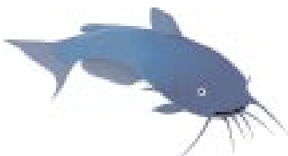
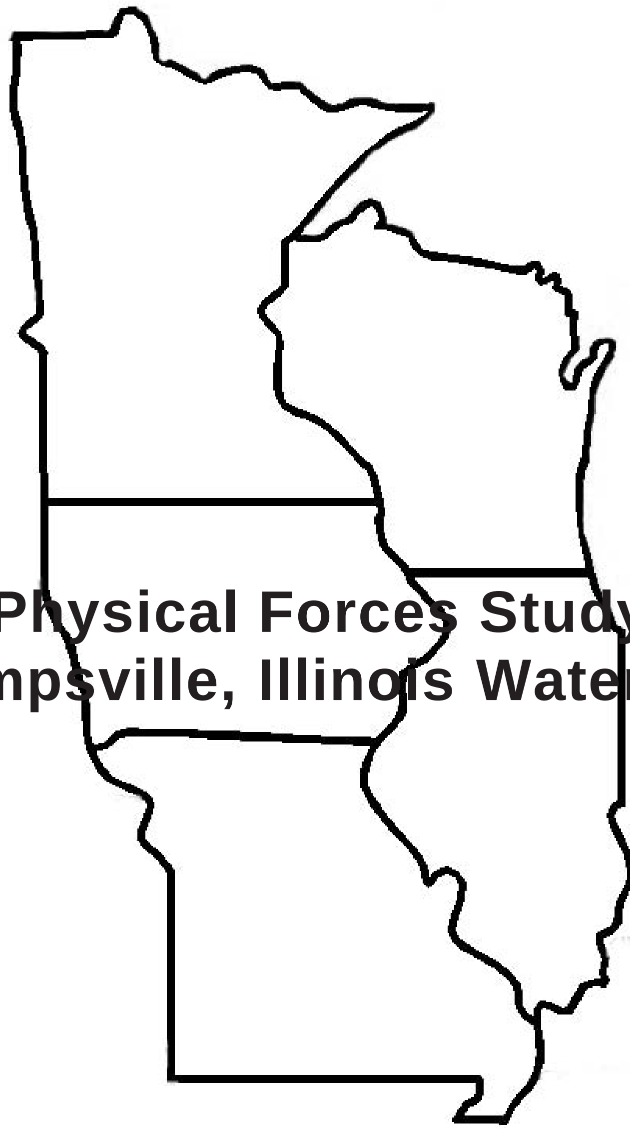
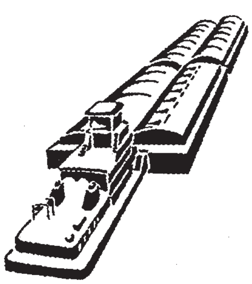
ENV Report 3

# Interim Report For The Upper Mississippi River - Illinois Waterway System Navigation Study





## Physical Forces Study, Kampsville, Illinois Waterway



September 1997


Rock Island District
St. Louis District
St. Paul District

US Army Corps
of Engineers

ENV Report 3
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# Physical Forces Study, Kampsville, Illinois Waterway

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Interim report



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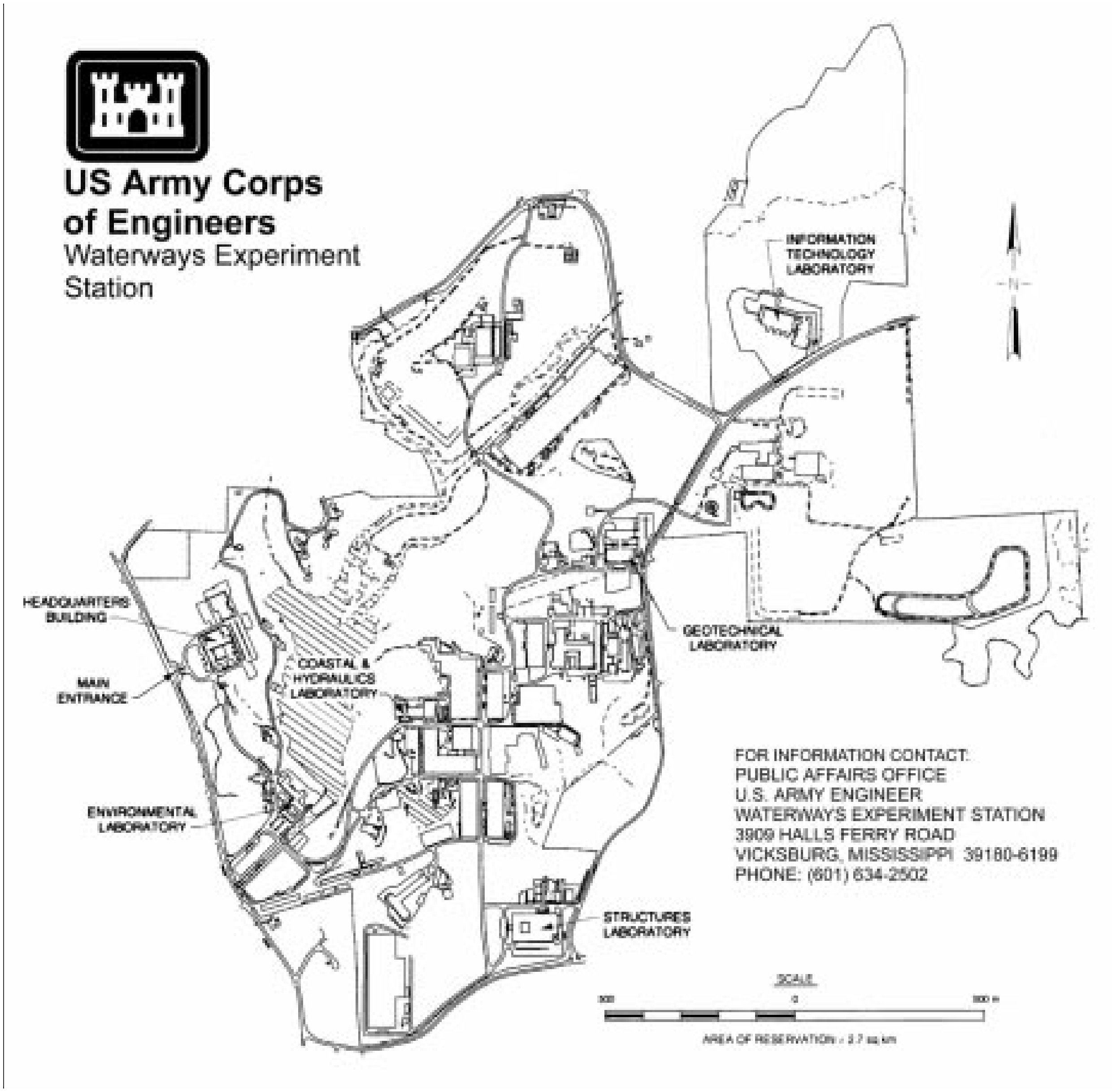


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# Contents

# Preface

The work reported herein was conducted as part of the Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study. The information generated for this interim effort will be considered as part of the plan formulation process for the System Navigation Study.

The UMR-IWW System Navigation Study is being conducted by the U.S. Army Engineer Districts of Rock Island, St. Louis, and St. Paul under the authority of Section 216 of the Flood Control Act of 1970. Commercial navigation traffic is increasing, and in consideration of existing system lock constraints, will result in traffic delays that will continue to grow into the future. The system navigation study scope is to examine the feasibility of navigation improvements to the Upper Mississippi River and Illinois Waterway to reduce delays to commercial navigation traffic. The study will determine the location and appropriate sequencing of potential navigation improvements on the system, prioritizing the improvements for the 50-year planning horizon from 2000 through 2050. The final product of the System Navigation Study is a Feasibility Report, which is the decision document for processing to Congress.

The work was performed by personnel of the Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES) during 1994-1996. The study was under the direction of Mr. Frank A. Herrmann, Jr., Director, Hydraulics Laboratory (HL); Mr. Richard A. Sager, Assistant Director, HL; and Dr. Larry L. Daggett, Chief of the Navigation Division (HN), HL. The study was conducted by Dr. S. T. Maynord and Dr. S. K. Martin, both of the Navigation Effects Group, HN.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin, and the Commander was COL Robin R. Cababa, EN.

# 1 Introduction

## Background

The Upper Mississippi River-Illinois Waterway System (UMR-IWWS) Navigation Study evaluates the justification of additional lockage capacity at sites on the UMR-IWWS while maintaining the social and environmental qualities of the river system. The system navigation study is implemented by the Initial Project Management Plan (IPMP) outlined in U.S. Army Engineer Districts, St. Paul, Rock Island, and St. Louis (1994). The IPMP outlines Engineering, Economic, Environmental, and Public Involvement Plans.

The Environmental Plan identifies the following: significant environmental resources on the UMR-IWWS; the impacts to threatened and endangered species; water quality; recreational resources; fisheries; mussels and other macro invertebrates; waterfowl; aquatic and terrestrial macrophytes; and historic properties. In a preliminary way the plan also considers the systemwide impacts of navigation capacity increases, while assessing potential construction effects of improvement projects. The physical forces studies are part of the Environmental Plan.

## Physical Forces Objectives

According to the IPMP the objectives of the physical forces studies are as follows:

*a.* Use Illinois State Water Survey (ISWS) field data to calibrate and validate the physical model.

*b.* Increase density of field measurements to refine their spatial distribution.

*c.* Make a range of measurements which could not be made in the field.

*d.* Expand measurements to different cross sections.

*e.* Carry out statistical data analyses.

*f.* Develop models by combining existing field data with new data developed from physical model.

*g.* Evaluate the feasibility of developing numerical solutions.

## Scope of Report

The Kampsville site was one of several sites used in the physical model to achieve the physical forces objectives outlined in the previous paragraph. (Several references are made to the Clark's Ferry site on the Mississippi River, the second site examined.) Specifically, the Kampsville site study evaluated the far field velocities and drawdown induced by underway tows. Far field refers to all areas except those beneath and immediately adjacent to the tow. The Kampsville study gives primarily the following: physical force data, an understanding for developing analytical models, and numerical model verification of far field effects.

# 2 Prototype Kampsville

## Prototype Data Collection

ISWS collected physical data on the hydrodynamic changes associated with tow and barge traffic movement on the UMR-IWWS. These data were collected from the Illinois and Mississippi Rivers. A detailed report on the Kampsville prototype investigation is found in Bhowmik, Soong, and Xia (1993).

The Kampsville site is located on the IWWS at river mile (RM) 35.2 in a relatively straight reach (Figure 1). A reconnaissance trip, before the actual field data collection, gathered information on site characteristics, bathymetry, cross-sectional profiles, discharge, suspended sediment, and bed materials. The actual field data collection trip included collecting data on ambient conditions and during an event. Data were taken for three periods relative to each tow event: (a) pre-passage, (b) actual passage, and (c) post-passage. Trip 1 field data were collected for seven consecutive days (October 11-17, 1990), and trip 2 for three consecutive days (August 13-15, 1991). Trip 2 collected wave and velocity data especially during evening hours when water surface was calm. Figures 2 and 3 show cross sections for trips 1 and 2, respectively.

## Instrumentation

Data were collected with (a) two Interocean current meters (model S4's), (b) two Marsh McBirney (MMB) 527 velocity meters, (c) four MMB511's, and (d) one wave gauge. The instruments were placed in the experiment reach for data collection. Velocity data in both the x- and y-directions were sampled at one sample per second. Positive x-velocities were downstream and positive y-velocities were toward the left bank. Wave data were sampled at 10 samples per second.

For trip 1, velocity meters were deployed as shown in Figure 2. The three MMB511's at 33.5 m from the right bank were mounted at vertical heights of 0.31, 1.22, and 2.44 m above the riverbed. These MMB511 meters were utilized to measure the variations of horizontal velocity components at various heights above the bed. The trip 1 wave gauge was 11.3 m from the right bank.

For trip 2 the velocity was measured at locations shown in Figure 3. Three MMB511's were mounted at vertical heights of 0.46, 1.31, and 2.13 m above the riverbed 22.9 m from the right bank. The trip 2 wave gauge was 9.1 m from the right bank.

Discharges and stages were measured at different times during trip 1 and trip 2. Table 1 shows discharges, average channel velocities, average flow depths, and water-surface elevations.

The average water-surface slope on this reach was 0.196 m/km (0.096 ft/mile) during trip 1 and 0.051 m/km (0.025 ft/mile) during trip 2. These slopes are determined by the daily stages at Hardin, IL, RM 21.6 and Pearl, IL, RM 43.1.

## Events

Trip 1 monitored 25 barge trips and trip 2 monitored 22 barge events. Tables 2 and 3 (trips 1 and 2, respectively) give the name, date, draft, barge configuration, tow speed relative to earth, distance from the center line of the tow to the bank, and the tow direction.

## Analysis of Data

Prototype and physical model data contained velocity and water level changes not caused by the tow. These changes included the normal fluctuations found in turbulent flow, eddies shedding from upstream bends, and changes from upstream structures or tributaries. Comparisons between the model and prototype must be based on tow-induced motion and not on extraneous components found in both prototype and physical model. Filtering out unwanted information, if a limiting frequency can be identified, is one alternative. Since prototype tows are generally 300 m long and travel at about 3 m/sec, the time the tow is adjacent to the measuring point is about 100 sec, which roughly defines the period of the event and leads to a frequency of 0.01-Hz interest. To make certain that tow information is not filtered, a limiting frequency of 0.02 Hz was selected for filtering the data. Filtering out fluctuations above a certain frequency was needed because model velocity, prototype velocity, and wave meters had different frequency responses. For example, the prototype electromagnetic velocity meters sampled at 1 Hz, but the acoustic Doppler velocity meters used in the physical model sampled at 25 Hz, equivalent to 5 Hz in the prototype. A fast Fourier transform (FFT) filtered out components of velocity or drawdown occurring at frequencies greater than 0.02 Hz in both the prototype and the physical model. The physical model was filtered after scaling values to their prototype equivalent. Plots are presented in Figures 4 to 12 of unfiltered and filtered data from the *William C. Norman* prototype tow. These plots suggest that under the trip 1 flow and pool elevation, ambient conditions in the Illinois River vary significantly due to long period variations that have frequencies similar to the tow event.

## Tows Selected for Comparison with Physical Model

Six prototype tows were selected for comparison with the physical model. Selection was based on the following:

*a.* *Number of meters functioning during experiments*. Some tows were not used because one or more meters malfunctioned.

*b.* *Tow configuration and draft*. To simulate tow events producing the maximum deviation from ambient conditions, only 3-wide by 4- or 5-long, loaded barges were used in the adjustment/calibration of the physical model. Events producing the maximum deviation from ambient were desired so the model would correctly reproduce the worst river conditions. Also note that the 3-wide by 5-long, loaded tow is a standard configuration.

The six tows selected were *William C. Norman, Rambler, Charles Lehman,* and *Mr. Lawrence* from trip 1 and *Jack D. Wofford* and *Olmstead* from trip 2.

## Definitions

Experiment result terms are defined as follows:

*a.* The terms “left bank” or “right of the thalweg” refer to positions in the cross section when looking at the cross section in a downstream direction.

*b.* Ambient velocity is the velocity measured without tow traffic effects but close enough to the tow passage to eliminate variations due to flow and/or stage changes. In the Illinois Waterway at Kampsville, the prototype data presented for the *William C. Norman* suggest that ambient velocity should be measured over at least 5 minutes to obtain a representation of the mean.

*c.* Impact velocity is the maximum velocity or minimum velocity that occurs during the tow event for a given mechanism. For example, the impact velocity from return currents would be the maximum velocity (for upbound tows) or minimum velocity (for downbound tows) that occurs adjacent to the vessel. The return velocity is the difference between the impact velocity and the ambient velocity.

## Variation in Prototype Data

It is important to recognize that the prototype data in the verification process are subject to variation caused by measurement inaccuracy in tow speed, tow draft, tow position, tow alignment, water velocity, water level variation, and ambient discharge. Also of concern is the following: lack of knowledge about the propeller speed, applied horsepower, shape of the barge bow, and whether the physical model had a straight constant cross section whereas that of the prototype varied longitudi- nally. All barges in the prototype verification experiments were reported to have a 2.74-m draft. The writers' experience suggests that the draft of the loaded barges could have been ± 0.15 m (6 in.). Tow alignment relative to the river axis could be skewed by several degrees resulting in an effective tow width greater than the sum of the widths of the barges. To screen the prototype data for possible inconsisten- cies, the Schijf (1949) equation was used to compute the average return velocity and drawdown (Table 4). Therefore, consider that the Schijf equation provides a cross- sectional average return velocity and the prototype data are near-bottom velocity data from which a maximum value was extracted. The prototype data for each tow event were examined for a similar ratio of maximum observed return velocity/Schijf average return velocity. The filtered data from each prototype velocity meter were analyzed for the maximum return current/Schijf average return current (Table 5). For the Kampsville site, meters not close to the channel boundary were expected to have similar values for a given tow event. Meters 332, 642, 1000, 999, 040, and 071 were not close to the boundary. Meters 999 and 1000 were also expected to give similar results because they were at the same lateral position and are away from the channel perimeter. The only data that are clearly suspect are *Olmstead* meter 1000 and *Mr. Lawrence* meter 1000 because they differ significantly from the other meters for that tow event. The other meters gave similar values as expected.

It is not possible to define the variability of the prototype data by comparing the same event run numerous times as will be done in the physical model experiments. However, two tow events, the *Jack D. Wofford* and the *Olmstead*, were nearly identical in speed, direction, distance from right bank, draft, configuration, channel cross-sectional area, and flow rate. As shown in Table 5, these two tows produced similar values at all meters.

The variation of the ambient velocity about the mean from the filtered data could establish the significance of tow-induced changes. For example, if natural stream velocity variations over periods about 100 sec (100 sec based on period of tow event) are ± 5 cm/sec, one might conclude that tow-induced changes less than 5 cm/sec are no different from the natural variations. The filtered prototype data were analyzed for the maximum and minimum values prior to any tow effects. The relative ambient velocity variation was found by dividing the difference between maximum and minimum values by two and then dividing by the mean ambient velocity (Table 6). Using an average value from Table 6 as a guide, natural velocity fluctuations (with periods similar to a tow event period) fluctuate about the mean ambient current an average of ±12 percent.

# 3 Physical Model Description

## Similitude

Similarity of form resistance, flow patterns, and water surface changes in navigation models is best achieved when the ratio of inertia to gravitational forces is the same in model and prototype. This ratio, the Froude number *F*, is defined as

$$F = \frac{V}{\sqrt{gD}} \tag{1}$$

where

$V$ = generally the vessel speed

$g$ = gravitational constant

$D$ = characteristic length such as depth, draft, or vessel length

The equations of hydraulic similitude, based on the Froude criteria, express the mathematical relations between the dimensions of hydraulic model and prototype quantities. General relations for transferring 1:25 scale model data to prototype equivalents are as follows:

| Characteristic | Dimension[1] | Scale Relations Model: Prototype |
|---|---|---|
| Length | $L_r = L_p/L_m$ | 1:25 |
| Area | $A_r = L_r^2$ | 1:625 |
| Velocity | $V_r = L_r^{1/2}$ | 1:5 |
| Time | $T_r = L_r^{1/2}$ | 1:5 |
| Discharge | $Q_r = L_r^{5/2}$ | 1:3,125 |
| Roughness Coefficient | $N_r = L_r^{1/6}$ | 1:1.71 |
| Force | $F_r = L_r^3$ | 1:15,625 |
| Revolutions or frequency | $R_r = 1/L_r^{1/2}$ | 5:1 |

[1]Dimensions are in terms of length.

However, viscous forces cannot be neglected in physical navigation models. If interest is in the forces on a vessel (for example, towing tank studies), the relatively higher viscous forces in the physical model cause greater frictional resistance on the model vessel. If the interest is in the forces the vessel imposes on the waterway (such as this study), the relatively higher viscous forces in the model cause the model vessel to be effectively larger than the prototype vessel due to the larger boundary layer effects. The following section on model calibration will show how this model dissimilarity is overcome.

## Model Flume and Appurtenances

The navigation effects flume (Figures 13 and 14) is 125 m long, 21.3 m wide, and has a maximum 1.22-m depth. The last 1.52 m on both ends has a 2.13-m depth. Ten pumps, each having an approximate discharge capacity of 0.16 cu m/sec, recirculate flow through the flume. A sharp-crested overflow weir at the upstream end of the flume evenly distributes the flow across the flume.

The center 61 m of the flume was used for the 1:25-scale Kampsville experiment site. Marine plywood sections were installed to form a composite cross section representing conditions at mile 35.2 on the Illinois River. The upstream end of the plywood section had curved entrance walls for a smooth transition into the experiment section. The data collected by the Illinois River Hydrographic Survey on 6/22/88 and the data collected by ISWS on 10/15/90 and 8/8/91 determined the composite cross section. This composite section was heavily weighted toward the ISWS data. The coordinates of the physical model section are as follows:

| **Distance from Thalweg , m** | **Elevation**[1] |
|---|---|
| -213.0 (top of left bank) | 428.0 |
| -152.5 | 409.0 |
| -61.0 | 406.5 |
| 0.0 (Thalweg) | 406.5 |
| 61.0 | 406.5 |
| 100.6 | 410.0 |
| 155.5 (top of right bank) | 428.0 |

[1] All elevations (el) cited in this report are in feet referred to the National Geodetic Vertical Datum (NGVD). To convert to meters, multiply by 0.3048.

This cross section was used along the full length of the 61-m-long plywood section.

The 1:25-scale towboat (Figure 15) was modeled after the Corps' Motor Vessel (MV) *Benyaurd* and is 52 m long by 12.3 m wide by 2.74-m draft. The model towboat is equipped with two main and four flanking rudders, open-wheel 2.74-m diameter propellers, and can be radio controlled for self-propelled operation. The 1:25-scale sheet metal barges simulated 59.5-m-long by 10.7-m-wide barges with variable draft. Individual barges were connected by C-clamps to form the desired tow configuration. All barges had boxed ends except the lead barge the bow of which had a raked end. All experiments (except a limited series of experiments to evaluate the effects of the rake angle) were run with an 0.8-rad (45-deg) rake on the lead barge.

A towing carriage maintained consistent speed and alignment for the model tow and operated on steel rails set to grade that extended the length of the flume. The connection between the tow and the towing carriage was designed to allow complete freedom of vertical movement, push the tow at one point near the center of gravity, and maintain the desired tow alignment (Figure 16).

This study focuses on the far field effects of the tow. A previous study by Maynord (1990) conducted with and without propeller operation suggests the propeller has little impact on far field flows in these channel sizes. Analysis of the flow amount passing through the propellers shows that about 2 percent of the waterway is passing through the propellers, which suggests limited impact on far field effects. The present study began with a series of experiments to further evaluate the effects of propeller flows on far field velocity and drawdown. Results of the physical model experiments suggested little impact but were not conclusive enough to conduct experiments without propeller operation. So, the speed to operate the propellers was a problem since prototype data collected by ISWS did not include the power or revolutions per minute (RPM) in the prototype experiments. The method used in the study described in this report first calibrated the model towboat bollard push (push when speed = 0) against propeller speed and applied voltage on a d-c power supply. Next an equation was applied that was developed by Toutant (1982) defining the bollard push for an open-wheel propeller as

$$BP_o = 23.57(Hp)^{0.974} \tag{2}$$

or for a kort nozzle as

$$BP_k = 31.82(Hp)^{0.974} \tag{3}$$

where *BP* is the bollard push in pounds and *Hp* is the total towboat horsepower. Knowing towboat horsepower from the ISWS data, the BP was computed using the Toutant equations. This BP provided an upper limit for a given horsepower towboat. The power setting, with some adjustment for tow speed, used 75 percent of the upper limit in most experiments. This approximate method is appropriate for far field experiments but will not be used in subsequent physical forces studies that address the near field area beneath and immediately adjacent to the tow.

## Instrumentation

Wave heights were measured with two wave gauges in the nearshore zone on both channel sides. The wave gauges were capacitance type gauges manufactured at the U.S. Army Engineer Waterways Experiment Station.

Velocity measurements were taken using eight acoustic Doppler velocimeters (ADV's) (Kraus, Lohrmann, and Cabrera 1994). Six probes were three-dimensional (3-D) and two were two-dimensional (2-D) side-looking probes that measured velocity in the horizontal plane. One and sometimes two of the 3-D probes were upward-looking probes and the remainder were downward-looking probes. The ADV’s took data approximately 5 cm from the transmit and receive transducers. The side-looking 2-D probes were needed for shallow-water velocities since the 3-D probes would not work in shallow water due to the 5-cm offset. The ADV's use acoustic sensing techniques to measure flow in a remote sampling volume. No cables enter in the water, and the measured flow is relatively undisturbed by the presence of the probe. Data are available at an output rate up to 25 Hz. The horizontal velocity range is ±2.5 m/sec and no zero-offset in the velocity output. Data can be collected as close as 5 mm from a solid boundary. The ADV's require certain size particles present in the water to measure the water velocity. Hollow glass spheres having a mean diameter of 10 microns and specific gravity slightly greater than one were used as the seed material in the model. Using low or no ambient velocity causes a problem since the seed will settle to the bottom while waiting for the model to stop moving as a result of distributing the seed. However, this was not a major problem because ambient velocities were high enough to keep the seed in suspension. Positive x-velocities were downstream and positive y-velocities were toward the left bank.

The ADV's and the wave gauges were positioned at approximately the midpoint of the plywood experiment section at station 62 (62 m from downstream end of concrete flume). A wave gauge and 2-D and 3-D ADV's are shown in Figure 17.

When the physical model was selected for studying navigation effects on the UMRS, the ambient conditions in the physical model were envisioned as free from the significant variations observed in the prototype data. This was not the case since the model had significant variations in ambient conditions. These variations were attributed to pump variations, eddies in the approach and exit to the plywood experiment section, and long-period oscillations in the basin set up by vessel movement. To overcome these variations, the physical model data were filtered like the prototype data. After scaling the physical model data to its prototype equivalent, an FFT filtered out all data frequency greater than 0.02 Hz.

# 4 Model Calibration

## Introduction

Model calibration adjusted parameters in the physical model until the physical model and the ISWS prototype data agreed. The following three areas are suspected of causing differences between the model and prototype:

*a.* The physical model needs adjustment because the boundary layer along the vessel and along the channel perimeter grows faster in the physical model than in the prototype. This phenomenon occurs in all physical navigation models operated according to the previously presented Froudian scaling criteria. By using equal Froude numbers in a navigation model that is smaller than the prototype, the Reynolds number will be smaller in the model than in the prototype. The smaller Reynolds number in the model results in a faster growing boundary layer that causes the tow's effective size to be larger than in the prototype. To quantify the boundary layer effects, the displacement thickness is computed. This thickness indicates the distance by which the external streamlines are shifted owing to the formation of the boundary layer. Using the Prandtl-Schlichting skin friction equation for a smooth flat plate at zero incidence (Schlichting 1968) and computing the displacement thickness results in the following derived equation

$$\mathrm{d}_l = \frac{0.292L}{[\mathrm{Log}(R_L)]^{2.58}} \qquad (4)$$

where

$\mathrm{d}_l$ = displacement thickness

$L$ = plate length, set equal to the total barge length herein

$R_L$ = plate Reynolds number defined as $VL/\mathrm{n}$

$V$ = free stream velocity set equal to vessel speed relative to the water and determined from $V = V_s + V_r + V_a$

$V_s$ = vessel speed relative to the ground

$V_r$ = average return velocity from Schijf

$V_a$ = ambient velocity, positive for upbound, negative for downbound

n = kinematic viscosity of water

In an unpublished study, a 1:37.5-scale navigation effects model was adjusted by reducing the draft of the barges to account for the dissimilarity of boundary layer. This comparison between model and prototype was approximate because the channel shape was a rough representation. Vessel length was 304.8 m. The required draft correction $D_C$ is shown in the following tabulation.

| **River** | **Vessel Speed m/sec** | **Return Velocity m/sec** | $D_c$ **m** | $\delta_{1m}$ **m** | $d_{1p}$ **m** | $d_{1m}$ - $d_{1p}$ **m** | $D_c/d_{1m} - d_{1p}$ |
|---|---|---|---|---|---|---|---|
| Ohio | 3.30 | 0.10 | 0.46 | 0.70 | 0.31 | 0.39 | 1.18 |
| Illinois | 2.77 | 0.19 | 0.69 | 0.72 | 00.31 | 0.41 | 1.68 |

$d_{1p}$ = prototype displacement thickness
$d_{1m}$ = model displacement thickness *37.5

Model and prototype temperatures were 10 and 20 °C, respectively. In this tabulation all the dissimilarities between boundary layer on the vessel and the channel perimeter have been lumped into conditions on the vessel. The draft correction can be computed from

$$D_C = C(d_{1m} - d_{1p}) \tag{5}$$

$$d_e = d_a + D_C \tag{6}$$

where $C$ is a coefficient that must be determined experimentally. Adding $D_C$ to the actual model draft $d_a$ results in effective draft $d_e$ of barges. The Ohio and Illinois River results in the tabulation show a value of C of 1.18 and 1.68. These values will be compared to the Kampsville experiments in the draft correction section below.

*b.* When the physical model is started from rest, flume length limitations dictate a faster acceleration than in the prototype. The acceleration for the physical model is shown in Figure 18. The tow in conjunction with the towing carriage becomes a wave generator that creates a wave in front of the tow. This wave is not as significant in the prototype because of the slower prototype acceleration and also tow motion in the prototype is initiated much farther from the measurement point. The “wavemaker” in the prototype (the barges) generally is powered by about a 3,728-kW (5,000-hp) towboat whereas the towing carriage in the model has a scaled power of up to 111,855 kW (150,000 hp). Stated differently, the inertia of the vessel and the water in front of the vessel is significant compared to the power of the prototype tow and the resulting acceleration is low. These inertial forces in the model are insignificant compared to the power of the carriage.

*c.* The physical model flume length prohibits velocity/wave measurements for a significant time after tow passage because the startup wave generated by the tow bounces off the flume end wall and returns to the experiment section. Once this happens, the physical model data are not valid. Wave suppression devices are not effective for the long-period wave and are difficult to employ when flowing water is part of the experiment flume.

The verification process will show that the physical model reproduces the most significant tow displacement effects—the maximum return velocity and drawdown.

## Verification

The Kampsville verification compared maximum return velocity and drawdown for three tow events and developed rules for adjusting the model that resulted in agreement between model and prototype. These rules were then applied to three different tow events to determine the level of agreement between model and prototype. All six tows were three barges wide, loaded to 2.74 m, and either four or five barges long. The tows for developing the adjustment rules were the *William C. Norman* (trip 1), *Jack D. Wofford* (trip 2), and *Olmstead* (trip 2). The *Jack D. Wofford* and *Olmstead* were nearly identical in all respects. The ambient depth-averaged velocity distribution in the physical model for the *William C. Norman* conditions is shown in Figure 19. The three tows used to research the rules and to determine the level of agreement between model and prototype were the *Rambler, Charles Lehman,* and *Mr. Lawrence* (Oct 15) and were from trip 1 at Kampsville. For each of the six prototype tows, five replicate runs of the physical model were conducted. At each probe, the five replicate runs were analyzed for maximum (or minimum) velocity alongside the tow, maximum drawdown, and the ambient velocity or water level before the tow effects arrived at the measurement location. These values were analyzed for outliers using the Chauvenet criterion given in Coleman and Steele (1989). This criterion specifies that all points should be retained that fall within a band around the mean that corresponds to a probability of 1-1/(2N) using Gaussian probabilities. For the five replicate experiments in Kampsville, Chauvenet's criterion specifies that data were discarded only if they departed from the mean by more than $1.65S_x$ where $S_x$ is the standard deviation of the sample of five points. All remaining experiments were averaged for comparison with the prototype data. The ambient velocities were averaged as were the maximum (or minimum) velocities alongside the tow for each probe. The difference between these two averages defined the maximum return velocity that represented the physical model for each probe. The same technique was used for drawdown.

The initial experiment series was conducted with all physical model parameters scaled to the previously presented Froudian criteria, which require geometric similarity between model and prototype. Results comparing maximum return velocity and drawdown for the *William C. Norman*, *Olmstead*, and *Jack D. Wofford* are shown in Table 7. It is quite clear that the physical model over estimates return velocity and drawdown when using geometric scaling and the Froude criteria. This was the expected result based on the boundary layer concerns presented previously. The next series of experiments was conducted with reduced model barge draft to offset the greater boundary layer growth in the physical model. Also of concern at this stage was the startup wave, which was not present in the prototype data. Efforts were directed at reducing the magnitude of the startup wave because of concern that the presence of the startup wave might affect the return velocity and drawdown. Various model accelerations were tried with no significant impact, probably because the limited model length prevented significant reduction of the acceleration. The best agreement of return velocity and drawdown with the least startup wave was found with a 2.28-m draft on all barges except that the bow of the lead barge was drafted 1.14 m. This change in draft on the lead barge had no apparent impact on the return velocity but minimized the amplitude of the startup wave. Results for the *William C. Norman, Olmstead,* and *Jack D. Wofford* are presented in Tables 8 and 9. This same draft correction was used to simulate the *Rambler, Charles Lehman,* and *Mr. Lawrence* which were not used to develop the draft correction. Results are shown in Tables 10, 11, and 12, respectively.

To compare the model and prototype, the most consistent data were expected at meters farthest from the channel perimeter. Meters close to the perimeter (998 and 1001) could easily be affected by local channel bottom irregularities and by differences between boundary layer growth in the model and prototype. Scatter plots of meters 332, 642, 999, 1000, 040, and 071 are shown in Figures 20 and 21 for the three rule development tows and the three tows used to research the rules, respectively. Lateral distribution of return velocity in both model and prototype is shown in Figures 22-26 for each tow. Actual and filtered time-histories for the *William C. Norman* physical model data using the corrected draft are shown in Figures 27-33.

## Draft Correction

In order to obtain an effective draft of 2.74 m, the actual draft was adjusted by the draft correction. The draft correction used for the six Kampsville verification experiments was 2.74 m - 2.28 m = 0.46 m and is compared in Table 13 to the difference in displacement thickness for the six tows used in the verification process. The six verification experiments yielded an average $C$ for Equation 5 of 1.72, which is close to the value determined in the previous experiments for the Illinois River. A draft correction coefficient $C$ of 1.72 from the Kampsville experiments will be used to compute $D_C$ (Equation 5) and effective draft $d_e$ (Equation 6) in the Kampsville experiments and will be compared to subsequent experiments using the Clark's Ferry reach on the Mississippi River.

These results showed that the physical model is limited in the minimum draft that can be simulated in the model. Unloaded model barges draft about 0.6 m. With a draft correction of approximately 0.46 m for five long barges, the minimum draft that can be researched in the physical model is about 1.06 m at the 1:25 scale.

## One-Barge-Wide Verification Experiments

After completion of the production experiments described in the next chapter, two attempts were made at comparing the physical model to prototype data from loaded, one-barge-wide tows. The first experiments were run with the *Luke Burton* from trip 1. Bhowmik, Soong, and Xia (1993) show this is a one-wide by three-long "mixed" tow. Experiments were conducted with three 10.7-m by 59.5-m barges end to end (Table 14). Model values were about 60 percent of prototype values. The average return velocity from the Schijf equation was 0.115 m/sec and yielded an average ratio of physical model return velocity to Schijf return velocity of 1.18, consistent with previous results. Further examination of the prototype experiments showed that the mixed tow was actually a mixed chemical tow of unspecified length. The difference in widths made this comparison invalid. The unknown size of the prototype prevented further comparisons with this prototype tow.

The second one-barge-wide experiments were run with the *Dixie Express* from trip 2. Based on conversations with the company owning the *Dixie Express,* this tow consisted of two asphalt barges 15.9 m wide by 76.2 m and 83.8 m long for a total length of 160.0 m. Two model barges 13.3 m wide by 74.4 m long were placed end to end for a total length of 148.8 m. To offset the lesser model beam width, the model barges were drafted to an equivalent draft of (15.9*2.74)/13.3 = 3.28 m. To account for boundary layer differences, an actual model draft of 2.93 m was used and was based on a value of $C$ in Equation 5 of 1.72. Model results are shown in Table 15. The average of the four prototype return velocities divided by the Schijf average return velocity is 1.19, which is consistent with previous results. The average of the four physical model experiments divided by the Schijf average return velocity was 0.63, which is different from all previous results and from the subsequent production experiments. It is possible that offsetting the lesser beam width with increased draft had some effect on these results, but the low ratio of physical model return velocity/Schijf suggests a problem with the physical model data. The need to proceed with the subsequent Clark's Ferry site prevented additional experiments to resolve this problem.

# 5 Production Experiments and Results

Experiments evaluated the return velocity and drawdown for experiment conditions and meter positions not addressed in the prototype experiments, after adjusting the physical model to reproduce the prototype. The verification experiments were conducted with the same meter position as the prototype tests. Where to measure the velocities in the vertical was an issue that had to be resolved. Analysis of vertical velocity profile data showed that if the meter was too close to the bed, the maximum change resulting from tow passage may not have been captured. The physical forces study also compared physical model results to a depth-averaged numerical model, the HIVEL-2D (Stockstill, Martin, and Berger 1995). With the exception of the vertical velocity profile experiments, all velocities in the production runs were measured at 60 percent of the local depth below the water surface. This position ensured that the maximum change produced by the tow will be measured and, therefore, directly compared to HIVEL-2D. The following paragraphs detail each experiment series.

## Series 1, Rake Experiments

An initial experiment series determined the influence of rake configuration on navigation-induced forces. The rake configuration refers to the shape of the bow on the lead barges. All experiments were conducted with boxed ends at all connections between barges. Previous experiments have shown a significant increase in the resistance of barges with increasing rake angle at medium to high vessel Froude numbers (Latorre and Ashcroft 1981). However, at low vessel Froude numbers that are typical of UMRS tows, results from Latorre and Ashcroft show a small effect of tow configuration on barge resistance. It is not known if this low Froude number effect also applies to rake angle. Data were collected and evaluated for experiments run at variable speeds with bow rake angles of 0.05, 0.08, and 0.16 rad (26, 45, and 90 deg) in conjunction with stern rake angles of 0.16, 0.16, and 0.08 rad (90, 90, and 45 deg), respectively. Tow configuration for these experiments was two wide by four long and actual draft of 2.74 m. The experiments were conducted with no flow and water-surface el 422.9.

The first experiments, also the first experiments in the navigation effects flume, were conducted with the 0.08-rad (45-deg) rake angle. These data were not as consistent as later data, had a high degree of variability, and are not shown on the drawdown and return velocity (X-direction only) plots versus tow speed in Fig-ures 34-38. As discussed in the previous paragraph, these experiments were run with the rake angle on the stern of the barges varying as well as the bow rake angle.

Subsequent experiments and the previously discussed verification experiments were conducted with an 0.08-rad (45-deg) rake angle. By adjusting the model draft until the model return velocity and drawdown matched the prototype data, the 0.08-rad (45-deg) rake angle was forced to mimic whatever rake angle was represented by the prototype data. The distribution of actual rake angles occurring in the prototype was not known.

Analysis of rake angle data will be conducted after rake angle data are collected in the Clark's Ferry physical model.

## Series 2, Pool El 418.0

Two experiments (five replicates for each experiment) were conducted at pool el 418.0, with a discharge of 625 cu m/sec, and loaded three-wide by four-long tows. The tow was positioned 1.5 m left of the thalweg and the bollard push propeller thrust was 354.5 kN (79,688 lb). A cross section showing velocity probe locations is shown in Figure 39 and a summary of experiment conditions is shown in Table 16. All velocity probes were set at 60 percent of the depth below the water surface except for probe 4, which was set at 38 percent below the water surface. Wave gauges were set at 70 m right of the thalweg and 100 m left of the thalweg. Ambient, maximum impact velocity, maximum return velocity, and maximum drawdown below normal water level are shown in Tables 17 and 18.

## Series 3, Pool El 419.4

Fifteen experiments (five replicates each) were conducted at pool el 419.4, with a discharge of 180 cu m/sec, loaded and partially loaded barges, and two drafts. The cross section is shown in Figure 40 and a summary of experiment conditions is shown in Table 19. Ambient, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 20-34. To obtain a representative data set for vector plots shown in Fig- ures 41-57, the five replicate experiments were averaged, and one was selected as the most representative of the mean of the five experiments. Because the vector plots can provide only a finite number of vectors, the maximum value was not always indicated but is provided in the tables. Table 35 summarizes the positions of the velocity probes for each experiment.

## Series 4, Pool El 427.0

Twelve experiments (five replicates each) were conducted at pool el 427.0, with discharges of 1,281 and 2,094 cu m/sec, three-wide by five-long barges, and loaded and partially loaded barges. The cross section is shown in Figure 58, and experiment conditions are summarized in Table 36. The ambient velocity distribution is shown in Figure 59. Ambient velocity, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 37-48. Vector plots for each representative experiment selected based on the mean of the five replicates are shown in Figures 60-71. Because the vector plots can provide only a finite number of vectors, maximum values were not necessarily shown in the vector plots but are provided in the tables. The position of the velocity probes for each experiment is summarized in Table 49.

## Series 5, Vertical Velocity Distribution Experiments

Three experiments (five replicates each) determined the vertical distribution of velocity changes induced by the tow. Table 50 shows the vertical distribution for the downbound *William C. Norman* experiment ND58VD at 81.25 m left of the thalweg. Table 51 shows the distribution of vertical velocity for pool 419.4 experiment KLU488 at 81.25 m left of the thalweg. Table 52 shows the distribution for pool 427.0 upbound experiment KHVU38 at 87.5 m left of the thalweg.

## Series 6, Stationary Boat Experiment

Experiment WCNSP evaluated the determination of return velocity and drawdown by running water past a stationary vessel. The advantage was that a highly dynamic event was changed into a steady event where measurements were easier. The average channel velocity was set equal to vessel speed relative to the water. An attempt was made to simulate the conditions in the *William C. Norman* experiments, but the water surface in the flume became relatively rough when the average channel velocity approached the 2.4-m/sec relative vessel speed. The stationary boat experiment was conducted with an average channel velocity of 2.1 m/sec with all other conditions the same as in the *William C. Norman* experiment. Velocity probes were numbered from 1 to 8 starting on the left bank and were positioned at station 62 and probe position PP1 from the pool el 419.4 experiments. The pool elevation was 421.8 and all probes were set at 60 percent of the local depth below the water surface. First the velocity was measured at the eight probes with the tow far downstream of the meters to establish the ambient condition. Then, the bow of the tow was positioned at stations 52-80 in 2-m increments and velocities were measured for about 180 sec (model) at each station. Finally, the average velocity over the 180-sec time period was determined for each probe at each tow location. The average ambient velocity for each probe was subtracted from the average velocity for each probe at each location. Results are shown in Figure 72 and Table 53 with the maximum value shown at the bottom. The average of the maximums is 0.23 m/sec, which is 1.26 times the computed Schijf average return velocity of 0.183 m/sec. The ratio of 1.26 is consistent with prototype results shown in Chapter 2. Note that the data show the highest return velocities were near the vessel and near the shoreline with lesser magnitude between. Additional stationary boat experiments were not conducted because it is difficult to simulate the higher vessel speeds because of the rough water surface and because boundary conditions are different caused by the channel bottom not moving relative to the boat.

## Series 7, Variability of Physical Model Return Velocity Data

The variability of the physical model was evaluated by replicating experiment ND58Q2 nine times. All experiments were run in one day, which eliminated the variability due to setting the flow and stage in the model. Experiment conditions were identical to those for *William C. Norman* and velocity meter locations were the same as the PP1 in the pool el 419.4 experiments. The verification runs were different from those of the *William C. Norman* because the vertical position of the velocity meters was set at 60 percent of the depth from the surface. Results of the nine replicates are shown in Table 54. Comparison of the maximum return velocity average from the nine experiments with the physical model verification run from *William C. Norman* and the *William C. Norman* prototype data are shown in Figure 73. Replicate D was closest to the mean of all nine replicates. Velocity vectors for replicate D are shown in Figure 74.

## Series 8, Drawdown Distribution

In conjunction with the nine replicate experiments of ND58Q2 on variability of return velocity data, the wave gauges were positioned at various locations across the channel to measure the distribution of drawdown during vessel passage. Results are shown in Table 55.

## Series 9, Numerical Model Output

The November 1994 version of HIVEL-2D simulated the *William C. Norman* condition of experiment ND58Q2. Comparison of maximum return velocity from prototype, physical model, and numerical model is shown in Figure 73. Comparisons of the time-histories between numerical model and physical model for replicate D are shown in Figures 75-82. Probe positions PP1 (Table 35) for pool el 419.4 were used in the experiments.

HIVEL-2D was also used to assess the adequacy of the navigation effects flume's length. Was the 61-m-long asymmetric section long enough for currents to establish around the tow that are representative of long river reaches? The HIVEL-2D output for the *William C. Norman* downbound tow was plotted at stations 42 to 92 in 10-m increments (Figure 83). A similar plot for an upbound tow traveling at 1.9 m/sec (identical to *William C. Norman* in all other respects) is shown in Figure 84. Ignore magnitudes in Figures 83 and 84 since these are presented in physical model units. Figures 83 and 84 show that the tow reaches a near-equilibrium magnitude of return velocity suggesting that flume length is adequate for measurements at station 62.

A second numerical simulation used the Kampsville section in a reach much longer than represented by the physical model. Results from the numerical model of the long reach and the numerical model of the flume simulation were nearly identical. Comparison of magnitudes of maximum return velocity for the *William C. Norman* from numerical model and prototype showed that the numerical model was 6 percent greater than meter 999; 5 percent greater than meter 332; 2 percent greater than meter 642; 26 percent greater than meter 040; and 4 percent greater than meter 071. The average of the five meters was 9 percent.

# 6 Analysis

## Vertical Velocity Profile

In addition to the physical model data on vertical velocity profile, the Kampsville prototype data from meters 998, 999, and 1000 were analyzed for vertical profile changes. The number of events where all three meters were functioning was limited; trip 2 did not have enough events to be useful. Maximum return velocity was determined from the ISWS report by taking the difference between the impact and the ambient velocity. Only those events producing a maximum return velocity of 0.1 m/sec or greater were used in the analysis because lesser values are difficult to separate from ambient velocity. For trip 1 conditions, meter 998 was 0.31 m above the bottom, meter 999 was 1.22 m above the bottom, and meter 1000 was 2.44 m above the bottom at a location where the local depth was about 3.4 m.

Results from the physical model and the prototype data in Table 56 suggested the flow depth can be separated into two zones: (a) an upper zone where the velocity change due to vessel-induced return velocity is nearly uniform, and (b) a lower zone where the changing boundary layer tends to limit the maximum tow-induced return velocity. The dividing zone between the two is probably not a fixed percentage of the depth but depends on channel boundary layer growth, which in turn, depends on vessel speed and length, return velocity magnitude, boundary roughness, local depth, and ambient velocity magnitude. From the model and prototype tows where vertical distribution was measured, the return velocity change at the position farthest from the bed was treated as being in the upper zone and used to normalize velocities measured at all positions closer to the bed. Upbound and downbound prototype data near the bed were highly variable. For the upbound tows shown in Table 56, the velocity profile is uniform except for the meter located at 0.31 m above the bed. This suggests that the dividing line between the upper and lower zones is somewhere between 0.31 and 1.2 m above the bed. For downbound tows, the profile has a similar but greater reduction near the bed but also has a peak at a point about 1 m above the bed that is not found in the upbound data. In either case the use of measured velocities at 60 percent of the local depth below the water surface captures close to the maximum tow-induced return velocity.

## Upbound/Downbound/Influence of Ambient Currents

Data from pool el 418.0, pool el 419.4, and pool el 427.0 are plotted in dimensionless form in Figures 85-98. Velocities are normalized by dividing by the Schijf average return velocity computed using the vessel speed relative to the water and the effective draft.

One question that must be answered in development of analytical models of tow effects is how do tow-induced currents add or subtract from ambient currents for upbound and downbound tows? At present, analytical models assume that tow currents add directly to ambient currents. For example, return current from the tow is added to ambient current for an upbound tow and subtracted from the ambient current for downbound tows. Tow speed relative to the water is presently determined by vessel speed over the ground minus (for downbound) or plus (for upbound) the average channel velocity. The question then is should the velocity near the tow, rather than the average channel velocity, determine the vessel speed relative to the water for use in analytical models? To evaluate this hypothesis, tow events were plotted where upbound and downbound tows had the same or nearly the same speed relative to the water. Results for events with similar speeds are shown in Figures 85-90 and 93-96. Results show that adding and subtracting from ambient flows produces similar results for pool el 418.0 and 419.4 experiments in Figures 85-90. Three of the four pool el 427.0 experiments in Figures 93-96 show the average return velocity for the upbound tows higher than return velocity for downbound tows for one channel side. The conclusion on the correct addition of ambient currents will await further data collection in the Clark's Ferry physical model.

## Normalized Velocity Distribution

A second issue in development of the analytical model is developing a dimensionless or "unit" time-history of the return velocity. In the analytical model, equations predict the maximum return velocity during vessel passage. This maximum return velocity is the basis for normalized time-histories of return velocity. Return velocity was normalized by first subtracting the ambient velocity and then dividing by the maximum return velocity. Time was normalized by dividing by the time required for barge passage defined as total barge length/vessel speed relative to the ground. Prototype, physical model, and numerical model return velocities were normalized using this procedure and are shown in Figure 99. Proto- type data from the six verification tows were averaged to develop the empirical time history in Figure 99. Meter 999 was used from the prototype data because its vertical position relative to the bed is similar to this study's physical model experi- ments where the meters were positioned 60 percent of the local depth below the water surface. The three upbound tows and the three downbound tows from the prototype experiments showed no significant difference when normalized using this procedure. The physical model experiments used to develop the average normalized curve were (a) the upbound KLU335C, KLU488C, KLRU49C, and KLLU49C; and (b) the downbound KLLD51C and KLRD49C. All physical model analysis used the probe closest to prototype meter 999. The numerical model curve was based on the *William C. Norman* tow using the position closest to meter 999. The physical model and prototype data differ only near the bow of the tow where the physical model experiences a significant bow velocity not observed in the prototype for reasons previously discussed. The numerical model reaches a peak return velocity earlier in the tow event and departs from the prototype and physical model after tow passage, possibly related to the absence of propellers.

## Data Variability

The nine *William C. Norman* physical model experiments (Table 54) were used to determine the standard deviation of the maximum return velocity. The maximum return velocity was determined for each experiment by taking the difference between the ambient and the maximum impact. The standard deviation was determined for each probe based on the nine replicates. The average standard deviation for the eight probes was 12 percent of the maximum return velocity. For example the nine replicates from probe 6 had an average maximum return velocity of 0.234 m/sec. The standard deviation of the nine probe 6 replicates was 0.12(0.234) = 0.028 m/sec.

# 7 Summary and Conclusions

Ambient flow conditions in both the physical model and the prototype had significant variations at a large range of frequencies including the frequency at which the tow effects occur. A fast Fourier transform filtered information above 0.02 Hz.

Prototype return velocity and drawdown compared to physical model return velocity and drawdown in the Kampsville site showed that the Froude model with geometric scaling of vessel size resulted in model values greater than the prototype. The physical model draft had to be reduced from purely geometric scaling for agreement between model and prototype. The physical model also generated a wave and flow at the bow greater than the prototype data. This bow effect was likely related to the rapid acceleration that must be used in the physical model because of the limited flume length.

Variability of return velocity was evaluated using nine identical experiments in the physical model. The standard deviation of the maximum return velocity was 12 percent of the maximum return velocity.

Rake angle experiments determined the effect on return velocity and drawdown. It appears from Figures 34-38 that values for drawdown and return current are consistently higher for 0.16 rad (90 deg) than 0.05 rad (26 deg). Further conclusions will await additional experiments on the Clark's Ferry physical model.

Experiments were conducted using a stationary boat in a flow moving at the speed of the vessel, which changed a dynamic event to a steady one making measurements much easier. However, the rough water surface present when simulating high vessel speeds makes this form of experimenting questionable.

The vertical profile of return velocity change was investigated to determine how to interpret and compare return velocities taken at different distances from the bottom. During passage of a tow, the flow depth can be separated into a lower zone in which boundary layer growth can inhibit maximum return velocity and an upper zone in which the return velocity is nearly uniform. The lower zone is generally confined to the lower 0.5 m of the depth.

Experiments were conducted to determine the influence of upbound versus downbound tows relative to variable magnitudes of ambient currents. For low ambient currents, influences were negligible. Further conclusions regarding this issue will await additional data from the Clark's Ferry model.

A normalized return velocity time-history was developed for future use in analytical models that require the time-history of vessel changes. The magnitude of return velocity was normalized by the maximum return velocity, and time was normalized by the time required for the barges to pass a given point.

A numerical simulation using the HIVEL-2D model assessed the flume length adequacy as well as comparing return velocity and drawdown from the prototype, the physical model, and the numerical model. Numerical simulations of the physical model flume and of a much longer reach with the same cross section (over the entire length) as the experiment section showed that the 61-m-long experiment section in the physical model resulted in return velocity and drawdown equal to long river reaches. The return velocity magnitude in the numerical model and the prototype *William C. Norman* were compared. The maximum return velocity from the numerical model was 9 percent greater than the prototype based on the average of results at five velocity meters.

A large body of far field physical forces data in the form of return velocity and drawdown form were developed in this study. These data are available for future development of analytical models and for numerical model verification.

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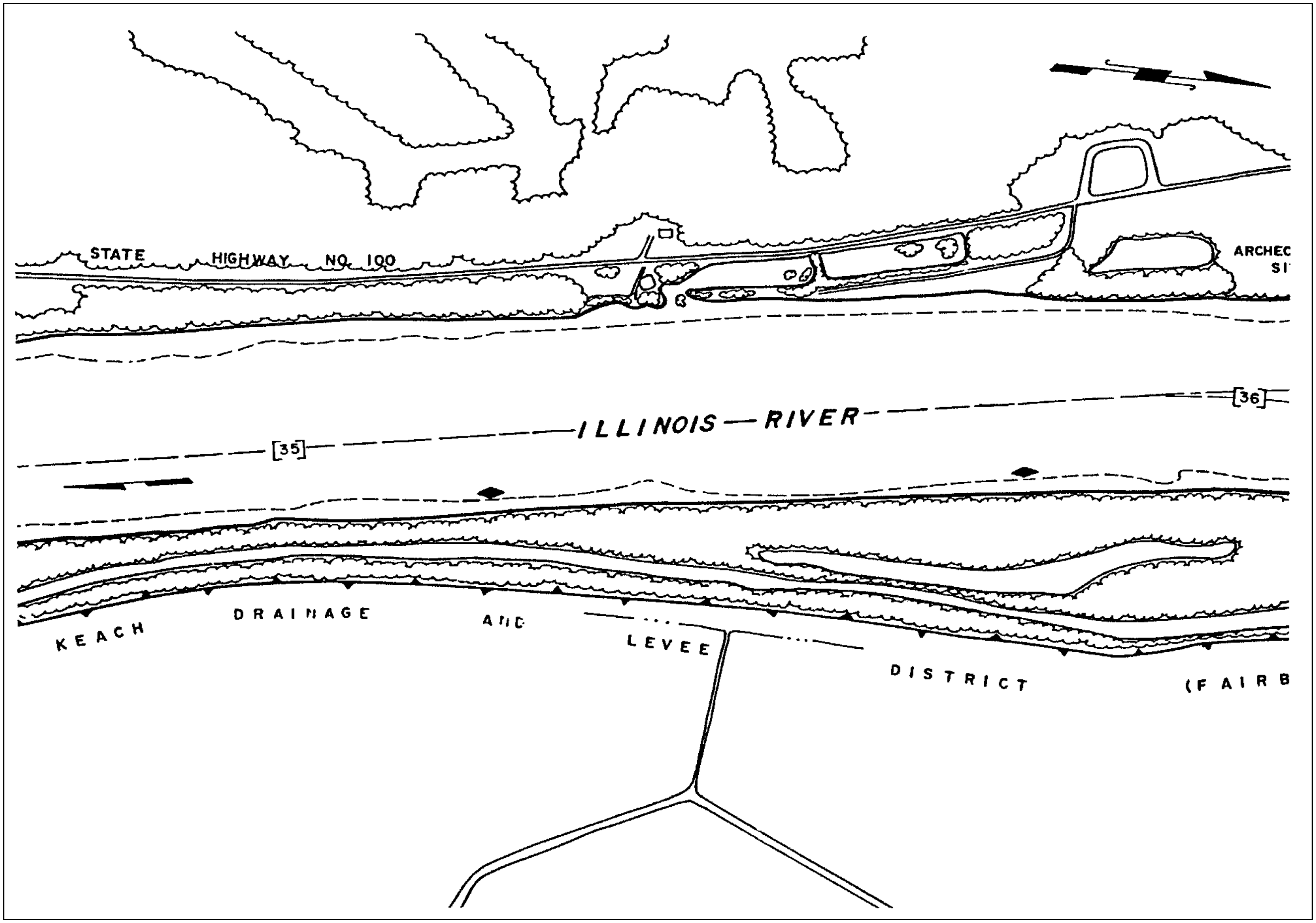



