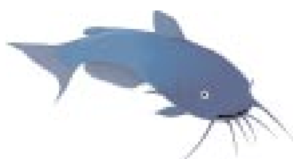
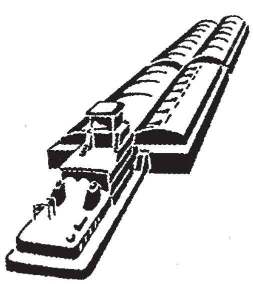
ENV Report 6

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



Upper Mississippi River Navigation and Sedimentation Field Data Collection Summary Report



US Army Corps of Engineers

November 1998

Rock Island District
St. Louis District
St. Paul District

Upper Mississippi River - Illinois Waterway
System Navigation Study

ENV Report 6
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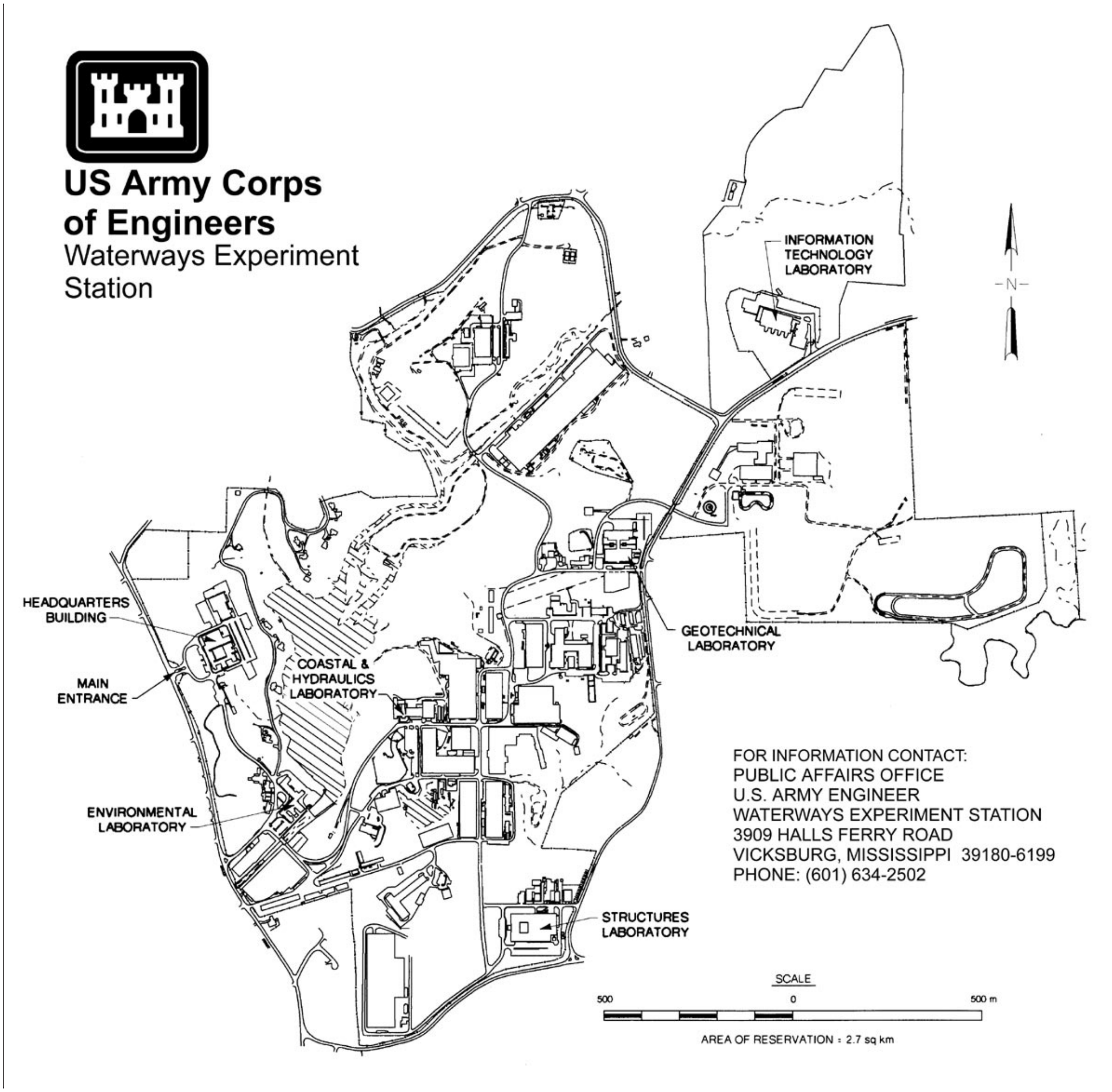
Upper Mississippi River Navigation and Sedimentation Field Data Collection Summary Report

by Timothy L. Fagerburg, Thad C. Pratt

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

Interim report

Prepared for U.S. Army Engineer District, Rock Island
Rock Island, IL 61204-2004
U.S. Army Engineer District, St. Louis
St. Louis, MO 63103-2833
U.S. Army Engineer District, St. Paul
St. Paul, MN 55101-1638



Waterways Experiment Station Cataloging-in-Publication Data

Fagerburg, Timothy L.

Upper Mississippi River navigation and sedimentation field data collection summary report / by Timothy L. Fagerburg, Thad C. Pratt ; prepared for U.S. Army Engineer District, Rock Island, U.S. Army Engineer District, St. Louis, U.S. Army Engineer District, St. Paul.

156 p. : ill. ; 28 cm.

"ENV report 6"

Includes bibliographic references.

1. Illinois Waterway (Ill.) — Navigation. 2. Sedimentation and deposition —Mississippi River. 3. Mississippi River — Navigation. I. Pratt, Thad C. II. United States. Army. Corps of Engineers. Rock Island District. III. United States. Army. Corps of Engineers. St. Louis District. IV. United States. Army. Corps of Engineers. St. Paul District. V. U.S. Army Engineer Waterways Experiment Station. VI. Upper Mississippi River-Illinois Waterway System Navigation Study. VII. Title. VIII. Title: Interim report for the Upper Mississippi River-Illinois Waterway System Navigation Study.

TA7 W3499 R5U7 ENV rept.6 1998

Contents

Preface

The field investigation 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 in 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 for this interim effort was performed by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, during the months of October 1995, July 1996, and September 1996. This effort was funded by the Rock Island District under the management of Mr. Ken Barr. The WES liaison was Mr. Thomas J. Pokrefke, Waterways and Estuaries Division, Coastal and Hydraulics Laboratory (CHL).

Personnel of the CHL Hydraulic Analysis Group (HAG) performed the work under the general supervision of Dr. James R. Houston, Jr., Director, CHL; Mr. Charles C. Calhoun, Jr., Assistant Director, CHL; Mr. William A. McAnally, Chief, Estuaries and Hydrosciences Division; and Dr. Robert T. McAdory, Chief, Tidal Hydraulics Branch. The data collection program was designed by Messrs. Timothy L. Fagerburg, Howard A. Benson, and Thad C. Pratt, Prototype and Field Studies Group (PFSG). Data reduction was performed by Ms. Clara J. Coleman and Messrs. Pratt, Benson, and Fagerburg, PFSG. Laboratory analyses of water samples were performed by Ms. Coleman. This report was prepared by Mr. Fagerburg with the assistance of Mr. Pratt.

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

1 Introduction

Background

The Upper Mississippi River and Illinois Waterway (UMR-IWW) Navigation Study was designed to resolve technical issues regarding the plan to evaluate the effects of navigation on the resuspension of bottom sediments and determine the migration patterns of these sediments and feasibility of restoring the system's biological resources. Questions have been raised concerning the ecological integrity within the interwoven system of backwater areas and marshes within the study area—the study of hydraulic and hydrologic parameters in a system such as that in the UMR-IWW complex. A number of physical processes operate in the river, and their relative importance can vary both spatially and temporally. Bathymetry and geometry of the river, meteorologically induced currents, wind-induced circulation, inflow from tributaries, and navigation traffic effects are major factors determining riverwide circulation and suspended-sediment patterns. To determine these effects in a technically defensible manner, a sophisticated approach using state-of-the-art equipment for the field investigations is necessary to capture data that are spatially and temporally variable.

Purpose

The purpose of the overall field data collection program was to provide a hydrodynamic and hydrologic monitoring program with emphasis on obtaining information including bathymetry at monitoring stations, currents, water levels, suspended-sediment concentrations, wind velocity, and concurrent navigation data. These parameters will be used in the evaluation of controlling landscape features, ecosystem stability, river morphology, and sediment-transport characterization in three study areas located in the UMR-IWW system. The areas of interest are located in Pools 26 and 8 on the Mississippi River and La Grange Pool on the Illinois River. These data are then to be used in the hydrodynamic and sediment transport modeling efforts to provide the necessary boundary conditions, initial conditions, and verification data for comprehensive numerical simulations. The purpose of this report is to provide a permanent record of the instrumentation and techniques employed during the field investigation and to make the data available for use.

Scope

This report presents representative results of the field investigation of the UMR-IWW Sedimentation Study during the months of October 1995, July 1996, and September 1996. Measurements consisted of the following:

a. Current speed and direction.

b. Suspended-sediment concentrations.

c. Bottom-sediment samples.

d. Water-level fluctuations (waves and navigation traffic drawdown effects).

e. Meteorological conditions.

f. Navigation vessel information.

This report describes the field investigation equipment and methods used to collect the data, shows representative results of the data reduction efforts, and summarizes the results of these efforts.

2 Data Collection Program and Equipment

Data Collection Program

The field effort, as stated previously, included continuous monitoring of the water-level changes due to vessel waves, current speed and directions, wind speed and direction, and suspended-sediment fluctuations at various locations within the proposed study areas. Concurrent with these measurements, intensive data collection efforts were performed during navigation traffic passage events to obtain current speeds, directions, and suspended-sediment samples. The data were to be obtained during approximate high-, mean-, and low-flow stages of the river at each of the proposed monitoring sites. However, all the monitored flows for Pools 26 and La Grange are below the 50-percent duration flow. The data obtained during these efforts were collected at regular intervals over 3 consecutive days at each site for each data collection period. Navigation traffic passages through the study areas were sampled more frequently by the data collection boats onsite to determine changes in suspended-sediment concentrations. This plan utilized a minimum of three boats for monitoring three to four data collection ranges at each study area. A typical arrangement of data collection ranges are shown in Plates 1-7.

Data were collected in the UMR-IWW Sedimentation Study during the months of October/November 1995, July 1996, and September 1996. The actual dates of the data collection period are listed below:

Pool 8	2-3 Nov. 1995	-	13-14 Sept. 1996
Pool 26	8-9 Nov. 1995	11-12 July 1996	5-6 Sept. 1996
La Grange (Illinois R.)	-	15-16 July 1996	9-10 Sept. 1996

The data collection efforts are described in further detail in subsequent sections of this report.

Water-Level Fluctuation Measurements

Instruments were deployed for monitoring of water-level fluctuations from boat waves and drawdown effects. These instrument deployment locations are identified in Plates 1-7 and in Table 1. Water-level fluctuations were monitored using microwave water-level recorders, as described in Appendix A. A typical installation of the wave/water-level sensors is shown in Figure 1. The sensor is secured inside a weighted aluminum tripod mounting unit and lowered to the bottom of the river in the nearshore area in water depth of 1.2 to 1.5 m. A retrieval line is secured to the tripod and the opposite end, then attached to a secure object (tree, piling, etc.) on the shore.

Fixed-Depth Velocity and Direction

Fixed-depth velocity and direction measurements within areas of the main river and in off-channel locations were recorded using ENDECO model 174 SSM current meters similar to that described in the section on recording velocity meters of Appendix A. A typical installation of the velocity meter is shown in Figure 2. At each location, a single meter was deployed and positioned at a fixed point from the bottom equivalent to 0.4 of the total water depth at the deployment location. A surface float was attached to the meter suspension line to mark the location and provide flotation support for the velocity meter. Listings of the instrument locations and their positions are presented in Table 1. The sampling interval of these recording current meters was set at 10 sec.

Suspended-Sediment Measurements

The suspended-sediment measurements for determination of background and navigation effect changes in concentration levels were obtained with optical backscatterance (OBS) sensors and portable water-sampling equipment, as described in the suspended-sediment concentrations measurements section of Appendix A. These instruments were deployed in areas relatively close to the navigation channel and in water depths ranging from 1 to 5.5 m. A data collection platform was designed for use in a riverflow environment. A typical installation of the OBS data collection platform is shown in Plate 8. The sensors were positioned at various intervals below the water surface depending on the overall water depth at the deployment location. Generally, three sensors were used when water depths were less than 3.6 m, and five sensors were used when depths were greater than 3.6 m. The locations designated by ranges are indicated in Table 1 and in the location maps shown in Plates 1-7. For safety and security of the instruments, the data collection platforms were outfitted with reflective signs and flashing lights to warn approaching vessels of their proximity to the navigation channel. The sampling interval for these suspended-sediment concentration sensors was 240 readings per minute.

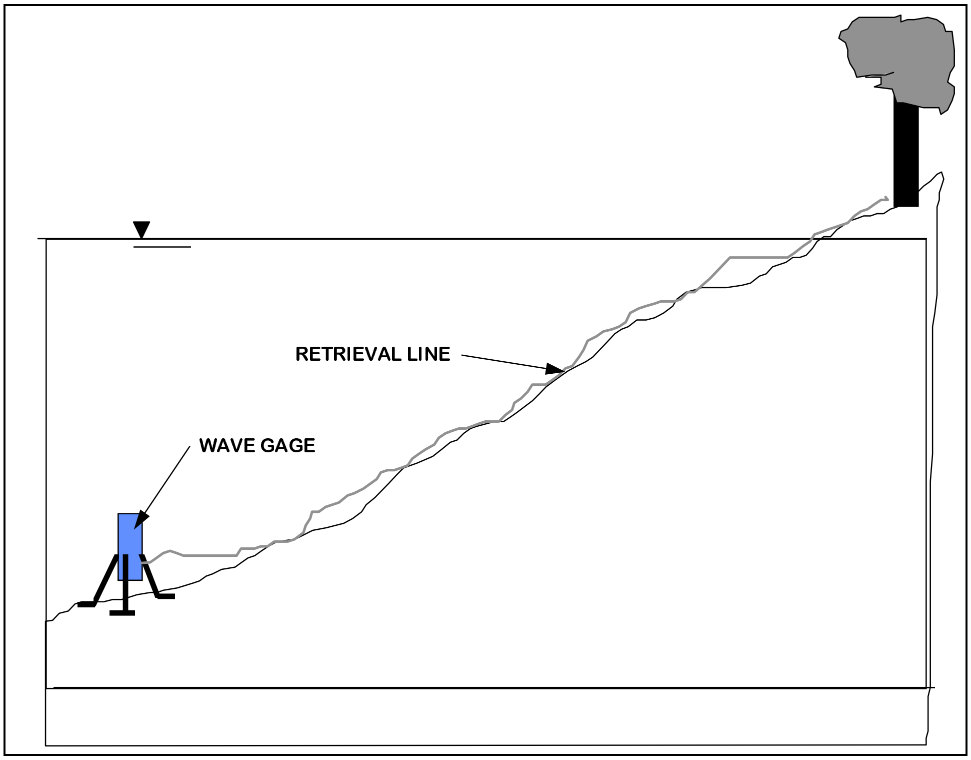


Figure 1. Typical wave gauge deployment

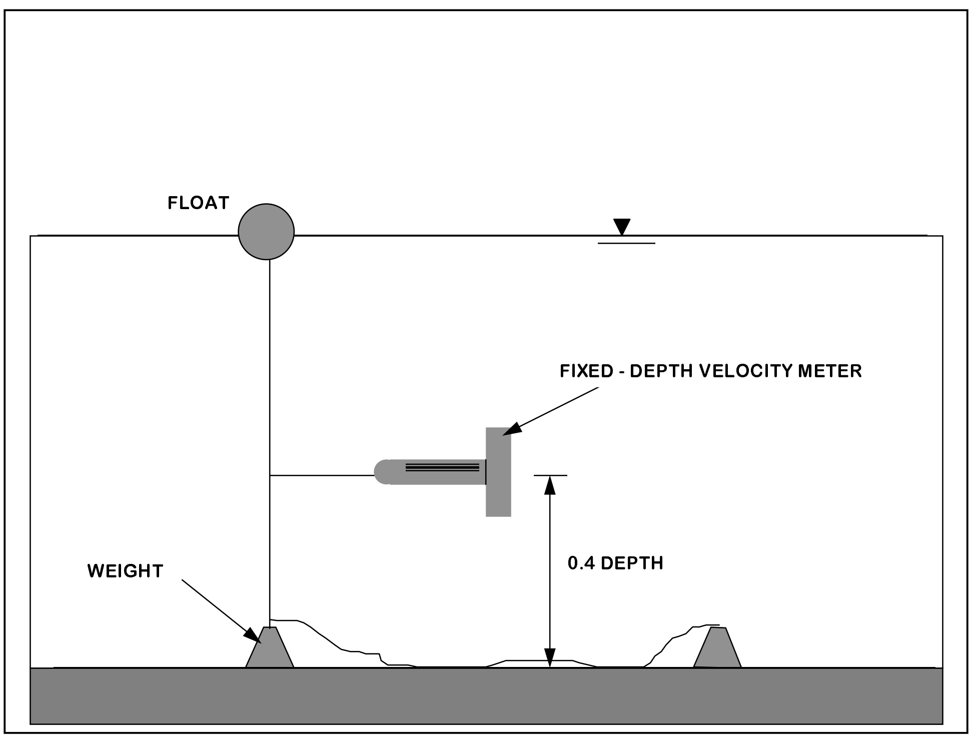


Figure 2. Typical deployment of the fixed-depth velocity meter

Water samples were collected during several of the data collection transects along each range at a minimum of three depths: near bottom, middepth, and surface. The near-bottom sample was obtained approximately 0.6 m above the actual bottom. The middepth sample was obtained at the actual middepth measurement. The surface sample was obtained at approximately 1.0 m below the water surface. The samples were obtained by pumping the water from the desired depth to a collection point at the surface. The pumping system used is described in the suspended-sediment sample section of Appendix A. Laboratory analysis of these water samples provided a means of quantifying the suspended-sediment concentrations.

Velocity and Direction Profile Measurements

During the intensive data collection efforts, boat-mounted Acoustic Doppler Current Profilers (ADCP), as described in Appendix A, were used to collect profiles of velocity and direction. A total of three boats were used in each study area, and ADCP instruments were employed to monitor data collection ranges within the main river and in a few of the entrances of off-channel areas (side channels, backwater channels, etc.). The data collection ranges were selected to yield the information most applicable for the numerical model studies. The general location of these ranges are shown in Plates 1-7 and listed in Table 1 for the various study areas. Water samples were obtained at various depths at each data collection range throughout the data collection period for determination of sediment-concentration profiles, as described in the previous section. These samples were obtained to determine background sediment levels during the periods of no navigation traffic and to determine changes in sediment levels following a vessel passage.

Laboratory Analysis of Water Samples for Suspended-Sediment Concentrations

The individual water samples collected during the intensive field effort were analyzed for sediment content in the laboratory at the U.S. Army Engineer Waterways Experiment Station (WES). The analysis techniques used are described in the Laboratory Equipment and Sample Analysis section of Appendix A.

Boat Procedures

Global position system (GPS) equipment on each data collection boat were used to monitor the data collection boat position at the start and end of each transect and the water sample collection points. At each of the data collection ranges, the assigned boat moved into position using the same GPS starting point for the respective transect, initialized the ADCP, and slowly traversed the transect. The data at each transect were obtained hourly whenever possible. Along each transect, the boat position, current speed, direction, and depth data were recorded electronically via computer. After traversing the data collection transect, the boat returned to predetermined locations along each transect where the water samples were obtained for later analysis of suspended-sediment concentrations.

River-Bottom Sediment Sampling

Sediments from the river bottom were obtained at each of the OBS sensor data collection platform deployments both for calibration of the OBS sensors and for riverbed sediment material characterization. Samples were obtained by using a push core sampler as described in Appendix A.

Laboratory Analysis of Bottom-Sediment Samples for Sediment Characterization

The individual bottom material samples collected during the data collection periods were analyzed for sediment characterization in the laboratory at WES. The analysis techniques used are described in the Laboratory Equipment and Sample Analysis section of Appendix A.

3 Data Presentation

ADCP Velocity and Direction Profile Measurements

Plates 9-14 are representative time history plots of the ADCP velocity and direction data obtained during the data collection periods. The orientations of the directions of flow in the plots are all downstream. The left and right sides of the plots are the left- and right-descending banks, respectively. The flow directions were 90 deg to the orientation of the range.

Maximum magnitudes of velocities within the main river ranged from 0.20 to 1.16 m/sec. It should be noted that these magnitudes are for the background (no river traffic effects) levels near the channel of the main river. With the exception of those ranges positioned in the inlets to the backwater or side channels, no ADCP velocity measurements were made in the remote off-channel areas (back-water and side channels). The observed maximum velocity magnitudes for the ADCP measurements are summarized below:

Main River Channel Maximum ADCP Velocity Magnitude, m/sec					
Location	Date	R1.0	R2.0	R3.0	R5.0
Pool 8	10/95	1.04	N/A	1.07	N/A
	09/96	0.22	N/A	0.7	N/A
Pool 26	11/95	1.13	N/A	N/A	1.13
	07/96	1.16	N/A	N/A	1.13
	09/96	0.55	N/A	N/A	0.79
La Grange	07/96	N/A	0.79	0.76	0.85
	09/96	N/A	0.49	0.52	0.52
N/A = not a main river channel velocity range location.					

Significant discharges existed during the October-November 1995 data collection effort at Pools 8 and 26. All the monitored flows for Pools 26 and La Grange are below the 50-percent duration flow and therefore do not reflect the full range of high, medium, and low flows. Discharges over the entire study period ranged from 248 to 1,438 cu m/sec. No significant eddies or unusual flow patterns were observed at any of the data collection ranges.

Fixed-Depth Velocity Measurements

Representative time histories of the fixed-depth velocity meter recordings during the data collection periods illustrating tow passage events and the effects on the current magnitudes near the channel boundary limit in the main river and the off-channel monitoring locations are shown in Plates 15-30. Average magnitudes of current speeds within the channel borders of the main river ranged from 0.10 to 0.47 m/sec. It should be noted that these magnitudes are for the background (prior to a river traffic event) levels near the channel of the main river. Average magnitudes of current speeds within the off-channel areas (backwater and side channels) ranged from 0.10 to 0.60 m/sec. The observed maximum and average velocity magnitudes for the fixed-depth current meters from each data collection site are summarized in the Tables 2-5.

Direction of travel, loading, and barge configurations play a part in the overall effect of changes in velocity magnitude and flow direction. Upbound tows and downbound tows passing within close proximity to the current meters in the main river create totally different effects on velocity readings. Upbound tows have a tendency to increase the longitudinal velocity magnitude near the channel border, whereas downbound tows will have the opposite effect. Loaded tows that are upbound were observed to increase the longitudinal velocities near the channel border by a factor of 2 in wide channels, such as Pool 26, and by a factor of as much as 4 in narrow channels, such as La Grange Pool. The decrease in velocities caused by downbound loaded barges within the narrow channels were accompanied with a change in flow direction that ranged from 180 to 200 deg. Plate 24 illustrates the effects of both a downbound and upbound towboat. From Table 10, the direction of travel and time of arrival of the boats at Range 5 can be determined. The upbound vessel (Boat B04) arrived at 10:16 a.m., and the downbound vessel (Boat B05) arrived at 11:00.

The observed net increase or decrease in velocity magnitudes is relatively short term in duration, depending on the length of the entire vessel and the time required to pass the instrument location. The duration of the changes in velocity magnitudes and flow direction ranged from 1.5 min to 5 min.

Velocity instruments located in the off-channel areas displayed varied effects due to the tow passage, from no effect at all to slight changes in background velocity magnitudes. The most significant effect was observed in the off-channel areas in the La Grange Pool study area. Plates 27-30 represent tow passage effects in a small tributary (low-flow outfall slough) and a side channel around an island, respectively.

Water-Surface Waves and Drawdown Measurements

The variation of water-surface waves due to wind and navigation traffic observed during the various data collection efforts is shown in the representative time history plots (Plates 31-44).

The values of maximum wave height for upbound and downbound vessels did not differ significantly. The range of maximum wave heights from barge traffic varied between 0.06 and 0.12 m. The largest wave heights observed (0.24 - 0.30 m) were produced by recreational boat traffic on the Illinois River and are shown in Plate 44. The maximum measured drawdown produced by passing barge traffic, 0.2 m, occurred in the main channel at the La Grange Pool study area. The combination of the narrow channel width and shallow depth at the study site contributed to the significance of the drawdown effect.

The data from the water-level recorders in the main river were used as a reference for comparison with the data from the other off-channel locations in order to estimate water-level differences between the main river and off-channel reaches of the study areas. This comparison illustrated that minimum wave effects were observed in the off-channel areas at all the study sites ranging from 0.0 to 0.02 m. Plates 6 and 7 illustrate the most notable effects, which were measured in a side-channel location (Sugar Creek Island) on the Illinois River near ranges R4 and R5. Physically, this side channel was relatively short in length, in close proximity to the main channel, and connected to the main river at both ends. The maximum recorded drawdown in this side channel was 0.14 m as shown in Plate 42. Maximum wave heights in the side channel during tow passage were less than 0.05 m. The maximum wave heights observed in the off-channel monitoring locations due to vessel traffic on the main river ranged from no change above background level to 0.06 m. During the study periods, no sustained winds occurred that could produce significant wind waves.

Suspended-Sediment Concentration Measurements

General observations on the suspended-sediment concentrations for both background data and changes due to navigation traffic through the study areas indicated some general trends occurring. Plates 45-89 are typical representative plots of suspended-sediment levels during background observations and increases during barge-tow events. The observed mean background suspended-sediment concentrations for the data collection periods ranged from 19.9 to 225 and 19.9 to 135 mg/L for the main channel and off-channel monitoring locations, respectively.

Following tow passage events, the increases in suspended-sediment concentrations in the main river ranged from no change above background levels to 400 mg/L. Pulsing of the sediment plume after a tow passage, particularly a loaded tow in the upbound direction, was found to occur at all three sites. This pulsing can be defined by sharply increasing and decay of sediment-concentration levels followed by multiple smaller increases and decays. The pulses following the tow passage may exist in the main river channel for periods of time varying from 20 to 60 min before suspended-sediment concentrations return to ambient levels. An example of this is shown in Plates 78-80.

In the off-channel monitoring locations, the changes in suspended-sediment concentrations ranged from no increase above background levels to 330 mg/L. In general, suspended-sediment concentration values at the profile locations within the backwater inlets connected to the main river indicate no significant increases due to tows passing the inlets to the off-channel areas. The majority of sediments resuspended by the navigation traffic appeared to remain in the main river channel. The Sugar Creek Island side channel entrance site, La Grange Pool, experienced some of the most significant responses due to tow passage as shown in Plates 84-86. A significant increase in suspended-sediment concentration level in the near-surface measurement zone generally occurred following an upbound tow passage. Downbound tows did not raise the concentrations above the measured background levels. These increases, however, also displayed some of the pulsing characteristics discussed earlier. These high levels of suspended sediment could possibly be due to a combination of the sediment plume from the passing vessel and the resuspension of nearshore sediments from the vessel drawdown and waves.

Grain-Size Distribution of Bottom Materials

In addition to suspended-sediment concentration, bottom-material sediment samples were analyzed to determine representative ranges of grain sizes typical of both the main river channels and off-channel locations in each study area. All samples were composed of medium to fine sand, silt, and clay. The La Grange Pool samples from the main river contained some shell and fragments. The median diameter (d_{50}) grain size of bed material for the Mississippi River in Pool 26 ranged from 0.38 to 0.58 mm and from 0.16 to 0.50 mm within the main channel and off-channel locations, respectively. For Pool 8 of the Mississippi River, the d_{50} grain size of bed material ranged from 0.43 to 0.48 and 0.26 to 0.46 mm within the main and off-channel locations, respectively. La Grange Pool main channel bed material d_{50} grain sizes ranged from 0.07 to 0.42 mm, whereas, the off-channel bed material d_{50} grain size ranged from 0.08 to 0.18 mm. Plates 90-96 are representative gradation curves of the bed material for each study area.

Vessel Traffic Characteristics

Tables 6-12 present the field observations made of navigation vessel characteristics from each of the data collection sites. The information includes the total number of barge-tows that transited each site, loading, configuration of barges, estimated length, direction of travel, vessel speed, sailing line, and vessel identification. A total of 69 vessel traffic events were recorded during the various trips to the study sites. Vessels during the study periods varied from small recreational vessels to large tow configurations of three barges wide by five long.

4 Summary

The data presented herein were collected from the intensive data collection survey of the UMR-IWW study areas in Pool 8, Pool 26, and La Grange. The following observations were made:

a. Maximum magnitudes of ambient velocities within the main river at the ADCP transects ranged from 0.20 to 1.16 m/sec.

b. Average magnitudes of ambient velocities from the fixed-depth velocity meters within the channel borders of the main river ranged from 0.10 to 0.47 m/sec. Average magnitudes of ambient velocities at the off-channel monitoring locations (backwater and side channels) ranged from 0.10 to 0.60 m/sec.

c. Direction of travel, loading, and barge configurations play a part in the overall effect of changes in velocity magnitude and flow direction. Upbound tows caused an increase of the longitudinal velocity magnitude near the channel border, whereas downbound tows had the opposite effect. Loaded tows navigating in the upbound direction increased the longitudinal velocities near the channel border by a factor of 2 in wide channels, such as Pool 26, and by a factor of as much as 4 in narrow channels, such as La Grange Pool. The decrease in velocities caused by downbound loaded barges within the narrow channels were accompanied with a change in flow direction that ranged from 180 to 200 deg. The observed net increase or decrease in velocity magnitudes is relatively short term in duration ranging from 1.5 to 5 min.

d. The values of maximum wave height for upbound and downbound vessels did not differ significantly. The range of maximum wave heights from barge traffic varied between 0.06 and 0.12 m. The largest wave heights observed (0.24 to 0.30 m) were produced by recreational boat traffic on the Illinois River at the La Grange study site. The maximum measured drawdown produced by passing barge traffic, 0.12 m, occurred in the main channel at the Pool 8 and La Grange Pool study areas. The maximum wave heights observed in the off-channel monitoring locations due to vessel traffic on the main river ranged from no change above background level to 0.06 m. During the study periods, no sustained winds occurred that could produce significant wind waves.

e. The observed mean background suspended-sediment concentrations for the data collection periods ranged from 19.9 to 225 and 19.9 to 135 mg/L for the main channel and off-channel monitoring locations, respectively. Following tow passage events, increases in suspended-sediment concentrations in the main river ranged from no change above background levels to 400 mg/L. In the off-channel monitoring locations, the changes in suspended-sediment concentrations ranged from no change above background levels to 330 mg/L. Suspended-sediment concentration values at the profile locations within the main river indicate that no significant increases in the suspended-sediment concentrations were found to enter the off-channel areas for the majority of the sites visited. The majority of sediments resuspended by the navigation traffic remained in the main channel carried by the flow within the river.

f. Pulsing of the sediment plume after a tow passage, particularly a loaded tow in the upbound direction, was found to occur at all three sites. The pulses following the tow passage may exist in the main river channel for periods of time varying from 20 to 60 min before suspended-sediment concentrations return to ambient levels.

g. A significant increase in suspended-sediment concentration level in near-surface measurement zone generally occurred following an upbound tow passage. Downbound tows did not raise the concentrations above the measured background levels. These high levels of suspended sediment could possibly be due to a combination of the sediment plume from the passing vessel and the resuspension of nearshore sediments from the vessel drawdown and waves.

h. A total of 69 vessel traffic events were recorded during the various trips to the study sites. Vessels during the study periods varied from small recreational vessels to large tow configurations of three barges wide by five long.

Table 1
Equipment Location

Date	Range	Instrument	ID/Serial Number	Position[1] X	Position[1] Y
			Pool 8		
November 1995	1	OBS sensor	Unit 3	3352520	623943
		Current meter	0205	3352556	623922
		Wave gauge	10346	3352635	624015
	2	OBS sensor	Unit 1	3353276	622184
		Current meter	0183	3353345	622084
	3	OBS sensor	Unit 2	3352051	618591
		Current meter	0157	3352039	618675
		Wave gauge (small boat survey)	10346	3351999	618337
		Wave gauge	10349	3352070	618324
		Wave gauge	10350	3352120	618314
	4	OBS sensor	Unit 7	3351609	616262
		Current meter	0224	3351836	616045
	5	OBS sensor	Unit 8	3355621	620551
		Current meter	0309	3351266	620427
		Wave gauge	10347	3355559	620761
	6	OBS sensor	Unit 4	3356092	616173
		Current meter	0095	3356117	616278
		Wave gauge	10348	3355957	616141
	7	OBS sensor	Unit 6	3352695	619954
	8	OBS sensor	Unit 5	3352812	618251
September 1996	1	OBS sensor	Unit 3	3352455	623993
		Current meter	0095	3352455	623993
		Wave gauge	10346	3352635	624015
	2	OBS sensor	Unit 1	3353359	622016
		Current meter	0224	3353359	622016
	3	OBS sensor	Unit 2	3615189	626277
		Current meter	0298	3615189	626277

(Sheet 1 of 5)

[1]Pool 8 positions are NAD 83 State Plane Zone 2203, U.S. foot.
Pool 26 positions are NAD 83 State Plane Zone 2401, U.S. foot.
La Grange Pool positions are NAD 83 State Plane Zone 1202, U.S. foot.

Table 1 (Continued)

Date	Range	Instrument	ID/Serial Number	Position X	Position Y
		Wave gauge	10349	3611589	626277
	4	OBS sensor	Unit 7	3351637	615795
		Current meter	0157	3351637	615795
	5	OBS sensor	Unit 8	3355745	620517
		Current meter	0309	3355745	620517
		Wave gauge	10347	3355560	620762
	6	OBS sensor	Unit 4	3356201	616407
		Current meter	0205	3356201	616407
		Wave gauge	10348	3355948	616179
	7	OBS sensor	Unit 6	3352695	619955
	8	OBS sensor	Unit 5	3352813	618250
Pool 26					
November 1995	1	OBS sensor	Unit 1	799662	1105880
		Current meter	0183	799596	1106011
		Wave gauge	10350	799733	1105880
	2	OBS sensor	Unit 4	802475	1103000
	3	OBS sensor	Unit 7	808730	1105949
		Current meter	0224	808692	1106333
		Wave gauge	10346	808781	1105964
	4	OBS sensor	Unit 8	815323	1110572
		Current meter	0095	815450	1110181
		Wave gauge	10349	814953	1110525
	5	OBS sensor	Unit 3	814338	1115025
		Current meter	0157	814288	1114867
	7	OBS sensor	Unit 2	819476	1118666
		Current meter	0309	819523	1118795
		Wave gauge	10348	819373	1118685
	8	OBS sensor	Unit 6	823581	1127298
	9	OBS sensor	Unit 5	824485	1130368
		Current meter	0205	824399	1130232
		Wave gauge	10347	824643	1129867

(Sheet 2 of 5)

Table 1 (Continued)					
				Position	
Date	Range	Instrument	ID/Serial Number	X	Y
July 1996	1	OBS sensor	Unit 1	800042	1105547
		Current meter	0183	800050	1105673
		Wave gauge	10347	800050	1105673
	2	OBS sensor	Unit 4	802412	1103118
	3	OBS sensor	Unit 7	808820	1106048
		Current meter	0205	808800	1106040
		Wave gauge	10346	808504	1106351
	4	OBS sensor	Unit 8	815462	1098458
		Current meter	0095	815500	1110670
		Wave gauge	10349	815464	1110193
	5	OBS sensor	Unit 3	814674	1115353
		Current meter	0224	814674	1115353
	7	OBS sensor	Unit 2	819487	1118410
		Current meter	0205	819508	1118550
		Wave gauge	10348	819339	1118489
	8	OBS sensor	Unit 6	823527	1127188
	9	OBS sensor	Unit 5	824554	1130629
		Current meter	0309	824554	1130629
		Wave gauge	10350	824633	1129920
September 1996	1	OBS sensor	Unit 1	800041	1105547
		Current meter	0095	800050	1105673
		Wave gauge	10346	800000	1105490
	2	OBS sensor	Unit 4	802412	1103118
	3	OBS sensor	Unit 7	808820	1106048
		Current meter	0224	808840	1106000
		Wave gauge	10348	808504	1106351
	4	OBS sensor	Unit 8	815462	1098458
		Current meter	0183	815501	1110671
		Wave gauge	10347	815464	1110193

(Sheet 3 of 5)

Table 1 (Continued)

Date	Range	Instrument	ID/Serial Number	Position X	Position Y
	5	OBS Sensor	Unit 3	814674	1115353
		Current meter	0205	814604	1115300
	7	OBS sensor	Unit 2	819487	1118410
		Current meter	0157	819508	1118550
		Wave gauge	10349	819339	1118488
	8	OBS sensor	Unit 6	823527	1127189
	9	OBS sensor	Unit 5	824554	1130629
		Current meter	0298	824500	1130600
		Wave gauge	10350	824633	1129920
La Grange Pool					
July 1996	1	OBS sensor	Unit 2	2249314	1261164
		Current meter	0183	2249383	1261154
		Wave gauge	10347	2249314	1261164
	2	OBS sensor	Unit 6	2247109	1261226
		Current meter	0095	2247109	1261226
		Wave gauge	10349	2247109	1261226
	3	OBS sensor	Unit 5	2238067	1256824
		Current meter	0309	2238098	1256962
		Wave gauge	10350	2238067	1256824
	4	OBS sensor	Unit 3	2235018	1249695
		Current meter	0205	2235029	1249730
		Wave gauge	10346	2235018	1249695
	5	OBS sensor	Unit 1	2233803	1245310
		Current meter	0157	2233803	1245310
		Wave gauge	10348	2233803	1245310
September 1996	1	OBS sensor	Unit 2	2249484	1261114
		Current meter	0157	2249484	1261114
		Wave gauge	10347	2249484	1261114
	2	OBS sensor	Unit 6	2247092	1261264
		Current meter	0224	2247092	1261264
		Wave gauge	10349	2247092	1261264

(Sheet 4 of 5)

Table 1 (Concluded)					
				Position	
Date	**Range**	**Instrument**	**ID/Serial Number**	**X**	**Y**
	3	OBS sensor	Unit 5	2238096	1256962
		Current meter	0309	2238096	1256962
		Wave gauge	10350	2238096	1256962
	4	OBS sensor	Unit 3	2234985	1249832
		Current meter	0095	2234985	1249832
		Wave gauge	10346	2234985	1249832
	5	OBS sensor	Unit 1	2233787	1245303
		Current meter	0205	2233787	1245303
		Wave gauge	10348	2233787	1245303
					(Sheet 5 of 5)

Table 2
Data Summary

Location		Pool 8			Pool 26				La Grange	
		11/95	9/96		11/95	7/96	9/96		7/96	9/96
Average Suspended Sediment (Background)										
Main River	mg/L	19.9	19.9		91	91	35		225	135
Off-channel	mg/L	19.9	19.9		91	90	35		135	135
Maximum Suspended Sediment Concentration Following Tow Passage										
Main River	mg/L	*	50-70		96-122	107-114	36-68		250-350	200-400
Off-channel	mg/L	*	*		*	*	*		180-330	190-250
Average Velocity at Each Meter Location (Background)										
Main River	m/sec	0.25-0.40	0.10-0.20		0.20-0.47	0.40-0.47	0.14-0.28		0.21-0.35	0.10-0.23
Off-channel	m/sec	0.10-0.20	0.17-0.18		0.28-0.51	0.49-0.60	0.18-0.25		0.26-0.32	0.10-0.25
Maximum Drawdown Due to Tow Passage										
Main River	m	0.12	0.06		0.06	0.09	0.09		0.12	0.12
Off-channel	m	0.0	0.02		0.0	0.0	0.0		0.0	0.12
Maximum Wave Height Due to Tow Passage										
Main River	m	0.06	0.06		0.12	0.06	0.09		0.04	0.06
Off-channel	m	*	*		0.06	0.06	*		0.04	0.06
Note: * = Not detectable above background data.										

Table 3
Fixed-Depth Velocity Data Summary Pool 8

Meter Location No.	Area of River	Velocity, m/sec			
		10/95		9/96	
		Average	Maximum	Average	Maximum
R1.0	M	0.30	0.37	0.20	0.80
R2.0	M	0.40	0.60	0.10	0.21
R3.0	M	0.25	0.45	0.20	0.45
R4.0	O	0.15	0.21	*	*
R5.0	O	0.42	0.60	0.17	0.24
R6.0	O	0.30	0.45	0.18	0.25

Note: * = No meter deployed at this location; M = Main river; O = Off-channel area.

Table 4
Fixed-Depth Velocity Data Summary La Grange Pool

Meter Location No.	Area of River	Velocity, m/sec			
		7/96		9/96	
		Average	Maximum	Average	Maximum
R1.0	O	0.26	0.49	0.01	0.24
R2.0	M	0.35	0.97	0.15	0.80
R3.0	M	0.35	0.96	0.23	0.82
R4.0	O	0.32	0.80	0.25	0.67
R5.0	O	0.21	0.75	0.10	0.31

Note: * = No meter deployed at this location; M = Main river; O = Off-channel area.

Table 5
Fixed-Depth Velocity Data Summary Pool 26

Meter Location No.	Area of River	Velocity, m/sec					
		11/95		7/96		9/96	
		Average	Maximum	Average	Maximum	Average	Maximum
R1.0	M	0.47	0.59	0.40	0.51	0.24	0.32
R3.0	O	0.51	0.77	0.50	0.77	0.25	0.39
R4.0	O	0.36	0.45	0.60	0.80	*	*
R5.0	M	0.33	0.43	0.47	0.61	0.28	0.42
R7.0	O	0.28	0.35	0.49	0.64	0.18	0.24
R9.0	M	0.20	0.28	*	*	0.14	0.48

Note: * = No meter deployed at this location; M = Main river; O = Off-channel area.

