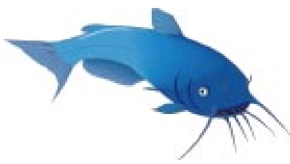
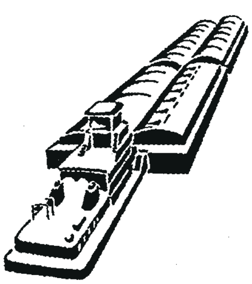
ENV Report 5

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



Physical Forces Study, Clark's Ferry, Mississippi River



August 1998

Rock Island District
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US Army Corps
of Engineers

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Physical Forces Study, Clark's Ferry, Mississippi River

by Stephen T. Maynord, Sandra K. Knight

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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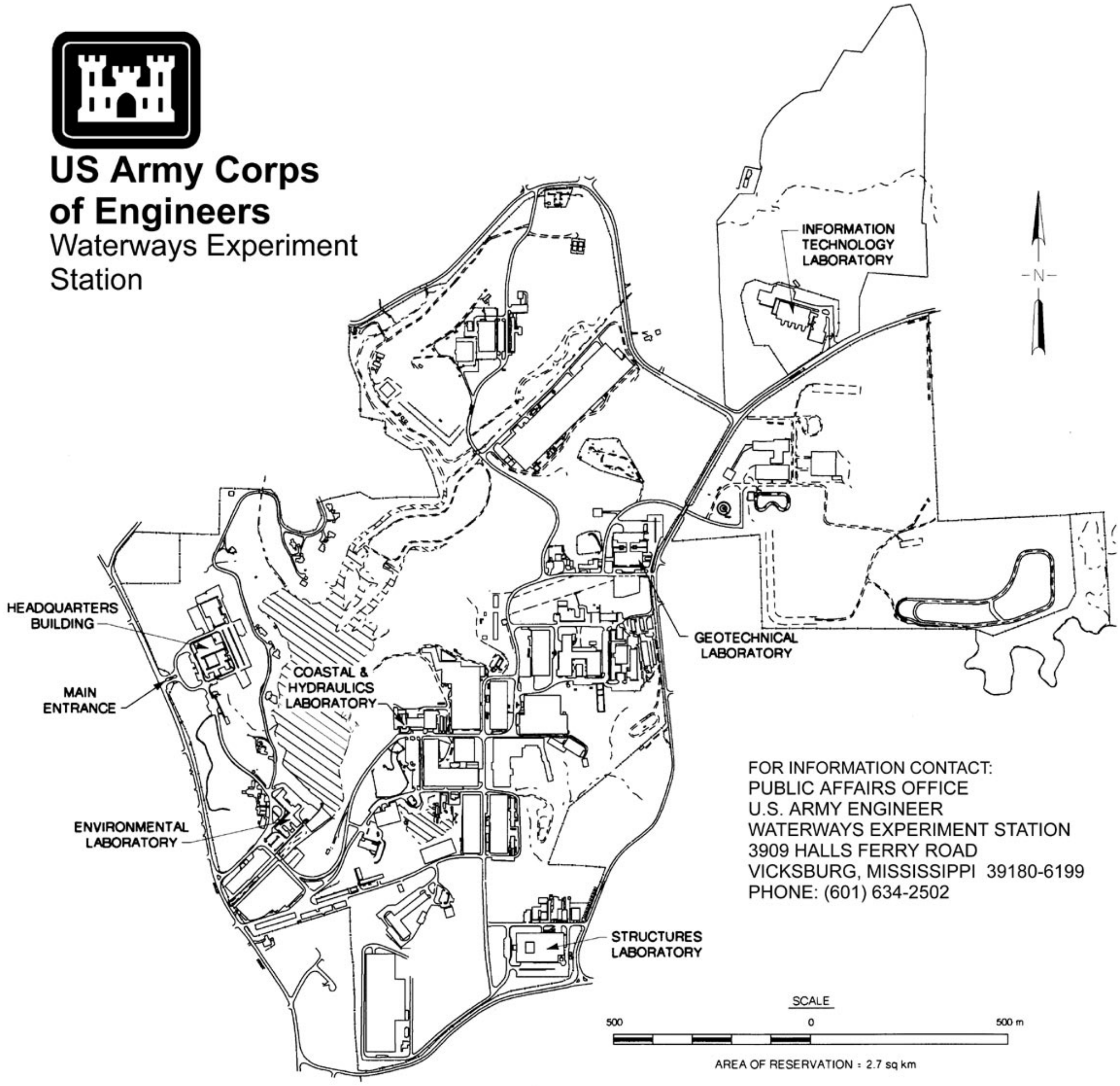

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Contents

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 Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Waterways Experiment Station (WES) during 1995-1998. The study was under the direction of Dr. James R. Houston, Director, CHL; Mr. Charles C. Calhoun, Jr., Assistant Director, CHL; and Mr. C. E. Chatham, Jr., Chief of the Navigation and Harbors Division (NHD), CHL. The study was conducted by Drs. S. T. Maynord and S. K.Knight, both of the Navigation Branch, NHD.

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 providing 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 Corps of Engineers (1994). The IPMP outlines engineering, economic, environmental, and public involvement plans.

The environmental plan identifies the following: significant environmental resources on the UMR-IWWS; impacts to threatened and endangered species; water quality; recreational resources; fisheries; mussels and other macroinvertebrates; waterfowl; aquatic and terrestrial macrophytes; and historic properties. The plan considers the system-wide impacts of navigation capacity increases, while assessing potential construction effects of improvement projects. The physical forces studies are part of the environmental plan.

Physical Force 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 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 the physical model.

g. Evaluate the feasibility of developing numerical solutions.

Scope of Report

The Clark s Ferry site was one of two sites used in the physical model to achieve the physical force objectives outlined above. The first experimental site was at Kampsville on the Illinois River and is referenced in this report. Specifically, the Clark s Ferry 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 Clark s Ferry study provides physical force data and an understanding for developing analytical models.

2 Prototype Clark s Ferry Section

Prototype Data Collection

The ISWS collected physical data on the hydrodynamic changes associated with tow and barge traffic movement on the Upper Mississippi River System. These data were collected from both the Illinois and Mississippi Rivers. The detailed report on the Clark s Ferry prototype experiments is given in Bhowmik, Soong, and Xia (1994).

The Clark s Ferry site is located at River Mile 468.2 in a relatively straight reach as shown in Figure 1. The prototype measurement site is in Pool 16, approximately 18 km (11 miles) upstream of the dam. Like many areas of the Upper Mississippi River, Clark s Ferry has submerged dikes located about 300 m apart. The dikes in the Clark s Ferry reach are angled upstream and located on the left descending bank. 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: (a) pre-passage, (b) actual passage, and (c) post-passage. Trip 1 field data were collected for seven consecutive days (May 16-22, 1991), and trip 2 for four consecutive days (October 17-20, 1991). Trip 1 was conducted during an intermediate flow period and trip 2 was conducted during a low flow. Figures 2 and 3 show cross sections for trips 1 and 2, respectively.

Prototype Instrumentation

Instrumentation used for data collection were: (a) five interocean current meters (model S4's), (b) two Marsh McBirney (MMB) 527 velocity meters, (c) six MMB511's, and (d) one wave gauge. The instruments were placed in the experimental 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 on Figure 4. Two MMB511's at 28.0 m from the right bank were mounted at vertical heights of 0.33 and 1.52 m above the river bottom. Three MMB511's at 43.0 m from the right bank were mounted at vertical heights of 0.36, 1.62, and 2.53 m above the riverbed. These meters were utilized to measure the variations of horizontal velocity components at various heights above the bed. The trip 1 wave gauge was 22.87 m from the right bank.

For trip 2, the velocity was measured at the locations shown in Figure 5. Three MMB511's at 41.1 m from the right bank were mounted at vertical heights of 0.51, 1.24, and 2.16 m above the riverbed. Two MMB511's at 68.6 m from the right bank were mounted at heights of 0.50 and 1.21 m above the bed. The trip 2 wave gauge was 18.3 m from the right bank.

Events

Discharges and stages were measured at different times during trip 1 and trip 2. Table 1 shows discharges, velocities, flow depths, and water surface elevations. The average water surface slope on this reach was 0.333 ft/mile (0.679 m/km) during trip 1 and 0.060 ft/mile (0.122 m/km) during trip 2. These slopes are determined by the daily stages at river mile 473.75 and river mile 468.2.

Trip 1 monitored 33 barge events and trip 2 monitored 28 barge events. Tables 2 and 3 (trips 1 and 2, respectively) give the name, date, draft, barge configuration, tow speed relative to earth, distance of the center line of the tow to the bank, and the tow direction for each event.

Data Filtering

Prototype and physical model data contain 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. Model to prototype comparisons must be based on tow-induced motion and not on extraneous components found in both the 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 interest of 0.01 Hz. Data were filtered at a limiting frequency of 0.02 Hz to make certain that tow information is not filtered. Fluctuations above a certain frequency needed to be filtered out because model velocity, prototype velocity, and wave meters had different frequency response. For example, the prototype electromagnetic velocity meters sampled at 1 Hz, whereas 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. Physical model data were filtered after scaling values to their prototype equivalent.

Tows Selected for Comparison to Physical Model

To achieve the first objective of the study, validation of the model, prototype events were selected to simulate in the physical model based on the following:

a. Number of meters functioning during experiments. Some events 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 loaded barges that were three wide by four or five long were used in the adjustment/calibration of the physical model. Events producing the maximum deviation from ambient were desired because small deviations from ambient conditions are difficult to extract from the ambient fluctuations found in the river. Also note that the 3-wide by 5-long, loaded tow is a standard configuration.

The eight tows initially selected were *JD Wofford*, *Pearl B.*, and *Donnie Ray Jr.(2)* from trip 1 and *Conti-Nan(1)*, *Kevin Michael*, *Deborah Valentine*, *Kathy Ellen*, and *Cooperative Ambassador* from trip 2.

Definitions

Terms used herein are defined as follows:

a. Left bank, or right of the thalweg, refers to a position 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. At Clark s Ferry the prototype data presented for the *Kevin Michael* suggest that ambient velocity should be measured over at least 5 min 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.

Ambient Velocity Fluctuations

The variation of the ambient velocity about the mean could establish the significance of tow-induced changes. For example, if natural stream velocity variations over periods of about 100 sec (100 sec based on duration of tow event) are ±5 cm/sec, one might conclude that tow-induced changes less than 5 cm/sec are no different than the natural variations. The filtered prototype data were analyzed for the maximum and minimum values over a 100-sec time interval prior to any tow effects. The relative ambient velocity variation shown in Table 4 was found by dividing the difference between maximum and minimum values by two and then dividing by the mean ambient velocity. Using an average value from Table 4 as a guide, natural velocity fluctuations (with periods similar to a tow event period) fluctuate about the mean ambient current an average of ±20 percent and ±15 percent for the trip 1 and trip 2 data, respectively. The unfiltered prototype data for the eight verification tows were analyzed for standard deviation as a percentage of the mean ambient velocity at the velocity probe (referred to as the coefficient of variation, *CV*). *CV* values for trip 1 and trip 2 were 0.13 and 0.17, respectively. Whether using the maximum fluctuation over the duration of a tow event or the standard deviation, fluctuations in the river probably mask any tow-induced return velocities that are less than about 15 percent of the mean 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 the variation in the prototype cross sections up- and downstream of the cross section measured by the ISWS. All barges selected for the prototype verification had a 2.74-m draft. The writers' experience suggests that the loaded barges' draft could have been ±0.15 m (6 in.). Tow alignment relative to the river axis could have been skewed by several degrees, resulting in an effective tow width greater than the sum of the barges' widths.

One of the greatest sources of uncertainty in the prototype data is extracting the tow impact from the ambient fluctuations in the river. This was not a problem for the trip 2 data, which were collected at low flow conditions. The relatively low return velocity (because of the large cross-sectional area) at Clark s Ferry in conjunction with the higher ambient velocities presents a problem for the trip 1 data. The changes induced by the tow in trip 1 are small and close to the magnitude of the natural velocity fluctuations having periods similar to the tow event. For example, the *JD Wofford* prototype data showed no significant change when the tow passed. The ambient velocity fluctuations from the filtered prototype data varied about an average of ±18.5 percent of the mean velocity, which in absolute terms was about ± 0.08 m/sec. The physical model data from *JD Wofford* showed that the average return velocity from the tow event was about 0.12 m/sec. The physical model value was difficult to determine because the physical model has variation about the mean of ± 0.06 m/sec. Since the tow change and the natural variations are close in magnitude for the trip 1 experiments, only the five tows from the trip 2 data will be used to calibrate the physical model.

To screen the prototype data for possible inconsistencies, the Schijf (1949) equation was used to compute the average return velocity and drawdown (Table 5). The Schijf equation provides a cross-sectional average return velocity whereas the prototype data are near bottom velocity data from which a maximum value was extracted. While these two velocities are different, their ratio should be relatively constant at a given meter, and meters physically close to each other should not vary significantly. Each tow event's prototype data 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 velocity/ Schijf average return velocity (Table 6). Velocity meters not close to the channel boundary would be expected to give similar values for a given tow event. Meters 999, 1000, 1131, 834, 151, 832, 642, 040, and 332 from trip 2 are not close to the boundary. One would also expect meters 999 and 1000 to give similar results because they are at the same lateral position and are located away from the channel perimeter. Meters 1131, 332, and 642 should also give the same response because of their similar positions. Based on Table 6, the only velocity meters in question are 151, 832, and 834 for the *Deborah Valentine* event because their values are less than the value from the Schijf equation whereas other events are greater. Meters 332 and 642 will not be used in the calibration/ verification because they are the same distance from the boundary and give the same result as meter 1131. Meter 1000 was omitted because it was at the same lateral position as 999 and because the physical model velocity meter at the position of 1000 malfunctioned for many of the experiments.

3 Physical Model Description

Similitude

Similarity of 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* is generally the vessel speed, *g* is the gravitational constant, and *D* is a characteristic length such as depth, draft, or vessel length. The equations of hydraulic similitude, based on the Froude criteria, expressed mathematical relations between the dimensions of hydraulic model and prototype quantities. General relations for transferring 1:30 scale model data to prototype equivalents are as follows:

Characteristic	Dimension[1]	Scale Relations Model: Prototype
Length	$L_r=L_p/L_m$	1:30
Area	$A_r=L_r^2$	1:900
Velocity	$V_r=L_r^{1/2}$	1:5.48
Time	$T_r=L_r^{1/2}$	1:5.48
Discharge	$Q_r=L_r^{5/2}$	1:4929.5
Roughness coefficient	$N_r=L_r^{1/6}$	1:1.76
Force	$F_r=L_r^3$	1:27000
Revolutions	$R_r=1/L_r^{1/2}$	5.48:1
[1] Dimensions are in terms of length.		

Viscous forces cannot be neglected in physical navigation models. If interest is in the forces on a vessel, 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. The following section on model calibration will show how this model dissimilarity is overcome.

Model Flume and Appurtenances

The navigation effects flume (Figures 6-8) 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 1:30-scale Clark's Ferry experimental reach. Marine plywood sections were installed to form the composite cross section representing 1.8 km of river conditions near mile 468.2 on the Mississippi River. The upstream end of the plywood section had curved entrance walls for a smooth transition into the experimental section. The data collected by the Mississippi River Hydrographic Survey in 1945 and in 1994 and data collected by the Illinois State Water Survey on 5/13/91 - 5/24/91 and 10/15/91 - 10/20/91 determined the composite cross section. This composite section was heavily weighted toward the ISWS data. The 1994 hydrographic survey was dike center-line elevations and some data on either side of the center line. One obvious difference between model and prototype was that the model was straight with a constant cross section whereas the prototype is rarely straight and has a variable cross section. The coordinates of the section used in the physical model are shown as follows:

Distance from Thalweg, m	Design Elevation, NGVD	As-built at Sta 63 NVGD
-370.4 (top of left bank)	572.7	572.7
-370.4	538.0	548.0
-329.0	537.5	538.5
-256.1	537.4	538.2
-182.9	536.7	536.9
-73.2	530.7	531.1
0.0 (Thalweg)	528.8	528.8
109.8	530.0	531.0

Distance from Thalweg, m	Design Elevation, NGVD	As-built at Sta 63 NVGD
182.9	533.7	534.3
248.5	540.1	540.5
259.1	554.5	554.5
259.1 (top of right bank)	572.7	572.7

The same cross section was used along the full length of the 61-m-long plywood section. The left bank dikes shown in Figures 6 and 7 were about 340 m long, extended from the thalweg elevation of 528.8 up to el 538.0 at 85.3 m from the thalweg. From there the dikes extended over to el 539.0 at the left bank. The dikes were angled with the channel center line at 78 deg and the side slopes were 1V:3H.

The towboat (Figure 9) is modeled after the Corps' Motor Vessel 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-diam propellers, and can be radio-controlled for self-propelled operation. The 1:30 scale plexiglass barges simulated 59.5 m long by 32 m wide by variable draft. Sets of barges were connected by C-clamps to form the desired tow configuration. All barges had boxed ends except for the lead barge, which had a raked end. Experiments were conducted with either a 45- or a 26-deg rake angle 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 10).

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 return velocity and drawdown adjacent to the vessel in these channel sizes. Analysis of the flow amount passing through the propellers shows that about 1 percent of the waterway is passing through the propellers, which suggests limited impact on far field effects. The Kampsville study (Maynord and Martin 1997) 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 those experiments without propeller operation. Propeller operation was used in the Clark's Ferry experiments as well. Propeller speed had to be estimated, since prototype data collected by ISWS did not include the applied power or rpm. The model towboat was calibrated for bollard push (push when speed = 0) against propeller speed and applied voltage on a DC power supply. An equation developed by Toutant (1982) was used to define the bollard push (*BP*) 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 = bollard push, pounds

hp = total 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.

Physical Model Instrumentation

The instrumentation was positioned laterally across the channel at approximately the midpoint of the plywood experimental section at station 63 (63 m from downstream end of concrete flume, Figure 6). A wave gauge and two-dimensional (2-D) and three-dimensional (3-D) acoustic Doppler velocimeters (ADV's) are shown in Figure 11.

Wave heights were measured by using two wave gauges placed in the near-shore zone on both channel sides. The wave gauges were capacitance type gauges manufactured at the U.S. Army Engineer Waterways Experiment Station and sampled at 25 Hz.

Velocity measurements were taken using eight ADV's (Kraus, Lohrmann, and Cabrera 1994). Four probes were 3-D downward-looking probes and four were 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 were in the water and the measured flow is relatively undisturbed by the presence of the probe. Data were available at an output rate of up to 25 Hz. The horizontal velocity range is ±2.5 m/sec and there is no zero-offset in the velocity output. Data can be collected as close as 5 mm from a solid boundary. The ADV's require that a certain size of particles be 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. Under low or no ambient velocity conditions, a problem occurs with settlement of the seed between experiments. Generally, ambient velocities were high enough to keep seed in suspension. Positive *x* velocities were downstream and positive *y* velocities were toward the left bank.

Observations of ambient conditions in the physical model were found to have significant variations similar to the prototype. These variations were attributed to pump variations, eddies in the approach and exit to the plywood experimental 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 with a frequency greater than 0.02 Hz.

4 Model Calibration

Introduction

In the model calibration, parameters in the physical model were adjusted until agreement was reached between the physical model and the ISWS prototype return velocity data from trip 2. The following four 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 equating the Froude number in a navigation model that is smaller than the prototype, the Reynolds number will be smaller in the model than in the prototype. The lesser Reynolds number in the model results in a faster growing boundary layer that causes the tow's effective size to be larger than the prototype. To quantify the boundary layer effects, the displacement thickness is computed, which 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

$$\delta_1 = \frac{0.292L}{[Log\,(R_L)]^{2.58}} \tag{4}$$

where

δ_1 = displacement thickness

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

R_L = plate Reynolds number defined as VL/ν

V = free stream velocity set equal to the 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)

ν = 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 Table 7. Model and prototype temperatures were 10 and 20 °C, respectively. In Table 7 all the dissimilarity between the boundary layer on the vessel and the channel perimeter have been lumped into conditions on the vessel. The draft correction can be computed from

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

where C is the experimentally determined draft correction coefficient, δ_{1m} is the displacement thickness in the model scaled to its prototype equivalent, and δ_{1p} is the displacement thickness in the prototype. The effective draft becomes

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

where d_e is the effective draft and d_a is the actual draft. The Ohio and Illinois River results in Table 7 show C values of 1.18 and 1.68, respectively. The previous study on Kampsville on the Illinois River (Maynord and Martin 1997) resulted in an average C of 1.72 based on six tow events. These values will be compared to the required C for the Clark's Ferry experiments.

b. The second model/prototype source of scale effects results from flume length considerations. When starting the physical model from rest, flume length limitations dictate a faster acceleration than in the prototype. The acceleration for the physical model is shown in Figure 12. 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 is initiated much farther from the measurement point. The "wave-maker" in the prototype (the barges) generally is powered by about a 3,730-kW (5,000-hp) towboat whereas the towing carriage in the model has a scaled power of up to 112,000 kW (150,000 hp). Stated differently, the inertia of the vessel and the water in front of the vessel are significant compared to the power of the prototype tow and the resulting acceleration is low. The inertial forces in the model are small 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 endwall and returns to the experimental section. Once this happens, the physical model data are not valid. Wave suppression devices are not effective for the long-period waves set up by vessel startup and are difficult to employ when flowing water is part of the experimental flume.

d. The fourth area involves the unknown parameters from the prototype data such as the alignment (skew) of the tow, variations in the prototype cross section, and effects of the shape, particularly the bow, of the prototype barges. Uncertainties in both model and prototype measurements of speed, draft, tow position, etc., all contribute to differences between model and prototype.

The calibration process will show that the physical model reproduces the most significant tow displacement effects, the maximum return velocity. As stated earlier, the calibration will be based on the low-flow trip 2 tows because of the difficulty of extracting tow effects from the higher ambient velocities of trip 1. Since trip 2 prototype data did not have a recording wave gauge, calibration will be based on comparisons with return velocity only.

Verification

The Clark's Ferry verification process compared maximum return velocity for the tow events and developed rules for adjusting the model that resulted in agreement between model and prototype. All five tows from trip 2 were three barges wide, loaded to 2.74 m, and either four or five barges long. The ambient depth-averaged velocity distribution in the physical model for the trip 2 Pool 546.0 conditions is shown in Figure 13. For each of the 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 (where N is the number of experiments). For the five replicate experiments in Clark's Ferry, Chauvenet's criterion specifies that data were discarded only if they departed from the mean by more that $1.65S_x$ 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 initial experiments were conducted with all physical model parameters scaled to the previously presented Froudian criteria, which requires geometric similarity between model and prototype. Results comparing maximum return velocity for the *Kevin Michael*, *Kathy Ellen*, *Deborah Valentine*, *Cooperative Ambassador*, and *Conti-Nan(1)* are shown in Table 8. The physical model overestimates return velocity for most velocity meters when using geometric scaling and the Froude criteria. This was the expected result based on the boundary layer concerns presented above. 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 was found with a 2.13-m draft on all barges. Results for the *Kevin Michael*, *Kathy Ellen*, and *Deborah Valentine* are presented in Tables 9, 10, and 11. This same draft correction was used to simulate the *Cooperative Ambassador* and *Conti-Nan(1)*. Results are shown in Tables 12 and 13.

Plots of prototype return velocity versus physical model return velocity are shown in Figures 14 and 15 for the 2.74- and 2.13-m drafts, respectively. Filtered time histories for the *Coop Ambassador* prototype and physical model data using the corrected draft are shown in Figures 16 to 25. Both prototype and model data demonstrate the difficulty in extracting changes caused by the tow from ambient fluctuations.

Draft Correction

In order to obtain an effective draft of 2.74 m, the actual draft is adjusted by the draft correction. The draft correction used for the five *Trip 2* calibration/verification experiments was 2.74 m - 2.13 m = 0.61 m and is compared in Table 14 to the difference in displacement thickness for the tows used in the verification process. Omitting the *Kevin Michael*, which was the only four-barge-long tow, the verification experiments yield an average C for Equation 2 of 1.82, which is similar to the value determined in both previous experiments for the Illinois River (shown on Table 7 and in Maynord and Martin (1997)). A draft correction coefficient C of 1.72 will be used to compute D_C (Equation 5) and effective draft d_e (Equation 6) in the Clark's Ferry experiments.

These results show that the actual physical model draft along with the draft correction can be used to simulate the typical 2.74-m draft of loaded barges. However, the effective draft of an unloaded barge (about 0.6 m) cannot be obtained in the physical model. With a draft correction of approximately 0.61 m for five-barge-long tows, the minimum effective draft that can be obtained in the physical model is about 1.21 m at the 1:30 scale used herein.

5 Production Experiments and Analysis

Experiments evaluated the return velocity and drawdown for 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 lateral and vertical positions of the velocity and wave gauges in the model and prototype experiments. The vertical position of the velocity gauges in the production experiments was an issue that had to be resolved. Analysis of vertical velocity profile data (presented subsequently) shows that if the meter is too close to the bed, the maximum change resulting from tow passage may not be captured because the friction on the channel bottom retards the near-bottom velocities. The physical forces study also compared physical model results to a depth-averaged numerical model, HIVEL-2D (Stockstill, Martin, and Berger 1995). With the exception of the vertical velocity profile and the near dike experiments, all velocities in the production runs were measured at 60 percent of the local depth below the water surface. This position is standard for riverine surveys and ensured that the maximum change produced by the tow will be measured and could be directly compared to HIVEL-2D. The following paragraphs detail each experimental series.

Experimental Series 1—Pool Elevation 546.0

Experimental series 1 (pool 546.0), 5 (pool 551.5), and 7(pool 572.7) were used to evaluate the effects of a range of blockage ratios (channel area/vessel area) on the far-field effects of navigation. Twenty-four experiments (three replicates for each experiment) were conducted at a pool elevation of 546.0, with a discharge of 690 cms, using three-wide by five-long barges, and various tow speeds, directions, lateral positions, and drafts. The cross section is shown in Figure 26 and experimental conditions are summarized in Table 15. All experiments in this series were conducted with a 45-deg rake angle. Ambient velocity, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 16 to 39. To obtain a representative data set for the vector plots shown in Figures 27 to 50, the three replicate experiments were averaged and one was selected as the most representative of the mean of the three experiments. The vector plots are not based on one tow position with many different velocity meter positions as might be inferred from the vector plots. The vector plots were based on a single velocity meter position (Sta 63) and many different boat positions. Evaluating the vector plots is straightforward when the cross section is constant as in the case of the Kampsville study (Maynord and Martin 1997) where no dikes were present. When the cross section is variable, such as in the presence of the dikes at Clark's Ferry, the vector plots must be viewed with caution because the tow is a different distance from the dikes at each point in time. Because the vector plots can only provide a finite number of vectors, the maximum value was not always indicated but is provided in the tables. Table 40 summarizes the position of the velocity probes used in each experiment.

Experimental Series 2—Tow Length Experiments

Sixteen experiments (three replicates each) were conducted to determine the influence of the length of the barges on the navigation-induced forces. A pool elevation of 546.0 and a discharge of 690 cms was used with loaded barges, upbound and downbound, one sailing line, and variable boat speeds. Experimental conditions are summarized in Table 41. Ambient velocity, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 42 to 57. Vector plots for each representative experiment selected based on the mean of the three replicates are shown in Figures 51 to 66. Because the vector plots can only provide a finite number of vectors, the maximum value was not always indicated but is provided in the tables. Maximum return velocity for all four vessel speeds are plotted in Figures 67 and 68. Table 58 summarizes the position of the velocity probes used in each experiment. Plots of maximum drawdown versus vessel length for two speeds and left and right bank are shown in Figures 69 and 70. Both return velocity and drawdown in Figures 67 to 70 are normalized using the computed Schijf average return velocity or drawdown using the vessel speed relative to the water and the effective draft. The plots of return velocity show that the one- and two-barge-long tows tend to have high return velocity near the vessel and low return velocity away from the vessel compared to the longer vessels. Return velocity for the three-barge or longer tows are similar in magnitude. Drawdown, which was measured near the bank, was similar in magnitude for the four- and five-barge-long tows. Using vessel length to channel width as the pertinent ratio, results suggest that the return velocity and drawdown become constant for the four-barge-long vessels, which is L/B = 238/615 = 0.39. Additional work is being conducted with the numerical model HIVEL (Stockstill, Martin, and Berger 1975) to evaluate vessel length effects.

Experimental Series 3—Rake Experiments

Four experiments (three replicates each) were conducted to determine the influence of the rake configuration on the navigation-induced forces. The rake configuration refers to the shape of the bow of the lead barges. All experiments conducted herein were conducted with boxed ends at all connections between barges. Previous experiments by Latorre and Ashcroft (1981) have shown a significant increase in the resistance of barges with increasing rake angle for a vessel Froude number (based on vessel length) of 0.1. At low vessel Froude numbers that are typical of UMRS tows (about 0.06), results from Latorre and Ashcroft show a small effect of tow configuration on barge resistance, but it is not known if this low Froude number effect also applies to rake angle. All previous 546.0 pool experiments were conducted with a 45-deg rake angle. Data were collected and evaluated for experiments run at variable speeds with a bow rake angle of 26 deg. A tow configuration of three wide by five long was used in these experiments. The 26-deg rake was created as a plexiglass extension to be added to the tow with the 45-deg rake. This increased the length of the tow by 7 m (28 cm in model). The experiments were conducted with a flow of 690 cms and a water surface elevation of 546.0. All experimental conditions were identical to the previous pool 546.0 experiments except for the rake angle. Experimental conditions are summarized in Table 59. Impact, ambient, and maximum return velocity and drawdown below normal water level for each experiment are shown in Tables 60 to 63. Vector plots for each representative experiment are shown in Figures 71 to 74. Because the vector plots can only provide a finite number of vectors, the maximum value was not always indicated but is provided in the tables. Plots of return velocity for the two rake angles and four vessel speeds are shown in Figures 75 and 76. The drawdown comparison for the 45-deg versus the 26-deg rake angle was inconclusive because of the scatter in the data. The difference between the return velocity caused by the 45-deg rake and the 26-deg rake is negligible. All experiments hereafter were done with a 26-deg rake.

Experimental Series 4—Vertical Velocity Distribution Experiments

Six experiments (three replicates each) were conducted to determine the vertical distribution of velocity changes induced by the tow. Experiments were conducted at a pool elevation of 546.0, with a discharge of 690 cms, three-wide by five-long barges, barges on thalweg, and loaded barges. Experimental conditions are shown in Table 64. Experiment LCVUCD (Table 65) shows the vertical distribution for an upbound tow and Experiment LCVDCD (Table 66) shows the vertical distribution for a downbound tow, 34 m left of the thalweg. Experiment LCVUBE (Table 67) shows the vertical distribution for an upbound tow and Experiment LCVDBE (Table 68) shows the vertical distribution for a downbound tow, 172 m left of the thalweg. Experiment LCVUAF (Table 69) shows the distribution for an upbound tow and Experiment LCVDAF (Table 70) shows the vertical distribution for a downbound tow, 318 m left of the thalweg. Results show a near uniform change in return velocity from 20 to 80 percent of the depth of flow from the bed. Results from Kampsville (Maynord and Martin 1997) show an upper zone where the return velocity is uniform and a lower zone where the near-bed velocity is retarded by the boundary resistance. The dividing line between the two zones was somewhere between 0.3 and 1.1 m above the bed for the depths used in the experiments.

Experimental Series 5—Pool Elevation 551.5

Twelve experiments (three replicates for each experiment) were conducted at a pool elevation of 551.5, with a discharge of 1,285 cms, a three-wide by five-long barge configuration, and loaded barges. The cross section is shown in Figure 77 and experimental conditions are summarized in Table 71. Ambient, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each test are shown in Tables 72 to 83. The ambient velocity distribution is shown in Figure 78. The three replicate tests were averaged and one of the three was selected as being most representative of the mean of the three tests. Vector plots for each representative test are shown in Figures 79 to 90. Because the vector plots can only provide a finite number of vectors, the maximum value was not always indicated but is provided in the tables. Table 84 summarizes the position of the velocity probes used in each test.

Experimental Series 6—Dike Experiments

Pool 551.5 dike experiments

Four experiments (three replicates each) were conducted at a pool elevation of 551.5, discharge of 1,285 cms, three-wide by five-long barge configuration, and loaded barges. All ADV's were moved from their normal position at the 63-m station downstream to the 59-m mark (keeping the lateral locations the same). Two probes were positioned directly on top of the dike and slightly upstream of 59 m. A plan view is shown in Figure 91. Experimental conditions are shown in Table 85. Impact, ambient and maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 86 to 89. Experiment H59D29 can be compared to HCD292, experiment H59D47 can be compared to HCD477, experiment H59U22 can be compared to HCU228, and experiment H59U41 can be compared to HCU416 as shown in Figure 92. Velocity for an upbound tow going 4.16 m/s is shown in Figures 93 and 94 for probes 3 and 4. Velocity for a downbound tow going 4.77 m/sec is shown in Figures 95 and 96 for probes 3 and 4. The dike velocities are greater for probe 3, which is the probe located on the part of the dike with the highest elevation. All other probes had a consistent velocity from the 63-m mark to the 59-m mark. Shapes of all velocities at the 59-m mark were consistent with those at the 63-m mark.

Pool 546.0 dike experiments

Detailed velocities were measured around the Clark's Ferry dike at the 70-m mark (first dike upstream of the 63-m location) and a generic dike having a different shape that was remolded at the 70-m mark. Both dikes had Clark's Ferry dikes upstream and downstream. Five velocity meters were placed around the base of the dike and one was positioned on the top of the dike. The instruments were placed 0.6 m off the bottom of the channel and off the top of the dike (Figure 97). All experiments were conducted with six dikes placed in the model extending from the left bank to the thalweg at an angle of 78 deg upstream and spaced 304.7 m apart. The Clark's Ferry dike shape, referred to as the low dike, had a crest elevation of 539.0 on the left descending bank, to 538.0 at 85.3 m from the thalweg, to 528.8 on the thalweg. Each low dike was molded out of concrete and had a 3.0-m top width and a 1 on 3 slope down to the base at the channel bottom (see Figure 98). The generic dike shape, referred to as the high dike, had a constant crest elevation of 539.0, extending from the left bank to a point 4.7 m left of the thalweg. This elevation represents 60 percent of the total water depth at the thalweg. From this point the dike went down on a 1 on 1.5 slope to the channel bottom, elevation 528.8 (Figure 99). The high dike was formed by covering the low dike with riprap. All experiments were conducted with a pool elevation of 546.0 and a discharge of 690 cms, which resulted in an average channel velocity of 0.32 m/sec. Tow speeds relative to the ground during dike experiments were 3.82 m/sec for the downbound tow and 3.18 m/sec for the upbound tow, resulting in the same tow speed through the water for both tow directions. The tow had a three-wide by five-long barge configuration, an effective draft of 2.74 m, and a 26-deg rake on the lead barges. The sailing line was parallel to the ends of the dikes, 120 m right of the thalweg. During the experiment, velocities and direction of flow were determined for each probe location at various points in time. These points were determined by the position of the tow and its relationship to the dike. Data were recorded at eight points in time during each event. Each set of data was labeled with the position of the tow for both downbound (Figure100) and upbound runs (Figure 101). Velocities during tow passage are shown in Figures 102 to 105.

Experimental Series 7—Open River Experiment, Pool 572.7

Six experiments (three replicates of each) were conducted at a pool elevation of 572.7, with a three-wide by five-long barge configuration, and loaded barges. The open river tests required installation of vertical walls along the Clark's Ferry channel banks to simulate the larger open river depths. The Clark's Ferry water surface width is similar to the open river reach. A relatively low ambient velocity was used in the open river model tests to facilitate extraction of the tow effects, which were low because of the large section, from the ambient fluctuations. The cross section is shown in Figure 106 and experimental conditions are summarized in Table 90. Ambient, maximum impact velocity, maximum return velocity, and drawdown below normal water level for each experiment are shown in Tables 91 to 96. Velocity meters were positioned as in the Pool 551.5 experiments. Vector plots are shown in Figures 107 to 112.

Experimental Series 8—Drawdown Distribution

Detailed drawdown data were taken at six positions across the width of the channel. Results for Pool 546.0 with flow are shown in Tables 65 through 70. Drawdown data without flow were conducted at the higher pool elevations to improve the extraction of the relatively low drawdown magnitude from the ambient fluctuations. Experimental conditions for pool elevation 551.5 are shown in Table 97. Results for pool 551.5 with no flow are shown in Tables 98 to 100. Experimental conditions for pool elevation 572.7 are shown in Table 101. Results for pool elevation 572.7 are shown in Tables 102 to 104.

6 Summary and Conclusions

Ambient flow conditions in both the Clark's Ferry physical model and the prototype had significant variations, which made extraction of the tow effects difficult. This was less of a problem in the previous Kampsville study (Maynord and Martin 1997) because the cross section was smaller, which caused the return velocity and drawdown to be larger. A fast Fourier transform filtered information above 0.02 Hz, but ambient fluctuations were present at the same frequency as the tow impact. Analysis of the Clark's Ferry prototype data show that the ambient fluctuations having about the same period as the tow impact average 15 percent of the mean ambient velocity.

Prototype return velocity was compared to physical model return velocity and 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 which was 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.

One of the primary purposes of this report was to provide data for a wide range of conditions. Return velocity and drawdown data were collected for several pool elevations, tow speeds, and upbound versus downbound vessels.

The vertical profile of return velocity 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 the boundary layer growth can inhibit maximum return velocity and an upper zone in which the return velocity is nearly uniform. From the Kampsville study (Maynord and Martin 1997), the lower zone is generally confined to the lower 0.3 to 1.0 m of the depth and velocities are less in the lower zone. Measurements reported herein show a uniform velocity change at and above 20 percent of the depth from the bottom, which was the lowest position measured.

Tow length effects showed that the return velocity for tows one and two barges long (10 and 20 percent of the channel width) is high near the tow and low away from the vessel, compared to longer tows. Return velocity for tows three barges long (29 percent of channel width), is similar in magnitude to tows four or five barges long. Drawdown for tows four barges long (39 percent of channel width), is similar in magnitude to five-barge-long tows.

Return velocity and drawdown were compared for a vessel having a 26-deg and a 45-deg rake angle. Return velocity was similar for both angles. Scatter in the drawdown data for the two angles prevented a conclusion.

Velocity measurements near dikes were conducted for both upbound and downbound tows and show the change in velocity that occurs during tow passage.

Open river experiments were conducted by adding vertical walls along the banks of the Clark's Ferry channel to simulate the deeper depths found in the open river section. Return velocity and drawdown were measured with a low ambient velocity to allow extraction of the tow effect from ambient fluctuations. Use of typical open river ambient velocities would have made it difficult to extract return velocity and drawdown.

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Table 1
Water Discharge, Average Velocity, Average Depth, and Water Surface Elevation for the Clark's Ferry Site

Date	Qw cms	V m/s	D m	Water Surface Elevation, NGVD
Trip 1				
05/14/91	2,351	0.83	4.41	--
05/17/91	--	--	--	548.83
05/19/91	--	--	--	549.35
05/20/91	--	--	--	549.47
05/21/91	--	--	--	549.61
05/22/91	2,072	0.78	4.18	549.64
05/23/91	2,428	0.85	4.36	--
Trip 2				
10/17/91 - 10/20/91	--	--	--	546.0
10/19/91	673	0.32	3.40	546.0

Table 2
Traffic Characteristics, Trip 1

Date	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
5/16	*C. W. Rushing*(1)	1,200	1	n	32.3	10.4	2	1x2	Cargo	2.74	2.02	325	Up
	Donnie Ray Jr (1)	5,600	2	y	53.7	12.2	15	3x5	Cargo	2.66	3.35	250	Down
	Samantha(1)	1,000	2	n	18.2	6.7	1	1x1	Coal	2.74	3.66	270	Down
	Samantha(2)	1,000	2	n	18.2	6.7	0			2.74	2.61	270	Up
5/17	*Quad City Queen*											250	Down
	C.W. Rushing(2)	1,200	1	n	32.3	10.4	1	1x1	Cargo	1.52	2.02	270	Down
	Jemco Towing						4	2x2	Cargo	2.74	2.97	275	Up
	T.S. Kunsman	4,200	2	n	45.7	10.7	12	3x4	Cargo	2.74	2.54	370	Down
	Dell Butcher	5,000	2	y	51.8	12.2	10	2x5	Cargo	2.74	2.16	270	Up
5/18	*William Earthman*	4,100	2	y	43.9	10.7	4	2x2	Chemical	1.52	2.54		Up
	Lady Lone Star	760	2	n	23.8	7.3	0			2.74	2.98	250	Up
5/19	*Pearl B.*	4,400	2	n	42.7	9.1	12	3x4	Cargo	2.74	2.87	250	Down
	Conti-Afton	4,200	2	n	42.7	13.4	15	3x5	Cargo	2.74	3.88	300	Down
	Jack D. Wofford	5,000	2	y	51.8	12.2	12	3x4	Cargo	2.74	3.70	300	Down
	Creole Belle	3,900	2	n	39.6	11.3	16	3x5+1	Empty	0.61	2.03	225	Up
5/20	*Donnie Ray Jr*(2)	5,600	2	y	53.7	12.2	15	3x5	Cargo	2.74	3.00	225	Up
	Sunflower	825	3	n	16.8	6.7	1	1x1	Cargo	0.61	5.59	250	Down
	America Beauty(1)	5,000	2	y	51.8	13.7	15	3x5	Cargo	0.61	3.23	275	Up
5/21	*Sierra Dawn*	5,000	2	y	50.0	12.2	12	3x4	Cargo	2.64	3.33	270	Down

(Continued)

Table 2 (Concluded)													
Date	**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**
	Cindy Erickson	3,900	2	n	36.6	11.6	15	3x5	Cargo	0.61	2.37	250	Up
	Frank H. Peavey	3,800	2	n	42.7	11.6	12	3x4	Cargo	2.74	3.28	275	Down
	Helen M. Clements	5,100	3	n	42.7	13.7	12	3x4	Cargo	0.61	2.51	260	Up
	Sunflowers (2)	825	3	n	16.8	6.7	1	1x1	Cargo	1.52	5.60	225	Down
	Dell Butcher(2)	5,000	2	y	51.8	12.2	12	3x4	Cargo	2.74	3.24	300	Down
	Hornet	4,300	2	n	44.5	11.6	12	3x4	Cargo	0.61	2.97	280	Up
	Volunteer State	4,320	2	n	45.7	14.6	15	3x5	Cargo	0.61	3.51	250	Up
	Enterprise Star						15	3x5	Cargo	2.74	3.51	275	Down
5/22	*Edward J Hancock*	4,320	2	y	45.1	10.4	13	3x4+1	Cargo	0.61	1.83	250	Up
	Joe/Nut	5,600	4	n	49.3	13.7	1			2.74	2.74	300	Up
	Starfire	3,200	2	n	47.6	10.7	10	1+3x3	Cargo	1.89	1.98	250	Up
	Conti-Karla	3,060	2	n	34.7	10.5	16	3x5+1	Cargo	0.74	2.00	275	Up
	America Beauty(2)	5,000	2	y	51.8	13.7	3	1+2x1	Cargo	1.52	5.18	300	Down

Table 3
Traffic Characteristics for Trip 2

Date	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
10/17	*C.W. Rushing*	1,200	1	n	32.3	10.4	2	2x1	Hopper	1.52	3.98	220	Down
	Evey-T	4,300	2	n	42.7	11.6	13	1+3x4	Empty	0.61	2.41	260	Up
	Sunflower(1)	825	3	n	16.8	6.7	1	1x1	Empty	0.61	4.25	185	Down
	Evelyn C.	2,200	2	n	25.9	10.7	5	1+2x2	Corps work barge	2.74	1.92	220	Down
	Sunflower(2)	825	3	n	16.8	6.7	1	1x1	Hopper	2.74	3.13	210	Up
	Conti-Nan(1)			n			15	3x5	Hopper	2.74	2.41	260	Down
	Night 1			n			1	1x1	Work	2.74		250	Up
	Night 2			n			1	1x1	Hopper	1.52	4.25	230	Up
	Night 3			n			6	3x2	Work	2.74		230	Down
10/18	*Lady Lone Star*	760	2	n	23.8	7.3	1	1x1	Coal	2.74	2.38	200	Down
	Lady Lone Star	760	2	n	23.8	7.3	0			2.74	3.40	260	Up
	Kevin Michael	5,600	2	n	54.0	12.8	12	3x4	Closed hopper	2.74	2.31	245	Down
	Deborah Valentine	4,300	2	y	47.0	12.2	15	3x5	Closed hopper	2.74	2.14	210	Down
	Volunteer State	4,320	2	y	45.7	14.6	4	2x2	Closed hopper	2.74	4.25	185	Down
	Sunflower(3)	825	3	n	16.8	6.7	1	1x1	Closed hopper	0.61	4.25	230	Down
	Frank Stegbauer	3,200	2	n	39.6	10.7	3	1+2x1	Empty chemical	0.61	2.57	185	Down

(Continued)

Table 3 (Concluded)

Date	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
10/18	*Joshua*	1,000	2	n	18.3	6.7	1	1x1	Coal	2.74	2.48	240	Down
10/19	*Kathy Ellen*	3,800	2	n	46.0	10.7	15	3x5	Closed hopper	2.74	1.92	195	Down
	Jack Bullard	5,600	2	y	44.2	14.6	14	2x1+3x4	Hopper	2.74	2.38	215	Up
	Marc	1,000	2	n	18.3	6.7	4	2x2	Coal	2.74	2.70	205	Down
	Conti-Nan(2)	4,200	2	n	42.7	13.4	6	3x2	Empty chemical	0.61	2.84	185	Up
	Cristina Ecstein	3,200	2	n	35.4	10.5	8	3x2+2x1	Empty	0.61	2.88	215	Up
	Coast Guard 65504	600	2	n	19.8	6.4	1	1x1	Buoy tender/ work	2.74	4.95	225	Down
	Prairie Dawn	5,000	2	y	50.0	12.2	11	3x3+2	Empty	0.61	3.40	190	Up
10/20	*Noname*						2	2x1	Chemical	2.74	2.63	230	Down
	Coop Ambassador	3,800	2	y	48.8	12.2	15	3x5	Closed hopper	2.74	2.22	190	Down
	Yazoo City	4,300	2	n	44.8	10.7	14	2+3x4	Closed hopper		2.09	230	Up
	George W. Banta	2,400	2	n	30.2	9.1	3	1x3	Petroleum	2.74	2.00	200	Up

Table 4
Relative Ambient Velocity Variation

	Meter										
Tow	**1001**	**1130**	**1131**	**998**	**999**	**1000**	**151**	**834**	**832**	**332**	**642**
Trip 1 (Avg. Channel Velocity 0.78 - 0.85 m/sec)											
JD Wofford	21 (0.22)	22 (0.41)	11 (0.51)	18 (0.40)	10 (0.62)	9 (0.68)	25 (0.24)	25 (0.39)	29 (0.30)	19 (0.52)	15 (0.51)
Pearl B.	* (*)	* (*)	* (*)	* (*)	* (*)	* (*)	29 (0.15)	34 (0.25)	33 (0.21)	20 (0.50)	15 (0.51)
Donnie Ray	26 (0.21)	18 (0.41)	14 (0.49)	23 (0.39)	14 (0.61)	13 (0.67)	* (*)	* (*)	* (*)	23 (0.47)	17 (0.48)
Avg.	24	20	13	21	12	11	29	30	31	21	16
Trip 2 (Avg. Channel Velocity 0.32 m/sec)											
Conti-Nan	14 (0.12)	18 (0.25)	14 (0.28)	18 (0.18)	9 (0.23)	13 (0.25)	11 (0.33)	* (*)	18 (0.30)	20 (0.26)	19 (0.25)
K Michael	26 (0.09)	20 (0.22)	17 (0.25)	16 (0.16)	11 (0.22)	7 (0.24)	14 (0.30)	14 (0.41)	10 (0.27)	15 (0.23)	20 (0.23)
Valentine	19 (0.10)	13 (0.23)	15 (0.26)	16 (0.12)	13 (0.21)	9 (0.23)	* (*)	* (*)	* (*)	13 (0.23)	13 (0.23)
K Ellen	24 (0.11)	14 (0.24)	11 (0.27)	18 (0.16)	10 (0.22)	11 (0.25)	13 (0.32)	14 (0.41)	16 (0.27)	19 (0.24)	17 (0.24)
Ambassador	22 (0.11)	21 (0.24)	14 (0.27)	14 (0.19)	14 (0.22)	8 (0.24)	11 (0.31)	16 (0.39)	17 (0.28)	17 (0.23)	30 (0.25)
Avg.	21	17	14	16	11	10	12	15	15	17	20

Note: (Maximum - Minimum)/(2 * Ambient at Velocity Probe) * 100
(Ambient at Velocity Probe, m/sec)

Table 5
Schijf Return Velocity and Drawdown for Trip 2 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	Schijf Drawdown m
Conti-Nan (3x5)	Down	2.09	2,212	613	0.100	0.022
K Michael (3x4)	Down	1.99	2,212	613	0.094	0.019
Valentine (3x5)	Down	1.82	2,212	613	0.084	0.016
K Ellen (3x5)	Down	1.60	2,212	613	0.072	0.012
Ambassador (3x5)	Down	1.90	2,212	613	0.088	0.018

Table 6
Maximum Return Velocity/Schijf Average Return Velocity for Trip 2 Verification Tows

	Meter								
Tow	832	151	834	1131	999	1000	332	642	040
Conti-Nan	1.47	1.39	--	1.50	1.40	1.26	1.47	1.68	*
K Michael	1.42	1.22	1.28	1.36	1.13	1.22	1.31	1.10	*
Valentine	0.65	0.49	0.73	1.30	1.22	1.11	1.31	1.35	*
K Ellen	1.05	1.21	1.98	1.76	1.98	1.49	1.59	0.88	*
Ambassador	1.08	1.43	1.55	1.27	1.22	1.09	1.10	1.18	*

Table 7
Draft Correction (unpublished data)

River	Vessel Speed m/sec	Return Velocity m/sec	DC m	δ_{lm} m	δ_{lp} m	$\delta_{lm} - \delta_{lp}$ m	$C = \frac{D_c}{\delta_{lm} - \delta_{lp}}$
Ohio	3.30	0.10	0.46	0.70	0.31	0.39	1.18
Illinois	2.77	0.19	0.69	0.72	0.31	0.41	1.68

δ_{lp} = Prototype displacement thickness

δ_{lm} = Model displacement thickness * 37.5

Table 8
Verification Data Using Geometrically Similar Froude Model, *Kevin Michael, Conti-Nan* (1), *Deborah Valentine, Kathy Ellen*, and *Coop Ambassador*

Probe Number	Physical Model, Return Velocity[1] m/sec	Pototype Ambient Velocity, m/sec	Prototype Maximum Velocity, m/sec	Prototype Return Velocity[1] m/sec
Kevin Michael				
832	0.167	0.269	0.1356	0.1334
151	0.1806	0.301	0.1862	0.1148
834	0.0804	0.418	0.2977	0.1203
1131	0.1213	0.252	0.1238	0.1282
999	0.134	0.22	0.114	0.106
***Conti-Nan* (1)**				
832	0.1622	0.2980	0.1510	0.1470
151	0.1522	0.3280	0.1892	0.1388
834	0.0440	---	---	----
1131	0.1343	0.2920	0.1420	0.1500
999	0.1460	0.2320	0.0920	0.1400
Deborah Valentine				
832	0.1227	0.2670	0.2121	--
151	0.1344	0.2980	0.2572	--
834	0.0756	0.4170	0.3554	--
1131	0.1596	0.2620	0.1526	0.1094
999	0.1527	0.2180	0.1158	0.1022
Kathy Ellen				
832	0.0889	0.2730	0.1973	0.0757
151	0.1047	0.3190	0.2319	0.0871
834	0.1312	0.4080	0.2654	0.1426
1131	0.1341	0.2840	0.1573	0.1267
999	0.1254	0.2320	0.0892	0.1428
Coop Ambassador				
832	0.1228	0.2940	0.1988	0.0952
151	0.1273	0.3010	0.1752	0.1258
834	0.0827	0.4080	0.2720	0.1360
1131	0.1562	0.2800	0.1679	0.1121
999	0.1831	0.2280	0.1204	0.1076

[1] Ambient - maximum velocity.

Table 9
Verification Data, *Kevin Michael,* Barge Draft 2.13 m

Probe Number	Physical Model Velocity, m/sec, Replicate A	B	C	D	E	AVG	Prototype Velocity m/sec	Return Velocity, m/sec[1] Physical Model	Prototype
Ambient Velocity									
832	0.2698	0.2780	0.2847	0.2957	0.2865	0.2829	0.269	0.1363	0.1334
151	0.3072	0.2997	0.3054	0.3015	0.3091	0.3046	0.301	0.1409	0.1148
834	------	------	------	------	------	------	0.418	---	0.1203
1131	0.314	0.3113	0.3060	0.3232	0.3222	0.3153	0.252	0.0817	0.1282
999	0.3244	0.3043	0.3212	0.3088	0.3162	0.3150	0.220	0.0939	0.1060
Minimum Velocity									
832	0.1494	0.1465	0.1632	0.1475	0.1262	0.1466	0.1356		
151	0.1708	0.1650	0.1639	0.1642	0.1546	0.1637	0.1862		
834	------	------	------	------	------	------	0.297		
1131	0.2121	0.2333	0.2260	0.2419	0.2546	0.2336	0.1238		
999	0.2211	0.2254	0.2143	0.2348	0.2097	0.2211	0.1140		
Physical Model Drawdown, cm, for Replicate									
	A	**B**	**C**	**D**	**E**	**AVG**		**Prototype Drawdown, cm**	
	3.25	3.21	3.22	3.20	3.14	3.204		-----	

[1] Ambient - minimum velocity.

Table 10
Verification Data, *Kathy Ellen,* Barge Draft 2.13 m

Probe Number	Physical Model Velocity, m/sec, Replicate						Prototype Velocity m/sec	Return Velocity, m/sec[1]	
	A	B	C	D	E	AVG		Physical Model	Prototype
Ambient Velocity									
832	0.2789	0.2938	0.2761	0.2780	0.2730	0.2800	0.2730	0.0905	0.0757
151	0.3093	0.2903	0.3047	0.2912	0.3059	0.3003	0.3190	0.1062	0.0871
834	0.3784	0.3944	0.3801	0.3662	0.3773	0.3793	0.4080	0.1417	0.126
1131	0.3186	0.3304	0.3160	0.3192	0.3159	0.3200	0.2840	0.1111	0.1267
999	0.3222	0.3042	0.3219	0.3173	0.3058	0.3143	0.2320	0.1155	0.1428
1000							0.2600		0.1072
Minimum Velocity									
832	0.1788	0.1905	0.1760	0.1975	0.2048	0.1895	0.1973		
151	0.1948	0.2097	0.1795	0.1819	0.2048	0.1941	0.2319		
834	0.2193	0.2494	0.2279	0.2413	0.2503	0.2376	0.2654		
1131	0.1918	0.2161	0.2012	0.2055	0.2300	0.2089	0.1573		
999	0.1831	0.2043	0.1992	0.2118	0.1958	0.1988	0.0892		
1000							0.1528		
Physical Model Drawdown, cm, for Replicate									
	A	**B**	**C**	**D**	**E**	**AVG**		**Prototype Drawdown, cm**	
	1.80	1.62	1.49	2.04	1.83	1.756		------	

[1] Ambient - minimum velocity.

Table 11
Verification Data, *Deborah Valentine,* Barge Draft 2.13 m

Probe Number	Physical Model Velocity, m/sec, Replicate A	B	C	D	E	AVG	Prototype Velocity m/sec	Return Velocity, m/sec[1] Physical Model	Prototype
Ambient Velocity									
832	0.2972	0.2973	0.2857	0.2750	0.2646	0.2840	0.2670	0.1067	---
151	0.2810	0.2895	0.2910	0.2886	0.3073	0.2915	0.2980	0.0985	---
834	0.3620	0.3445	0.3568	0.3534	0.3540	0.3541	0.4170	0.1437	---
1131	0.3514	0.3247	0.3378	0.3544	0.3458	0.3428	0.2620	0.1172	0.1094
999	0.3217	0.3080	0.3109	0.3109	0.3163	0.3136	0.2180	0.1128	0.1022
Minimum Velocity									
832	0.1497	0.1941	0.1990	0.1596	0.1839	0.1773	0.2121		
151	0.1842	0.1903	0.2018	0.1994	0.1892	0.1930	0.2572		
834	0.1937	0.2163	0.2325	0.2030	0.2066	0.2104	0.3554		
1131	0.2315	0.2304	0.2212	0.2174	0.2273	0.2256	0.1526		
999	0.2153	0.1788	0.2114	0.1859	0.2124	0.2008	0.1158		
Physical Model Drawdown, cm, for Replicate									
	A	**B**	**C**	**D**	**E**	**AVG**		**Prototype Drawdown, cm**	
	2.64	2.68	2.32	-----	-----	2.547		-----	

[1] Ambient - minimum velocity.

Table 12
Verification Data, *Coop Ambassador,* Barge Draft 2.13 m

Probe Number	Physical Model Velocity, m/sec, Replicate A	B	C	D	E	AVG	Prototype Velocity m/sec	Return Velocity, m/sec[1] Physical Model	Return Velocity, m/sec[1] Prototype
Ambient Velocity									
832	0.2887	-----	0.2578	0.2675	0.2729	0.272	0.2940	0.0945	0.0952
151	0.2788	-----	0.3254	0.292	0.2994	0.299	0.3010	0.1123	0.1258
834	0.3907	0.3652	0.3661	0.3746	0.361	0.372	0.4080	0.1449	0.1360
1131	0.3072	0.3258	0.3126	0.3166	0.3025	0.313	0.2800	0.1232	0.1121
999	0.3144	0.3246	0.3233	0.319	0.3258	0.321	0.2280	0.1319	0.1076
Minimum Velocity									
832	0.1985	-----	0.1722	0.1713	0.1666	0.1772	0.1988		
151	0.1881	-----	0.1815	0.1948	0.1821	0.1866	0.1752		
834	0.2099	0.2592	0.1970	0.2205	0.2466	0.2266	0.2720		
1131	0.1941	0.1816	0.2038	0.1871	0.1820	0.1897	0.1679		
999	0.2101	0.1572	0.2059	0.2129	0.1612	0.1895	0.1204		
Physical Model Drawdown, cm, for Replicate									
	A	**B**	**C**	**D**	**E**	**AVG**		**Prototype Drawdown, cm**	
	2.42	-----	-----	2.36	2.74	2.507		-----	

[1] Ambient – minimum velocity.

Table 13
Verification Data, *Conti-Nan* (1), Barge Draft 2.13 m

Probe Number	Physical Model Velocity, m/sec, Replicate A	B	C	D	E	AVG	Prototype Velocity m/sec	Return Velocity, m/sec[1] Physical Model	Prototype
Ambient Velocity									
832	0.2623	0.2749	0.2716	0.2952	0.2669	0.2735	0.2980	0.1343	0.1470
151	0.2834	0.3008	0.3154	0.3034	0.2914	0.2914	0.3280	0.1491	0.1388
834	0.3601	0.3663	0.3553	0.3511	0.3541	0.3443	-----	0.1331	-----
1131	0.3527	0.3385	0.3435	0.3465	0.342	0.3476	0.2920	0.1290	0.1500
999	0.3237	0.3025	0.3281	0.3337	0.3194	0.3231	0.2320	0.1187	0.1400
Minimum Velocity									
832	0.1369	0.1443	0.1622	0.1208	0.1318	0.1392	0.1510		
151	0.1334	0.1341	0.1425	0.1824	0.1324	0.1450	0.1892		
834	0.2101	0.2132	0.2242	0.1963	0.2124	0.2112	-----		
1131	0.2202	0.2069	0.2318	0.2316	0.2027	0.2186	0.1420		
999	0.2049	0.2038	0.1932	0.2207	0.1992	0.2044	0.0920		

	Physical Model Drawdown, cm, for Replicate A	B	C	D	E	AVG		Prototype Drawdown, cm
	2.82	3.38	3.60	3.75	3.88	3.486		-----

[1] Ambient - minimum velocity.

Table 14
Draft Correction Computations

Tow	Length Prototype m	Temperature, °C Model	Temperature, °C Prototype	Kinematic Viscosity Model M**2/sec	Kinematic Viscosity Prototype 10**6
K Michael	237.8	12.5	15	1.23	1.15
Valentine	297.3	10.5	15	1.30	1.15
K Ellen	297.3	9.0	9	1.36	1.36
Conti-Nan (1)	297.3	14.0	11	1.18	1.28
Ambassador	297.3	9.0	8.5	1.36	1.38

Tow	Vessel Speed m/sec	Return Velocity m/sec	DC M	δ_{lm} m	δ_{lp} m	$\delta_{lm} - \delta_{lp}$ m	$C = \frac{D_c}{\delta_{lm} - \delta_{lp}}$
K Michael	1.99	0.094	0.61	0.535	0.261	0.274	2.23
Valentine	1.82	0.084	0.61	0.662	0.320	0.342	1.79
K Ellen	1.60	0.072	0.61	0.678	0.333	0.345	1.77
Conti-Nan (1)	2.09	0.100	0.61	0.640	0.319	0.321	1.90
Ambassador	1.90	0.088	0.61	0.661	0.326	0.335	1.82

δ_{lp} = Prototype displacement thickness.

δ_{lm} = Model displacement thickness * 37.5.

Table 15
Clark's Ferry Pool 546.0 Experiment Conditions

Experiment No.	Up Or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] Cm
LCU138	U	1.38	252.7	16	2.13	2.78	3X5	54	8.0	1.4
LCU183	U	1.83	252.7	16	2.13	2.75	3X5	67.5	10.7	2.4
LCU228	U	2.28	252.7	20.5	2.13	2.71	3X5	81	13.9	3.8
LCU273	U	2.73	252.7	20.5	2.13	2.69	3X5	94.5	18.1	5.8
LCU318	U	3.18	252.7	20.5	2.13	2.67	3X5	108	24.2	8.9
LCD202	D	2.02	252.7	18	2.13	2.77	3X5	54	8.0	1.4
LCD247	D	2.47	252.7	16	2.13	2.75	3X5	67.5	10.7	2.4
LCD292	D	2.92	252.7	16	2.13	2.72	3X5	81	13.9	3.8
LCD337	D	3.37	252.7	16	2.13	2.70	3X5	94.5	18.1	5.8
LCD382	D	3.82	252.7	16	2.13	2.68	3X5	108	24.2	9.0
LRU228	U	2.28	131.7	20.5	2.13	2.71	3X5	81	13.9	3.8
LRU318	U	3.18	131.7	20.5	2.13	2.67	3X5	108	24.2	8.9
LRD292	D	2.92	131.7	16	2.13	2.72	3X5	81	13.9	3.8
LRD382	D	3.82	131.7	16	2.13	2.68	3X5	108	24.3	9.0
LLU228	U	2.28	294.7	18.5	2.13	2.71	3X5	81	13.9	3.8
LLU318	U	3.18	294.7	18.5	2.13	2.67	3X5	108	24.2	8.9
LLD292	D	2.92	294.7	16	2.13	2.72	3X5	81	13.9	3.8
LLD382	D	3.82	294.7	16	2.13	2.68	3X5	108	24.3	9.0
LCUU22	U	2.28	252.7	21.0	0.91	1.47	3X5	81	7.3	2.0
LCUU31	U	3.18	252.7	21.0	0.91	1.44	3X5	108	12.3	4.5
LCUU40	U	4.08	252.7	22.2	0.91	1.41	3X5	135	24.6	11.3
LCUD29	D	2.92	252.7	22.2	0.91	1.47	3X5	81	7.3	2.0
LCUD38	D	3.82	252.7	22.2	0.91	1.44	3X5	108	12.3	4.5
LCUD47	D	4.72	252.7	22.2	0.91	1.41	3X5	135	24.6	11.3

Note: Water surface width 614.8 m, area 2170 sq m, q 690 cms, water surface elevation 546.0, average ambient velocity 0.32 m/sec, 45^{o} rake.
[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 16
Clark's Ferry, Pool El 546.0, LCU138, Run 17 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2492	0.2409	0.2417	0.2439	
2	0.2428	0.2404	0.2338	0.2390	
3	0.2923	0.2817	0.2809	0.2850	
4	0.3583	0.3584	0.3459	0.3542	
5	0.4293	0.4372	0.4176	0.4280	
6	0.4044	0.3866	0.4023	0.3978	
7	0.4011	0.4136	0.3944	0.4030	
8	0.1082	0.0963	0.1071	0.1039	
Impact Velocity, m/sec					
1	0.3212	0.3459	0.3577	0.3416	0.0977
2	0.3241	0.3495	0.3376	0.3371	0.0981
3	0.4147	0.4269	0.4340	0.4252	0.1402
4	0.5073	0.4977	0.5341	0.5130	0.1588
5	0.6136	0.5745	0.5763	0.5881	0.1601
6	0.5314	0.5174	0.5090	0.5193	0.1215
7	0.5595	0.5242	0.5403	0.5413	0.1383
8	0.1887	0.1554	0.1880	0.1774	0.0735
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	1.066	0.795	---	0.9305	
171 m RB	1.378	0.795	---	1.0865	

[1] Impact - ambient velocity.

Table 17
Clark's Ferry, Pool El 546.0, LCU183, Run 18 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2412	0.2551	0.2412	0.2458	
2	0.2435	0.2416	0.2427	0.2426	
3	0.2954	0.2952	0.3157	0.3021	
4	0.3494	0.3638	0.3536	0.3556	
5	0.4506	0.4157	0.4096	0.4253	
6	0.4047	0.3887	0.3820	0.3918	
7	0.4198	0.3972	0.4064	0.4078	
8	0.1100	0.1040	0.0780	0.0973	
Impact Velocity, m/sec					
1	0.3217	0.3411	0.3179	0.3269	0.0811
2	0.3463	0.3395	0.3279	0.3379	0.0953
3	0.4233	0.4533	0.4419	0.4395	0.1374
4	0.5352	0.5515	0.5400	0.5422	0.1866
5	0.6312	0.6479	0.6217	0.6336	0.2083
6	0.5245	0.5483	0.5502	0.5410	0.1492
7	0.5469	0.5575	0.5658	0.5567	0.1489
8	0.1630	0.1754	0.1645	0.1676	0.0703
Drawdown, cm					
Distance from Thalweg M	**A**	**B**	**C**	**AVG**	
186 m LB	1.3210	2.5190	2.3570	2.0660	
171 m RB	2.8570	6.3070	3.5900	4.2513	

[1] Impact - ambient velocity.

Table 18
Clark's Ferry, Pool El 546.0, LCU228, Run 19 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2380	0.2387	0.2293	0.2353	
2	0.2345	0.2398	0.2238	0.2327	
3	0.2889	0.3007	0.2785	0.2894	
4	0.3598	0.3439	0.3393	0.3477	
5	0.3870	0.4126	0.3986	0.3994	
6	0.3740	0.3823	0.3931	0.3831	
7	0.4041	0.3950	0.3961	0.3984	
8	0.0945	0.1013	0.0986	0.0981	
Impact Velocity, m/sec					
1	0.3586	0.3639	0.3949	0.3725	0.1372
2	0.3584	0.3619	0.3734	0.3646	0.1319
3	0.4798	0.4600	0.4797	0.4732	0.1838
4	0.6227	0.5788	0.5950	0.5988	0.2511
5	0.6726	0.6917	0.6706	0.6783	0.2789
6	0.5529	0.5731	0.5299	0.5520	0.1689
7	0.5935	0.5863	0.5383	0.5727	0.1743
8	0.2205	0.1995	0.1710	0.1970	0.0989
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.8720	5.3640	4.4000	4.8787	
171 m RB	5.5640	5.7450	5.2350	5.1470	

[1] Impact - ambient velocity.

Table 19
Clark's Ferry, Pool El 546.0, LCU273, Run 19 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2334	0.2450	0.2427	0.2404	
2	0.2353	0.2282	0.2336	0.2323	
3	0.2904	0.2947	0.2779	0.2877	
4	0.3496	0.3475	0.3441	0.3471	
5	0.4098	0.3971	0.4122	0.4064	
6	0.3770	0.3838	0.3744	0.3784	
7	0.4036	0.3971	0.3893	0.3967	
8	0.0903	0.1137	0.0954	0.0998	
Impact Velocity, m/sec					
1	0.4186	0.4175	0.4228	0.4196	0.1792
2	0.4313	0.4167	0.4152	0.4211	0.1888
3	0.5346	0.4983	0.4872	0.5067	0.2190
4	0.6262	0.6423	0.6470	0.6385	0.2914
5	0.7045	0.7038	0.7074	0.7052	0.2988
6	0.5665	0.5775	0.5882	0.5774	0.1990
7	0.6491	0.5919	0.6201	0.6204	0.2237
8	0.2151	0.2188	0.1993	0.2111	0.1113
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	5.3330	5.8330	6.4450	5.8703	
171 m RB	8.4450	7.7230	8.0000	8.0559	

[1] Impact - ambient velocity.

Table 20
Clark's Ferry, Pool El 546.0, LCU318, Run 20 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2359	0.2415	0.2376	0.2383	
2	0.2412	0.2377	0.2407	0.2399	
3	0.2949	0.2888	0.2832	0.2890	
4	0.3441	0.3299	0.3526	0.3422	
5	0.4134	0.4304	0.3960	0.4133	
6	0.3854	0.3845	0.3851	0.3850	
7	0.3953	0.4081	0.3952	0.3995	
8	0.1132	0.1045	0.1061	0.1079	
Impact Velocity, m/sec					
1	0.5174	0.5314	0.4966	0.5151	0.2768
2	0.4794	0.4924	0.5055	0.4924	0.2525
3	0.5651	0.5699	0.5606	0.5652	0.2762
4	0.7298	0.7007	0.7160	0.7155	0.3733
5	0.7910	0.7431	0.7405	0.7582	0.3449
6	0.6497	0.6534	0.6096	0.6376	0.2526
7	0.6644	0.6300	0.6528	0.6491	0.2496
8	0.2818	0.2038	0.2440	0.2432	0.1353
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	10.5560	9.8890	11.4450	10.6300	
171 m RB	9.9450	10.8890	9.2230	10.0189	

[1] Impact - ambient velocity.

Table 21
Clark's Ferry, Pool El 546.0, LCD202, Run 11 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2502	0.2505	0.2269	0.2425	
2	0.2354	0.2648	0.2316	0.2439	
3	-----	------	------	------	
4	0.3425	0.3515	0.3345	0.3428	
5	0.4208	0.4087	0.3953	0.4083	
6	0.3750	0.3796	0.3761	0.3769	
7	0.3978	0.3707	0.3821	0.3835	
8	-----	0.1165	0.0545	0.0855	
Impact Velocity, m/sec					
1	0.1818	0.1802	0.1573	0.1731	0.0694
2	0.1849	0.1934	0.1678	0.1820	0.0619
3	-----	-----	-----	-----	-----
4	0.1863	0.2140	0.1583	0.1862	0.1566
5	0.2421	0.2366	0.2469	0.2419	0.1664
6	0.2845	0.2982	0.2526	0.2784	0.0985
7	0.2934	0.2678	0.2982	0.2865	0.0970
8	-----	0.0659	0.0286	0.0473	0.0382
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	1.6670	-----	-----	1.6670	
171 m RB	1.9830	-----	-----	1.9830	

[1] Impact - ambient velocity.

