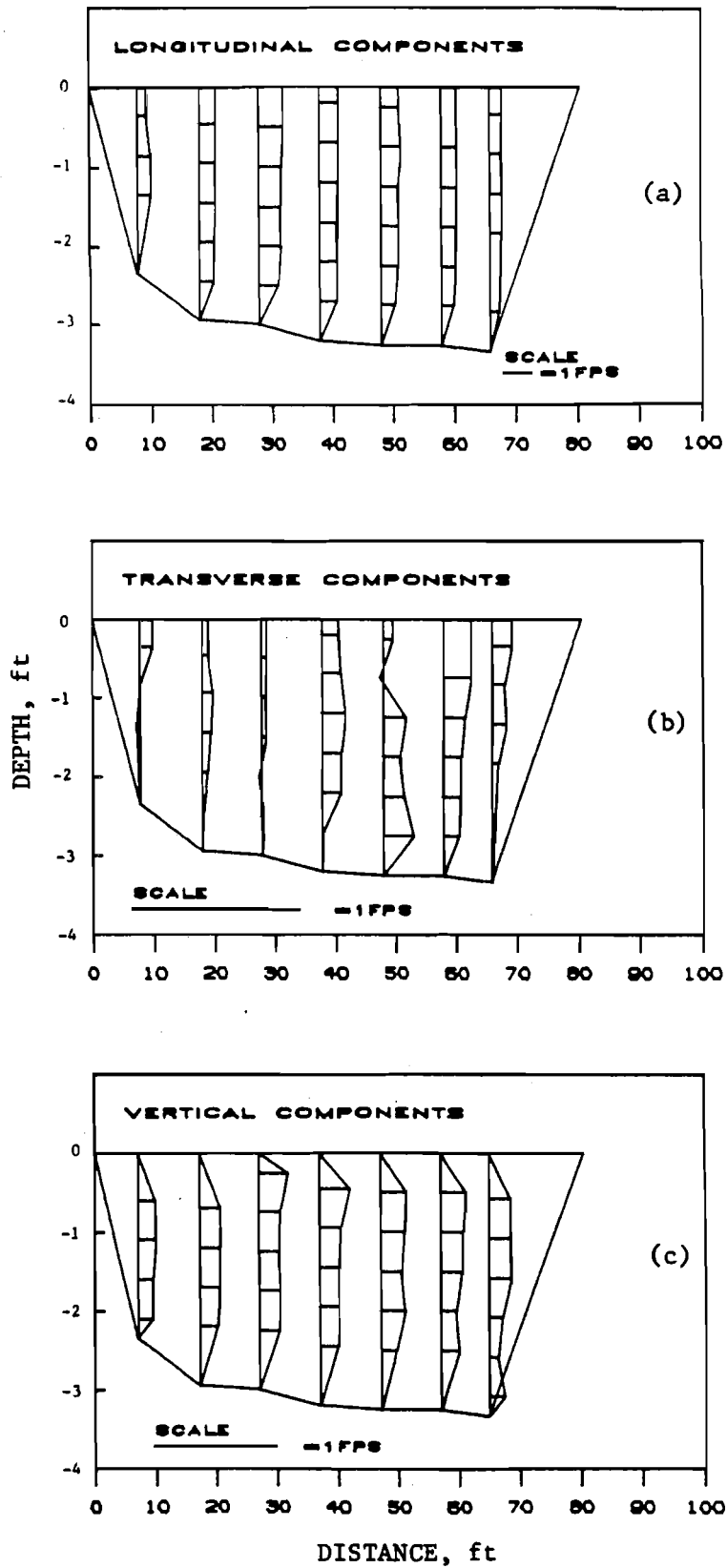


Figure B-7. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 5, June 29, 1984

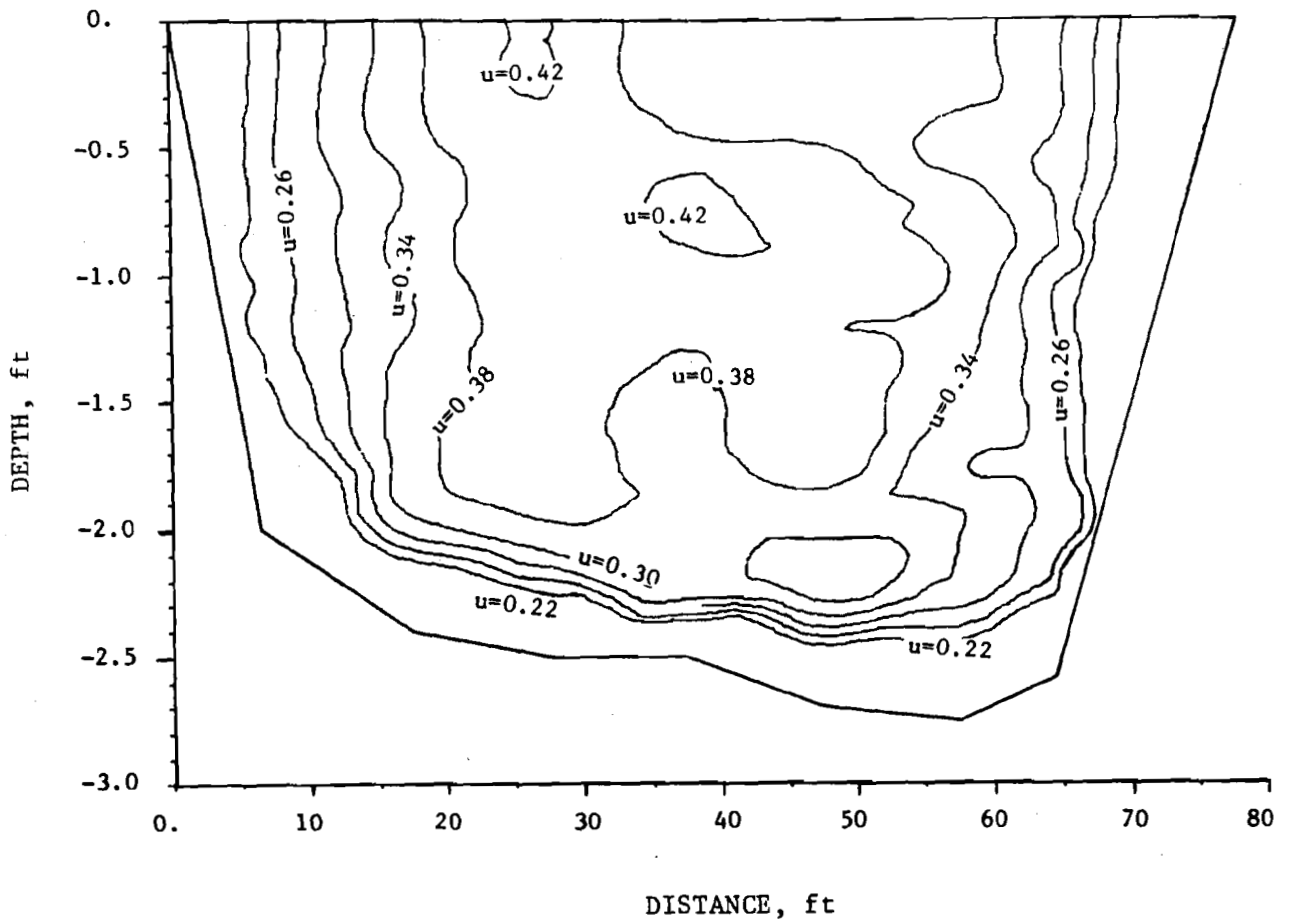


Figure B-8. Isovells of longitudinal velocity at cross section 5, June 29, 1984

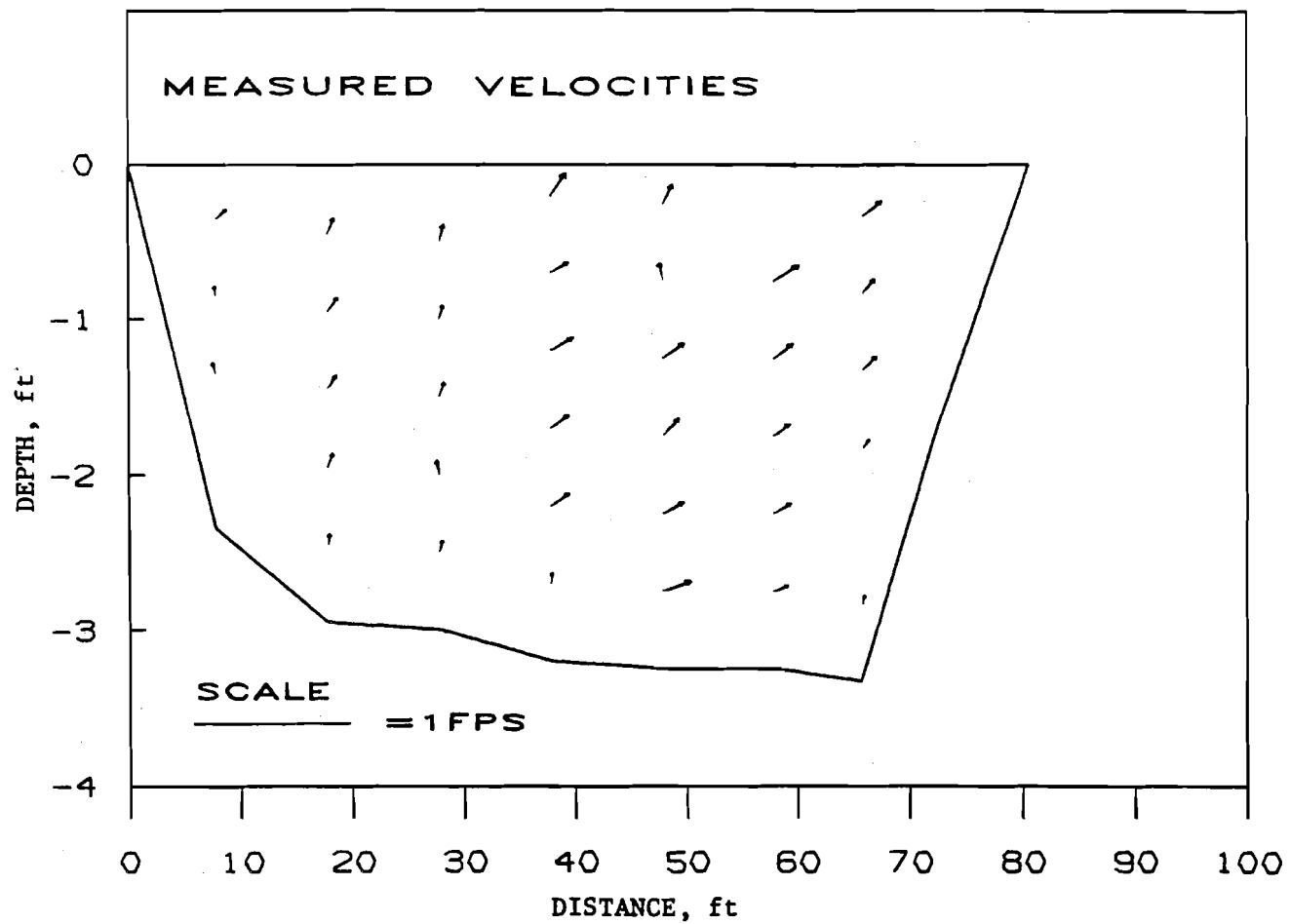


Figure B-9. Measured secondary current vectors at cross section 5, June 19, 1984

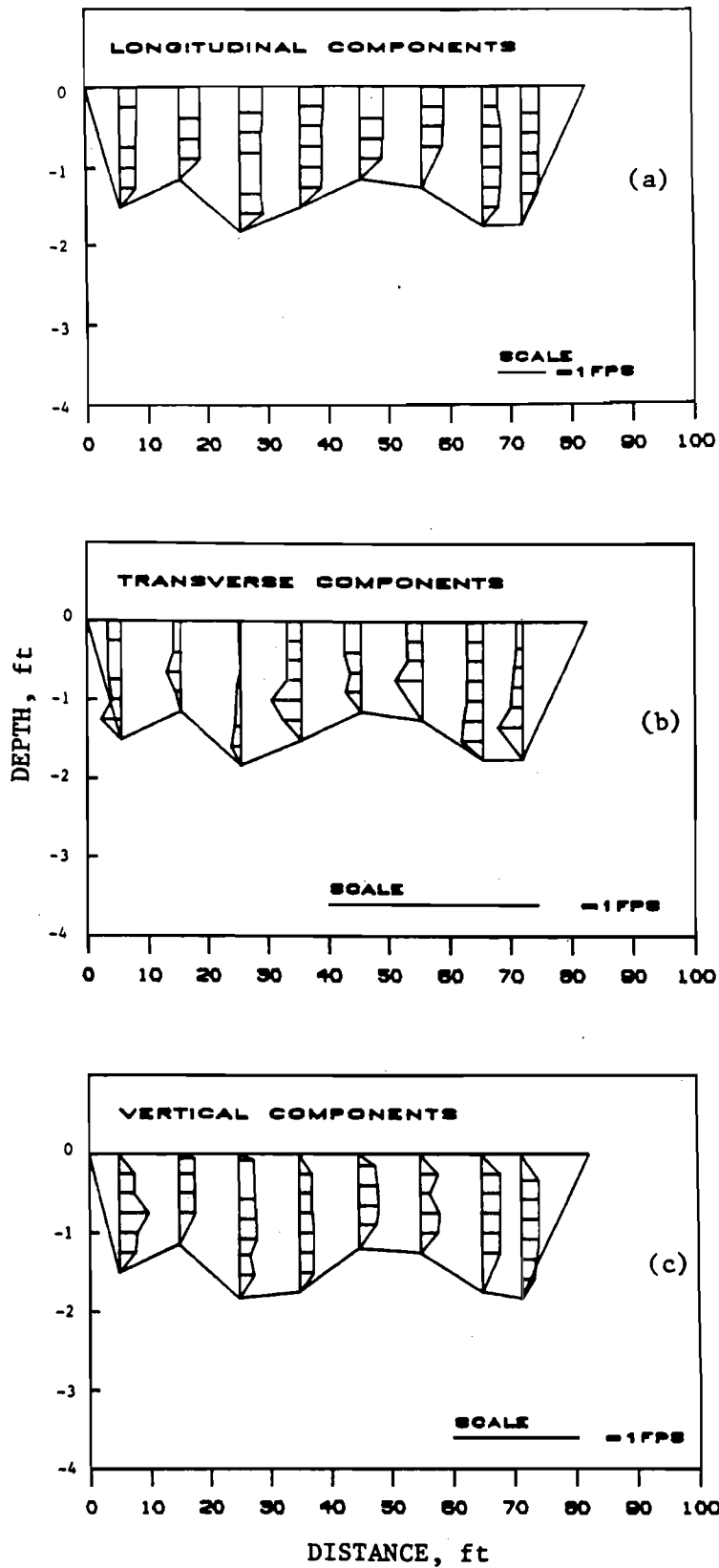


Figure B-10. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 3, July 9, 1984



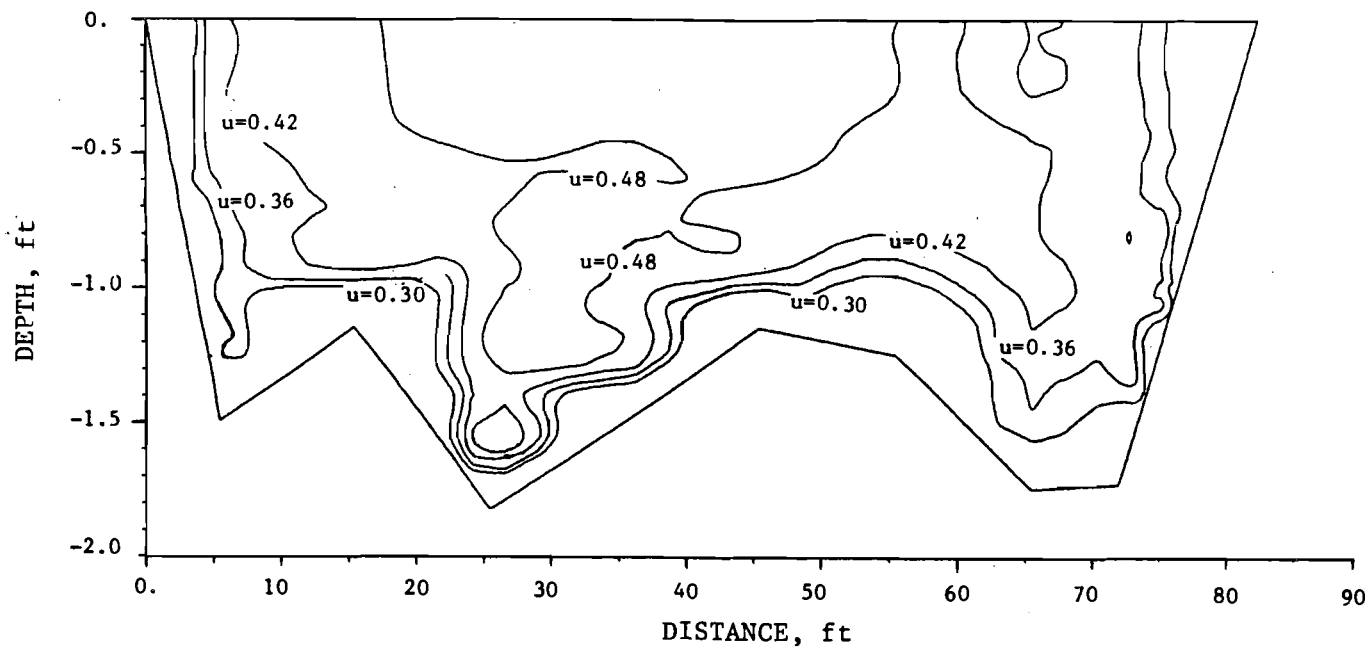


Figure B-11. Isovets of longitudinal velocity at cross section 3, July 9, 1984

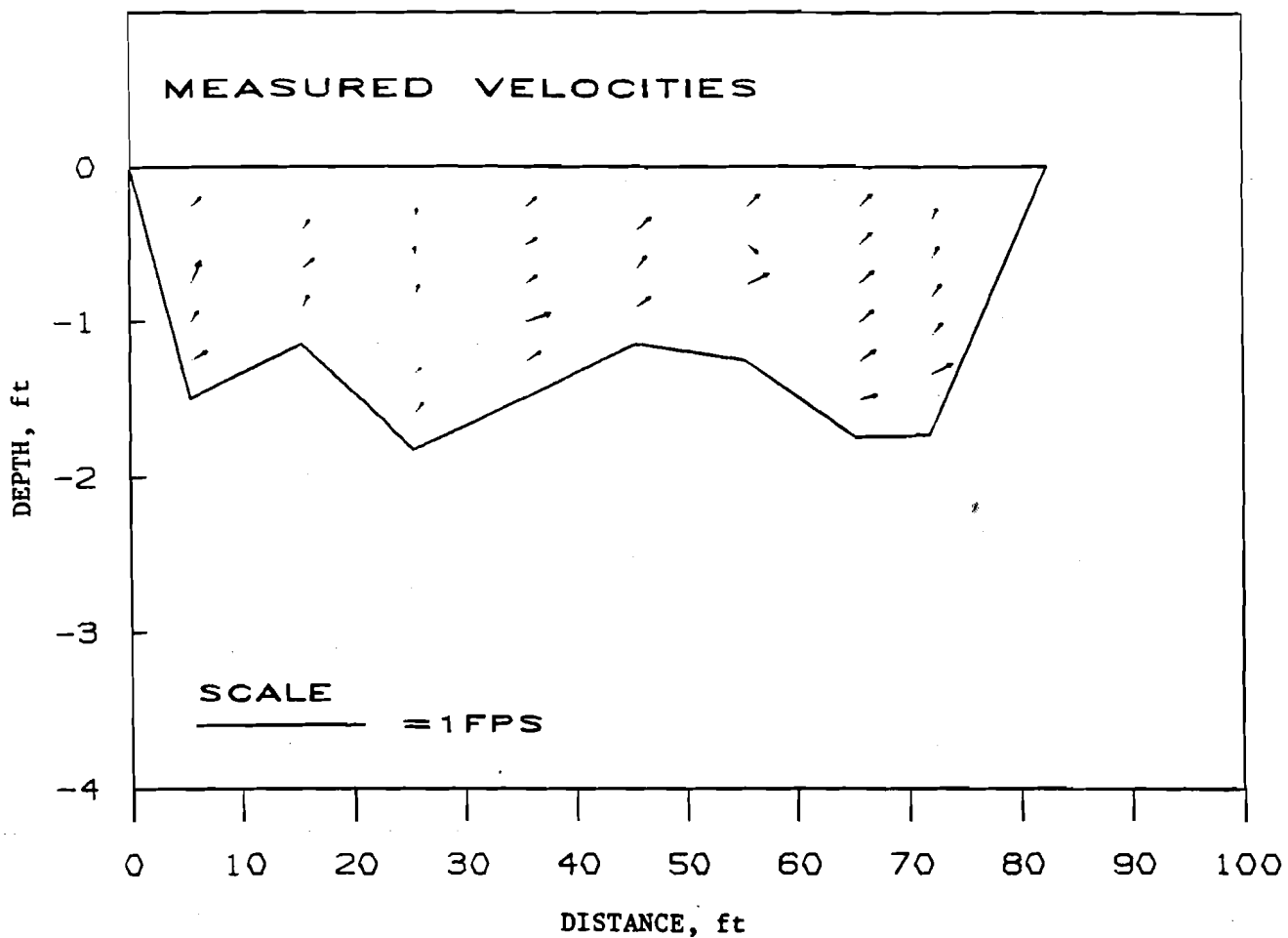


Figure B-12. Measured secondary current vectors at cross section 3, July 9, 1984

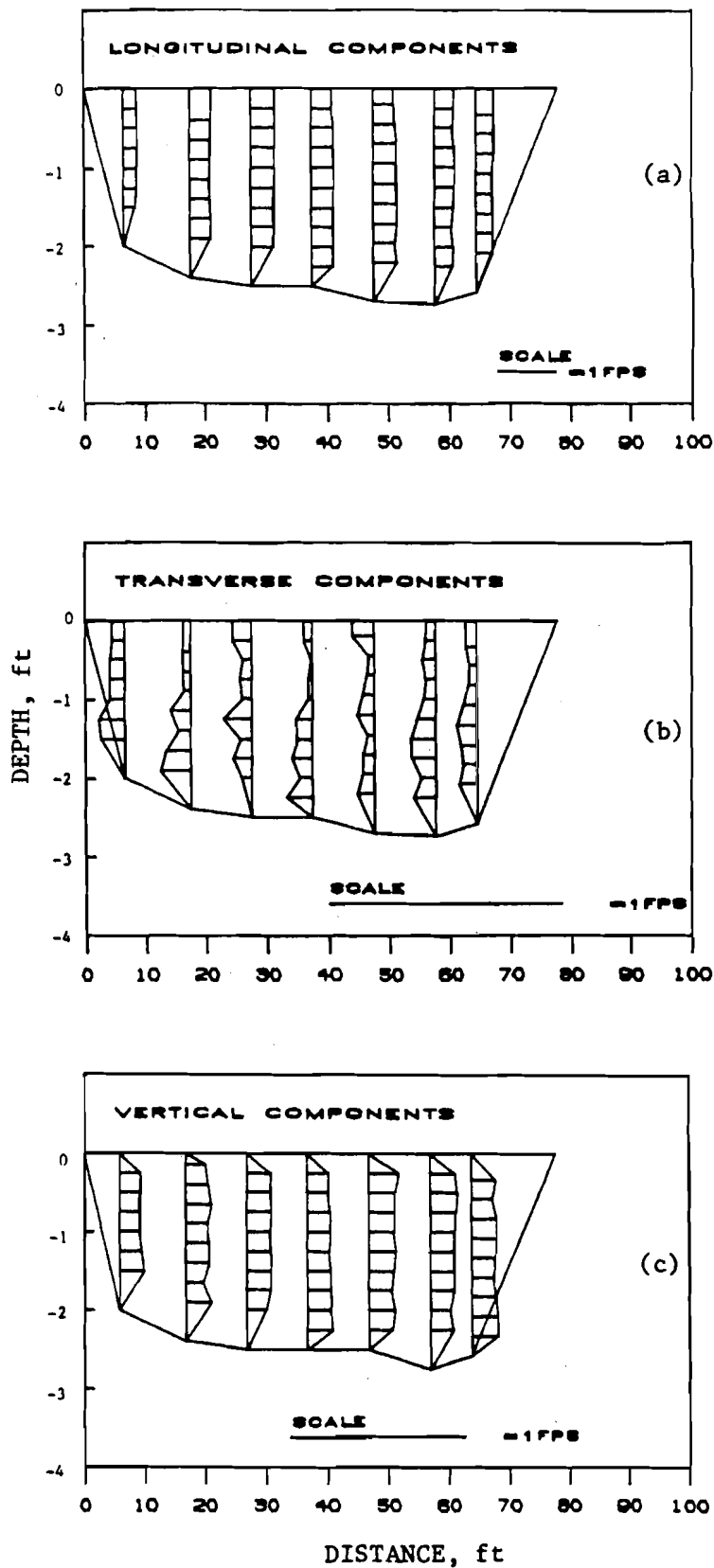


Figure B-13. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 4, July 10, 1984