Figure 1. Kampsville site on the Illinois River, RM 35.2

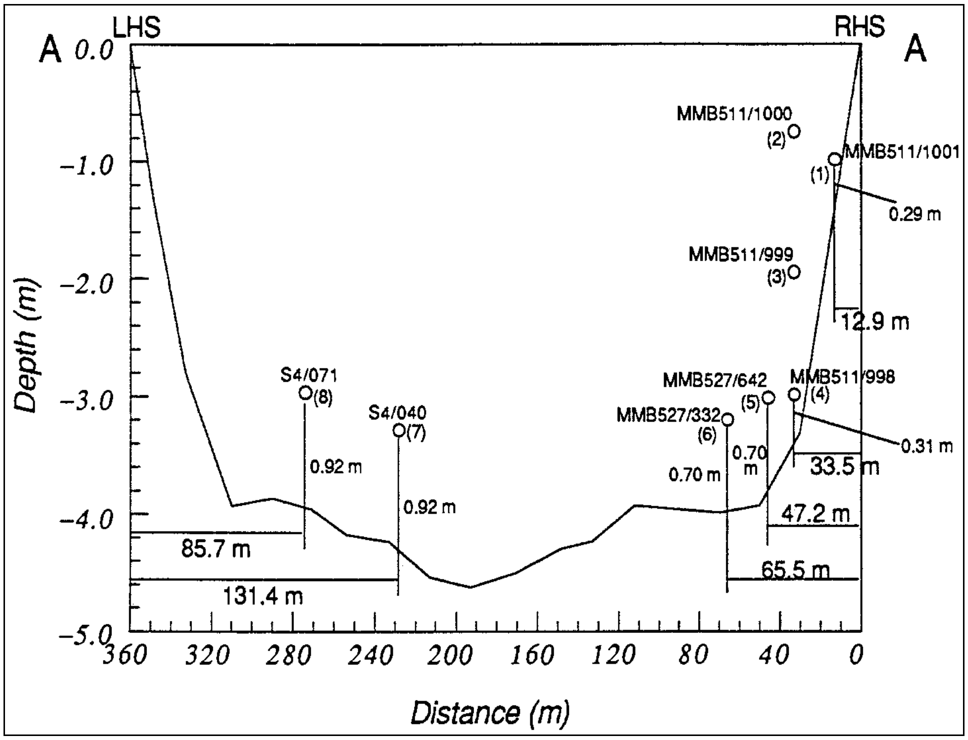



Figure 2. Cross section of the Illinois River at the Kampsville site for trip 1

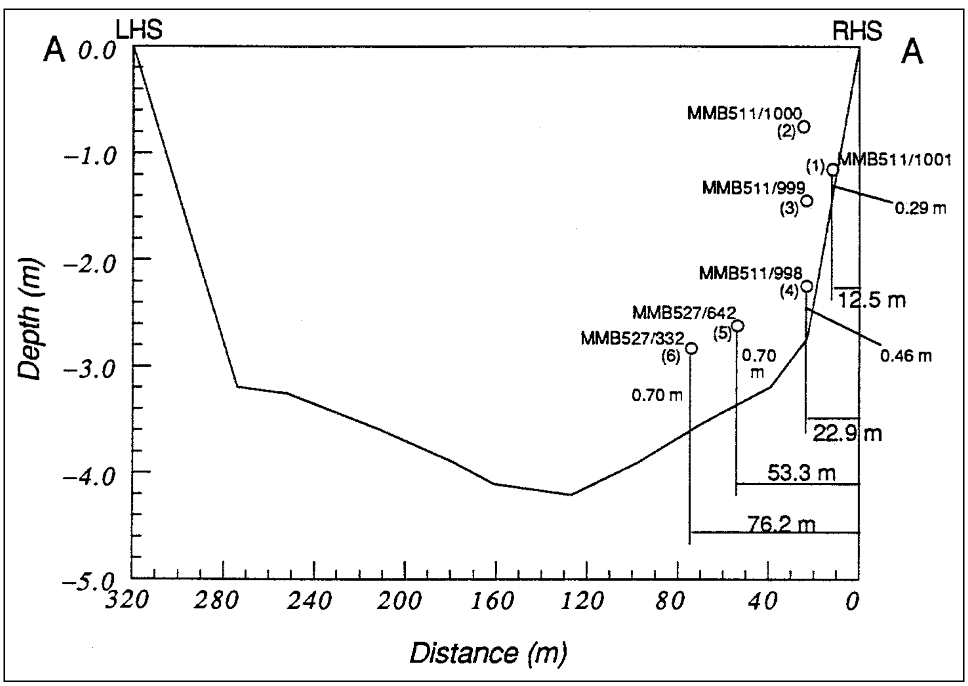



Figure 3. Cross section of the Illinios River at the Kampsville site for trip 2

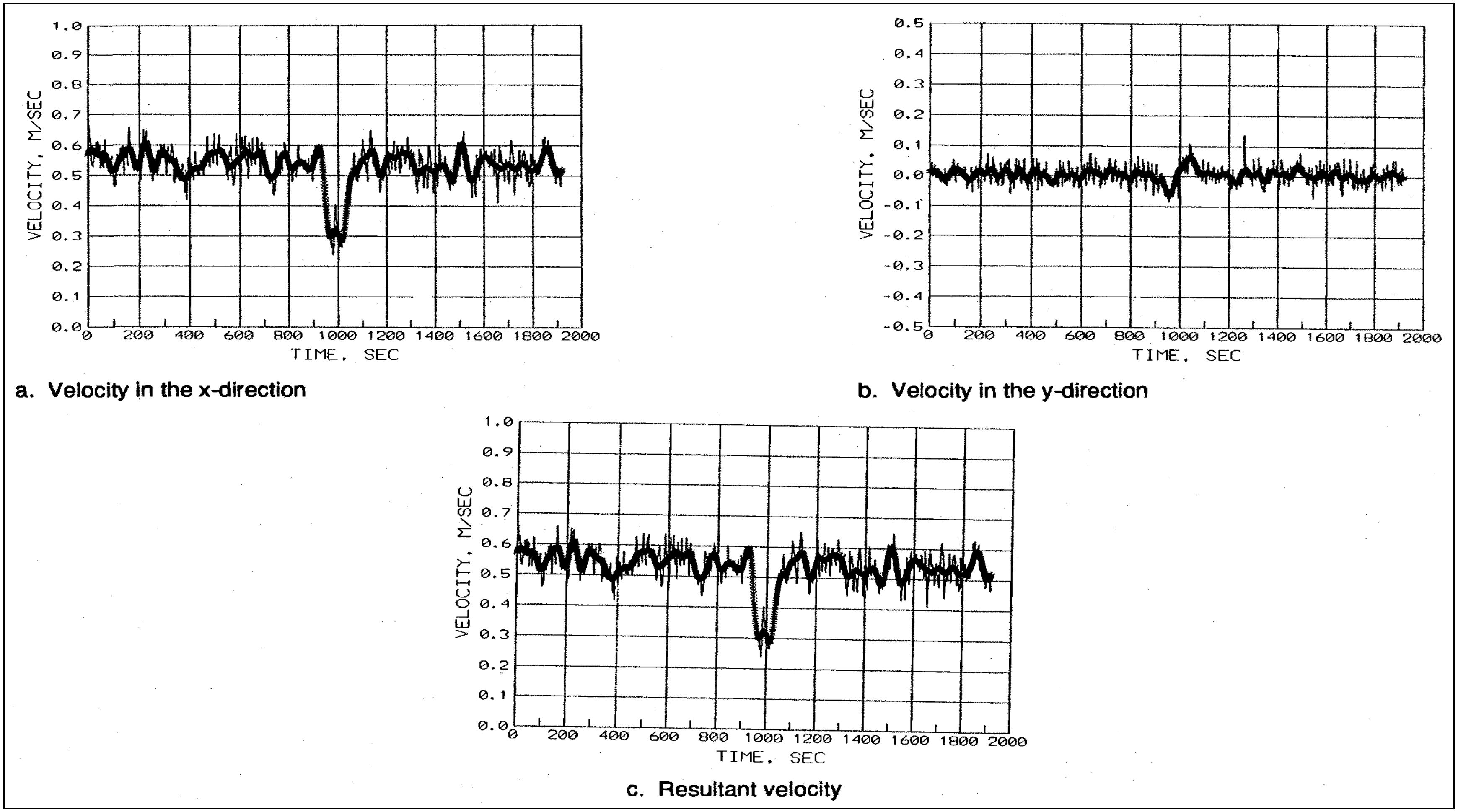
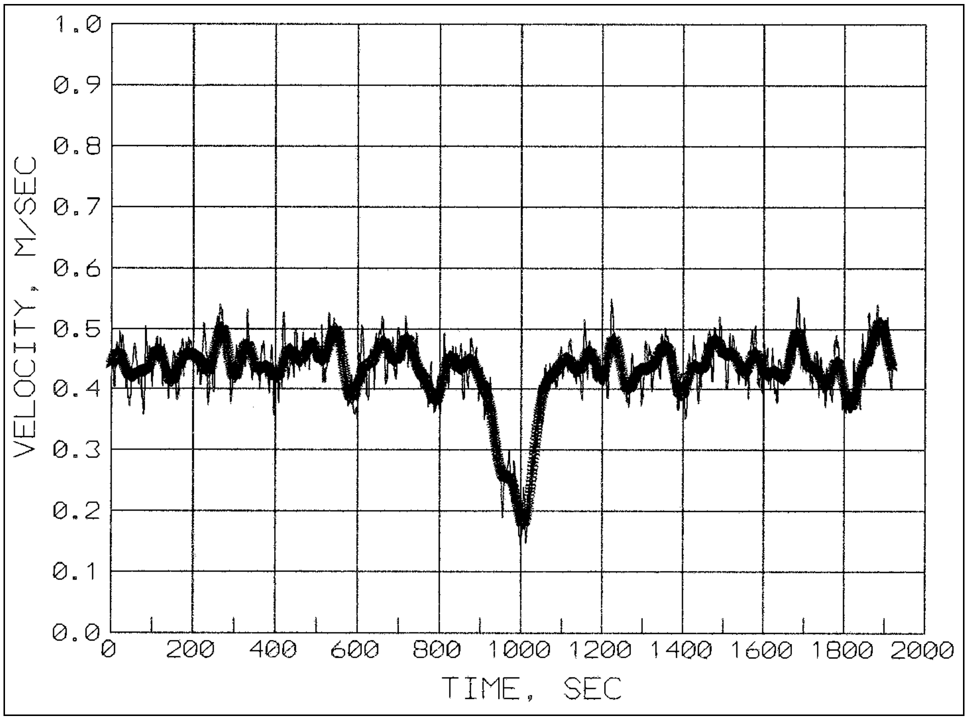
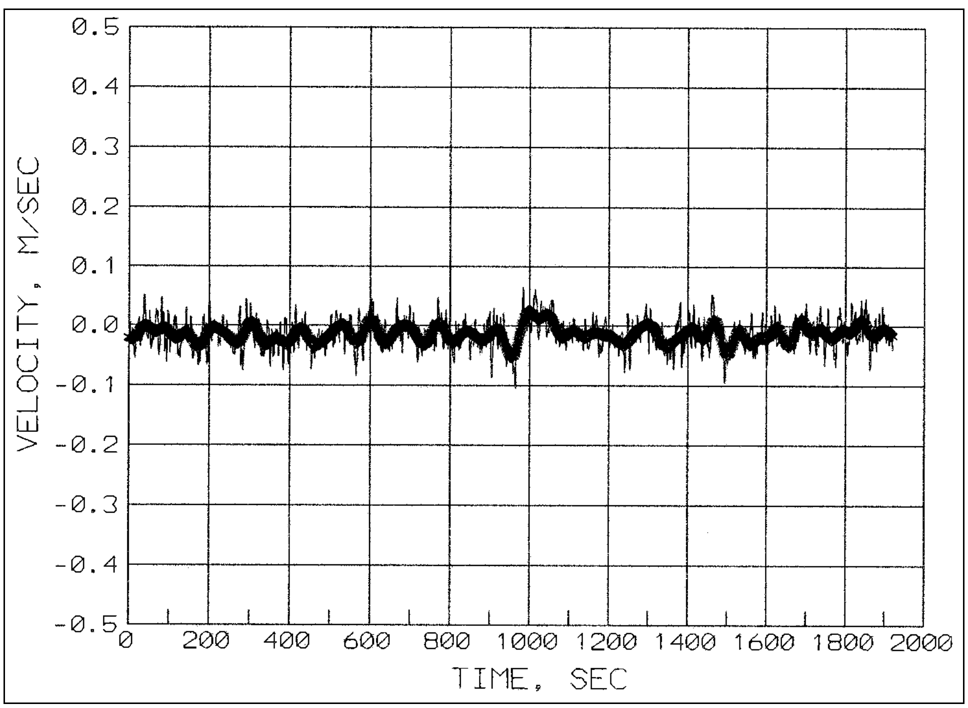



Figure 4. Prototype data, *William C. Norman*, meter MMB527/332

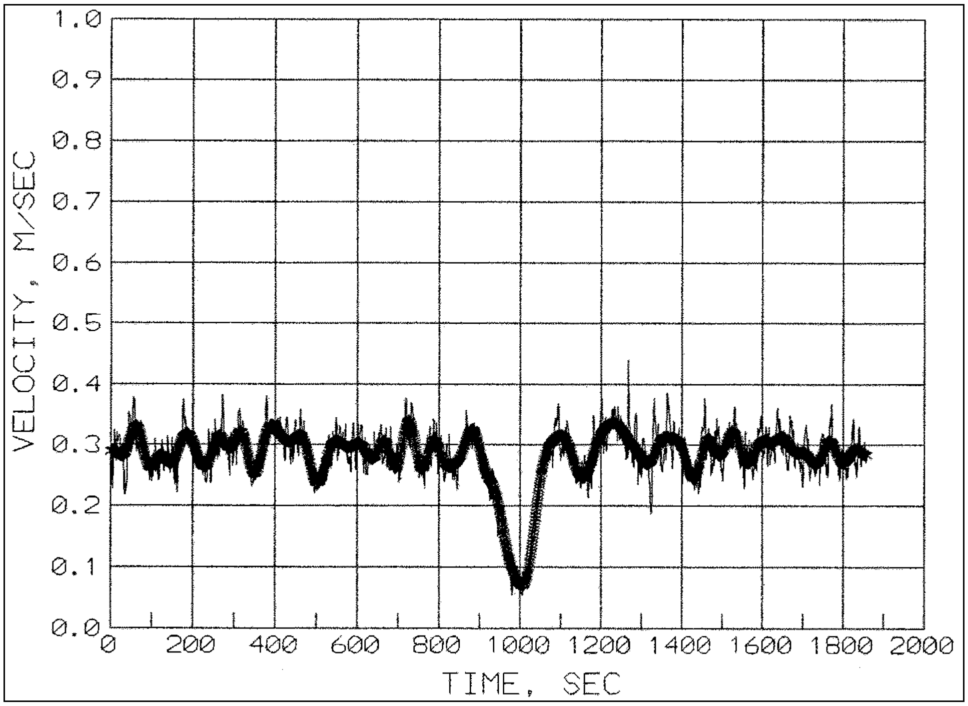



a. Velocity in the x-direction

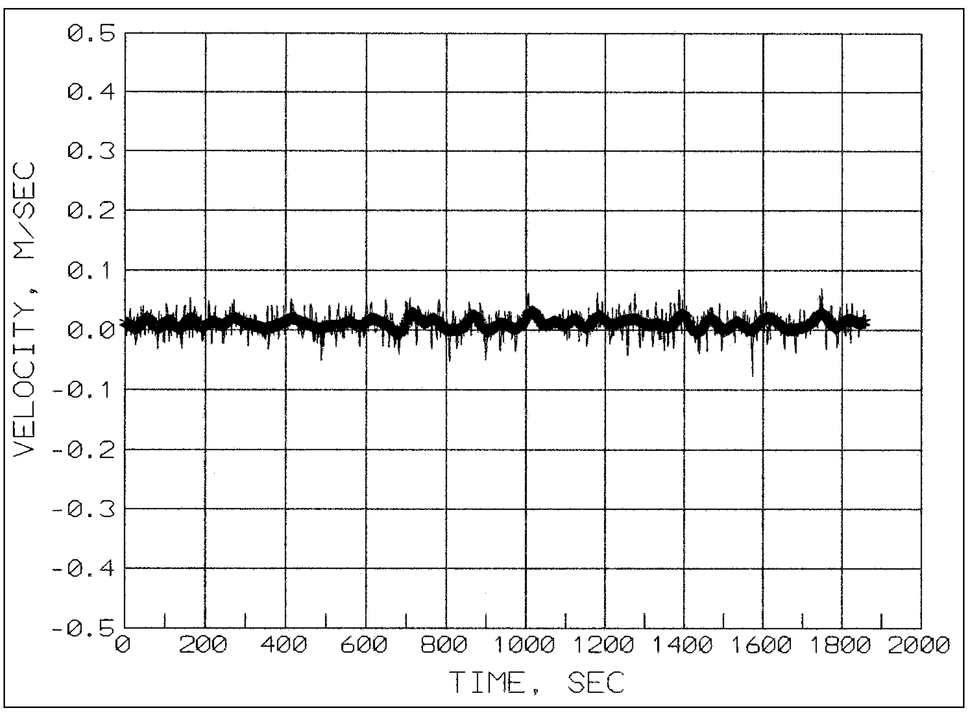



b. Velocity in the y-direction

Figure 5. Prototype data, *Wiliiam C. Norman*, meter MMB527/642

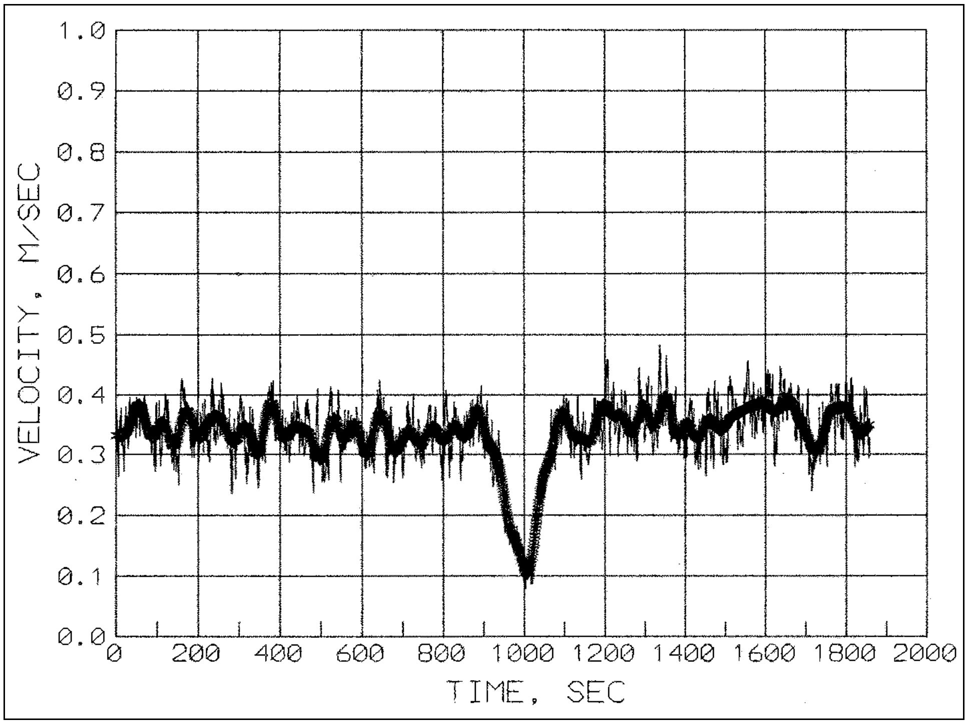



a. Velocity in the x-direction

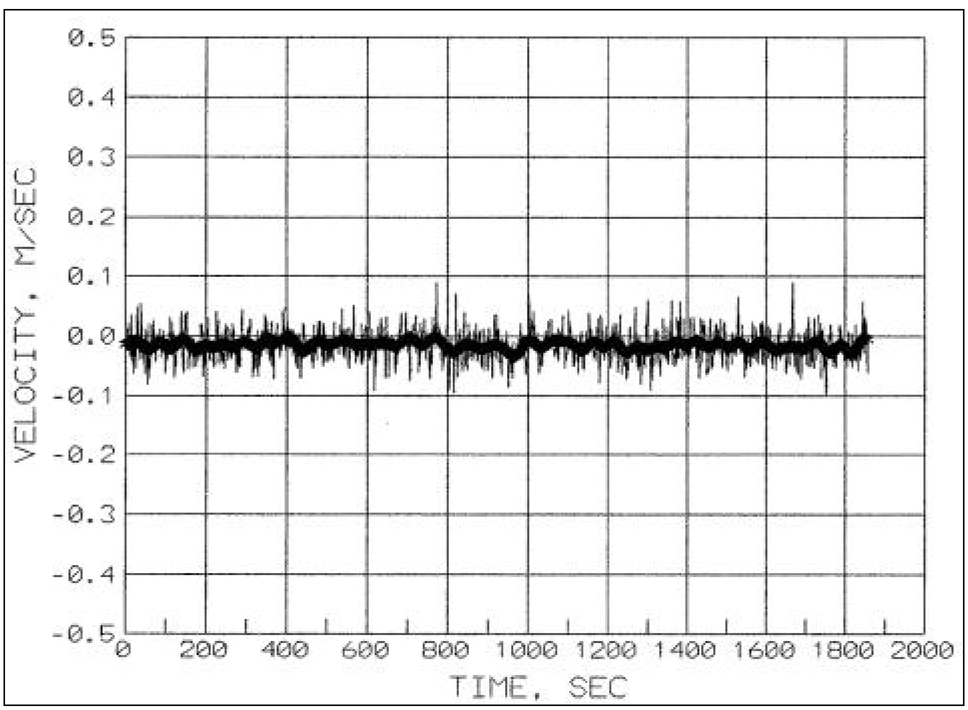



b. Velocity in the y-dirction

Figure 6. Prototype data, *William C. Norman*, meter MMB511/998

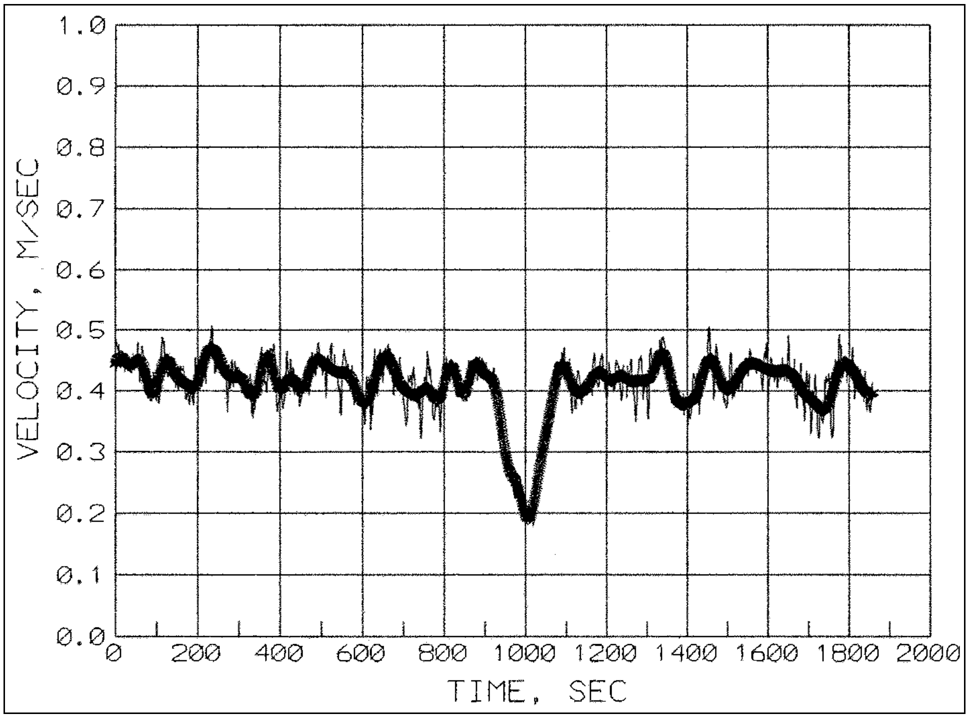



a. Velocity in the x-direction

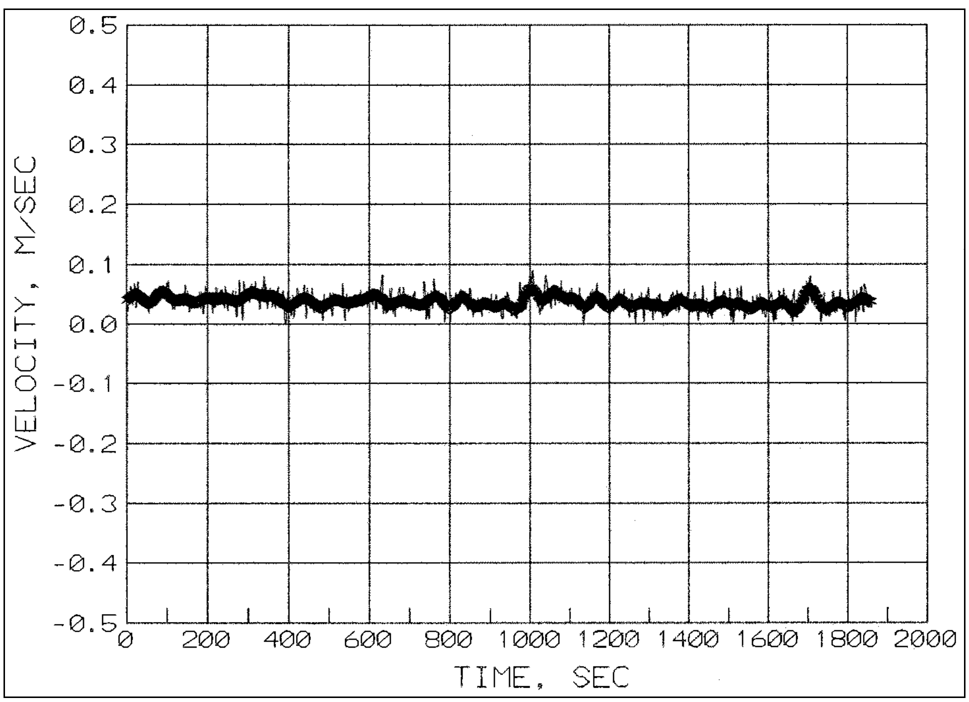



b. Velocity in the y-direction

Figure 7. Prototype data, *William C. Norman*, meter MMB511/999

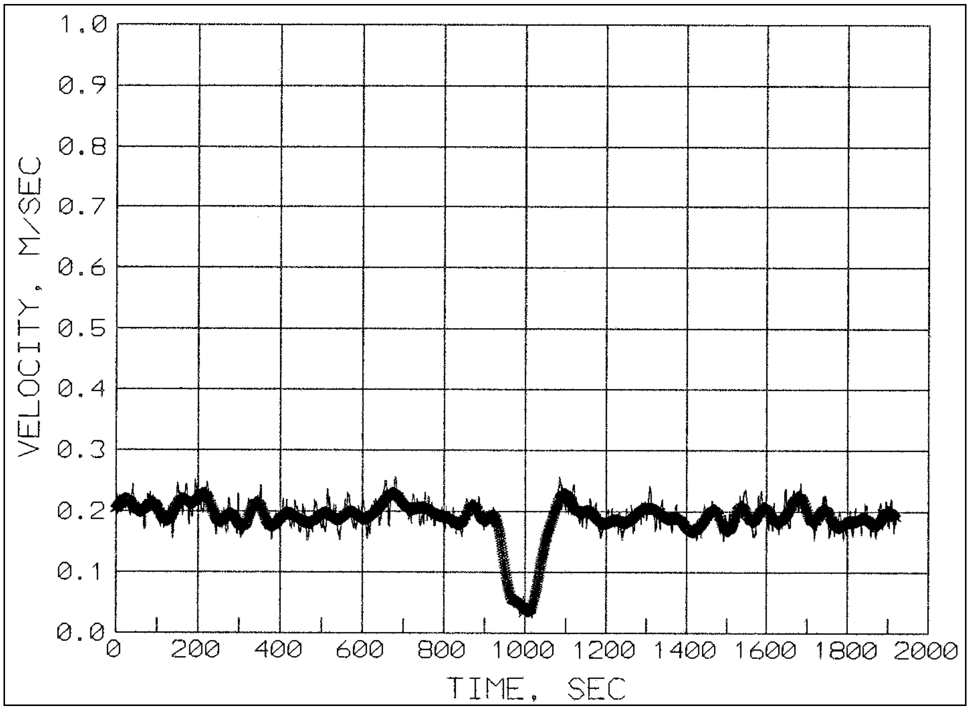



a. Velocity in the x-direction

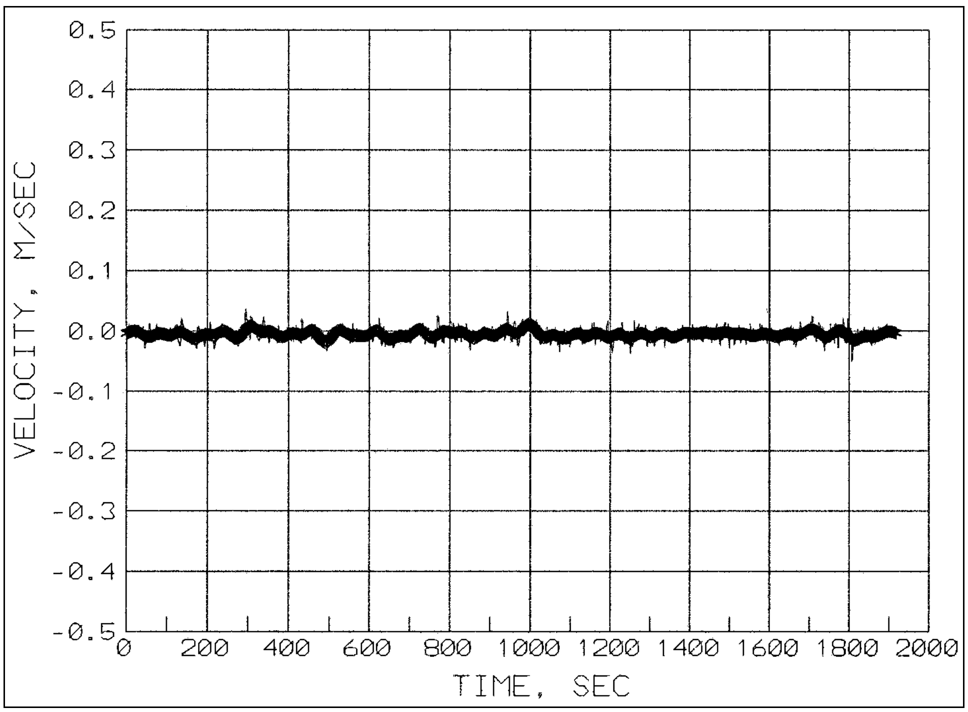



b. Velocity in the y-direction

Figure 8. Prototype data, *William C. Norman*, meter MMB511/1000

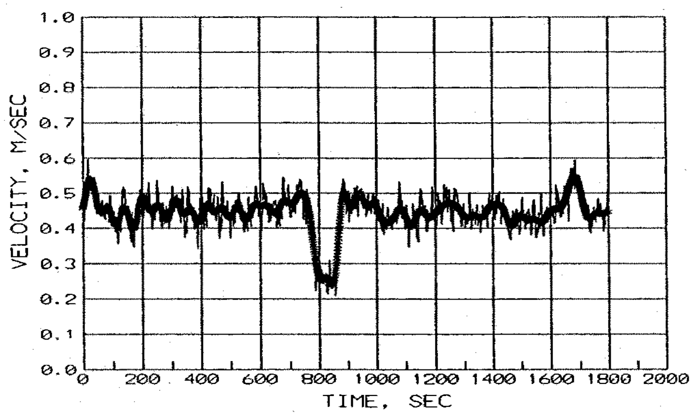



a. Velocity in the x-direction

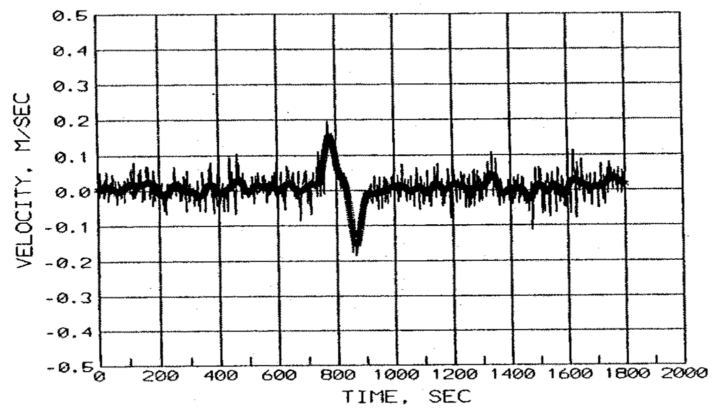



b. Velocity in the y-direction

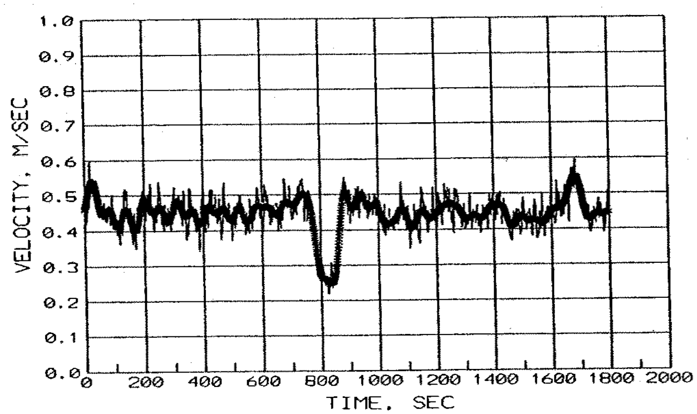
Figure 9. Prototype data, *William C. Norman*, meter MMB511/1001




a. Velocity in the x-direction

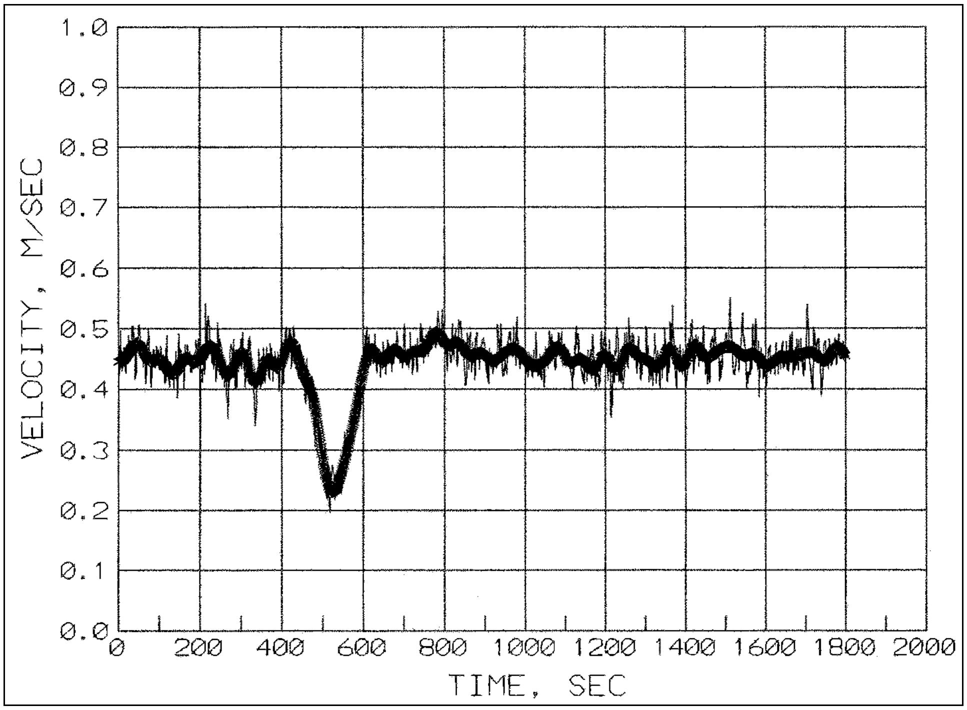



b. Velocity in the y-direction

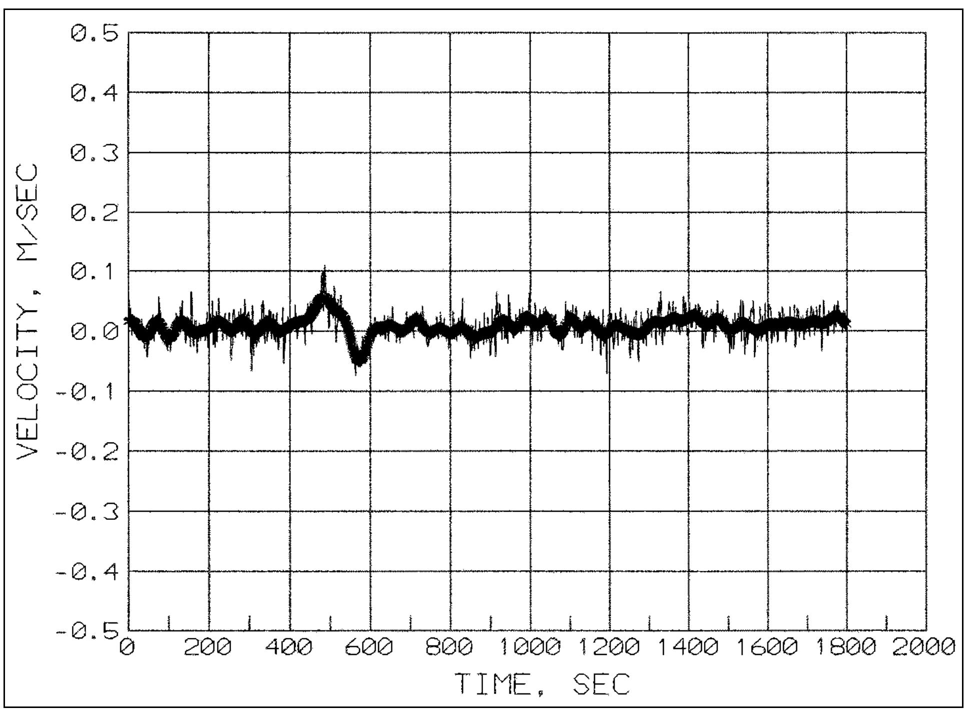



c. Resultant velocity

Figure 10. Prototype data, *William C. Norman*, meter S4/040




a. Velocity in the x-direction




b. Velocity in the y-direction

Figure 11. Prototype data, *William C. Norman*, meter S4/071

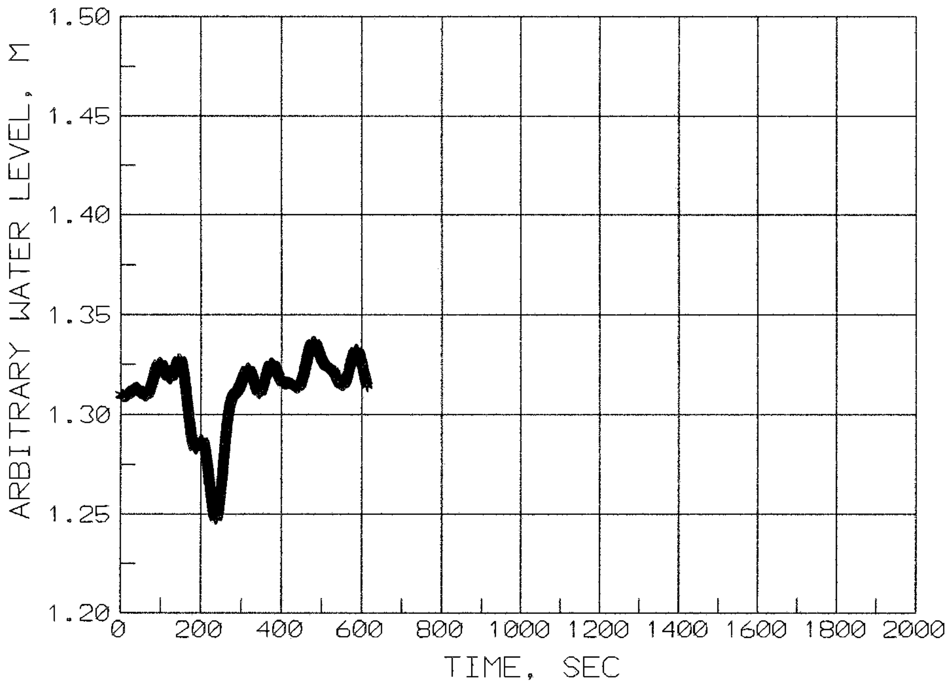
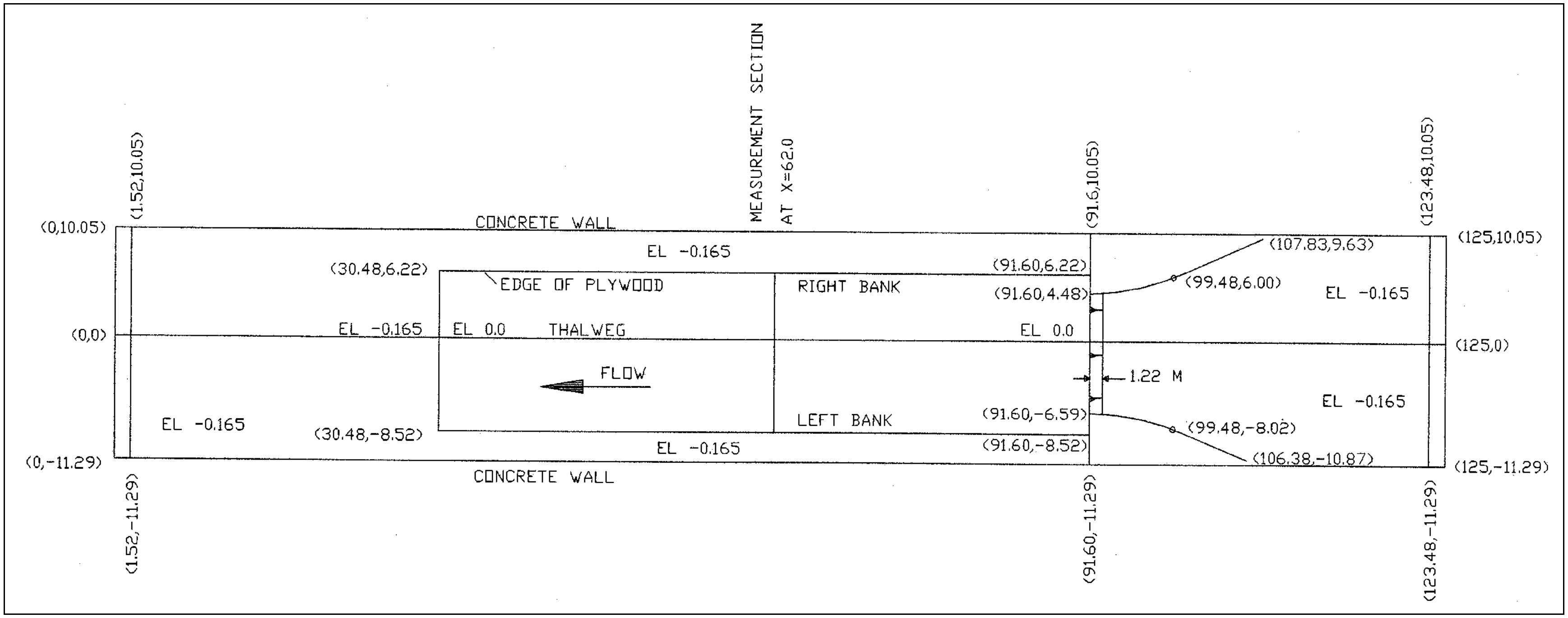
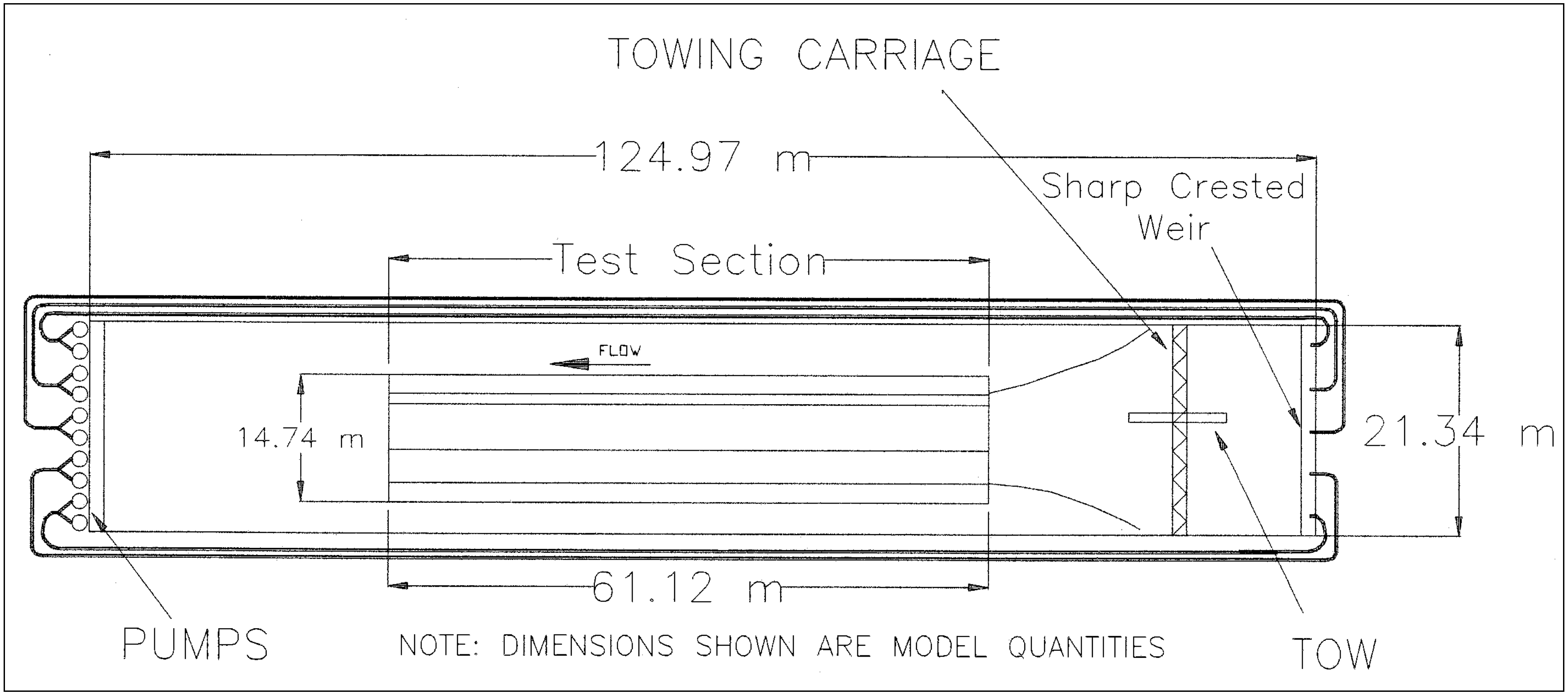



Figure 12. Prototype data, *William C. Norman*, wave gauge




a. Flume dimensions

Figure 13. Dimensions and schematic of Kampsville Reach in navigation effects flume (Continued)




b. Details of discharge system

Figure 13. (Concluded)

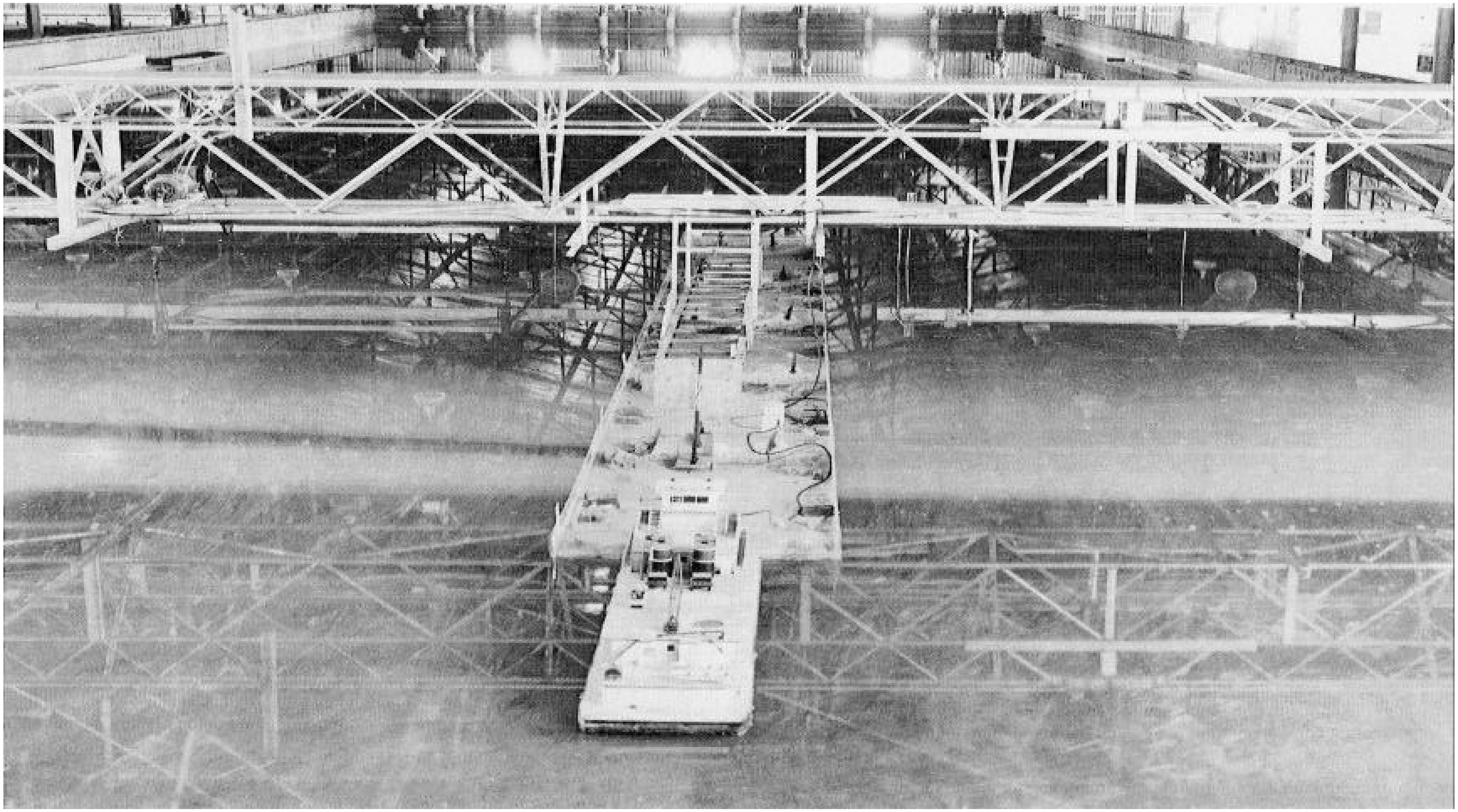


Figure 14. Navigation effects flume (looking downstream)

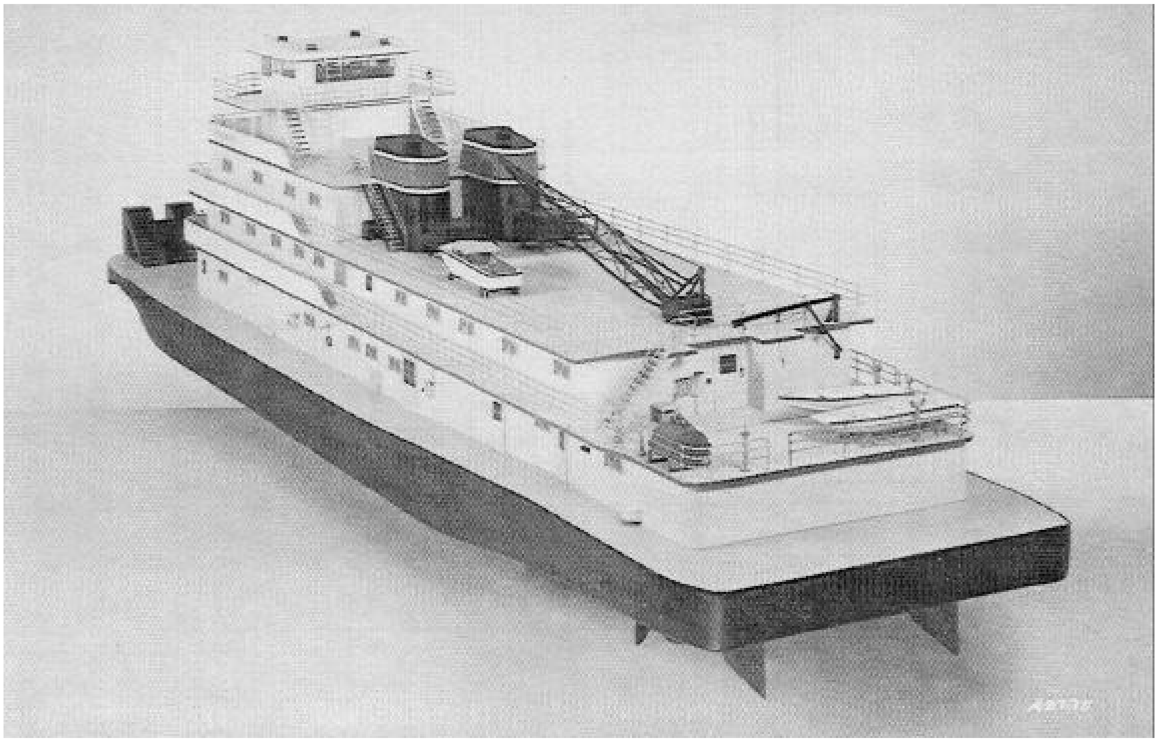
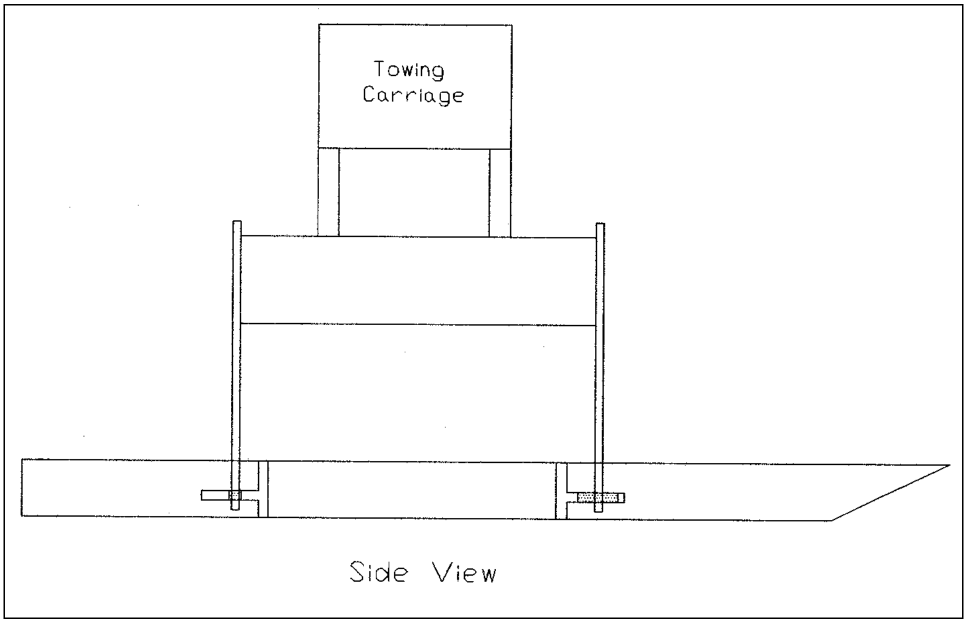
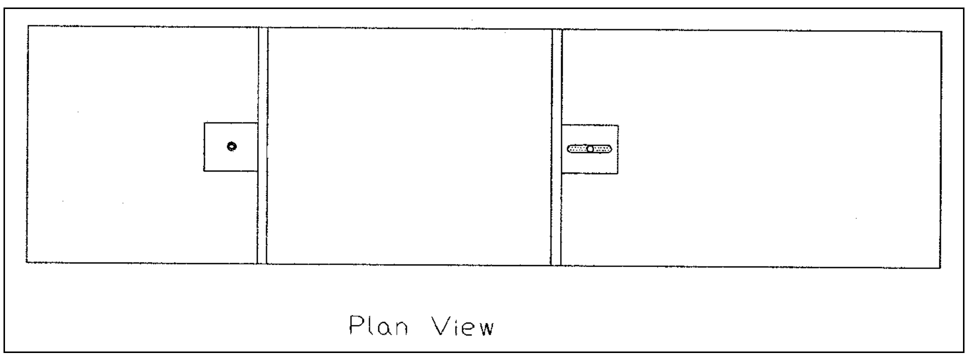


Figure 15. 1:25-scale towboat *MV Benyaurd*




a. Side view




b. Plan view

Figure 16. Connection between tow and towing carriage

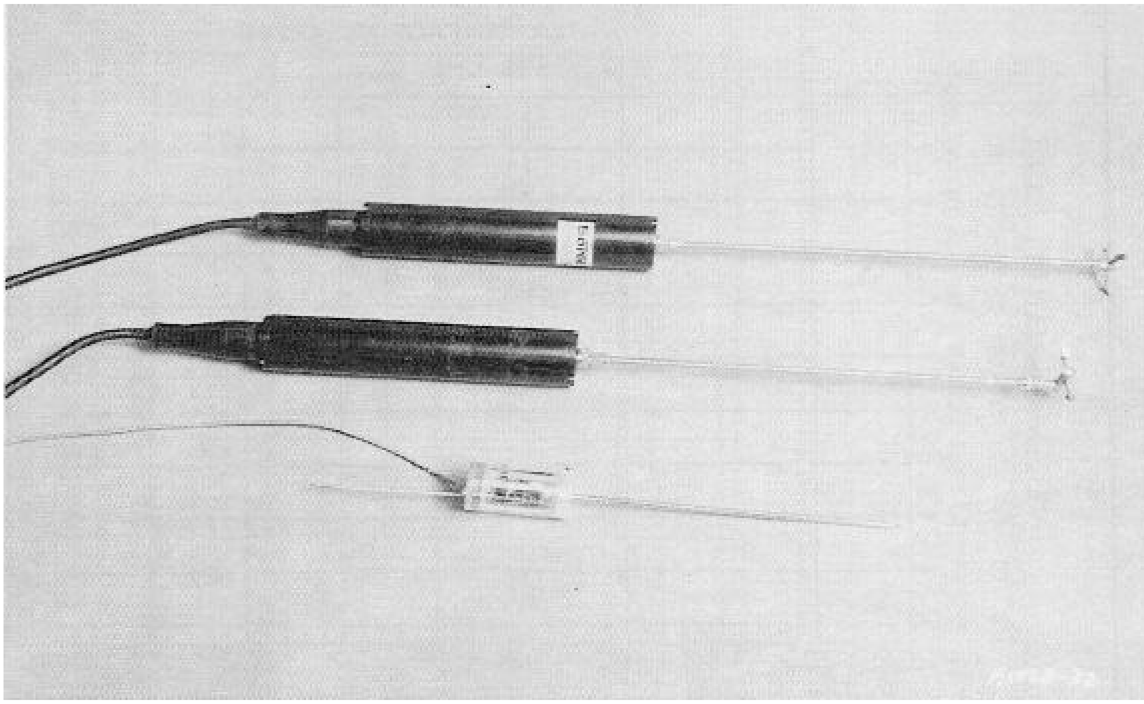


Figure 17.   2-D and 3-D ADV's and wave gauge

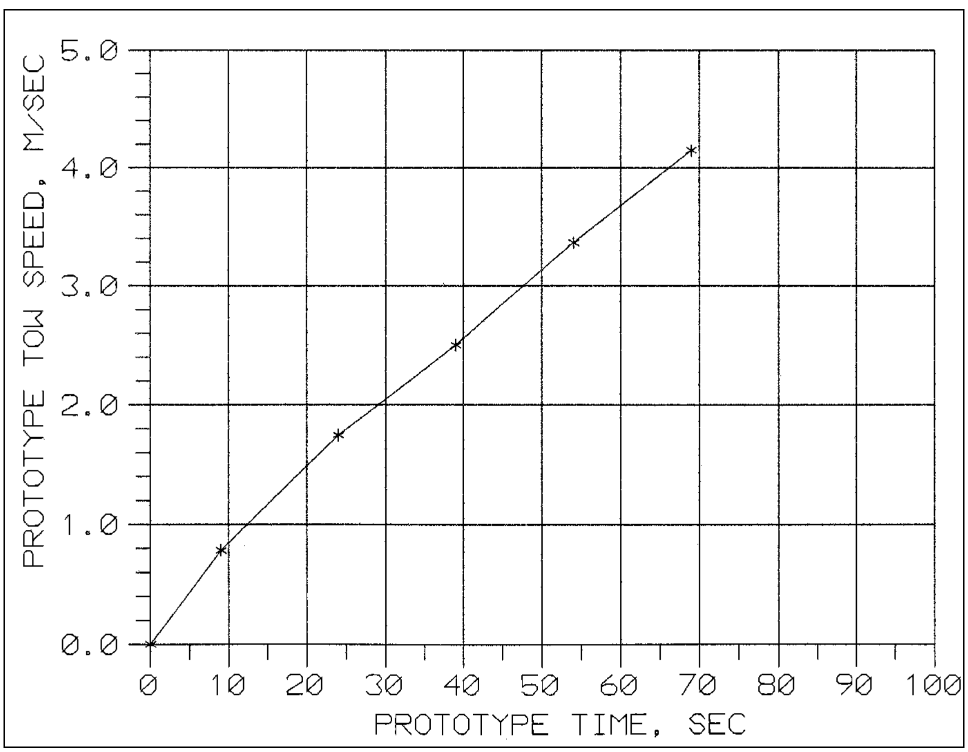



Figure 18.   Acceleration of model tow

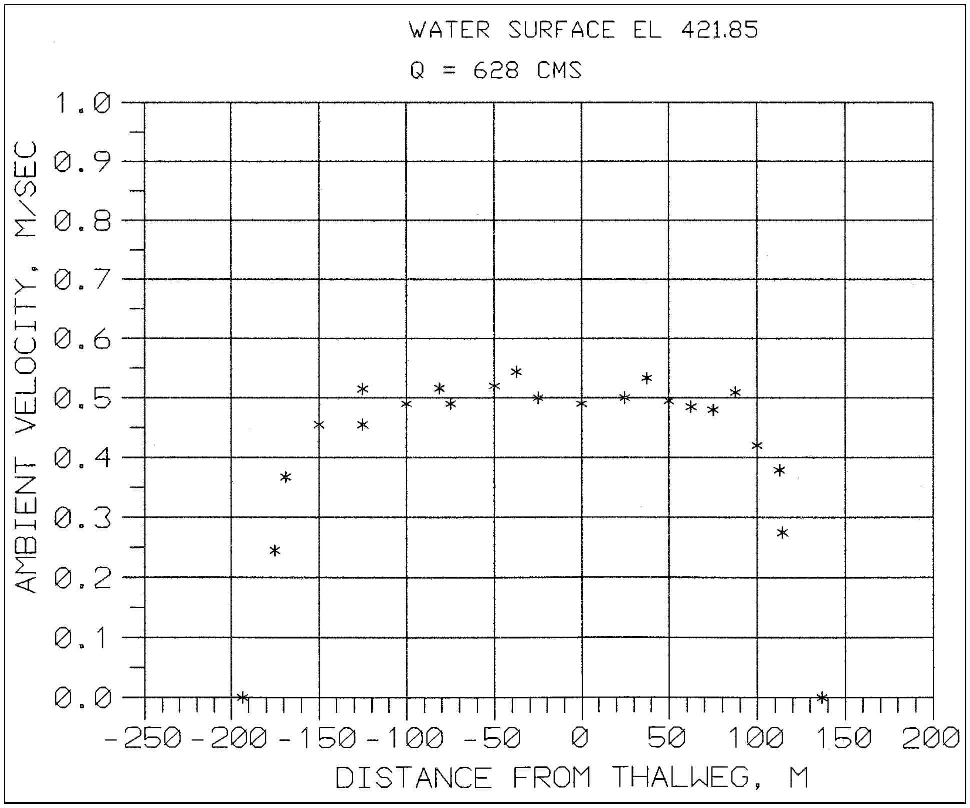



Figure 19. Ambient velocity distribution for *William C. Norman* test condition

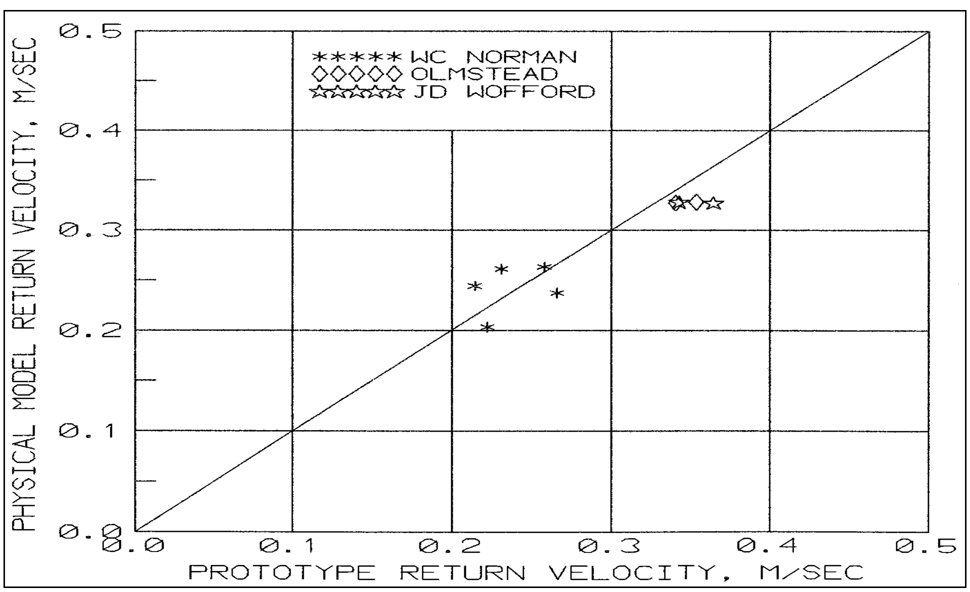



Figure 20. Physical model return velocity versus prototype return velocity, verification runs for vessels *William C. Norman*, *Olmstead*, and *Jack D. Wofford* with 2.28-m draft

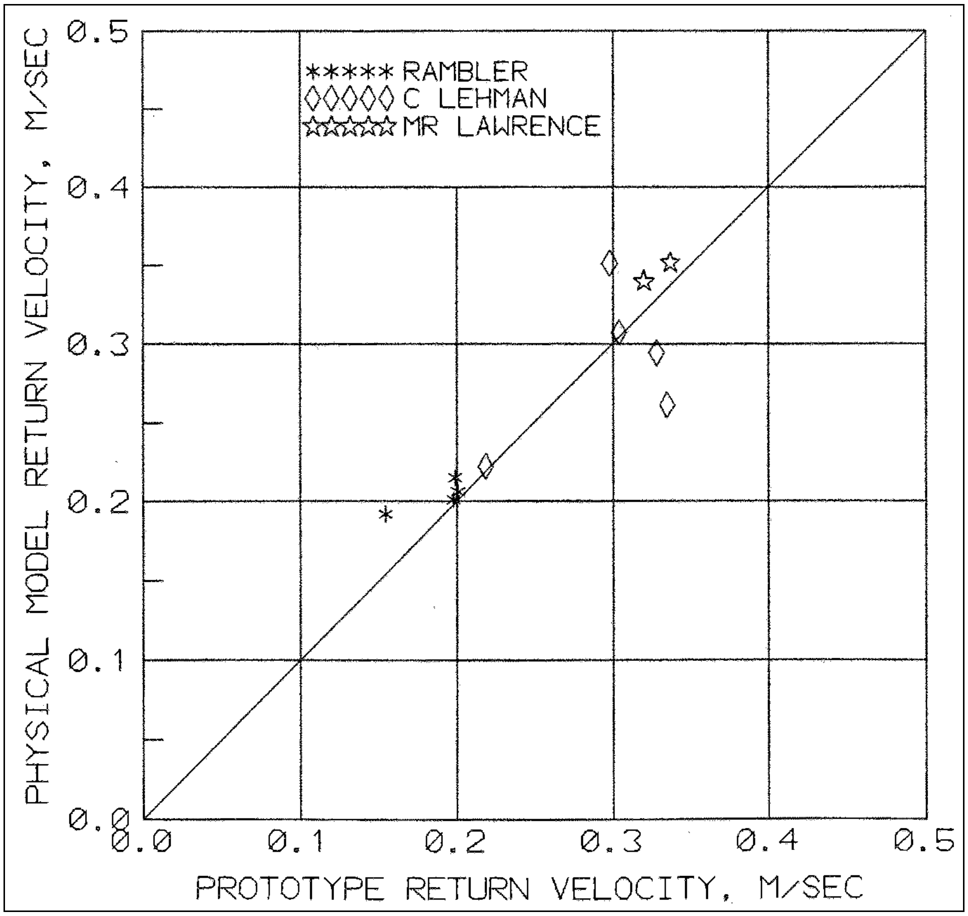



Figure 21. Physical model return velocity versus prototype return velocity, verification runs for vessels *Rambler*, *Charles Lehman*, and *Mr. Lawrence* with 2.28-m draft