Table 22
Clark's Ferry, Pool El 546.0, LCD247, Run 12 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2654	0.2481	0.2499	0.2545	
2	0.2463	0.2382	0.2484	0.2443	
3	-----	-----	-----	-----	
4	0.3678	0.3636	0.3520	0.3611	
5	0.4112	0.3987	0.3789	0.3963	
6	0.3707	0.3664	0.3566	0.3646	
7	0.3878	0.3865	0.3706	0.3816	
8	0.0517	0.1132	0.0982	0.0877	
Impact Velocity, m/sec					
1	0.1267	0.1426	0.1489	0.1394	0.1151
2	0.1621	0.1478	0.1613	0.1571	0.0872
3	-----	-----	-----	-----	-----
4	0.1775	0.1674	0.1596	0.1682	0.1929
5	0.2680	0.2238	0.2452	0.2457	0.1506
6	0.2159	0.2469	0.2393	0.2340	0.1306
7	0.2878	0.2894	0.2517	0.2763	0.1053
8	0.0016	0.0413	0.0409	0.0279	0.0598
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.9990	2.9530	2.6910	2.8810	
171 m RB	3.2000	3.5190	4.0770	3.5986	

[1] Impact - ambient velocity.

Table 23
Clark's Ferry, Pool El 546.0, LCD292, Run 13 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2171	0.2424	0.2252	0.2282	
2	0.2443	0.2423	0.2496	0.2454	
3	0.3052	0.2893	0.2888	0.2944	
4	0.3468	0.3378	0.3513	0.3453	
5	0.4147	0.4281	0.4183	0.4204	
6	0.3783	0.3929	0.3932	0.3881	
7	0.3889	0.3890	0.3983	0.3921	
8	0.1090	0.0897	0.0754	0.0914	
Impact Velocity, m/sec					
1	0.1105	0.1148	0.1176	0.1143	0.1139
2	0.1094	0.1101	0.1245	0.1147	0.1307
3	0.1416	0.1377	0.1402	0.1398	0.1546
4	0.1261	0.1391	0.1331	0.1328	0.2125
5	0.1955	0.1620	0.1574	0.1716	0.2488
6	0.1972	0.2493	0.1932	0.2132	0.1749
7	0.2465	0.2709	0.2321	0.2498	0.1423
8	0.0066	0.0501	-0.0059	0.0169	0.0745
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	5.4000	5.4450	4.9630	5.2692	
171 m RB	4.8600	4.8890	4.9630	4.9038	

[1] Impact - ambient velocity.

Table 24
Clark's Ferry, Pool El 546.0, LCD337, Run 13 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2354	0.2276	0.2252	0.2294	
2	0.2355	0.2407	0.2464	0.2409	
3	0.2766	0.2872	0.2847	0.2828	
4	0.3450	-----	0.3462	0.3456	
5	0.4233	0.4201	0.4297	0.4244	
6	0.3976	0.3844	0.3915	0.3912	
7	0.4075	0.4080	0.4077	0.4077	
8	0.0833	0.1206	0.0893	0.0977	
Impact Velocity, m/sec					
1	0.0735	0.0897	0.0759	0.7970	0.1497
2	0.0903	0.0687	0.0733	0.0774	0.1635
3	0.1123	0.0896	0.0929	0.0983	0.1845
4	0.1197	-----	0.0867	0.1032	0.2424
5	0.1050	0.1385	0.0858	0.1098	0.3146
6	0.1978	0.1778	0.1954	0.1903	0.2009
7	0.2184	0.2063	0.1787	0.2011	0.2066
8	0.0050	-0.0185	0.0135	0.0000	0.0977
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	7.5900	7.1840	8.2710	7.6816	
171 m RB	7.1280	6.6840	6.9410	6.9177	

[1] Impact - ambient velocity.

Table 25
Clark's Ferry, Pool El 546.0, LCD382, Run 14 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2355	0.2626	0.2408	0.2463	
2	0.2288	0.2496	0.2550	0.2445	
3	0.2818	0.2871	0.2861	0.2850	
4	0.3712	0.3602	0.3550	0.3621	
5	0.4348	0.4196	0.4126	0.4223	
6	0.4063	0.4000	0.3889	0.3984	
7	0.4118	0.4130	0.4112	0.4120	
8	0.1154	0.1087	0.1266	0.1169	
Impact Velocity, m/sec					
1	-0.0287	0.0099	-0.0071	-0.0086	0.2549
2	0.0237	0.0095	0.0528	0.0287	0.2158
3	0.0539	0.0359	0.0314	0.0404	0.2446
4	0.0411	0.0353	-0.0125	0.0213	0.3408
5	0.0857	0.0812	0.0751	0.0807	0.3416
6	0.1474	0.1940	0.1519	0.1644	0.2340
7	0.1494	0.1145	0.1870	0.1503	0.2617
8	-0.0083	-0.0171	-0.0032	-0.0095	0.1264
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	-----	-----	-----	------	
171 m RB	-----	-----	-----	------	

[1] Impact - ambient velocity.

Table 26
Clark's Ferry, Pool El 546.0, LRU228, Run 25 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2784	0.2672	0.2611	0.2689	
2	0.2725	0.2641	0.2548	0.2638	
3	0.3335	0.3294	0.3175	0.3268	
4	0.4001	0.4181	0.3805	0.3996	
5	0.4149	0.4323	0.4209	0.4227	
6	0.4150	0.4152	0.4129	0.4144	
7	0.3742	0.3905	0.3738	0.3795	
8	0.0846	0.0945	0.0765	0.0852	
Impact Velocity, m/sec					
1	0.3849	0.3552	0.3806	0.3736	0.1047
2	0.4001	0.3852	0.4001	0.3951	0.1313
3	0.4923	0.4695	0.4917	0.4845	0.1577
4	0.6111	0.5854	0.5551	0.5839	0.1843
5	0.7033	0.7289	0.6955	0.7092	0.2865
6	0.7755	0.7719	0.7604	0.7693	0.3549
7	0.6882	0.6817	0.7064	0.6921	0.3126
8	0.2937	0.2885	0.2484	0.2769	0.1917
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.1030	3.3740	3.4110	3.6292	
171 m RB	9.4360	9.5300	8.6410	9.2023	

[1] Impact - ambient velocity.

Table 27
Clark's Ferry, Pool El 546.0, LRU318, Run 25 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2605	0.2557	0.2603	0.2588	
2	0.2614	0.2731	0.2776	0.2707	
3	0.3233	0.3352	0.3374	0.3320	
4	0.3946	0.4142	0.4105	0.4064	
5	0.4042	0.4049	0.4149	0.4080	
6	0.4115	0.4080	0.4116	0.4104	
7	0.3722	0.3723	0.3688	0.3711	
8	0.0953	0.0821	0.1420	0.1065	
Impact Velocity, m/sec					
1	0.5016	0.5061	0.5109	0.5062	0.2474
2	0.4826	0.4701	0.4913	0.4813	0.2106
3	0.5496	0.5828	0.5714	0.5679	0.2359
4	0.6540	0.6384	0.6573	0.6499	0.2435
5	0.8316	0.8241	0.8113	0.8223	0.4143
6	0.9380	0.9209	0.9177	0.9255	0.5151
7	0.8882	0.8666	0.8407	0.8652	0.4941
8	0.3356	0.3051	0.2811	0.3073	0.2008
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	8.3080	8.1200	7.7950	8.0743	
171 m RB	20.2940	19.8300	20.5890	20.1220	

[1] Impact - ambient velocity.

Table 28
Clark's Ferry, Pool El 546.0, LRD292, Run 26 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2537	0.2572	0.2434	0.2514	
2	0.2455	0.2499	0.2706	0.2553	
3	0.3176	0.3146	0.3253	0.3192	
4	0.3954	0.3741	0.3848	0.3848	
5	0.3919	0.3934	0.3889	0.3914	
6	0.3893	0.3856	0.3763	0.3837	
7	0.3626	0.3554	0.3609	0.3596	
8	0.1043	0.0608	0.0760	0.0804	
Impact Velocity, m/sec					
1	0.1528	0.1307	0.1457	0.1431	0.1084
2	0.1322	0.1256	0.1424	0.1334	0.1219
3	0.1733	0.1683	0.2227	0.1881	0.1311
4	0.2574	0.2692	0.2088	0.2451	0.1397
5	0.0999	0.1250	0.1649	0.1299	0.2615
6	0.1099	0.1201	0.0805	0.1035	0.2802
7	0.1245	0.1081	0.1202	0.1176	0.2420
8	-0.0509	-0.0907	-0.0957	-0.0791	0.1595
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.4080	2.9240	2.4100	2.5807	
171 m RB	6.9070	8.3580	9.3330	8.1993	

[1] Impact - ambient velocity.

Table 29
Clark's Ferry, Pool El 546.0, LRD382, Run 27 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2348	0.2502	0.2634	0.2495	
2	0.2466	0.2682	0.2492	0.2547	
3	0.3320	0.3297	0.3057	0.3225	
4	0.3686	0.3941	0.3662	0.3763	
5	0.3810	0.3846	0.3982	0.3879	
6	0.3857	0.3738	0.3746	0.3780	
7	0.3586	0.3542	0.3584	0.3571	
8	0.0770	0.0591	0.1064	0.0808	
Impact Velocity, m/sec					
1	0.0755	0.0803	0.0718	0.0759	0.1736
2	0.0806	0.0962	0.0773	0.0847	0.1700
3	0.1318	0.1063	0.1554	0.1312	0.1913
4	0.2028	0.1755	0.1775	0.1853	0.1910
5	0.0574	0.0439	-0.0008	0.0335	0.3544
6	-0.0267	-0.0243	-0.0049	-0.0186	0.3966
7	-0.0155	-0.0152	0.0078	-0.0076	0.3647
8	-0.0827	-0.0463	-0.1277	-0.0856	0.1664
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	7.4440	7.9620	8.0280	7.8113	
171 m RB	10.0000	13.0550	13.4090	12.1547	

[1] Impact - ambient velocity.

Table 30
Clark's Ferry, Pool El 546.0, LLU228, Run 1 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2543	0.2553	0.2514	0.2537	
2	0.2441	0.2373	0.2447	0.2420	
3	0.3080	0.3118	0.3017	0.3072	
4	0.3106	0.3088	0.3221	0.3138	
5	0.3661	0.3477	0.3629	0.3589	
6	0.4076	0.4277	0.4180	0.4178	
7	0.4054	0.4195	0.4300	0.4183	
8	0.1077	0.1304	0.1353	0.1245	
Impact Velocity, m/sec					
1	0.4345	0.4170	0.4156	0.4224	0.1687
2	0.3858	0.4151	0.3858	0.3956	0.1536
3	0.4958	0.5059	0.5115	0.5044	0.1972
4	0.6223	0.6128	0.6066	0.6139	0.3001
5	0.6183	0.6333	0.6154	0.6223	0.2634
6	0.6015	0.5649	0.6061	0.5908	0.1730
7	0.5924	0.5864	0.5741	0.5843	0.1660
8	0.1962	0.2198	0.2553	0.2238	0.0993
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	6.2570	6.1020	6.2820	6.2137	
171 m RB	5.3840	5.2300	7.5380	6.0508	

[1] Impact - ambient velocity.

Table 31
Clark's Ferry, Pool El 546.0, LLU318, Run 2 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2679	0.2550	0.2580	0.2603	
2	0.2476	0.2376	0.2409	0.2420	
3	0.3072	0.3165	0.3074	0.3104	
4	0.3295	0.3330	0.3071	0.3232	
5	0.3775	0.3566	0.3499	0.3613	
6	0.3590	0.4123	0.4319	0.4011	
7	0.4236	0.4215	0.4095	0.4182	
8	0.1175	0.1499	0.1494	0.1389	
Impact Velocity, m/sec					
1	0.6409	0.6149	0.6389	0.6316	0.3713
2	0.5892	0.5828	0.5908	0.5876	0.3456
3	0.6963	0.6850	0.6553	0.6789	0.3685
4	0.7453	0.7361	0.7483	0.7432	0.4200
5	0.7481	0.7354	0.7419	0.7418	0.3805
6	0.7173	0.6897	0.7052	0.7041	0.2774
7	0.7047	0.6614	0.6899	0.6853	0.2671
8	0.2713	0.2884	0.2656	0.2751	0.1362
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	19.4440	17.8800	19.2310	18.8517	
171 m RB	9.8890	9.7700	9.8720	9.8437	

[1] Impact - ambient velocity.

Table 32
Clark's Ferry, Pool El 546.0, LLD292, Run 28 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2460	0.2525	0.2529	0.2505	
2	0.2418	0.2496	0.2461	0.2458	
3	0.3208	0.3248	0.3043	0.3166	
4	0.3129	0.3282	0.3178	0.3196	
5	0.3416	0.3442	0.3727	0.3528	
6	0.4141	0.4116	0.4066	0.4108	
7	0.4175	0.3999	0.4179	0.4118	
8	0.1386	0.1249	0.1077	0.1237	
Impact Velocity, m/sec					
1	0.1397	0.0535	0.0993	0.0975	0.1530
2	0.0740	0.0721	0.1164	0.0875	0.1583
3	0.1305	0.1317	0.1106	0.1243	0.1923
4	0.0892	0.0705	0.0797	0.0798	0.2398
5	0.1263	0.1714	0.1293	0.1423	0.2105
6	0.2204	0.2599	0.2292	0.2365	0.1743
7	0.2408	0.2334	0.2354	0.2365	0.1753
8	0.0443	0.0137	-0.0112	0.0156	0.1081
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	7.5100	6.2050	5.6920	6.4690	
171 m RB	4.5330	4.6140	4.1540	4.4337	

[1] Impact - ambient velocity.

Table 33
Clark's Ferry, Pool El 546.0, LCD382, Run 28 Apr 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2424	0.2506	0.2500	0.2477	
2	0.2348	0.2331	0.2283	0.2321	
3	0.2849	0.3076	0.3110	0.3012	
4	0.3060	0.3127	0.3044	0.3077	
5	0.3636	0.3520	0.3749	0.3635	
6	0.4162	0.4100	0.4044	0.4102	
7	0.4002	0.3858	0.3897	0.3919	
8	0.1041	0.0956	0.1001	0.0999	
Impact Velocity, m/sec					
1	-0.0280	0.0039	-0.0291	-0.0177	0.2654
2	0.0027	-0.0434	-0.0825	-0.0411	0.2732
3	0.0457	0.0353	-0.0384	0.0142	0.2870
4	-0.0565	-0.0228	-0.0461	-0.0418	0.3495
5	0.0435	0.0581	0.0206	0.0407	0.3228
6	0.1969	0.2095	0.1625	0.1896	0.2206
7	0.2391	0.2084	0.1960	0.2145	0.1774
8	-0.0065	-0.0173	-0.0505	-0.0248	0.1247

Drawdown, cm

Distance from Thalweg m	A	B	C	AVG	
186 m LB	13.2200	8.2810	9.2780	10.2596	
171 m RB	8.3360	11.3310	10.5550	10.0739	

[1] Impact - ambient velocity.

Table 34
Clark's Ferry, Pool El 546.0, LCUU22, Run 23 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2399	0.2284	0.2330	0.2338	
2	0.2497	0.2455	0.2538	0.2497	
3	0.3005	0.2943	0.2866	0.2938	
4	0.3496	0.3626	0.3604	0.3575	
5	0.3893	0.3784	0.3771	0.3816	
6	0.4250	0.4052	0.4022	0.4108	
7	0.4097	0.3990	0.3998	0.4028	
8	0.0777	0.0990	0.0693	0.0820	
Impact Velocity, m/sec					
1	0.3238	0.3019	0.3274	0.3177	0.0839
2	0.3300	0.3272	0.3283	0.3285	0.0788
3	0.4255	0.4007	0.4073	0.4112	0.1174
4	0.5910	0.5809	0.5623	0.5781	0.2206
5	0.5703	0.5693	0.5375	0.5590	0.1774
6	0.5350	0.5219	0.4804	0.5124	0.1016
7	0.5268	0.5061	0.5104	0.5144	0.1116
8	0.2193	0.2006	0.2190	0.2130	0.1310

Drawdown, cm

Distance from Thalweg m	A	B	C	AVG	
186 m LB	2.8210	2.7700	2.6410	2.7438	
171 m RB	1.9480	1.6920	1.6990	1.7797	

[1] Impact - ambient velocity.

Table 35
Clark's Ferry, Pool El 546.0, LCUU31, Run 23 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2382	0.2429	0.2353	0.2388	
2	0.2533	0.2472	0.2450	0.2485	
3	0.2991	0.2867	0.3009	0.2956	
4	0.3556	0.3451	0.3487	0.3498	
5	0.3698	0.3996	0.3827	0.3840	
6	0.4012	0.4057	0.4089	0.4053	
7	0.3933	0.3980	0.4122	0.4012	
8	0.1119	0.0951	0.1110	0.1060	
Impact Velocity, m/sec					
1	0.3936	0.3951	0.3891	0.3926	0.1538
2	0.4121	0.4164	0.3822	0.4036	0.1551
3	0.4558	0.4613	0.4620	0.4597	0.1641
4	0.6135	0.6249	0.5867	0.6084	0.2586
5	0.5965	0.6055	0.5877	0.5966	0.2126
6	0.5498	0.5618	0.5200	0.5439	0.1386
7	0.5412	0.5438	0.5744	0.5531	0.1519
8	0.2678	0.2167	0.2104	0.2316	0.1256
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	7.4680	7.2670	6.7040	7.1463	
171 m RB	4.1330	4.1990	4.2940	4.2087	

[1] Impact - ambient velocity.

Table 36
Clark's Ferry, Pool El 546.0, LCUU40, Run 24 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2337	0.2393	0.2264	0.2331	
2	0.2537	0.2446	0.2425	0.2469	
3	0.2915	0.2743	0.3085	0.2914	
4	0.3621	0.3639	0.3487	0.3582	
5	0.3966	0.3864	0.3929	0.3920	
6	0.4262	0.4255	0.4195	0.4237	
7	0.4253	0.3917	0.3959	0.4043	
8	0.0839	0.1150	0.1225	0.1071	
Impact Velocity, m/sec					
1	0.5601	0.5391	0.5451	0.5481	0.3150
2	0.5088	0.5029	0.4998	0.5038	0.2569
3	0.5430	0.5522	0.5203	0.5385	0.2437
4	0.6637	0.6922	0.7029	0.6863	0.3281
5	0.7318	0.7021	0.7094	0.7144	0.3224
6	0.6580	0.6474	0.6464	0.6506	0.2269
7	0.6621	0.6576	0.6489	0.6562	0.2519
8	0.2012	0.2181	0.2390	0.2194	0.1123
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	13.7180	13.7170	14.4440	13.9597	
171 m RB	9.2310	8.4860	9.0000	8.9057	

[1] Impact - ambient velocity.

Table 37
Clark's Ferry, Pool El 546.0, LCUD29, Run 25 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2356	0.2404	0.2360	0.2373	
2	0.2534	0.2324	0.2433	0.2430	
3	0.2864	0.2920	0.2938	0.2907	
4	0.3739	0.3455	0.3560	0.3585	
5	0.4027	0.3893	0.3834	0.3918	
6	0.4130	0.4137	0.4124	0.4130	
7	0.4138	0.4137	0.4183	0.4153	
8	0.0789	0.1067	0.0707	0.0854	
Impact Velocity, m/sec					
1	0.1525	0.1854	0.1737	0.1705	0.0668
2	0.1908	0.1658	0.1851	0.1806	0.0624
3	0.1888	0.2236	0.2021	0.2048	0.0859
4	0.2547	0.2570	0.2299	0.2472	0.1113
5	0.2136	0.1883	0.1781	0.1933	0.1985
6	0.3157	0.2764	0.2775	0.2899	0.1231
7	0.2776	0.3150	0.3062	0.2996	0.1157
8	-0.0028	0.0127	0.0026	0.0042	0.0812
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.1770	2.0880	2.1690	2.1447	
171 m RB	2.4010	2.3560	2.4460	2.4010	

[1] Impact - ambient velocity.

Table 38
Clark's Ferry, Pool El 546.0, LCUD38, Run 25 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2327	0.2404	0.2313	0.2348	
2	0.2460	0.2630	0.2410	0.2500	
3	0.2828	0.3100	0.3010	0.2979	
4	0.3535	0.3524	0.3537	0.3532	
5	0.3912	0.3778	0.3618	0.3769	
6	0.4302	0.3967	0.3858	0.4042	
7	0.4152	0.3928	0.4046	0.4042	
8	0.1291	0.0874	0.0670	0.0945	
Impact Velocity, m/sec					
1	0.1294	0.1563	0.1302	0.1386	0.0962
2	0.1409	0.1323	0.1444	0.1392	0.1108
3	0.1596	0.1903	0.1537	0.1679	0.1300
4	0.2007	0.1915	0.2038	0.1987	0.1545
5	0.1572	0.1686	0.1274	0.1511	0.2258
6	0.2621	0.2543	0.2280	0.2481	0.1561
7	0.2197	0.2603	0.2539	0.2446	0.1596
8	-0.0084	-0.0246	-0.0054	-0.0128	0.1073
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	5.4120	4.6310	5.6360	5.2263	
171 m RB	3.6470	3.0530	2.9090	3.2030	

[1] Impact - ambient velocity.

Table 39
Clark's Ferry, Pool El 546.0, LCUD47, Run 26 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2303	0.2528	0.2320	0.2384	
2	0.2484	0.2416	0.2511	0.2470	
3	0.2931	0.2801	0.2933	0.2888	
4	0.3726	0.3680	0.3668	0.3691	
5	0.3768	0.3689	0.3762	0.3740	
6	0.4229	0.4048	0.4089	0.4122	
7	0.4254	0.4208	0.4262	0.4241	
8	0.0938	0.0969	0.1046	0.0984	
Impact Velocity, m/sec					
1	0.0799	0.0718	0.0225	0.0581	0.1803
2	0.1166	0.1170	0.1166	0.1167	0.1303
3	0.1496	0.1349	0.1542	0.1462	0.1426
4	0.1420	0.1401	0.1543	0.1455	0.2236
5	0.0976	0.0782	0.1073	0.0944	0.2796
6	0.1611	0.1479	0.1856	0.1649	0.2473
7	0.1572	0.1375	0.1280	0.1409	0.2832
8	-0.0220	-0.0034	-0.0396	-0.0217	0.1201
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	6.2970	6.0190	6.5280	6.2813	
171 m RB	9.7220	8.9820	10.0930	9.5990	

[1] Impact - ambient velocity.

Table 40
Clark's Ferry, Pool El 546.0, Experiments, Meter Positions

	Probe Number							
Probe Position[1] Experiment No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PP1 (LCU138, LCU183, LCU228, LCU273, LCU318, LCD202, LCD247, LCD292, LCD337, LCD382, LCUU22, LCUU31, LCUU40, LCUD29, LCUD38, LCUD40)	321.0 Left	228.0 Left	126.0 Left	30.0 Left	30.0 Right	99.0 Right	168.0 Right	237.0 Right
PP2** (LRU228, LRU318, LRD292, LRD382)	321.0 Left	216.0 Left	114.0 Left	12.0 Left	90.0 Right	150.0 Right	195.0 Right	240.0 Right
PP3** (LLU228, LLU318, LLD292, LLD382)	321.0 Left	237.0 Left	159.0 Left	75.0 Left	15.0 Left	69.0 Right	150.0 Right	237.0 Right

[1] Probe position, distance in meters from thalweg, looking downstream.

Table 41
Clark's Ferry Pool 546.0 Experiment Conditions, Tow Length Experiment

Experiment No.	Up or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] cm
LC1U22	U	2.28	252.7	21.0	2.13	2.29	3X1	81	11.6	3.1
LC1U31	U	3.18	252.7	21.0	2.13	2.27	3X1	108	20.2	7.4
LC1D29	D	2.92	252.7	21.0	2.13	2.29	3X1	81	11.6	3.1
LC1D38	D	3.82	252.7	21.0	2.13	2.27	3X1	108	20.2	7.4
LC2U22	U	2.28	252.7	21.0	2.13	2.41	3X2	81	12.2	3.3
LC2U31	U	3.18	252.7	21.0	2.13	2.39	3X2	108	21.4	7.9
LC2D29	D	2.92	252.7	21.0	2.13	2.41	3X2	81	12.2	3.3
LC2D38	D	3.82	252.7	21.0	2.13	2.39	3X2	108	21.4	7.9
LC3U22	U	2.28	252.7	21.0	2.13	2.51	3X3	81	12.8	3.5
LC3U31	U	3.18	252.7	21.0	2.13	2.49	3X3	108	22.4	8.2
LC3D29	D	2.92	252.7	21.0	2.13	2.51	3X3	81	12.8	3.5
LC3D38	D	3.82	252.7	21.0	2.13	2.47	3X3	108	22.2	8.2
LC4U22	U	2.28	252.7	18.5	2.13	2.61	3X4	81	13.3	3.6
LC4U31	U	3.18	252.7	18.5	2.13	2.57	3X4	108	23.2	8.5
LC4D29	D	2.92	252.7	18.5	2.13	2.61	3X4	81	13.3	3.6
LC4D38	D	3.82	252.7	18.5	2.13	2.58	3X4	108	23.2	8.5

Note: Water surface width 614.8 m, area 2170 sq m, q 690 cms, water surface elevation 546.0, average ambient velocity 0.32 m/sec, 45^{o} rake.
[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 42
Clarks Ferry, Pool El 546.0, LC1U22, Run 19 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2542	0.2373	0.2461	0.2459	
2	0.2546	0.2544	0.2607	0.2566	
3	0.2987	0.3050	0.3085	0.3041	
4	0.3773	0.3723	0.3491	0.3662	
5	0.3653	0.3753	0.3969	0.3792	
6	0.3986	0.4131	0.4109	0.4075	
7	0.3976	0.4136	0.4161	0.4091	
8	0.0943	0.1226	0.0942	0.1037	
Impact Velocity, m/sec					
1	0.3143	0.2932	0.4077	0.3384	0.0925
2	0.3296	0.3291	0.4210	0.3599	0.1033
3	0.4229	0.4285	0.4948	0.4487	0.1446
4	0.7391	0.2757	0.8081	0.6076	0.2414
5	0.7042	0.7113	0.8083	0.7413	0.3621
6	0.5165	0.5159	0.5886	0.5403	0.1328
7	0.4677	0.5059	0.5726	0.5154	0.1063
8	0.1677	0.1955	0.2121	0.1918	0.0881

Drawdown, cm

Distance from Thalweg m	A	B	C	AVG	
186 m LB	-----	3.3760	3.5760	3.4760	
171 m RB	1.5900	2.0900	2.0000	1.8933	

[1] Impact - ambient velocity.

Table 43
Clark's Ferry, Pool El 546.0, LC1U31, Run 19 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2308	0.2461	0.2456	0.2408	
2	0.2450	2,607.0000	0.2569	0.2542	
3	0.2938	0.3085	0.2864	0.2962	
4	0.3578	0.3491	0.3501	0.3523	
5	0.3931	0.3969	0.3993	0.3964	
6	0.3878	0.5592	0.4070	0.4513	
7	0.4088	0.5037	0.4129	0.4418	
8	0.1040	0.0942	0.1011	0.0998	
Impact Velocity, m/sec					
1	0.4325	0.3063	0.4248	0.3879	0.1471
2	0.4141	0.3166	0.4131	0.3813	0.1271
3	0.5257	0.4184	0.5261	0.4901	0.1939
4	0.8466	0.7271	0.8319	0.8019	0.4496
5	0.8081	0.6883	0.8158	0.7707	0.3743
6	0.5957	0.5592	0.5933	0.5827	0.1314
7	0.5921	0.5037	0.6068	0.5675	0.1257
8	0.1724	0.2473	0.2051	0.2083	0.1085
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	9.3220	9.2470	8.3770	8.9820	
171 m RB	6.9440	6.9450	6.5670	6.8187	

[1] Impact - ambient velocity.

Table 44
Clark s Ferry, Pool El 546.0, LC1D29, Run 18 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	-----	0.2401	0.2542	0.2472	
2	-----	0.2700	0.2507	0.2604	
3	-----	0.2872	0.3175	0.3024	
4	-----	0.3541	0.3803	0.3672	
5	-----	0.3833	0.3826	0.3830	
6	-----	0.4981	0.4060	0.4521	
7	-----	0.4094	0.4077	0.4086	
8	-----	0.0970	0.0962	0.0966	
Impact Velocity, m/sec					
1	-----	0.1908	0.1965	0.1937	0.0535
2	-----	0.1963	0.1881	0.1922	0.0682
3	-----	0.2146	0.2225	0.2186	0.0838
4	-----	0.0462	0.0864	0.0663	0.3009
5	-----	0.0931	0.0424	0.0678	0.3152
6	-----	0.2909	0.3077	0.2993	0.1528
7	-----	0.2954	0.3278	0.3116	0.0970
8	-----	-0.0001	-0.0032	-0.0017	0.0983
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	-----	1.5660	2.8200	2.1930	
171 m RB	-----	1.6330	1.4870	1.5600	

[1] Impact - ambient velocity.

Table 45
Clark's Ferry, Pool El 546.0, LC1D38, Run 18 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2371	0.2396	0.2384	0.2384	
2	0.2532	0.2440	0.2478	0.2483	
3	0.2965	0.3080	0.3040	0.3028	
4	0.3788	0.3795	0.3653	0.3745	
5	0.4008	0.3838	0.4038	0.3961	
6	0.4441	0.4173	0.4163	0.4259	
7	0.4252	0.4127	0.4171	0.4183	
8	0.1006	0.1068	0.0892	0.0989	
Impact Velocity, m/sec					
1	0.1292	0.0775	0.1267	0.1111	0.1273
2	0.1117	0.1301	0.1424	0.1281	0.1202
3	0.1523	0.1017	0.1323	0.1288	0.1740
4	-0.0196	-0.0103	0.0021	-0.0093	0.3838
5	0.0122	0.0247	0.0264	0.0211	0.3750
6	0.2458	0.2375	0.2390	0.2408	0.1851
7	0.3143	0.3267	0.2830	0.3080	0.1103
8	0.0084	0.0314	0.0048	0.0149	0.0840
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	8.4290	7.9310	6.9650	7.7750	
171 m RB	1.9990	1.7250	1.5810	1.7473	

[1] Impact - ambient velocity.

Table 46
Clark's Ferry, Pool El 546.0, LC2U22, Run 12 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2357	0.2353	0.2234	0.2315	
2	0.2464	0.2427	0.2500	0.2464	
3	0.2975	0.2927	0.3042	0.2981	
4	0.3641	0.3712	0.3717	0.3690	
5	0.3784	0.3989	0.3823	0.3865	
6	0.4160	0.4237	0.4204	0.4200	
7	0.4100	0.4091	0.4113	0.4101	
8	0.1105	0.1131	0.1099	0.1112	
Impact Velocity, m/sec					
1	0.3228	0.3177	0.3410	0.3272	0.0957
2	0.3716	0.3616	0.3417	0.3583	0.1119
3	0.4452	0.4134	0.4459	0.4348	0.1367
4	0.6188	0.5864	0.6139	0.6064	0.2374
5	0.6334	0.6405	0.6249	0.6329	0.2464
6	0.5644	0.5492	0.5094	0.5410	0.1210
7	0.5282	0.5279	0.5084	0.5215	0.1114
8	0.1881	0.2249	0.1859	0.1996	0.0884
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	3.2460	2.3200	3.6450	3.0703	
171 m RB	2.6210	2.4600	2.8870	2.6560	

[1] Impact - ambient velocity.

Table 47
Clark's Ferry, Pool El 546.0, LC2U31, Run 12 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2377	0.2222	0.2408	0.2336	
2	0.2443	0.2649	0.2506	0.2533	
3	0.3002	0.3040	0.2962	0.3001	
4	0.3608	0.3747	0.3527	0.3627	
5	0.3667	0.3964	0.3901	0.3844	
6	0.4002	0.4085	0.4189	0.4092	
7	0.4018	0.4059	0.4089	0.4055	
8	0.1059	0.1024	0.1026	0.1036	
Impact Velocity, m/sec					
1	0.4551	0.3835	0.3713	0.4033	0.1697
2	0.4609	0.4320	0.3970	0.4300	0.1767
3	0.5428	0.5047	0.5214	0.5230	0.2229
4	0.8108	0.7164	0.7411	0.7561	0.3934
5	0.8171	0.7230	0.7420	0.7607	0.3763
6	0.6567	0.6420	0.5979	0.6322	0.2230
7	0.6152	0.6047	0.5803	0.6001	0.1946
8	0.2249	0.2057	0.2239	0.2182	0.1146
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	9.5370	6.8660	6.2430	7.5487	
171 m RB	5.6020	5.1340	4.8480	5.1947	

[1] Impact - ambient velocity.

Table 48
Clark's Ferry, Pool El 546.0, LC1U22, Run 19 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2353	0.2358	0.2425	0.2379	
2	0.2483	0.2437	0.2535	0.2485	
3	0.2956	0.2916	0.2988	0.2953	
4	0.3496	0.3554	0.3560	0.3537	
5	0.3972	0.3948	0.3809	0.3910	
6	0.4158	0.4295	0.4090	0.4181	
7	0.4157	0.4101	0.4112	0.4123	
8	0.1019	0.1019	0.1052	0.1030	
Impact Velocity, m/sec					
1	0.1705	0.1804	0.1764	0.1758	0.0621
2	0.1779	0.1607	0.1577	0.1654	0.0831
3	0.1486	0.1813	0.1925	0.1741	0.1212
4	0.0900	0.1454	0.2136	0.1497	0.2040
5	0.1205	0.1262	0.1371	0.1279	0.2631
6	0.2031	0.2320	0.2457	0.2269	0.1912
7	0.2739	0.3004	0.2959	0.2901	0.1222
8	0.0315	0.0150	-0.0442	0.0008	0.1022
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	1.9640	2.9830	2.1000	2.3490	
171 m RB	4.1070	2.6170	3.3330	3.3523	

[1] Impact - ambient velocity.

Table 49
Clark's Ferry, Pool El 546.0, LC2D38, Run 15 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2269	0.2391	0.2277	0.2312	
2	0.2466	0.2380	0.2442	0.2429	
3	0.2991	0.2914	0.2756	0.2887	
4	0.3572	0.3518	0.3530	0.3540	
5	0.3746	0.3993	0.3888	0.3876	
6	0.4077	0.4138	0.4214	0.4143	
7	0.4057	0.4072	0.3663	0.3931	
8	0.0906	0.0926	0.1039	0.0957	
Impact Velocity, m/sec					
1	0.0669	0.0473	0.0665	0.0602	0.1710
2	0.1106	0.0966	0.1191	0.1088	0.1341
3	0.0718	0.1219	0.0911	0.0949	0.1938
4	0.0008	0.1132	0.1225	0.0788	0.2752
5	0.0270	0.0278	0.0155	0.0234	0.3642
6	0.1642	0.1934	0.1601	0.1726	0.2417
7	0.2691	0.2534	0.2820	0.2682	0.1249
8	-0.0208	-0.0652	-0.0366	-0.0409	0.1366
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	8.3780	7.7780	-----	8.0780	
171 m RB	4.3780	4.8150	-----	4.5963	

[1] Impact - ambient velocity.

Table 50
Clark's Ferry, Pool El 546.0, LC3U22, Run 10 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2375	0.2518	0.2424	0.2436	
2	0.2554	0.2482	0.2394	0.2477	
3	0.2994	0.3019	0.2907	0.2973	
4	0.3728	0.3634	0.3578	0.3647	
5	0.3721	0.3883	0.4118	0.3907	
6	0.4115	0.4173	0.4172	0.4153	
7	0.3838	0.4067	0.4239	0.4048	
8	0.1129	0.1056	0.1179	0.1121	
Impact Velocity, m/sec					
1	0.3465	0.3331	0.3469	0.3422	0.0986
2	0.3658	0.3529	0.3545	0.3577	0.1100
3	0.4676	0.4750	0.4677	0.4701	0.1728
4	0.6207	0.6188	0.6151	0.6182	0.2535
5	0.6100	0.6377	0.6097	0.6191	0.2284
6	0.5495	0.5859	0.5569	0.5641	0.1488
7	0.5484	0.5614	0.5201	0.5433	0.1385
8	0.1876	0.1950	0.3094	0.2307	0.1186
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.0000	3.1180	2.7540	3.2907	
171 m RB	2.1550	2.2590	2.4680	2.2938	

[1] Impact - ambient velocity.

Table 51
Clark's Ferry, Pool El 546.0, LC3U31, Run 9 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2346	0.2329	0.2329	0.2335	
2	0.2481	0.2476	0.2428	0.2462	
3	0.3004	0.2880	0.2801	0.2895	
4	0.3491	0.3628	0.3509	0.3543	
5	0.3896	0.3860	0.3872	0.3876	
6	0.3994	0.4060	0.4017	0.4024	
7	0.4100	0.4055	0.4151	0.4102	
8	0.0845	0.0880	0.1057	0.0927	
Impact Velocity, m/sec					
1	0.4702	0.4587	0.4900	0.4730	0.2395
2	0.4636	0.4691	0.4707	0.4678	0.2216
3	0.5698	0.5553	0.5585	0.5612	0.2717
4	0.7038	0.6885	0.5009	0.6311	0.2768
5	0.6918	0.6741	0.6993	0.6884	0.3008
6	0.6235	0.6329	0.6481	0.6348	0.2324
7	0.6148	0.6307	0.5968	0.6141	0.2039
8	0.2431	0.2254	0.1880	0.2188	0.1261
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	9.4340	9.6230	9.3400	9.4657	
171 m RB	5.4700	6.1320	6.1320	5.9113	

[1] Impact - ambient velocity.

Table 52
Clark’s Ferry, Pool El 546.0, LC3D29, Run 8 May 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2323	0.2435	0.2263	0.2340	
2	0.2600	0.2439	0.2348	0.2462	
3	0.3038	0.3016	0.2855	0.2970	
4	0.3550	0.3593	0.3654	0.3599	
5	0.3816	0.4005	0.3746	0.3856	
6	0.3935	0.4289	0.4079	0.4101	
7	0.4036	0.4027	0.4088	0.4050	
8	0.1154	0.0609	0.0988	0.0917	
Impact Velocity, m/sec					
1	0.1512	0.1608	0.1238	0.1453	0.0887
2	0.1510	0.1736	0.1370	0.1539	0.0923
3	0.1948	0.1701	0.1594	0.1748	0.1222
4	0.1354	0.1318	0.1161	0.1278	0.2321
5	0.1377	0.1383	0.1473	0.1411	0.2445
6	0.2626	0.2600	0.2630	0.2619	0.1482
7	0.2184	0.2194	0.2977	0.2452	0.1598
8	0.0369	0.0087	0.0019	0.0158	0.0759

Drawdown, cm

Distance from Thalweg m	A	B	C	AVG	
186 m LB	3.1340	1.8420	2.1070	2.3610	
171 m RB	2.8670	3.2370	3.6420	3.2487	

[1] Impact - ambient velocity.

Table 53
Clark's Ferry, Pool El 546.0, LC3D38, Run 9 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	-----	0.2363	0.2379	0.2371	
2	-----	0.2441	0.2429	0.2435	
3	-----	0.2957	0.2956	0.2957	
4	-----	0.3432	0.3455	0.3444	
5	0.3711	0.3626	0.3840	0.3726	
6	0.4019	0.4167	0.3990	0.4059	
7	0.4171	0.4267	0.3956	0.4131	
8	0.0741	0.0855	0.0943	0.0846	
Impact Velocity, m/sec					
1	-----	0.0404	0.0366	0.0385	0.1986
2	-----	0.0597	0.0731	0.0664	0.1771
3	-----	0.0605	0.0633	0.0619	0.2338
4	-----	0.0533	0.0263	0.0398	0.3046
5	0.0665	0.0639	0.0847	0.0717	0.3009
6	0.2197	0.1697	0.1343	0.1746	0.2313
7	0.2271	0.2462	0.1907	0.2213	0.1918
8	-0.0572	-0.0054	0.0114	-0.0171	0.1017
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	10.9430	9.2450	9.1510	9.7797	
171 m RB	5.3770	5.4700	6.3200	5.7223	

[1] Impact - ambient velocity.

Table 54
Clark's Ferry, Pool El 546.0, LC4U22, Run 4 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2535	0.2224	0.2334	0.2364	
2	0.2475	0.2381	0.2479	0.2445	
3	0.2836	0.2887	0.2824	0.2849	
4	0.3514	0.3490	0.3637	0.3547	
5	0.3639	0.3769	0.3850	0.3753	
6	0.4279	0.4029	0.3995	0.4101	
7	0.4277	0.3990	0.4091	0.4119	
8	0.0395	0.0817	0.1118	0.0777	
Impact Velocity, m/sec					
1	0.3663	0.3551	0.3397	0.3537	0.1173
2	0.3800	0.3765	0.3818	0.3794	0.1349
3	0.4593	0.4868	0.4501	0.4654	0.1805
4	0.5798	0.6002	0.6017	0.5939	0.2392
5	0.6146	0.6023	0.5879	0.6016	0.2263
6	0.5959	0.5736	0.5567	0.5754	0.1653
7	0.5540	0.5746	0.5570	0.5619	0.1500
8	0.1716	0.1974	0.2042	0.1911	0.1134
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.4880	4.0880	4.4880	4.3547	
171 m RB	4.8890	4.5310	5.1080	4.8427	

[1] Impact - ambient velocity.

Table 55
Clark's Ferry, Pool El 546.0, LC4U31, Run 4 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2406	0.2259	0.2270	0.2312	
2	0.2516	0.2421	0.2462	0.2466	
3	0.2969	0.2837	0.3074	0.2960	
4	0.3443	0.3465	0.3595	0.3501	
5	0.3816	0.3775	0.3543	0.3711	
6	0.4064	0.4039	0.3951	0.4018	
7	0.4142	0.3982	0.4088	0.4071	
8	0.0842	0.1002	0.0903	0.0916	
Impact Velocity, m/sec					
1	0.4632	0.4793	0.4804	0.4743	0.2431
2	0.5016	0.4986	0.4951	0.4984	0.2518
3	0.5702	0.5767	0.5804	0.5758	0.2798
4	0.6650	0.6849	0.7279	0.6926	0.3425
5	0.6923	0.6946	0.7238	0.7036	0.3325
6	0.6370	0.6346	0.6707	0.6474	0.2456
7	0.6267	0.6523	0.6604	0.6465	0.2394
8	0.2037	0.2332	0.2131	0.2167	0.1251
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	11.2150	11.0000	11.6660	11.2937	
171 m RB	8.4600	8.8880	9.1100	8.8193	

[1] Impact - ambient velocity.

Table 56
Clark's Ferry, Pool El 546.0, LC4D29, Run 5 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2337	0.2272	0.2431	0.2347	
2	0.2478	0.2529	0.2467	0.2491	
3	0.2953	0.2880	0.2904	0.2912	
4	0.3533	0.3385	0.3521	0.3480	
5	0.3721	0.3841	0.3751	0.3771	
6	0.4023	0.4094	0.3968	0.4028	
7	0.4131	0.4057	0.4032	0.4073	
8	0.0996	0.0693	0.0890	0.0860	
Impact Velocity, m/sec					
1	0.1229	0.1332	0.1645	0.1402	0.0945
2	0.1278	0.1388	0.1442	0.1369	0.1122
3	0.1413	0.1430	0.1754	0.1532	0.1380
4	0.1583	0.1157	0.1287	0.1342	0.2138
5	0.1347	0.1065	0.1266	0.1226	0.2545
6	0.2401	0.2285	0.2348	0.2345	0.1683
7	0.2753	0.2726	0.2219	0.2506	0.1567
8	-0.0065	0.0100	-0.0153	-0.0039	0.0899
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.8160	4.5250	4.1070	4.4827	
171 m RB	4.9870	4.8420	4.9990	4.9427	

[1] Impact - ambient velocity.

Table 57
Clark's Ferry, Pool El 546.0, LC4D38, Run 5 May 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2311	0.2331	0.2408	0.2350	
2	0.2321	0.2463	0.2400	0.2395	
3	0.2481	0.2836	0.2775	0.2817	
4	0.3410	0.3423	0.3560	0.3464	
5	0.3675	0.3722	0.3876	0.3758	
6	0.4032	0.3845	0.3981	0.3953	
7	0.3914	0.3921	0.3918	0.3918	
8	0.1301	0.0839	0.0670	0.0937	
Impact Velocity, m/sec					
1	0.0659	-0.0115	0.0387	0.0310	0.2040
2	0.0187	0.0588	0.0308	0.0361	0.2034
3	0.0455	0.0525	0.0826	0.0602	0.2215
4	0.0624	0.0837	0.1064	0.0842	0.2622
5	0.0895	0.0747	0.0469	0.0704	0.3054
6	0.2022	0.0863	0.1552	0.1479	0.2474
7	0.2122	0.1850	0.1514	0.1829	0.2089
8	0.0054	0.0050	-0.0494	-0.0130	0.1067

Drawdown, cm

Distance from Thalweg m	A	B	C	AVG	
186 m LB	11.1110	11.4820	11.2710	11.2880	
171 m RB	6.7600	6.7600	6.9800	6.8333	

[1] Impact - ambient velocity.

Table 58 **Clark's Ferry, Pool El 546.0, Tow Length Experiments, Meter Positions**								
	Probe Number							
N **Probe Position[1]** **Experiment o.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
PP1 (LC1U22, LC1U31, LC1D29, LC1D29, LC1D38, LC2U22, LC2U31, LC2D29, LC2D38, LC3U22, LC3U31, LC3D29, LC3D38, LC4U22, LC4U31, LC4D29, LC4D38)	321.0 Left	228.0 Left	126.0 Left	30.0 Left	30.0 Right	99.0 Right	168.0 Right	237.0 Right
[1] Probe position, distance in meters from thalweg, looking downstream.								

Table 59 **Clark's Ferry Pool 546.0 Experiment Conditions – Rake Experiments**										
Experiment No.	**Up or Down**	**Tow Speed[1] m/sec**	**Position[2]**	**Temp ° C**	**Actual Draft m**	**Effective Draft[3] m**	**Barge W X L**	**Prop Thrust 1,000 lb**	**Schijf Velocity[4] cm/sec**	**Schijf Drawdown[4] cm**
LCEU22	U	2.28	252.7	24.0	2.13	2.68	3X5	81	13.7	3.7
LCEU31	U	3.18	252.7	24.0	2.13	2.64	3X5	108	23.9	8.8
LCED29	D	2.92	252.7	22.5	2.13	2.68	3X5	81	13.7	3.7
LCED38	D	3.82	252.7	24.0	2.13	2.65	3X5	108	24.0	8.9

Note: Water surface width 614.8 m, area 2,170 sq m, q 690 cms, water surface elevation 546.0, average ambient velocity 0.32 m/sec, 26° rake.
[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 60
Clark's Ferry, Pool El 546.0, LCEU22, Run 6 Jun 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2395	0.2262	0.2326	0.2328	
2	0.2498	0.2468	0.2571	0.2512	
3	0.2957	0.2970	0.2962	0.2963	
4	0.3627	0.3545	0.3507	0.3560	
5	0.3740	0.3917	0.3817	0.3825	
6	0.4077	0.4104	0.4064	0.4082	
7	0.3922	0.4031	0.4038	0.3997	
8	0.0790	0.1212	0.0825	0.0942	
Impact Velocity, m/sec					
1	0.3653	0.3782	0.3689	0.3708	0.1380
2	0.3907	0.3963	0.4090	0.3987	0.1475
3	0.4956	0.4826	0.4923	0.4902	0.1939
4	0.6158	0.6783	0.6472	0.6371	0.2811
5	0.6335	0.6702	0.6269	0.6435	0.2610
6	0.5779	0.5394	0.5705	0.5626	0.1544
7	0.5769	0.5667	0.5631	0.5689	0.1692
8	0.1731	0.2396	0.2205	0.2111	0.1169
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.7550	5.3850	6.0010	5.3803	
171 m RB	5.9530	5.0260	5.6410	5.5401	

[1] Impact - ambient velocity.

Table 61
Clark's Ferry, Pool El 546.0, LCEU31, Run 6 Jun 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2197	0.2462	0.2273	0.2311	
2	0.2452	0.2489	0.2417	0.2453	
3	0.2865	0.2983	0.2990	0.2946	
4	0.3530	0.3556	0.3692	0.3593	
5	0.3865	0.3856	0.3660	0.3794	
6	0.4072	0.4035	0.3919	0.4009	
7	0.3949	0.3930	0.4133	0.4004	
8	0.0840	0.0803	0.0915	0.0853	
Impact Velocity, m/sec					
1	0.5533	0.5267	0.5492	0.5431	0.3120
2	0.5536	0.5311	0.5300	0.5382	0.2929
3	0.6291	0.6179	0.6424	0.6298	0.3352
4	0.7440	0.7480	0.7586	0.7502	0.3909
5	0.7333	0.7175	0.7202	0.7237	0.3443
6	0.6700	0.6788	0.6539	0.6676	0.2667
7	0.6621	0.6571	0.6751	0.6648	0.2644
8	0.2705	0.1799	0.2096	0.2200	0.1347
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	13.6660	14.1110	14.3330	14.0367	
171 m RB	10.3320	9.8880	9.8880	10.0360	

[1] Impact - ambient velocity.

Table 62
Clark's Ferry, Pool El 546.0, LCED29, Run 2 Jun 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2509	0.2389	0.2302	0.2400	
2	0.2361	0.2374	0.2267	0.2334	
3	0.3043	0.2922	0.2988	0.2984	
4	0.3454	0.3345	0.3481	0.3427	
5	0.3908	0.3774	0.3609	0.3764	
6	0.3954	0.3906	0.3873	0.3911	
7	0.3889	0.3927	0.3966	0.3927	
8	0.1592	0.0949	0.1234	0.1258	
Impact Velocity, m/sec					
1	0.1272	0.0900	0.1307	0.1160	0.1240
2	0.0895	0.1359	0.1224	0.1159	0.1175
3	0.1364	0.1522	0.1154	0.1347	0.1637
4	0.1304	0.1422	0.1360	0.1362	0.2065
5	0.1363	0.1274	0.1338	0.1325	0.2439
6	0.2362	0.2172	0.2035	0.2190	0.1721
7	0.2440	0.1968	0.2545	0.2318	0.1609
8	-0.0833	0.0011	0.0209	-0.0204	0.1462
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.5870	4.4890	3.6760	4.2507	
171 m RB	2.9550	2.6790	4.9810	3.5383	

[1] Impact - ambient velocity.

Table 63
Clark's Ferry, Pool El 546.0, LCED38, Run 5 Jun 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
1	0.2338	0.2316	0.2348	0.2334	
2	0.2495	0.2488	0.2480	0.2488	
3	0.2940	0.2901	0.2985	0.2942	
4	0.3422	0.3569	0.3454	0.3482	
5	0.3835	0.3683	0.3708	0.3742	
6	0.4233	0.4003	0.3924	0.4053	
7	0.4051	0.4035	0.4111	0.4066	
8	0.0943	0.0804	0.0918	0.0888	
Impact Velocity, m/sec					
1	0.0005	0.0000	0.0339	0.0115	0.2219
2	0.0501	0.0278	0.2480	0.1086	0.1402
3	0.0383	0.0257	0.2985	0.1208	0.1734
4	0.0485	0.0566	-0.0131	0.0307	0.3175
5	0.0377	0.0590	0.0426	0.0464	0.3278
6	0.1441	0.1484	0.1563	0.1496	0.2557
7	0.2024	0.1709	0.1661	0.1798	0.2268
8	-0.0396	-0.0018	-0.0015	-0.0143	0.1031
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	11.7870	10.0600	11.6480	11.1650	
171 m RB	4.5150	2.6990	3.9830	3.7320	

[1] Impact - ambient velocity.

Table 64
Clark's Ferry Pool 546.0 Conditions for Vertical Distribution Experiments

Experiment No.	Up or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] cm
LCVUCD	U	3.18	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9
LCVDCD	D	3.82	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9
LCVUBE	U	3.18	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9
LCVDBE	D	3.82	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9
LCVUAF	U	3.18	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9
LCVDAF	D	3.82	252.7	22.0	2.13	2.67	3X5	108	24.2	8.9

Note: Water surface width 614.8 m, area 2,170 sq m, Q 690 cms, water surface elevation 546.0, average ambient velocity 0.32 m/sec, 26° rake.
[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 65
Clark's Ferry, Pool El 546.0, LCVDCD, Run 12 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
80	0.3901	0.4141	0.3986	0.4009	
50	0.3160	0.3160	0.3069	0.3130	
20	0.3620	0.3612	0.3534	0.3589	
Impact Velocity, m/sec					
80	0.0670	0.0569	0.0889	0.0709	0.3328
50	-0.0379	0.0248	-0.0150	-0.0094	0.3224
20	0.0585	0.0717	0.0534	0.0612	0.2977
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
351 m LB	11.9630	10.6560	11.3330	11.3173	
234 m RB	10.6660	9.1850	9.5930	9.8147	

Note: Local water depth 5.0 m, LB 34 m left of thalweg.
[1] Impact - ambient velocity.

Table 66
Clark's Ferry, Pool El 546.0, LCVUCD, Run 13 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
80	0.3932	0.3877	0.3969	0.3926	
50	0.3150	0.2936	0.3157	0.3081	
20	0.3481	0.3400	0.3600	0.3494	
Impact Velocity, m/sec					
80	0.7559	0.7610	0.7743	0.7637	0.3711
50	0.6281	0.6759	0.7136	0.6725	0.3644
20	0.6702	0.6846	0.7126	0.6891	0.3397
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
351 m LB	12.0000	11.9450	11.9450	11.9633	
234 m RB	13.0000	13.0560	13.1480	13.0680	

Note: Local water depth 5.0 m, LB 34 m left of thalweg.
[1] Impact - ambient velocity.

Table 67
Clark's Ferry, Pool El 546.0, LCVUBE, Run 14 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
80	0.3158	0.3028	0.3040	0.3075	
50	0.2758	0.2724	0.2656	0.2713	
20	0.2558	0.2532	0.2485	0.2525	
Impact Velocity, m/sec					
80	0.5881	0.6025	0.6009	0.5972	0.2897
50	0.5615	0.5874	0.5830	0.5773	0.3060
20	0.5391	0.5582	0.5507	0.5493	0.2968
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
30 m LB	19.7140	20.5900	20.7360	20.3467	
30 m RB	15.3010	15.4410	15.8820	15.5413	

Note: Local water depth 5.0 m, LB 172 m left of thalweg.
[1] Impact - ambient velocity.

Table 68
Clark's Ferry, Pool El 546.0, LCVDBE, Run 14 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
80	0.3130	0.3119	0.2959	0.3069	
50	0.2883	0.2757	0.2615	0.2752	
20	0.2627	0.2487	0.2385	0.2500	
Impact Velocity, m/sec					
80	0.0932	0.0917	0.0676	0.0842	0.2227
50	0.0684	0.0633	0.0308	0.0542	0.2210
20	0.0646	0.0492	0.0389	0.0509	0.1991
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
30 m LB	16.0310	17.4360	17.5640	17.0103	
30 m RB	13.4740	17.1790	16.9220	15.8583	

Note: Local water depth 3.10 m, LB 172 m left of thalweg.
[1] Impact - ambient velocity.

Table 69
Clark's Ferry, Pool El 546.0, LCVUAF, Run 16 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
Ambient Velocity, m/sec					
80	0.2549	0.2593	0.2522	0.2555	
50	0.2664	0.2729	0.2711	0.2701	
20	0.1869	0.1976	0.1811	0.1885	
Impact Velocity, m/sec					
80	0.5849	0.5821	0.5780	0.5817	0.3262
50	0.5934	0.5701	0.5723	0.5768	0.3085
20	0.4795	0.4855	0.4738	0.4796	0.2911
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
171 m LB	10.4630	11.0190	10.3330	10.6050	
138 m RB	9.2600	14.3520	8.8880	10.8333	

Note: Local water depth 2.64 m, LB 318 m left of thalweg.
[1] Impact - ambient velocity.

Table 70
Clark's Ferry, Pool El 546.0, LCVDAF, Run 16 Jun 95, Vertical Distribution

Depth off Bottom, %	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
80	0.2590	0.2736	0.2528	0.2618	
50	0.2673	0.2807	0.2588	0.2689	
20	0.2060	0.2095	0.1976	0.2044	
	Impact Velocity, m/sec				
80	0.0434	0.0589	0.0763	0.0595	0.2023
50	0.0489	0.0174	0.0009	0.0224	0.2465
20	-0.0176	0.0079	0.0186	0.0030	0.2014
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
171 m LB	16.2220	15.9260	15.2790	15.8090	
138 m RB	9.3330	9.0740	9.2130	9.2067	

Note: Local water depth 2.64 m, LB 318 m left of thalweg.
[1] Impact - ambient velocity.

Table 71
Clark's Ferry Pool 551.5 Conditions

Experiment No.	Up or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] cm
HCU138	U	1.38	256.9	26.0	2.13	2.73	3X5	54	5.3	1.0
HCU183	U	1.83	256.9	26.0	2.13	2.71	3X5	67.5	6.9	1.6
HCU228	U	2.28	256.9	26.0	2.13	2.69	3X5	81	8.7	2.4
HCU273	U	2.73	256.9	26.0	2.13	2.67	3X5	94.5	10.8	3.5
HCU318	U	3.18	256.9	26.0	2.13	2.65	3X5	108	13.4	5.0
HCU416	U	4.16	256.9	26.0	2.13	2.63	3X5	135	22.6	10.8
HCD202	D	2.02	256.9	26.0	2.13	2.76	3X5	54	4.8	0.8
HCD247	D	2.47	256.9	26.0	2.13	2.73	3X5	67.5	6.4	1.4
HCD292	D	2.92	256.9	26.0	2.13	2.70	3X5	81	8.1	2.1
HCD337	D	3.37	256.9	26.0	2.13	2.68	3X5	94.5	10.0	3.1
HCD382	D	3.82	256.9	26.0	2.13	2.67	3X5	108	12.5	4.4
HCD477	D	4.77	256.9	26.0	2.13	2.64	3X5	135	20.2	9.2

Note: Water surface width 627 m, area 3,215 sq m, Q 1,285 cms, water surface elevation 551.5, 26° rake.
[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 72
Clark's Ferry, Pool El 551.5, HCU138, Run 4 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3202	0.3398	0.3377	0.3326	
2	0.3595	0.3672	0.3692	0.3653	
3	0.4393	0.4214	0.4495	0.4367	
4	0.4362	0.4398	0.4454	0.4405	
5	0.4421	0.4829	0.4825	0.4692	
6	0.5024	0.5067	0.5047	0.5046	
7	0.4057	0.3785	0.4184	0.4009	
8	0.1714	0.1738	0.1847	0.1766	
	Impact Velocity, m/sec				
1	0.4397	0.4350	0.4173	0.4307	0.1001
2	0.4673	0.4768	0.4525	0.4655	0.1002
3	0.5278	0.5139	0.5447	0.5288	0.0921
4	0.5719	0.5486	0.5847	0.5684	0.1279
5	0.5910	0.5995	0.6148	0.6018	0.1326
6	0.5465	0.6111	0.6129	0.5902	0.0856
7	0.4749	0.4975	0.4662	0.4795	0.0786
8	0.3607	0.3581	0.3761	0.3650	0.1884
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	1.2500	1.7500	1.5000	1.5000	
180 m RB	0.5500	0.7550	0.6500	0.6517	

[1] Impact - ambient velocity.

Table 73
Clark's Ferry, Pool El 551.5, HCU183, Run 3 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3589	0.3435	0.3282	0.3435	
2	0.3743	0.3684	0.3737	0.3721	
3	0.4249	0.4542	0.4290	0.4360	
4	0.4471	0.4400	0.4302	0.4391	
5	0.4412	0.4468	0.4715	0.4532	
6	0.4751	0.4814	0.4900	0.4822	
7	0.4014	0.3696	0.4077	0.3929	
8	0.1344	0.1277	0.2517	0.1713	
	Impact Velocity, m/sec				
1	0.4281	0.4417	0.4237	0.4312	0.0877
2	0.4735	0.4607	0.4777	0.4706	0.0985
3	0.5519	0.5366	0.5303	0.5396	0.1036
4	0.5901	0.6361	0.6134	0.6132	0.1741
5	0.6679	0.6479	0.6577	0.6578	0.2046
6	0.5880	0.5934	0.5815	0.5876	0.1054
7	0.4655	0.4768	0.4704	0.4709	0.0780
8	0.3551	0.3396	0.3679	0.3542	0.1829
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.7500	2.9300	2.6000	2.7600	
180 m RB	1.1000	0.9890	1.2000	1.0963	

[1] Impact - ambient velocity.

Table 74
Clark's Ferry, Pool El 551.5, HCU228, Run 3 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3651	0.3643	0.3416	0.3570	
2	0.3800	0.3696	0.3802	0.3766	
3	0.4319	0.4302	0.4303	0.4308	
4	0.4287	0.4217	0.4371	0.4292	
5	0.4703	0.4716	0.4596	0.4672	
6	0.4932	0.4882	0.4758	0.4857	
7	0.3770	0.3745	0.3748	0.3754	
8	0.1668	0.0941	0.1762	0.1457	
	Impact Velocity, m/sec				
1	0.4148	0.4177	0.4472	0.4266	0.0696
2	0.5042	0.4911	0.4718	0.4890	0.1124
3	0.5250	0.5366	0.5642	0.5419	0.1111
4	0.6241	0.6333	0.6133	0.6236	0.1944
5	0.6129	0.6216	0.6087	0.6144	0.1472
6	0.6014	0.5771	0.6216	0.6000	0.1143
7	0.4750	0.4814	0.4834	0.4799	0.1045
8	0.2934	0.3776	0.2974	0.3228	0.1771
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.2000	4.7500	4.6300	4.5267	
180 m RB	2.0500	2.3000	2.3890	2.2463	

[1] Impact - ambient velocity.

Table 75
Clark's Ferry, Pool El 551.5, HCU273, Run 3 Aug 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3387	0.3137	0.3361	0.3295	
2	0.3422	0.3413	0.3861	0.3565	
3	0.4449	0.4404	0.4298	0.4384	
4	0.4053	0.4375	0.4544	0.4324	
5	0.4632	0.4540	0.4574	0.4582	
6	0.5074	0.5024	0.4874	0.4991	
7	0.3937	0.4055	0.4083	0.4025	
8	0.1082	0.1464	0.0946	0.1164	
	Impact Velocity, m/sec				
1	0.4645	0.4042	0.4337	0.4341	0.1046
2	0.4772	0.4449	0.4850	0.4690	0.1125
3	0.6042	0.5844	0.5452	0.5779	0.1395
4	0.6928	0.6523	0.6487	0.6646	0.2322
5	0.6331	0.6357	0.6981	0.6556	0.1974
6	0.6035	0.6622	0.6339	0.6332	0.1341
7	0.4743	0.4873	0.4811	0.4809	0.0784
8	0.2868	0.3766	0.2895	0.3176	0.2012
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	5.9050	5.6860	5.8290	5.8067	
180 m RB	3.1740	2.8570	2.9710	3.0007	

[1] Impact - ambient velocity.

Table 76
Clark's Ferry, Pool El 551.5, HCU318, Run 2 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3250	0.3433	0.3480	0.3388	
2	0.3668	0.3433	0.3590	0.3564	
3	0.4260	0.3650	0.4413	0.4108	
4	0.4443	0.4112	0.4444	0.4333	
5	0.4658	0.4255	0.4488	0.4467	
6	0.4699	0.4467	0.4574	0.4580	
7	0.3657	0.3740	0.3864	0.3754	
8	0.1291	0.1686	0.1663	0.1547	
	Impact Velocity, m/sec				
1	0.4194	0.4713	0.5035	0.4647	0.1259
2	0.5167	0.4713	0.5080	0.4987	0.1423
3	0.6120	0.5412	0.6207	0.5913	0.1805
4	0.6845	0.5992	0.6998	0.6612	0.2279
5	0.6440	0.6589	0.6827	0.6619	0.2152
6	0.6603	0.6461	0.6807	0.6624	0.2044
7	0.5370	0.5295	0.5209	0.5291	0.1537
8	0.3649	0.3027	0.2009	0.2895	0.1348
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	9.9300	8.8390	9.5550	9.4413	
180 m RB	6.1780	5.8930	5.3330	5.8013	

[1] Impact - ambient velocity.

Table 77
Clark's Ferry, Pool El 551.5, HCU416, Run 4 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3261	0.3533	0.3500	0.3431	
2	0.3662	0.3688	0.3756	0.3702	
3	0.4445	0.4619	0.4422	0.4495	
4	0.4279	0.4187	0.4315	0.4260	
5	0.4184	0.4318	0.4533	0.4345	
6	0.4643	0.4803	0.4935	0.4794	
7	0.3915	0.3871	0.3922	0.3903	
8	0.1427	0.1695	0.2300	0.1807	
	Impact Velocity, m/sec				
1	0.5438	0.5619	0.5470	0.5509	0.2078
2	0.5825	0.6212	0.6222	0.6086	0.2384
3	0.6636	0.6889	0.6670	0.6732	0.2237
4	0.8056	0.7789	0.7373	0.7739	0.3479
5	0.6913	0.7035	0.7035	0.6994	0.2649
6	0.6771	0.6672	0.6614	0.6686	0.1891
7	0.5791	0.5862	0.5914	0.5856	0.1953
8	0.3976	0.3809	0.3201	0.3662	0.1855
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	16.6250	17.3750	16.6250	16.8750	
180 m RB	9.3130	9.1250	9.3130	9.2503	

[1] Impact - ambient velocity.

Table 78
Clark's Ferry, Pool El 551.5, HCD202, Run 31 Jul 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3331	0.3272	0.3399	0.3334	
2	0.3816	0.3630	0.3708	0.3718	
3	0.4134	0.4083	0.4335	0.4184	
4	0.4561	0.4349	0.4576	0.4495	
5	0.4694	0.4638	0.4563	0.4632	
6	0.4855	0.5176	0.4541	0.4857	
7	0.3835	0.3532	0.3704	0.3690	
8	0.1208	0.1529	0.1456	0.1398	
	Impact Velocity, m/sec				
1	0.2763	0.2697	0.3058	0.2839	0.0495
2	0.3013	0.3193	0.3111	0.3106	0.0612
3	0.3204	0.3541	0.3387	0.3377	0.0807
4	0.3569	0.3347	0.3399	0.3438	0.1057
5	0.3379	0.3049	0.3167	0.3198	0.1434
6	0.4095	0.3647	0.3939	0.3894	0.0963
7	0.3216	0.3194	0.2842	0.3084	0.0606
8	0.1208	0.1529	0.1456	0.1398	0.0000
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	-----	-----	-----	-----	
180 m RB	-----	-----	-----	-----	

[1] Impact - ambient velocity.

Table 79
Clark's Ferry, Pool El 551.5, HCD247 Run 31 Jul 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.2979	0.3413	0.3339	0.3244	
2	0.3310	0.3598	0.3943	0.3617	
3	0.4219	0.4356	0.4057	0.4235	
4	0.4425	0.4704	0.4366	0.4498	
5	0.4614	0.4213	0.4251	0.4359	
6	0.4904	0.4791	0.4705	0.4800	
7	0.3527	0.3846	0.3712	0.3695	
8	0.2000	0.1996	0.2334	0.2110	
	Impact Velocity, m/sec				
1	0.2159	0.2762	0.2539	0.2487	0.0757
2	0.2673	0.3073	0.3359	0.3035	0.0582
3	0.3734	0.3372	0.3349	0.3485	0.0750
4	0.3048	0.3278	0.3045	0.3124	0.1374
5	0.2596	0.2833	0.3324	0.2918	0.1441
6	0.3719	0.3678	0.3613	0.3670	0.1130
7	0.3527	0.2530	0.2994	0.3017	0.0678
8	0.2000	-0.1100	0.0477	0.0459	0.2619
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.0000	1.5000	2.0000	1.8333	
180 m RB	1.5000	1.5000	1.5000	1.5000	

[1] Impact - ambient velocity.

Table 80
Clark's Ferry, Pool El 551.5, HCD292, Run 1 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3243	0.3229	0.3430	0.3301	
2	0.3682	0.3668	0.3715	0.3688	
3	0.4243	0.4030	0.4207	0.4160	
4	0.4146	0.4404	0.4509	0.4353	
5	0.4601	0.4521	0.4592	0.4571	
6	0.4887	0.4792	0.4768	0.4816	
7	0.3891	0.3987	0.3826	0.3901	
8	0.1632	0.2274	0.0827	0.1578	
	Impact Velocity, m/sec				
1	0.2746	0.2777	0.2571	0.2698	0.0603
2	0.2963	0.3181	0.3159	0.3101	0.0587
3	0.3519	0.3615	0.3171	0.3435	0.0725
4	0.2737	0.3149	0.3181	0.3056	0.1297
5	0.3030	0.2566	0.2690	0.2762	0.1809
6	0.3171	0.3502	0.3194	0.3289	0.1527
7	0.3368	0.2725	0.2754	0.2949	0.0952
8	0.0385	0.0467	-0.0456	0.0132	0.1446
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	3.2180	2.5710	2.7860	2.8583	
180 m RB	3.5210	3.0000	4.0000	3.5070	

[1] Impact - ambient velocity.

Table 81
Clark's Ferry, Pool El 551.5, HCD337, Run 2 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3291	0.3538	0.3123	0.3317	
2	0.3736	0.3619	0.3472	0.3609	
3	0.4212	0.3984	0.4292	0.4163	
4	0.4409	0.4352	0.4401	0.4387	
5	0.4499	0.4622	0.4495	0.4539	
6	0.4751	0.5104	0.5080	0.4978	
7	0.3792	0.3893	0.3807	0.3831	
8	0.1768	0.1779	0.1662	0.1736	
	Impact Velocity, m/sec				
1	0.2682	0.2604	0.2376	0.2554	0.0763
2	0.2913	0.2564	0.2827	0.2768	0.0841
3	0.2953	0.3471	0.3058	0.3161	0.1002
4	0.3156	0.2382	0.2682	0.2740	0.1647
5	0.2228	0.2827	0.2884	0.2646	0.1893
6	0.3436	0.3298	0.3175	0.3303	0.1675
7	0.2690	0.2817	0.2805	0.2771	0.1060
8	0.0880	0.0270	0.0635	0.0595	0.1141
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	4.6000	4.3500	4.2250	4.3917	
180 m RB	3.7500	4.0500	3.8000	3.8667	

[1] Impact - ambient velocity.

Table 82
Clark's Ferry, Pool El 551.5, HCD382, Run 2 Aug 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3151	0.3033	0.3041	0.3075	
2	0.3614	0.3537	0.3547	0.3566	
3	0.4264	0.4426	0.4279	0.4323	
4	0.4315	0.4240	0.4258	0.4271	
5	0.4172	0.4487	0.4611	0.4423	
6	0.4916	0.4885	0.4913	0.4905	
7	0.3646	0.3715	0.3749	0.3703	
8	0.2148	0.0981	0.2418	0.1849	
	Impact Velocity, m/sec				
1	0.2366	0.1898	0.2149	0.2138	0.0937
2	0.2569	0.2828	0.2356	0.2584	0.0982
3	0.2832	0.2724	0.2920	0.2825	0.1498
4	0.2519	0.2653	0.2408	0.2527	0.1744
5	0.1837	0.2248	0.2320	0.2135	0.2288
6	0.2878	0.2569	0.3040	0.2829	0.2076
7	0.2765	0.2596	0.1852	0.2404	0.1299
8	0.0103	-0.0805	-0.0165	-0.0289	0.2138
		Drawdown, cm			
Distance from Thalweg m	A	B	C	AVG	
186 m LB	5.7500	4.8240	5.8860	5.4867	
180 m RB	4.6870	4.7340	4.7990	4.7400	

[1] Impact - ambient velocity.