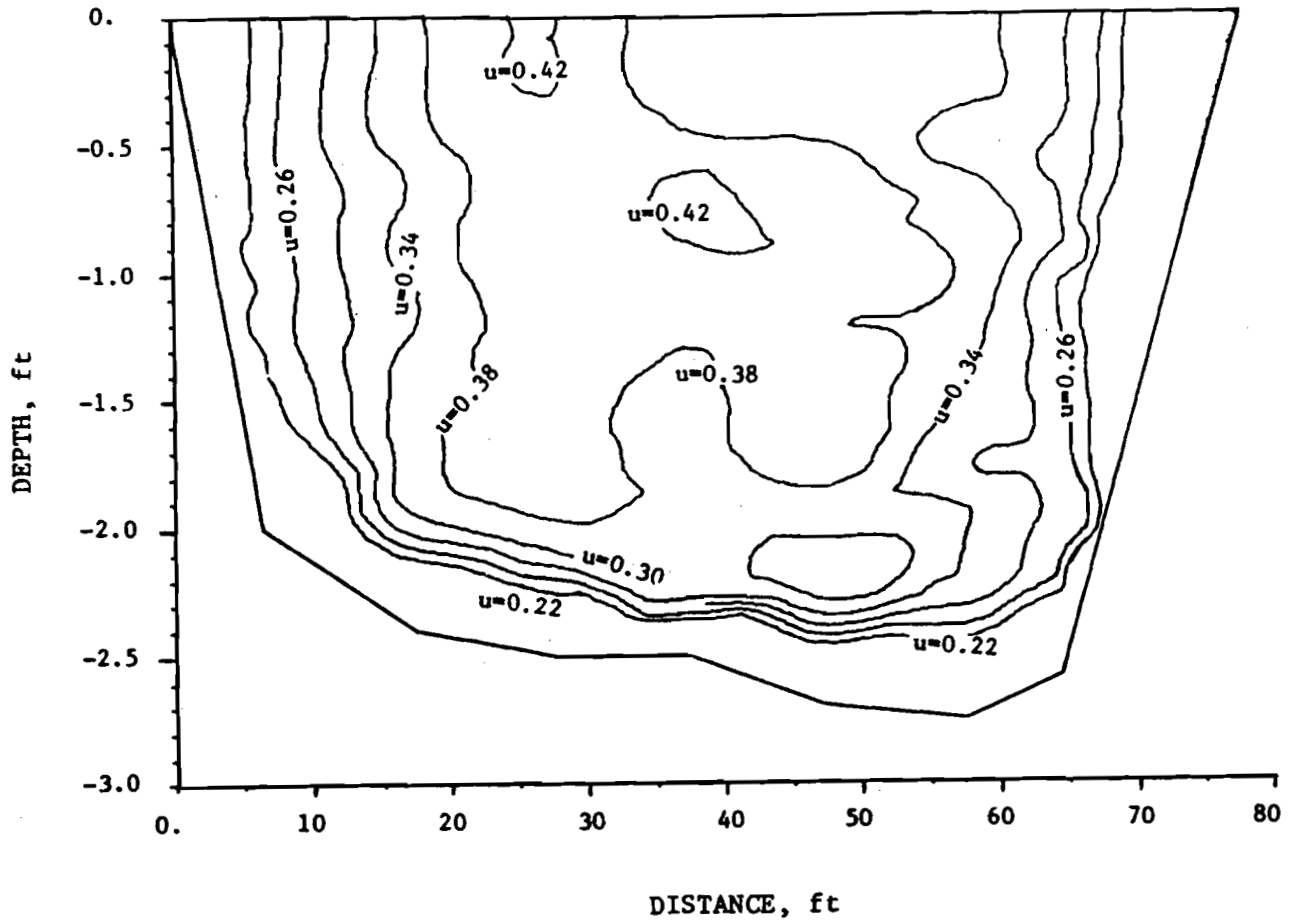


Figure B-14. Isovets of longitudinal velocity at cross section 4, July 10, 1984

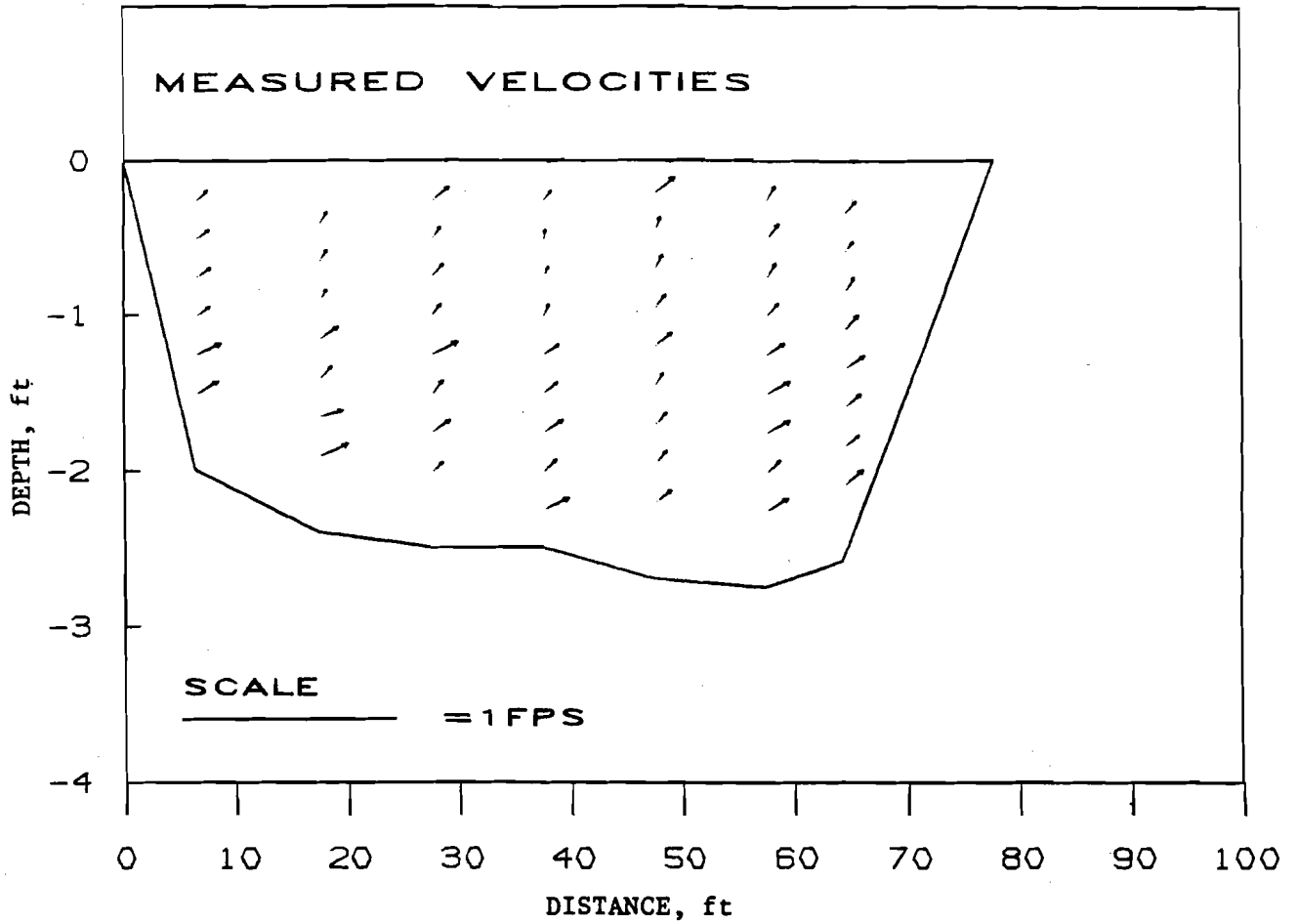


Figure B-15. Measured secondary current vectors at cross section 4,  
July 10, 1984

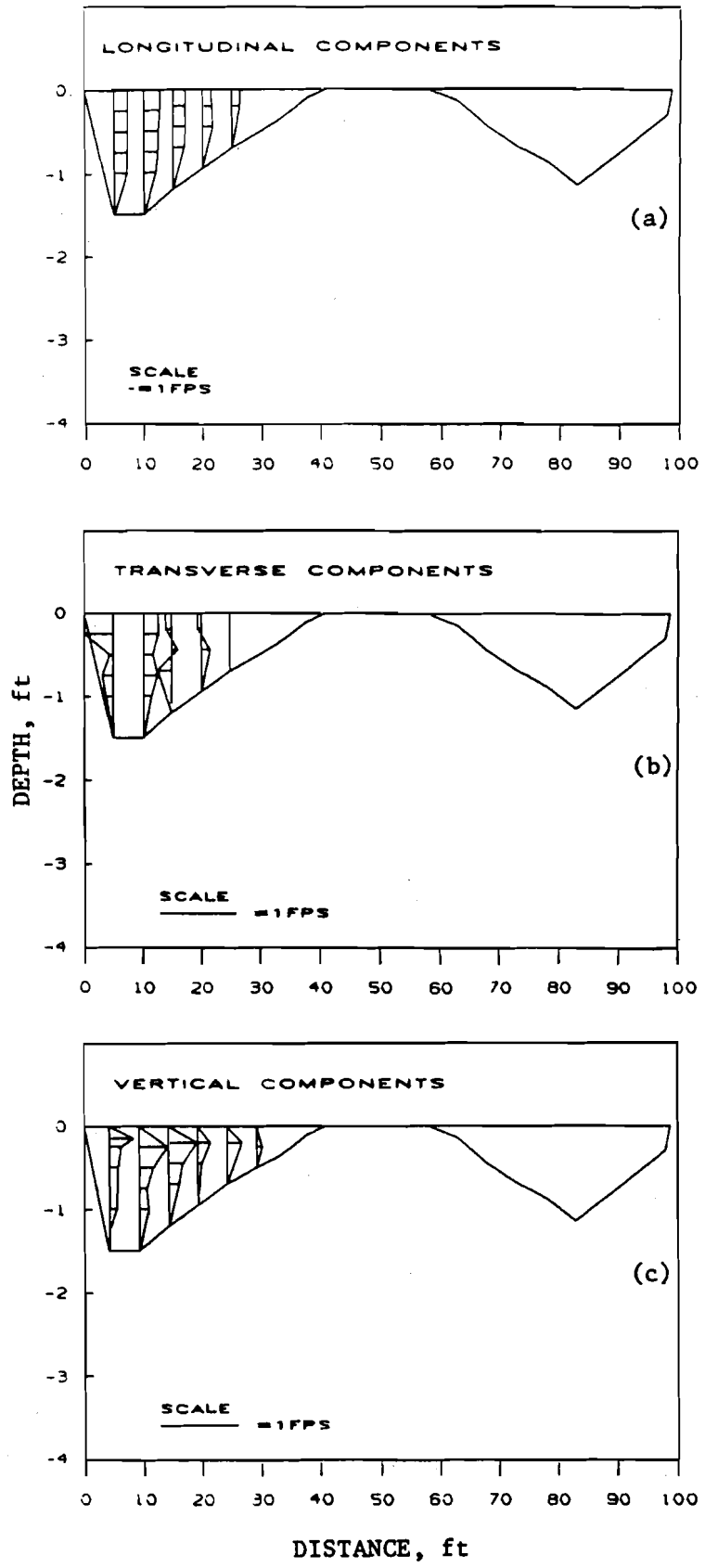


Figure B-16. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 2, July 12, 1984

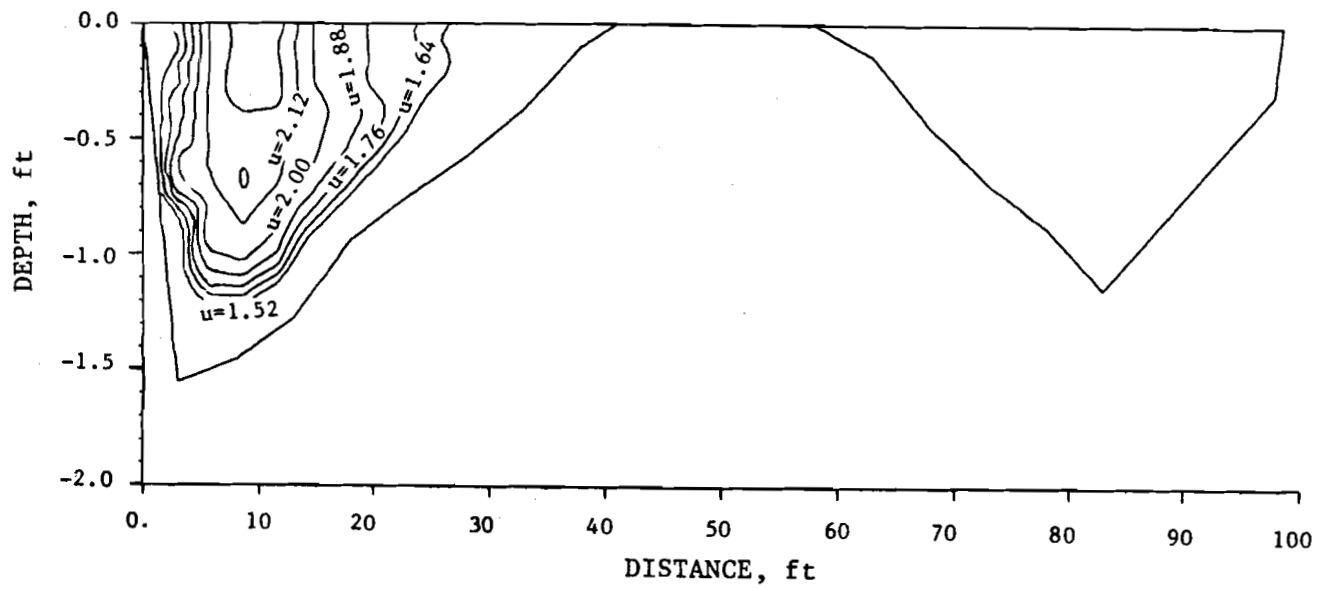


Figure B-17. Isovells of longitudinal velocity at cross section 2, July 12, 1984

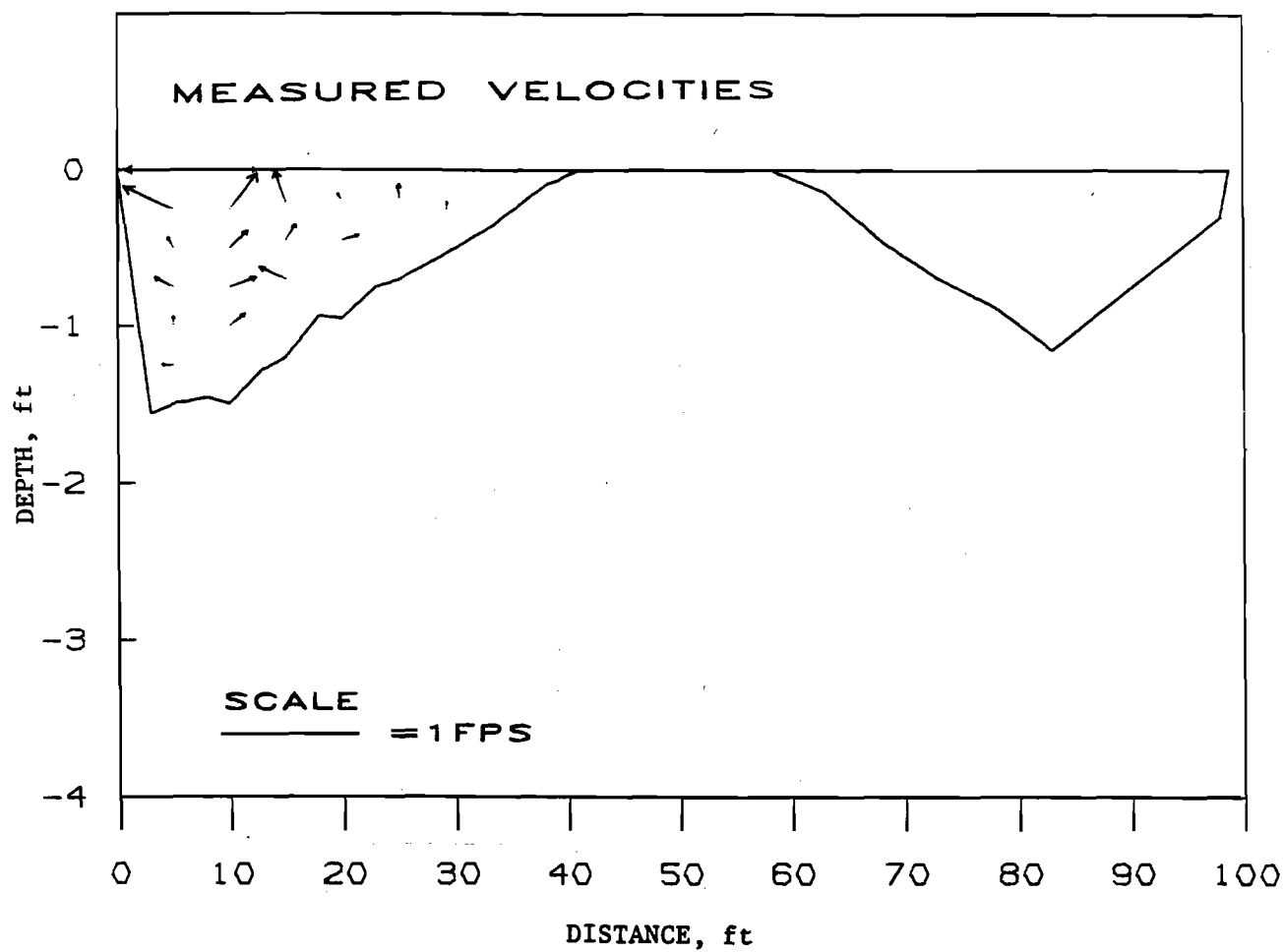


Figure B-18. Measured secondary current vectors at cross section 2, July 12, 1984



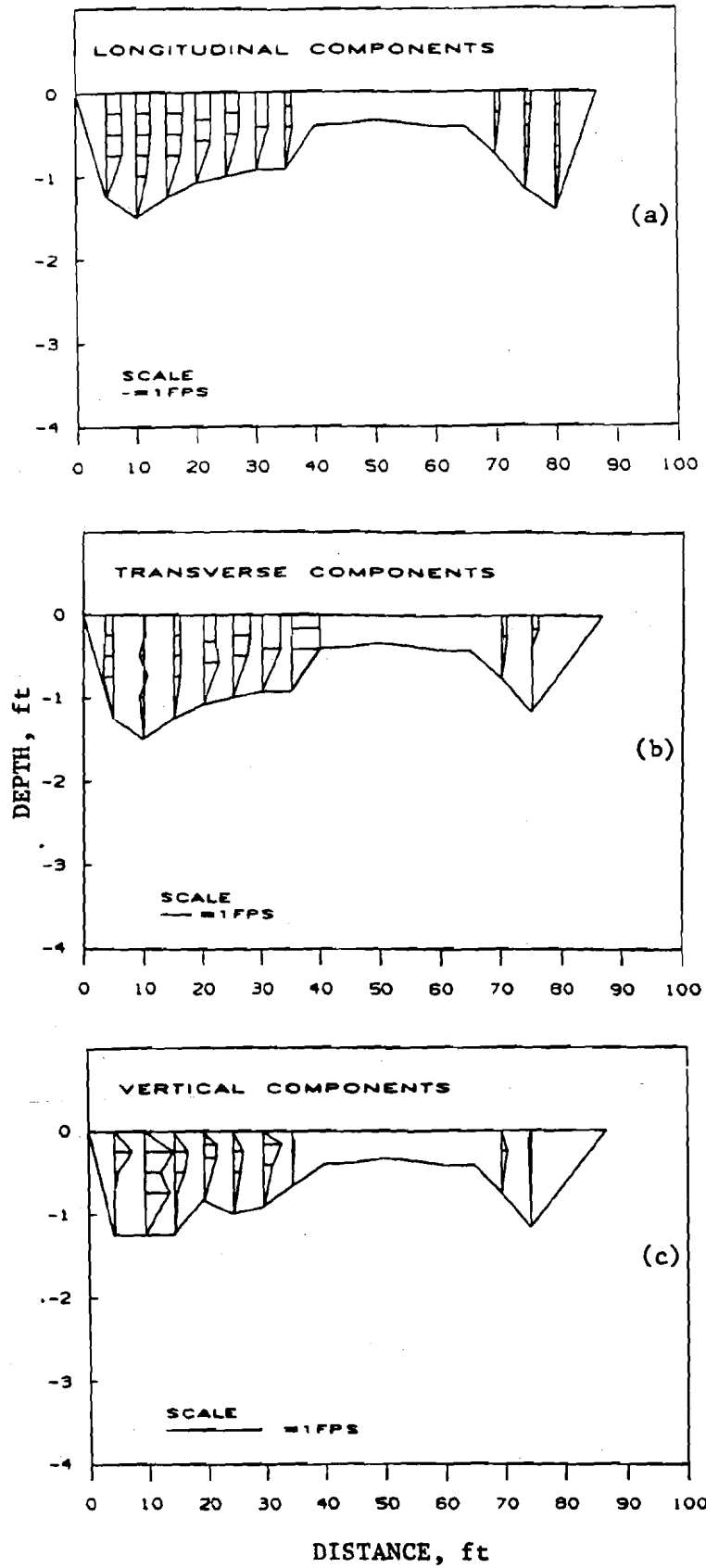


Figure B-19. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 1, July 13, 1984

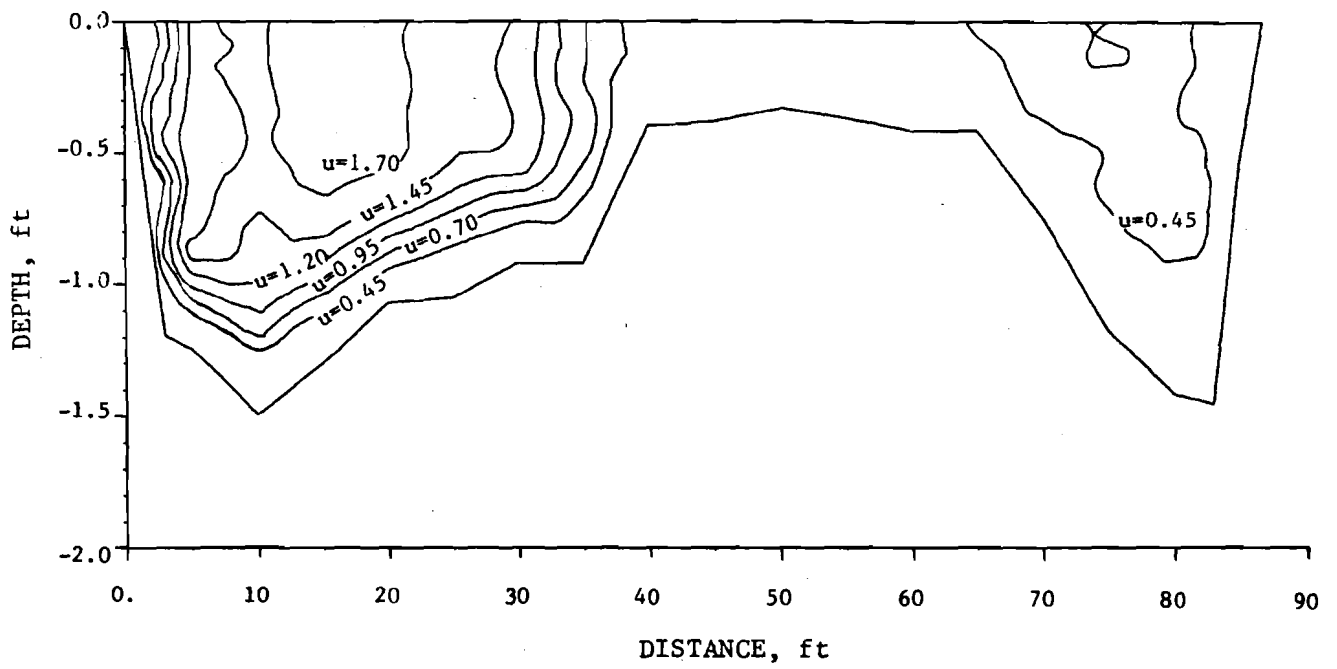


Figure B-20. Isovells of longitudinal velocity at cross section 1, July 13, 1984

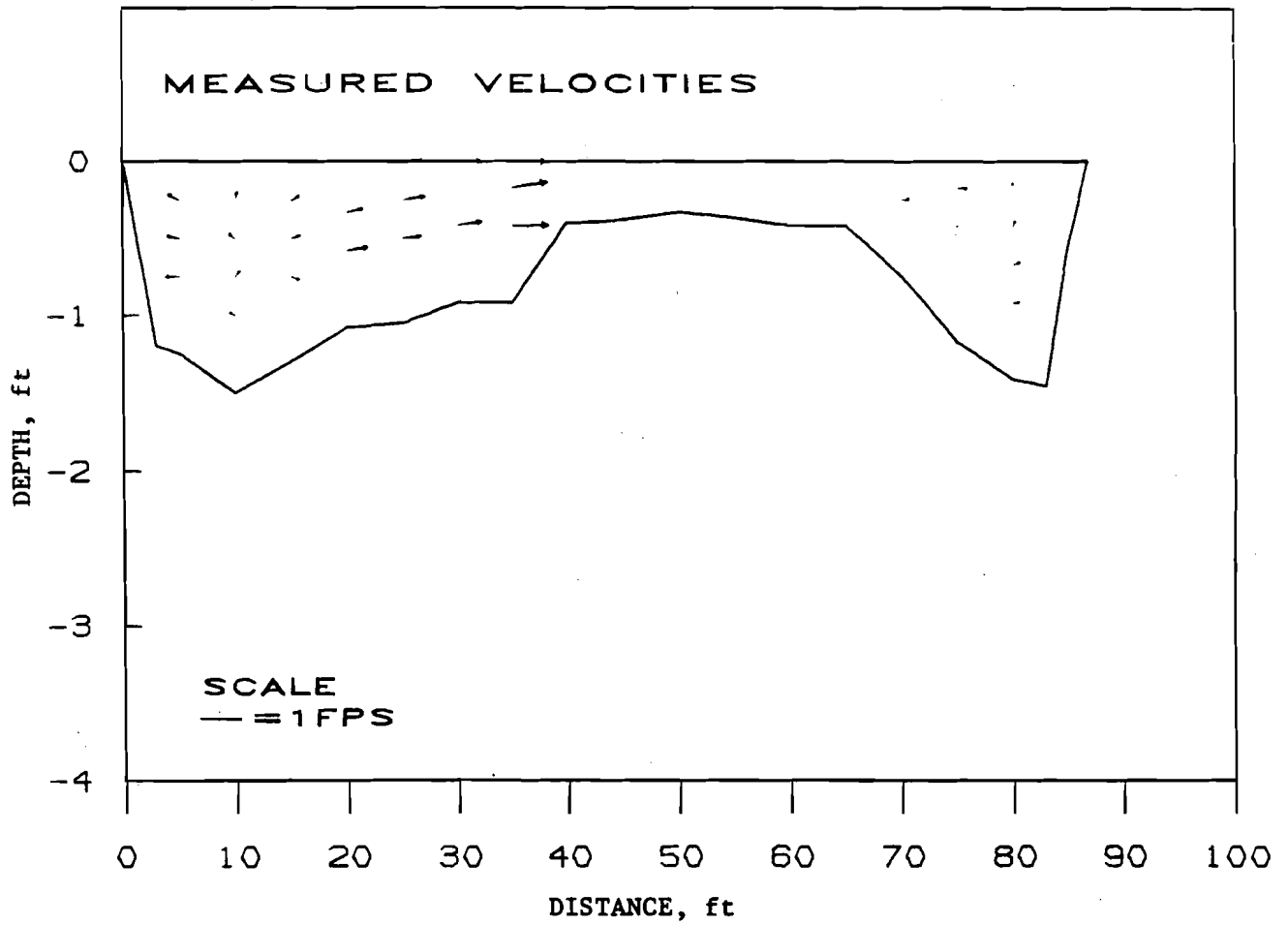


Figure B-21. Measured secondary current vectors at cross section 1, July 13, 1984

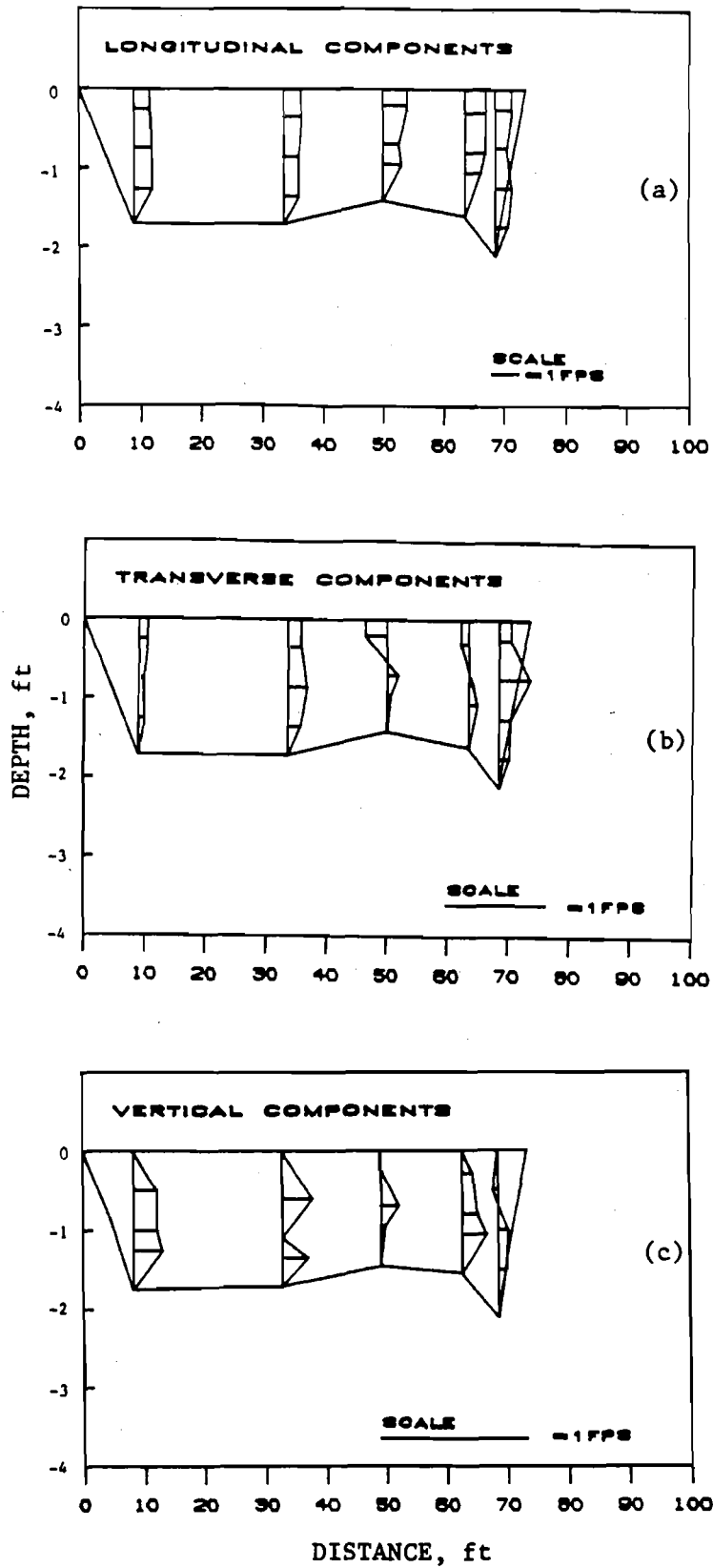


Figure B-22. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 5, August 5, 1985