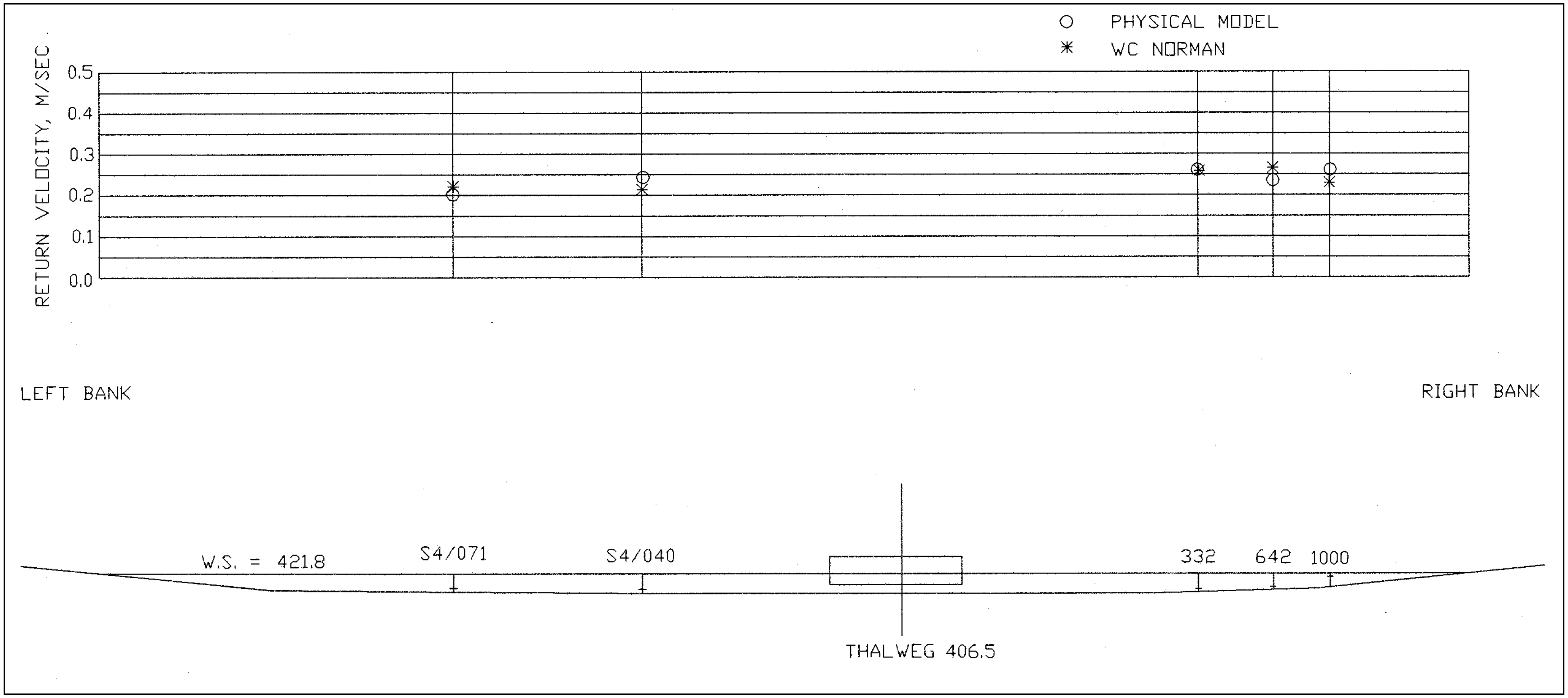



Figure 22. Physical model return velocity versus prototype for *William C. Norman*

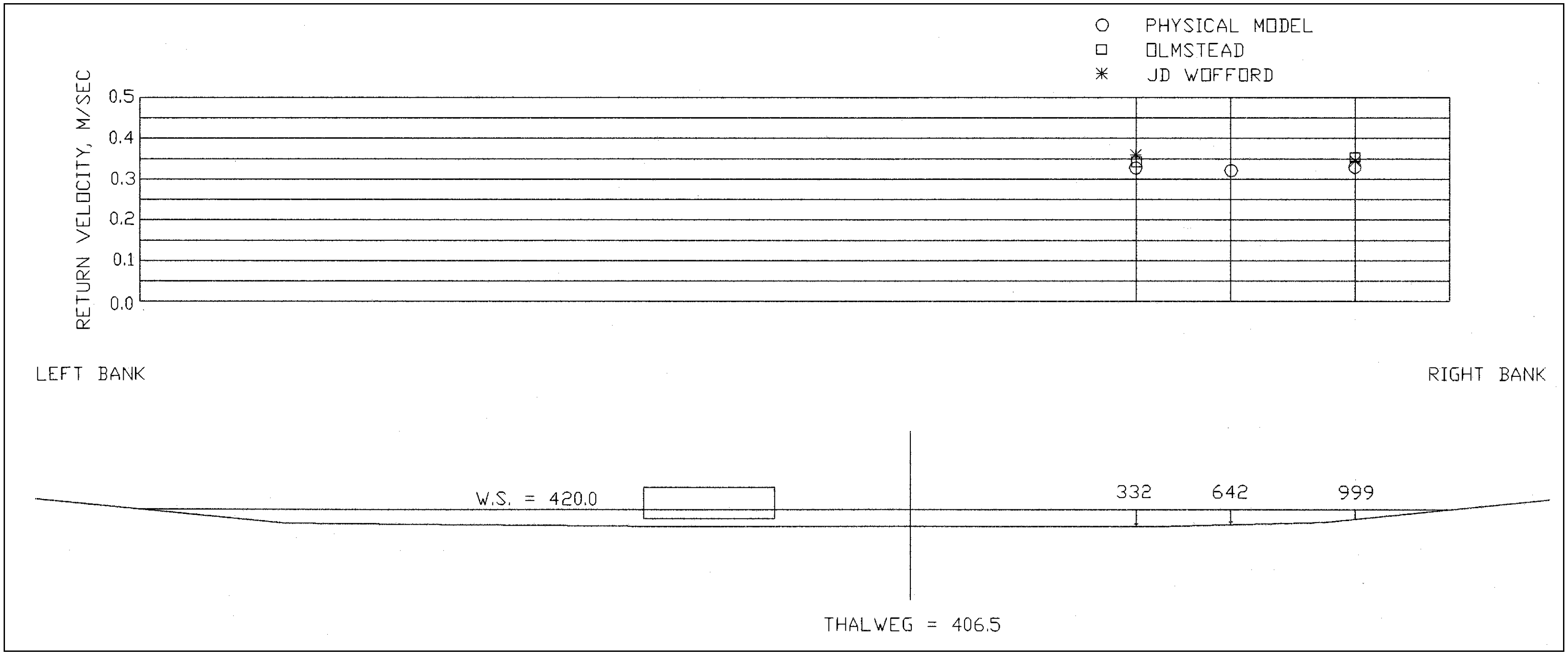



Figure 23. Physical model return velocity versus prototype return velocity for *Olmstead* and *Jack D. Wofford*

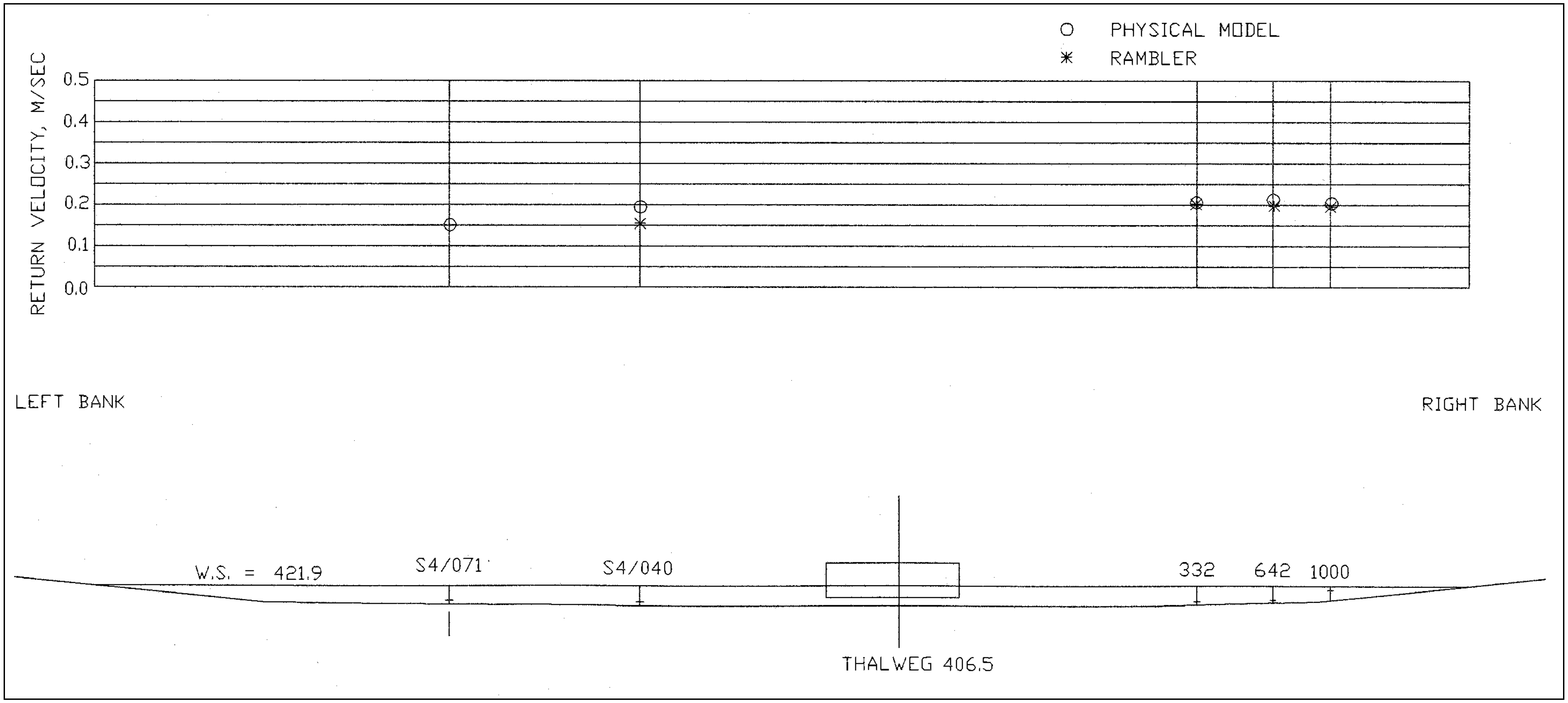



Figure 24. Physical model return velocity versus prototype return velocity for *Rambler*

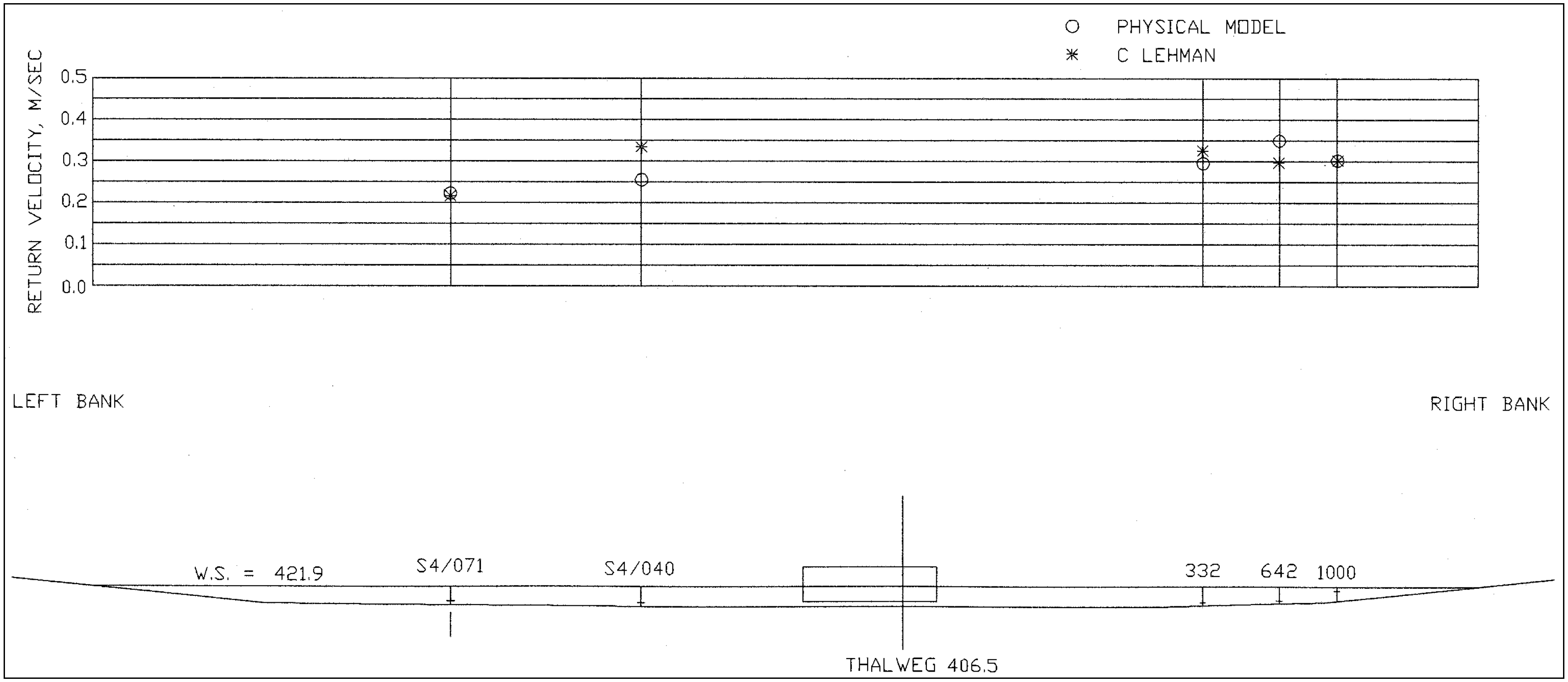



Figure 25. Physical model return velocity versus prototype return velocity for *Charles Lehman*

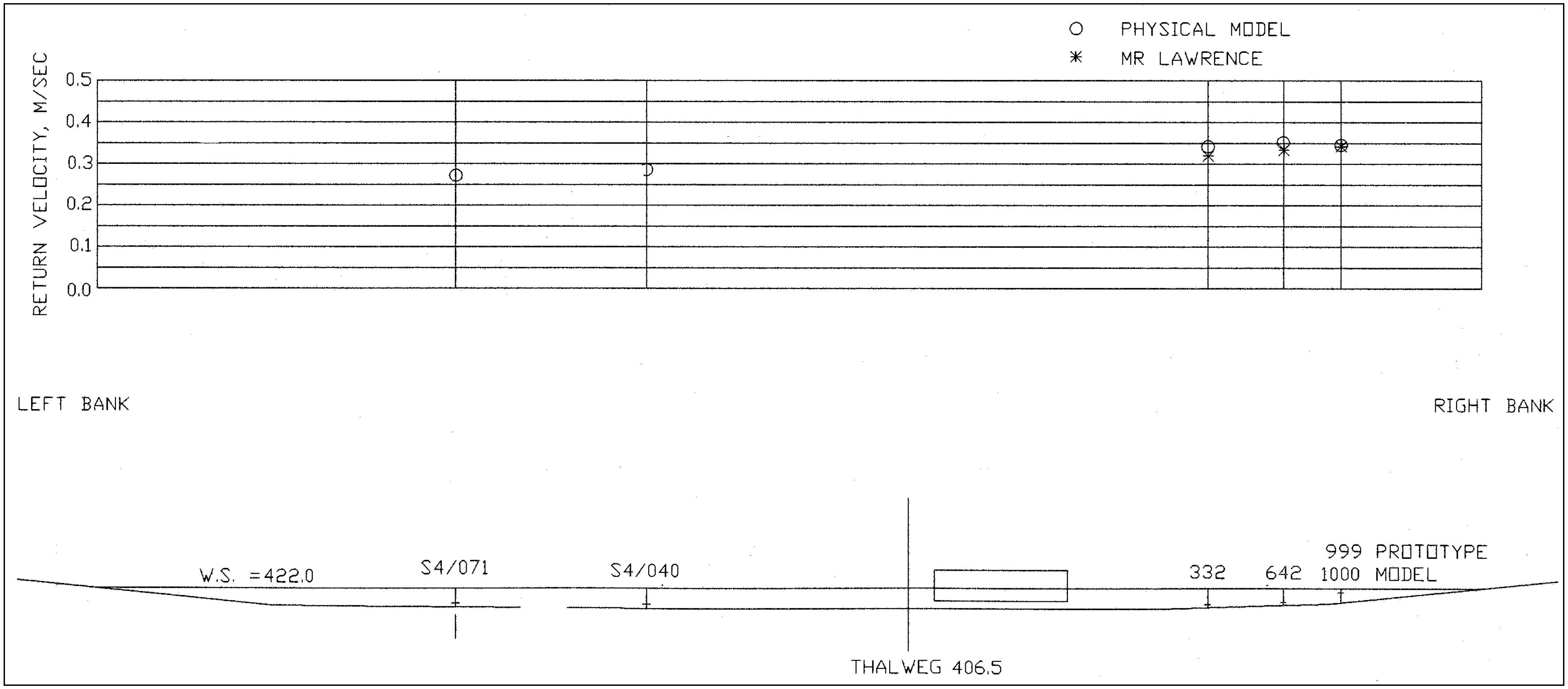



Figure 26. Physical model return velocity versus prorotype return velocity for *Mr. Lawrence*

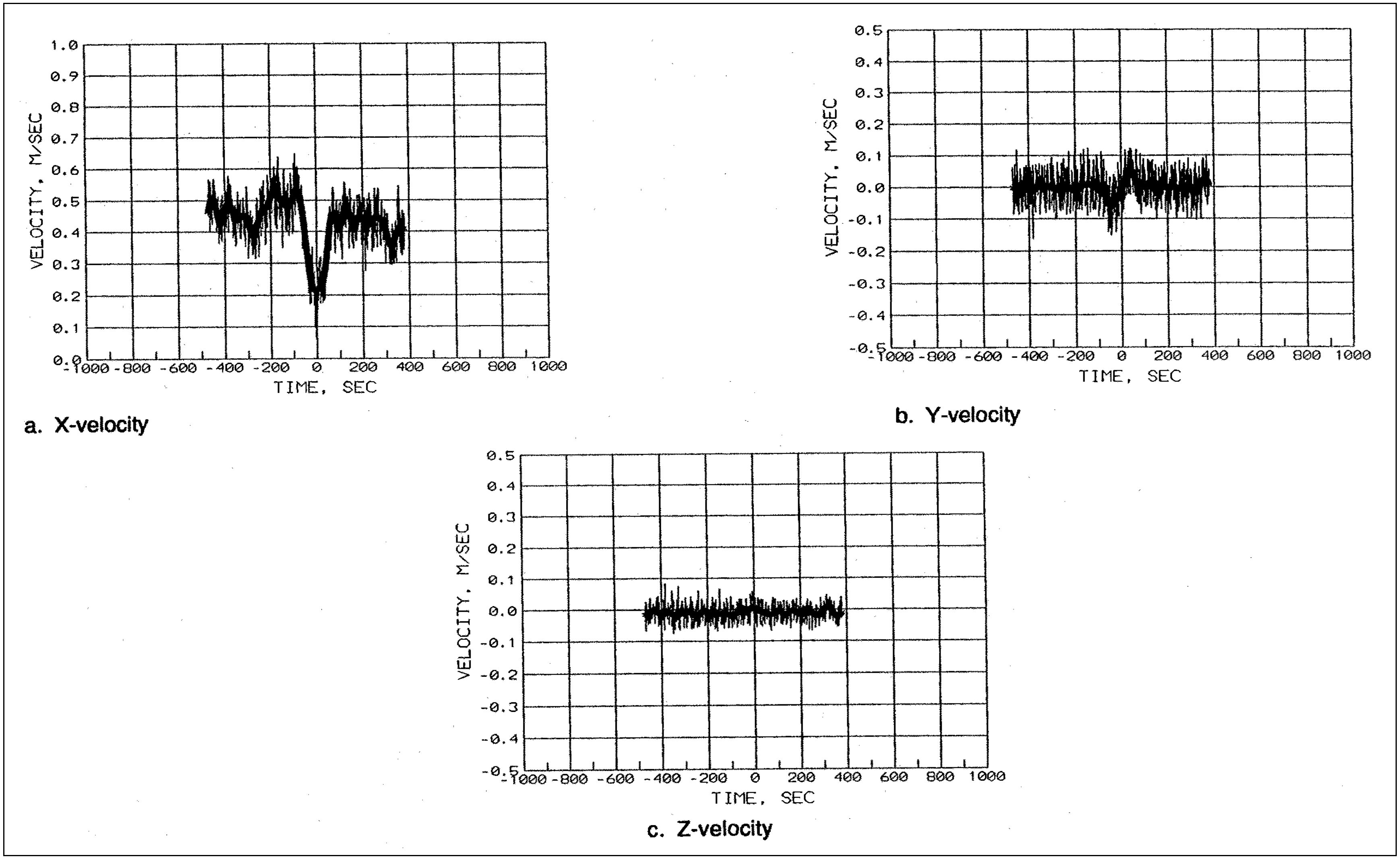



Figure 27. Physical model data, *William C. Norman*, meter at location of MMB527/332

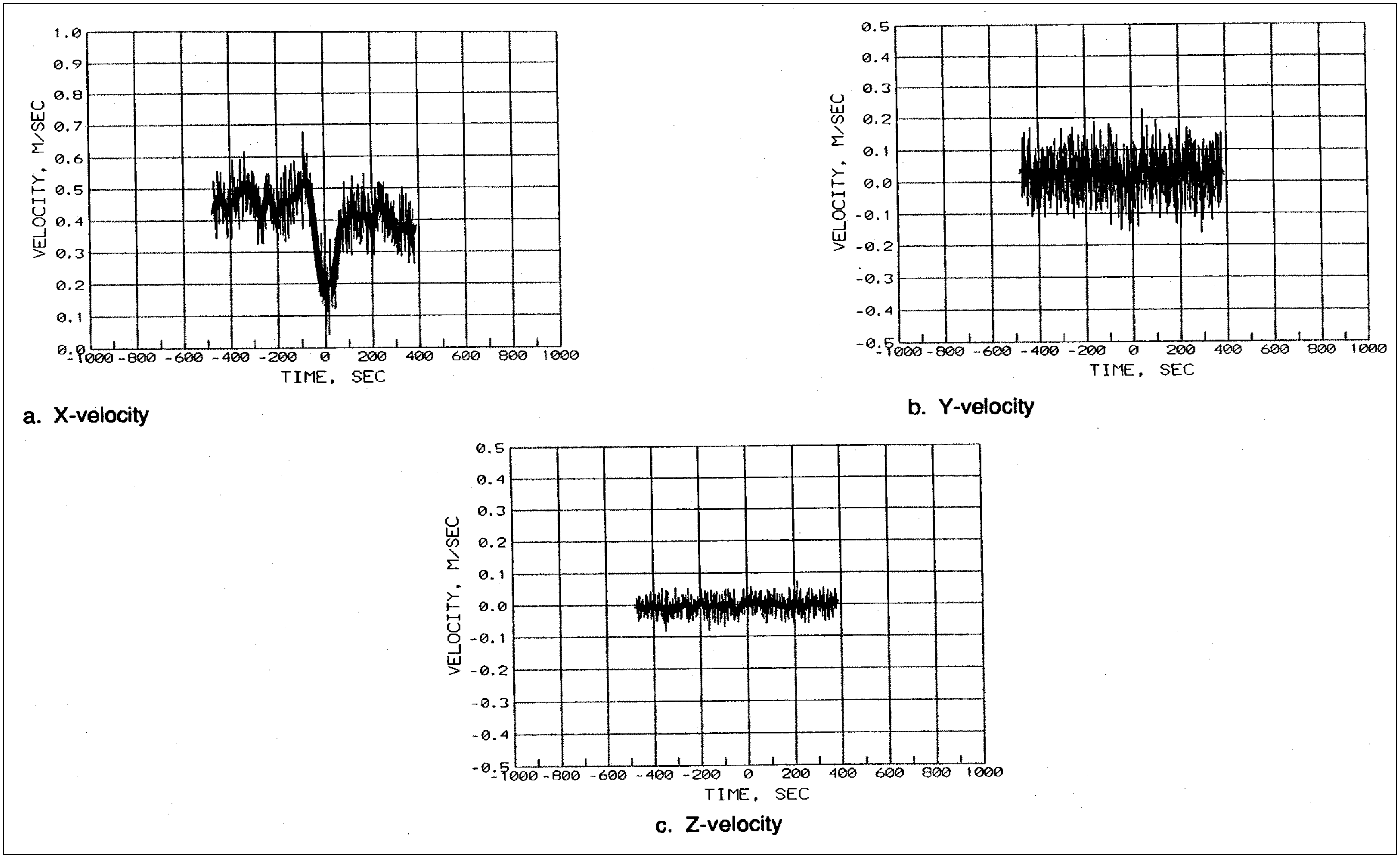



Figure 28. Physical model data, *William C. Norman*, meter at location of MMB527/642

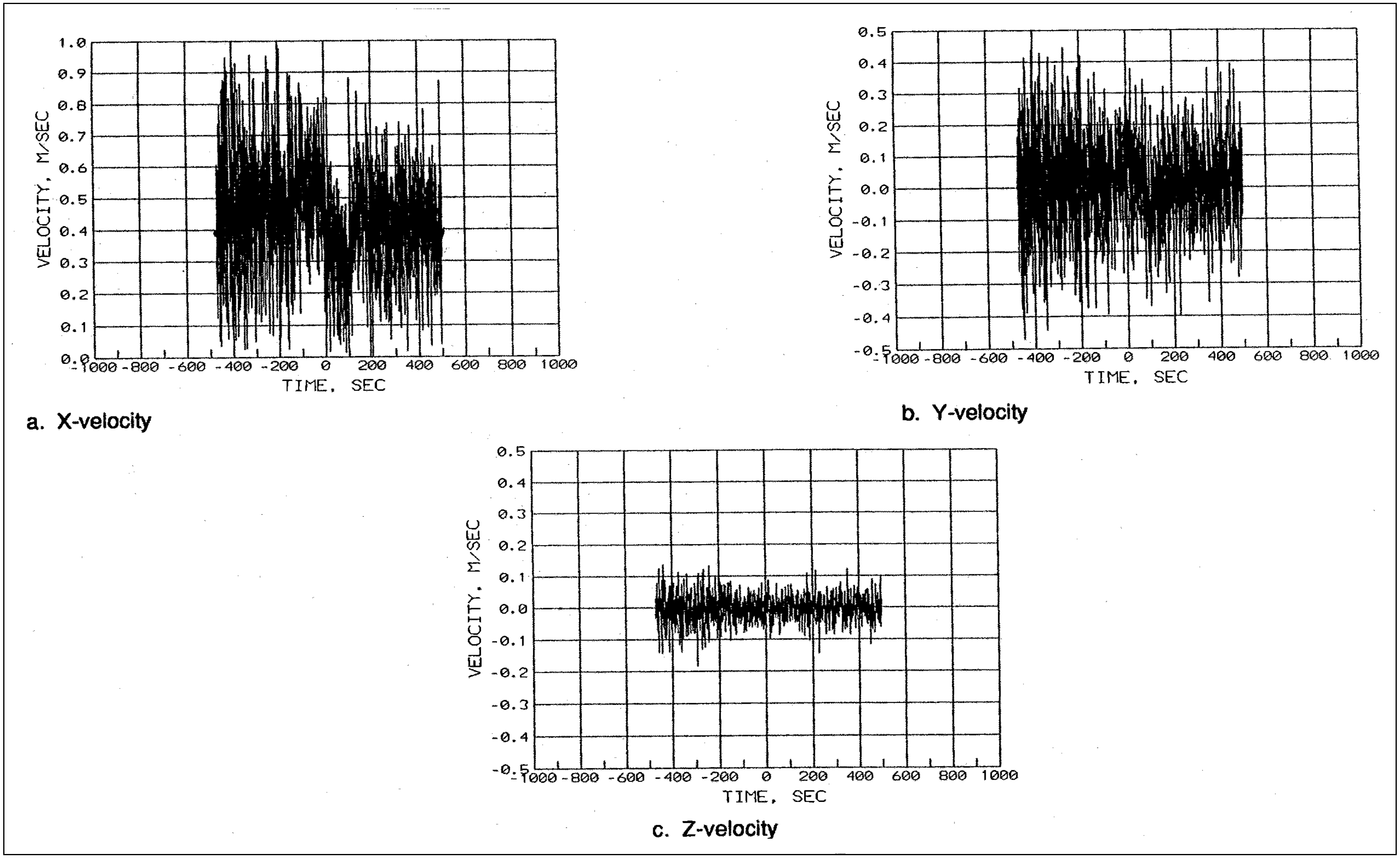



Figure 29.   Physical model data, *William C. Norman*, meter at location of S4/040

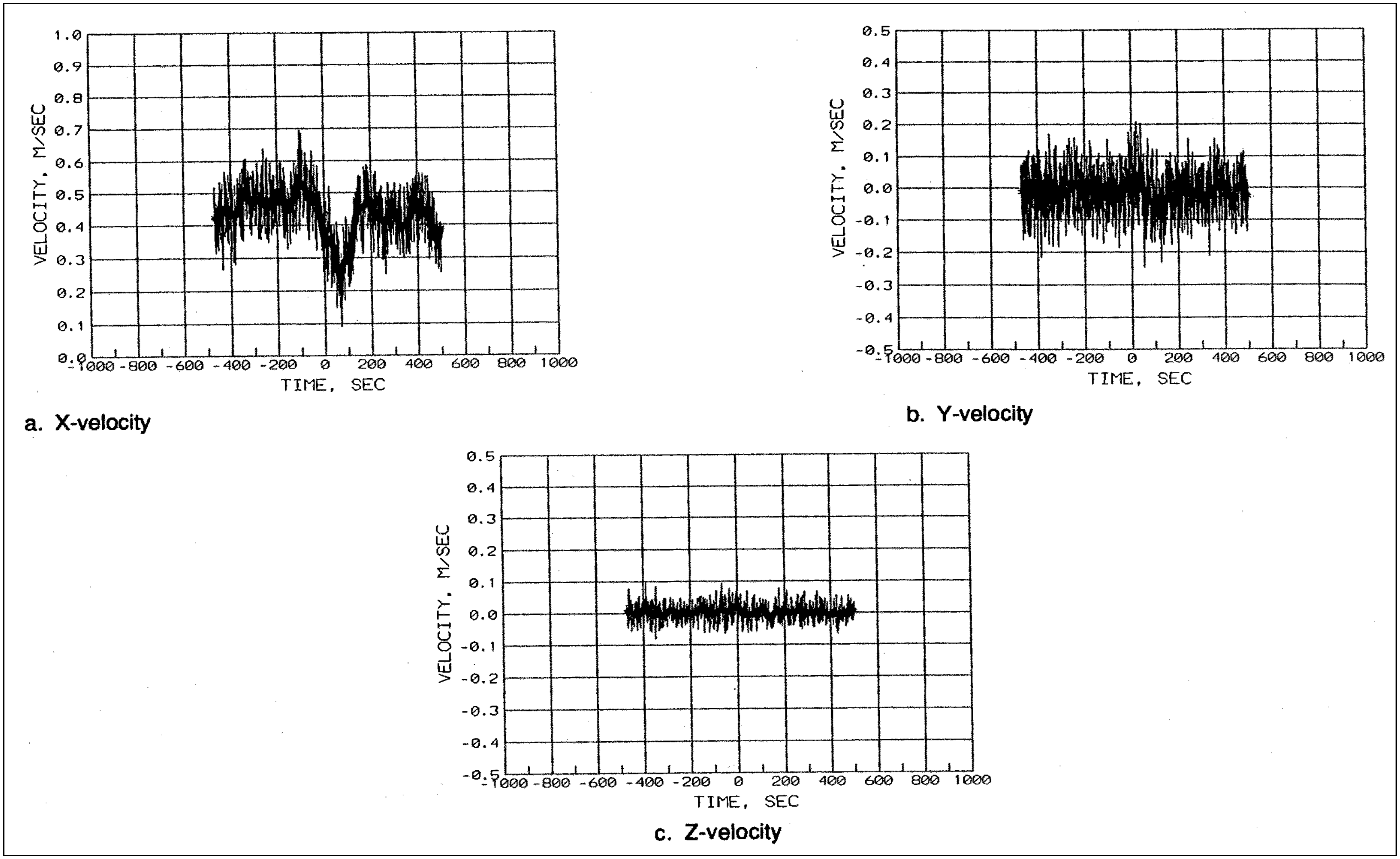
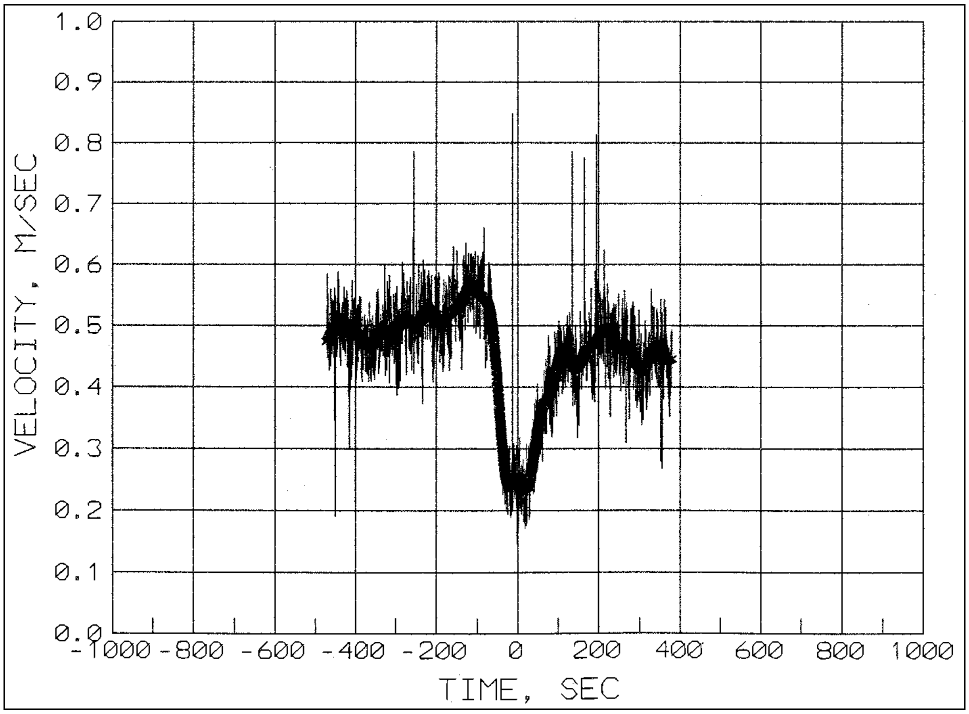
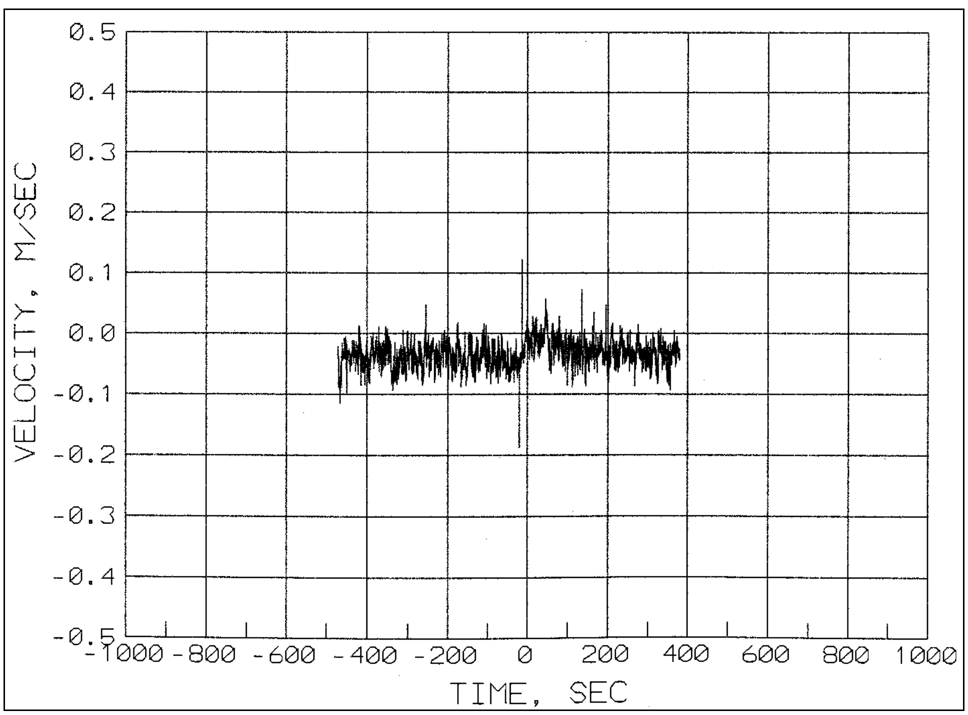



Figure 30. Physical model data, *William C. Norman*, meter at location of S4/071

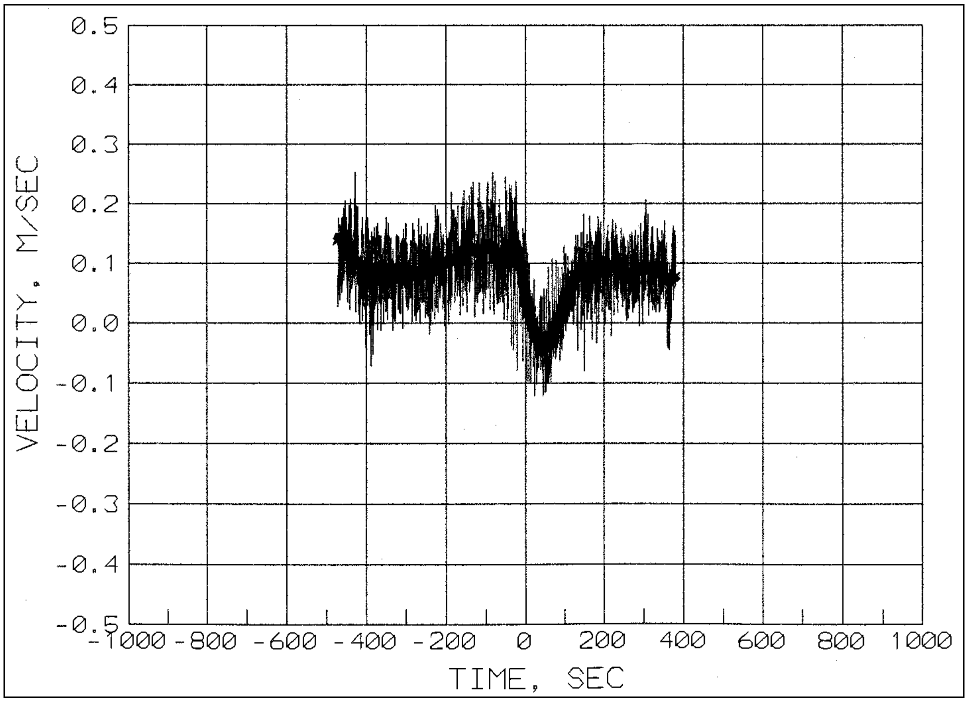



a. X-velocity

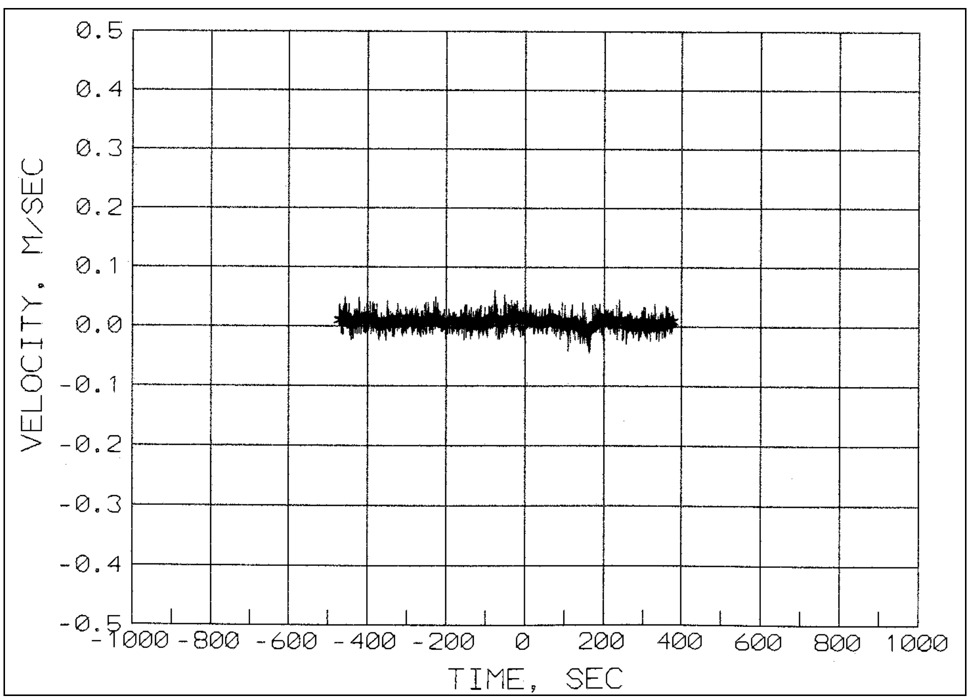



b. Y-velocity

Figure 31. Physical model data, *William C. Norma*, meter at location of MMB511/1000




a. X-velocity




b. Y-velocity

Figure 32. Physical model data, *William C. Norman*, meter at location of MMB511/1001

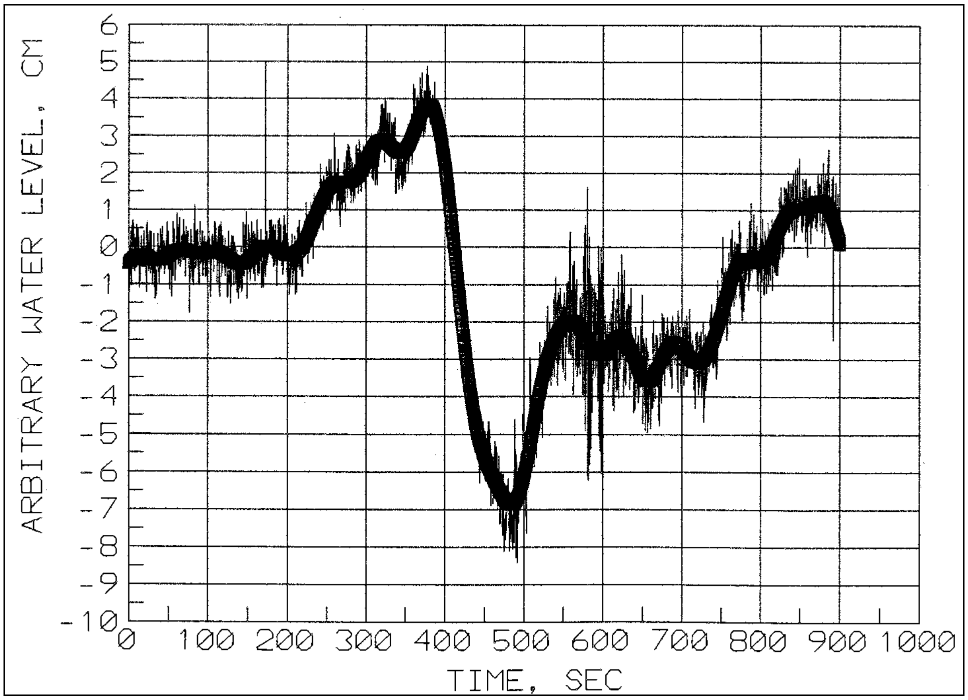



Figure 33. Physical model data, *William C. Norman*, wave gauge

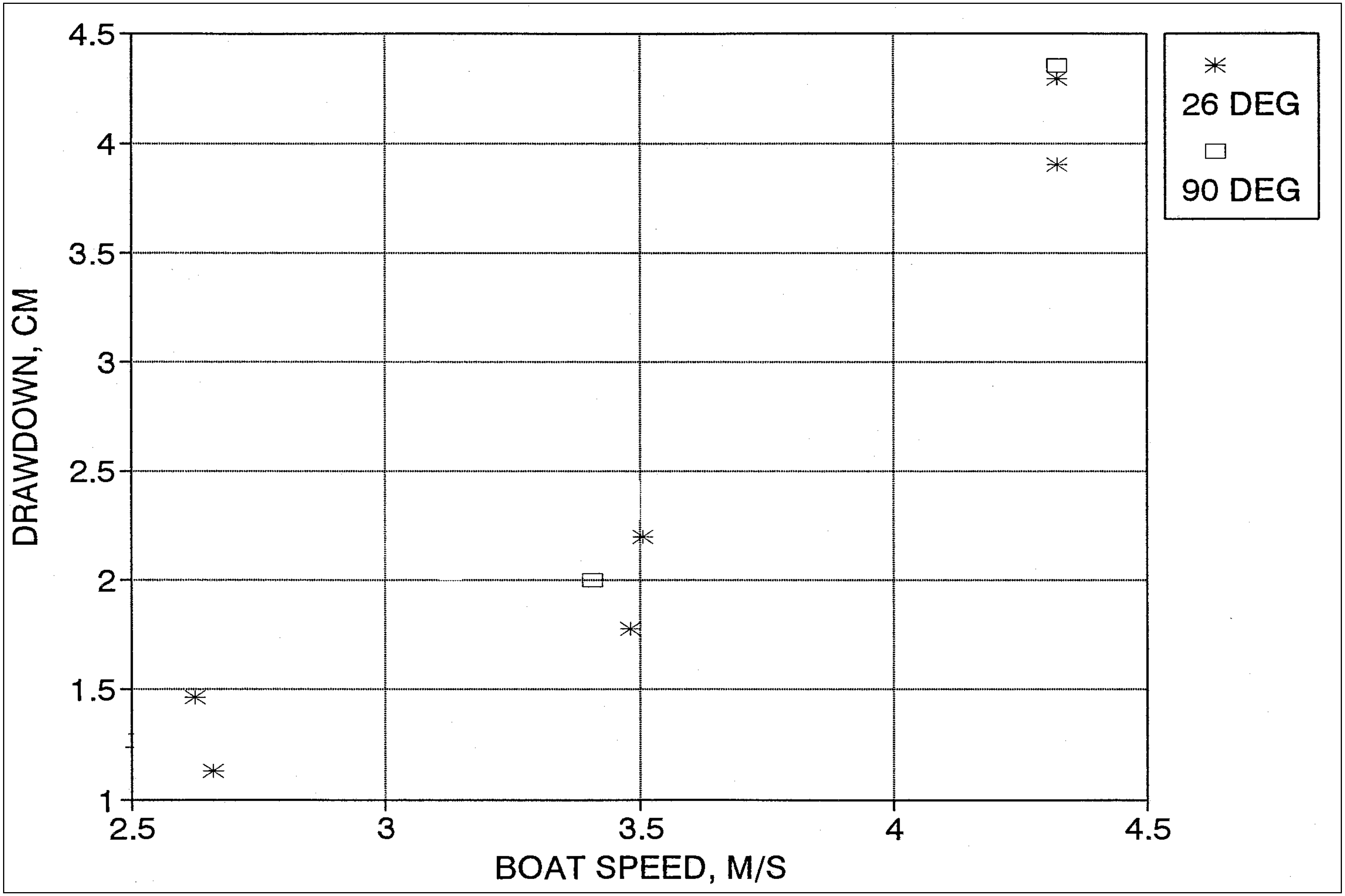



Figure 34. Rake experiments, drawdown, rod 2, 226.5 m from right bank

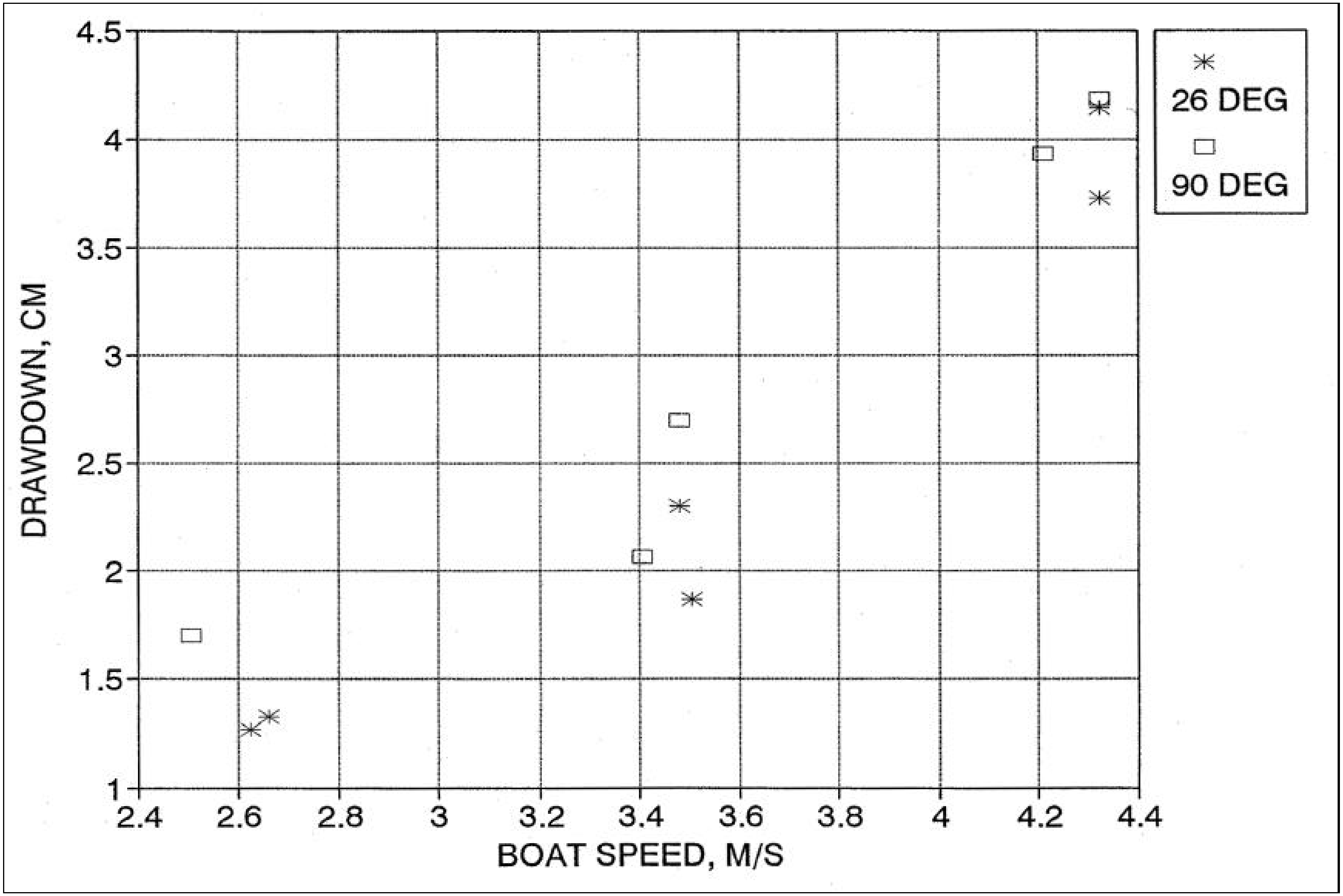



Figure 35. Rake experiments, drawdown, rod 1, 56.5 m from right bank

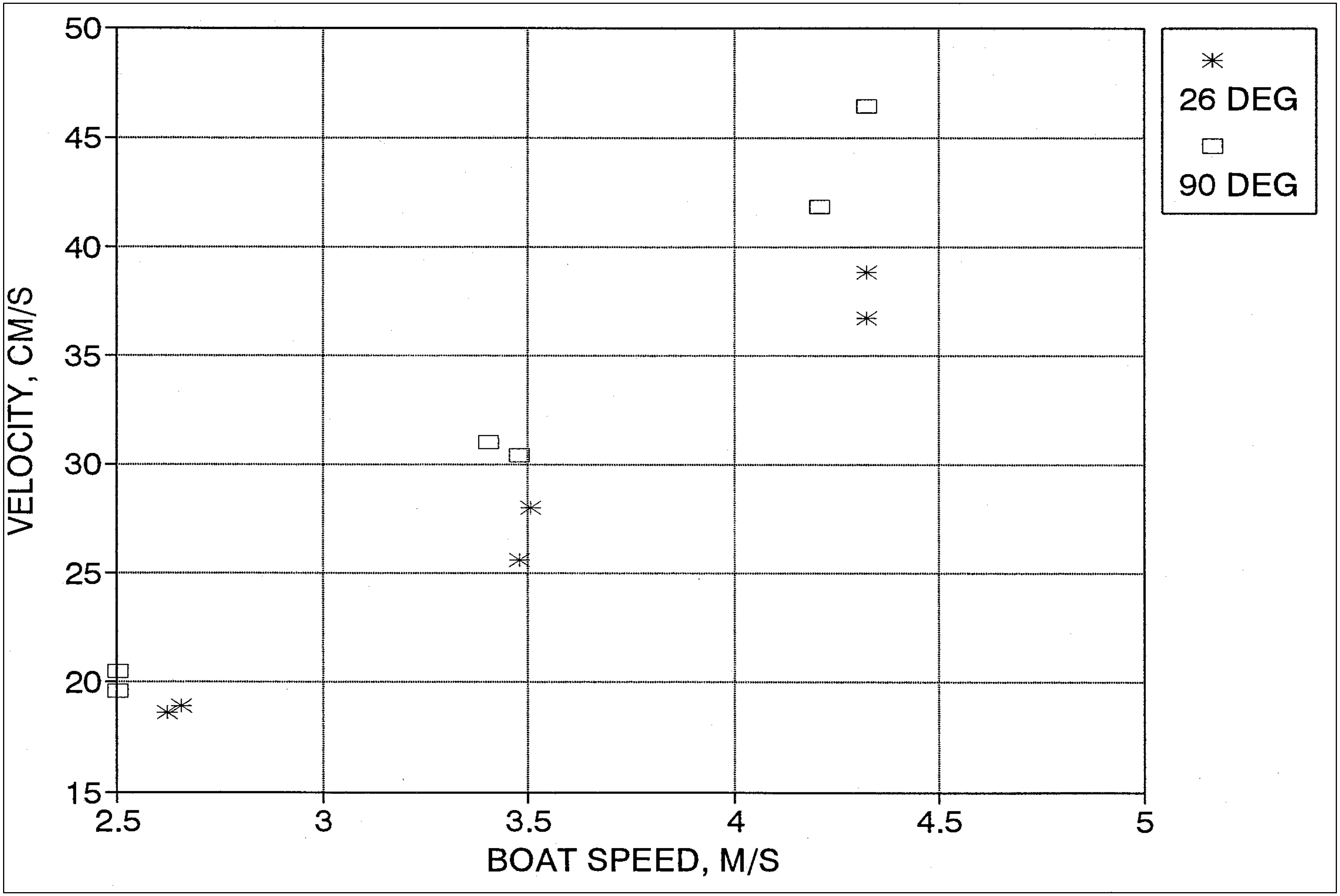



Figure 36. Rake experimetns, return velocity, x velocity, near tow

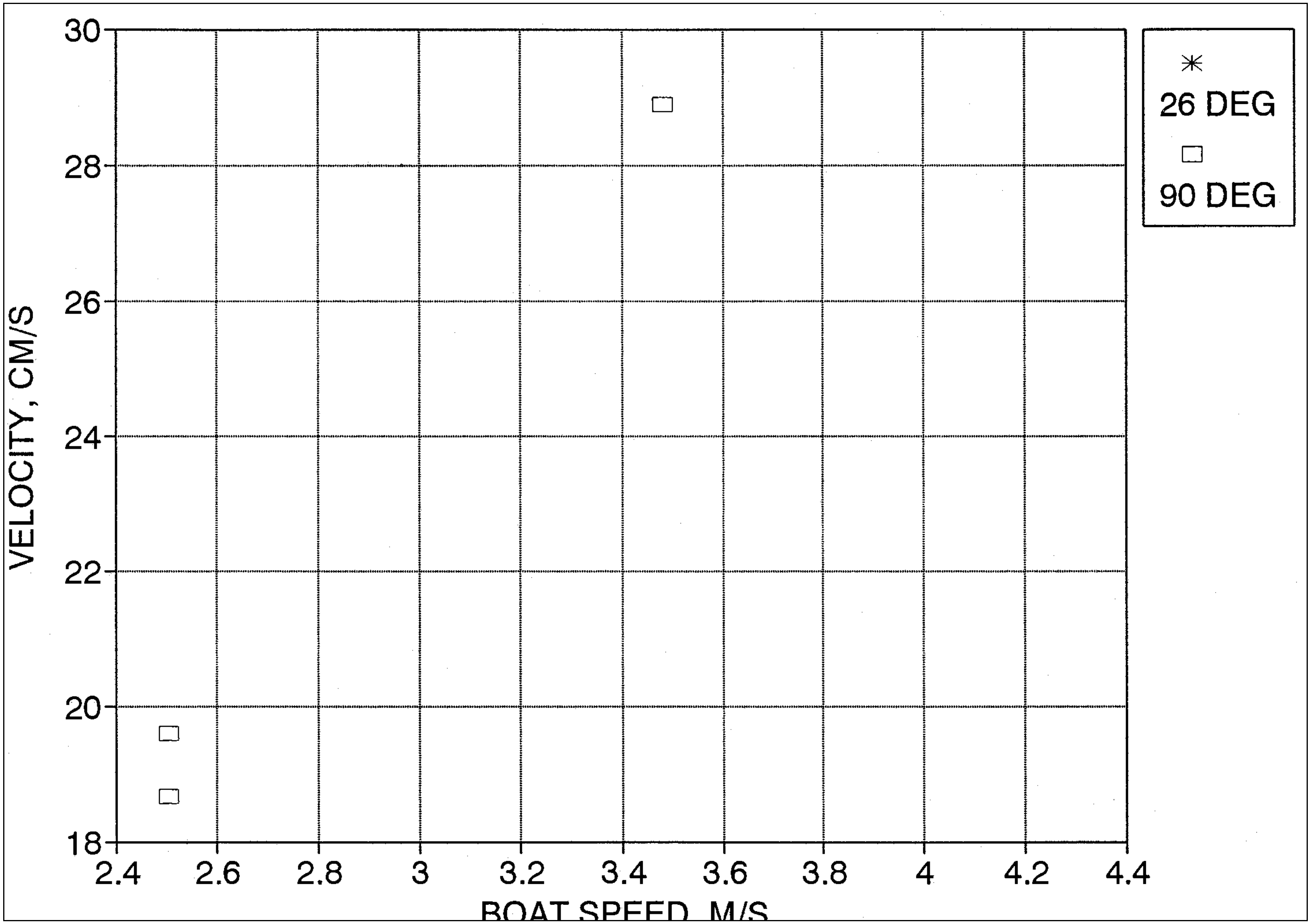



Figure 37. Rake experiments, return velocity, x velocity, midway between tow and bank