Table 83
Clark's Ferry, Pool El 551.5, HCD477, Run 2 Aug 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3487	0.3279	0.3300	0.3355	
2	0.3493	0.3680	0.3835	0.3669	
3	0.4200	0.4480	0.4487	0.4389	
4	0.4570	0.4487	0.4345	0.4467	
5	0.4517	0.4643	0.4588	0.4583	
6	0.4881	0.4586	0.4746	0.4738	
7	0.4000	0.4048	0.3903	0.3984	
8	0.2065	0.2334	0.1945	0.2115	
	Impact Velocity, m/sec				
1	0.1615	0.1731	0.1906	0.1751	0.1604
2	0.2348	0.2396	0.2303	0.2349	0.1320
3	0.2413	0.2607	0.2543	0.2521	0.1868
4	0.2214	0.1844	0.2405	0.2154	0.2313
5	0.2090	0.2016	0.2252	0.2119	0.2464
6	0.2647	0.2815	0.3102	0.2855	0.1883
7	0.1548	0.1971	0.1455	0.1658	0.2326
8	0.0649	0.0677	0.0537	0.0621	0.1494
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	11.0870	11.6300	11.6300	11.4900	
180 m RB	9.4020	9.6740	5.6500	8.2420	

[1] Impact - ambient velocity.

Table 84
Clark's Ferry, Pool El 551.5, Experiments, Meter Positions

N

Probe Position[1] Experiment o.	Probe Number 1	2	3	4	5	6	7	8
PP1 (HCU138, HCU183, HCU228, HCU273, HCU318, HCU416, HCD202, HCD247, HCD292, HCD337, HCD382, HCD477)	321.0 Left	228.0 Left	129.0 Left	30.0 Left	30.0 Right	99.0 Right	168.0 Right	237.0 Right

[1] Probe position, distance in meters from thalweg, looking downstream.

Table 85
Clark's Ferry Pool 551.5 Experiment Conditions for Dikes

Experiment No.	Up or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] cm
H59D29	D	2.92	256.9	26.0	2.13	2.70	3X5	81	8.1	2.1
H59D47	D	4.77	256.9	26.0	2.13	2.64	3X5	135	20.3	9.2
H59U22	U	2.28	256.9	26.0	2.13	2.69	3X5	81	8.7	2.4
H59U41	U	4.16	256.9	26.0	2.13	2.63	3X5	135	22.6	10.8

Note: Water surface width 627 m, area 3,215 sq m, Q 1,285 cms, water surface elevation 541.5, 26° rake.
[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 86
Clark's Ferry, Pool El 551.5, H59D29, Run 7 Aug 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3534	0.3508	0.3557	0.3533	
2	0.3708	0.3710	0.3873	0.3764	
3	0.5586	0.5738	0.5762	0.5695	
4	0.4815	0.4748	0.4766	0.4776	
5	0.4590	0.4483	0.4467	0.4513	
6	0.5009	0.4881	0.5108	0.4999	
7	0.3867	0.3945	0.3983	0.3932	
8	0.1395	0.1295	0.1328	0.1339	
	Impact Velocity, m/sec				
1	0.3091	0.3001	0.2852	0.2981	0.0552
2	0.2929	0.3084	0.3376	0.3130	0.0634
3	0.4685	0.4960	0.4786	0.4810	0.0885
4	0.3106	0.2399	0.2965	0.2823	0.1953
5	0.3143	0.3242	0.3100	0.3162	0.1351
6	0.3217	0.3699	0.3637	0.3518	0.1481
7	0.2919	0.2992	0.2930	0.2947	0.0985
8	0.1395	0.1295	0.1328	0.1339	0.0000
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	3.6250	0.3750	3.6880	3.6877	
180 m RB	4.1250	3.5000	4.1250	3.9167	

[1] Impact - ambient velocity.

Table 87
Clark's Ferry, Pool El 551.5, H59D47, Run 7 Aug 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3601	0.3669	0.3490	0.3587	
2	0.3802	0.3927	0.3768	0.3832	
3	0.5641	0.5847	0.5830	0.5773	
4	0.4383	0.4716	0.4770	0.4623	
5	0.4970	0.4434	0.4388	0.4597	
6	0.3890	0.5061	0.4591	0.4514	
7	0.3837	0.3985	0.4664	0.4162	
8	0.3669	0.1198	0.0700	0.1856	
	Impact Velocity, m/sec				
1	0.2136	0.1807	0.2098	0.2014	0.1573
2	0.2417	0.2274	0.2453	0.2381	0.1451
3	0.3495	0.2864	0.2789	0.3049	0.2724
4	0.1627	0.2820	0.2331	0.2259	0.2364
5	0.3364	0.1942	0.2209	0.2505	0.2092
6	0.1768	0.3061	0.1858	0.2229	0.2285
7	-0.0173	0.2441	0.1640	0.1303	0.2859
8	0.3669	0.1198	0.0700	0.1856	0.0000
	Drawdown, cm				
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	9.3550	10.4840	13.2260	11.0217	
180 m RB	9.0490	10.0000	9.5170	9.5219	

[1] Impact - ambient velocity.

Table 88
Clark's Ferry, Pool El 551.5, H59U22, Run 16 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3573	0.3478	0.3650	0.3567	
2	0.3490	0.3589	0.3525	0.3535	
3	0.5490	0.5185	0.5746	0.5474	
4	0.4719	0.4301	0.4516	0.4512	
5	0.4285	0.4586	0.4330	0.4400	
6	0.4693	0.4638	0.4620	0.4650	
7	0.3906	0.3776	0.3790	0.3824	
8	0.0153	0.0829	0.0280	0.0421	
	Impact Velocity, m/sec				
1	0.4297	0.4363	0.4212	0.4291	0.0724
2	0.4632	0.4594	0.4741	0.4656	0.1121
3	0.7202	0.6831	0.7035	0.7023	0.1549
4	0.5101	0.5538	0.5166	0.5268	0.0756
5	0.6036	0.5566	0.5483	0.5695	0.1295
6	0.5566	0.5740	0.5919	0.5742	0.1092
7	0.4738	0.4401	0.4611	0.4583	0.0759
8	0.3123	0.3586	0.3380	0.3363	0.2942
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.6960	3.6780	3.5640	3.3127	
180 m RB	2.2170	2.7510	2.5360	2.5013	

[1] Impact - ambient velocity.

Table 89
Clark's Ferry, Pool El 551.5, H59U41, Run 16 Aug 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.3563	0.3498	0.3726	0.3596	
2	0.3629	0.3589	0.3507	0.3575	
3	0.5559	0.5609	0.5541	0.5570	
4	0.4318	0.4735	0.4374	0.4476	
5	0.4301	0.4157	0.4127	0.4195	
6	0.4565	0.4771	0.4422	0.4586	
7	0.3933	0.3661	0.3677	0.3757	
8	-0.0232	0.0719	0.0540	0.0342	
	Impact Velocity, m/sec				
1	0.5441	0.5457	0.5278	0.5392	0.1796
2	0.5659	0.5530	0.5478	0.5556	0.1981
3	0.8822	0.9008	0.8702	0.8844	0.3274
4	0.5239	0.7857	0.7899	0.6998	0.2522
5	0.6257	0.6415	0.6569	0.6414	0.2219
6	0.6382	0.6561	0.6005	0.6316	0.1730
7	0.5290	0.5524	0.5255	0.5356	0.1599
8	0.4118	0.4611	0.2778	0.3836	0.3494
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	11.8190	12.4550	11.1820	11.8187	
180 m RB	6.8180	6.7270	6.7270	6.7573	

[1] Impact - ambient velocity.

Table 90
Clark's Ferry Pool 572.7 Experiment Conditions

Experiment No.	Up or Down	Tow Speed[1] m/sec	Position[2]	Temp ° C	Actual Draft m	Effective Draft[3] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[4] cm/sec	Schijf Drawdown[4] cm
CHU228	U	2.28	259.1	24.0	2.13	2.69	3X5	81	3.2	0.8
CHU318	U	3.18	259.1	24.0	2.13	2.66	3X5	108	4.4	1.5
CHU408	U	4.08	259.1	24.0	2.13	2.64	3X5	135	6.2	2.8
CHD292	D	2.92	259.1	24.0	2.13	2.69	3X5	81	3.5	1.0
CHD382	D	3.82	259.1	24.0	2.13	2.66	3X5	108	4.7	1.7
CHD472	D	4.77	259.1	24.0	2.13	2.64	3X5	135	6.5	3.0

Note: Water surface width 629.5 m, area 7,283 sq m, water surface elevation 572.7, 26^{o} rake.
[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 91
Clark's Ferry, Pool El 572.7, CHU228, Run 8 Sep 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.1751	0.1456	0.1149	0.1452	
2	0.3792	0.2993	0.1602	0.2796	
3	0.4225	0.3554	0.1625	0.3135	
4	0.2491	0.2545	0.1267	0.2101	
5	0.2343	0.3068	0.2116	0.2509	
6	0.2569	0.2889	0.2084	0.2514	
7	0.4340	0.2550	0.1905	0.1630	
8	-----	0.3269	0.1470	0.2370	
	Impact Velocity, m/sec				
1	0.2652	0.2660	0.1149	0.2150	0.0700
2	0.3792	0.2993	0.1602	0.2796	0.0000
3	0.4225	0.4669	0.1625	0.3506	0.0370
4	0.2491	0.2545	0.3542	0.2859	0.0760
5	0.3249	0.3234	0.2870	0.3118	0.0610
6	0.3492	0.3637	0.2957	0.3362	0.0850
7	0.0434	0.3661	0.1905	0.2000	0.0370
8	-----	0.3269	0.1470	0.2370	0.0000
Drawdown, cm					
Distance from Thalweg m	A	B	C	AVG	
186 m LB	1.0000	1.0000	1.2500	1.0833	
171 m RB	1.0000	0.7500	1.0000	0.9167	

[1] Impact - ambient velocity.

Table 92
Clark's Ferry, Pool El 572.7, CHU318, Run 8 Sep 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.1148	0.0775	0.1139	0.1021	
2	0.1445	0.1056	0.1482	0.1328	
3	0.1446	0.1228	0.1190	0.1288	
4	0.1188	0.1667	0.1337	0.1397	
5	0.2342	0.2412	0.2327	0.2360	
6	0.2417	0.3123	0.2093	0.2544	
7	0.2100	0.2011	0.1719	0.1943	
8	-----	-----	-----	-----	
	Impact Velocity, m/sec				
1	0.1148	0.1308	0.1139	0.1198	0.0180
2	0.1886	0.1511	0.1855	0.1751	0.0420
3	0.2618	0.2145	0.2188	0.2317	0.1030
4	0.2889	0.3700	0.2479	0.3023	0.1630
5	0.2882	0.3159	0.3007	0.3016	0.0660
6	0.3412	0.3610	0.3333	0.3542	0.0910
7	0.2907	0.2840	0.2144	0.2630	0.0690
8	-----	-----	-----	-----	-----
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.0000	1.5000	1.7500	1.7500	
171 m RB	2.0000	2.0000	1.0000	1.6667	

[1] Impact - ambient velocity.

Table 93
Clark's Ferry, Pool El 572.7, CHU408, Run 11 Sep 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.1897	0.1859	0.1795	0.1850	
2	0.2657	0.2588	0.3163	0.2803	
3	0.3310	0.3181	0.2870	0.3120	
4	0.3480	0.3473	0.2841	0.3265	
5	0.3321	0.2648	0.2607	0.2859	
6	0.3031	0.2646	0.2813	0.2830	
7	0.2710	0.3182	0.3525	0.3139	
8	0.2189	0.1955	0.0276	0.1473	
	Impact Velocity, m/sec				
1	0.2387	0.2723	0.2455	0.2522	0.0670
2	0.3212	0.3407	0.3021	0.3213	0.0410
3	0.4602	0.4833	0.3465	0.4300	0.1180
4	0.3962	0.3302	0.2841	0.3368	0.0100
5	0.3998	0.3801	0.3374	0.3724	0.0870
6	0.3711	0.3861	0.3627	0.3733	0.0900
7	0.3456	0.3665	0.3861	0.3661	0.0520
8	0.2189	0.1955	0.0276	0.1473	0.0000
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	3.6670	4.1930	4.0000	3.9533	
171 m RB	2.9030	3.2900	3.3720	3.1883	

[1] Impact - ambient velocity.

Table 94
Clark's Ferry, Pool El 572.7, CHD292, Run 6 Sep 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.0865	0.1090	0.1222	0.1059	
2	0.1350	0.1704	0.1611	0.1555	
3	0.1728	0.1546	0.1364	0.1546	
4	0.1026	0.1689	0.0947	0.1221	
5	0.2206	0.1896	0.1896	0.1990	
6	0.2392	0.2371	0.2270	0.2344	
7	0.1588	0.1671	0.1431	0.1563	
8	0.2987	-----	-----	0.2987	
	Impact Velocity, m/sec				
1	0.0865	0.1090	0.1222	0.1059	0.0000
2	0.1350	0.1704	0.1611	0.1555	0.0000
3	0.1728	0.1546	0.0255	0.1176	0.0370
4	0.1026	0.1689	0.0947	0.1221	0.0000
5	0.1415	0.1433	0.1265	0.1371	0.0620
6	0.2392	0.1457	0.1239	0.1696	0.0650
7	0.1588	0.0800	0.0612	0.1000	0.0563
8	0.2987	-----	-----	0.2987	0.0000
	Drawdown, cm				
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	1.0000	1.0000	1.2500	1.0833	
171 m RB	1.0000	1.2000	1.5000	1.2333	

[1] Impact - ambient velocity.

Table 95
Clark's Ferry, Pool El 572.7, CHD382, Run 7 Sep 95

Probe	Replicate A	B	C	AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.2172	0.2720	0.2279	0.2390	
2	0.3232	0.3495	0.2454	0.3060	
3	0.2773	0.3387	0.4155	0.3438	
4	0.2672	0.3186	0.3181	0.3013	
5	0.2963	0.2388	0.2731	0.2694	
6	0.3331	0.2299	0.2726	0.2785	
7	0.2186	0.2098	0.1627	0.1970	
8	-----	-----	-----	-----	
	Impact Velocity, m/sec				
1	0.2172	0.2213	0.2279	0.2221	0.0170
2	0.2403	0.2998	0.2454	0.2618	0.0440
3	0.2773	0.2267	0.2521	0.2520	0.0920
4	0.2672	0.1002	0.0751	0.1475	0.1540
5	0.1990	0.1642	0.1975	0.1869	0.0830
6	0.2387	0.1851	0.1785	0.2008	0.0780
7	0.1565	0.1474	0.0706	0.1248	0.0720
8	-----	-----	-----	-----	-----
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	2.4300	2.9310	2.5600	2.6403	
171 m RB	1.7590	2.4480	2.2000	2.1357	

[1] Impact - ambient velocity.

Table 96
Clark's Ferry, Pool El 572.7, CHD472, Run 7 Sep 95

Probe	Replicate A	Replicate B	Replicate C	Replicate AVG	Return Velocity[1] m/sec
	Ambient Velocity, m/sec				
1	0.2393	0.2058	0.2078	0.2176	
2	0.3036	0.3532	0.3336	0.3301	
3	0.3496	0.3152	0.3402	0.3350	
4	0.2953	0.2446	0.2880	0.2760	
5	0.2684	0.2876	0.2562	0.2707	
6	0.3352	0.2323	0.2277	0.2651	
7	0.2152	0.1838	0.1880	0.1957	
8	-----	-----	-----	-----	
	Impact Velocity, m/sec				
1	0.2393	0.2058	0.2078	0.2176	0.0000
2	0.3036	0.2939	0.2795	0.2923	0.0380
3	0.1965	0.2213	0.2061	0.2080	0.1270
4	0.0702	-0.1077	0.0307	-0.0023	0.2780
5	0.1836	0.1697	0.1693	0.1742	0.0970
6	0.1832	0.1294	0.2277	0.1801	0.0850
7	0.1253	0.1517	0.1342	0.1371	0.0590
8	-----	-----	-----	-----	-----
Drawdown, cm					
Distance from Thalweg m	**A**	**B**	**C**	**AVG**	
186 m LB	3.6430	4.1960	3.7110	3.8500	
171 m RB	3.4640	3.9280	3.7740	3.7220	

[1] Impact - ambient velocity.

Table 97
Clark's Ferry Pool 551.5 Drawdown Experiment Conditions

Experiment No.	Up or Down[1]	Tow Speed[2] m/sec	Position[3]	Temp ° C	Actual Draft m	Effective Draft[4] m	Barge W X L	Prop Thrust 1,000 lb	Schijf Velocity[5] cm/sec	Schijf Drawdown[5] cm
CHF260	-	2.60	256.9	9.0	2.13	2.75	3X5	81	8.6	2.3
CHF350	-	3.50	256.9	9.0	2.13	2.71	3X5	108	13.2	4.8
CHF376	-	3.76	256.9	9.0	2.13	2.70	3X5	135	15.0	5.9

Note: Water surface width 627 m, area 3,215 sq m, water surface elevation 551.5, 26° rake.
[1] Slack water.
[2] Relative to ground.
[3] Meters from right bank.
[4] Actual draft + draft correction.
[5] Schijf equation using effective draft and vessel speed relative to water.

Table 98
Clark's Ferry, Pool El 551.5, CHF260, Run 2 Jan 96

Drawdown, cm				
	Replicate			
Distance from Thalweg m	A	B	C	AVG
30 m RB	5.0950	4.8230	4.1110	4.6763
30 m LB	5.5960	5.1250	4.5580	5.0930
120 m RB	3.4230	3.1560	3.0380	3.2057
180 m LB	3.5180	3.3600	3.0300	3.3027
233 m RB	2.2770	3.7460	2.0830	2.7020
279 m LB	2.6160	2.0020	2.3760	2.3313

Table 99
Clark's Ferry, Pool El 551.5, CHF350, Run 3 Jan 96

Drawdown, cm				
	Replicate			
Distance from Thalweg m	A	B	C	AVG
30 m RB	10.9020	10.2400	9.3990	10.1803
30 m LB	11.7110	10.4150	10.2700	10.7987
120 m RB	5.5610	5.2260	5.4830	5.4233
180 m LB	5.5520	5.6380	5.1030	5.4310
233 m RB	4.7990	3.6830	4.9980	4.4933
279 m LB	4.6860	4.4510	4.1270	4.4213

Table 100
Clark's Ferry, Pool El 551.5, CHF376, Run 4 Jan 96

Drawdown, cm				
	Replicate			
Distance from Thalweg m	A	B	C	AVG
30 m RB	11.6300	11.4640	10.9990	11.3643
30 m LB	12.3230	12.5590	12.2330	12.3717
120 m RB	6.5190	6.3900	6.5650	6.4913
180 m LB	5.6610	5.8100	5.8550	5.7753
233 m RB	5.8400	6.0410	6.1780	6.0197
279 m LB	5.3160	4.9630	4.7840	5.0210

Table 101 **Clark's Ferry Pool 572.7 Drawdown Experiment Conditions**										
Experiment No.	**Up or Down[1]**	**Tow Speed[2] m/sec**	**Position[3]**	**Temp ° C**	**Actual Draft m**	**Effective Draft[4] m**	**Barge W X L**	**Prop Thrust 1,000 lb**	**Schijf Velocity[5] cm/sec**	**Schijf Drawdown[5] cm**
COR260	-	2.60	268.3	9.5	2.13	2.75	3X5	81	3.4	0.9
COR350	-	3.50	268.3	9.5	2.13	2.71	3X5	108	4.7	1.7
COR376	-	3.76	268.3	9.5	2.13	2.70	3X5	135	5.2	2.0

Note: Water surface width 629.5 m, area 7,283 sq m, water surface elevation 572.7, 26^{o} rake.
[1] Slack water.
[2] Relative to ground.
[3] Meters from right bank.
[4] Actual draft + draft correction.
[5] Schijf equation using effective draft and vessel speed relative to water.

Table 102 **Clark's Ferry, Pool El 572.7, COR260, Run 27 Dec 96**				
	Drawdown, cm			
	Replicate			
Distance from Thalweg m	**A**	**B**	**C**	**AVG**
30 m RB	1.7530	1.7590	1.7340	1.7487
30 m LB	2.6660	2.1900	1.9960	2.2840
120 m RB	1.5670	1.1840	0.7740	1.1750
180 m LB	0.8840	1.0240	0.6330	0.8740
233 m RB	0.4410	1.7840	1.3340	1.1863
279 m LB	0.8690	0.8410	0.9400	0.8833

Table 103 **Clark's Ferry, Pool El 551.5, COR350, Run 28 Dec 96**				
Drawdown, cm				
Distance from Thalweg m	**Replicate**			
	A	**B**	**C**	**AVG**
30 m RB	4.3780	3.1150	2.5790	3.3573
30 m LB	4.0850	4.0450	3.1350	3.7550
120 m RB	1.6140	1.5500	1.8080	1.6573
180 m LB	1.4070	1.2480	1.4470	1.3673
233 m RB	1.4680	1.8440	1.5830	1.6317
279 m LB	1.1400	1.3730	1.2570	1.2567

Table 104 **Clark's Ferry, Pool El 551.5, COR376, Run 29 Dec 96**				
Drawdown, cm				
Distance from Thalweg m	**Replicate**			
	A	**B**	**C**	**AVG**
30 m RB	3.0250	5.4120	3.9670	4.1347
30 m LB	4.2600	4.8680	4.5540	4.5608
120 m RB	2.1430	1.8870	1.5910	1.8737
180 m LB	1.9440	2.1130	1.4870	1.8480
233 m RB	2.0070	1.3280	1.5000	1.6117
279 m LB	1.5760	1.1960	1.3390	1.3703

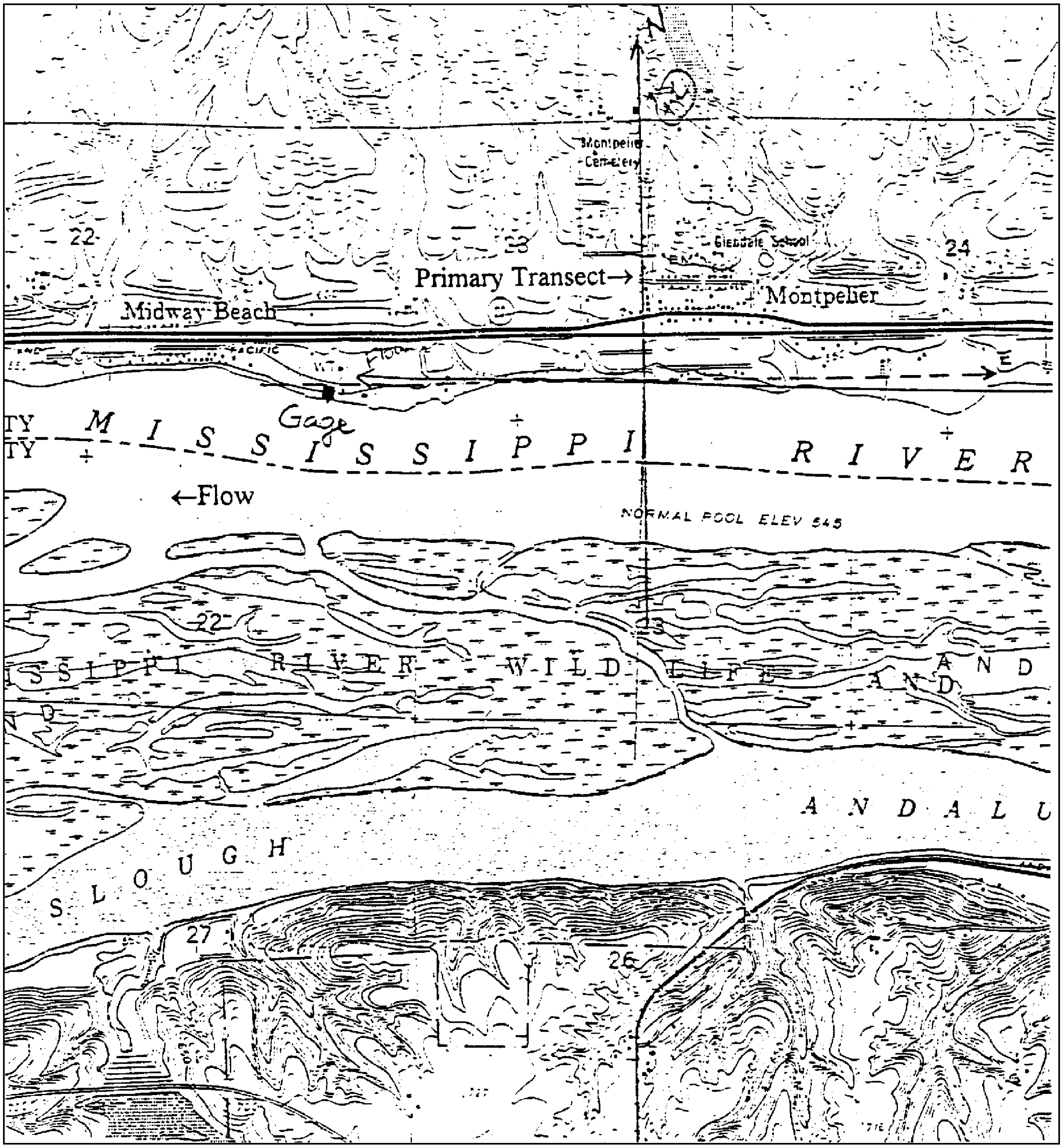


Figure 1. Clark’s Ferry site on the Mississippi River, RM 468.2

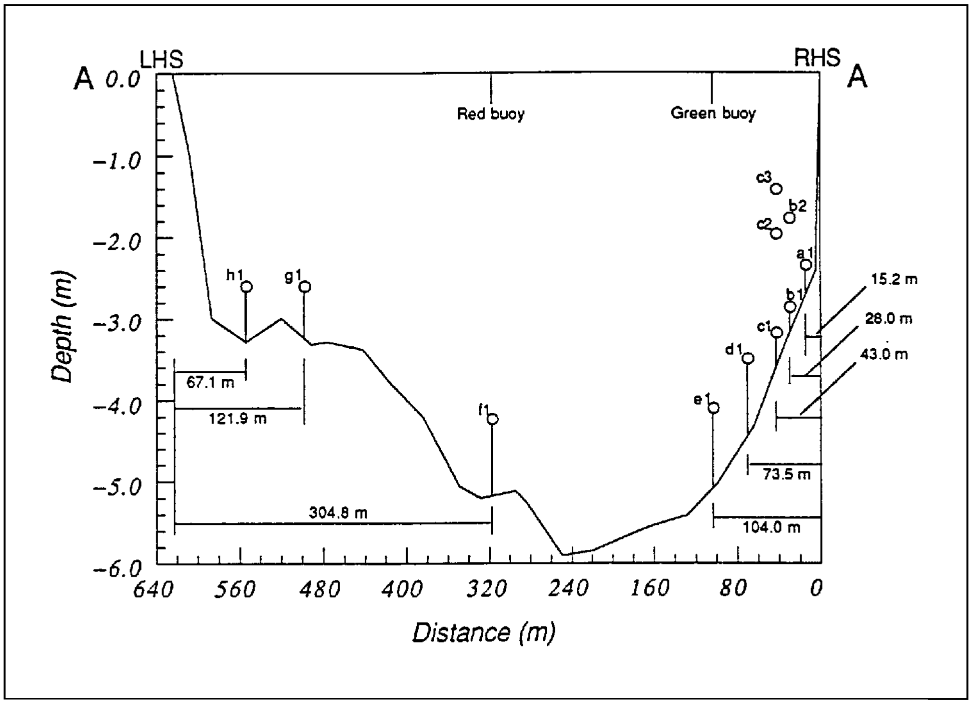


Figure 2. Cross section of the Mississippi River at the Clark's Ferry site for trip 1

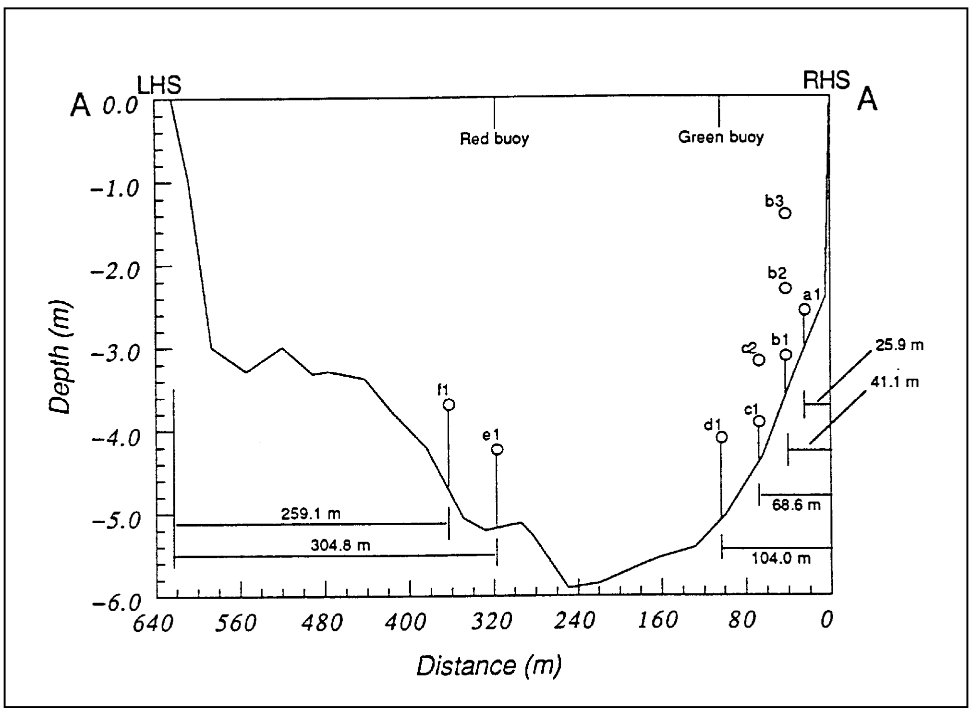
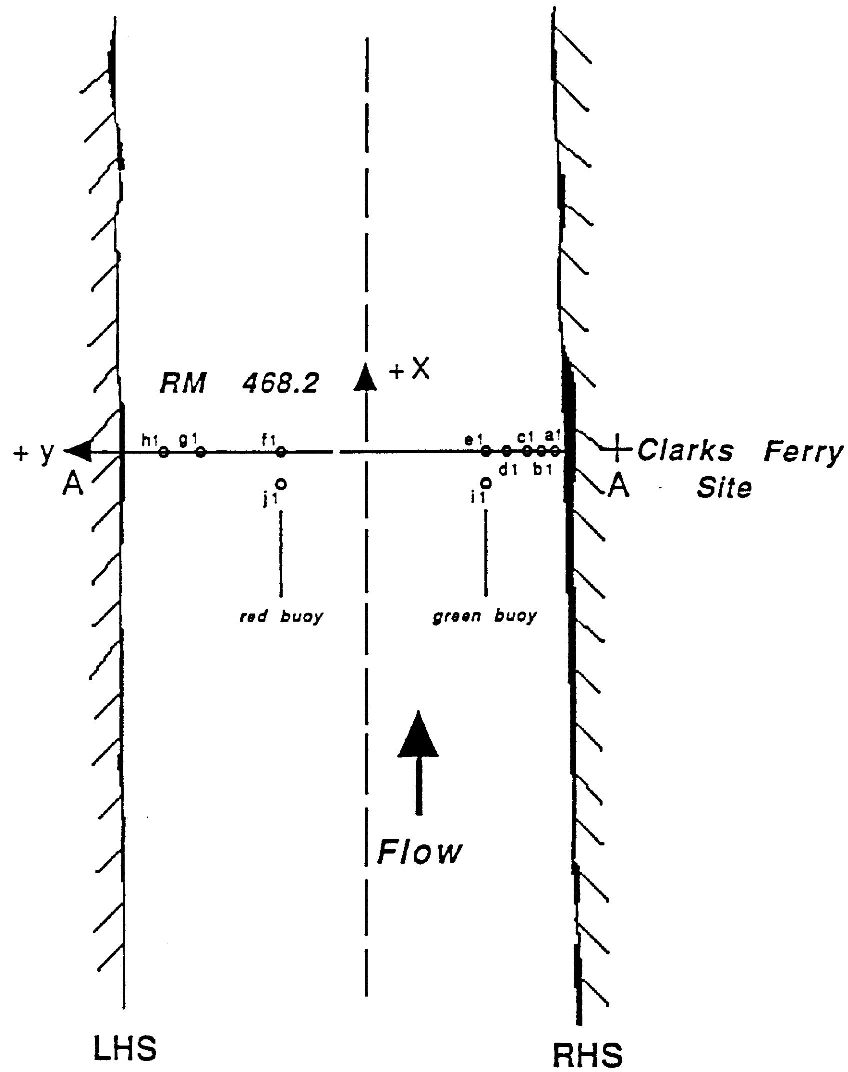


Figure 3. Cross section of the Mississippi River at the Clark's Ferry site for trip 2



a1 - MMB511/1001, 0.35 m above river bed
b1 - MMB511/1330, 0.33 m above river bed
b2 - MMB511/1331, 1.52 m above river bed
c1 - MMB511/998, 0.36 m above river bed
c2 - MMB511/999, 1.62 m above river bed
c3 - MMB511/1000, 2.53 m above river bed
d1 - S4/151, 1.0 m above river bed
e1 - S4/834, 1.0 m above river bed
f1 - S4/040, 1.0 m above river bed
g1 - MMB527/332, 0.70 m above river bed
h1 - MMB527/642, 0.70 m above river bed
i1 - S4/832, 1.0 m above river bed
j1 - S4/071, 1.0 m above river bed

Figure 4. Plan view of the Clark's Ferry site for trip 1 (locations of the current meters are shown)

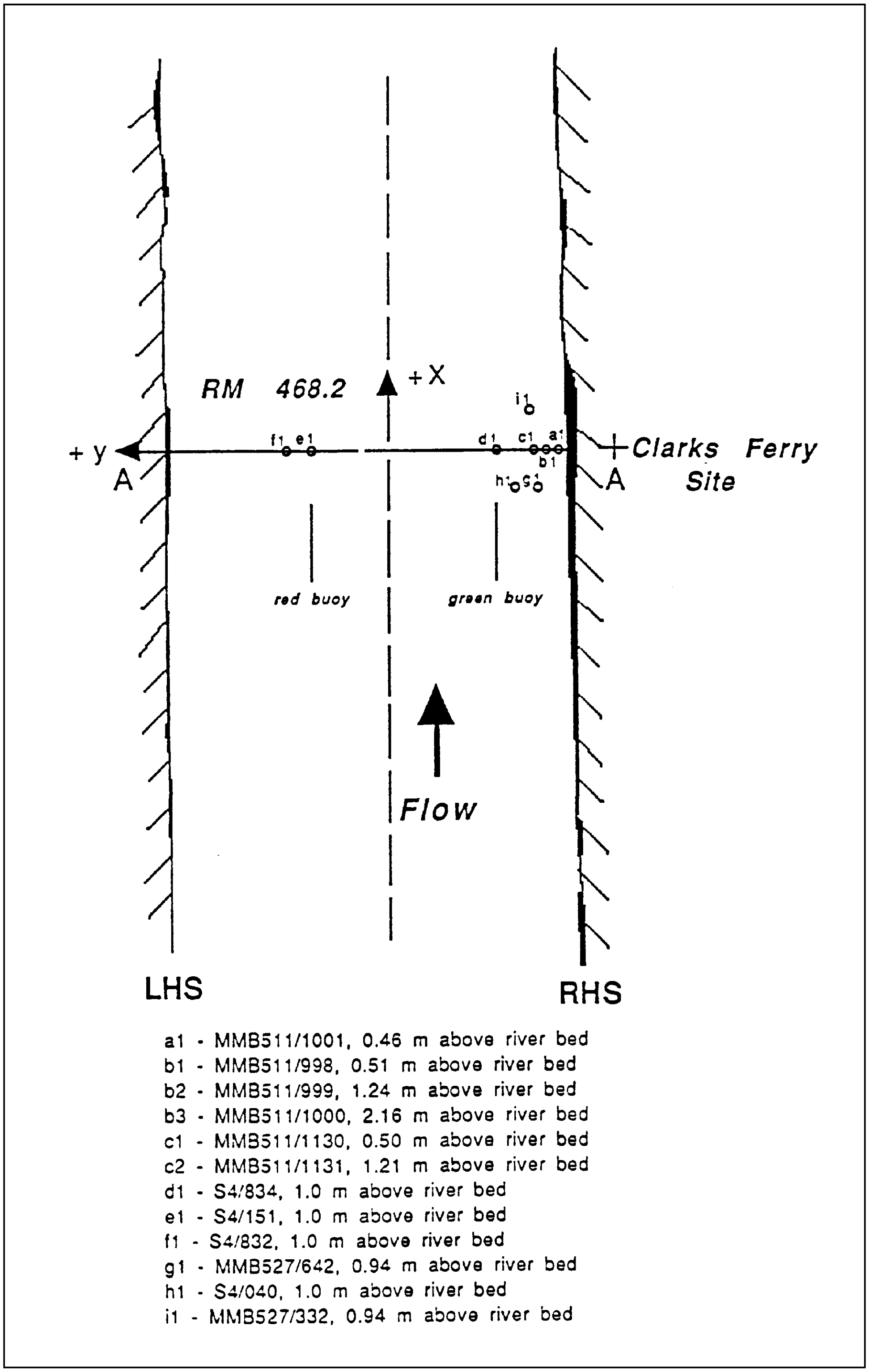


Figure 5. Plan view of the Clark's Ferry site on the Mississippi River for trip 2

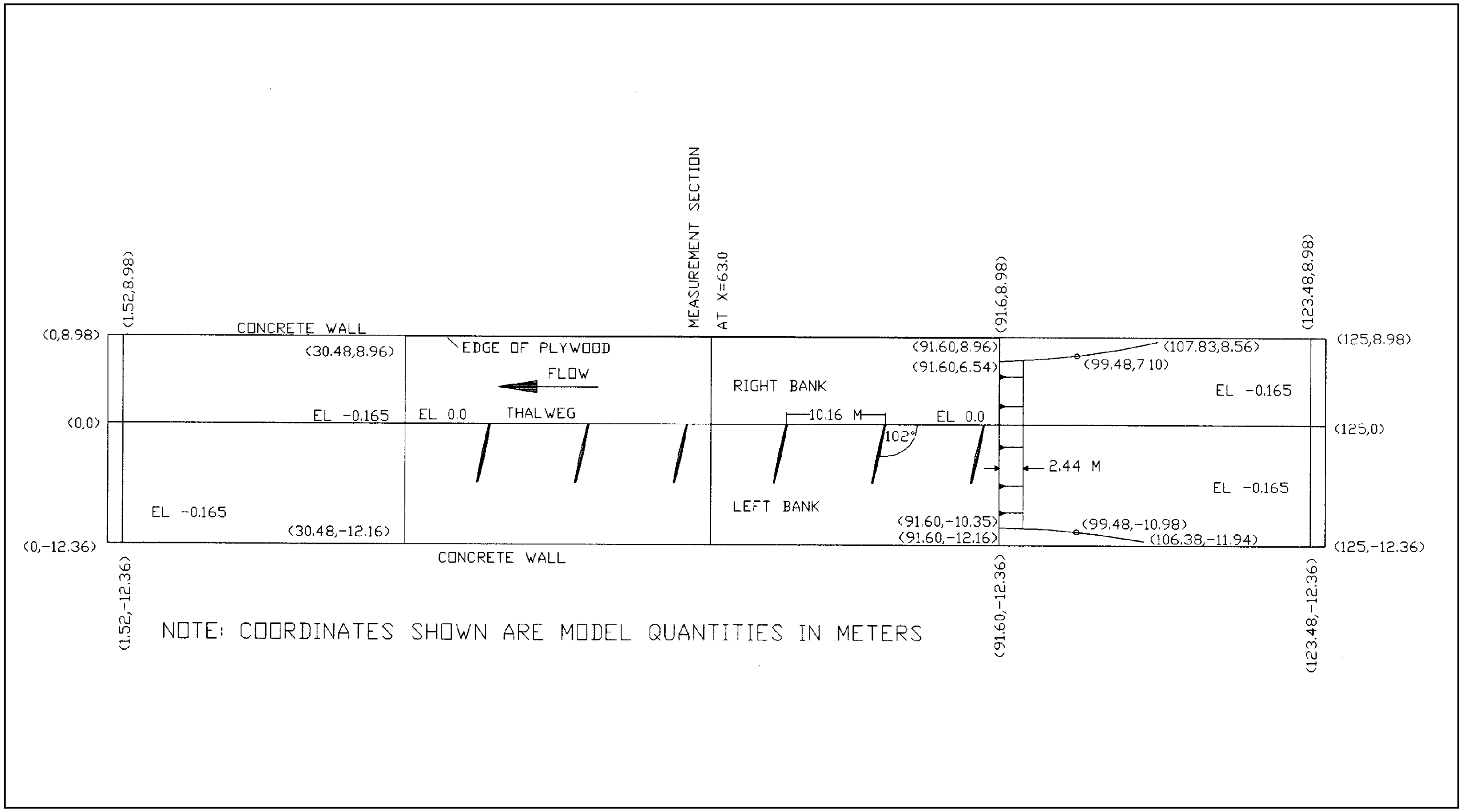


Figure 6. Plan view of 1:30 scale model of Clark’s Ferry

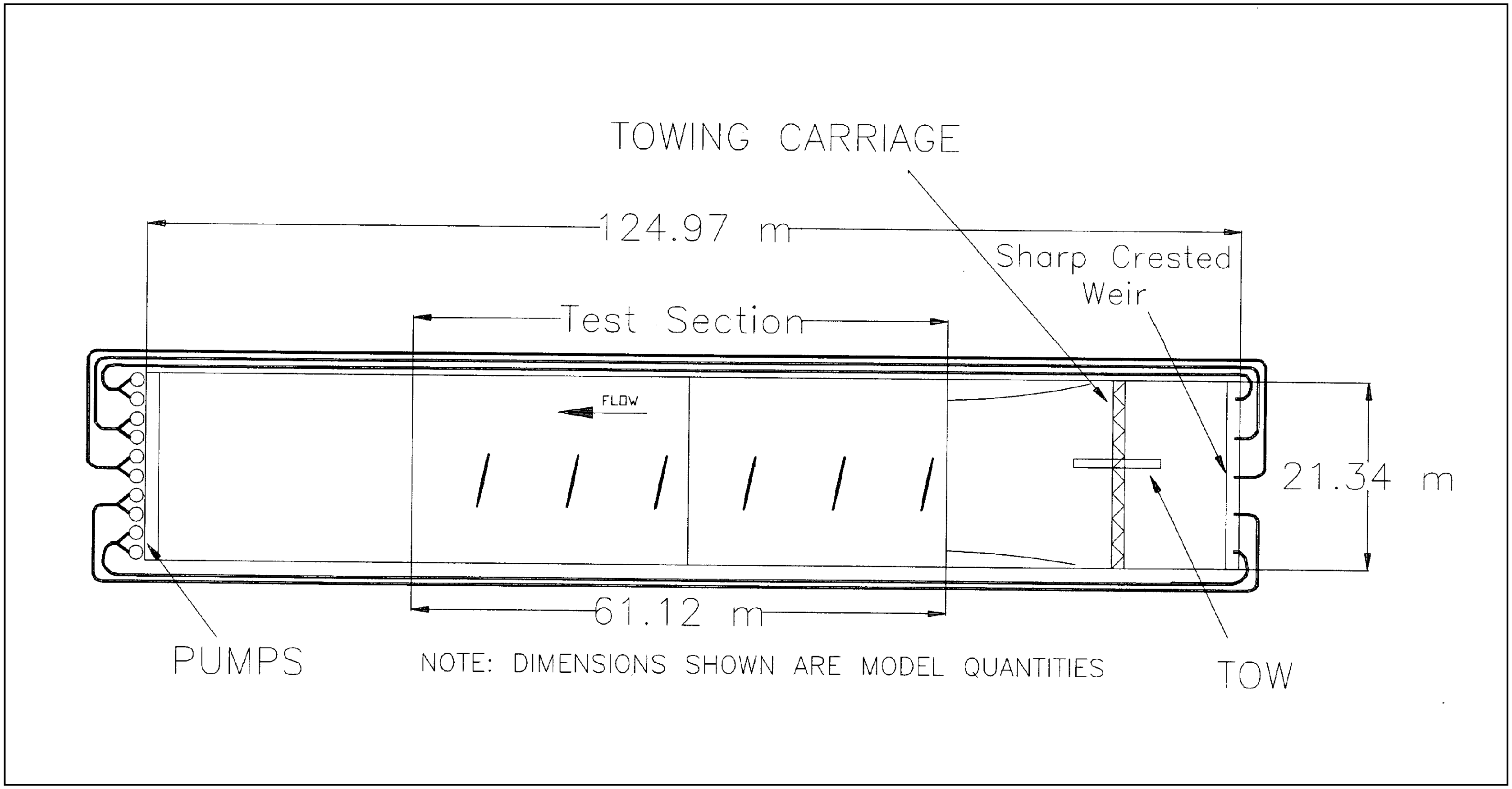


Figure 7. Schematic of navigation effects model

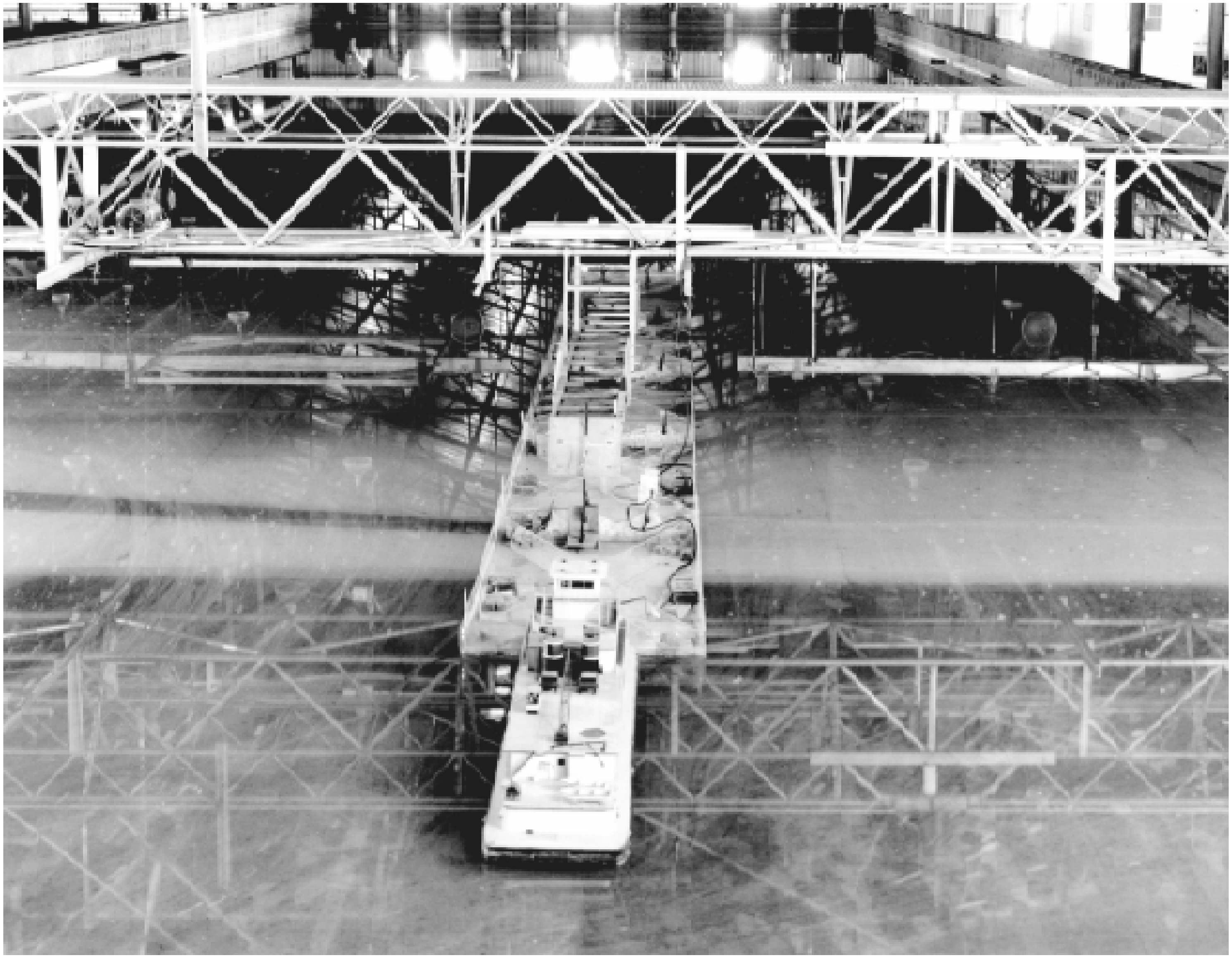


Figure 8. Tow effects flume looking downstream

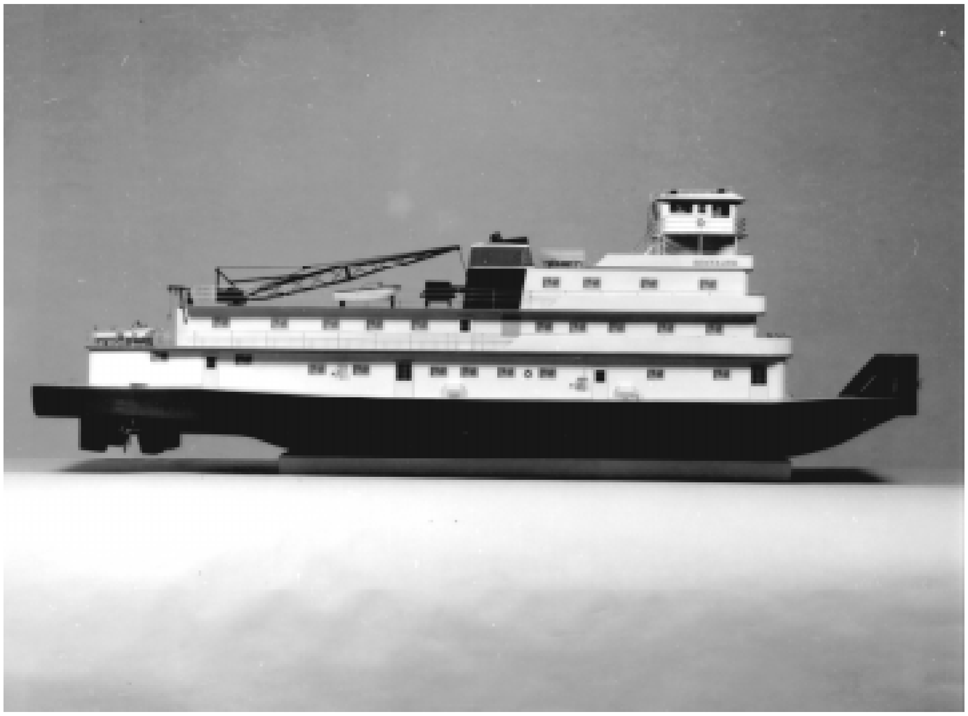


Figure 9. Model M/V *Benyaurd*

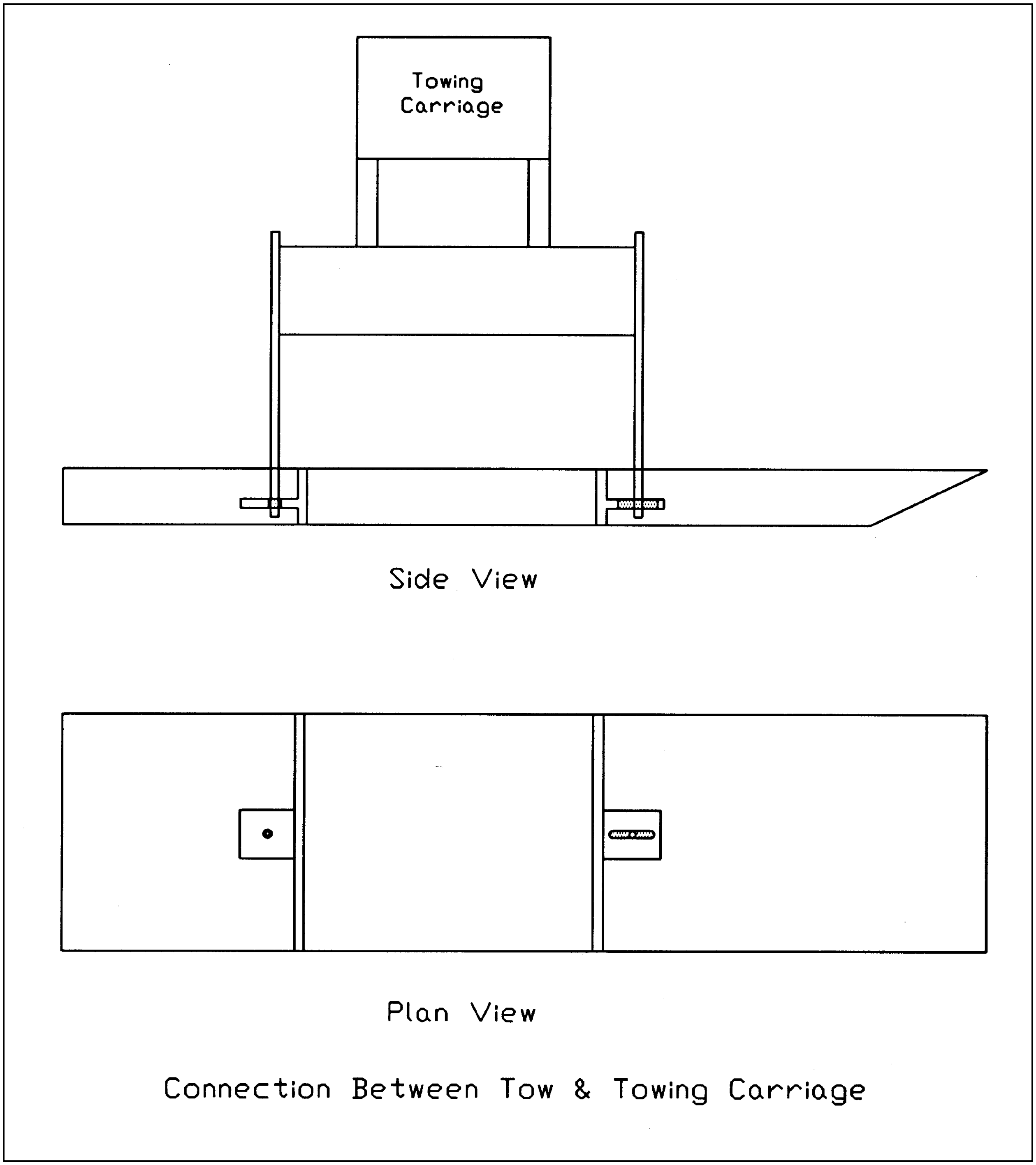


Figure 10. Connection between tow and towing carriage

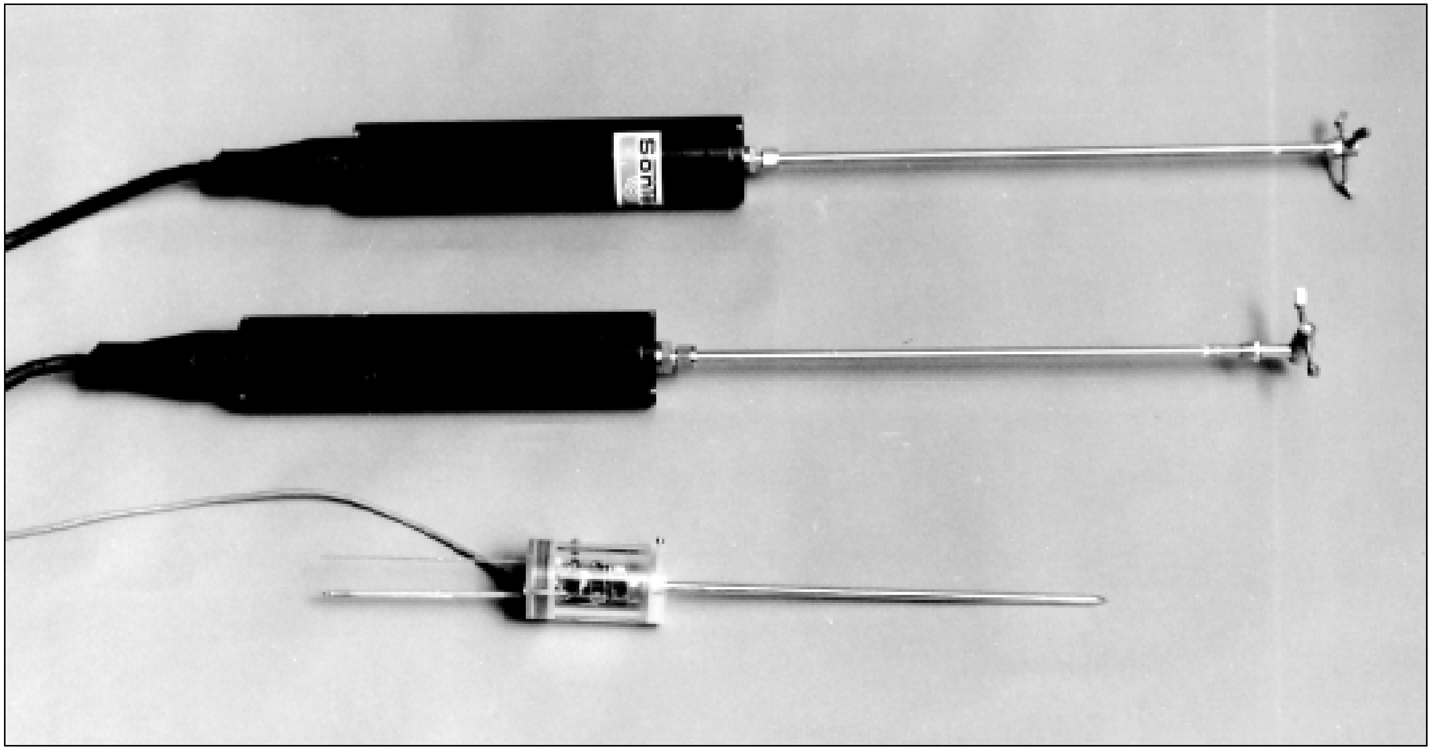


Figure 11. Photo of 2D, 3D ADV's and wave gauge

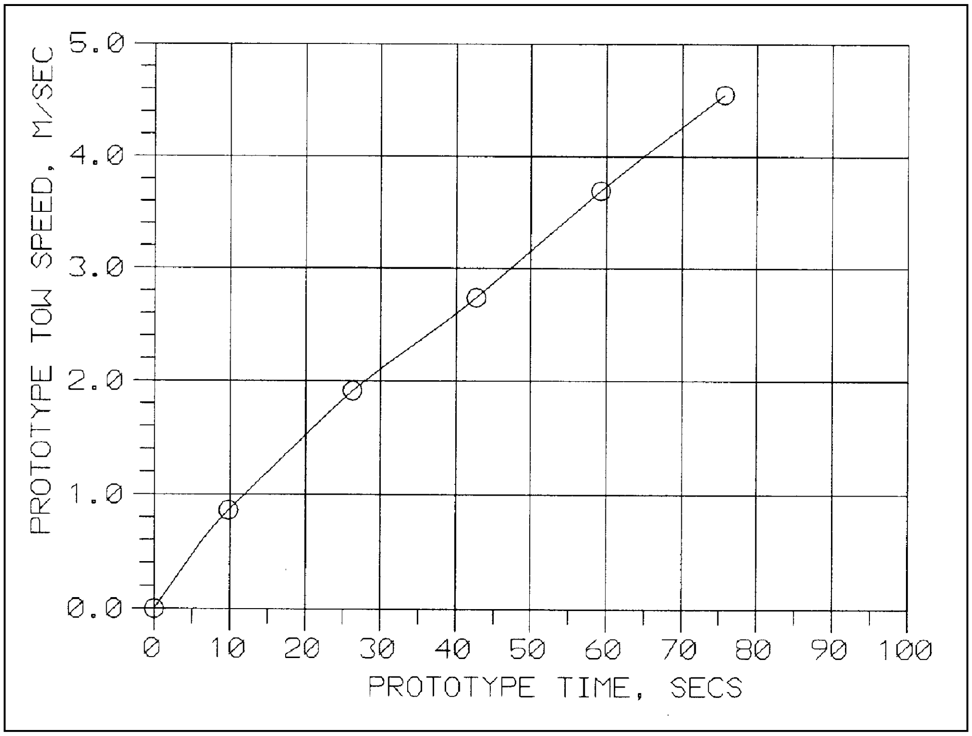


Figure 12. Acceleration of model tow

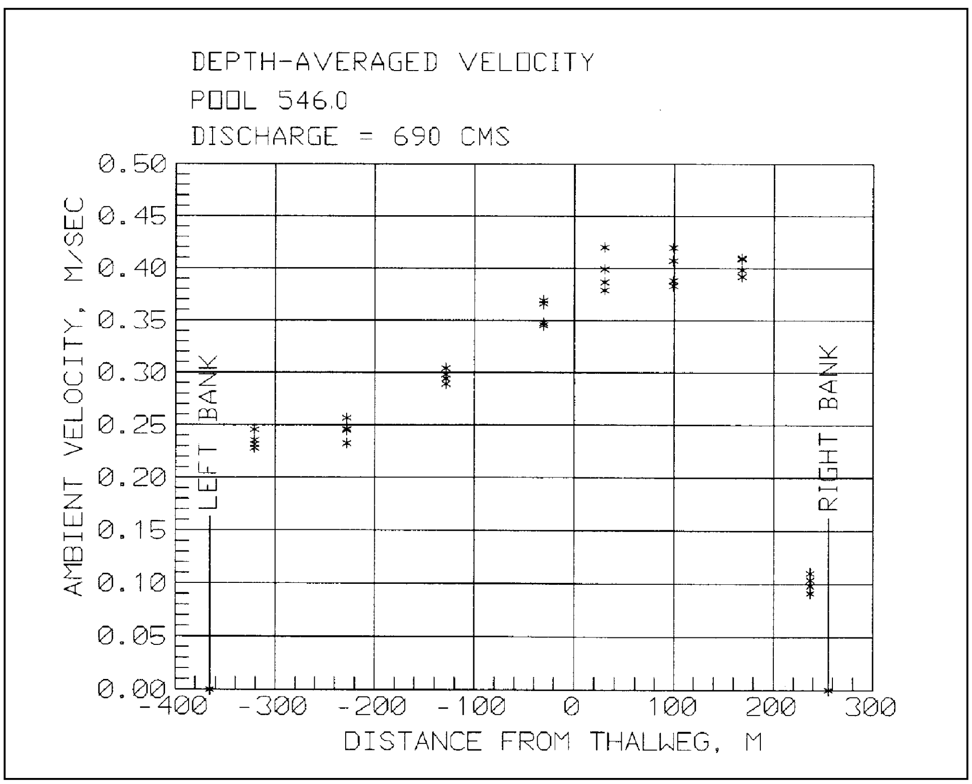


Figure 13. Depth-averaged ambient velocity distribution for Pool 546.0, Q = 690 cms

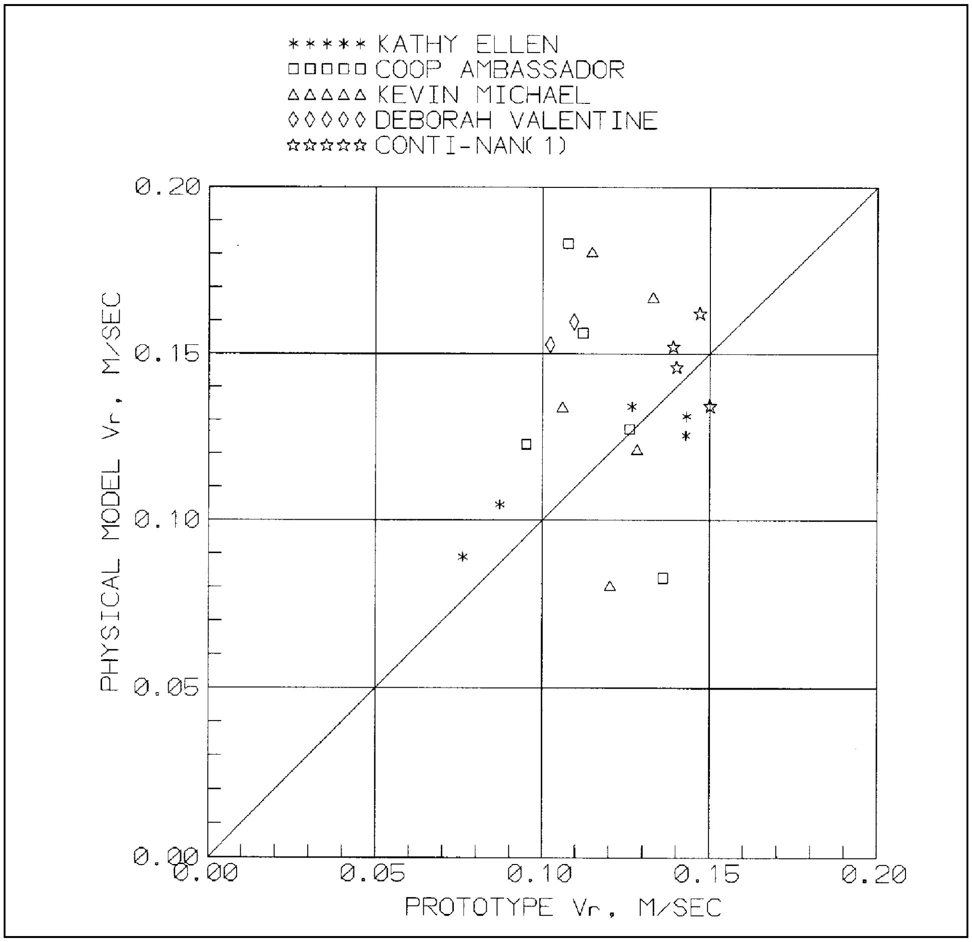


Figure 14. Trip 2 verification data, 2.74-m draft

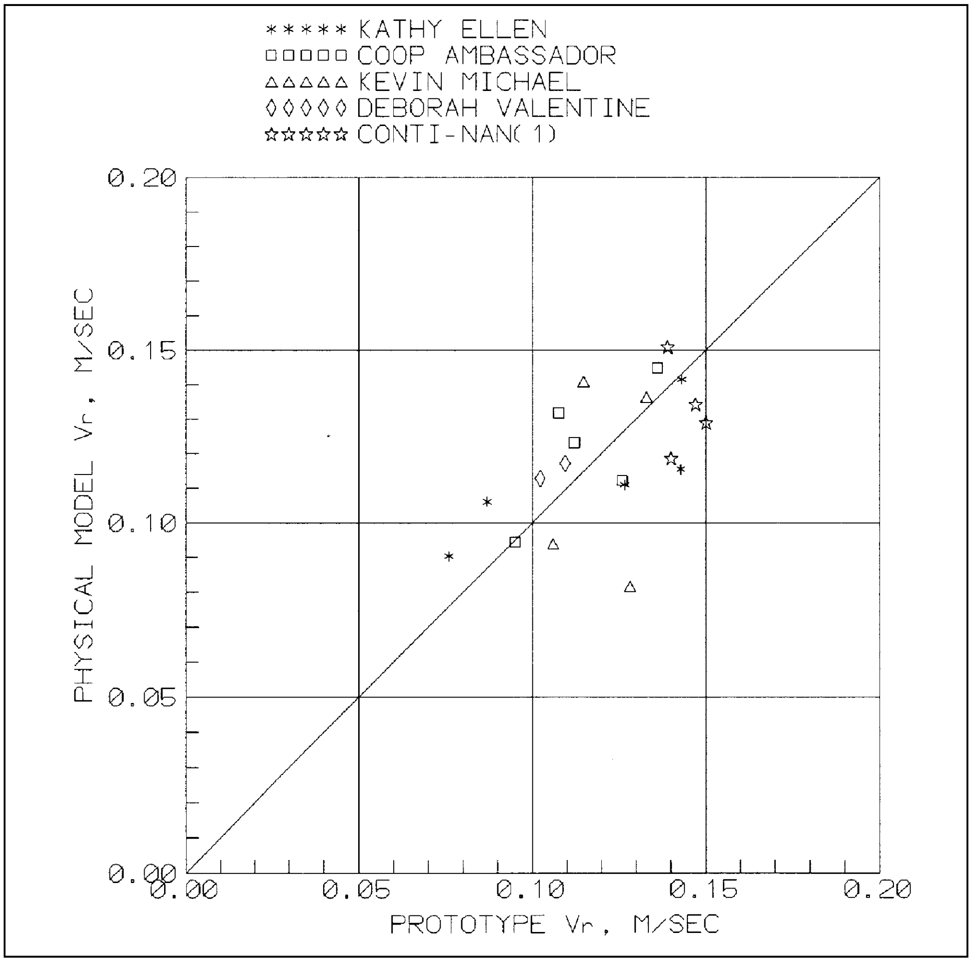


Figure 15. Trip 2 verification data, 2.13-m draft

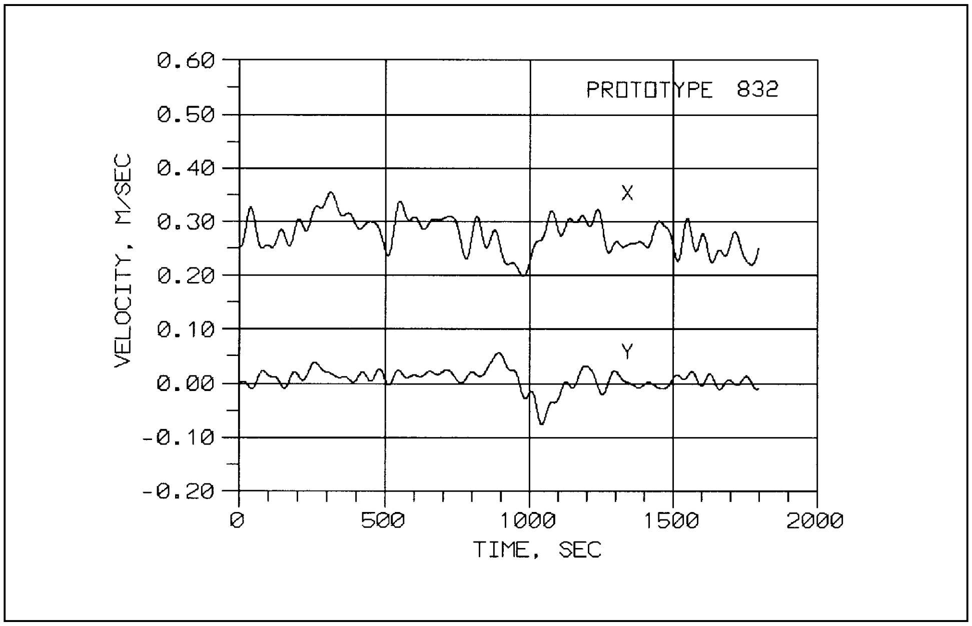


Figure 16. Velocity time history for *Coop Ambassador*, Probe number 832, prototype data