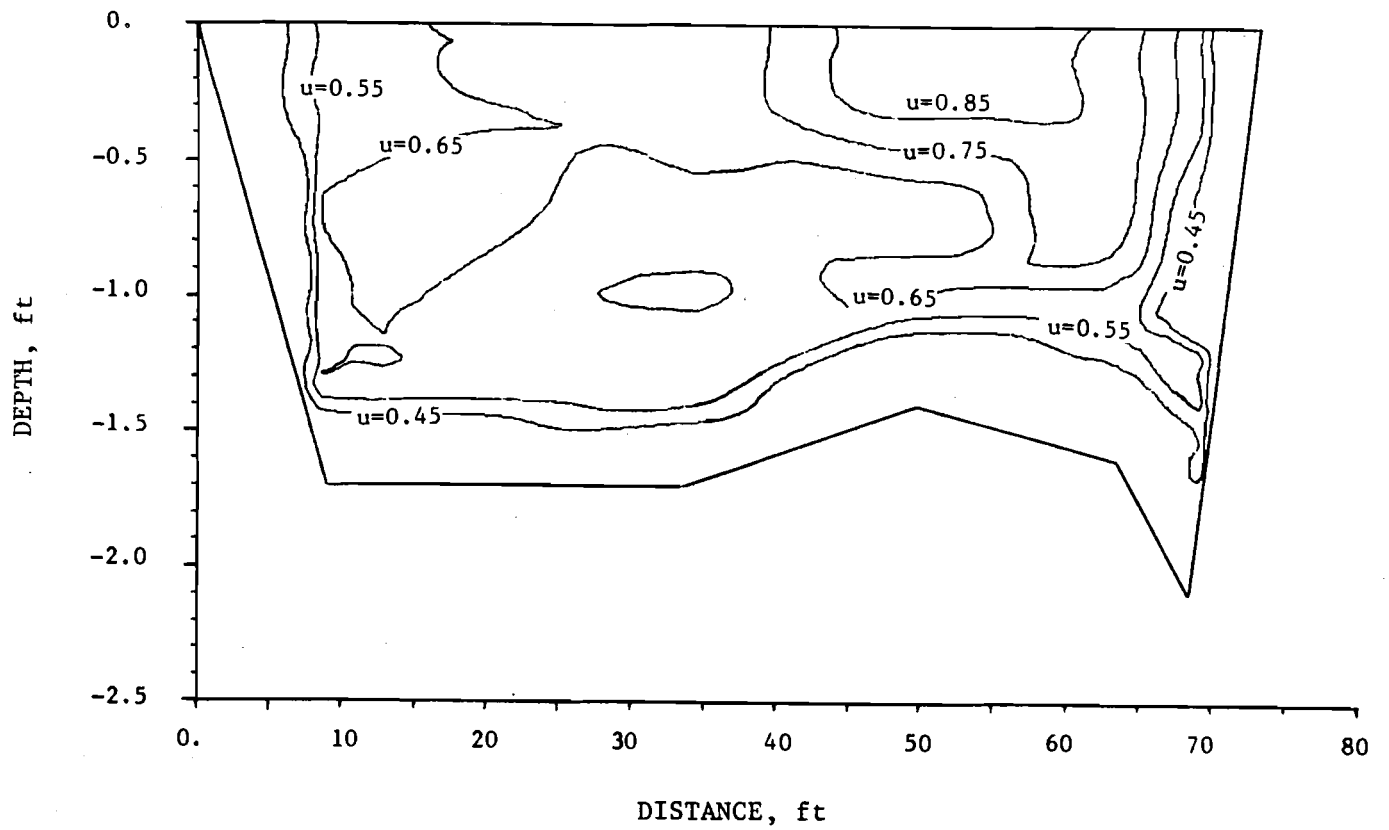


Figure B-23. Isovels of longitudinal velocity at cross section 5, August 5, 1985

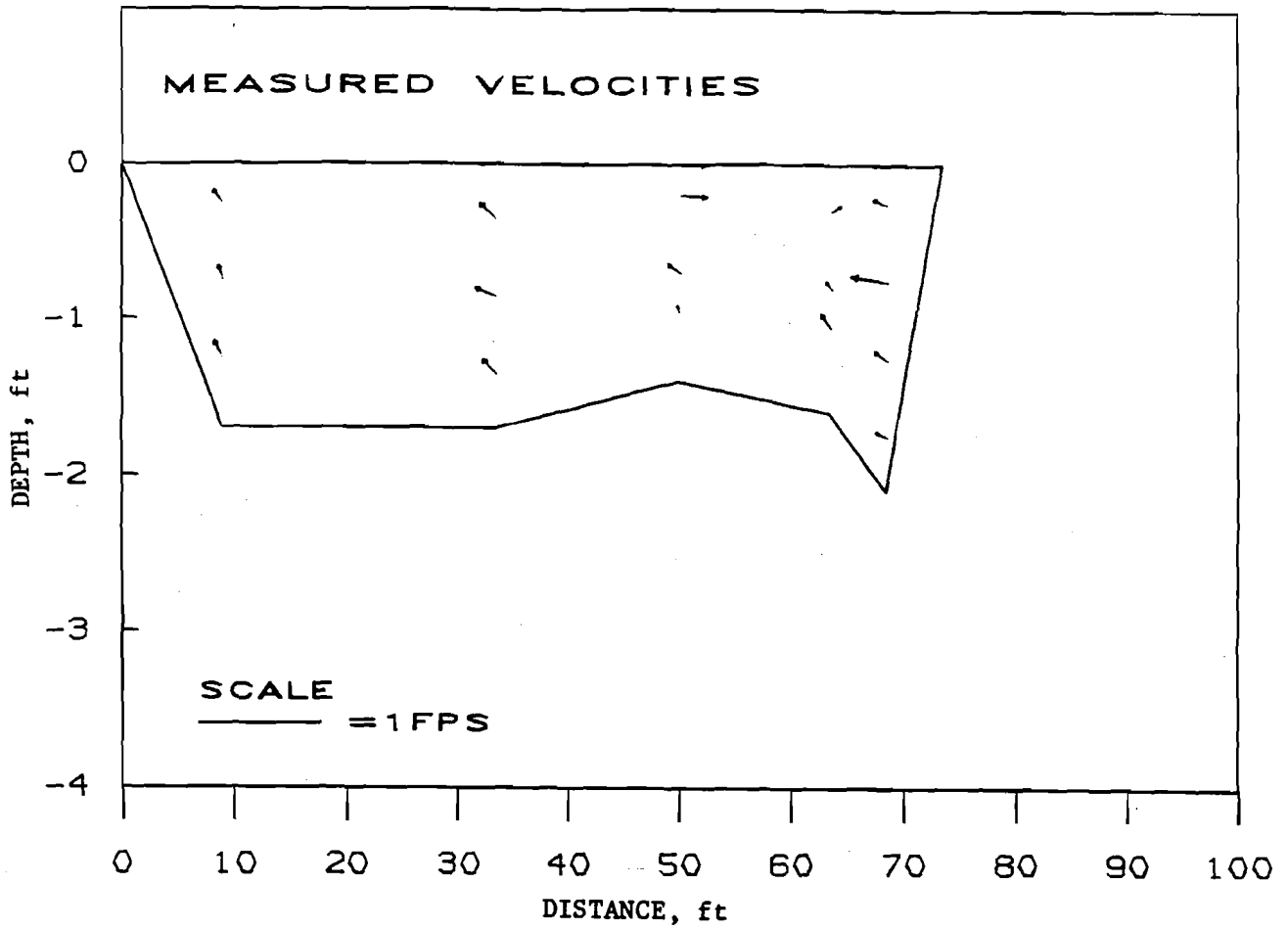


Figure B-24. Measured secondary current vectors at cross section 5, August 5, 1985

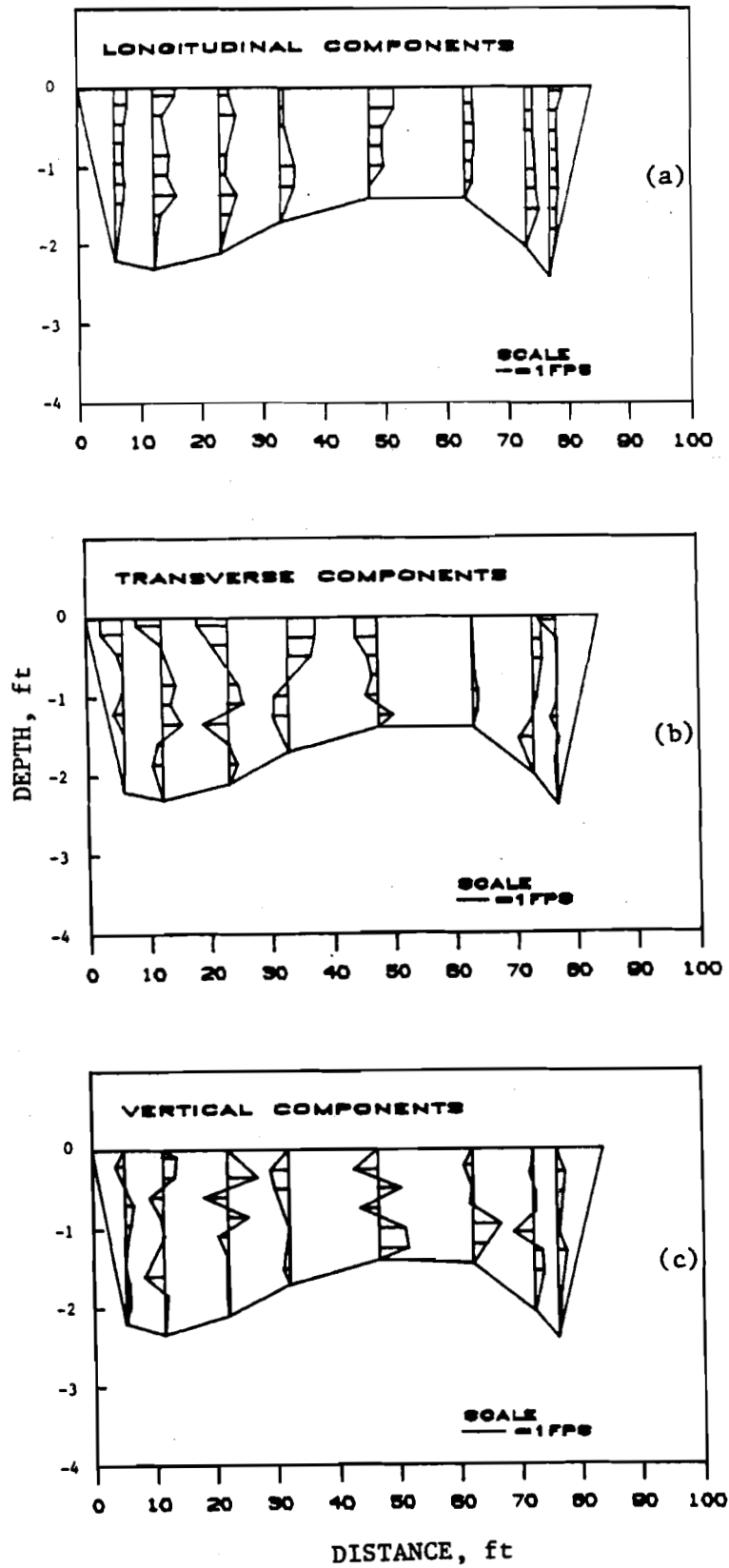


Figure B-25. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 6, August 6, 1985

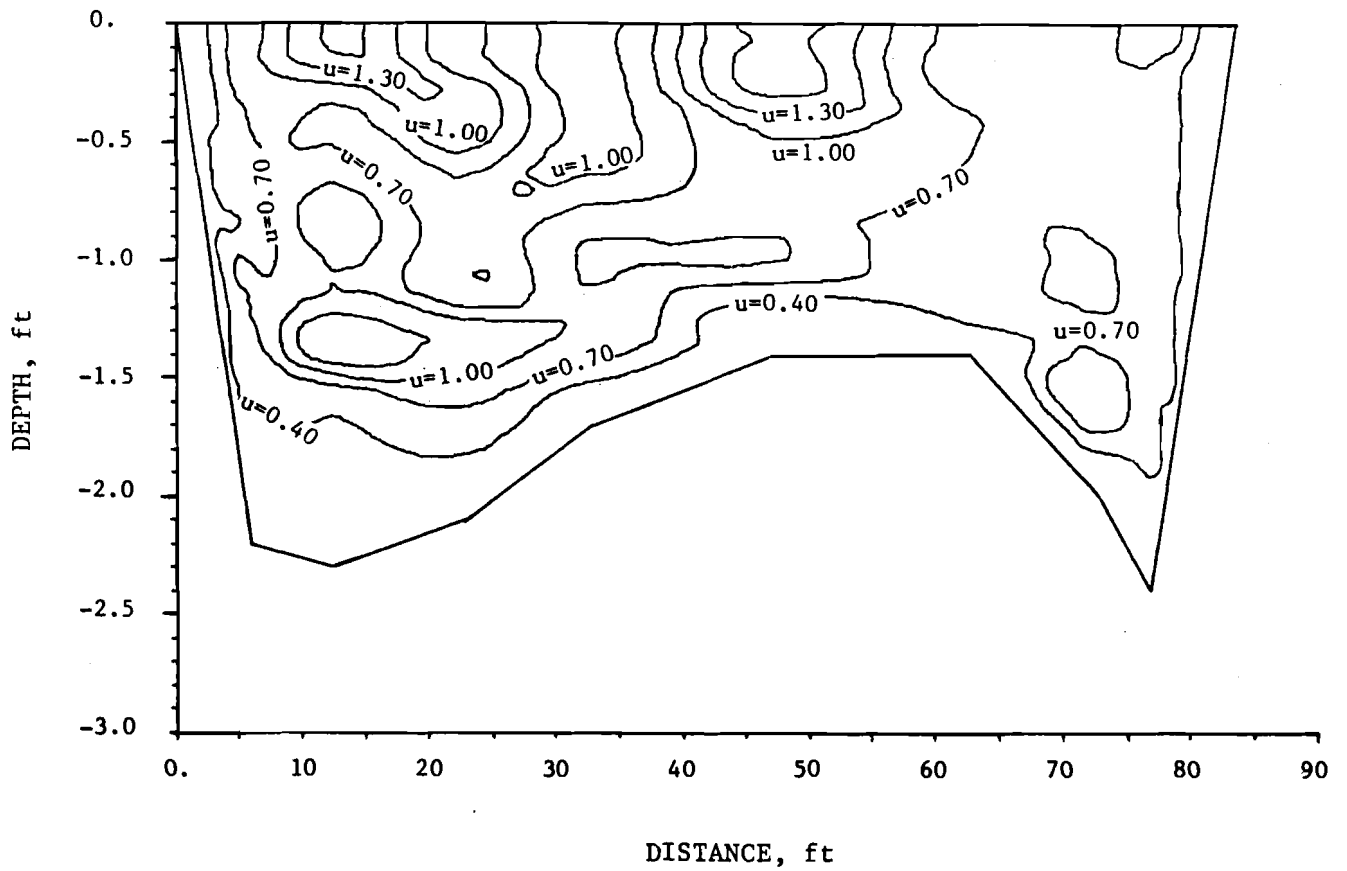


Figure B-26. Isovets of longitudinal velocity at cross section 6, August 6, 1985



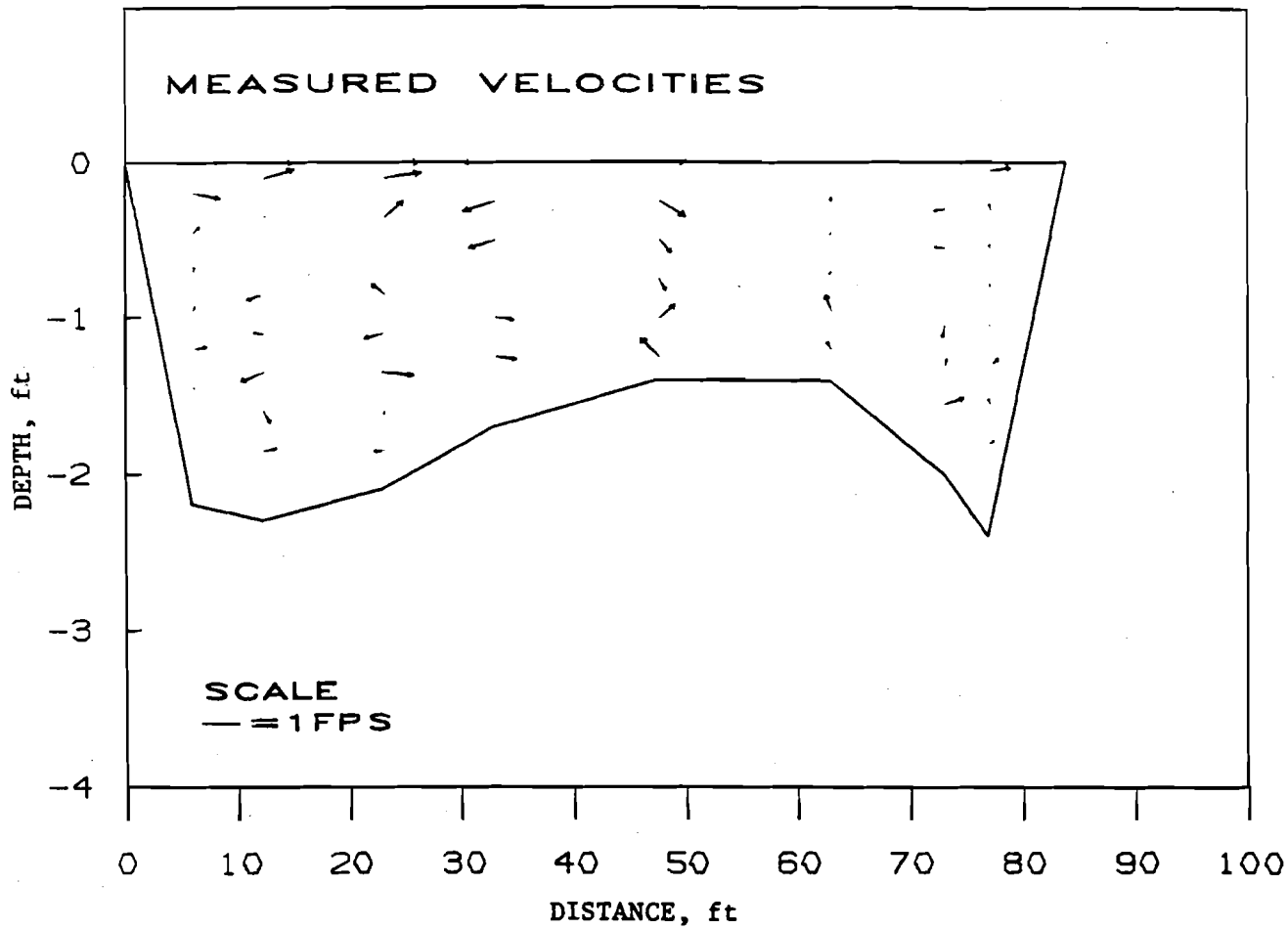


Figure B-27. Measured secondary current vectors at cross section 6, August 6, 1985

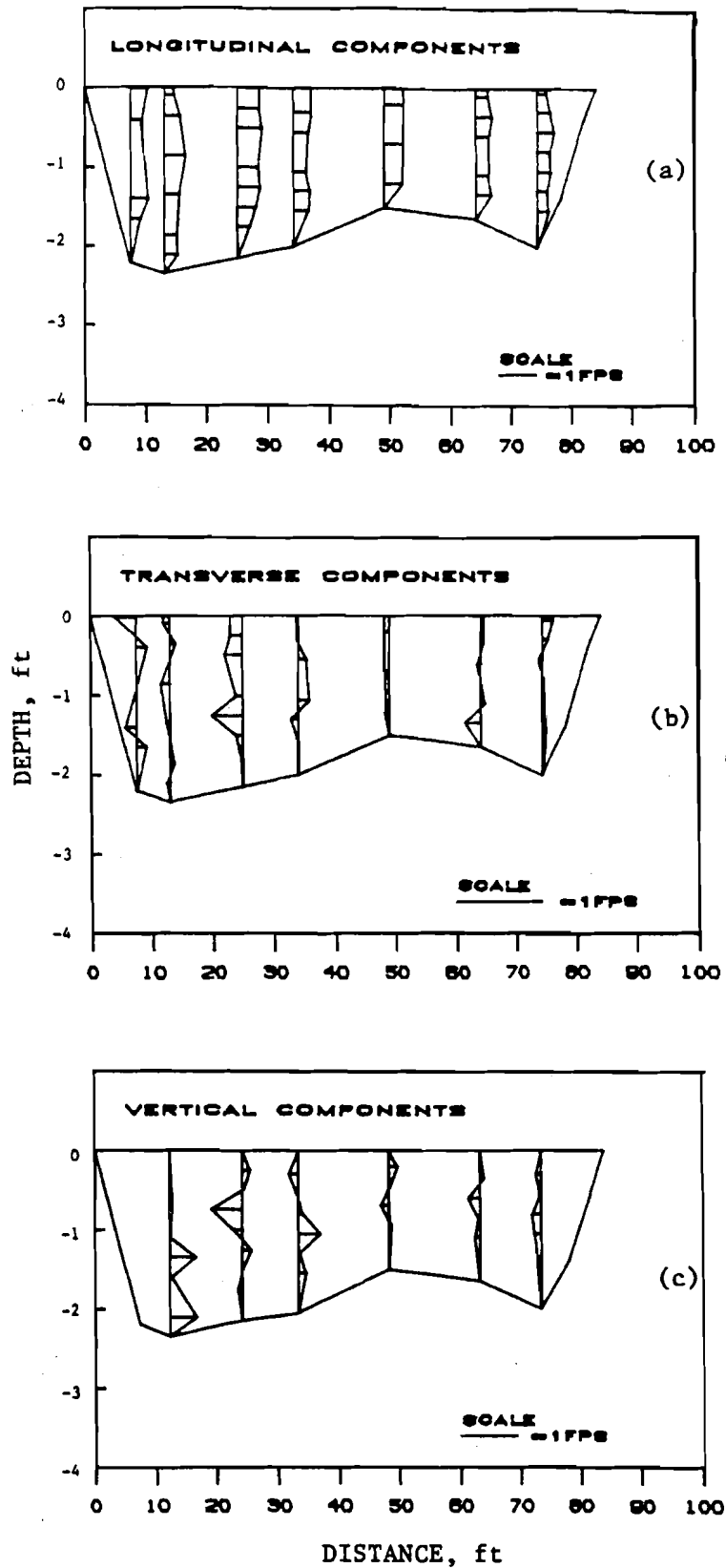


Figure B-28. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 7, August 7, 1985

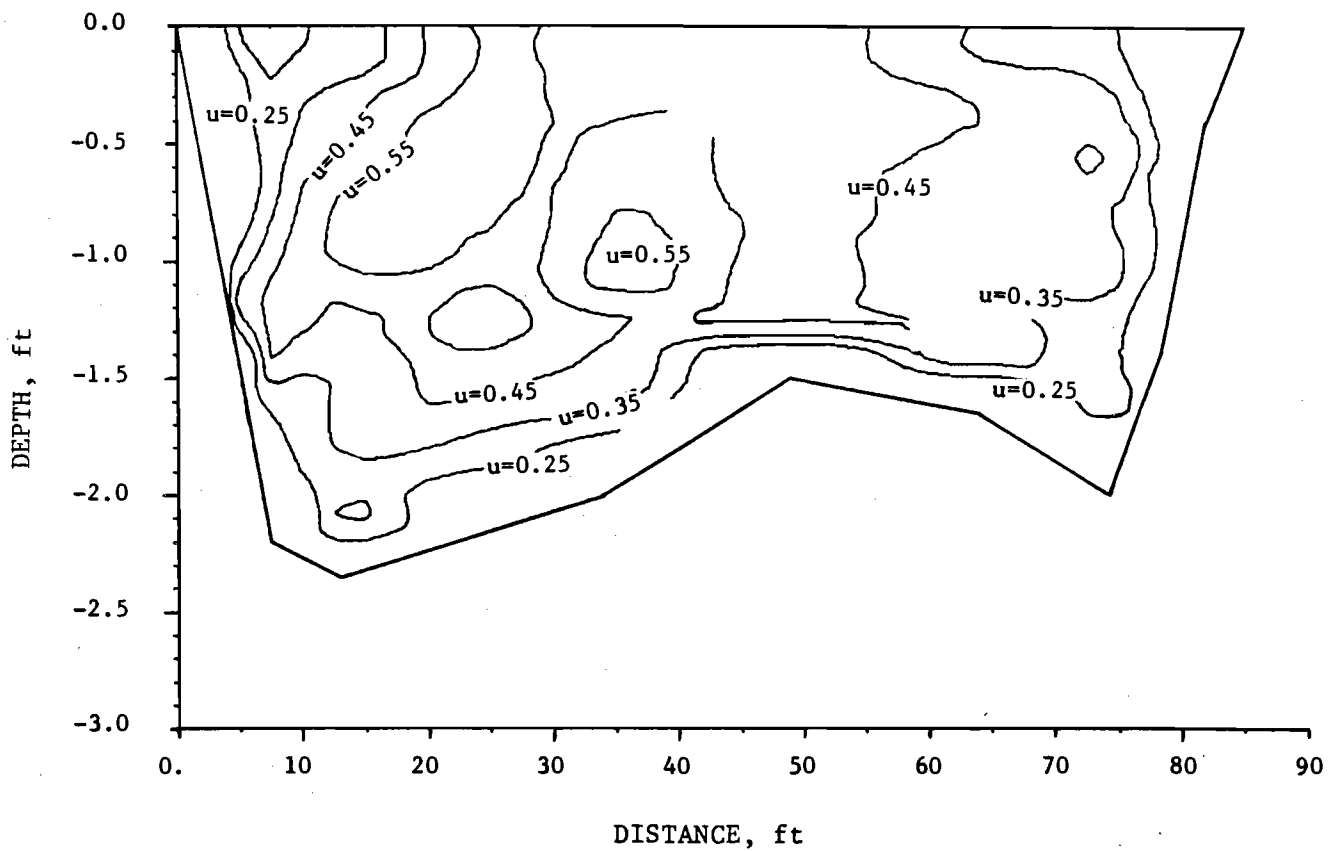


Figure B-29. Isovels of longitudinal velocity at cross section 7, August 7, 1985

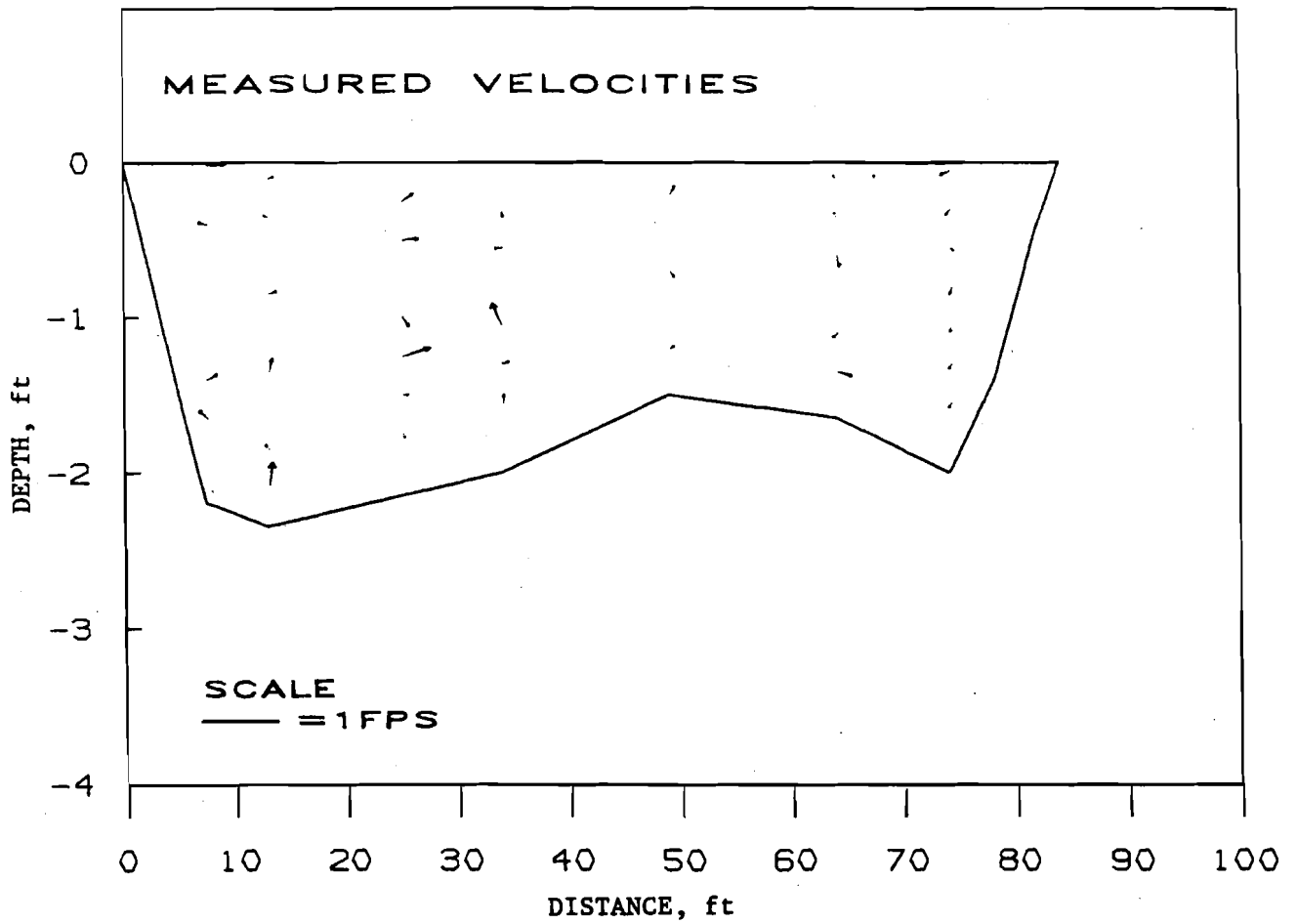


Figure B-30. Measured secondary current vectors at cross section 7, August 7, 1985