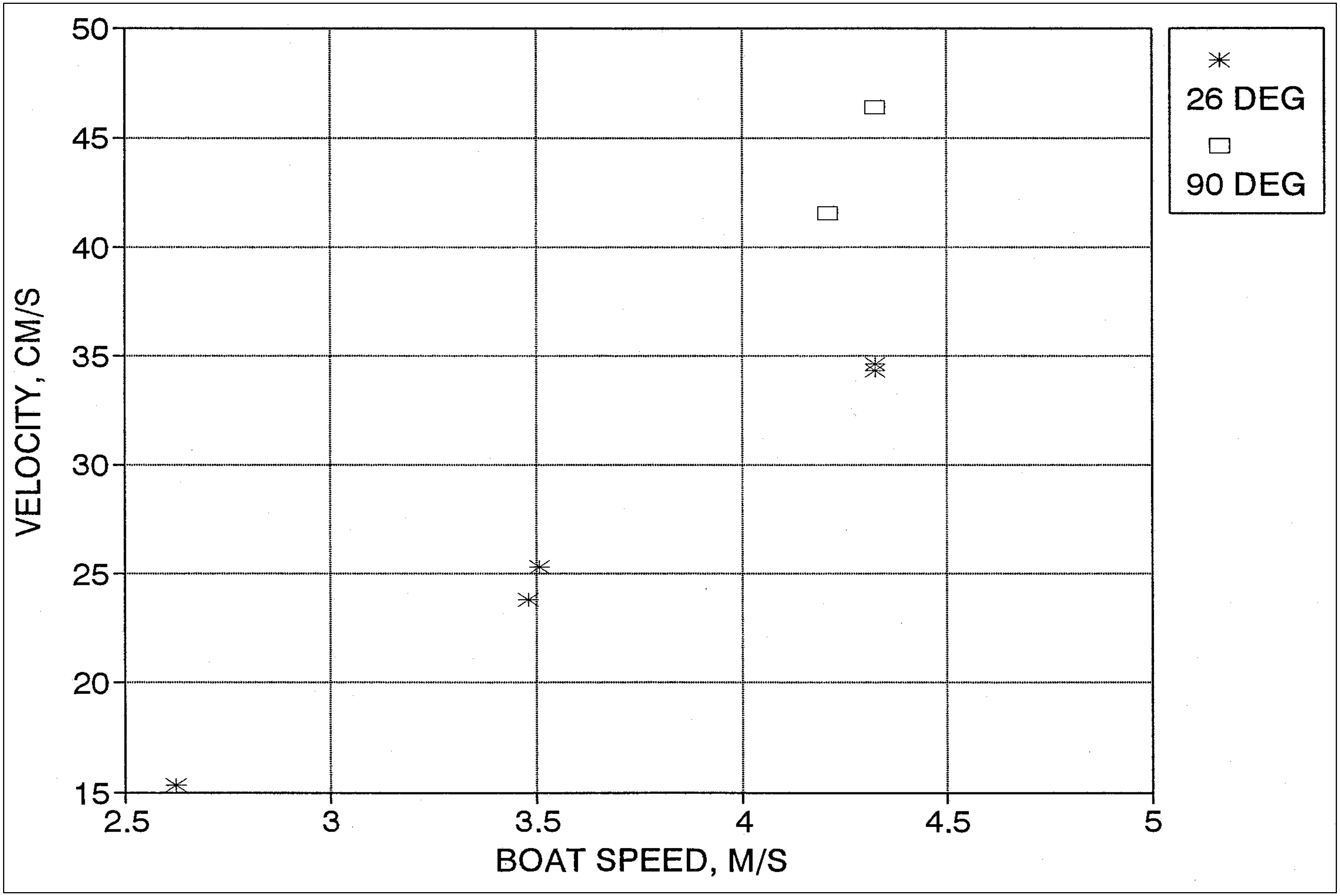



Figure 38. Rake experiments, return velocity, x direction, near bank

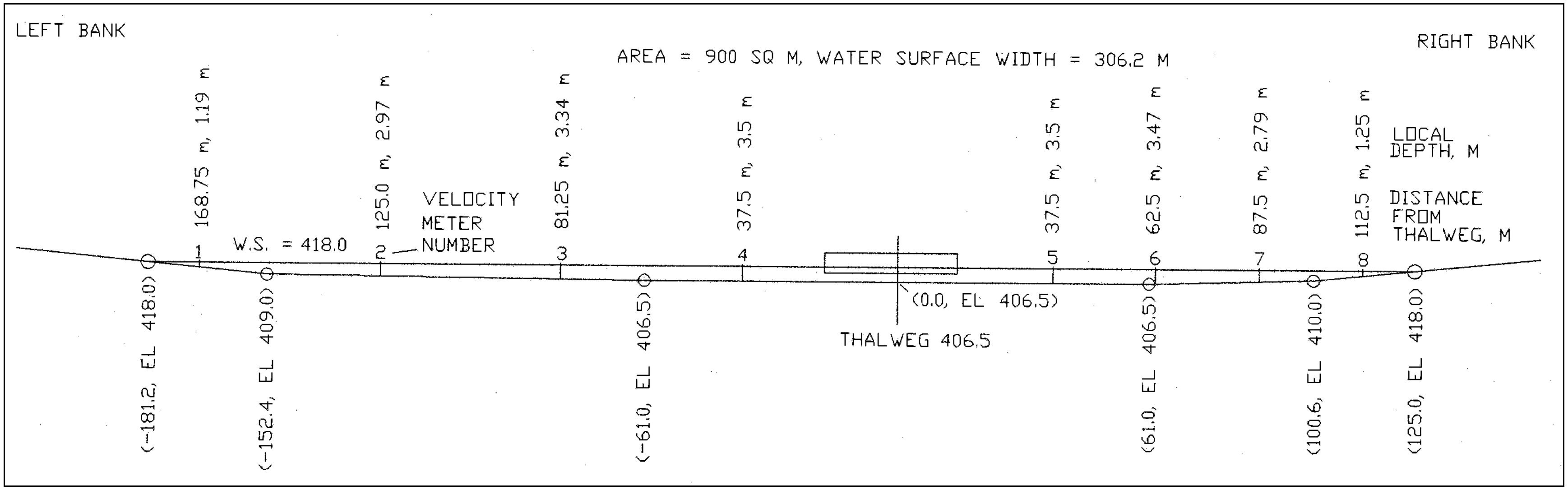



Figure 39. Cross section and meter locations for pool el 418.0 experiments

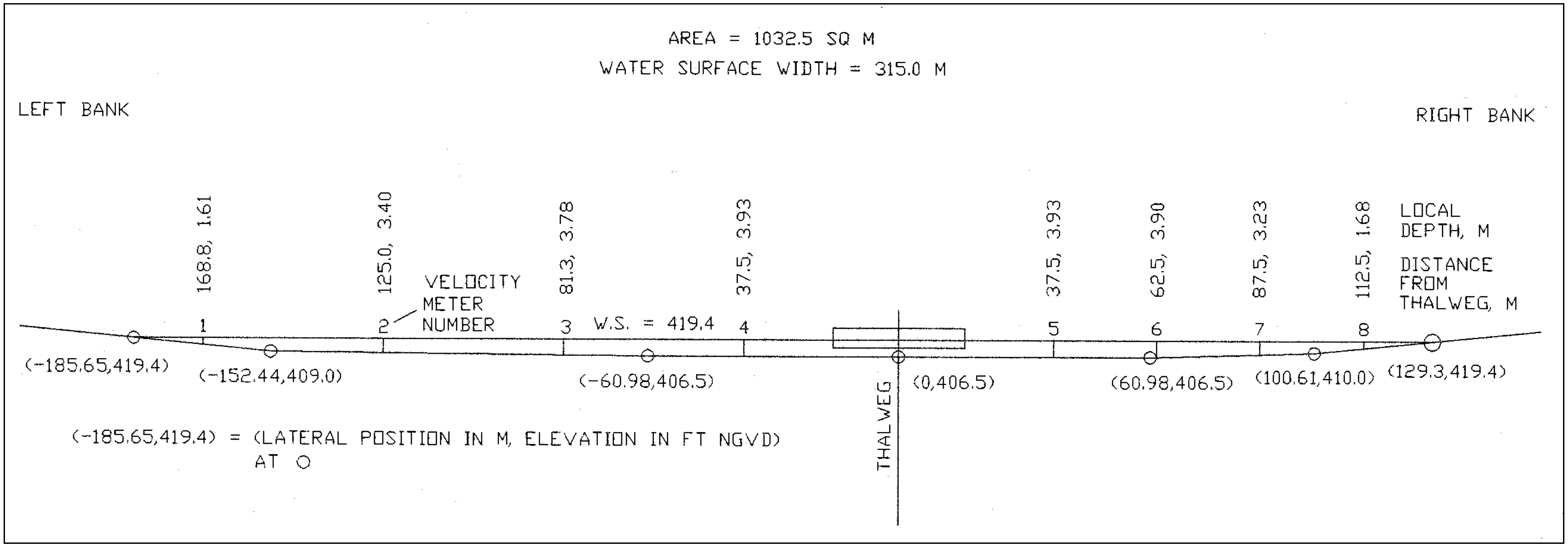



Figure 40. Cross section and meter locations for pool el 419.4 experiments

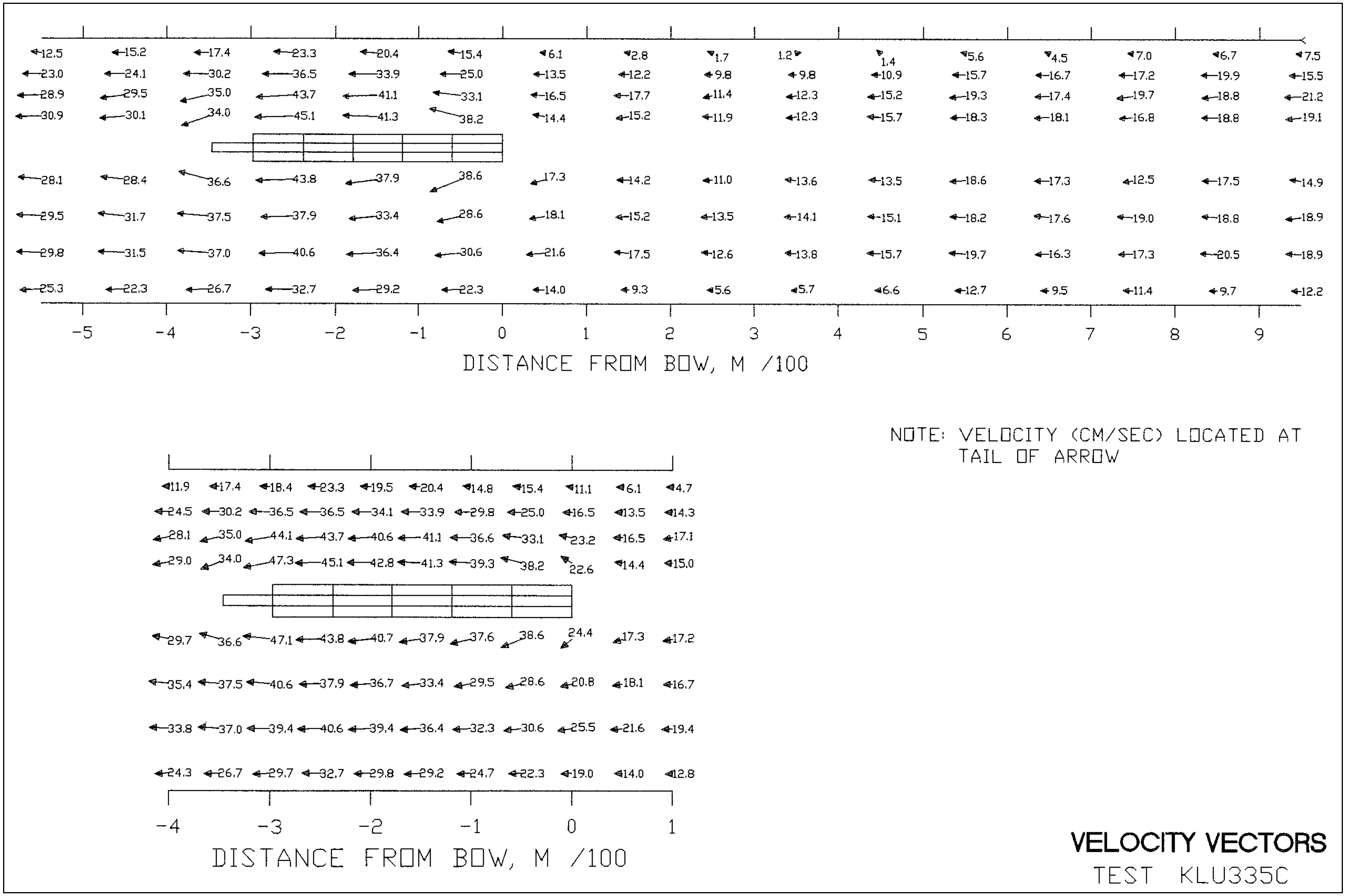



Figure 41. Velocity vectors, experiment KLU335C

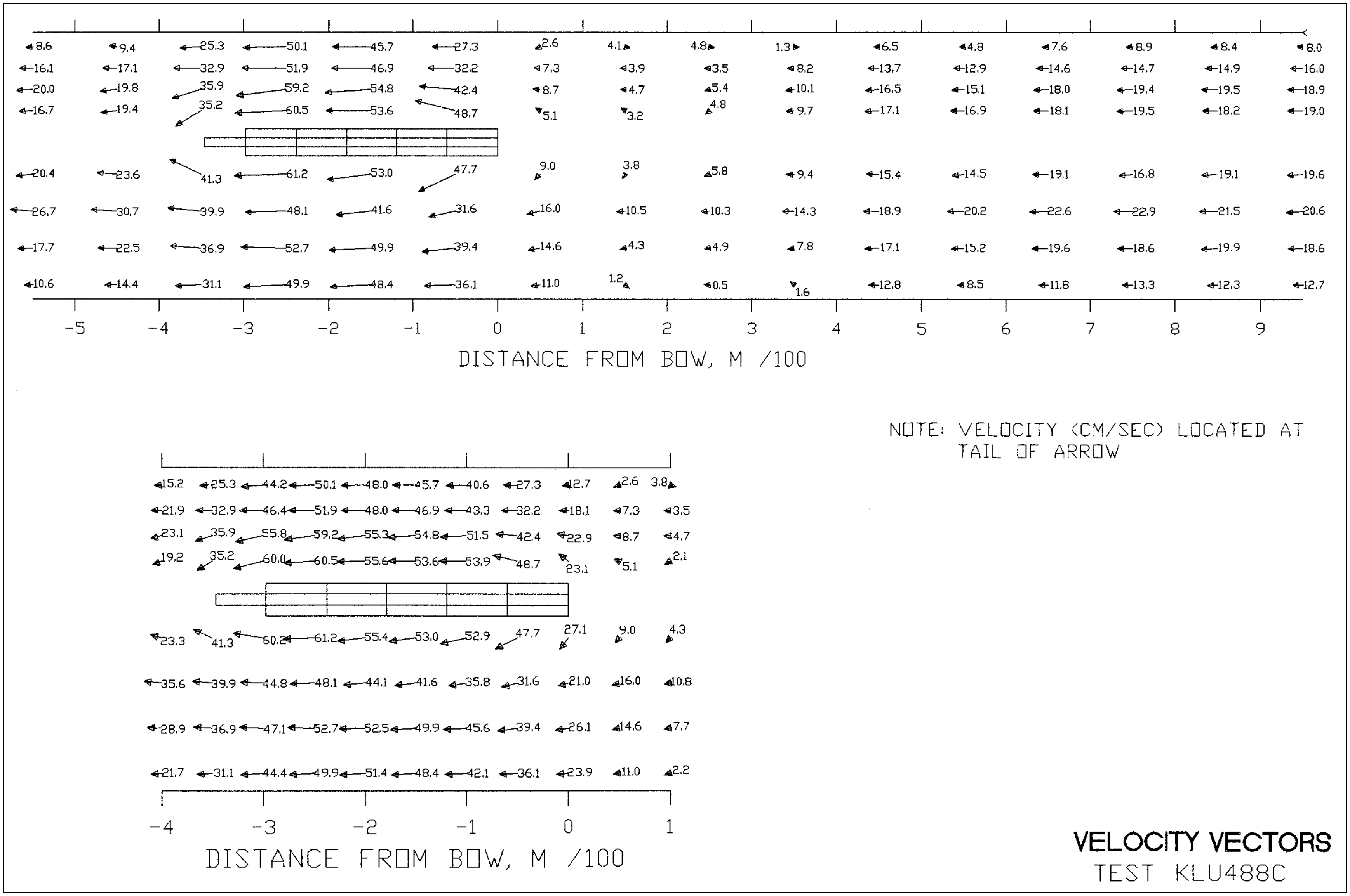



Figure 42. Velocity vectors, experiment KLU488C

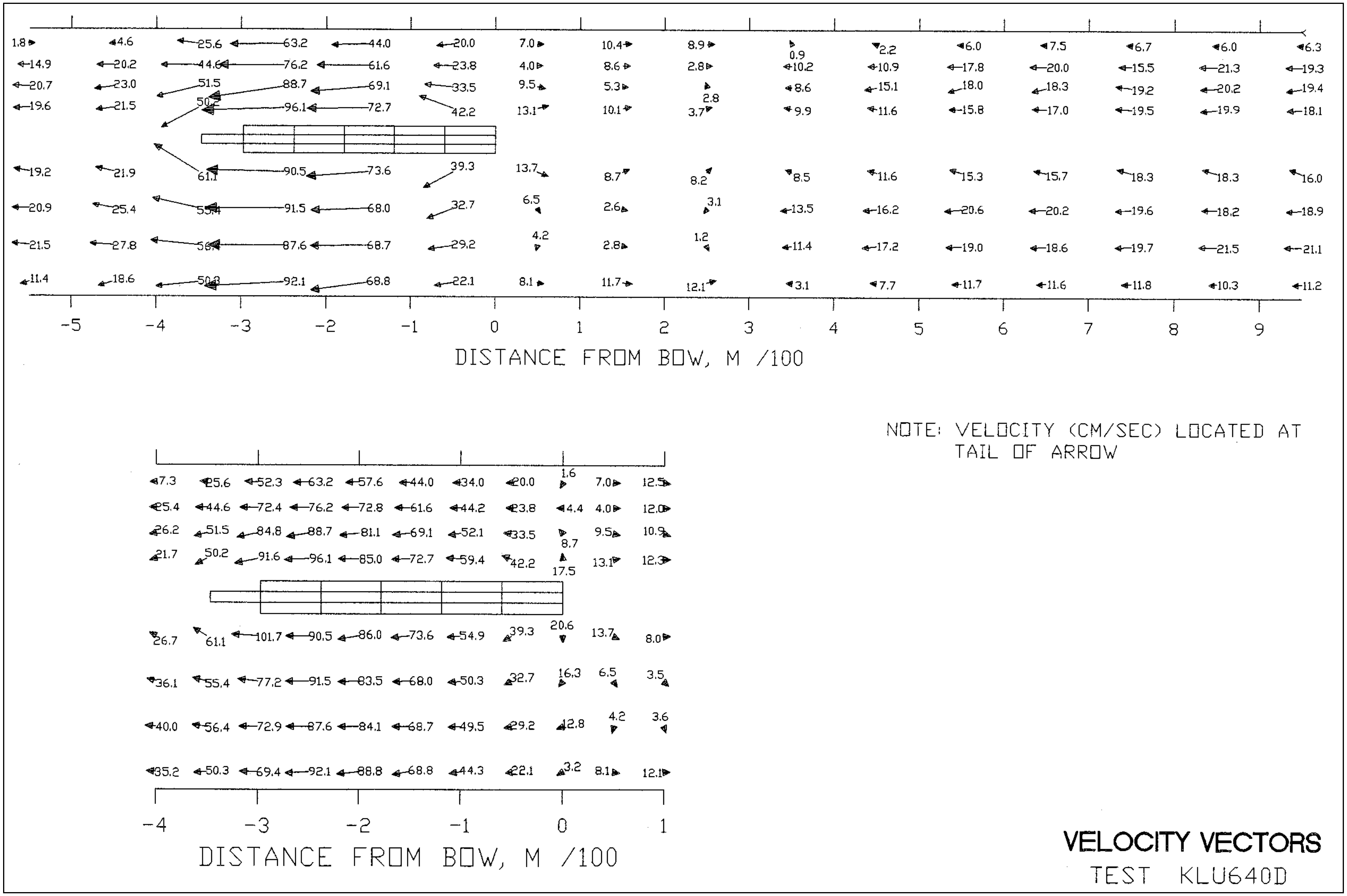



Figure 43. Velocity vectors, experiment KLU640D

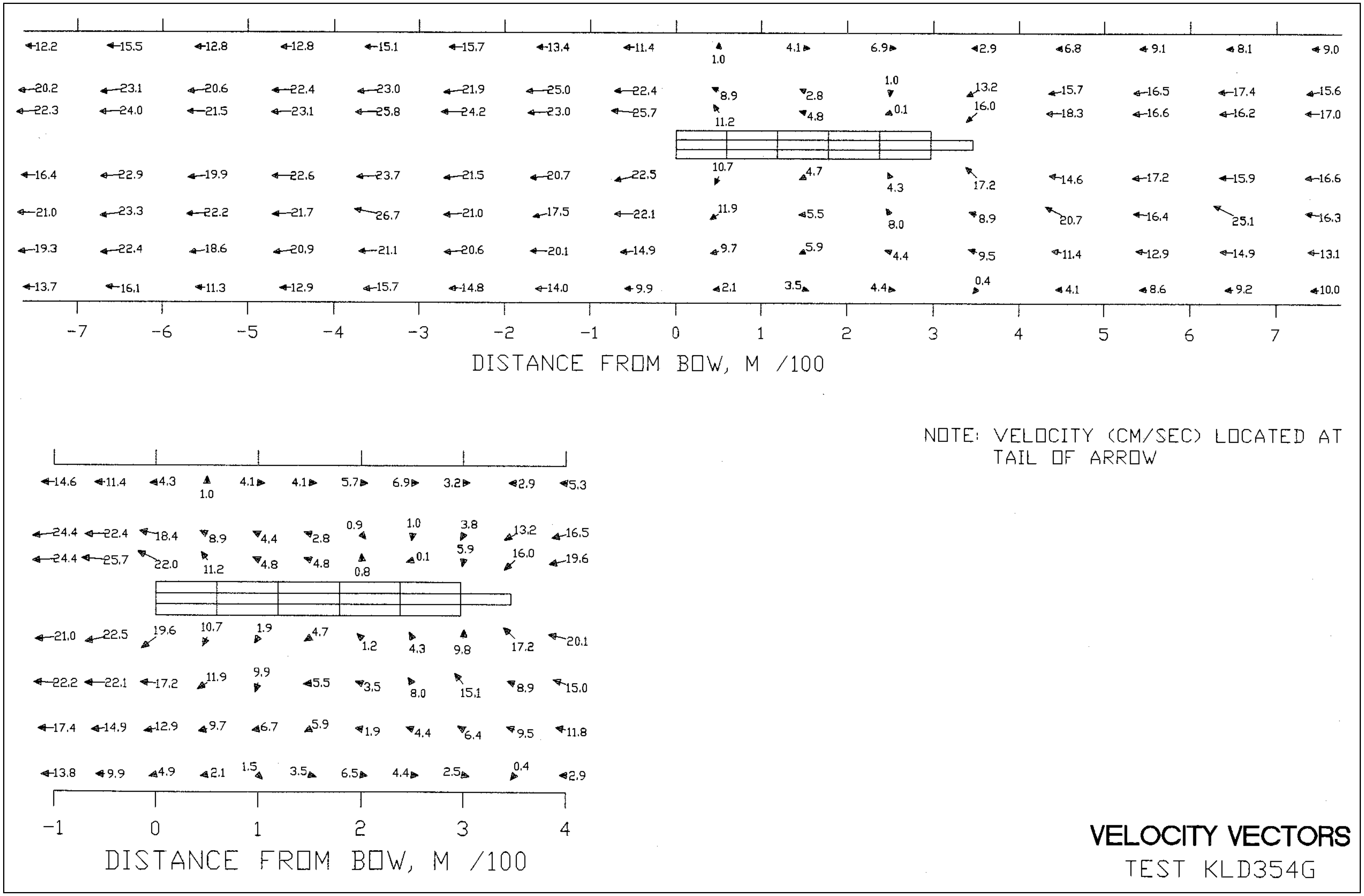



Figure 44. Velocity vectors, experiment KLD354G

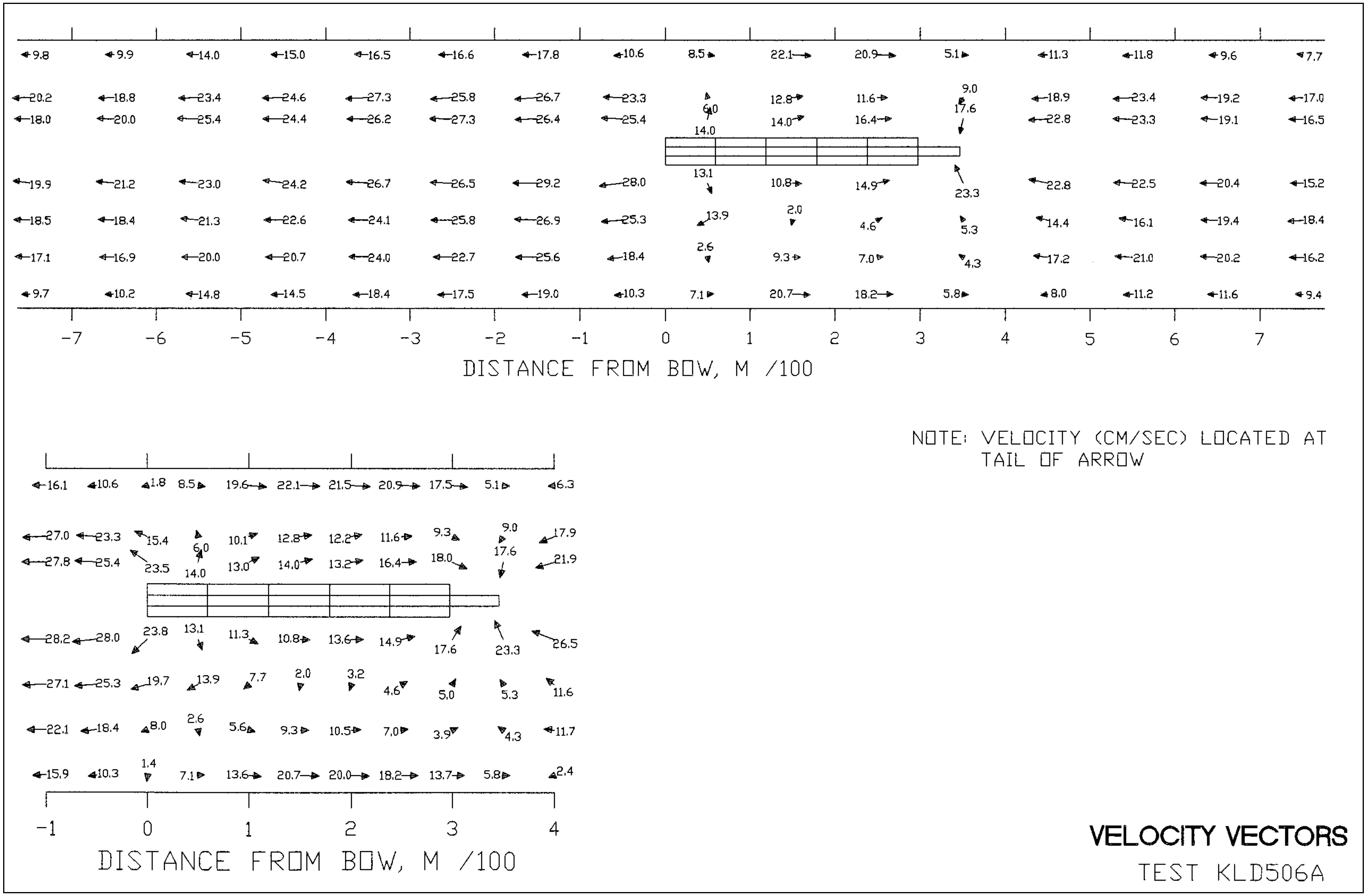



Figure 45. Velocity vectors, experiment KLD506A

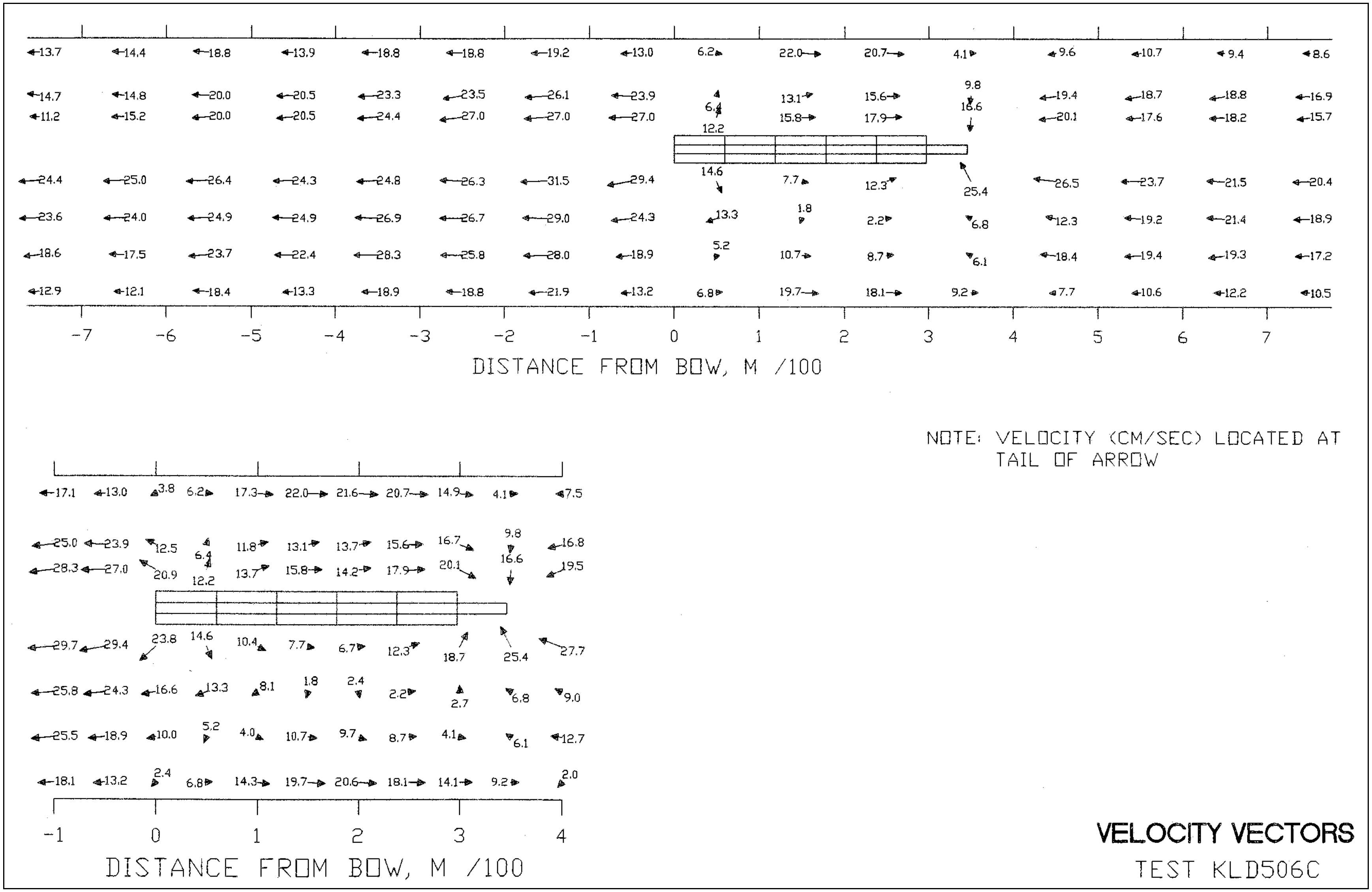



Figure 46. Velocity vectors, experimetn KLD506C

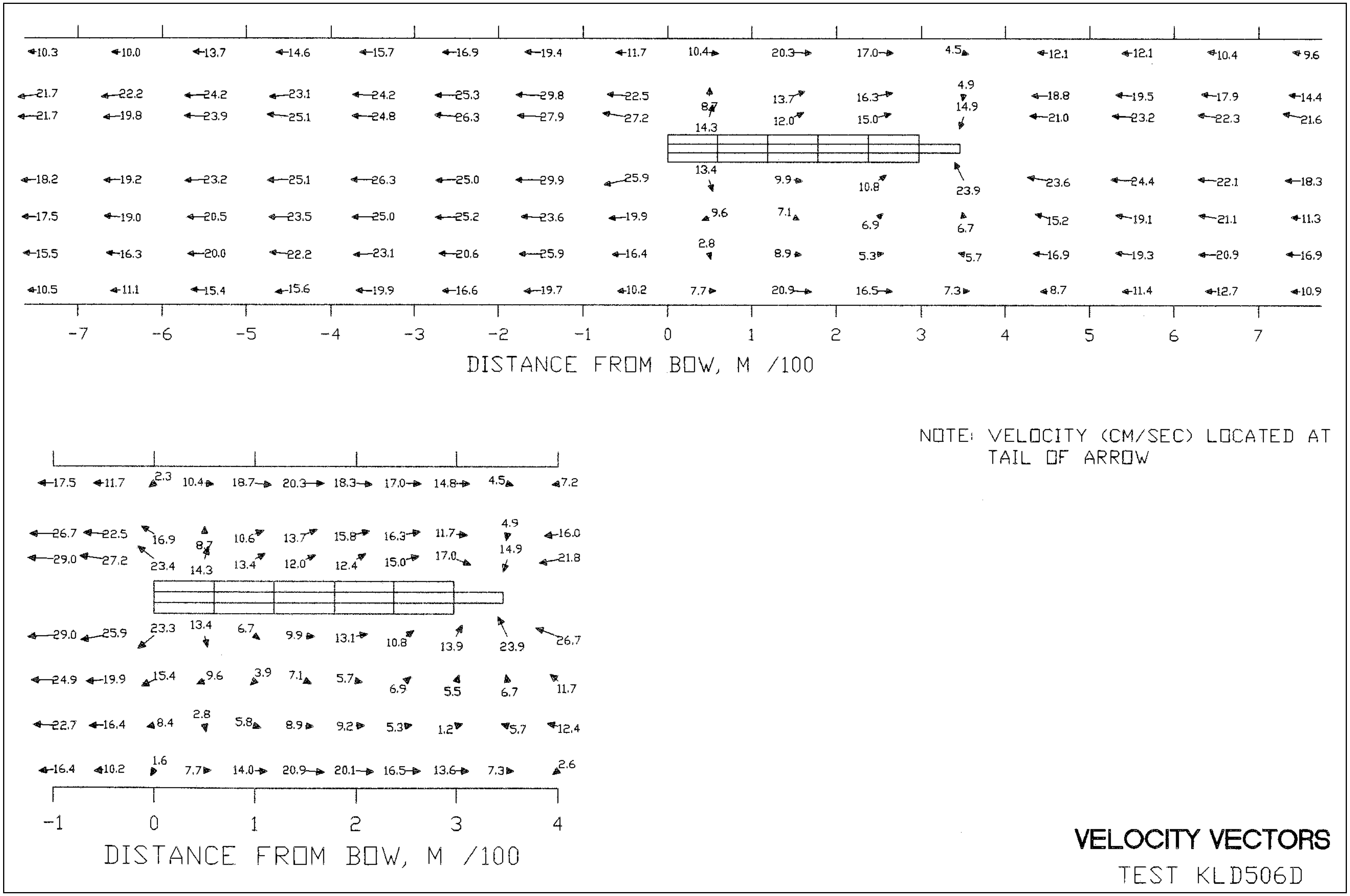



Figure 47. Velocity vectors, experiment KLD506D

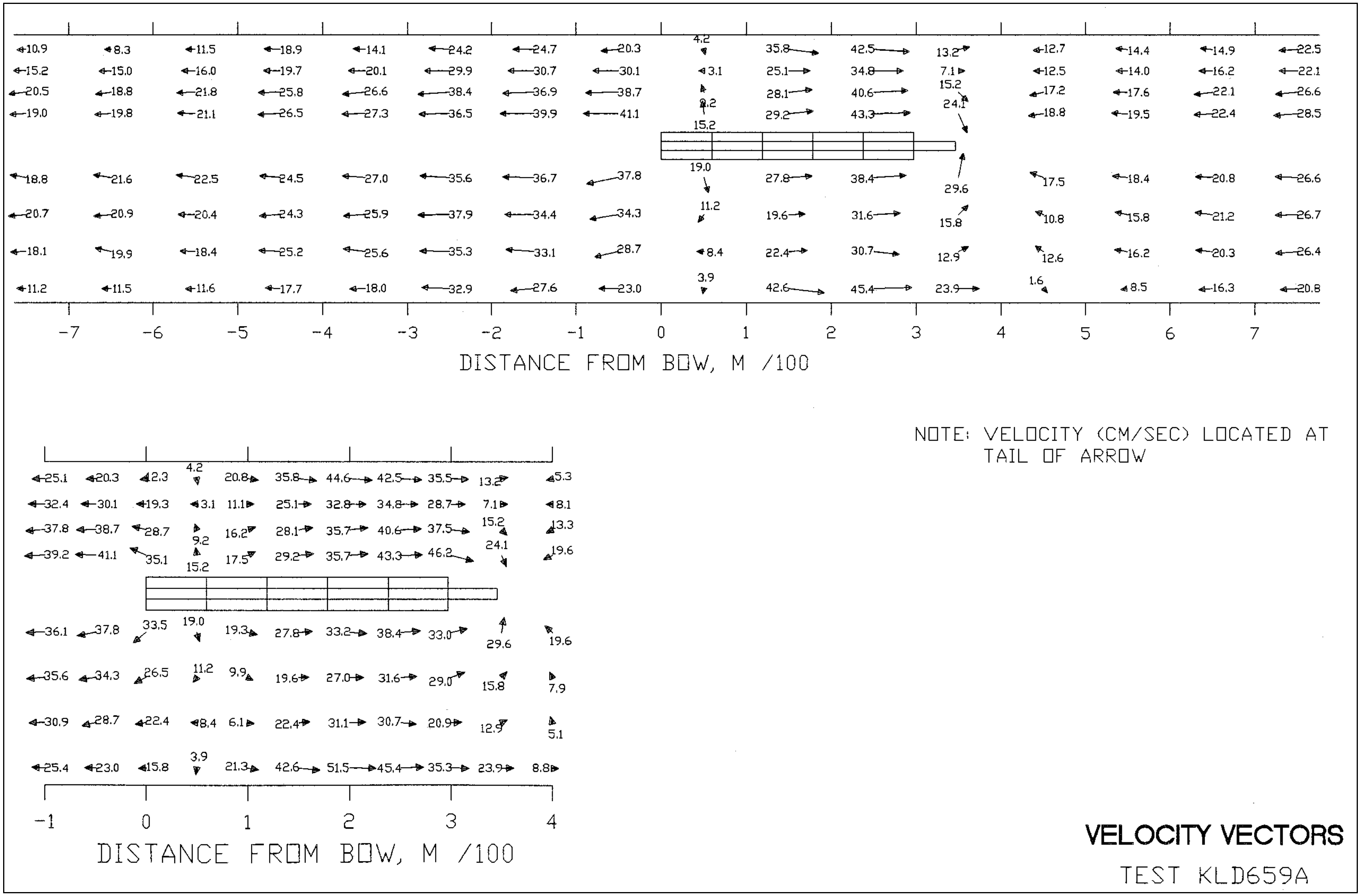



Figure 48. Velocity vectors, experimetn KLD659A

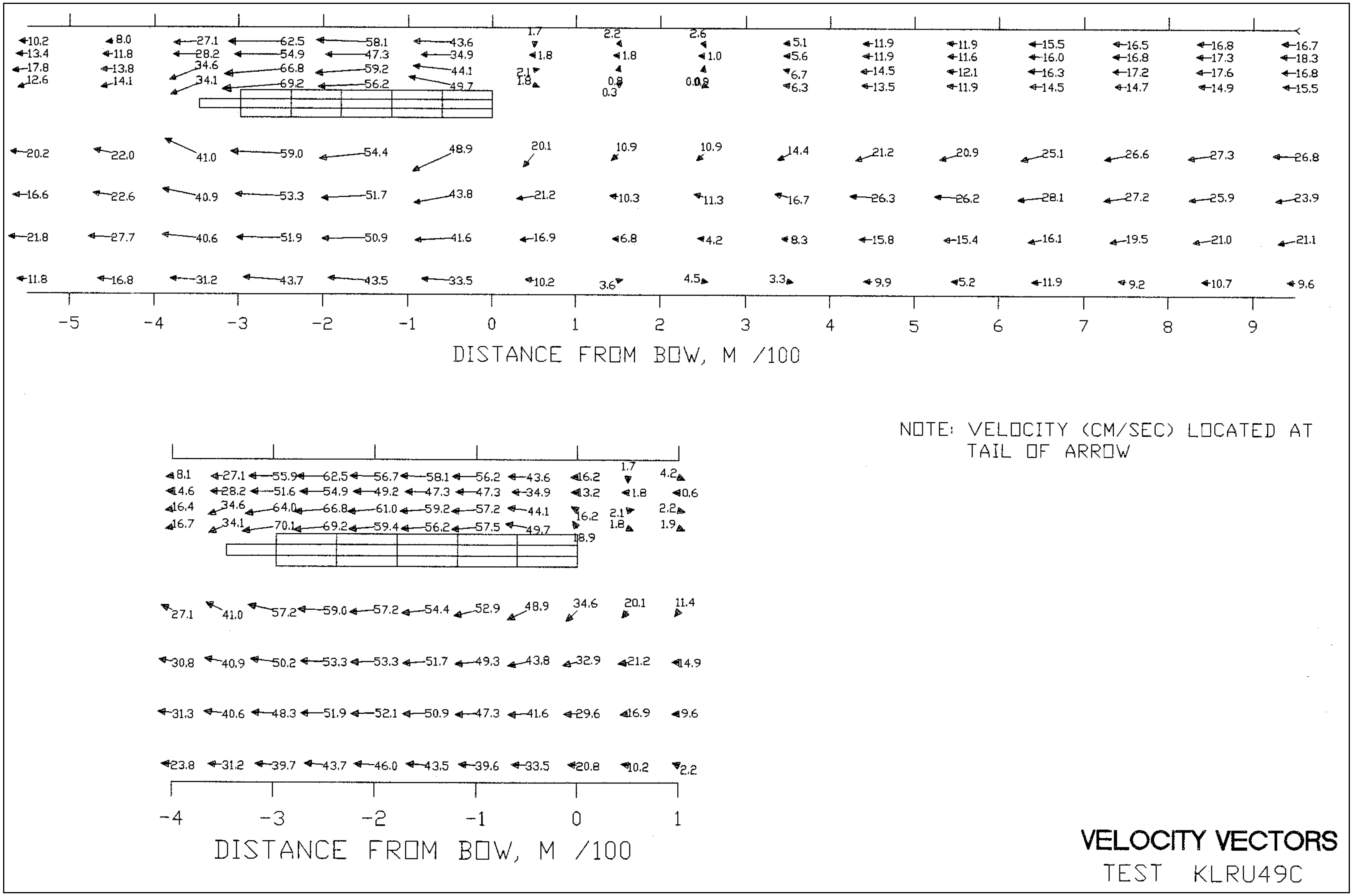



Figure 49. Velocity vectors, experimetn KLRU49C

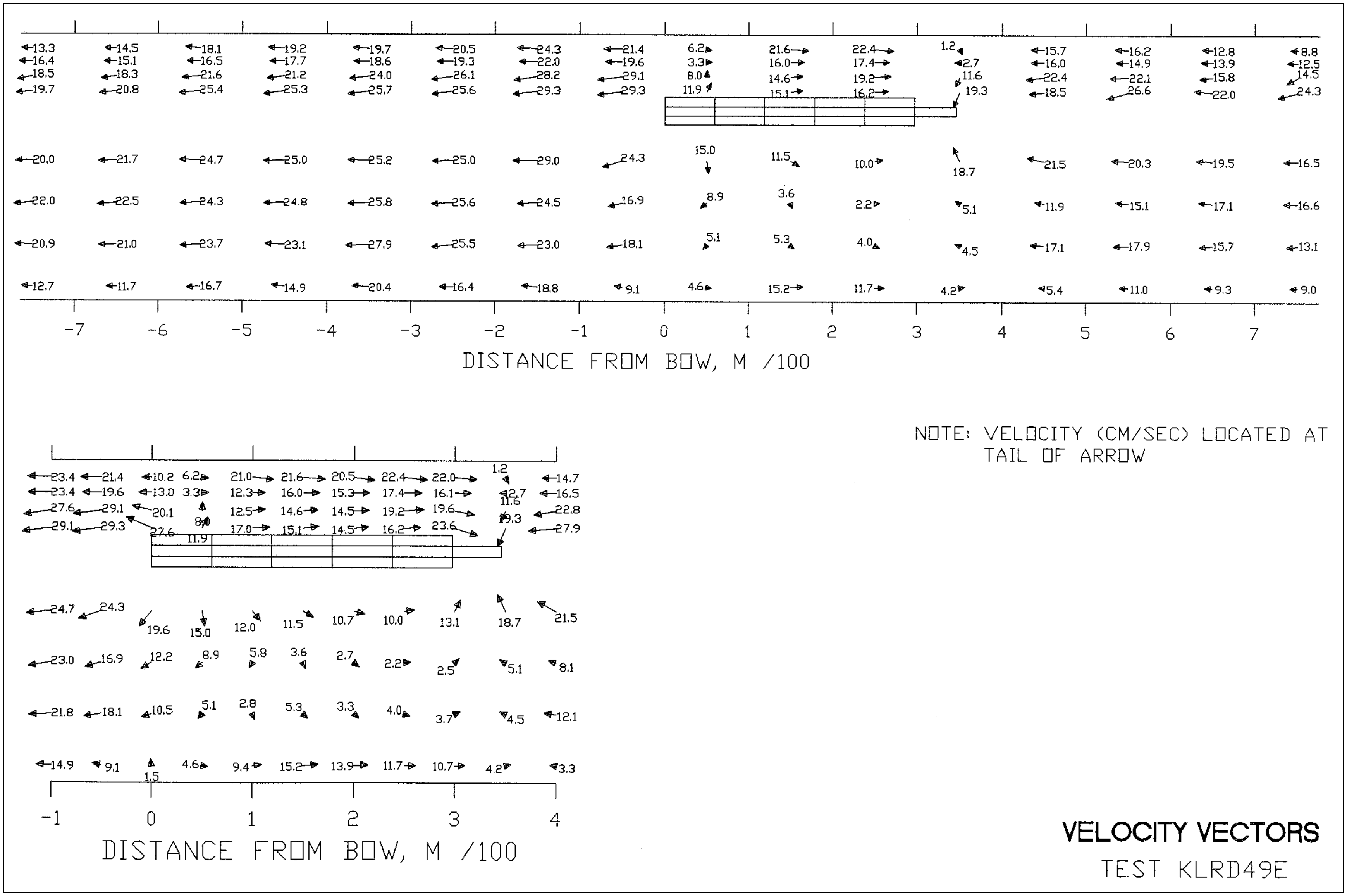



Figure 50. Velocity vectors, experimetn KLRD49E

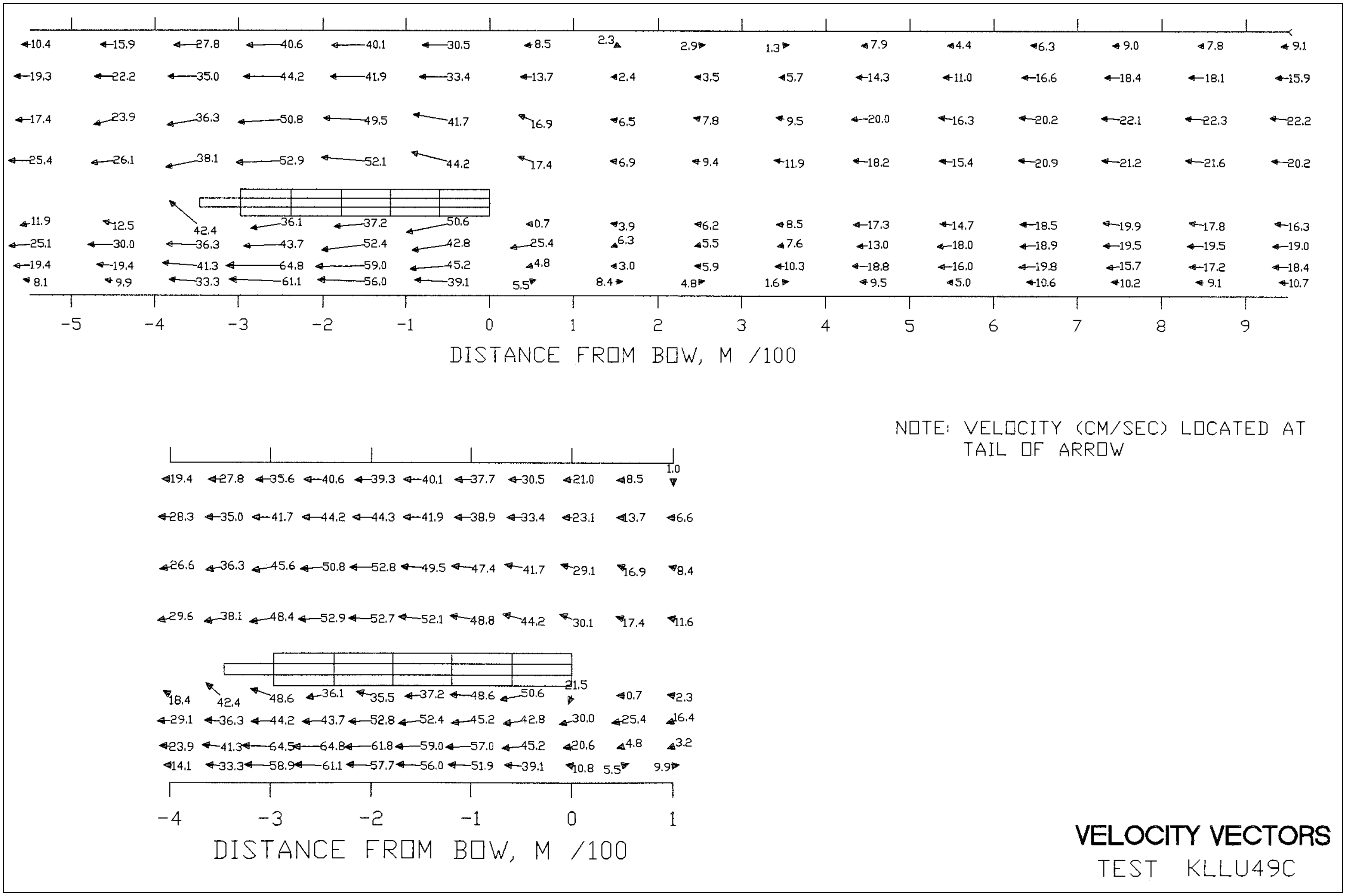



Figure 51. Velocity vectors, experiment KLLU49C

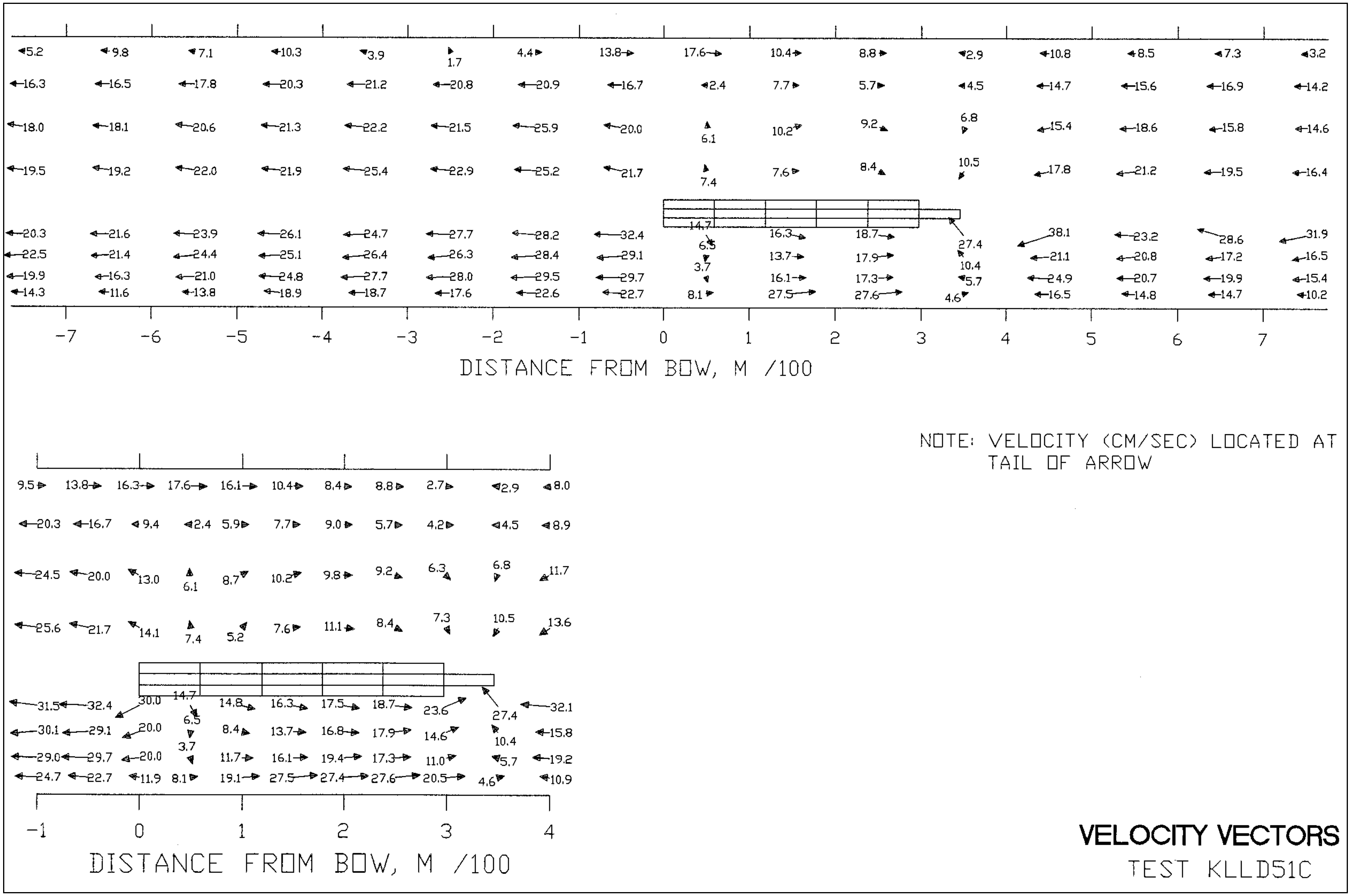



Figure 52. Velocity vectors, expeirment KLLD51C

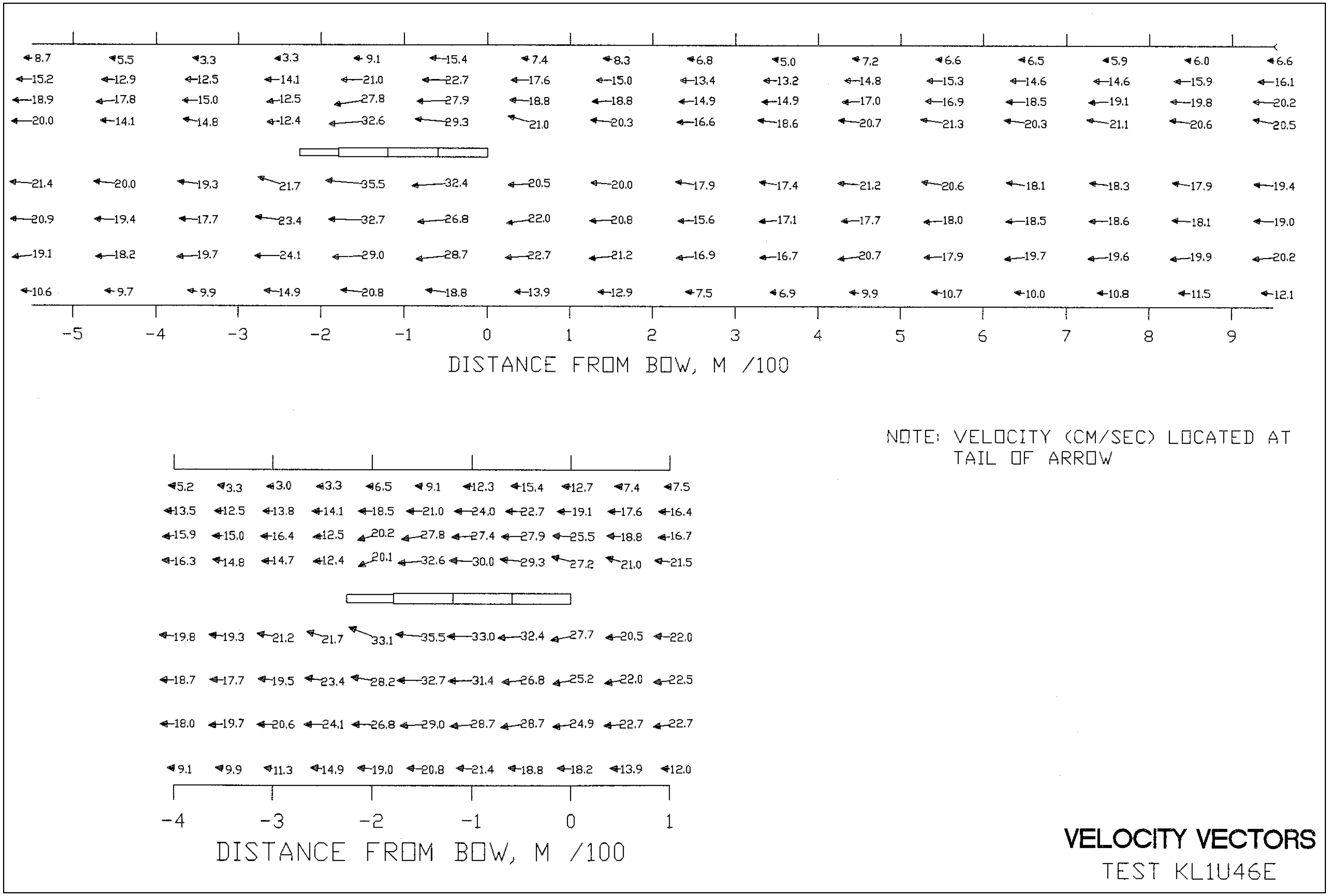



Figure 53. Velocity vectors, experiment KL1U46E

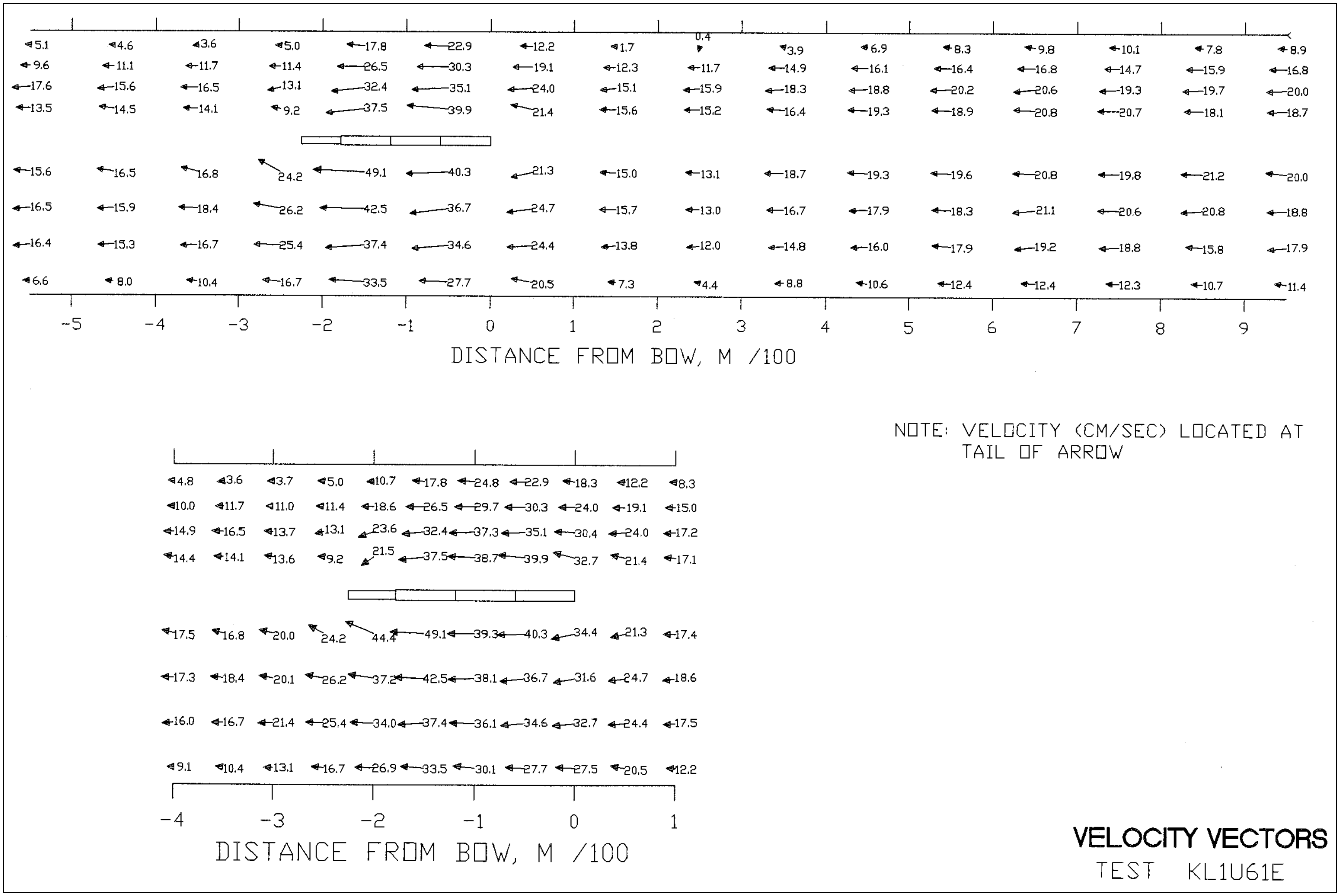



Figure 54. Velocity vectors, experiment KL1U61E

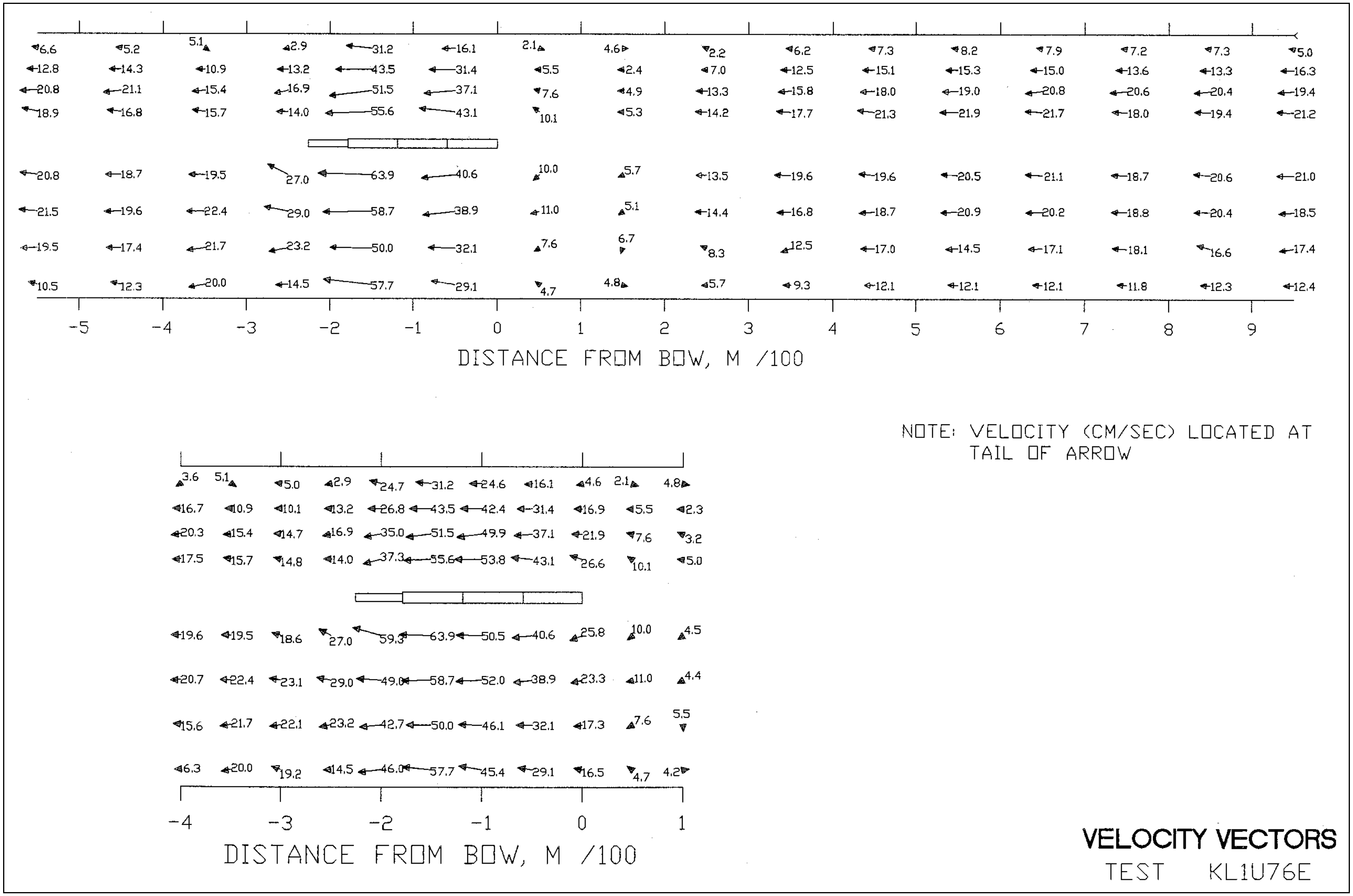



Figure 55. Velocity vectors, experiment KL1U76E

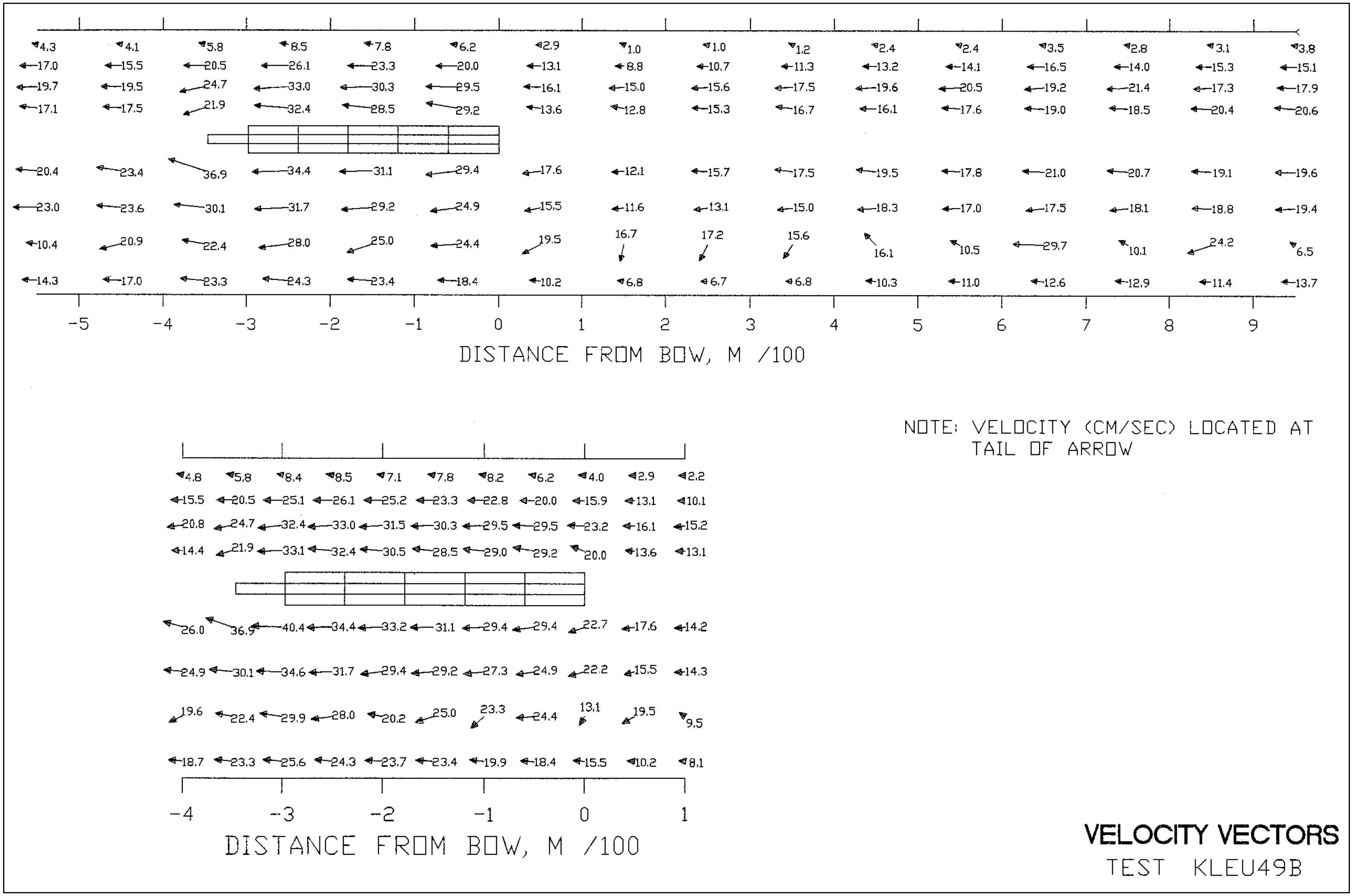