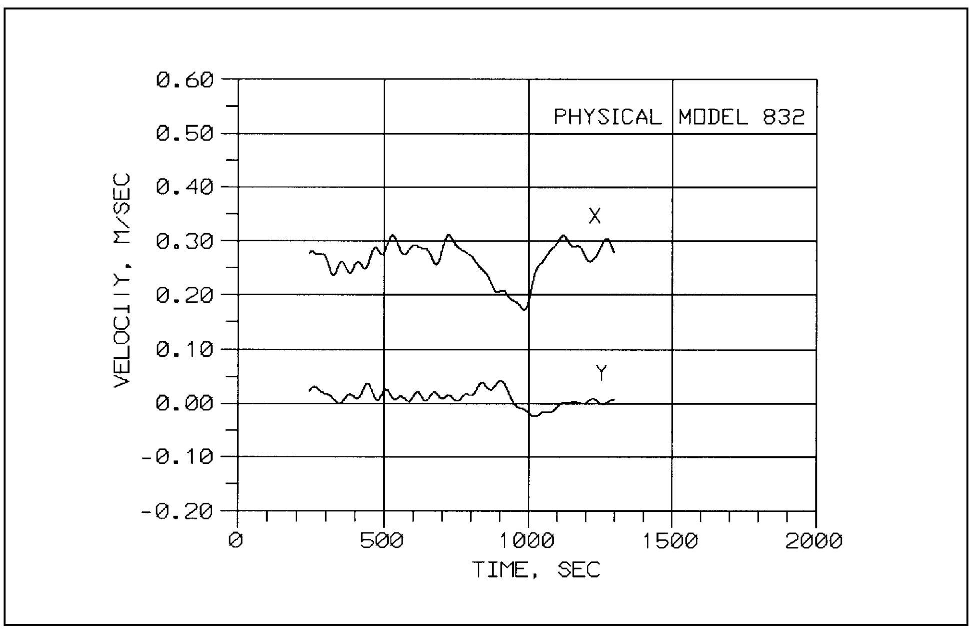


Figure 17. Velocity time history for *Coop Ambassador*, Probe number 832, physical model data

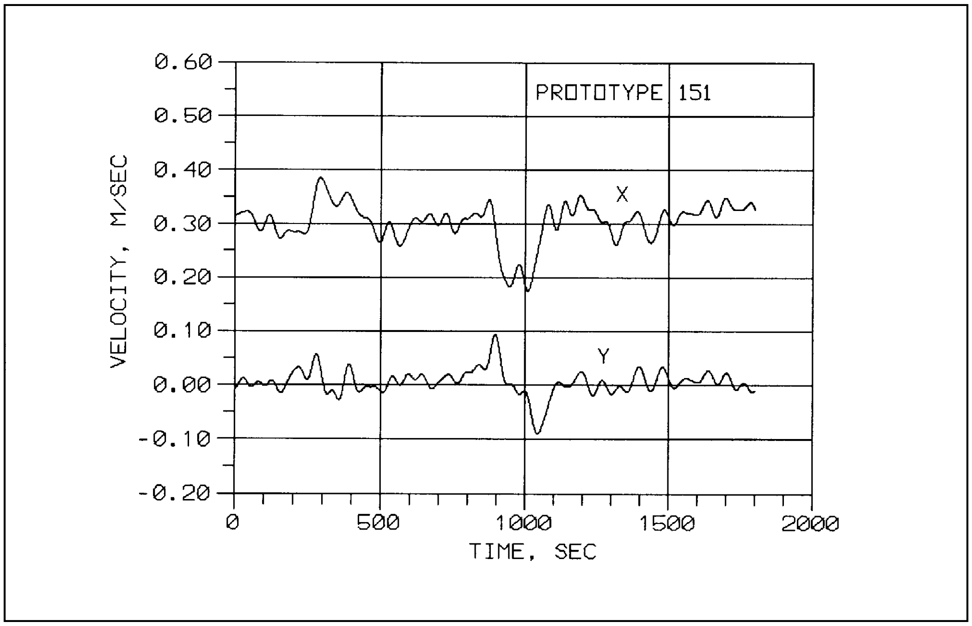


Figure 18. Velocity time history for *Coop Ambassador*, Probe number 151, prototype data

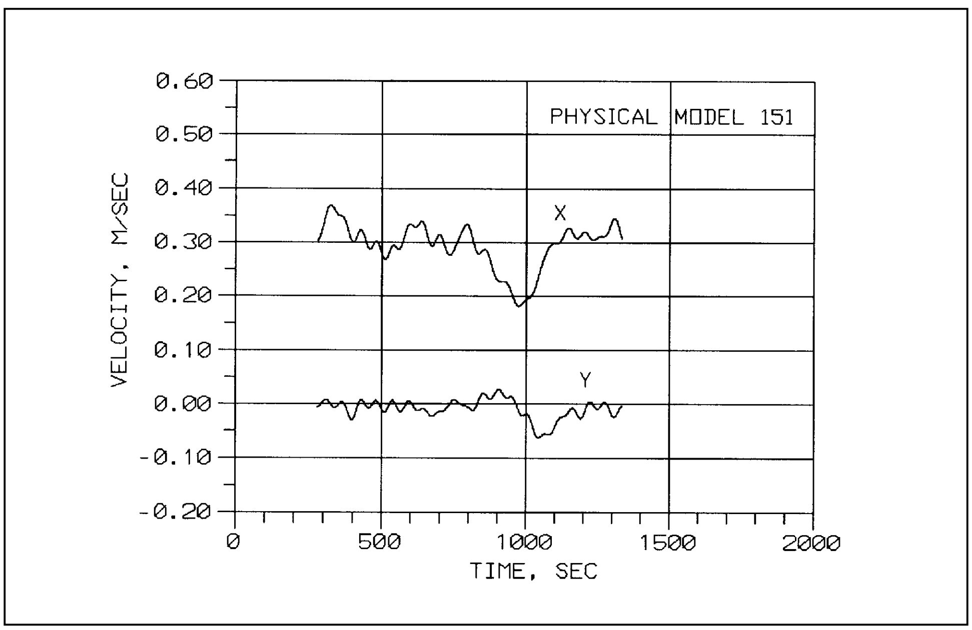


Figure 19. Velocity time history for *Coop Ambassador*, Probe number 151, physical model data

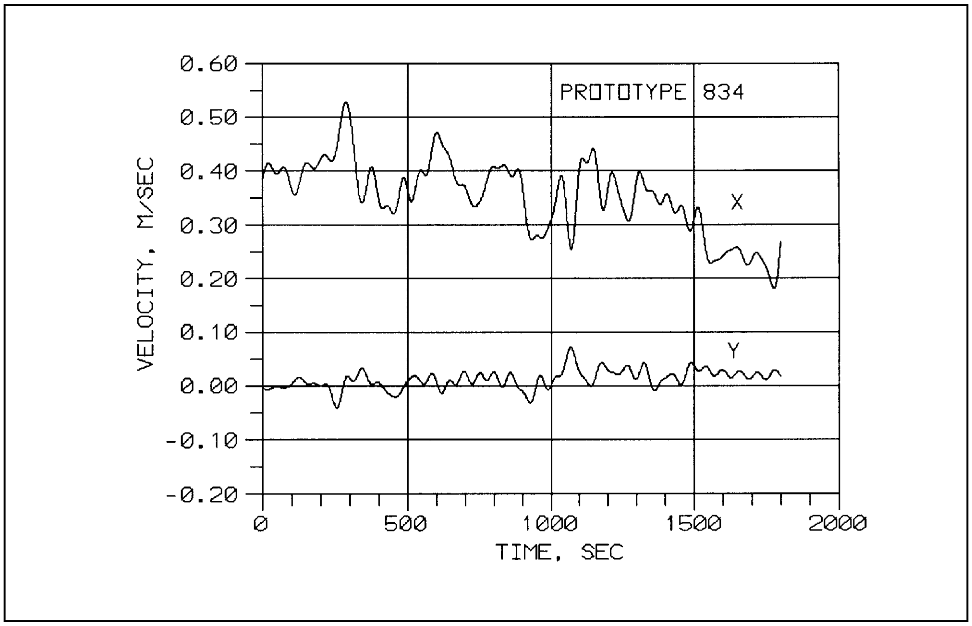


Figure 20. Velocity time history for *Coop Ambassador*, Probe number 834, prototype data

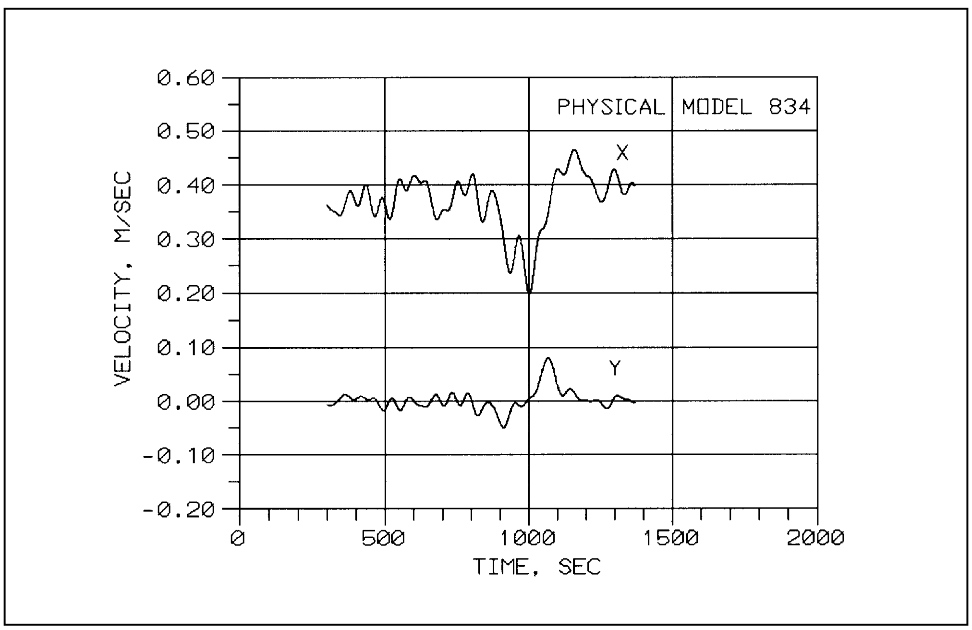


Figure 21. Velocity time history for *Coop Ambassador*, Probe number 834, physical model data

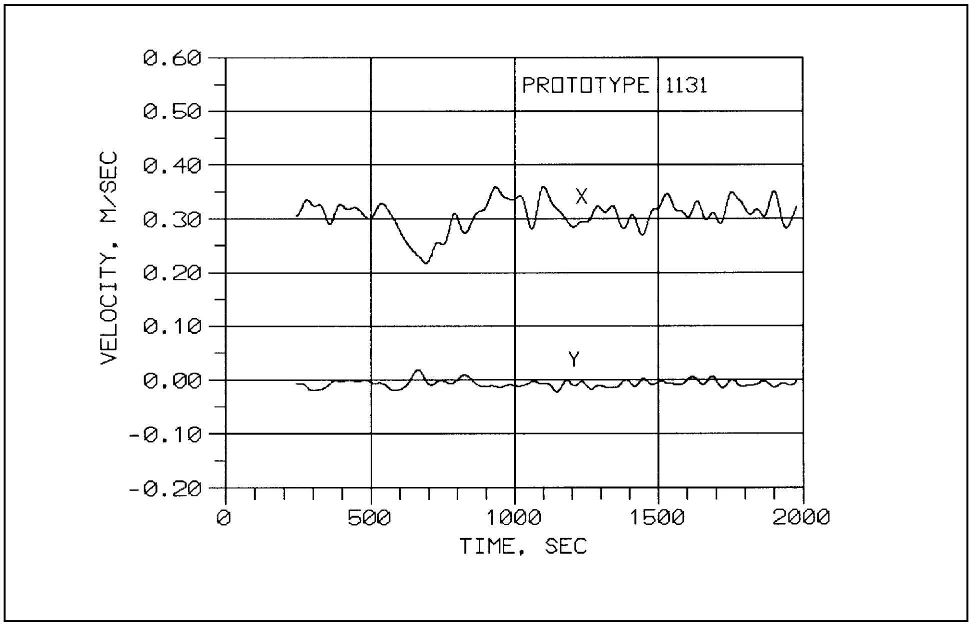


Figure 22. Velocity time history for *Coop Ambassador*, Probe number 1131, prototype data

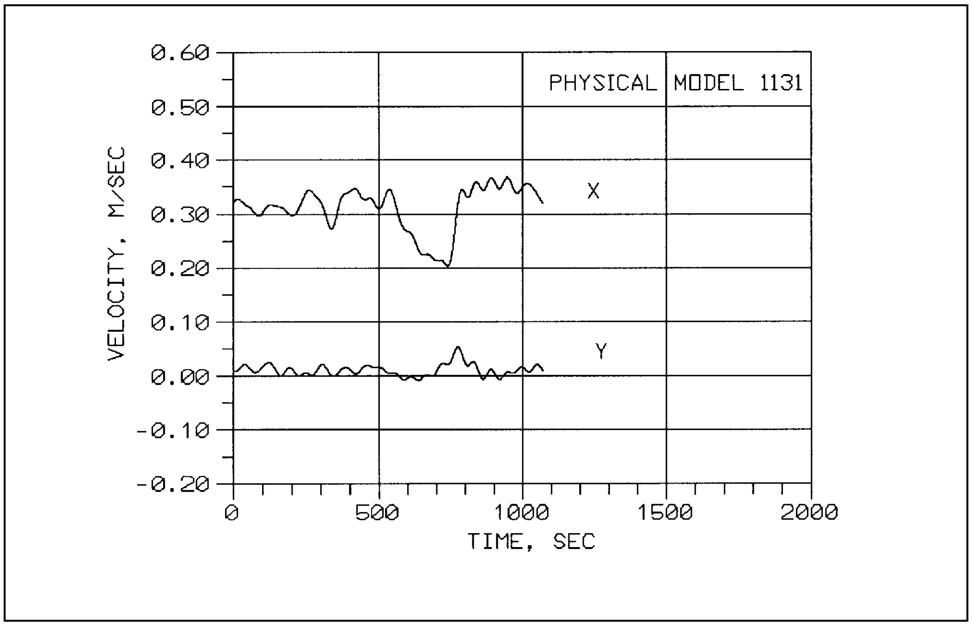


Figure 23. Velocity time history for *Coop Ambassador*, Probe number 1131, physical model data

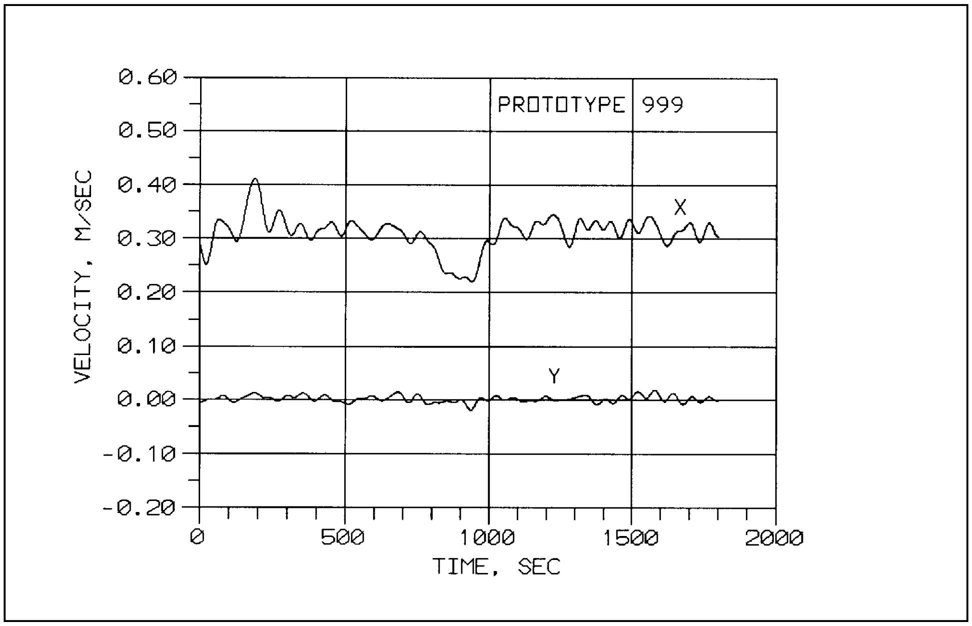


Figure 24. Velocity time history for *Coop Ambassador*, Probe number 999, prototype data

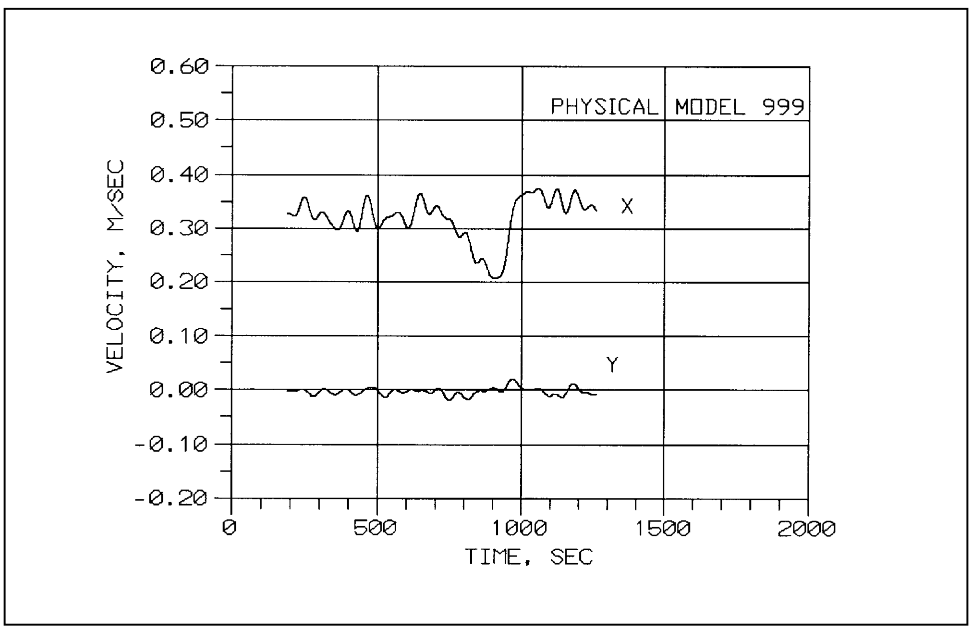


Figure 25. Velocity time history for *Coop Ambassador*, Probe number 999, physical model data