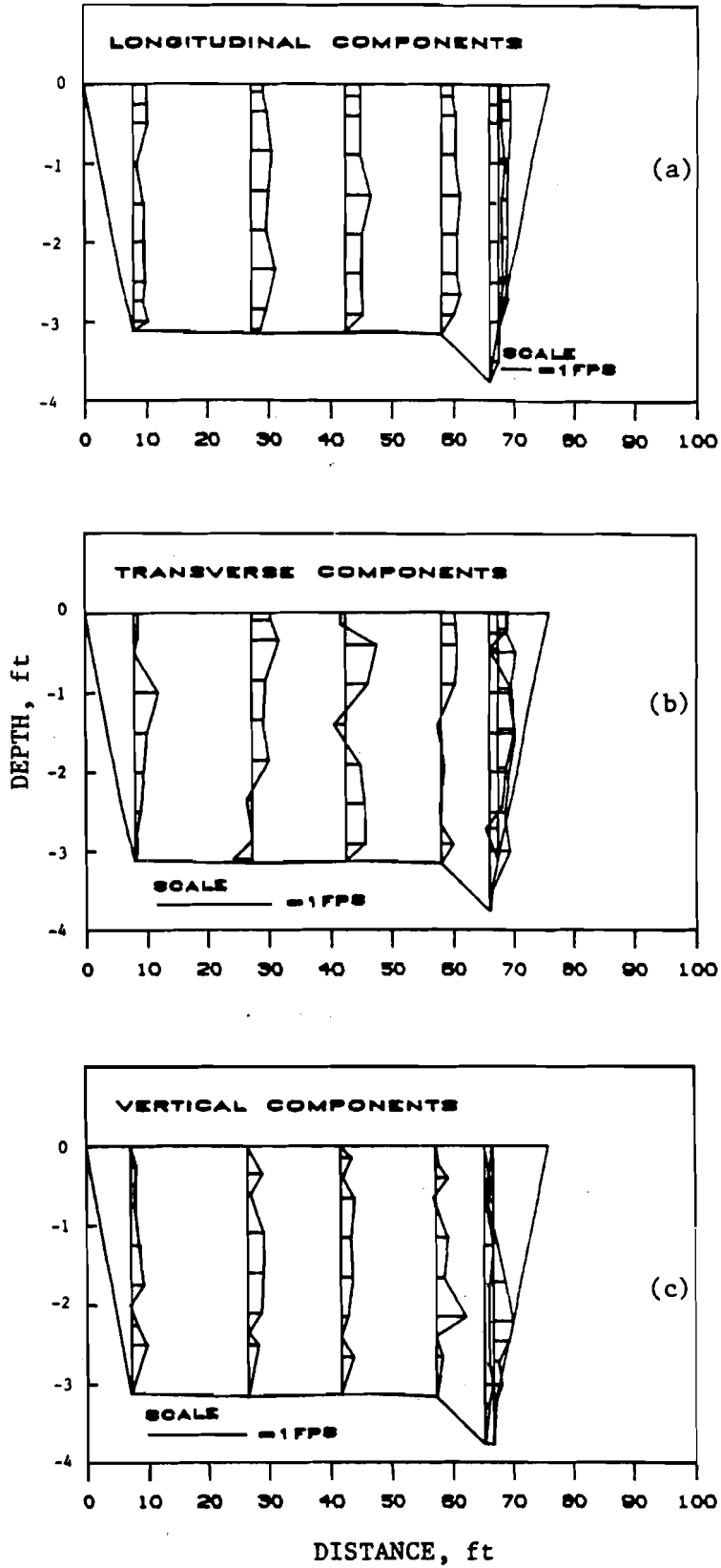


Figure B-31. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 8, August 8, 1985

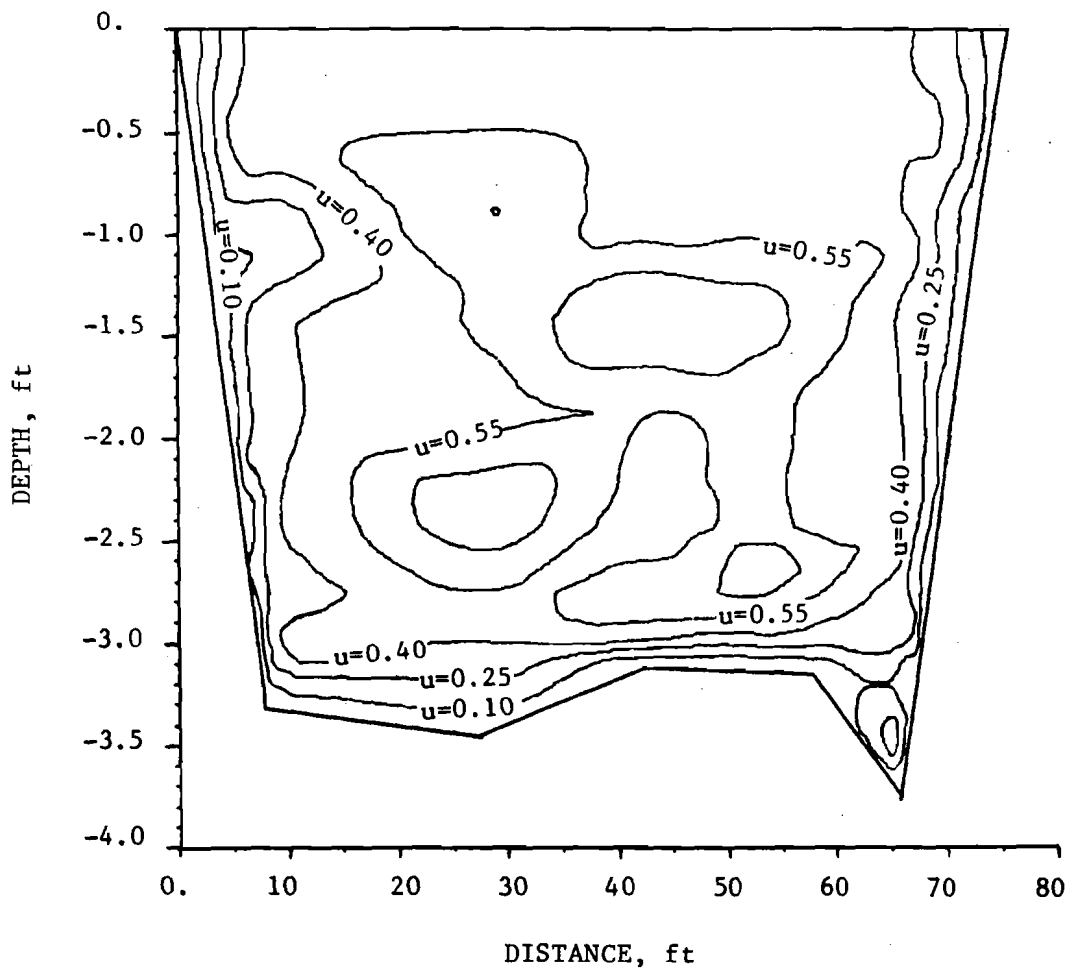


Figure B-32. Isovells of longitudinal velocity at cross section 8, August 8, 1985

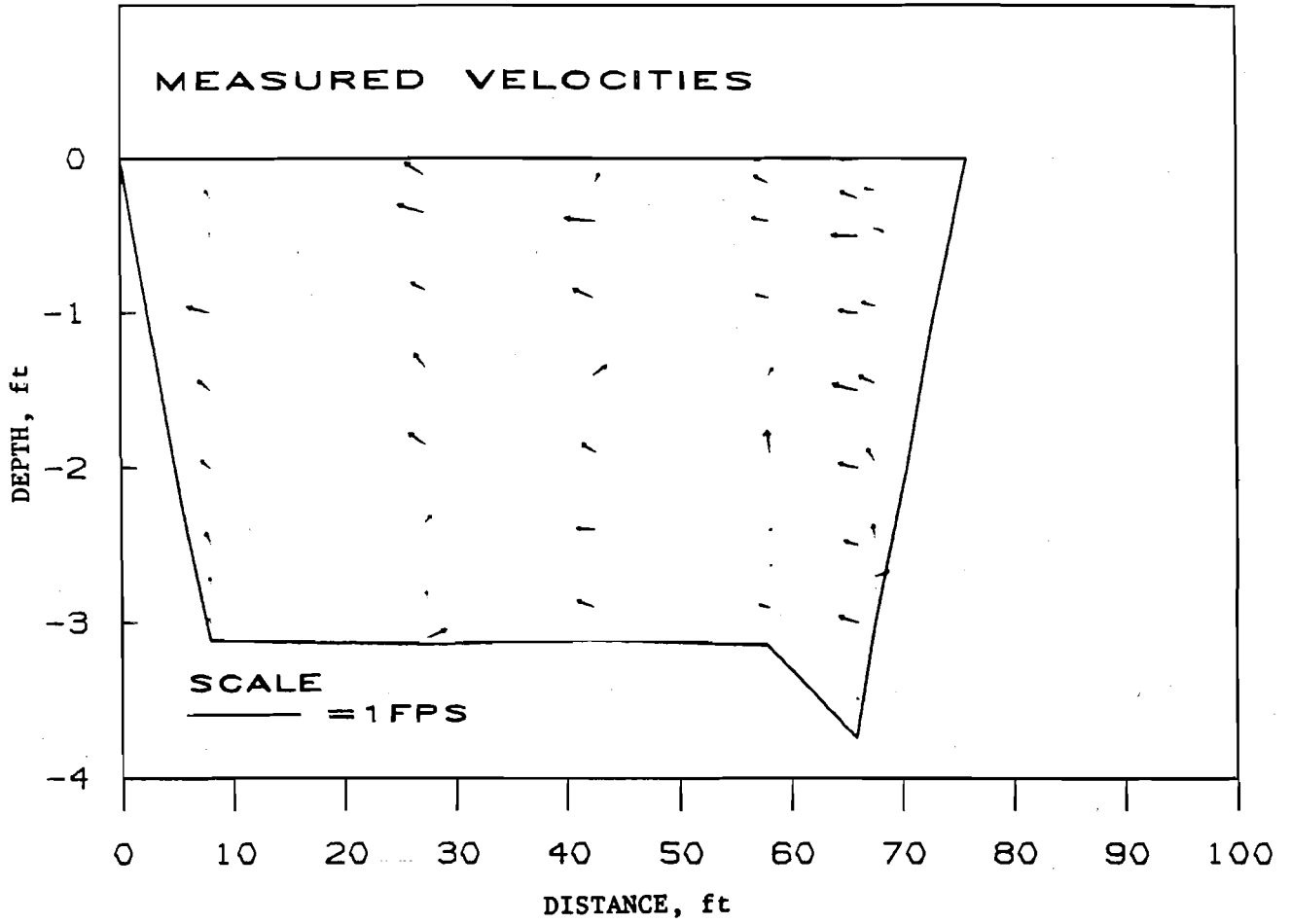


Figure B-33. Measured secondary current vectors at cross section 8, August 8, 1985

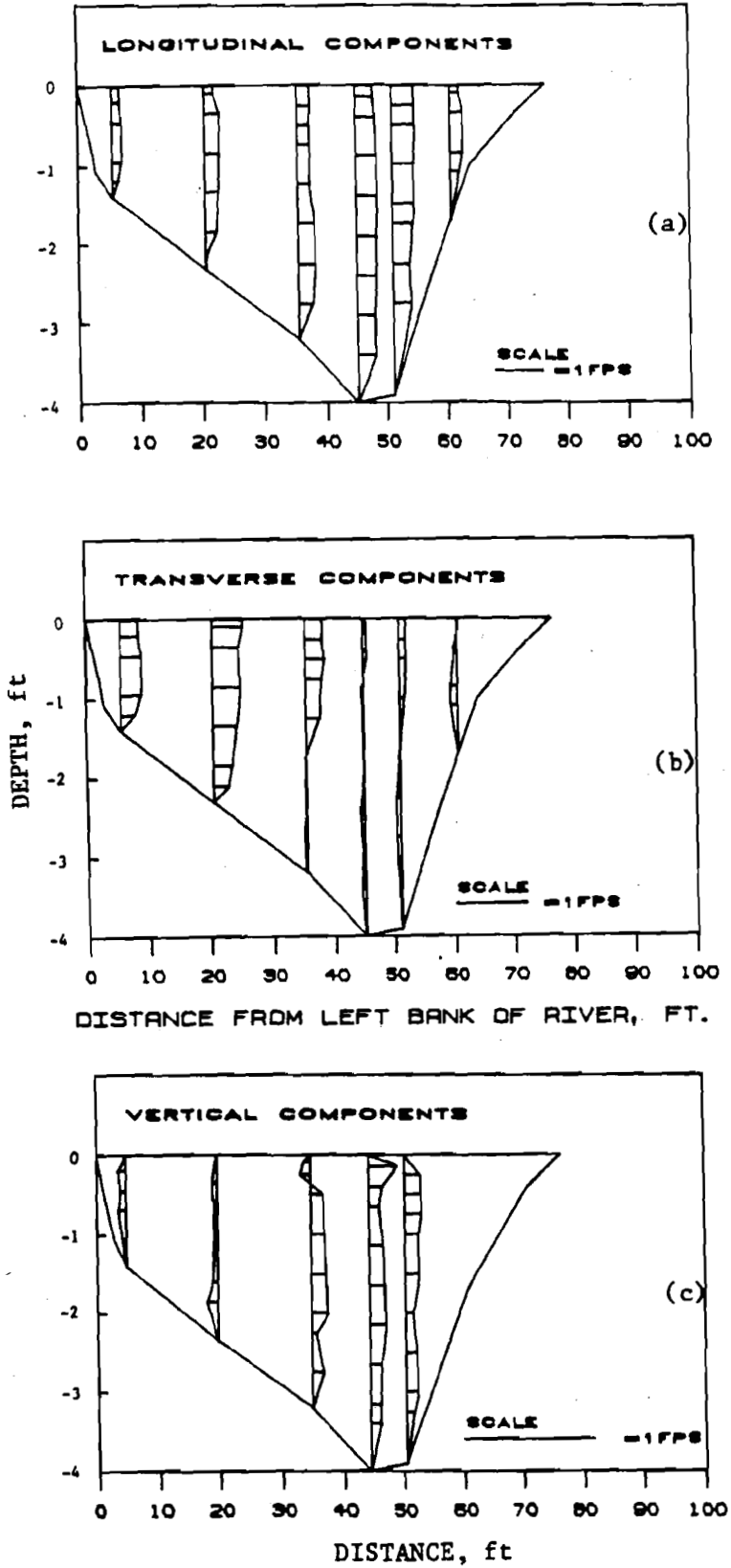


Figure B-34. Distribution of measured longitudinal, transverse and vertical components of velocity at cross section 9, August 9, 1985



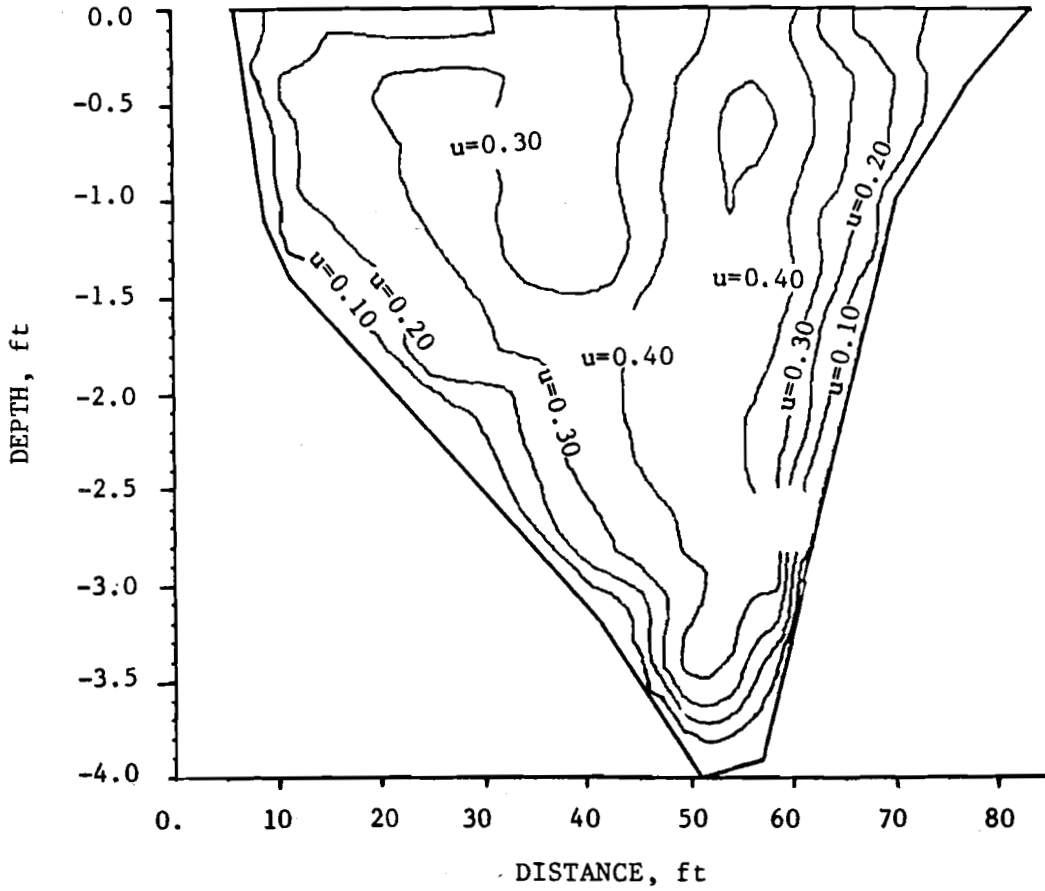


Figure B-35. Isovells of longitudinal velocity at cross section 9, August 9, 1985

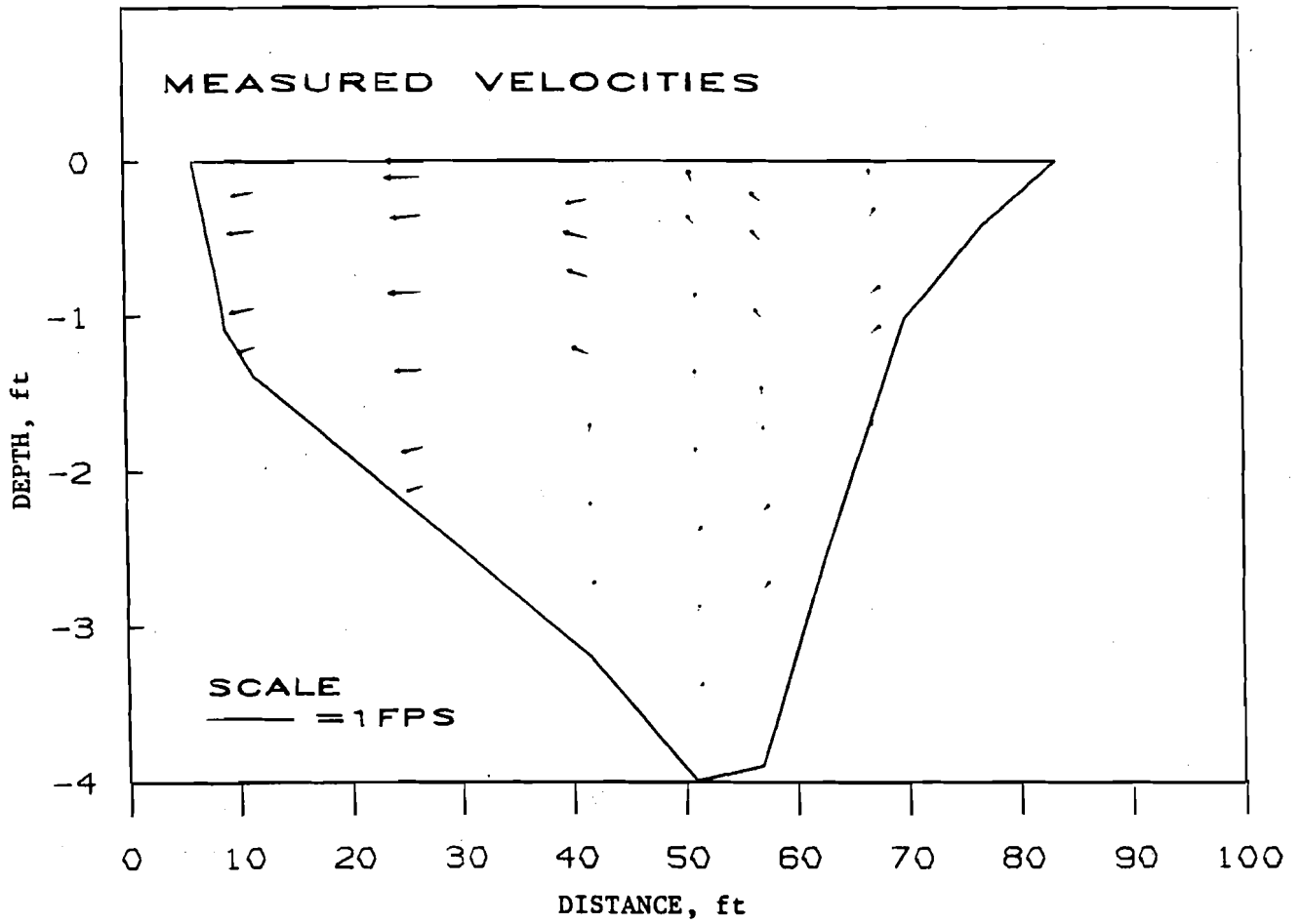


Figure B-36. Measured secondary current vectors at cross section 9, August 9, 1985

TABLE B-1 SANGAMON RIVER CROSS SECTION 7 JUNE 27 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
7.00	.50	.05	.61	8.25	.25	.21	.71
7.00	1.00	.03	.72	8.25	.75	.19	.68
7.00	1.50	.13	.68	10.95	.25	.10	.77
7.00	2.00	.01	.64	10.95	.75	.13	.71
9.70	1.00	-.06	.70	10.95	1.25	.12	.70
9.70	1.50	.01	.59	10.95	1.75	.17	.74
9.70	2.00	-.07	.54	25.75	.50	.22	.98
24.50	.25	.21	.90	25.75	1.00	.27	.97
24.50	.75	.04	.95	25.75	1.50	.13	.98
24.50	1.25	-.01	.94	25.75	2.00	.19	.85
24.50	1.75	.08	.96	35.75	.25	.22	.96
24.50	2.25	.09	.90	35.75	.75	.24	.98
34.50	.50	.12	.97	35.75	1.25	.20	.97
34.50	1.00	.00	.92	35.75	1.75	.25	.85
34.50	2.00	.06	.81	50.75	.58	.24	.90
49.50	.33	.02	.83	50.75	1.08	.24	.82
49.50	.83	.02	.82	50.75	1.58	.21	.78
49.50	1.33	-.04	.79	50.75	2.08	.15	.62
49.50	1.83	-.06	.74	65.75	.58	.27	.77
64.50	.33	-.19	.76	65.75	1.08	.23	.76
64.50	.83	-.02	.75	65.75	1.58	.21	.67
64.50	1.33	-.03	.74				
64.50	1.83	.09	.70				

TABLE B-2 SANGAMON RIVER CROSS SECTION 6 JUNE 28 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
8.00	.45	-.08	.53	8.75	.20	.05	.36
8.00	.95	-.08	.25	8.75	.70	.03	.24
8.00	1.45	-.06	.39	8.75	1.20	.03	.40
8.00	1.95	-.07	.42	8.75	1.70	.05	.37
8.00	2.45	-.08	.28	8.75	2.20	.02	.27
18.00	.25	-.09	.78	18.75	.50	.03	.89
18.00	.75	-.12	.83	18.75	1.00	.04	.85
18.00	1.25	-.12	.79	18.75	1.50	.01	.82
18.00	1.75	-.10	.76	18.75	2.00	.04	.71
18.00	2.25	-.16	.71	33.75	.35	.00	1.07
33.00	.60	-.51	.90	33.75	.85	.01	.99
33.50	1.10	.05	1.00	33.75	1.35	.07	.90
33.50	1.60	-.16	.96	48.75	.35	.03	.79
33.50	2.10	-.06	.97	48.75	.85	.04	.77
48.00	.60	-.19	.71	48.75	1.35	.04	.78
48.00	1.10	-.12	.79	48.75	1.85	.06	.70
48.00	1.60	-.10	.71	48.75	2.35	.08	.59
48.00	2.10	-.16	.68	58.75	.20	.05	.81
48.00	2.60	-.16	.57	58.75	.70	.05	.78
58.00	.45	-.24	.85	58.75	1.20	.08	.67
58.00	.95	-.23	.74	58.75	1.70	.06	.71
58.00	1.45	-.22	.70	58.75	2.20	.05	.65
58.00	1.95	-.18	.76	58.75	2.70	.08	.54
58.00	2.45	-.17	.63	66.25	.35	.06	.57
65.50	.60	-.17	.51	66.25	.85	.04	.59
65.50	1.10	-.14	.56	66.25	1.35	.05	.57
65.50	1.60	-.15	.50	66.25	1.85	.05	.57
65.50	2.10	-.18	.46	66.25	2.35	.07	.48
65.50	2.60	-.12	.49	66.25	2.85	.07	.42

TABLE B-3 SANGAMON RIVER CROSS SECTION 5 JUNE 29 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
7.80	.35	-.07	.32	8.55	.60	.09	.43
7.80	.85	.00	.48	8.55	1.10	.09	.45
7.80	1.35	.02	.47	8.55	1.60	.07	.41
17.80	.45	-.04	.62	8.55	2.10	.07	.34
17.80	.95	-.07	.58	18.55	.70	.13	.61
17.80	1.45	-.06	.59	18.55	1.20	.11	.62
17.80	1.95	-.03	.55	18.55	1.70	.11	.56
17.80	2.45	-.01	.51	18.55	2.20	.09	.51
27.80	.50	-.03	.86	28.55	.25	.18	.84
27.80	1.00	-.02	.78	28.55	.75	.12	.76
27.80	1.50	-.03	.75	28.55	1.25	.11	.73
27.80	2.00	.02	.77	28.55	1.75	.11	.64
27.80	2.50	-.02	.65	28.55	2.25	.11	.65
37.80	.20	-.10	.67	38.55	.45	.19	.77
37.80	.70	-.11	.68	38.55	.95	.12	.70
37.80	1.20	-.14	.65	38.55	1.45	.10	.66
37.80	1.70	-.12	.60	38.55	1.95	.11	.60
37.80	2.20	-.12	.62	38.55	2.45	.09	.57
37.80	2.70	-.01	.60	48.55	.50	.16	.68
47.80	.25	-.06	.66	48.55	1.00	.14	.69
47.80	.75	.02	.74	48.55	1.50	.11	.61
47.80	1.25	-.14	.62	48.55	2.00	.15	.63
47.80	1.75	-.10	.64	48.55	2.50	.07	.60
47.80	2.25	-.13	.61	58.55	.50	.15	.60
47.80	2.75	-.18	.50	58.55	1.00	.13	.58
57.80	.75	-.17	.53	58.55	1.50	.11	.54
57.80	1.25	-.12	.53	58.55	2.00	.07	.49
57.80	1.75	-.11	.52	58.55	2.50	.10	.50
57.80	2.25	-.11	.51	66.55	.58	.12	.45
57.80	2.75	-.10	.44	66.55	1.08	.11	.44
65.80	.33	-.12	.43	66.55	1.58	.12	.45
65.80	.83	-.07	.39	66.55	2.08	.06	.35
65.80	1.33	-.08	.44	66.55	2.58	.02	.37
65.80	1.83	-.04	.40	66.55			
65.80	2.83	-.01	.32			.07	.30