Figure 56. Velocity vectors, experiment KLEU49B

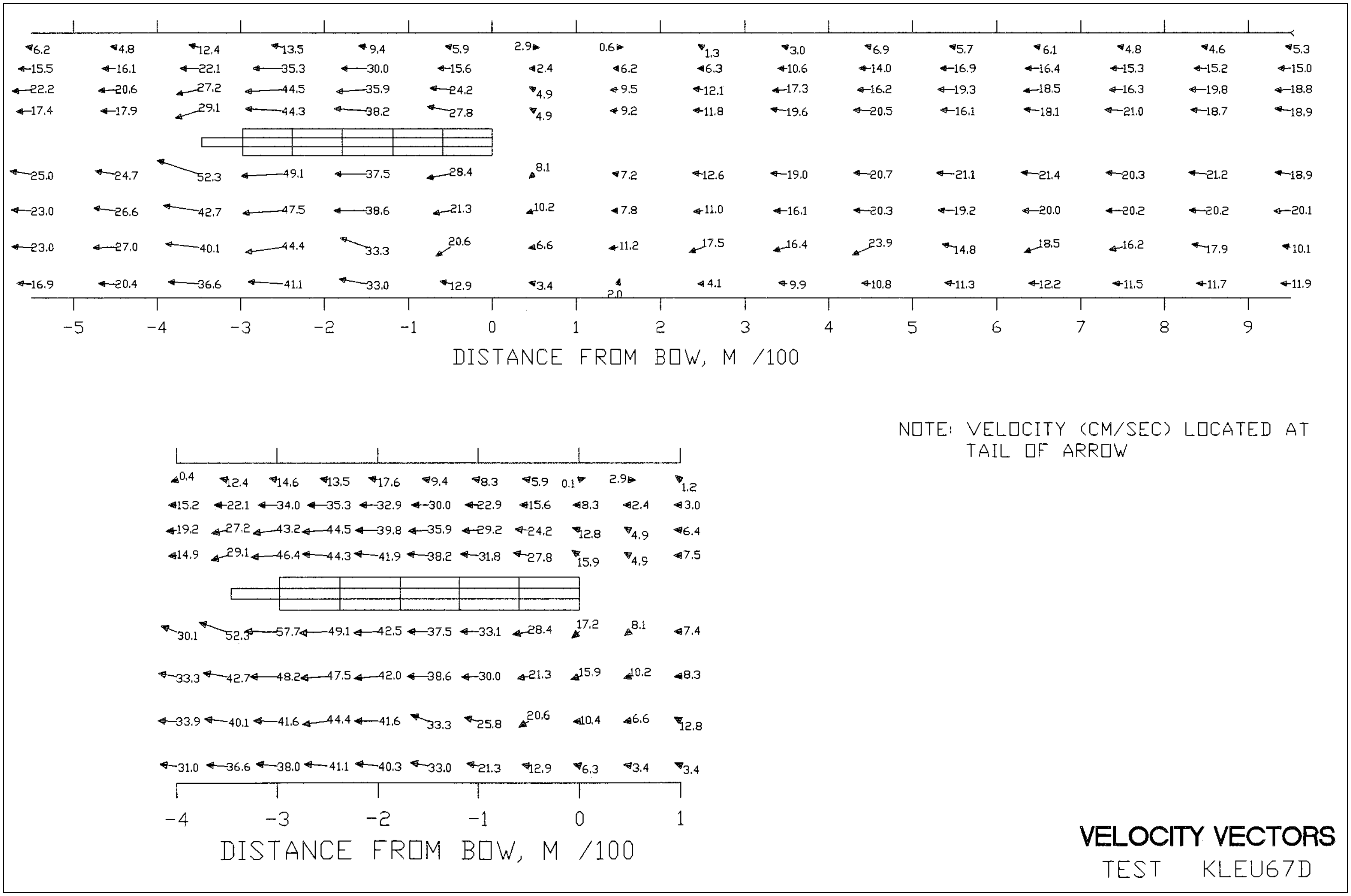



Figure 57. Velocity vectors, experiment KLEU67D

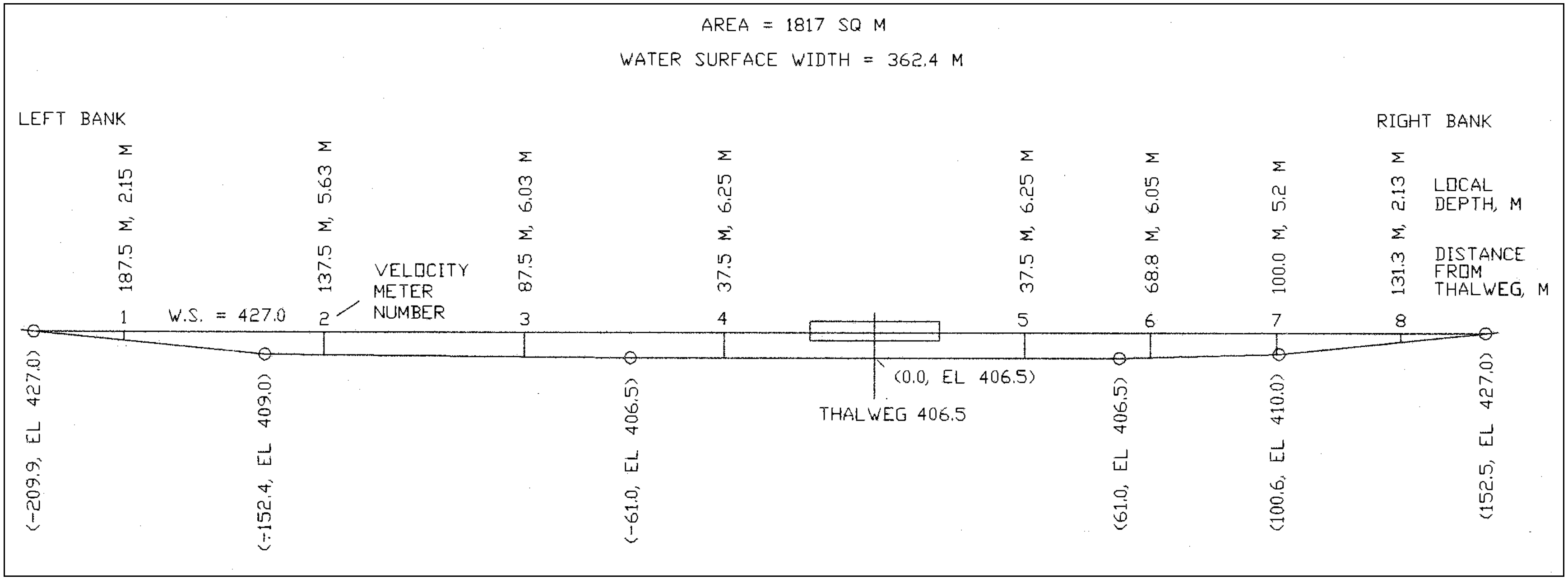



Figure 58. Cross section and meter locations for pool el 427.0 experiments

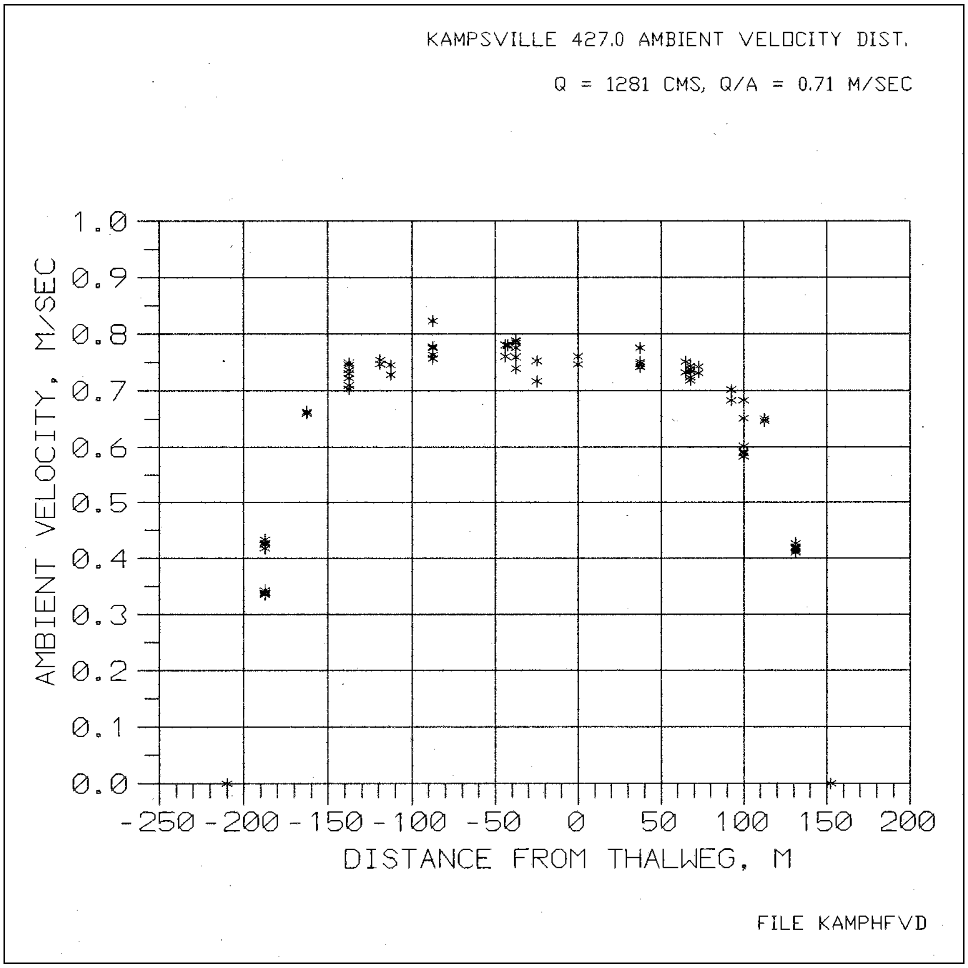



Figure 59. Ambient velocity distribution for pool el 427.0, disharge 1,281 cu m/sec, average channel velocity 0.71 m/sec

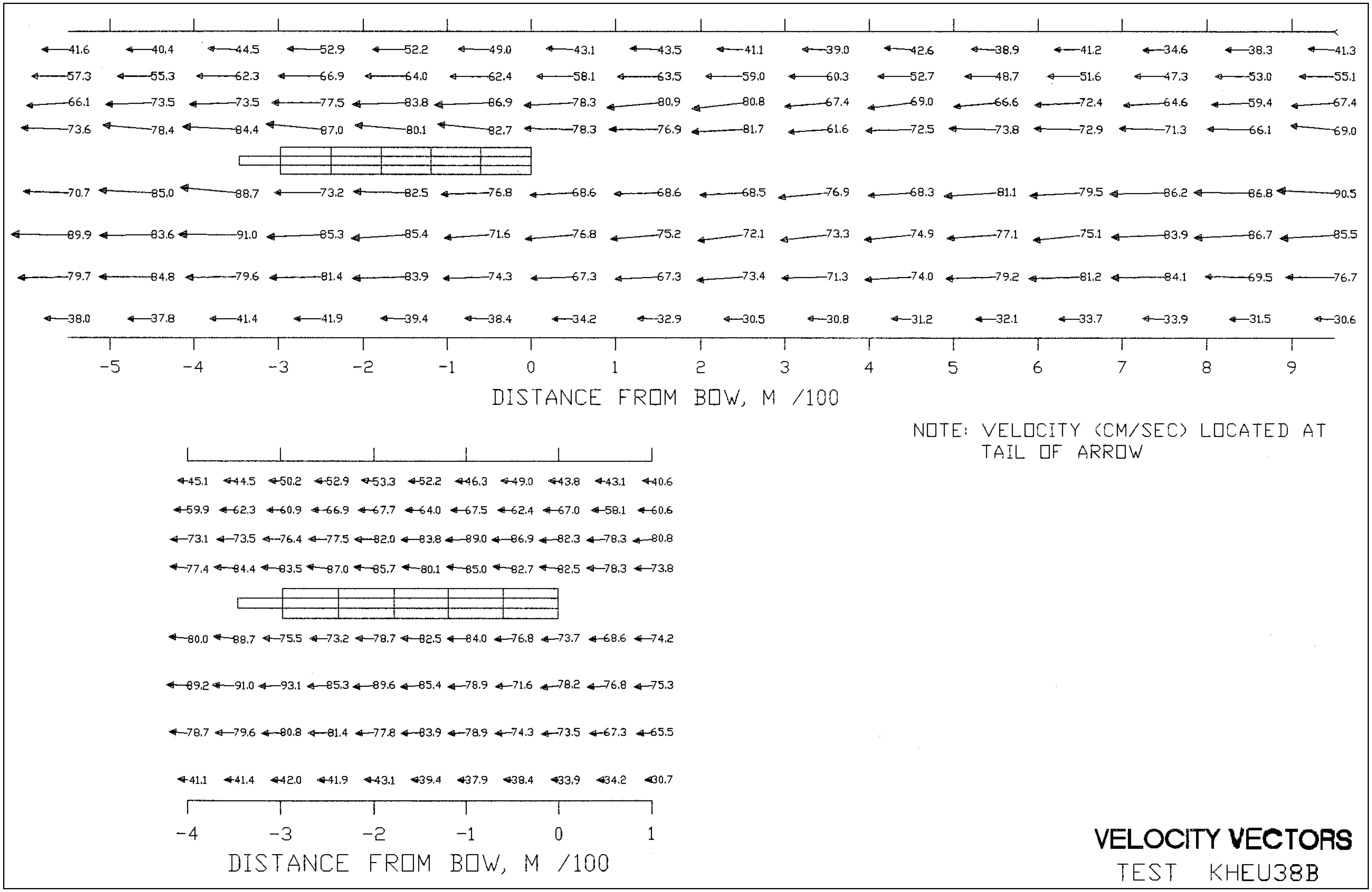



Figure 60. Velocity vectors, experiment KHEU38B

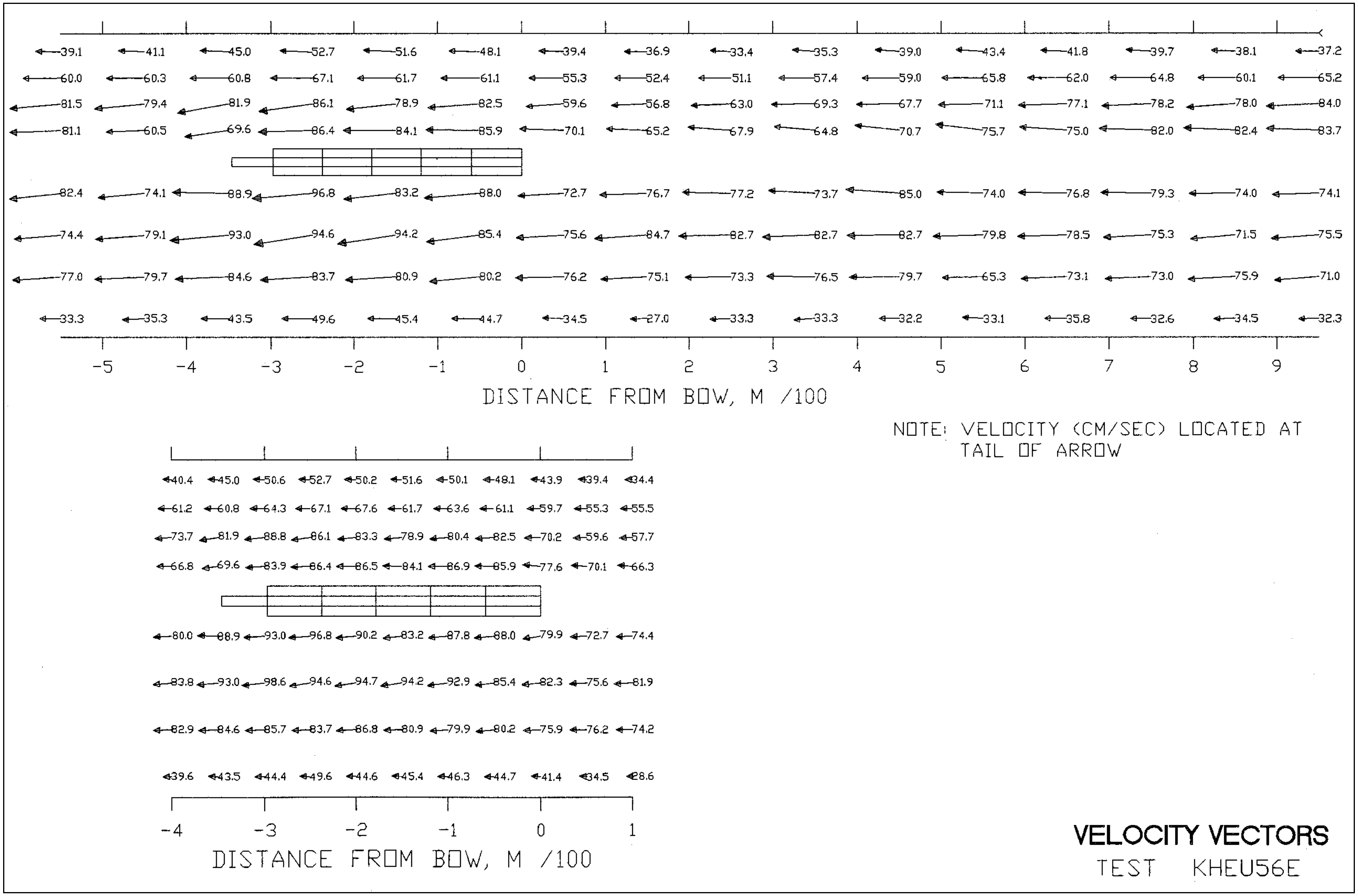



Figure 61. Velocity vectors, experiment KHEU56E

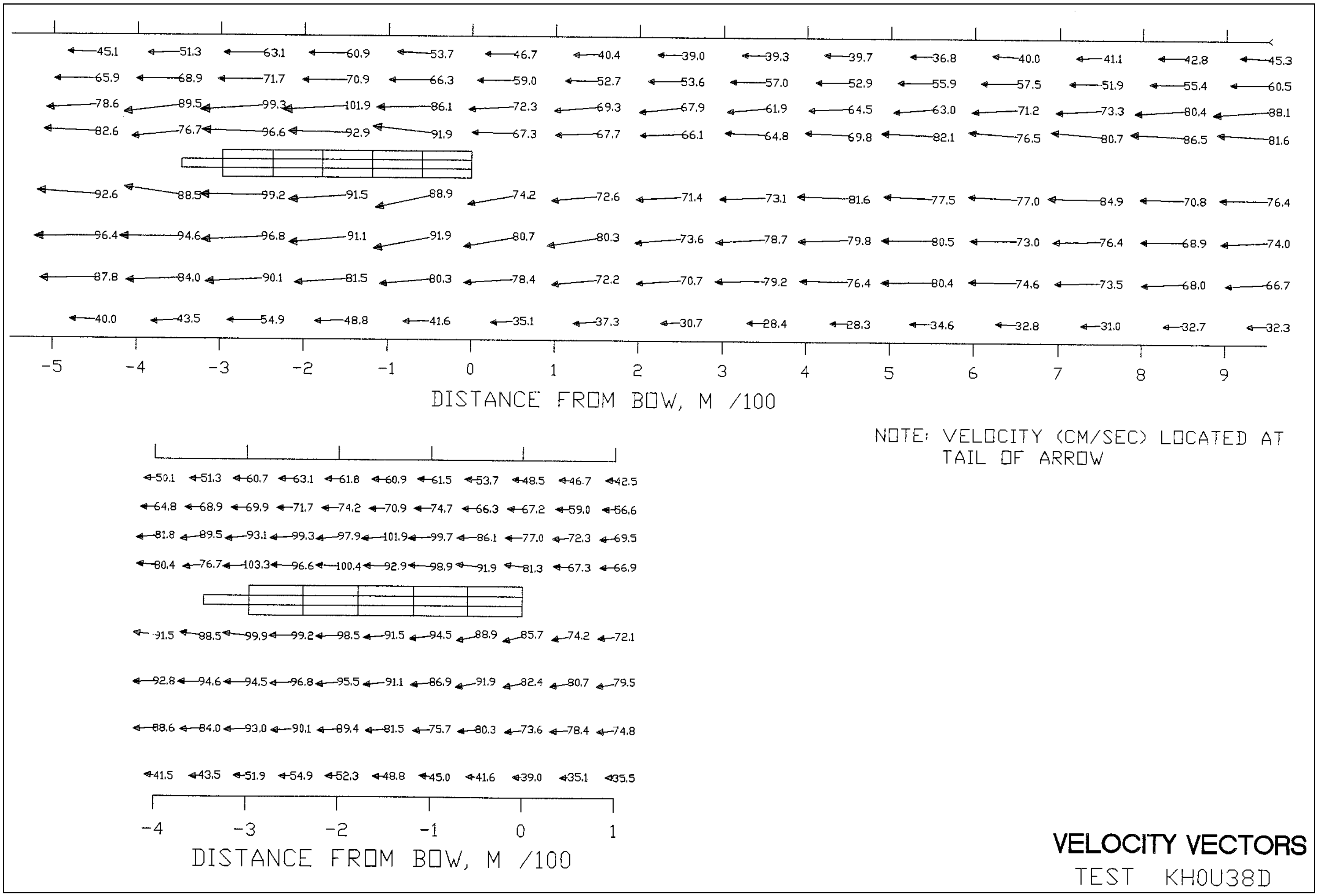



Figure 62. Velocity vectors, experimetn KHOU38D

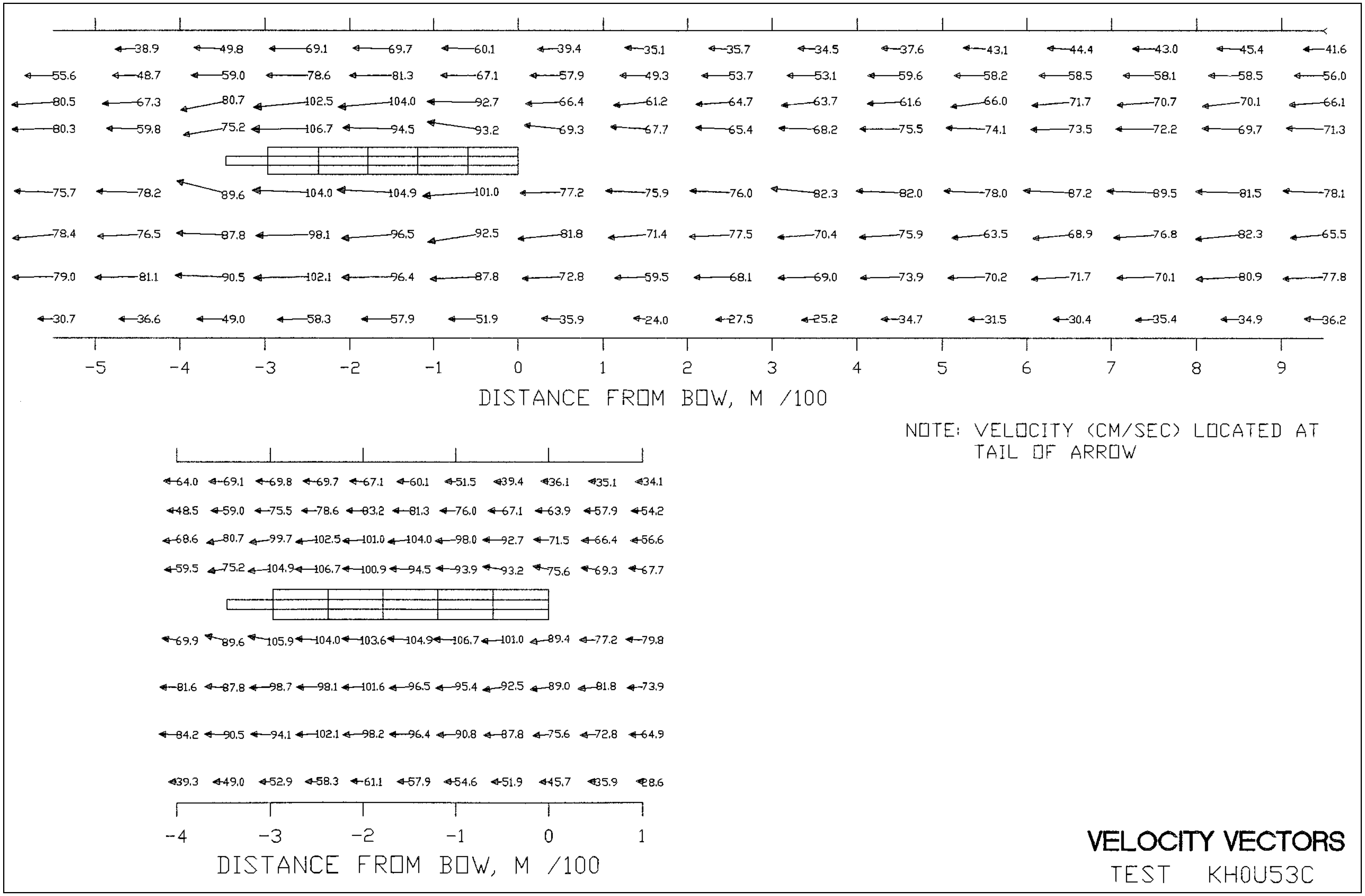



Figure 63. Velocity vectors, experiment KHOU53C

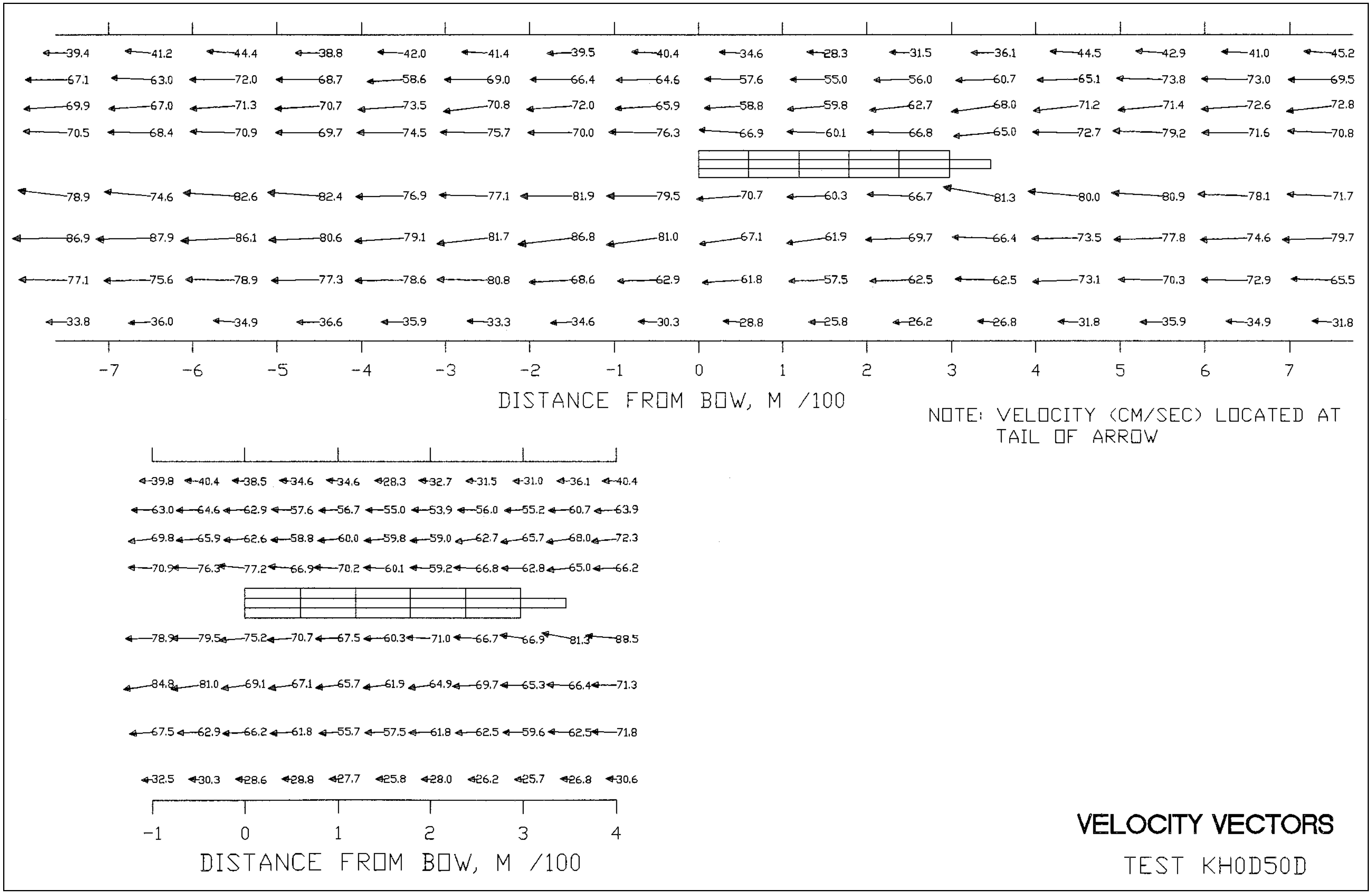



Figure 64. Velocity vectors, experiment KHOD50D

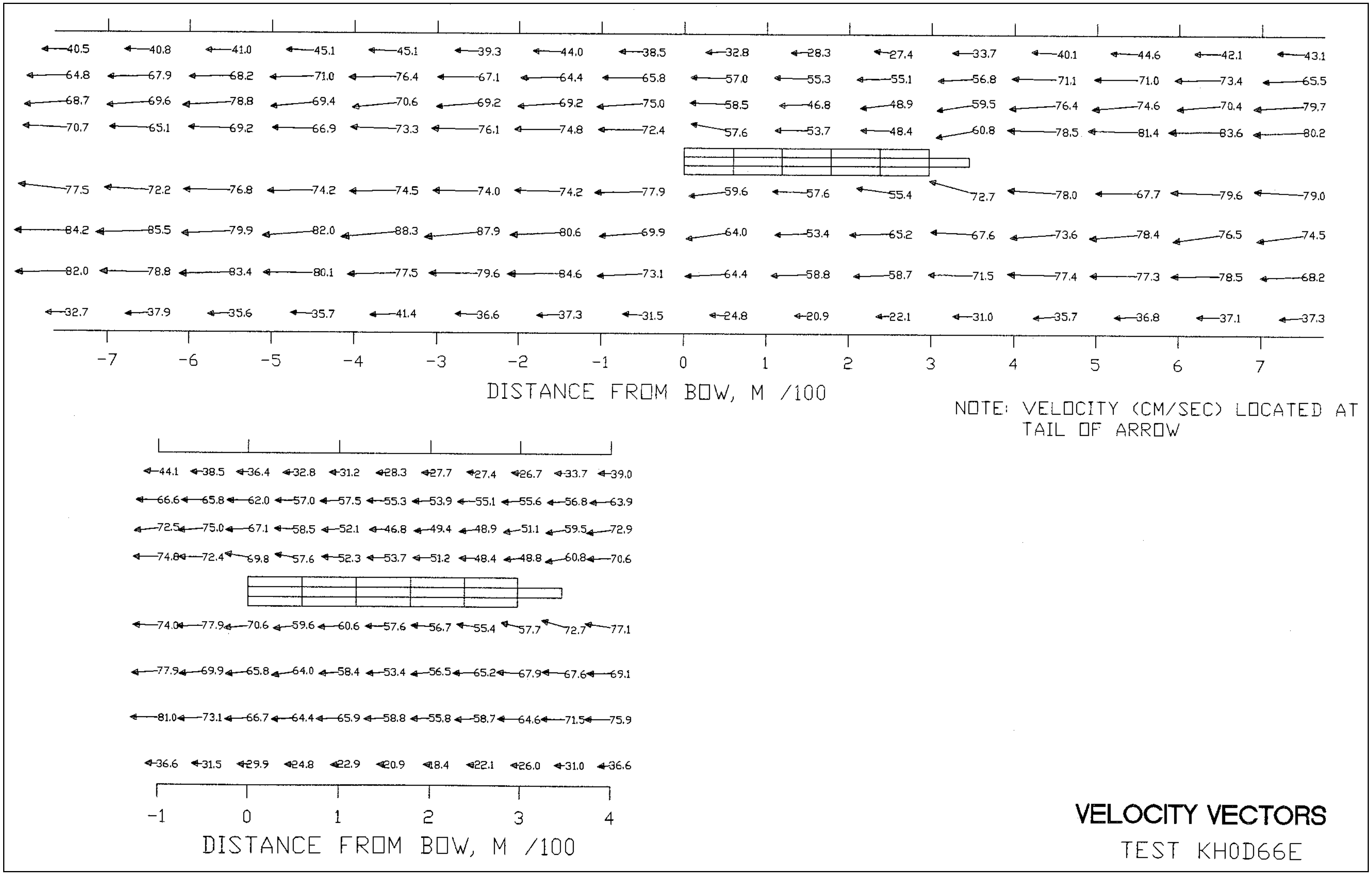



Figure 65. Velocity vectors, experimetn KHOD66E

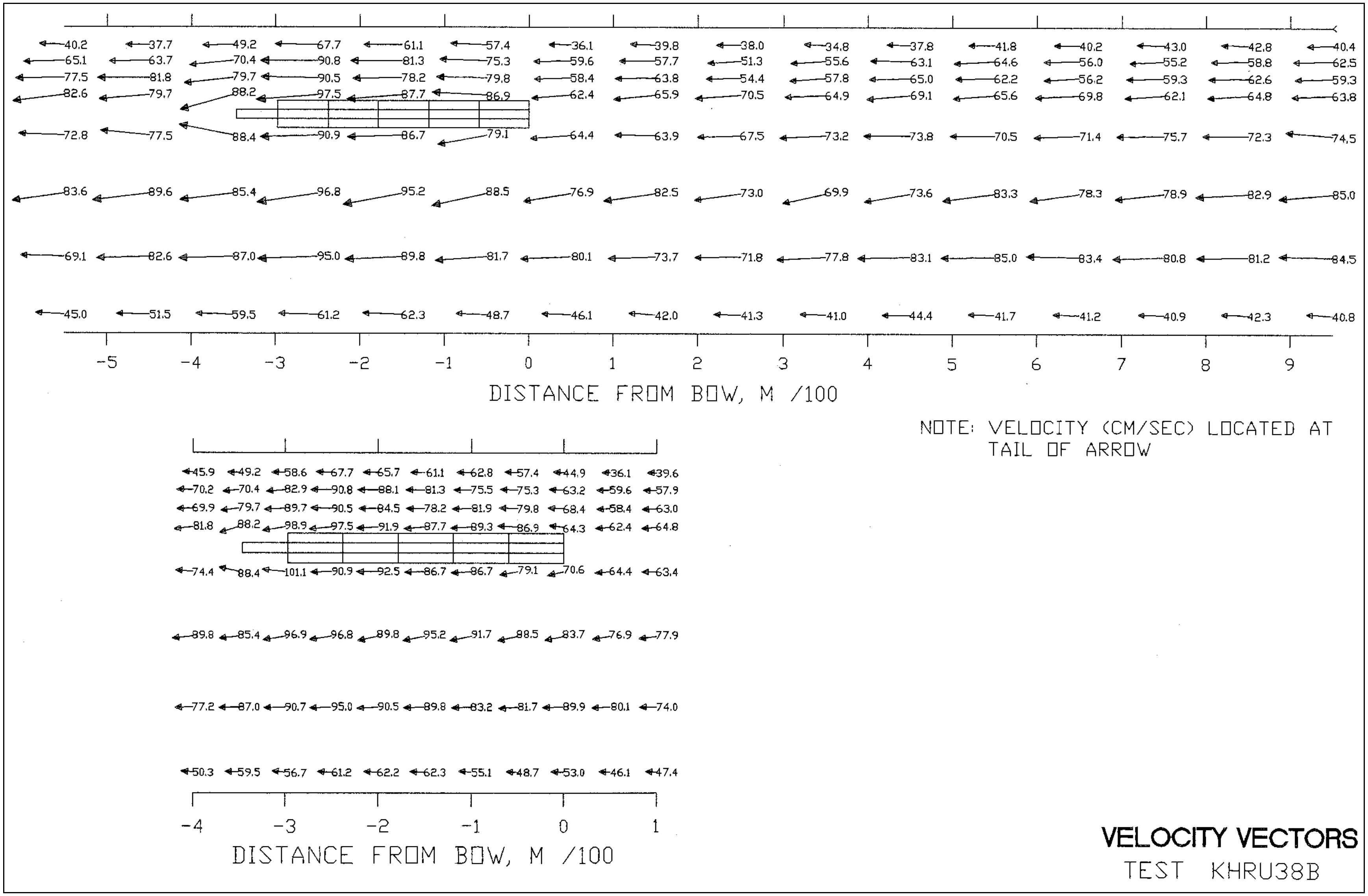



Figure 66. Velocity vectors, experiment KHRU38B

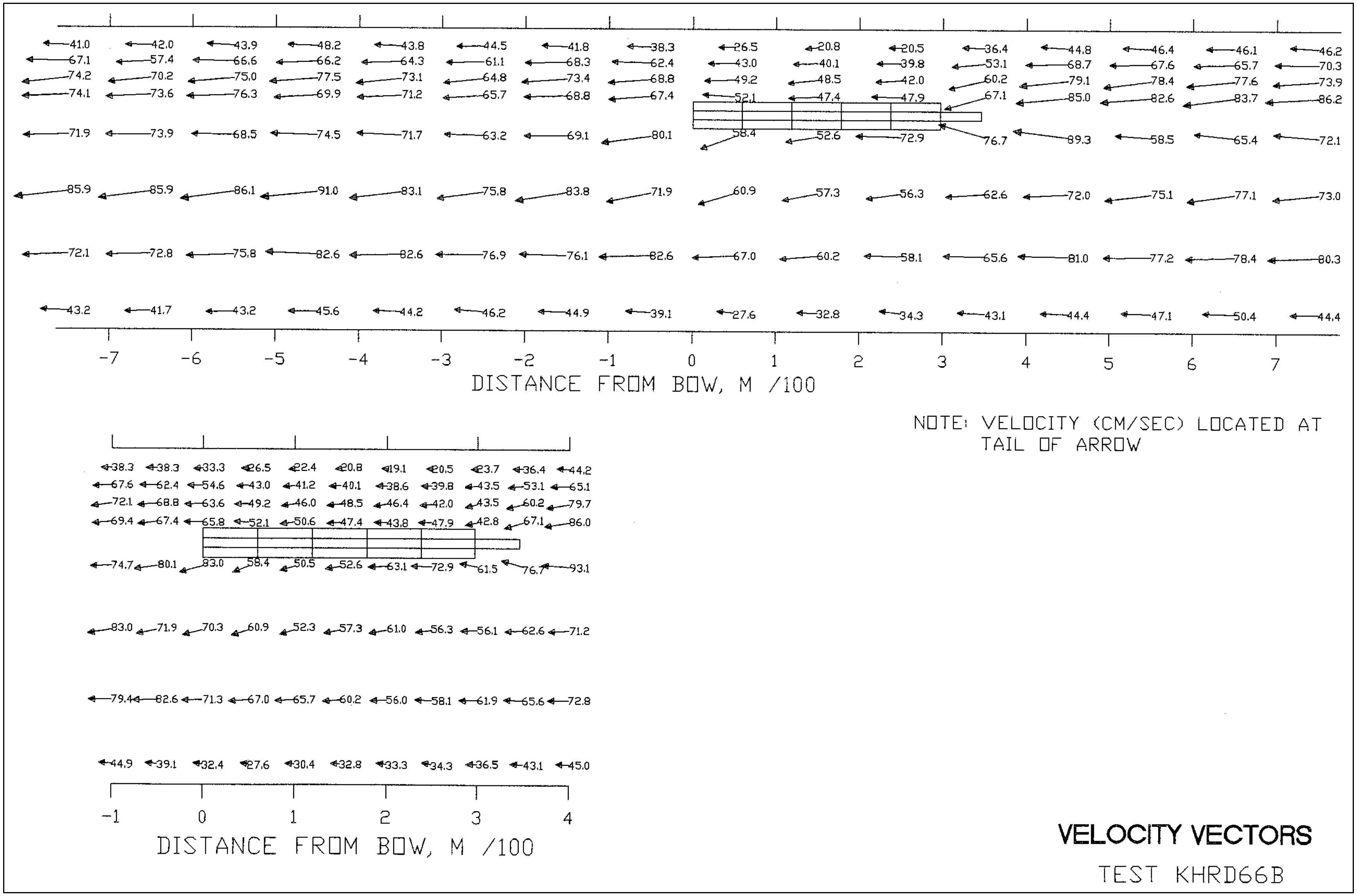



Figure 67. Velocity vectors, experiment KHRD66B

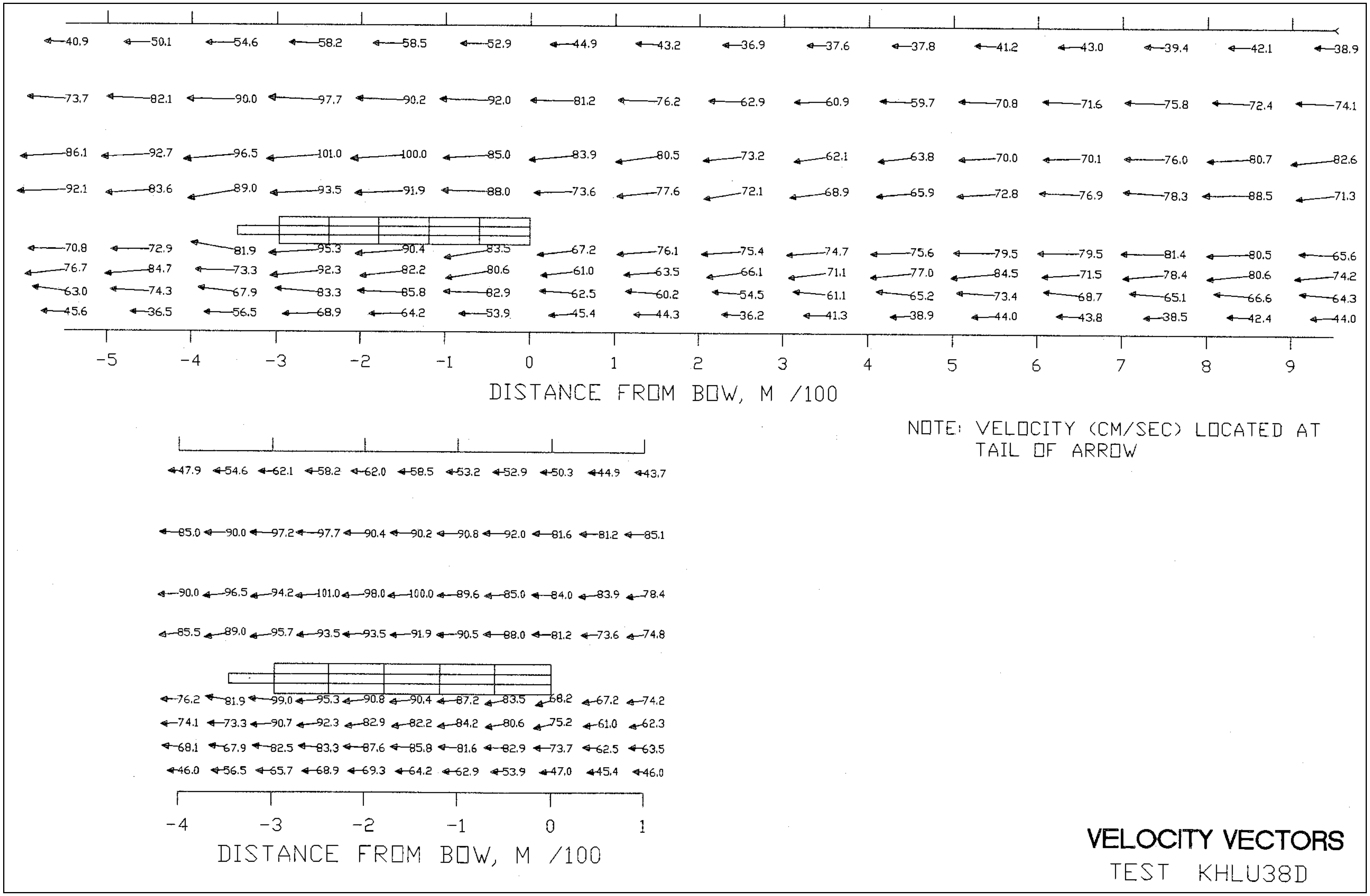



Figure 68. Velocity vectors, experiment KHLU38D

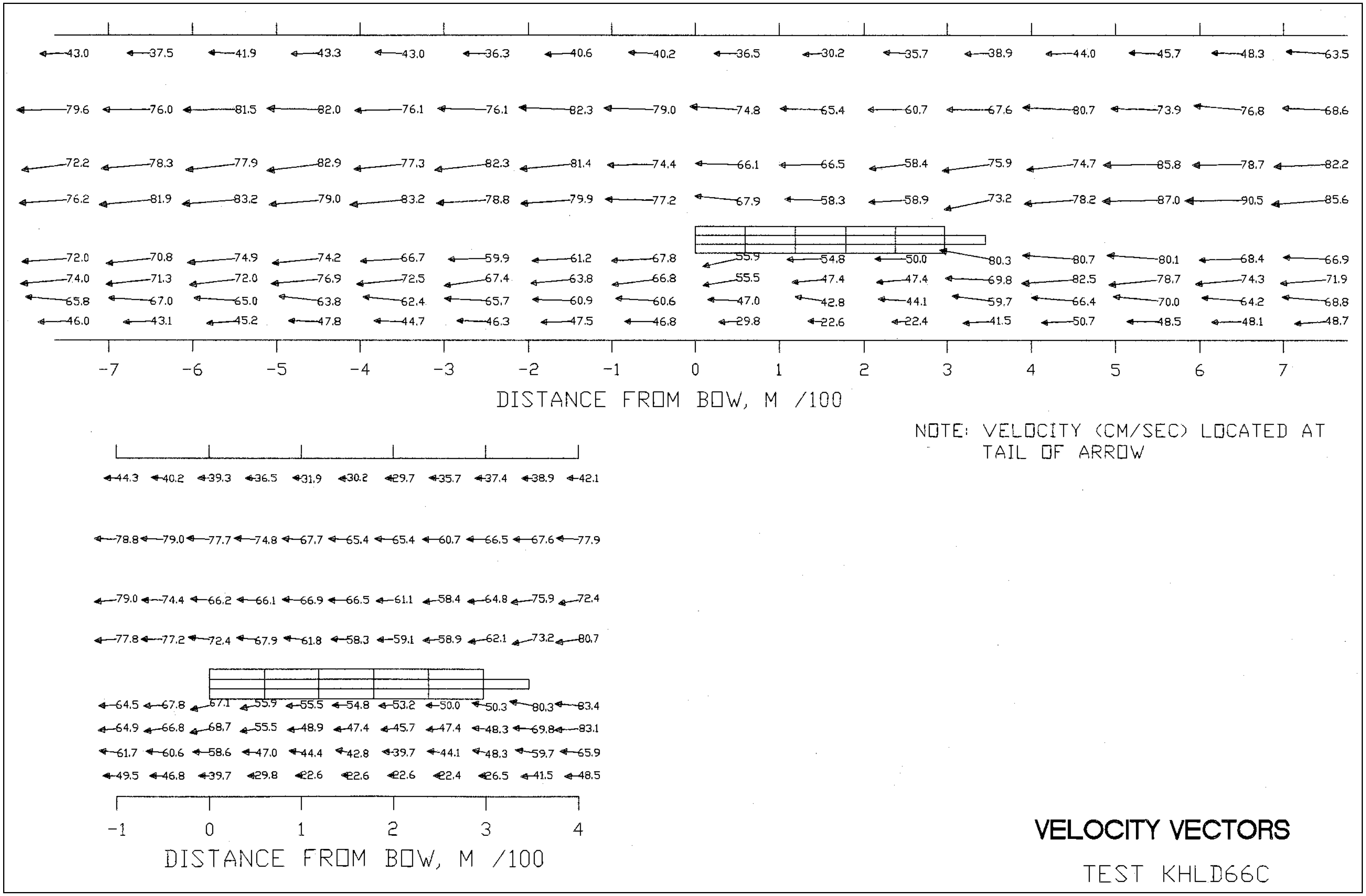



Figure 69. Velocity vectors, experimetn KHLD66C

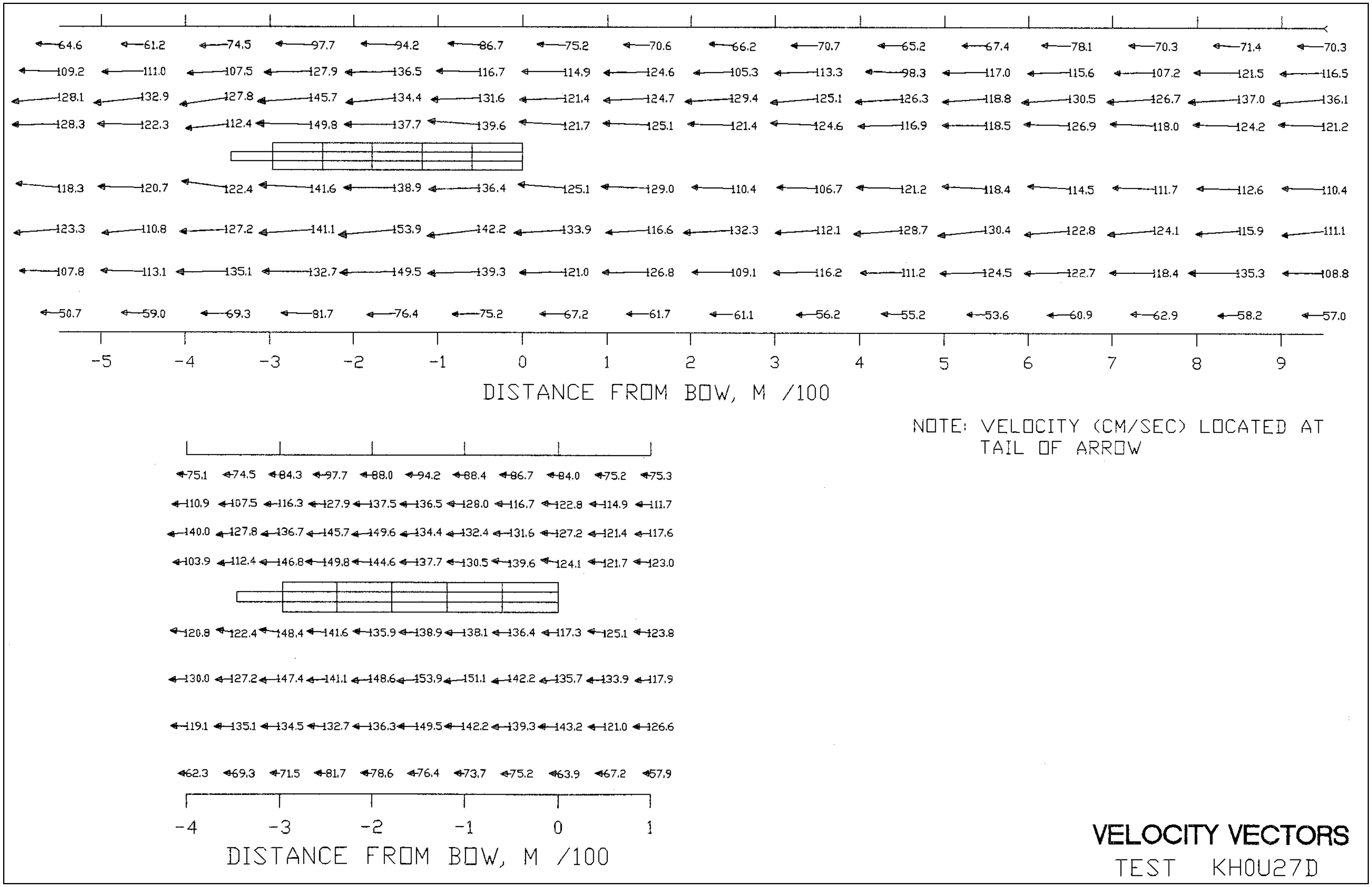



Figure 70. Velocity vectors, experiment KHOU27D

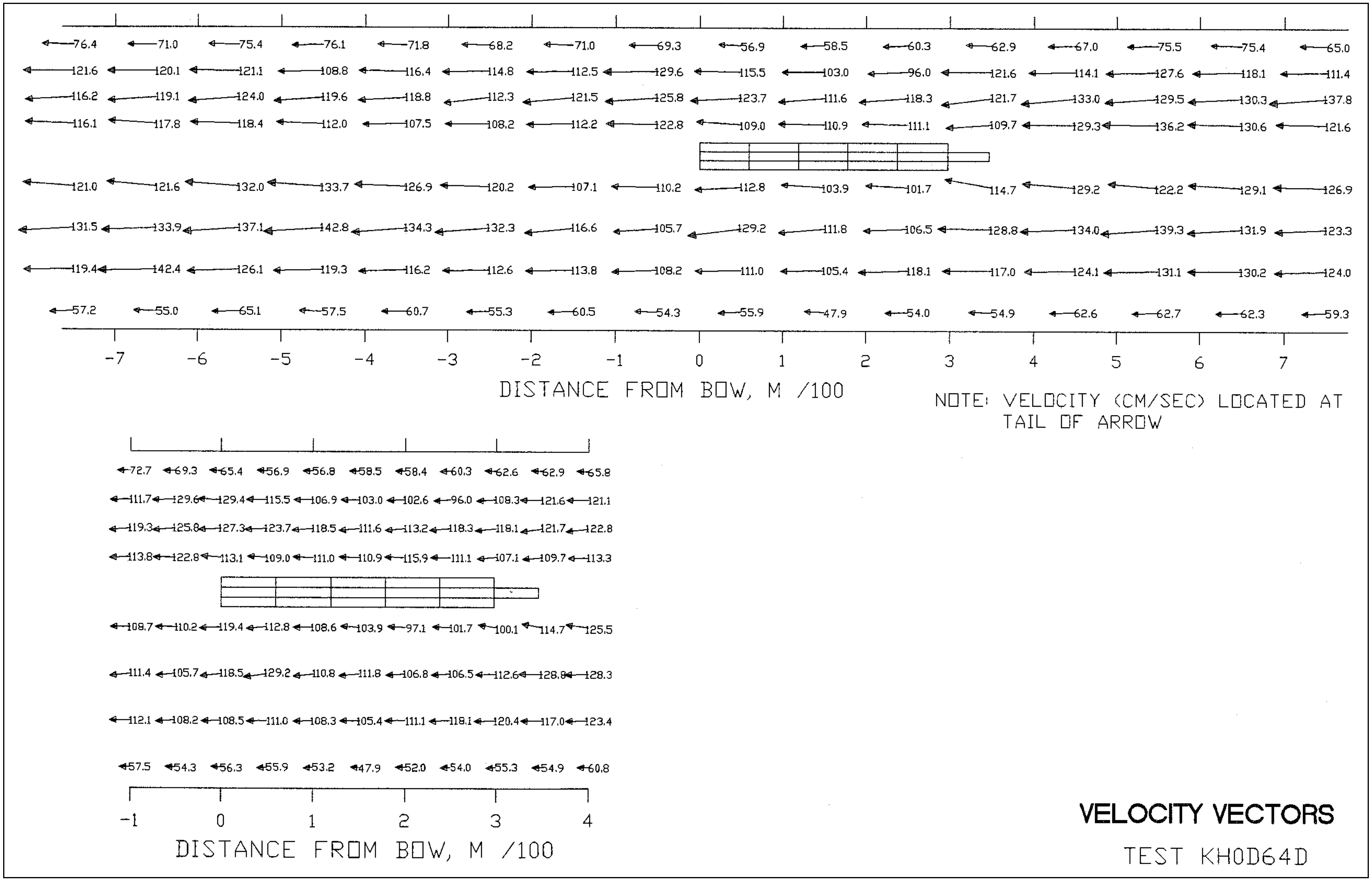



Figure 71. Velocity vectors, experiment KHOD64D

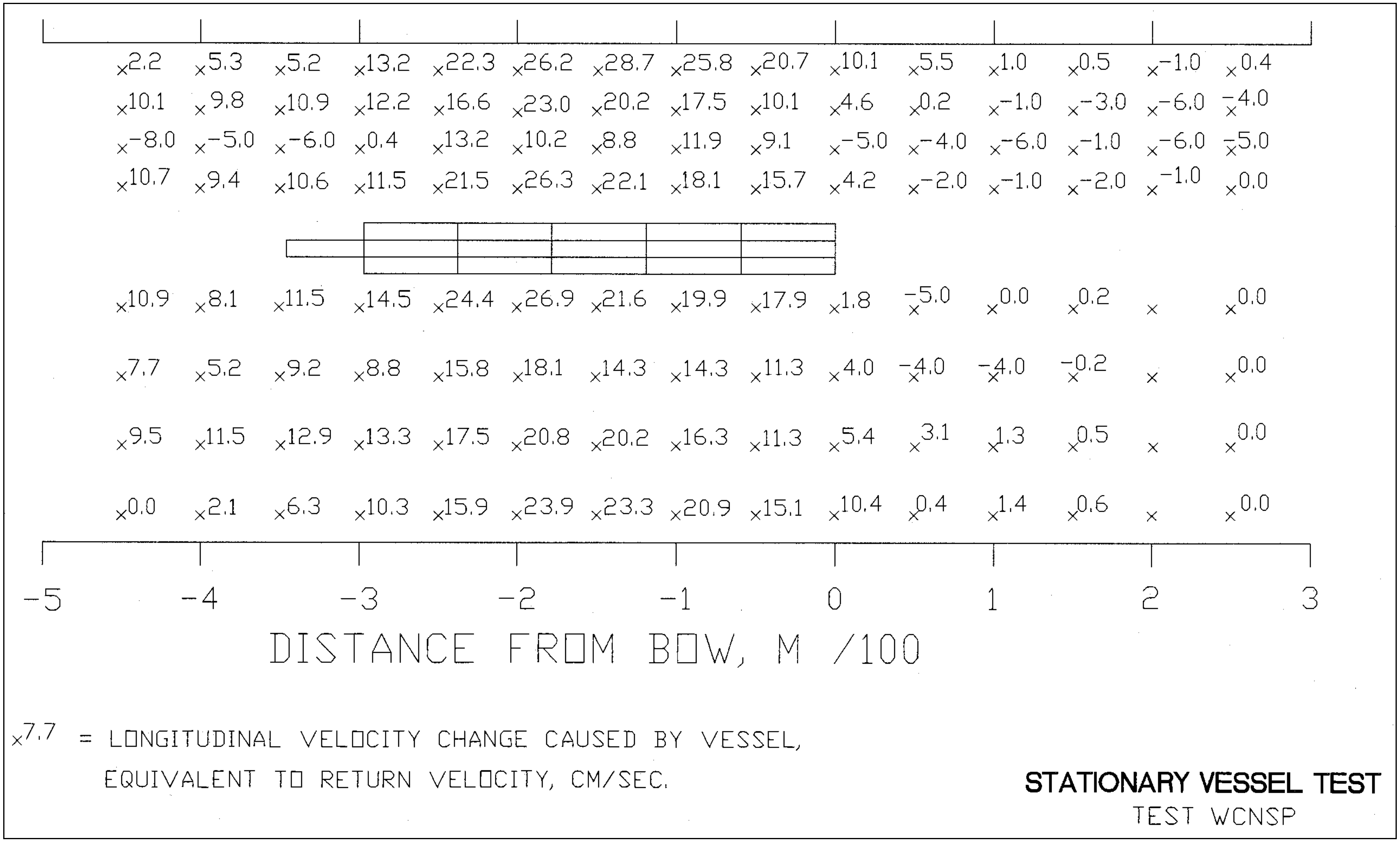



Figure 72. Stationary vessel test, experiment WCNSP

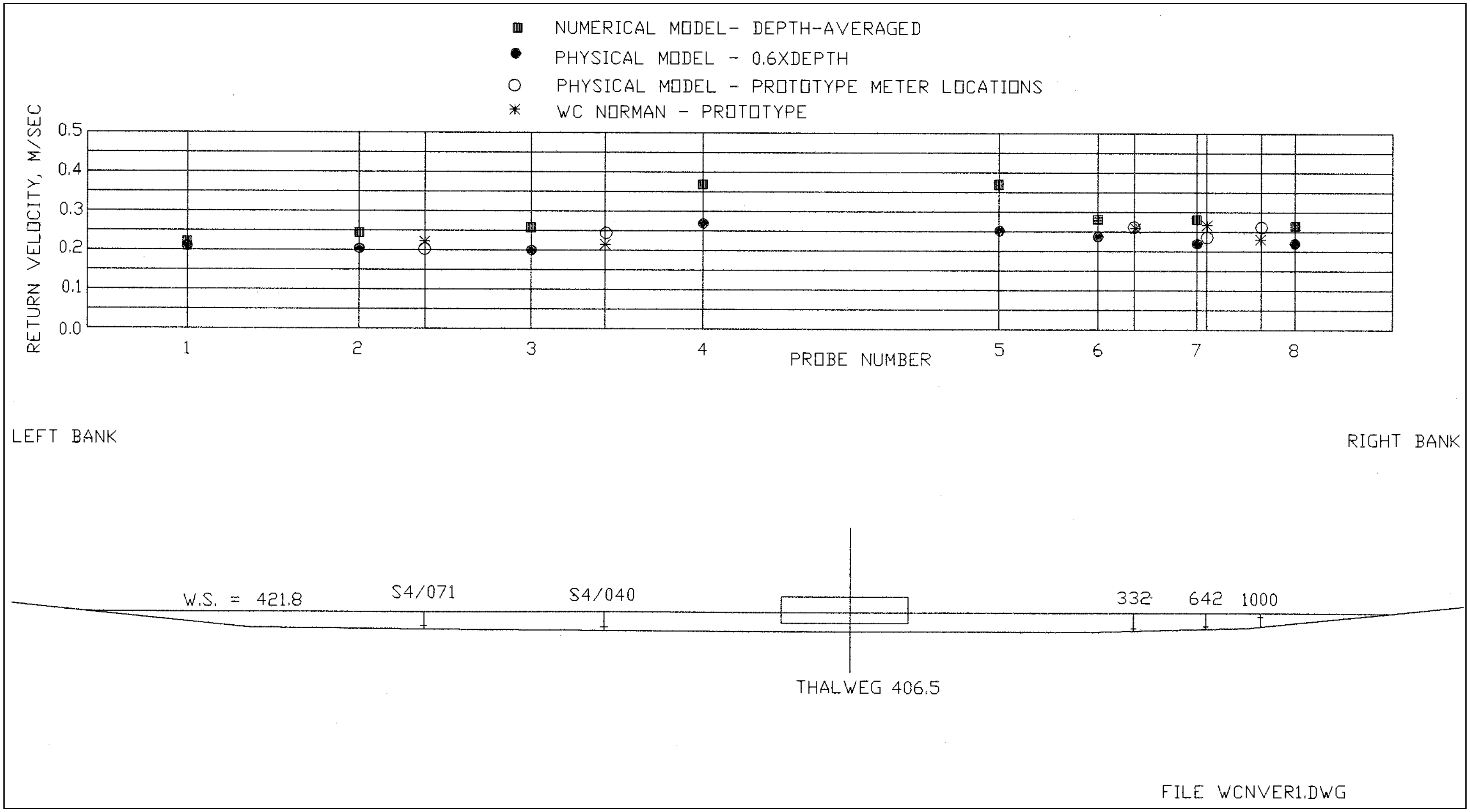



Figure 73. Return velocities for physical model, numerical model, and prototype for *William C. Norman*