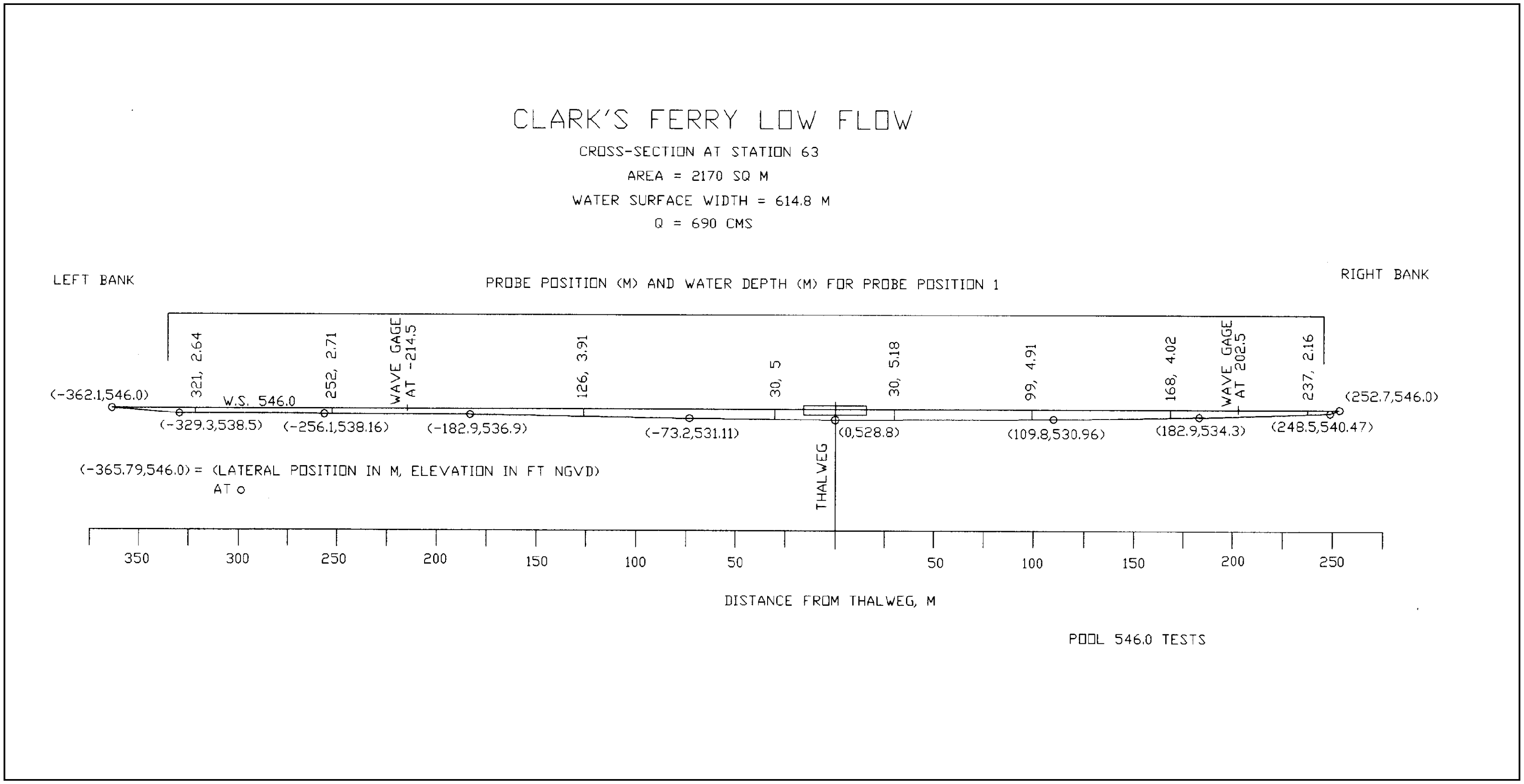


Figure 26. Cross section, experimental series 1

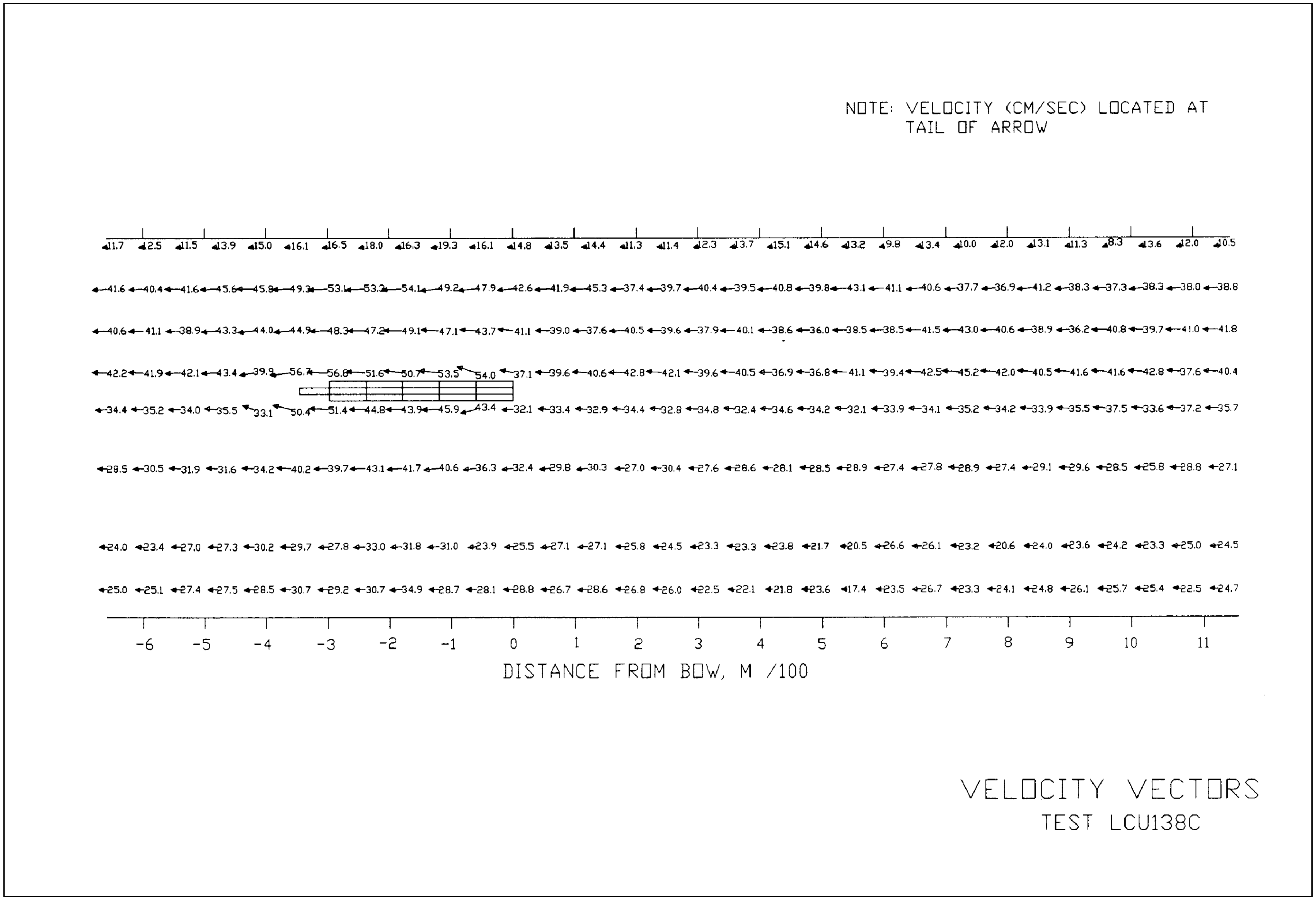


Figure 27. Vector plot, test LCU138C

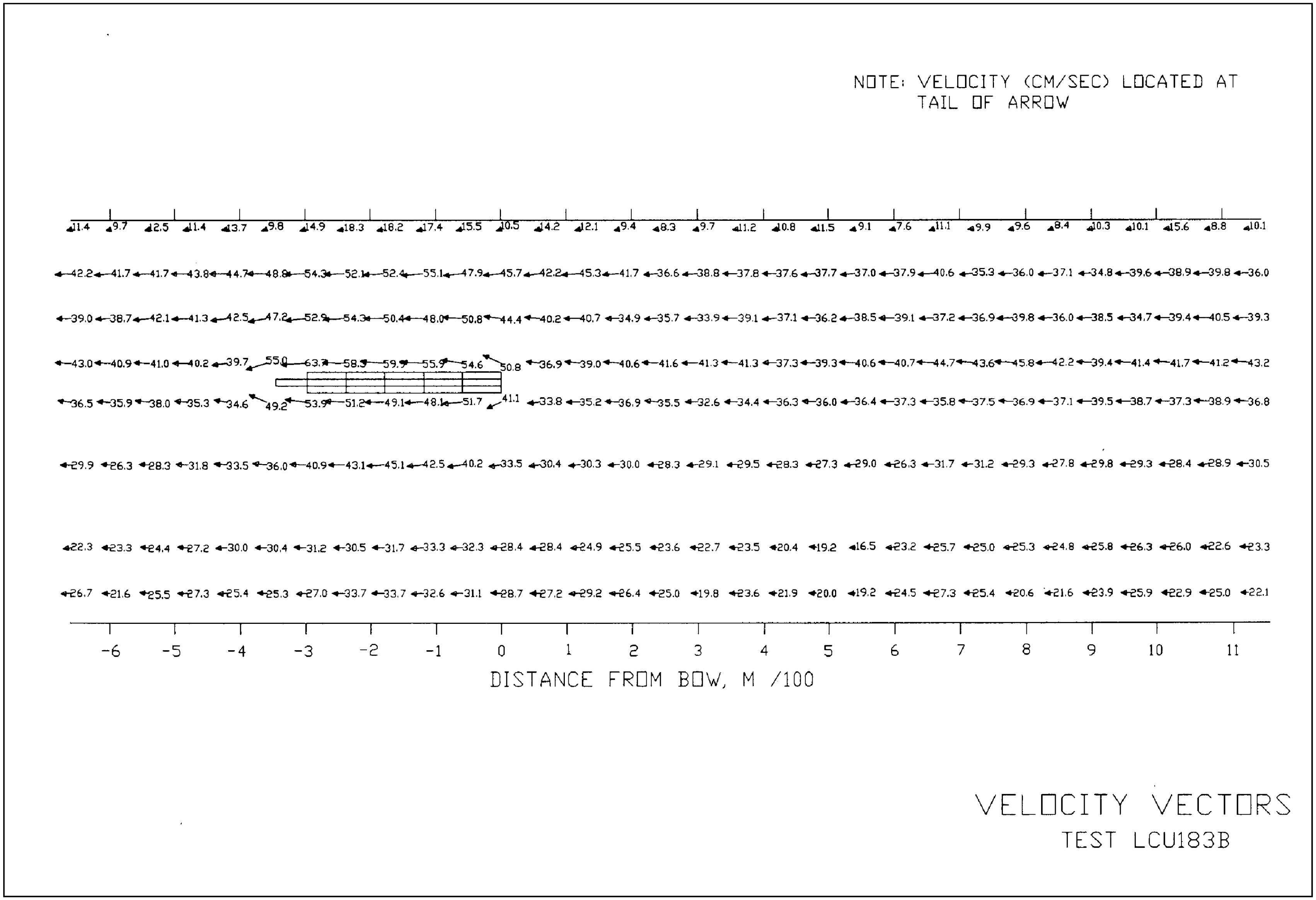


Figure 28. Vector plot, test LCU183B

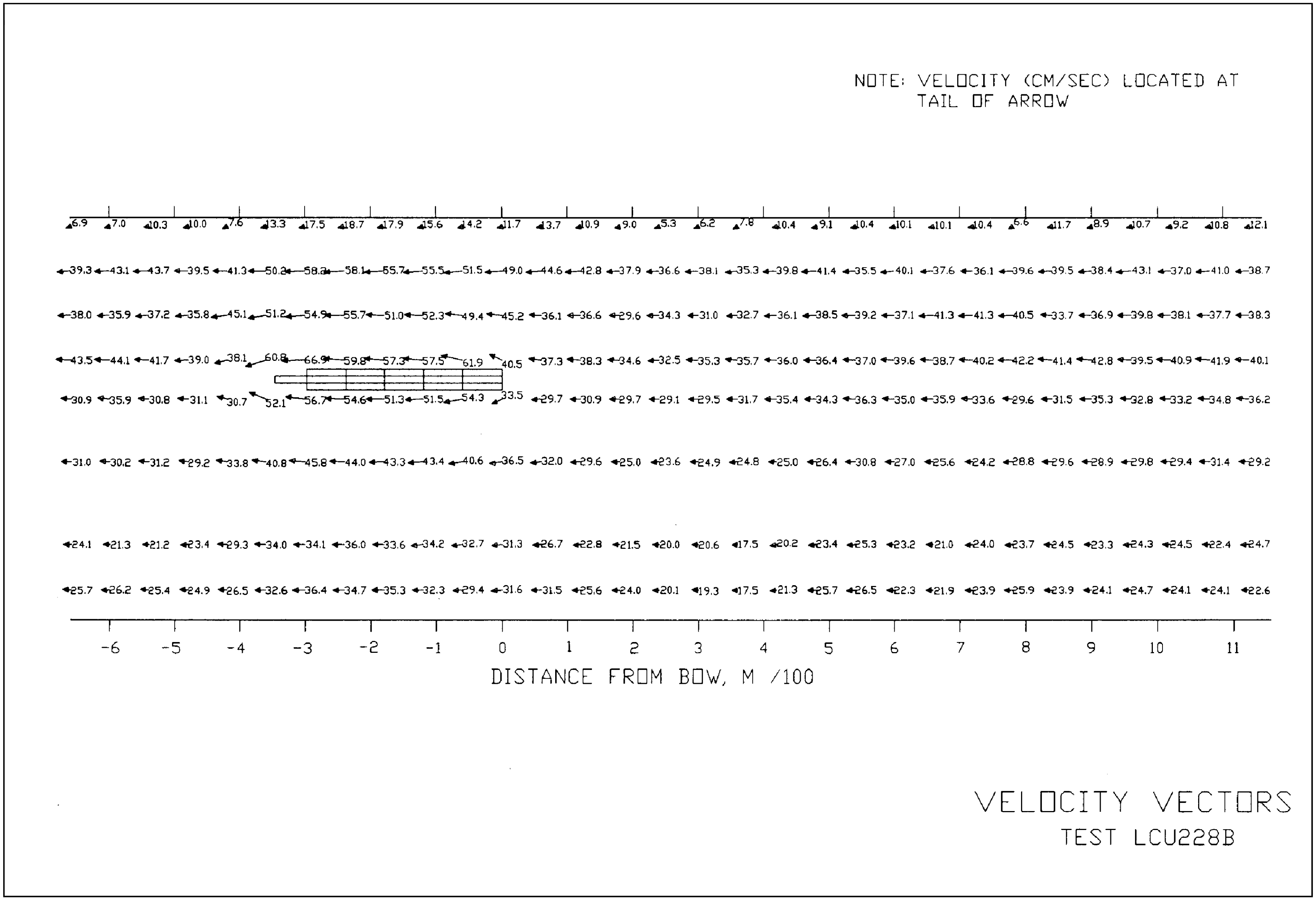


Figure 29. Vector plot, test LCU228B

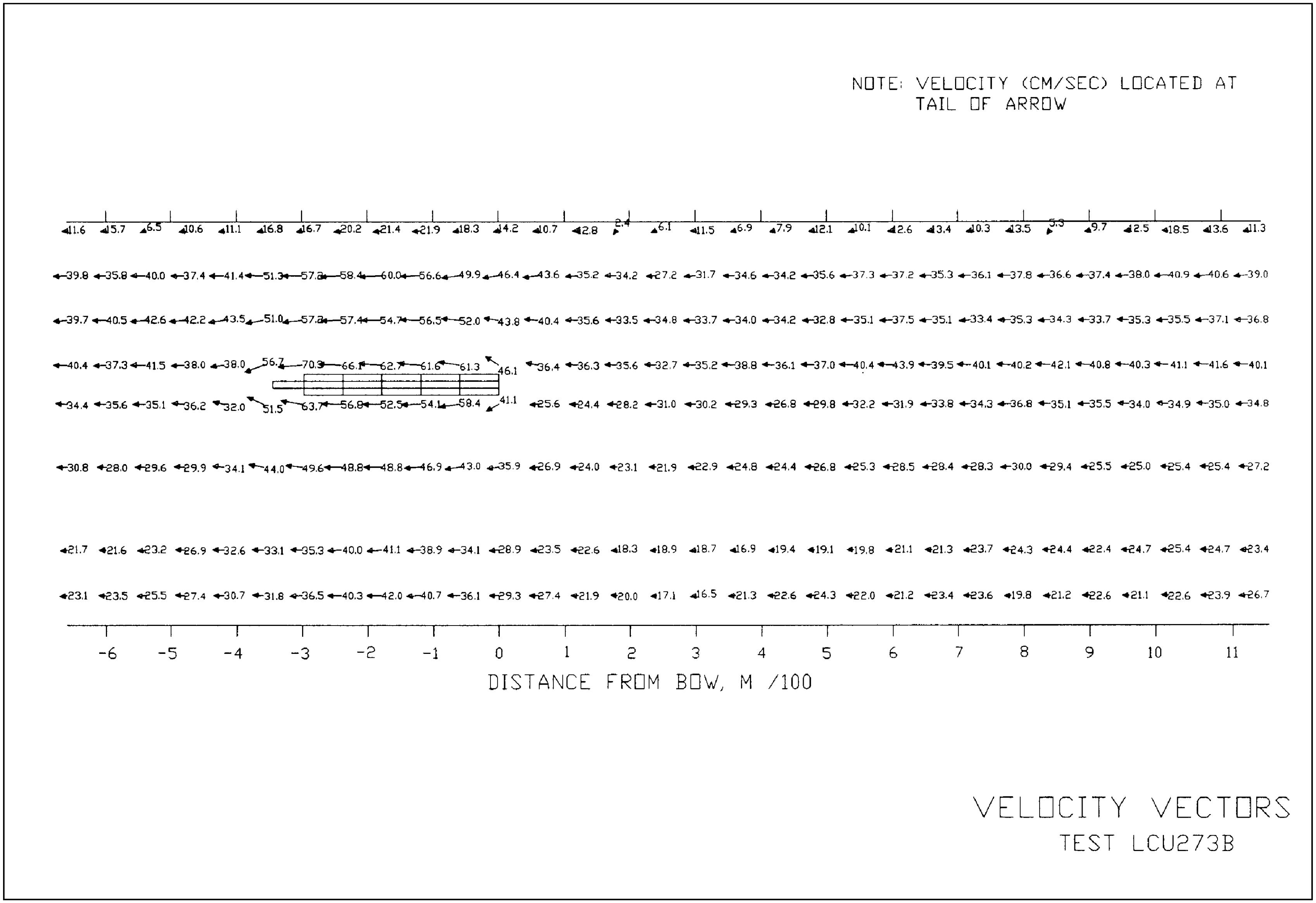


Figure 30. Vector plot, test LCU273B

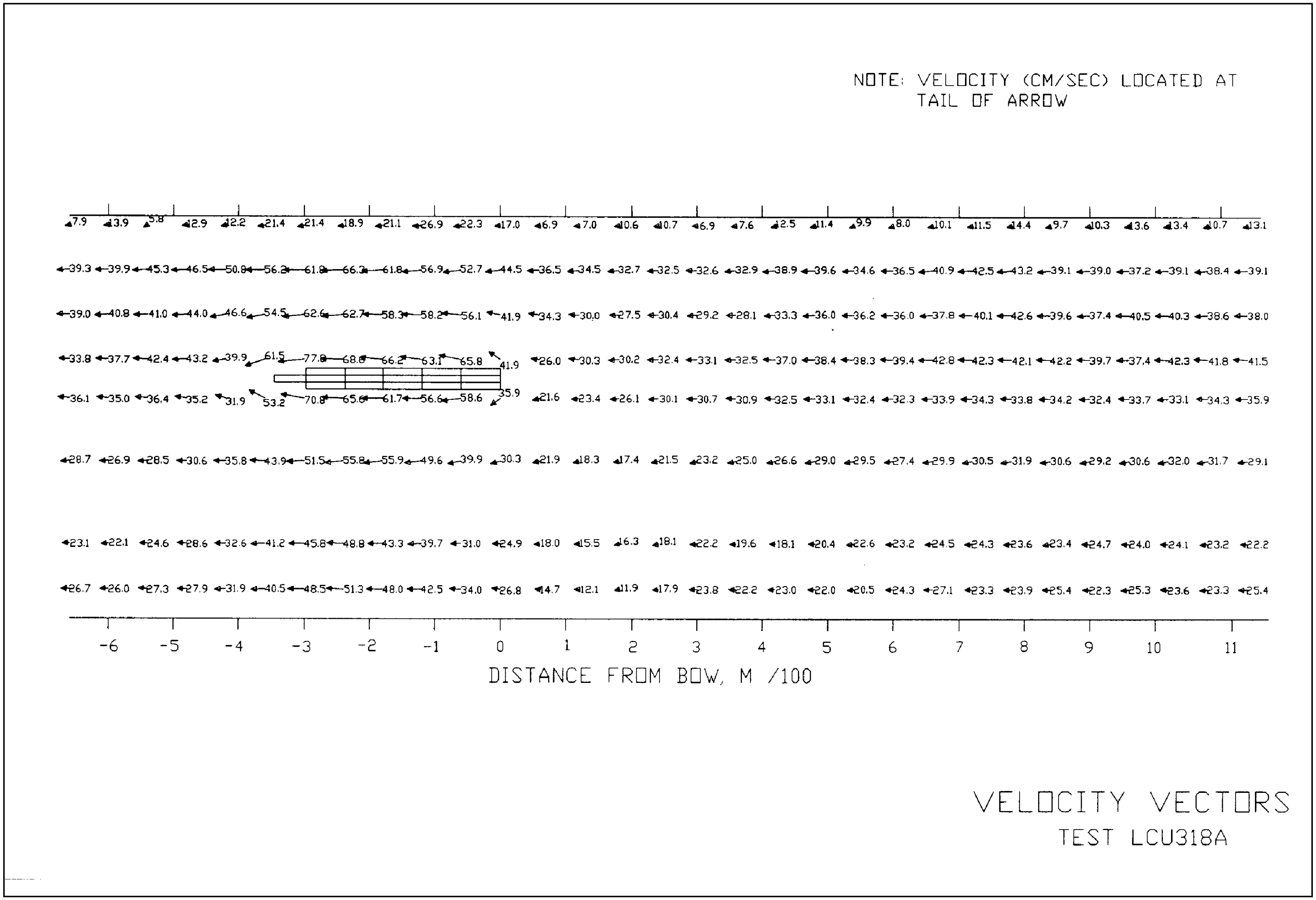


Figure 31. Vector plot, test LCU318A

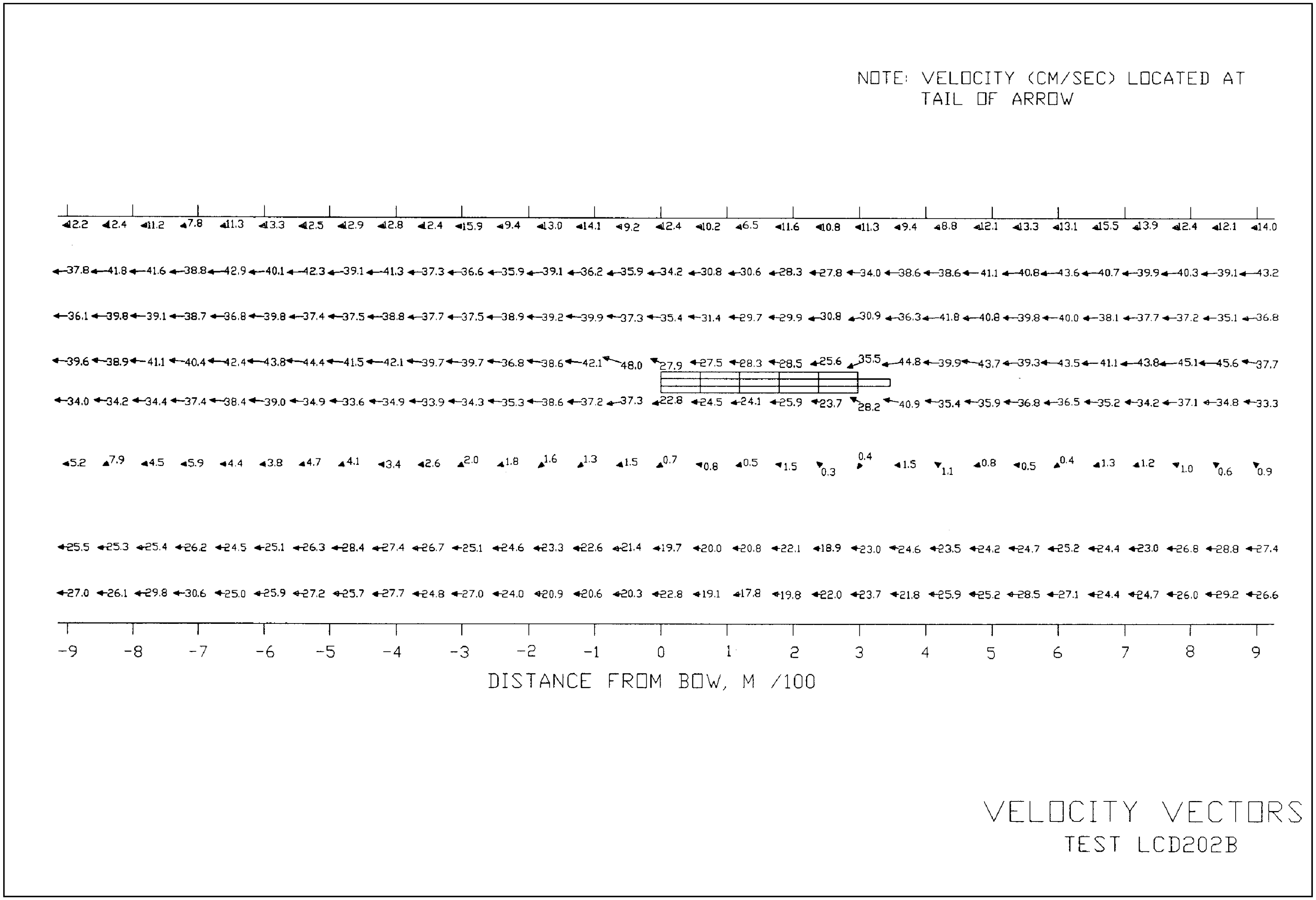


Figure 32. Vector plot, test LCD202B

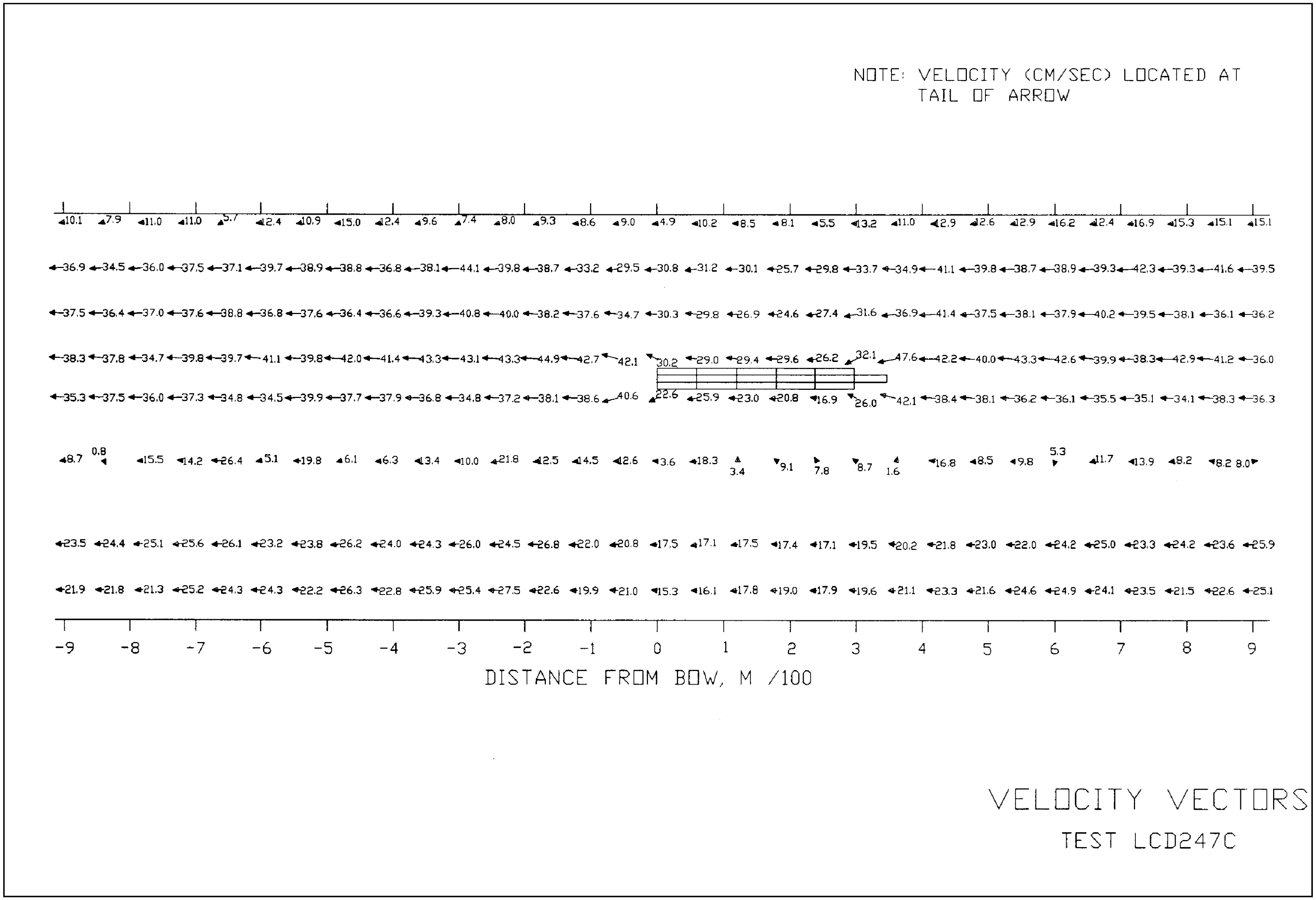


Figure 33. Vector plot, test LCD247C

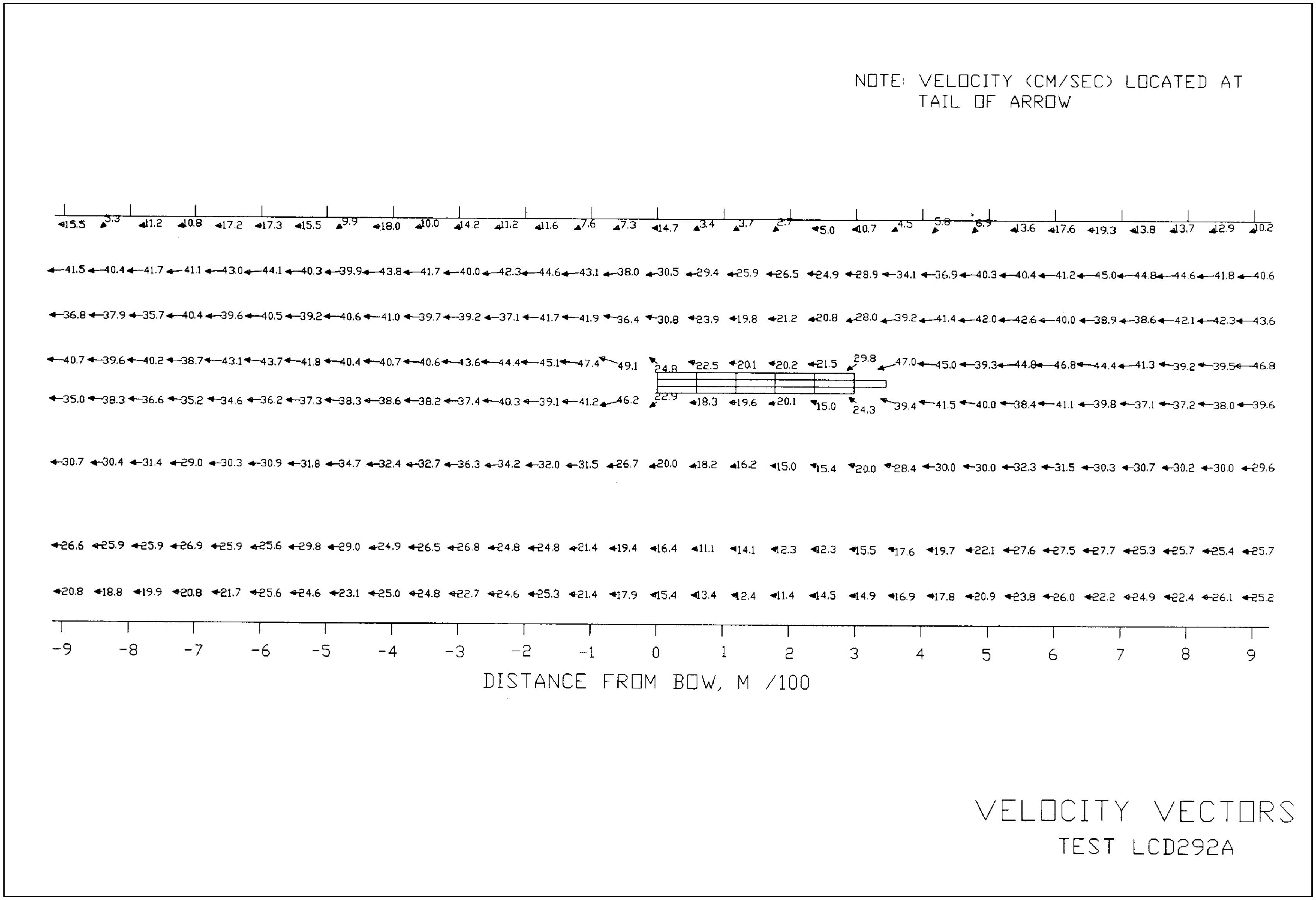


Figure 34. Vector plot, test LCD292A

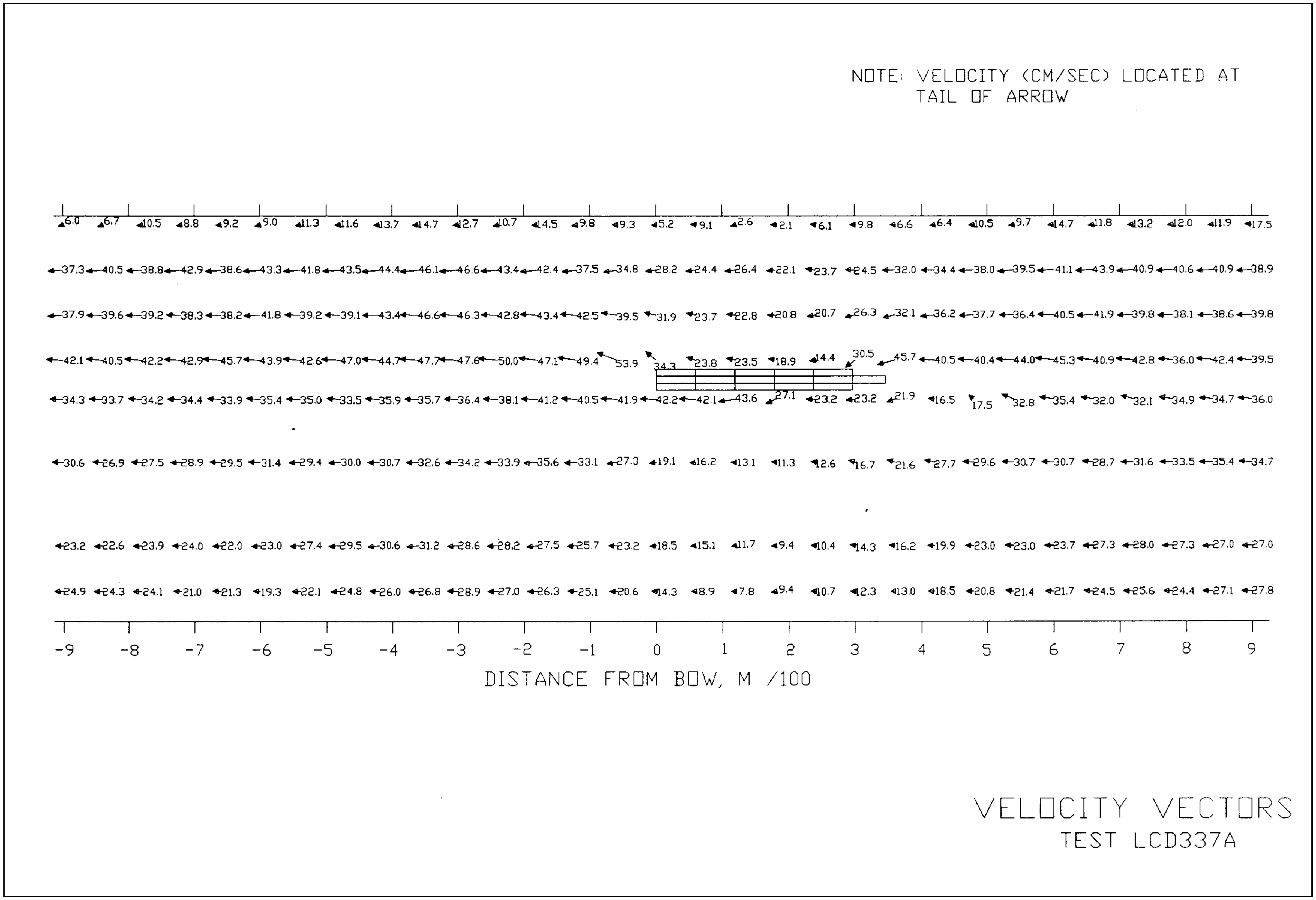


Figure 35.   Vector plot, test LCD337A

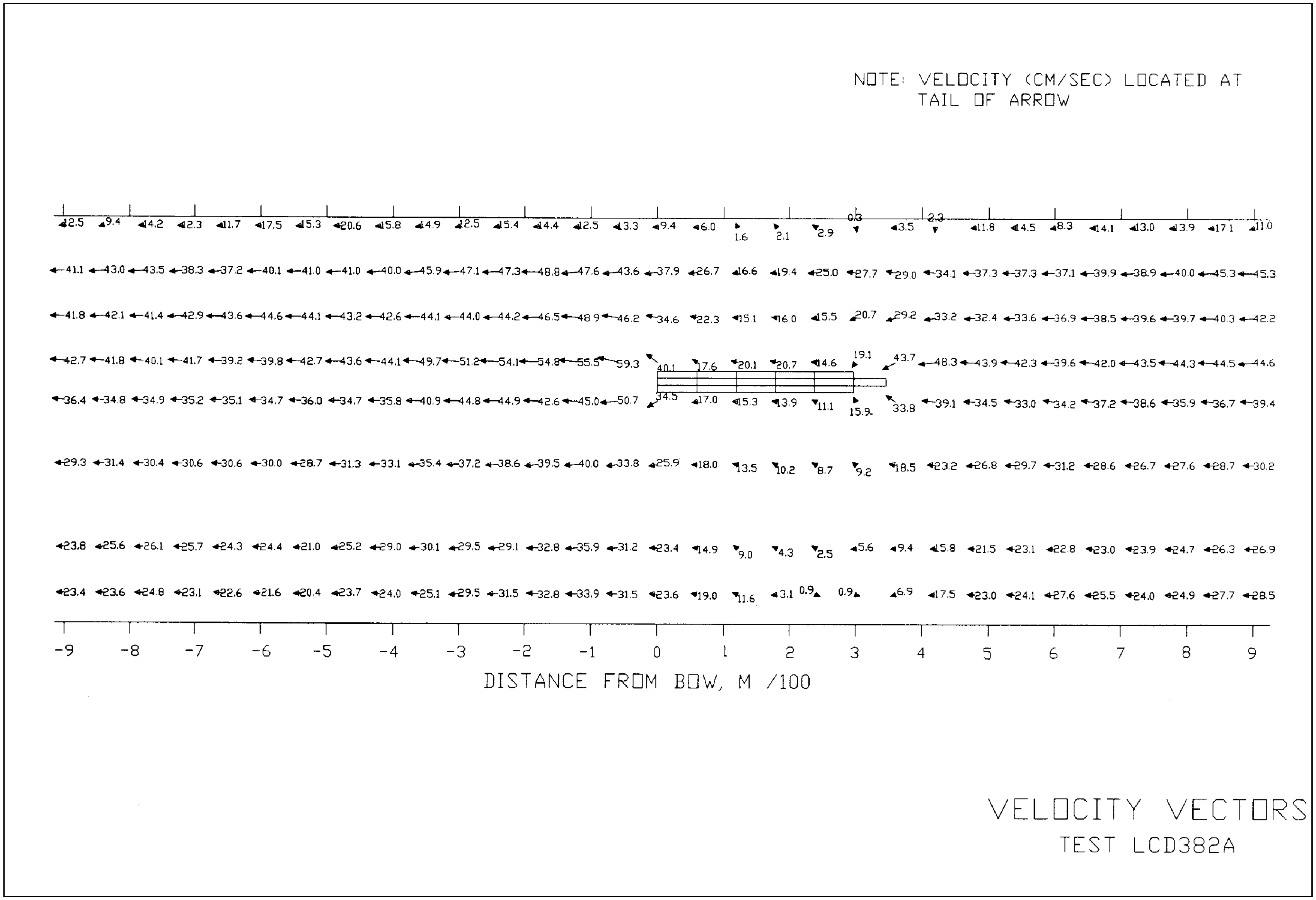


Figure 36. Vector plot, test LCD382A

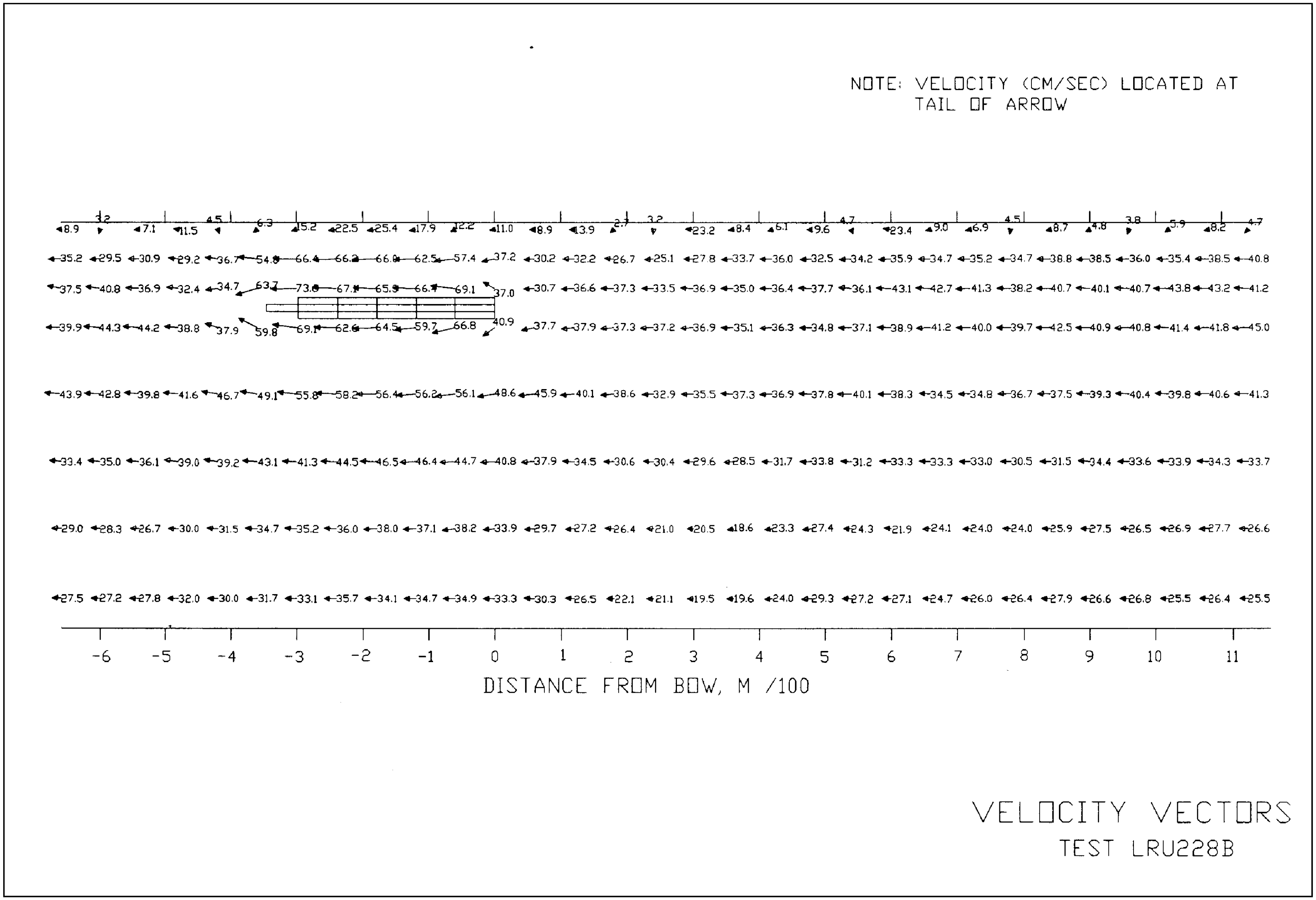


Figure 37. Vector plot, test LRU228B

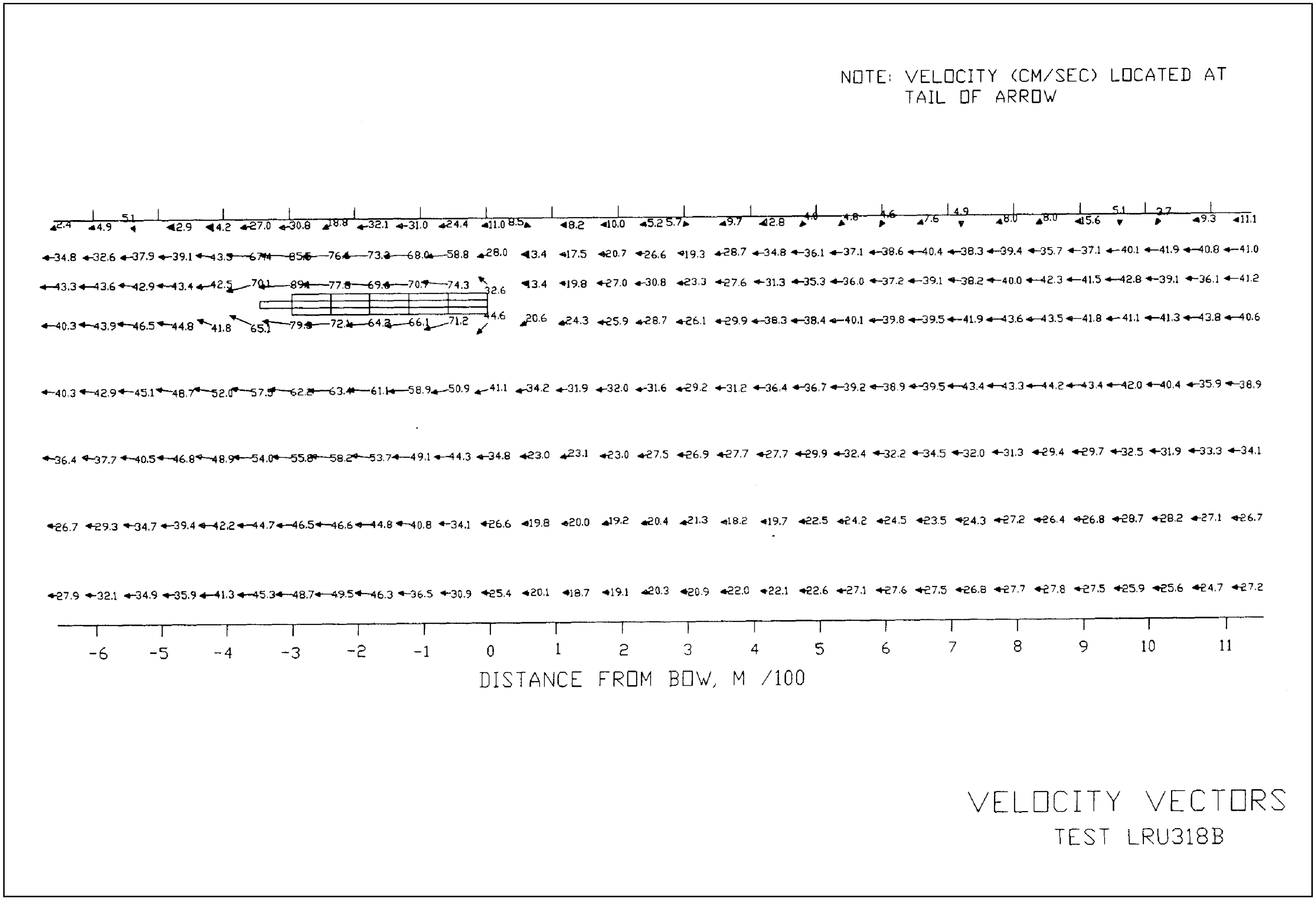


Figure 38. Vector plot, test LRU318B

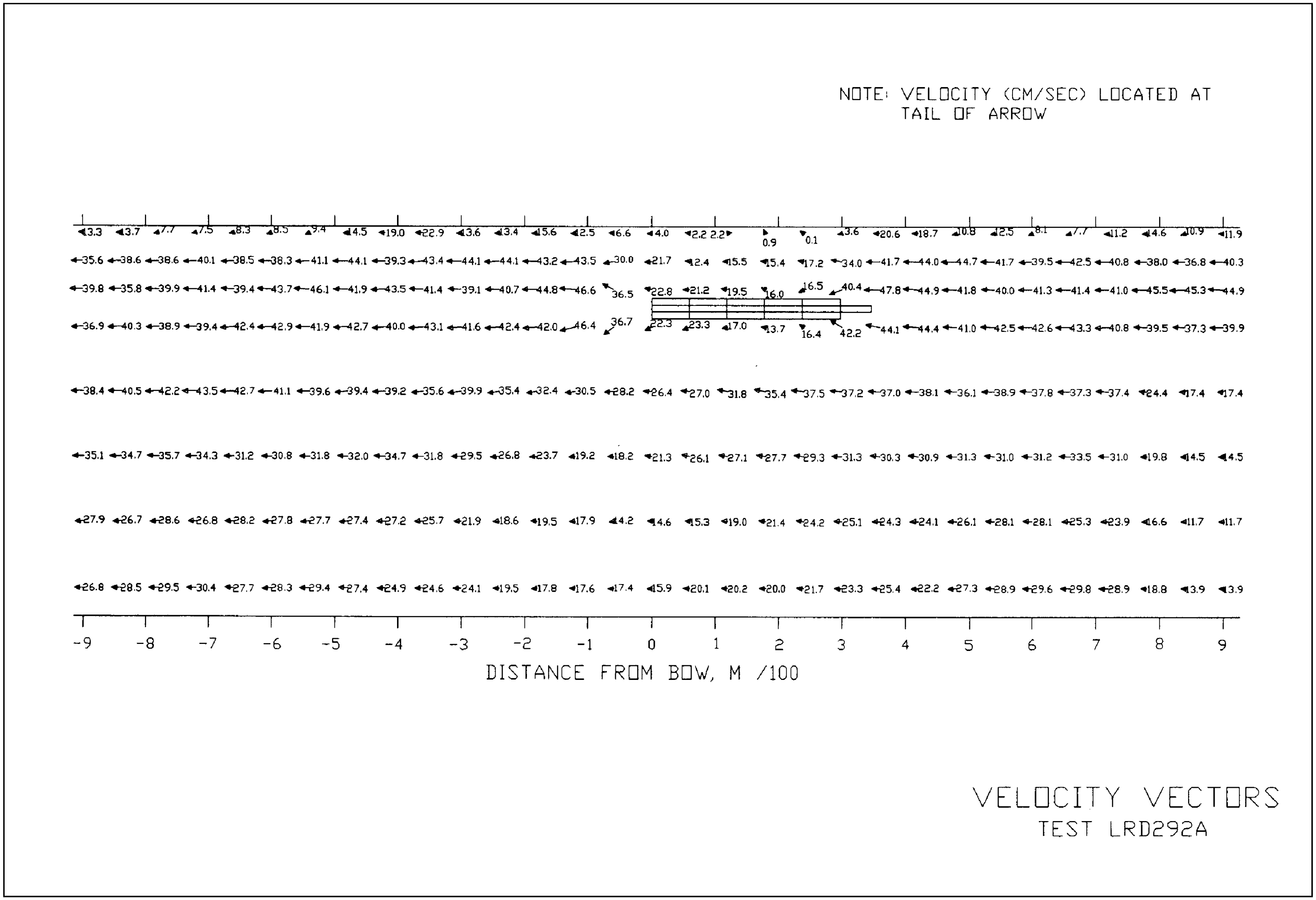


Figure 39. Vector plot, test LRD292A

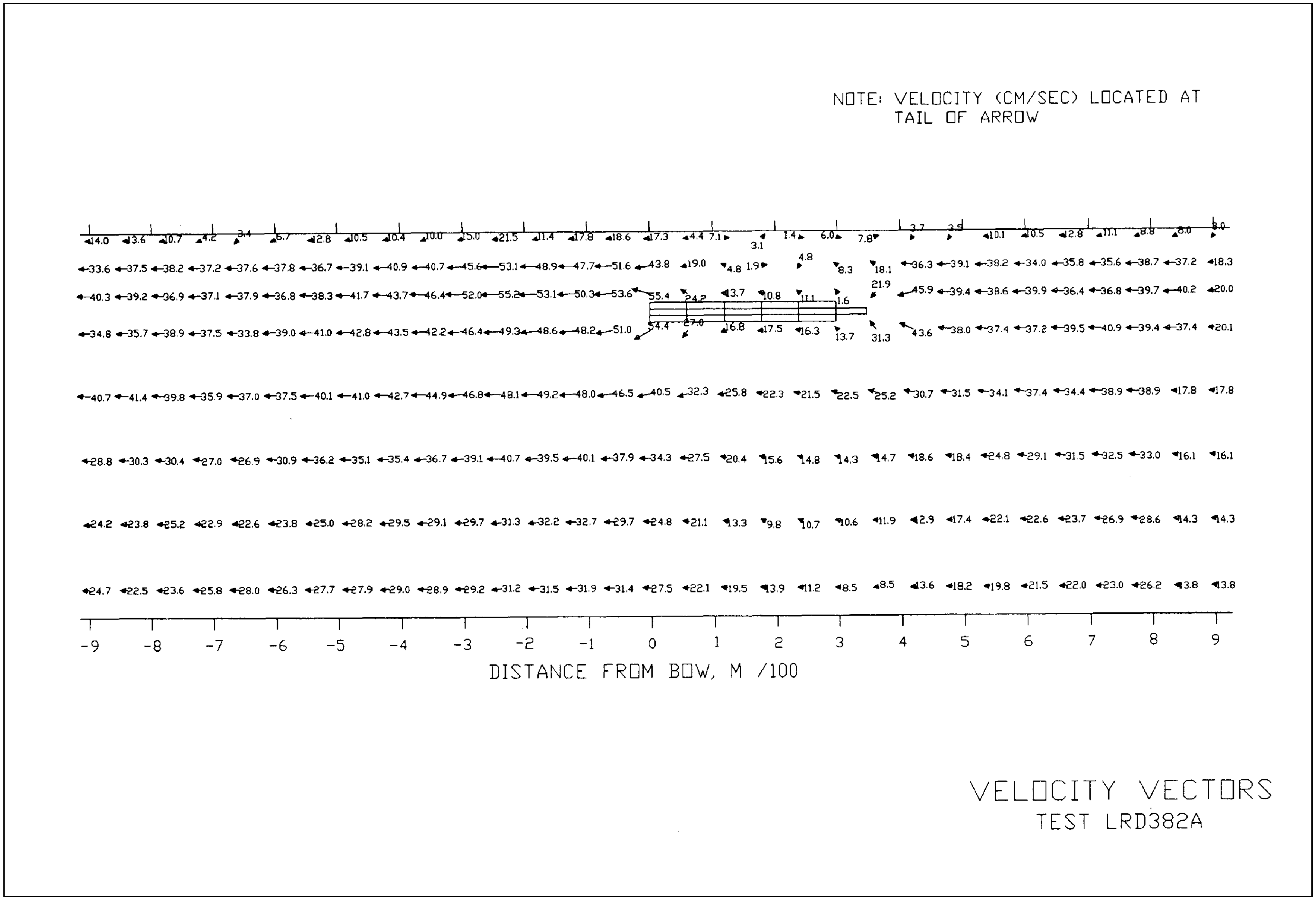


Figure 40. Vector plot, test LRD382A

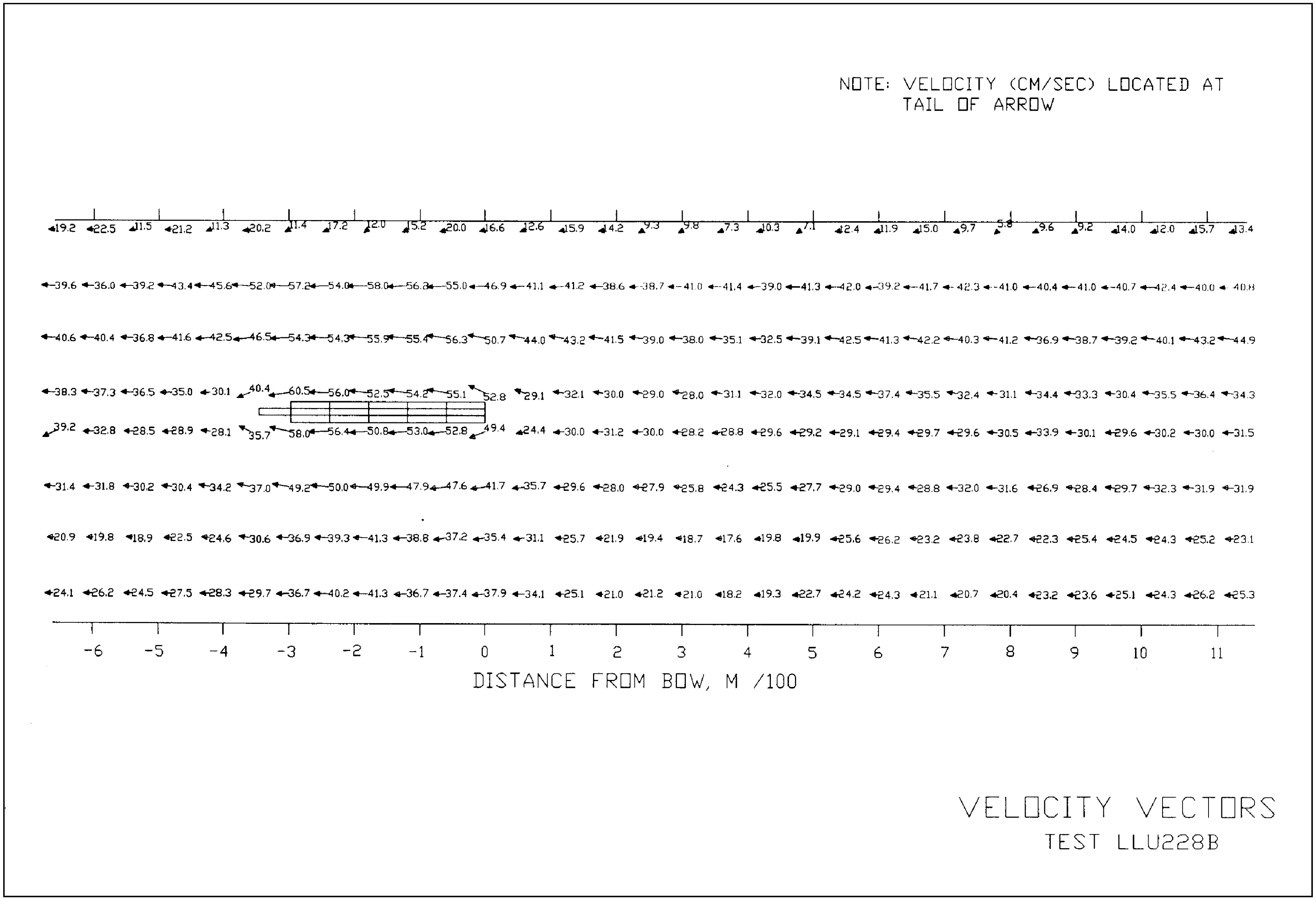


Figure 41. Vector plot, test LIU228B

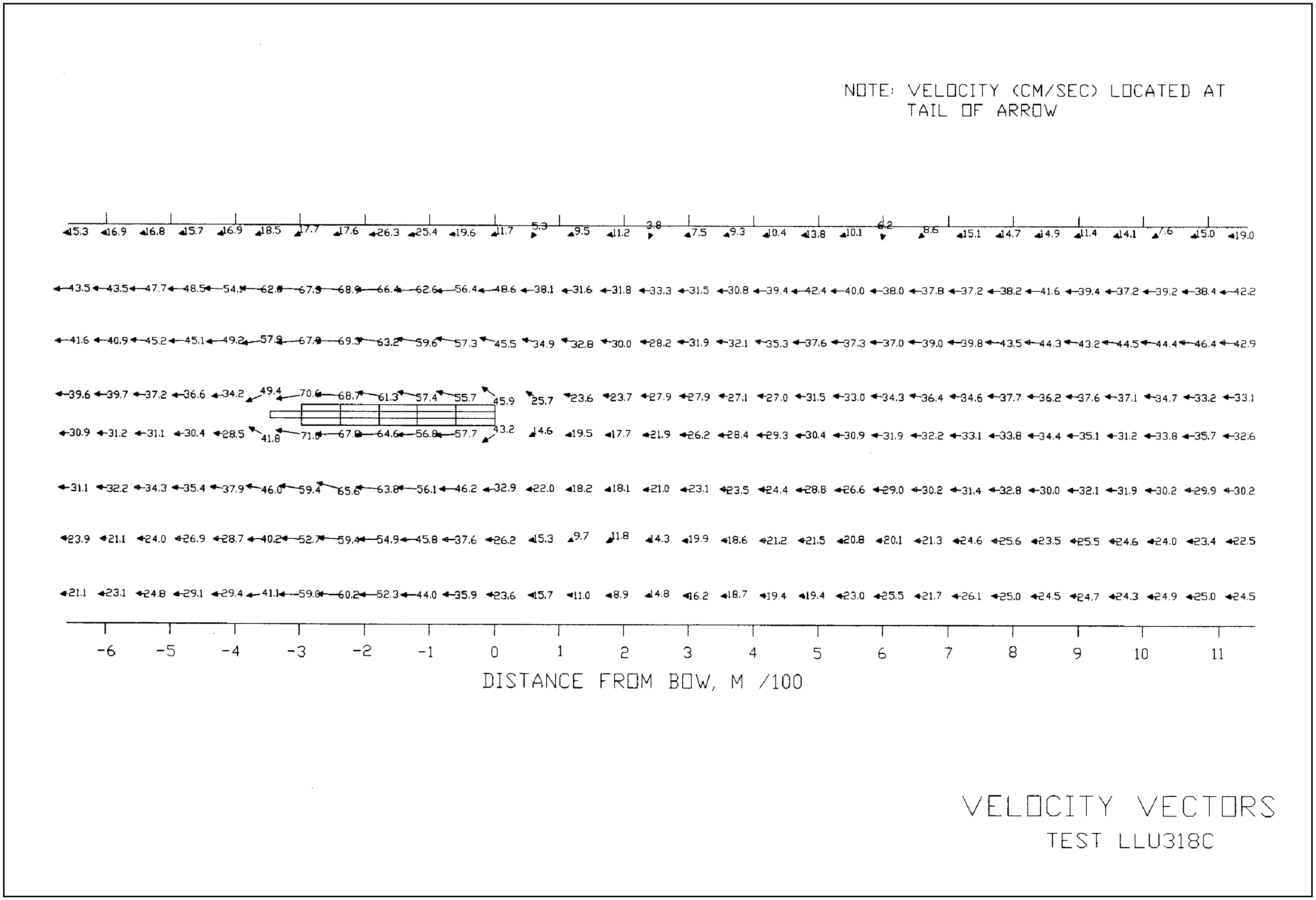


Figure 42. Vector plot, test LLU318C

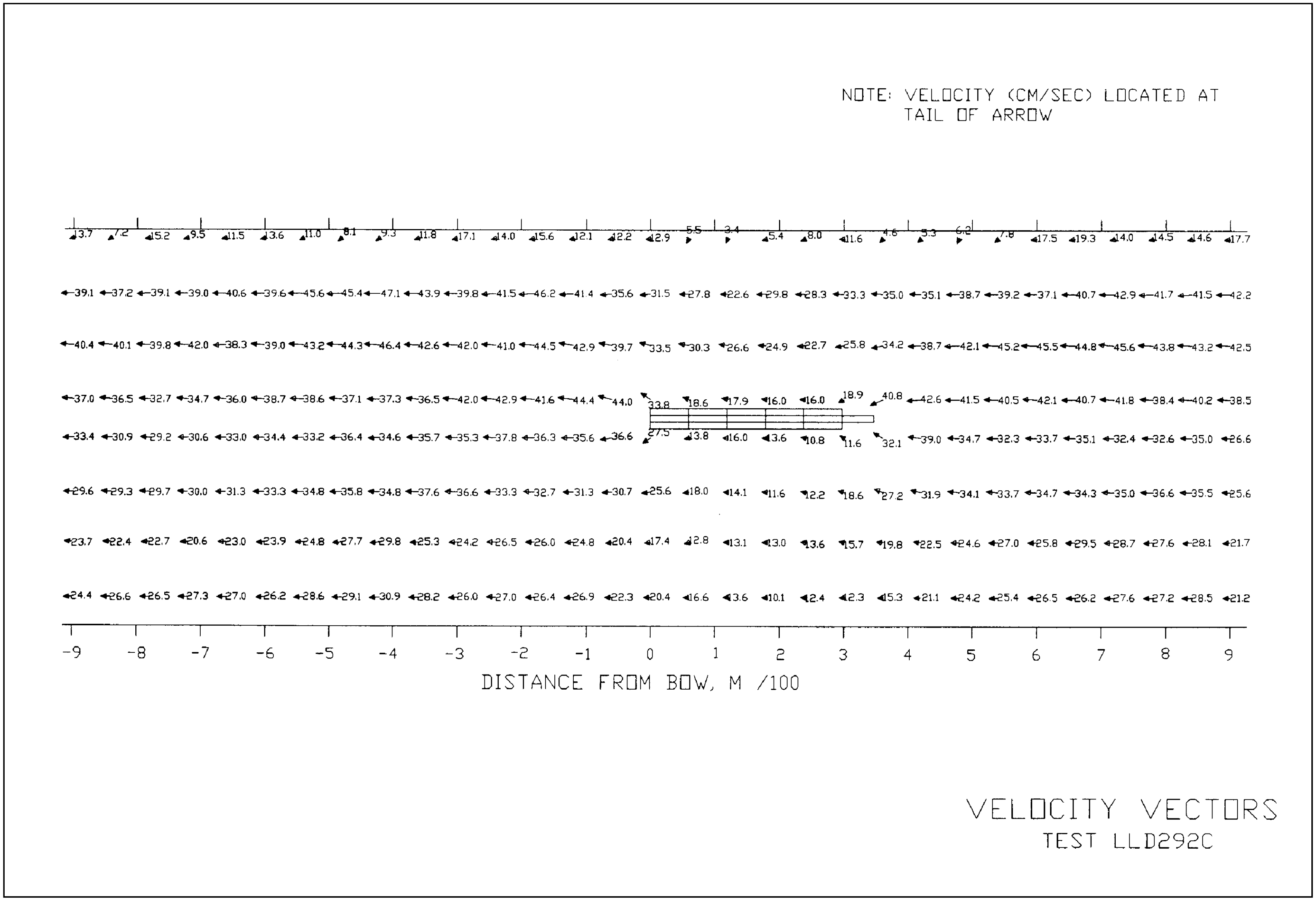


Figure 43. Vector plot, test LLD292C

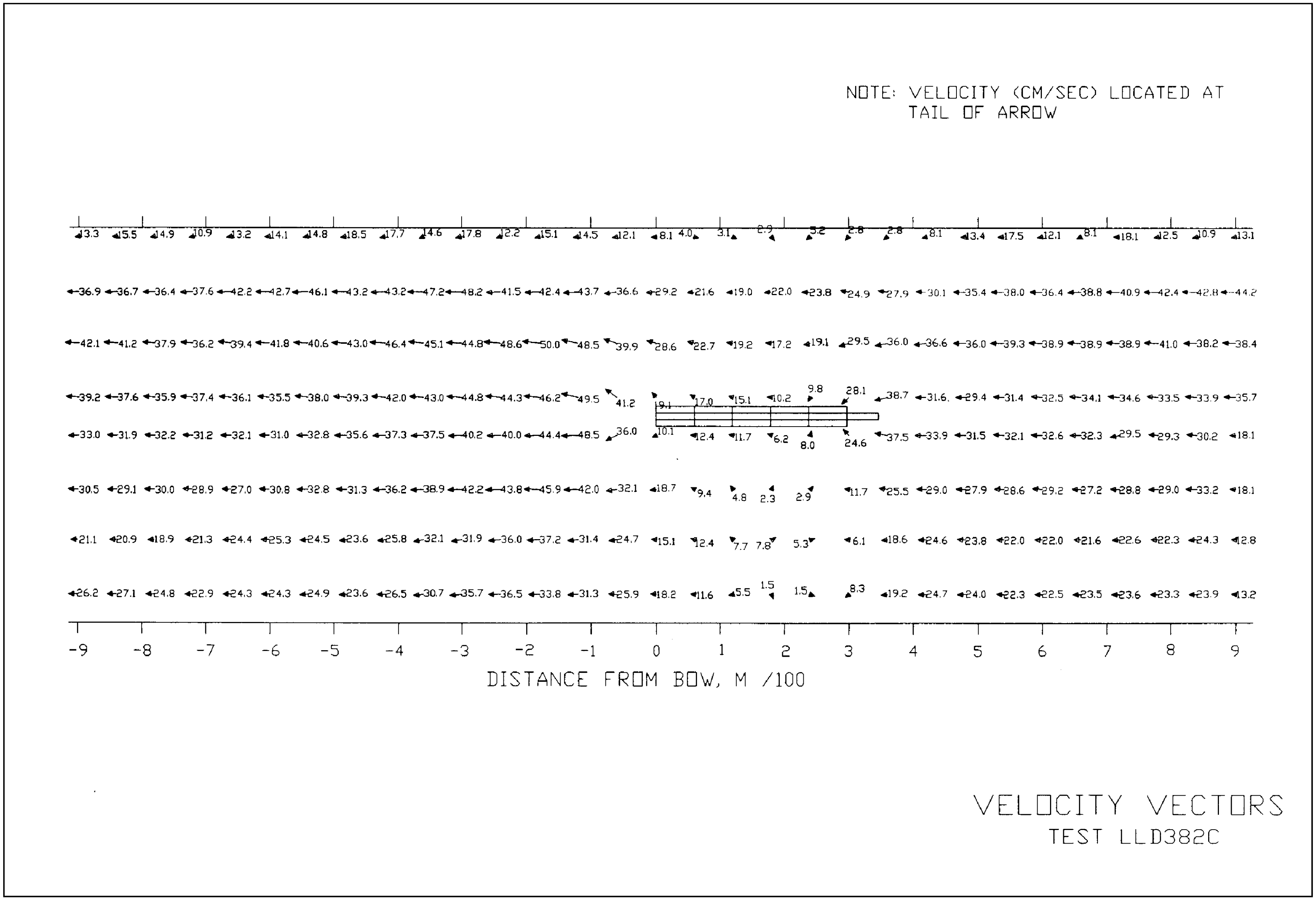


Figure 44. Vector plot, test LLD382C

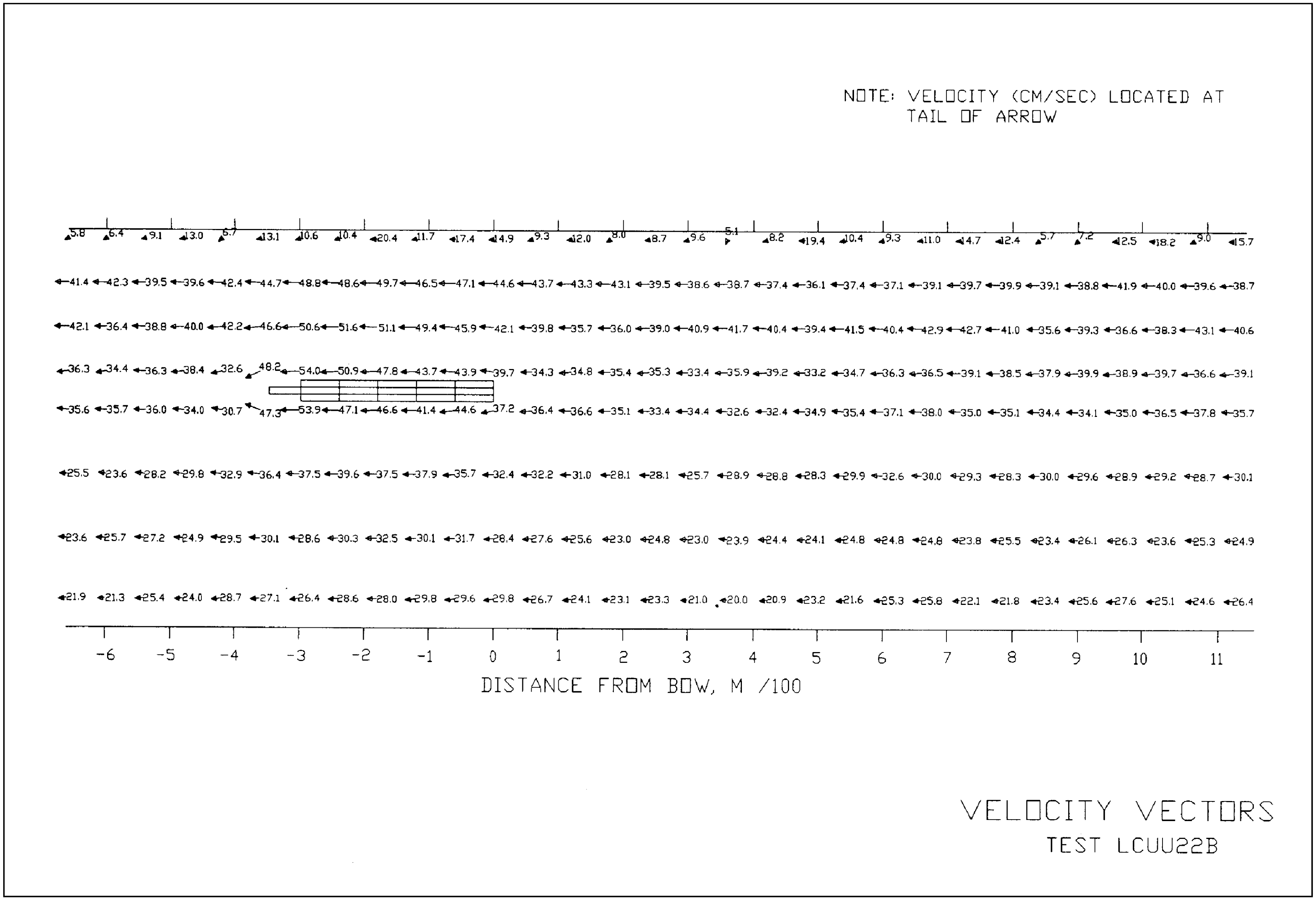


Figure 45. Vector plot, test LCUU22B

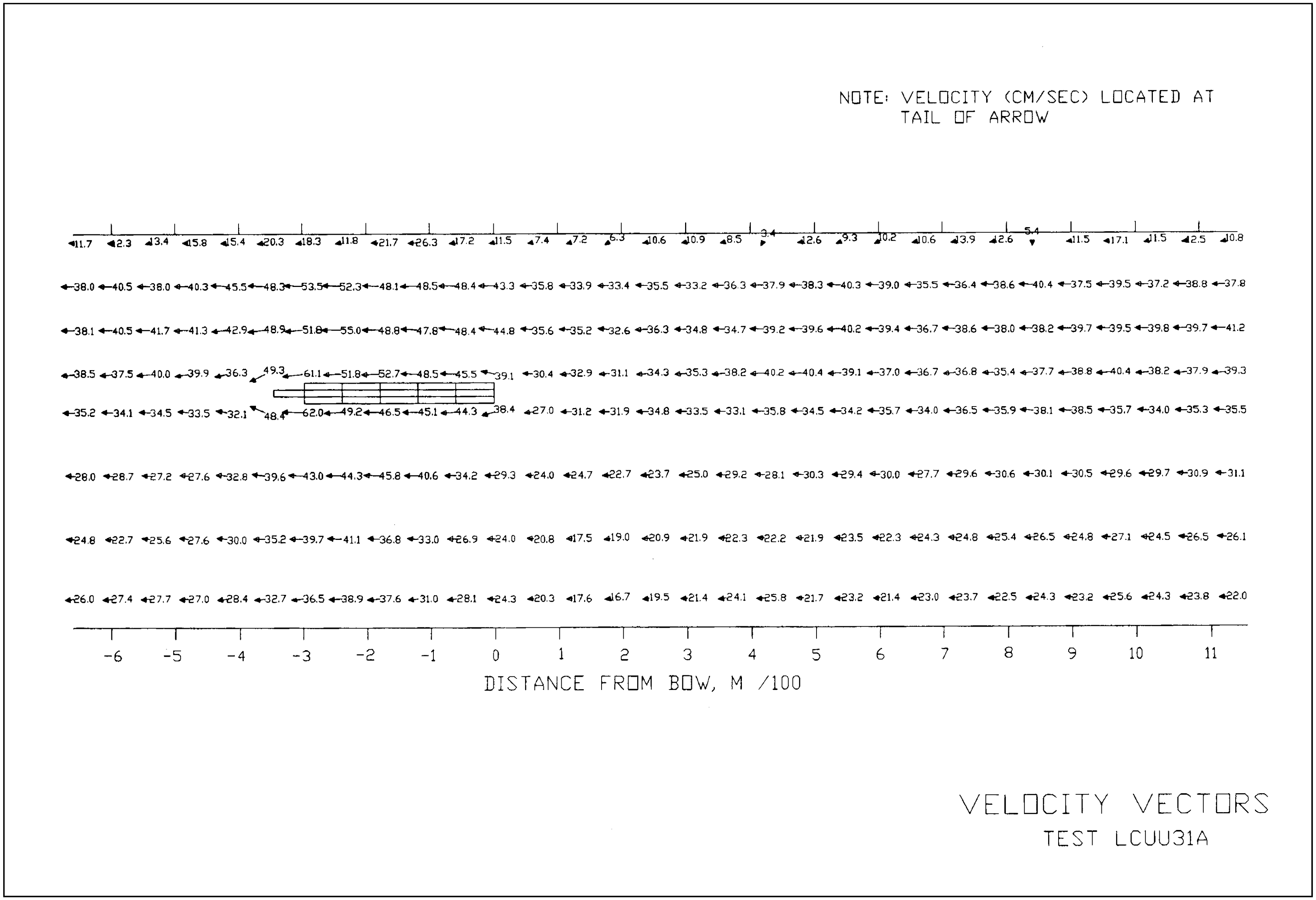


Figure 46. Vector plot, test LCUU31A

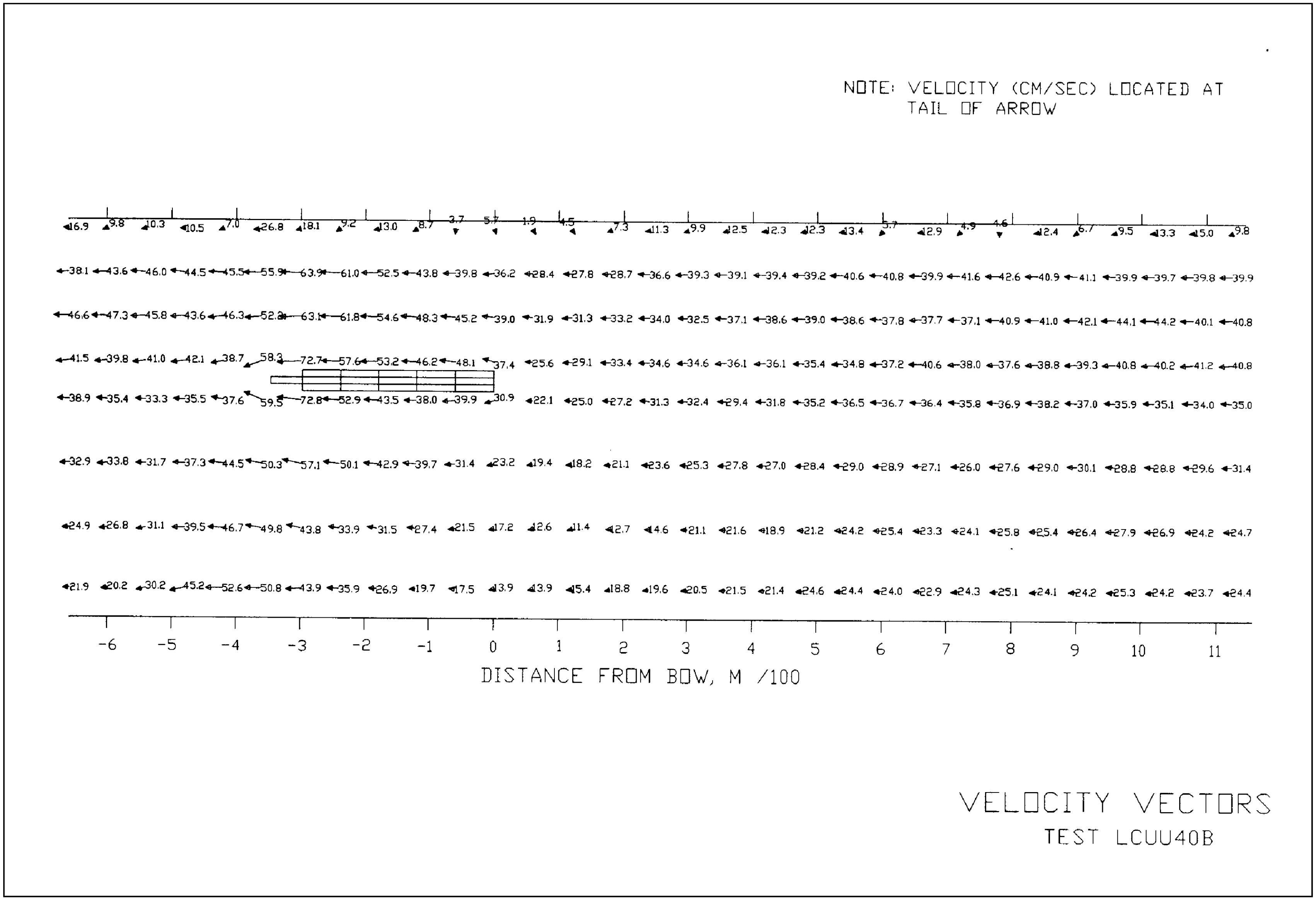


Figure 47. Vector plot, test LCUU40B