TABLE B-4 SANGAMON RIVER CROSS SECTION 3 JULY 9 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
5.50	.25	.06	.41	6.25	.25	.15	.37
5.50	.75	.06	.35	6.25	.50	.15	.40
5.50	1.00	.04	.35	6.25	.75	.27	.53
5.50	1.25	.09	.34	6.25	1.00	.17	.37
15.50	.40	.04	.46	6.25	1.25	.16	.36
15.50	.65	.07	.44	16.25	.05	.15	.49
15.50	.90	.03	.45	16.25	.25	.15	.51
15.50	.33	.01	.51	16.25	.50	.15	.50
25.50	.58	.00	.47	16.25	.75	.16	.51
25.50	.83	.02	.47	26.25	.08	.15	.57
25.50	1.33	.03	.47	26.25	.58	.16	.50
25.50	1.58	.05	.52	26.25	.83	.17	.50
35.50	.25	.07	.52	26.25	1.08	.17	.52
35.50	.50	.07	.47	26.25	1.28	.12	.43
35.50	.75	.07	.50	26.25	1.53	.16	.45
35.50	1.00	.15	.46	36.25	.25	.14	.53
35.50	1.25	.09	.47	36.25	.50	.13	.51
45.50	.40	.09	.52	36.25	.75	.14	.50
45.50	.65	.06	.47	36.25	1.00	.15	.50
45.50	.90	.08	.46	36.25	1.25	.15	.46
55.50	.25	.08	.48	36.25	1.50	.14	.42
55.50	.50	.07	.45	46.25	.15	.16	.50
55.50	.75	.13	.44	46.25	.40	.18	.52
55.50	.25	.08	.35	46.25	.65	.18	.50
65.50	.50	.08	.43	46.25	.90	.16	.46
65.50	.75	.08	.42	56.25	.25	.17	.47
65.50	1.00	.08	.43	56.25	.50	.10	.43
65.50	1.25	.09	.40	56.25	.75	.18	.44
65.50	1.50	.11	.35	56.25	1.00	.16	.40
72.00	.33	.03	.40	66.25	.25	.18	.46
72.00	.58	.04	.39	66.25	.50	.18	.45
72.00	.83	.05	.37	66.25	.75	.18	.45
72.00	1.08	.06	.39	66.25	1.00	.17	.45
72.00	1.33	.12	.35	66.25	1.25	.17	.39
				72.75	.33	.17	.43
				72.75	.58	.17	.41
				72.75	.83	.17	.42
				72.75	1.08	.18	.40
				72.75	1.33	.15	.40
				72.75	1.58	.13	.28

TABLE B-5 SANGAMON RIVER CROSS SECTION 4 JULY 10 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
6.50	.25	.05	.24	7.25	.25	.15	.20
6.50	.50	.06	.25	7.25	.50	.14	.26
6.50	.75	.07	.24	7.25	.75	.14	.20
6.50	1.00	.06	.23	7.25	1.00	.14	.24
6.50	1.25	.11	.24	7.25	1.25	.16	.22
6.50	1.50	.10	.20	7.25	1.50	.16	.19
17.50	.40	.03	.37	18.25	.15	.14	.38
17.50	.65	.03	.34	18.25	.40	.16	.36
17.50	.90	.03	.36	18.25	.65	.17	.22
17.50	1.15	.09	.34	18.25	.90	.15	.35
17.50	1.40	.05	.36	18.25	1.15	.16	.36
17.50	1.65	.11	.36	18.25	1.40	.16	.32
17.50	1.90	.13	.35	18.25	1.65	.12	.27
27.50	.25	.08	.42	18.25	1.90	.17	.26
27.50	.50	.04	.42	28.25	.25	.16	.44
27.50	.75	.05	.41	28.25	.50	.16	.43
27.50	1.00	.04	.41	28.25	.75	.17	.43
27.50	1.25	.12	.40	28.25	1.00	.15	.42
27.50	1.50	.04	.39	28.25	1.25	.16	.40
27.50	1.75	.08	.39	28.25	1.50	.17	.39
27.50	2.00	.04	.37	28.25	1.75	.16	.35
37.50	.25	.04	.35	28.25	2.00	.14	.30
37.50	.50	.01	.39	38.25	.25	.14	.41
37.50	.75	.02	.37	38.25	.50	.14	.40
37.50	1.00	.02	.38	38.25	.75	.15	.41
37.50	1.25	.07	.38	38.25	1.00	.16	.39
37.50	1.50	.06	.37	38.25	1.25	.15	.38
37.50	1.75	.09	.37	38.25	1.50	.16	.40
37.50	2.00	.06	.36	38.25	1.75	.16	.38
47.50	.20	.11	.35	38.25	2.00	.16	.35
47.50	.45	.09	.36	38.25	2.25	.17	.28
47.50	.70	.02	.38	48.25	.25	.20	.47
47.50	.95	.03	.40	48.25	.50	.17	.42
47.50	1.20	.05	.38	48.25	.75	.17	.39
47.50	1.45	.07	.38	48.25	1.00	.16	.40
47.50	1.70	.03	.41	48.25	1.25	.18	.41
47.50	1.95	.05	.41	48.25	1.50	.16	.40
47.50	2.20	.07	.36	48.25	1.75	.15	.37
57.50	.25	.04	.41	48.25	2.00	.17	.35
57.50	.50	.06	.36	48.25	2.25	.15	.29
57.50	.75	.04	.32	58.25	.25	.17	.35
57.50	1.00	.04	.35	58.25	.50	.19	.39
57.50	1.25	.05	.38	58.25	.75	.17	.37
57.50	1.50	.08	.36	58.25	1.00	.17	.33
57.50	1.75	.10	.33	58.25	1.25	.16	.38
57.50	2.00	.10	.30	58.25	1.50	.16	.35
57.50	2.25	.06	.34	58.25	1.75	.16	.34

TABLE B-5 SANGAMON RIVER CROSS SECTION 4 JULY 10 1984 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	V (FPS)	U (FPS)	DISTANCE (FT)	DEPTH (FT)	W (FPS)	U (FPS)
57.50	2.25	.10	.32	58.25	2.00	.14	.32
64.50	.33	.05	.31	58.25	2.25	.16	.27
64.50	.58	.03	.29	65.25	.33	.16	.29
64.50	.83	.04	.32	65.25	.58	.14	.25
64.50	1.08	.06	.26	65.25	.83	.17	.27
64.50	1.33	.09	.27	65.25	1.08	.17	.27
64.50	1.58	.07	.28	65.25	1.33	.16	.30
64.50	1.83	.06	.28	65.25	1.58	.15	.22
64.50	2.08	.08	.29	65.25	1.83	.17	.23
				65.25	2.08	.18	.24
				65.25	2.33	.17	.22



TABLE B-6 SANGAMON RIVER CROSS SECTION 2 JULY 12 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
2.00	0.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
7.00	.25	2.176	.040	-.374	.047	( - )	0.000	87.529	.000
7.00	.50	2.218	.025	-.044	.033	( - )	0.000	74.824	.000
7.00	.75	2.139	.068	-.141	.051	( - )	0.000	77.647	.000
7.00	1.00	2.054	.054	-.093	.026	( - )	0.000	76.235	0.000
7.00	1.50	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
12.00	.25	2.598	.105	.206	.124	( - )	0.000	77.647	.000
12.00	.50	2.316	.081	.130	.087	( - )	0.000	81.882	.000
12.00	.75	2.296	.055	.194	.064	( - )	0.000	80.471	.000
12.00	1.00	2.004	.046	.113	.034	( - )	0.000	80.471	.000
12.00	1.50	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
17.00	.20	1.979	.063	-.078	.121	( - )	0.000	84.706	.000
17.00	.45	2.046	.061	.071	.063	( - )	0.000	80.471	.000
17.00	.70	1.839	.114	-.192	.148	( - )	0.000	86.118	.000
17.00	1.20	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
22.00	.20	1.548	.059	-.037	.104	( - )	0.000	81.882	.000
22.00	.45	1.677	.059	.119	.036	( - )	0.000	81.882	.000
22.00	.95	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
27.00	.20	1.350	.104	-.003	.106	( - )	0.000	86.118	.000
27.00	.70	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
2.00	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
4.25	0.00	2.296	.150	( - )	0.000	.311	.109	76.235	0.000
4.25	.25	2.246	.047	( - )	0.000	.151	.026	76.299	.301
4.25	.50	2.163	.021	( - )	0.000	.111	.016	74.824	.000
4.25	1.00	2.050	.043	( - )	0.000	.098	.082	74.885	.294
4.25	1.25	1.711	.036	( - )	0.000	.007	.014	74.824	.000
4.25	1.75	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000

TABLE B-6 SANGAMON RIVER CROSS SECTION 2 JULY 12 1984 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
9.25	.25	2.676	.036	( - )	0.000	.371	.055	79.059	.000
9.25	.50	2.615	.036	( - )	0.000	.180	.044	79.059	.000
9.25	.75	2.364	.084	( - )	0.000	.098	.131	79.059	.000
9.25	1.00	2.004	.059	( - )	0.000	.124	.089	79.059	.000
9.25	1.50	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
14.25	.20	2.483	.052	( - )	0.000	.372	.063	83.294	.000
14.25	.45	2.189	.060	( - )	0.000	.187	.030	84.706	.000
14.25	.70	1.667	.055	( - )	0.000	.138	.039	84.706	.000
14.25	1.20	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
19.25	.20	2.153	.067	( - )	0.000	.169	.042	74.824	0.000
19.25	.45	1.644	.043	( - )	0.000	.055	.034	74.824	.000
19.25	.95	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
24.25	.20	1.860	.079	( - )	0.000	.190	.073	87.529	.000
24.25	.70	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
29.25	-.50	1.589	.085	( - )	0.000	.076	.050	69.176	.000

TABLE B-7 SANGAMON RIVER CROSS SECTION 1 JULY 13 1984

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
0.00	0.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
5.00	.25	1.759	.047	-.260	.168	( - )	0.000	81.882	.000
5.00	.50	1.907	.053	-.298	.131	( - )	0.000	84.706	.000
5.00	.75	1.826	.040	-.333	.074	( - )	0.000	83.294	.000
5.00	1.25	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
10.00	.25	1.637	.047	.050	.139	( - )	0.000	77.647	.000
10.00	.50	1.663	.125	-.155	.083	( - )	0.000	83.294	.000
10.00	.75	1.418	.080	.118	.153	( - )	0.000	83.294	.000
10.00	1.00	1.194	.050	-.137	.079	( - )	0.000	84.706	.000
10.00	1.50	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
15.00	.25	1.890	.065	.202	.093	( - )	0.000	83.294	.000
15.00	.50	1.780	.036	.205	.086	( - )	0.000	83.294	.000
15.00	.75	1.592	.058	.198	.087	( - )	0.000	83.294	.000
15.00	1.25	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
20.00	.33	1.736	.133	.396	.195	( - )	0.000	79.059	.000
20.00	.58	1.679	.155	.503	.352	( - )	0.000	83.294	.000
20.00	1.08	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
25.00	.25	1.587	.052	.551	.079	( - )	0.000	83.294	.000
25.00	.50	1.493	.051	.452	.109	( - )	0.000	83.294	.000
25.00	1.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
30.00	.42	1.447	.051	.604	.086	( - )	0.000	87.529	.000
30.00	.92	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
35.00	.17	.721	.265	.876	.129	( - )	0.000	84.706	.000
35.00	.42	.845	.222	.916	.101	( - )	0.000	81.882	.000
35.00	.92	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
70.00	.25	.604	.072	.186	.056	( - )	0.000	84.706	.000
70.00	.75	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000

TABLE B-7 SANGAMON RIVER CROSS SECTION 1 JULY 13 1984 - (CONTINUED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
75.00	.17	.715	.086	.231	.075	( - )	0.000	81.882	.000
75.00	.42	.488	.045	-.024	.057	( - )	0.000	81.882	.000
75.00	.67	.477	.060	.013	.086	( - )	0.000	81.882	.000
75.00	1.17	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
60.00	.17	.524	.073	-.008	.113	( - )	0.000	76.235	0.000
80.00	.42	.472	.029	.051	.068	( - )	0.000	77.714	.308
80.00	.67	.570	.064	.148	.063	( - )	0.000	80.471	.000
80.00	.92	.474	.049	.143	.062	( - )	0.000	76.235	0.000
80.00	1.42	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
0.00	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
4.25	.25	2.184	.045	( - )	0.000	.188	.075	73.412	.000
4.25	.50	2.022	.035	( - )	0.000	.035	.034	73.341	.316
4.25	.75	1.847	.027	( - )	0.000	-.003	.060	73.412	.000
4.25	1.25	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
9.25	.25	2.118	.072	( - )	0.000	.303	.123	74.824	.000
9.25	.50	1.798	.066	( - )	0.000	.172	.054	74.824	.000
9.25	.75	1.586	.032	( - )	0.000	.266	.051	74.824	.000
9.25	1.25	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
14.25	.25	2.049	.049	( - )	0.000	.151	.070	81.882	0.000
14.25	.50	1.765	.048	( - )	0.000	.113	.044	81.882	.000
14.25	.75	1.463	.044	( - )	0.000	.031	.098	81.882	.000
14.25	1.25	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
19.25	.17	2.058	.076	( - )	0.000	.139	.103	81.479	.654
19.25	.08	1.737	.048	( - )	0.000	.055	.115	81.882	.000
19.25	.33	1.602	.049	( - )	0.000	.133	.106	81.882	.000
19.25	.83	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
24.25	.25	1.516	.053	( - )	0.000	.107	.051	81.882	.000
24.25	.50	1.394	.032	( - )	0.000	.074	.039	81.882	.000
24.25	1.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
29.25	.17	1.535	.047	( - )	0.000	.203	.053	80.471	.000
29.25	.42	1.147	.052	( - )	0.000	.105	.048	81.882	.000
29.25	.92	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000

TABLE B-7 SANGAMON RIVER CROSS SECTION 1 JULY 13 1984 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
34.25	.17	.888	.112	( - )	0.000	.027	.374	74.824	.000
34.25	.67	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
69.25	.25	.697	.028	( - )	0.000	.068	.022	79.059	.000
69.25	.75	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
74.25	.17	.678	.052	( - )	0.000	-.023	.067	83.697	21.257
74.25	.67	.530	.088	( - )	0.000	-.005	.065	79.059	.000
74.25	1.17	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
79.25	.17	.665	.050	( - )	0.000	.181	.062	76.235	0.000
79.25	.42	.539	.065	( - )	0.000	.187	.068	76.165	.316
79.25	.67	.506	.087	( - )	0.000	.078	.052	74.824	.000
79.25	.67	.290	.077	( - )	0.000	.019	.048	76.235	0.000

TABLE B-8 SANGAMON RIVER CROSS SECTION 5 AUGUST 5 1985

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U				V				W				ANGLE (DEGREE)	S.D.
		(FPS)	S.D.	(FPS)	S.D.	(FPS)	S.D.	(FPS)	S.D.	(FPS)	S.D.	(FPS)	S.D.		
0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000	0.000	0.000
9.00	.25	.580	.353	-.083	.256	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	77.647	0.000
9.00	.75	.654	.329	-.037	.211	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	79.385	.603
9.00	1.25	.648	.394	-.067	.292	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	83.294	.000
9.00	1.75	0.000	0.000	0.000	0.000	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000
33.50	.35	.678	.357	-.142	.222	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.235	.000
33.50	.85	.570	.362	-.190	.203	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.235	.000
33.50	1.35	.586	.287	-.125	.201	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.235	0.000
33.50	1.85	0.000	0.000	0.000	0.000	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000
50.00	.20	.901	.442	.218	.359	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	77.647	.000
50.00	.70	.575	.368	-.106	.274	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	84.706	.000
50.00	.95	.674	.390	-.025	.252	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	79.710	.718
50.00	1.45	0.000	0.000	0.000	0.000	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000
63.50	.30	.814	.543	.080	.404	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	72.000	.000
63.50	.80	.764	.458	-.050	.271	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	83.294	.000
63.50	1.05	.587	.260	-.089	.181	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	79.007	.272
63.50	1.55	0.000	0.000	0.000	0.000	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000
74.00	.25	.619	.429	-.125	.338	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	75.953	.576
74.00	.75	.447	.238	-.305	.209	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.235	.000
74.00	1.25	.626	.265	-.114	.193	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.074	.456
74.00	1.75	.487	.230	-.100	.169	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	76.191	.250
74.00	2.25	0.000	0.000	0.000	0.000	( - )	( - )	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000
0.00	0.00	0.000	0.000	( - )	0.000	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000	0.000	0.000
8.25	.50	.746	.299	( - )	0.000	( - )	( - )	( - )	( - )	.160	.324	81.882	.000	81.882	.000
8.25	1.00	.805	.394	( - )	0.000	( - )	( - )	( - )	( - )	.182	.305	81.882	.000	81.882	.000
8.25	1.25	.801	.391	( - )	0.000	( - )	( - )	( - )	( - )	.197	.287	81.882	.000	81.882	.000
8.25	1.75	0.000	0.000	( - )	0.000	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000	0.000	0.000
32.75	.60	.685	.307	( - )	0.000	( - )	( - )	( - )	( - )	.207	.256	70.588	.000	70.588	.000
32.75	1.10	.518	.301	( - )	0.000	( - )	( - )	( - )	( - )	-.002	.234	69.257	.332	69.257	.000
32.75	1.35	.809	.397	( - )	0.000	( - )	( - )	( - )	( - )	.181	.323	69.176	.000	69.176	.000
32.75	1.85	0.000	0.000	( - )	0.000	( - )	( - )	( - )	( - )	0.000	0.000	0.000	0.000	0.000	0.000

TABLE B-8 SANGAMON RIVER CROSS SECTION 5 AUGUST 5 1985 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
49.25	.20	.633	.336	( - )	0.000	-.014	.395	76.235	.000
49.25	.70	.677	.315	( - )	0.000	.117	.323	74.824	.000
49.25	.95	.718	.220	( - )	0.000	.029	.209	74.824	.000
49.25	1.45	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
62.75	.30	.557	.322	( - )	0.000	.076	.301	72.000	.000
62.75	.80	.708	.329	( - )	0.000	.111	.344	72.000	.000
62.75	1.05	.847	.281	( - )	0.000	.169	.227	72.000	.000
62.75	1.55	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
73.25	.50	.539	.323	( - )	0.000	-.049	.292	76.235	0.000
73.25	1.00	.587	.239	( - )	0.000	.071	.194	76.188	.258
73.25	1.50	.562	.324	( - )	0.000	.055	.240	70.203	.638

TABLE B-9 SANGAMON RIVER CROSS SECTION 6 AUGUST 6 1965

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U		V		W		ANGLE		S. D.
		(FPS)	S. D.	(FPS)	S. D.	(FPS)	S. D.	(DEGREE)	(DEGREE)	
0.00	0.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000
6.00	.20	.934	.829	.732	1.365	( - )	0.000	84.711	0.000	0.000
6.00	.45	.725	.316	.179	.449	( - )	0.000	81.888	0.000	0.000
6.00	.70	.604	.311	.021	.341	( - )	0.000	83.299	0.000	0.000
6.00	.95	.514	.184	.043	.259	( - )	0.000	77.652	0.000	0.000
6.00	1.20	.719	.292	.358	.492	( - )	0.000	75.339	0.000	0.000
6.00	1.45	.543	.459	.019	.532	( - )	0.000	87.535	0.000	0.000
6.00	1.95	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000
12.25	.10	1.644	.661	.825	.492	( - )	0.000	83.299	0.000	0.000
12.25	.35	.679	.666	.031	.437	( - )	0.000	83.299	0.000	0.000
12.25	.85	1.154	.449	-.463	.305	( - )	0.000	83.299	0.000	0.000
12.25	1.10	.991	.550	-.278	.447	( - )	0.000	81.888	0.000	0.000
12.25	1.35	1.574	.346	-.627	.227	( - )	0.000	77.652	0.000	0.000
12.25	1.60	.458	.537	.189	.311	( - )	0.000	76.241	0.000	0.000
12.25	1.85	.262	.320	.340	.249	( - )	0.000	77.652	0.000	0.000
12.25	2.35	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000
23.00	.10	.781	.515	1.007	.717	( - )	0.000	86.123	0.000	0.000
23.00	.35	1.250	.385	.514	.376	( - )	0.000	86.123	0.000	0.000
23.00	.85	.511	.443	-.346	.650	( - )	0.000	86.123	0.000	0.000
23.00	1.10	.404	.386	-.544	.570	( - )	0.000	81.888	0.000	0.000
23.00	1.35	1.225	.242	.821	.352	( - )	0.000	79.110	0.000	.254
23.00	1.60	.728	.512	-.028	.561	( - )	0.000	83.299	0.000	0.000
23.00	1.85	.367	.466	-.300	.646	( - )	0.000	83.299	0.000	0.000
23.00	2.35	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000
33.00	.25	.279	.414	-.891	.460	( - )	0.000	81.888	0.000	0.000
33.00	.50	.308	.218	-.730	.313	( - )	0.000	81.888	0.000	0.000
33.00	1.00	1.031	.394	.472	.431	( - )	0.000	81.888	0.000	0.000
33.00	1.25	.956	.349	.539	.397	( - )	0.000	83.299	0.000	0.000
33.00	1.75	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000
47.50	.25	1.716	.713	.718	.566	( - )	0.000	97.417	0.000	0.000
47.50	.50	.979	.363	.330	.341	( - )	0.000	86.123	0.000	0.000
47.50	.75	.891	.618	.187	.633	( - )	0.000	88.764	0.000	.481
47.50	1.00	1.014	.521	.420	.580	( - )	0.000	87.535	0.000	0.000
47.50	1.25	.035	.399	-.495	.328	( - )	0.000	93.182	0.000	0.000
47.50	1.75	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000	0.000



TABLE B-9 SANGAMON RIVER CROSS SECTION 6 AUGUST 6 1985 - (CONTINUED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
63.00	.20	.617	.212	-.013	.241	( - )	0.000	87.535	.000
63.00	.70	.672	.179	-.077	.159	( - )	0.000	87.535	0.000
63.00	1.20	.528	.396	-.136	.262	( - )	0.000	98.829	.000
63.00	1.70	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
73.00	.30	.568	.307	-.302	.234	( - )	0.000	86.123	.000
73.00	.55	.571	.325	-.289	.356	( - )	0.000	87.535	.000
73.00	1.05	.748	.366	-.073	.363	( - )	0.000	87.535	.000
73.00	1.30	.688	.311	.032	.397	( - )	0.000	77.652	.000
73.00	1.55	.991	.505	.492	.743	( - )	0.000	77.652	.000
73.00	2.05	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
77.00	.05	.950	.839	.574	.814	( - )	0.000	74.829	.000
77.00	.30	.519	.335	-.025	.502	( - )	0.000	79.064	.000
77.00	.55	.533	.132	-.013	.185	( - )	0.000	79.064	.000
77.00	.80	.511	.268	-.015	.393	( - )	0.000	79.064	.000
77.00	1.05	.542	.240	-.009	.291	( - )	0.000	81.888	.000
77.00	1.30	.628	.485	.228	.710	( - )	0.000	79.064	.000
77.00	1.55	.447	.437	-.044	.622	( - )	0.000	80.476	.000
77.00	1.80	.503	.350	.101	.419	( - )	0.000	80.476	.000
77.00	2.30	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
0.00	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
5.25	.20	.545	.163	( - )	0.000	-.212	.283	77.652	.000
5.25	.45	.598	.330	( - )	0.000	.007	.322	77.652	.000
5.25	.70	.764	.433	( - )	0.000	.197	.406	84.711	.000
5.25	.95	.727	.445	( - )	0.000	.130	.437	84.437	.567
5.25	1.20	.588	.311	( - )	0.000	.053	.293	80.476	.000
5.25	1.45	.553	.267	( - )	0.000	.001	.242	80.476	.000
5.25	1.70	.590	.373	( - )	0.000	.107	.332	80.476	.000
5.25	1.95	.497	.489	( - )	0.000	.091	.403	80.476	.000
5.25	2.45	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
11.50	.35	.420	.401	( - )	0.000	.285	.260	81.928	.239
11.50	.60	.944	.752	( - )	0.000	-.313	.765	77.652	.000
11.50	.85	.819	.459	( - )	0.000	-.037	.478	77.652	.000
11.50	1.10	.641	.429	( - )	0.000	.026	.401	77.652	.000
11.50	1.60	1.020	.296	( - )	0.000	-.459	.297	77.652	.000
11.50	1.85	.400	.268	( - )	0.000	.083	.290	77.652	.000
11.50	2.35	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000

TABLE B-9 SANGAMON RIVER CROSS SECTION 6 AUGUST 6 1985 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
22.25	.35	1.390	.337	( - )	0.000	.727	.336	80.476	.000
22.25	.60	.195	.404	( - )	0.000	-.580	.357	79.064	.000
22.25	.85	1.085	.295	( - )	0.000	.470	.362	80.476	.000
22.25	1.35	.678	.586	( - )	0.000	-.043	.553	80.637	.456
22.25	1.60	.525	.532	( - )	0.000	-.100	.479	81.846	.242
22.25	2.10	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
32.25	.25	.532	.362	( - )	0.000	-.439	.391	79.064	.000
32.25	.50	.591	.304	( - )	0.000	-.323	.267	80.203	.567
32.25	1.00	.689	.507	( - )	0.000	-.013	.548	76.454	.514
32.25	1.00	.426	.535	( - )	0.000	-.159	.472	77.652	.000
32.25	1.50	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
46.75	.25	.263	.311	( - )	0.000	-.582	.298	79.064	.000
46.75	.50	1.183	.414	( - )	0.000	.530	.369	62.081	.242
46.75	1.00	1.254	.353	( - )	0.000	.619	.316	62.123	.000
46.75	1.25	1.368	.548	( - )	0.000	.715	.401	62.123	.000
46.75	1.75	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
62.25	.20	.763	.160	( - )	0.000	-.227	.241	81.888	.000
62.25	.45	.717	.258	( - )	0.000	-.038	.246	81.888	.000
62.25	.70	.581	.364	( - )	0.000	-.076	.384	94.549	.250
62.25	.95	1.370	.460	( - )	0.000	.679	.416	93.229	.258
62.25	.95	.734	.552	( - )	0.000	.313	.442	94.543	.267
62.25	1.45	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
72.25	.30	.614	.277	( - )	0.000	-.075	.258	84.711	0.000
72.25	.55	.752	.487	( - )	0.000	.049	.452	84.711	0.000
72.25	.80	.694	.903	( - )	0.000	.049	.855	75.698	.700
72.25	1.05	.213	.644	( - )	0.000	-.489	.569	74.829	.000
72.25	1.30	.874	.677	( - )	0.000	.226	.603	74.829	0.000
72.25	1.55	.874	.436	( - )	0.000	.245	.363	74.829	.000
72.25	2.05	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
76.25	.30	.578	.200	( - )	0.000	.208	.232	79.064	.000
76.25	.55	.539	.390	( - )	0.000	.139	.417	77.652	.000
76.25	.80	.505	.292	( - )	0.000	.099	.283	77.652	.000
76.25	1.05	.464	.222	( - )	0.000	.046	.203	78.098	.665
76.25	1.30	.600	.416	( - )	0.000	.241	.365	75.906	.608
76.25	1.80	.440	.192	( - )	0.000	.068	.142	74.829	.000

TABLE B-10 SANGAMON RIVER CROSS SECTION 7 AUGUST 7 1985

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
1.00	0.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
8.50	.40	.220	.358	-.215	.411	( - )	0.000	86.919	.709
8.50	1.40	.427	.277	.103	.274	( - )	0.000	87.529	.000
8.50	1.90	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
14.00	.10	.239	.242	.090	.333	( - )	0.000	79.059	0.000
14.00	.35	.415	.117	-.070	.124	( - )	0.000	80.426	.250
14.00	.85	.512	.414	.035	.482	( - )	0.000	83.294	.000
14.00	1.85	.266	.308	-.119	.390	( - )	0.000	84.706	.000
14.00	2.10	.352	.415	.039	.455	( - )	0.000	84.578	.412
14.00	2.60	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
26.00	.25	.573	.598	.148	.668	( - )	0.000	83.294	0.000
26.00	.50	.646	.343	.221	.433	( - )	0.000	84.706	.000
26.00	1.00	.525	.372	.087	.391	( - )	0.000	86.125	.100
26.00	1.25	.597	.328	.355	.420	( - )	0.000	77.647	.000
26.00	1.50	.480	.312	.077	.328	( - )	0.000	88.941	0.000
26.00	1.75	.337	.298	.025	.294	( - )	0.000	84.706	.000
26.00	2.25	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
35.00	.30	.495	.402	.019	.502	( - )	0.000	81.882	.000
35.00	.55	.389	.390	-.102	.359	( - )	0.000	88.941	.000
35.00	1.05	.331	.316	-.133	.277	( - )	0.000	89.590	.713
35.00	1.30	.463	.332	.084	.327	( - )	0.000	80.471	.000
35.00	1.55	.400	.336	.009	.306	( - )	0.000	88.941	.000
35.00	2.05	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
50.00	.20	.507	.480	.070	.508	( - )	0.000	84.706	.000
50.00	.70	.497	.415	.058	.433	( - )	0.000	84.706	.000
50.00	1.20	.482	.436	.049	.469	( - )	0.000	84.706	.000
50.00	1.70	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
65.00	.10	.343	.214	-.043	.176	( - )	0.000	84.706	.000
65.00	.35	.449	.388	-.037	.440	( - )	0.000	84.749	.246
65.00	.60	.378	.257	.031	.331	( - )	0.000	84.706	.000
65.00	1.10	.355	.306	-.063	.345	( - )	0.000	84.706	.000
65.00	1.35	.429	.385	.182	.334	( - )	0.000	83.294	.000
65.00	1.85	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000