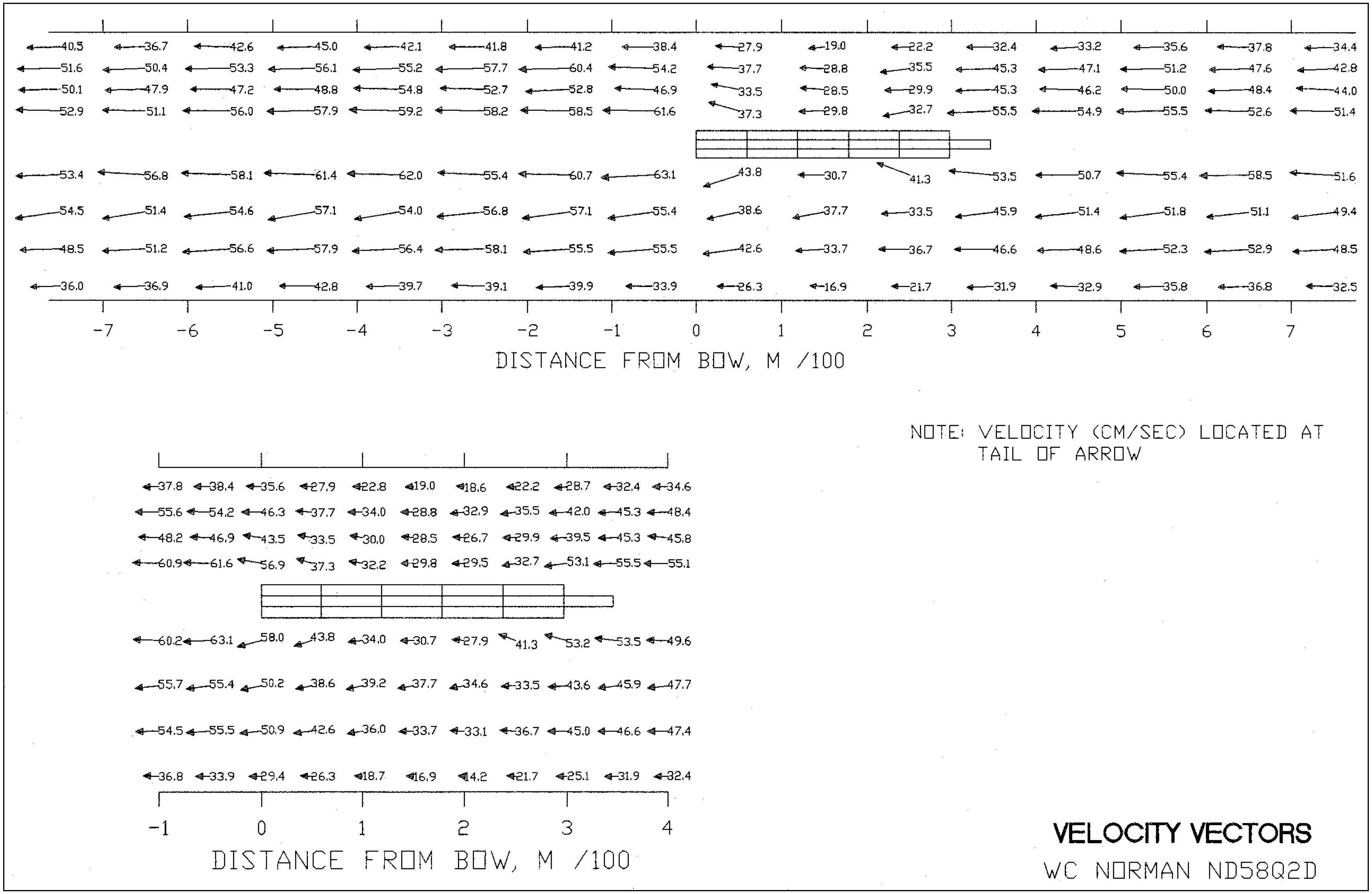



Figure 74. Velocity vectors, *William C. Norman* ND58Q2D

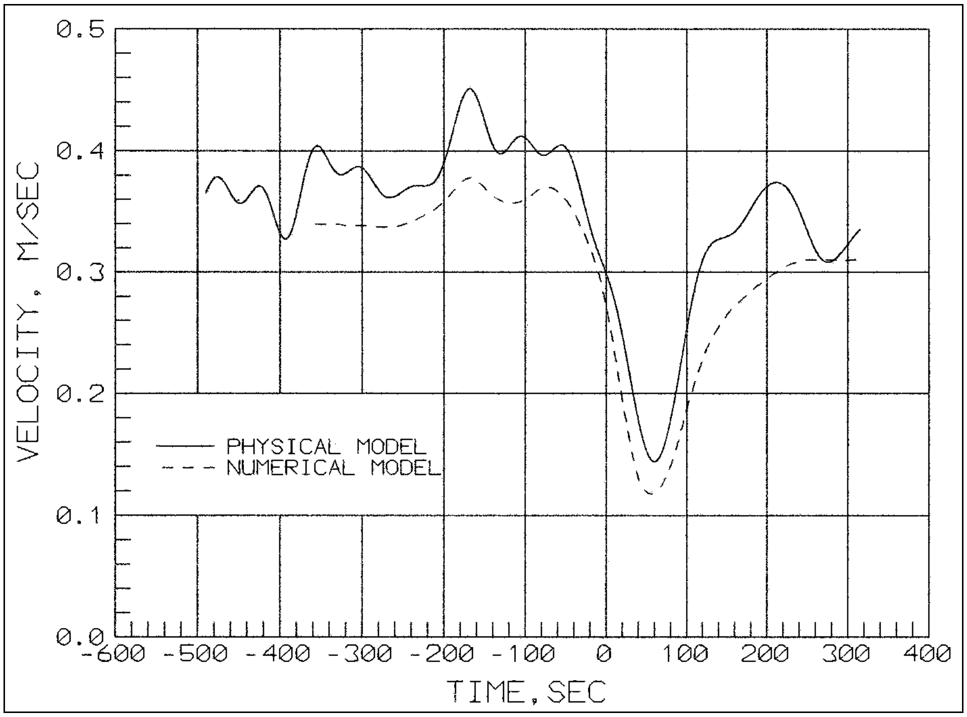



Figure 75. Physical model versus numerical model, probe 1, 168.8 m left of Thalweg

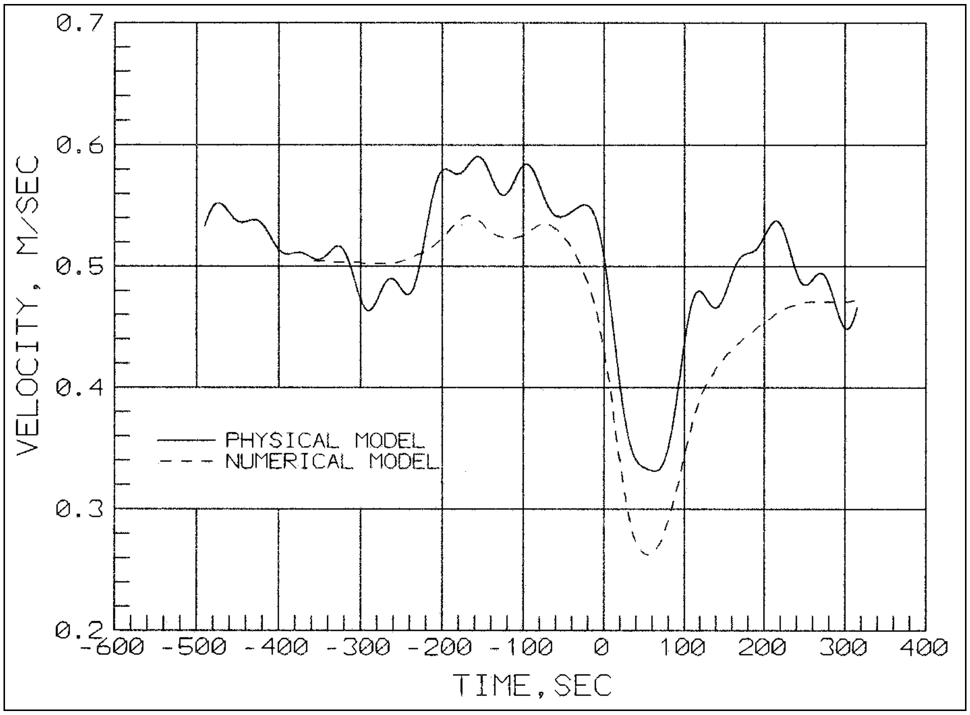



Figure 76. Physical model versus numerical model, probe 2, 125.0 m left of thalweg

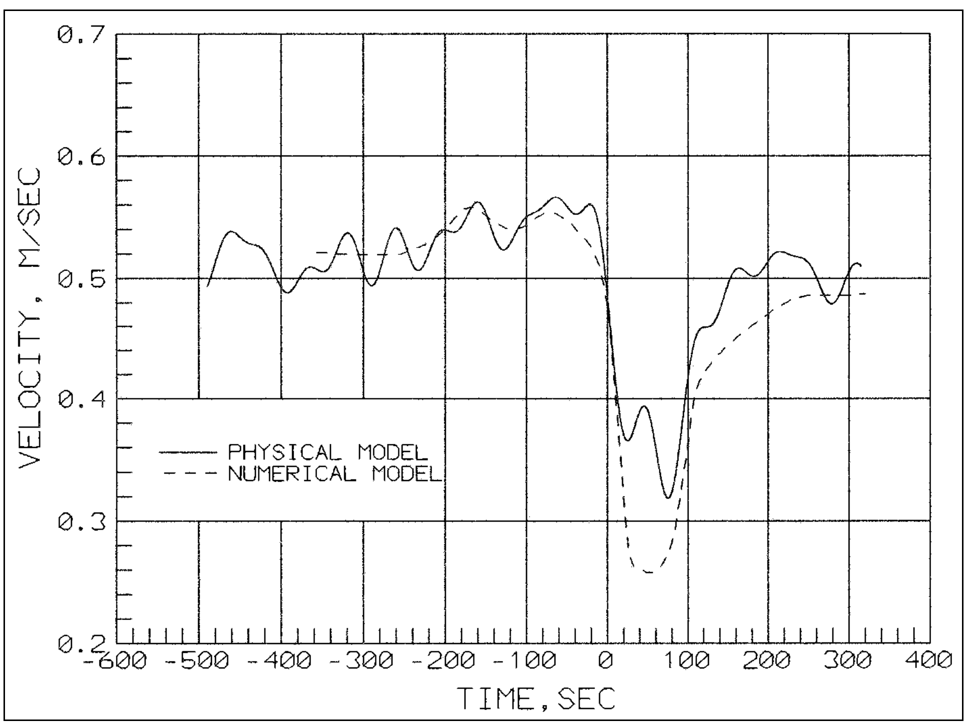



Figure 77. Physical model versus numerical model, probe 3, 81.3 m left of thalweg

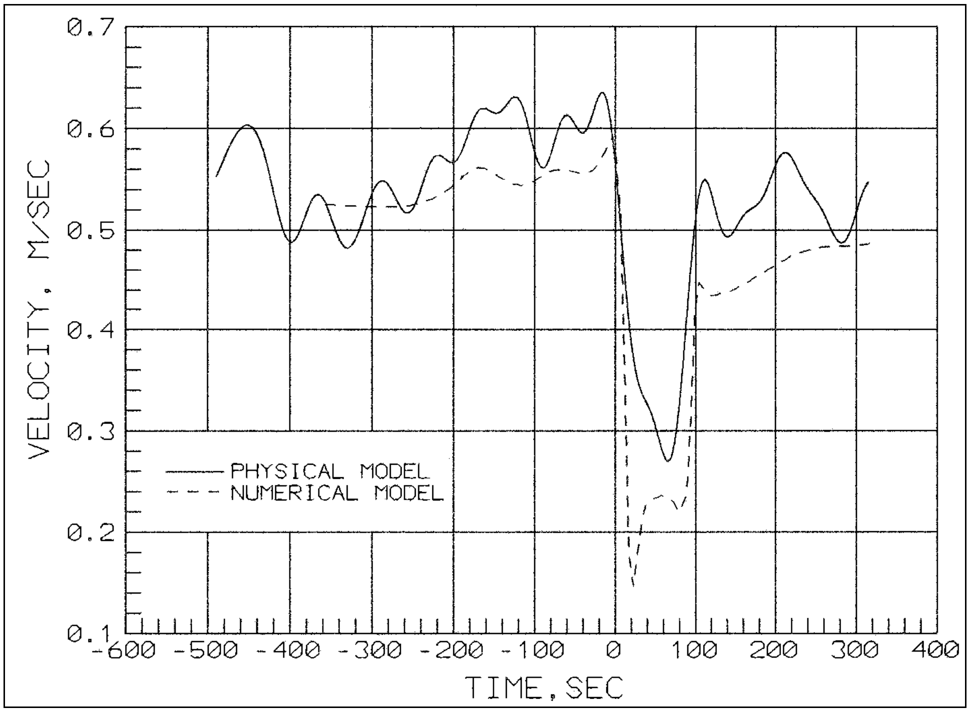



Figure 78. Physical model versus numerical model, probe 4, 37.5 m left of Thalweg

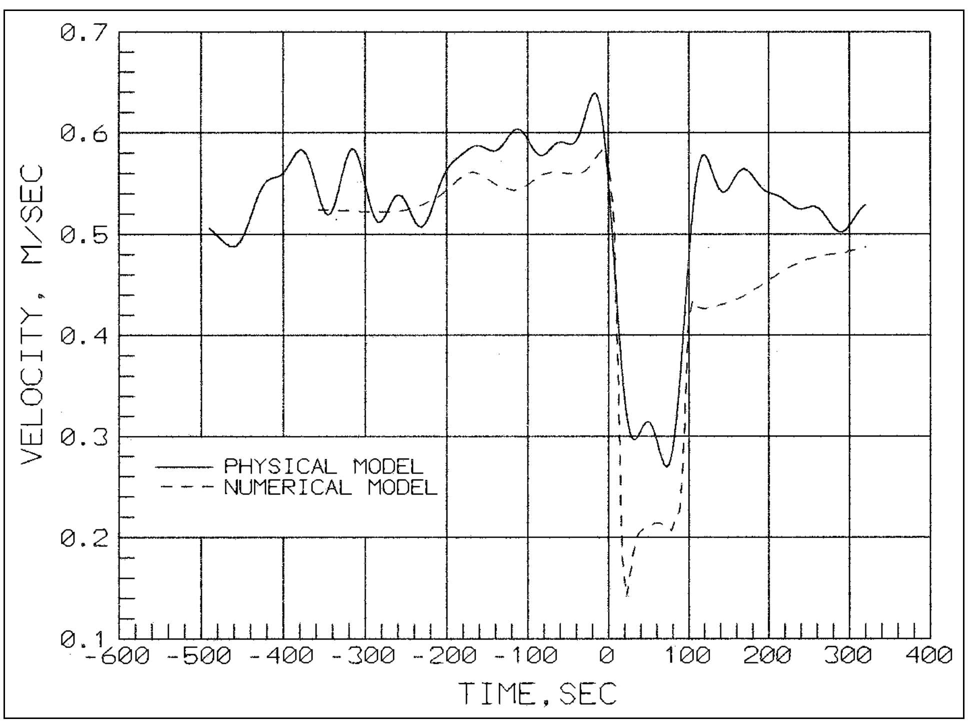



Figure 79. Physical model versus numerical model, probe 5, 37.5 m right of thalweg

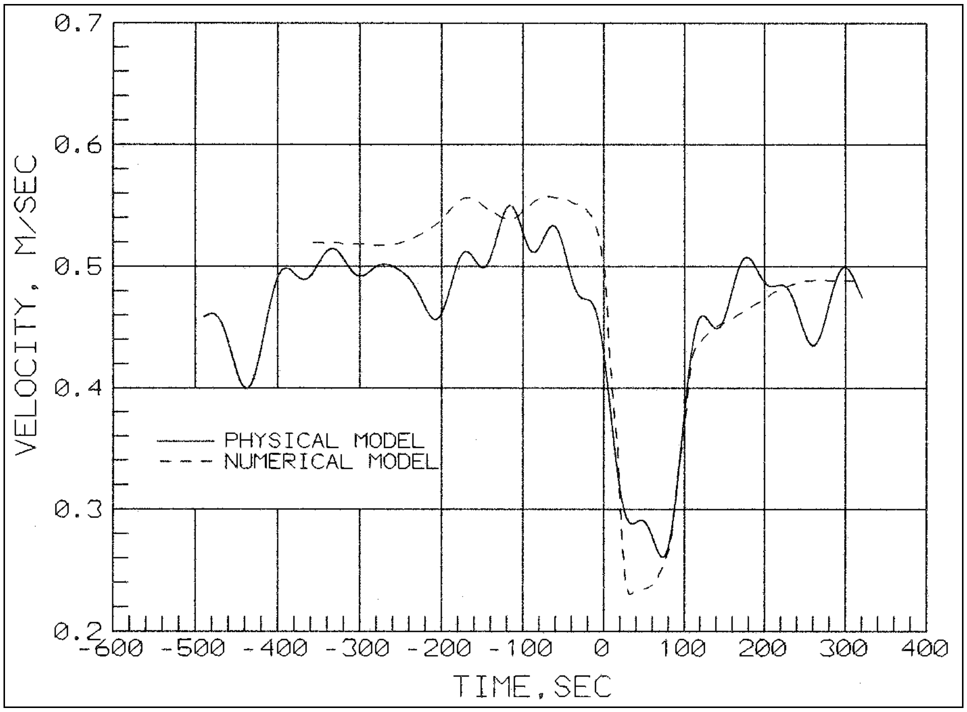



Figure 80. Physical model versus numerical model, probe 6, 62.5 m right of thalweg

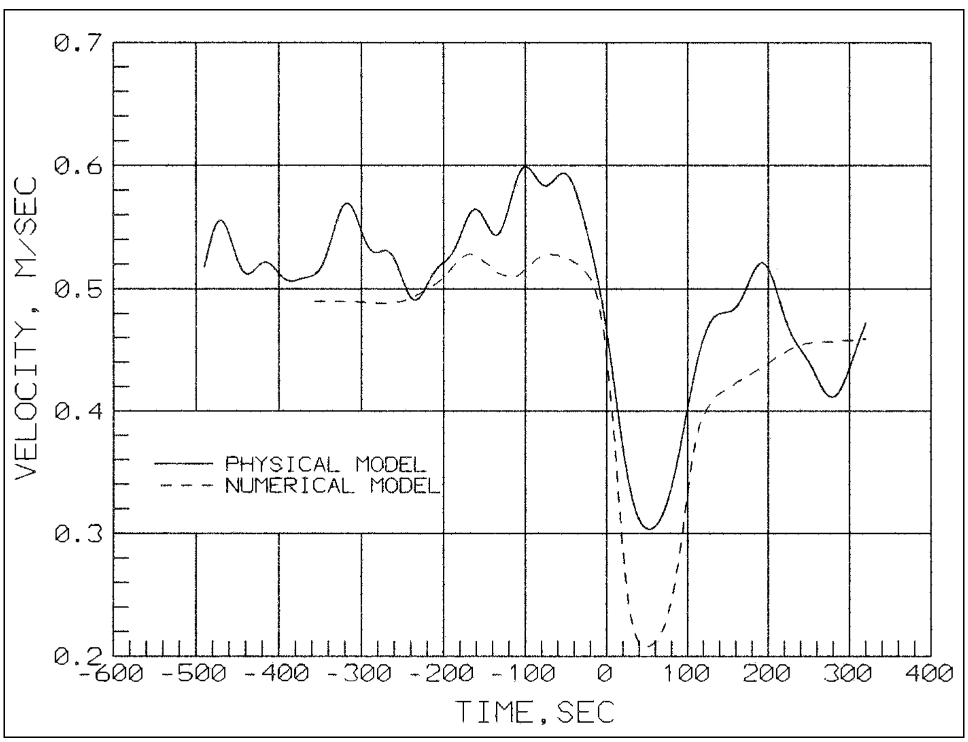



Figure 81. Physical model versus numerical model, probe 7, 87.5 m right of thalweg

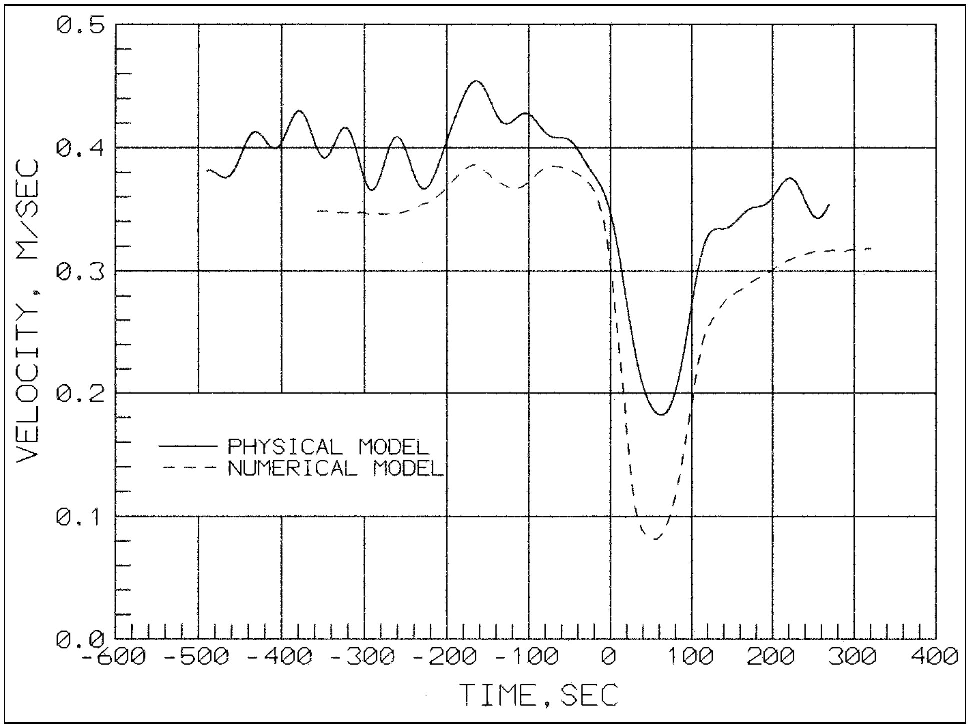



Figure 82. Physical model versus numerical model, probe 8, 112.5 m right of thalweg

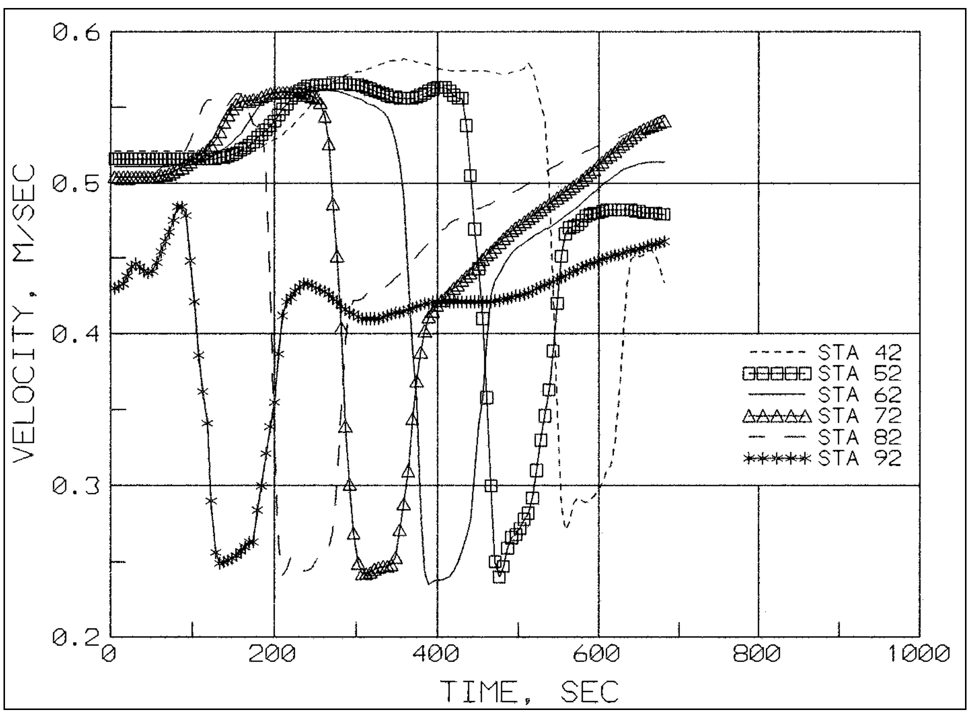



Figure 83. Variation of vessel effects along length of physical model, downbound tow, based on probe 6 of numerical model

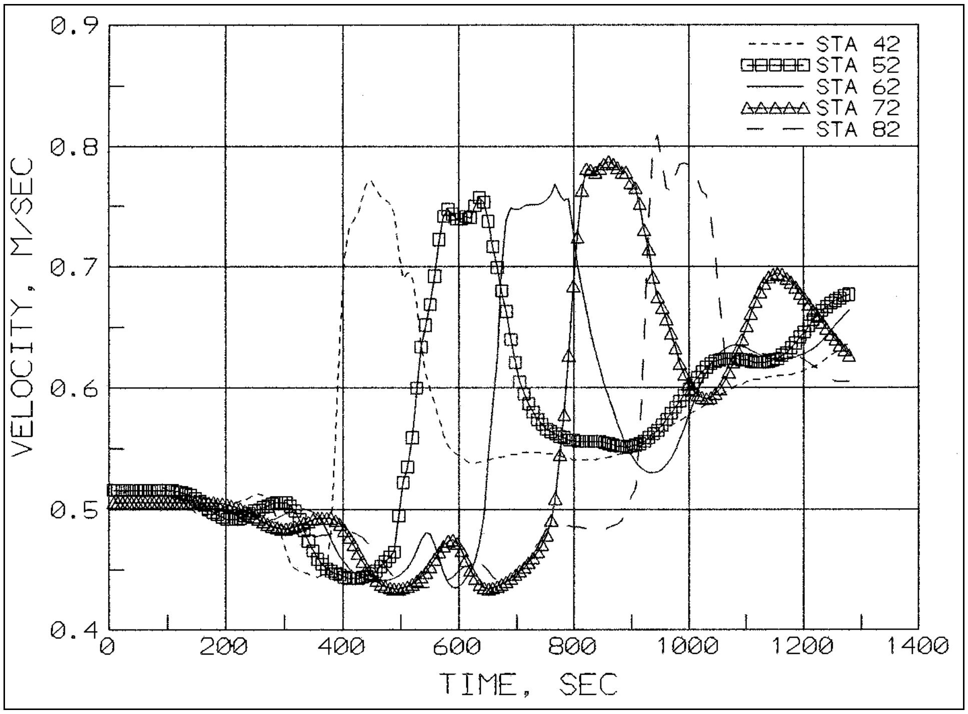



Figure 84. Variation of vessel effects along length of physical model, upbound tow, based on probe 6 of numerical model

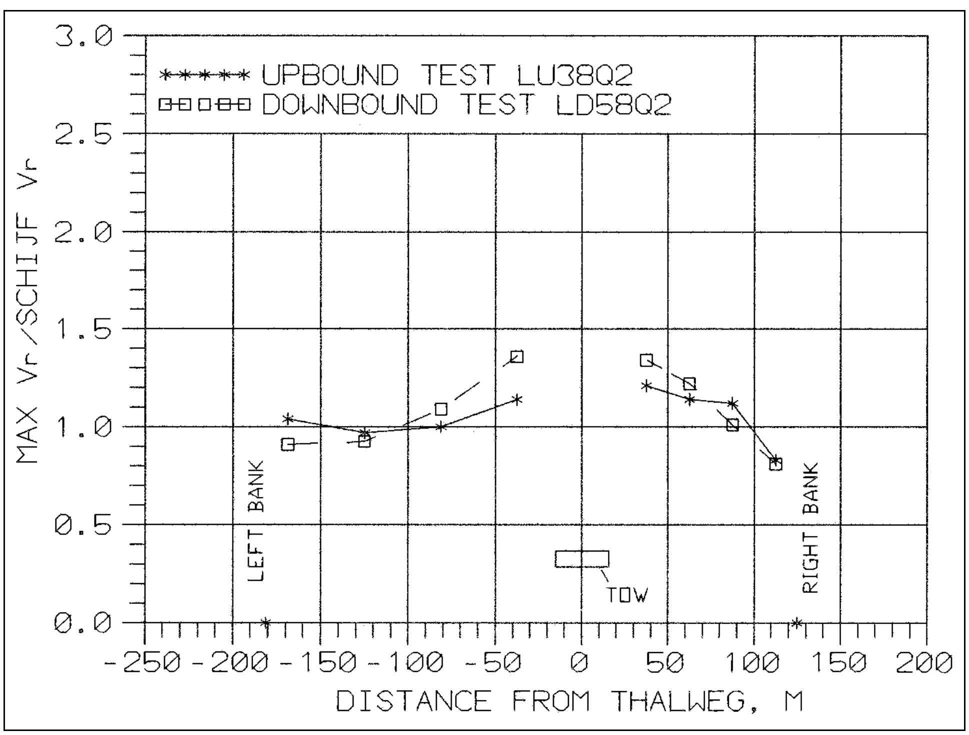



Figure 85. Dimensionless return velocity, experiments LU38Q2 and LD58Q2

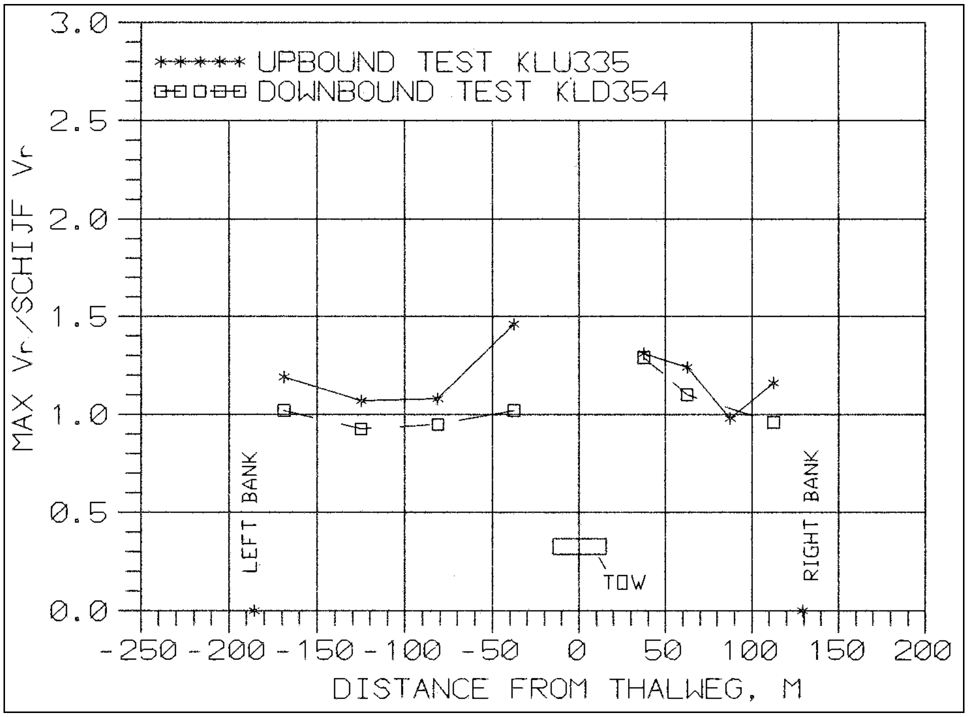



Figure 86. Dimensionless return velocity, experiments DKU335 and KLD354

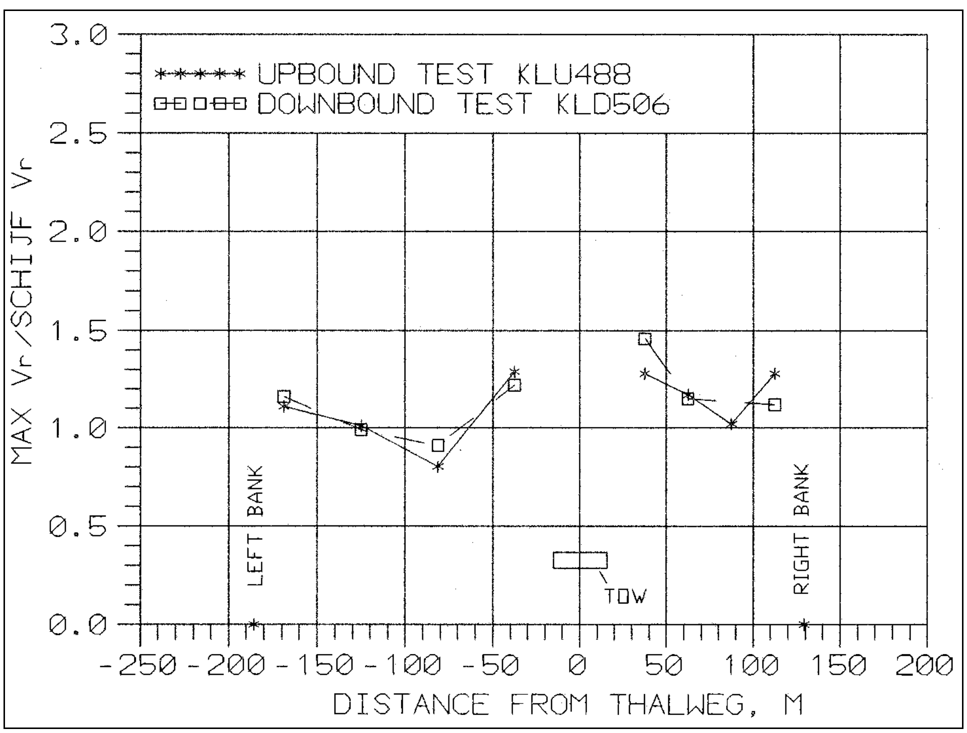



Figure 87. Dimensionless return velocity, experiments KLU488 and KLD506

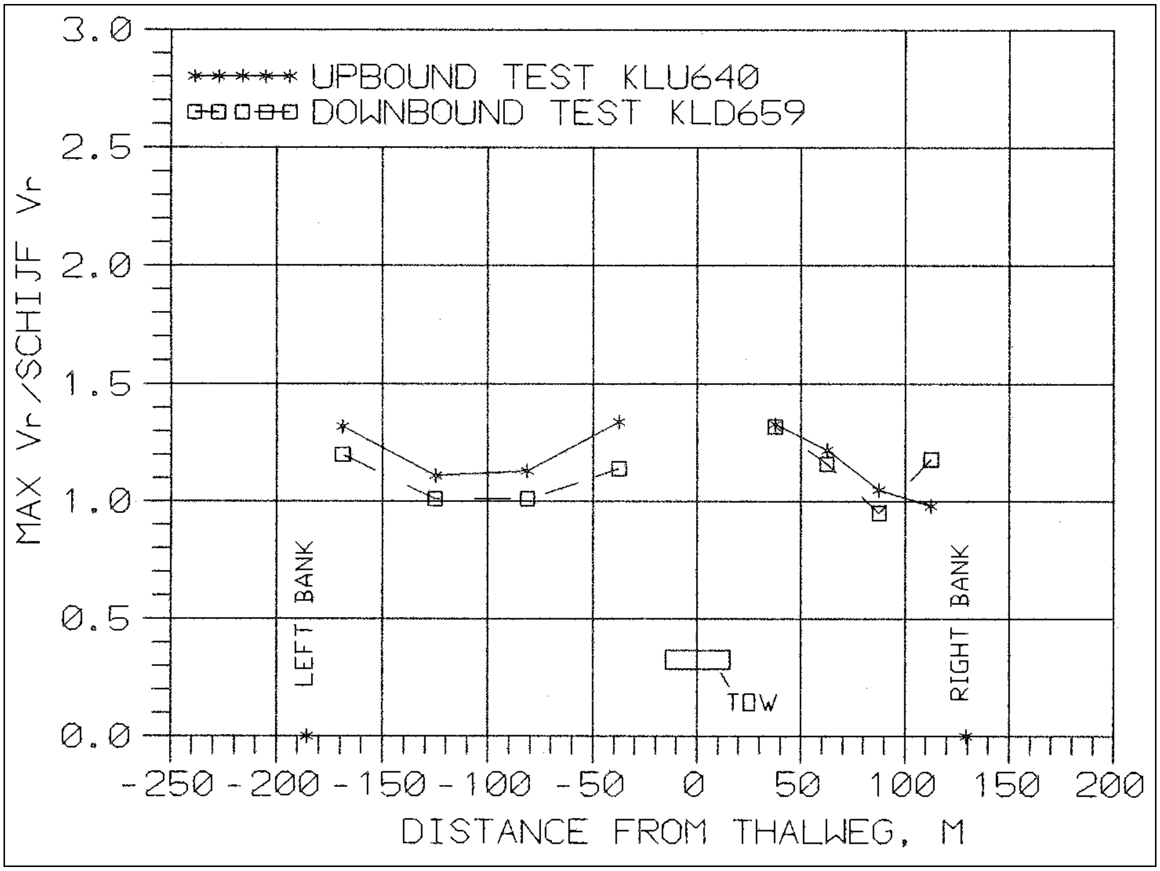



Figure 88. Dimensionless return velocity, experiments KLU640 and KLD659

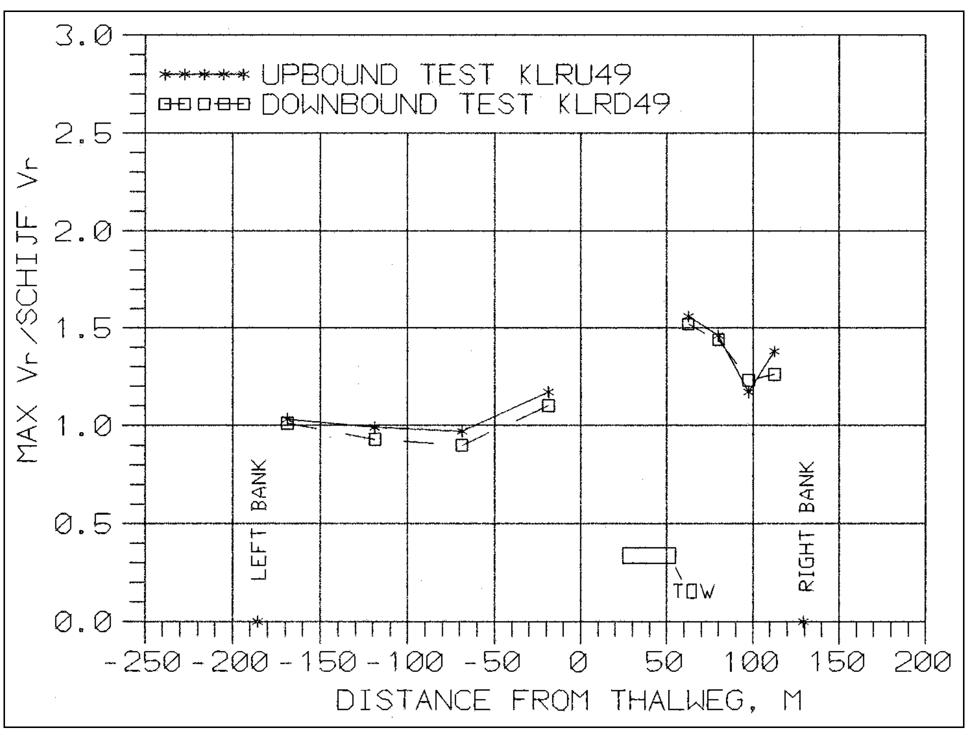



Figure 89. Dimensionless return velodity, experiments KLRU49 and KLRD49

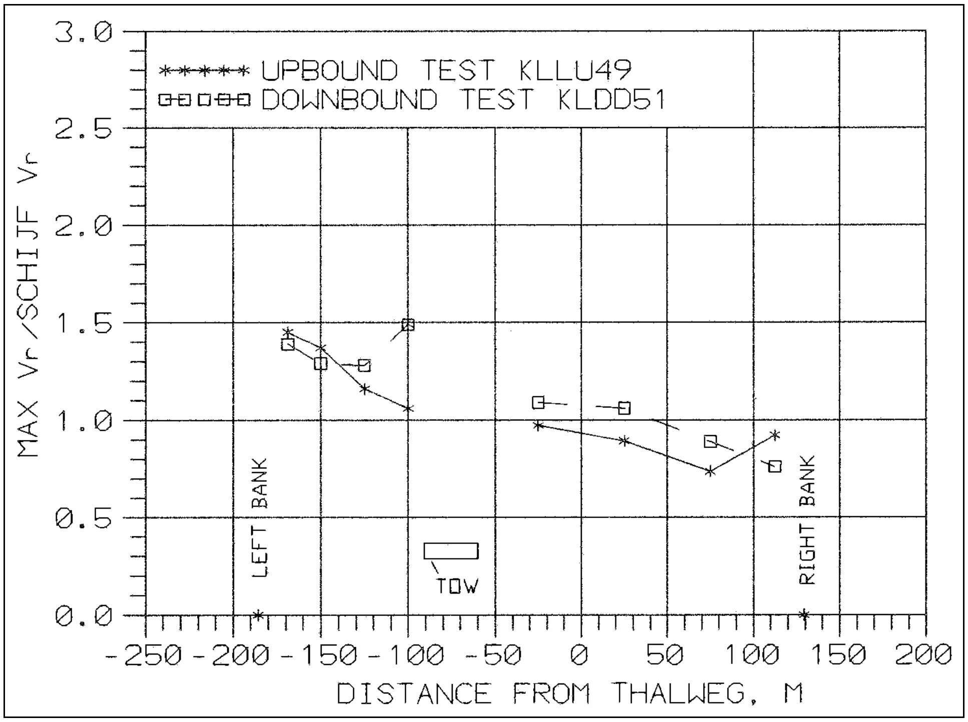



Figure 90. Dimensionless return velocity, experiments KLLU49 and KLDD51

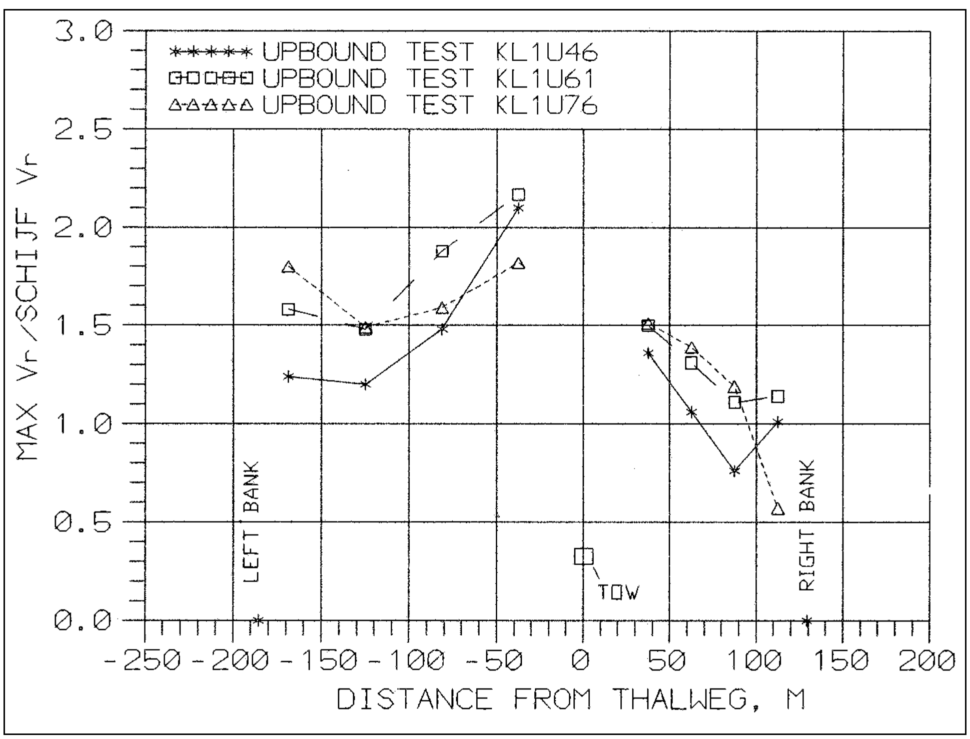



Figure 91. Dimensionless return velocity, experiments KL1U46, KL1U61, and KL1U76

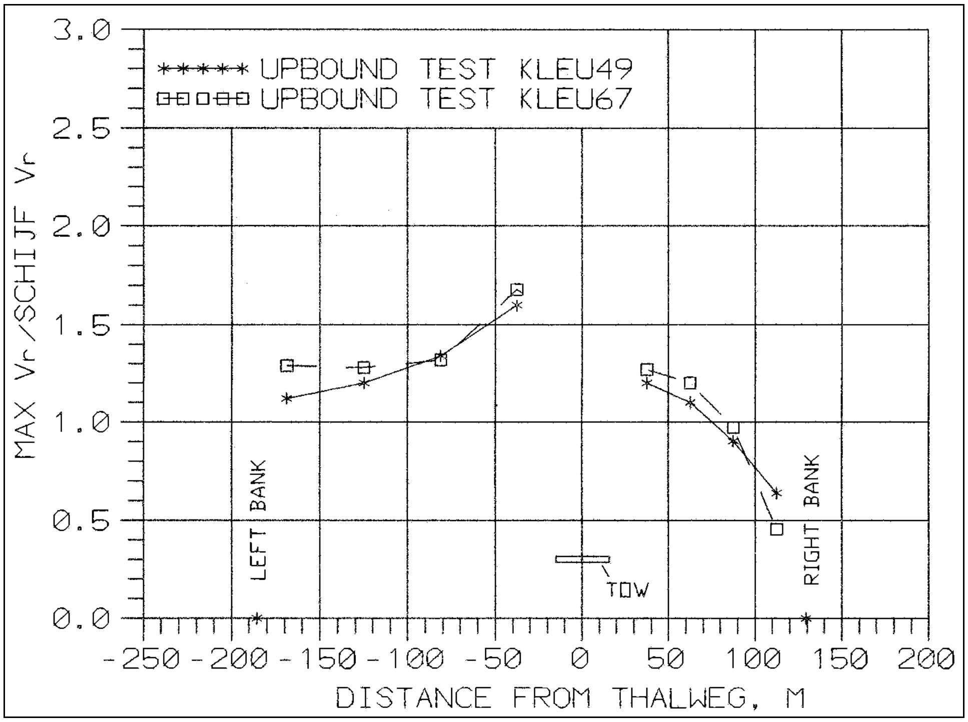



Figure 92. Dimensionless return velocity, experiments KLEU49 and KLEU67

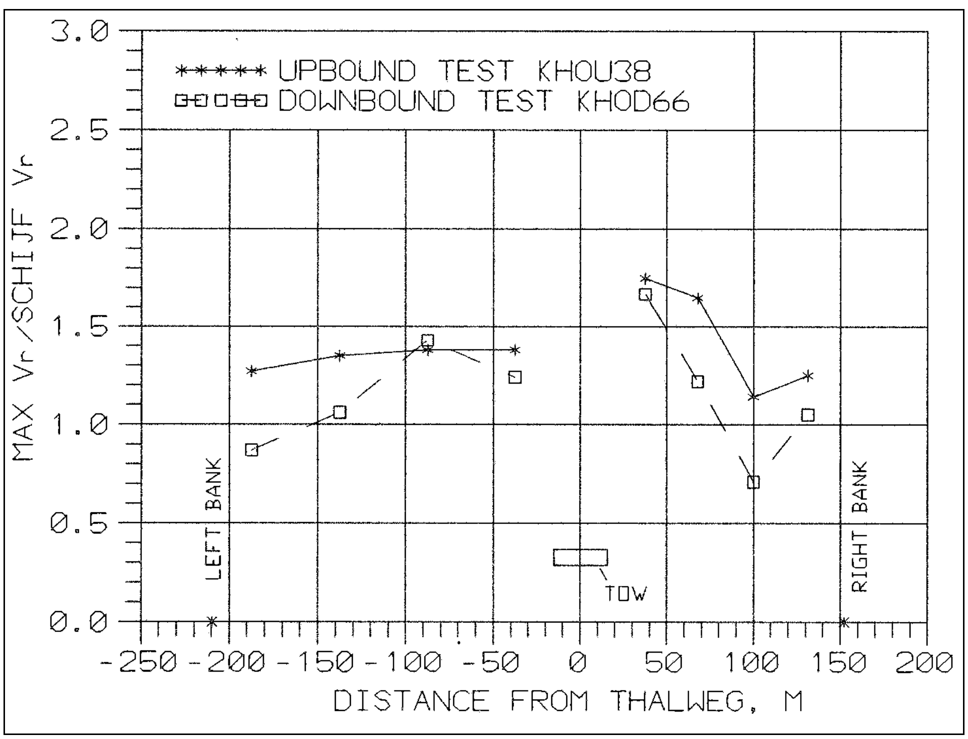



Figure 93. Dimensionless return velocity, experiments KHOU38 and KHOD66

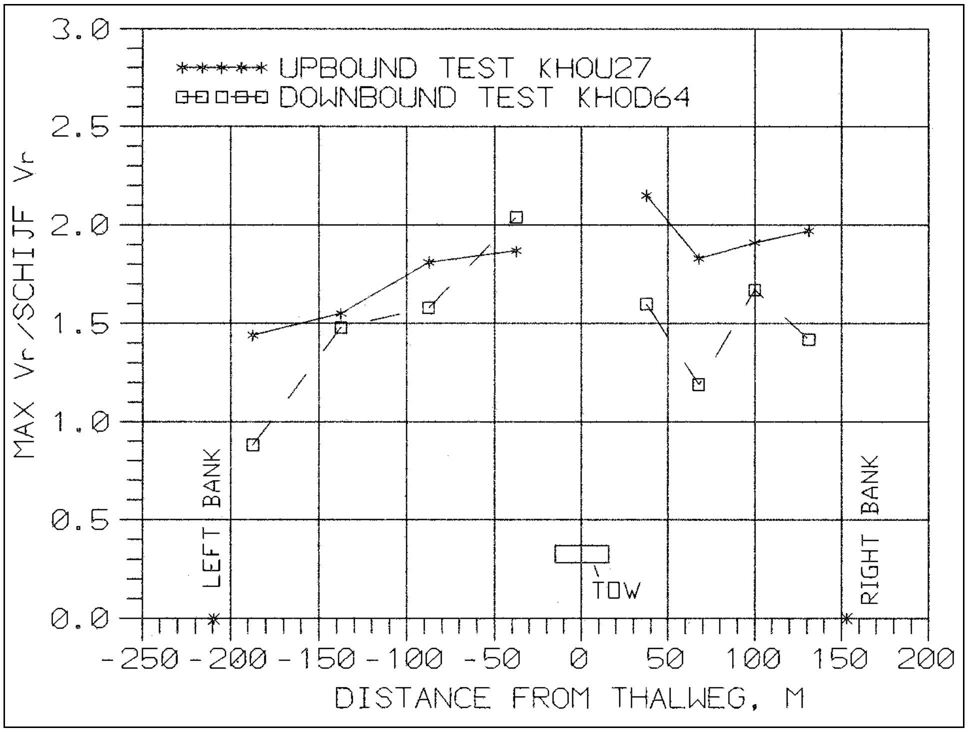



Figure 94. Dimensionless return velocity, experiments KHOU27 and KHOD64

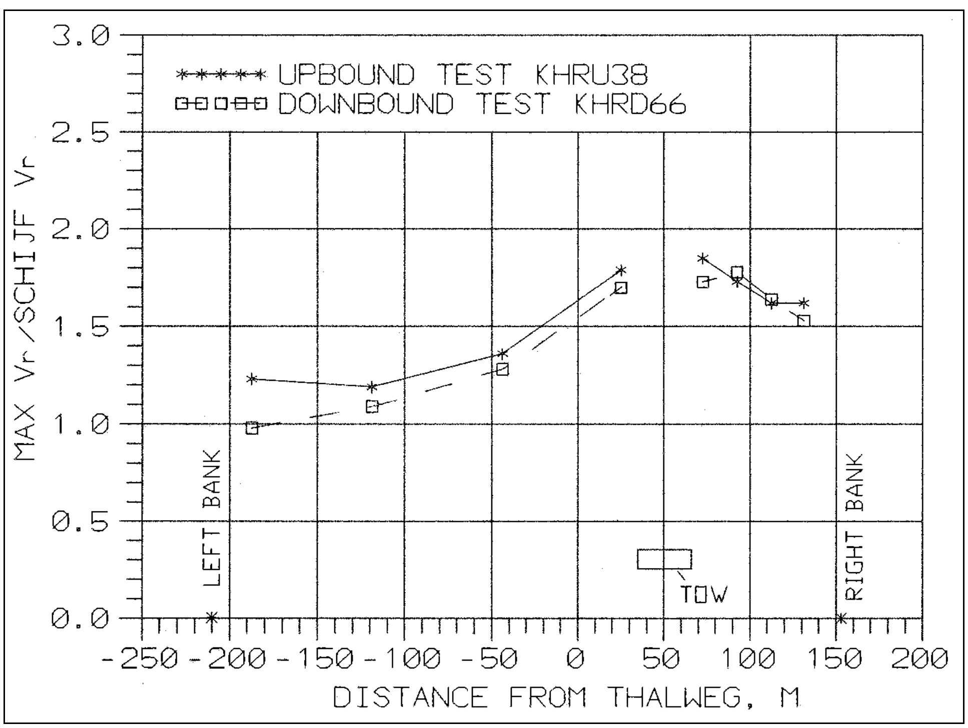



Figure 95. Dimensionless return velocity, experiments KHRU38 and KHRD66

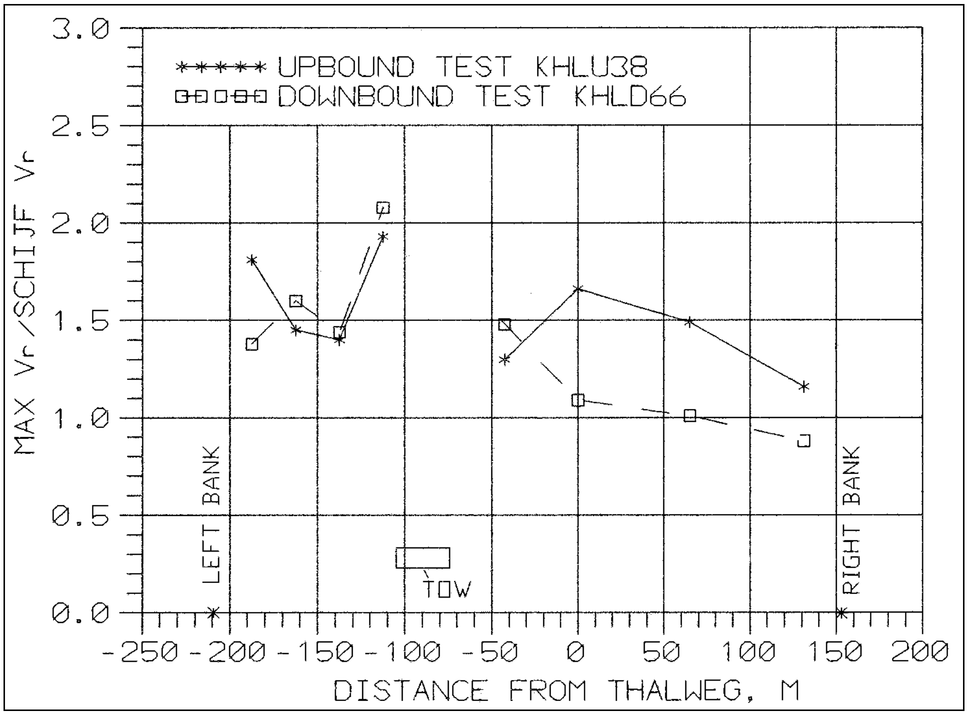



Figure 96. Dimensionless return velocity, experiments KHLU38 and KHLD66

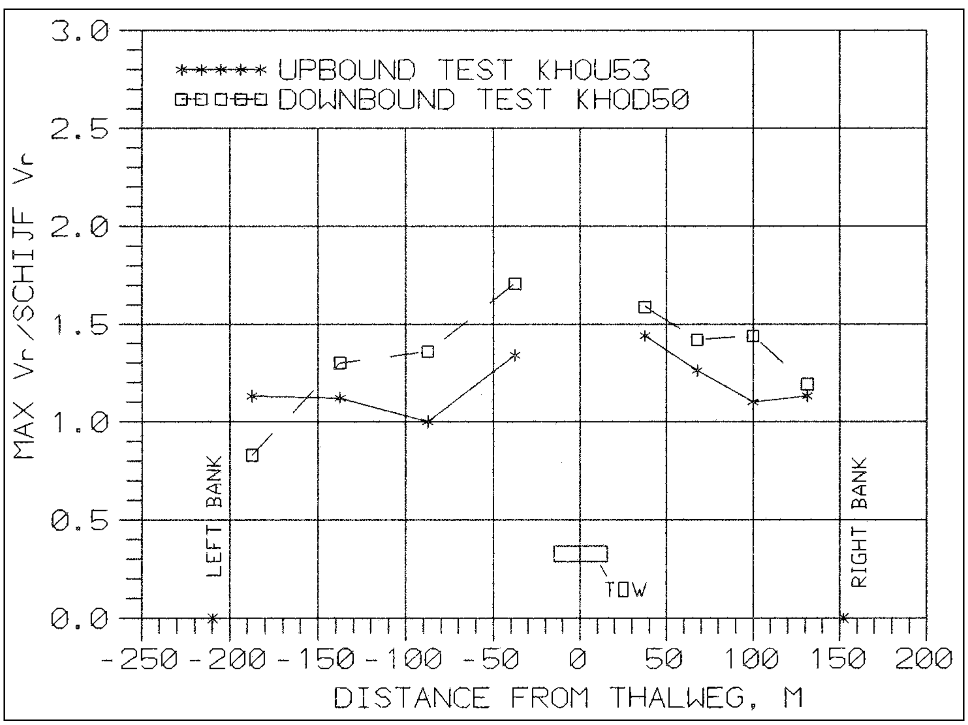



Figure 97. Dimensionless return velocity, experiments KHOU53 and KHOD50

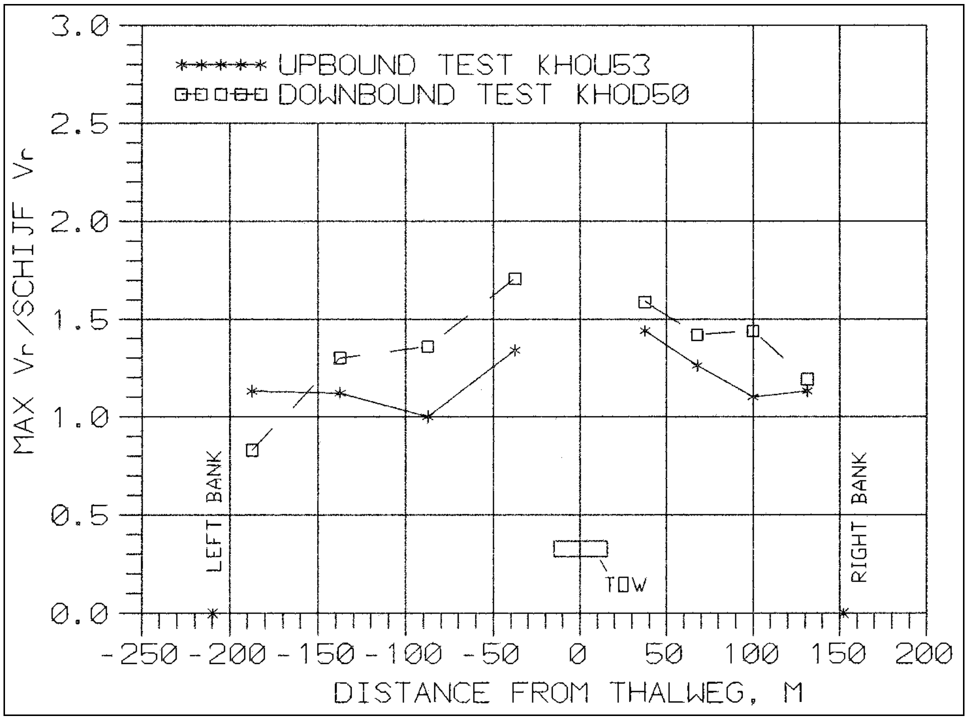



Figure 98. Dimensionless return velocity, experiments KHEU38 and KHEU56

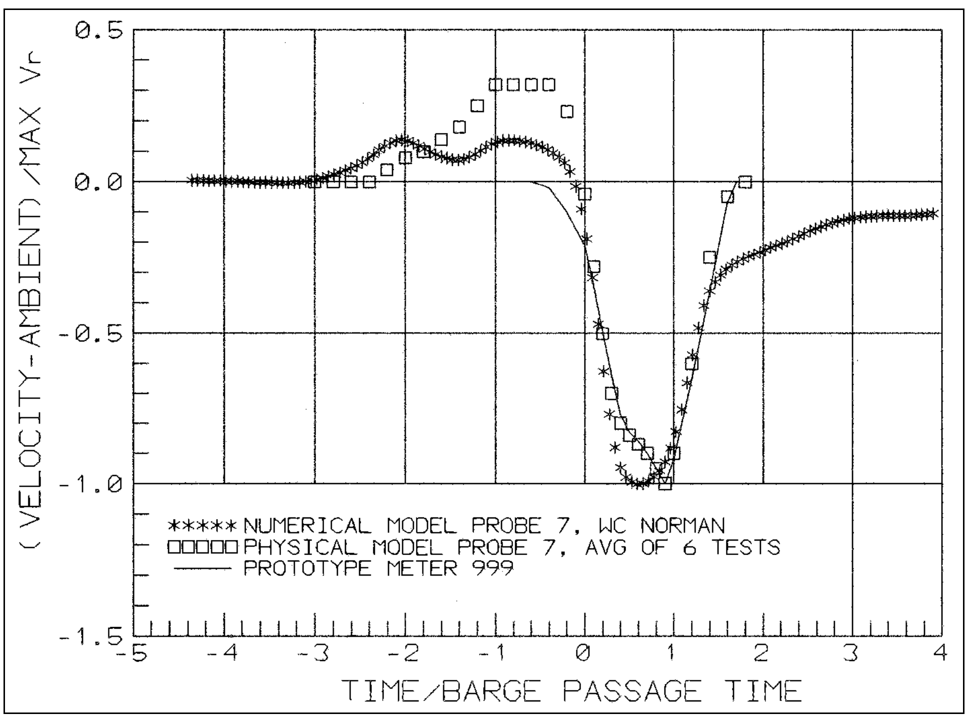



Figure 99. Dimensionless time-history of return velocity

**Table 1**
**Water Discharge, Average Velocity, Average Depth, and Water-Surface Elevation for the Kampsville Site**

| Date | Discharge cu m/sec | Average Channel Velocity m/sec | Average Flow Depth m | Water- Surface Elevation[1] |
|---|---|---|---|---|
| | | **Trip 1** | | |
| 10/10/90 | 413 | 0.36 | 3.44 | -- |
| 10/11/90 | -- | -- | -- | 420.7 |
| 10/12/90 | -- | -- | -- | 421.2 |
| 10/13/90 | -- | -- | -- | 421.8 |
| 10/14/90 | -- | -- | -- | 421.9 |
| 10/15/90 | 772 | 0.58 | 3.64 | 422.0 |
| 10/16/90 | -- | -- | -- | 422.1 |
| 10/17/90 | -- | -- | -- | 422.2 |
| 10/18/90 | 817 | 0.61 | 3.91 | -- |
| | | **Trip 2** | | |
| 8/8/91 | 329 | 0.29 | 3.51 | -- |
| 8/12/91-8/15/91 | -- | -- | -- | 420.0 |

[1]In feet referred to the National Geodetic Vertical Datum.