Table 6
Pool 8 - Trip 1 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line m (ft)	Speed from Range 1 to Range 2[1] m/sec (ft/sec)	Speed from Range 2 to Range 4[2] m/sec (ft/sec)	Remarks
1 November 1995								
B01	*Christine Bailey*	Down	R1 R2 R4	15:39:11 15:44:05 15:57:36	NR NR NR	NA	2.3 (7.6)	3 wide/5 long Draft 2.6 m (8.5 ft) Length 344.4 m (1,130 ft) 400 rpm's
2 November 1995								
B02	Day cruiser	Down	R4	08:30:00	NR	NA	NA	Length 9.7 m (32 ft)
B03	Corps survey boat	Up	R4 R2 R1	09:46:46 09:49:24 09:52:02	NR NR NR	4.2 (13.9)	4.0 (13.1)	Draft 1.1 m (3.7 ft) Length 10.7 m (35 ft)
B04	Pleasure craft	Down	R2	11:04:46	NR	6.9 (22.6)	5.8 (19.2)	
B05	*Louis H. Meece*	Up	R4 R2 R1	11:52:37 12:04:59 12:10:00	NR NR NR	NA	2.5 (8.0)	3 wide/5 long 2 front corner barges empty
B06	*Mary H. Morrison*	Up	R4 R2 R1	14:10:56 14:23:59 14:28:56	NR NR NR	NA	2.3 (7.6)	3 wide/4 long Empty Draft 0.9 m (3 ft)

Notes: NR = Data not recorded; NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 1 and 2 = 669.0 m (2,195 ft).
[2]Distance between Ranges 2 and 4 = 1,870.6 m (6,137 ft)

Table 7
Pool 26 - Trip 1 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line[1] m (ft)	Speed from Range 1 to Range 3[2] m/sec (ft/sec)	Speed from Range 3 to Range 5[3] m/sec (ft/sec)	Remarks
8 November 1995								
B01	*Kimberly Ann*	Down	R1 R3	08:55:47 09:06:22	NR NR	3.6 (12.0)	NA	3 wide/5 long Draft 2.7 m (9 ft)
B02	*Greenville*	Up	R5 R3 R1	09:47:10 10:26:44 11:07:38	NR NR NR	1.0 (3.3)	NA	3 wide/5 long Empty/1 alongside Draft 0.6 (2 ft)
B03	*Marquette*	Down	R1 R3 R5	10:24:20 10:35:32 10:52:22	NR NR NR	3.5 (11.6)	4.7 (15.5)	3 wide/5 long Loaded Draft 2.7 m (9 ft)
B04	Tow	Up	R5 R1	10:54:04 11:10:24	NR NR	2.5 (8.1)	NA	3 barges 2 empty/1 loaded with fuel Draft 2.7 m (9 ft)
B05	*Jim Butry*	Down	R1 R3 R5	10:55:28 11:06:04 11:20:29	NR NR NR	2.5 (8.2)	3.9 (12.7)	1 wide/1 long Loaded Draft 2.7 m (9 ft)
B06	*Jane Huffman*	Up	R5 R3 R1	14:11:00 14:12:00 14:28:26	NR NR NR	2.5 (8.0)	2.2 (7.2)	3 wide/5 long Empty/1 alongside Draft 0.6 m (2 ft)
B07	*Brimstone*	Up	R5 R3 R1	14:20:18 14:33:37 14:42:29	NR NR NR	4.4 (14.5)	6.9 (22.8)	1 wide/1 long Empty Draft 0.6 m (2 ft)

Continued)

Notes: NR = Data not recorded; NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Estimated values from left-descending bank.
[2]Distance between Ranges 1 and 3 = 2,465.5 m (8,089 ft).
[3]Distance between Ranges 3 and 5 = 3,280.3 m (10,762 ft).

Table 7 (Concluded)

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line[1] m (ft)	Speed from Range 1 to Range 3[2] m/sec (ft/sec)	Speed from Range 3 to Range 5[3] m/sec (ft/sec)	Remarks
9 November 1995								
B08	*Kathy Ellen*	Up	R3 R1	07:55:23 08:15:00	274 (900) NR	1.9 (6.4)	NA	3 wide/5 long 1 alongside Little waves Draft 0.6 m (2 ft)
B09	*Roy Claverie*	Up	R5 R3 R1	07:55:23 08:09:45 08:19:31	183 (600) NR NR	4.2 (13.9)	3.8 (12.5)	2 wide/1 long Empty High speed/good waves Draft 0.6 m (2 ft)
B10	*Cecilia Carol*	Down	R1 R3 R5	09:11:00 09:24:04 09:41:51	192 (630) NR NR	3.3 (10.8)	3.1 (10.1)	3 wide/5 long Loaded Little waves Draft 2.7 m (9 ft)
B11	*Bob Stith*	Down	R1 R3 R5	11:15:20 11:26:38 11:42:52	192 (630) NR NR	3.6 (11.9)	3.4 (11.0)	3 wide/5 long Loaded Draft 2.7 m (9 ft)
B12	*Crimson Gem*	Down	R1 R3 R5	13:42:13 13:55:08 14:13:00	305 (1,000) NR NR	3.2 (10.4)	3.1 (10.0)	3 wide/5 long Loaded Draft 2.7 m (9 ft)
B13	*Martha R. Ingram*	Down	R1 R3 R5	16:02:59 16:13:26 16:28:32	305 (1,000) NR NR	3.9 (12.8)	3.6 (11.9)	3 wide/5 long Loaded Draft 2.7 m (9 ft)

Table 8
Pool 26 - Trip 2 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line Northing	Sailing Line Westing	Speed from Range 1 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	Remarks
11 July 1996									
B01	*Gilda Shurden*	Up	R1 R5	08:10:00 07:40:00	38°52'7.5" 38°53'51"	090°34'13.4" 090°31'12"	3.0 (9.8)	3.0 (9.8)	2 wide/1 long Empty/fuel barges Draft 0.6-0.9 m (2-3 ft)
B02	*Kathryn Beesecker*	Up	R5 R1	08:12:50 08:39:00	38°52'7.9" 38°53'52"	090°34'13" 090°31'13"	3.0 (10.0)	2.7 (8.9)	3 wide/5 long Empty/bulk barges Draft 0.3-0.9 m (1-3 ft)
B03	*D. Ray Miller*	Down	R1 R5	13:30:00	38°52'7.4" 38°53'52"	090°34'12.5" 090°31'14"	3.4 (11.0)	3.4 (11.2)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft)
B04	*Martha R. Ingram*	Up	R1 R3 R5	16:02:53 15:46:36 15:22:48	38°52'8.1" 38°53'52"	090°34'9.5" 090°31'13"	2.5 (8.3)	2.2 (7.2)	3 wide/5 long Empty/bulk barges 2 port rear and 2 center rear loaded Draft 0.3-0.9 m (1-3 ft)
B05	*Midwest II*	Up	R1 R3 R5	16:29:38 16:18:00 16:48:02	38°52'8.2" 38°53'52"	090°34'13" 090°31'13"	2.1 (6.9)	1.8 (6.0)	1 wide/3 long Loaded/rock barges Draft 1.8-2.7 m (6-9 ft)
12 July 1996									
B06	Tow	Down	R5	06:20:00	NR	NR	NA	NA	2 wide/2 long Draft 2.7 m (9 ft)
B07	*George King*	Up	R1 R5	06:49:00 06:20:00	38°52'7.3" NR	090°34'14.5" NR	3.0 (9.9)	NA	3 wide/5 long Bulk barges/1 alongside Draft 0.3-0.9 m (1-3 ft)

(Continued)

Notes: NR = Data not recorded; NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 1 and 3 = 2,465.5 m (8,089 ft).
[2]Distance between Ranges 3 and 5 = 3,280.3 m (10,762 ft).

Table 8 (Concluded)									
Boat No.	**Boat Name**	**Direction Bound**	**Range**	**Time of Tow Passage CST**	**Sailing Line**		**Speed from Range 1 to Range 3[1] m/sec (ft/sec)**	**Speed from Range 3 to Range 5[2] m/sec (ft/sec)**	**Remarks**
					Northing	**Westing**			
B08	*Midwest II*	Down	R1 R3 R5	07:08:00 07:16:54 07:28:54	38°52'7.3" 38°53'51"	090°34'14.5" 090°31'13"	5.8 (19.1)	4.5 (14.9)	1 wide/3 long Empty/flat barges Hugged centerline Draft 0.3-0.9 m (1-3 ft)
B09	*Roberta Tabor*	Up	R1 R3 R5	08:07:00 07:53:29 07:35:00	38°52'8.2" 38°53'51"	090°34'11.6" 090°31'14"	2.8 (9.3)	2.5 (8.3)	3 wide/5 long Empty/bulk barges Hugged red buoy Draft 0.3-0.9 m (1-3 ft)
B10	*Prairie Dawn*	Down	R1 R3 R5	09:16:00 09:31:27 09:50:00	38°52'8" 38°53'52"	090°34'11.6" 090°31'14"	2.7 (8.7)	2.8 (9.3)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft)
B11	*J. W. Hershey*	Up	R1 R3 R5	09:18:00 09:00:31 08:37:21	38°52'6.8" 38°53'51"	090°34'14.8" 090°31'13"	2.2 (7.3)	2.4 (7.7)	3 wide/5 long 12 loaded/bulk barges Front 3 empty 1 alongside empty Draft 2.7 m (9 ft)
B12	*Mississippi*	Down	R1 R5	10:14:00 10:30:00	38°52'6.9" 38°53'52"	090°34'14" 090°31'14"	NA	NA	No barges Draft 2.4 m (8 ft)
B13	*Miss Claudette*	Down	R1 R5	10:21:00 10:41:00	38°52'6.9" 38°53'52"	090°34'14" 090°31'14"	NA	NA	No barges Waves 0.3 m (1 ft) Draft 1.8 m (6 ft)
B14	*Hugh Blake*	Down	R1 R3 R5	10:27:00 10:16:53 10:54:00	38°52'6.6" 38°53'52"	090°34'10.8" 090°31'14"	3.7 (12.1)	3.5 (11.3)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft)
B15	*Ann Holly*	Up	R1 R3 R5	13:52:49 13:29:50 12:55:00	38°52'6.2" 38°53'52"	090°34'15.4" 090°31'14"	1.8 (5.8)	1.6 (5.3)	3 wide/5 long Loaded/coal barges Draft 2.7 m (9 ft)
B16	*L. J. Sullivan*	Up	R1 R3 R5	14:09:02 13:50:35 13:24:20	38°52'7.4" 38°53'52"	090°34'13.4" 090°31'14"	2.2 (7.2)	2.1 (6.8)	3 wide/5 long Loaded/coal barges 1 empty alongside Draft 0.9 m (3 ft) on starboard 6 Draft 2.7 m (9 ft) on port 10

Table 9
La Grange Pool - Trip 2 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line		Speed from Range 2 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	Remarks
					Northing	Westing			
15 July 1996									
B01	*Channnahon*	Up	R2 R3 R5	08:26:48 08:00:30 07:38:00	40°07'46.3" 40°05'07"	090°20'40.2" 090°23'30"	2.5 (8.3)	2.3 (7.7)	1 wide/2 long 1 work barge alongside Corps dredge Draft 1.5-2.7 m (5-9 ft)
B02	*W. W. Crum*	Up	R2 R3 R5	09:30:22 09:23:11 09:02:53	40°07'46.3" 40°05'07"	090°20'40.2" 090°23'30"	3.3 (10.8)	3.0 (10.0)	1 wide/2 long Fuel barge Loaded with asphalt Water level dropped 0.3 m (1 ft) Draft 2.7 m (9 ft)
B03	*Logsdon*	Up	R2 R3 R5	10:50:40 10:31:40 10:12:14	40°07'46.3" 40°05'07"	090°20'40.2" 090°23'30"	3.0 (9.8)	2.6 (8.6)	2 wide/1 long Crane barge/2 push boats Draft 0.9-1.8 m (3-6 ft)
16 July 1996									
B04	*City of Huntington*	Down	R2 R3 R5	07:42:52 08:16:33 08:55:00	40°07'47.2" 40°05'07"	090°20'40.2" 090°23'30"	1.7 (5.5)	1.7 (5.7)	3 wide/5 long Half loaded Draft 0.6 m (2 ft) for front 10 Draft 2.7 m (9 ft) for back 5
B05	*Orleanian*	Down	R2 R3 R5	14:36:20 14:56:22 14:32:58	40°07'46.7" 40°05'07"	090°20'40.2" 090°23'30"	2.8 (9.2)	2.6 (8.7)	2 wide 3 wide/2 long 8 loaded/5 empty Draft 0.9 m (3 ft) for front 2 Draft 2.7 m (9 ft) for back 6
B06	*Larry Tilley*	Up	R2 R3 R5	16:32:00 16:12:38 15:48:00	40°07'47.4" 40°05'07"	090°20'39.3" 090°23'30"	2.8 (9.3)	2.5 (8.3)	1 wide/2 long Draft 2.7 m (9 ft)
B07	40-ft cruiser	NA	R2	16:46:00	NR	NR	NA	NA	Major erosion

Notes: NR = Data not recorded; NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 2 and 3 = 3,393.6 m (11,134 ft).
[2]Distance between Ranges 3 and 5 = 3,705.1 m (12,156 ft).

Table 10
Pool 26 - Trip 3 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line Northing	Sailing Line Westing	Speed from Range 1 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	Remarks
5 September 1996									
B01	*Shirley Stapp*	Up	R5 R3 R1	07:37:21 07:53:36 08:05:09	38°53'34.2" 38°52'8.6"	090°31'14.4" 090°34'14.5"	3.6 (11.8)	3.4 (11.1)	1 wide/3 long Loaded/fuel barges Draft 2.7 m (9 ft)
B02	*Susan Ponther*	Up	R5 R3 R1	12:16:37 12:33:34 12:47:13	38°53'34.2" 38°52'7.3"	090°31'14.4" 090°34'14.1"	3.0 (9.9)	3.2 (10.6)	1 wide/3 long Loaded/fuel barges Draft 2.7 m (9 ft)
6 September 1996									
B03	*Nora Pickett*	Up	R1 R3 R5	 06:46:00 	38°52'10.4" NA NA	090°34'14.8" NA NA	NA	NA	1 wide/3 long Fuel flats Draft 0.6 m (2 ft)
B04	*Robin Ingram*	Up	R5 R3 R1	10:16:37 11:15:18 11:31:14	38°53'48.6" 38°52'7.8"	090°31'13.2" 090°34'14.6"	2.6 (8.5)	0.9 (3.1)	2 wide/1 long (front) 3 wide/5 long Tow waited for downbound Loaded - coal/bulk barges Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B05	*Admiral Cockburn*	Down	R1 R3 R5	10:28:22 10:41:46 11:00:49	38°52'8.4" 38°53'50.4"	090°34'13.4" 090°31'13.8"	3.1 (10.1)	2.9 (9.4)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft)
B06	*Enterprise*	Down	R1 R3 R5	10:37:10 10:49:17 11:06:00	38°52'9" 38°53'50.4"	090°34'13.3" 090°31'13.8"	3.4 (11.1)	3.2 (10.6)	2 wide/1 long Empty/fuel barges Draft 0.6 m (2 ft) Length 76.2 (250 ft)

(Continued)

Notes: NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 1 and 3 = 2,465.5 m (8,089 ft).
[2]Distance between Ranges 3 and 5 = 3,280.3 m (10,762 ft).

Table 10 (Concluded)									
				Time of Tow Passage CST	Sailing Line		Speed from Range 1 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	
Boat No.	**Boat Name**	**Direction Bound**	**Range**		**Northing**	**Westing**			**Remarks**
B07	*Dick Harbison*	Up	R5 R3 R1	12:27:03 12:51:20 13:08:24	38°53'52.2" 38°52'7.9"	090°31'11.4" 090°34'14.0"	2.4 (7.9)	2.3 (7.4)	3 wide/5 long 1 alongside Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B08	*Pere Marquette*	Up	R5 R3 R1	13:33:07 13:50:33 14:03:18	38°53'52.8" 38°52'8"	090°31'11.4" 090°34'16.1"	3.2 (10.6)	3.1 (10.3)	1 wide/1 long 2 wide/1 long Loaded/fuel barge 1 bulk/1 fuel Draft 2.7 m (9 ft) Length 152.4 m (500 ft)

Table 11
La Grange Pool - Trip 3 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line Northing	Sailing Line Westing	Speed from Range 2 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	Remarks
9 September 1996									
B01	Yacht	Down	R2	08:43:00	40°07'46.8"	090°20'40.4"	NA	NA	Length 10.7 m (35 ft) Cut back engines
B02	*S. R. Tennessee*	Up	R5 R3 R2	08:57:35 09:35:25 10:06:46	40°05'5.4" 40°07'46.8"	090°23'28.8" 090°20'40.4"	1.8 (5.9)	2.2 (7.3)	2 wide/4 long Loaded Draft 2.6 m (8.5 ft) Length 335.3 m (1,100 ft)
B03	*Midland*	Up	R5 R3 R2	10:09:22 10:52:34 11:29:37	40°05'5.4" 40°07'47"	090°23'28.8" 090°20'39.7"	1.5 (5.0)	1.4 (4.7)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B04	*Jay Luhr*	Up	R5 R3 R2	12:00:50 12:37:04 13:08:06	40°05'5.4" 40°07'46.7"	090°23'28.8" 090°20'40.1"	1.8 (6.0)	1.7 (5.6)	2 wide/2 long 3 wide/3 long Loaded/rock barges Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B05	Yacht	Down	R2	13:47:00	40°07'46.7"	090°20'40.1"	NA	NA	Length 12.2 m (40 ft) Passed wave gauge/current meter
B06	Yacht	Up	R2	13:50:00	40°07'46.7"	090°20'40.1"	NA	NA	Length 10.7 m (35 ft) Centerline Passed wave gauge/current meter
B07	Yacht	Down	R2	14:16:00	40°07'46.7"	090°20'40.1"	NA	NA	Length 12.2 m (40 ft) Centerline Passed wave gauge/current meter

(Continued)

Notes: NA = Not applicable.
Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 2 and 3 = 3,393.6 m (11,134 ft).
[2]Distance between Ranges 3 and 5 = 3,705.1 m (12,156 ft).

Table 11 (Concluded)

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line		Speed from Range 2 to Range 3[1] m/sec (ft/sec)	Speed from Range 3 to Range 5[2] m/sec (ft/sec)	Remarks
					Northing	Westing			
10 September 1996									
B08	Yacht	Down	R2	07:32:00	40°07'46.7"	090°20'40.1"	NA	NA	Length 10.7 m (35 ft) Centerline
B09	*Sheila Johnson*	Up	R5 R3 R2	07:48:23 08:18:16 08:42:46	40°05'7.6" 40°07'46.3"	090°23'30.4" 090°20'40"	2.3 (7.6)	2.1 (6.8)	2 wide/4 long 1 alongside 5 empty/bulk barges Draft 0.6 m (2 ft) 4 loaded/fuel barges Draft 2.7 m (9 ft) Length 274.3 m (900 ft)
B10	*Stephen Joseph*	Down	R2 R3 R5	10:55:37 11:22:48 11:51:10	40°07'46.3" 40°05'7.6"	090°20'39.8" 090°23'30.4"	2.1 (6.8)	3.4 (11.1)	2 wide/4 long 7 bulk barges 4 loaded Draft 2.7 m (9 ft) Length 274.3 m (900 ft)
B11	Yacht	Down	R2	14:13:00	40°07'46.3"	090°20'40"	NA	NA	Centerline
B12	*Dell Butcher*	Up	R5 R3 R2	15:49:01 16:25:20 16:52:41	40°05'7.6" 40°07'47.3"	090°23'30.4" 090°20'38.6"	2.1 (6.8)	1.7 (5.6)	3 wide/3 long Outside 6 empty Draft 0.6 m (2 ft) Inside 3 loaded/coal barges Draft 2.7 m (9 ft) Length 213.4 m (700 ft)

Table 12
Pool 8 - Trip 3 - Boat Passages

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line Northing	Sailing Line Westing	Speed from Range 1 to Range 2[1] m/sec (ft/sec)	Speed from Range 2 to Range 4[2] m/sec (ft/sec)	Remarks
13 September 1996									
B01	*Dick Harbison*	Up	R4 R2 R1	10:25:13 10:41:21 10:46:58	43°45'19.8" 43°46'38.8"	091°15'7.8" 090°14'43"	2.0 (6.5)	1.9 (6.3)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B02	*Bruce R. Birmingham*	Up	R4 R2 R1	12:04:04 12:17:32 12:22:24	43°45'19.8" 43°46'40.7"	091°15'7.8" 090°14'46.4"	2.3 (7.5)	2.3 (7.6)	3 wide/5 long 10 empty Draft 0.6 m (2 ft) 5 loaded Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
14 September 1996									
B03	*Phyllis*	Down	R1 R2 R4	07:41:34 07:47:21 08:03:36	43°46'41.6" 43°45'19.8"	090°14'45.8" 091°15'7.8"	1.9 (6.3)	2.2 (7.3)	3 wide/5 long Loaded/bulk barges Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B04	*Teresa Renee Beesecker*	Down	R1 R2 R4	10:30:10 10:34:31 10:48:36	43°46'42" 43°45'19.8"	090°14'44" 091°15'7.8"	2.6 (8.4)	2.2 (7.3)	3 wide/5 long 12 empty Draft 0.6 m (2 ft) 3 loaded Draft 2.7 m (9 ft) Length 335.3 m (1,100 ft)
B05	*Roy E. Claverie*	Down	R1 R2 R4	12:35:42 12:38:59 12:49:45	43°46'40.9" 43°45'19.8"	090°14'44.9" 091°15'7.8"	3.4 (11.1)	2.9 (9.5)	3 wide/4 long Bulk barges Draft 2.7 m (9 ft) Length 274.3 m (900 ft)

(Continued)

Note: Multiply m/sec by 1.9438 to convert to knots.
[1]Distance between Ranges 1 and 2 = 669.0 m (2,195 ft).
[2]Distance between Ranges 2 and 4 = 1,870.6 m (6,137 ft).

Table 12 (Concluded)

Boat No.	Boat Name	Direction Bound	Range	Time of Tow Passage CST	Sailing Line		Speed from Range 1 to Range 2[1] m/sec (ft/sec)	Speed from Range 2 to Range 4[2] m/sec (ft/sec)	Remarks
					Northing	Westing			
B06	*John Manning*	Down	R1 R2 R4	12:46:05 12:49:58 13:02:20	43°46'39.1" 43°45'19.8"	090°14'46.3" 091°15'7.8"	2.9 (9.4)	2.5 (8.3)	1 long/spud barge Draft 2.7 m (9 ft) Length 45.7 m (150 ft)
B07	*Sir Randy J*	Down	R1 R2 R4	13:30:16 13:33:43 13:44:00	43°46'40.6" 43°45'19.8"	090°14'46.5" 091°15'7.8"	3.2 (10.6)	3.0 (9.9)	2 wide/3 long Empty Draft 0.6 m (2 ft) Length 198.1 m (650 ft)

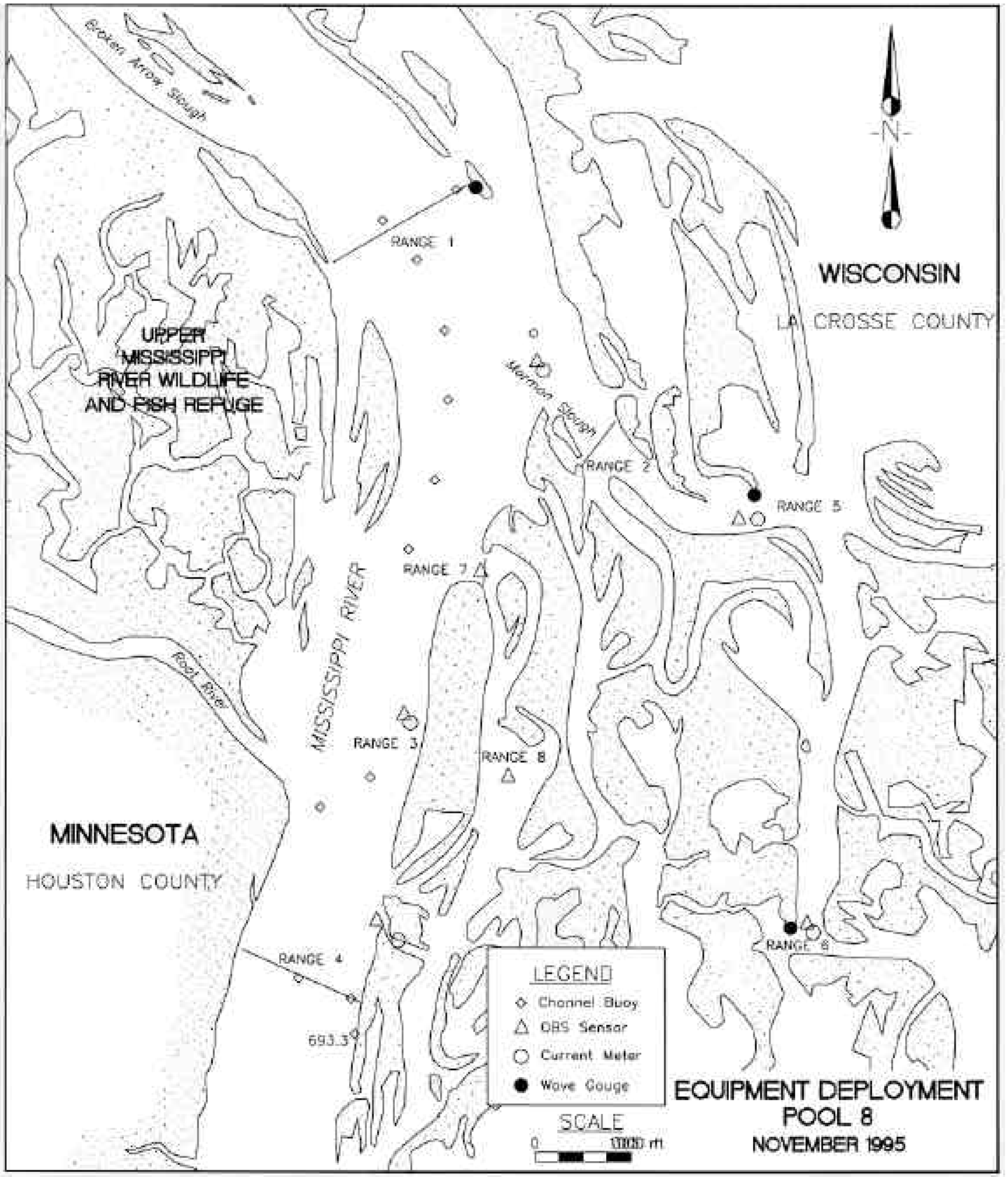

Broken Arrow Slough
RANGE 1
WISCONSIN
LA CROSSE COUNTY
UPPER MISSISSIPPI RIVER WILDLIFE AND FISH REFUGE
Mormon Slough
RANGE 2
RANGE 5
RANGE 7
MISSISSIPPI RIVER
Root River
RANGE 3
RANGE 8
MINNESOTA
HOUSTON COUNTY
RANGE 4
693.3
RANGE 6
LEGEND
Channel Buoy
OBS Sensor
Current Meter
Wave Gauge
SCALE
0
1000 ft
EQUIPMENT DEPLOYMENT
POOL 8
NOVEMBER 1995
N

Plate 1

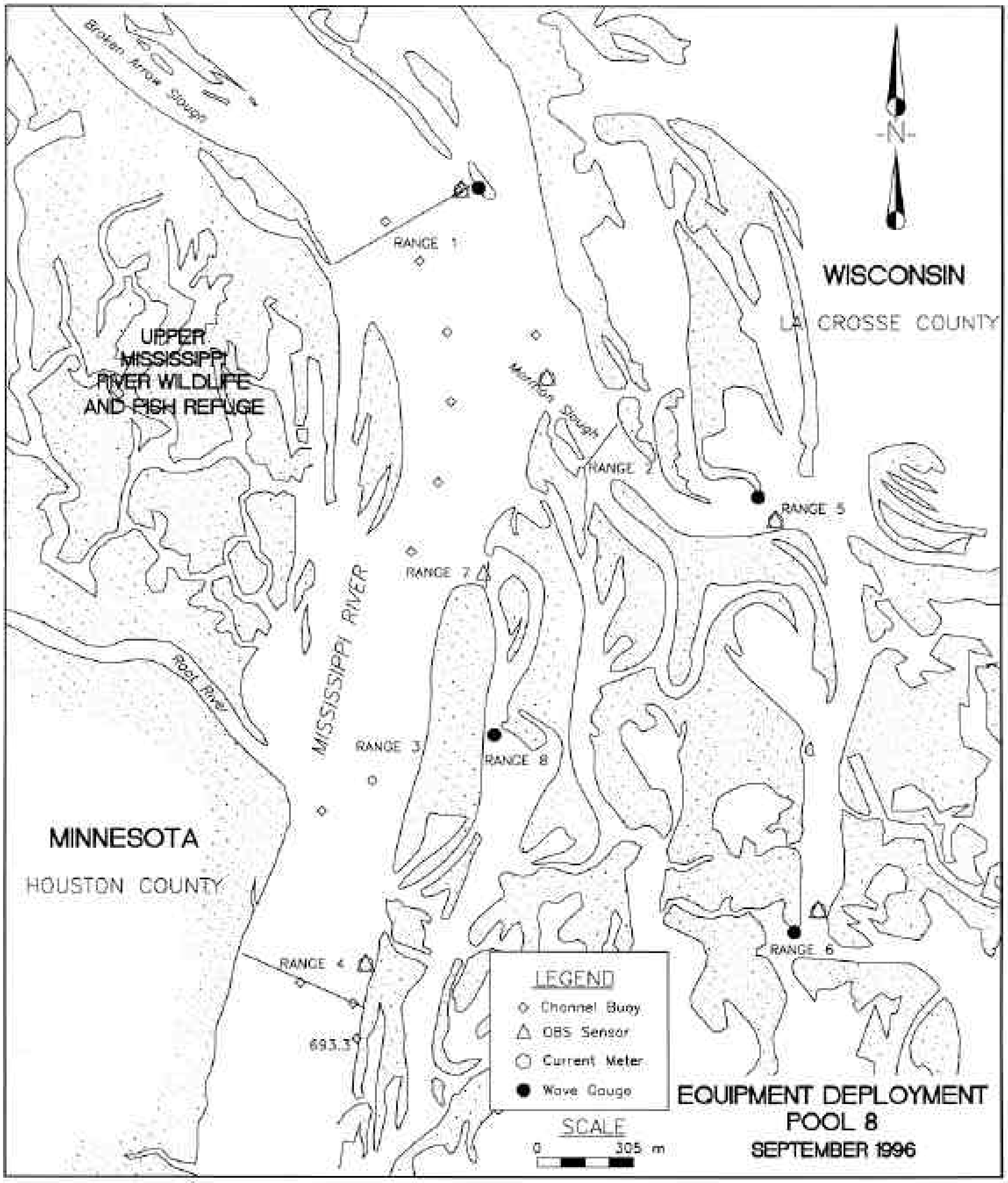
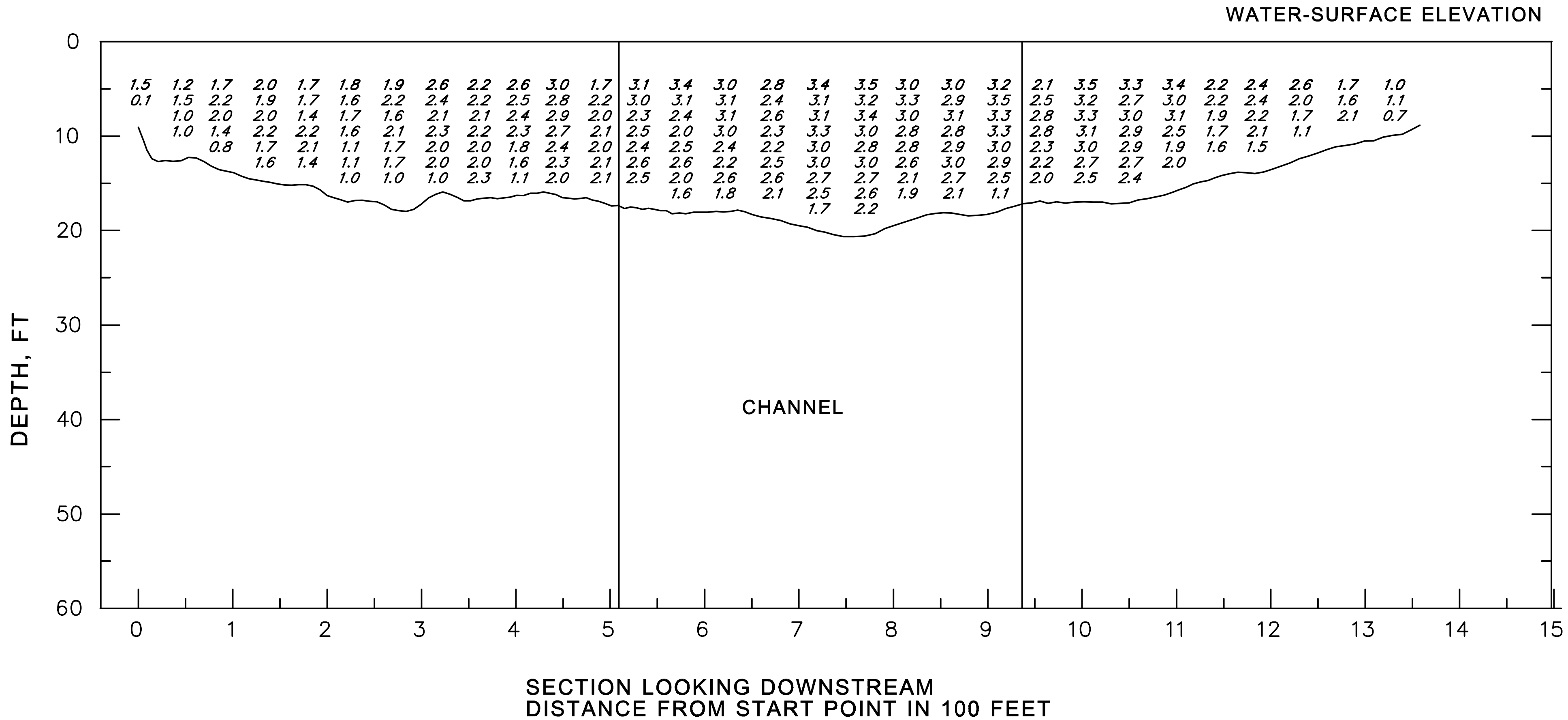
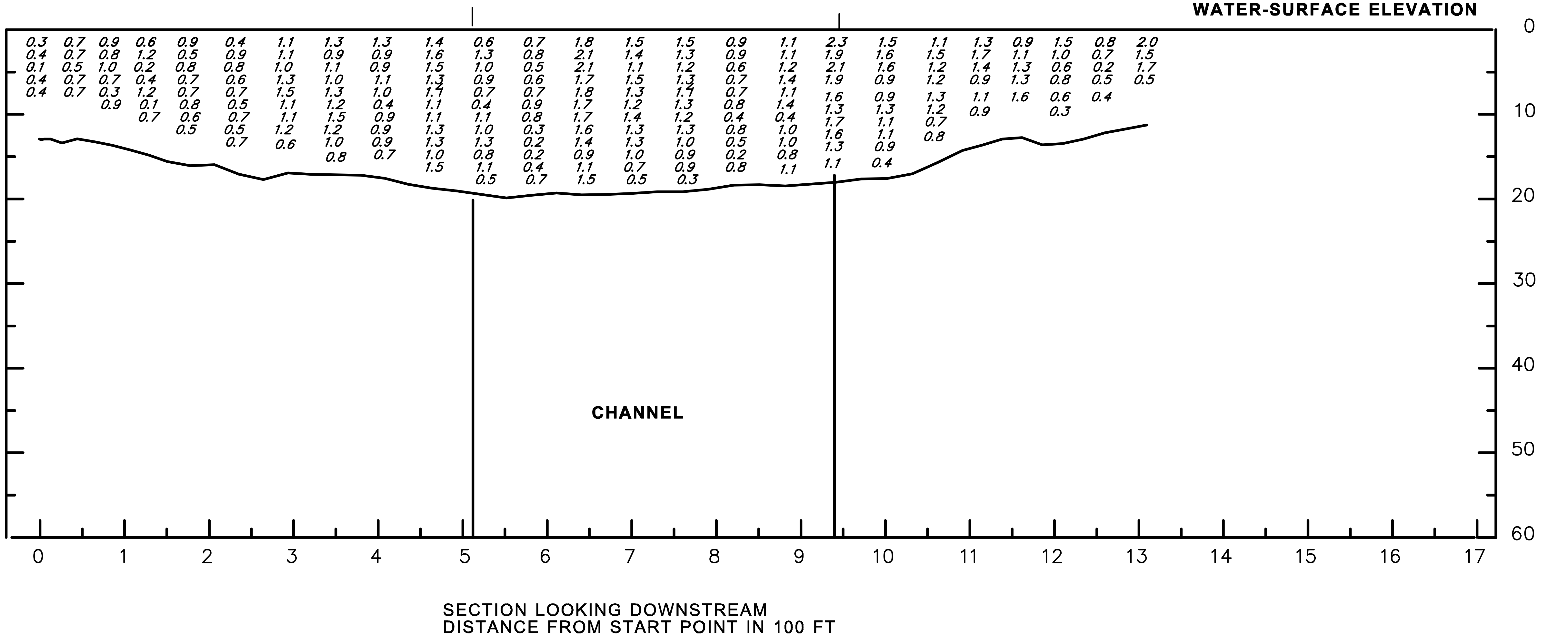

Broken Arrow Slough
RANGE 1
WISCONSIN
LA CROSSE COUNTY
UPPER MISSISSIPPI RIVER WILDLIFE AND FISH REFUGE
Morrison Slough
RANGE 2
RANGE 5
RANGE 7
MISSISSIPPI RIVER
Root River
RANGE 3
RANGE 8
MINNESOTA
HOUSTON COUNTY
RANGE 4
RANGE 6
693.3
LEGEND
Channel Buoy
OBS Sensor
Current Meter
Wave Gauge
SCALE
0
305 m
EQUIPMENT DEPLOYMENT
POOL 8
SEPTEMBER 1996

Plate 2



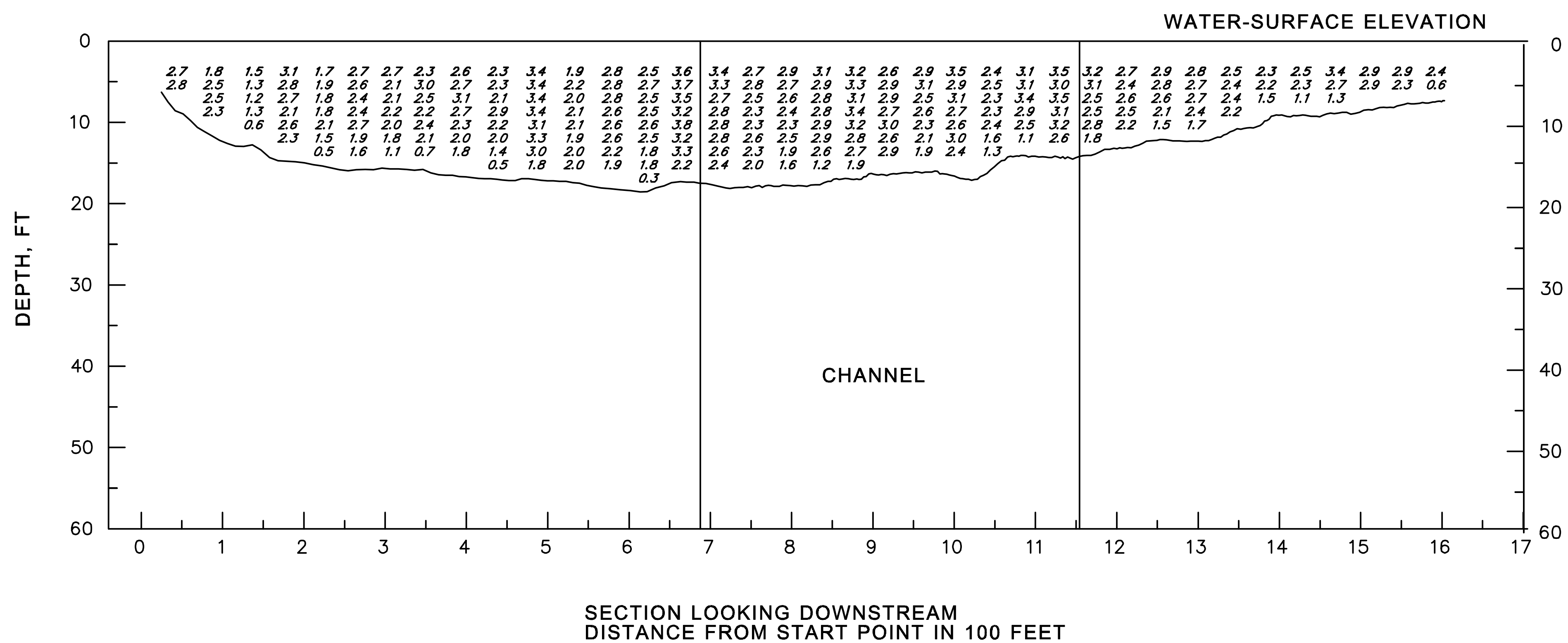
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES, AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT TO METERS MULTIPLY BY 0.3048.

COMPOSITE VELOCITIES
POOL 8, NOVEMBER 1995
RANGE 3
DISCHARGE = 1,331 cu m/sec, Area = 1,875 m2



NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT TO METERS MULTIPLY BY 0.3048

COMPOSITE VELOCITIES
POOL 8, SEPTEMBER 1996
RANGE 3
DISCHARGE = 449 cu m/sec, AREA = 1,445 m2



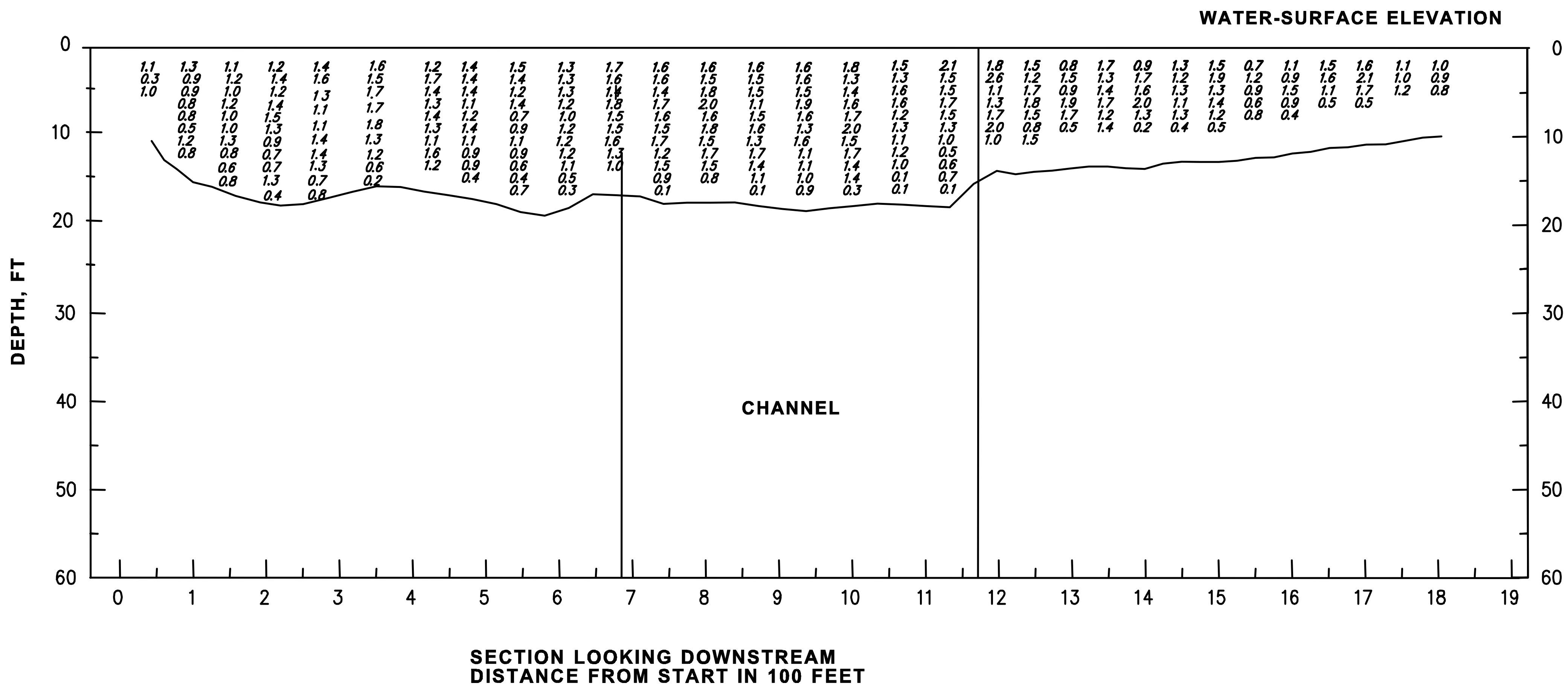
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT TO METERS MULTIPLY BY 0.3048.