TABLE B-10 SANGAMON RIVER CROSS SECTION 7 AUGUST 7 1985 - (CONTINUED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
75.25	.05	.261	.234	-.132	.192	( - )	0.000	87.529	0.000
75.25	.30	.360	.438	-.068	.453	( - )	0.000	86.118	0.000
75.25	.55	.449	.430	.041	.455	( - )	0.000	87.529	0.000
75.25	.80	.355	.468	-.029	.385	( - )	0.000	87.529	0.000
75.25	1.05	.374	.338	-.050	.371	( - )	0.000	81.882	0.000
75.25	1.30	.284	.215	-.048	.204	( - )	0.000	81.882	0.000
75.25	1.55	.299	.229	-.049	.174	( - )	0.000	88.941	0.000
75.25	2.05	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
1.00	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
12.25	.35	.499	.193	( - )	0.000	.030	.154	81.882	0.000
12.25	.60	.461	.209	( - )	0.000	.070	.215	81.882	0.000
12.25	1.10	.325	.460	( - )	0.000	-.066	.411	79.059	0.000
12.25	1.35	.900	.658	( - )	0.000	.471	.603	77.647	0.000
12.25	1.60	.423	.517	( - )	0.000	.053	.481	77.647	0.000
12.25	2.10	.129	1.289	( - )	0.000	-.151	1.050	77.647	0.000
12.25	2.60	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
24.25	.25	.648	.324	( - )	0.000	.139	.411	83.294	0.000
24.25	.50	.563	.231	( - )	0.000	.017	.243	83.294	0.000
24.25	.75	-.038	.328	( - )	0.000	-.556	.359	84.339	.626
24.25	1.00	.300	.429	( - )	0.000	-.173	.376	83.294	0.000
24.25	1.25	.629	.586	( - )	0.000	.154	.549	80.471	0.000
24.25	1.50	.382	.217	( - )	0.000	-.001	.248	80.471	0.000
24.25	1.75	.251	.346	( - )	0.000	-.102	.306	80.582	.687
24.25	2.25	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
33.25	.30	.462	.291	( - )	0.000	-.146	.335	87.529	0.000
33.25	.55	.547	.516	( - )	0.000	-.019	.498	87.529	0.000
33.25	.80	.559	.479	( - )	0.000	.098	.433	86.118	0.000
33.25	1.05	.860	.492	( - )	0.000	.410	.489	86.118	0.000
33.25	1.30	.498	.592	( - )	0.000	.006	.493	86.118	0.000
33.25	1.55	.577	.701	( - )	0.000	.151	.502	86.118	0.000
33.25	2.05	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
48.25	.20	.688	.412	( - )	0.000	.158	.569	81.882	0.000
48.25	.45	.458	.434	( - )	0.000	.012	.379	79.059	0.000
48.25	.70	.319	.436	( - )	0.000	-.140	.357	79.059	0.000
48.25	.95	.534	.337	( - )	0.000	.030	.225	79.059	0.000
48.25	1.45	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000

TABLE B-10 SANGAMON RIVER CROSS SECTION 7 AUGUST 7 1985 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
63.25	.35	.483	.344	( - )	0.000	.079	.329	80.511	.239
63.25	.60	.260	.592	( - )	0.000	-.208	.545	90.353	.000
63.25	.85	.343	.506	( - )	0.000	-.025	.465	88.941	.000
63.25	1.10	.269	.426	( - )	0.000	-.092	.373	88.941	.000
63.25	1.60	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
73.50	.30	.343	.300	( - )	0.000	-.085	.323	80.471	.000
73.50	.55	.425	.235	( - )	0.000	-.016	.183	80.471	.000
73.50	.80	.202	.282	( - )	0.000	-.150	.240	87.571	.242
73.50	1.05	.275	.371	( - )	0.000	-.118	.333	87.529	.000

TABLE B-11 SANGAMON RIVER CROSS SECTION 8 AUGUST 8 1985

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
2.50	0.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
10.50	.25	.470	.676	-.044	.434	( - )	0.000	110.269	.434
10.50	.50	.500	.518	-.000	.318	( - )	0.000	107.299	.000
10.50	1.00	.131	.423	-.203	.288	( - )	0.000	107.299	.000
10.50	1.50	.351	.337	-.108	.236	( - )	0.000	108.711	.000
10.50	2.00	.344	.389	-.083	.251	( - )	0.000	110.123	.000
10.50	2.50	.375	.295	-.045	.206	( - )	0.000	107.563	.555
10.50	2.75	.303	.440	-.020	.208	( - )	0.000	114.213	1.159
10.50	3.00	.486	.848	-.028	.327	( - )	0.000	115.770	.000
10.50	3.50	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
29.75	.10	.422	.272	-.166	.158	( - )	0.000	110.160	.229
29.75	.35	.512	.585	-.236	.408	( - )	0.000	109.894	.781
29.75	.85	.693	.527	-.119	.353	( - )	0.000	110.087	.226
29.75	1.85	.494	.408	-.149	.279	( - )	0.000	111.535	.000
29.75	2.35	.779	.408	.048	.280	( - )	0.000	109.583	.852
29.75	2.85	.506	.562	-.010	.333	( - )	0.000	113.025	.328
29.75	3.10	.259	.678	.140	.599	( - )	0.000	114.358	.000
29.75	3.60	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
45.00	.15	.496	1.128	.040	.882	( - )	0.000	109.874	.546
45.00	.40	.476	.544	-.264	.355	( - )	0.000	107.299	.000
45.00	.90	.451	.672	-.210	.476	( - )	0.000	108.711	.000
45.00	1.40	.830	.513	.105	.386	( - )	0.000	105.888	.000
45.00	1.90	.550	.481	-.122	.263	( - )	0.000	105.888	.000
45.00	2.90	.570	.497	-.166	.249	( - )	0.000	114.358	.000
45.00	3.40	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
60.50	.15	.412	.636	-.124	.628	( - )	0.000	101.652	.000
60.50	.40	.476	.358	-.148	.204	( - )	0.000	111.535	.000
60.50	.90	.466	.382	-.118	.262	( - )	0.000	105.888	.000
60.50	1.40	.643	.462	.033	.258	( - )	0.000	104.476	.000
60.50	1.90	.512	.395	-.024	.309	( - )	0.000	104.476	.000
60.50	2.40	.509	.441	.017	.286	( - )	0.000	110.123	.000
60.50	2.65	.623	.554	-.013	.316	( - )	0.000	111.535	.000
60.50	2.90	.427	.493	-.101	.268	( - )	0.000	115.808	.525
60.50	3.40	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000

TABLE B-11 SANGAMON RIVER CROSS SECTION 8 AUGUST 8 1985 - (CONTINUED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
41.75	.15	1.469	1.299	( - )	0.000	.115	.431	104.476	.000
41.75	.40	.610	.391	( - )	0.000	.025	.381	103.064	.000
41.75	.65	.662	.389	( - )	0.000	.128	.347	103.064	.000
41.75	1.15	.658	.407	( - )	0.000	.098	.481	100.241	.000
41.75	1.65	.686	.325	( - )	0.000	.117	.268	100.241	0.000
41.75	2.15	.554	.339	( - )	0.000	.063	.361	111.535	.000
41.75	2.40	.442	.323	( - )	0.000	-.001	.325	112.946	.000
41.75	2.65	.636	.408	( - )	0.000	.124	.301	112.946	.000
41.75	3.15	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
57.25	.40	.577	.273	( - )	0.000	.123	.295	103.904	.703
57.25	.65	.495	.315	( - )	0.000	-.031	.383	103.064	.000
57.25	1.15	.533	.395	( - )	0.000	.122	.358	104.476	.000
57.25	1.65	.501	.481	( - )	0.000	.074	.431	105.888	.000
57.25	2.15	.770	.424	( - )	0.000	.303	.415	114.358	.000
57.25	2.40	.398	.455	( - )	0.000	-.009	.451	113.079	.418
57.25	2.65	.390	.524	( - )	0.000	.058	.420	112.946	.000
57.25	3.15	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
65.25	.50	.455	.256	( - )	0.000	.080	.296	117.182	.000
65.25	.75	.453	.205	( - )	0.000	.027	.206	117.182	.000
65.25	1.25	.538	.253	( - )	0.000	.093	.201	114.358	.000
65.25	1.75	.468	.280	( - )	0.000	.058	.269	114.358	.000
65.25	2.75	.305	.356	( - )	0.000	.050	.335	111.535	.000
65.25	3.00	.399	.295	( - )	0.000	.085	.312	118.594	.000
65.25	3.25	.290	.401	( - )	0.000	.039	.353	118.594	.000
65.25	3.75	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
66.75	.45	.273	.255	( - )	0.000	-.065	.243	88.946	0.000
66.75	.70	.319	.285	( - )	0.000	-.062	.297	90.358	.000
66.75	1.20	.336	.287	( - )	0.000	.042	.290	84.711	.000
66.75	1.70	.358	.296	( - )	0.000	.128	.282	84.711	.000
66.75	2.20	.383	.344	( - )	0.000	.193	.279	96.005	.000
66.75	2.45	.362	.377	( - )	0.000	.157	.310	96.005	.000
66.75	2.70	.195	.313	( - )	0.000	.049	.217	98.102	.716

TABLE B-11 SANGAMON RIVER CROSS SECTION 8 AUGUST 8 1985 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
68.50	.25	.418	.541	-.153	.293	( - )	0.000	115.770	.000
68.50	.50	.409	.394	-.234	.201	( - )	0.000	115.770	.000
68.50	1.00	.513	.345	-.173	.188	( - )	0.000	115.770	.000
68.50	1.50	.405	.354	-.230	.211	( - )	0.000	115.770	.000
68.50	2.00	.433	.357	-.177	.197	( - )	0.000	117.182	.000
68.50	2.50	.454	.333	-.132	.168	( - )	0.000	114.358	.000
68.50	3.50	.382	.453	-.091	.142	( - )	0.000	124.241	.000
68.50	3.50	.295	.409	-.019	.228	( - )	0.000	117.182	.000
68.50	4.00	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
70.00	.20	.401	.477	-.084	.613	( - )	0.000	86.035	.347
70.00	.45	.458	.289	.083	.348	( - )	0.000	86.123	.000
70.00	.95	.325	.269	-.111	.357	( - )	0.000	87.535	.000
70.00	1.45	.279	.273	-.141	.301	( - )	0.000	88.946	0.000
70.00	1.95	.333	.241	-.067	.297	( - )	0.000	93.182	.000
70.00	2.45	.258	.268	-.022	.291	( - )	0.000	88.946	0.000
70.00	2.70	.338	.320	.116	.272	( - )	0.000	96.005	.000
70.00	3.20	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
2.50	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
7.25	.25	.468	.322	( - )	0.000	.060	.385	105.888	.000
7.25	.50	.405	.329	( - )	0.000	.040	.373	105.888	.000
7.25	.75	.383	.300	( - )	0.000	.046	.284	105.888	.000
7.25	1.25	.429	.261	( - )	0.000	.095	.256	103.064	.000
7.25	1.75	.418	.305	( - )	0.000	.139	.295	103.064	.000
7.25	2.00	.279	.268	( - )	0.000	-.015	.262	105.888	.000
7.25	2.25	.319	.258	( - )	0.000	.073	.239	105.888	.000
7.25	2.50	.423	.480	( - )	0.000	.163	.326	103.064	.000
7.25	3.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
26.50	.35	.715	.507	( - )	0.000	.156	.484	105.888	.000
26.50	.60	.601	.338	( - )	0.000	.027	.416	105.888	.000
26.50	1.10	.661	.475	( - )	0.000	.165	.425	108.711	.000
26.50	1.60	.671	.422	( - )	0.000	.157	.373	108.711	.000
26.50	2.10	.586	.319	( - )	0.000	.135	.274	98.787	.242
26.50	2.35	.427	.413	( - )	0.000	.006	.353	98.829	.000
26.50	2.50	.464	.469	( - )	0.000	.111	.363	105.888	.000
26.50	3.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000



TABLE B-12 SANGAMON RIVER CROSS SECTION 9 AUGUST 9 1985

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U		V		W		ANGLE (DEGREE)	S.D.
		(FPS)	(FPS)	(FPS)	(FPS)	(FPS)	(FPS)		
0.00	0.00	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000
11.50	.20	.175	.262	-.253	.168	( - )	( - )	124.235	.000
11.50	.45	.218	.152	-.299	.115	( - )	( - )	125.862	.513
11.50	.95	.192	.122	-.285	.090	( - )	( - )	127.059	.000
11.50	1.20	.136	.132	-.202	.123	( - )	( - )	125.647	.000
11.50	1.70	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000
26.50	.10	.182	.319	-.420	.259	( - )	( - )	117.176	.000
26.50	.35	.326	.108	-.355	.104	( - )	( - )	121.412	.000
26.50	.35	.317	.129	-.388	.086	( - )	( - )	121.412	.000
26.50	1.35	.291	.092	-.321	.087	( - )	( - )	117.176	0.000
26.50	1.85	.245	.126	-.252	.108	( - )	( - )	120.000	0.000
26.50	2.10	.057	.177	-.199	.134	( - )	( - )	122.012	.707
26.50	2.60	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000
41.50	.25	.282	.187	-.233	.139	( - )	( - )	120.409	1.464
41.50	.50	.247	.108	-.269	.075	( - )	( - )	118.588	.000
41.50	.75	.275	.115	-.225	.096	( - )	( - )	115.765	.000
41.50	1.25	.258	.107	-.189	.077	( - )	( - )	118.588	.000
41.50	1.75	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000
51.00	.15	.390	.142	-.051	.099	( - )	( - )	120.000	0.000
51.00	.40	.437	.120	-.071	.100	( - )	( - )	116.887	.662
51.00	1.40	.453	.023	-.009	.032	( - )	( - )	114.353	0.000
51.00	1.90	.450	.030	-.010	.024	( - )	( - )	118.657	.308
51.00	2.40	.447	.053	.052	.040	( - )	( - )	115.765	0.000
51.00	2.90	.402	.063	.030	.048	( - )	( - )	118.588	.000
51.00	3.40	.423	.060	.058	.037	( - )	( - )	122.824	.000
51.00	3.90	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000
57.00	.25	.472	.042	-.101	.038	( - )	( - )	116.016	.546
57.00	.50	.515	.041	-.092	.039	( - )	( - )	115.765	.000
57.00	1.00	.471	.039	-.070	.044	( - )	( - )	115.765	.000
57.00	1.50	.474	.031	-.003	.031	( - )	( - )	111.529	.000
57.00	1.75	.430	.056	.015	.051	( - )	( - )	116.336	.701
57.00	2.25	.370	.037	.067	.041	( - )	( - )	111.529	.000
57.00	2.75	.421	.086	.061	.060	( - )	( - )	115.154	1.080
57.00	3.25	0.000	0.000	0.000	0.000	( - )	( - )	0.000	0.000

TABLE B-12 SANGAMON RIVER CROSS SECTION 9 AUGUST 9 1985 - (CONTINUED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
66.75	.10	.187	.185	-.008	.136	( - )	0.000	113.682	.714
66.75	1.10	.180	.069	.111	.061	( - )	0.000	114.353	0.000
66.75	1.60	0.000	0.000	0.000	0.000	( - )	0.000	0.000	0.000
0.00	0.00	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
10.75	.20	.319	.060	( - )	0.000	-.057	.085	124.235	.000
10.75	.45	.343	.092	( - )	0.000	-.036	.112	124.235	.000
10.75	.70	.250	.124	( - )	0.000	-.055	.083	136.412	.692
10.75	1.20	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
25.75	.10	.589	.749	( - )	0.000	-.019	.120	118.588	.000
25.75	.35	.353	.103	( - )	0.000	-.045	.089	117.341	.458
25.75	.60	.372	.092	( - )	0.000	-.025	.109	117.176	.000
25.75	1.10	.349	.118	( - )	0.000	-.024	.107	118.562	.192
25.75	1.60	.242	.094	( - )	0.000	-.046	.079	120.000	0.000
25.75	1.85	.218	.137	( - )	0.000	-.082	.237	119.872	.409
25.75	2.35	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
40.75	0.00	.354	.079	( - )	0.000	-.044	.088	114.353	0.000
40.75	.25	.266	.105	( - )	0.000	-.071	.105	112.941	.000
40.75	.50	.449	.228	( - )	0.000	.101	.189	117.169	.100
40.75	.50	.422	.066	( - )	0.000	.102	.056	117.176	.000
40.75	2.25	.283	.167	( - )	0.000	.037	.181	118.588	.000
40.75	2.75	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
50.25	.15	.614	.075	( - )	0.000	.229	.147	114.353	.000
50.25	.40	.488	.064	( - )	0.000	.107	.058	114.353	0.000
50.25	.65	.442	.069	( - )	0.000	.083	.071	114.284	.308
50.25	1.15	.460	.035	( - )	0.000	.118	.022	111.529	.000
50.25	1.65	.446	.026	( - )	0.000	.113	.024	111.529	.000
50.25	2.15	.446	.037	( - )	0.000	.131	.027	115.765	.000
50.25	2.65	.410	.064	( - )	0.000	.089	.046	115.445	.596
50.25	3.15	.363	.046	( - )	0.000	.083	.041	116.040	.566
50.25	3.40	.325	.039	( - )	0.000	.077	.039	115.765	.000
50.25	3.90	0.000	0.000	( - )	0.000	0.000	0.000	0.000	0.000
56.25	.25	.534	.039	( - )	0.000	.121	.025	110.118	.000
56.25	.50	.486	.041	( - )	0.000	.129	.029	110.118	.000
56.25	.75	.498	.084	( - )	0.000	.127	.113	110.118	.000
56.25	1.00	.494	.043	( - )	0.000	.108	.039	196.460	.522

TABLE B-12 SANGAMON RIVER CROSS SECTION 9 AUGUST 9 1985 - (CONCLUDED)

MEASURED DATA

DISTANCE (FT)	DEPTH (FT)	U (FPS)	S.D.	V (FPS)	S.D.	W (FPS)	S.D.	ANGLE (DEGREE)	S.D.
56.25	1.50	.444	.048	( - )	0.000	.113	.039	197.647	.000
56.25	2.00	.390	.054	( - )	0.000	.065	.043	111.529	.000
56.25	2.50	.340	.056	( - )	0.000	.089	.043	111.529	.000
56.25	3.00	.315	.068	( - )	0.000	.093	.053	112.941	.000
56.25	3.25	.169	.154	( - )	0.000	.063	.072	112.543	.644