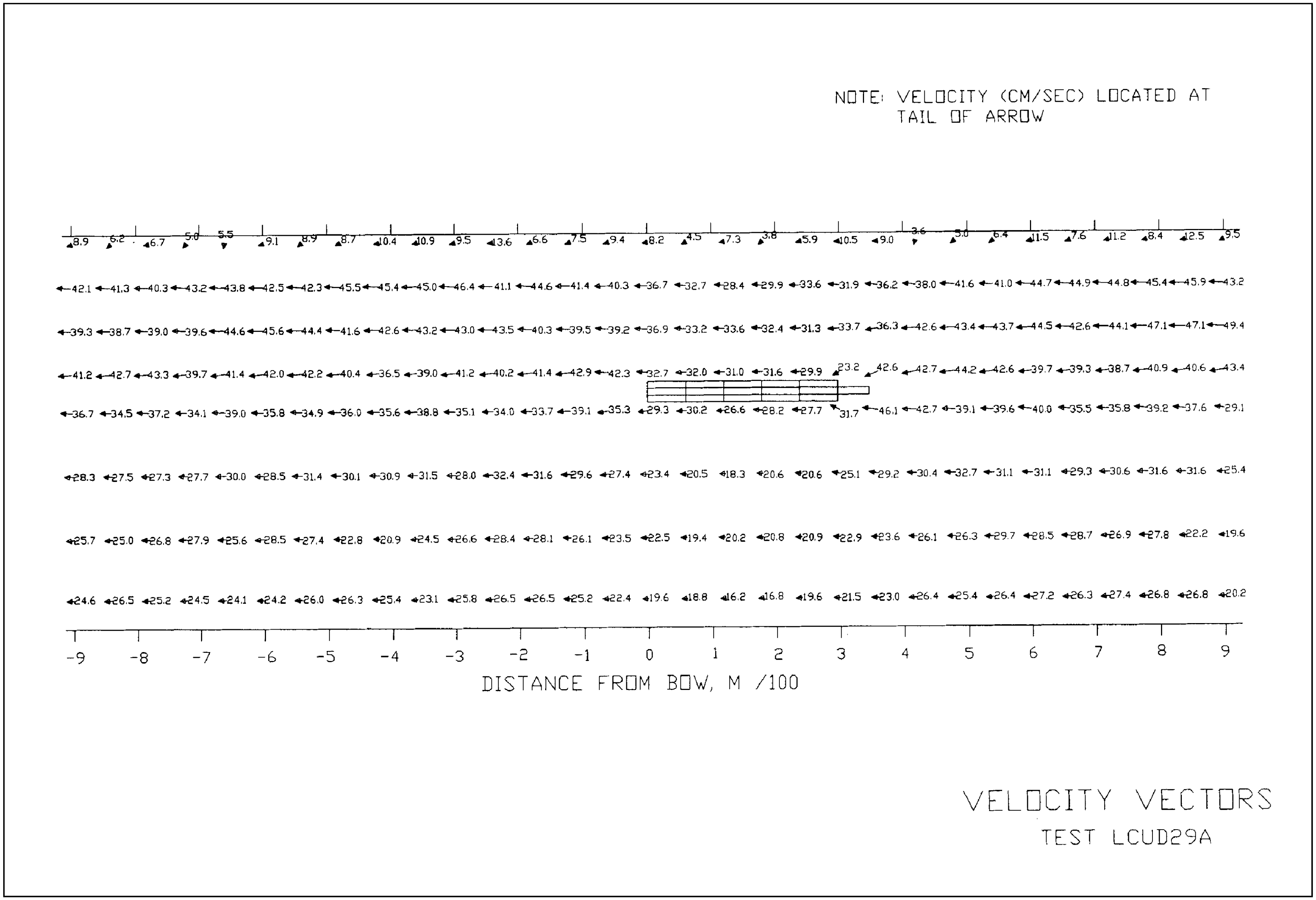


Figure 48. Vector plot, test LCUD29A

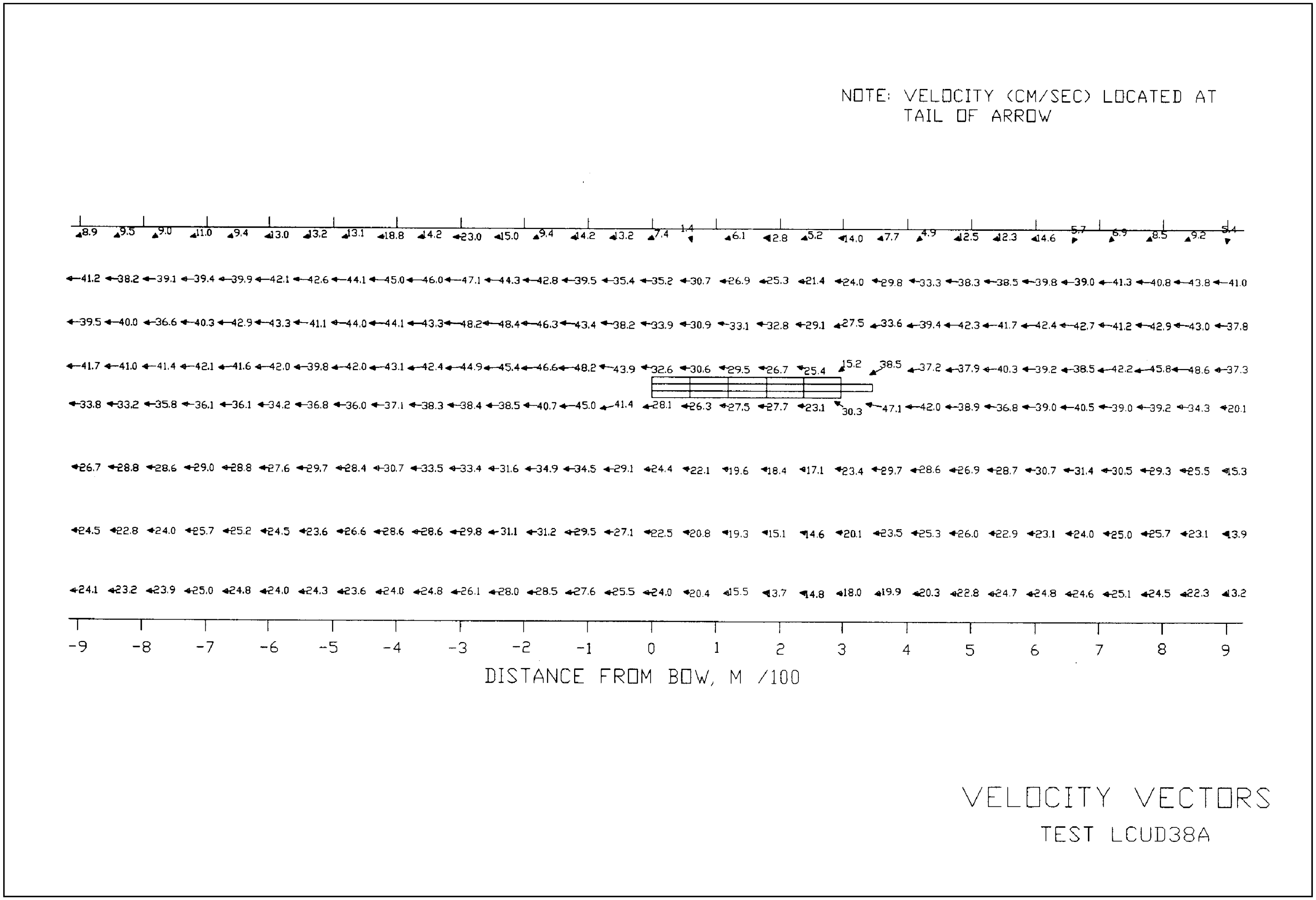


Figure 49. Vector plot, test LCUD38A

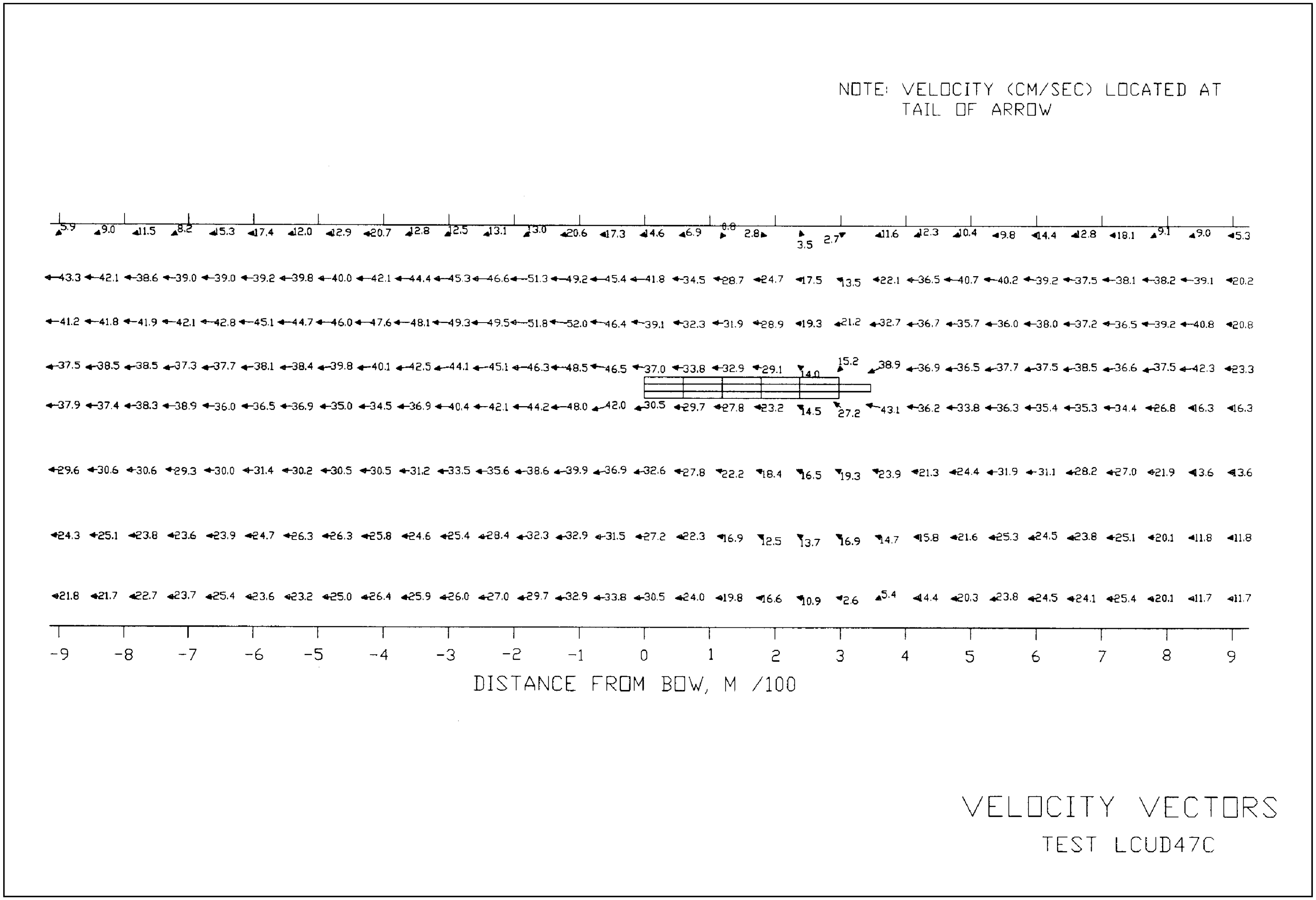


Figure 50. Vector plot, test LCUD47C

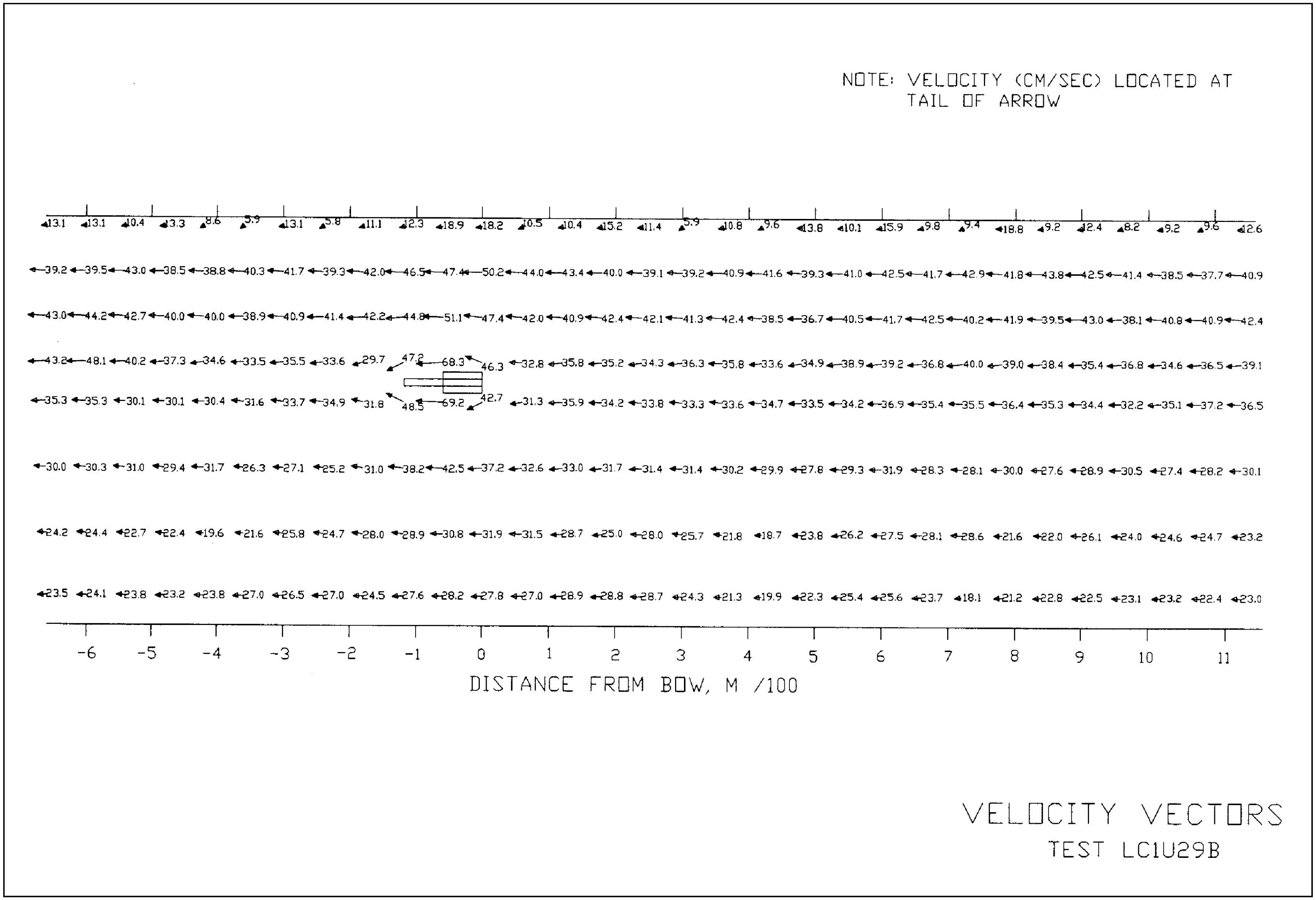


Figure 51. Vector plot, test LC1U29B

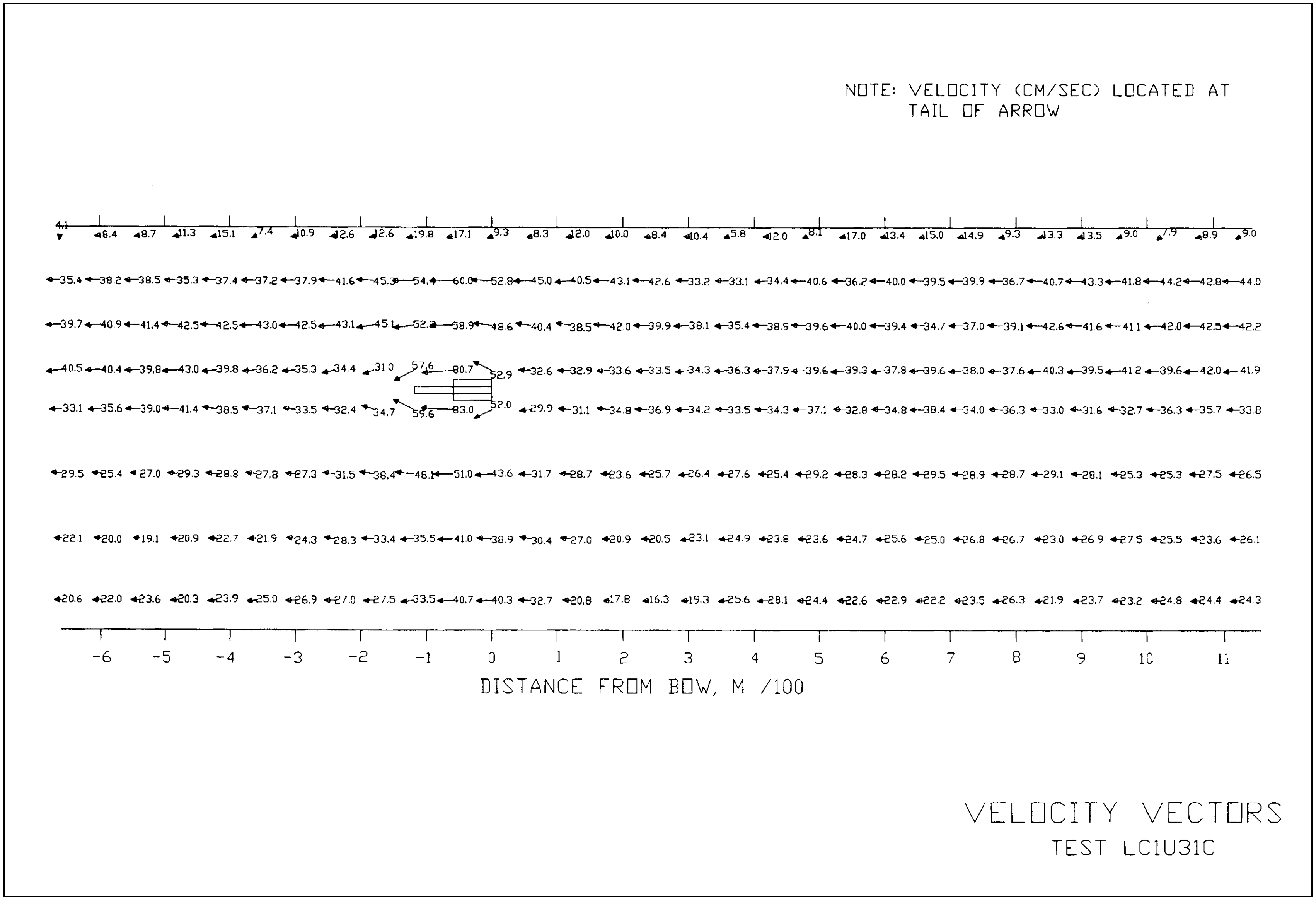


Figure 52. Vector plot, test LC1U31C

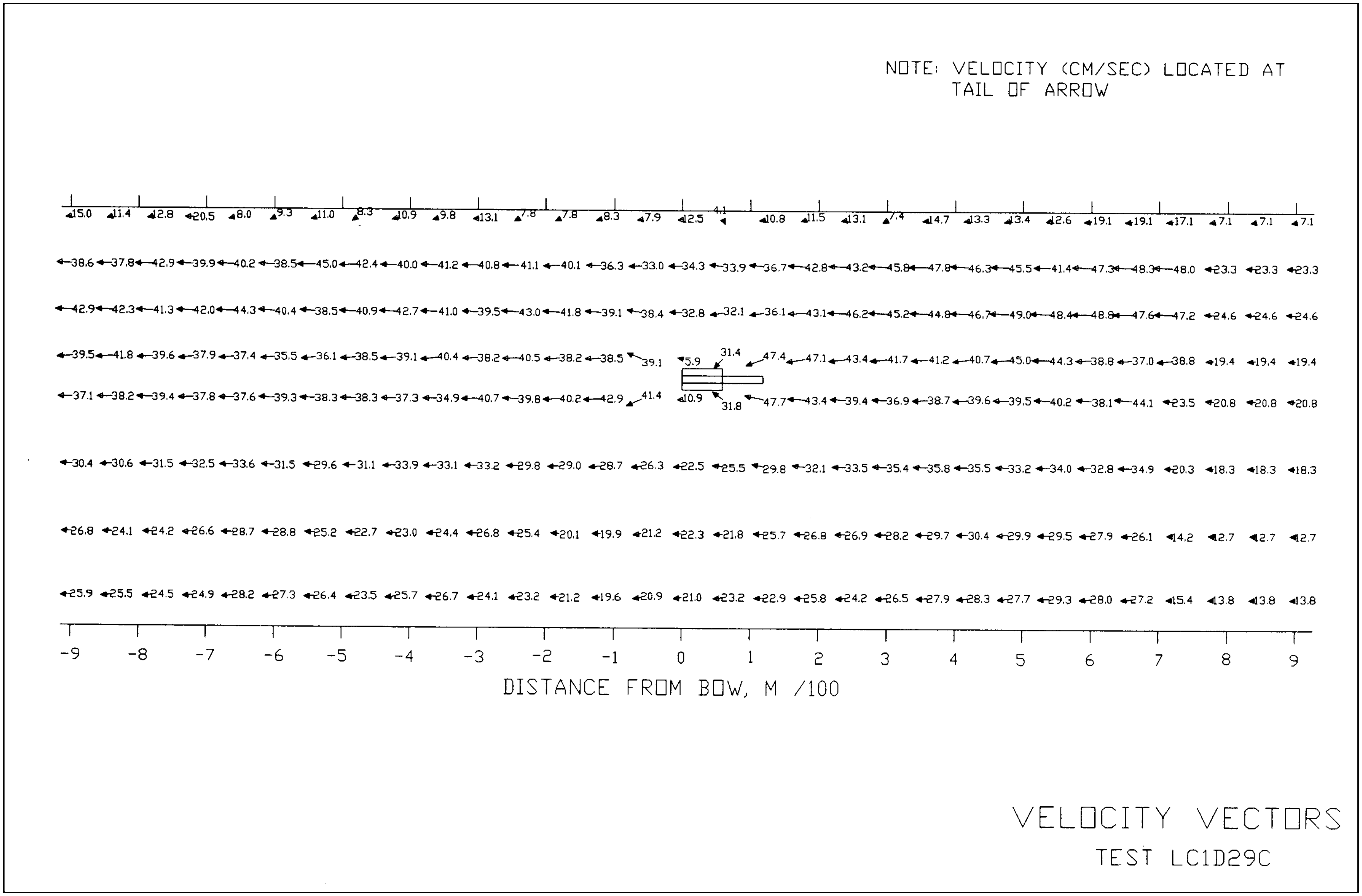


Figure 53. Vector plot, test LC1D29C

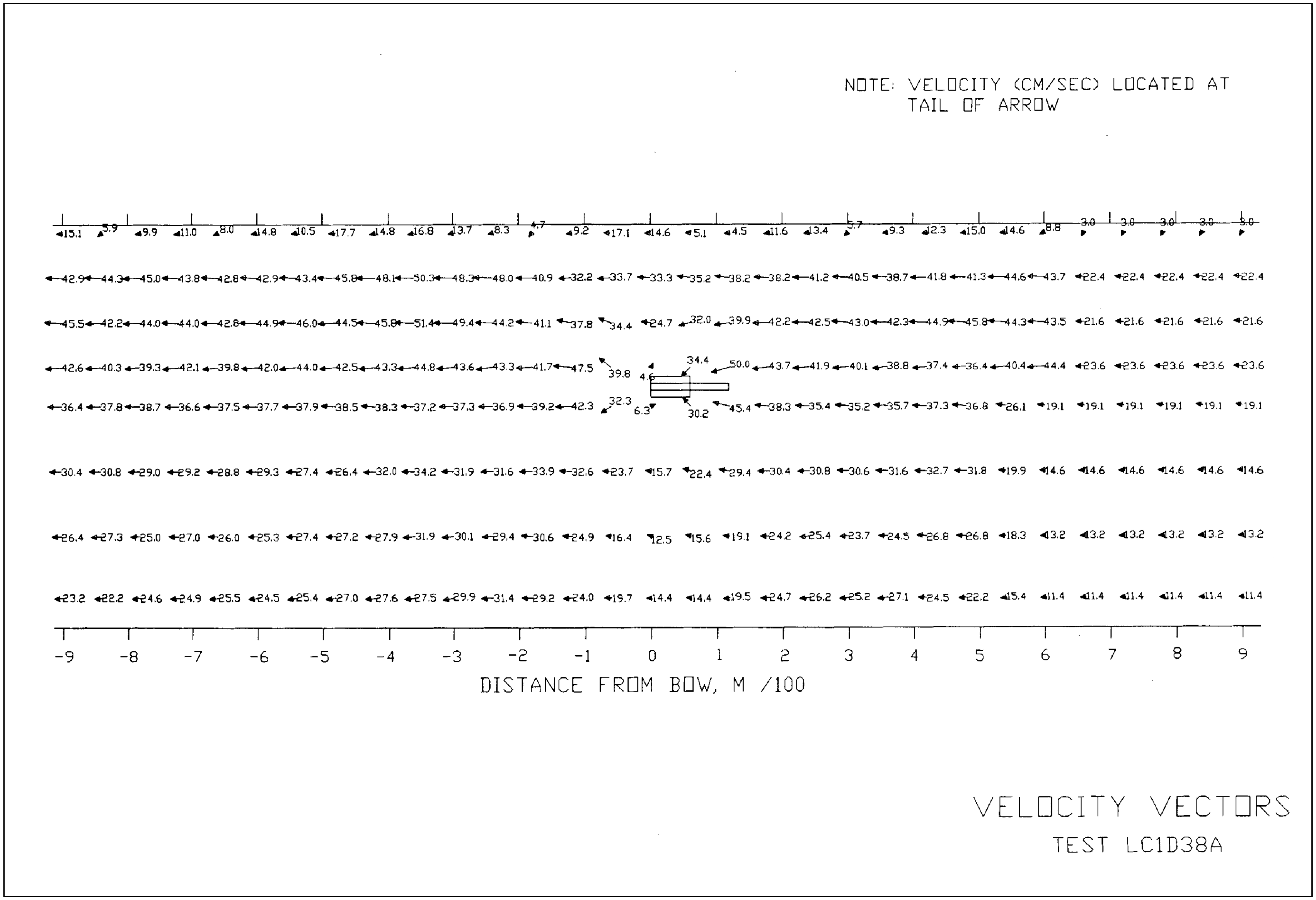


Figure 54. Vector plot, test LC1D38A

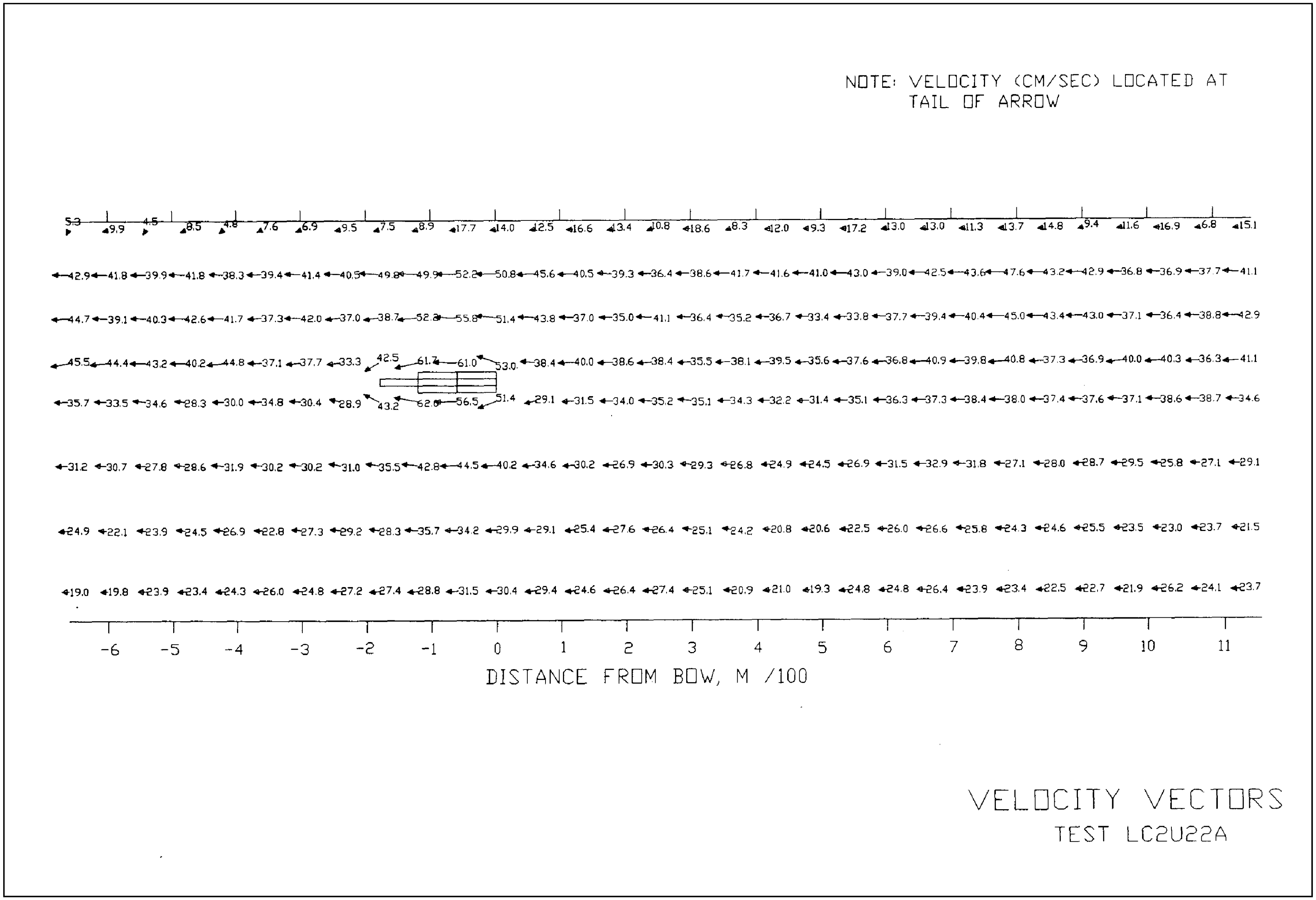


Figure 55. Vector plot, test LC2U22A

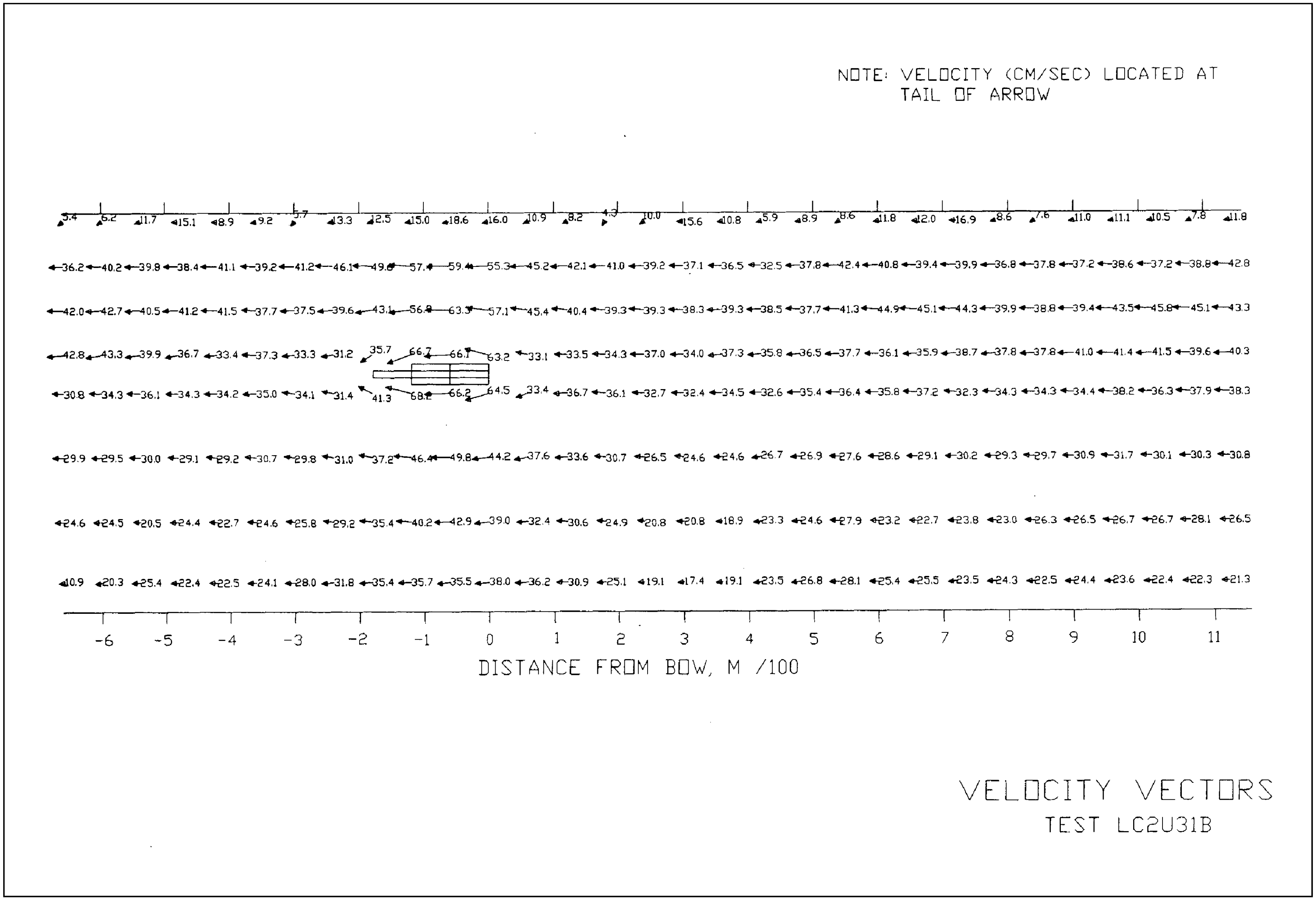


Figure 56. Vector plot, test LC2U31B

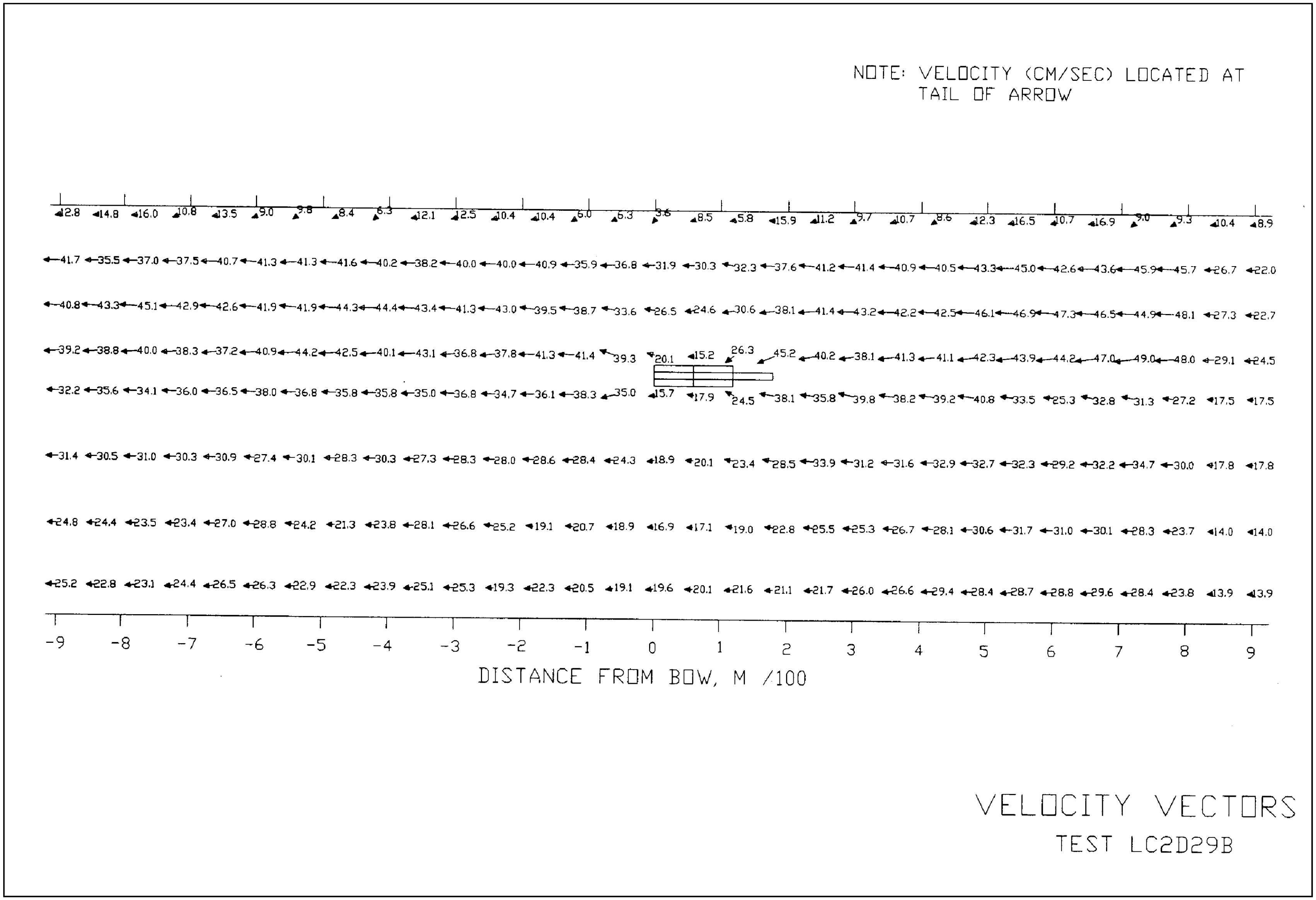


Figure 57. Vector plot, test LC2D29B

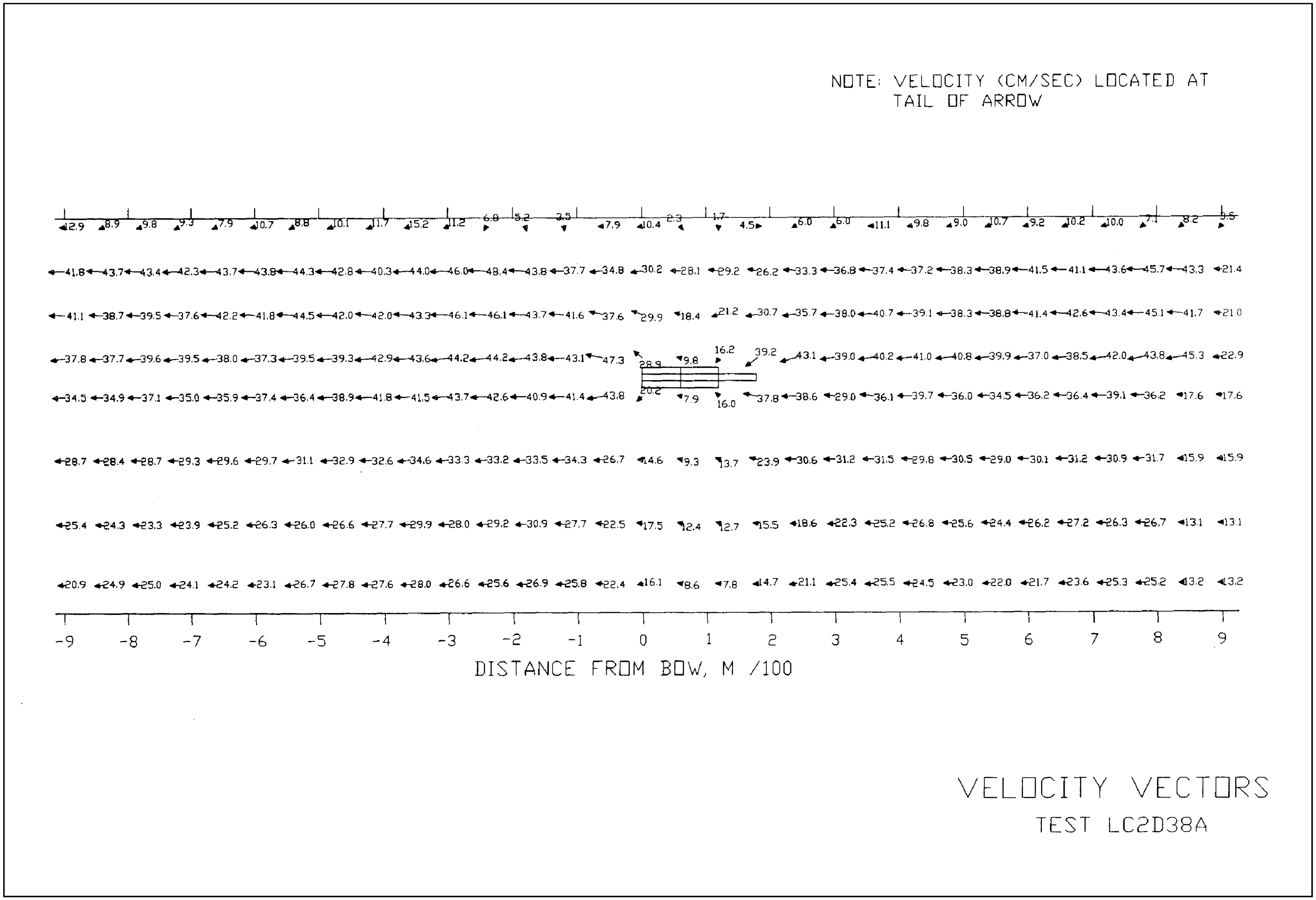


Figure 58. Vector plot, test LC2D38A

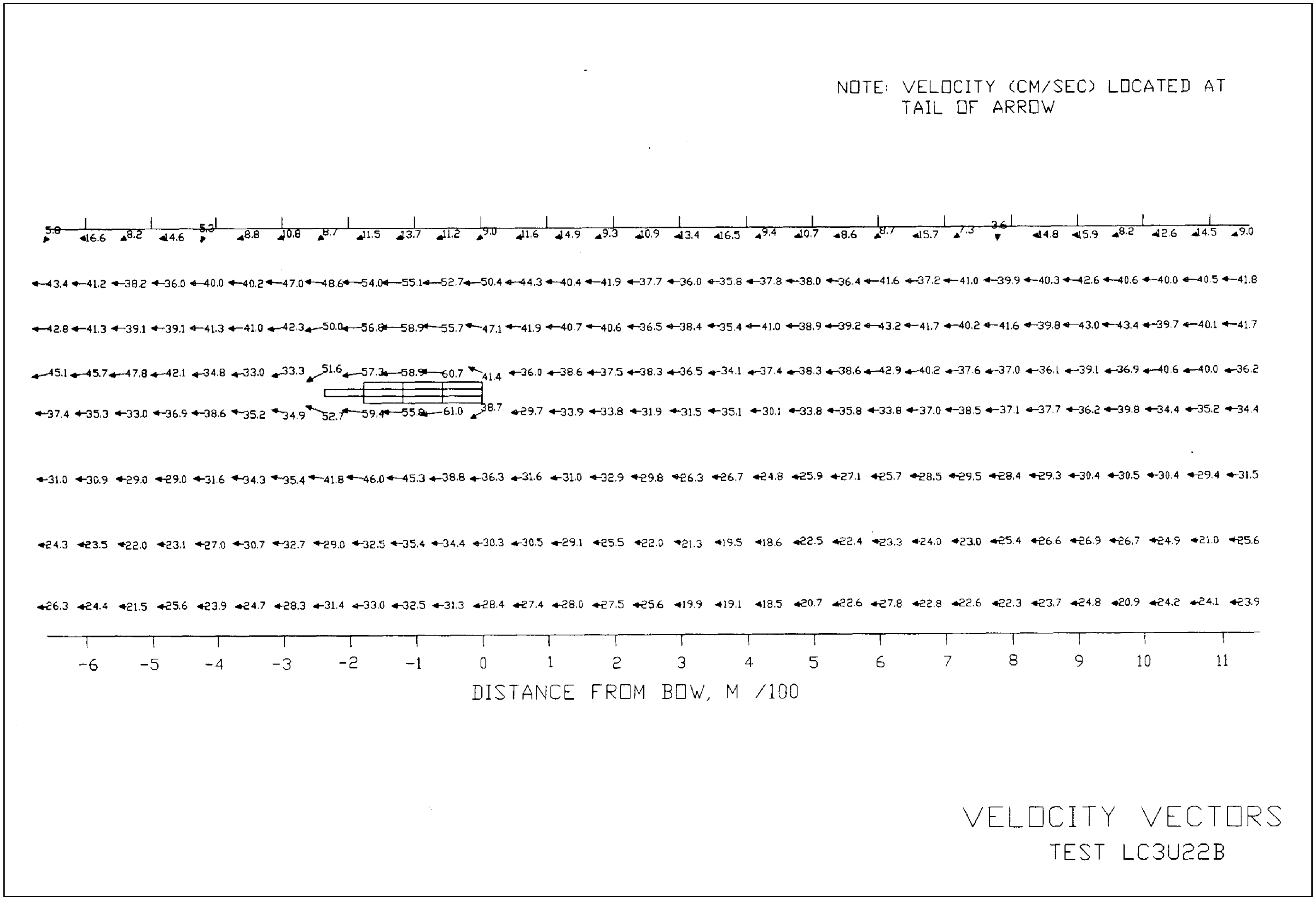


Figure 59. Vector plot, test LC3U22B

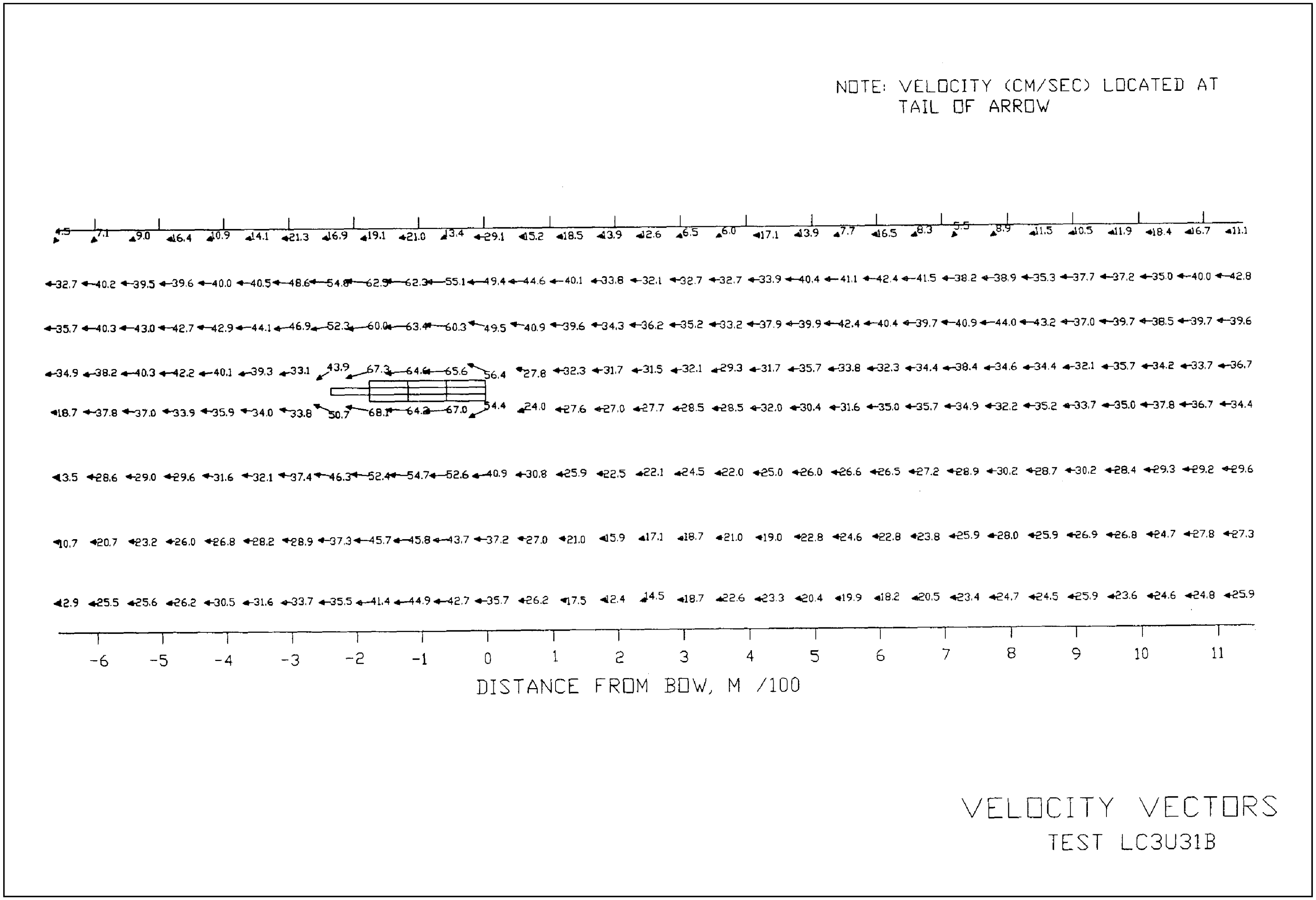


Figure 60. Vector plot, test LC3U31B

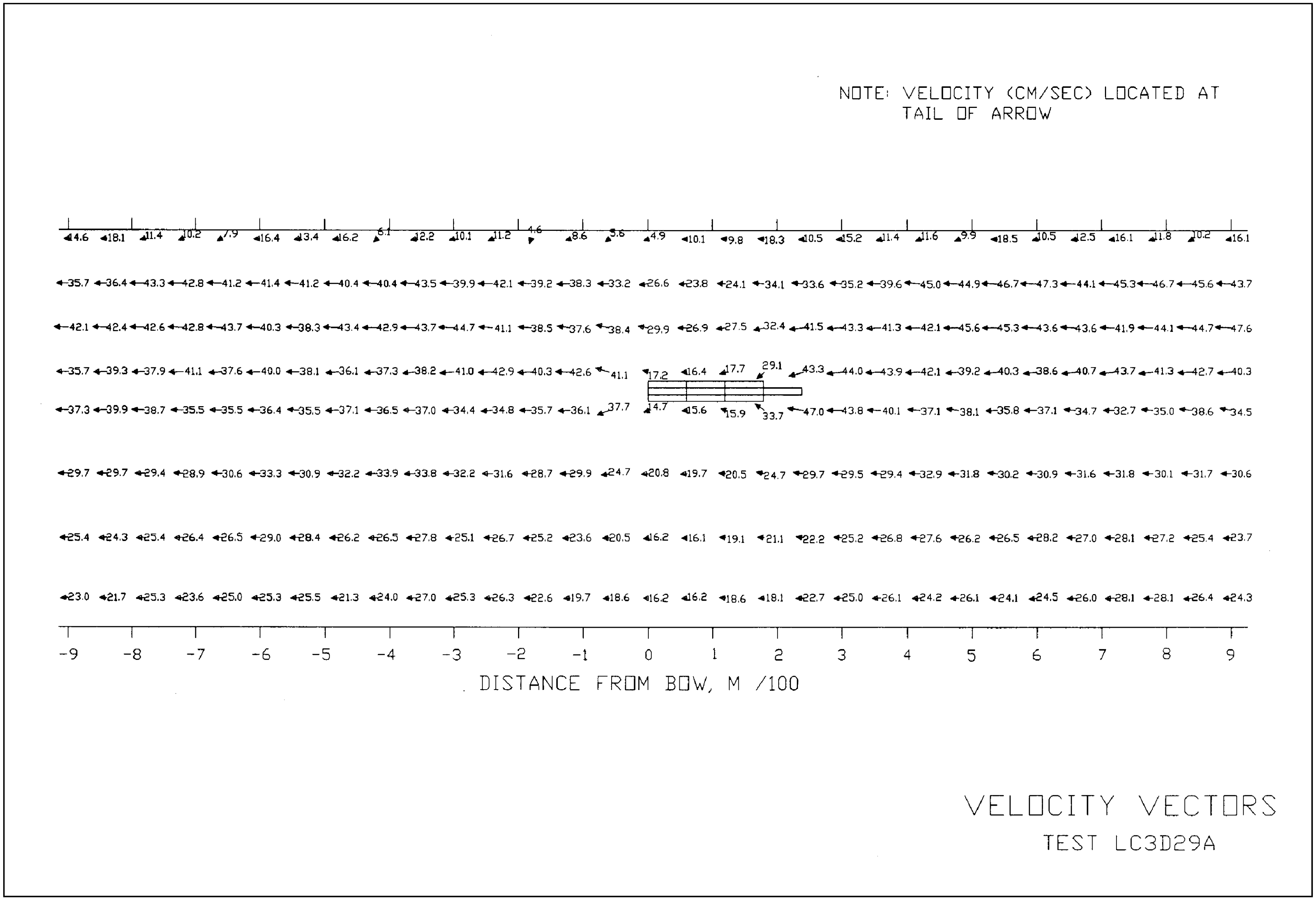


Figure 61. Vector plot, test LC3D29A

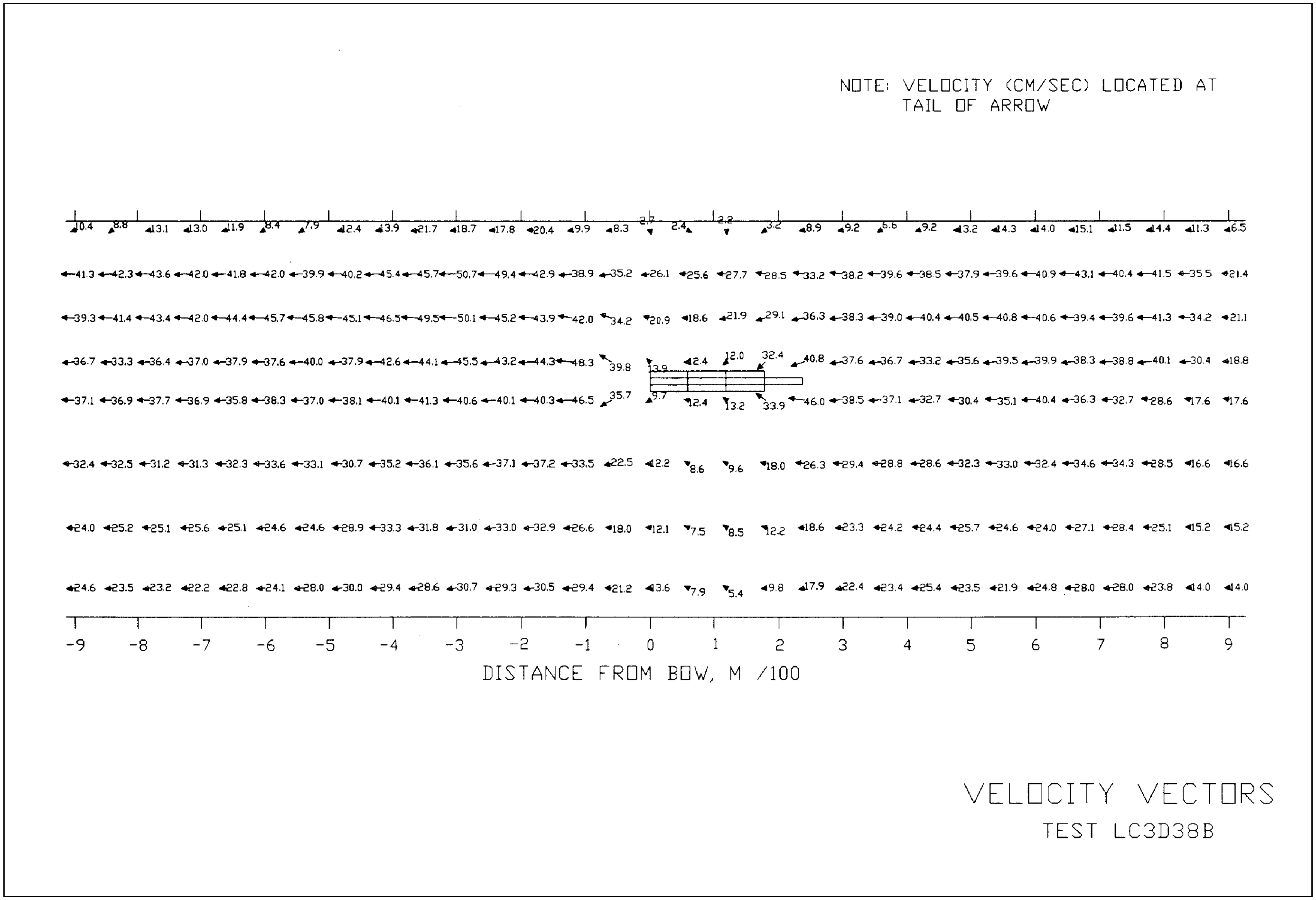


Figure 62. Vector plot, test LC3D38B

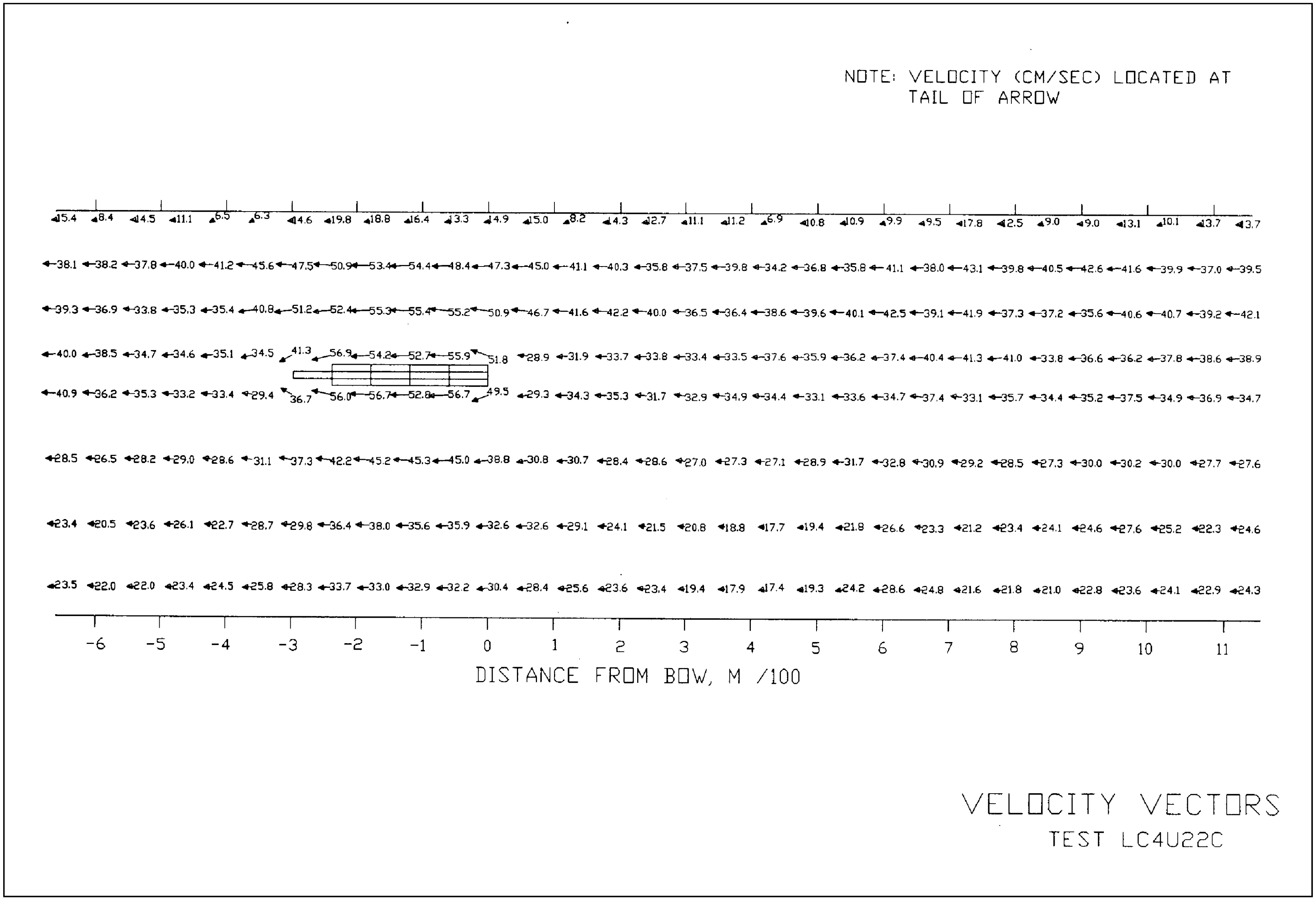


Figure 63. Vector plot, test LC4U22C

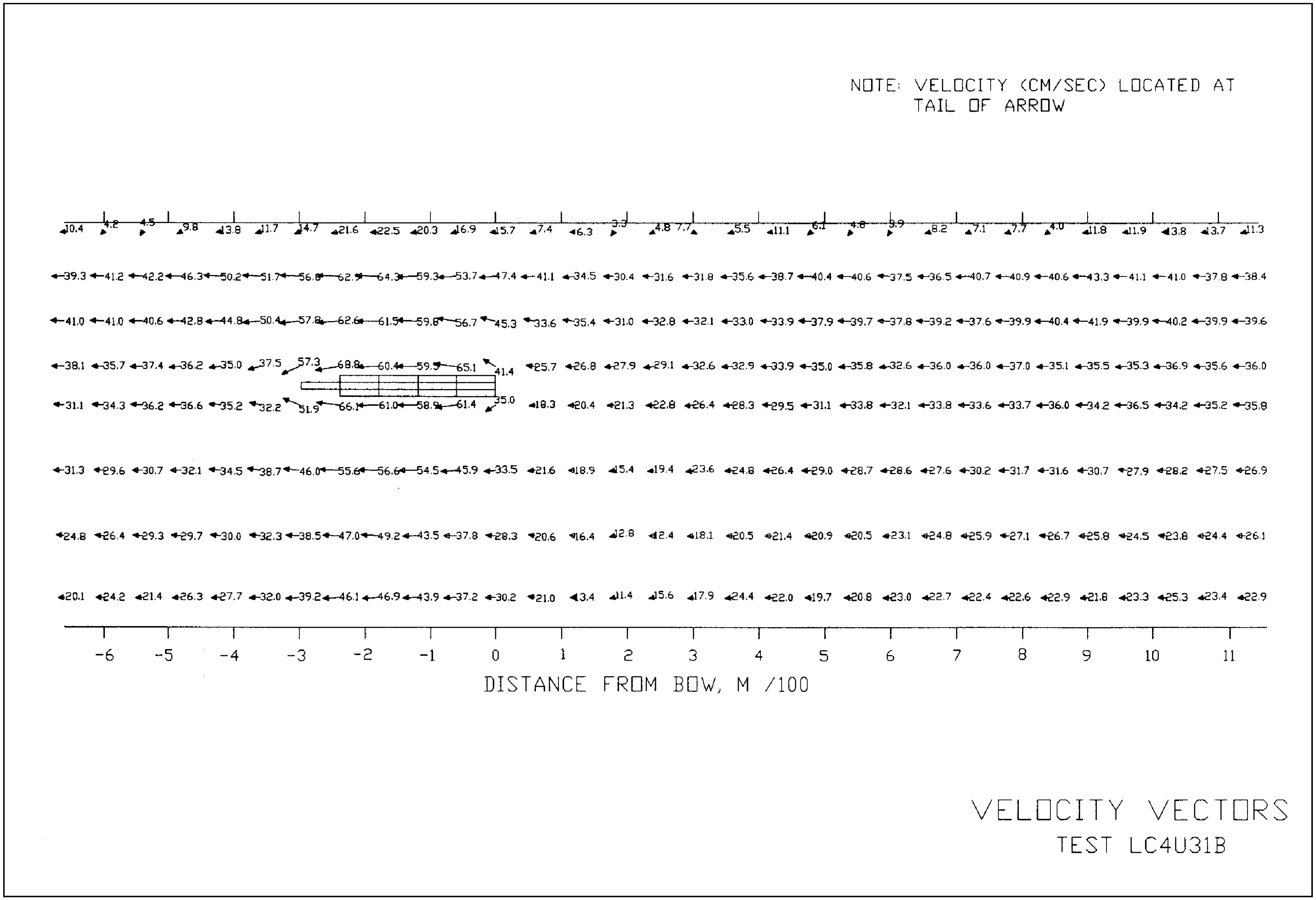


Figure 64. Vector plot, test LC4U31B

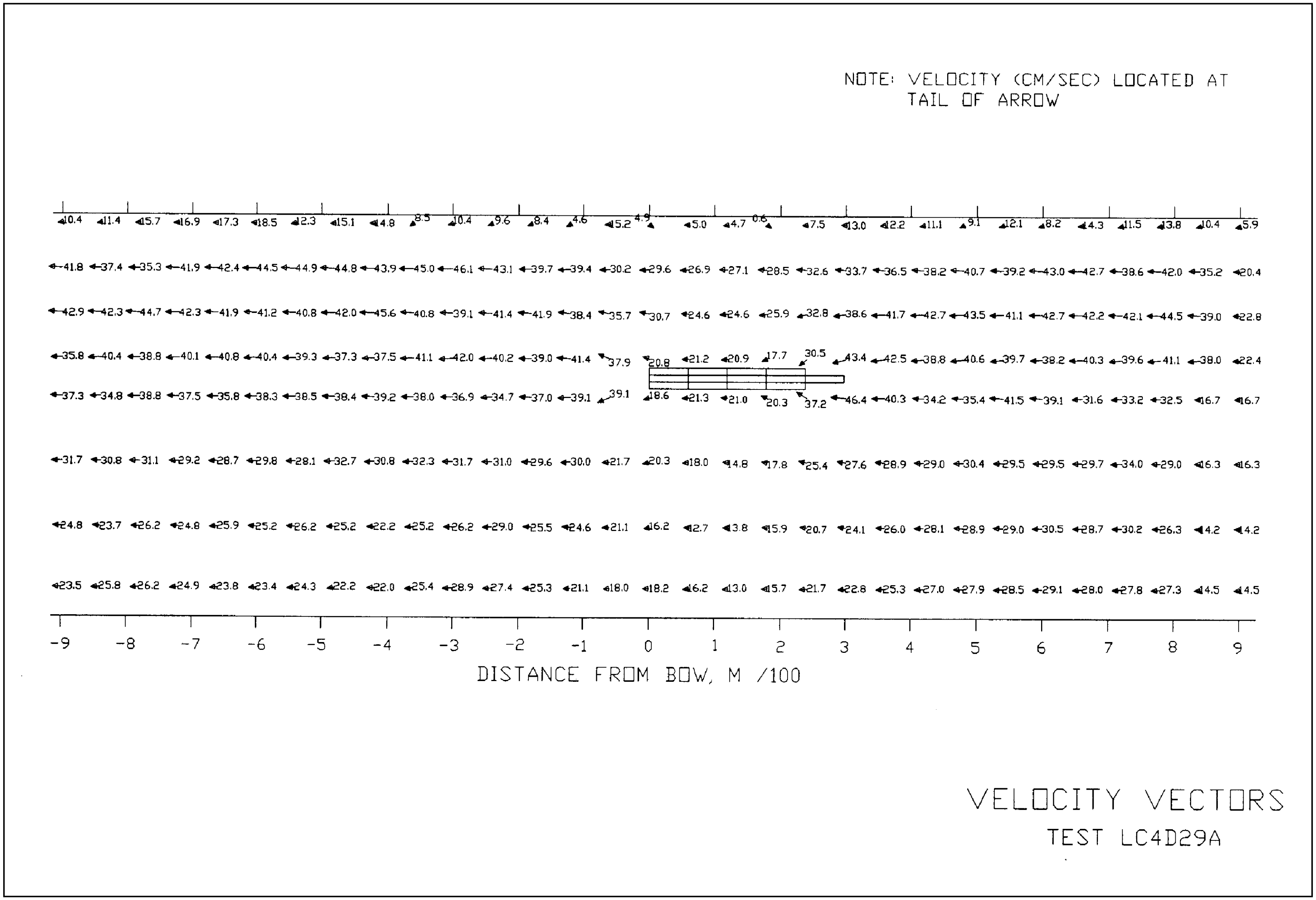


Figure 65. Vector plot, test LC4D29A

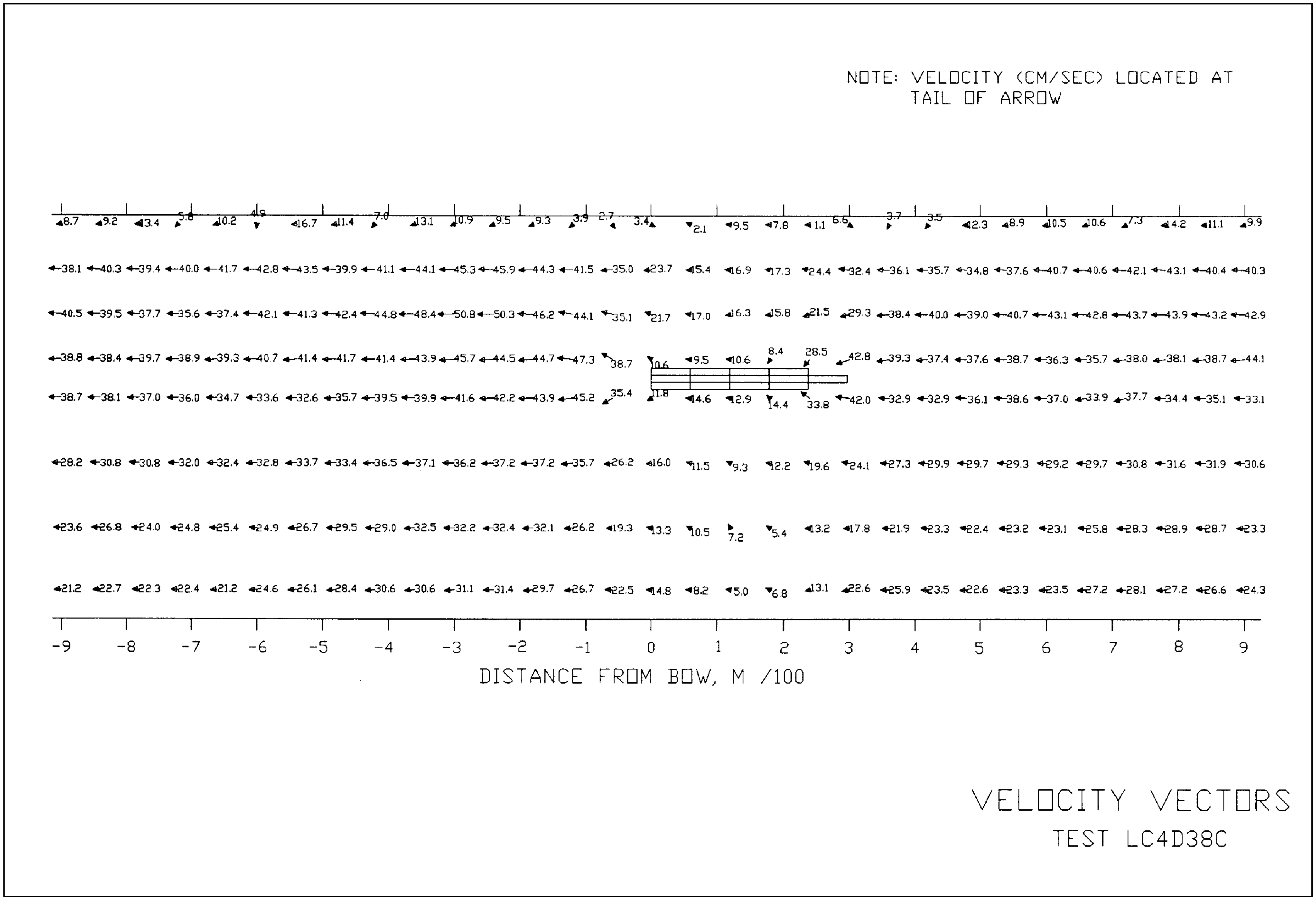


Figure 66. Vector plot, test LC4D38C

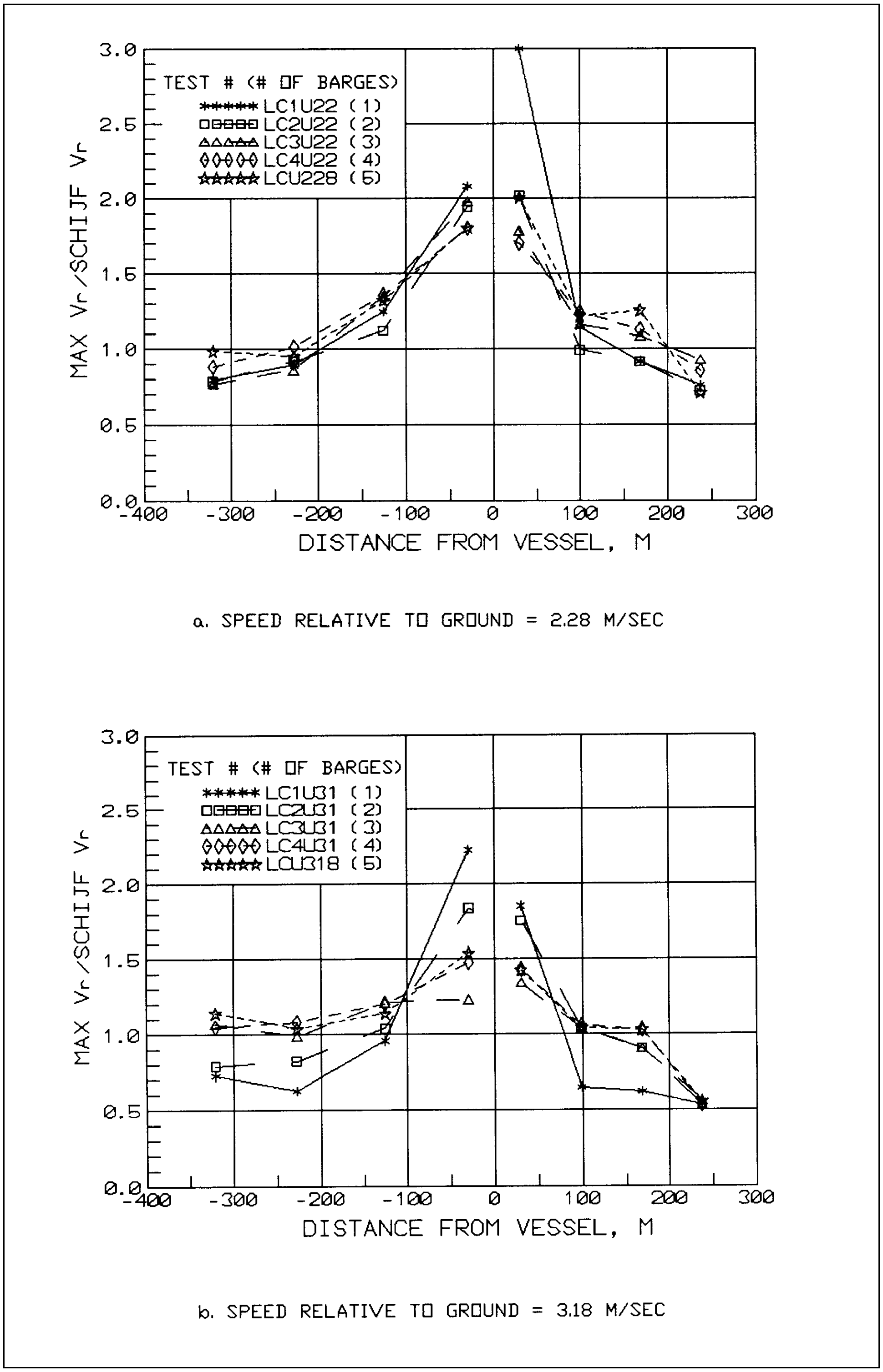


Figure 67. Return velocity, tow length effects, upbound tow

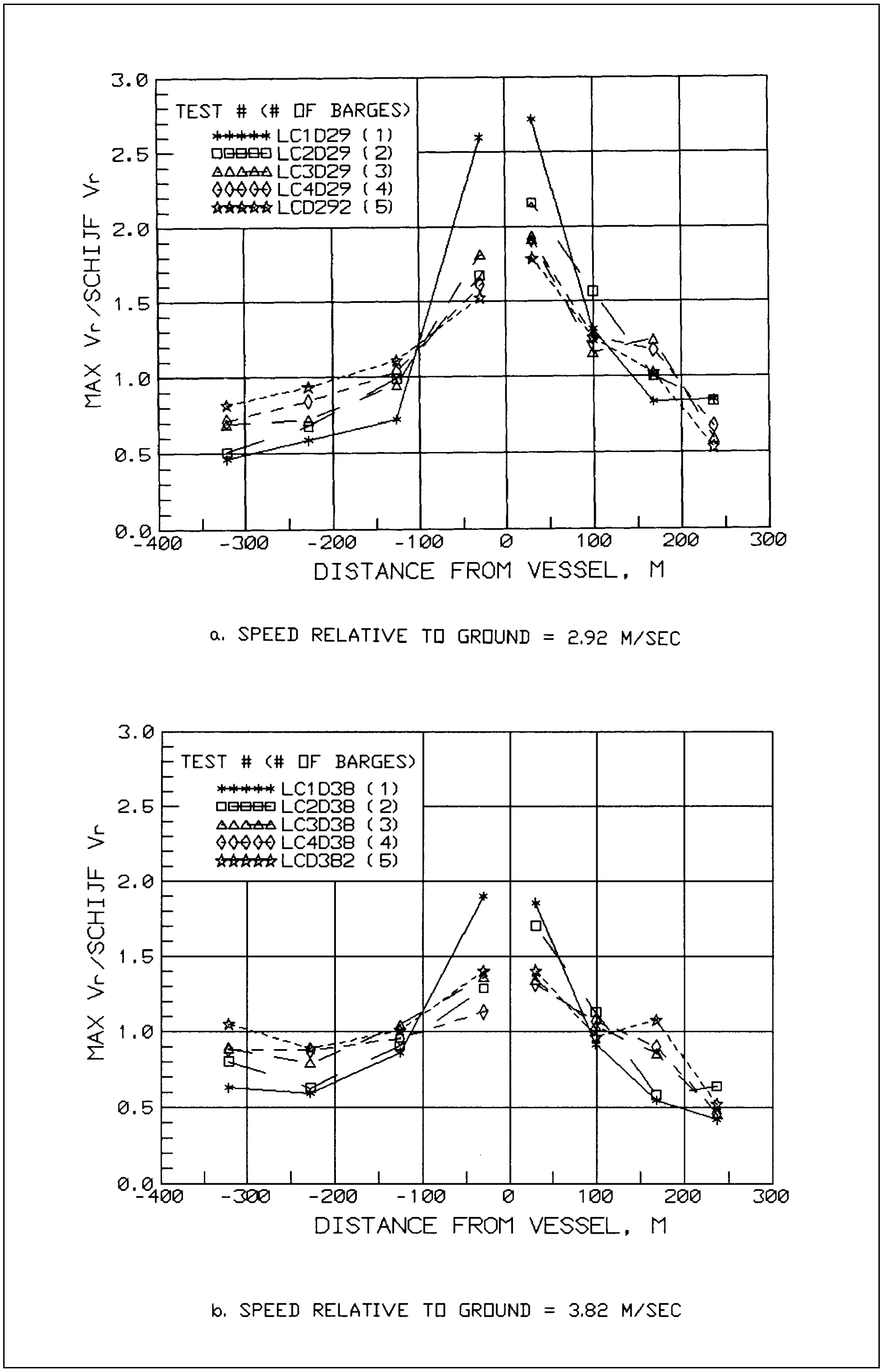
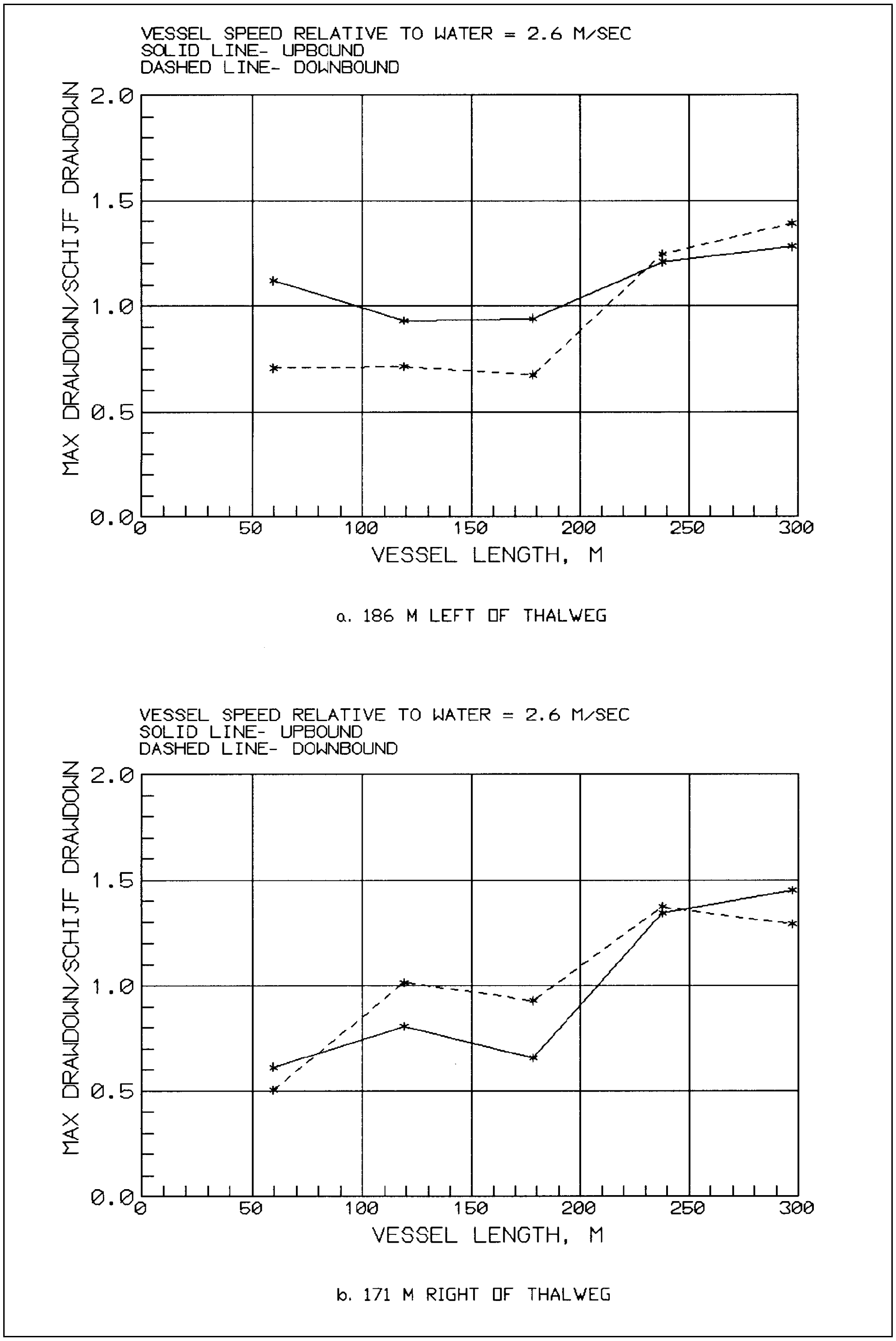


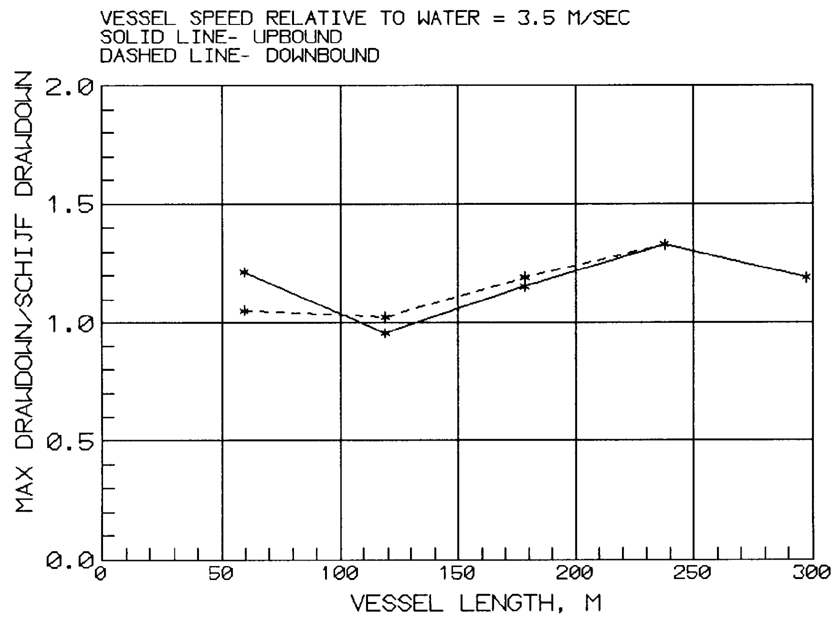
Figure 68. Return velocity, tow length effects, downbound tow