COMPOSITE VELOCITIES

POOL 26, NOVEMBER 1995

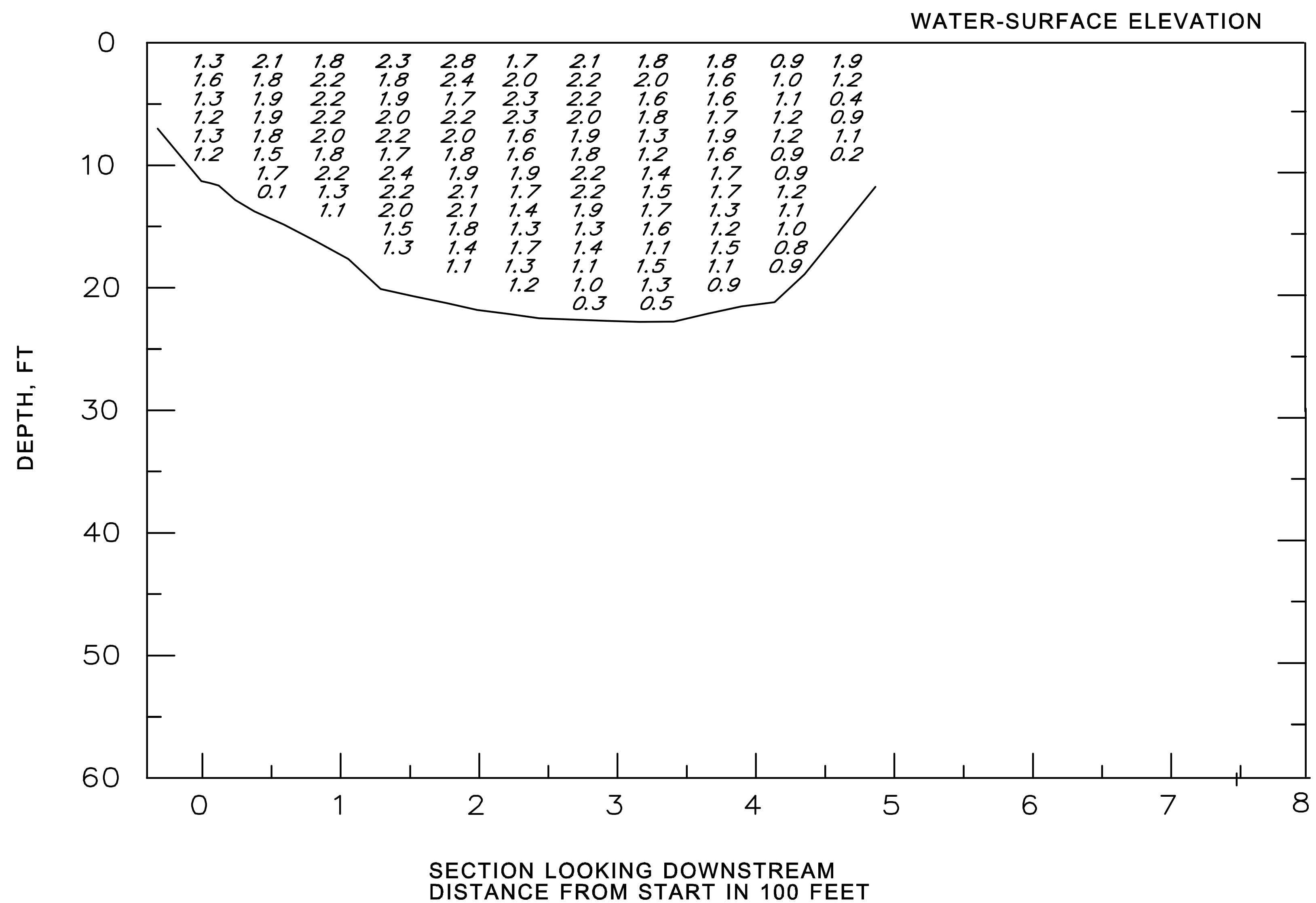
RANGE 5

DISCHARGE = 1483 cu m/sec, AREA = 1,942 m2



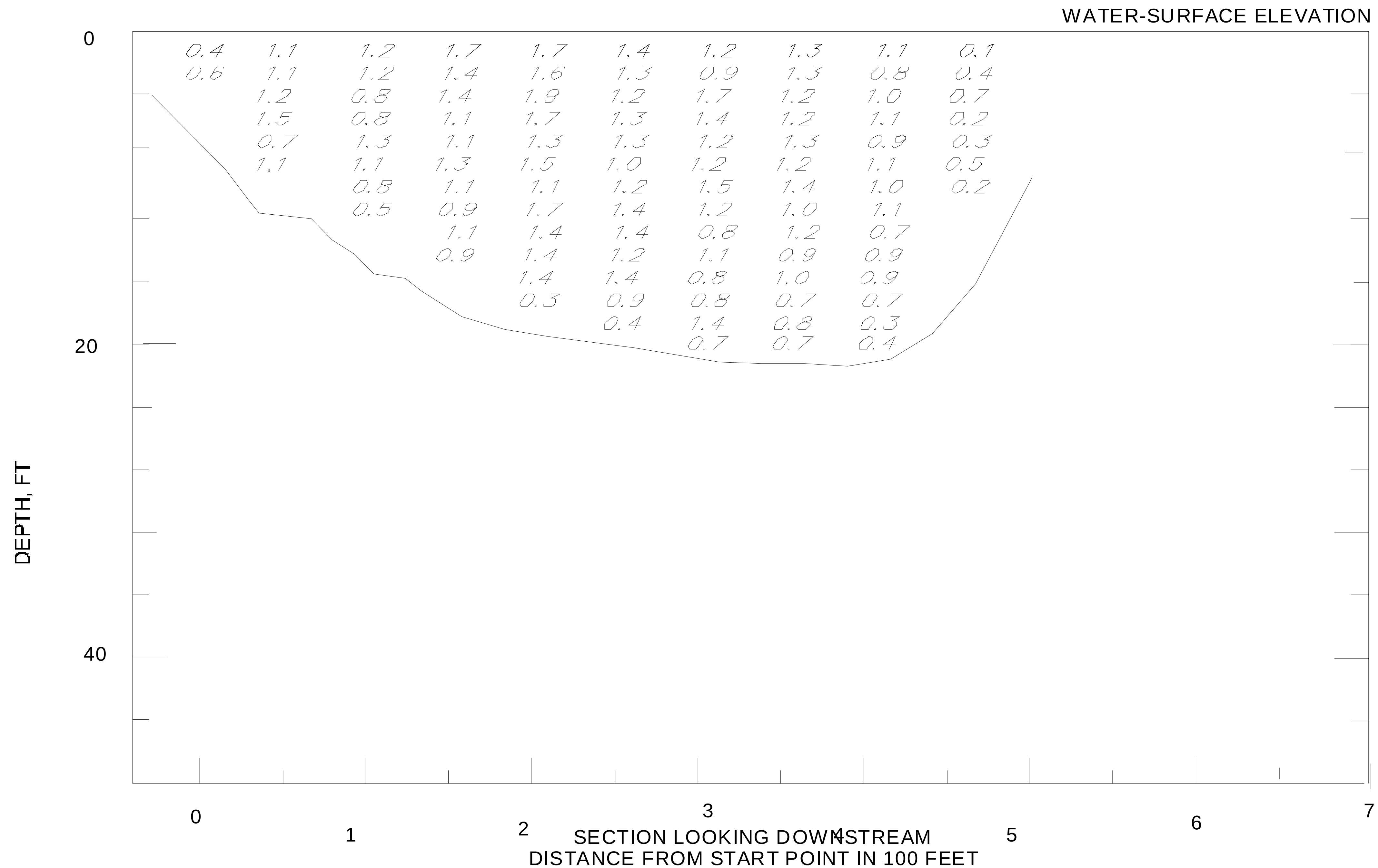
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT TO METERS MULTIPLY BY 0.3048

COMPOSITE VELOCITIES
POOL 26, SEPTEMBER 1996
RANGE 5
DISCHARGE = 609 cu m/sec, AREA = 1,812 m2



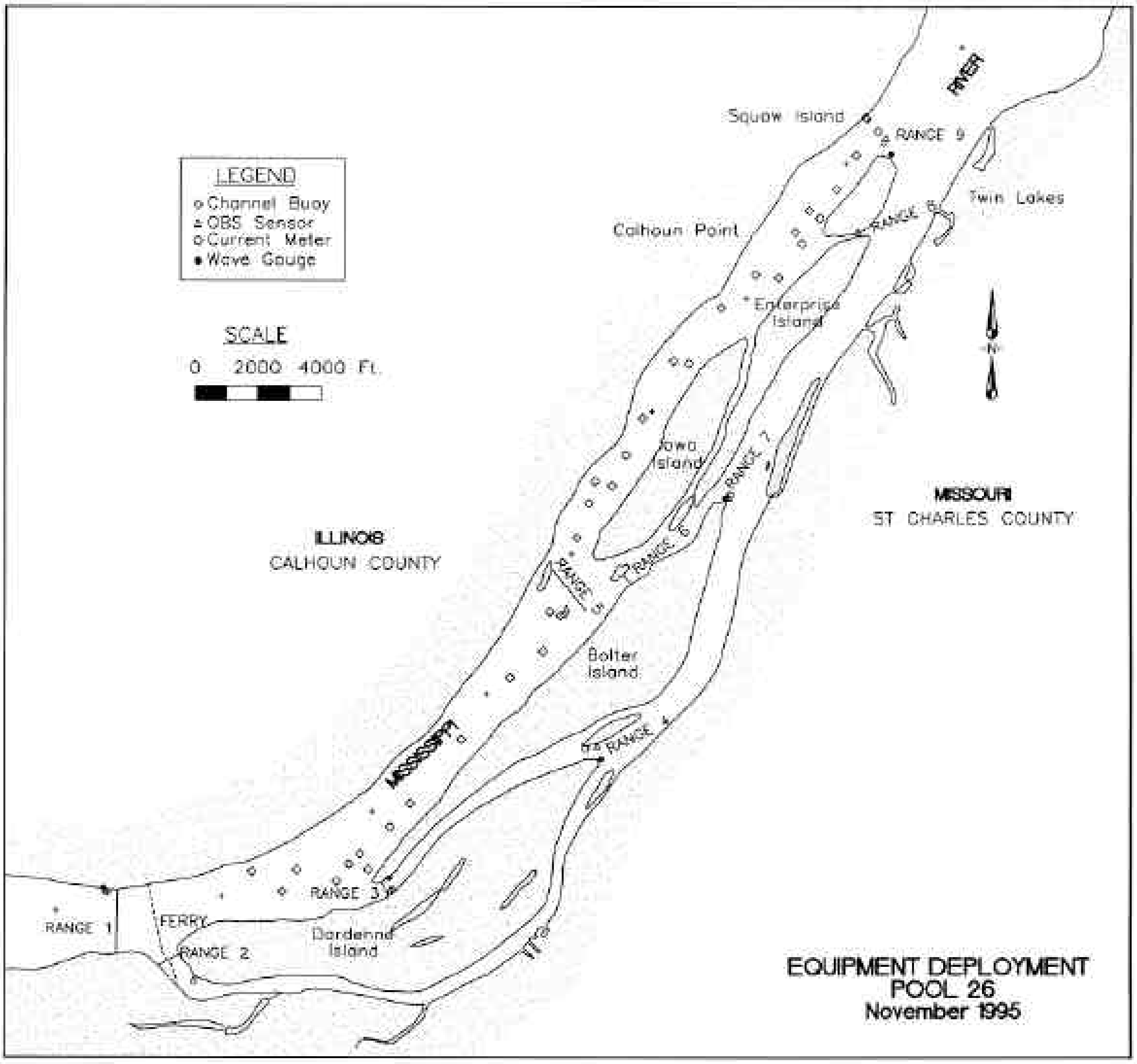
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES, AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT METERS MULTIPLY BY 0.3048

COMPOSITE VELOCITIES
LA GRANGE POOL, JULY 1996
RANGE 5
DISCHARGE = 307 cu m/sec, AREA = 600 m2



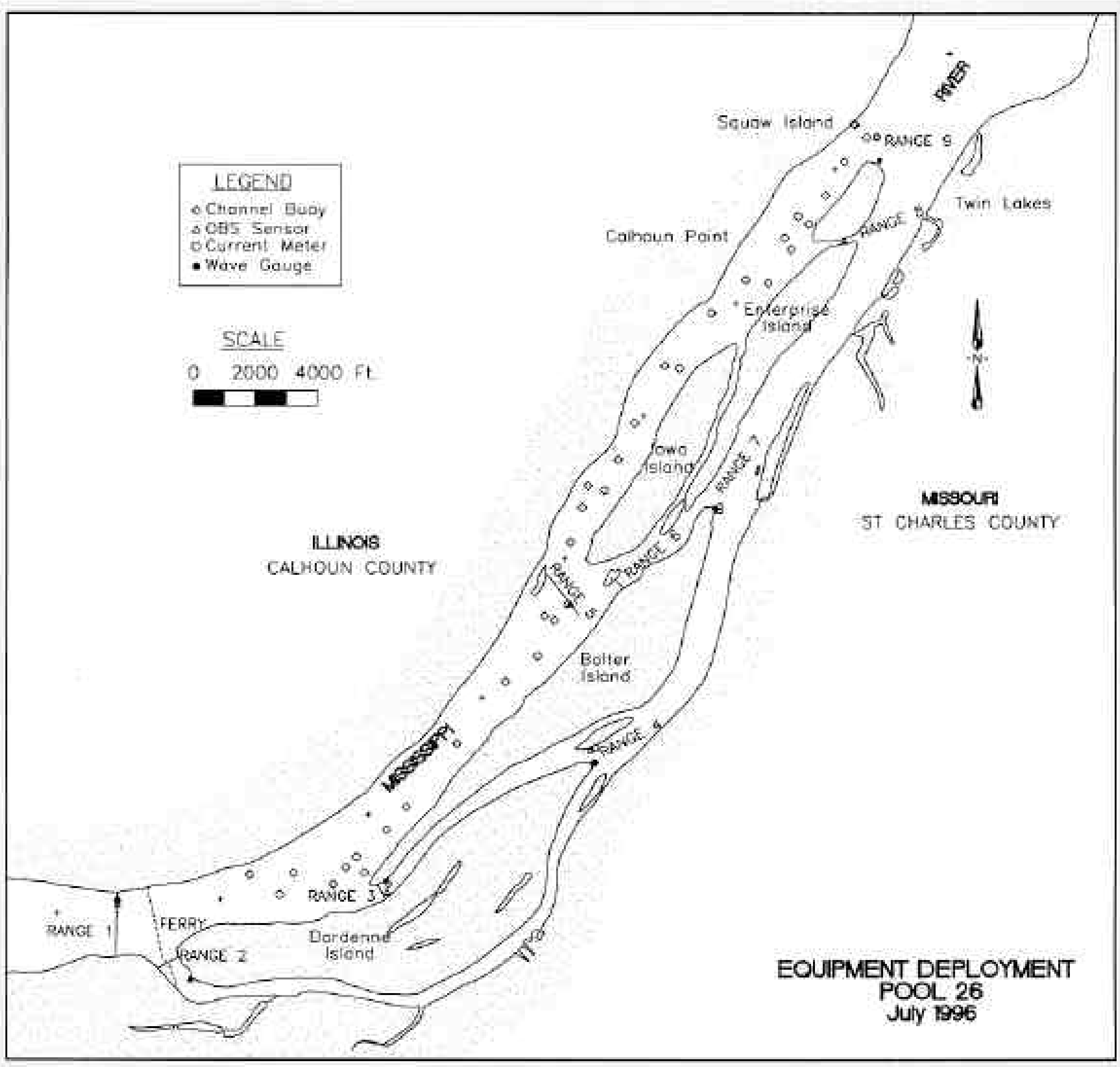
NOTE : VELOCITIES AND CURRENT DIRECTION OBTAINED WITH ACOUSTIC DOPPLER CURRENT PROFILER. DEPTHS, DISTANCES, AND VELOCITIES ARE IN FEET AND FEET PER SECOND, RESPECTIVELY. TO CONVERT METERS MULTIPLY BY 0.3048

COMPOSITE VELOCITIES
LA GRANGE POOL, SEPTEMBER 1996
RANGE 5
DISCHARGE = 248 cu m/sec, AREA = 595 m^2



LEGEND
Channel Buoy
OBS Sensor
Current Meter
Wave Gouge
SCALE
0 2000 4000 Ft.
Squaw Island
RANGE 9
RIVER
Twin Lakes
RANGE 8
Calhoun Point
Enterprise Island
Iowa Island
RANGE 7
RANGE 6
RANGE 5
MISSOURI
ST CHARLES COUNTY
ILLINOIS
CALHOUN COUNTY
Bolter Island
MISSISSIPPI
RANGE 4
RANGE 3
RANGE 1
FERRY
RANGE 2
Dardenne Island
EQUIPMENT DEPLOYMENT
POOL 26
November 1995

Plate 3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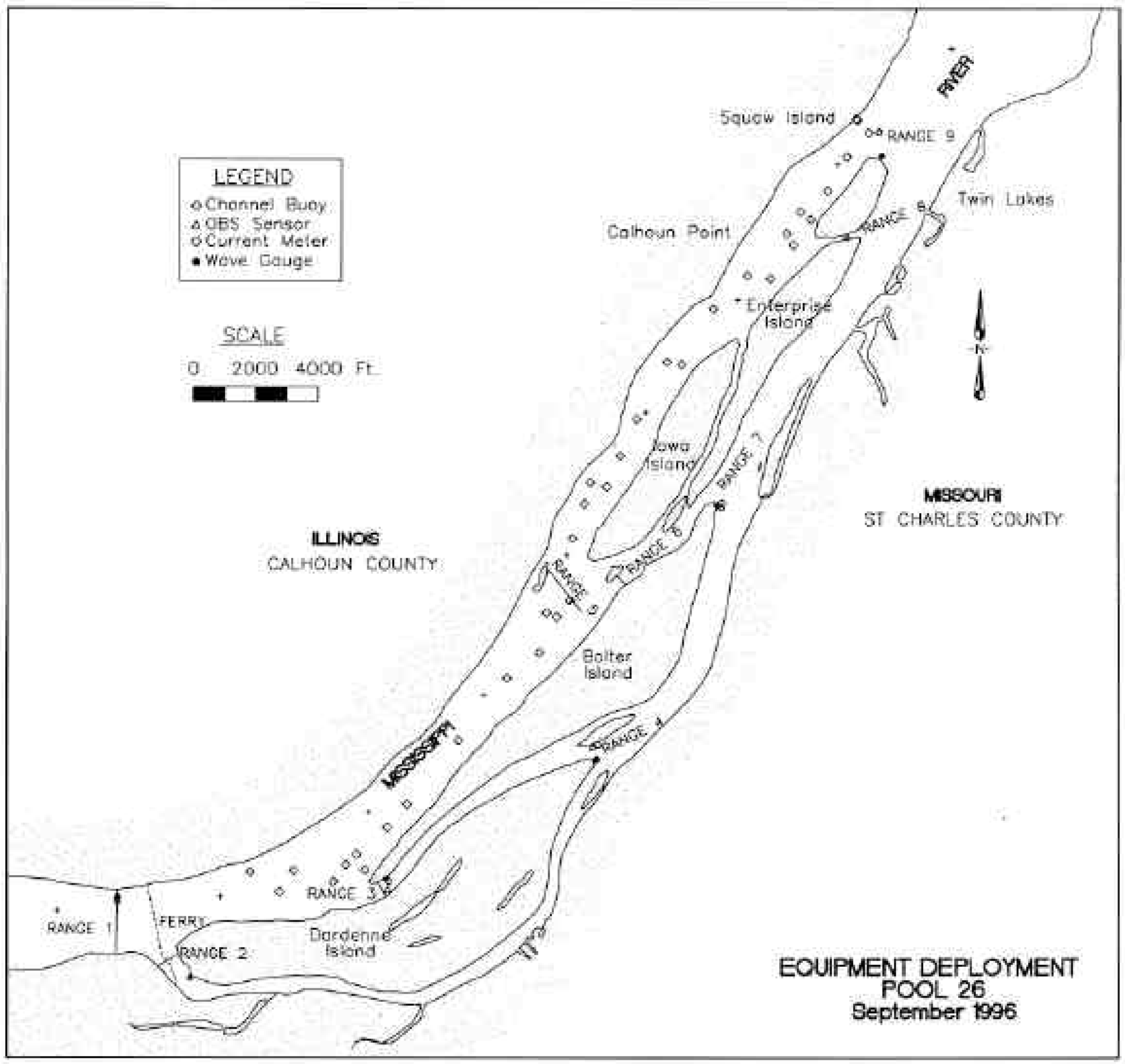
Channel Buoy
OBS Sensor
Current Meter
Wave Gauge
SCALE
0 2000 4000 Ft.
RIVER
Squaw Island
RANGE 9
Twin Lakes
Calhoun Point
RANGE 8
Enterprise Island
Iowa Island
RANGE 7
RANGE 6
MISSOURI
ST CHARLES COUNTY
ILLINOIS
CALHOUN COUNTY
RANGE 5
Batter Island
MISSISSIPPI
RANGE 4
RANGE 3
RANGE 1
FERRY
RANGE 2
Dardenne Island
EQUIPMENT DEPLOYMENT
POOL 26
July 1996

Plate 4



LEGEND
Channel Buoy
OBS Sensor
Current Meter
Wave Gauge
SCALE
0 2000 4000 Ft.
Squaw Island
RANGE 9
RIVER
Twin Lakes
Calhoun Point
RANGE 8
Enterprise Island
Iowa Island
RANGE 7
RANGE 6
RANGE 5
MISSOURI
ST CHARLES COUNTY
ILLINOIS
CALHOUN COUNTY
Bolter Island
RANGE 4
MISSISSIPPI
RANGE 3
RANGE 1
FERRY
RANGE 2
Dardenne Island
EQUIPMENT DEPLOYMENT
POOL 26
September 1996

Plate 5

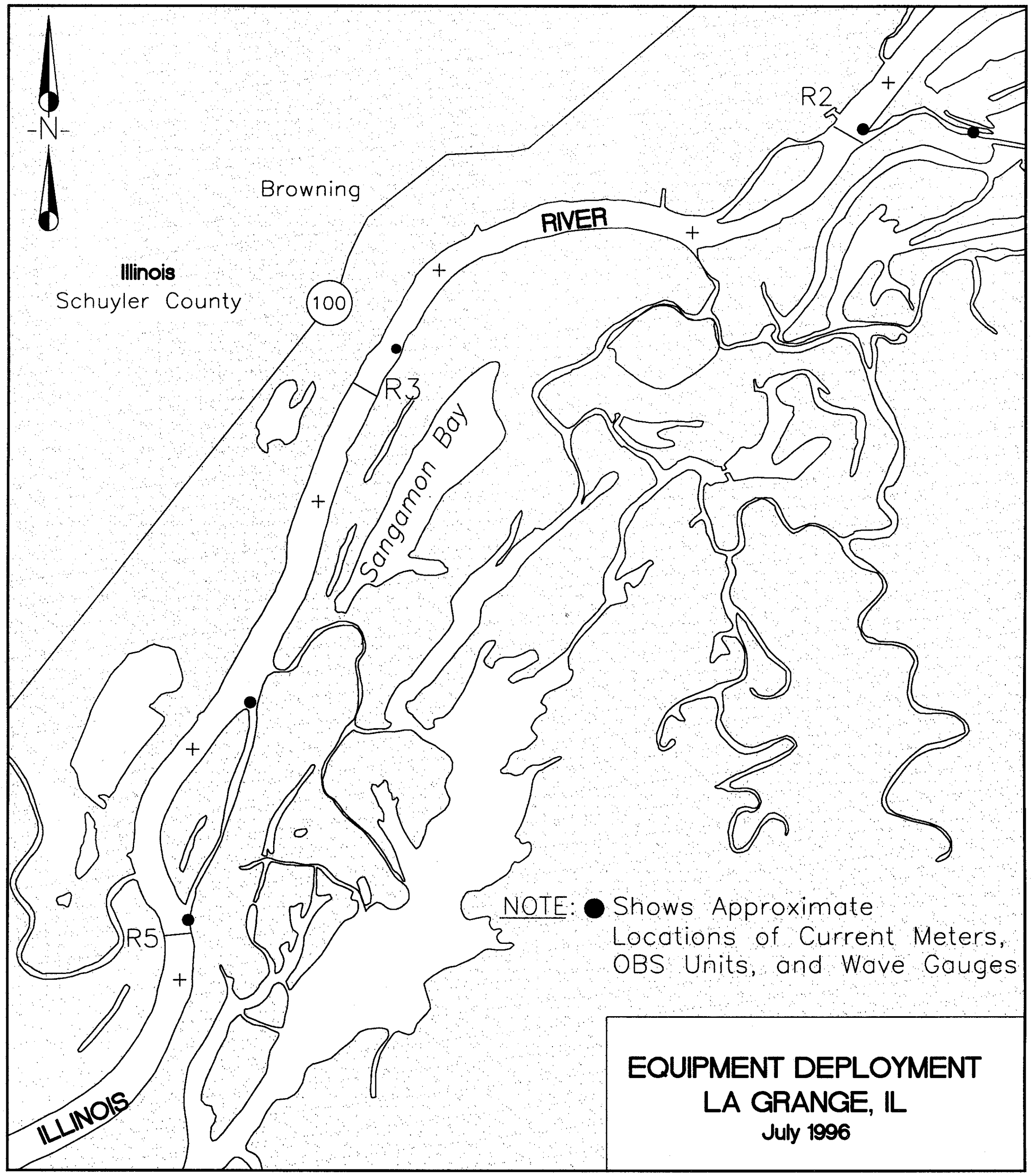

-N-
Browning
Illinois
Schuyler County
100
RIVER
R2
R3
Sangamon Bay
R5
ILLINOIS
NOTE: ● Shows Approximate Locations of Current Meters, OBS Units, and Wave Gauges
EQUIPMENT DEPLOYMENT
LA GRANGE, IL
July 1996

Plate 6

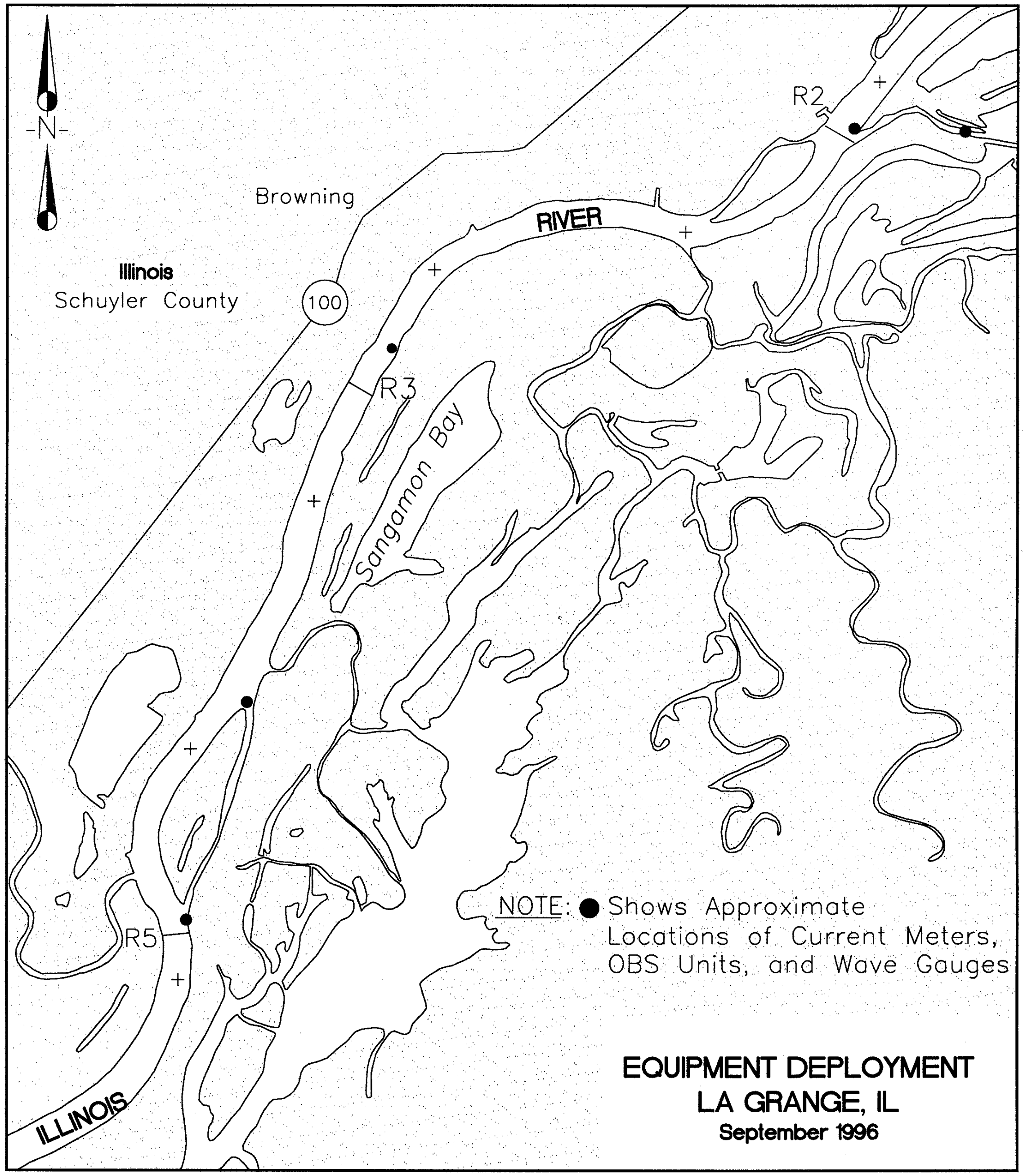
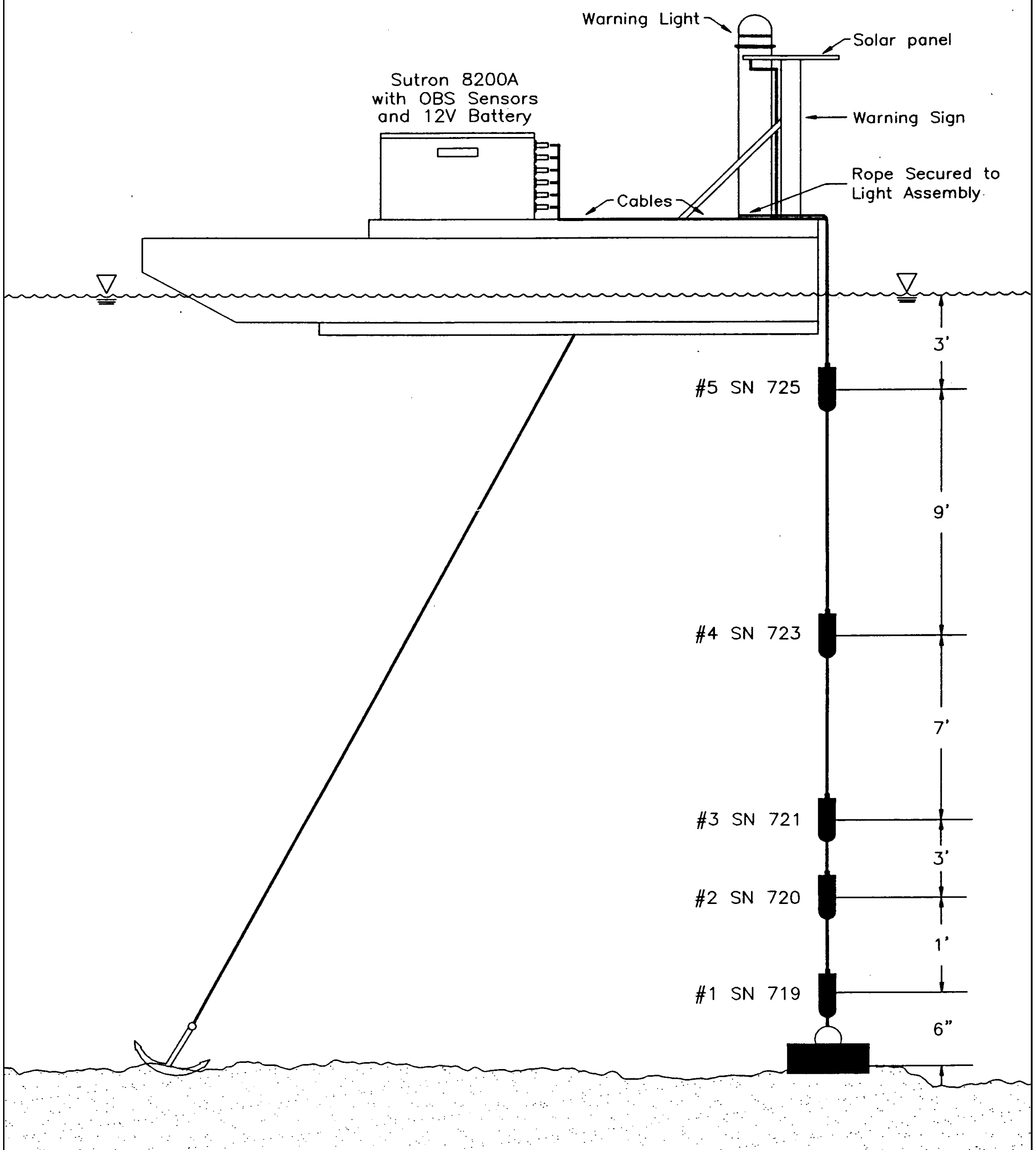
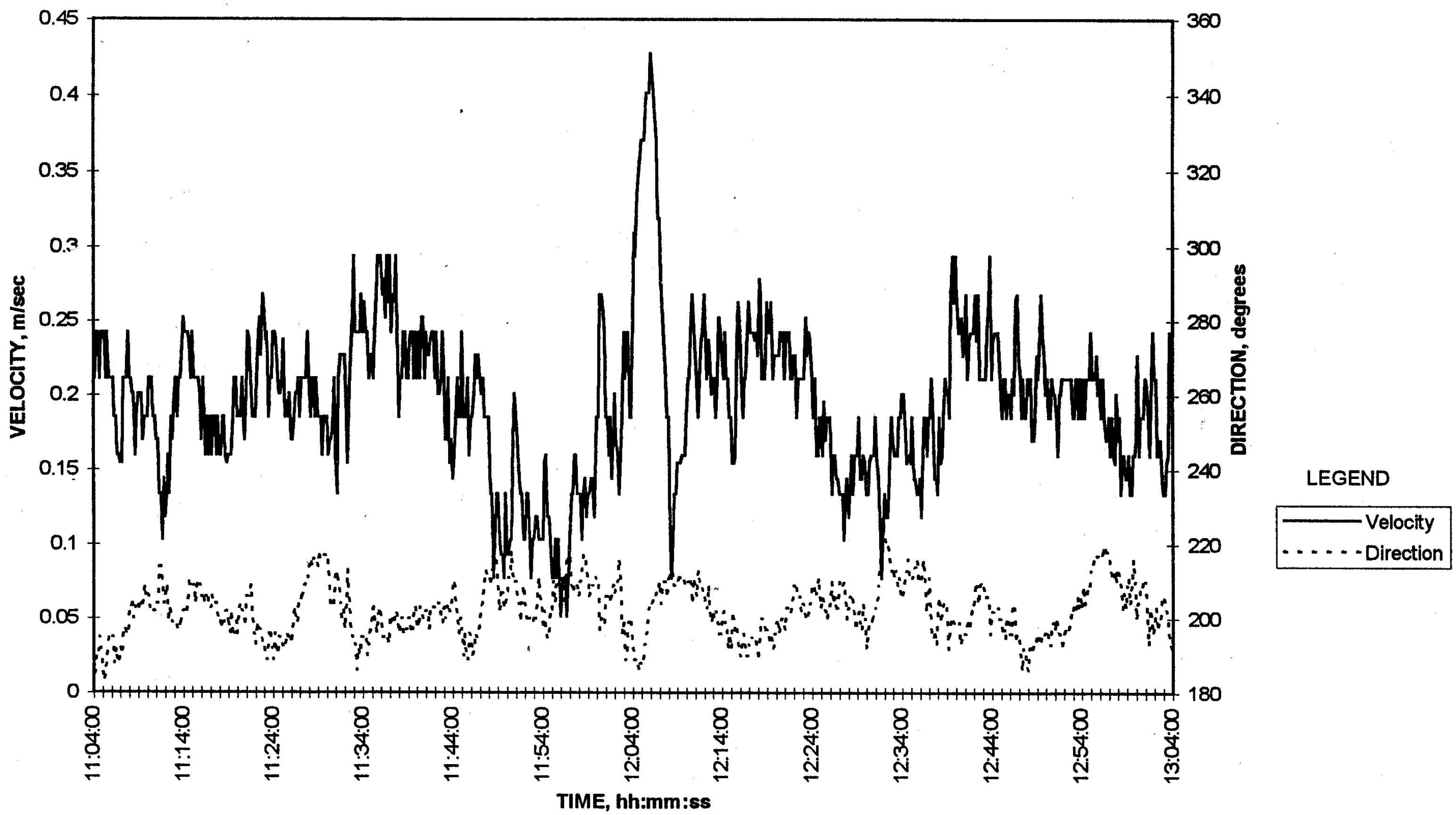

-N-
Browning
Illinois
Schuyler County
100
RIVER
R2
R3
Sangamon Bay
R5
ILLINOIS
NOTE: ● Shows Approximate Locations of Current Meters, OBS Units, and Wave Gauges
EQUIPMENT DEPLOYMENT
LA GRANGE, IL
September 1996