Appendix C

Computed Velocities

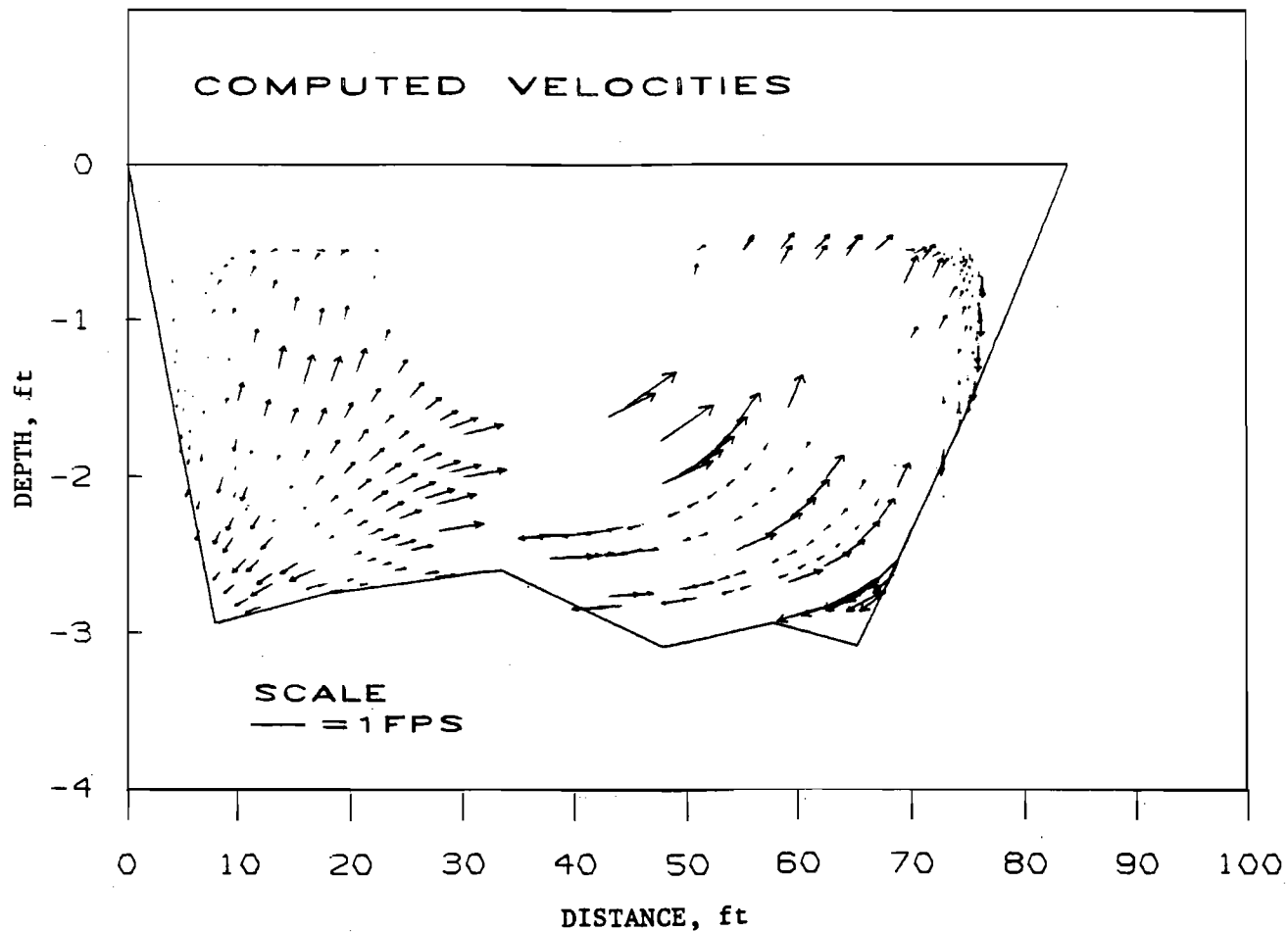


Figure C-1. Computed secondary current vectors at cross section 6, June 28, 1984

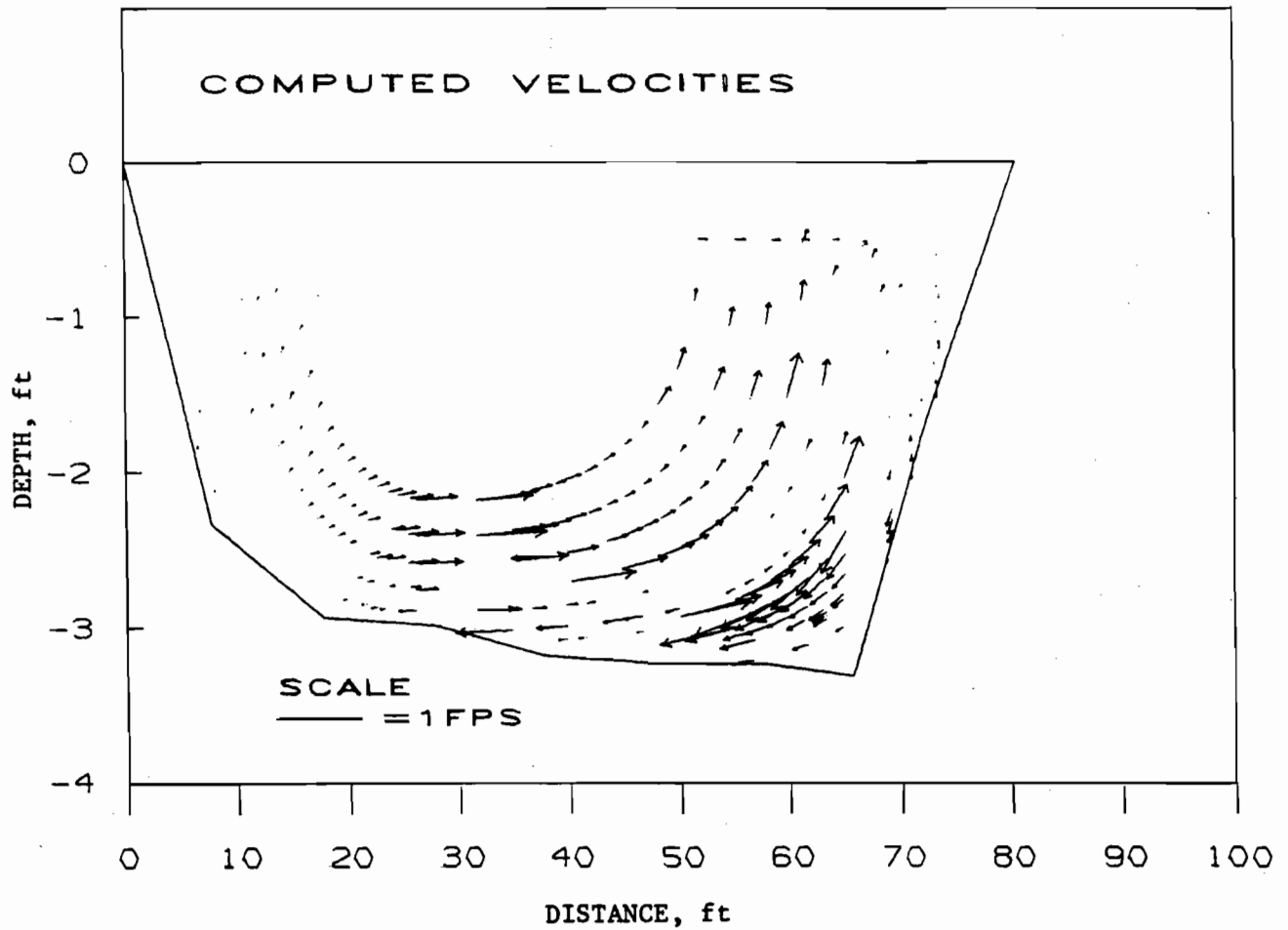


Figure C-2. Computed secondary current vectors at cross section 5, June 29, 1984

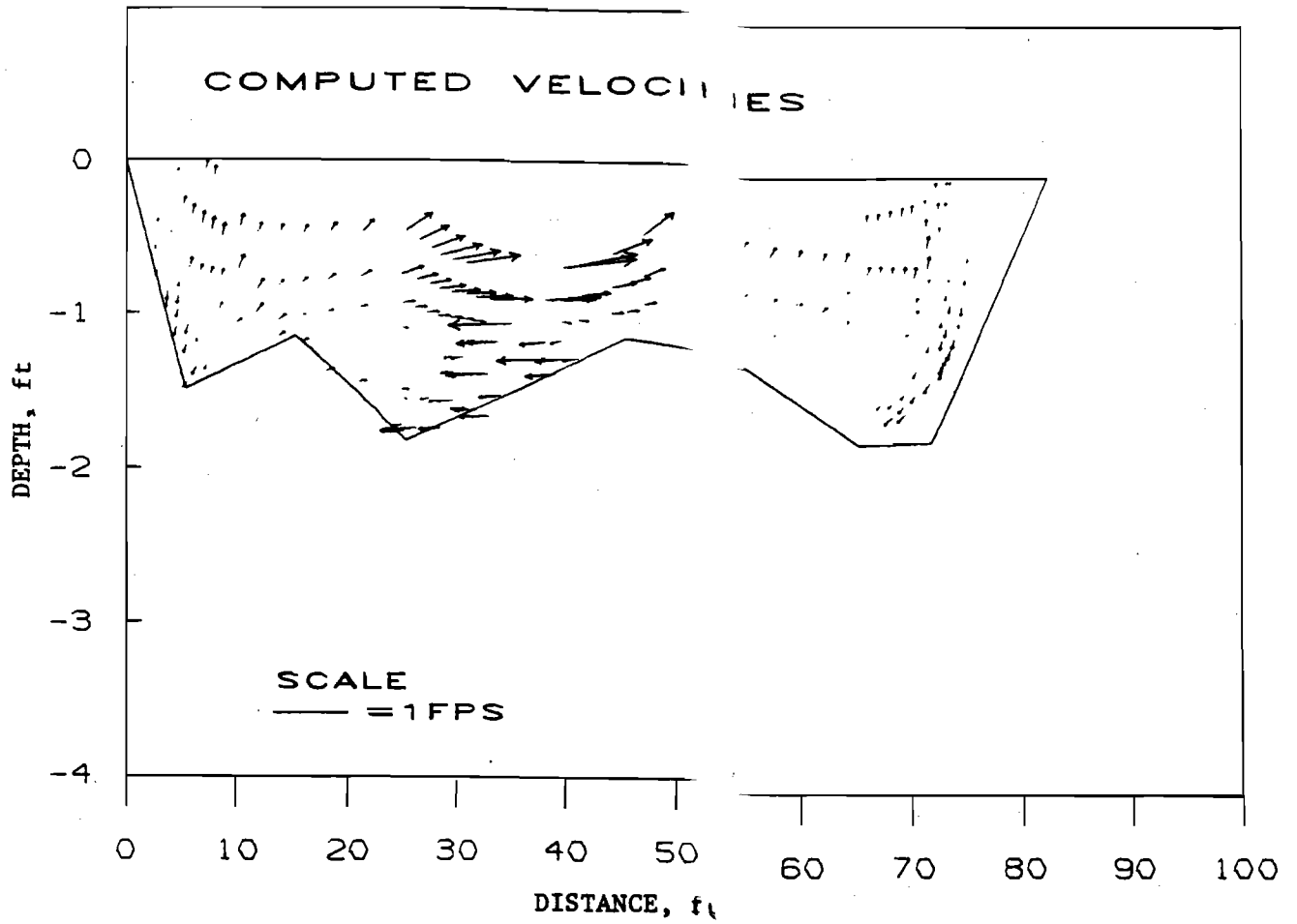


Figure C-3. Computed secondary current vectors at cross section 3, July 9, 1984

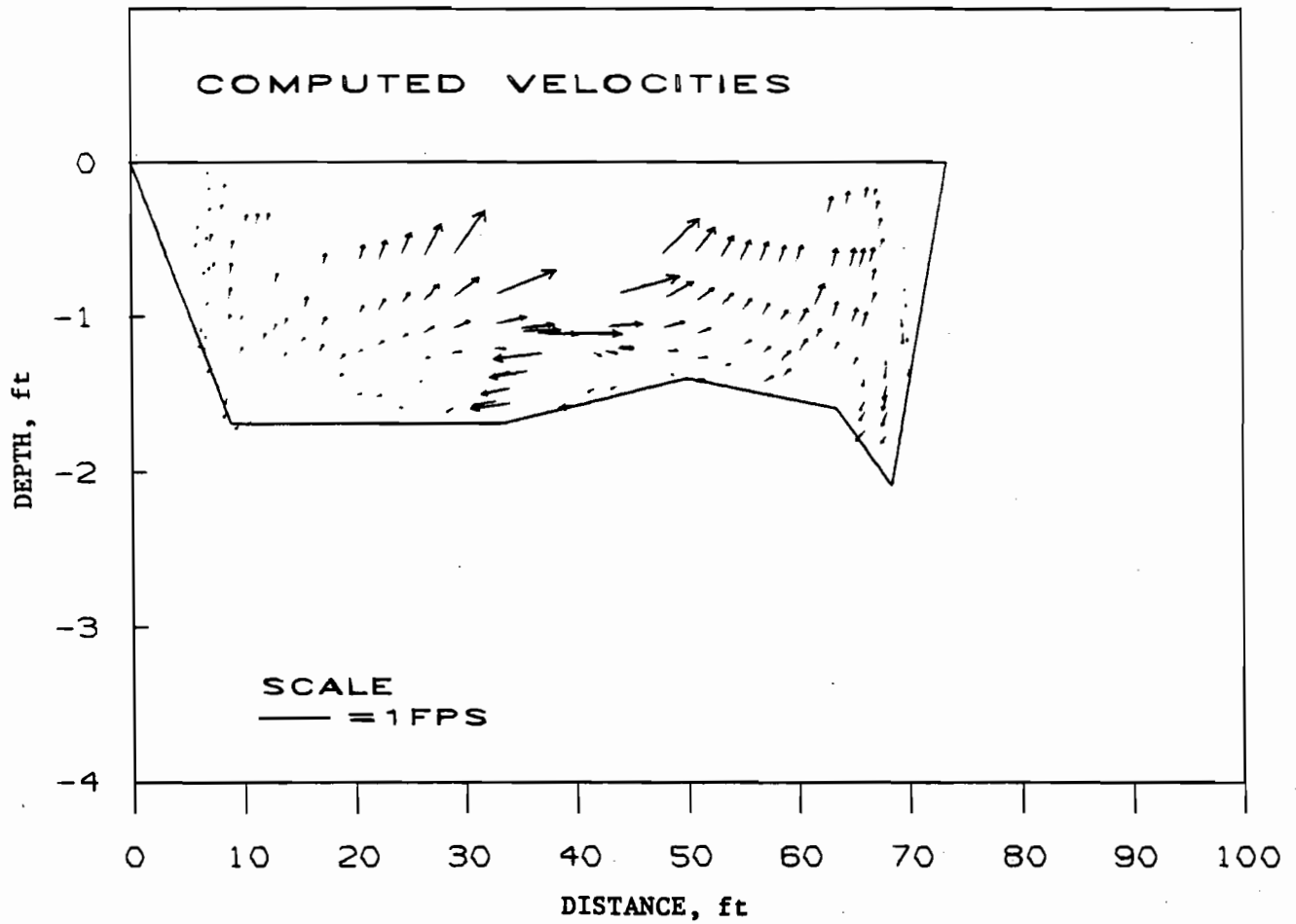


Figure C-5. Computed secondary current vectors at cross section 5, August 5, 1985



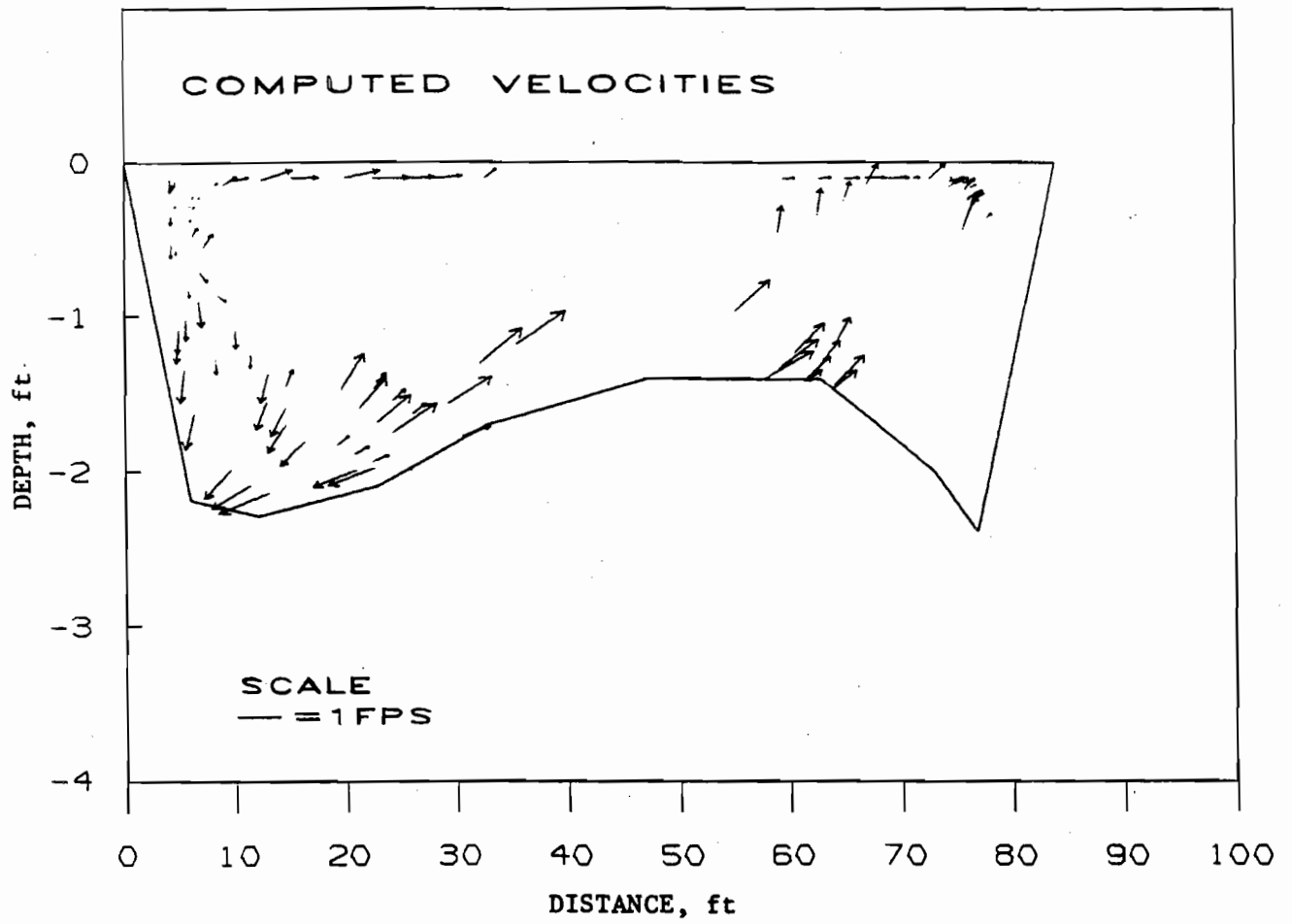


Figure C-6. Computed secondary current vectors at cross section 6, August 6, 1985

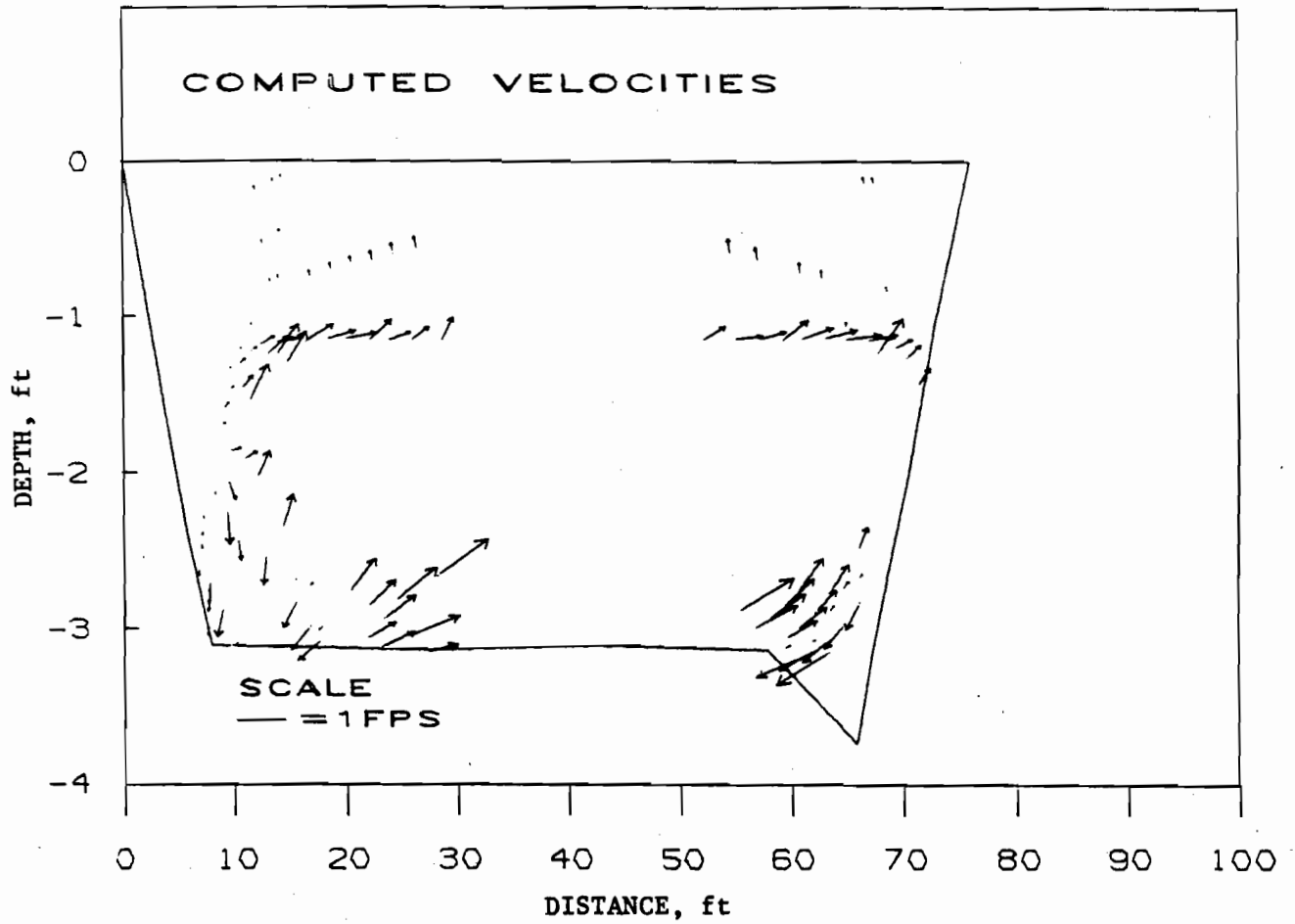


Figure C-7. Computed secondary current vectors at cross section 8, August 8, 1985

TABLE C-1 SANGAMON RIVER CROSS SECTION 6 JUNE 28 1984

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
19.25	1.64	.20	.46	29.80	1.73	.76	.26
19.44	.99	.05	.34	37.83	2.53	.81	.06
20.35	2.66	.12	.05	37.83	2.38	.61	.08
20.35	2.50	.13	.07	39.46	2.52	.60	.06
20.36	2.32	.23	.17	39.46	2.37	.61	.08
20.37	2.09	.29	.30	41.09	2.51	.47	.07
20.40	1.79	.23	.37	41.09	2.36	.48	.09
20.47	1.33	.18	.61	42.69	1.62	.91	.65
21.52	2.69	.14	.04	42.71	2.84	.62	.05
21.53	2.54	.15	.07	42.71	2.50	.38	.07
21.53	2.37	.27	.16	42.71	2.34	.39	.09
21.53	2.16	.34	.28	42.72	2.77	.62	.06
21.55	1.90	.28	.33	44.32	1.55	.94	.90
21.56	1.54	.20	.42	44.34	2.49	.32	.07
21.60	1.55	.12	0.00	44.34	2.32	.33	.10
21.81	.74	.03	.08	44.35	2.83	.52	.05
21.90	.57	.18	.06	44.35	2.76	.52	.06
22.71	2.41	.32	.15	45.97	2.47	.27	.07
22.71	2.22	.41	.26	45.97	2.30	.28	.10
22.72	1.99	.34	.31	47.58	1.77	.96	.93
22.73	1.67	.19	.27	47.59	2.05	.94	.59
22.76	1.15	.10	.37	49.21	1.99	.80	.64
23.89	2.73	.21	.04	49.22	2.80	.33	.06
23.89	2.60	.21	.06	49.22	2.72	.33	.07
23.89	2.44	.38	.14	49.22	2.41	.20	.08
23.90	2.27	.48	.24	49.22	2.22	.21	.12
23.91	2.05	.40	.28	50.60	.72	.06	.33
23.92	1.77	.23	.25	50.71	.55	.17	.14
23.96	1.35	.20	.41	50.83	1.92	.69	.70
25.06	2.75	.23	.04	50.84	2.17	.18	.13
25.07	2.47	.45	.13	50.85	2.78	.29	.06
25.08	2.10	.49	.27	50.85	2.70	.29	.08
25.09	1.85	.28	.23	50.85	2.38	.18	.09
25.12	1.49	.27	.38	52.45	1.82	.59	.79
26.25	2.63	.30	.05	52.46	2.11	.15	.14
26.26	2.14	.60	.25	52.48	2.67	.26	.08
26.27	1.90	.35	.21	54.06	1.70	.50	.92
26.28	1.58	.35	.35	54.08	2.03	.13	.15
27.43	2.65	.38	.05	54.10	2.64	.23	.09
27.43	2.35	.88	.21	54.10	2.48	.79	.43
27.43	2.17	.74	.24	54.10	2.28	.14	.10
27.44	1.95	.44	.20	54.11	2.74	.22	.07
27.45	1.65	.40	.29	54.90	.57	.20	.38
28.62	1.98	.58	.19	54.90	.55	.23	.37
28.63	1.69	.53	.27	55.71	1.93	.11	.16
29.79	2.66	.68	.05	55.72	2.21	.12	.11
29.79	2.00	.82	.19	55.74	2.71	.20	.08

TABLE C-1 SANGAMON RIVER CROSS SECTION 6 JUNE 28 1984 - (CONTINUED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
4.17	.75	0.00	-.07	11.02	1.88	.04	.14
4.23	1.00	0.00	-.08	11.02	.59	.10	.15
4.28	.99	0.00	-.07	11.04	.72	.10	.26
4.36	1.26	0.00	-.10	11.35	1.17	.08	.44
4.48	1.19	0.00	-.07	12.07	2.84	-.30	-.17
4.59	1.53	-.01	-.15	12.10	2.52	-.28	-.35
4.68	1.44	-.01	-.11	12.13	2.23	-.21	-.44
4.97	1.80	-.03	-.21	12.14	2.12	-.02	-.05
5.02	1.72	-.02	-.17	12.26	1.63	.11	.49
5.14	1.55	0.00	-.11	12.84	.56	.12	.08
5.24	1.44	0.00	-.07	12.90	.82	.09	.28
5.49	.71	0.00	.02	13.26	2.88	-.36	-.16
5.58	2.07	-.05	-.27	13.26	2.68	-.45	-.35
5.66	1.87	-.03	-.21	13.27	2.61	-.34	-.32
5.71	1.68	-.02	-.19	13.29	2.37	-.27	-.39
5.92	1.47	-.01	-.16	13.30	2.27	-.04	-.06
6.60	2.35	-.09	-.27	13.35	1.91	.07	.18
6.65	2.14	-.07	-.29	13.53	1.33	.11	.67
6.76	1.84	-.02	-.24	14.44	2.86	-.40	-.17
6.91	1.56	.01	-.15	14.45	2.60	-.12	-.09
6.94	.84	.04	.06	14.50	2.09	.06	.12
7.18	1.25	.04	.01	14.57	1.68	.14	.48
7.50	.71	.04	.05	14.74	.55	.14	0.00
7.59	.97	.06	.12	14.93	.95	.07	.38
8.10	.78	.07	.14	15.62	2.84	-.54	-.21
8.53	2.61	-.16	-.24	15.63	2.54	-.40	-.33
8.57	2.33	-.17	-.42	15.66	2.22	.07	.10
8.65	2.00	-.10	-.44	15.70	1.90	.12	.27
8.65	.67	.07	.10	15.81	1.41	.17	.77
8.71	1.79	.01	0.00	16.79	.61	.08	.16
8.82	1.55	.05	.20	16.79	.55	.17	0.00
9.01	1.27	.05	.09	16.81	2.71	-.16	-.08
9.21	.61	.08	.04	16.81	2.60	-.47	-.30
9.34	.99	.20	.23	16.82	2.32	.08	.09
9.71	2.70	-.20	-.22	16.85	2.05	.14	.23
9.75	2.37	-.23	-.48	16.91	1.69	.18	.50
9.77	2.24	-.17	-.43	17.14	1.03	.07	.43
9.79	2.10	-.03	-.12	17.99	2.69	-.18	-.08
9.84	1.93	-.02	-.10	18.00	2.40	.10	.08
9.90	1.74	-.06	-.40	18.02	2.17	.17	.20
9.99	1.52	-.09	-.48	18.05	1.86	.20	.38
10.69	2.79	-.25	-.19	18.13	1.41	.19	.72
10.92	2.51	-.30	-.43	19.08	.58	.07	.10
10.96	2.18	-.05	-.13	19.08	.55	.15	0.00
10.98	2.04	-.15	-.48	19.17	2.73	-.21	-.08
11.01	.56	.09	.02	19.16	2.25	.20	.18
				19.20	1.99	.24	.33

TABLE C-1 SANGAMON RIVER CROSS SECTION 6 JUNE 28 1984 - (CONTINUED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
57.31	1.79	.08	.17	69.94	1.12	.12	.29
57.34	2.12	.11	.13	70.24	.57	.22	.15
57.36	2.57	.18	.10	70.37	2.41	-.39	-.83
57.36	2.37	.60	.51	70.39	2.59	-.51	-.77
58.36	.64	.21	.47	71.04	.61	.21	.39
58.37	.55	.26	.43	71.04	.56	.14	.04
58.91	1.59	.30	.94	71.82	.75	.19	.59
58.96	2.00	.09	.15	71.84	.59	.13	.10
58.98	2.29	.52	.56	72.46	1.06	.13	.35
58.99	2.69	.65	.33	72.65	.66	.12	.23
58.99	2.64	-.15	-.09	72.65	.59	.06	.07
58.99	2.51	.16	.11	72.79	1.47	.02	-.27
60.56	1.84	.09	.21	72.94	1.81	-.08	-.70
60.59	2.19	.44	.63	72.97	1.90	-.17	-.13
60.61	2.58	-.13	-.09	72.99	1.98	-.17	-.97
61.42	2.45	.14	.12	73.03	2.13	-.17	-.76
61.43	.55	.24	.43	73.04	2.20	-.19	-.74
62.21	2.05	.28	.38	73.06	2.29	-.28	-.93
62.23	2.36	.37	.73	73.42	.85	.11	.25
62.24	2.59	.12	.14	73.47	.67	.06	.13
62.24	2.52	.49	.39	73.47	.61	.02	.09
62.25	2.85	-.85	-.36	74.00	1.23	.06	.15
63.85	2.25	.10	.17	74.12	1.37	.03	-.18
63.86	2.43	-.09	-.11	74.21	1.50	0.00	-.34
63.87	2.52	.42	.43	74.25	.86	.05	.19
63.88	2.81	-.73	-.39	74.29	1.63	-.03	-.49
64.23	.59	.27	.56	74.29	.71	.02	.13
64.23	.55	.30	.37	74.30	.65	.01	.11
65.45	2.09	.10	.23	74.31	.57	0.00	.11
65.48	2.32	-.07	-.12	74.34	1.75	-.05	-.59
65.49	2.42	.35	.49	74.38	1.86	-.09	-.70
65.50	2.74	-.67	-.48	74.42	1.96	-.12	-.80
65.51	2.77	-.62	-.42	74.48	.96	.05	.19
66.88	.55	.30	.37	74.55	.77	.02	.16
67.09	2.16	-.05	-.13	74.57	.68	.01	.14
67.10	2.29	.29	.57	74.58	.63	0.00	.13
67.13	2.76	-.59	-.47	74.69	1.08	.04	.13
67.13	2.68	-.56	-.54	74.81	.73	.02	.15
67.13	2.65	-.61	-.63	74.84	.73	.01	.13
68.67	1.91	-.01	-.09	74.85	.65	0.00	.13
68.70	2.09	.23	.71	74.99	1.36	.01	-.13
68.75	2.55	-.50	-.71	75.04	.94	.02	.13
68.76	2.70	-.68	-.71	75.10	.78	.01	.12
68.76	2.62	-.42	-.53	75.11	1.50	-.01	-.37
69.41	.76	.23	.69	75.12	.69	0.00	.11
69.44	.55	.17	.02	75.13	.61	0.00	.11
				75.19	1.64	-.04	-.57

TABLE C-1 SANGAMON RIVER CROSS SECTION 6 JUNE 28 1984 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
75.26	1.06	.01	.06
75.36	.86	.01	.07
75.39	.73	0.00	.07
75.40	.63	0.00	.07
75.45	1.19	0.00	-.11
75.65	1.37	-.03	-.58
75.82	1.08	0.00	-.18
75.92	.87	0.00	-.14
75.93	1.15	-.02	-.52
75.96	.69	0.00	-.12
75.98	1.18	-.02	-.62
75.99	.89	0.00	-.30
76.05	.92	-.01	-.41
76.18	.96	-.01	-.59
76.18	.72	0.00	-.43
76.25	.73	0.00	-.52

TABLE C-2 SANGAMON RIVER CROSS SECTION 5 JUNE 29 1984

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
6.54	1.84	0.00	.03	23.37	2.13	.19	.06
6.73	1.60	.01	.02	24.23	2.38	.28	.05
10.45	.90	.02	.05	24.24	2.15	.24	.06
10.75	1.26	.02	.07	25.11	2.75	.18	.01
11.34	1.63	.02	.07	25.11	2.59	.37	.04
11.99	.89	.02	.06	25.11	2.40	.38	.05
12.38	1.28	.02	.10	25.11	2.17	.33	.06
13.05	1.61	.03	.11	25.98	2.90	.22	.01
13.63	.84	.02	.05	25.98	2.76	.27	.01
13.84	1.84	.04	.08	25.98	2.59	.56	.03
14.07	1.23	.02	.10	25.99	2.41	.58	.05
14.66	2.01	.04	.07	25.99	2.18	.50	.06
14.78	1.53	.04	.12	31.26	2.90	.49	.02
15.51	2.14	.05	.06	31.28	2.41	.87	.07
15.58	1.74	.04	.09	31.28	2.18	.70	.08
15.82	1.08	.02	.07	32.96	2.90	.33	.02
16.37	2.23	.06	.06	32.96	2.40	.58	.07
16.42	1.90	.05	.08	32.96	2.17	.46	.08
16.53	1.39	.04	.11	34.64	2.58	.68	.09
17.24	2.31	.07	.05	34.64	2.38	.43	.08
17.27	2.01	.06	.07	34.64	2.15	.34	.08
17.33	1.59	.05	.10	34.65	3.03	.69	.04
18.11	2.37	.08	.05	36.32	2.37	.34	.08
18.13	2.10	.08	.07	36.32	2.12	.27	.09
18.17	1.74	.06	.08	36.33	2.89	.19	.02
18.98	2.42	.09	.05	38.00	2.34	.27	.08
19.00	2.17	.09	.06	38.00	2.09	.22	.09
19.02	1.85	.07	.08	38.01	2.55	.45	.04
19.84	2.83	.05	.01	39.67	2.05	.18	.09
19.85	2.46	.10	.04	39.68	2.31	.23	.08
19.86	2.23	.10	.06	39.69	3.09	.12	.01
19.88	1.93	.09	.07	39.69	3.00	.38	.04
20.72	2.69	.06	.01	39.69	2.86	.13	.02
20.74	2.28	.12	.06	39.69	2.71	.81	.17
20.75	2.00	.10	.07	39.69	2.52	.37	.10
21.59	2.86	.07	.01	41.35	2.00	.15	.10
21.60	2.71	.07	.01	41.36	2.28	.19	.09
21.60	2.53	.15	.04	41.37	3.08	.10	.01
21.61	2.31	.15	.05	41.37	2.85	.11	.02
21.62	2.05	.12	.07	43.03	1.93	.13	.11
22.47	2.88	.08	.01	43.03	2.23	.16	.09
22.48	2.55	.18	.04	43.05	2.46	.27	.11
22.49	2.09	.15	.06	44.70	1.84	.11	.12
23.35	2.89	.09	.01	44.72	2.42	.23	.12
23.35	2.74	.10	.01	44.72	2.17	.14	.10
23.35	2.56	.22	.04	44.73	2.63	.52	.19
23.36	2.37	.22	.05	44.74	2.96	.25	.05

TABLE C-2 SANGAMON RIVER CROSS SECTION 5 JUNE 29 1984 - (CONTINUED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
46.37	1.73	.09	.13	58.18	2.85	-.62	-.43
46.39	2.10	.12	.11	58.19	2.99	-.32	-.16
46.40	2.37	.20	.13	58.29	.50	.13	0.00
46.41	2.94	-.22	-.05	59.69	1.53	.15	.77
46.41	2.78	.07	.02	59.80	2.13	.03	.06
46.42	3.04	-.07	-.01	59.84	2.51	-.07	-.10
48.03	1.57	.14	.29	59.85	2.61	.37	.44
48.06	2.01	.10	.12	59.86	2.86	-.39	-.30
48.08	2.31	.18	.14	59.86	2.78	-.53	-.47
48.09	2.55	.40	.22	59.87	2.94	-.28	-.18
49.66	1.34	.10	.35	61.00	.91	.05	.38
49.72	1.89	.09	.14	61.19	.52	.07	.22
49.75	2.23	.15	.15	61.19	.50	.09	0.00
49.77	2.89	-.17	-.06	61.44	1.87	.06	.21
49.77	2.49	.35	.23	61.51	2.36	-.05	-.11
49.78	2.94	.86	.27	61.52	2.48	.31	.50
51.19	.90	.03	.20	61.53	2.69	-.45	-.53
51.39	1.72	.09	.18	61.54	2.87	-.23	-.20
51.43	2.13	.13	.16	61.54	2.78	-.33	-.33
51.44	2.42	.30	.26	61.55	3.12	-.19	-.09
51.46	2.91	.76	.29	61.55	3.12	-.18	-.09
51.55	.50	.12	0.00	61.55	2.95	-.26	-.19
53.02	1.48	.12	.39	62.97	1.44	.06	.43
53.09	2.00	.11	.19	63.15	2.15	-.03	-.10
53.12	2.34	.26	.28	63.18	2.31	.25	.59
53.14	3.04	-.68	-.22	63.20	2.57	-.37	-.60
54.56	1.06	.04	.31	63.22	2.78	-.20	-.22
54.74	1.82	.10	.24	63.22	2.68	-.27	-.37
54.79	2.22	.22	.32	63.23	2.96	-.16	-.12
54.81	2.76	-.11	-.07	63.23	2.93	-.17	-.14
54.82	2.83	.58	.33	63.23	2.91	-.18	-.16
54.83	3.01	-.60	-.23	63.23	2.88	-.22	-.21
55.13	.50	.13	0.00	63.89	.73	.06	.16
56.37	1.54	.12	.49	63.93	.50	.08	.01
56.45	2.07	.19	.36	64.76	1.83	.05	.22
56.49	2.70	-.10	-.08	64.81	2.05	.19	.72
56.50	3.22	-.28	-.07	64.87	2.39	-.29	-.70
56.50	2.91	-.72	-.39	64.88	2.53	-.22	-.43
56.50	2.77	.51	.36	64.89	2.66	-.16	-.25
56.51	3.09	-.41	-.15	64.90	2.78	-.18	-.24
56.51	3.03	-.37	-.15	64.91	3.00	-.12	-.10
57.85	1.05	.05	.36	64.91	2.81	-.15	-.18
58.10	1.86	.16	.47	66.58	.54	.06	.05
58.15	2.30	.03	.05	66.59	.51	.05	.01
58.17	2.70	.44	.39	67.40	.63	.06	.18
58.17	2.61	-.08	-.09	68.15	.86	.05	.16
58.18	2.92	-.45	-.27	68.69	1.25	.03	.07