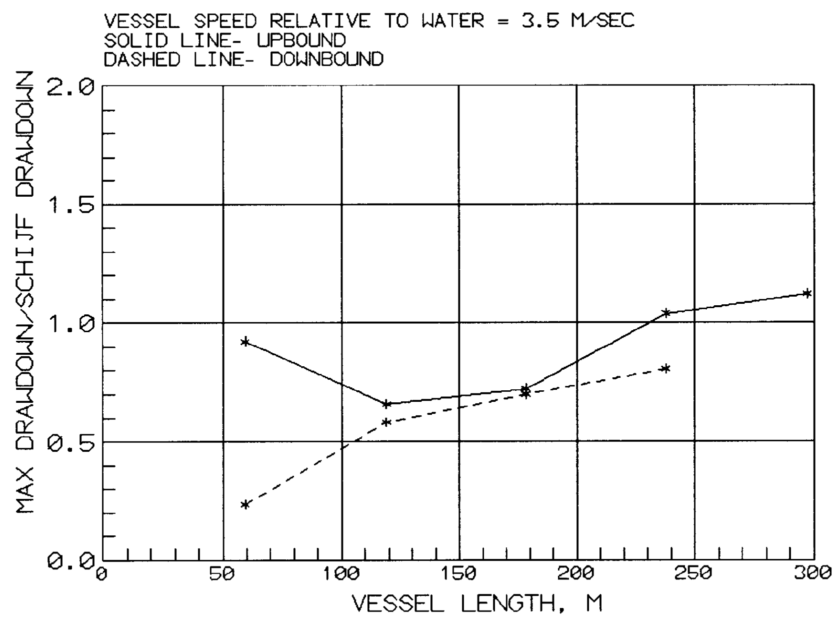
a. 186 M LEFT OF THALWEG

b. 171 M RIGHT OF THALWEG

Figure 69. Drawdown versus tow length, tow speed relative to water = 2.6 m/sec



a. 186 M LEFT OF THALWEG



b. 171 M RIGHT OF THALWEG

Figure 70. Drawdown versus tow length, tow speed relative to water = 3.5 m/sec

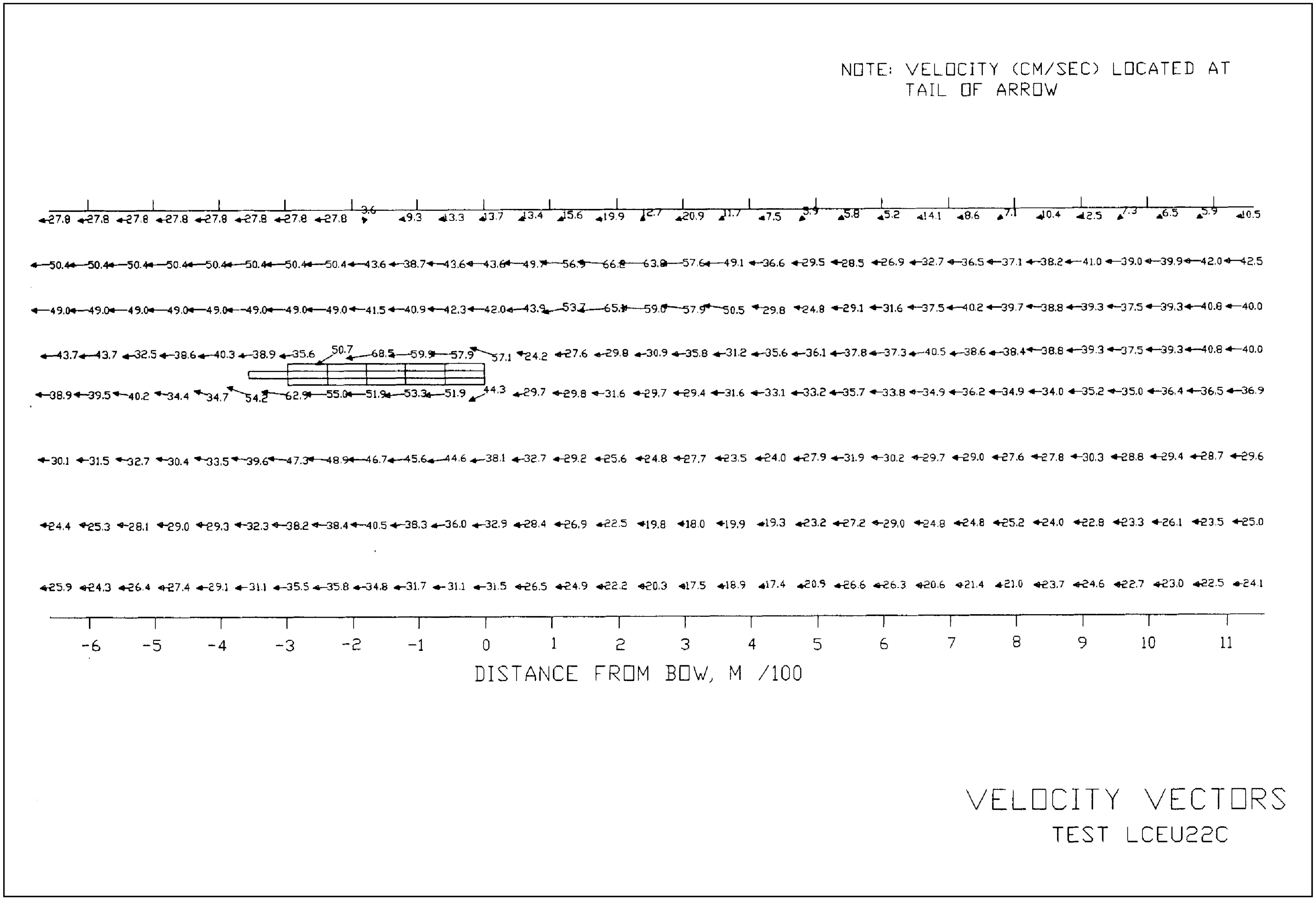


Figure 71. Vector plot, test LCEU22C

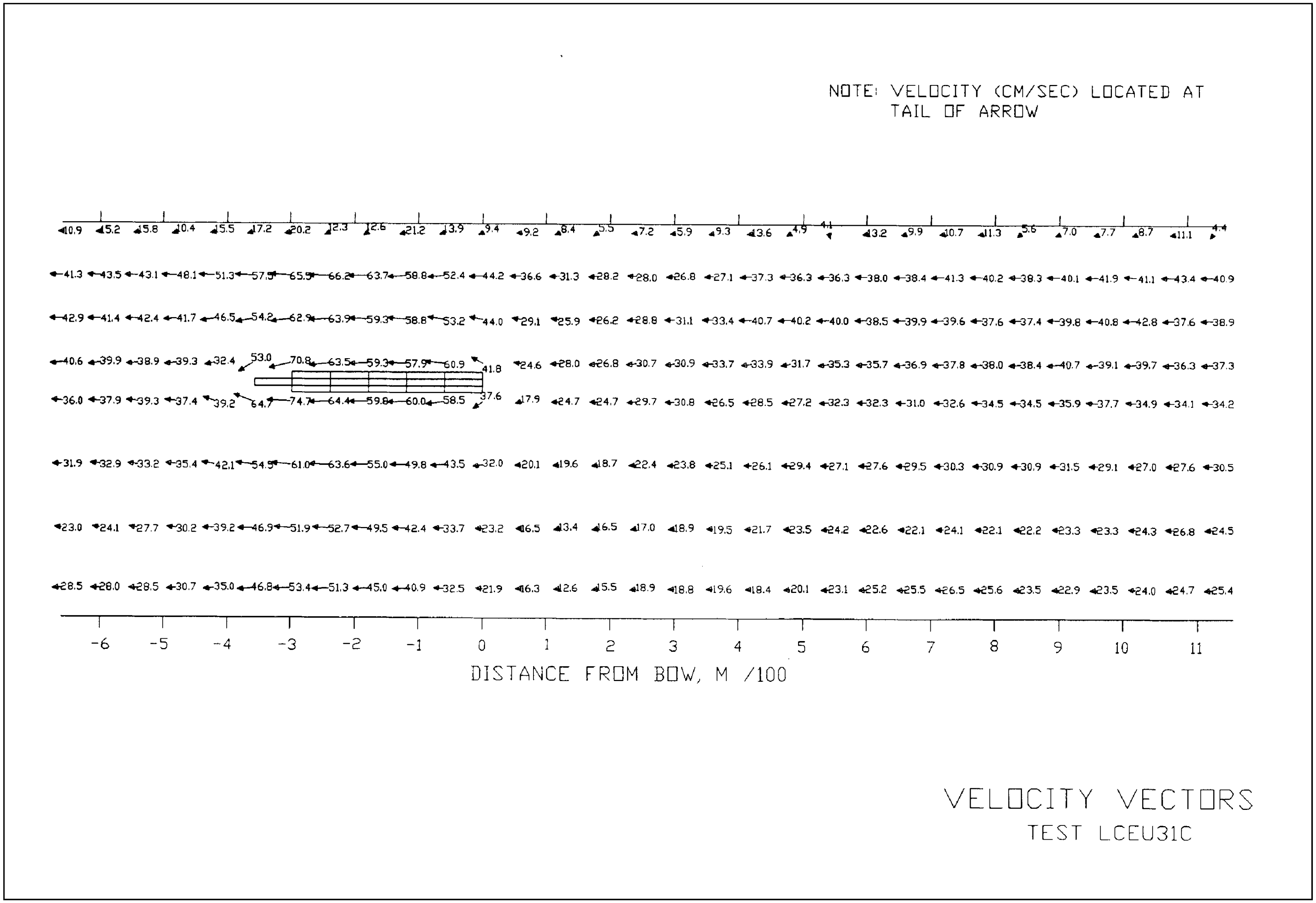


Figure 72. Vector plot, test LCEU31C

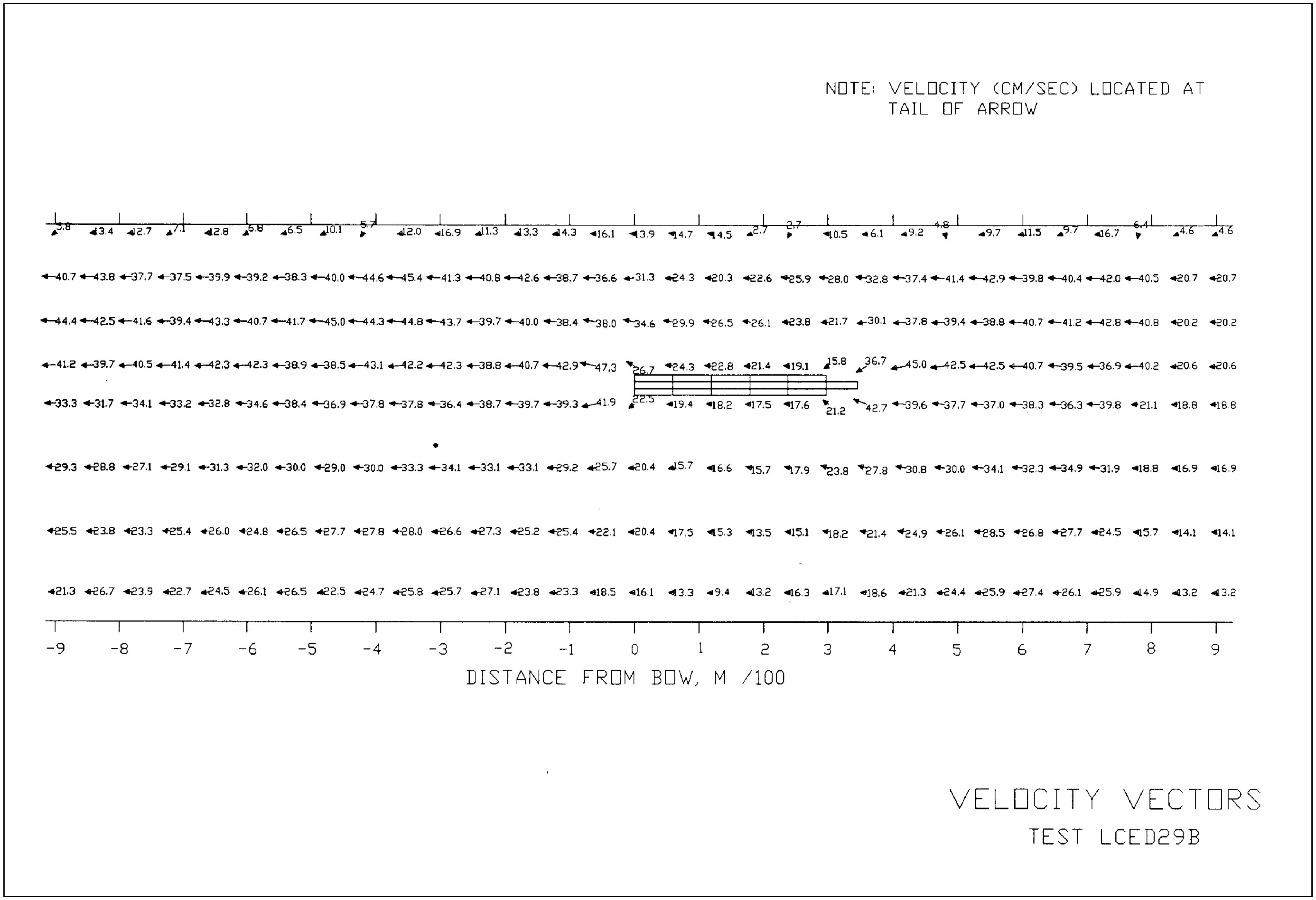


Figure 73. Vector plot, test LCED29B

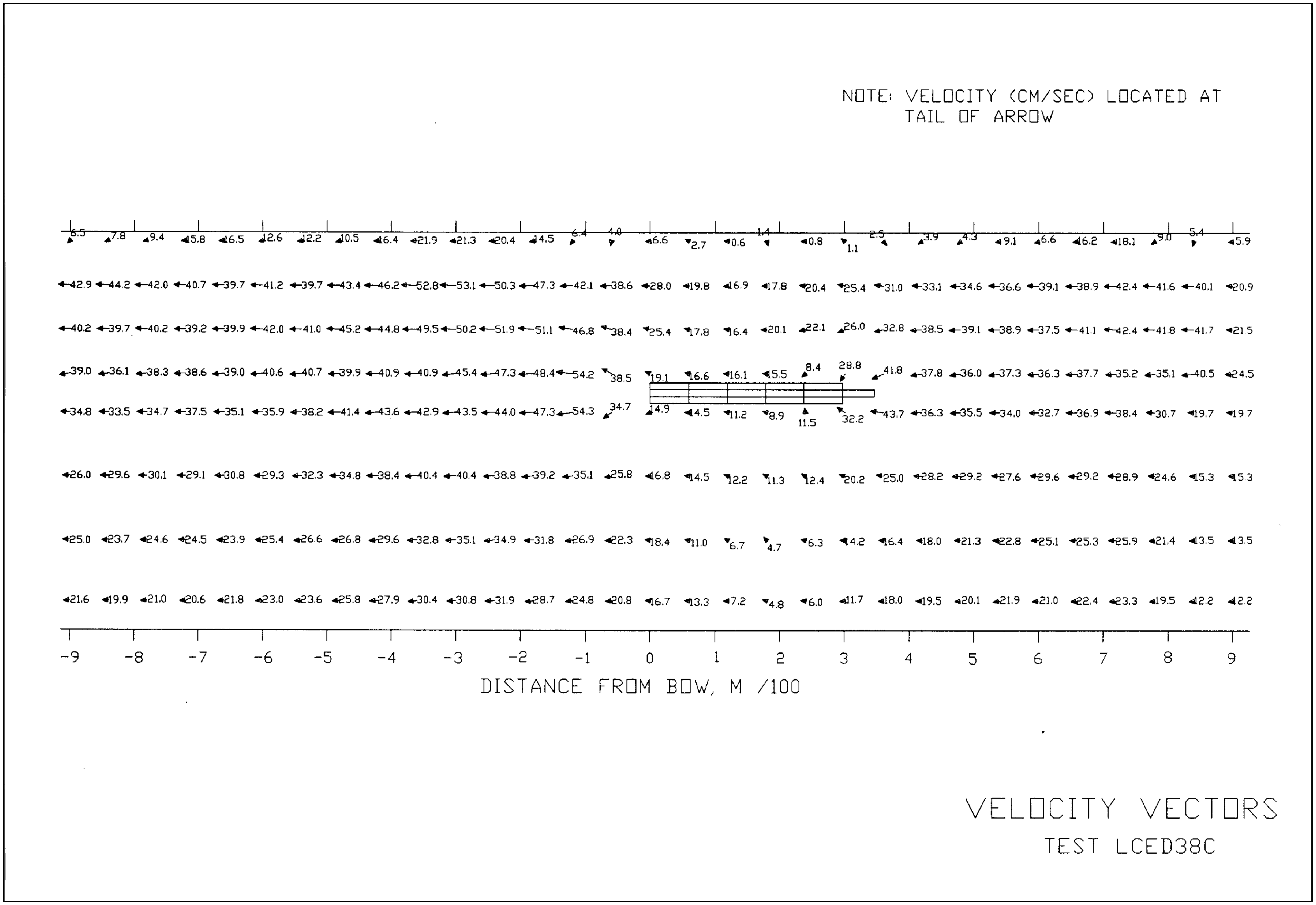


Figure 74. Vector plot, test LCED38C

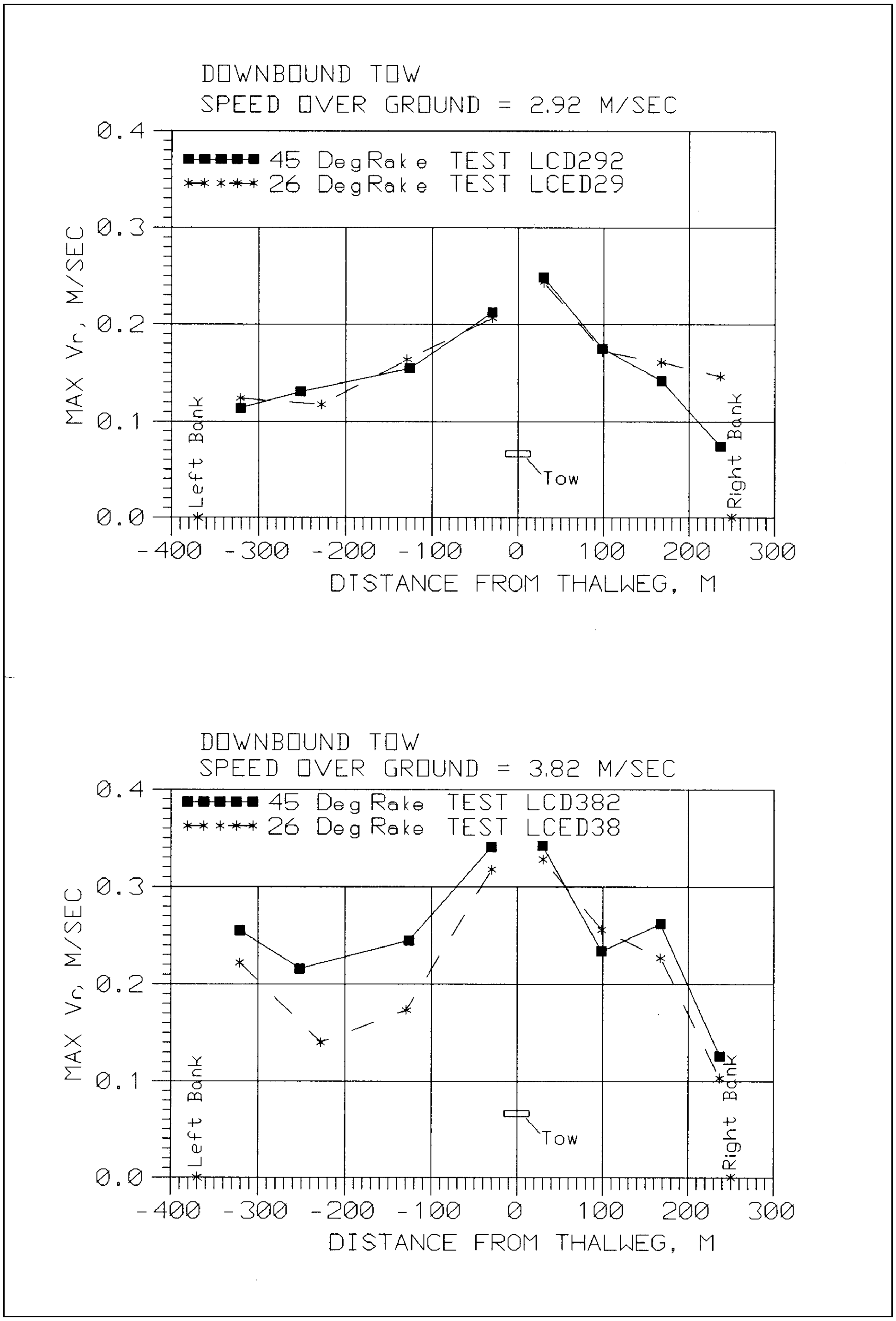


Figure 75. Return velocity, rake angle effects, downbound tow

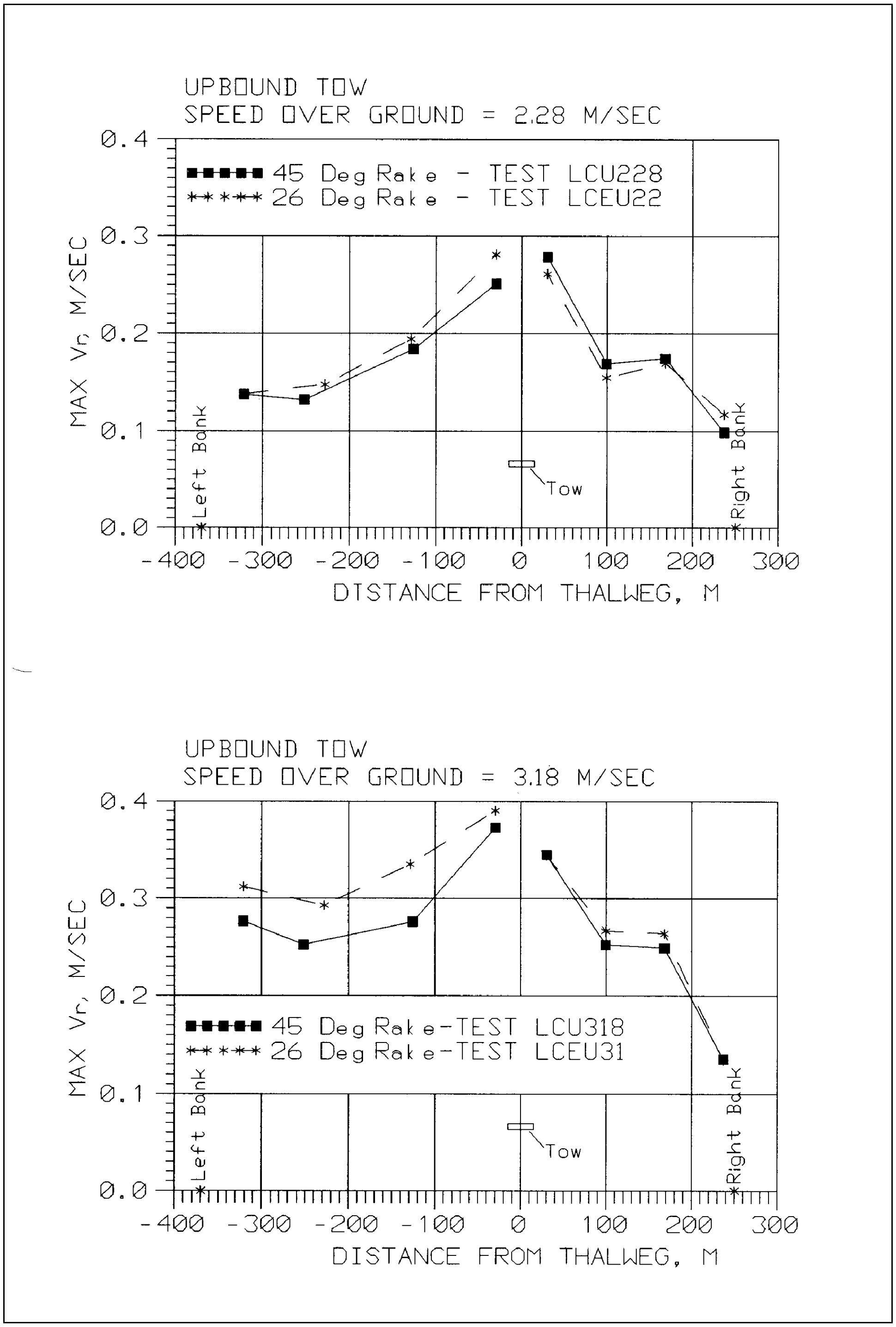


Figure 76. Return velocity, rake angle effects, upbound tow

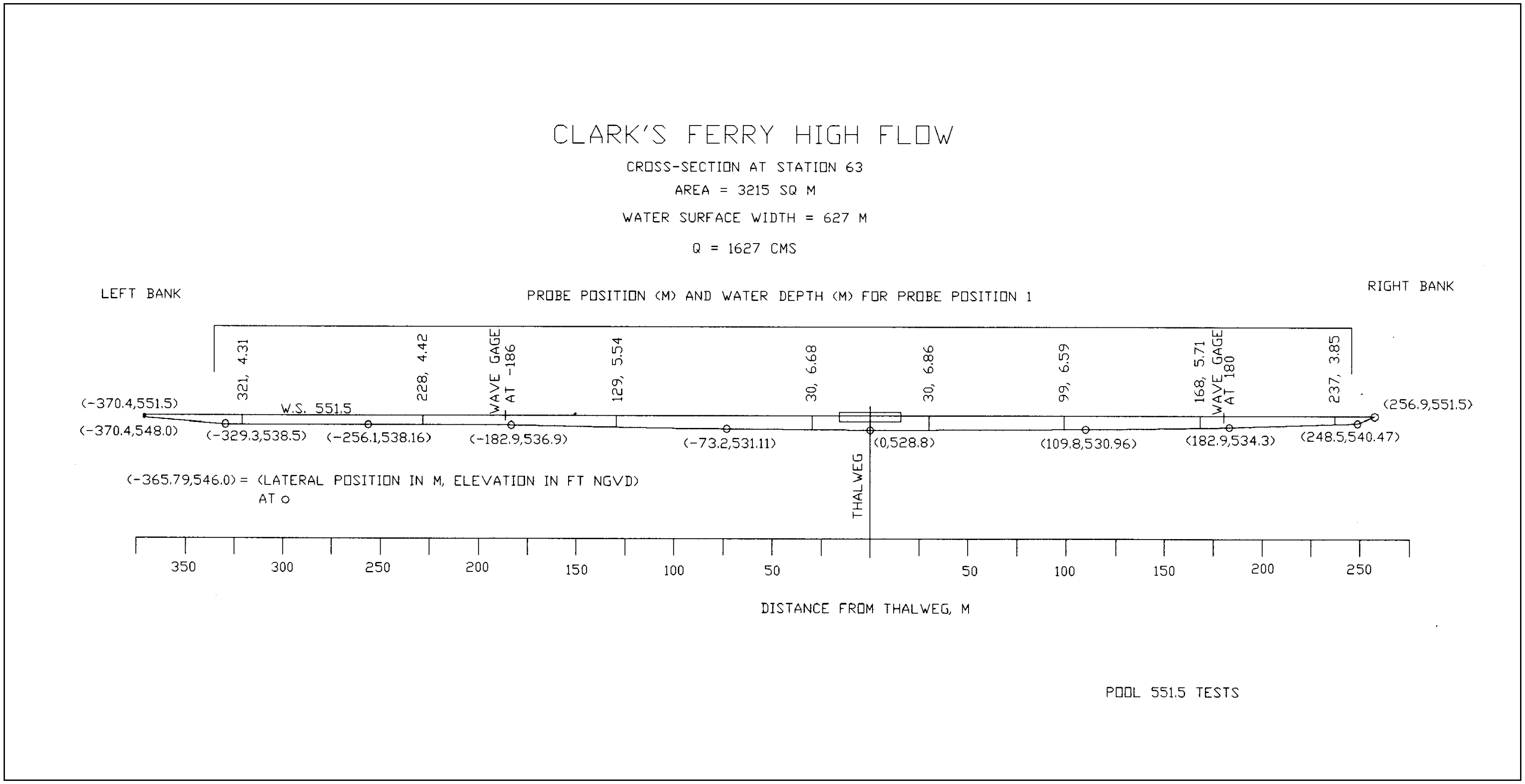


Figure 77. Cross section, experimental series 5

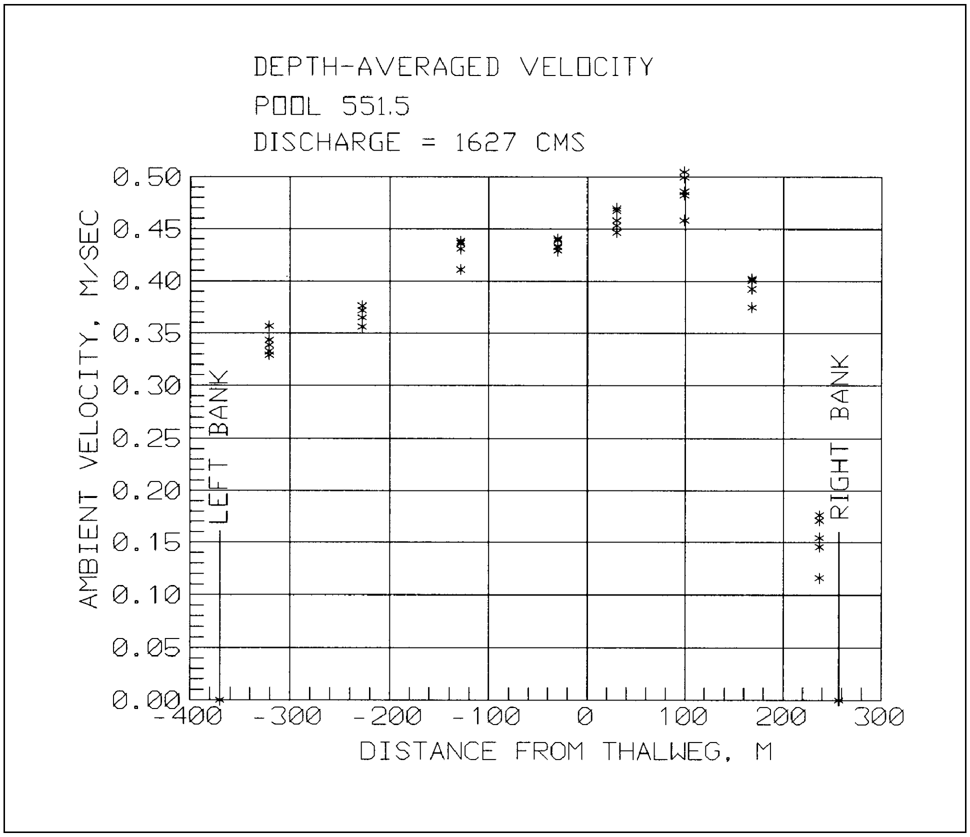


Figure 78. Ambient velocity distribution, experimental series 5

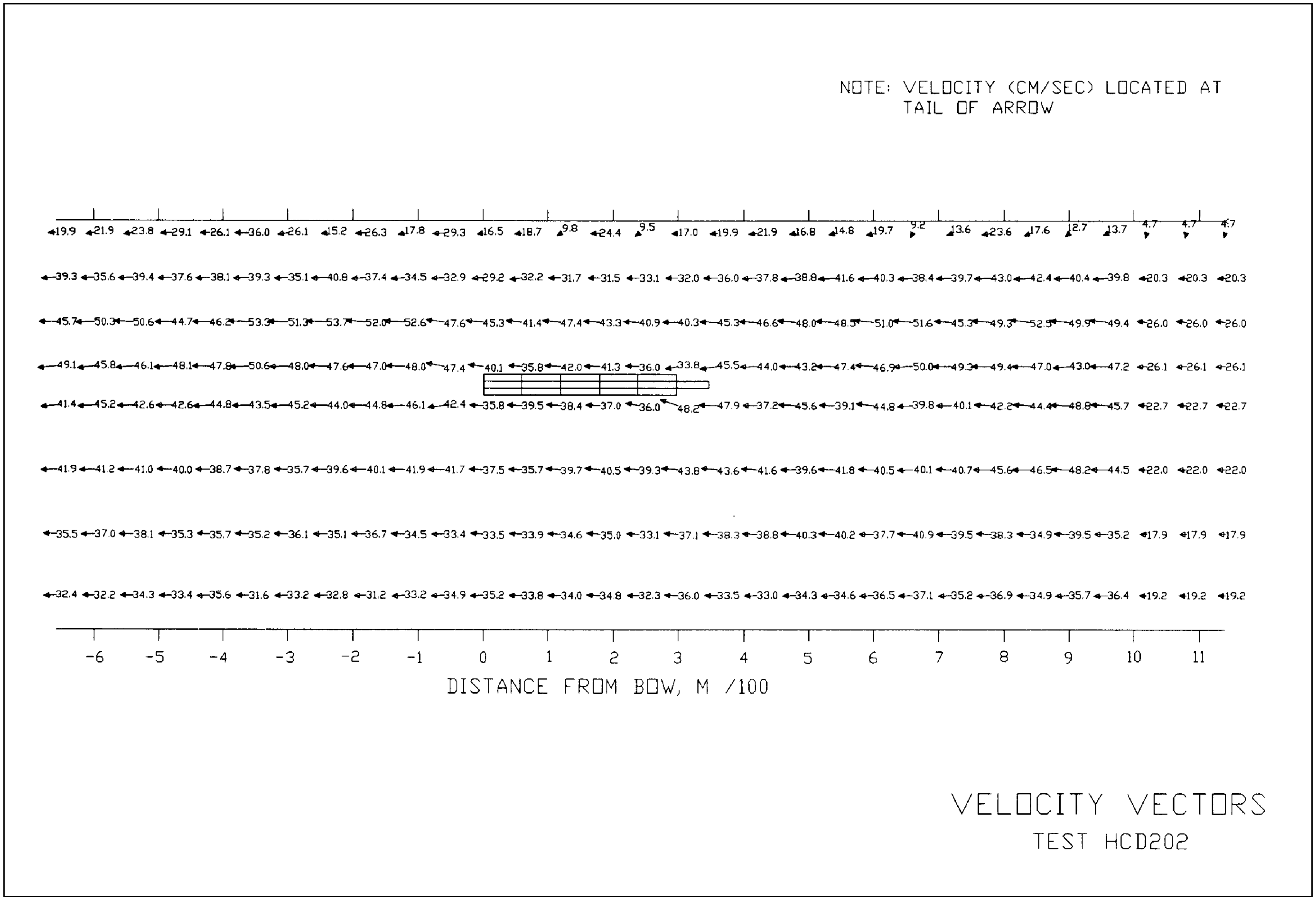


Figure 79. Vector plot, test HCD202

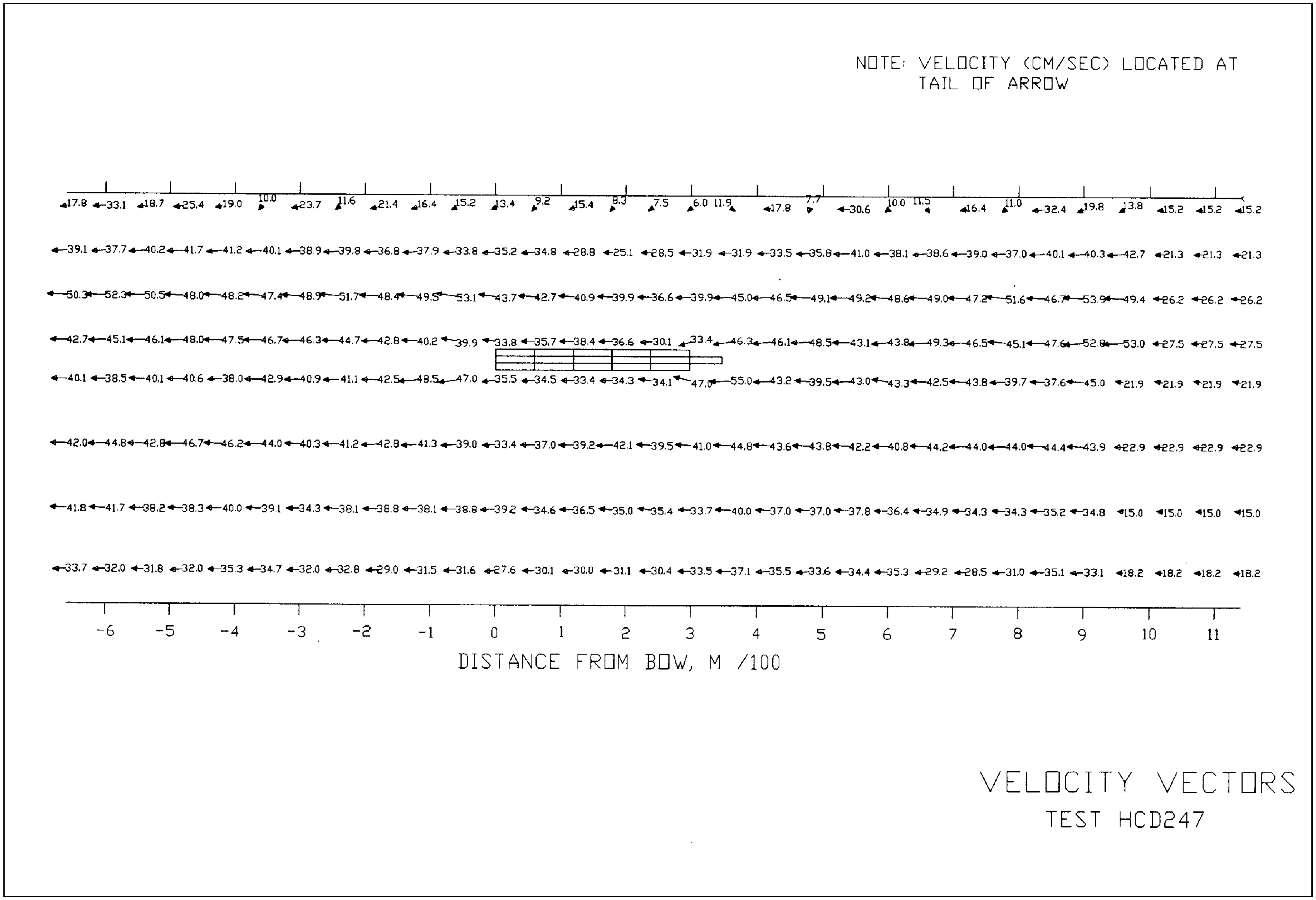


Figure 80. Vector plot, test HCD247

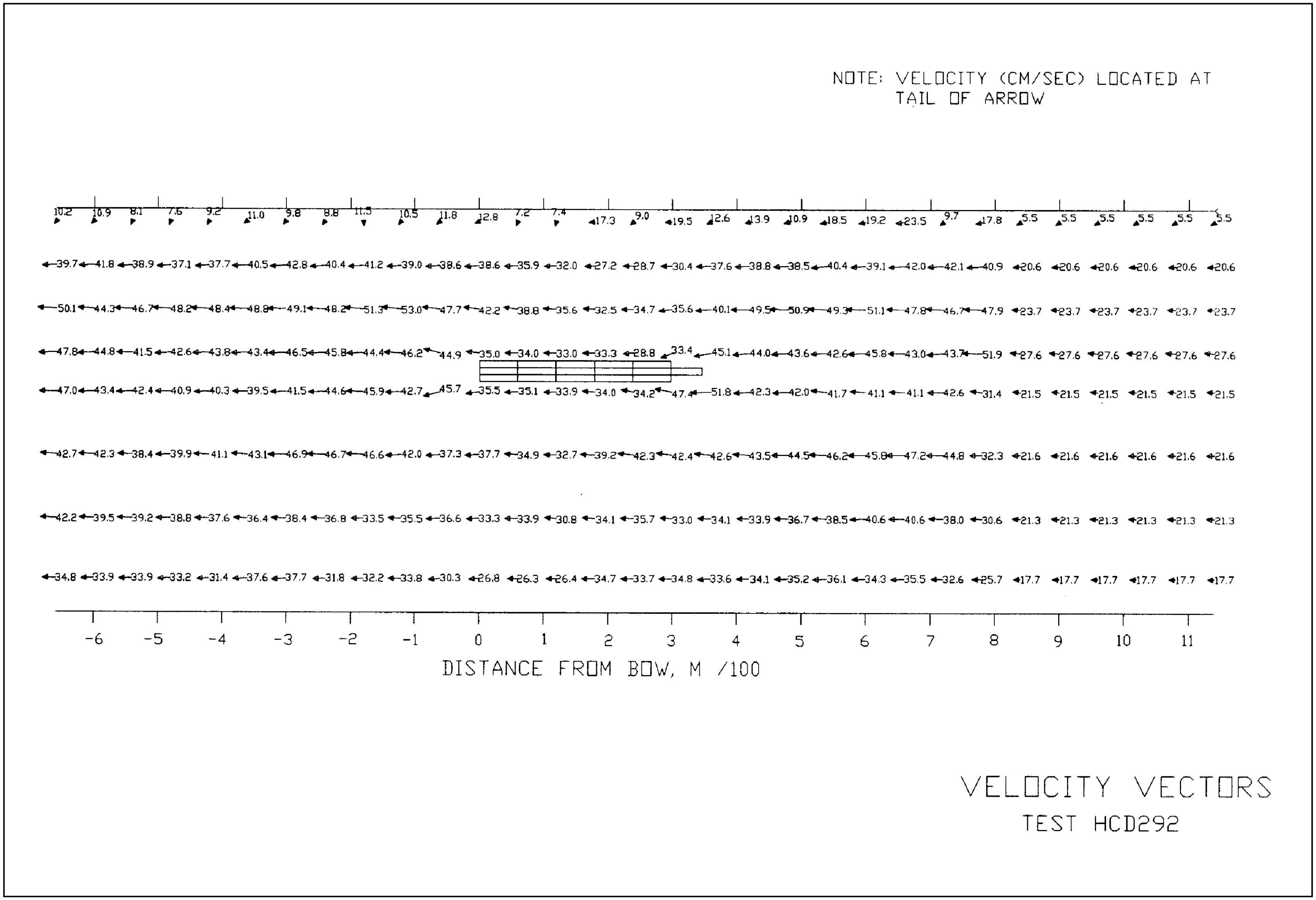


Figure 81. Vector plot, test HCD292

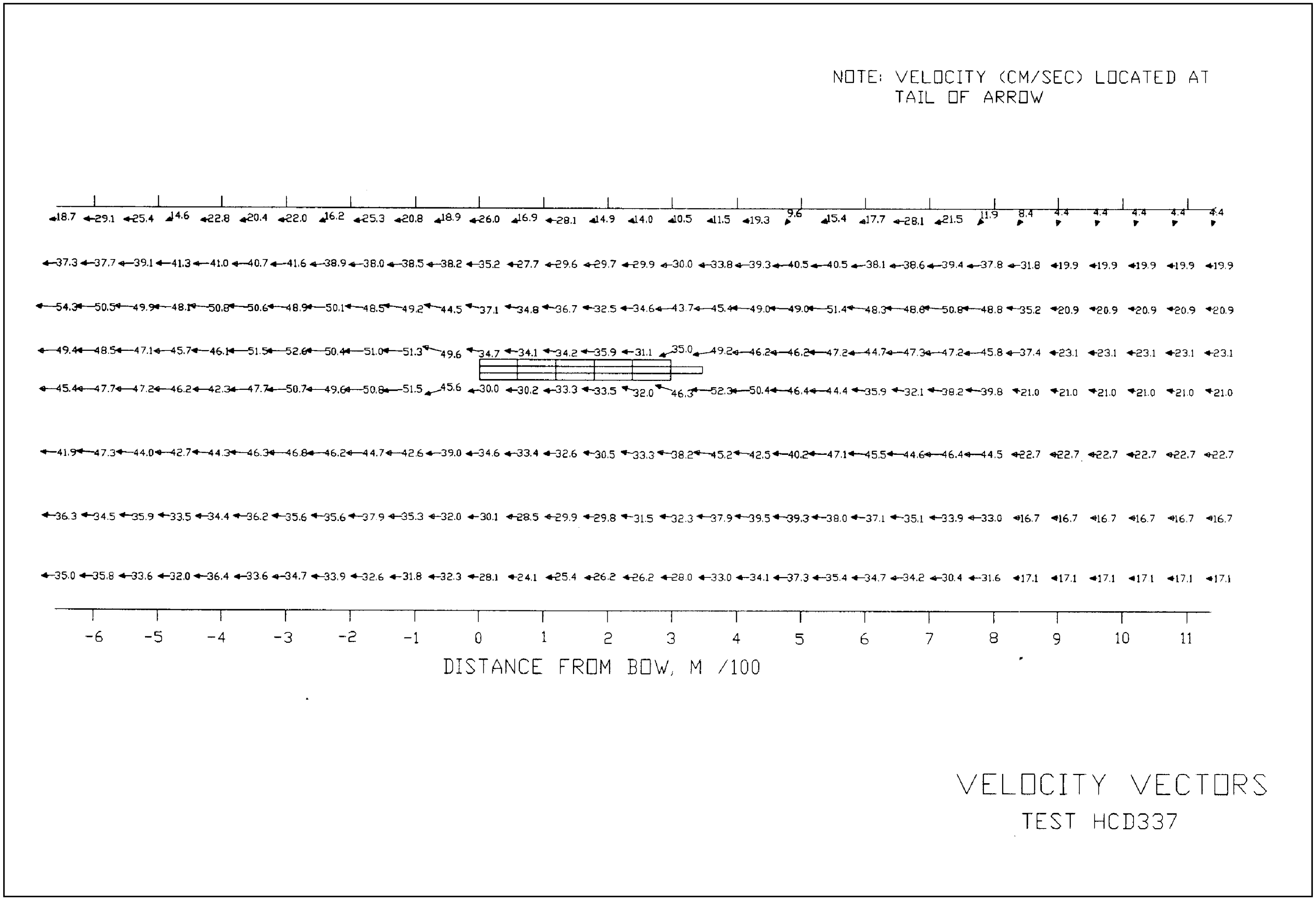


Figure 82. Vector plot, Test HCD337

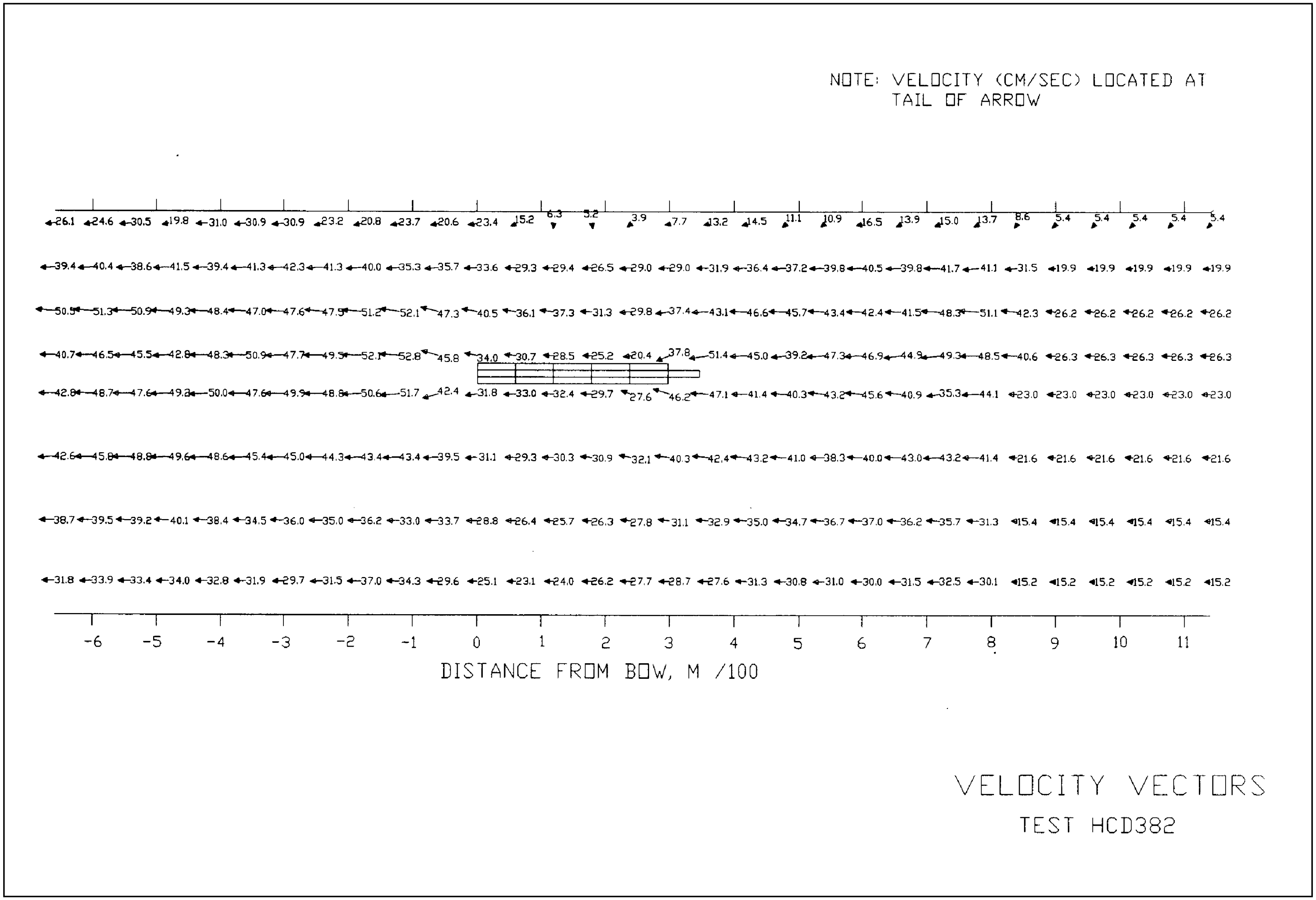


Figure 83. Vector plot, test HCD382

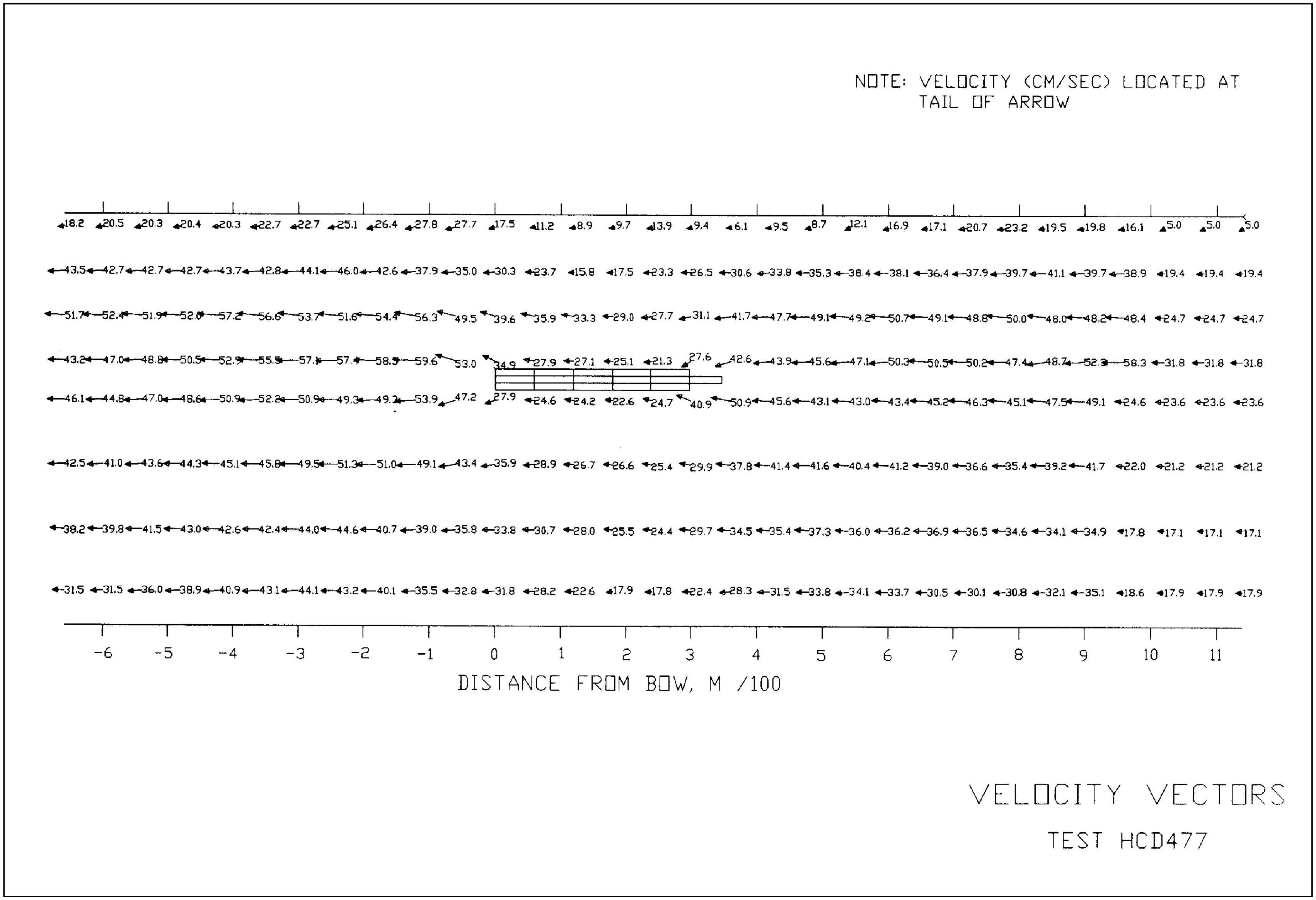


Figure 84. Vector plot, test HCD477

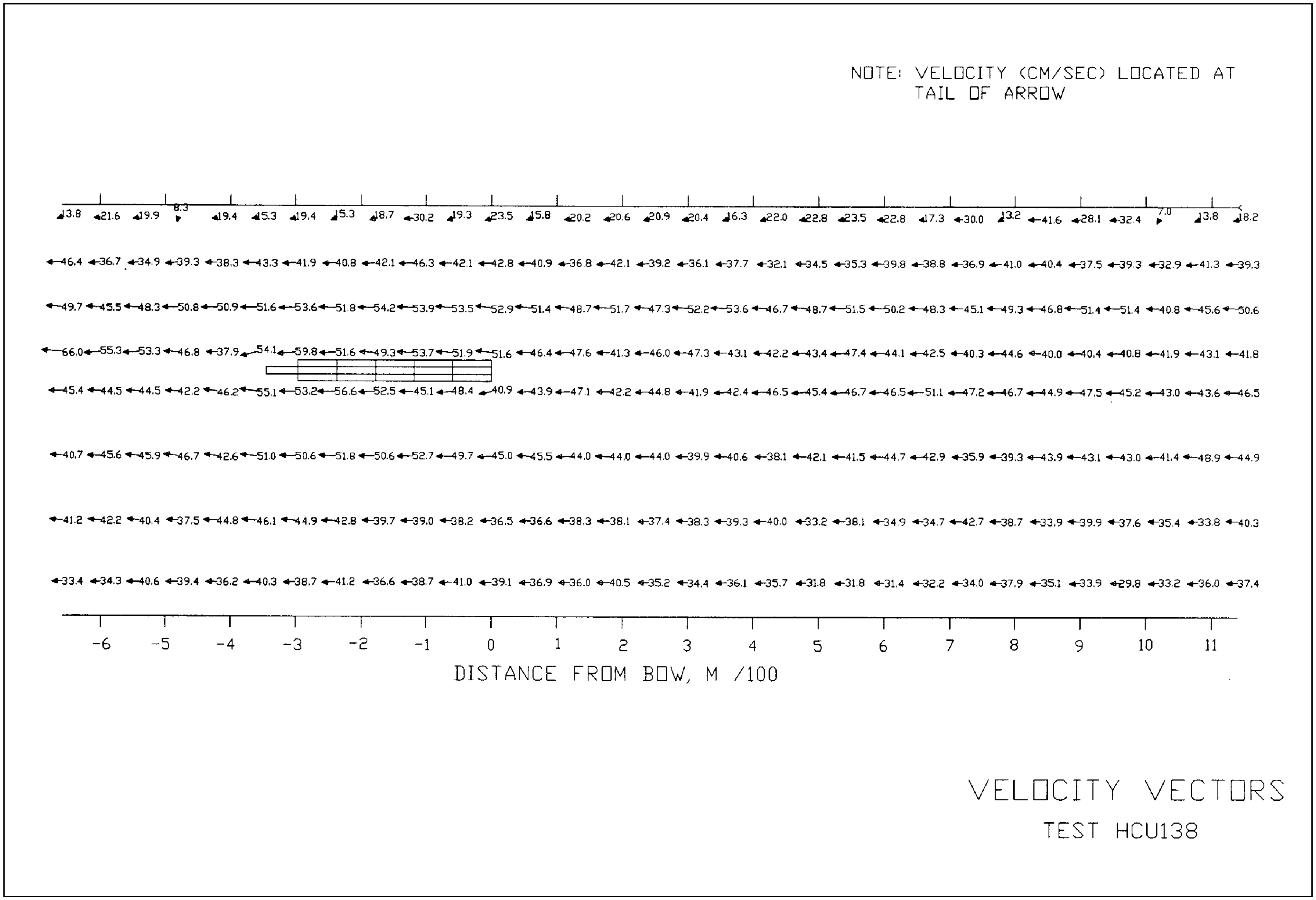


Figure 85. Vector plot, test HCU138

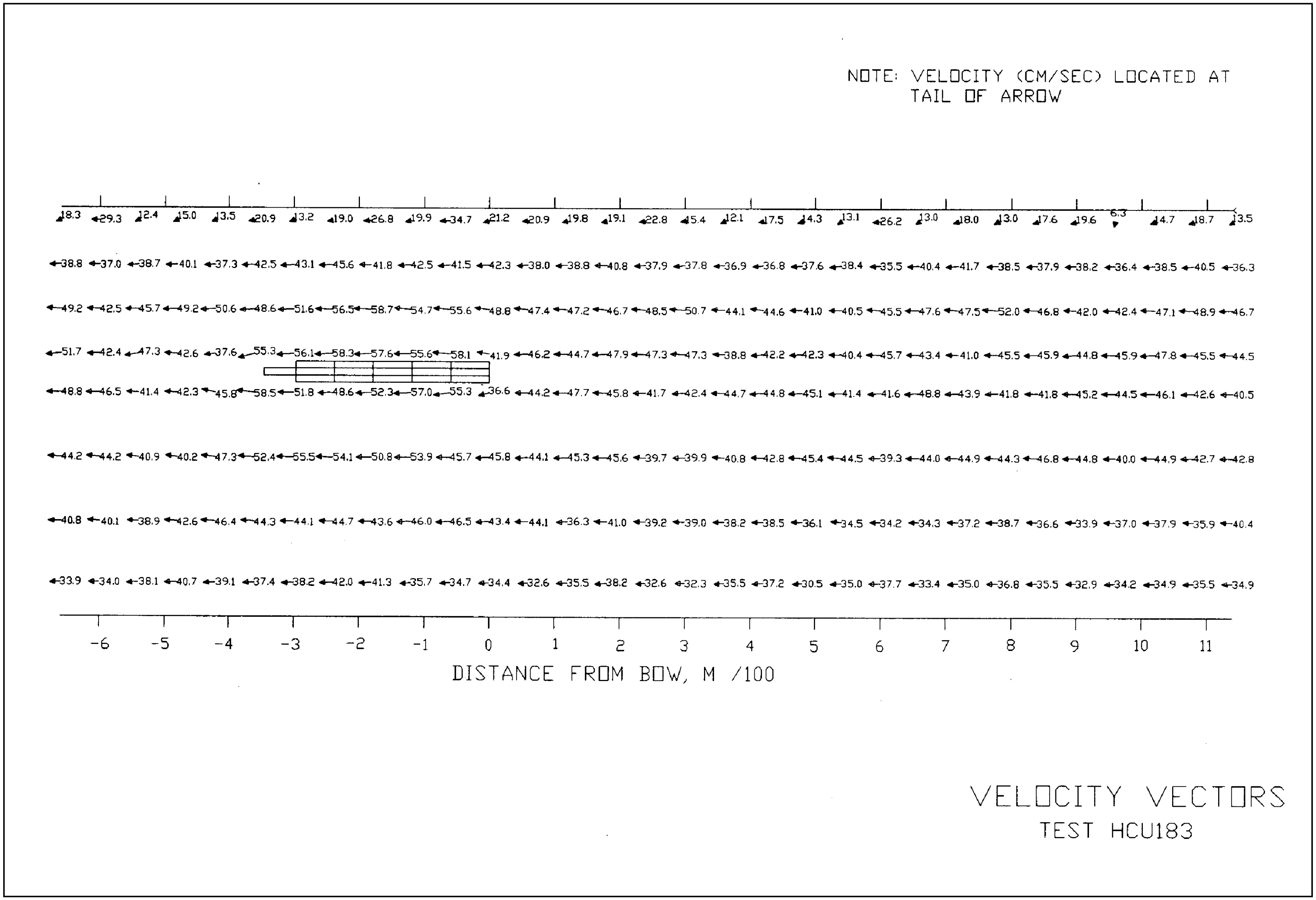


Figure 86. Vector plot, test HCU183

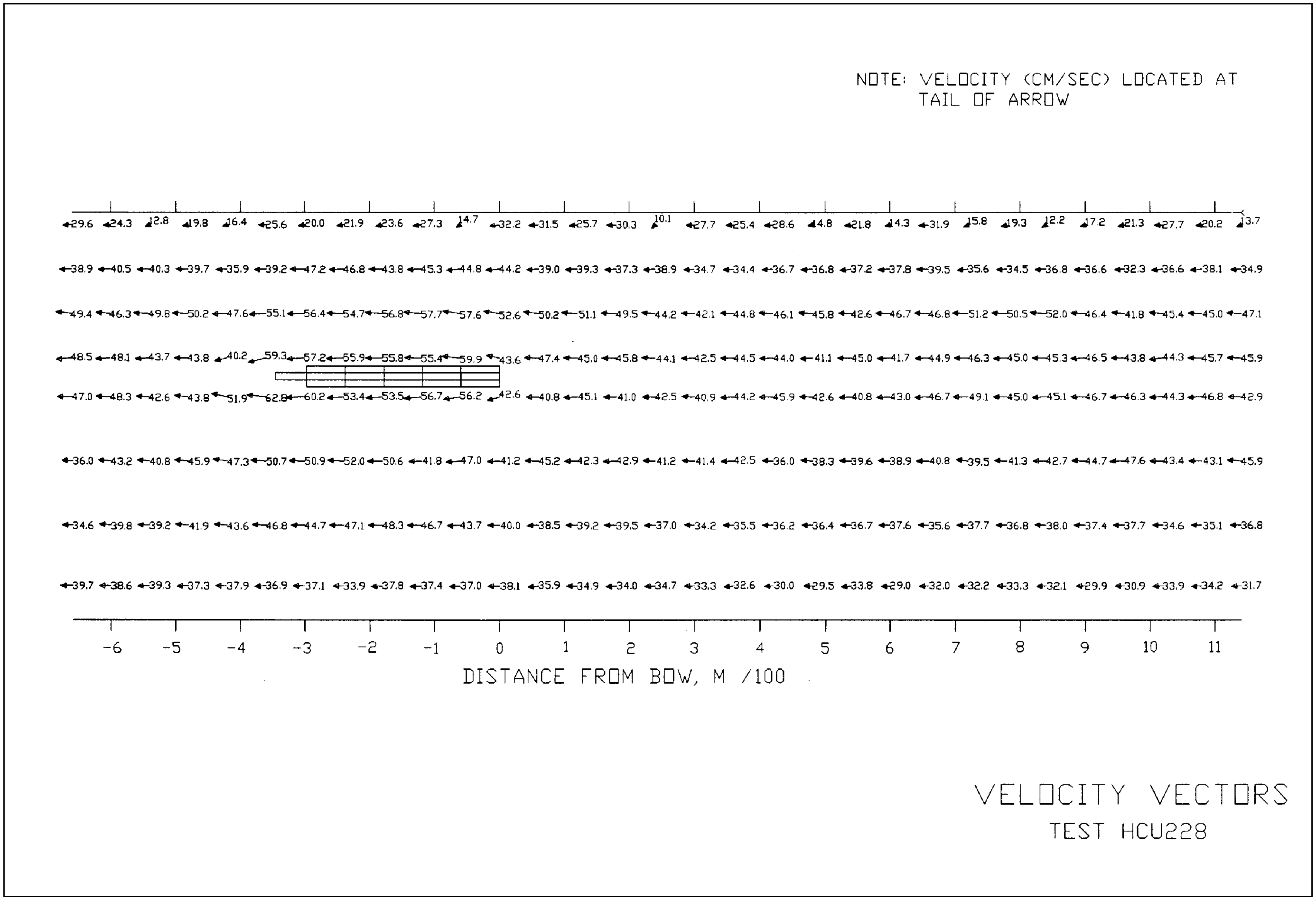


Figure 87. Vector plot, test HCU228

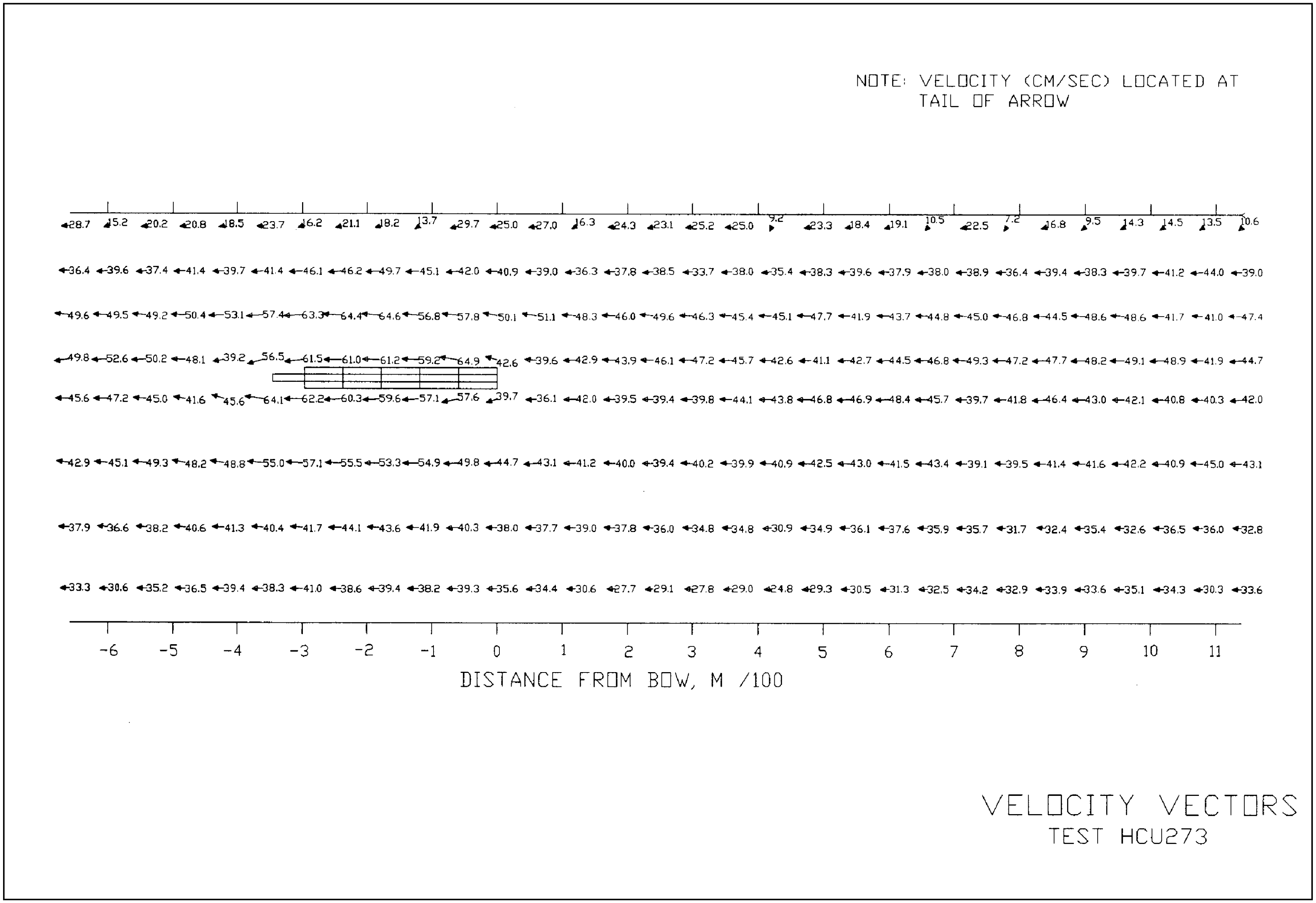


Figure 88. Vector plot, test HCU273

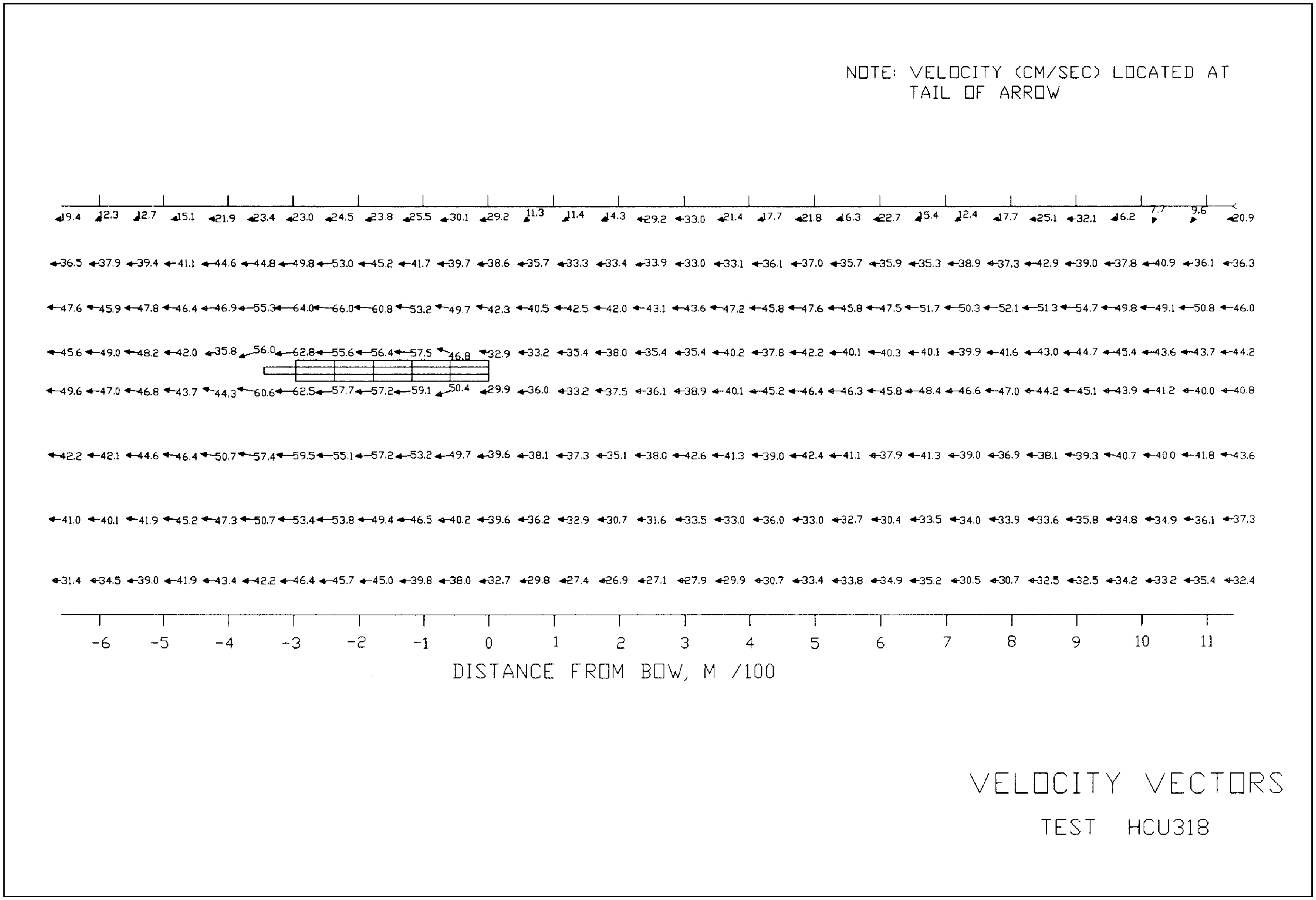


Figure 89. Vector plot, test HCU318

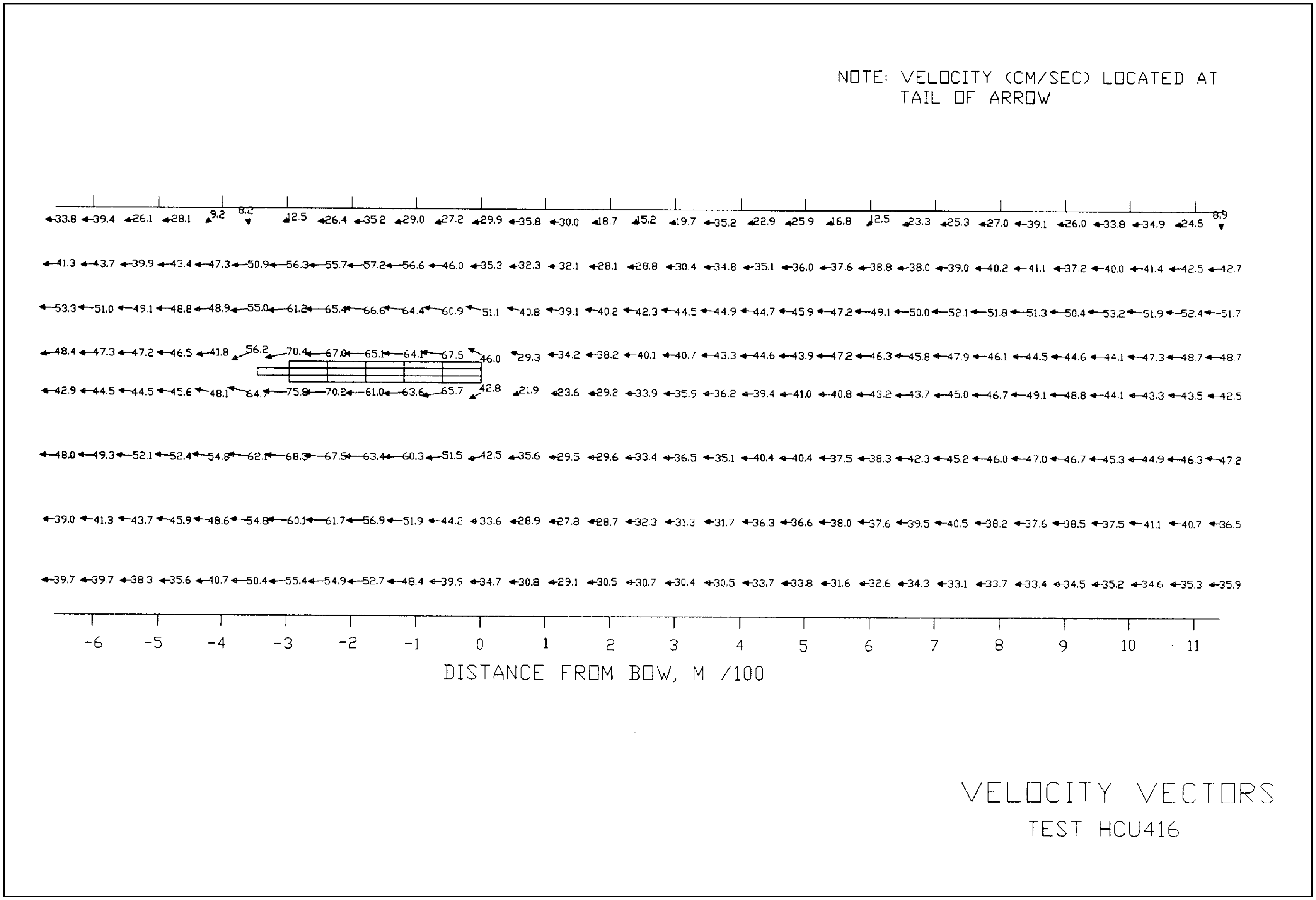


Figure 90. Vector plot, test HCU416

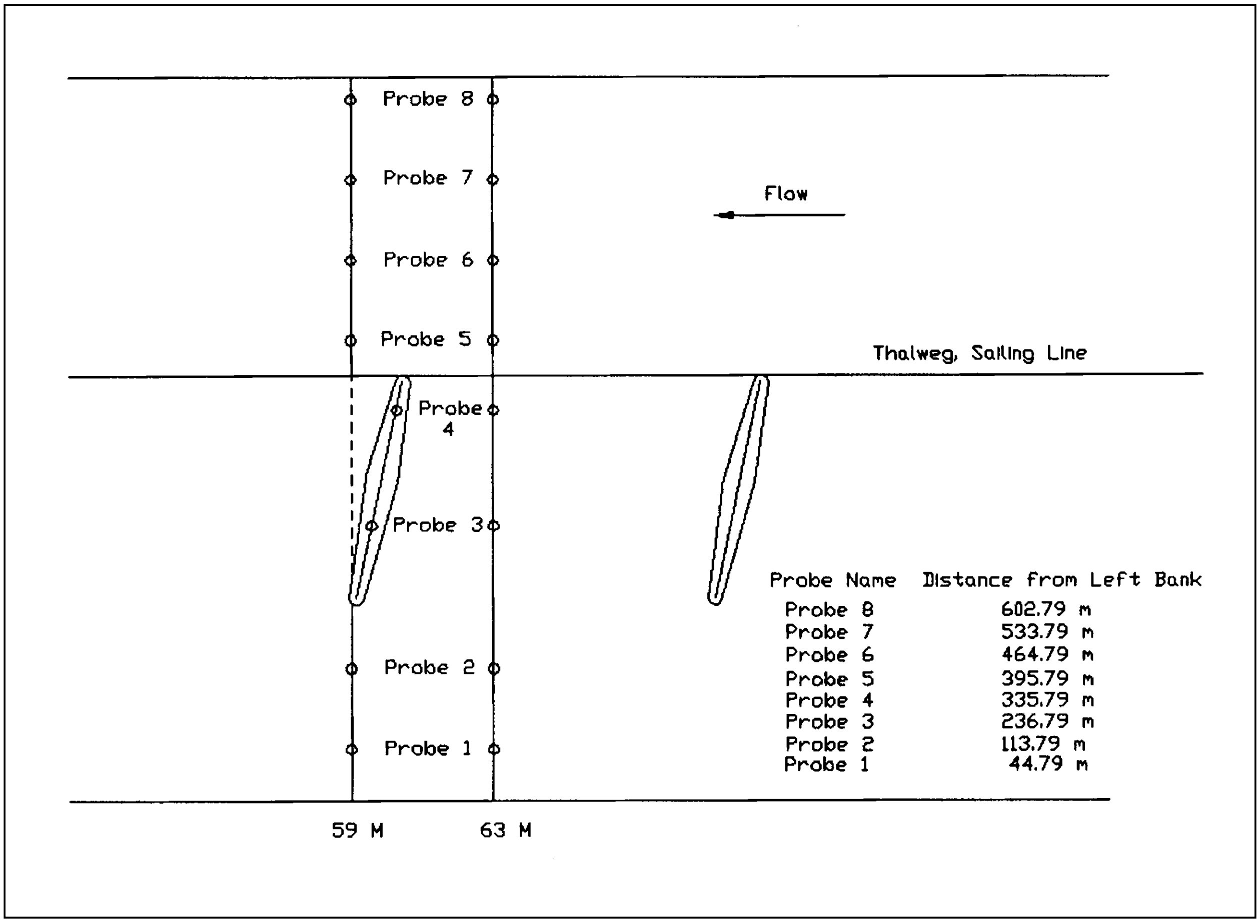


Figure 91. Plan view, experimental series 6

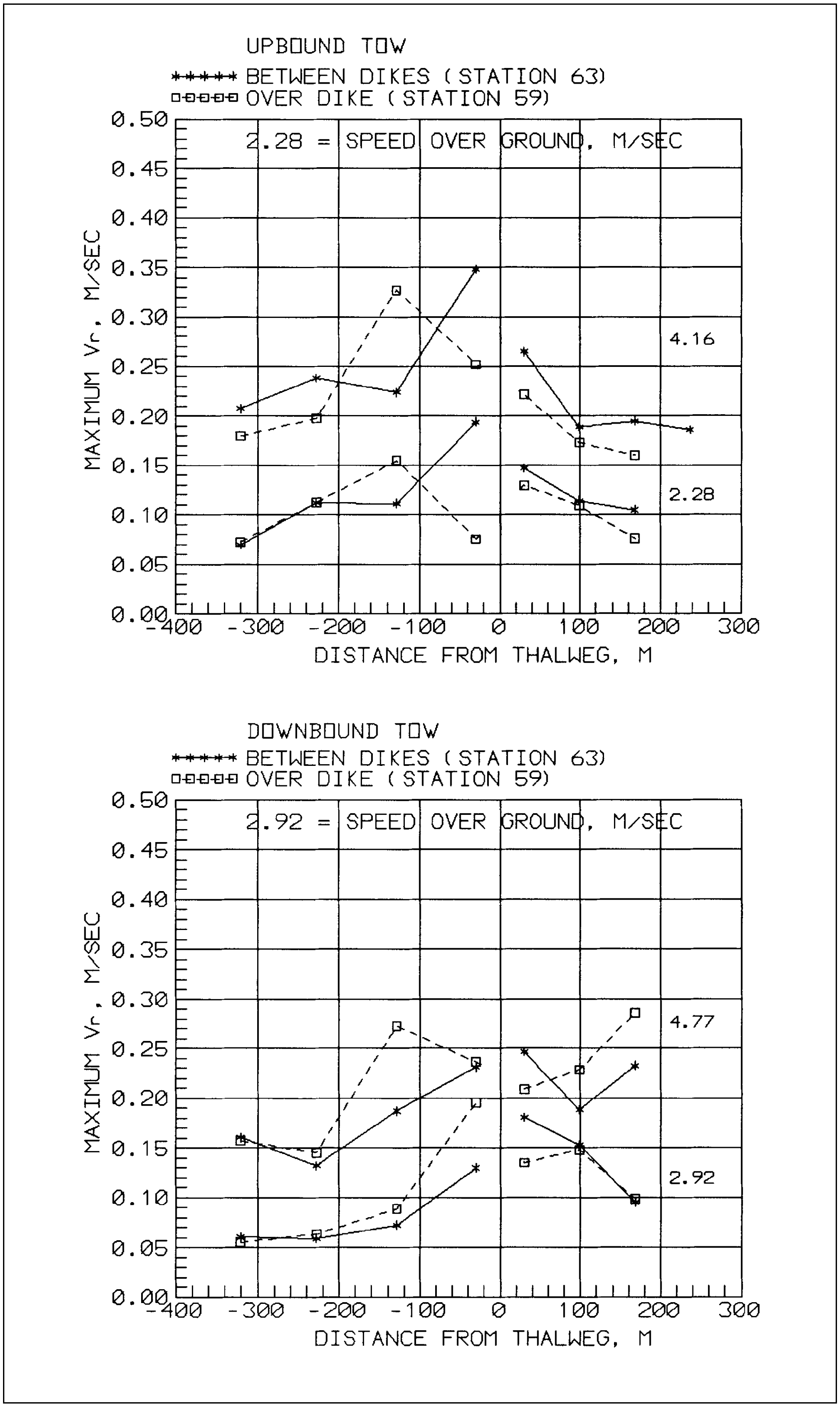


Figure 92. Comparison of experiments in experimental series 6

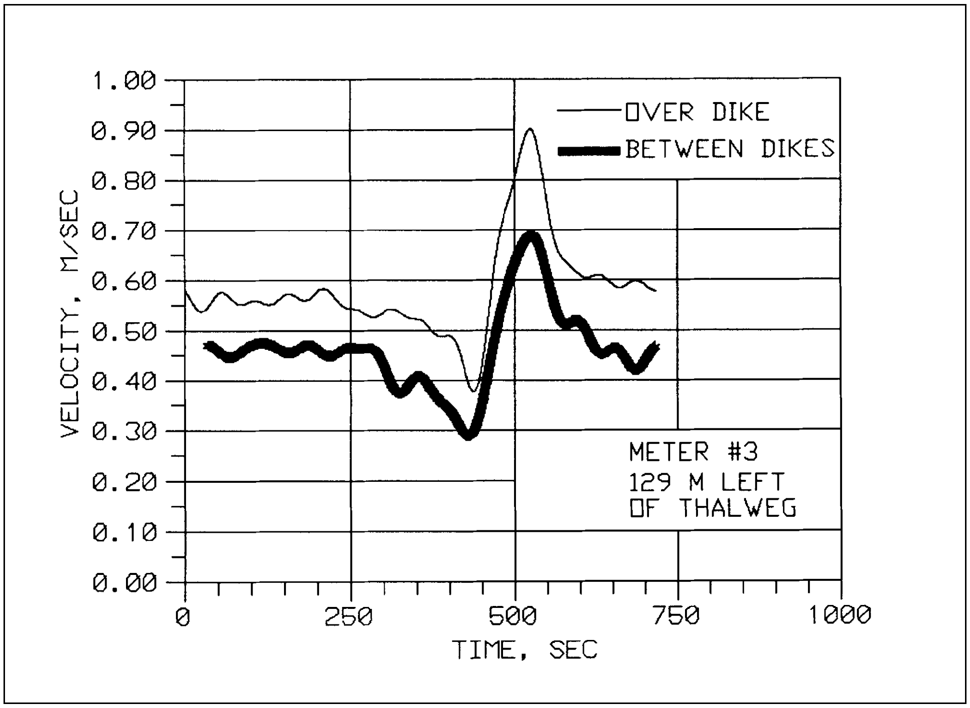


Figure 93.Velocity time history, upbound tow, meter No. 3, tow speed relative to ground = 4.16 m/sec

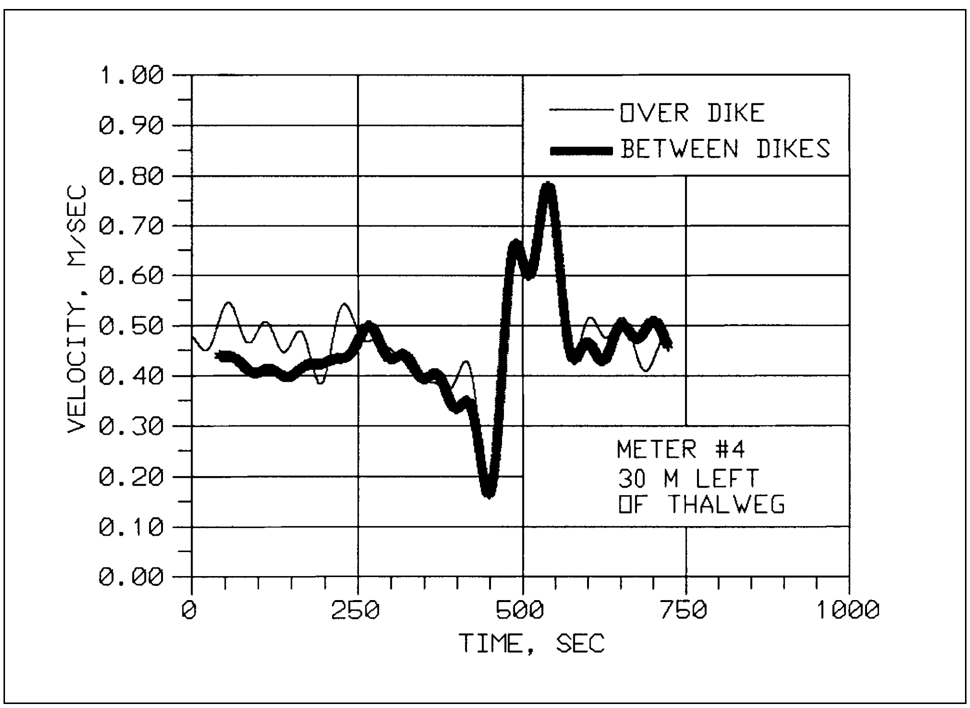


Figure 94. Velocity time history, upbound tow, meter No. 4, tow speed relative to ground = 4.16 m/sec

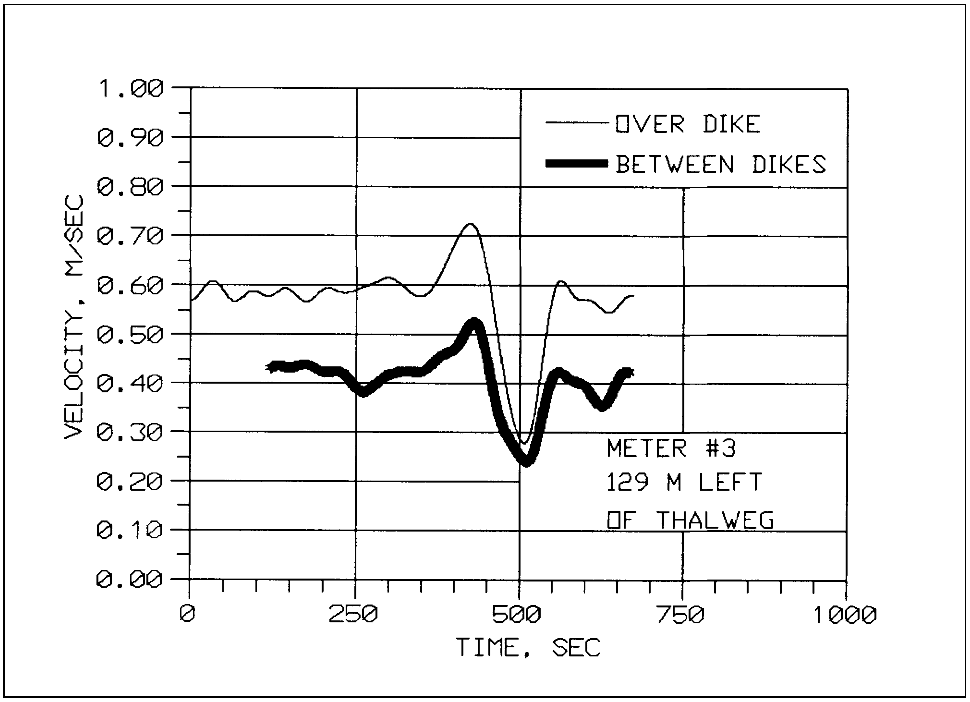


Figure 95. Velocity time history, downbound tow, meter No. 3, tow speed relative to ground = 4.77 m/sec

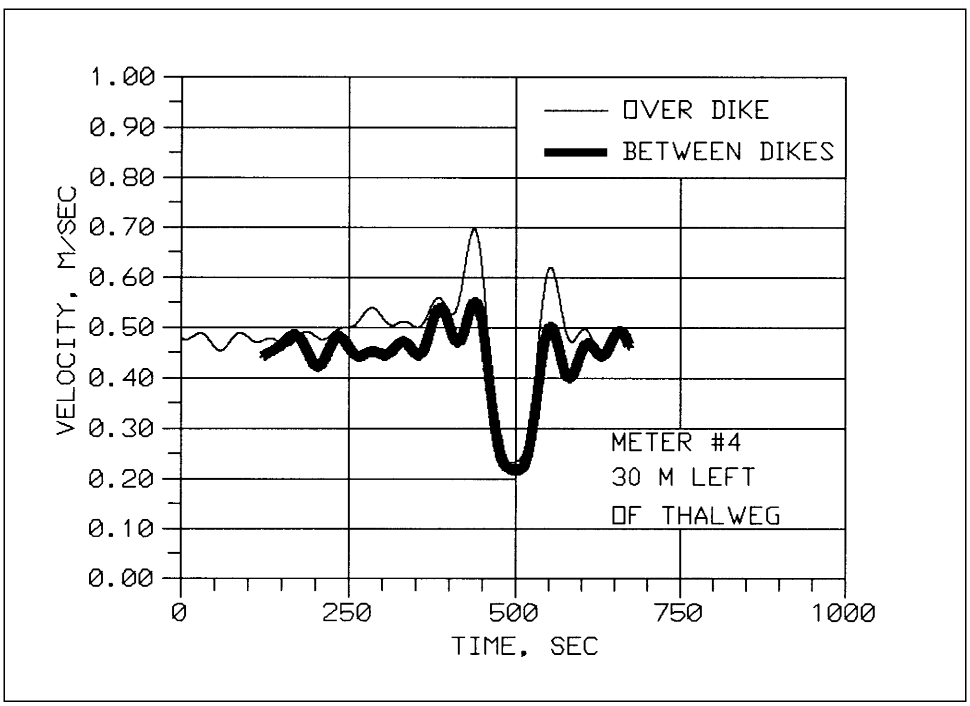


Figure 96. Velocity time history, downbound tow, meter No. 4, tow speed relative to ground = 4.77 m/sec

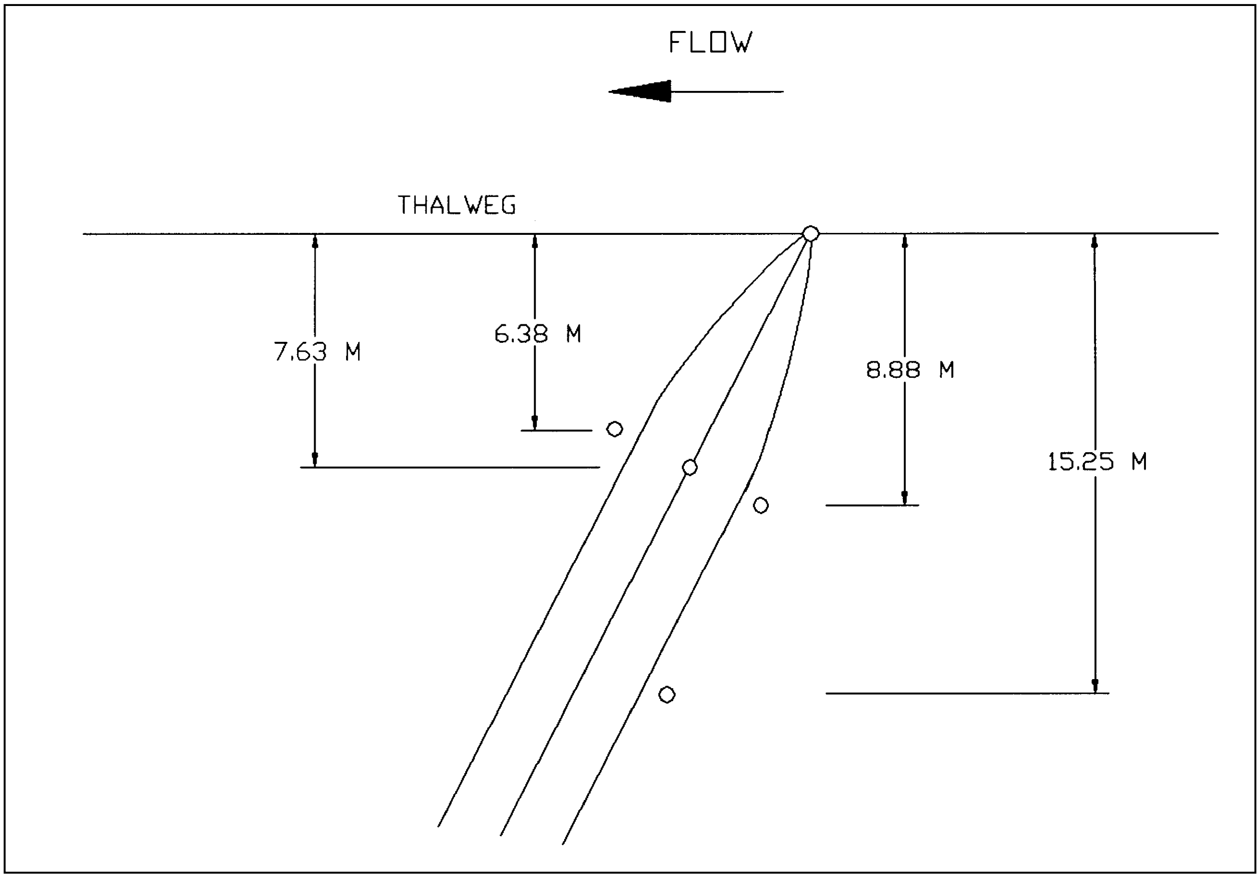


Figure 97. Location of velocity meters in dike experiments

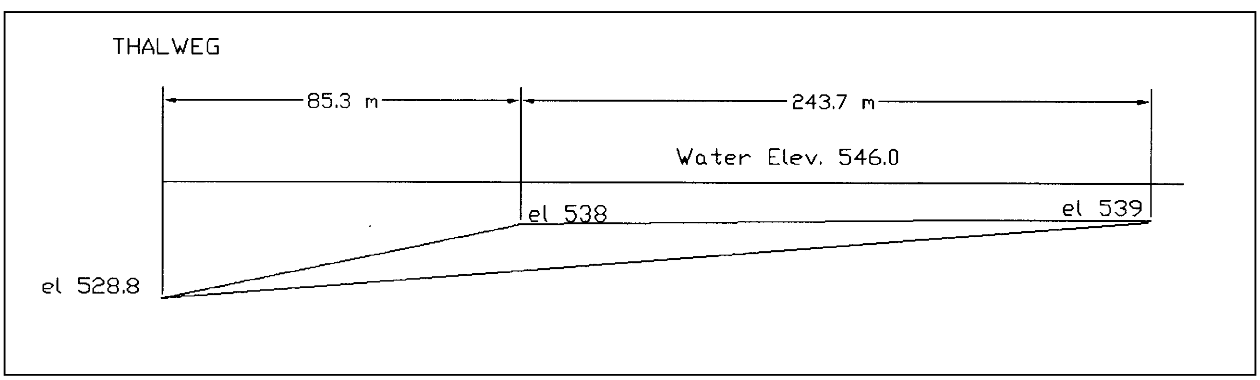


Figure 98. Profile of low dike (looking upstream)

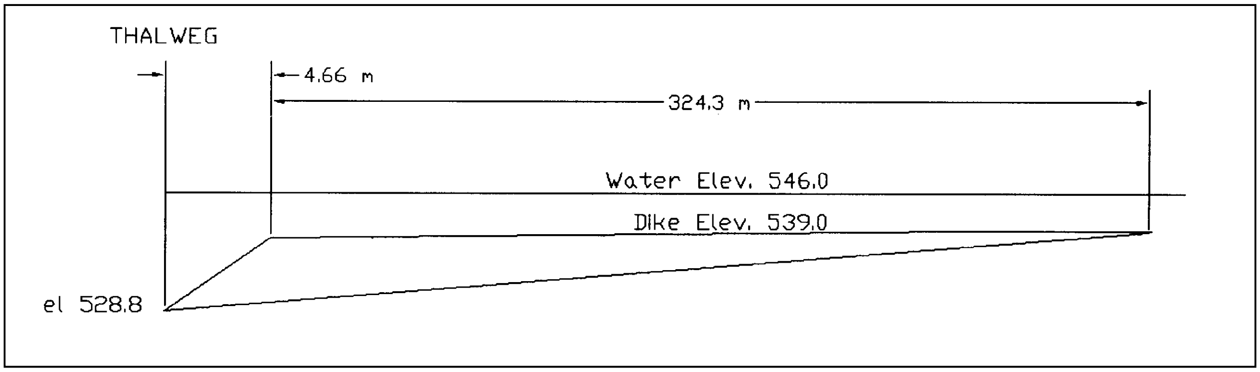


Figure 99. Profile of high (generic) dike (looking upstream)