Plate 7



OBS DATA COLLECTION PLATFORM

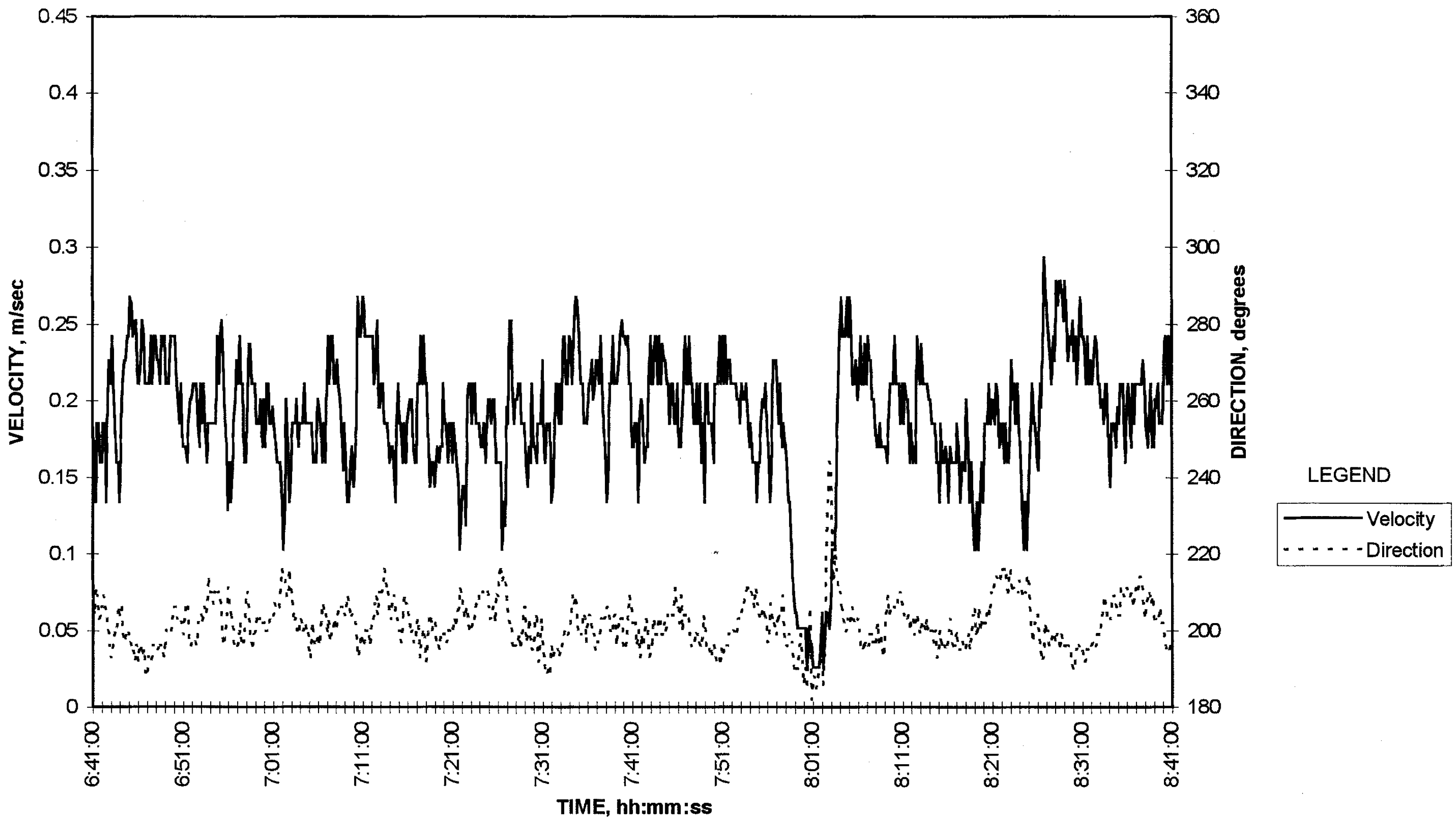
Plate 8



NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

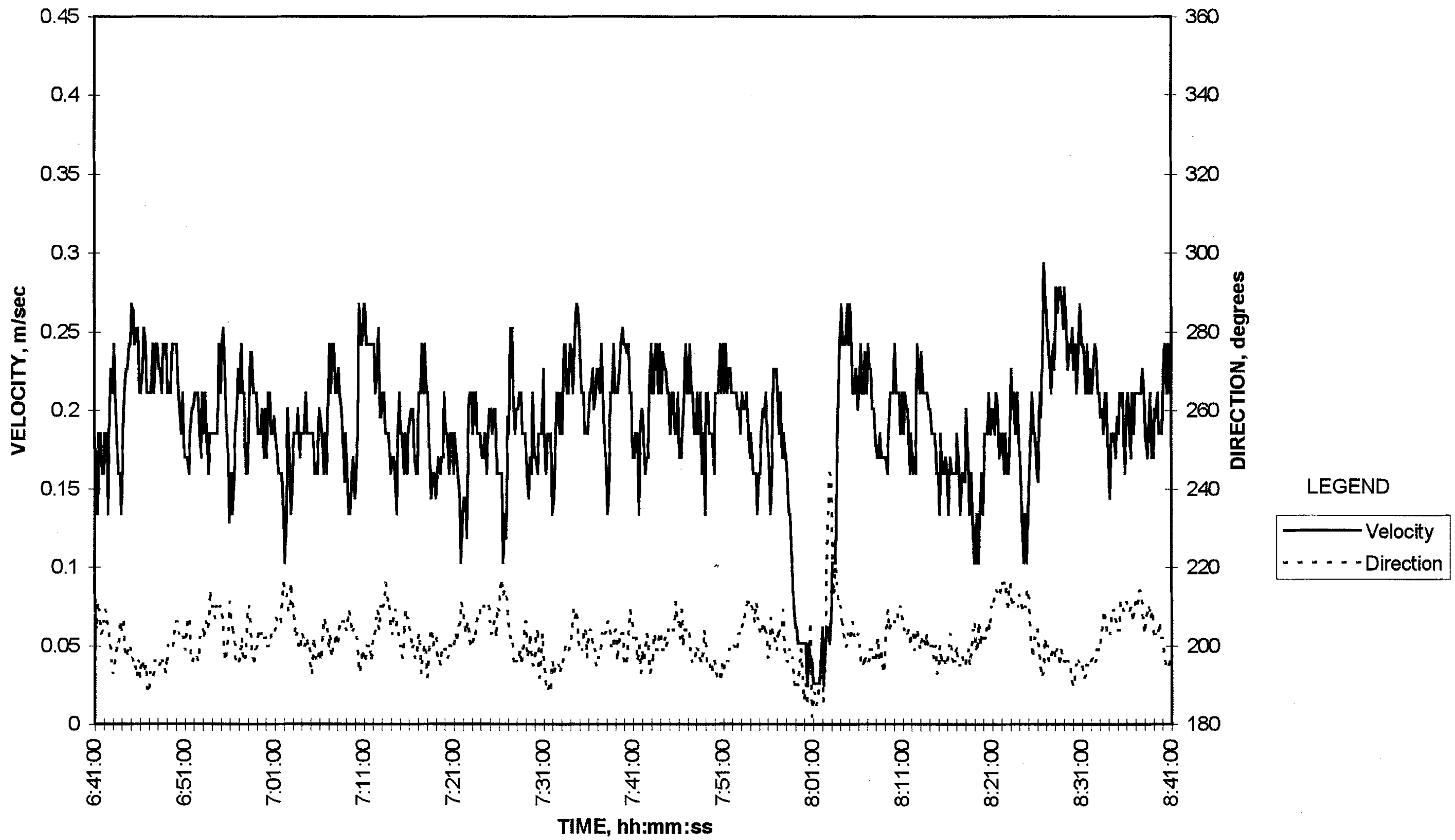
FIXED-DEPTH VELOCITY METER
POOL 8, RANGE 3
BOAT B02
09/13/96

Plate 16



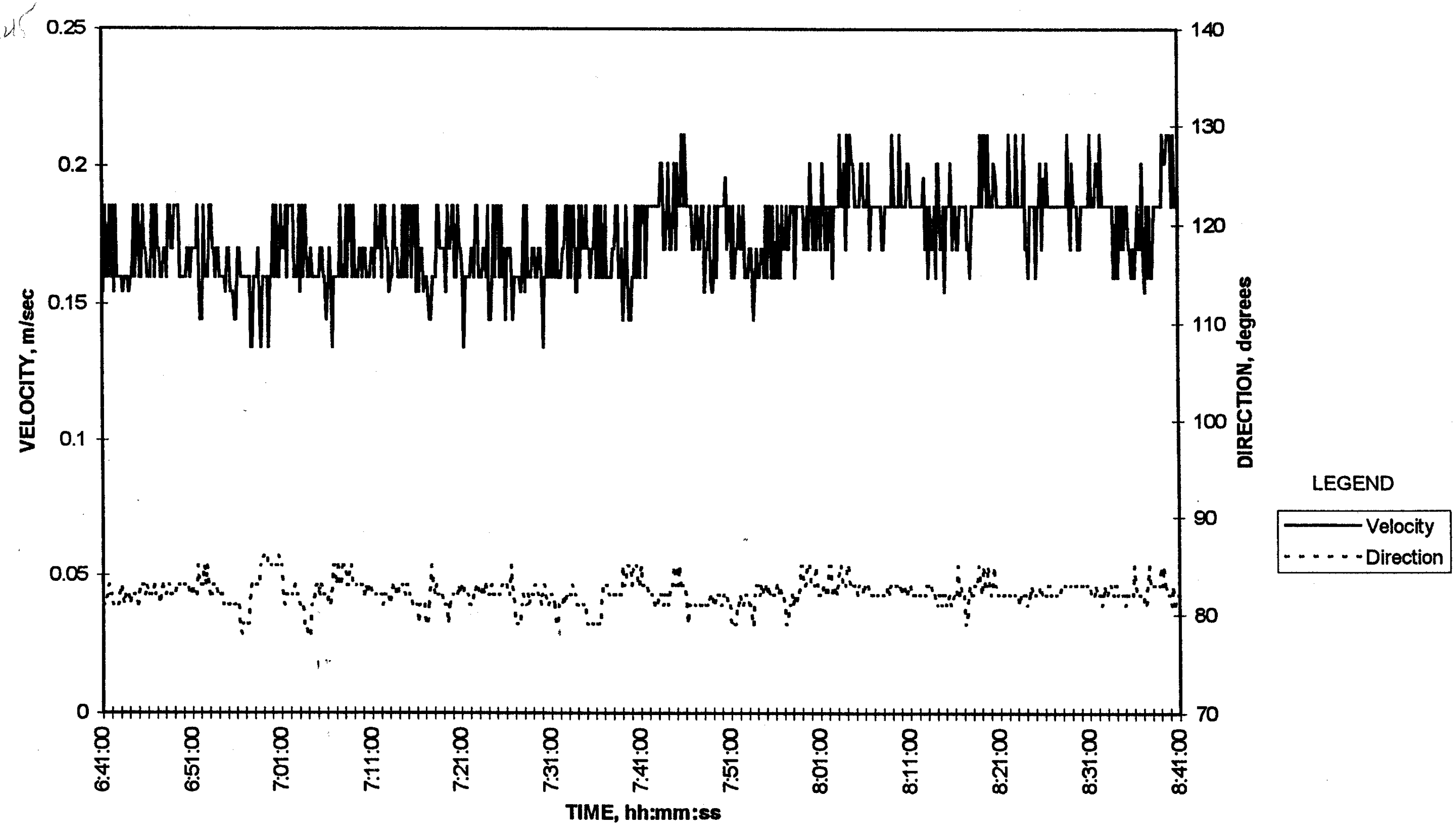
NOTE: Direction measured from 0 degrees north azimuth;
to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 8, RANGE 3
BOAT B03
09/14/96



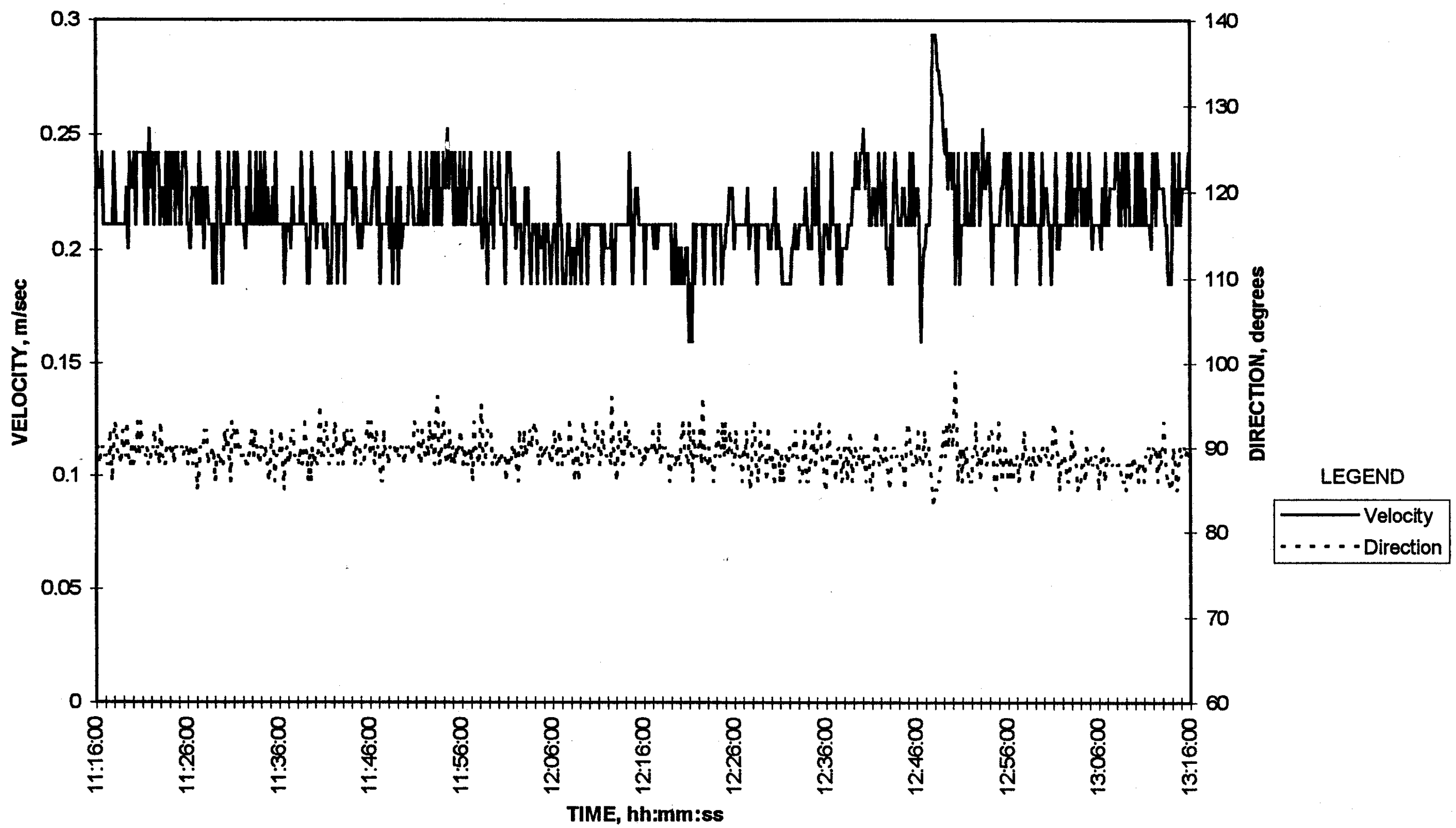
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 8, RANGE 3
BOAT B03
09/14/96



NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

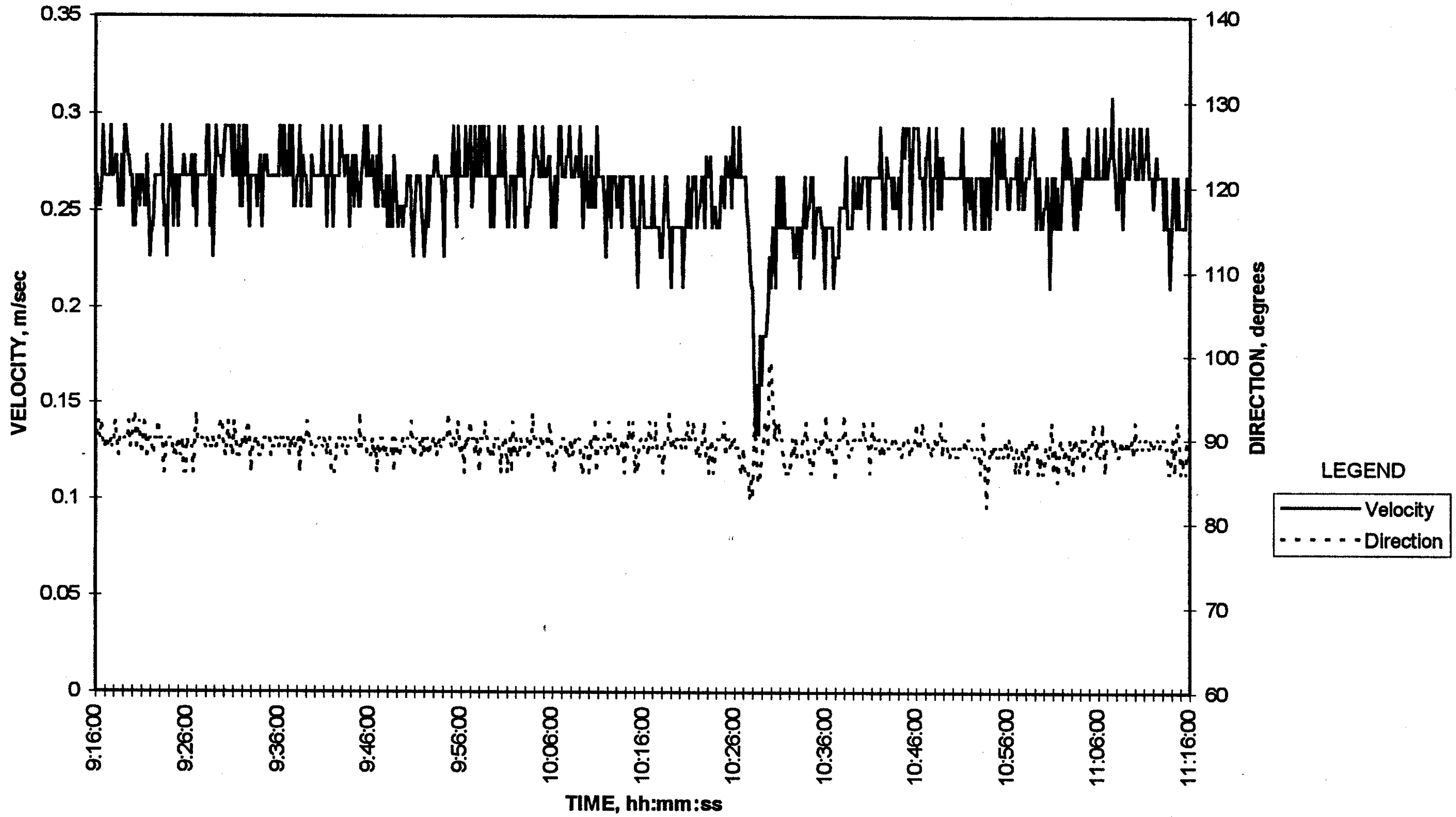
FIXED-DEPTH VELOCITY METER
POOL 8, RANGE 5
BOAT B03
09/14/96



NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

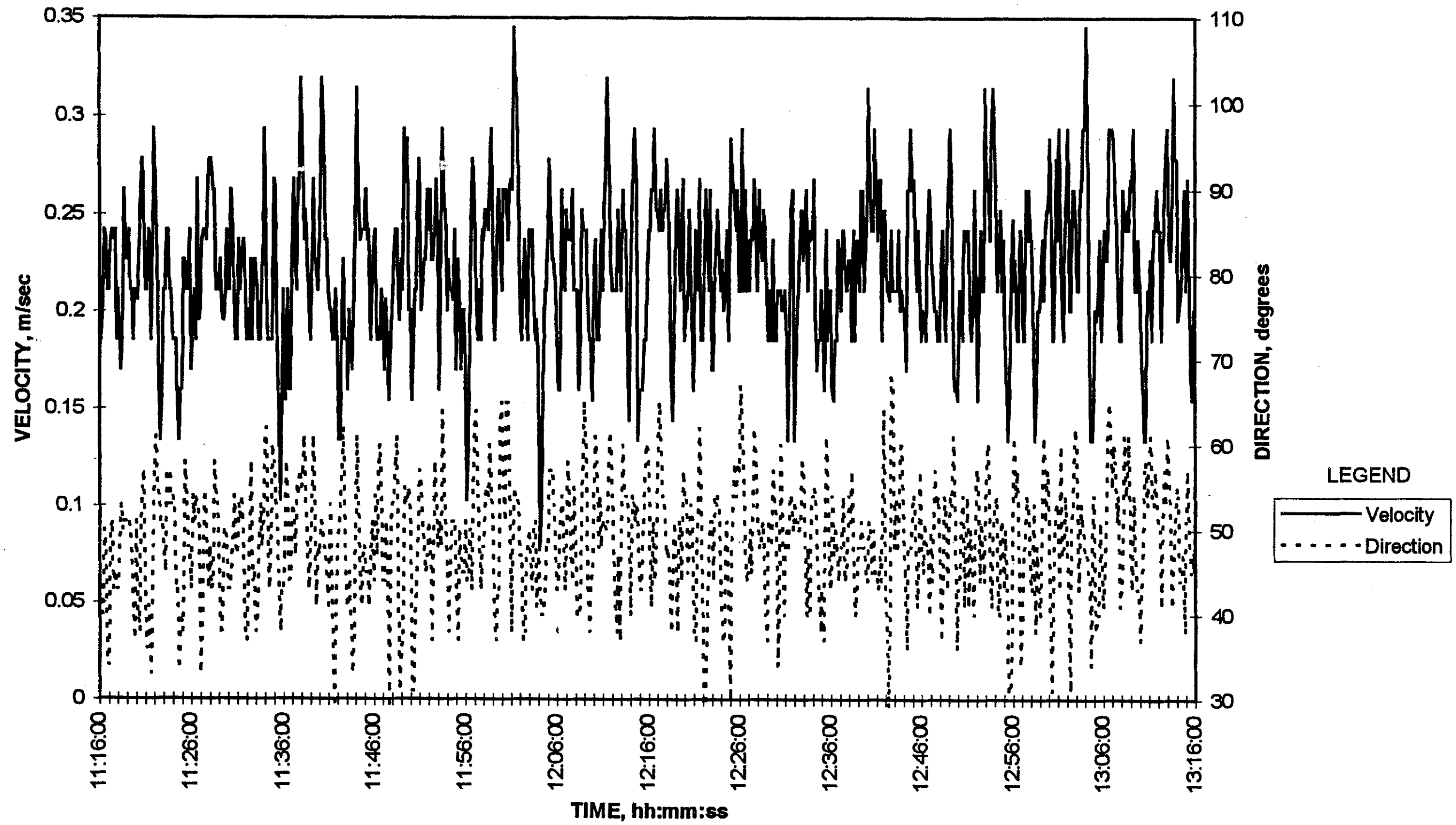
FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 1
BOAT BO2
09/05/96

Plate 20



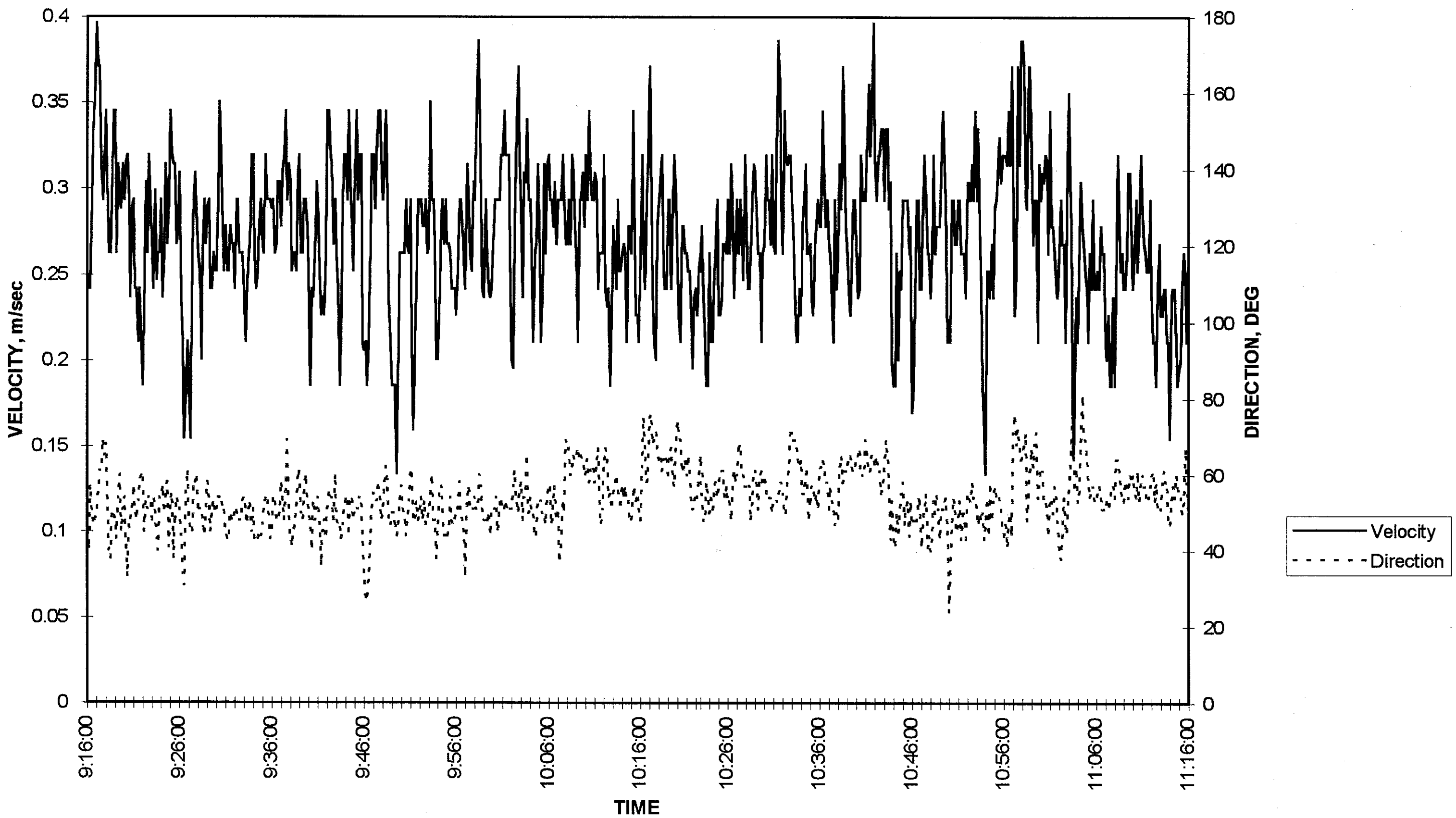
NOTE: Direction measured from 0 degrees north azimuth;
to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 1
BOAT BO4
09/06/96

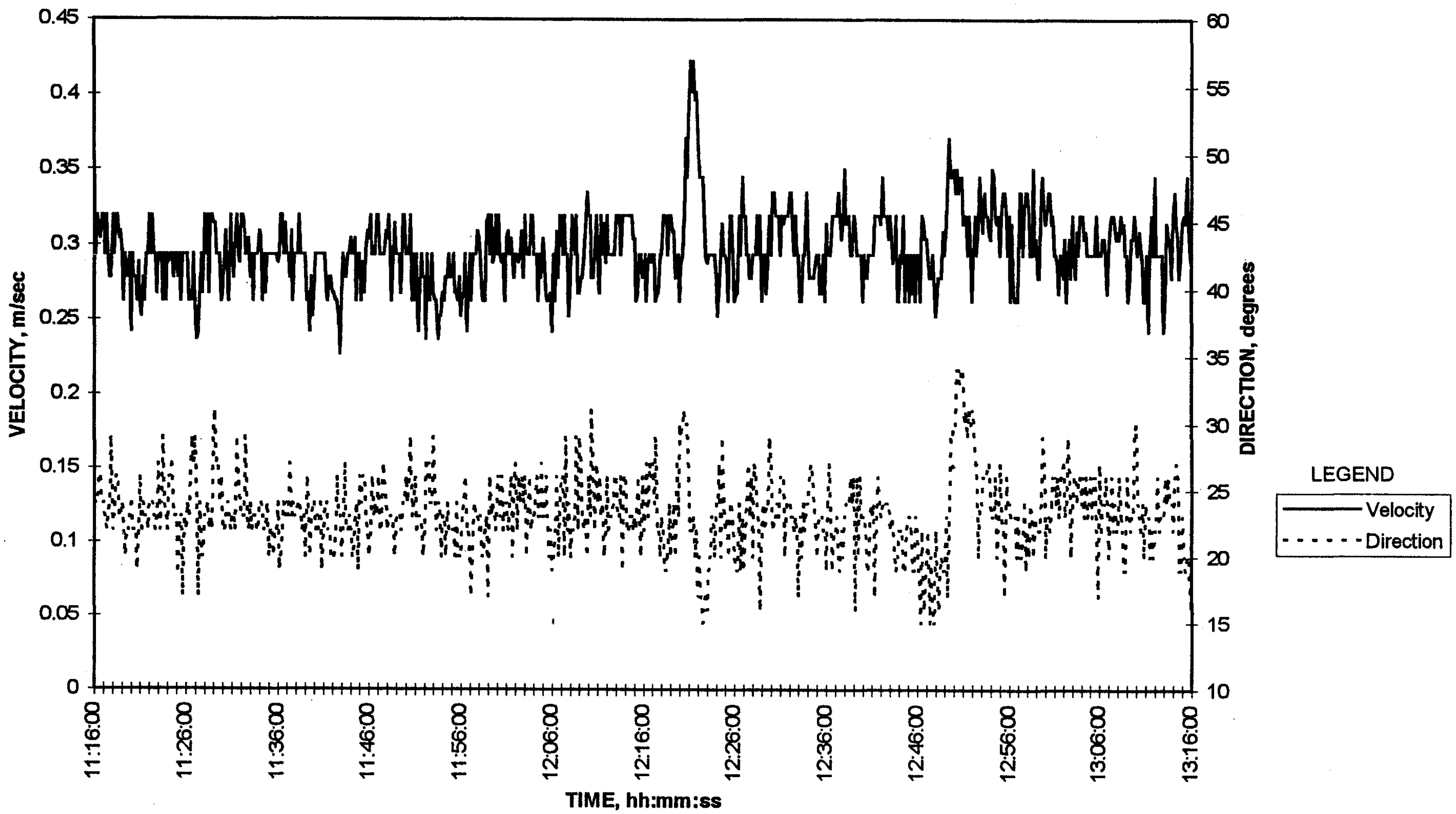


NOTE: Direction measured from 0 degrees north azimuth;
to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 3
BOAT B02
09/05/96

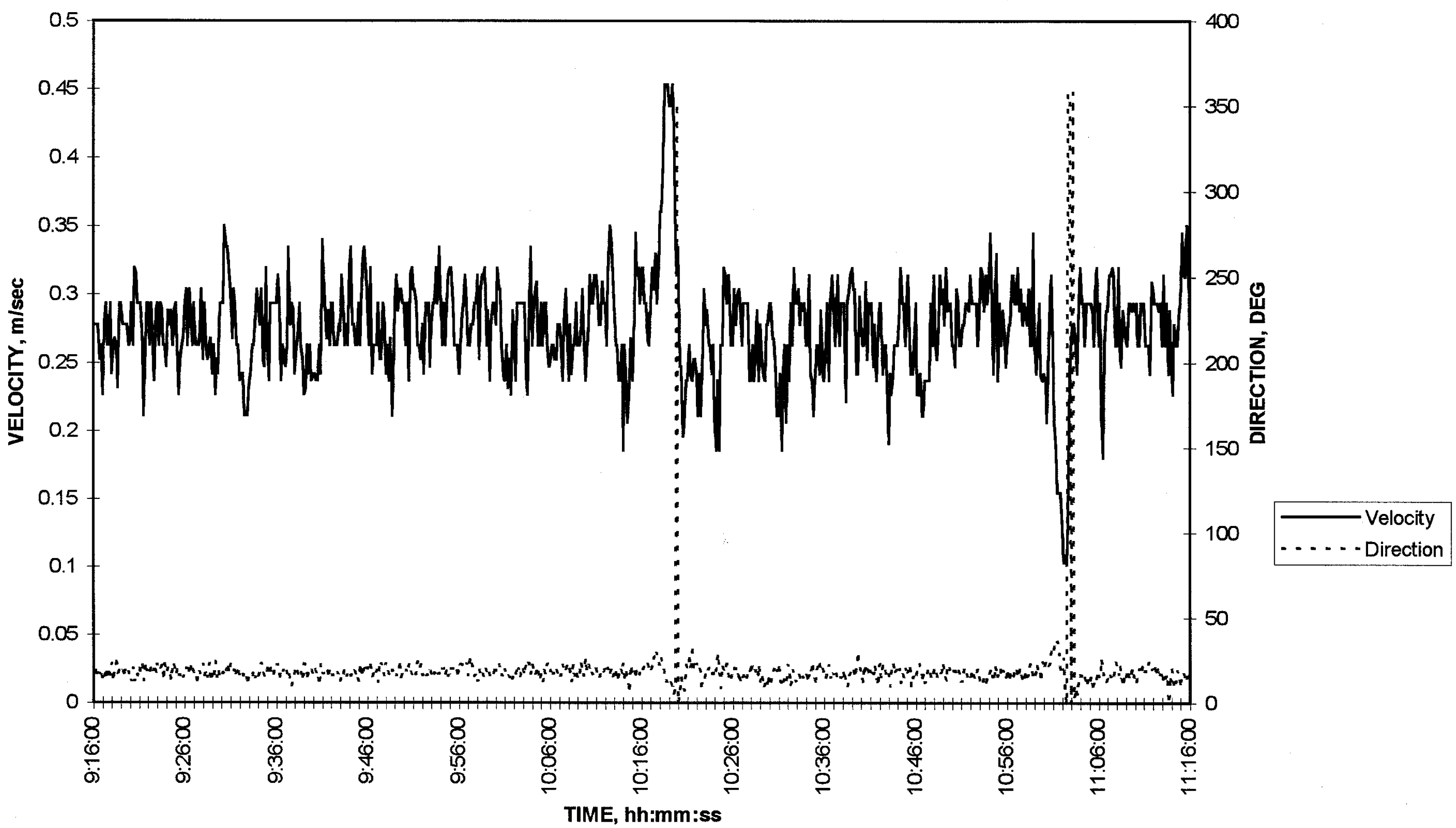


FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 3
BOAT B04
09/06/96



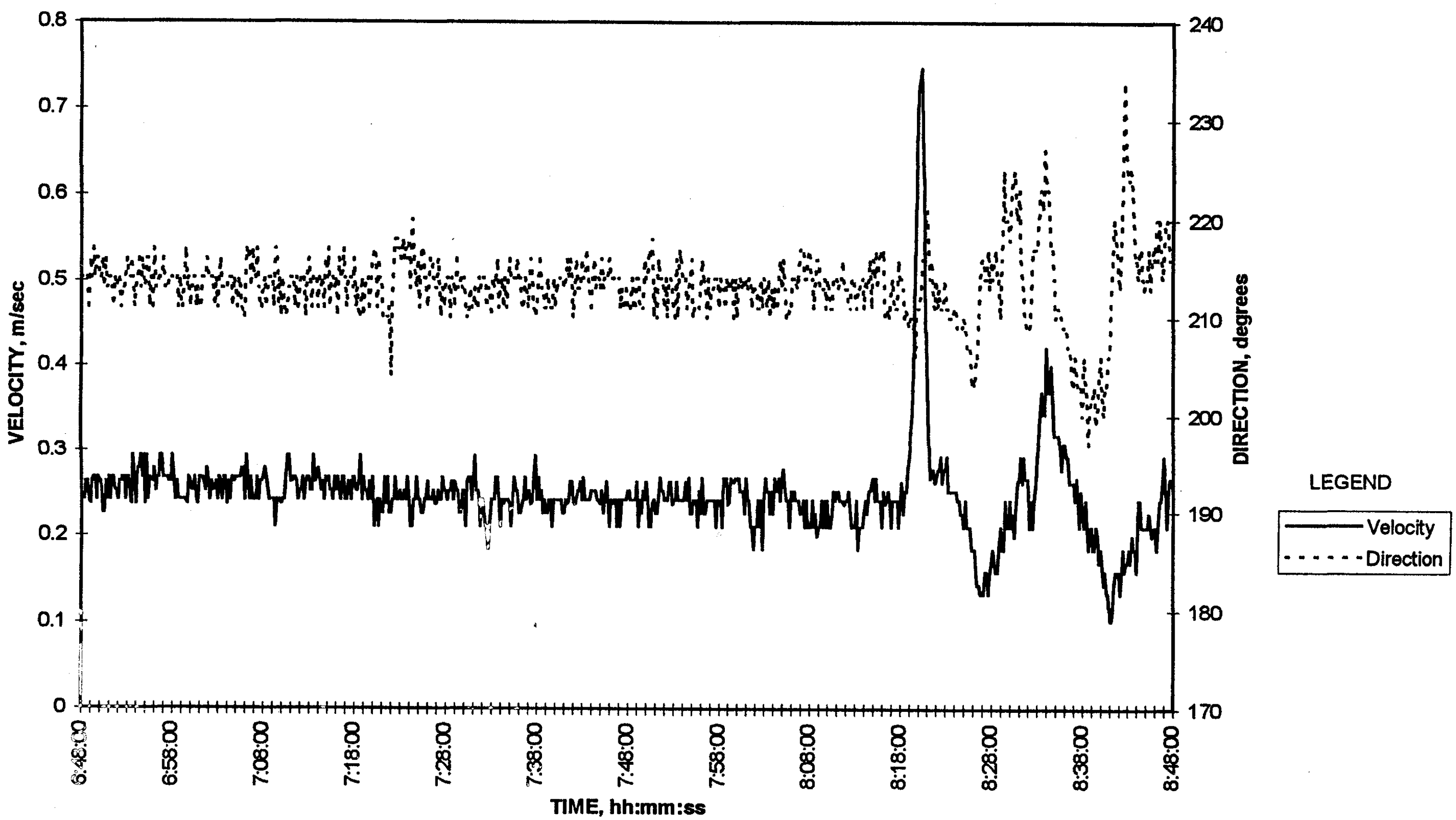
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 5
BOAT B02
09/06/96



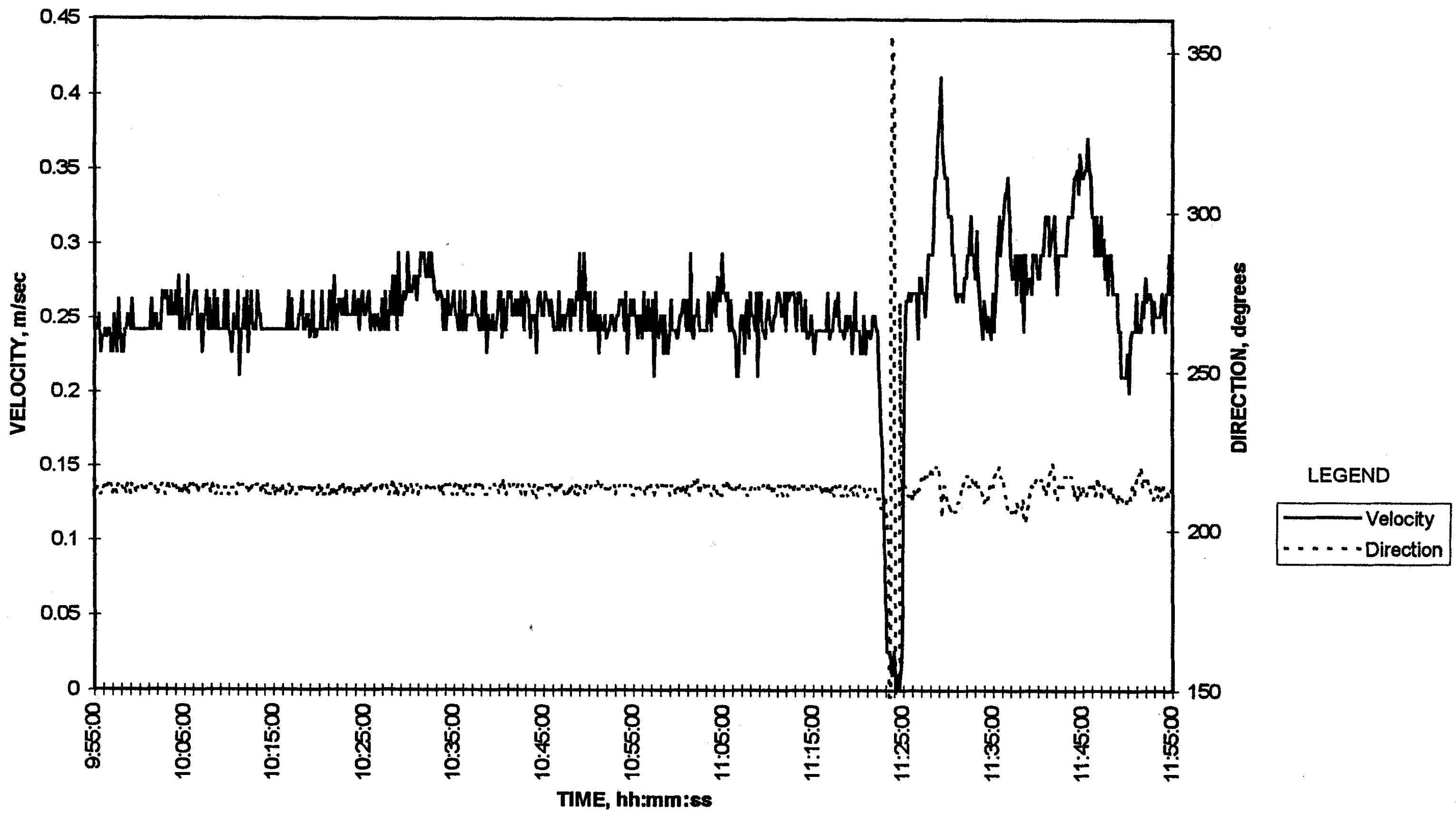
NOTE: Direction measured from 0 degrees north azimuth;
to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
POOL 26, RANGE 5
BOAT NO. B04
09/06/96



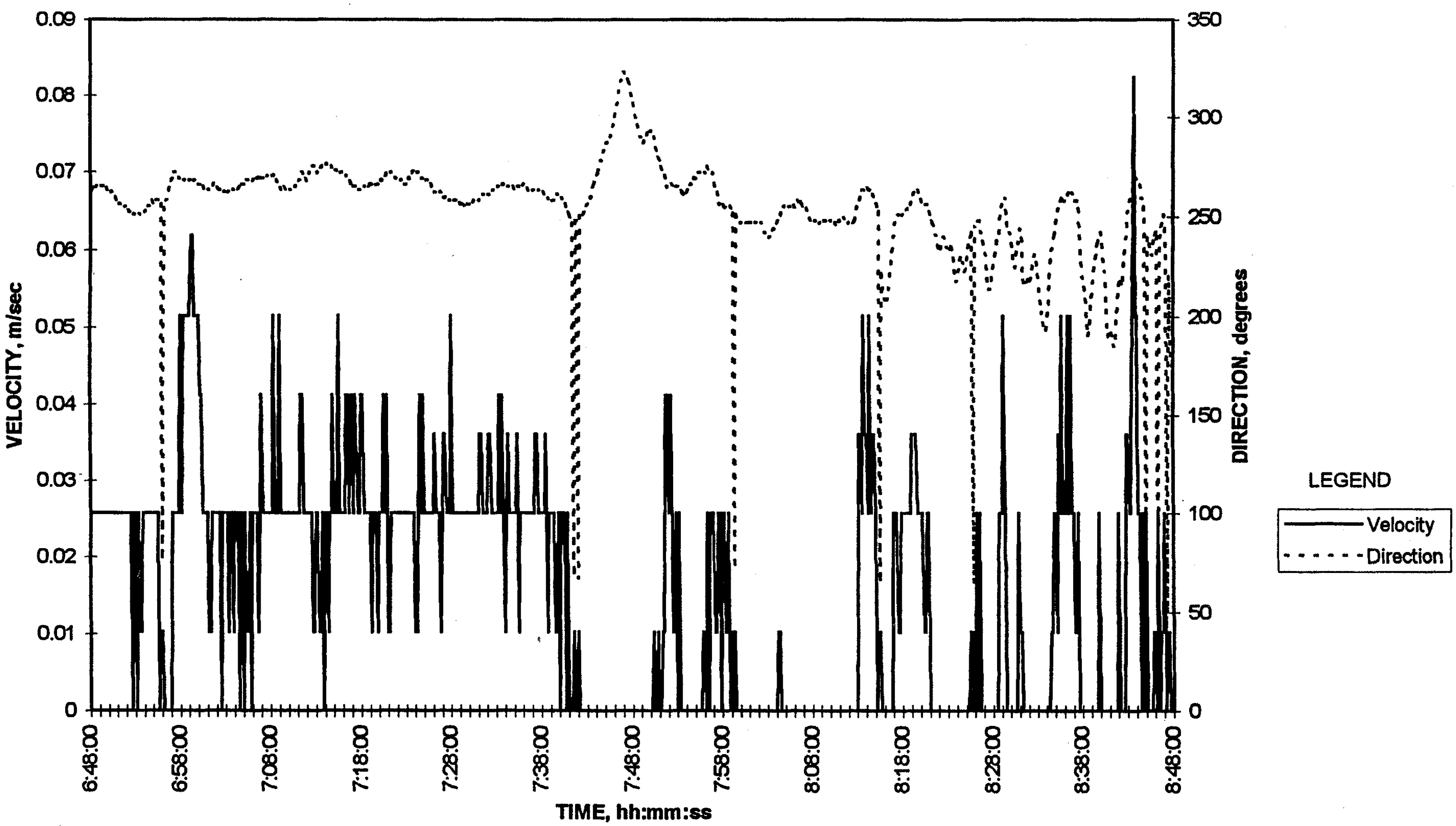
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 3
BOAT B09
09/10/96