TABLE C-2 SANGAMON RIVER CROSS SECTION 5 JUNE 29 1984 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
68.96	1.65	.01	0.00
69.10	1.97	-.03	-.22
69.17	2.24	-.07	-.30
69.18	2.31	-.06	-.25
69.20	2.38	-.06	-.22
69.22	2.52	-.06	-.18
69.23	2.58	-.07	-.17
69.24	2.70	-.08	-.16
69.24	2.63	-.07	-.17
69.84	.82	.04	.08
70.86	1.62	.01	-.06
70.94	1.75	-.01	-.14
71.00	1.87	-.01	-.17
71.05	1.98	-.02	-.18
71.09	2.09	-.03	-.18
71.12	2.19	-.03	-.19
71.15	2.31	-.04	-.18
71.15	2.28	-.04	-.20
71.16	2.35	-.04	-.18
71.16	2.33	-.04	-.18
71.17	2.40	-.05	-.20
71.17	2.37	-.05	-.20
71.92	1.51	0.00	-.06
73.05	1.28	0.00	-.06
73.19	1.39	0.00	-.10
73.21	1.02	0.00	-.04
73.28	1.47	-.01	-.13
73.28	.79	0.00	-.04
73.31	.58	0.00	-.04
73.45	1.14	0.00	-.09
73.49	.85	0.00	-.06
73.51	1.17	0.00	-.10

TABLE C-3 SANGAMON RIVER CROSS SECTION 3 JULY 9 1984

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)		DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)		DEPTH (FT)	V (FPS)	W (FPS)
2.68		.57	0.00	-.06	13.71		1.05	.10	.11
2.85		.73	-.01	-.11	13.74		.82	.07	.09
2.93		.39	0.00	-.03	13.80		.48	.06	.18
3.70		1.15	-.04	-.22	15.77		1.28	.11	.06
3.80		.91	-.02	-.19	15.78		1.19	.10	.06
3.82		.86	-.01	-.18	15.79		1.02	.06	.04
4.11		.46	-.02	-.05	15.81		.80	.08	.09
4.65		.09	.03	.08	15.86		.49	.08	.19
4.66		1.37	-.08	-.21	18.16		1.69	-.16	-.04
4.73		1.07	-.05	-.25	18.17		1.37	.11	.03
4.77		.96	-.03	-.22	18.18		.99	.08	.04
4.79		.88	-.02	-.19	18.19		.78	.10	.10
4.83		.79	0.00	-.13	18.22		.48	.12	.22
5.20		.30	.04	.17	21.06		1.73	-.29	-.04
5.61		1.46	-.10	-.18	21.07		1.44	.11	.02
5.65		1.19	-.06	-.22	21.08		.96	.11	.04
5.68		1.08	-.04	-.18	21.09		.76	.16	.11
5.71		.71	.03	.13	21.13		.48	.19	.27
5.80		.37	.04	.19	24.98		1.73	-.16	-.02
6.01		.04	.04	.23	24.99		1.09	.08	-.01
6.45		.02	.03	.16	24.99		.93	.17	.03
6.54		1.53	-.13	-.17	25.00		1.77	-.55	-.04
6.57		1.34	-.09	-.20	25.01		.74	.29	.14
6.60		1.15	-.03	-.11	25.02		1.76	-.47	-.04
6.70		.74	.04	.16	25.02		1.49	.09	0.00
6.86		.43	.05	.27	25.03		1.55	.05	-.02
7.22		.06	.03	.17	25.04		.47	.40	.37
7.48		1.52	-.13	-.15	26.12		1.75	-.44	-.03
7.50		1.33	-.06	-.12	26.13		.96	.17	.02
7.62		.76	.05	.17	26.13		.78	.31	.11
7.73		.47	.05	.28	26.14		.53	.46	.31
8.01		.10	.03	.19	27.22		1.56	-.10	-.02
8.42		1.61	-.16	-.13	27.22		.99	.17	.01
8.43		1.42	-.08	-.11	27.24		.81	.33	.09
8.49		.97	.04	.10	27.25		.58	.51	.26
8.54		.77	.05	.16	28.33		1.75	-.29	-.02
8.63		.51	.06	.29	28.34		1.57	-.14	-.02
10.07		1.60	-.19	-.13	28.34		1.01	.16	0.00
10.07		1.50	-.08	-.08	28.34		.84	.36	.07
10.11		1.06	.05	.07	28.35		.62	.58	.22
10.18		.71	.08	.27	29.44		1.57	-.20	-.02
10.25		.45	.06	.29	29.45		1.38	-.15	-.04
11.61		1.60	-.15	-.09	29.46		1.28	-.10	-.04
11.85		.99	.09	.15	29.45		1.02	.16	-.01
11.87		.84	.09	.19	29.45		.86	.39	.05
11.95		.47	.05	.18	29.46		.65	.67	.19
13.71		1.16	.10	.09	30.55		1.62	-.19	-.02

TABLE C-3 SANGAMON RIVER CROSS SECTION 3 JULY 9 1984 - (CONTINUED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
30.56	1.39	.23	.04	51.31	.48	.20	.32
30.56	1.28	.17	.04	51.33	.76	.16	.13
30.56	1.03	.15	.02	51.35	.96	.10	.04
30.56	.87	.44	.04	54.63	.49	.12	.25
30.56	.67	.78	.17	54.65	.79	.10	.10
31.66	1.63	.29	.02	57.39	.51	.08	.21
31.66	1.39	.35	.04	57.42	.81	.07	.08
31.67	1.17	.12	.04	57.44	1.03	.05	.03
31.67	1.04	.13	.03	59.82	.52	.06	.18
31.67	.89	.51	.03	59.87	.84	.05	.07
32.77	1.67	.40	.02	62.04	.53	.05	.15
32.77	1.54	.11	.02	62.09	.87	.05	.08
32.77	1.39	.58	.04	64.11	.54	.04	.18
32.77	1.18	.26	.05	64.16	.77	.04	.10
32.78	1.05	.09	.03	64.19	.95	.03	.05
32.78	.90	.62	.01	65.99	.29	.03	.17
33.88	1.54	.30	.02	66.11	.63	.04	.15
33.88	1.18	.60	.05	67.09	.28	.02	.17
34.99	1.06	.87	.05	67.23	.63	.03	.16
38.17	1.29	.69	.06	67.35	1.48	.06	.08
38.17	1.18	.38	.06	68.17	.26	.02	.16
38.17	.90	.67	.03	68.34	.64	.03	.17
39.62	.69	.99	.19	68.47	1.56	.13	.14
39.63	1.39	.51	.06	68.47	1.46	.07	.11
39.63	1.29	.37	.06	69.24	.24	.02	.16
39.63	1.17	.16	.05	69.44	.64	.03	.18
39.63	1.04	.12	.03	69.53	1.05	.03	.09
39.63	.89	.51	.04	69.57	1.40	.07	.13
39.63	.67	.43	.06	69.58	1.54	.12	.16
41.08	.67	.78	.23	69.59	1.48	.10	.15
41.09	1.53	.50	.05	70.29	.22	.02	.15
41.09	1.48	.42	.05	70.54	.65	.03	.20
41.09	1.28	.22	.05	70.60	.83	.03	.14
41.09	1.03	.14	.01	70.62	.91	.03	.13
42.55	1.47	.30	.05	70.68	1.26	.05	.13
42.55	1.38	.22	.05	70.69	1.41	.09	.17
42.55	1.27	.13	.05	71.34	.18	.02	.12
43.99	.60	.55	.31	71.48	.33	.02	.20
44.00	.99	.16	.01	71.56	.47	.03	.27
44.00	.82	.34	.11	71.63	.59	.03	.24
44.01	1.46	.21	.05	71.67	.70	.02	.11
45.45	.79	.31	.13	71.78	1.09	.03	.14
45.46	1.35	.10	.04	71.81	1.34	.08	.19
45.46	.97	.16	.03	71.82	.12	.01	.07
46.89	.47	.41	.45	72.08	-.03	.02	.11
46.93	.93	.16	.05	72.31	.08	.02	.15
46.93	.74	.29	.17	72.37	-.04	.02	.10

TABLE C-3 SANGAMON RIVER CROSS SECTION 3 JULY 9 1984 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
72.49	.22	.02	.17
72.62	.37	.02	.14
72.88	.92	-.02	-.17
72.92	1.05	-.04	-.21
72.95	1.21	-.06	-.21
72.96	1.24	-.06	-.23
73.10	.20	.02	.13
73.16	.76	-.01	-.12
73.20	.06	.02	.10
73.23	.97	-.03	-.21
73.27	1.15	-.05	-.22
73.45	.64	0.00	-.09
73.50	.05	.02	.08
73.52	.82	-.02	-.19
73.60	1.11	-.05	-.24
73.93	1.03	-.04	-.25
74.25	.93	0.00	-.12
74.55	.82	-.02	-.23
74.83	.64	-.01	-.16
75.08	.51	-.01	-.11

TABLE C-4 SANGAMON RIVER CROSS SECTION 4 JULY 10 1984

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
3.34	.70	0.00	-.07	23.14	1.78	.88	.17
3.98	.98	0.00	-.08	23.15	1.53	.76	.21
5.73	1.38	-.01	-.22	34.03	1.77	.65	.12
5.88	1.17	.02	-.14	35.73	1.77	.51	.13
6.35	.74	.07	.06	37.44	1.48	.67	.32
6.68	.56	.08	.10	39.14	1.44	.56	.35
7.80	1.61	-.02	-.10	40.84	1.37	.46	.38
7.98	.24	.11	.08	40.85	1.90	.82	.31
8.27	.79	.09	.22	40.85	1.67	.29	.15
8.81	1.16	.07	.21	42.54	1.30	.39	.42
9.45	.15	.13	.03	42.55	1.62	.25	.16
9.52	.44	.11	.25	42.56	1.86	.70	.33
9.84	.81	.10	.40	44.23	1.19	.37	.53
11.08	.16	.14	.13	44.26	1.82	.61	.35
11.06	.14	.16	.06	44.26	1.56	.21	.18
11.12	.39	.11	.27	44.27	2.21	.92	.29
11.23	1.39	.10	.22	45.95	1.47	.18	.20
11.49	.77	.11	.53	45.97	1.76	.53	.38
12.16	1.08	.19	.61	45.98	2.18	.80	.30
12.87	.14	.14	.09	47.65	1.37	.16	.23
12.88	1.68	.10	.12	47.67	1.69	.46	.42
12.90	.28	.10	.18	47.68	2.14	.70	.32
12.94	1.30	.19	.41	47.69	2.31	.88	.30
13.21	.63	.09	.40	49.11	.36	.08	.45
13.76	1.45	.20	.32	49.26	.13	.30	.01
13.88	.95	.20	.64	49.34	1.22	.26	.54
14.60	1.56	.23	.28	49.37	1.61	.39	.46
14.66	1.16	.24	.50	49.39	2.28	.77	.32
15.02	.13	.15	.01	49.39	2.10	.62	.35
15.09	.34	.07	.15	51.06	1.49	.34	.53
15.44	1.65	.27	.25	51.09	2.04	.54	.38
15.48	1.31	.22	.34	51.10	2.24	.68	.34
15.64	.71	.12	.45	52.75	1.33	.31	.68
16.29	1.72	.31	.23	52.80	2.20	.59	.37
16.32	1.42	.25	.29	52.80	1.98	.47	.41
16.40	.94	.24	.56	53.18	.13	.37	0.00
17.21	1.10	.30	.48	54.41	1.09	.48	1.72
18.01	1.57	.34	.24	54.50	1.89	.41	.46
18.04	1.22	.28	.33	54.51	2.14	.51	.40
18.87	1.63	.39	.23	55.98	.67	.20	1.48
18.89	1.30	.32	.29	56.19	1.78	.35	.52
19.73	1.37	.37	.27	56.21	2.07	.44	.43
20.57	1.71	.52	.20	56.55	.13	.31	0.00
20.59	1.43	.44	.25	57.88	1.63	.30	.61
21.44	1.47	.52	.23	57.91	1.97	.37	.48
22.28	1.76	.72	.18	59.59	.13	.25	0.00
22.29	1.50	.62	.22	59.61	1.84	.30	.54

TABLE C-4 SANGAMON RIVER CROSS SECTION 4 JULY 10 1984 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	S
59.63	2.22	.80	.77	
61.29	1.67	.22	.57	
61.33	2.12	.67	.86	
62.36	.39	.21	.77	
62.44	.13	.33	.04	
62.94	1.40	.18	.70	
63.05	2.29	.57	.61	
65.16	.16	.26	.22	
65.16	.13	.23	.01	
65.99	.24	.25	.95	
66.72	.50	.19	.72	
67.13	.91	.12	.66	
67.29	1.26	.05	.19	
67.44	1.86	.31	-1.00	
67.45	1.91	.29	.86	
67.46	2.02	.35	.86	
67.46	1.97	.30	.82	
68.46	.39	.17	.46	
68.51	.19	.10	.15	
69.05	.77	.09	.16	
69.33	1.18	.01	.18	
69.33	.32	.10	.26	
69.38	1.30	.08	.85	
69.42	1.40	.11	.93	
69.45	1.50	.13	.88	
69.47	1.59	.16	.91	
70.05	.63	.07	.29	
70.18	.35	.04	.19	
70.21	.20	.01	.14	
70.21	.13	0.00	.14	
70.43	.43	.04	.23	
70.46	1.05	.01	.27	
70.60	1.30	.08	.86	
70.75	.26	.01	.16	
70.88	.66	.03	.11	
71.19	.94	.01	.42	
71.59	.29	0.00	.12	
71.64	.79	.01	.42	
71.80	.54	0.00	.30	
71.86	.56	.01	.53	
71.87	.34	0.00	.26	
71.89	.15	0.00	.24	
71.92	.60	.01	.63	
72.03	.66	.03	.88	
72.14	.40	.01	.71	
72.18	.16	0.00	.65	

TABLE C-5 SANGAMON RIVER CROSS SECTION 5 AUGUST 5 1985

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
5.79	.55	.02	.05	20.39	.64	.08	.33
5.94	.44	.02	.07	22.06	1.52	.06	.03
6.18	1.17	-.01	-.11	22.08	1.18	.08	.08
6.23	1.07	0.00	-.07	22.11	.95	.11	.20
6.44	.74	.02	.08	22.16	.63	.11	.39
6.57	1.21	-.01	-.10	24.00	1.59	.05	0.00
6.61	1.12	0.00	-.07	24.02	1.14	.11	.10
6.66	.52	.02	.11	24.04	.92	.15	.24
6.71	.93	.02	.05	24.09	.61	.16	.48
6.84	.08	.01	.05	24.35	0.00	.01	0.00
6.85	.72	.02	.10	26.19	1.75	-.10	-.05
6.87	.19	.02	.08	26.19	1.41	-.04	-.02
6.93	1.33	-.02	-.11	26.20	1.27	.09	.03
6.94	.33	.02	.11	26.21	1.10	.15	.12
7.06	.51	.02	.13	26.22	.89	.22	.30
7.25	.70	.02	.13	26.26	.60	.25	.61
8.05	.32	.02	.15	28.85	1.60	-.09	-.06
8.32	.18	.02	.12	28.86	1.23	.13	.03
8.50	1.62	-.05	-.12	28.87	1.07	.24	.14
8.51	1.53	-.03	-.10	28.87	.87	.37	.38
8.65	1.03	.03	.14	28.90	.59	.45	.85
8.71	.88	.03	.21	32.75	1.55	-.34	-.10
8.80	.72	.03	.21	32.76	1.20	.15	-.01
8.93	.56	.03	.17	32.76	1.04	.43	.13
9.63	1.70	-.06	-.10	32.77	.85	.84	.48
9.70	1.23	.03	.10	34.08	1.74	-.58	-.07
9.77	1.02	.02	.08	34.08	1.56	-.57	-.11
10.18	.39	.03	.16	34.08	1.46	-.42	-.12
10.68	1.68	-.04	-.07	34.08	1.35	-.20	-.10
11.19	.39	.03	.18	35.08	1.07	.46	.07
11.68	1.75	-.05	-.06	35.40	1.36	-.51	-.12
11.77	1.14	.03	.09	35.40	1.09	.50	.02
12.15	.39	.03	.19	36.72	1.24	-.66	-.12
12.73	1.09	.03	.11	36.73	1.10	.53	-.03
12.83	.79	.04	.23	39.42	1.10	.72	-.03
13.62	1.26	.03	.06	41.60	1.57	-.52	-.08
13.67	1.05	.04	.12	41.60	1.47	-.10	-.06
15.31	1.16	.03	.06	41.60	1.23	.10	-.06
15.36	.95	.06	.24	42.69	1.22	.16	-.04
16.94	1.23	.06	.12	42.69	1.06	.50	.05
16.97	1.07	.08	.20	42.69	1.56	-.32	-.07
17.06	.67	.05	.24	43.78	.85	.86	.35
18.58	1.40	.06	.07	43.79	1.55	-.20	-.07
18.59	1.28	.08	.11	43.79	1.45	-.12	-.07
20.27	1.51	.06	.03	43.79	1.20	.20	-.02
20.29	1.23	.06	.06	47.92	.59	.50	.70
20.32	.98	.08	.17	43.79	1.20	.20	-.02

TABLE C-5 SANGAMON RIVER CROSS SECTION 5 AUGUST 5 1985 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
47.96	1.07	.27	.11	66.62	.91	.05	.20
47.97	1.23	.16	.02	66.74	.22	.05	.15
47.97	.87	.39	.30	66.95	.32	.05	.22
47.98	1.49	.04	-.03	67.15	.43	.05	.20
47.98	1.37	.09	-.02	67.33	.55	.05	.15
50.50	0.00	.02	0.00	67.85	1.27	0.00	-.13
50.70	.60	.28	.55	67.88	1.33	-.02	-.20
50.73	.90	.24	.25	67.91	1.45	-.05	-.26
50.75	1.11	.18	.10	67.93	1.51	-.06	-.29
50.76	1.41	.09	0.00	67.96	1.62	-.08	-.27
50.76	1.27	.13	.03	67.98	1.76	-.09	-.19
52.93	.62	.19	.45	69.29	1.01	.01	-.15
52.98	.92	.17	.22	69.37	1.10	0.00	-.18
53.01	1.32	.11	.04	69.48	.55	.01	-.01
54.87	.63	.14	.40	69.49	.81	.01	-.07
54.93	.95	.13	.20	69.59	.91	.01	-.09
54.95	1.18	.11	.09	69.61	.63	.01	-.02
56.63	.63	.11	.36	69.75	.71	.01	-.03
56.70	.98	.11	.19	69.78	1.12	0.00	-.11
56.74	1.23	.10	.10	69.94	1.34	-.01	-.13
56.75	1.42	.14	.11				
58.28	.64	.09	.33				
58.37	1.02	.10	.19				
58.40	1.28	.13	.17				
58.41	1.39	.13	.15				
59.85	.64	.08	.32				
59.96	1.05	.13	.31				
59.99	1.22	.12	.23				
61.48	.92	.12	.43				
61.53	1.13	.07	.15				
62.66	.32	.06	.32				
62.93	.69	.08	.41				
63.05	.99	.07	.26				
63.11	1.22	.07	.16				
64.24	.28	.05	.29				
64.63	.68	.07	.38				
64.81	1.03	.07	.25				
64.89	1.31	.05	.13				
65.51	.67	.07	.35				
65.73	1.06	.07	.28				
65.83	1.41	-.02	-.12				
65.86	1.55	-.06	-.18				
65.87	1.62	-.07	-.17				
65.88	1.74	-.13	-.20				
65.88	.24	.05	.24				
66.43	.65	.06	.30				
66.54	.78	.06	.27				



TABLE C-6 SANGAMON RIVER CROSS SECTION 6 AUGUST 6 1985

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
4.21	.12	0.00	-.38	22.48	1.99	-1.07	-.57
4.23	.33	0.00	-.40	22.48	1.94	.38	.23
4.29	.54	-.01	-.44	22.49	1.70	.87	.98
4.43	.12	0.00	-.28	22.51	1.46	.28	.50
4.65	.12	0.00	-.17	24.09	1.56	.34	.44
4.66	.26	0.00	-.17	24.08	1.76	1.04	.99
4.75	.56	0.00	-.22	25.07	1.10	.79	.04
4.96	1.14	-.05	-.66	25.66	2.00	.51	.20
5.00	1.09	-.04	-.79	25.67	1.64	.40	.40
5.51	1.35	-.11	-1.11	28.05	1.10	.66	.08
5.69	1.02	0.00	-.71	28.86	1.58	1.10	.97
5.87	.81	0.05	-.33	30.44	1.78	.66	.33
5.97	.30	.02	.11	32.05	1.30	.99	1.14
6.00	.40	.04	.14	32.50	1.10	.31	.32
6.33	.24	.02	.12	35.22	1.20	1.18	1.20
6.35	.31	.04	.15	55.19	.96	.80	1.01
6.40	1.62	-.23	-1.24	57.71	1.57	1.01	.60
6.40	.47	.11	.24	57.70	1.40	1.13	.92
6.69	.25	.05	.14	58.81	.45	.12	.88
6.73	.69	.08	-.94	58.94	1.34	.92	.98
6.91	.71	.17	-.33	58.95	1.53	.83	.62
7.14	.55	.24	.45	59.25	1.10	.32	.01
8.05	.15	.13	.12	60.19	1.25	.74	1.05
8.28	1.29	.01	-.44	60.20	1.48	.68	.66
8.49	.86	.19	-.19	61.44	1.40	.56	.70
9.01	.14	.32	.27	62.40	.34	.11	.88
9.75	1.99	-.67	-.98	62.53	1.10	.33	.02
9.91	.11	.37	.09	62.68	1.31	.45	.76
9.94	1.08	.03	-.68	62.70	1.53	.84	.93
11.34	2.10	-.90	-.76	63.90	1.18	.37	.88
12.44	.11	.73	.32	63.93	1.45	.69	1.01
12.93	2.15	-1.16	-.68	64.70	.25	.19	.64
11.45	1.25	-.02	-.42	64.74	1.10	.41	.01
12.98	1.54	-.29	-1.01	66.75	1.16	.30	.77
13.00	1.37	-.19	-.97	66.75	1.10	.49	.01
14.54	1.71	-.43	-.89	68.66	1.10	.55	.01
14.58	1.59	-.36	-.96	70.51	1.10	.32	.01
14.57	1.45	.18	.53	74.33	1.16	.36	.33
14.95	.10	.69	.01	74.33	1.12	.34	.07
16.13	1.82	-.56	-.78	72.39	1.11	.41	.51
19.30	1.83	.27	.28	74.33	1.10	.09	0.00
19.33	1.49	.60	1.28	74.97	1.14	.31	.22
19.84	.10	.88	.25	75.62	1.19	.29	.44
20.89	2.00	-1.02	-.58	75.55	.44	.32	1.22
20.89	1.89	.32	.25	75.63	1.13	.16	.04
20.91	1.61	.73	1.10	76.31	1.16	.15	.08
22.38	.10	.91	.03	76.29	.31	.28	.67

TABLE C-6 SANGAMON RIVER CROSS SECTION 6 AUGUST 6 1985 - (CONCLUDED)

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
77.02	.23	.14	.14
77.75	.37	.13	.18
80.81	.12	0.00	-.06

TABLE C-7 SANGAMON RIVER CROSS SECTION 8 AUGUST 8 1985

COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)	DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
6.86	2.64	.01	-.13	15.39	2.84	-.27	-.73
6.98	2.46	0.00	-.13	15.42	2.68	.02	-.02
7.05	2.37	0.00	-.12	16.49	1.16	.53	.47
7.13	2.28	.01	-.07	16.59	.74	-.01	.16
7.68	3.01	-.04	-.19	16.66	2.99	-.40	-.68
7.72	2.82	-.04	-.33	16.68	2.74	.07	.14
7.75	2.76	-.04	-.37	17.93	3.08	-.54	-.62
7.77	2.69	-.02	-.36	17.93	2.99	-.08	-.12
8.10	-.04	0.00	.03	18.34	1.15	.58	.26
8.83	1.71	.09	.08	18.48	.70	-.02	.20
8.96	3.14	-.13	-.34	20.13	1.15	.61	.17
9.01	2.86	-.16	-.89	20.32	.67	-.02	.25
9.19	1.58	.09	.12	20.48	3.20	-.85	-.53
9.29	2.27	.06	-.89	20.51	2.75	.47	.86
9.48	2.06	.14	-.53	21.77	3.07	.57	.46
9.48	-.08	-.01	.04	21.78	2.86	.57	.75
9.51	1.35	.03	.06	21.92	1.15	.47	.57
9.54	1.48	.09	.10	22.17	.64	-.03	.28
9.71	1.87	.20	.09	23.04	3.22	-.22	-.10
10.24	3.19	-.34	-.60	23.05	3.12	.68	.42
10.25	3.09	-.37	-.90	23.05	2.94	.69	.68
10.44	2.44	.04	-.57	23.75	1.15	.46	.23
10.56	1.30	.10	.12	24.10	.60	-.04	.32
10.56	1.21	.01	.06	24.32	3.25	-.32	-.09
10.60	1.48	.24	.42	24.34	2.82	.83	.93
10.64	1.92	.26	.20	25.60	3.19	.97	.37
11.48	1.22	.12	.10	25.61	3.05	1.00	.58
11.48	3.15	.01	.06	25.70	1.15	.38	.36
11.52	3.05	-.63	-1.11	26.19	.56	-.05	.33
11.54	1.53	.35	.96	26.89	3.29	-.37	-.08
11.78	.18	-.01	.09	28.18	2.66	1.01	1.04
11.93	2.05	.26	.80	28.44	1.15	.24	.63
12.31	1.18	.29	.23	29.45	3.28	.14	.02
12.45	.53	-.01	.10	29.45	3.28	.14	.02
12.79	3.24	-.92	-.99	30.73	3.29	.16	.02
12.92	2.54	-.08	-.83	52.25	1.15	.44	.39
13.08	1.24	.40	.48	54.67	.58	-.05	.38
13.14	.78	-.01	.10	55.16	1.15	.53	.10
13.46	.14	-.01	.13	55.34	2.89	1.09	.94
13.80	1.26	.44	.91	56.68	3.00	.86	.65
13.80	1.17	.35	.12	56.88	.63	-.04	.36
13.87	.76	-.01	.11	57.21	1.15	.53	.22
13.99	.47	-.01	.14	58.01	2.94	.71	.70
14.22	.12	-.02	.15	59.15	1.15	.53	.56
14.24	2.36	.22	.95	59.35	2.86	.59	.78
14.48	1.16	.38	.10	59.36	3.13	.10	.07
14.49	1.32	.45	.98	59.36	3.07	.65	.52

TABLE C-7 SANGAMON RIVER CROSS SECTION 8 AUGUST 8 1985 - (CONCLUDED)  
 COMPUTED SECONDARY VELOCITY

DISTANCE (FT)	DEPTH (FT)	V (FPS)	W (FPS)
60.67	2.75	.48	.89
60.69	3.00	.54	.58
60.70	3.20	.88	.54
60.86	.71	.02	.28
61.03	1.15	.61	.33
62.02	2.91	.44	.66
62.03	3.08	.04	.04
62.04	3.15	.71	.58
62.79	.75	.02	.23
62.91	1.15	.66	.26
63.34	2.78	.38	.82
63.36	2.89	.08	.12
63.37	3.08	.55	.64
63.38	3.16	-1.07	.94
64.67	2.74	.09	.19
64.70	2.98	.41	.70
64.86	1.07	0.00	.13
64.87	1.15	.70	.14
65.95	2.49	.17	.60
66.00	2.68	.05	.09
66.02	2.84	.28	.76
66.50	.13	.02	.15
66.98	1.16	.54	.16
67.26	.14	.02	.18
67.69	1.24	.49	.99
68.40	.83	.01	.11
68.44	1.16	.17	.10
69.25	1.21	.33	.25
70.11	1.28	.30	.39
70.80	1.90	.29	.34
71.04	1.45	.28	.52