**Table 2**
**Traffic Characteristics for Trip 1**

| Date | Name of Vessel | Hp | Screws | Kort | Length m | Width m | Number of Barges | Config-uration | Barge Type | Draft m | Speed m/sec | Distance from Center Line to Bank m | Direction Bound |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/11 | *Mallard* | 1650 | 2 | n | 26.8 | 9.1 | 2 | 1x2 | Chemical | 0.61 | 3.83 | 122 | Down |
| | *Nicolas Duncan* | 1530 | 2 | n | 39.0 | 8.5 | 9 | 3x3 | Grain | 1.32 | 2.88 | 155 | Down |
| | *Bill Gee* | 2800 | 2 | y | 36.9 | 10.1 | 3 | 2x1+1 | Coal | 1.31 | 4.76 | 140 | Down |
| 10/12 | *Mr. Aldo* | 5600 | 2 | y | 44.2 | 14.6 | 14 | 2x1+3x4 | Grain | 2.74 | 2.78 | 130 | Down |
| | *Floyd H. Blaske* | 5000 | 2 | y | 51.8 | 12.2 | 12 | 3x4 | Grain | 1.63 | 2.18 | 115 | Up |
| 10/13 | *Marvin E. Norman* | 1800 | 2 | n | 31.1 | 10.4 | 16 | 3x5+1 | Grain | 0.61 | 1.69 | 115 | Up |
| | *Luke Burton* | 4200 | 2 | y | 43.9 | 10.7 | 3 | 1x3 | Mixed | 2.74 | 2.93 | 138 | Up |
| | *Sugarland* | 3375 | 2 | n | 42.1 | 12.8 | 12 | 3x4 | Grain | 2.29 | 1.88 | 170 | Up |
| | *William C. Norman* | 1800 | 2 | n | 33.5 | 10.4 | 12 | 3x4 | Grain | 2.74 | 2.90 | 138 | Down |
| | *Frank H. Peavey* | 3800 | 2 | n | 42.7 | 11.6 | 23 | 4x5+3 | Grain | 1.17 | 1.75 | 150 | Up |
| | *Conti Karla* | 3060 | 2 | n | 34.8 | 10.5 | 16 | 3x5+1 | Grain | 2.34 | 1.70 | 145 | Up |
| | *Margaret O.* | 5600 | 2 | y | 42.1 | 13.4 | 10 | 2x5 | Grain | 2.53 | 2.75 | 150 | Up |
| 10/14 | *Lydia E. Campbell* | 4200 | 2 | y | 43.9 | 10.7 | 3 | 1x3 | Grain | 2.74 | 3.24 | 180 | Up |
| | *Mr. Paul* | 5600 | 2 | y | 44.2 | 14.6 | 8 | 2x4 | Chemical | 1.68 | 2.76 | 155 | Down |
| | *Rambler* | 2000 | 2 | n | 27.4 | 9.1 | 12 | 3x4 | Grain | 2.74 | 2.48 | 138 | Down |
| | *Mr. Lawrence* | 5600 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Grain | 1.75 | 2.56 | 165 | Up |
| | *Mallard* | 1650 | 2 | n | 26.8 | 9.1 | 7 | 3x2+1 | Mixed | 2.13 | 2.68 | 175 | Up |
| | *Charles Lehman* | 5600 | 2 | y | 44.2 | 14.6 | 13 | 1+3x4 | Coal | 2.74 | 1.85 | 145 | Up |
| | *Nicolas Duncan* | 1530 | 2 | n | 39.0 | 8.5 | 9 | 3x3 | Grain | 2.74 | 1.52 | 130 | Up |

***(Continued)***

**Table 2 (Concluded)**

| Date | Name of Vessel | Hp | Screws | Kort | Length m | Width m | Number of Barges | Config-uration | Barge Type | Draft m | Speed m/sec | Distance from Center Line to Bank m | Direction Bound |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/14 (Cont) | *Jeffboat* | 6000 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Grain | 2.74 | 1.84 | 115 | Up |
| | *Mary Ann* | 2250 | 2 | n | 30.5 | 9.1 | 15 | 3x5 | Grain | 0.61 | 1.90 | 105 | Up |
| 10/15 | *Ardyce Randall* | 5600 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Grain | 2.74 | 2.36 | 155 | Down |
| | *Mr. Paul* | 5600 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Grain | 1.61 | 2.25 | 130 | Up |
| | *Exxon St. Louis* | 3800 | 2 | n | 42.7 | 13.4 | 4 | 2x2 | Petroleum | 2.74 | 2.25 | 175 | Up |
| | *Margaret O.* | 5600 | 2 | y | 42.1 | 13.4 | 12 | 3x4 | Cargo | 2.03 | 3.83 | 130 | Down |
| | *Mr. Lawrence* | 5600 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Cargo | 2.74 | 3.16 | 115 | Down |
| 10/16 | *A.L. Smith* | 1800 | 2 | n | -- | -- | 8 | 2x4 | Cargo | 2.48 | 2.80 | 140 | Down |
| | *Ste. Genevieve* | 1600 | 2 | n | 23.2 | 7.9 | 12 | 3x4 | Cargo | 0.61 | 1.66 | 150 | Up |
| 10/17 | *Nicole Brent* | 1400 | 2 | n | 22.9 | 7.9 | 2 | 1x2 | Chemical | 2.74 | 2.86 | 150 | Up |
| | *Frank H. Peavey* | 3800 | 2 | n | 42.7 | 11.6 | 5 | 1+2x2 | Cargo | 2.74 | 3.05 | 170 | Down |

**Table 3**
**Traffic Characteristics for Trip 2**

| Date | Name of Vessel | Hp | Screws | Kort | Length m | Width m | Number of Barges | Config-uration | Barge Type | Draft m | Speed m/sec | Distance from Center Line to Bank m | Direction Bound |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/13 | *Ranger* | 850 | 2 | y | 21.3 | 6 | 5 | 2x2+1l | Hopper & Chemical | 2.74 | 1.90 | 230 | Down |
| | *Dixie Patriot* | 3200 | 2 | n | 33.5 | 10.4 | 3 | 1x3 | Hopper | 2.74 | 2.48 | 175 | Down |
| | *Orleanian* | 4300 | 2 | n | 42.7 | 11.6 | 13 | 3x4+1 | Hopper | 1.92 | 2.02 | 160 | Up |
| | *Pat Breen* | 5600 | 2 | y | 44.2 | 14.6 | 15 | 3x5 | Hopper | 2.66 | 2.29 | 160 | Down |
| | *Dixie Express* | 1700 | 2 | n | 26.2 | 8 | 2 | 1x2 | Asphalt | 1.52 | 3.40 | 180 | Down |
| | *J Anne Stegbauer* | 3200 | 2 | n | 36.6 | 10.7 | 2 | 1x2 | Chemical | 2.74 | 4.11 | 150 | Up |
| | *Ste. Genevieve* | 200 | 2 | n | 12.2 | 4 | 11 | 2x3x3 | Hopper | 0.61 | 2.48 | 100 | Up |
| | *Bob White* | 3600 | 2 | n | 40.5 | 10.5 | 9 | 3x3 | Closed Hopper | 2.74 | 1.37 | 285 | Down |
| 8/14 | *Night-14-01* | | | | | | 11 | 2+3x3 | Hopper | 2.74 | 1.62 | 140 | Up |
| | *Night-14-02* | | | | | | 9 | 3x3 | Chemical | 2.74 | 4.05 | 250 | Down |
| | *Irving Crown* | 2400 | 2 | n | 31.4 | 9 | 7 | 32x2 | Hopper | 2.74 | 1.59 | 220 | Up |
| | *Gordon Jones* | 4200 | 2 | n | 44.8 | 11.7 | 15 | 3x5 | Hopper | 2.74 | | 170 | Down |
| | *George W. Schamble* | 1800 | 2 | n | 26.1 | 9 | 2 | 2x1 | (Unknown) | 0.61 | 3.83 | 170 | Down |
| | *Katherine L.* | 1600 | 2 | n | 31.1 | 8 | 2 | 1x2 | Hopper | 0.61 | 3.21 | 200 | Down |
| | *T. B. Morto* | 4200 | 2 | n | 45.7 | 10.7 | 12 | 3x4 | Hopper | 1.52 | 2.18 | 200 | Up |
| | *Julie White* | 1700 | 2 | n | 26.8 | 11.6 | 12 | 3x2+2x3 | Hopper | 2.38 | 2.20 | 170 | Up |
| | *Ranger* | 850 | 2 | y | 21.3 | 6 | 1 | 1x1 | Hopper | 0.61 | 3.50 | 150 | Up |
| | *Illini* | 1600 | 2 | n | 24.4 | 8 | 12 | 3x4 | Hopper | 0.78 | 2.18 | 210 | Up |

***(Continued)***

**Table 3 (Concluded)**

| Date | Name of Vessel | Hp | Screws | Kort | Length m | Width m | Number of Barges | Config-uration | Barge Type | Draft m | Speed m/sec | Distance from Center Line to Bank m | Direction Bound |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/14 (Cont) | *Bronwynne Brent* | 5400 | 2 | y | 42.7 | 12.8 | 6 | 2x3 | Hopper | 0.61 | 2.32 | 180 | Down |
| | *Sugarland* | 3375 | 3 | n | 42.1 | 12.8 | 1 | 1x1 | Hopper | 0.61 | 2.67 | | Up |
| | *Frank Stegbauer* | 3200 | 2 | n | 39.6 | 10.7 | 1 | 1x1 | Chemical | 0.61 | 4.12 | | Down |
| 8/15 | *Bill McCormick* | 3200 | 2 | y | 45.3 | 10.5 | 8 | 2x4 | Hopper | 2.21 | 2.07 | | Down |
| | *Marvin E. Norman* | 1800 | 2 | n | 31.1 | 10.4 | 6 | 2x3 | Unknown | | 1.75 | 190 | Down |
| | *Olmstead* | 5920 | 2 | y | 42.1 | 13.4 | 15 | 3x5 | Coal | 2.74 | 2.19 | 180 | Up |
| | *Jack D. Wofford* | 5000 | 2 | y | 51.8 | 12.2 | 15 | 3x5 | Hopper | 2.74 | 2.22 | 180 | Up |
| | *Dixie Express* | 1800 | 2 | n | 30.5 | 8 | 2 | 1x2 | Asphalt | 2.74 | 2.58 | 200 | Up |
| | *Hal D. Miller* | 2400 | 2 | n | 32.9 | 9 | 2 | 1x2 | Work | 2.74 | 2.33 | 190 | Down |
| | *Jesse Brent* | 4300 | 2 | n | 36.6 | 12.2 | 2 | 2x1 | Hopper | 1.52 | 3.72 | 220 | Down |

**Table 4**
**Schijf Return Velocity and Drawdown for Verification Tows**

| Tow (Width x Length) | Direction Bound | Speed through Water m/sec | Channel Area, sq m | Channel Top Width m | Schijf | |
|---|---|---|---|---|---|---|
| | | | | | Return Velocity, m/sec | Drawdown, m |
| *William C. Norman* (3x4) | d | 2.40 | 1269 | 330 | 0.22 | 0.055 |
| *Olmstead* (3x5) | u | 2.50 | 1091 | 319 | 0.29 | 0.078 |
| *Jack D. Wofford* (3x5) | u | 2.50 | 1091 | 319 | 0.29 | 0.078 |
| *Rambler* (3x4) | d | 1.93 | 1279 | 331 | 0.16 | 0.078 |
| *Charles Lehman* (3x4) | u | 2.40 | 1279 | 331 | 0.22 | 0.055 |
| *Mr. Lawrence* (3x5) | u | 3.1 | 1289 | 331 | 0.24 | 0.064 |

**Table 5**
**Maximum Prototype Return Velocity/Schijf Average Return Velocity for Verification Tows**

| Tow | Meter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 332 | 642 | 1000 | 999 | 998 | 1001 | 040 | 071 |
| *William C. Norman* (3x4) | 1.17 | 1.21 | 1.05 | 1.11 | 1.01 | 0.72 | 0.97 | 1.01 |
| *Olmstead* (3x5) | 1.17 | -- | 0.23 | 1.22 | 0.70 | 1.04 | -- | -- |
| *Jack D. Wofford* (3x5) | 1.26 | -- | -- | 1.18 | 0.74 | 1.12 | -- | -- |
| *Rambler* (3x4) | 1.26 | 1.24 | 1.24 | 1.11 | 0.78 | 0.91 | 0.96 | -- |
| *Charles Lehman* (3x4) | 1.49 | 1.35 | 1.38 | 1.35 | 1.00 | 0.92 | 1.52 | 1.00 |
| *Mr. Lawrence* (3x5) | 1.33 | 1.40 | 0.78 | 1.42 | 1.34 | 0.94 | -- | -- |

**Table 6**
**Relative Ambient Velocity Variation in Prototype**

| Tow | Meter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 332 | 642 | 1000 | 999 | 998 | 1001 | 040 | 071 |
| *William C. Norman* | 12<br>(0.54) | 13<br>(0.45) | 11<br>(0.42) | 13<br>(0.35) | 15<br>(0.29) | 14<br>(0.20) | 15<br>(0.45) | 6<br>(0.45) |
| *Rambler* | 10<br>(0.53) | 13<br>(0.44) | 10<br>(0.48) | 12<br>(0.39) | 15<br>(0.29) | 12<br>(0.23) | 11<br>(0.45) | --<br>-- |

$$\text{Note:}\ \frac{(\text{Maximum} - \text{Minimum})/(2 * \text{Average Ambient Velocity}) * 100}{(\text{Ambient, m/sec})}$$

**Table 7**
**Verification Data Using Geometrically Similar Froude Model, *William C. Norman, Olmstead*, and *Jack D. Wofford***

| Probe Number | Physical Model Return Velocity[1] m/sec | Prototype Ambient Velocity, m/sec | Prototype Minimum Velocity, m/sec | Prototype Return Velocity[1] m/sec | Drawdown | |
|---|---|---|---|---|---|---|
| | | | | | Physical Model Average | Prototype |
| | | | ***William C. Norman*** | | | |
| 332 | 0.305 | 0.542 | 0.284 | 0.258 | 0.112 | 0.072 |
| 642 | 0.325 | 0.446 | 0.180 | 0.266 | | |
| 998 | - | 0.293 | 0.071 | 0.222 | | |
| 999 | - | 0.350 | 0.105 | 0.245 | | |
| 1000 | 0.306 | 0.423 | 0.192 | 0.231 | | |
| 1001 | 0.170 | 0.195 | 0.036 | 0.159 | | |
| 040 | 0.307 | 0.452 | 0.238 | 0.214 | | |
| 071 | 0.275 | 0.454 | 0.232 | 0.222 | | |
| | | | ***Olmstead*** | | | |
| 332 | 0.462 | 0.166 | 0.506 | 0.340 | 0.159 | 0.072 |
| 642 | 0.439 | | | | | |
| 998 | - | 0.070 | 0.272 | 0.202 | | |
| 999 | 0.441 | 0.126 | 0.479 | 0.353 | | |
| 1000 | - | 0.019 | 0.085 | 0.066 | | |
| 1001 | 0.393 | 0.053 | 0.356 | 0.303 | | |
| | | | ***Jack D. Wofford*** | | | |
| 332 | 0.462 | 0.140 | 0.504 | 0.364 | 0.159 | 0.086 |
| 642 | 0.439 | - | - | - | | |
| 998 | - | 0.063 | 0.277 | 0.214 | | |
| 999 | 0.441 | 0.117 | 0.459 | 0.342 | | |
| 1000 | - | - | - | - | | |
| 1001- | 0.393 | 0.038 | 0.364 | 0.326 | | |

[1]Ambient - minimum velocity.

**Table 8**
**Verification Data, *William C. Norman,* Barge Draft 2.28 m**

| Probe Number | Physical Model Velocity, m/sec, for Replicate | | | | | | Prototype Velocity m/sec | Return Velocity, m/sec[1] | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | | Physical Model | Prototype |
| **Ambient Velocity** | | | | | | | | | |
| 332 | 0.453 | 0.442 | 0.459 | 0.426 | 0.474 | 0.451 | 0.542 | 0.263 | 0.258 |
| 642 | 0.467 | 0.437 | 0.416 | 0.434 | 0.417 | 0.434 | 0.446 | 0.237 | 0.266 |
| 998 | | | | | | | 0.293 | | 0.222 |
| 999 | | | | | | | 0.350 | | 0.245 |
| 1000 | 0.489 | 0.478 | 0.473 | 0.469 | 0.498 | 0.481 | 0.423 | 0.261 | 0.231 |
| 1001 | 0.097 | 0.115 | 0.137 | 0.171 | 0.162 | 0.136 | 0.195 | 0.178 | 0.159 |
| 040 | 0.450 | 0.450 | 0.487 | 0.502 | 0.476 | 0.473 | 0.452 | 0.244 | 0.214 |
| 071 | 0.458 | 0.459 | 0.471 | 0.472 | 0.460 | 0.464 | 0.452 | 0.203 | 0.222 |
| Minimum Velocity | | | | | | | | | |
| 332 | 0.213 | 0.145 | 0.176 | 0.172 | 0.236 | 0.188 | 0.284 | | |
| 642 | 0.188 | 0.210 | 0.189 | 0.203 | 0.194 | 0.197 | 0.180 | | |
| 998 | | | | | | | 0.071 | | |
| 999 | | | | | | | 0.105 | | |
| 1000 | 0.236 | 0.213 | 0.206 | 0.196 | 0.249 | 0.220 | 0.192 | | |
| 1001 | -0.043 | -0.019 | -0.056 | -0.059 | -0.033 | -0.042 | 0.036 | | |
| 040 | 0.249 | 0.223 | 0.199 | 0.223 | 0.252 | 0.229 | 0.238 | | |
| 071 | 0.251 | 0.251 | 0.272 | 0.269 | 0.318 | 0.261 | 0.232 | | |
| **Physical Model Drawdown, m, for Replicate** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **AVG** | | **Prototype Drawdown, m** | |
| | 0.066 | 0.067 | 0.066 | 0.070 | 0.063 | 0.067 | | 0.072 | |

[1]Ambient – minimum velocity.

## Table 9
## Verification Data, *Olmstead/Jack D. Wofford,* Barge Draft 2.28 m

| Probe Number | Physical Model Velocity, m/sec, for Replicate | | | | | | Physical Model Return Velocity m/sec[1] | Prototype Velocity m/sec | | Prototype Return Velocity, m/sec[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | | *Olmstead* | *Jack D. Wofford* | *Olmstead* | *Jack D. Wofford* |
| **Ambient Velocity, m/sec** | | | | | | | | | | | |
| 332 | 0.216 | 0.198 | 0.221 | 0.246 | 0.238 | 0.224 | 0.327 | 0.166 | 0.140 | 0.340 | 0.364 |
| 642 | 0.219 | 0.193 | 0.198 | 0.247 | 0.214 | 0.214 | 0.320 | | - | - | - |
| 998 | | | | | | | - | 0.070 | 0.063 | 0.202 | 0.214 |
| 999 | 0.187 | 0.185 | 0.190 | 0.185 | 0.187 | 0.187 | 0.328 | 0.126 | 0.117 | 0.353 | 0.342 |
| 1000 | | | | | | | - | 0.019 | - | 0.066 | - |
| 1001 | 0.071 | 0.062 | 0.064 | 0.059 | 0.074 | 0.066 | 0.205 | 0.053 | 0.038 | 0.303 | 0.326 |
| **Maximum Velocity, m/sec** | | | | | | | | | | | |
| 332 | 0.554 | 0.523 | 0.529 | 0.570 | 0.578 | 0.551 | | 0.506 | 0.504 | | |
| 642 | 0.542 | 0.488 | 0.513 | 0.566 | 0.561 | 0.534 | | | - | | |
| 998 | | | | | | | | 0.272 | 0.277 | | |
| 999 | 0.523 | 0.484 | 0.504 | 0.541 | 0.518 | 0.514 | | 0.479 | 0.459 | | |
| 1000 | | | | | | | | 0.085 | - | | |
| 1001 | 0.284 | 0.265 | 0.241 | 0.404 | 0.295 | 0.271 | | 0.356 | 0.364 | | |
| **Drawdown[2], m** | | | | | | | | | | | |
| | 0.128 | - | 0.124 | 0.129 | 0.127 | | | | | | |

[1]Maximum - ambient velocity.
[2]The average physical model drawdown was 0.127 m, and the prototype drawdown was 0.072 m for *Olmstead* and 0.086 m for *Jack D. Wofford*.

## Table 10
## Verification Data, *Rambler*, Barge Draft 2.28 m

| Probe Number | Physical Model Velocity, m/sec, for Replicate | | | | | | Prototype Velocity m/sec | Return Velocity, m/sec[1] | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | | Physical Model | Prototype |
| **Ambient Velocity** | | | | | | | | | |
| 332 | 0.452 | 0.428 | 0.445 | 0.423 | 0.426 | 0.438 | 0.529 | 0.208 | 0.201 |
| 642 | 0.436 | 0.434 | 0.440 | 0.435 | 0.435 | 0.435 | 0.436 | 0.213 | 0.199 |
| 998 | | | | | | | 0.290 | - | 0.124 |
| 999 | | | | | | | 0.388 | - | 0.178 |
| 1000 | 0.470 | 0.476 | 0.469 | 0.478 | 0.500 | 0.473 | 0.480 | 0.203 | 0.198 |
| 1001 | 0.081 | 0.068 | 0.077 | 0.075 | 0.070 | 0.074 | 0.227 | 0.087 | 0.146 |
| 040 | 0.454 | 0.471 | 0.465 | 0.471 | 0.471 | 0.470 | 0.451 | 0.192 | 0.154 |
| 071 | 0.479 | 0.462 | 0.479 | 0.467 | 0.454 | 0.468 | - | 0.150 | - |
| **Minimum Velocity** | | | | | | | | | |
| 332 | 0.231 | 0.211 | 0.259 | 0.237 | 0.214 | 0.230 | 0.328 | | |
| 642 | 0.235 | 0.245 | 0.203 | 0.219 | 0.206 | 0.222 | 0.237 | | |
| 998 | | | | | | | 0.166 | | |
| 999 | | | | | | | 0.210 | | |
| 1000 | 0.287 | 0.262 | 0.301 | 0.270 | 0.228 | 0.270 | 0.282 | | |
| 1001 | -0.006 | -0.011 | -0.009 | -0.018 | -0.020 | -0.013 | 0.081 | | |
| 040 | 0.275 | 0.308 | 0.287 | 0.276 | 0.244 | 0.278 | 0.297 | | |
| 071 | 0.285 | 0.308 | 0.321 | 0.338 | 0.340 | 0.318 | - | | |
| **Physical Model Drawdown, m, for Replicate** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **AVG** | | **Prototype Drawdown, m** | |
| | 0.049 | 0.051 | 0.045 | 0.047 | 0.048 | 0.048 | | 0.045 | |

[1]Ambient - minimum velocity.

**Table 11**
**Verification Data, *Charles Lehman*, Barge Draft 2.28 m**

| Probe Number | Physical Model Velocity, m/sec, for Replicate | | | | | | Prototype Velocity m/sec | Return Velocity, m/sec[1] | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | | Physical Model | Prototype |
| **Ambient Velocity** | | | | | | | | | |
| 332 | 0.513 | 0.467 | 0.443 | 0.468 | 0.456 | 0.459 | 0.534 | 0.296 | 0.328 |
| 642 | 0.406 | 0.452 | 0.438 | 0.406 | 0.397 | 0.420 | 0.443 | 0.351 | 0.298 |
| 998 | | | | | | | 0.304 | - | 0.221 |
| 999 | | | | | | | 0.394 | - | 0.297 |
| 1000 | 0.461 | 0.469 | 0.473 | 0.461 | 0.416[1] | 0.466 | 0.485 | 0.304 | 0.304 |
| 1001 | 0.120 | 0.137 | 0.100 | 0.120 | 0.109 | 0.117 | 0.215 | 0.167 | 0.203 |
| 040 | 0.475 | 0.489 | 0.477 | 0.475 | 0.465 | 0.476 | 0.436 | 0.258 | 0.335 |
| 071 | 0.469 | 0.482 | 0.503 | 0.437 | 0.463 | 0.471 | 0.467 | 0.224 | 0.219 |
| **Maximum Velocity** | | | | | | | | | |
| 332 | 0.718 | 0.740 | 0.772 | 0.280 | 0.762 | 0.754 | 0.862 | | |
| 642 | 0.759 | 0.724 | 0.768 | 0.280 | 0.777 | 0.771 | 0.741 | | |
| 998 | | | | | | | 0.525 | | |
| 999 | | | | | | | 0.691 | | |
| 1000 | 0.780 | 0.767 | 0.766 | 0.723 | 0.812 | 0.770 | 0.789 | | |
| 1001 | 0.403 | 0.297 | 0.269 | 0.227 | 0.225 | 0.284 | 0.418 | | |
| 040 | 0.727 | 0.742 | 0.741 | 0.705 | 0.755 | 0.734 | 0.771 | | |
| 071 | 0.686 | 0.714 | 0.692 | 0.681 | 0.702 | 0.695 | 0.686 | | |
| **Physical Model Drawdown, m, for Replicate** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **AVG** | | **Prototype Drawdown, m** | |
| | - | 0.057 | 0.058 | 0.061 | 0.061 | 0.059 | | 0.070 | |

[1]Data point rejected as outlier.

## Table 12
## Verification Data, *Mr. Lawrence*, Barge Draft 2.28 m

| Probe Number | Physical Model Velocity, m/sec, for Replicate | | | | | | Prototype Velocity m/sec | Return Velocity, m/sec[1] | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | | Physical Model | Prototype |
| **Ambient Velocity** | | | | | | | | | |
| 332 | 0.461 | 0.428 | 0.447 | 0.474 | 0.436 | 0.449 | 0.529 | 0.341 | 0.320 |
| 642 | 0.441 | 0.411 | 0.434 | 0.473 | 0.434 | 0.439 | 0.481 | 0.352 | 0.337 |
| 998 | | | | | | | 0.371 | - | 0.322 |
| 999 | | | | | | | 0.432 | - | 0.341 |
| 1000 | 0.496 | 0.417 | 0.483 | 0.501 | 0.463 | 0.472 | 0.378 | 0.344 | 0.186 |
| 1001 | 0.134 | 0.134 | 0.191 | 0.187 | 0.206 | 0.171 | 0.225 | 0.276 | 0.225 |
| 040 | 0.489 | 0.513 | 0.512 | 0.485 | 0.510 | 0.501 | - | 0.279 | - |
| 071 | 0.500 | 0.481 | 0.508 | 0.481 | 0.483 | 0.491 | - | 0.271 | - |
| **Minimum Velocity** | | | | | | | | | |
| 332 | 0.136 | 0.099 | 0.095 | 0.156 | 0.053 | 0.108 | 0.209 | | |
| 642 | 0.098 | 0.089 | 0.072 | 0.097 | 0.078 | 0.087 | 0.144 | | |
| 998 | | | | | | | 0.049 | | |
| 999 | | | | | | | 0.091 | | |
| 1000 | 0.151 | 0.124 | 0.132 | 0.146 | 0.090 | 0.128 | 0.192 | | |
| 1001 | -0.105 | -0.105 | -0.140[1] | -0.110 | -0.103 | -0.106 | 0.000 | | |
| 040 | 0.229 | 0.251 | 0.228 | 0.197 | 0.207 | 0.222 | - | | |
| 071 | 0.243 | 0.202 | 0.208 | 0.194 | 0.254 | 0.220 | - | | |
| **Physical Model Drawdown, m, for Replicate** | | | | | | | | | |
| | **A** | **B** | **C** | **D** | **E** | **AVG** | | **Prototype Drawdown, m** | |
| | - | 0.133 | 0.129 | 0.125 | 0.125 | 0.128 | | 0.183[1] | |

[1]Value from staff gauge.

**Table 13**
**Draft Correction Computations**

| Tow | Length, Prototype m | Temperature, EC | | Kinematic Viscosity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Model | Prototype | Model $10^{-6}$ m²/sec | Prototype $10^{-6}$ m²/sec | Speed Through Water m/sec | Return Velocity m/sec | $D_c$ m | $d_{1m}$ | $d_{1p}$ | $d_{1m}$ - $d_{1p}$ | $\frac{D_c}{d_{1m} - d_{1p}}$ |
| *William C. Norman* | 237.8 | 24 | 16 | 0.92 | 1.12 | 2.40 | 0.22 | 0.46 | 0.51 | 0.26 | 0.25 | 1.84 |
| *Olmstead* | 297.3 | 25 | 22.2 | 0.90 | 0.96 | 2.50 | 0.29 | 0.46 | 0.60 | 0.31 | 0.29 | 1.59 |
| *Jack D. Wofford* | 297.3 | 25 | 22.2 | 0.90 | 0.96 | 2.50 | 0.29 | 0.46 | 0.60 | 0.31 | 0.29 | 1.59 |
| *Rambler* | 237.8 | 26 | 15.5 | 0.89 | 1.13 | 1.93 | 0.16 | 0.46 | 0.52 | 0.27 | 0.25 | 1.84 |
| *Charles Lehman* | 237.8 | 24 | 16 | 0.92 | 1.12 | 2.40 | 0.22 | 0.46 | 0.51 | 0.26 | 0.25 | 1.84 |
| *Mr. Lawrence* | 297.3 | 24 | 16 | 0.92 | 1.12 | 2.56 | 0.24 | 0.46 | 0.60 | 0.31 | 0.29 | 1.59 |

$d_{1m}$ = model displacement thickness *25.0
$d_{1p}$ = prototype displacement thickness

**Table 14**
***Luke Burton* Kampsville Trip 1, Pool El 422.0, LB1U59, Experiments Run November 23, 1994**

| Meter | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| S4/071 | 0.4805 | 0.4817 | 0.4774 | 0.4959 | 0.4924 | 0.4856 | |
| S4/040 | 0.4605 | 0.4969 | 0.4893 | 0.4880 | 0.4766 | 0.4823 | |
| MMB527/332 | 0.4724 | 0.4553 | 0.5005 | 0.4688 | 0.4603 | 0.4715 | |
| MMB527/642 | 0.4021 | 0.4580 | 0.4754 | 0.4463 | 0.4401 | 0.4444 | |
| MMB511/999 | 0.4257 | 0.4235 | 0.4263 | 0.4302 | 0.4262 | 0.4264 | |
| MMB511/1001 | 0.1547 | 0.1458 | 0.1765 | 0.1755 | 0.1641 | 0.1633 | |
| **Impact Velocity, m/sec** | | | | | | | |
| S4/071 | 0.6177 | 0.5737 | 0.6496 | 0.6386 | 0.6097 | 0.6179 | 0.1323 |
| S4/040 | 0.5814 | 0.3876 | 0.6352 | 0.6675 | 0.6240 | 0.5791 | 0.0968 |
| MMB527/332 | 0.6321 | 0.6128 | 0.6132 | 0.6543 | 0.6269 | 0.6279 | 0.1564 |
| MMB527/642 | 0.6149 | 0.5774 | 0.5124 | 0.5710 | 0.5738 | 0.5699 | 0.1255 |
| MMB511/999 | 0.5630 | 0.5542 | 0.5756 | 0.5766 | 0.5706 | 0.5680 | 0.1416 |
| MMB511/1001 | 0.3126 | 0.2166 | 0.3134 | 0.2946 | 0.2675 | 0.2809 | 0.1176 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 Right | 5.028 | 5.037 | 4.854 | 5.486 | 5.375 | 5.156 | |
| 170 Left | 4.896 | 4.976 | 4.864 | 5.055 | 4.721 | 4.94775 | |

**Table 15**
***Dixie Express*, Kampsville Trip 2, Pool El 420.0, DEU516, Experiments Run December 2, 1994**

| Meter | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| **Ambient Velocity, m/sec** | | | | | | | |
| MMB527/332 | 0.2755 | 0.2656 | 0.2701 | 0.2795 | 0.2639 | 0.2709 | |
| MMB527/642 | 0.2678 | 0.2724 | 0.2834 | 0.2558 | 0.2660 | 0.2691 | |
| MMB511/999 | ------- | 0.1747 | 0.2084 | 0.2096 | 0.2072 | 0.2000 | |
| MMB511/1001 | 0.0857 | 0.0648 | 0.0857 | 0.1063 | 0.1065 | 0.0898 | |
| **Impact Velocity, m/sec** | | | | | | | |
| MMB527/332 | 0.4037 | 0.3779 | 0.3815 | 0.3746 | 0.3929 | 0.3861 | 0.1152 |
| MMB527/642 | 0.3650 | 0.3646 | 0.3813 | 0.3815 | 0.3892 | 0.3763 | 0.1072 |
| MMB511/999 | ----- | 0.3165 | 0.3368 | 0.3384 | 0.3262 | 0.3295 | 0.1295 |
| MMB511/1001 | 0.1430 | 0.1354 | 0.1430 | 0.1595 | 0.1733 | 0.1508 | 0.06 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 Right | 2.263 | 2.495 | 2.341 | 2.452 | 2.43 | 2.3962 | |
| 170 Left | 5.526 | 5.587 | 4.696 | 5.339 | 5.33 | 5.287 | |

**Table 16**
**Kampsville Pool El 418.0 Experiment Conditions**

| Experiment No. | Up or Down | Tow Speed[1] m/sec | Position[2] | Temp •C | Actual Draft m | Effective Draft m[3] | Barge W X L | Propeller Thrust 1,000 lb | Schijf Velocity cm/sec[4] |
|---|---|---|---|---|---|---|---|---|---|
| LU38Q2 | U | 1.90 | 126.5 | 15.0 | 2.29 | 2.73 | 3X4 | 79 | 41.2 |
| LD58Q2 | D | 2.90 | 126.5 | 15.0 | 2.29 | 2.75 | 3X4 | 79 | 31.0 |

Note: Water-surface width 306.2 m, area 900.0 sq m, discharge 625 cu m/sec; water-surface el 418.0, average ambient velocity 69.4 cm/sec, Schijf limit speed 3.36 m/sec for 2.74-m draft.

[1] Relative to ground.
[2] Meters from right bank.
[3] Actual draft + draft correction.
[4] Schijf equation using effective draft and vessel speed relative to water.

**Table 17**
**Experiment LU38Q2, Pool El 418.0, Run November 22, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3840 | 0.3646 | 0.3687 | 0.3752 | 0.3514 | 0.3688 | |
| 2 | 0.6783 | 0.6894 | 0.6985 | 0.7097 | 0.6937 | 0.6939 | |
| 3 | 0.7110 | 0.6959 | 0.7066 | 0.7042 | 0.6678 | 0.6971 | |
| 4 | 0.7796 | 0.7883 | 0.7780 | 0.7930 | 0.7718 | 0.7821 | |
| 5 | 0.7357 | 0.7417 | 0.7208 | 0.7435 | 0.7424 | 0.7368 | |
| 6 | 0.7440 | 0.6934 | 0.7365 | 0.7679 | 0.7178 | 0.7319 | |
| 7 | 0.6725 | 0.6783 | 0.6793 | 0.6690 | 0.6660 | 0.6730 | |
| 8 | ------ | ------ | 0.2802 | 0.2759 | 0.2500 | 0.2687 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.7731 | 0.7884 | 0.8045 | 0.8223 | 0.7885 | 0.7954 | 0.4266 |
| 2 | 1.0951 | 1.0995 | 1.1003 | 1.0641 | 1.1309 | 1.0980 | 0.4041 |
| 3 | 1.1012 | 1.1404 | 1.1420 | 1.0994 | 1.0627 | 1.1091 | 0.4120 |
| 4 | 1.2941 | 1.2844 | 1.2285 | 1.2792 | 1.1946 | 1.2562 | 0.4741 |
| 5 | 1.2476 | 1.2376 | 1.2361 | 1.2365 | 1.2277 | 1.2371 | 0.5003 |
| 6 | 1.1630 | 1.1920 | 1.2190 | 1.1701 | 1.2426 | 1.1973 | 0.4654 |
| 7 | 1.1289 | 1.1395 | 1.1443 | 1.0993 | 1.1458 | 1.1316 | 0.4586 |
| 8 | ------ | ------ | 0.6227 | 0.6291 | 0.5623 | 0.6047 | 0.3360 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg, m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 14.002 | 14.325 | 14.112 | 14.093 | 14.000 | 14.1064 | |
| 100 left | 11.754 | 12.367 | 12.558 | 12.482 | 12.293 | 12.2908 | |

**Table 18**
**Experiment LD58Q2, Pool El 418.0, Run November 22, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3806 | 0.3708 | 0.3682 | 0.3716 | 0.3748 | 0.3732 | |
| 2 | 0.6901 | 0.6982 | 0.6909 | 0.6902 | 0.6990 | 0.6937 | |
| 3 | 0.7268 | 0.7204 | 0.6688 | 0.7027 | 0.7022 | 0.7042 | |
| 4 | 0.7689 | 0.7932 | 0.7710 | 0.7713 | 0.7863 | 0.7781 | |
| 5 | 0.7377 | 0.7402 | 0.7554 | 0.7543 | 0.7454 | 0.7466 | |
| 6 | 0.7408 | 0.7179 | 0.7476 | 0.7426 | 0.7218 | 0.7341 | |
| 7 | 0.6799 | 0.6761 | 0.6585 | 0.6711 | 0.6503 | 0.6672 | |
| 8 | 0.3059 | 0.3266 | 0.3007 | 0.2769 | 0.2673 | 0.2955 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.1212 | 0.0470 | 0.0992 | 0.1190 | 0.0768 | 0.0926 | 0.2806 |
| 2 | 0.3919 | 0.4317 | 0.4090 | 0.4096 | 0.3900 | 0.4064 | 0.2873 |
| 3 | 0.3468 | 0.4331 | 0.3493 | 0.3414 | 0.3621 | 0.3665 | 0.3377 |
| 4 | 0.3816 | 0.3624 | 0.3727 | 0.2958 | 0.3753 | 0.3576 | 0.4205 |
| 5 | 0.3502 | 0.3150 | 0.3528 | 0.3475 | 0.3001 | 0.3331 | 0.4135 |
| 6 | 0.3225 | 0.3618 | 0.3998 | 0.3772 | 0.3197 | 0.3562 | 0.3779 |
| 7 | 0.3794 | 0.3941 | 0.3626 | 0.3296 | 0.3109 | 0.3553 | 0.3119 |
| 8 | 0.0453 | 0.0623 | 0.0228 | 0.0588 | 0.0305 | 0.0439 | 0.2516 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 8.3680 | 8.7730 | 9.1100 | 9.1320 | 9.3670 | 8.95 | |
| 100 left | 7.0560 | 7.5160 | 7.3350 | 7.3720 | 7.5580 | 7.3674 | |

## Table 19
## Kampsville Pool 419.4 Experiment Conditions

| Experiment No. | Up or Down | Tow Speed[1] m/sec | Position[2] | Temp °C | Actual Draft m | Effective Draft m[3] | Barge W X L | Prop Thrust 1,000 lb | Schijf Velocity cm/sec[4] |
|---|---|---|---|---|---|---|---|---|---|
| KLU335 | U | 1.67 | 129 | 20.0 | 2.29 | 2.85 | 3X5 | 42 | 20.7 |
| KLU488 | U | 2.43 | 129 | 20.5 | 2.29 | 2.81 | 3X5 | 79 | 34.5 |
| KLU640 | U | 3.18 | 129 | 21.5 | 2.29 | 2.78 | 3X5 | 105 | 63.0 |
| | | | | | | | | | |
| KLD354 | D | 1.79 | 129 | 23.5 | 2.29 | 2.86 | 3X5 | 42 | 17.5 |
| KLD506 | D | 2.50 | 129 | 23.5 | 2.29 | 2.82 | 3X5 | 79 | 28.5 |
| KLD659 | D | 3.32 | 129 | 21.0 | 2.29 | 2.79 | 3X5 | 105 | 51.7 |
| | | | | | | | | | |
| KLRU49 | U | 2.43 | 89 | 20.0 | 2.29 | 2.81 | 3X5 | 79 | 34.5 |
| KLRD49 | D | 2.43 | 89 | 20.0 | 2.29 | 2.83 | 3X5 | 79 | 27.3 |
| | | | | | | | | | |
| KLLU49 | U | 2.45 | 204 | 17.0 | 2.29 | 2.82 | 3X5 | 79 | 35.1 |
| KLLD51 | D | 2.52 | 204 | 17.5 | 2.29 | 2.83 | 3X5 | 79 | 29.0 |
| | | | | | | | | | |
| KL1U46 | U | 2.28 | 129 | 17.0 | 2.29 | 2.65 | 1X3 | 79 | 8.7 |
| KL1U61 | U | 3.03 | 129 | 17.2 | 2.29 | 2.63 | 1X3 | 79 | 13.8 |
| KL1U76 | U | 3.81 | 129 | 19.3 | 2.29 | 2.61 | 1X3 | 79 | 24.9 |
| | | | | | | | | | |
| KLEU49 | U | 2.43 | 129 | 19.5 | 0.61 | 1.14 | 3X5 | 79 | 12.5 |
| KLEU67 | U | 3.34 | 129 | 19.1 | 0.61 | 1.14 | 3X5 | 105 | 22.2 |

Note: Water-surface width 315 m, area 1,032.5 sq m, discharge 180 cu m/sec, water-surface elevation 419.4, average ambient velocity 17.5 cm/sec.
[1] Relative to ground.
[2] Meters distance from right bank.
[3] Actual draft + draft correction.
[4] Schijf equation using effective draft and vessel speed relative to water.

**Table 20**
**Kampsville, Pool El 419.4, KLU335, Run September 27, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1073 | 0.1393 | 0.1244 | 0.1153 | 0.1236 | 0.1220 | |
| 2 | 0.1852 | 0.1862 | 0.1880 | 0.1809 | 0.1980 | 0.1877 | |
| 3 | 0.2036 | 0.1782 | 0.1994 | 0.1825 | 0.1952 | 0.1918 | |
| 4 | 0.1784 | 0.1801 | 0.1703 | 0.1826 | 0.1699 | 0.1763 | |
| 5 | 0.2021 | 0.1907 | 0.1925 | 0.1968 | 0.1951 | 0.1954 | |
| 6 | 0.1816 | 0.2048 | 0.1795 | 0.1869 | 0.2001 | 0.1906 | |
| 7 | 0.1728 | 0.1749 | 0.1735 | 0.1534 | 0.1951 | 0.1739 | |
| 8 | 0.0309 | 0.0651 | 0.0691 | 0.0287 | 0.0828 | 0.0553 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.3766 | 0.3873 | 0.3310 | 0.3810 | 0.3425 | 0.3637 | 0.2417 |
| 2 | 0.3950 | 0.3865 | 0.4118 | 0.4193 | 0.4158 | 0.4057 | 0.2180 |
| 3 | 0.4070 | 0.3865 | 0.4133 | 0.3781 | 0.4293 | 0.4028 | 0.2110 |
| 4 | 0.4839 | 0.4840 | 0.4713 | 0.4303 | 0.4941 | 0.4727 | 0.2964 |
| 5 | 0.4844 | 0.4675 | 0.4826 | 0.4696 | 0.4681 | 0.4744 | 0.2790 |
| 6 | 0.4576 | 0.4497 | 0.4546 | 0.4339 | 0.4494 | 0.4490 | 0.2584 |
| 7 | 0.3850 | 0.3812 | 0.3766 | 0.3542 | 0.3720 | 0.3738 | 0.1999 |
| 8 | 0.3040 | 0.3445 | 0.2370 | 0.4025 | 0.2042 | 0.2984 | 0.2431 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 6.798 | 6.963 | 6.416 | 6.283 | -- | 6.615 | |
| 100 left | 6.898 | 7.056 | 6.742 | 6.742 | -- | 6.8595 | |

## Table 21
## Kampsville, Pool El 419.4, KLU488, Run September 28, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.0925 | 0.1040 | 0.1252 | 0.1269 | 0.1321 | 0.1161 | |
| 2 | 0.1803 | 0.1773 | 0.1956 | 0.1807 | 0.1844 | 0.1837 | |
| 3 | 0.2049 | 0.2061 | 0.2024 | 0.2387 | 0.2097 | 0.2124 | |
| 4 | 0.1744 | 0.1872 | 0.1977 | 0.1660 | 0.2029 | 0.1856 | |
| 5 | 0.1925 | 0.2185 | 0.1922 | 0.1940 | 0.1766 | 0.1948 | |
| 6 | 0.1852 | 0.2008 | 0.1928 | 0.1905 | 0.1859 | 0.1910 | |
| 7 | 0.1697 | 0.1604 | 0.1635 | 0.1635 | 0.1582 | 0.1631 | |
| 8 | 0.0955 | 0.0538 | 0.0717 | 0.0292 | 0.1026 | 0.0706 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.5057 | 0.4372 | 0.5148 | 0.4876 | 0.5452 | 0.4981 | 0.3820 |
| 2 | 0.5370 | 0.5195 | 0.5329 | 0.5215 | 0.5309 | 0.5284 | 0.3447 |
| 3 | 0.5033 | 0.4697 | 0.4774 | 0.4552 | 0.5241 | 0.4859 | 0.2735 |
| 4 | 0.4951 | 0.6222 | 0.6353 | 0.6363 | 0.6387 | 0.6055 | 0.4199 |
| 5 | 0.6136 | 0.6607 | 0.6318 | 0.6496 | 0.6269 | 0.6365 | 0.4417 |
| 6 | 0.5785 | 0.5854 | 0.5962 | 0.5928 | 0.6116 | 0.5929 | 0.4019 |
| 7 | 0.5074 | 0.4808 | 0.5169 | 0.5169 | 0.5185 | 0.5081 | 0.3450 |
| 8 | 0.5277 | 0.5045 | 0.5082 | 0.3359 | 0.5658 | 0.4884 | 0.4178 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 12.33 | 12.543 | 12.69 | 12.531 | 12.618 | 12.5424 | |
| 100 left | 13.364 | 13.126 | 13.384 | 13.155 | 13.269 | 13.2573 | |

## Table 22
## Kampsville, Pool El 419.4, KLU640, Run October 3, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1320 | 0.1410 | 0.1123 | 0.1310 | 0.1241 | 0.1281 | |
| 2 | 0.1786 | 0.1819 | 0.2130 | 0.1843 | 0.1817 | 0.1879 | |
| 3 | 0.1966 | 0.1957 | 0.1960 | 0.1977 | 0.2093 | 0.1991 | |
| 4 | 0.2023 | 0.1631 | 0.1726 | 0.1107 | 0.1973 | 0.1692 | |
| 5 | 0.1968 | 0.1868 | 0.1817 | 0.2013 | 0.2081 | 0.1949 | |
| 6 | 0.1996 | 0.1755 | 0.1896 | 0.1995 | 0.2028 | 0.1934 | |
| 7 | 0.1629 | 0.1435 | 0.1710 | 0.1628 | 0.1745 | 0.1629 | |
| 8 | 0.0248 | 0.0797 | 0.0600 | 0.1268 | 0.1007 | 0.0784 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.9534 | 0.9706 | 0.9518 | 0.9718 | 0.9383 | 0.9572 | 0.8291 |
| 2 | 0.8943 | 0.8816 | 0.8857 | 0.8795 | 0.8635 | 0.8809 | 0.6930 |
| 3 | 0.9400 | 0.7565 | 0.9226 | 0.9185 | 0.8910 | 0.8857 | 0.6866 |
| 4 | 1.1730 | 0.9391 | 1.0330 | 1.0279 | 1.0106 | 1.0367 | 0.8675 |
| 5 | 1.0550 | 1.0252 | 1.0240 | 1.0324 | 1.0329 | 1.0339 | 0.8390 |
| 6 | 0.9925 | 0.9259 | 0.9184 | 0.9800 | 0.9967 | 0.9627 | 0.7693 |
| 7 | 0.8449 | 0.7404 | 0.7962 | 0.8609 | 0.8475 | 0.8180 | 0.6551 |
| 8 | 0.4172 | 0.5655 | 0.6542 | 0.9097 | 0.8897 | 0.6873 | 0.6089 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 29.691 | 29.461 | 29.30 | 30.135 | 30.038 | 29.275 | |
| 100 left | 30.181 | 30.681 | 30.146 | 30.255 | 30.243 | 30.3158 | |

**Table 23**
**Kampsville, Pool El 419.4, KLD354, Run September 16, 1994**

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| Ambient Velocity, m/sec | | | | | | | |
| 1 | 0.1116 | 0.1239 | 0.1311 | 0.1443 | 0.1173 | 0.1256 | |
| 2 | 0.1572 | 0.1614 | 0.2185 | 0.2465 | 0.1563 | 0.1880 | |
| 3 | 0.2276 | 0.1746 | 0.2000 | 0.1441 | 0.1925 | 0.1878 | |
| 4 | 0.1975 | 0.2032 | 0.1768 | 0.1626 | 0.1900 | 0.1860 | |
| 5 | 0.2252 | 0.2069 | 0.1793 | 0.2384 | 0.2087 | 0.2117 | |
| 6 | 0.2170 | 0.2000 | 0.1865 | 0.2197 | 0.1954 | 0.2037 | |
| 7 | ------ | ------ | ------ | ------ | ------ | ---- | |
| 8 | 0.0887 | 0.0548 | 0.1053 | 0.0937 | 0.1000 | 0.0885 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | -0.0542 | -0.0554 | -0.0558 | -0.0669 | -0.0417 | -0.0548 | 0.1804 |
| 2 | -0.0327 | 0.0128 | 0.0245 | 0.0160 | 0.0219 | 0.0085 | 0.1795 |
| 3 | 0.0102 | 0.0011 | 0.0437 | 0.0211 | 0.0388 | 0.0230 | 0.1648 |
| 4 | 0.0214 | -0.0384 | 0.0173 | -0.0073 | 0.0162 | 0.0018 | 0.1842 |
| 5 | -0.0103 | -0.0273 | -0.0056 | -0.0057 | -0.0200 | -0.0138 | 0.1979 |
| 6 | 0.0285 | 0.0132 | -0.0116 | -0.0096 | 0.0339 | 0.0109 | 0.2198 |
| 7 | ---- | ---- | ---- | ---- | ---- | ----- | ---- |
| 8 | -0.1049 | -0.0580 | -0.0515 | -0.0808 | -0.0840 | -0.0758 | 0.1643 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 5.0890 | 4.3990 | 4.5620 | 4.5750 | 4.0070 | 4.5264 | |
| 100 left | 4.8750 | 4.4410 | 4.4210 | 4.3210 | 4.0170 | 4.5145 | |

**Table 24**
**Kampsville, Pool El 419.4, KLD506, Run September 26, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.0953 | 0.1328 | 0.1319 | 0.1021 | 0.1116 | 0.1147 | |
| 2 | 0.1686 | 0.1865 | 0.1814 | 0.1671 | 0.1872 | 0.1782 | |
| 3 | 0.2261 | 0.2536 | 0.2024 | 0.1876 | 0.2317 | 0.2203 | |
| 4 | 0.2066 | 0.2092 | 0.2375 | 0.1962 | 0.2391 | 0.2177 | |
| 5 | 0.2052 | 0.1543 | 0.1479 | 0.2129 | 0.0524 | 0.1545 | |
| 6 | 0.2026 | 0.1794 | 0.1431 | 0.1875 | 0.1714 | 0.1768 | |
| 7 | ------ | ------ | ------ | ------ | ------ | | |
| 8 | 0.0964 | ------ | 0.1190 | 0.0923 | 0.0983 | 0.1015 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | -0.2141 | -0.1971 | -0.2128 | -0.2150 | -0.2163 | -0.2111 | 0.3258 |
| 2 | -0.1070 | -0.0981 | -0.1073 | -0.1008 | -0.0929 | -0.1012 | 0.2794 |
| 3 | -0.0440 | -0.0473 | -0.0234 | -0.0629 | -0.0202 | -0.0396 | 0.2599 |
| 4 | -0.1481 | -0.1422 | -0.1278 | -0.1208 | -0.1004 | -0.1279 | 0.3456 |
| 5 | -0.1900 | -0.1710 | -0.2012 | -0.1802 | -0.1054 | -0.1696 | 0.3241 |
| 6 | -0.1300 | -0.1353 | -0.1800 | -0.1631 | -0.1506 | -0.1518 | 0.3286 |
| 7 | --- | --- | --- | --- | --- | --- | ---- |
| 8 | -0.2250 | --- | -0.2307 | -0.2078 | -0.2204 | -0.2210 | 0.3225 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 11.486 | 11.743 | 11.600 | 11.562 | 12.484 | 11.775 | |
| 100 left | 12.455 | 12.668 | 12.167 | 12.094 | 12.775 | 12.346 | |

**Table 25**
**Kampsville, Pool El 419.4, KLD659, Run October 4, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.11 | 0.13 | 0.12 | 0.12 | 0.13 | 0.1227 | |
| 2 | 0.18 | 0.19 | 0.20 | 0.15 | 0.21 | 0.1871 | |
| 3 | 0.20 | 0.19 | 0.21 | 0.22 | 0.22 | 0.2069 | |
| 4 | 0.15 | 0.21 | 0.18 | 0.19 | 0.21 | 0.1890 | |
| 5 | 0.21 | 0.20 | 0.16 | 0.21 | 0.16 | 0.1887 | |
| 6 | 0.19 | 0.20 | 0.17 | 0.21 | 0.14 | 0.1817 | |
| 7 | 0.15 | 0.14 | 0.18 | 0.15 | 0.14 | 0.1508 | |
| 8 | 0.12 | 0.15 | 0.16 | 0.12 | 0.15 | 0.1417 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | -0.5229 | -0.5101 | -0.4681 | -0.4801 | -0.5029 | -0.4968 | 0.6195 |
| 2 | -0.3218 | -0.3610 | -0.3013 | -0.3648 | -0.3022 | -0.3302 | 0.5173 |
| 3 | -0.3225 | -0.0332 | -0.2782 | -0.2602 | -0.3405 | -0.2469 | 0.4538 |
| 4 | -0.4234 | -0.3035 | -0.3960 | -0.3821 | -0.4374 | -0.3885 | 0.5775 |
| 5 | -0.5010 | -0.4905 | -0.4870 | -0.4499 | -0.4908 | -0.4838 | 0.6725 |
| 6 | -0.4372 | -0.4212 | -0.4046 | -0.3908 | -0.4186 | -0.4145 | 0.5962 |
| 7 | -0.3704 | -0.3474 | -0.3405 | -0.3357 | -0.3216 | -0.3431 | 0.4939 |
| 8 | -0.4573 | -0.5004 | -0.4434 | -0.4675 | -0.4816 | -0.4700 | 0.6117 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 21.005 | 20.672 | 20.692 | 20.769 | 20.500 | 20.7276 | |
| 100 left | 23.091 | 22.341 | 22.307 | 22.095 | 22.390 | 22.4585 | |

## Table 26
## Kampsville, Pool El 419.4, KLRU49, Run October 6, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.10 | 0.12 | 0.11 | 0.13 | 0.14 | 0.1181 | |
| 2 | 0.20 | 0.18 | 0.20 | 0.17 | 0.22 | 0.1937 | |
| 3 | 0.21 | 0.23 | 0.24 | 0.20 | 0.19 | 0.2131 | |
| 4 | 0.19 | 0.19 | 0.22 | 0.17 | 0.08 | 0.1700 | |
| 5 | 0.20 | 0.21 | 0.15 | 0.20 | 0.19 | 0.1883 | |
| 6 | 0.15 | 0.19 | 0.18 | 0.18 | 0.17 | 0.1742 | |
| 7 | 0.16 | 0.17 | 0.19 | 0.16 | 0.13 | 0.1628 | |
| 8 | 0.08 | 0.13 | 0.15 | 0.13 | 0.08 | 0.1139 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.4618 | 0.4740 | 0.4591 | 0.5036 | 0.4835 | 0.4764 | 0.3583 |
| 2 | 0.5082 | 0.3610 | 0.2770 | 0.5324 | 0.5551 | 0.4467 | 0.2530 |
| 3 | 0.5680 | 0.3060 | 0.3690 | 0.5616 | 0.5417 | 0.4693 | 0.2562 |
| 4 | 0.5803 | 0.1500 | 0.9470 | 0.5852 | 0.5436 | 0.5612 | 0.3912 |
| 5 | 0.7130 | 0.6838 | 0.7531 | 0.7545 | 0.7260 | 0.7261 | 0.5378 |
| 6 | 0.6771 | 0.6430 | 0.6958 | 0.7070 | 0.6650 | 0.6776 | 0.5034 |
| 7 | 0.5625 | 0.5495 | 0.5683 | 0.6000 | 0.5703 | 0.5701 | 0.4073 |
| 8 | 0.4848 | 0.6048 | 0.6353 | 0.6825 | 0.5318 | 0.5878 | 0.4739 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 16.509 | 16.339 | 17.047 | 17.257 | 16.900 | 16.8104 | |
| 106 left | 19.624 | 17.026 | 18.112 | 18.296 | 17.950 | 18.2645 | |