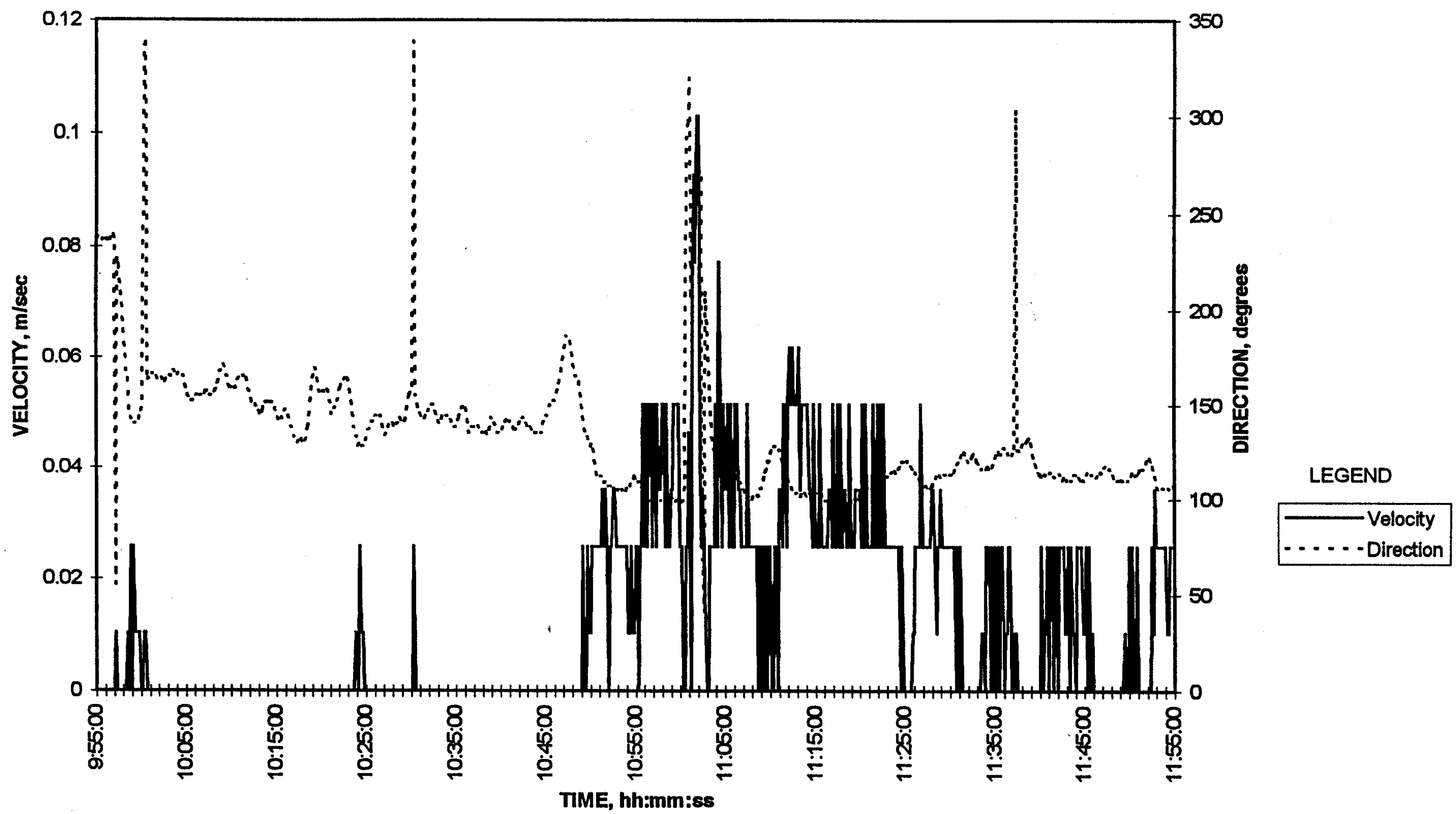
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 3
BOAT B10
09/10/96



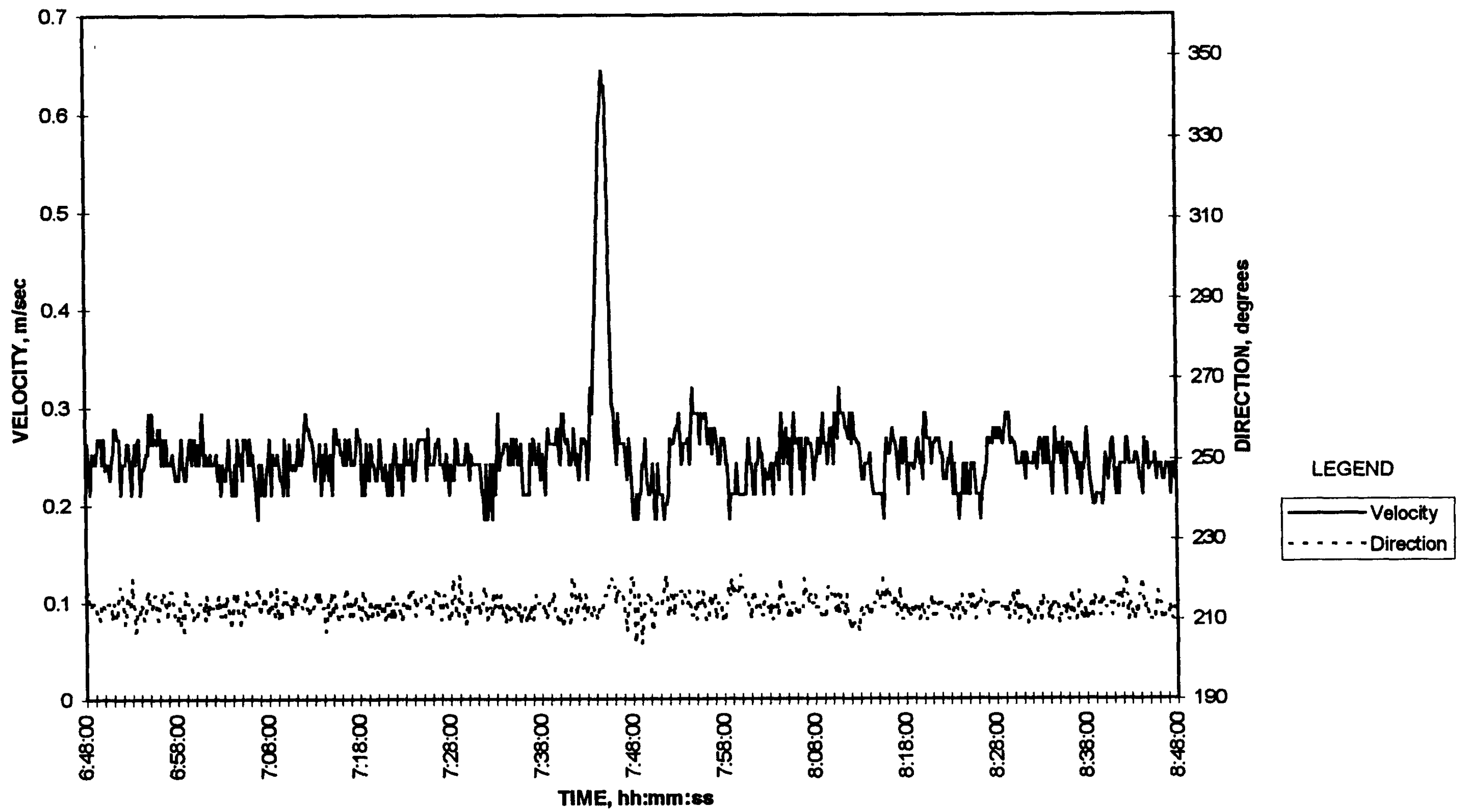
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 1
BOAT B09
09/10/96



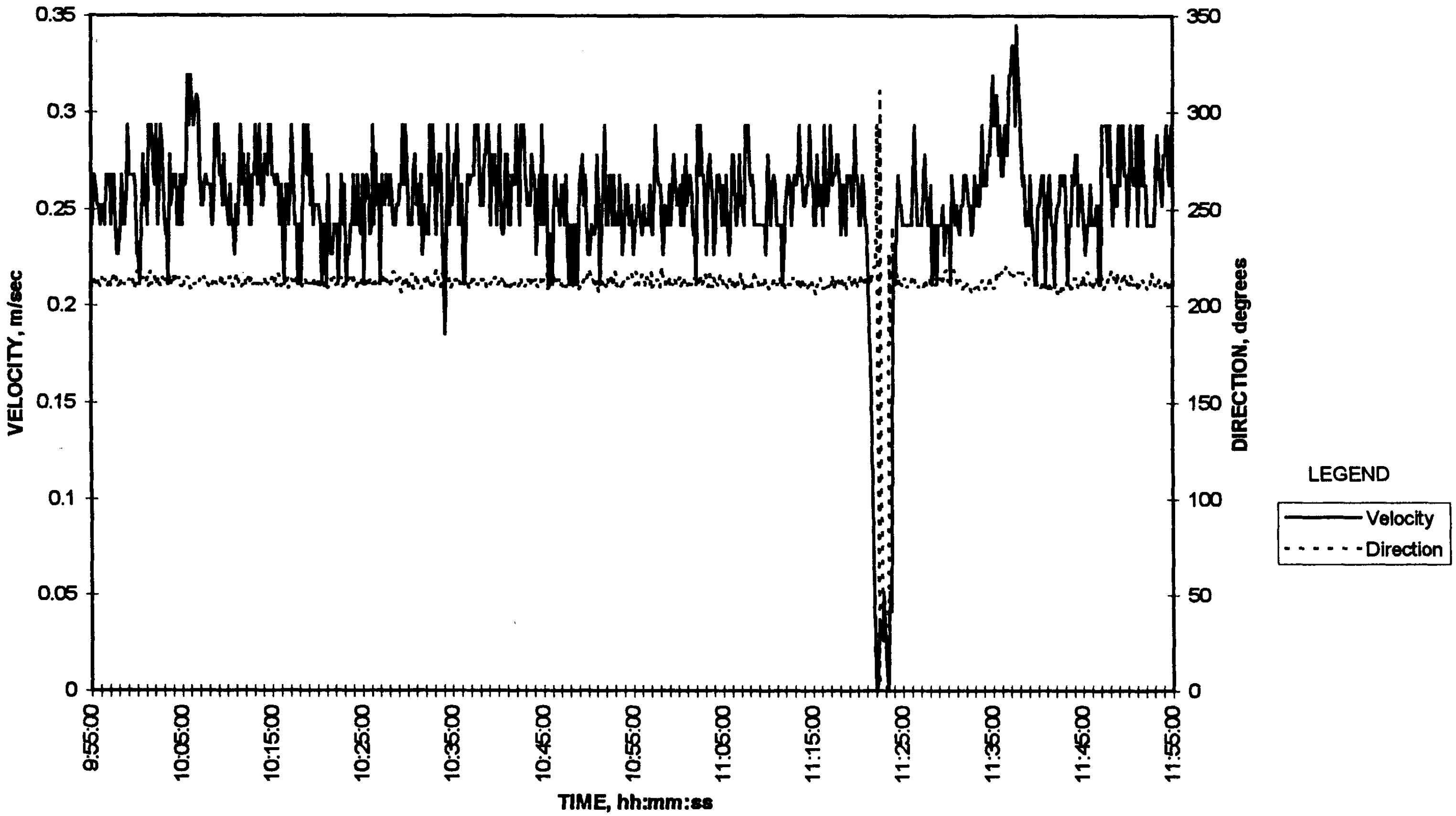
NOTE: Direction measured from 0 degrees north azimuth;
to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 1
BOAT B10
09/10/96



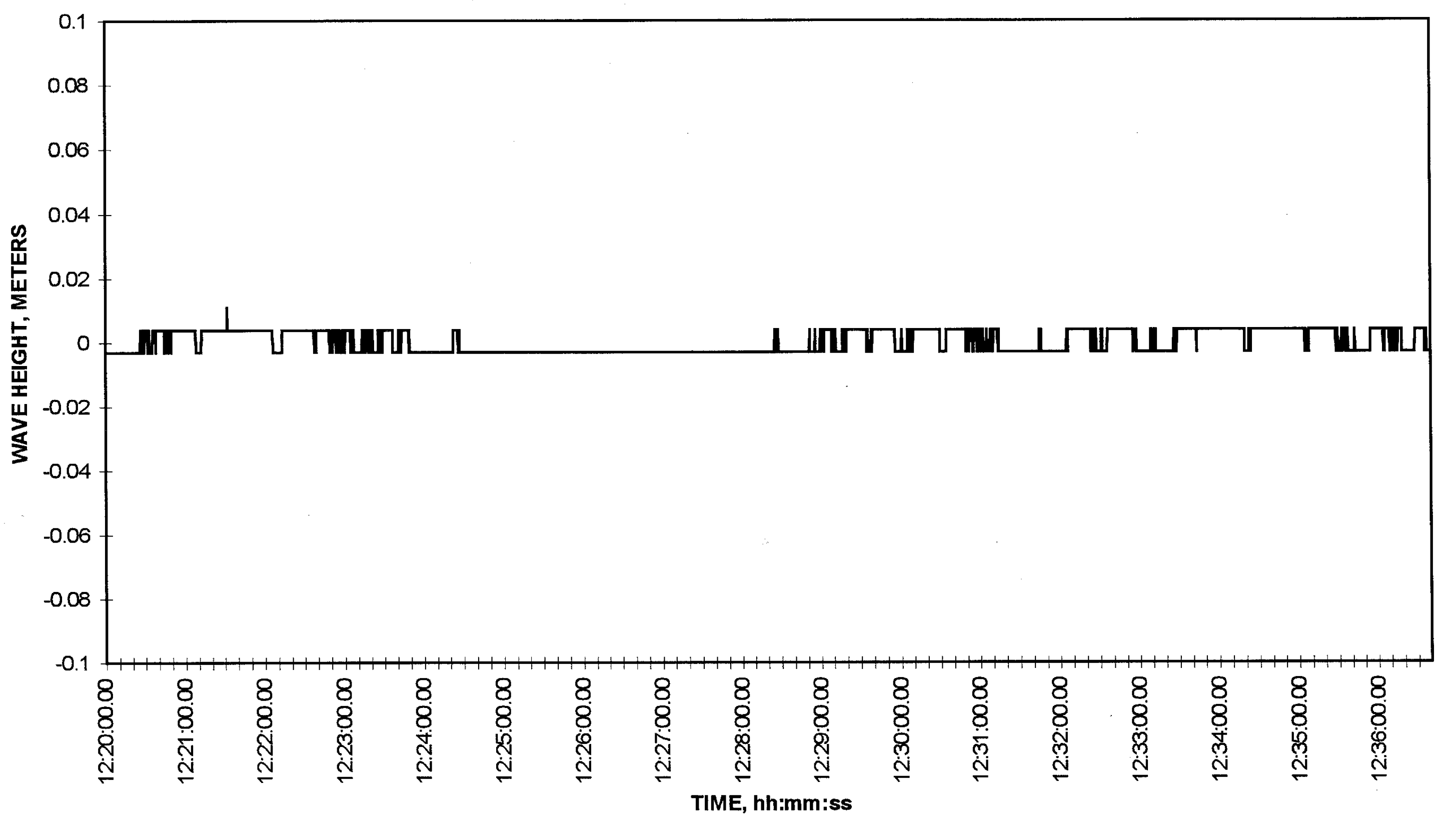
NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 4
BOAT B09
09/10/96

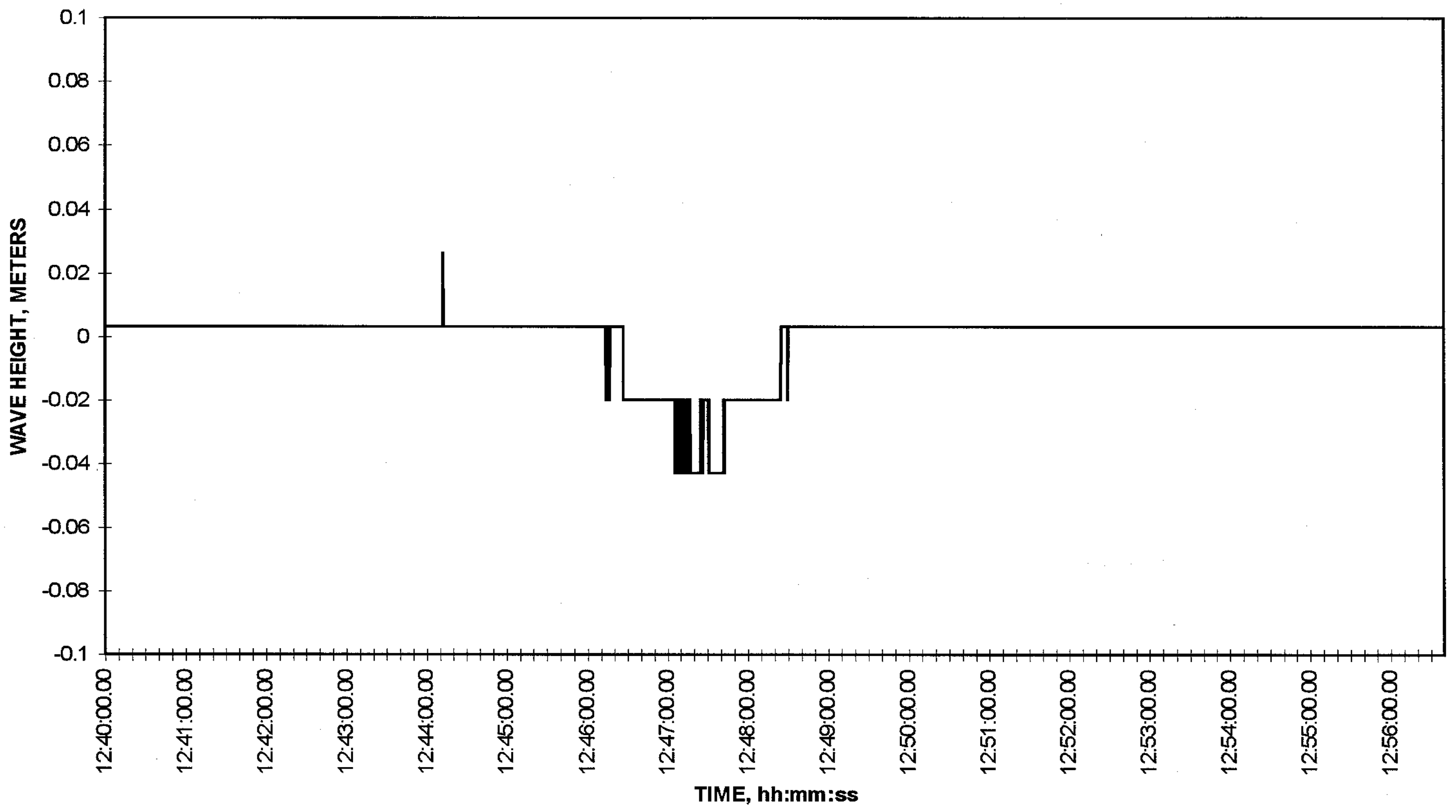


NOTE: Direction measured from 0 degrees north azimuth; to convert to radians multiply by 0.01745

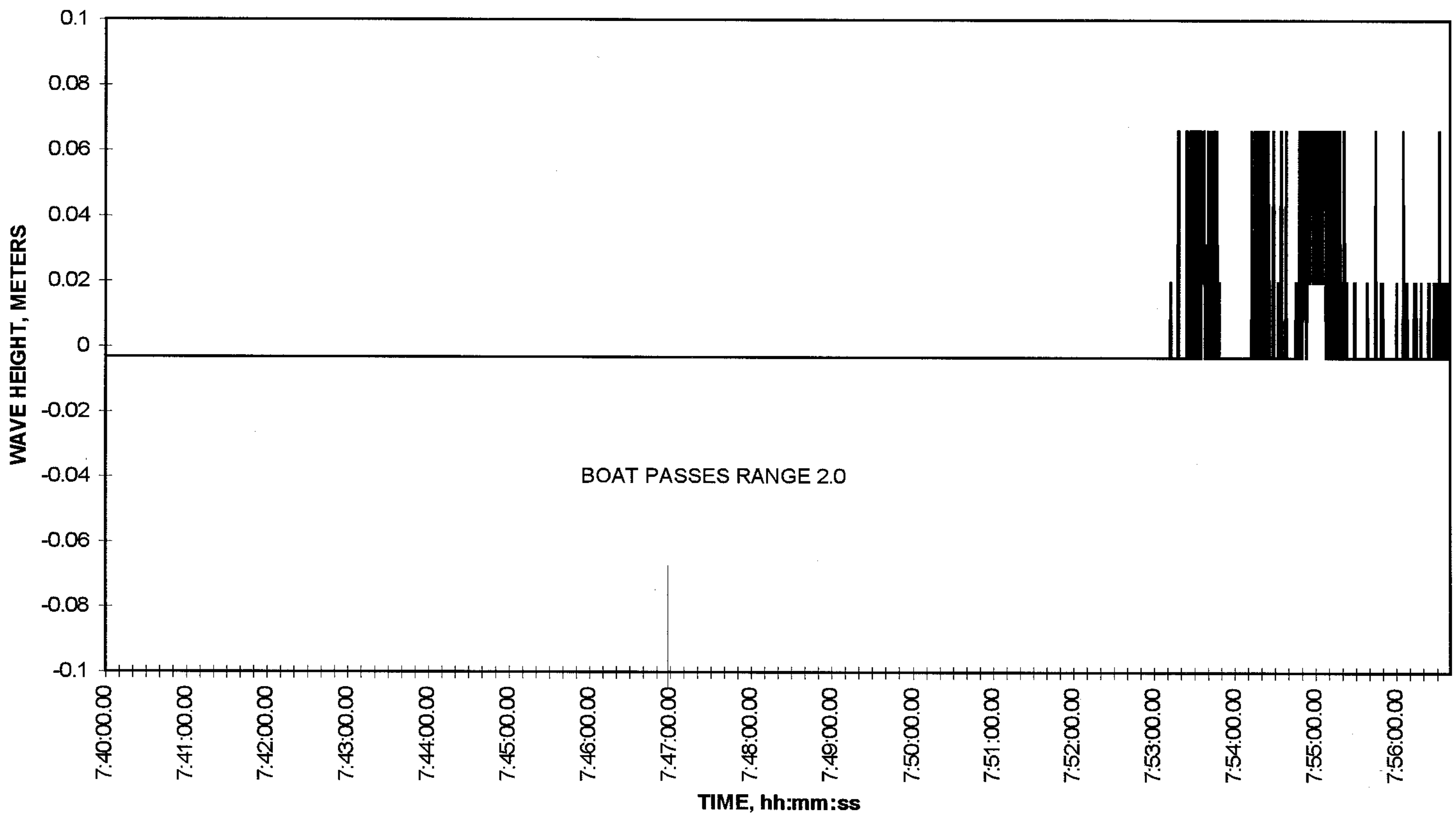
FIXED-DEPTH VELOCITY METER
LA GRANGE POOL, RANGE 4
BOAT B10
09/10/96



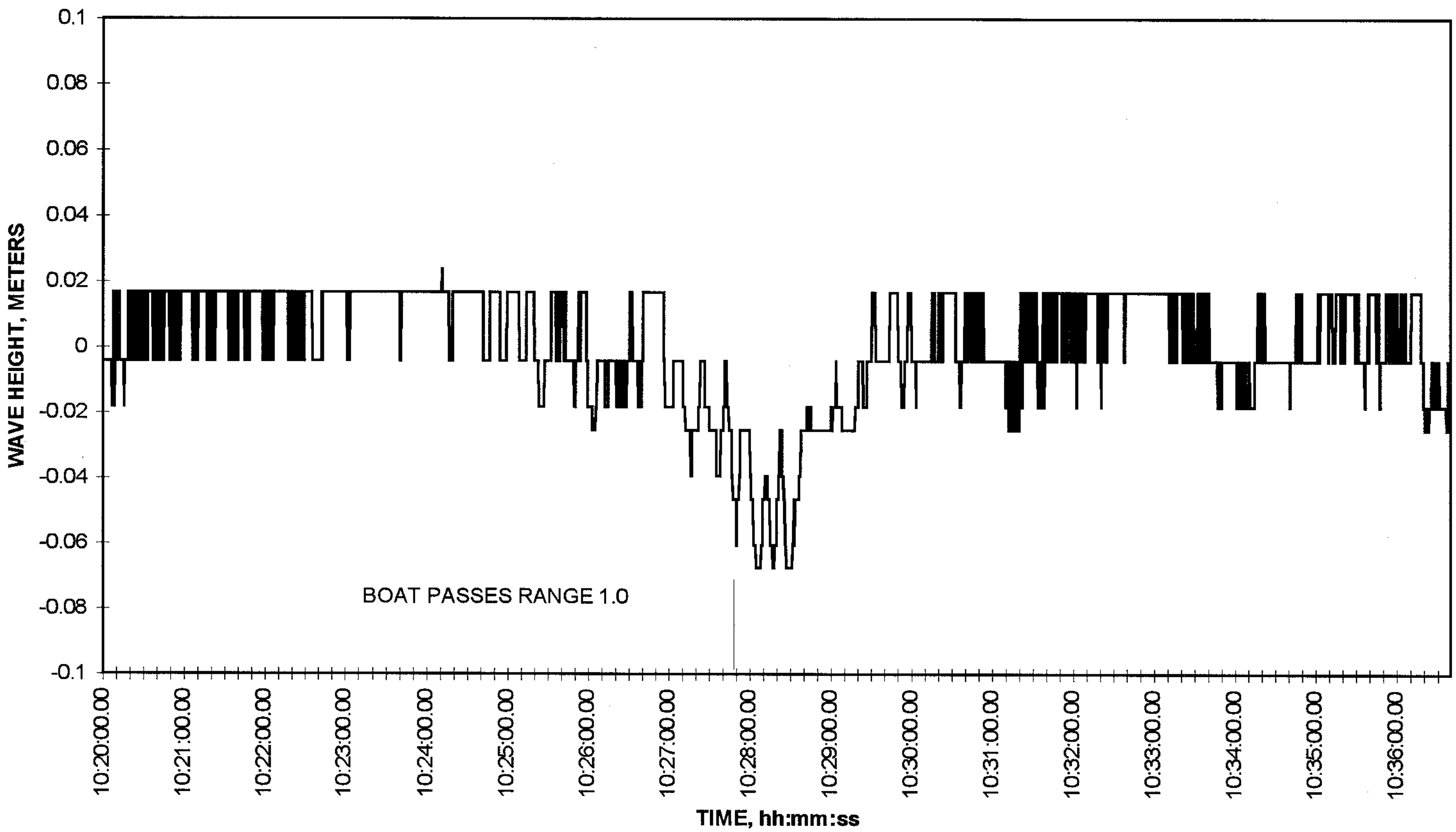
WAVE HEIGHT
POOL 8, RANGE 1
BOAT B02, UPBOUND EMPTY
09/13/96



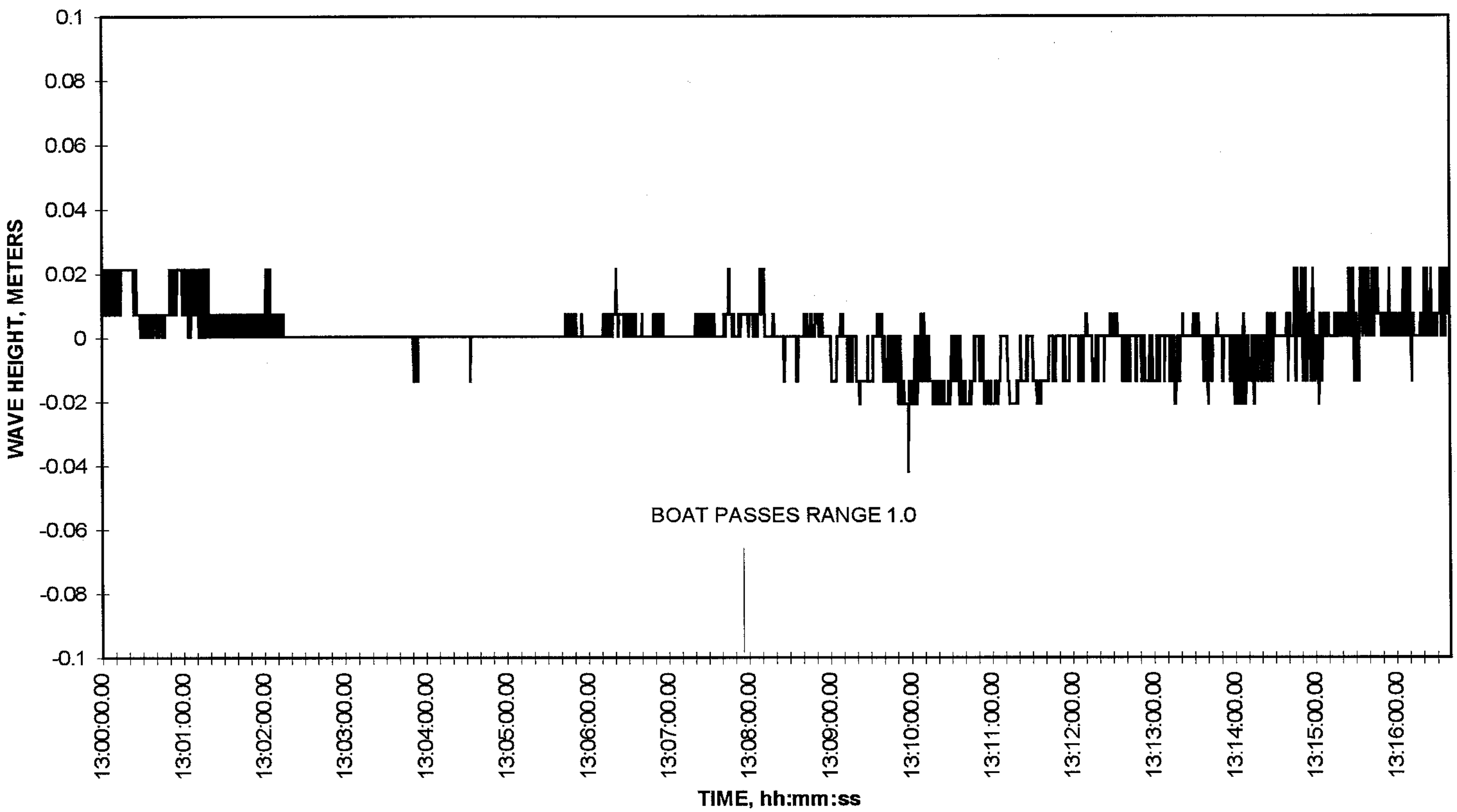
WAVE HEIGHT
POOL 8, RANGE 1
BOAT B06, DOWNBOUND LOADED
09/14/96



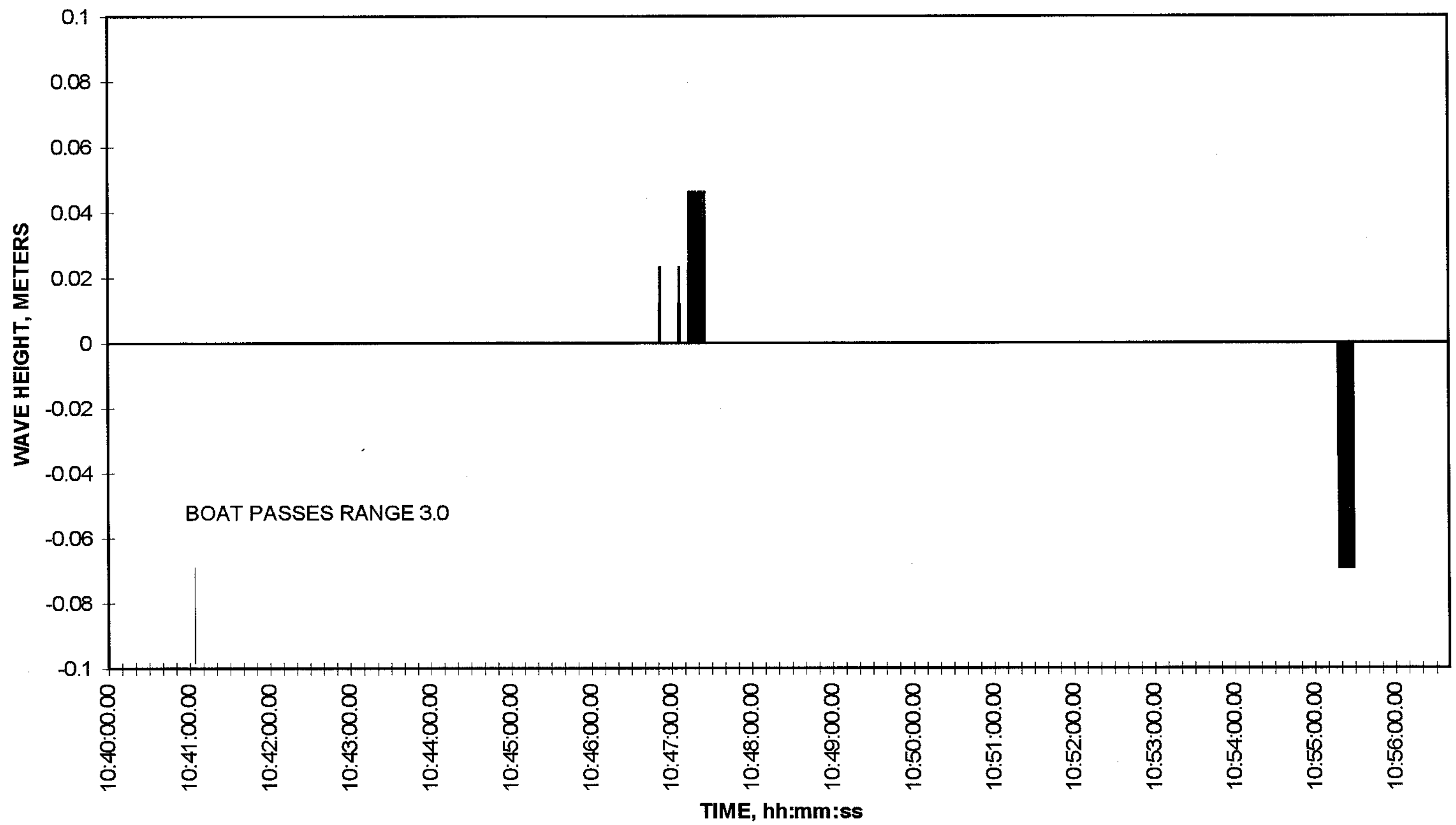
WAVE HEIGHT
POOL 8, RANGE 5
BOAT B03, DOWNBOUND LOADED
9/14/96



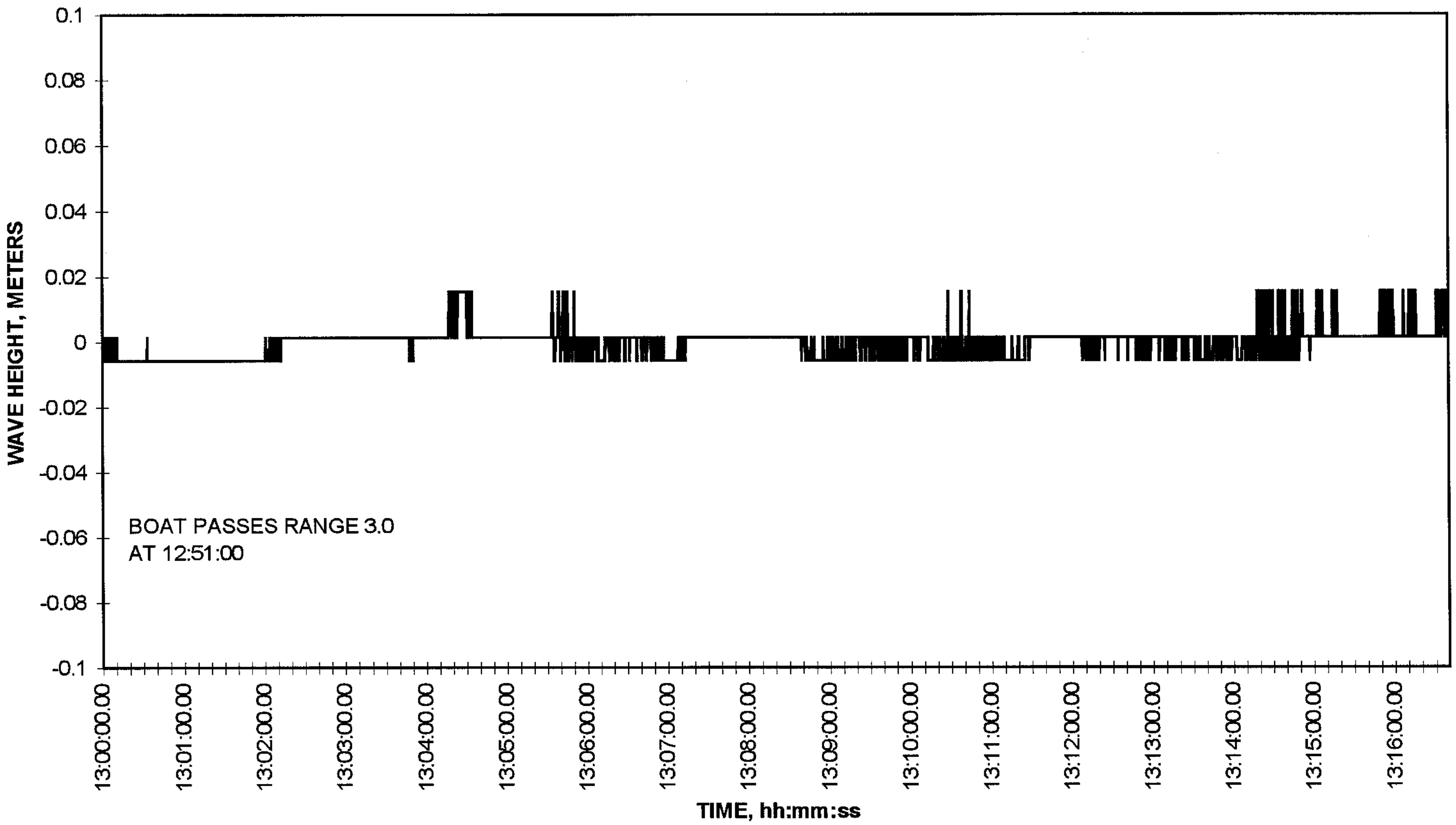
WAVE HEIGHT
POOL 26, RANGE 1
BOAT B05, DOWNBOUND LOADED
09/06/96