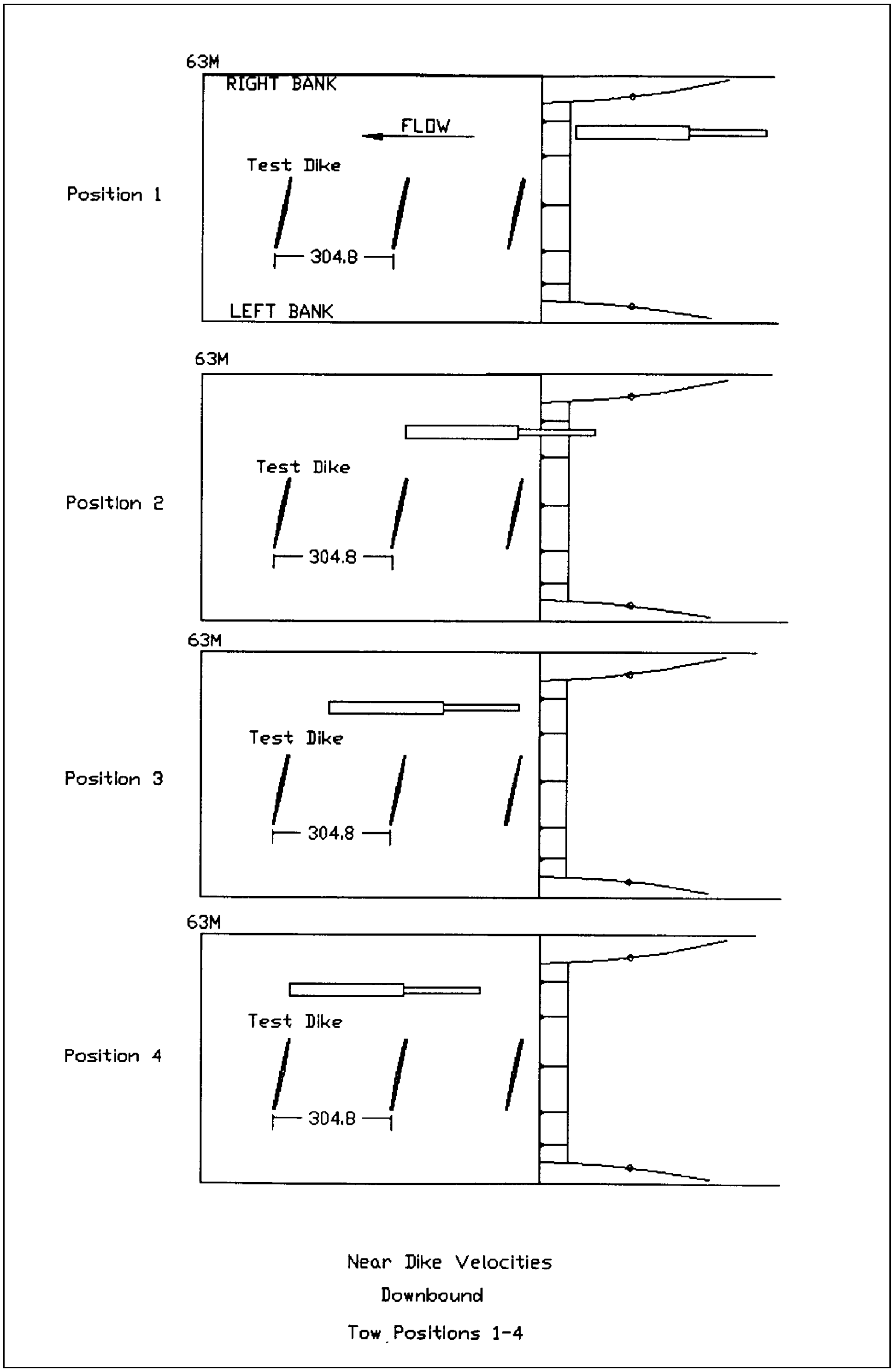


Figure 100. Experimental series 6, downbound runs (Continued)

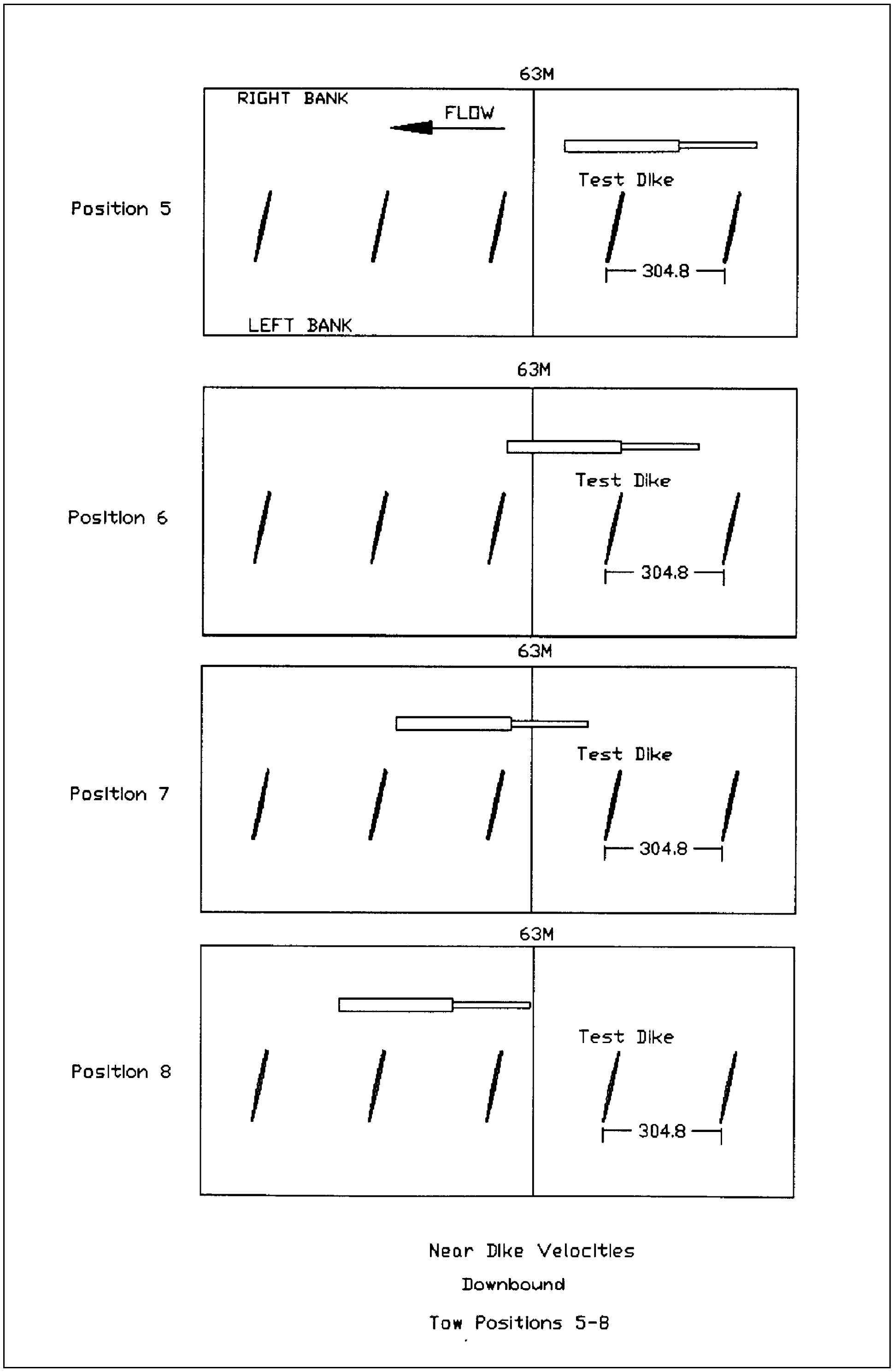


Figure 100. (Concluded)

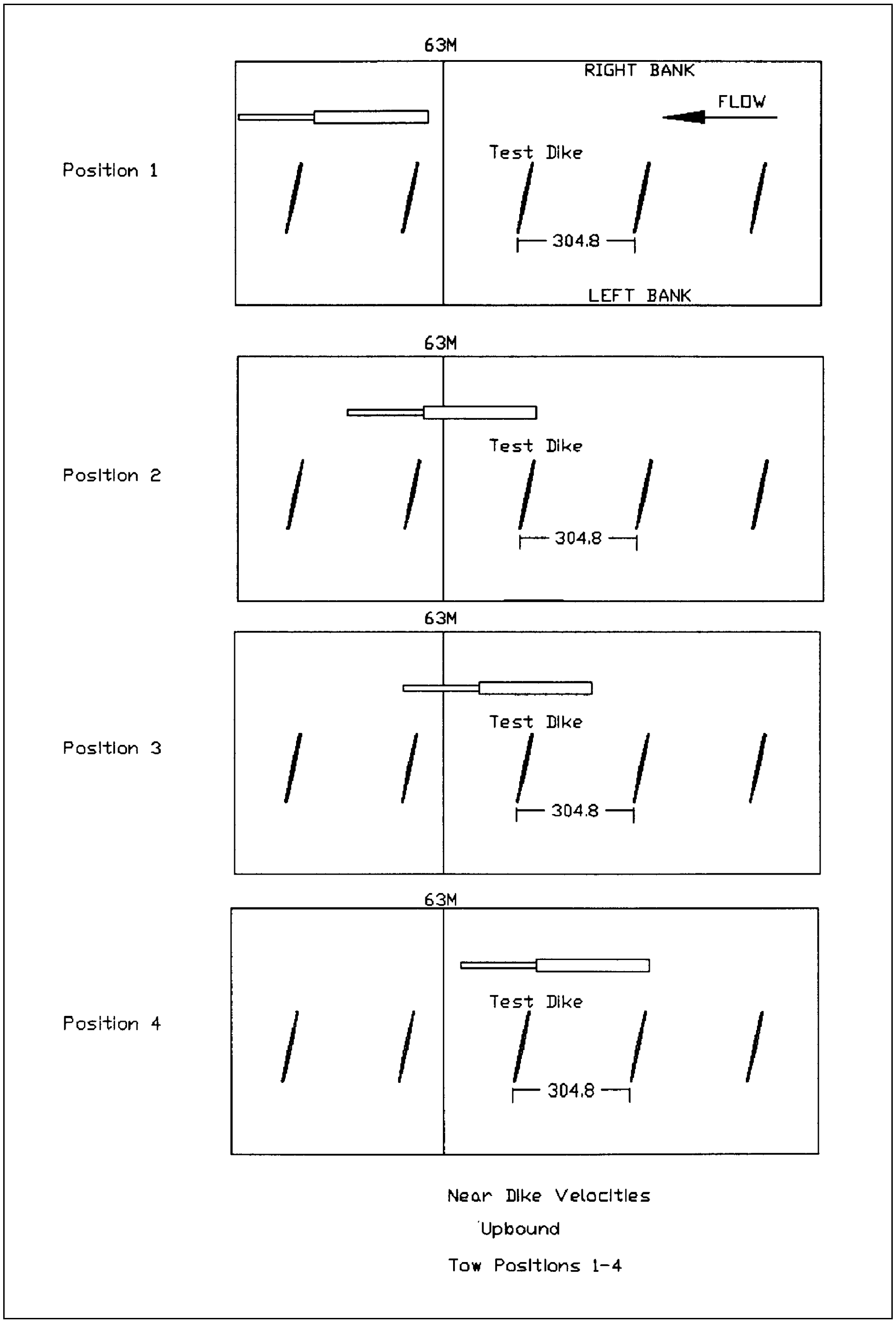
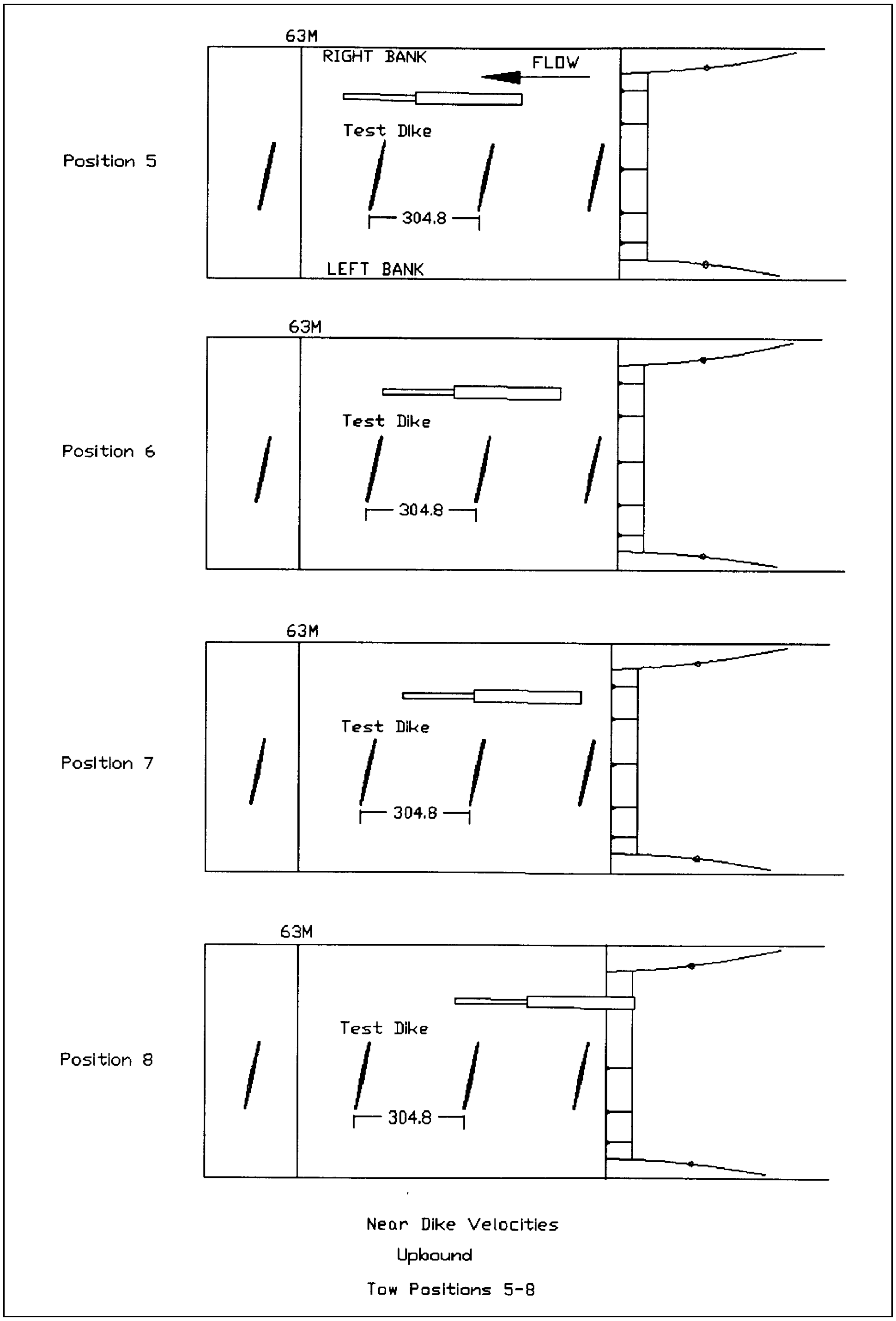


Figure 101. Experimental series 6, upbound runs (Continued)



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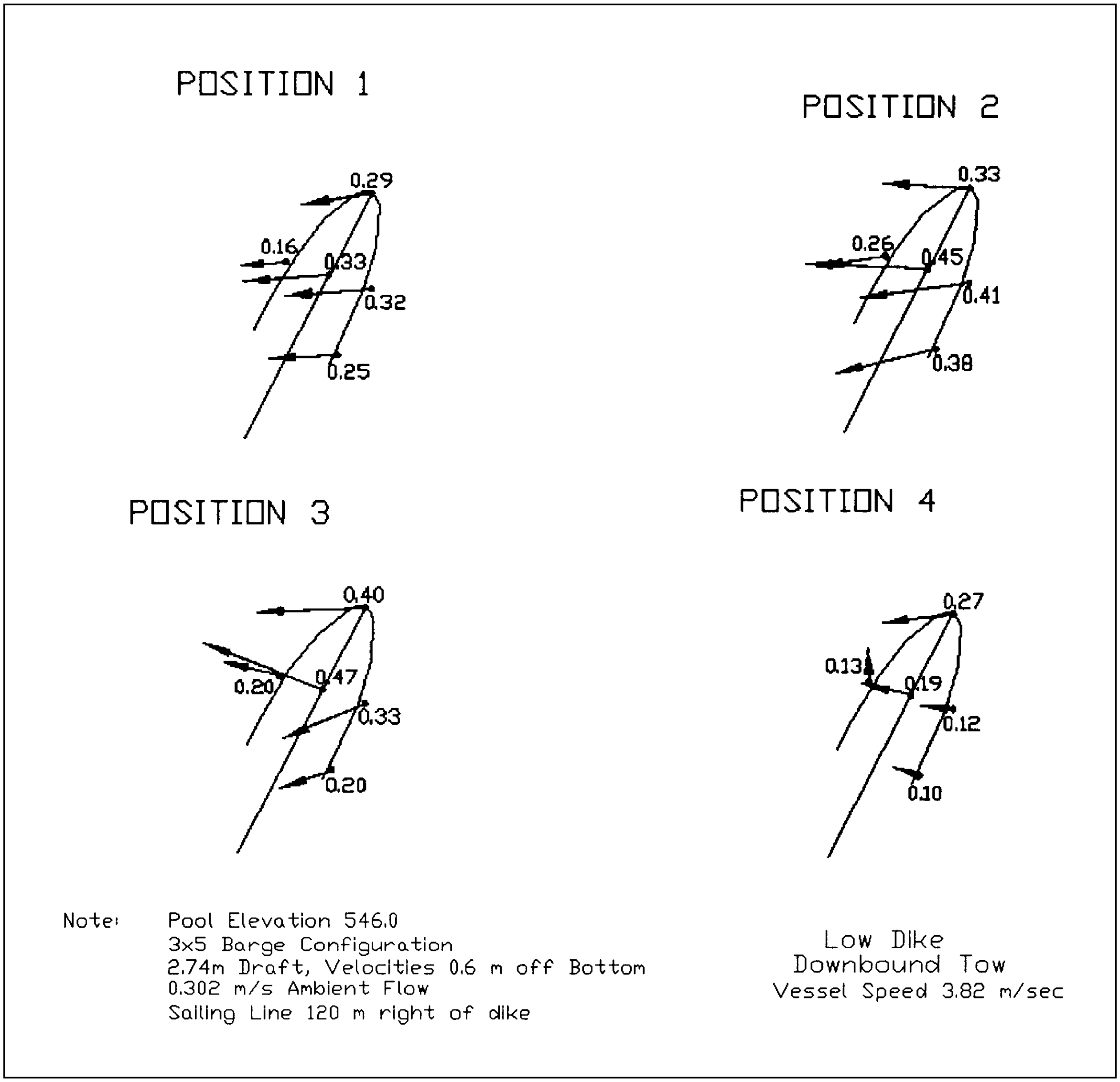
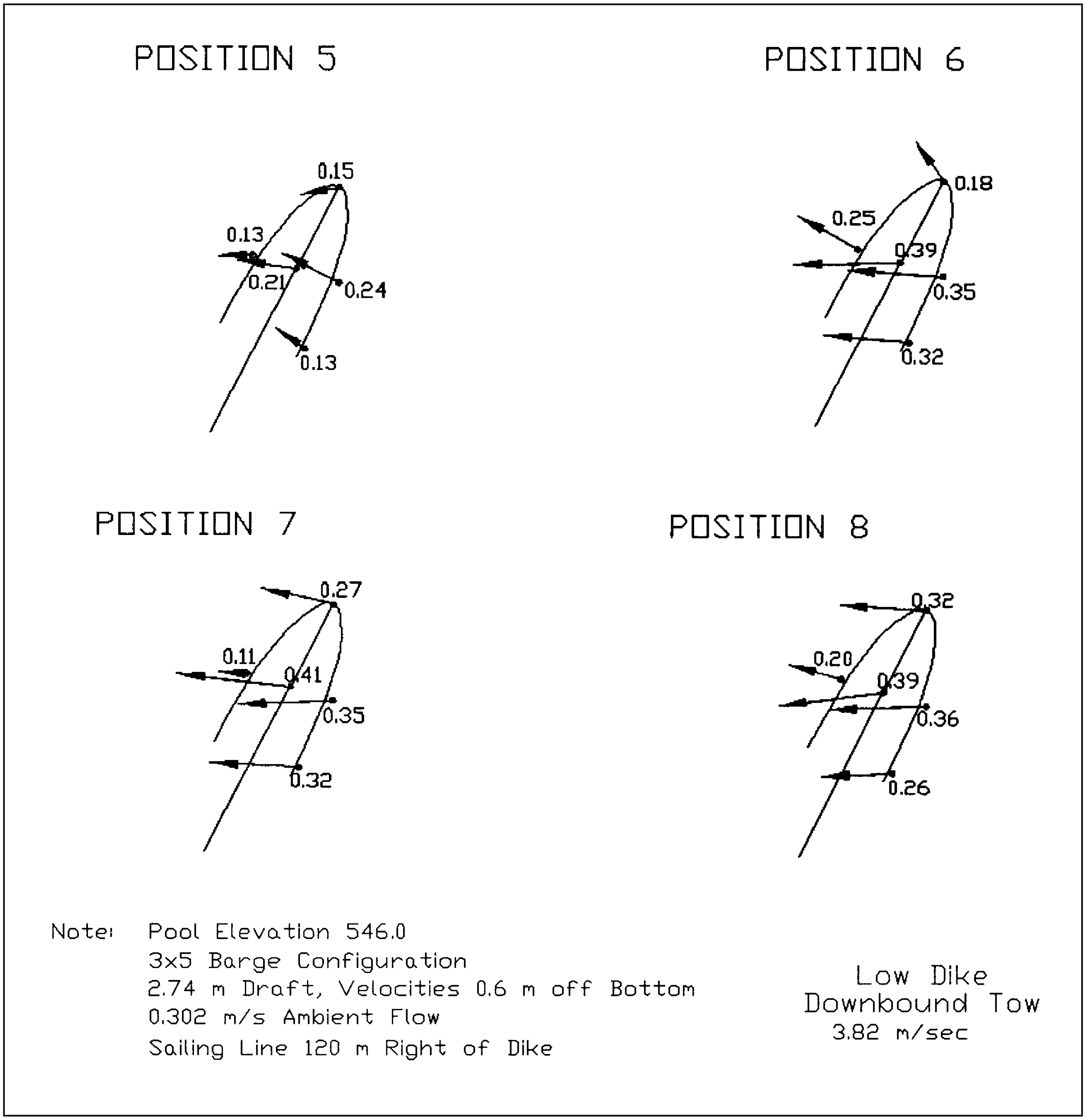


Figure 102. Velocities during tow passage, low dike, downbound tow (Continued)



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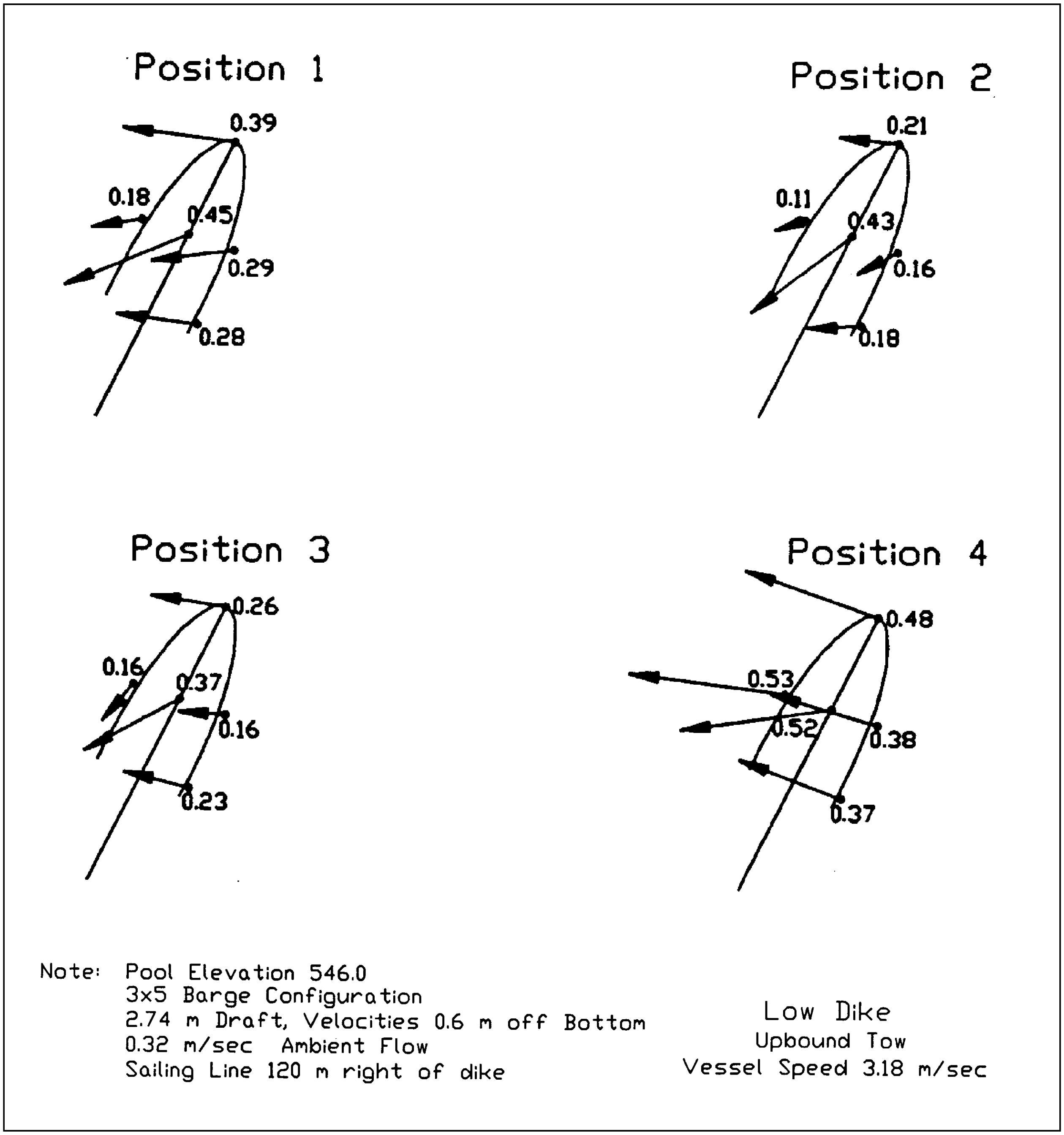
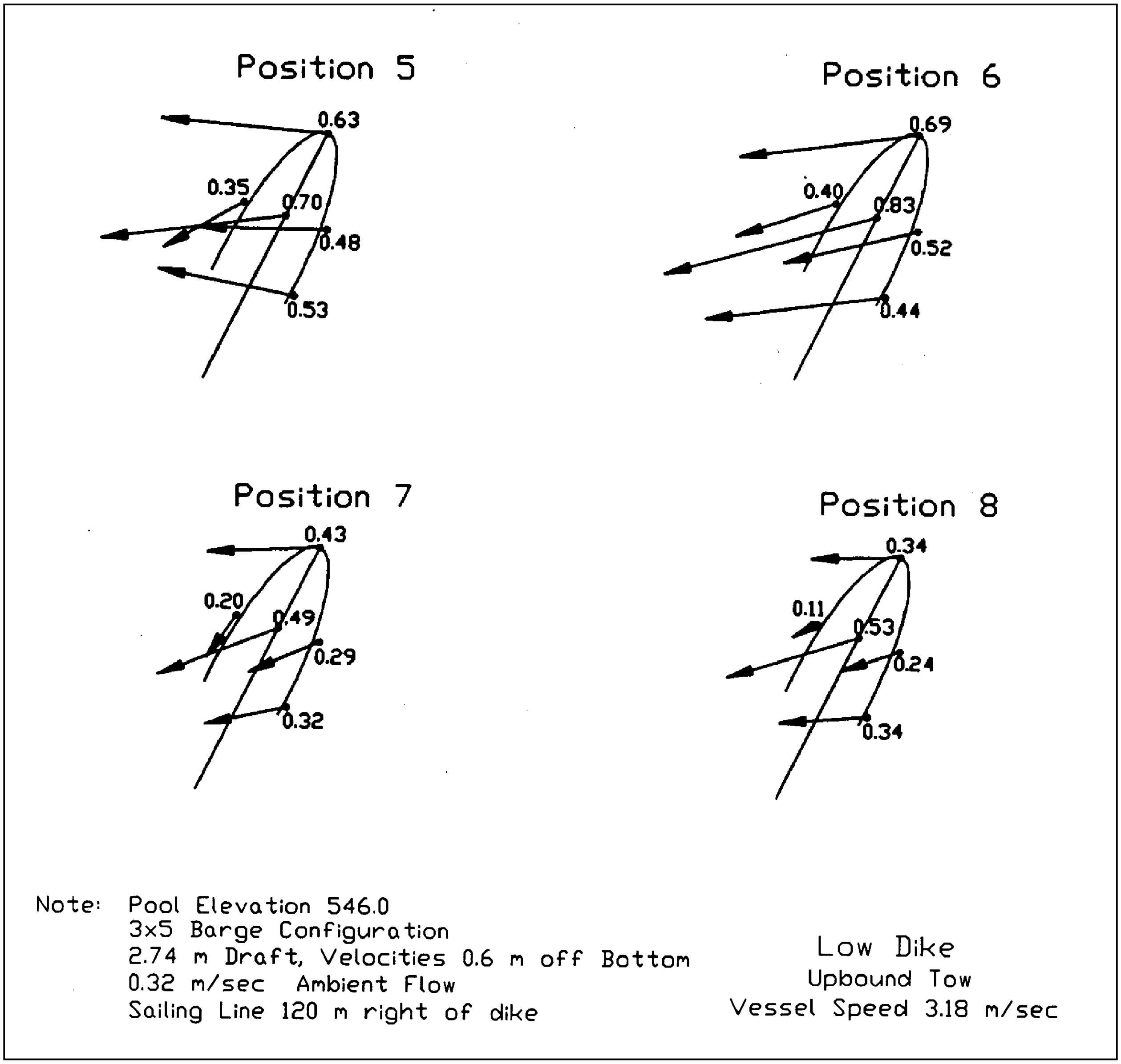


Figure 103. Velocities during tow passage, low dike, upbound tow (Continued)



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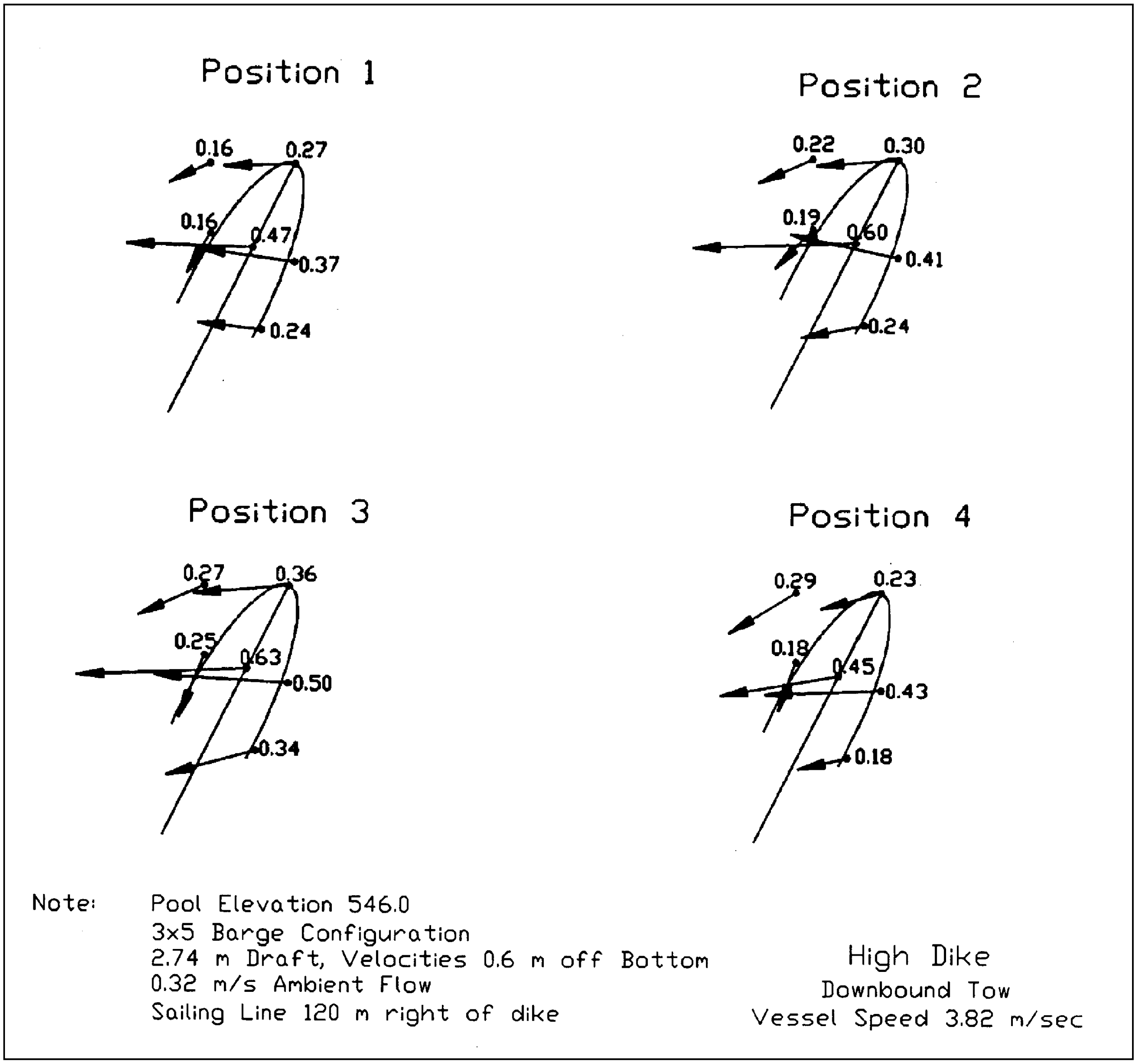
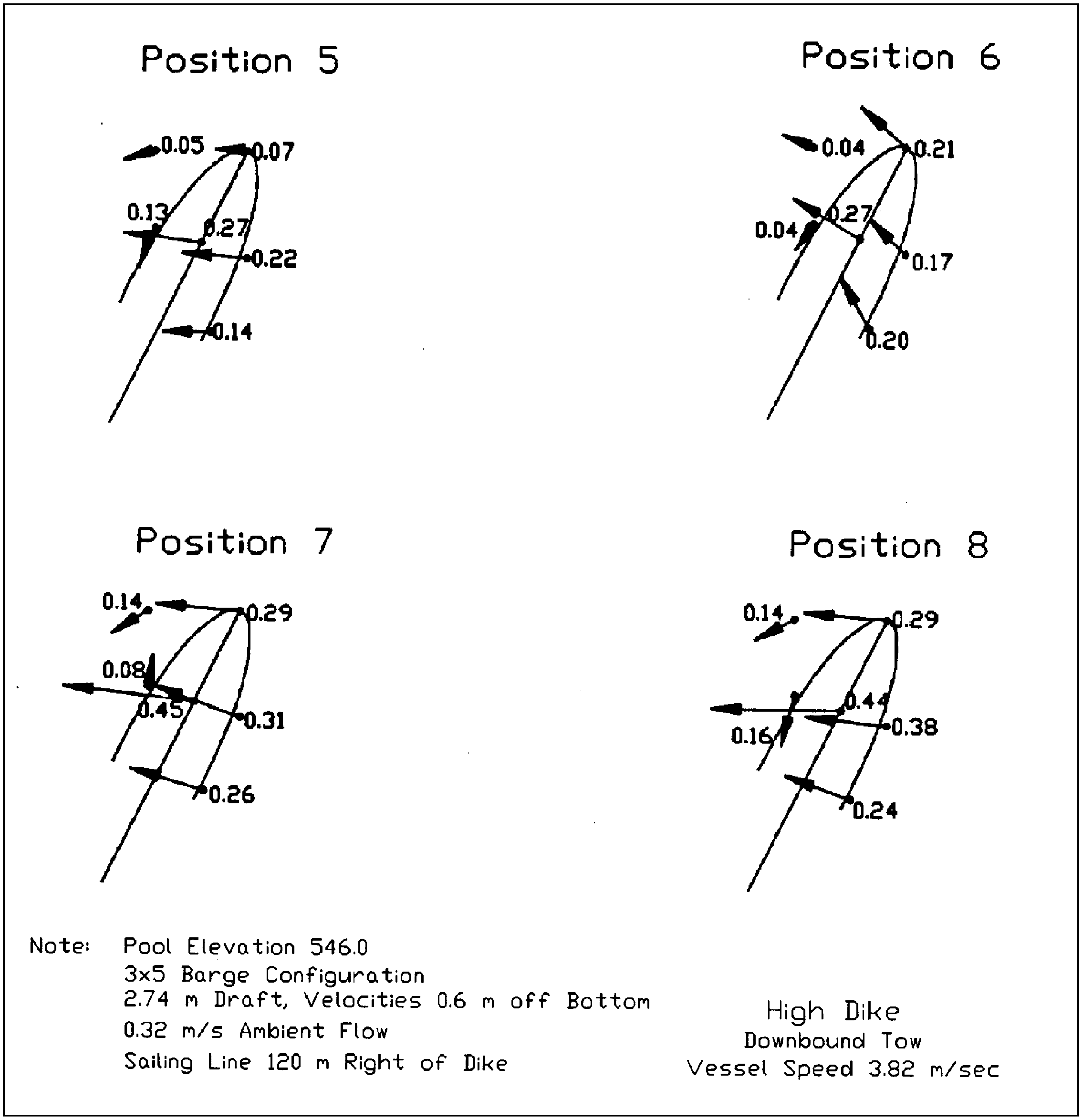


Figure 104. Velocities during tow passage, high dike, downbound tow (Continued)



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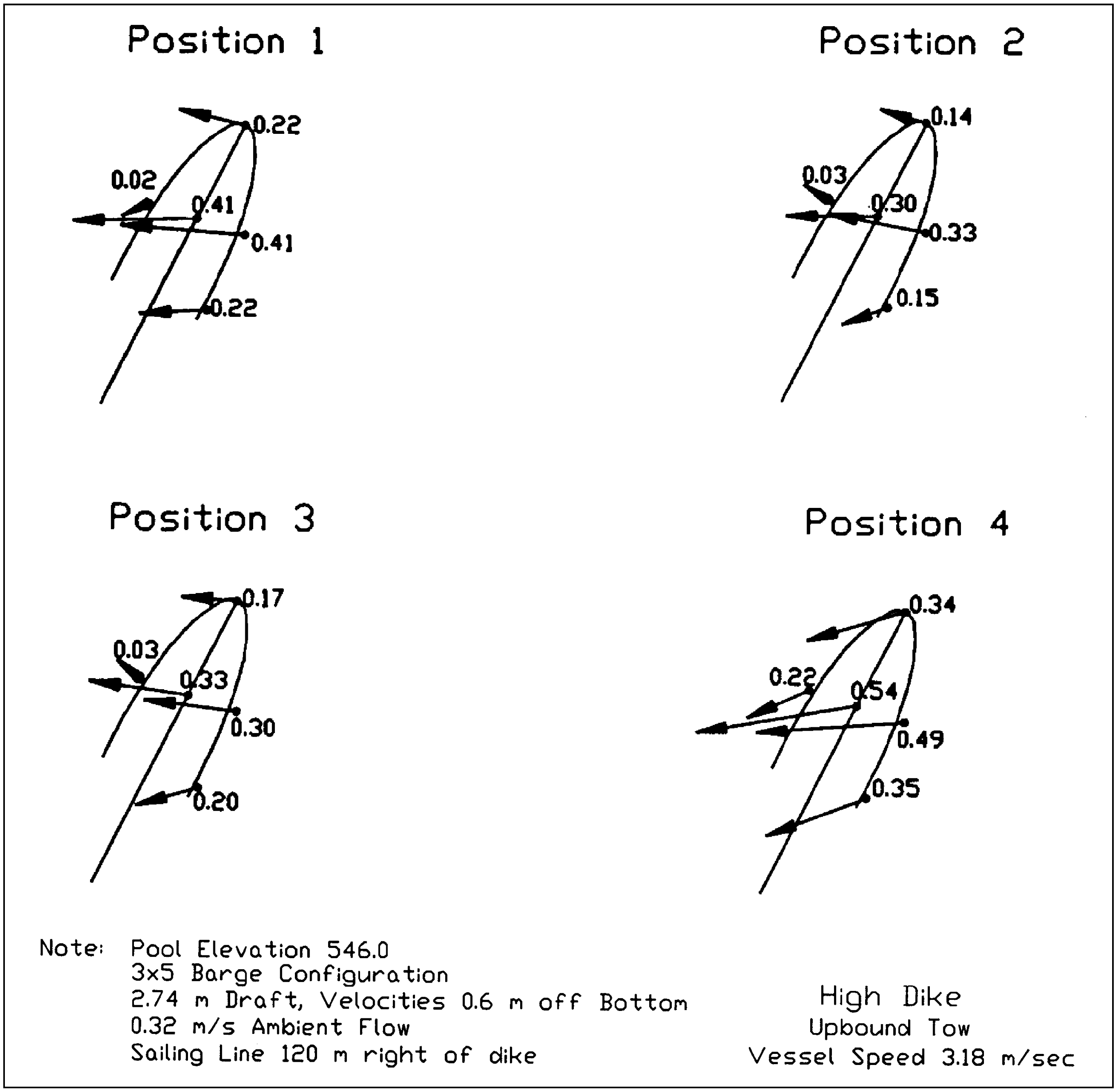
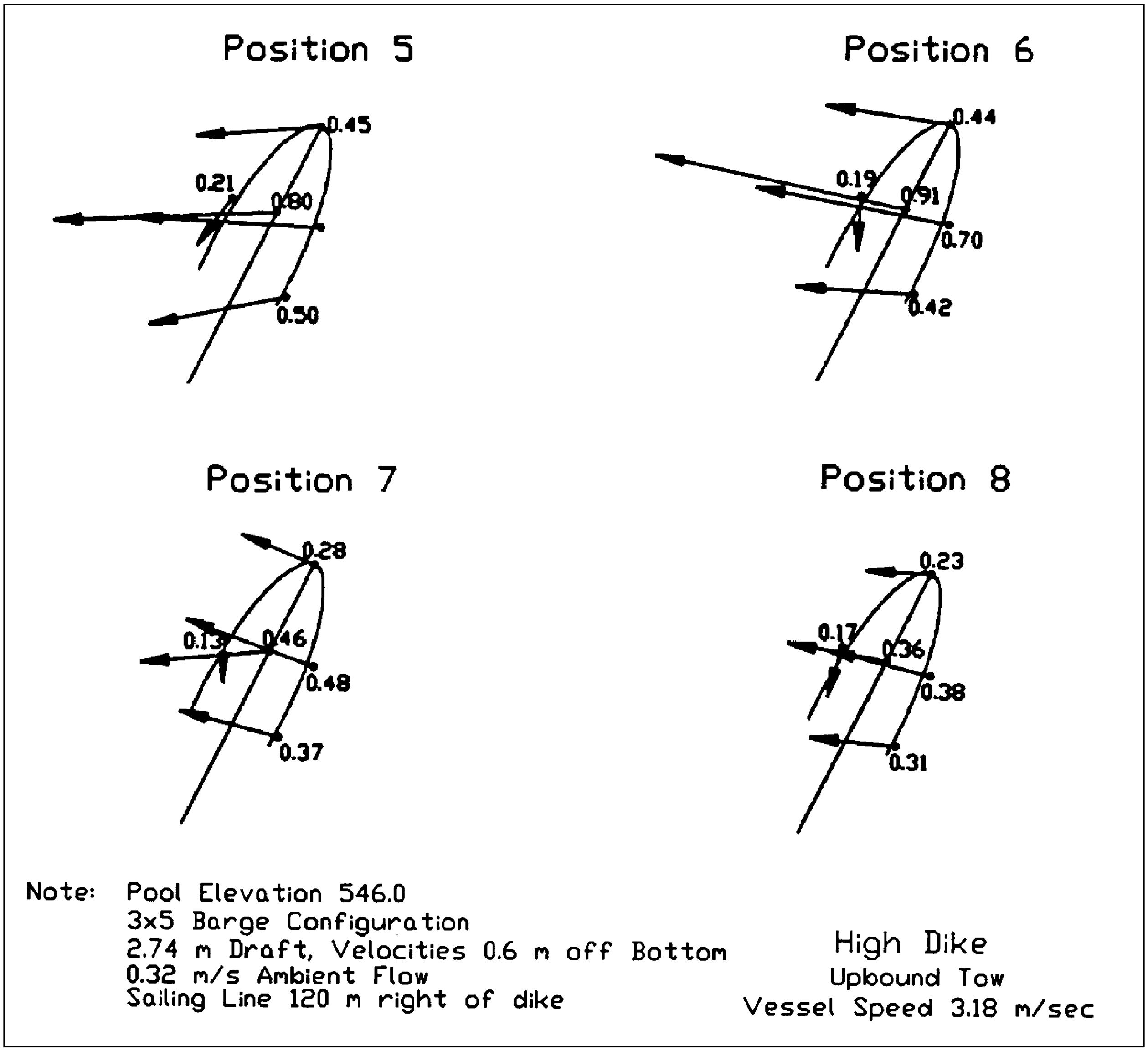


Figure 105. Velocities during tow passage, high dike, upbound tow (Continued)



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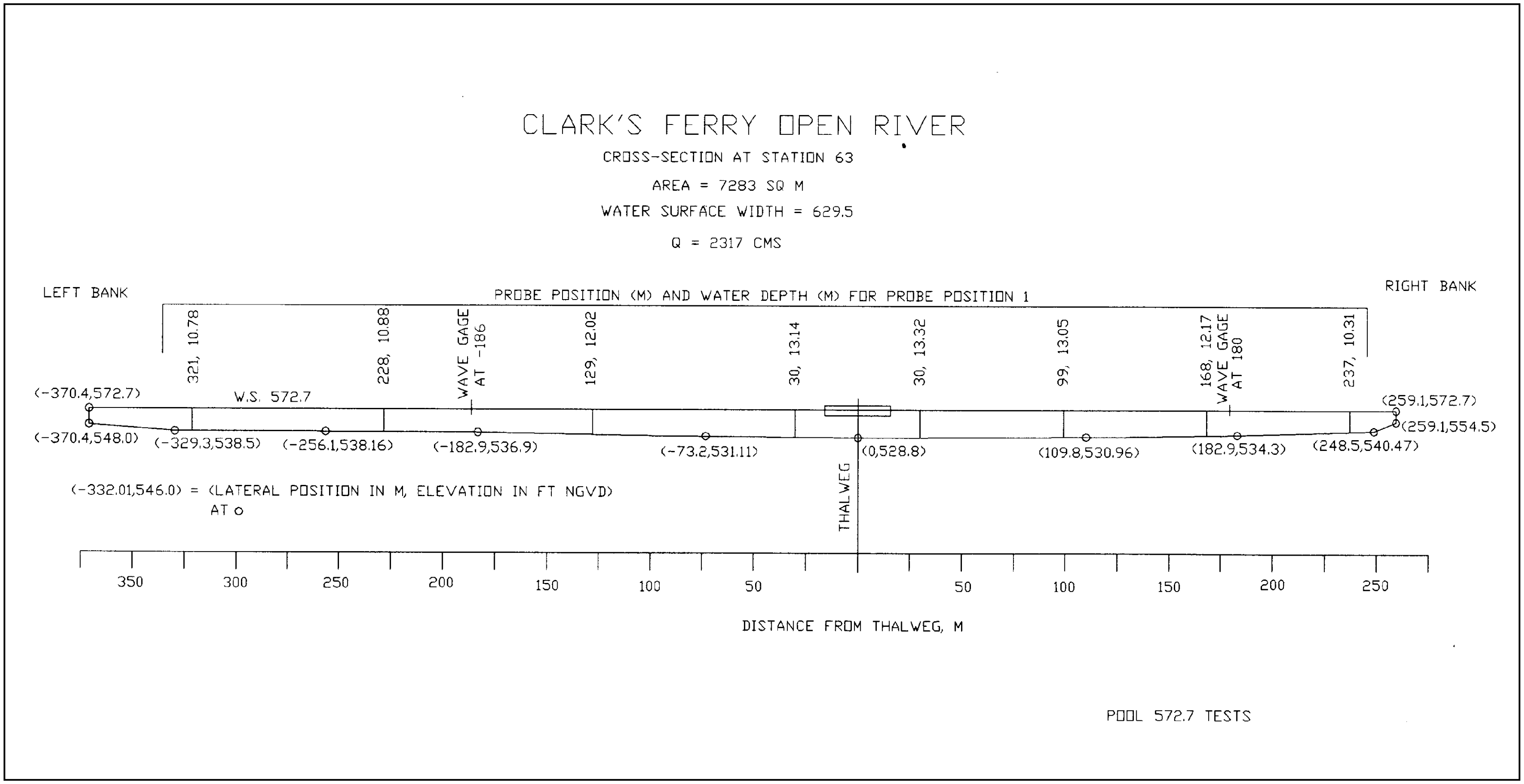

Figure 106. Cross section, experimental series 7

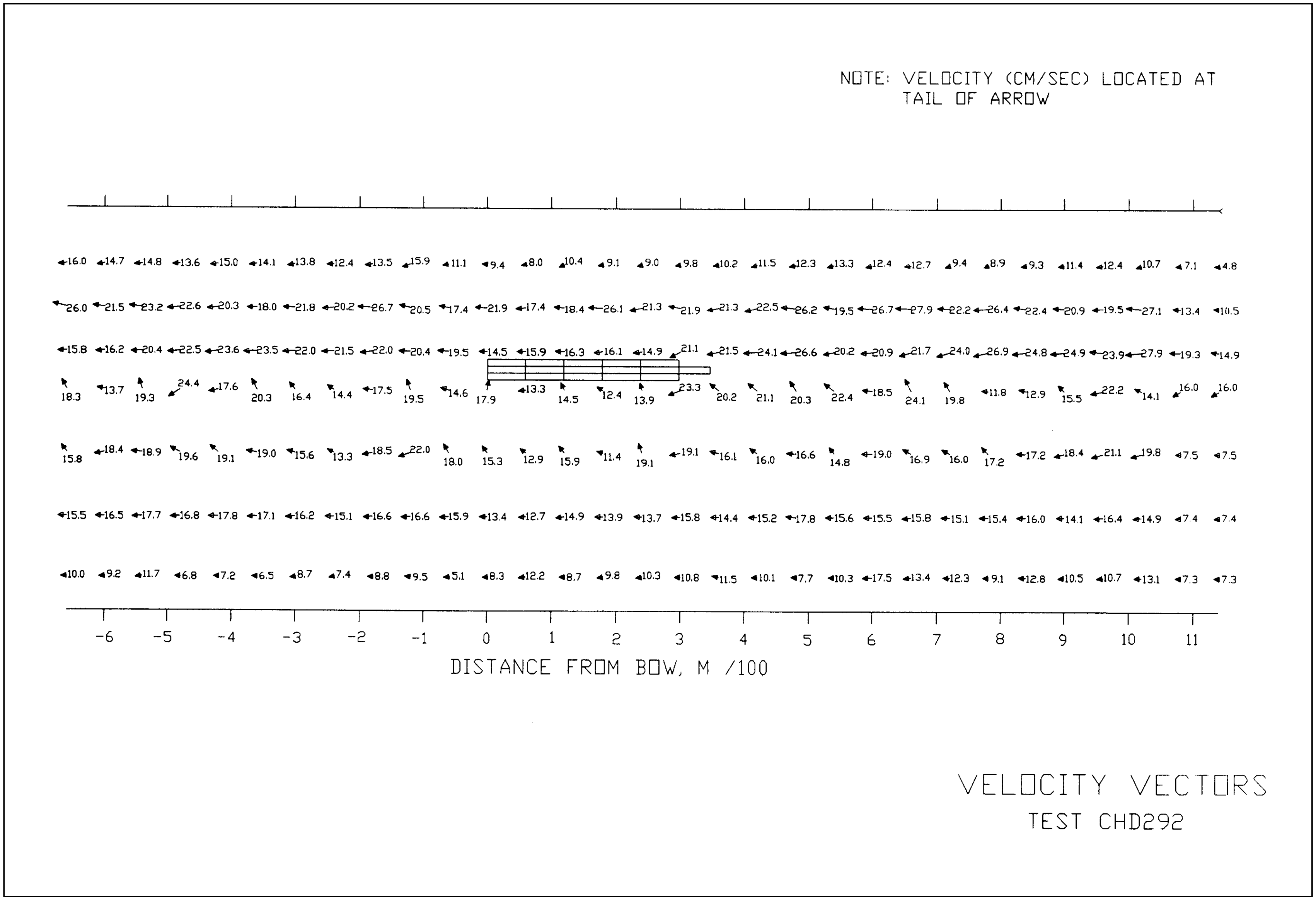

Figure 107. Vector plot, test CHD292

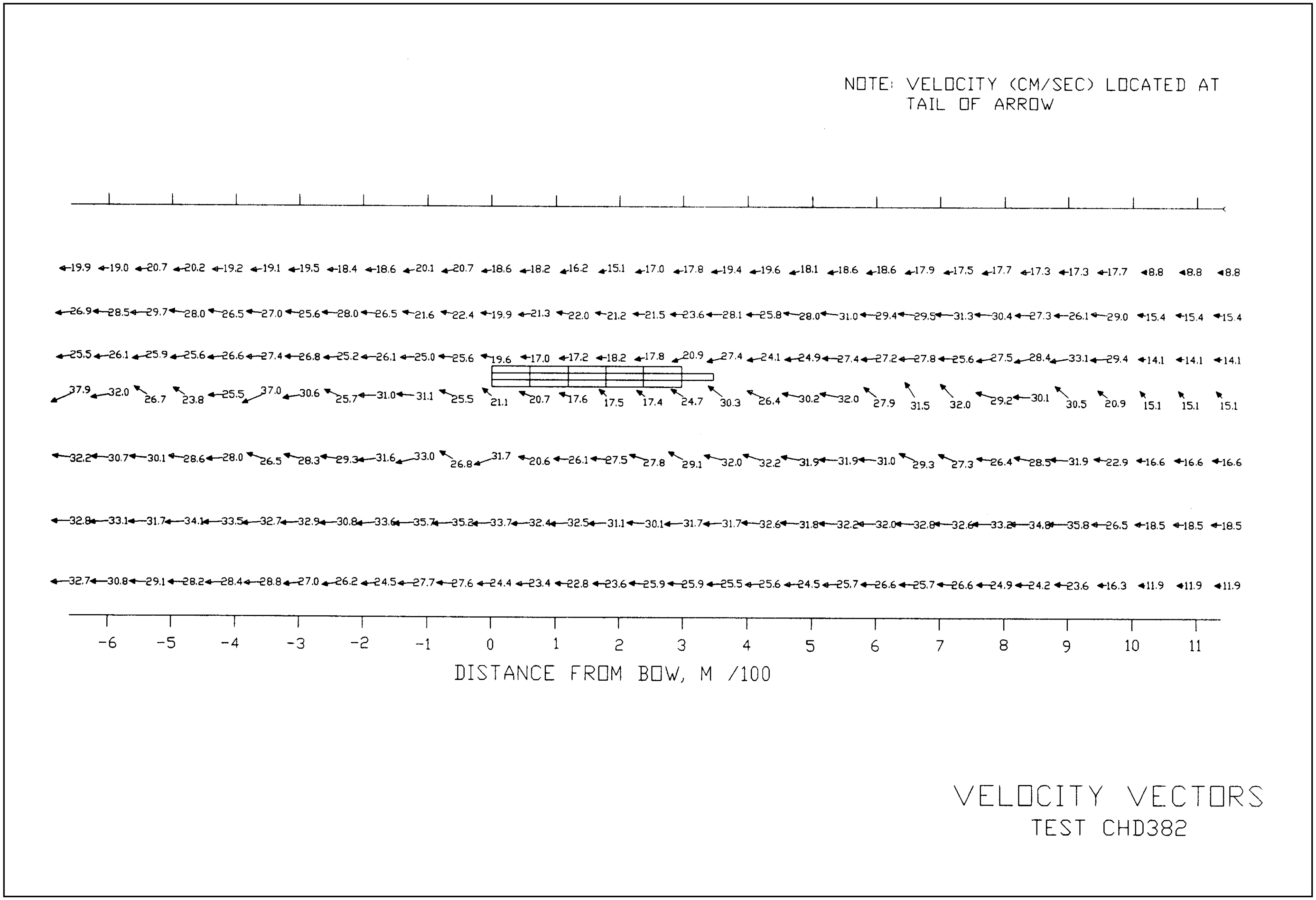

Figure 108. Vector plot, test CHD382

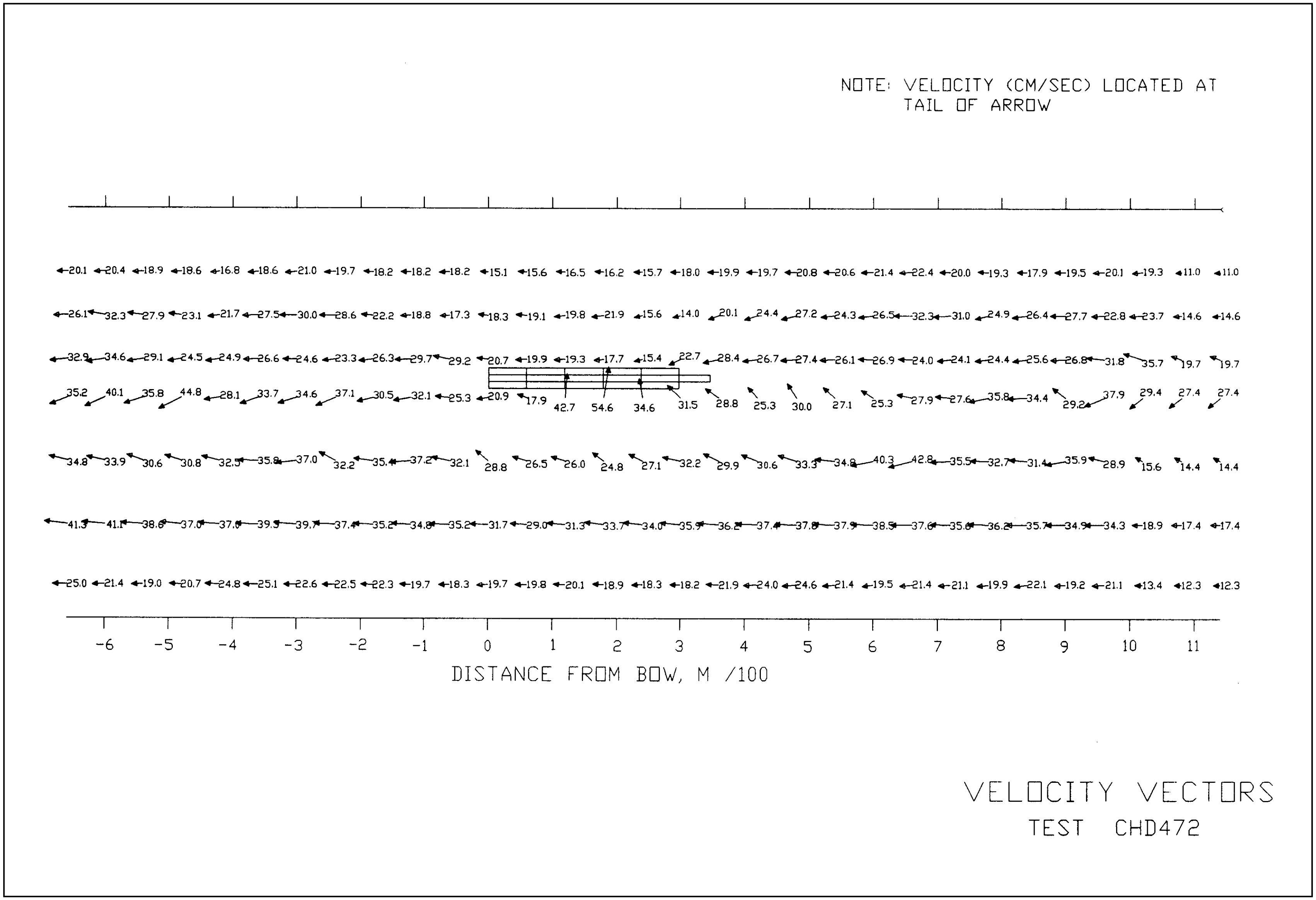

Figure 109. Vector plot, test CHE472

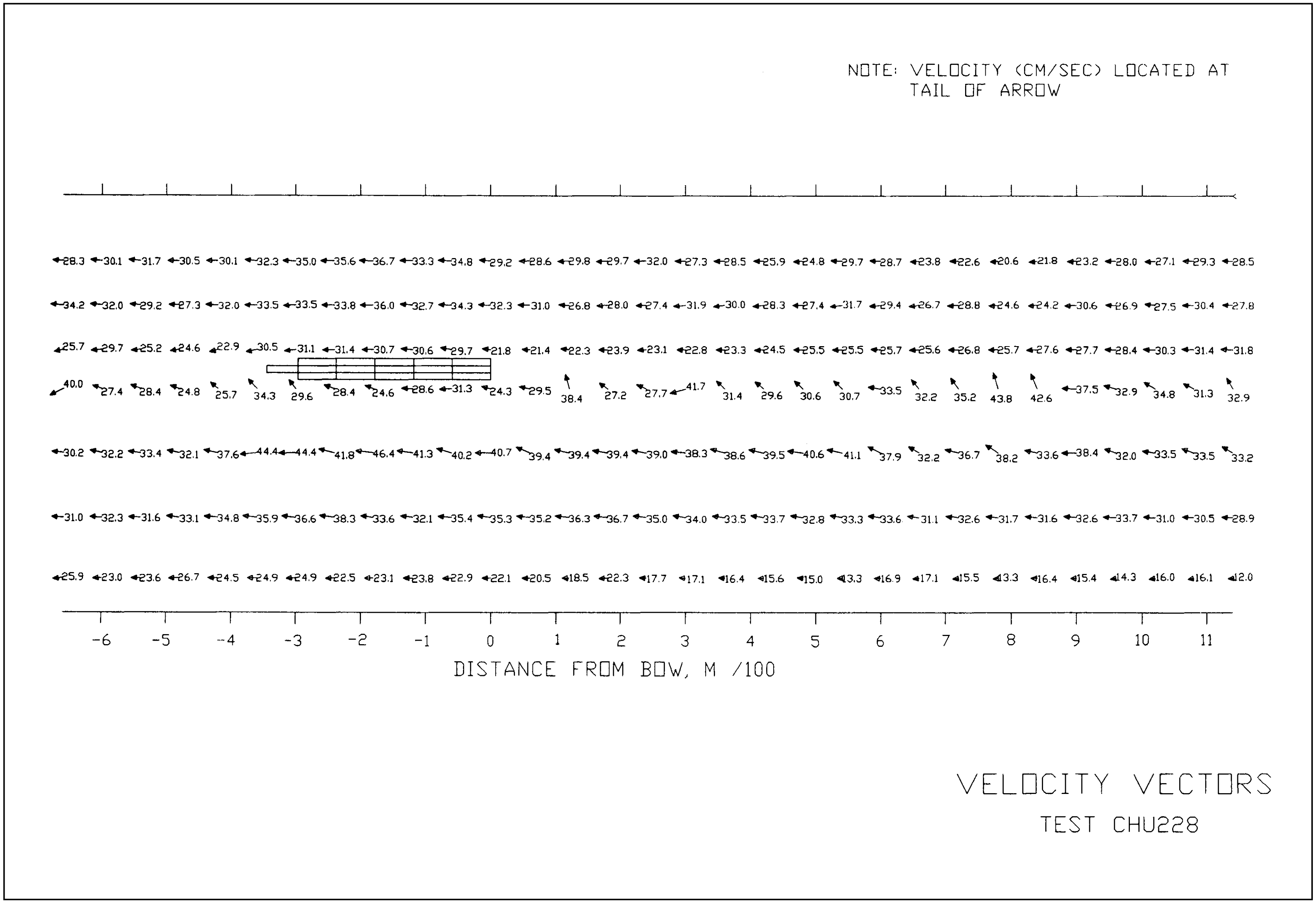

Figure 110. Vector plot, test CHU228

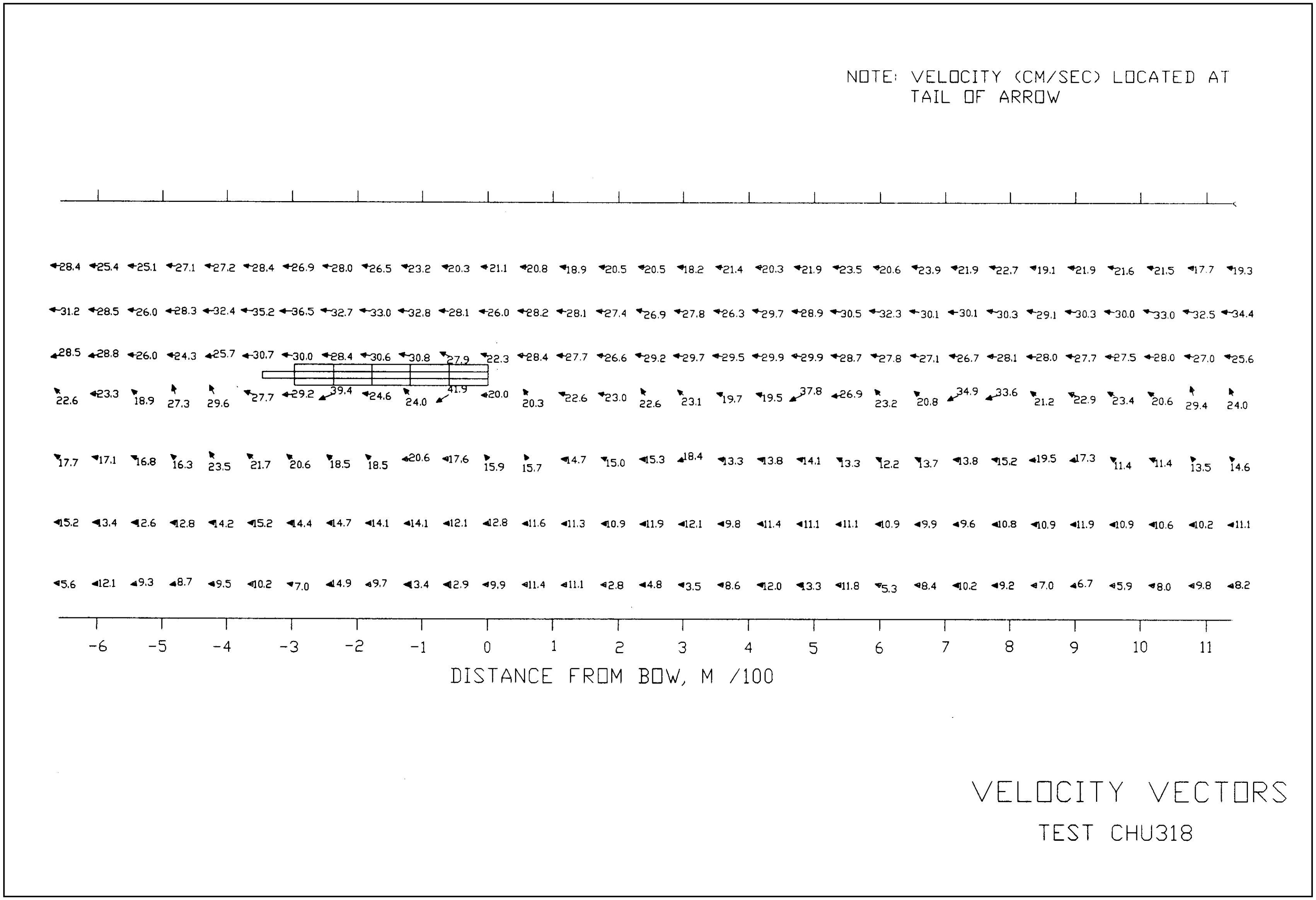

Figure 111. Vector plot, test CHU318

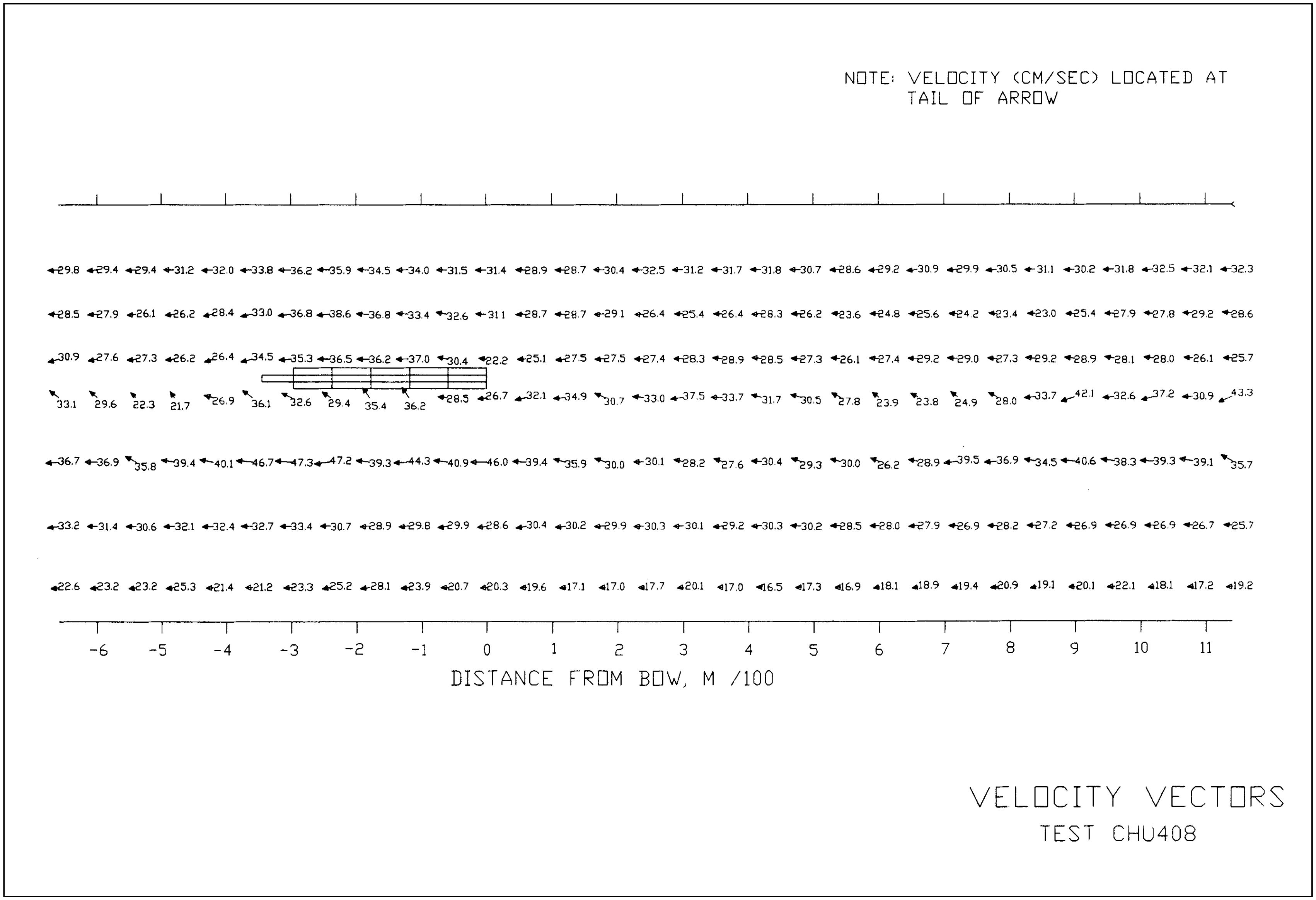

Figure 112. Vector plot, test CHU408

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13. ABSTRACT (*Maximum 200 words*)

A 1:30-scale model of the Mississippi River near Clark's Ferry, Iowa, 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 Clark's Ferry 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. Rake angle at the bow of the vessel of 26 deg and 45 deg was shown to produce similar return velocity. Velocity measurements near submerged dikes were documented during vessel passage. The Clark's Ferry model was used with a large depth to simulate open river conditions below St. Louis.

14. SUBJECT TERMS

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Environmental effects	Scale effects
Navigation	Physical model

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