**Table 27**
**Kampsville, Pool El 419.4, KLRD49, Run October 7, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1100 | 0.0959 | 0.1252 | 0.1308 | 0.1274 | 0.1179 | |
| 2 | 0.2240 | 0.2191 | 0.1689 | 0.1948 | 0.1988 | 0.2011 | |
| 3 | 0.1850 | 0.2092 | 0.2093 | 0.2355 | 0.2119 | 0.2102 | |
| 4 | 0.2126 | 0.2211 | 0.1089 | 0.1921 | 0.1799 | 0.1829 | |
| 5 | 0.1948 | 0.1576 | 0.1905 | 0.1779 | 0.1610 | 0.1764 | |
| 6 | 0.2016 | 0.1453 | 0.1842 | 0.1630 | 0.1759 | 0.1740 | |
| 7 | 0.1456 | 0.1466 | 0.1547 | 0.1361 | 0.1730 | 0.1512 | |
| 8 | 0.0957 | 0.0640 | 0.1138 | 0.1207 | 0.1143 | 0.1017 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | -0.1306 | -0.1764 | -0.1989 | -0.1573 | -0.1220 | -0.1570 | 0.2749 |
| 2 | -0.0435 | -0.0359 | -0.1168 | -0.0437 | -0.0659 | -0.0612 | 0.2623 |
| 3 | -0.0749 | -0.0123 | -0.0265 | -0.0255 | -0.0541 | -0.0387 | 0.2489 |
| 4 | -0.0765 | -0.0948 | -0.2651 | -0.1104 | -0.1066 | -0.1307 | 0.3136 |
| 5 | -0.1713 | -0.2835 | -0.2472 | -0.2431 | -0.2280 | -0.2346 | 0.4110 |
| 6 | -0.1413 | -0.2068 | -0.2308 | -0.2244 | -0.2257 | -0.2058 | 0.3798 |
| 7 | -0.1227 | -0.1975 | -0.2093 | -0.1884 | -0.1771 | -0.1790 | 0.3302 |
| 8 | -0.1454 | -0.2093 | -0.2897 | -0.2500 | -0.2456 | -0.2280 | 0.3297 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 70 right | 8.1860 | 12.480 | 13.926 | 13.422 | 12.916 | 12.186 | |
| 106 left | 9.8340 | 13.539 | 14.724 | 13.963 | 13.597 | 13.015 | |

## Table 28
## Kampsville, Pool El 419.4, KLLU49, Run October 12, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1061 | 0.1005 | 0.1050 | 0.1123 | 0.1632 | 0.1174 | |
| 2 | 0.1777 | 0.1751 | 0.1605 | 0.1937 | 0.2599 | 0.1934 | |
| 3 | 0.2093 | 0.1956 | 0.1953 | 0.1849 | 0.2117 | 0.1994 | |
| 4 | 0.2166 | 0.2177 | 0.1704 | 0.1254 | 0.1995 | 0.1859 | |
| 5 | 0.1922 | 0.1728 | 0.2025 | 0.1949 | 0.1693 | 0.1863 | |
| 6 | 0.2047 | 0.1818 | 0.2112 | 0.2010 | 0.1701 | 0.1938 | |
| 7 | 0.1722 | 0.1896 | 0.1801 | 0.1944 | 0.2001 | 0.1873 | |
| 8 | 0.0503 | 0.0881 | 0.1015 | 0.0888 | 0.1857 | 0.1029 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.6216 | 0.5971 | 0.6291 | 0.6040 | 0.6507 | 0.6205 | 0.5031 |
| 2 | 0.6649 | 0.6667 | 0.6782 | 0.6052 | 0.6552 | 0.6540 | 0.4606 |
| 3 | 0.6849 | 0.6844 | 0.5470 | 0.5755 | 0.5183 | 0.6020 | 0.4026 |
| 4 | 0.5591 | 0.6153 | 0.5626 | 0.5569 | 0.5795 | 0.5747 | 0.3888 |
| 5 | 0.5259 | 0.5245 | 0.5344 | 0.5350 | 0.4709 | 0.5181 | 0.3318 |
| 6 | 0.5139 | 0.5003 | 0.5256 | 0.5147 | 0.4563 | 0.5022 | 0.3084 |
| 7 | 0.4548 | 0.4418 | 0.4458 | 0.4467 | 0.4473 | 0.4473 | 0.2600 |
| 8 | 0.4473 | 0.3980 | 0.4036 | 0.3480 | 0.5001 | 0.4194 | 0.3165 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 8.7100 | 8.8890 | 8.8570 | 8.5880 | 9.3220 | 8.8732 | |
| 81 right | 8.6190 | 9.4420 | 9.6880 | 9.1720 | 9.7690 | 9.23025 | |

## Table 29
## Kampsville, Pool El 419.4, KLLD51, Run October 11, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1154 | 0.1074 | 0.1142 | 0.1223 | 0.1451 | 0.1209 | |
| 2 | 0.1916 | 0.1715 | 0.1661 | 0.1792 | 0.1653 | 0.1747 | |
| 3 | 0.2064 | 0.1954 | 0.2425 | 0.1984 | 0.1639 | 0.2013 | |
| 4 | 0.2229 | 0.2152 | 0.2084 | 0.2258 | 0.1761 | 0.2097 | |
| 5 | 0.2096 | 0.1791 | 0.1943 | 0.1998 | 0.2181 | 0.2002 | |
| 6 | 0.1971 | 0.1842 | 0.2035 | 0.2011 | 0.2063 | 0.1984 | |
| 7 | 0.1602 | 0.1746 | 0.1891 | 0.1730 | 0.1680 | 0.1730 | |
| 8 | 0.0364 | 0.0600 | 0.0334 | 0.0967 | ------ | 0.0566 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | -0.2760 | -0.2769 | -0.2814 | -0.3124 | -0.3011 | -0.2896 | 0.4105 |
| 2 | -0.1916 | -0.1920 | -0.1950 | -0.2176 | -0.2391 | -0.2071 | 0.3818 |
| 3 | -0.1627 | -0.1725 | -0.1929 | -0.1363 | -0.1758 | -0.1680 | 0.3693 |
| 4 | -0.1861 | -0.1944 | -0.2403 | -0.2182 | -0.2664 | -0.2211 | 0.4308 |
| 5 | -0.1006 | -0.1093 | -0.1070 | -0.1248 | -0.1783 | -0.1240 | 0.3242 |
| 6 | -0.1021 | -0.0991 | -0.0976 | -0.1465 | -0.1189 | -0.1128 | 0.3112 |
| 7 | -0.0762 | -0.1080 | -0.0882 | -0.0883 | -0.0788 | -0.0879 | 0.2609 |
| 8 | -0.0932 | -0.1667 | -0.1818 | -0.1783 | --- | -0.1550 | 0.2116 |
| Drawdown, cm | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 8.1290 | 9.2300 | 8.9690 | 9.3210 | 9.1640 | 8.9626 | |
| 81 right | 8.7550 | 9.8890 | 10.190 | 10.003 | 10.322 | 9.70925 | |

## Table 30
## Kampsville, Pool El 419.4, KL1U46, Run October 13, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1082 | 0.1178 | 0.1104 | 0.1022 | 0.1151 | 0.1107 | |
| 2 | 0.1447 | 0.2382 | 0.1949 | 0.1779 | 0.2008 | 0.1913 | |
| 3 | 0.1982 | 0.1762 | 0.1939 | 0.2087 | 0.1824 | 0.1919 | |
| 4 | 0.2047 | 0.2025 | 0.2011 | 0.2120 | 0.1920 | 0.2025 | |
| 5 | 0.2107 | 0.2201 | 0.2070 | 0.1997 | 0.1937 | 0.2062 | |
| 6 | 0.1916 | 0.1786 | 0.2025 | 0.2127 | 0.2102 | 0.1991 | |
| 7 | 0.1695 | 0.1695 | 0.1654 | 0.1706 | 0.1683 | 0.1687 | |
| 8 | 0.0635 | 0.0622 | 0.0962 | 0.0892 | 0.0872 | 0.0797 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.2211 | 0.2197 | 0.2214 | 0.2136 | 0.2166 | 0.2185 | 0.1078 |
| 2 | 0.2953 | 0.2793 | 0.3055 | 0.2980 | 0.2912 | 0.2938 | 0.1025 |
| 3 | 0.3242 | 0.3192 | 0.3068 | 0.3167 | 0.3330 | 0.3200 | 0.1281 |
| 4 | 0.3690 | 0.3981 | 0.4017 | 0.3845 | 0.3740 | 0.3855 | 0.1830 |
| 5 | 0.3051 | 0.3219 | 0.3179 | 0.3247 | 0.3384 | 0.3216 | 0.1154 |
| 6 | 0.2972 | 0.3021 | 0.1385 | 0.2988 | 0.2844 | 0.2642 | 0.0651 |
| 7 | 0.2298 | 0.2298 | 0.2339 | 0.2422 | 0.2420 | 0.2355 | 0.0668 |
| 8 | 0.1086 | 0.1463 | 0.2033 | 0.2394 | 0.1545 | 0.1704 | 0.0907 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 2.8250 | 2.7660 | 2.6680 | 2.4920 | 2.2490 | 2.6 | |
| 81 right | 3.4130 | 3.5190 | 3.5450 | 3.5710 | 3.5020 | 3.512 | |

## Table 31
## Kampsville, Pool El 419.4, KL1U61, Run October 14, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1051 | 0.1125 | 0.1196 | 0.1084 | 0.1119 | 0.1115 | |
| 2 | 0.1895 | 0.1873 | 0.1943 | 0.2384 | 0.1761 | 0.1971 | |
| 3 | 0.1941 | 0.1938 | 0.1997 | 0.2556 | 0.1988 | 0.2084 | |
| 4 | 0.1865 | 0.2006 | 0.2089 | 0.2048 | 0.2030 | 0.2008 | |
| 5 | 0.2090 | 0.1971 | 0.2105 | 0.1578 | 0.2001 | 0.1949 | |
| 6 | 0.1970 | 0.2071 | 0.1979 | 0.1589 | 0.1903 | 0.1902 | |
| 7 | 0.1517 | 0.1616 | 0.1781 | 0.1224 | 0.1585 | 0.1545 | |
| 8 | 0.0933 | 0.0723 | 0.0693 | 0.0561 | 0.0802 | 0.0742 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.3247 | 0.3391 | 0.3263 | 0.3172 | 0.3371 | 0.3289 | 0.2174 |
| 2 | 0.4092 | 0.3681 | 0.3980 | 0.4535 | 0.3761 | 0.4010 | 0.2039 |
| 3 | 0.4396 | 0.4325 | 0.4381 | 0.5006 | 0.4282 | 0.4478 | 0.2394 |
| 4 | 0.4974 | 0.5206 | 0.4960 | 0.5108 | 0.4840 | 0.5018 | 0.3010 |
| 5 | 0.4091 | 0.4392 | 0.4001 | 0.3739 | 0.4182 | 0.4081 | 0.2132 |
| 6 | 0.3905 | 0.3912 | 0.3642 | 0.3500 | 0.3748 | 0.3741 | 0.1839 |
| 7 | 0.3090 | 0.3121 | 0.3333 | 0.2870 | 0.3084 | 0.3099 | 0.1554 |
| 8 | 0.2893 | 0.2211 | 0.2221 | 0.1705 | 0.2501 | 0.2306 | 0.1564 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 7.6530 | 8.7010 | 8.1750 | 8.2850 | 8.3740 | 8.2376 | |
| 81 right | 6.1800 | 7.8060 | 6.9570 | 7.5820 | 6.9900 | 7.13125 | |

## Table 32
## Kampsville, Pool El 419.4, KL1U76, Run October 19, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1080 | 0.1095 | 0.1099 | 0.1255 | 0.1103 | 0.1126 | |
| 2 | 0.1217 | 0.1630 | 0.1395 | 0.1759 | 0.1649 | 0.1530 | |
| 3 | 0.1883 | 0.1931 | 0.1921 | 0.1975 | 0.1901 | 0.1922 | |
| 4 | 0.2219 | 0.2005 | 0.1975 | 0.2012 | 0.1931 | 0.2028 | |
| 5 | 0.2095 | 0.2052 | 0.1828 | 0.2106 | 0.1911 | 0.1998 | |
| 6 | 0.2054 | 0.2056 | 0.1938 | 0.1873 | 0.1988 | 0.1982 | |
| 7 | 0.1442 | 0.1541 | 0.1833 | 0.1555 | 0.1603 | 0.1595 | |
| 8 | 0.0426 | 0.0563 | 0.0489 | 0.0725 | 0.0370 | 0.0515 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.4802 | 0.5638 | 0.5512 | 0.5742 | 0.5550 | 0.5449 | 0.4323 |
| 2 | 0.5035 | 0.5601 | 0.5147 | 0.5207 | 0.5437 | 0.5285 | 0.3755 |
| 3 | 0.5542 | 0.5863 | 0.5945 | 0.5988 | 0.5781 | 0.5824 | 0.3902 |
| 4 | 0.6142 | 0.6516 | 0.6762 | 0.6486 | 0.6593 | 0.6500 | 0.4472 |
| 5 | 0.5075 | 0.5795 | 0.5763 | 0.5947 | 0.5764 | 0.5669 | 0.3671 |
| 6 | 0.4971 | 0.5424 | 0.5551 | 0.5384 | 0.5546 | 0.5375 | 0.3393 |
| 7 | 0.4132 | 0.4575 | 0.4473 | 0.4602 | 0.4500 | 0.4456 | 0.2861 |
| 8 | 0.1257 | 0.2048 | 0.1690 | 0.3160 | 0.1992 | 0.2029 | 0.1514 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 11.326 | 15.525 | 15.554 | 15.159 | 15.453 | 14.6034 | |
| 81 right | 11.996 | 16.862 | 17.195 | 17.035 | 16.902 | 15.772 | |

## Table 33
## Kampsville, Pool El 419.4, KLEU49, Run October 24, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1134 | 0.1262 | 0.1170 | 0.1198 | 0.1167 | 0.1186 | |
| 2 | 0.1526 | 0.1287 | 0.1366 | 0.1575 | 0.1738 | 0.1498 | |
| 3 | 0.2005 | 0.1915 | 0.1952 | 0.1941 | 0.1916 | 0.1946 | |
| 4 | 0.2080 | 0.1949 | 0.2048 | 0.2034 | 0.2044 | 0.2031 | |
| 5 | 0.1990 | 0.1965 | 0.1915 | 0.1821 | 0.2004 | 0.1939 | |
| 6 | 0.1969 | 0.1865 | 0.1990 | 0.2026 | 0.1843 | 0.1939 | |
| 7 | 0.1475 | 0.1733 | 0.1563 | 0.1432 | 0.1452 | 0.1531 | |
| 8 | 0.0197 | 0.0271 | ------ | 0.0278 | 0.0129 | 0.0219 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.2458 | 0.2594 | 0.2607 | 0.2594 | 0.2537 | 0.2558 | 0.1372 |
| 2 | 0.3104 | 0.0670 | 0.9650 | 0.2678 | 0.9300 | 0.5080 | 0.3582 |
| 3 | 0.3734 | 0.5070 | 0.3693 | 0.6370 | 0.4910 | 0.4755 | 0.2809 |
| 4 | 0.4120 | 0.2020 | 0.3871 | 0.4005 | 0.3996 | 0.3602 | 0.1571 |
| 5 | 0.3519 | 0.3447 | 0.3418 | 0.3420 | 0.3503 | 0.3461 | 0.1522 |
| 6 | 0.3312 | 0.3359 | 0.3191 | 0.3440 | 0.3281 | 0.3317 | 0.1378 |
| 7 | 0.2605 | 0.2658 | 0.2625 | 0.2639 | 0.2628 | 0.2631 | 0.1100 |
| 8 | 0.1106 | 0.1082 | --- | 0.0952 | 0.0987 | 0.1032 | 0.0813 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 3.6870 | 4.0220 | 3.8970 | 3.8340 | 3.5970 | 3.8074 | |
| 81 right | 5.1250 | 4.8420 | 4.9510 | 5.0180 | 4.9750 | 4.984 | |

**Table 34**
**Kampsville, Pool El 419.4, KLEU67, Run October 25, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.1038 | 0.1258 | 0.1253 | 0.1216 | 0.1101 | 0.1173 | |
| 2 | 0.1614 | 0.1251 | 0.1421 | 0.1501 | 0.1812 | 0.1520 | |
| 3 | 0.1970 | 0.2002 | 0.2076 | 0.2020 | 0.2011 | 0.2016 | |
| 4 | 0.2016 | 0.1932 | 0.2343 | 0.2012 | 0.2148 | 0.2090 | |
| 5 | 0.2082 | 0.2022 | 0.2059 | 0.1960 | 0.2009 | 0.2026 | |
| 6 | 0.2101 | 0.2054 | 0.1987 | 0.1998 | 0.1990 | 0.2026 | |
| 7 | 0.2183 | 0.1506 | 0.1358 | 0.1551 | 0.1437 | 0.1607 | |
| 8 | 0.0624 | 0.0596 | 0.0534 | 0.0568 | 0.0631 | 0.0591 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.3906 | 0.4103 | 0.3866 | 0.4132 | 0.4183 | 0.4038 | 0.2865 |
| 2 | 0.4182 | 0.4401 | 0.4248 | 0.4486 | 0.4448 | 0.4353 | 0.2833 |
| 3 | 0.4913 | 0.4972 | 0.4818 | 0.4899 | 0.4973 | 0.4915 | 0.2899 |
| 4 | 0.5665 | 0.5729 | 0.5762 | 0.5851 | 0.5833 | 0.5768 | 0.3678 |
| 5 | 0.4842 | 0.4797 | 0.4833 | 0.4887 | 0.4963 | 0.4864 | 0.2838 |
| 6 | 0.4748 | 0.4607 | 0.4675 | 0.4651 | 0.4705 | 0.4677 | 0.2651 |
| 7 | 0.3634 | 0.3523 | 0.3653 | 0.3681 | 0.3742 | 0.3647 | 0.2040 |
| 8 | 0.1451 | 0.1577 | 0.1611 | 0.1641 | 0.2283 | 0.1713 | 0.1122 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 38 right | 9.4330 | 9.1070 | 9.2730 | 9.8910 | 9.7660 | 9.494 | |
| 81 right | 11.321 | 11.414 | 11.232 | 11.331 | 11.254 | 11.3245 | |

## Table 35
## Kampsville, Pool El 419.4, Experiments, Meter Positions

| Probe Position[1] Experiment No. | Probe Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| PP1 (KLU335C, KLU488C, KLU640D, KLD354G, KLD506A, KLD506C, KLD506D, KLD659A, KL1U46E, KL1U61E, KL1U76E, KLEU49B, KLEU67D) | 168.8 Left | 125.O Left | 81.3 Left | 37.5 Left | 37.5 Right | 62.5 Right | 87.5 Right | 112.5 Right |
| PP2 (KLRU49C, KLRD49E) | 168.8 Left | 118.8 Left | 68.8 Left | 18.8 Left | 62.5 Right | 80.0 Right | 97.5 Right | 112.5 Right |
| PP3 (KLLU49C, KLLD51C) | 168.8 Left | 150.0 Left | 125.0 Left | 100.0 Left | 25.0 Left | 25.0 Right | 75.0 Right | 112.5 Right |

[1] Probe position = distance from thalweg, m, looking downstream.

**Table 36**
**Kampsville Pool El 427.0 Experiment Conditions**

| Experiment No. | Up or Down | Tow Speed[1] m/sec | Position[2] | Temp °C | Actual Draft m | Effective Draft m[3] | Barge W X L | Propeller Thrust l,000 lb | Schijf Velocity cm/sec[4] |
|---|---|---|---|---|---|---|---|---|---|
| KHEU38 | U | 1.91 | 152.5 | 17.5 | 0.61 | 1.15 | 3X5 | 79 | 6.40 |
| KHEU56 | U | 2.82 | 152.5 | 16.0 | 0.61 | 1.12 | 3X5 | 105 | 9.70 |
| KH0U38 | U | 1.91 | 152.5 | 15.0 | 2.29 | 2.83 | 3X5 | 79 | 16.4 |
| KH0U53 | U | 2.67 | 152.5 | 18.0 | 2.29 | 2.79 | 3X5 | 105 | 24.3 |
| KH0D50 | D | 2.52 | 152.5 | 16.5 | 2.29 | 2.87 | 3X5 | 79 | 10.3 |
| KH0D66 | D | 3.28 | 152.5 | 16.5 | 2.29 | 2.83 | 3X5 | 105 | 16.0 |
| KHRU38 | U | 1.91 | 102.5 | 17.5 | 2.29 | 2.82 | 3X5 | 79 | 16.4 |
| KHRD66 | D | 3.28 | 102.5 | 18.0 | 2.29 | 2.82 | 3X5 | 105 | 16.0 |
| KHLU38 | U | 1.91 | 242.5 | 18.0 | 2.29 | 2.82 | 3X5 | 79 | 16.4 |
| KHLD66 | D | 3.28 | 242.5 | 18.0 | 2.29 | 2.82 | 3X5 | 105 | 16.0 |
| KH0U27[5] | U | 1.37 | 152.5 | 18.0 | 2.29 | 2.83 | 3X5 | 105 | 15.5 |
| KH0D64[5] | D | 3.20 | 152.5 | 16.5 | 2.29 | 2.86 | 3X5 | 105 | 12.1 |

Note: Water-surface width 362.35 m, area 1,817 sq m, discharge 1,281 cu m/sec, water-surface el 427.0, average ambient velocity 0.71 m/sec.

[1] Relative to ground.
[2] Meters distance from right bank.
[3] Actual draft + draft correction.
[4] Schijf equation using effective draft and vessel speed relative to water.
[5] Water-surface width 362.35 m, area 1,817 sq m, discharge 2,093.75 cu m/sec, water-surface el 427.0, average ambient velocity 1.152 m/sec.

## Table 37
## Kampsville, Pool El 427.0, KHEU38, Run October 31, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| Ambient Velocity, m/sec | | | | | | | |
| 1 | 0.3405 | 0.3372 | 0.3183 | 0.3470 | 0.3401 | 0.3366 | |
| 2 | 0.0711 | 0.7811 | 0.7705 | 0.7383 | 0.7391 | 0.6200 | |
| 3 | 0.7604 | 0.8484 | 0.7724 | 0.7649 | 0.7871 | 0.7866 | |
| 4 | 0.7944 | 0.8244 | 0.7345 | 0.7731 | 0.7855 | 0.7824 | |
| 5 | 0.7459 | 0.7121 | 0.7578 | 0.7478 | 0.7555 | 0.7438 | |
| 6 | 0.7389 | 0.6830 | 0.7387 | 0.7210 | 0.7412 | 0.7246 | |
| 7 | 0.6115 | 0.5344 | 0.5955 | 0.6001 | 0.6081 | 0.5899 | |
| 8 | 0.3978 | 0.4086 | 0.4172 | 0.4194 | 0.4165 | 0.4119 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.4499 | 0.4323 | 0.4518 | 0.4305 | 0.4553 | 0.4440 | 0.1074 |
| 2 | 0.8095 | 0.8998 | 0.8921 | 0.8440 | 0.8400 | 0.8571 | 0.2371 |
| 3 | 0.8500 | 0.9525 | 0.9498 | 0.8688 | 0.9149 | 0.9072 | 0.1206 |
| 4 | 0.8850 | 0.8750 | 0.9236 | 0.9024 | 0.8498 | 0.8872 | 0.1048 |
| 5 | 0.9170 | 0.8743 | 0.8650 | 0.9212 | 0.9420 | 0.9039 | 0.1601 |
| 6 | 0.9004 | 0.9034 | 0.8000 | 0.9033 | 0.8605 | 0.8735 | 0.1489 |
| 7 | 0.6975 | 0.6883 | 0.6676 | 0.6550 | 0.7166 | 0.6850 | 0.0951 |
| 8 | 0.5188 | 0.5337 | 0.5403 | 0.5125 | 0.5266 | 0.5264 | 0.1145 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 2.1330 | 2.1990 | 1.9490 | 2.0580 | 1.7520 | 2.0182 | |
| 171 left | 1.9590 | 2.2070 | 2.0330 | 2.1330 | 2.0390 | 2.083 | |

**Table 38**
**Kampsville, Pool El 427.0, KHEU56, Run November 1, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.2633 | 0.3422 | 0.3429 | 0.3306 | 0.3362 | 0.3230 | |
| 2 | 0.7642 | 0.8173 | 0.7386 | 0.7066 | 0.7324 | 0.7518 | |
| 3 | 0.7928 | 0.8371 | 0.7912 | 0.7459 | 0.7176 | 0.7769 | |
| 4 | 0.7804 | 0.8036 | 0.7972 | 0.7873 | 0.7562 | 0.7849 | |
| 5 | 0.7417 | 0.7042 | 0.7547 | 0.7301 | 0.8129 | 0.7487 | |
| 6 | 0.7061 | 0.7067 | 0.7188 | 0.7340 | 0.7857 | 0.7303 | |
| 7 | 0.5608 | 0.5663 | 0.5912 | 0.6080 | 0.6238 | 0.5900 | |
| 8 | 0.4227 | 0.4447 | 0.4253 | 0.4159 | 0.4135 | 0.4244 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.4416 | 0.4617 | 0.4937 | 0.4796 | 0.4800 | 0.4713 | 0.1483 |
| 2 | 0.8990 | 0.8140 | 0.9222 | 0.8401 | 0.8568 | 0.8664 | 0.1146 |
| 3 | 0.8928 | 1.0115 | 0.9271 | 0.9347 | 0.9839 | 0.9500 | 0.1731 |
| 4 | 0.9367 | 0.9432 | 0.9324 | 0.9844 | 0.9613 | 0.9516 | 0.1667 |
| 5 | 0.9559 | 0.8622 | 0.9196 | 0.9950 | 0.9154 | 0.9296 | 0.1809 |
| 6 | 0.9041 | 0.8424 | 0.8926 | 0.8697 | 0.8919 | 0.8801 | 0.1498 |
| 7 | 0.6873 | 0.6471 | 0.7553 | 0.6967 | 0.6862 | 0.6945 | 0.1045 |
| 8 | 0.5573 | 0.5305 | 0.5327 | 0.5546 | 0.5197 | 0.5390 | 0.1146 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 4.1050 | 4.6060 | 4.6700 | 3.6160 | 4.9770 | 4.3948 | |
| 171 left | 4.7590 | 4.9040 | 5.3310 | 4.6080 | 4.3840 | 4.9005 | |

## Table 39
## Kampsville, Pool El 427.0, KHOU38, Run November 2, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3400 | 0.3490 | 0.3386 | 0.3349 | 0.3148 | 0.3355 | |
| 2 | 0.7554 | 0.7233 | 0.7613 | 0.6612 | 0.6860 | 0.7174 | |
| 3 | 0.8217 | 0.8287 | 0.8357 | 0.7187 | 0.8191 | 0.8048 | |
| 4 | 0.7685 | 0.7848 | 0.8085 | 0.7449 | 0.8589 | 0.7931 | |
| 5 | 0.7540 | 0.8043 | 0.7660 | 0.8312 | 0.7389 | 0.7789 | |
| 6 | 0.7077 | 0.7692 | 0.7506 | 0.8142 | 0.6834 | 0.7450 | |
| 7 | 0.5663 | 0.5993 | 0.5667 | 0.6001 | 0.5839 | 0.5833 | |
| 8 | 0.4213 | 0.4385 | 0.4164 | 0.4381 | 0.4216 | 0.4272 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.5244 | 0.5419 | 0.5527 | 0.5473 | 0.5501 | 0.5433 | 0.2078 |
| 2 | 0.9457 | 0.9381 | 0.9536 | 0.9447 | 0.8818 | 0.9328 | 0.2154 |
| 3 | 1.0110 | 1.0222 | 0.9672 | 0.9987 | 0.9697 | 0.9938 | 0.1890 |
| 4 | 1.0455 | 1.0180 | 1.0086 | 1.0156 | 1.0100 | 1.0195 | 0.2264 |
| 5 | 1.0037 | 1.0206 | 1.0752 | 1.0544 | 1.0237 | 1.0355 | 0.2566 |
| 6 | 1.0600 | 1.0046 | 1.0020 | 1.0298 | 0.9644 | 1.0122 | 0.2672 |
| 7 | 0.7529 | 0.8780 | 0.7727 | 0.7474 | 0.7862 | 0.7874 | 0.2041 |
| 8 | 0.6100 | 0.6655 | 0.6186 | 0.6352 | 0.6435 | 0.6346 | 0.2074 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 6.2680 | 5.5450 | 6.1670 | 5.3140 | 7.6790 | 6.1946 | |
| 171 left | 4.9230 | 5.8130 | 5.4350 | 5.4980 | 5.7020 | 5.41725 | |

**Table 40**
**Kampsville, Pool El 427.0, KHOU53, Run November 4, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3388 | 0.3357 | 0.3515 | 0.3394 | 0.3319 | 0.3395 | |
| 2 | 0.8119 | 0.7269 | 0.7579 | 0.7627 | 0.6922 | 0.7503 | |
| 3 | 0.7732 | 0.7565 | 0.8172 | 0.7260 | 0.7376 | 0.7621 | |
| 4 | 0.8219 | 0.7547 | 0.7625 | 0.7608 | 0.8018 | 0.7803 | |
| 5 | 0.7091 | 0.7361 | 0.7577 | 0.7553 | 0.7304 | 0.7377 | |
| 6 | 0.6964 | 0.7375 | 0.7268 | 0.7457 | 0.7512 | 0.7315 | |
| 7 | 0.5701 | 0.6166 | 0.5666 | 0.5900 | 0.6382 | 0.5963 | |
| 8 | ------ | 0.4136 | 0.4200 | 0.4288 | 0.4226 | 0.4213 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.6115 | 0.6119 | 0.6392 | 0.5991 | 0.6160 | 0.6155 | 0.2760 |
| 2 | 1.0219 | 1.0457 | 1.0846 | 0.9934 | 0.9031 | 1.0097 | 0.2594 |
| 3 | 1.0076 | 1.0659 | 1.0101 | 0.9372 | 0.9797 | 1.0001 | 0.2389 |
| 4 | 1.0768 | 1.1930 | 1.0952 | 1.1275 | 1.0488 | 1.1083 | 0.3280 |
| 5 | 1.0984 | 1.0598 | 1.0775 | 1.1343 | 1.0940 | 1.0928 | 0.3551 |
| 6 | 1.0289 | 1.0055 | 0.9955 | 1.1274 | 1.0960 | 1.0507 | 0.3192 |
| 7 | 0.8297 | 0.7988 | 0.8243 | 0.9281 | 0.9266 | 0.8615 | 0.2652 |
| 8 | -- | 0.7020 | 0.7019 | 0.6903 | 0.6915 | 0.6964 | 0.2751 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 11.506 | 11.015 | 11.149 | 11.480 | 12.178 | 11.4656 | |
| 171 left | 10.728 | 10.575 | 10.819 | 11.460 | 10.390 | 10.8955 | |

## Table 41
## Kampsville, Pool El 427.0, KHOD50, Run November 7, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3492 | 0.3500 | 0.3393 | 0.3214 | 0.3319 | 0.3384 | |
| 2 | 0.6949 | 0.7334 | 0.6724 | 0.7260 | 0.7070 | 0.7067 | |
| 3 | 0.7616 | 0.7788 | 0.7192 | 0.7566 | 0.7539 | 0.7540 | |
| 4 | 0.7762 | 0.7175 | 0.7971 | 0.7464 | 0.7551 | 0.7585 | |
| 5 | 0.7575 | 0.7175 | 0.7709 | 0.7779 | 0.7218 | 0.7491 | |
| 6 | 0.6906 | 0.7055 | 0.7455 | 0.7353 | 0.7125 | 0.7179 | |
| 7 | 0.6568 | 0.6775 | 0.6836 | 0.6874 | 0.6918 | 0.6794 | |
| 8 | 0.4227 | 0.4164 | 0.4218 | 0.4320 | 0.4141 | 0.4214 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.2547 | 0.2452 | 0.2621 | 0.2440 | 0.2717 | 0.2555 | 0.0829 |
| 2 | 0.5880 | 0.6182 | 0.5690 | 0.5387 | 0.5689 | 0.5766 | 0.1301 |
| 3 | 0.6240 | 0.6206 | 0.6564 | 0.5963 | 0.6083 | 0.6211 | 0.1329 |
| 4 | 0.6053 | 0.5583 | 0.5527 | 0.6134 | 0.5864 | 0.5832 | 0.1753 |
| 5 | 0.5922 | 0.5583 | 0.5917 | 0.5750 | 0.6252 | 0.5885 | 0.1606 |
| 6 | 0.5778 | 0.5061 | 0.5709 | 0.5672 | 0.6030 | 0.5650 | 0.1529 |
| 7 | 0.5127 | 0.5461 | 0.5311 | 0.5256 | 0.5775 | 0.5386 | 0.1408 |
| 8 | 0.3419 | 0.3023 | 0.2970 | 0.2937 | 0.2625 | 0.2995 | 0.1219 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 1.6130 | 3.3480 | 3.2640 | 3.1880 | 3.0345 | 2.8895 | |
| 171 left | 2.9290 | 3.2760 | 2.5180 | 3.1450 | 3.0690 | 2.967 | |

## Table 42
## Kampsville, Pool El 427.0, KHOD66, Run November 7, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3459 | 0.3429 | 0.3420 | 0.3473 | 0.3426 | 0.3441 | |
| 2 | 0.6933 | 0.7665 | 0.7251 | 0.7836 | 0.7177 | 0.7372 | |
| 3 | 0.7561 | 0.7865 | 0.7252 | 0.7687 | 0.7635 | 0.7600 | |
| 4 | 0.7442 | 0.7107 | 0.7433 | 0.7657 | 0.7292 | 0.7386 | |
| 5 | 0.7408 | 0.7558 | 0.7683 | 0.6942 | 0.7437 | 0.7406 | |
| 6 | 0.7295 | 0.7100 | 0.7612 | 0.6304 | 0.7139 | 0.7090 | |
| 7 | 0.6343 | 0.6504 | 0.6785 | 0.5924 | 0.6671 | 0.6445 | |
| 8 | 0.4049 | 0.4072 | 0.4175 | 0.4111 | 0.4152 | 0.4112 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.1979 | 0.1988 | 0.2167 | 0.2178 | 0.2002 | 0.2063 | 0.1378 |
| 2 | 0.5882 | 0.5864 | 0.6034 | 0.5221 | 0.5546 | 0.5709 | 0.1663 |
| 3 | 0.5683 | 0.5521 | 0.4848 | 0.5259 | 0.5254 | 0.5313 | 0.2287 |
| 4 | 0.5671 | 0.5319 | 0.5598 | 0.5205 | 0.5286 | 0.5416 | 0.1970 |
| 5 | 0.4509 | 0.4689 | 0.4941 | 0.4956 | 0.4775 | 0.4774 | 0.2632 |
| 6 | 0.5203 | 0.5365 | 0.5112 | 0.5900 | 0.4762 | 0.5268 | 0.1822 |
| 7 | 0.5253 | 0.5613 | 0.5370 | 0.5322 | 0.5420 | 0.5396 | 0.1049 |
| 8 | 0.2396 | 0.2476 | 0.2332 | --- | 0.2585 | 0.2447 | 0.1665 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 7.4210 | 6.8910 | 7.0440 | 6.8830 | 7.3420 | 7.1162 | |
| 171 left | 6.4520 | 6.1950 | 6.2150 | 6.0280 | 6.3450 | 6.2225 | |

**Table 42**
**Kampsville, Pool El 427.0, KHOD66, Run November 7, 1994**

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.3459 | 0.3429 | 0.3420 | 0.3473 | 0.3426 | 0.3441 | |
| 2 | 0.6933 | 0.7665 | 0.7251 | 0.7836 | 0.7177 | 0.7372 | |
| 3 | 0.7561 | 0.7865 | 0.7252 | 0.7687 | 0.7635 | 0.7600 | |
| 4 | 0.7442 | 0.7107 | 0.7433 | 0.7657 | 0.7292 | 0.7386 | |
| 5 | 0.7408 | 0.7558 | 0.7683 | 0.6942 | 0.7437 | 0.7406 | |
| 6 | 0.7295 | 0.7100 | 0.7612 | 0.6304 | 0.7139 | 0.7090 | |
| 7 | 0.6343 | 0.6504 | 0.6785 | 0.5924 | 0.6671 | 0.6445 | |
| 8 | 0.4049 | 0.4072 | 0.4175 | 0.4111 | 0.4152 | 0.4112 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.1979 | 0.1988 | 0.2167 | 0.2178 | 0.2002 | 0.2063 | 0.1378 |
| 2 | 0.5882 | 0.5864 | 0.6034 | 0.5221 | 0.5546 | 0.5709 | 0.1663 |
| 3 | 0.5683 | 0.5521 | 0.4848 | 0.5259 | 0.5254 | 0.5313 | 0.2287 |
| 4 | 0.5671 | 0.5319 | 0.5598 | 0.5205 | 0.5286 | 0.5416 | 0.1970 |
| 5 | 0.4509 | 0.4689 | 0.4941 | 0.4956 | 0.4775 | 0.4774 | 0.2632 |
| 6 | 0.5203 | 0.5365 | 0.5112 | 0.5900 | 0.4762 | 0.5268 | 0.1822 |
| 7 | 0.5253 | 0.5613 | 0.5370 | 0.5322 | 0.5420 | 0.5396 | 0.1049 |
| 8 | 0.2396 | 0.2476 | 0.2332 | --- | 0.2585 | 0.2447 | 0.1665 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 7.4210 | 6.8910 | 7.0440 | 6.8830 | 7.3420 | 7.1162 | |
| 171 left | 6.4520 | 6.1950 | 6.2150 | 6.0280 | 6.3450 | 6.2225 | |

**Table 43**
**Kampsville, Pool El 427.0, KHRU38, Run November 14, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.4136 | 0.4168 | 0.4580 | 0.4285 | 0.4078 | 0.4249 | |
| 2 | 0.7309 | 0.7877 | 0.7181 | 0.7607 | 0.7381 | 0.7471 | |
| 3 | 0.7779 | 0.7671 | 0.7261 | 0.7224 | 0.8064 | 0.7600 | |
| 4 | 0.7146 | 0.7786 | 0.7927 | 0.7464 | 0.7300 | 0.7525 | |
| 5 | 0.7239 | 0.7014 | 0.7597 | 0.7855 | 0.7369 | 0.7415 | |
| 6 | 0.6726 | 0.6464 | 0.7396 | 0.7038 | 0.6516 | 0.6828 | |
| 7 | 0.6339 | 0.6630 | 0.6693 | 0.6511 | 0.6301 | 0.6495 | |
| 8 | 0.4134 | 0.4284 | 0.4203 | 0.4219 | 0.4119 | 0.4192 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.6447 | 0.6312 | 0.6126 | 0.5992 | 0.6399 | 0.6255 | 0.2006 |
| 2 | 0.8878 | 0.9570 | 0.9084 | 0.9711 | 0.9878 | 0.9424 | 0.1953 |
| 3 | 0.9695 | 0.9888 | 0.9670 | 1.0018 | 0.9879 | 0.9830 | 0.2230 |
| 4 | 1.1187 | 1.0375 | 1.0451 | 0.9967 | 1.0365 | 1.0469 | 0.2944 |
| 5 | 1.1439 | 1.0019 | 1.0295 | 1.0385 | 1.0078 | 1.0443 | 0.3028 |
| 6 | 1.0500 | 0.9237 | 0.9826 | 0.9675 | 0.9047 | 0.9657 | 0.2829 |
| 7 | 0.9205 | 0.8950 | 0.9330 | 0.9367 | 0.8856 | 0.9142 | 0.2647 |
| 8 | 0.6630 | 0.6861 | 0.6991 | 0.6832 | 0.6957 | 0.6854 | 0.2662 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 7.0550 | 6.8840 | 7.2510 | 4.9460 | 6.8810 | 6.6034 | |
| 171 left | 5.7190 | 5.9560 | 5.8380 | 5.9230 | 5.4280 | 5.859 | |

**Table 44**
**Kampsville, Pool El 427.0, KHRD66, Run November 15, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.420 | 0.4362 | 0.4179 | 0.4348 | 0.4292 | 0.4282 | |
| 2 | 0.7784 | 0.8109 | 0.7230 | 0.7589 | 0.6978 | 0.7538 | |
| 3 | 0.7776 | 0.7762 | 0.7948 | 0.7927 | 0.7591 | 0.7801 | |
| 4 | 0.6959 | 0.6920 | 0.7176 | 0.6907 | 0.7848 | 0.7162 | |
| 5 | 0.7058 | 0.7120 | 0.7219 | 0.7222 | 0.7950 | 0.7314 | |
| 6 | 0.6367 | 0.6812 | 0.6704 | 0.7454 | 0.7718 | 0.7011 | |
| 7 | 0.6200 | 0.6445 | 0.6310 | 0.6353 | 0.6998 | 0.6461 | |
| 8 | 0.4061 | 0.4279 | 0.4123 | 0.4219 | 0.4171 | 0.4171 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.2563 | 0.2810 | 0.2843 | 0.2574 | 0.2827 | 0.2723 | 0.1559 |
| 2 | 0.5693 | 0.5523 | 0.6111 | 0.5785 | 0.5901 | 0.5803 | 0.1735 |
| 3 | 0.5547 | 0.5116 | 0.6692 | 0.5507 | 0.5933 | 0.5759 | 0.2042 |
| 4 | 0.4698 | 0.4257 | 0.4632 | 0.4464 | 0.4156 | 0.4441 | 0.2721 |
| 5 | 0.5244 | 0.4010 | 0.4680 | 0.4687 | 0.4156 | 0.4555 | 0.2759 |
| 6 | 0.4595 | 0.3814 | 0.4067 | 0.3608 | 0.4787 | 0.4174 | 0.2837 |
| 7 | 0.3754 | 0.3841 | 0.3653 | 0.4065 | 0.3904 | 0.3843 | 0.2618 |
| 8 | 0.1786 | 0.1896 | 0.1948 | 0.1307 | 0.4858 | 0.2359 | 0.1812 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 9.2850 | 9.1960 | 8.6310 | 8.9500 | 8.9580 | 9.004 | |
| 171 left | 5.8010 | 5.9370 | 6.3970 | 5.8290 | 6.1100 | 5.991 | |

## Table 45
## Kampsville, Pool El 427.0, KHLU38, Run November 16, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.4142 | 0.4301 | 0.4166 | 0.4230 | 0.4077 | 0.4183 | |
| 2 | 0.6807 | 0.6175 | 0.6500 | 0.6634 | 0.6878 | 0.6599 | |
| 3 | 0.6889 | 0.7344 | 0.7340 | 0.7568 | 0.7383 | 0.7305 | |
| 4 | 0.7004 | 0.7369 | 0.7013 | 0.7326 | 0.7688 | 0.7280 | |
| 5 | 0.7696 | 0.7888 | 0.7894 | 0.7831 | 0.7671 | 0.7796 | |
| 6 | 0.7313 | 0.7294 | 0.7579 | 0.7789 | 0.7330 | 0.7461 | |
| 7 | 0.7994 | 0.6994 | 0.7099 | 0.7193 | 0.7382 | 0.7332 | |
| 8 | 0.4184 | 0.4249 | 0.4144 | 0.4236 | 0.4135 | 0.4190 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.7075 | 0.7376 | 0.7171 | 0.6975 | 0.7148 | 0.7149 | 0.2966 |
| 2 | 0.9355 | 0.8266 | 0.8524 | 0.8829 | 0.9871 | 0.8969 | 0.2370 |
| 3 | 0.9610 | 0.9516 | 0.9337 | 0.9507 | 1.0069 | 0.9608 | 0.2303 |
| 4 | 1.0231 | 1.0184 | 1.0248 | 0.0248 | 1.1293 | 0.8441 | 0.1161 |
| 5 | 1.0273 | 0.9536 | 1.0195 | 0.9525 | 1.0106 | 0.9927 | 0.2131 |
| 6 | 1.0267 | 1.0632 | 1.0440 | 1.0069 | 0.9496 | 1.0181 | 0.2720 |
| 7 | 0.9588 | 0.9403 | 1.0154 | 0.9928 | ------ | 0.9768 | 0.2436 |
| 8 | 0.6060 | 0.6051 | 0.5939 | 0.6171 | 0.6212 | 0.6087 | 0.1897 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 5.3100 | 4.8240 | 4.6860 | 4.5240 | 4.6520 | 4.7992 | |
| 171 left | 7.6280 | 7.9020 | 7.1980 | 7.4720 | 7.2570 | 7.55 | |

## Table 46
## Kampsville, Pool El 427.0, KHLD66, Run November 16, 1994

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.4323 | 0.4427 | 0.4334 | 0.4227 | 0.4383 | 0.4339 | |
| 2 | 0.6701 | 0.6949 | 0.6792 | 0.6379 | 0.6324 | 0.6629 | |
| 3 | 0.7141 | 0.7458 | 0.7033 | 0.6718 | 0.6820 | 0.7034 | |
| 4 | 0.7336 | 0.8048 | 0.7388 | 0.6975 | 0.7521 | 0.7454 | |
| 5 | 0.7776 | 0.7842 | 0.7399 | 0.7981 | 0.7954 | 0.7790 | |
| 6 | 0.7329 | 0.7553 | 0.7461 | 0.7657 | 0.7979 | 0.7596 | |
| 7 | 0.5809 | 0.7155 | 0.7559 | 0.8092 | 0.7225 | 0.7168 | |
| 8 | 0.4084 | 0.4141 | 0.4188 | 0.4235 | 0.4329 | 0.4195 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.2208 | 0.2473 | 0.2119 | 0.1952 | 0.1894 | 0.2129 | 0.2210 |
| 2 | 0.3758 | 0.3152 | 0.4093 | 0.4645 | 0.4679 | 0.4065 | 0.2564 |
| 3 | 0.4822 | 0.4296 | 0.4359 | 0.5081 | 0.5054 | 0.4722 | 0.2312 |
| 4 | 0.4237 | 0.4441 | 0.4407 | 0.4251 | 0.3338 | 0.4135 | 0.3319 |
| 5 | 0.5450 | 0.4711 | 0.5784 | 0.5907 | 0.5302 | 0.5431 | 0.2359 |
| 6 | 0.5863 | 0.5510 | 0.5614 | 0.6380 | 0.5930 | 0.5859 | 0.1737 |
| 7 | 0.5809 | 0.5724 | 0.6263 | 0.5367 | 0.6340 | 0.5901 | 0.1267 |
| 8 | 0.2871 | 0.2569 | 0.2816 | 0.2732 | 0.2920 | 0.2782 | 0.1413 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 5.8930 | 5.5820 | 5.8880 | 5.8270 | 5.8860 | 5.8152 | |
| 171 left | 8.8950 | 8.2460 | 8.5890 | 8.3640 | 8.1250 | 8.5235 | |

**Table 47**
**Kampsville, Pool El 427.0, KHOU27, Run November 9, 1994**

| Probe | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.5722 | ------ | 0.6130 | 0.5737 | 0.5784 | 0.5843 | |
| 2 | 1.1702 | ------ | 1.3280 | 1.3034 | 1.1820 | 1.2459 | |
| 3 | 1.2670 | ------ | 1.2000 | 1.3170 | 1.1990 | 1.2458 | |
| 4 | 1.2250 | ------ | 1.1840 | 1.2270 | 1.1860 | 1.2055 | |
| 5 | 1.2150 | ------ | 1.3130 | 1.2010 | 1.2790 | 1.2520 | |
| 6 | 1.2290 | ------ | 1.1710 | 1.2600 | 1.1820 | 1.2105 | |
| 7 | 1.1880 | ------ | 1.1240 | 1.1090 | 1.1420 | 1.1408 | |
| 8 | 0.6663 | ------ | 0.7050 | 0.7154 | 0.7061 | 0.6982 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.8411 | ------ | 0.8181 | 0.8060 | 0.7682 | 0.8084 | 0.2241 |
| 2 | 1.4875 | ------ | 1.5210 | 1.5270 | 1.4090 | 1.4861 | 0.2402 |
| 3 | 1.5310 | ------ | 1.5550 | 1.5660 | 1.4510 | 1.5258 | 0.2800 |
| 4 | 1.4660 | ------ | 1.5050 | 1.4850 | 1.5240 | 1.4950 | 0.2895 |
| 5 | 1.5850 | ------ | 1.5860 | 1.5870 | 1.5820 | 1.5850 | 0.3330 |
| 6 | 1.5300 | ------ | 1.5240 | 1.5100 | 1.4090 | 1.4933 | 0.2828 |
| 7 | 1.5030 | ------ | 1.3420 | 1.4150 | 1.4830 | 1.4358 | 0.2950 |
| 8 | 0.9858 | ------ | 1.0300 | 0.9783 | 1.0212 | 1.0038 | 0.3056 |
| **Drawdown, cm** | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 2.8180 | 2.6620 | 4.1790 | 3.1730 | 3.3410 | 3.2346 | |
| 171 left | 3.5670 | 3.6380 | 2.7610 | 3.7500 | 2.8700 | 3.429 | |

## Table 48
## Kampsville, Pool El 427.0, KHOD64, Run November 8, 1994

| Probe | Replicate A | B | C | D | E | AVG | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| **Ambient Velocity, m/sec** | | | | | | | |
| 1 | 0.5765 | 0.5893 | 0.5723 | 0.5644 | 0.5766 | 0.5758 | |
| 2 | 1.1859 | 1.2460 | 1.2050 | 1.2303 | 1.1850 | 1.2104 | |
| 3 | 1.2010 | 1.2563 | 1.3340 | 1.2594 | 1.2248 | 1.2551 | |
| 4 | 1.1610 | 1.2130 | 1.1738 | 1.2141 | 1.2520 | 1.2028 | |
| 5 | ------ | 1.2077 | 1.2349 | 1.2391 | 1.2047 | 1.2216 | |
| 6 | ------ | 1.2510 | 1.1556 | 1.1968 | 1.0244 | 1.1570 | |
| 7 | ------ | 1.1265 | 1.6510 | 1.2271 | 1.1267 | 1.2828 | |
| 8 | ------ | 0.7554 | 0.7422 | 0.7036 | 0.7128 | 0.7285 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 1 | 0.4572 | 0.4888 | 0.4655 | 0.4793 | 0.4517 | 0.4685 | 0.1073 |
| 2 | 1.1026 | 0.9573 | 0.9765 | 1.0531 | 1.0630 | 1.0305 | 0.1799 |
| 3 | 1.0700 | 1.0538 | 1.0460 | 1.0509 | 1.1000 | 1.0641 | 0.1910 |
| 4 | 0.9790 | 0.9315 | 0.9789 | 0.9815 | 0.9074 | 0.9557 | 0.2471 |
| 5 | ------ | 1.0457 | 1.0301 | 1.0280 | 1.0108 | 1.0287 | 0.1929 |
| 6 | ------ | 1.1309 | 1.0820 | 1.0701 | 0.9432 | 1.0566 | 0.1004 |
| 7 | ------ | 1.0048 | 0.8906 | 0.9619 | 0.9754 | 0.9582 | 0.3246 |
| 8 | ------ | 0.5862 | 0.4762 | 0.5545 | 0.6108 | 0.5569 | 0.1716 |
| Drawdown, cm | | | | | | | |
| **Distance from Thalweg m** | **A** | **B** | **C** | **D** | **E** | **AVG** | |
| 112 right | 5.7040 | 5.4090 | 6.7070 | 5.6410 | 6.4200 | 5.9762 | |
| 171 left | 5.0900 | 5.9850 | 5.0760 | 5.2260 | 4.7370 | 5.34425 | |

## Table 49
## Kampsville, Pool El 427.0, Experiments, Meter Positions

| Probe Position[1] (Experiment No.) | Probe Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| PP1 (KHEU38B, KHEU56E, KHOU38D, KHOU53C, KHOD50D, KHOD66E, KHOU27D, KHOD64D) | 187.5 Left | 137.5 Left | 87.5 Left | 37.5 Left | 37.5 Right | 67.75 Right | 100.0 Right | 131.3 Right |
| PP2 (KHRU38B, KHRD66B) | 187.5 Left | 118.8 Left | 43.75 Left | 25.0 Right | 72.5 Right | 92.5 Right | 112.5 Right | 131.3 Right |
| PP3 (KHLU38D, KHLD66C) | 187.5 Left | 162.5 Left | 137.5 Left | 112.5 Left | 42.5 Left | 0.00 | 65.0 Right | 131.3 Right |

[1] Probe Position = distance from thalweg, m, looking downstream.

## Table 50
## *William C. Norman*, Kampsville Trip 1, Pool El 421.8, ND58VD, Experiments Conducted November 21, 1994, Vertical Distribution

| Depth off Bottom, % | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 25 | 0.4671 | 0.4888 | 0.4948 | 0.4700 | 0.4915 | 0.4824 | |
| 5 | 0.1363 | ------ | 0.1504 | 0.1457 | 0.1296 | 0.1405 | |
| 50 | 0.5306 | 0.5182 | 0.5256 | 0.5195 | 0.5224 | 0.5233 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 25 | 0.2354 | 0.2680 | 0.2458 | 0.2702 | 0.2457 | 0.2530 | 0.2294 |
| 5 | 0.0354 | 0.0975 | 0.0900 | 0.0677 | 0.0527 | 0.0687 | 0.0718 |
| 50 | 0.3176 | 0.3026 | 0.3174 | 0.3365 | 0.3396 | 0.3227 | 0.2006 |

Note: Discharge 625 cu m/sec; water-surface el 421.8; area 1,269 sq m; water-surface width 330 m; average channel velocity 0.49 m/sec.

**Table 51**
**Kampsville Low Flow, Pool El 419.4, KLU488, Experiments Conducted October 5, 1994, Vertical Distribution**

| Depth off Bottom, % | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 80 | 0.2101 | 0.2257 | 0.2025 | 0.2208 | 0.2279 | 0.2174 | |
| 25 | 0.1172 | 0.1676 | 0.1165 | 0.1541 | 0.1505 | 0.1412 | |
| 50 | 0.0691 | 0.1899 | 0.3503 | 0.1923 | 0.1603 | 0.1924 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 80 | 0.5802 | 0.6157 | 0.5939 | 0.6061 | 0.6164 | 0.6025 | 0.3851 |
| 25 | 0.4405 | 0.5391 | 0.4239 | 0.5410 | 0.4602 | 0.4809 | 0.3397 |
| 50 | 0.6334 | 0.4598 | 0.6319 | 0.4259 | 0.5429 | 0.5388 | 0.3464 |

**Table 52**
**Kampsville High Flow, Pool El 427.0, KHVU38, Experiments Conducted November 10, 1994, Vertical Distribution**

| Depth off Bottom, % | Replicate | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | |
| 25 | 0.6794 | 0.6769 | 0.7024 | 0.7037 | 0.7101 | 0.6945 | |
| 75 | 0.7928 | 0.7953 | 0.8208 | 0.7950 | 0.8049 | 0.8018 | |
| 50 | 0.7579 | 0.7588 | 0.8001 | 0.7750 | 0.7872 | 0.7758 | |
| **Impact Velocity, m/sec** | | | | | | | |
| 25 | 1.0039 | 0.9112 | 0.9337 | 1.0312 | 0.8857 | 0.9531 | 0.2577 |
| 75 | 1.0880 | 1.0665 | 1.0456 | 1.0769 | 0.9950 | 1.0544 | 0.2526 |
| 50 | 1.0564 | 1.0075 | 1.0462 | 1.0790 | 0.9772 | 1.0333 | 0.2575 |

**Table 53**
***William C. Norman*, Kampsville Trip 1, Pool El 421.8, WCNSP, Experiments Conducted December 6, 1994, Stationary Vessel Experiments**

| Station | Velocity, m/sec, for Probe | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| 52 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | -0.05 | -0.04 | 0.004 |
| 54 | ------ | ------ | ------ | ------ | -0.01 | -0.06 | -0.06 | -0.01 |
| 56 | 0.006 | 0.005 | -0.02 | 0.015 | -0.02 | -0.01 | -0.03 | 0.005 |
| 58 | 0.014 | 0.013 | -0.04 | 0.00 | -0.01 | -0.06 | -0.01 | 0.010 |
| 60 | 0.004 | 0.031 | -0.04 | -0.05 | -0.02 | -0.04 | 0.002 | 0.055 |
| 62 | 0.104 | 0.054 | 0.040 | 0.018 | 0.042 | -0.05 | 0.046 | 0.101 |
| 64 | 0.151 | 0.113 | 0.110 | 0.179 | 0.157 | 0.091 | 0.101 | 0.207 |
| 66 | 0.209 | 0.163 | 0.143 | 0.199 | 0.181 | 0.119 | 0.175 | 0.258 |
| 68 | 0.233 | 0.202 | 0.143 | 0.216 | 0.221 | 0.088 | 0.202 | 0.287 |
| 70 | 0.239 | 0.208 | 0.181 | 0.269 | 0.263 | 0.102 | 0.230 | 0.262 |
| 72 | 0.159 | 0.175 | 0.158 | 0.244 | 0.215 | 0.132 | 0.166 | 0.223 |
| 74 | 0.103 | 0.133 | 0.088 | 0.145 | 0.115 | 0.004 | 0.122 | 0.132 |
| 76 | 0.063 | 0.129 | 0.092 | 0.115 | 0.106 | -0.06 | 0.109 | 0.052 |
| 78 | 0.021 | 0.115 | 0.052 | 0.081 | 0.094 | -0.05 | 0.098 | 0.053 |
| 80 | 0.00 | 0.095 | 0.077 | 0.109 | 0.107 | -0.08 | 0.101 | 0.022 |
| Max | 0.239 | 0.208 | 0.181 | 0.269 | 0.263 | 0.132 | 0.230 | 0.287 |

**Table 54**
***William C. Norman*, Kampsville Trip 1, Pool El 421.8, Experiments Conducted on November 18, 1994, Variability of Physical Model Data**

| Probe | Replicate | | | | | | | | | | Return Velocity m/sec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | AVG | |
| **Ambient Velocity, m/sec** | | | | | | | | | | | |
| 1 | 0.3689 | 0.3338 | 0.3691 | 0.3714 | 0.3729 | 0.3830 | 0.3715 | 0.3775 | 0.3589 | 0.3674 | |
| 2 | 0.5204 | 0.5086 | 0.4990 | 0.5202 | 0.5244 | 0.5239 | 0.5052 | 0.5017 | 0.5346 | 0.5153 | |
| 3 | 0.5076 | 0.5327 | 0.4960 | 0.5139 | 0.5196 | 0.5224 | 0.5170 | 0.5188 | 0.5165 | 0.5161 | |
| 4 | 0.5549 | 0.5533 | 0.5268 | 0.5361 | 0.5491 | 0.5458 | 0.5354 | 0.5240 | 0.5671 | 0.5436 | |
| 5 | 0.5187 | 0.5422 | 0.5256 | 0.5381 | 0.5507 | 0.5052 | 0.5233 | 0.5404 | 0.5467 | 0.5323 | |
| 6 | 0.5038 | 0.5098 | 0.5086 | 0.4712 | 0.4750 | 0.4477 | 0.4594 | 0.4654 | 0.5260 | 0.4852 | |
| 7 | 0.5172 | 0.4913 | 0.5024 | 0.5298 | 0.5202 | 0.5001 | 0.5005 | 0.5085 | 0.5104 | 0.5089 | |
| 8 | 0.3844 | 0.3859 | 0.3763 | 0.3865 | 0.3793 | 0.3712 | 0.3668 | 0.3822 | 0.3746 | 0.3786 | |
| **Impact Velocity, m/sec** | | | | | | | | | | | |
| 1 | 0.1748 | 0.1401 | 0.1498 | 0.1442 | 0.1654 | 0.1382 | 0.1757 | 0.1467 | 0.1877 | 0.1581 | 0.2093 |
| 2 | 0.3325 | 0.3155 | 0.3049 | 0.3313 | 0.2903 | 0.2817 | 0.3235 | 0.3005 | 0.3177 | 0.3109 | 0.2044 |
| 3 | 0.2301 | 0.2965 | 0.3220 | 0.3188 | 0.3467 | 0.3388 | 0.3431 | 0.3283 | 0.3318 | 0.3173 | 0.1988 |
| 4 | 0.2993 | 0.2793 | 0.2754 | 0.2704 | 0.2622 | 0.2625 | 0.2340 | 0.3047 | 0.2447 | 0.2703 | 0.2733 |
| 5 | 0.3025 | 0.2692 | 0.2365 | 0.2699 | 0.2623 | 0.3014 | 0.2775 | 0.3278 | 0.2817 | 0.2810 | 0.2513 |
| 6 | 0.3003 | 0.2851 | 0.2689 | 0.2610 | 0.1764 | 0.2294 | 0.2261 | 0.2415 | 0.2687 | 0.2508 | 0.2344 |
| 7 | 0.3071 | 0.3263 | 0.2784 | 0.3037 | 0.2683 | 0.2721 | 0.2639 | 0.2766 | 0.2811 | 0.2864 | 0.2225 |
| 8 | 0.1402 | 0.1499 | 0.1719 | 0.1825 | 0.1441 | 0.1557 | 0.1426 | 0.1836 | 0.1546 | 0.1583 | 0.2203 |

**Table 55**
***William C. Norman*, Kampsville Trip 1, Pool El 421.8, Experiments Conducted on November 18, 1994, Drawdown Distribution**

| Distance from Thalweg, m | Drawdown, cm | | | |
|---|---|---|---|---|
| | A | B | C | Avg |
| 106 right | 6.8 | 6.9 | 6.6 | 6.8 |
| 163 left | 5.2 | 5.8 | 5.3 | 5.4 |
| 34 right | 7.6 | 7.7 | 7.7 | 7.7 |
| 41 left | 6.7 | 6.9 | 6.8 | 6.8 |
| 70 right | 7.0 | 6.7 | 6.5 | 6.8 |
| 100 left | 5.4 | 5.4 | 5.6 | 5.5 |

**Table 56**
**Vertical Return Velocity Distribution**

| Experiment | Meter Distance Above Bed, m | *Max $V_r$/Max $V_r$ (Upper)* |
|---|---|---|
| **Downbound** | | |
| ND58VD-Phys Model | 0.22 | 0.39 |
| Meter 998-(5)[1] | 0.31 | 0.81 |
| ND58VD-Phys Model | 1.1 | 1.14 |
| Meter 999-(5)[1] | 1.22 | 1.08 |
| ND58VD-Phys Model | 2.2[2] | 1.0 |
| Meter 1000-(5)[1] | 2.44[3] | 1.0 |
| **Upbound** | | |
| Meter 998-(9)[1] | 0.31 | 0.91 |
| Meter 999-(9)[1] | 1.2 | 1.02 |
| KHVU38-Phys Model | 1.5 | 0.97 |
| Meter 1000-(9)[1] | 2.44[3] | 1.0 |
| KHVU38-Phys Model | 3.0 | 0.99 |
| KHVU38-Phys Model | 4.5[2] | 1.0 |

[1] Number of prototype experiments used to determine average value of *Max $V_r$/Max $V_r$ upper.*
[2] Maximum $V_r$ for this meter used to normalize physical model data.
[3] Maximum $V_r$ for this meter used to normalize prototype data.

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A 1:25-scale model of the Illinois Waterway near Kampsville, IL, was used to determine tow-induced return velocity and drawdown. The model was adjusted to account for scale effects based on a comparison of physical model and prototype data from the Kampsville reach. Return velocity and drawdown were determined for various pool elevations, tow positions, vessel speeds, drafts, and direction relative to flow. The vertical profile of return velocity was shown to be uniform, except near the bed. Physical model and prototype data were compared to a numerical model.

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