WAVE HEIGHT
POOL 26, RANGE 1
BOAT 07, UPBOUND LOADED
09/06/96

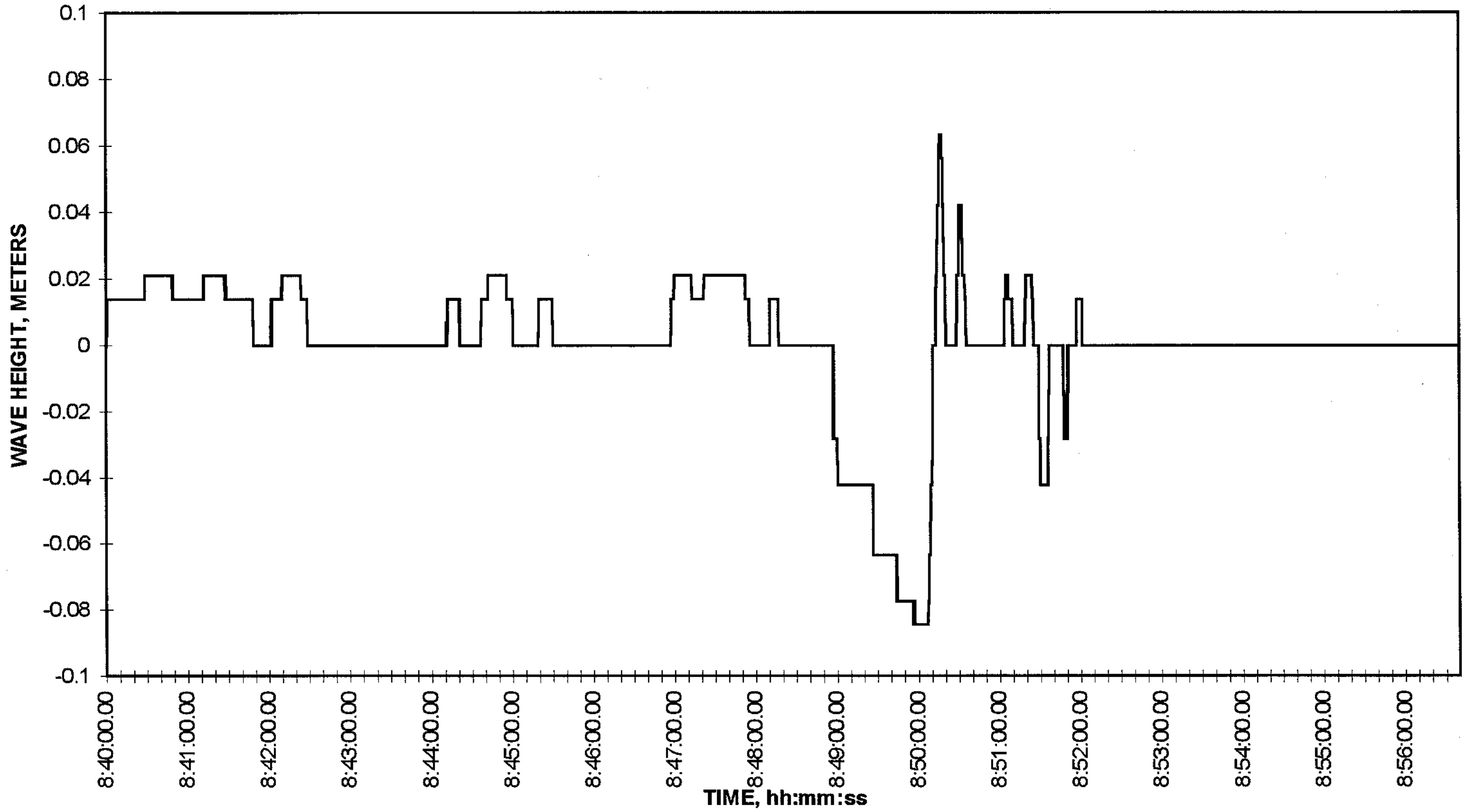


WAVE HEIGHT
POOL 26, RANGE 4
BOAT B05, DOWNBOUND LOADED
09/06/96

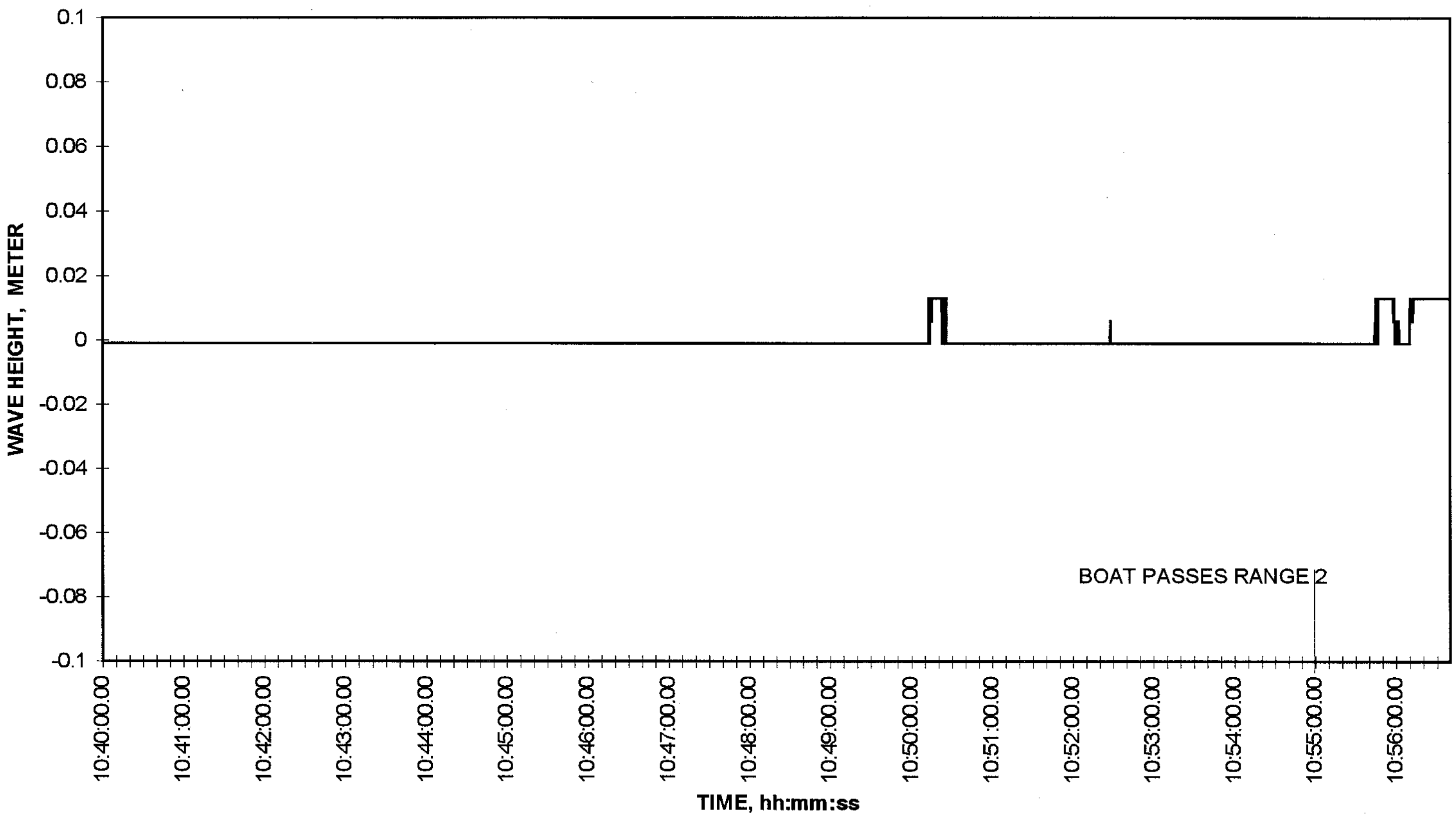


WAVE HEIGHT
POOL 26, RANGE 4
BOAT B07, UPBOUND LOADED
09/06/96

Plate 38



WAVE HEIGHT
LA GRANGE POOL, RANGE 1
BOAT B09, UPBOUND LOADED
09/10/96



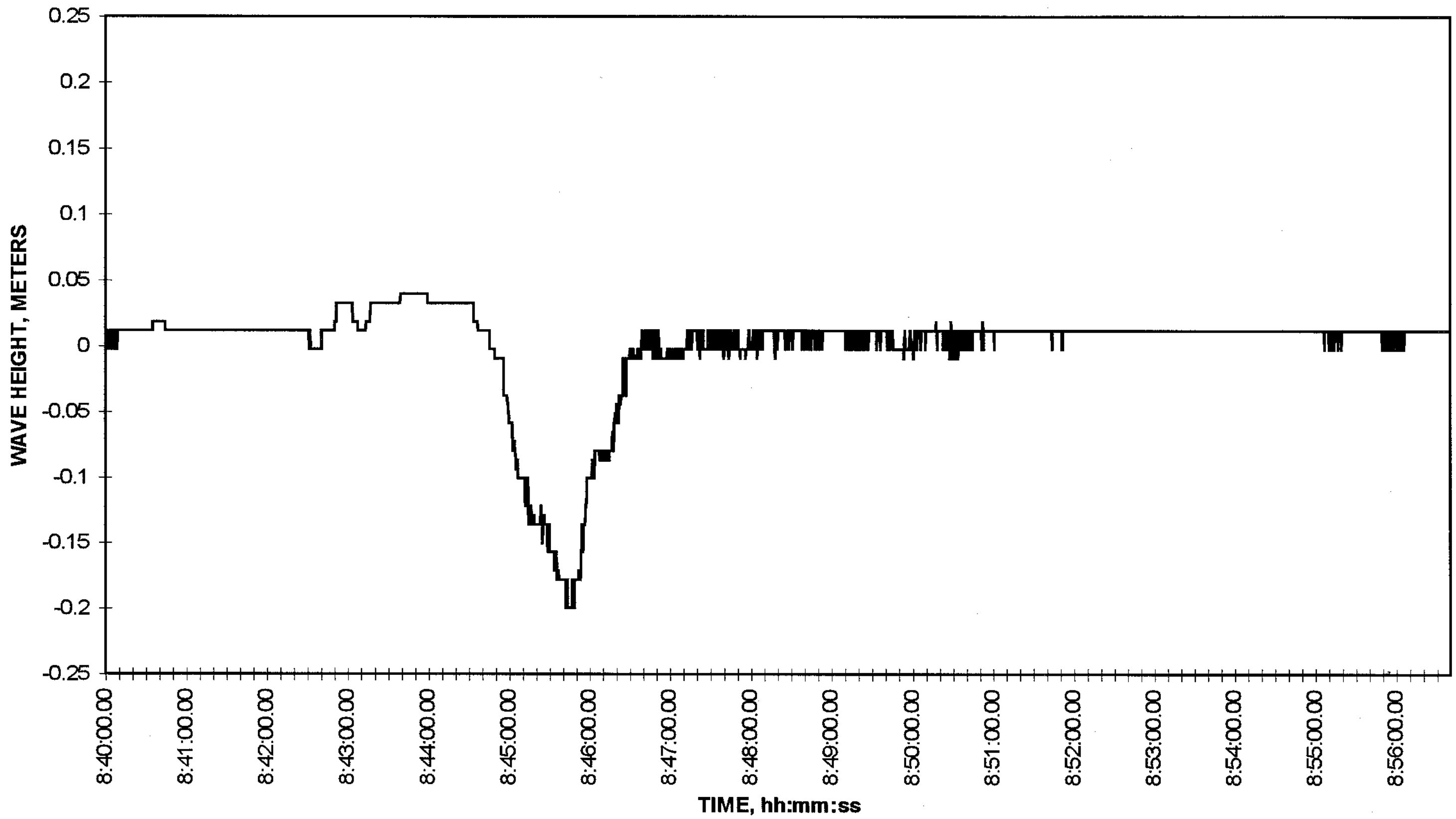
WAVE HEIGHT

LA GRANGE POOL, RANGE 1

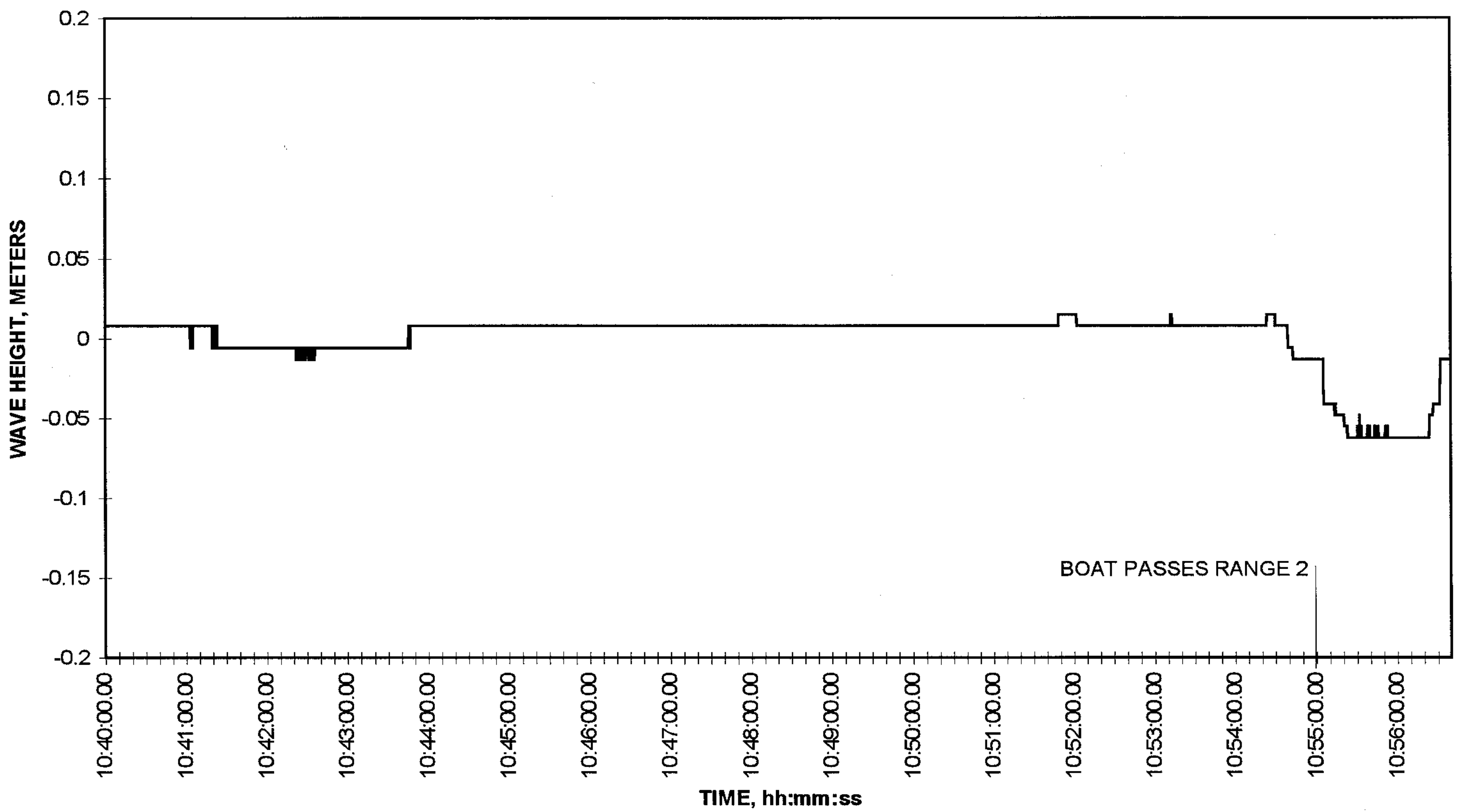
BOAT B10, DOWNBOUND LOADED

09/10/96

Plate 40

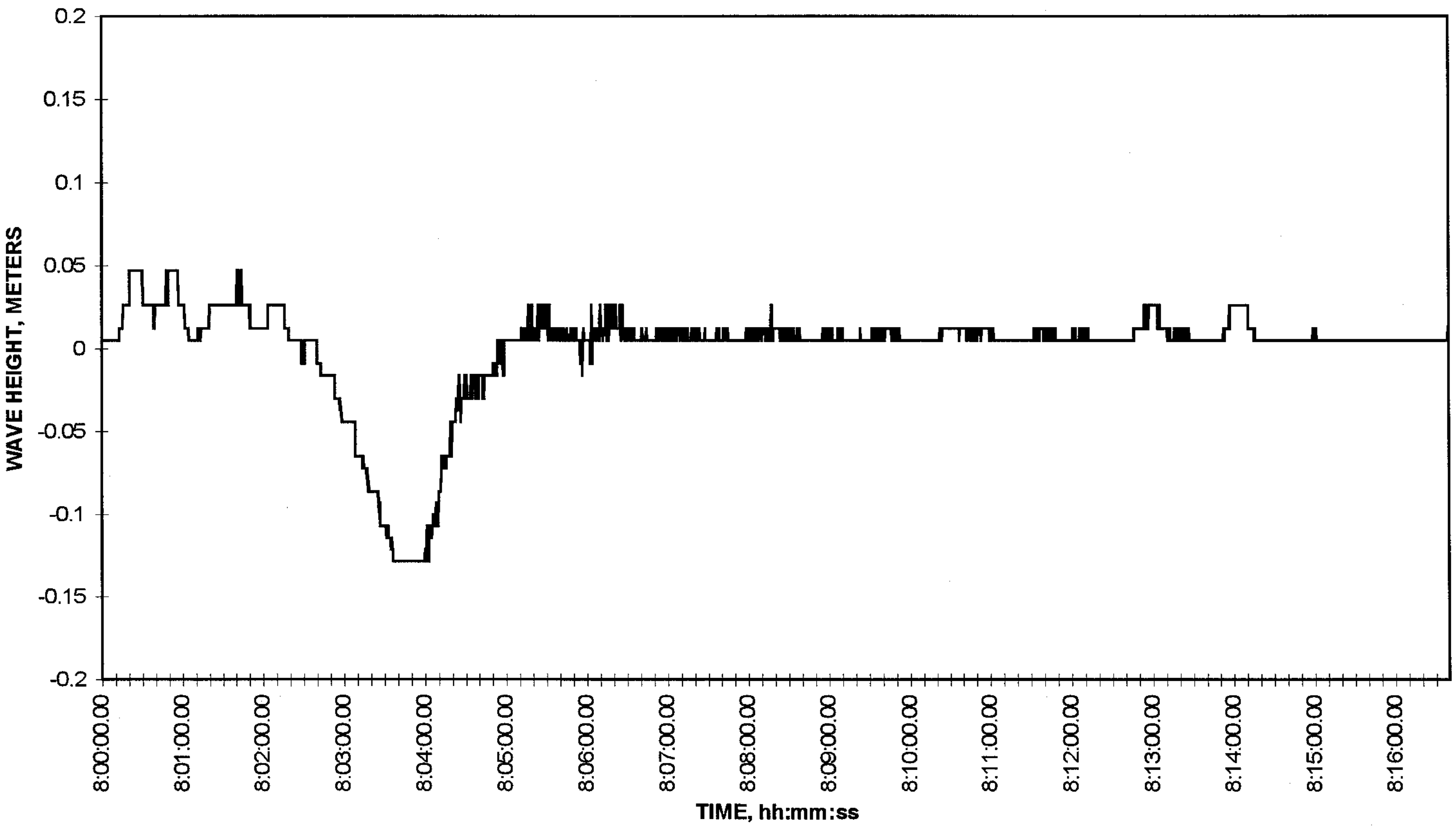


WAVE HEIGHT
LA GRANGE POOL, RANGE 2
BOAT B09, UPBOUND LOADED
09/10/96

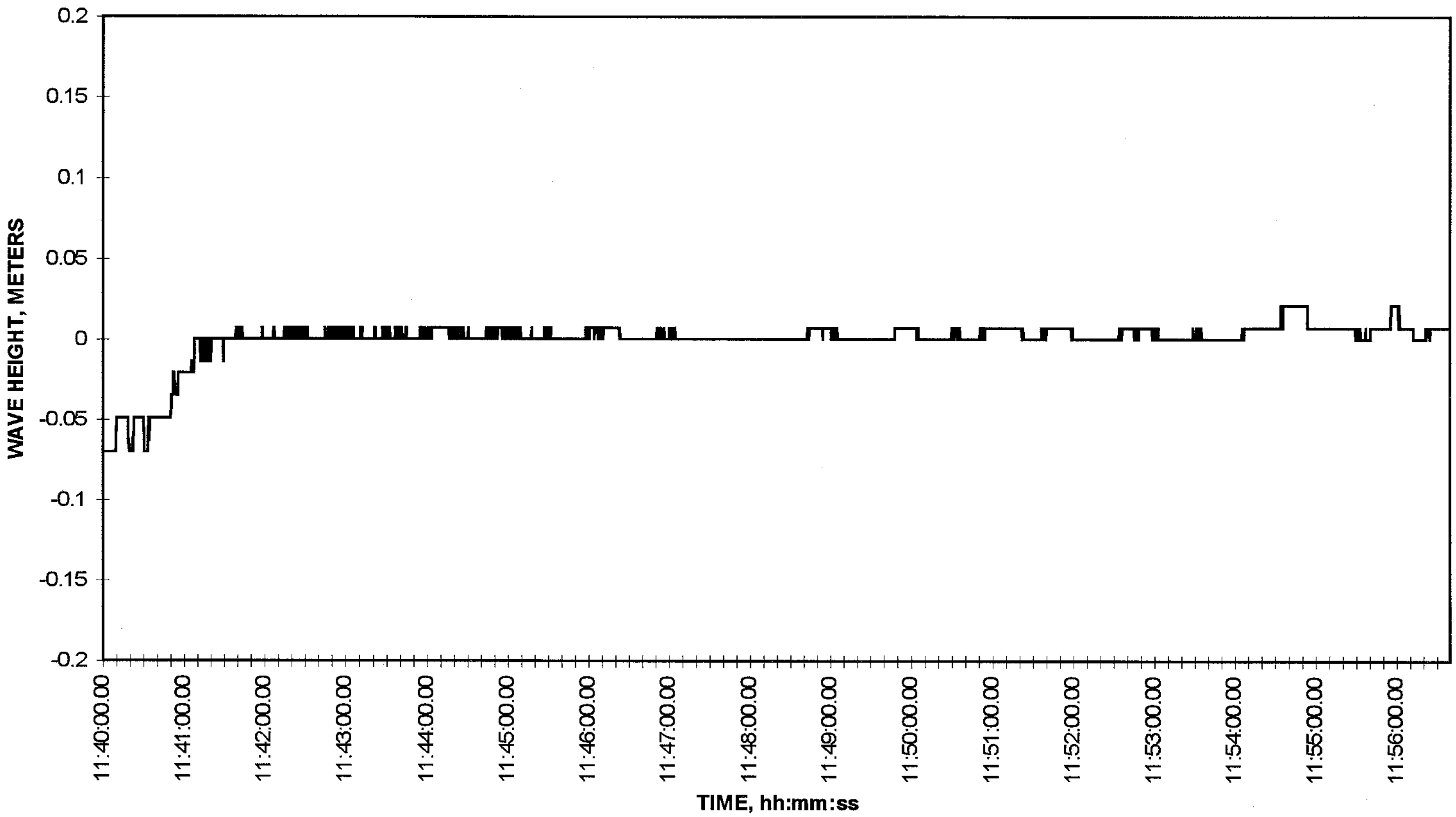


WAVE HEIGHT
LA GRANGE POOL, RANGE 2
BOAT B10, DOWNBOUND LOADED
09/10/96

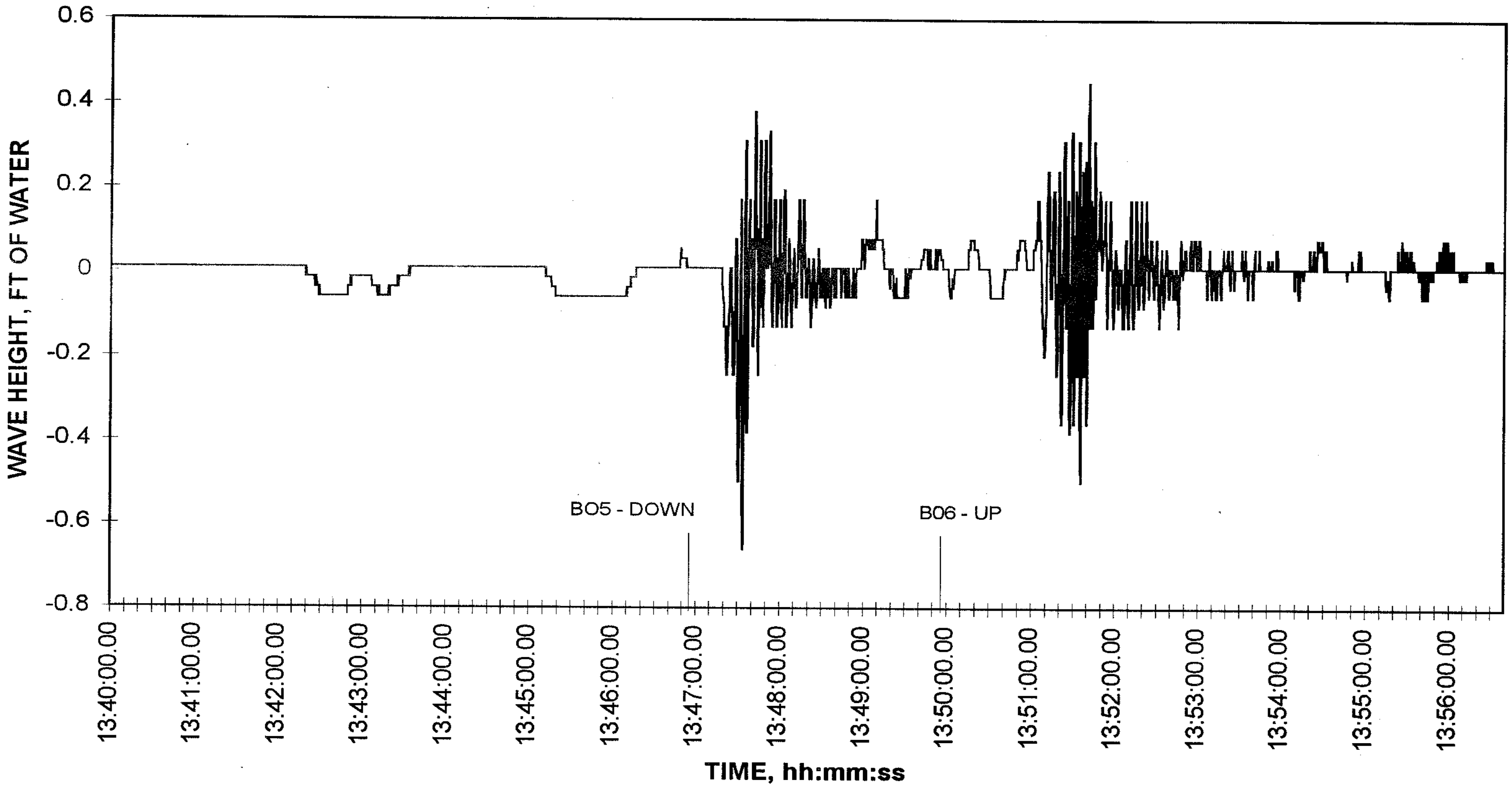
Plate 42



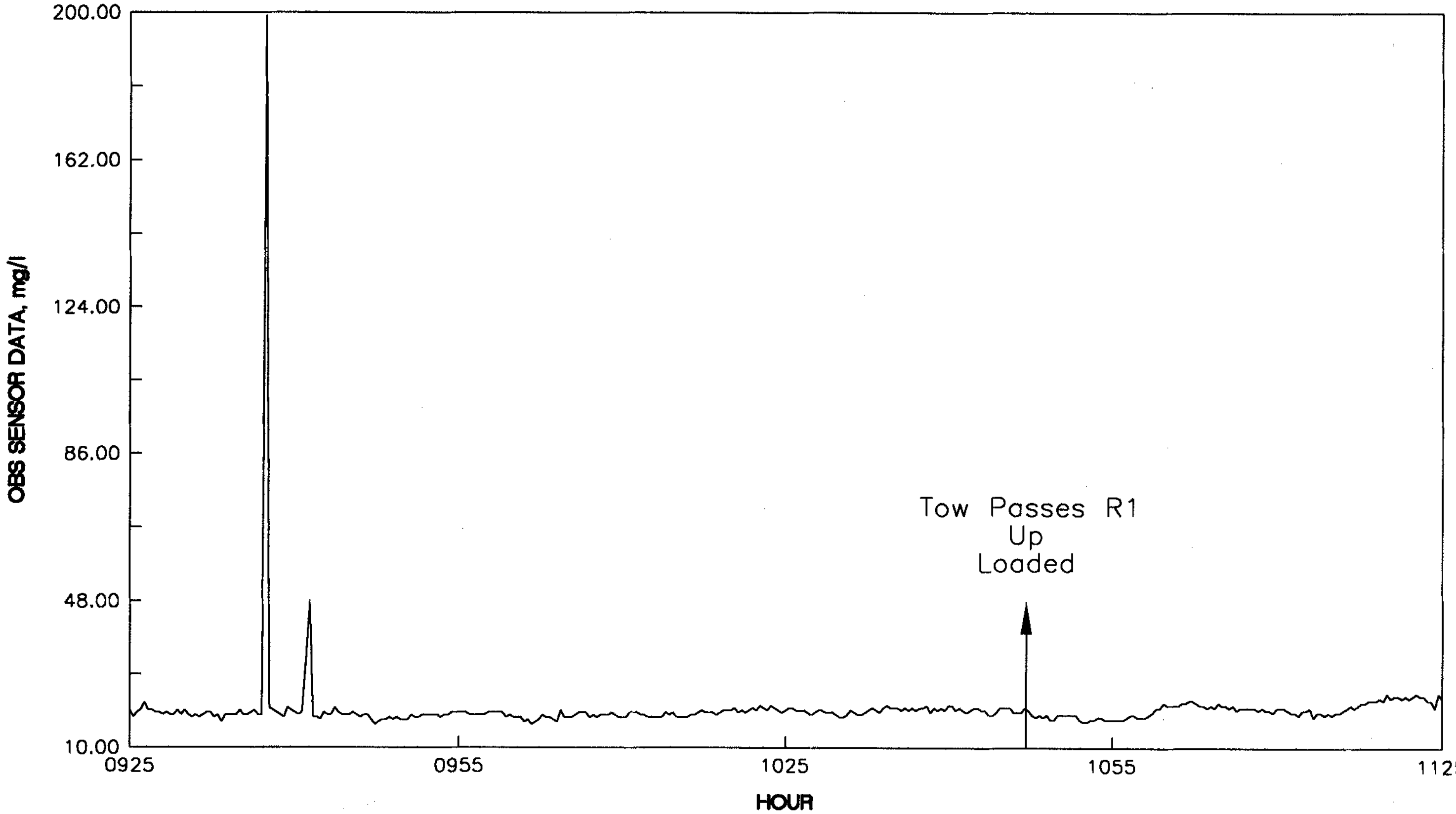
WAVE HEIGHT
LA GRANGE POOL, RANGE 4
BOAT B09, UPBOUND LOADED
09/10/96



WAVE HEIGHT
LA GRANGE POOL, RANGE 4
BOAT B10, DOWNBOUND LOADED
09/10/96



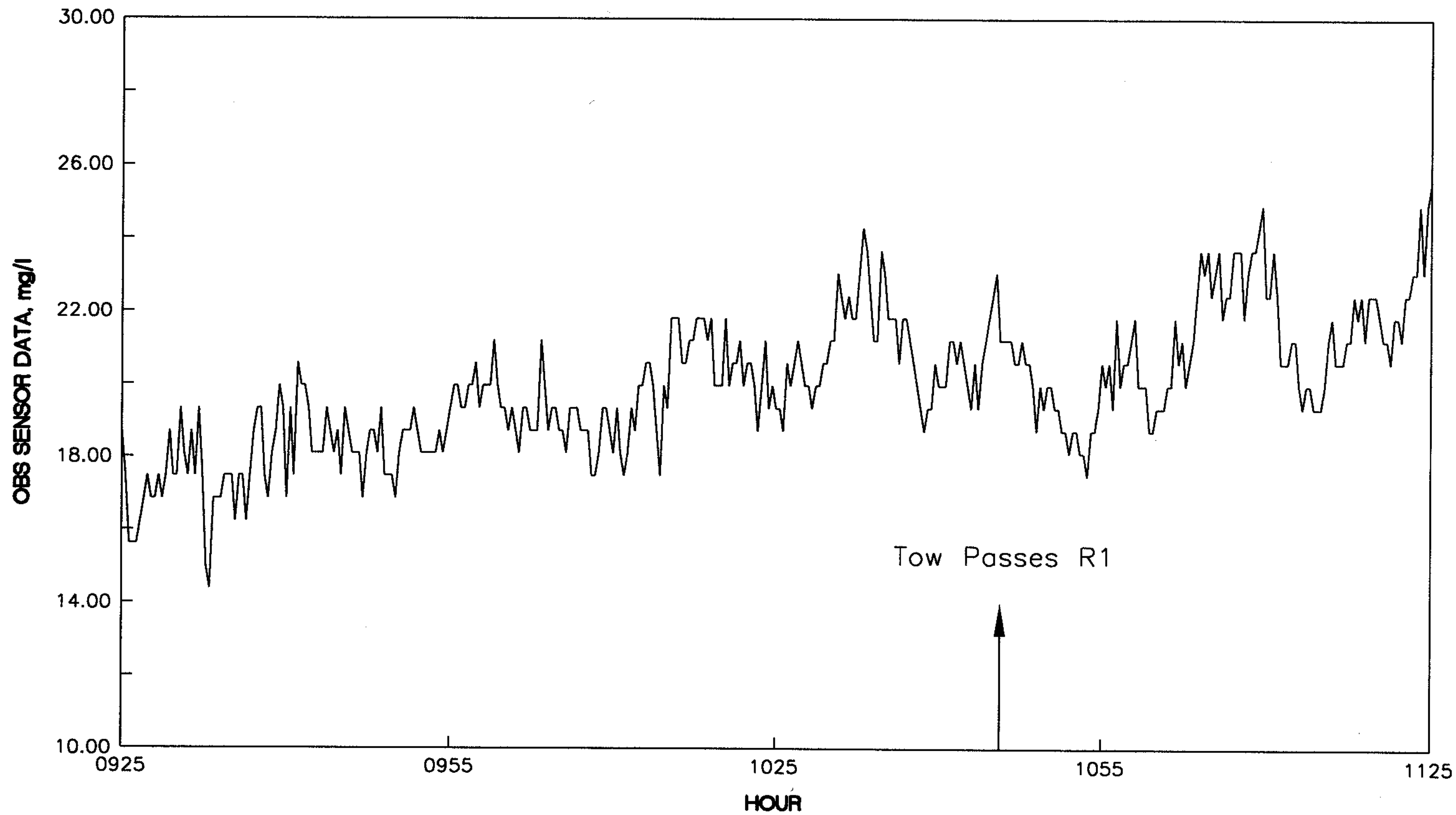
WAVE HEIGHT
LA GRANGE POOL, RANGE 2
BOATS B05 AND B06
9/9/96 - 9/9/96



MEAN IS 19.9400 mg/L

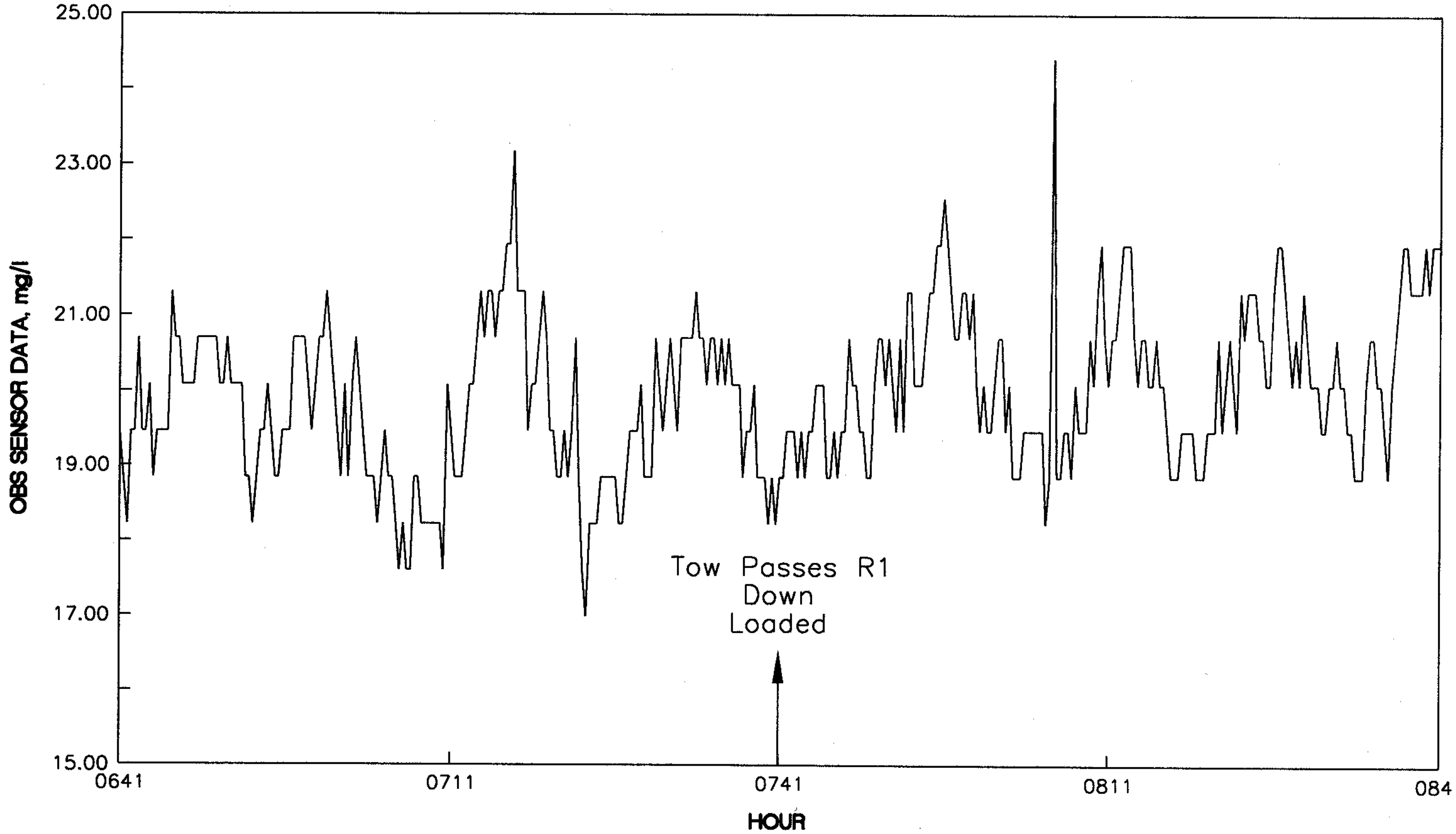
OBS SENSOR AT 8.5 FT
RANGE 1 POOL 08 BOAT 01
9/13/96-9/13/96

Plate 46



MEAN IS 19.9400 mg/L

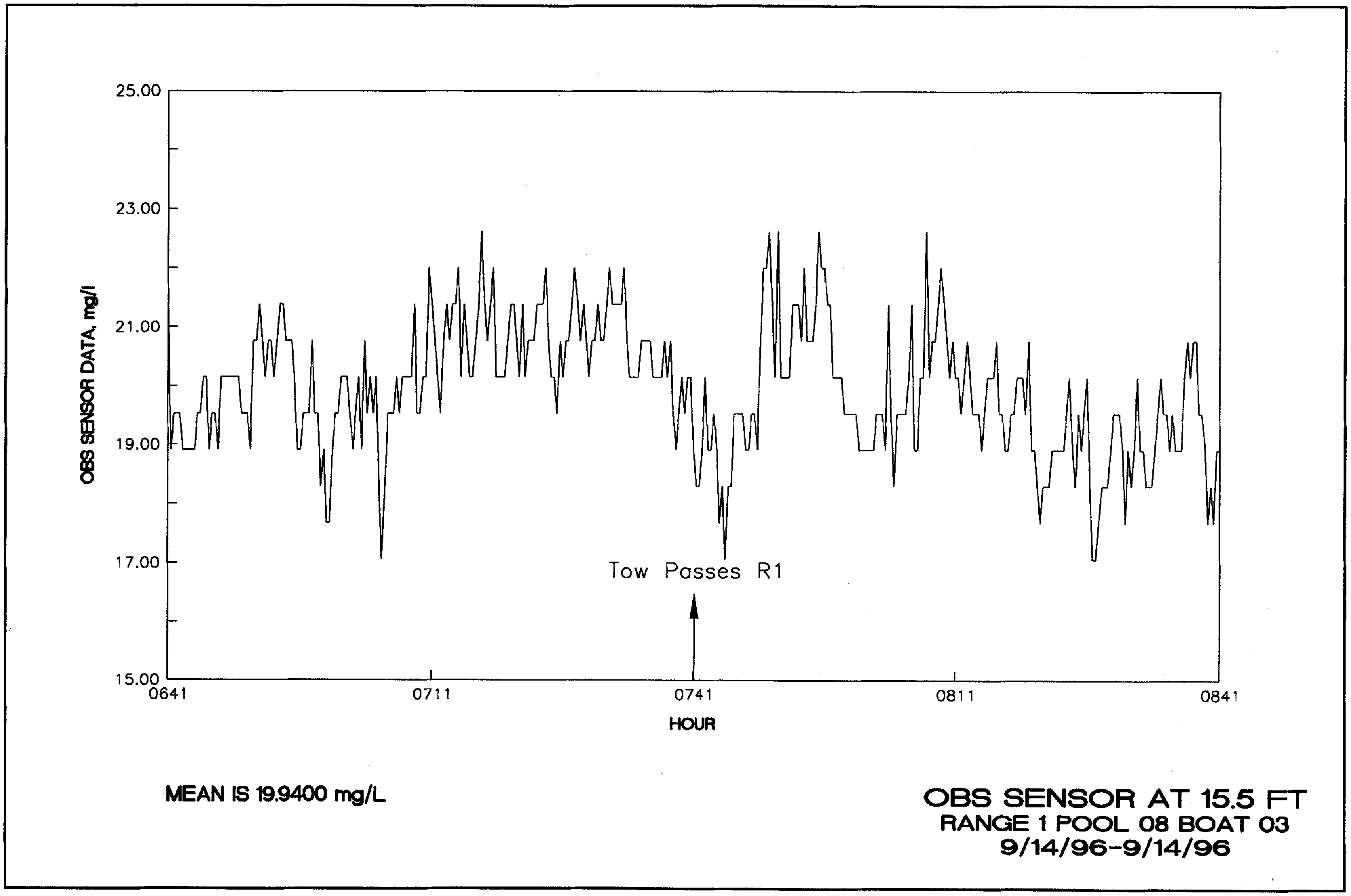
OBS SENSOR AT 14.5 FT
RANGE 1 POOL 08 BOAT 01
9/13/96-9/13/96



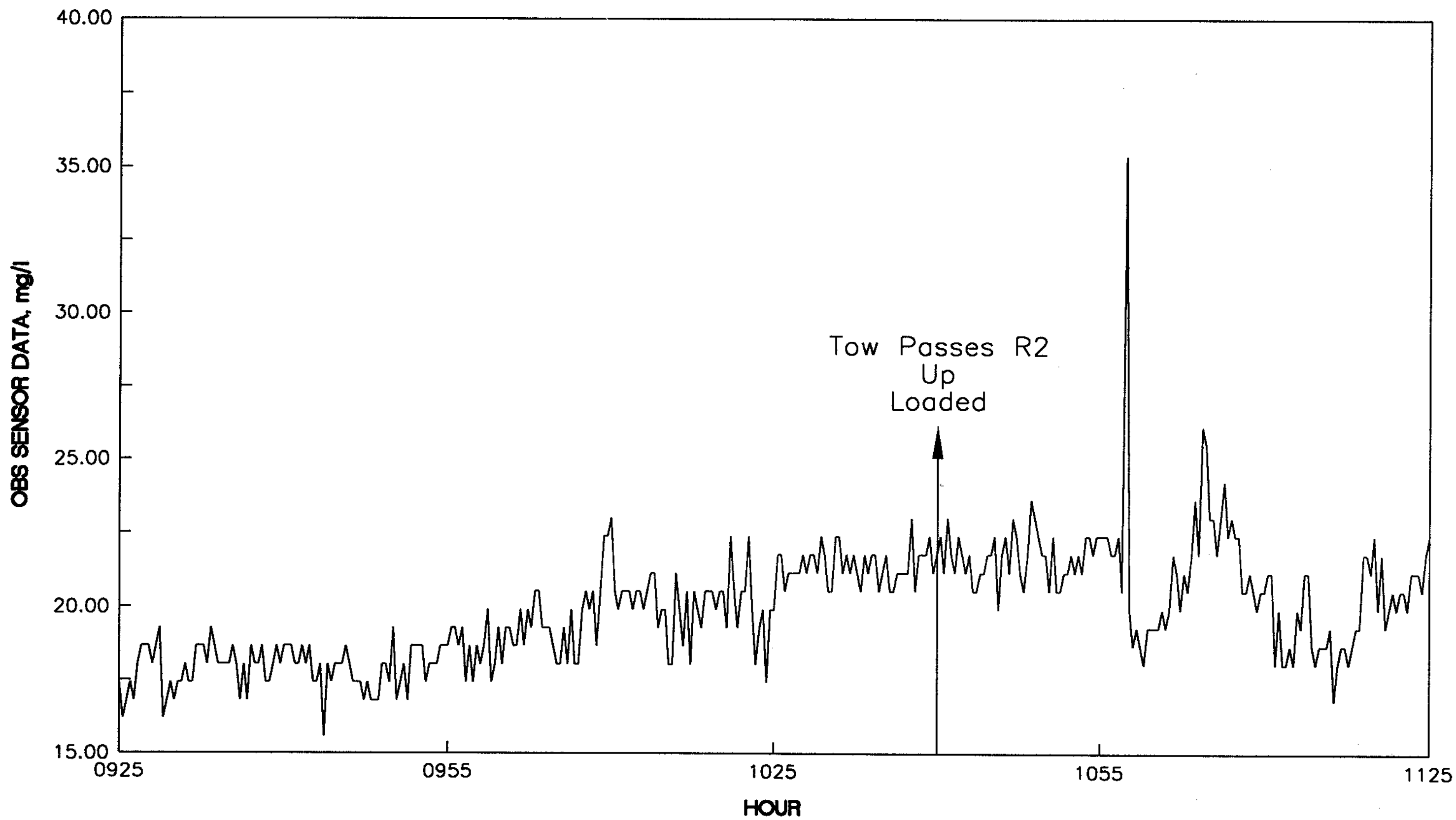
MEAN IS 19.9400 mg/L

OBS SENSOR AT 8.5 FT
RANGE 1 POOL 08 BOAT 03
9/14/96-9/14/96

Plate 48



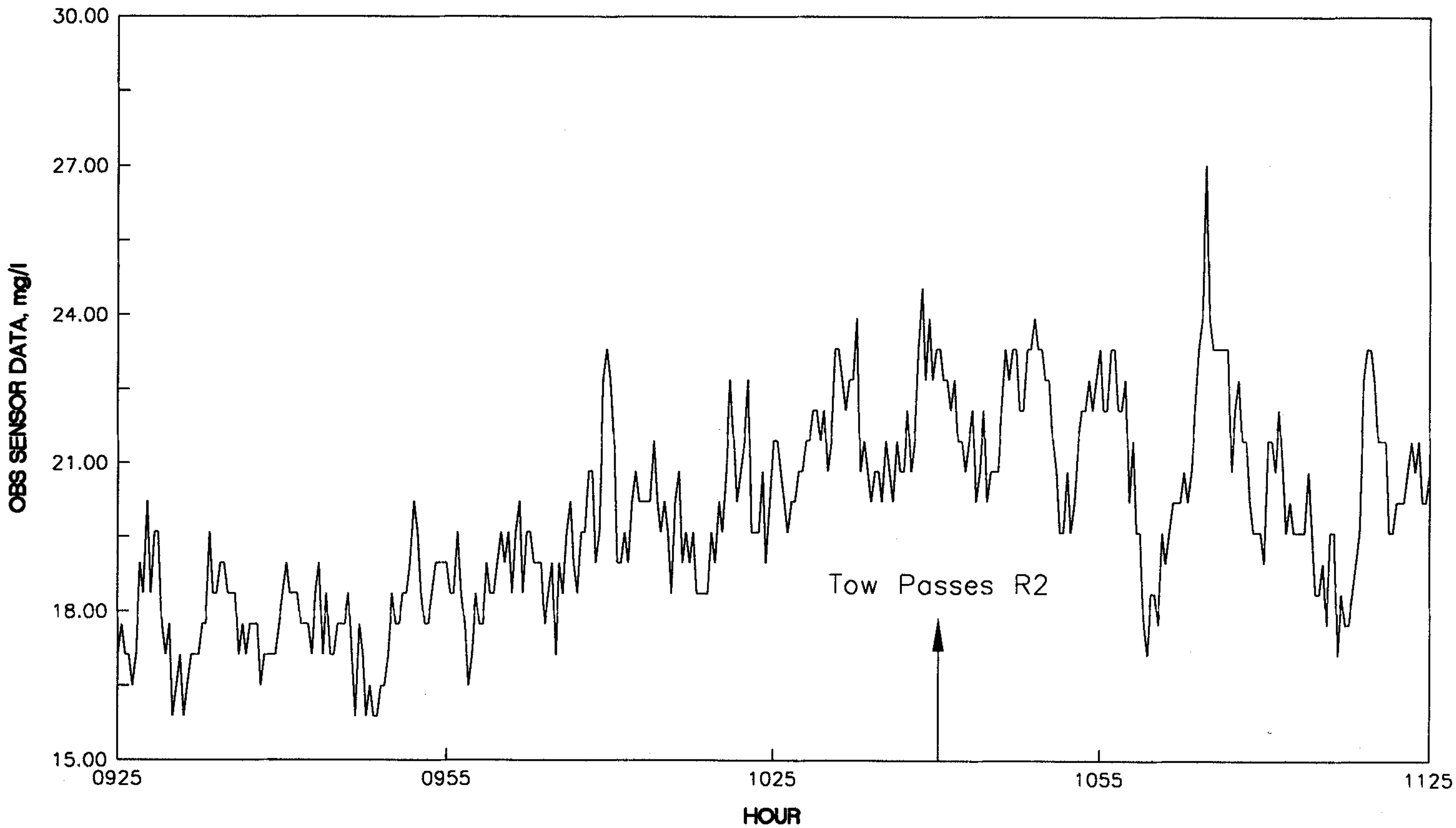
25.00
23.00
21.00
19.00
17.00
15.00
OBS SENSOR DATA, mg/l
Tow Passes R1
0641
0711
0741
0811
0841
HOUR
MEAN IS 19.9400 mg/L
OBS SENSOR AT 15.5 FT
RANGE 1 POOL 08 BOAT 03
9/14/96-9/14/96



MEAN IS 19.9400 mg/L

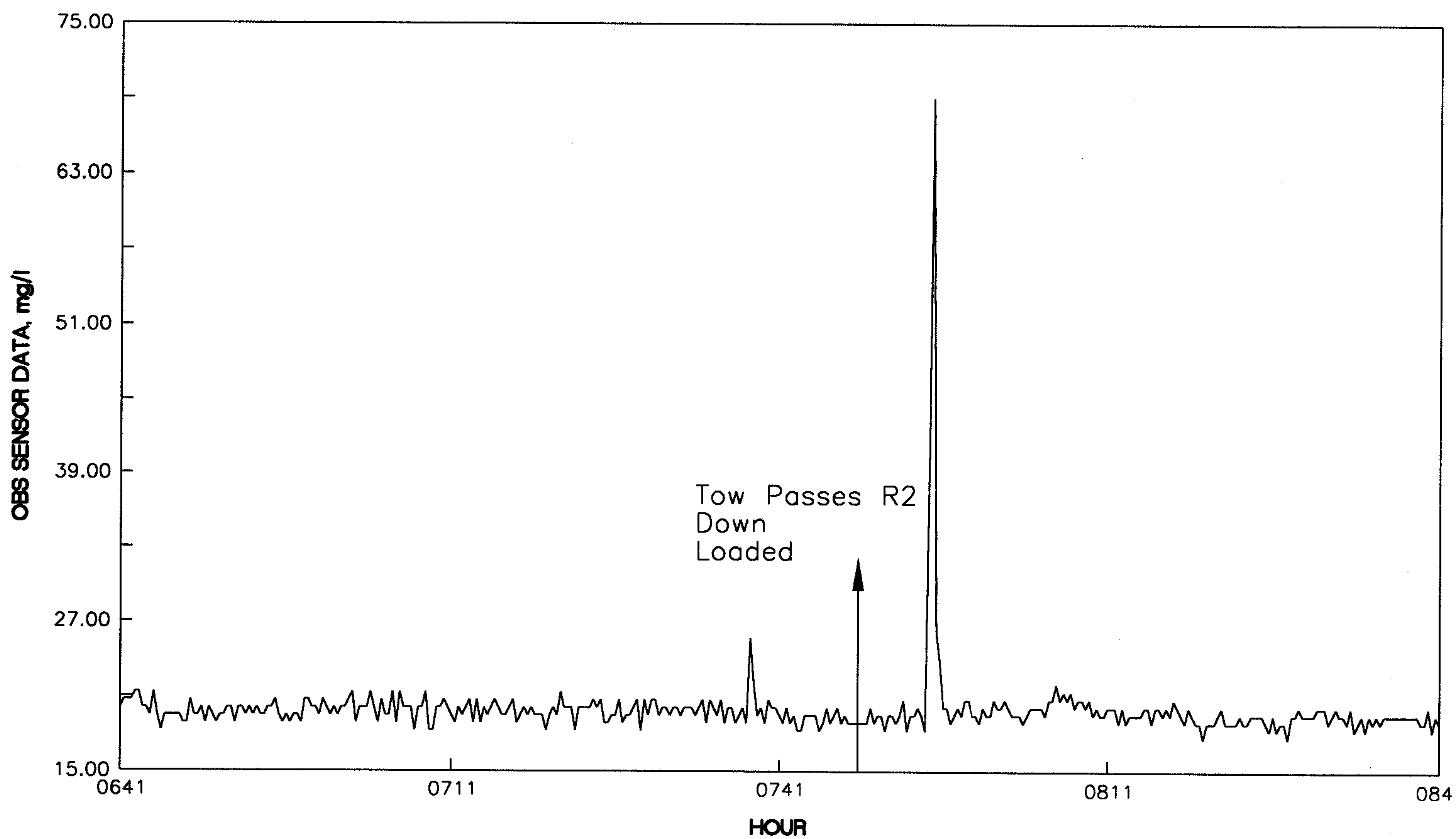
OBS SENSOR AT 16.5 FT
RANGE 2 POOL 08 BOAT 01
9/13/96-9/13/96

Plate 50



MEAN IS 19.9400 mg/L

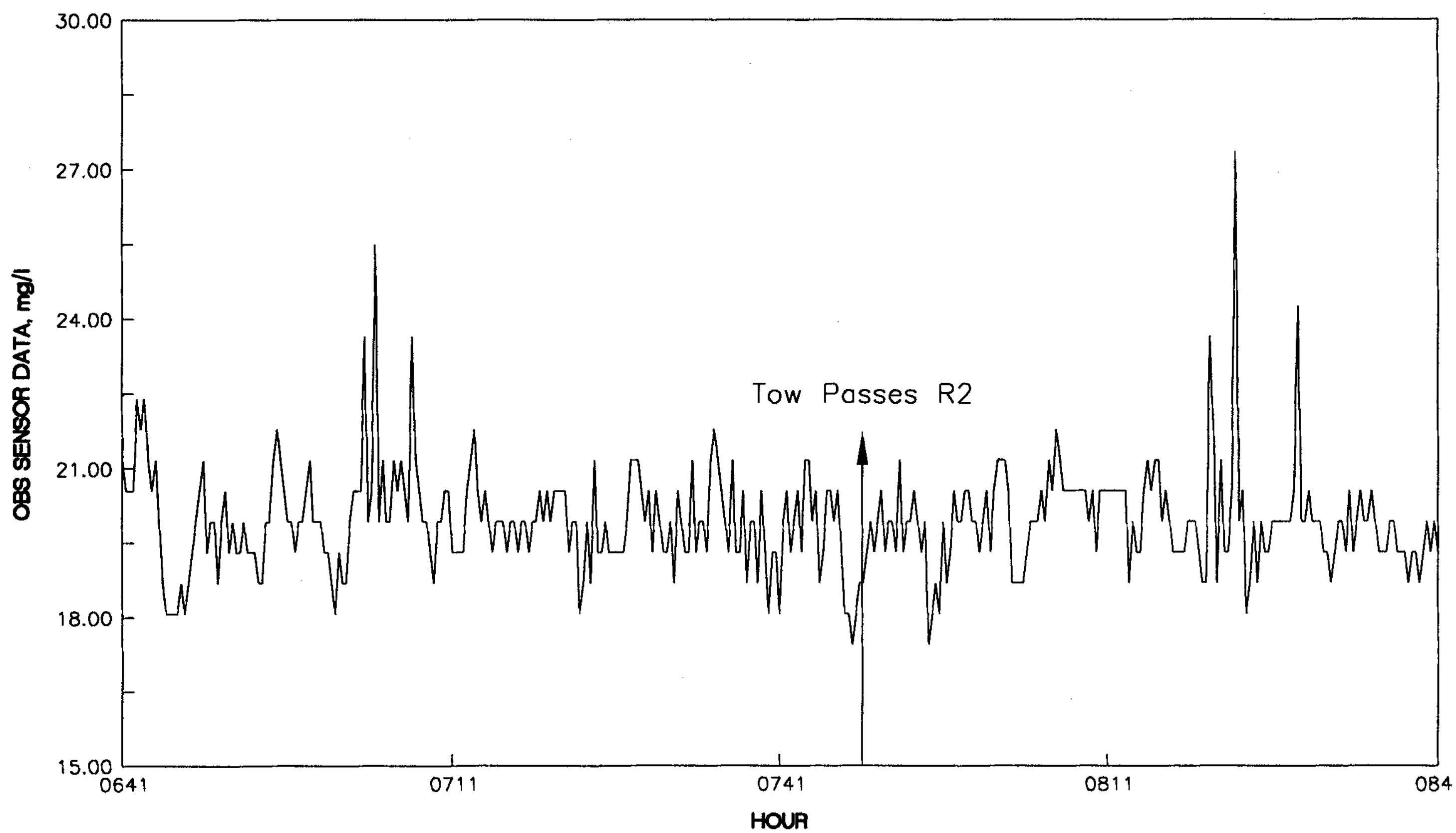
OBS SENSOR AT 19.5 FT
RANGE 2 POOL 08 BOAT 01
9/13/96-9/13/96



MEAN IS 19.9400 mg/L

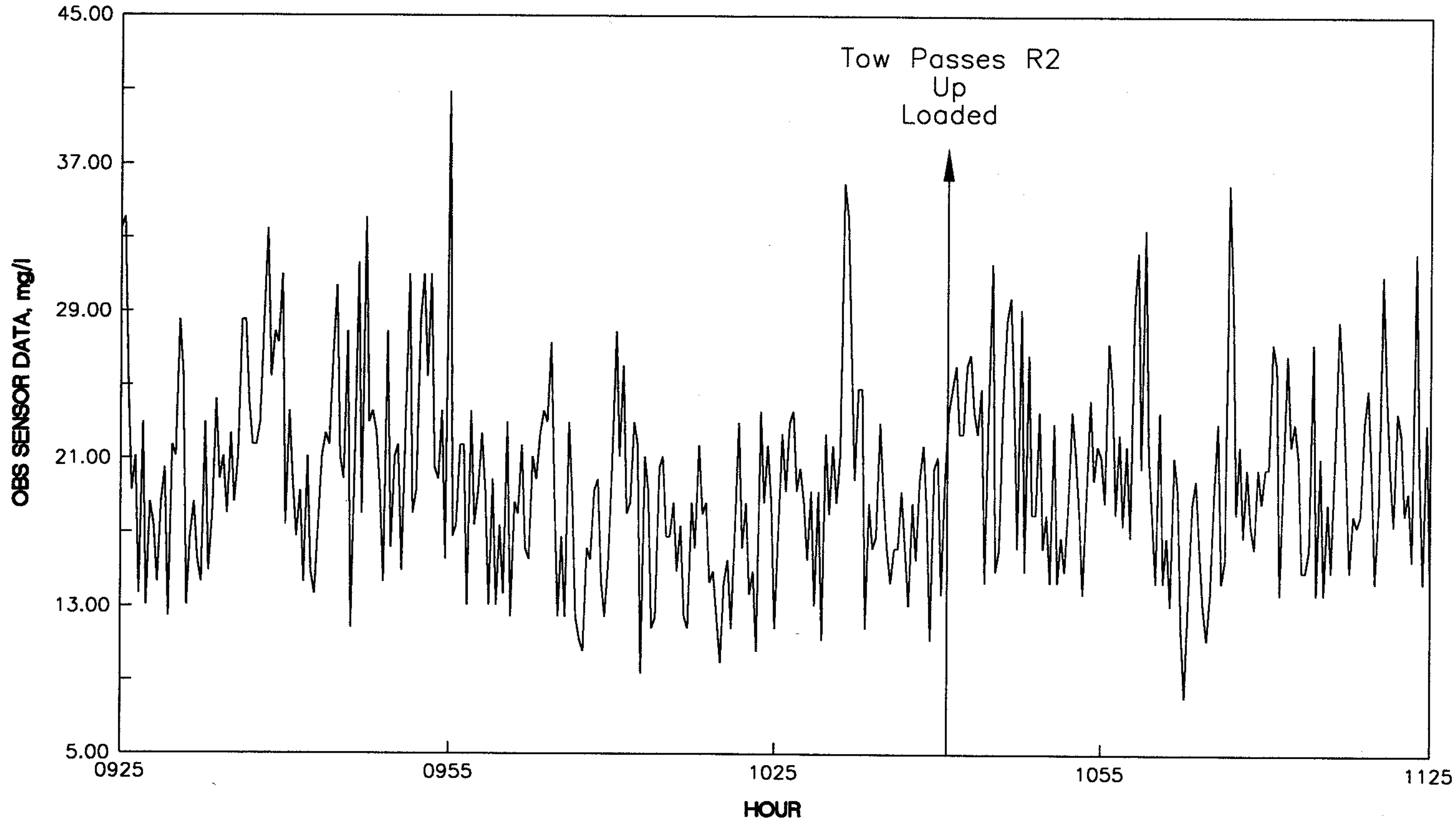
OBS SENSOR AT 16.5 FT
RANGE 2 POOL 08 BOAT 03
9/14/96-9/14/96

Plate 52



MEAN IS 19.9400 mg/L

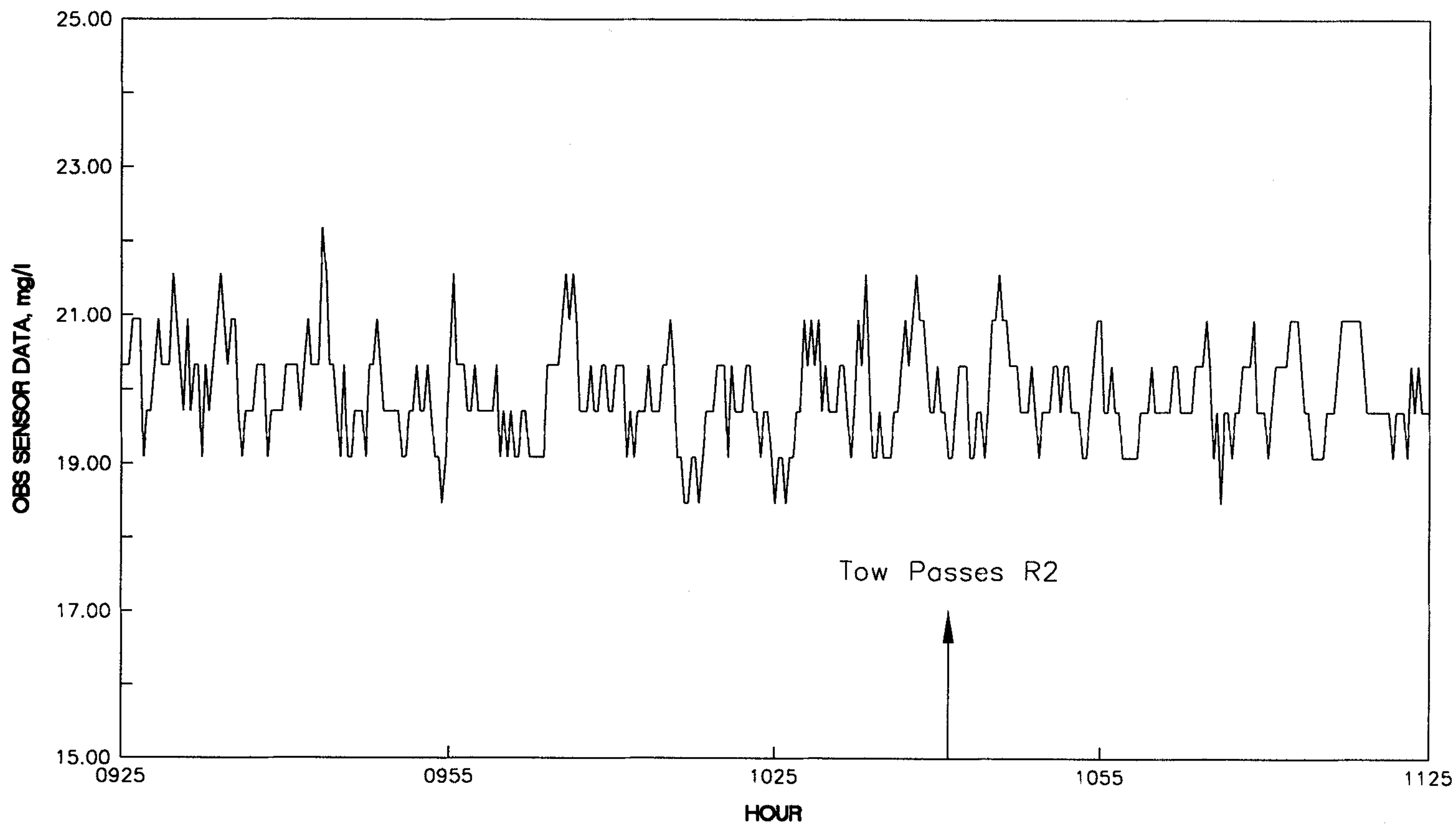
OBS SENSOR AT 19.5 FT
RANGE 2 POOL 08 BOAT 03
9/14/96-9/14/96



MEAN IS 19.9400 mg/L

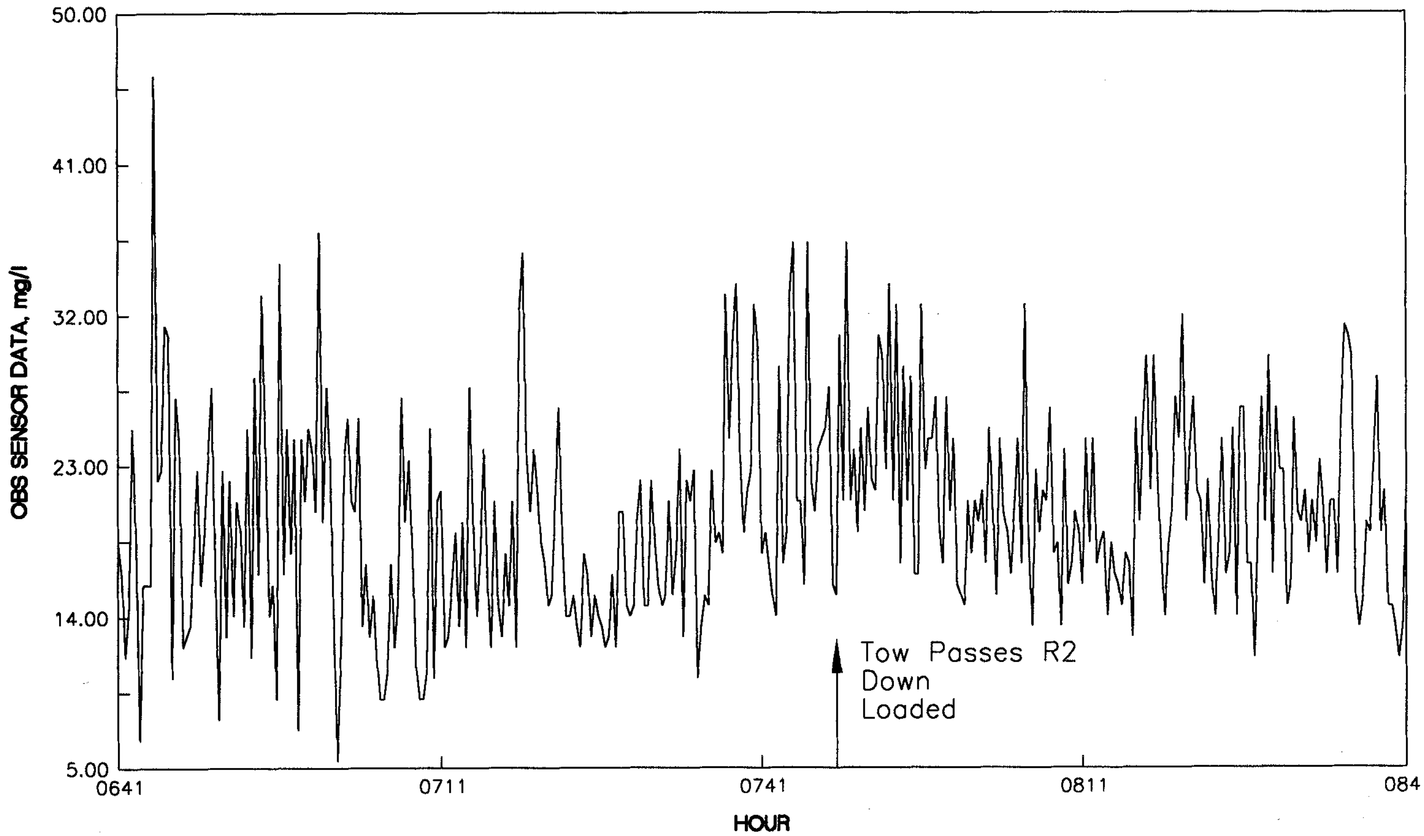
OBS SENSOR AT 1.5 FT
RANGE 5 POOL 08 BOAT 01
9/13/96-9/13/96

Plate 54



MEAN IS 19.9401 mg/L

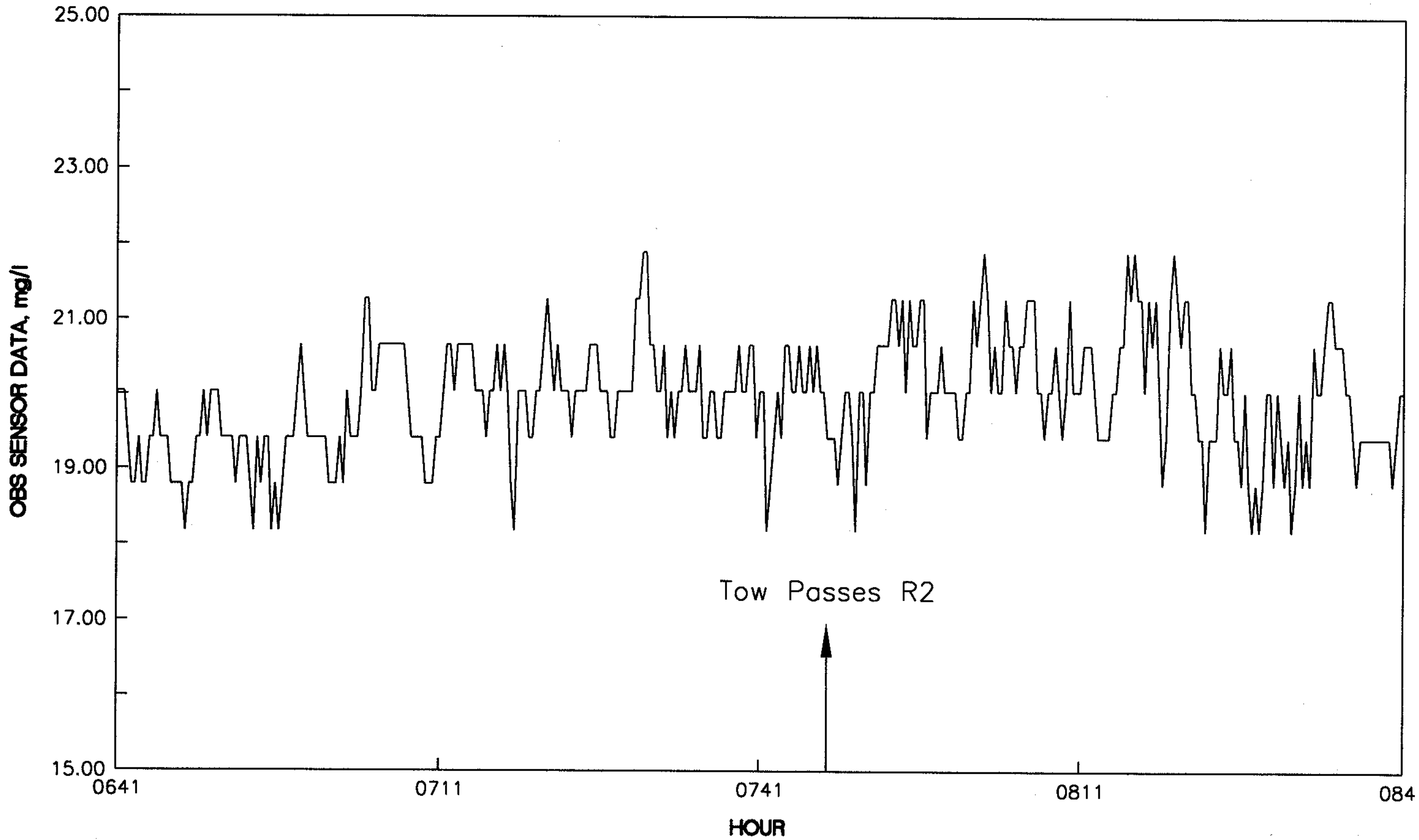
OBS SENSOR AT 16.5 FT
RANGE 5 POOL 08 BOAT 01
9/13/96-9/13/96



MEAN IS 19.9400 mg/L

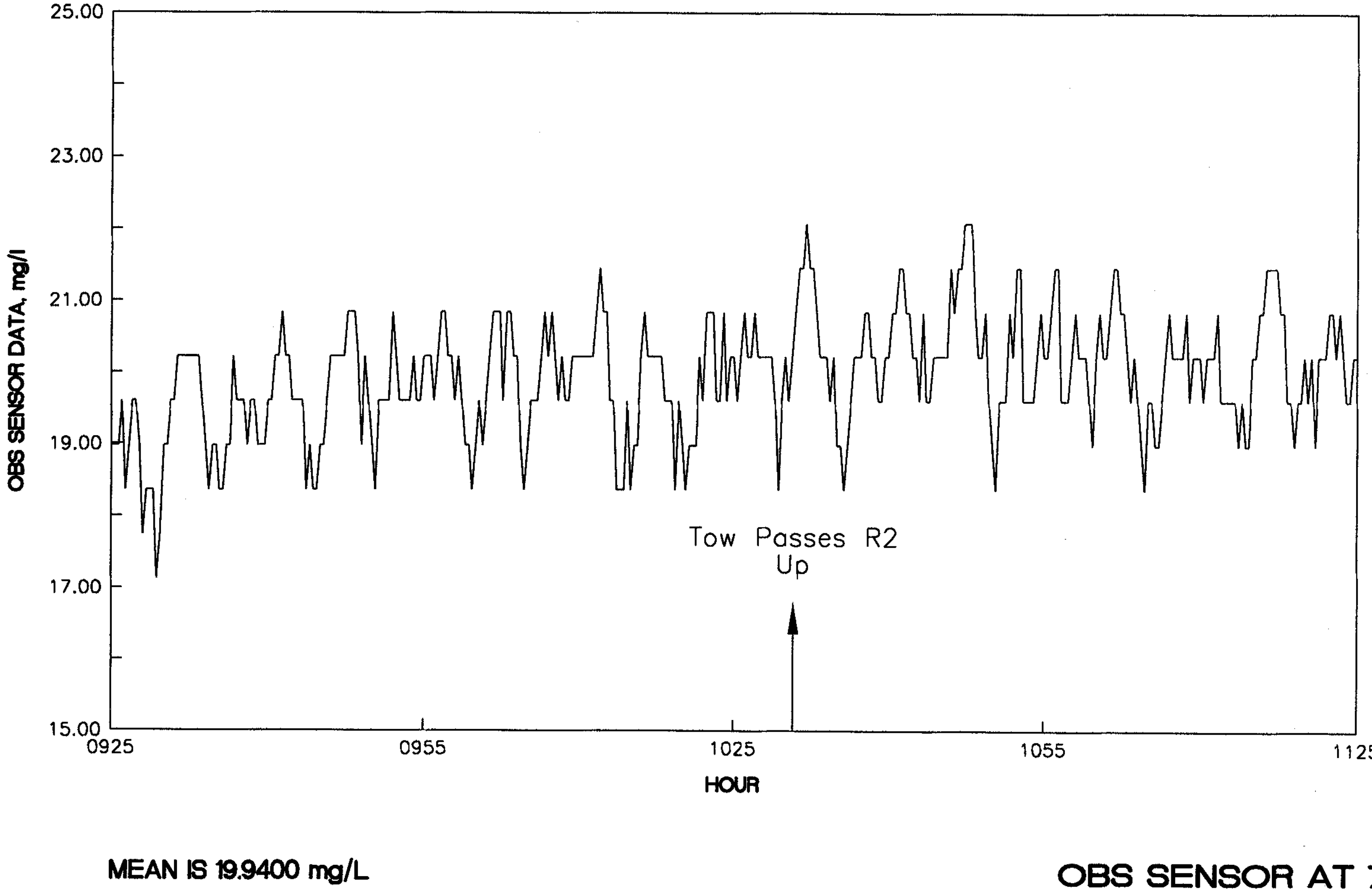
OBS SENSOR AT 1.5 FT
RANGE 5 POOL 08 BOAT 03
9/14/96-9/14/96

Plate 56



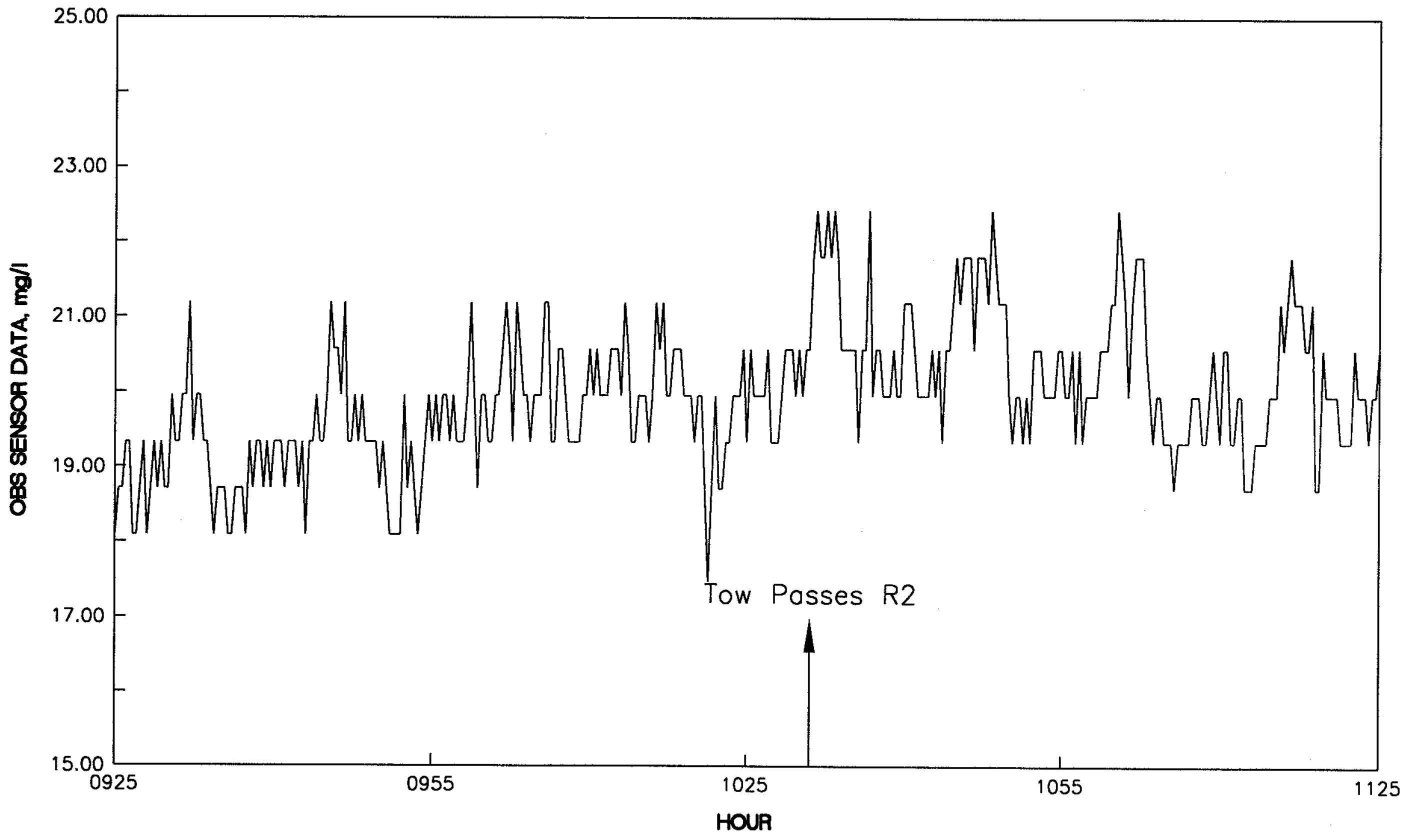
MEAN IS 19.9400 mg/L

OBS SENSOR AT 16.5 FT
RANGE 5 POOL 08 BOAT 03
9/14/96-9/14/96



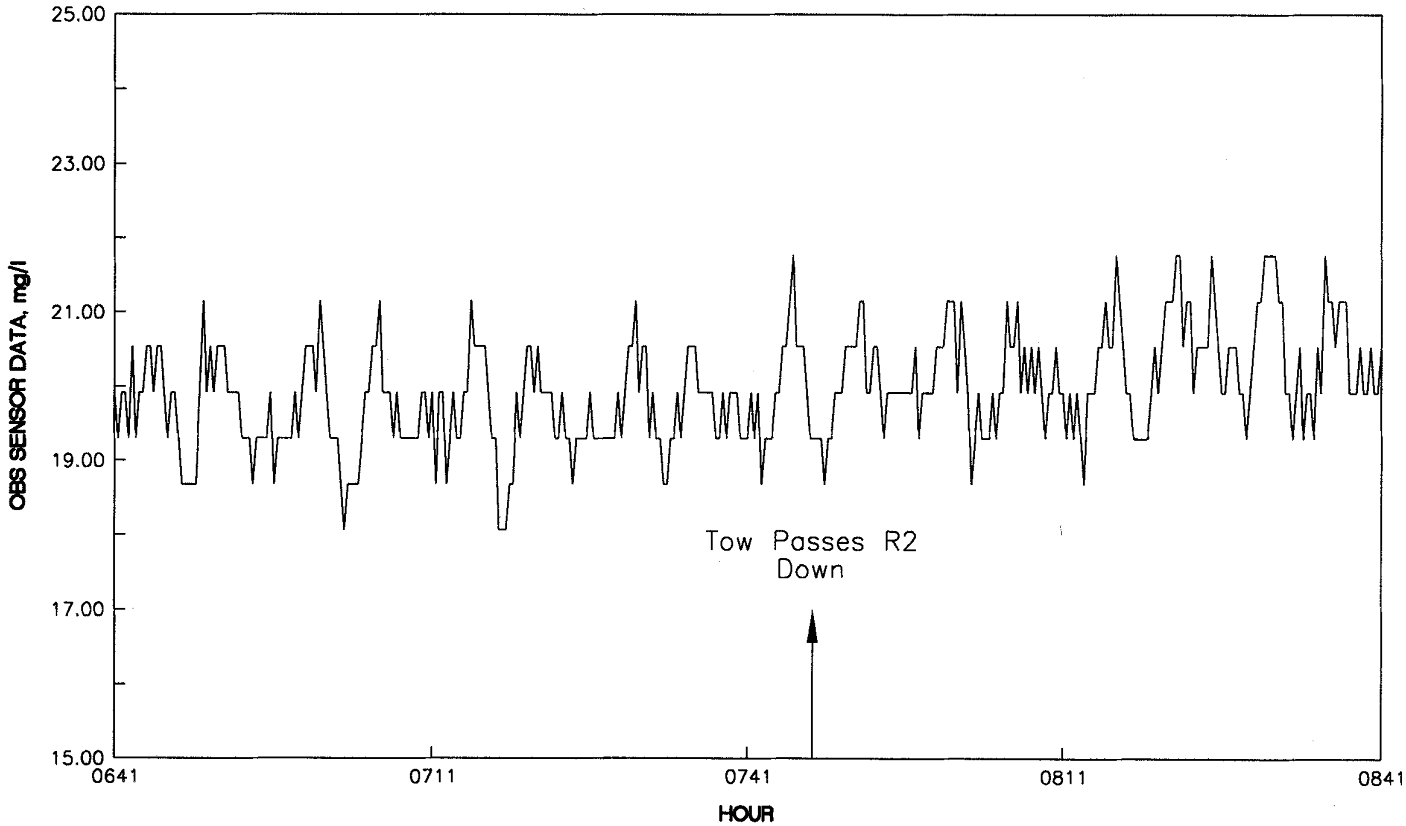
OBS SENSOR AT 7 FT
RANGE 6 POOL 08 BOAT 01
9/13/96-9/13/96

Plate 58



MEAN IS 19.9400 mg/L

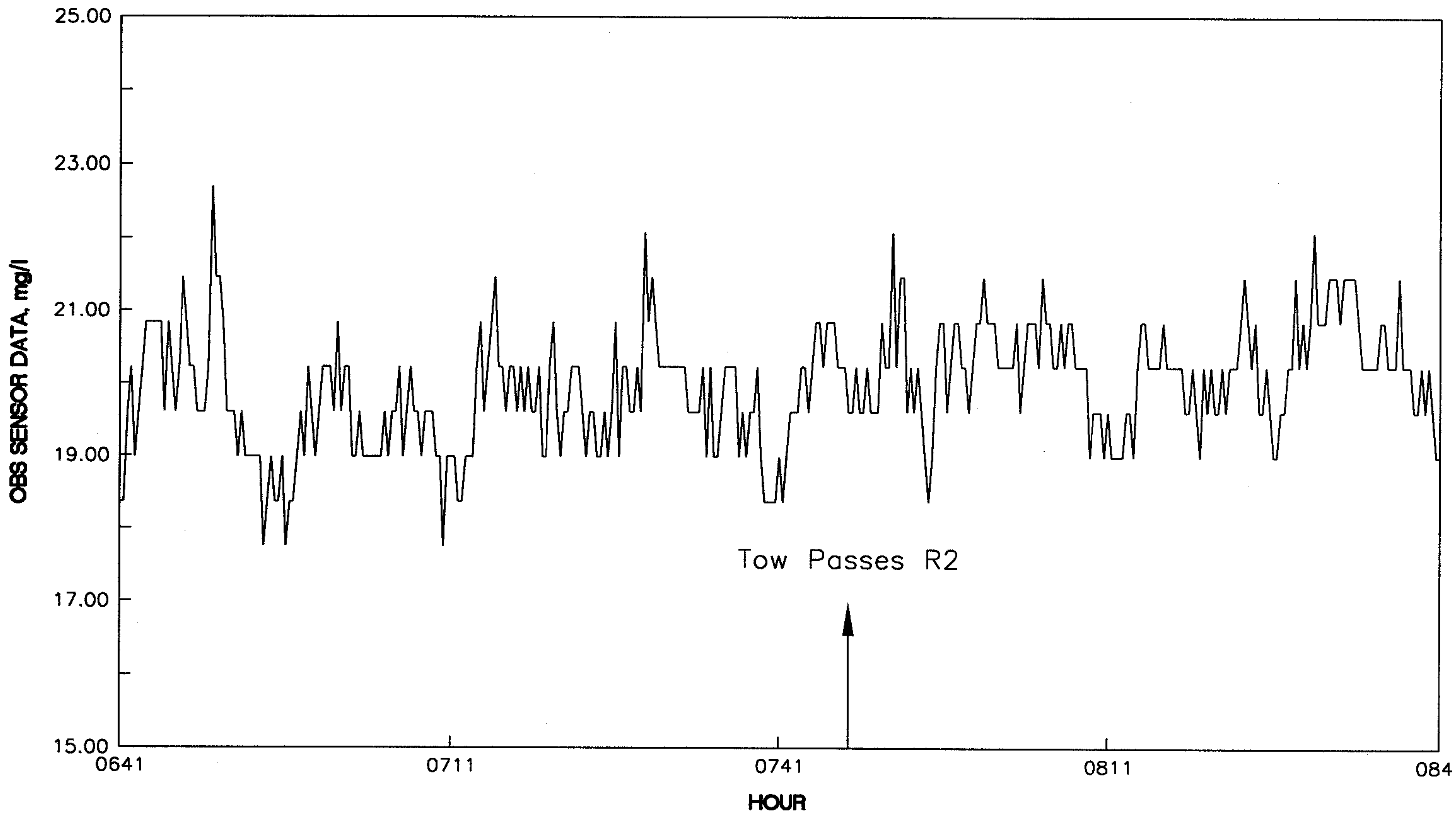
OBS SENSOR AT 9 FT
RANGE 6 POOL 08 BOAT 01
9/13/96-9/13/96



MEAN IS 19.9400 mg/L

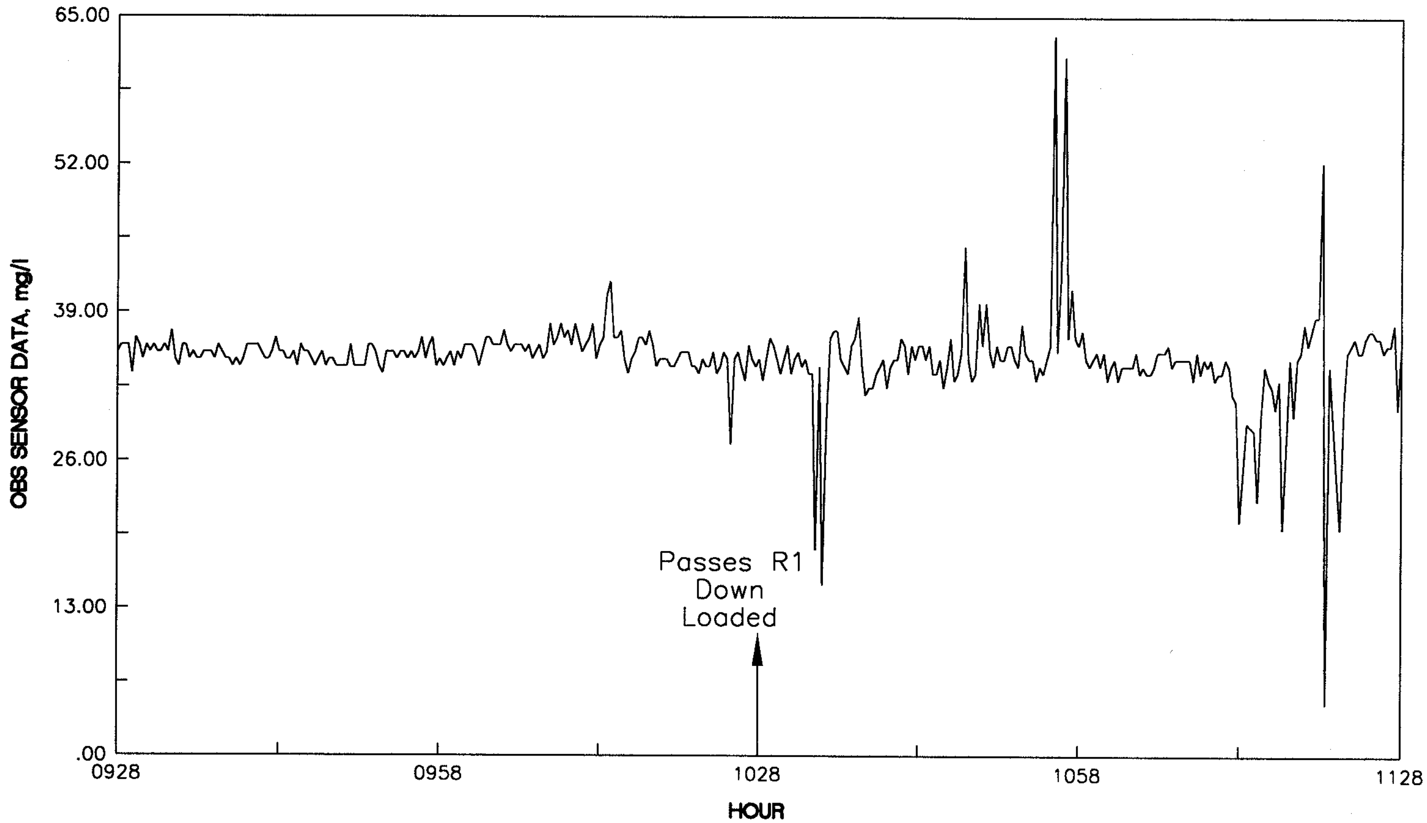
OBS SENSOR AT 7 FT
RANGE 6 POOL 08 BOAT 03
9/14/96-9/14/96

Plate 60



MEAN IS 19.9400 mg/L

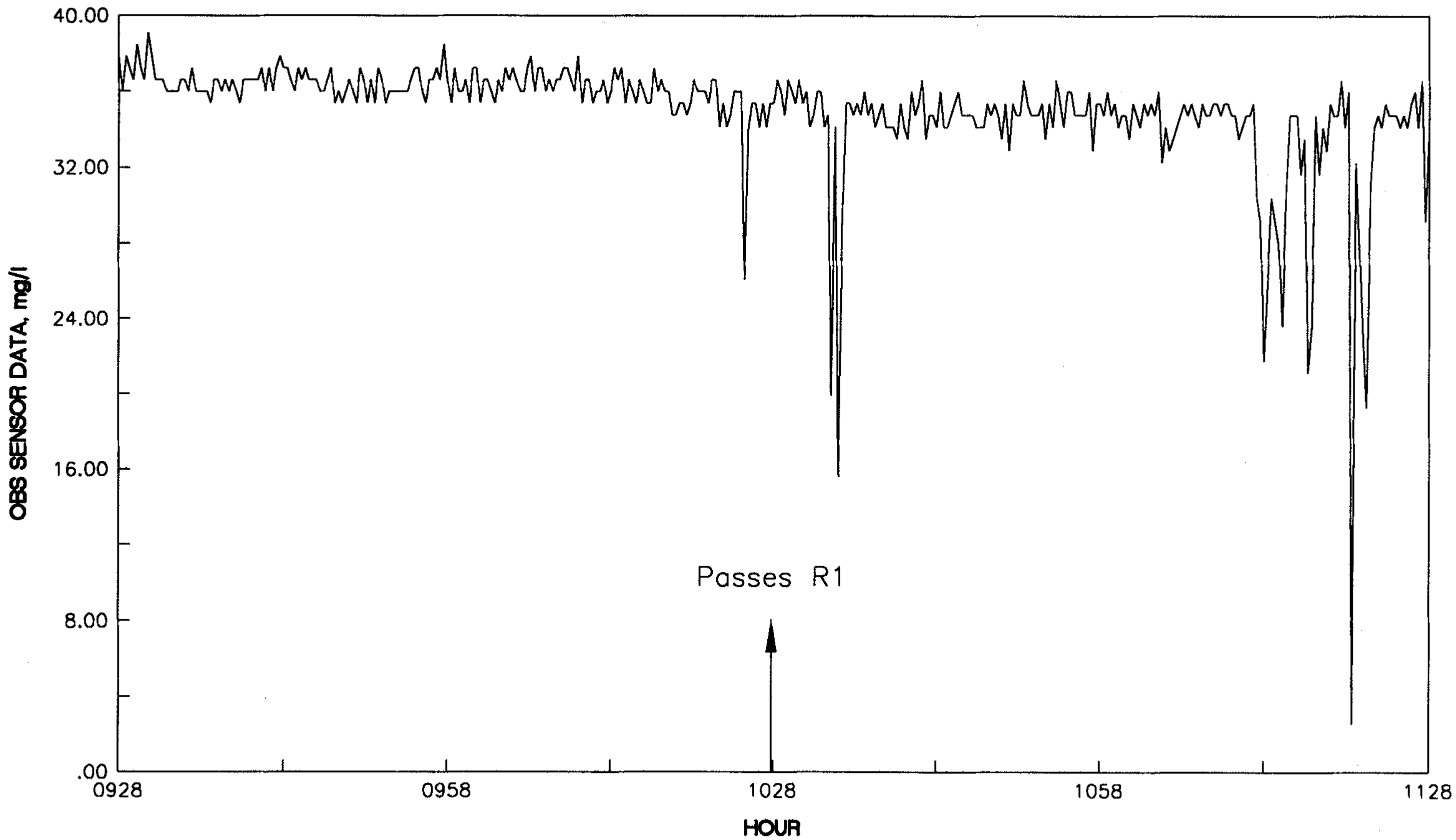
OBS SENSOR AT 9 FT
RANGE 6 POOL 08 BOAT 03
9/14/96-9/14/96



MEAN IS 35.0113 mg/l

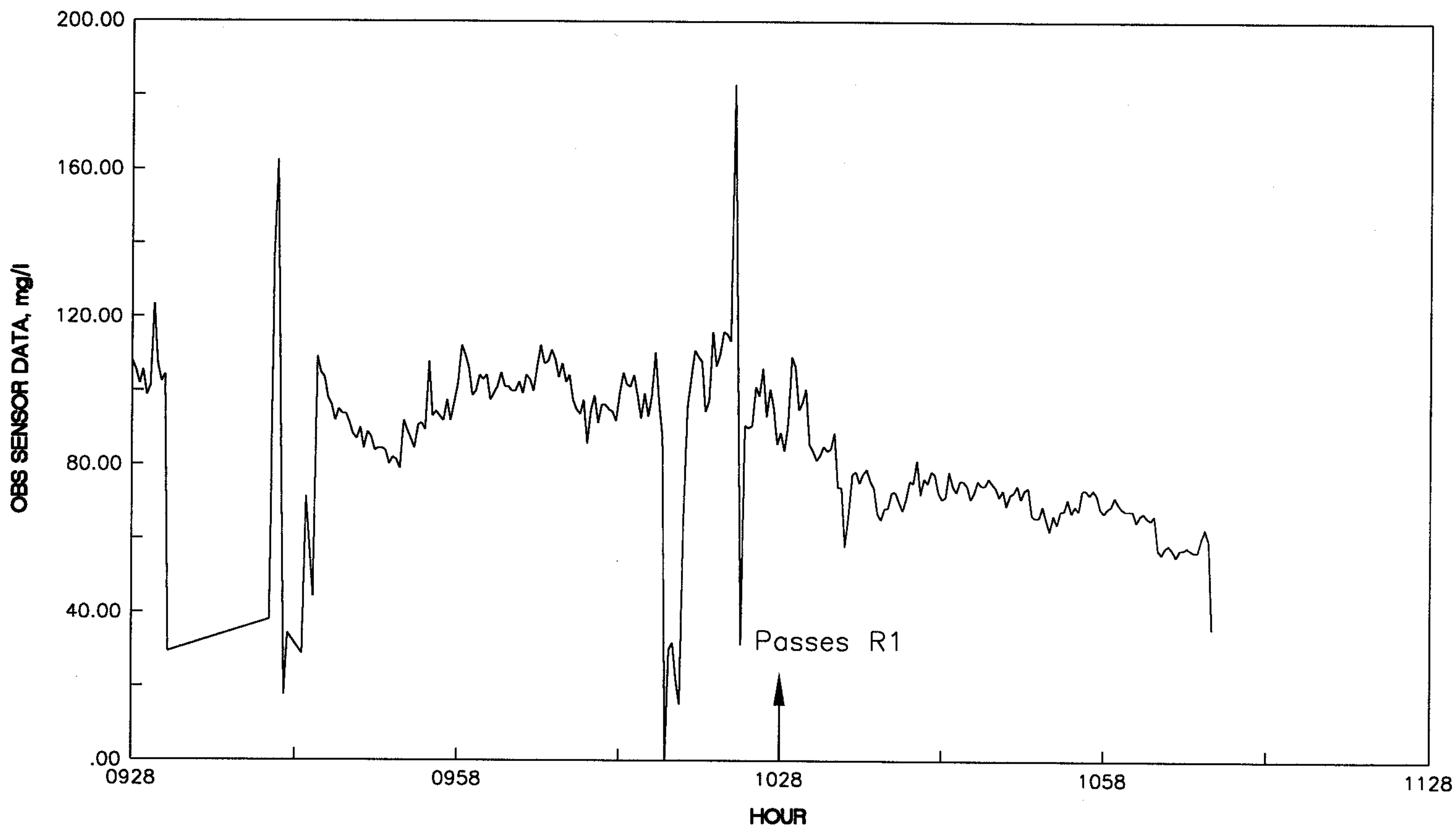
OBS SENSOR AT 3 FT
RANGE 1 POOL 26 BOAT 05
9/6/96-9/6/96

Plate 62



MEAN IS 35.0125 mg/l

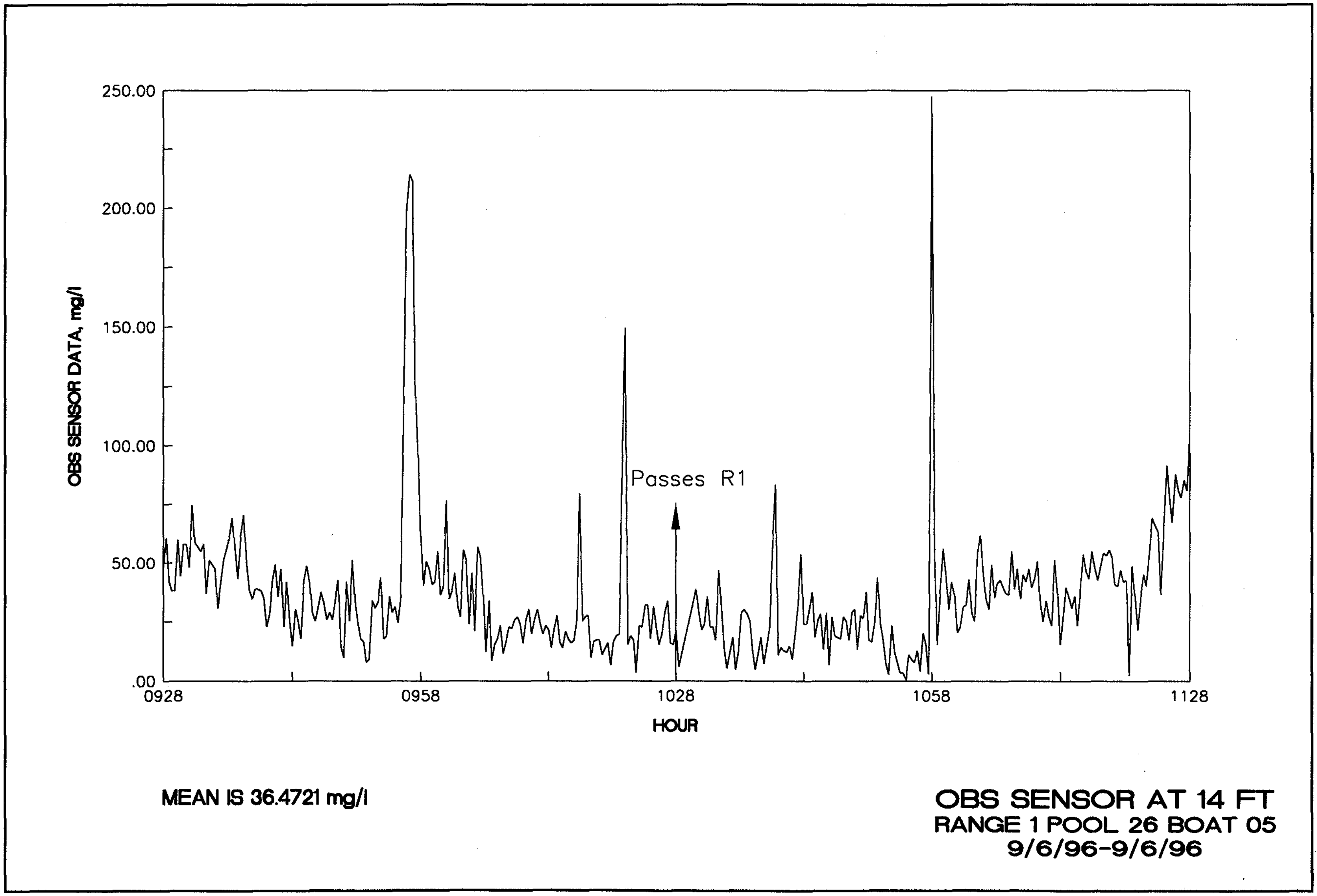
OBS SENSOR AT 10 FT
RANGE 1 POOL 26 BOAT 05
9/6/96-9/6/96

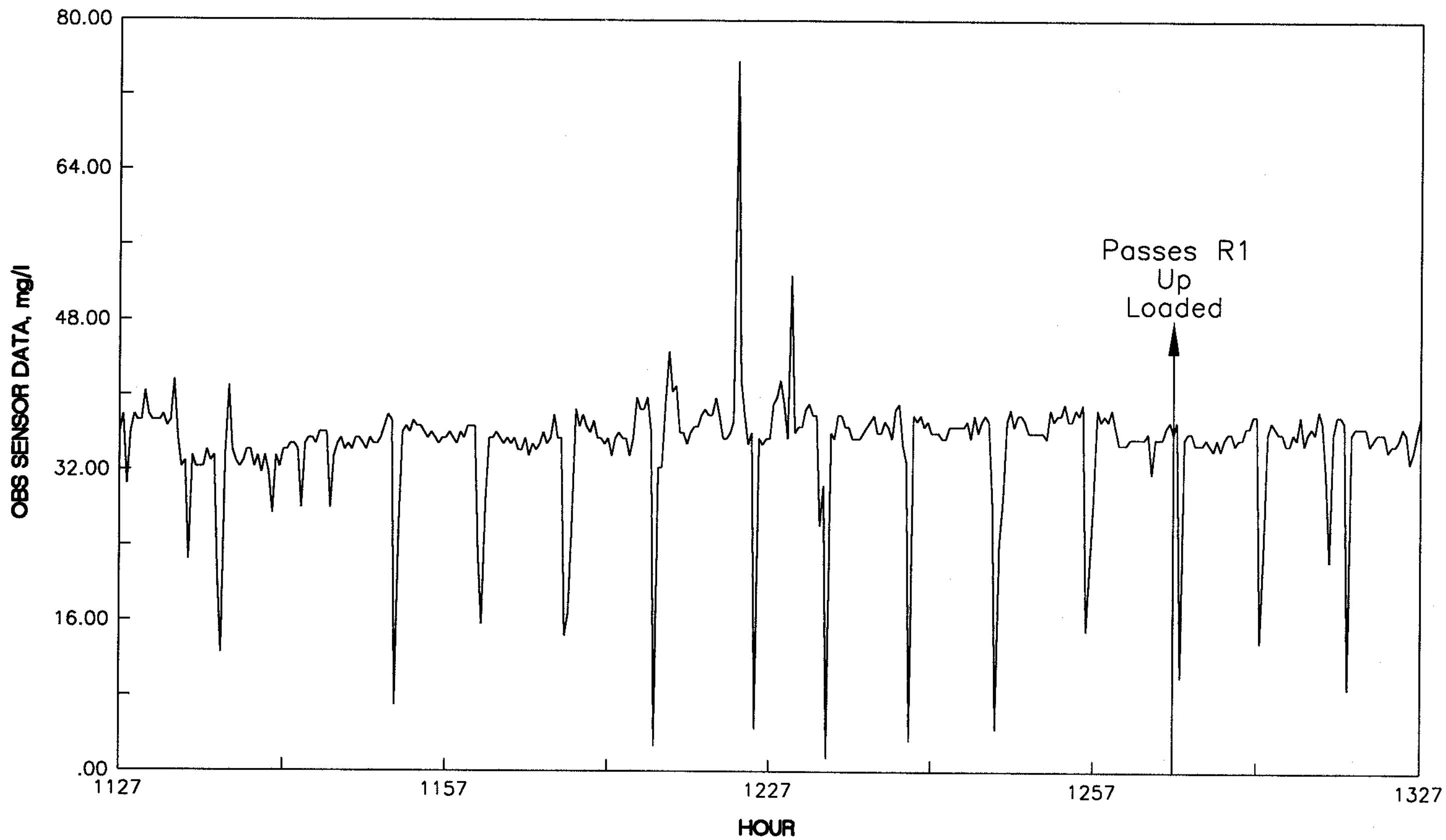


MEAN IS 83.7509 mg/l

OBS SENSOR AT 13 FT
RANGE 1 POOL 26 BOAT 05
9/6/96-9/6/96

Plate 64

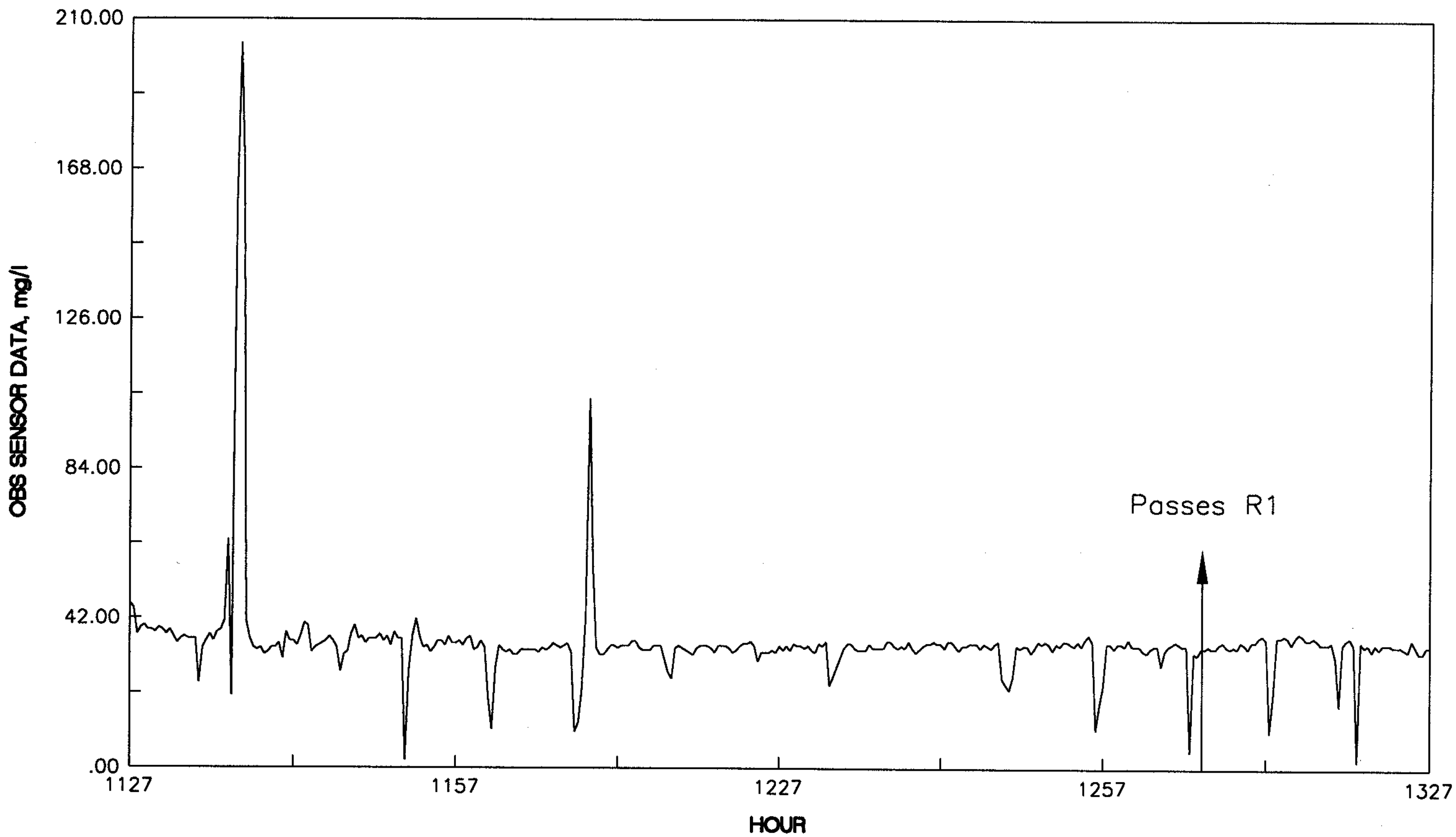

OBS SENSOR DATA, mg/l
250.00
200.00
150.00
100.00
50.00
.00
0928
0958
1028
1058
1128
HOUR
Passes R1
MEAN IS 36.4721 mg/l
OBS SENSOR AT 14 FT
RANGE 1 POOL 26 BOAT 05
9/6/96-9/6/96



MEAN IS 34.7000 mg/l

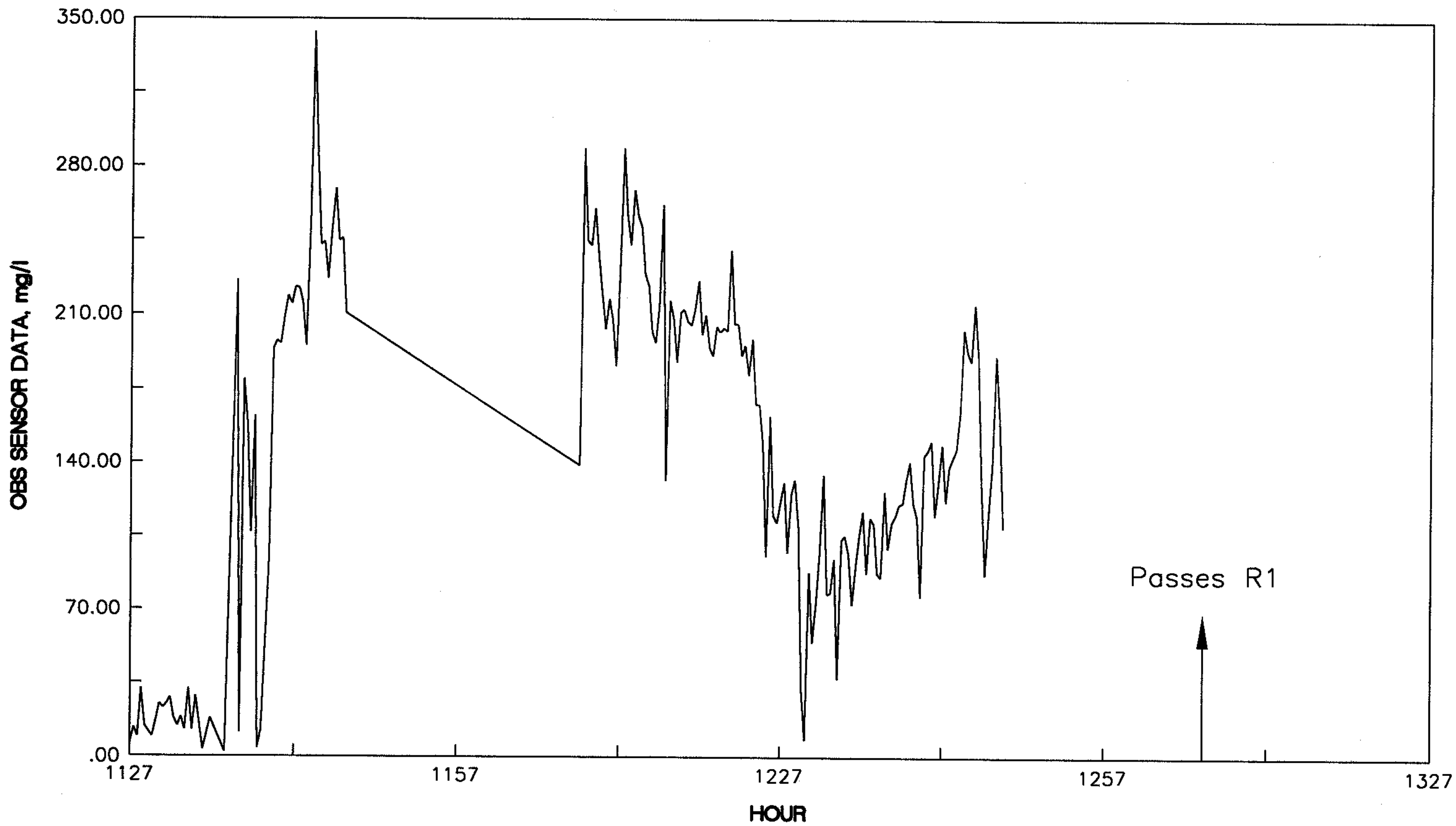
OBS SENSOR AT 3 FT
RANGE 1 POOL 26 BOAT 07
9/6/96-9/6/96

Plate 66



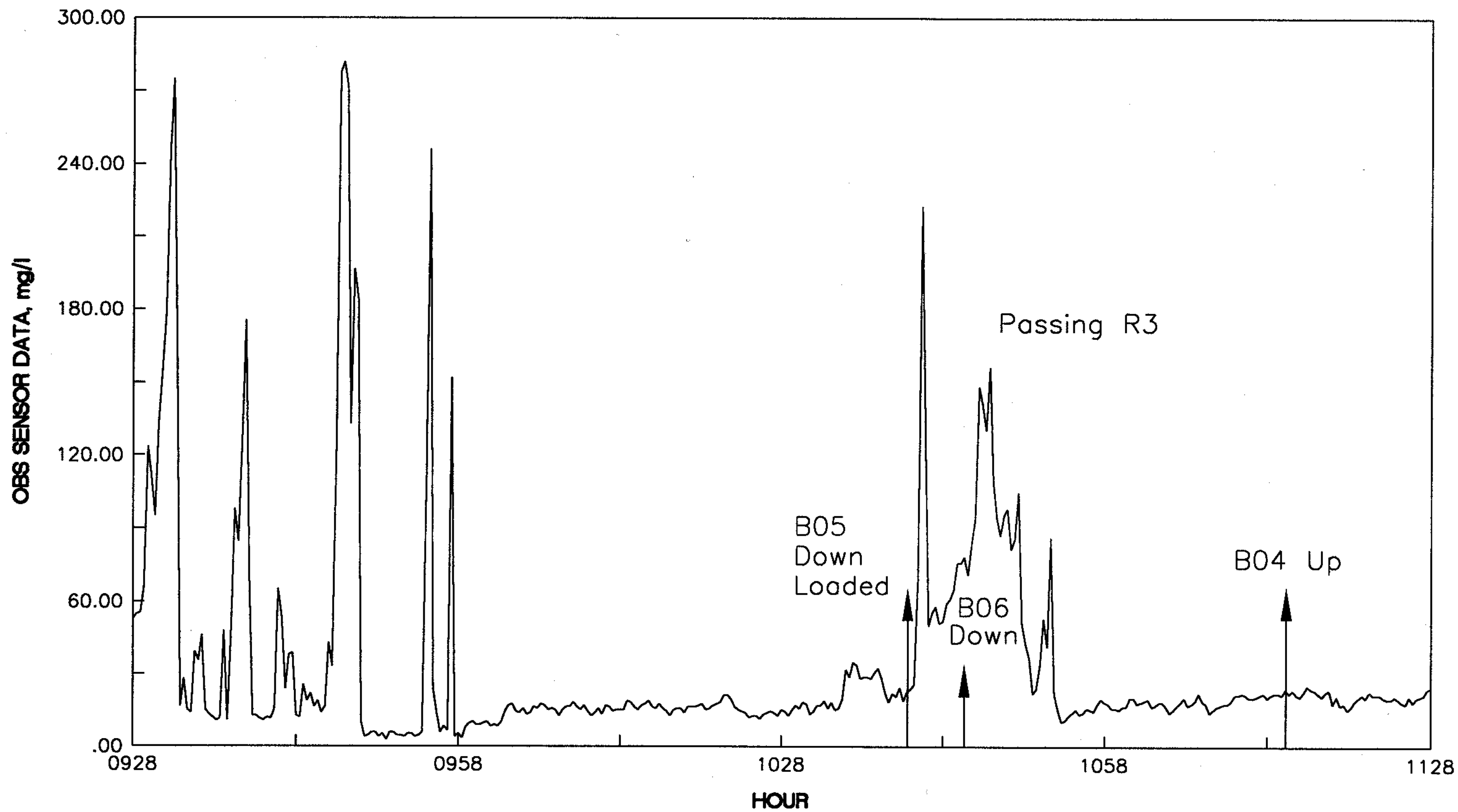
MEAN IS 35.2380 mg/l

OBS SENSOR AT 13 FT
RANGE 1 POOL 26 BOAT 07
9/6/96-9/6/96



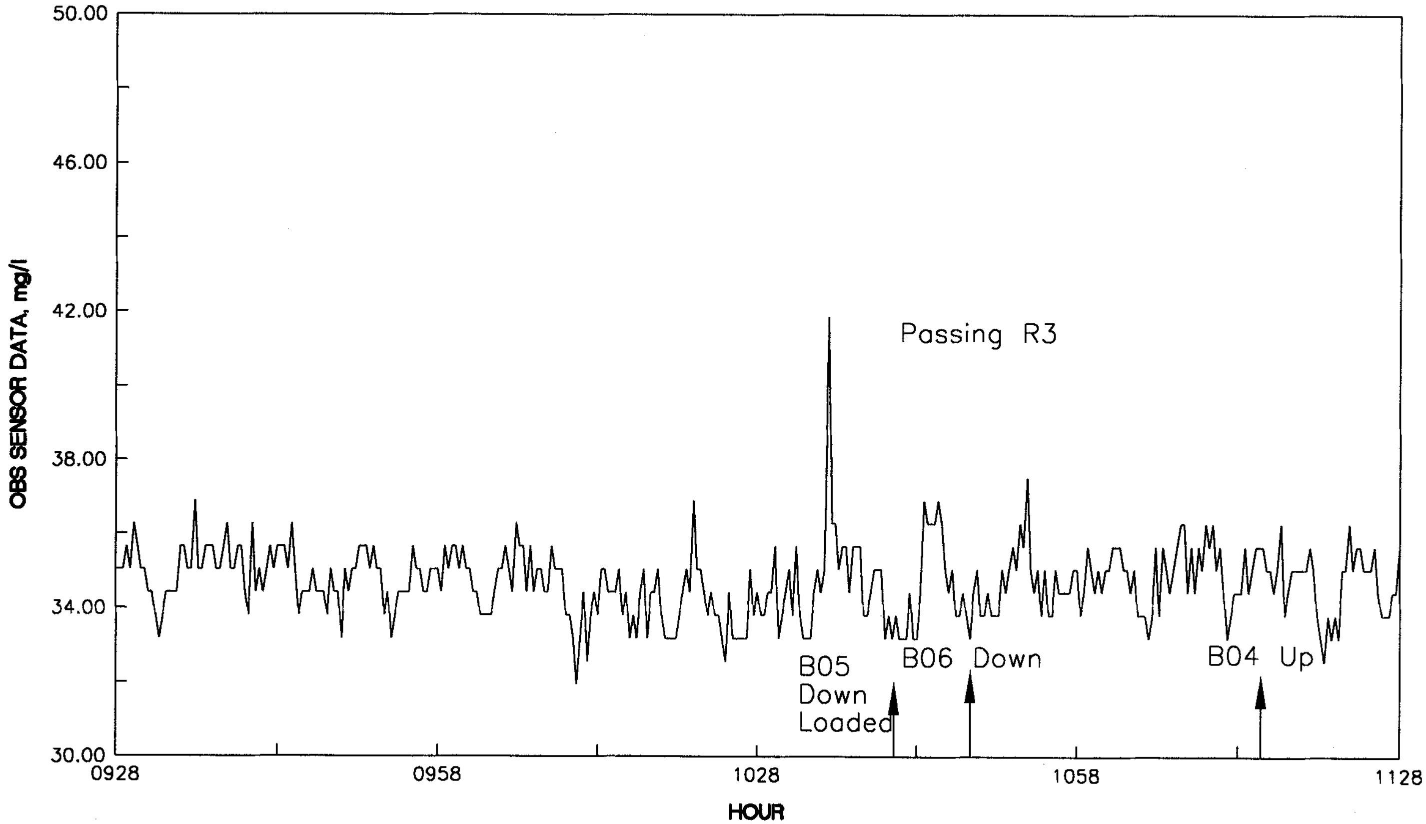
MEAN IS 147.5493 mg/l

OBS SENSOR AT 14 FT
RANGE 1 POOL 26 BOAT 07
9/6/96-9/6/96



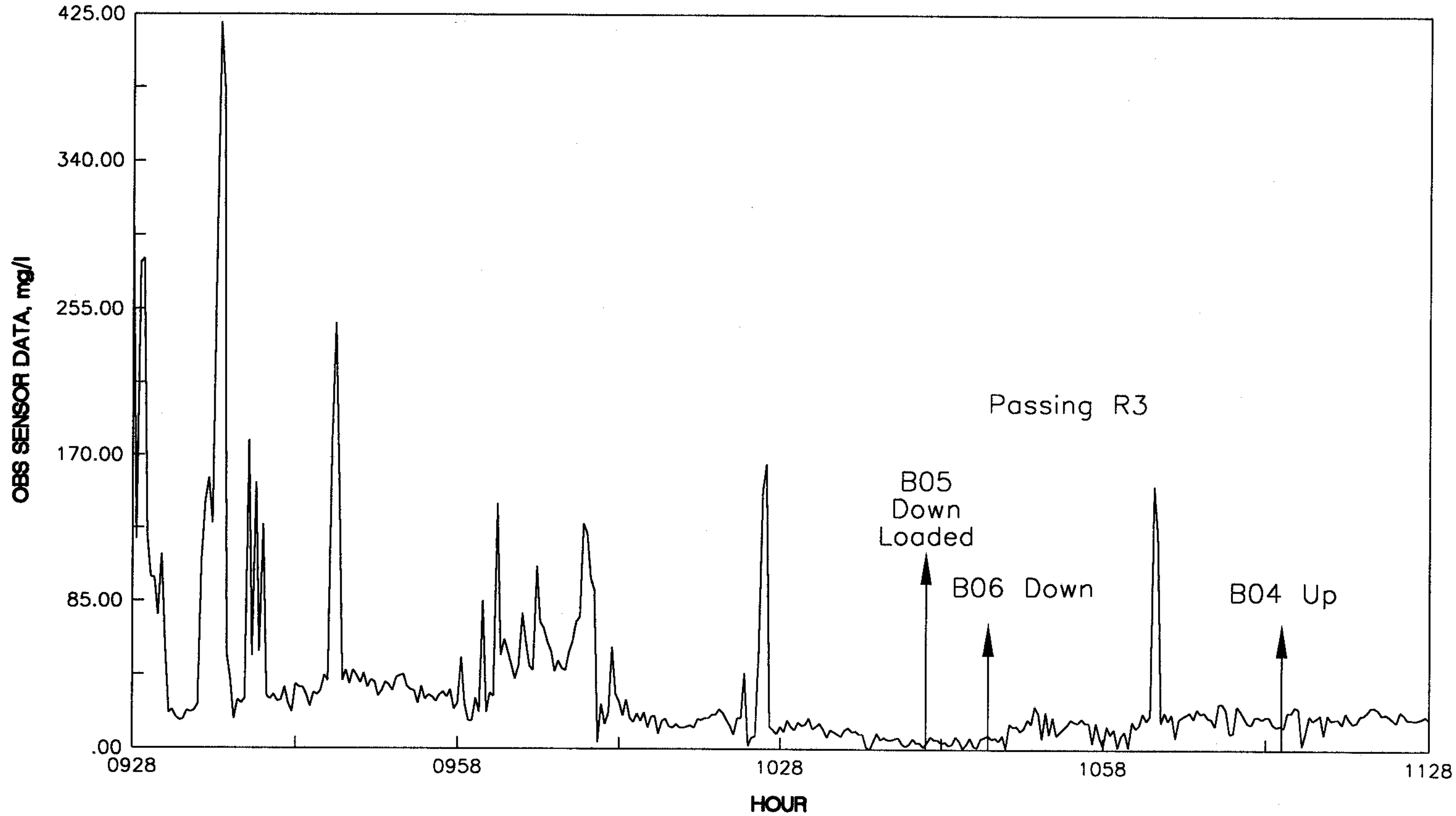
MEAN IS 34.7000 mg/l

OBS SENSOR AT 3 FT
RANGE 4 POOL 26 BOAT 05
9/6/96-9/6/96



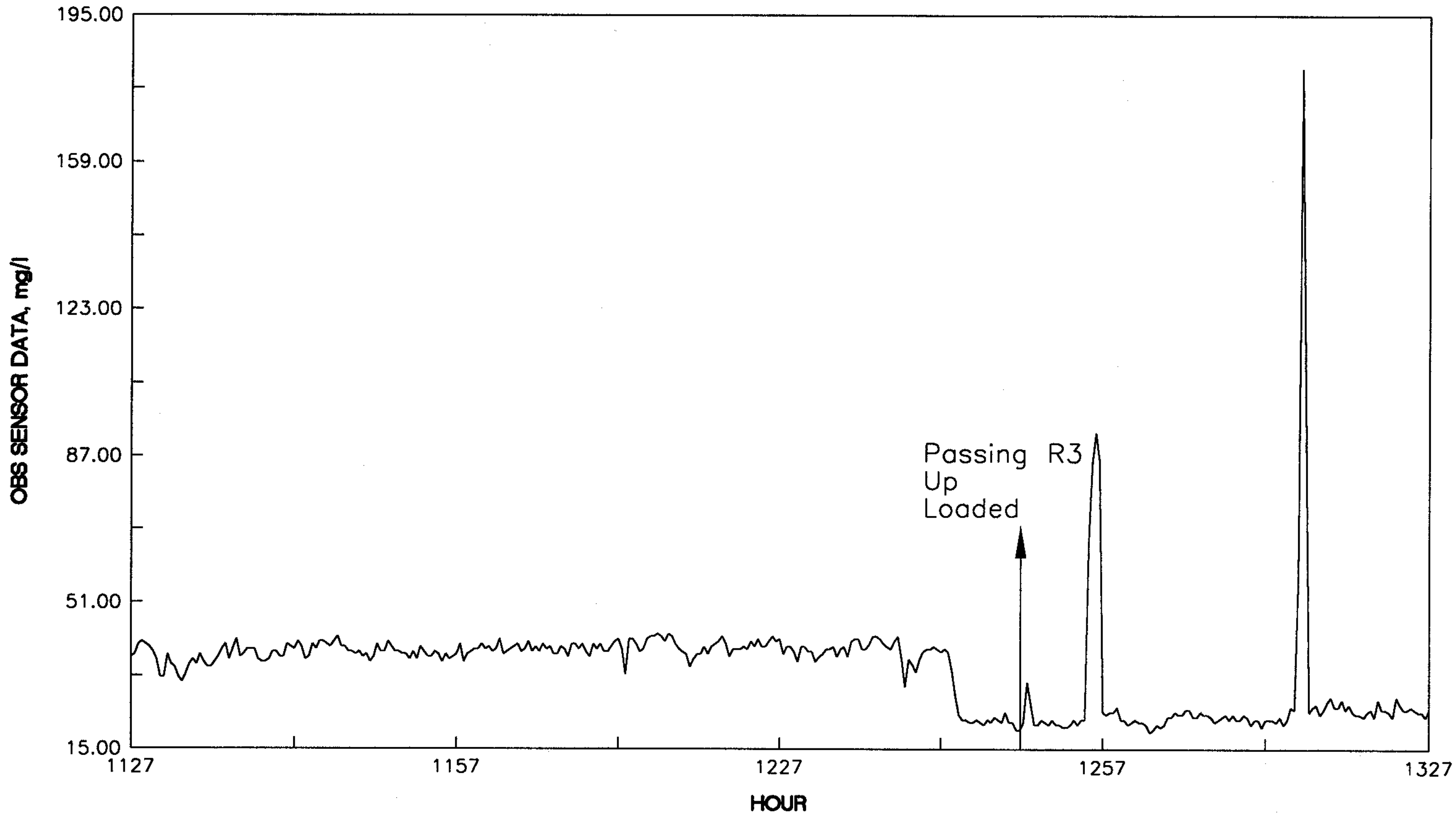
MEAN IS 34.7000 mg/l

OBS SENSOR AT 14 FT
RANGE 4 POOL 26 BOAT 05
9/6/96-9/6/96



MEAN IS 35.2638 mg/l

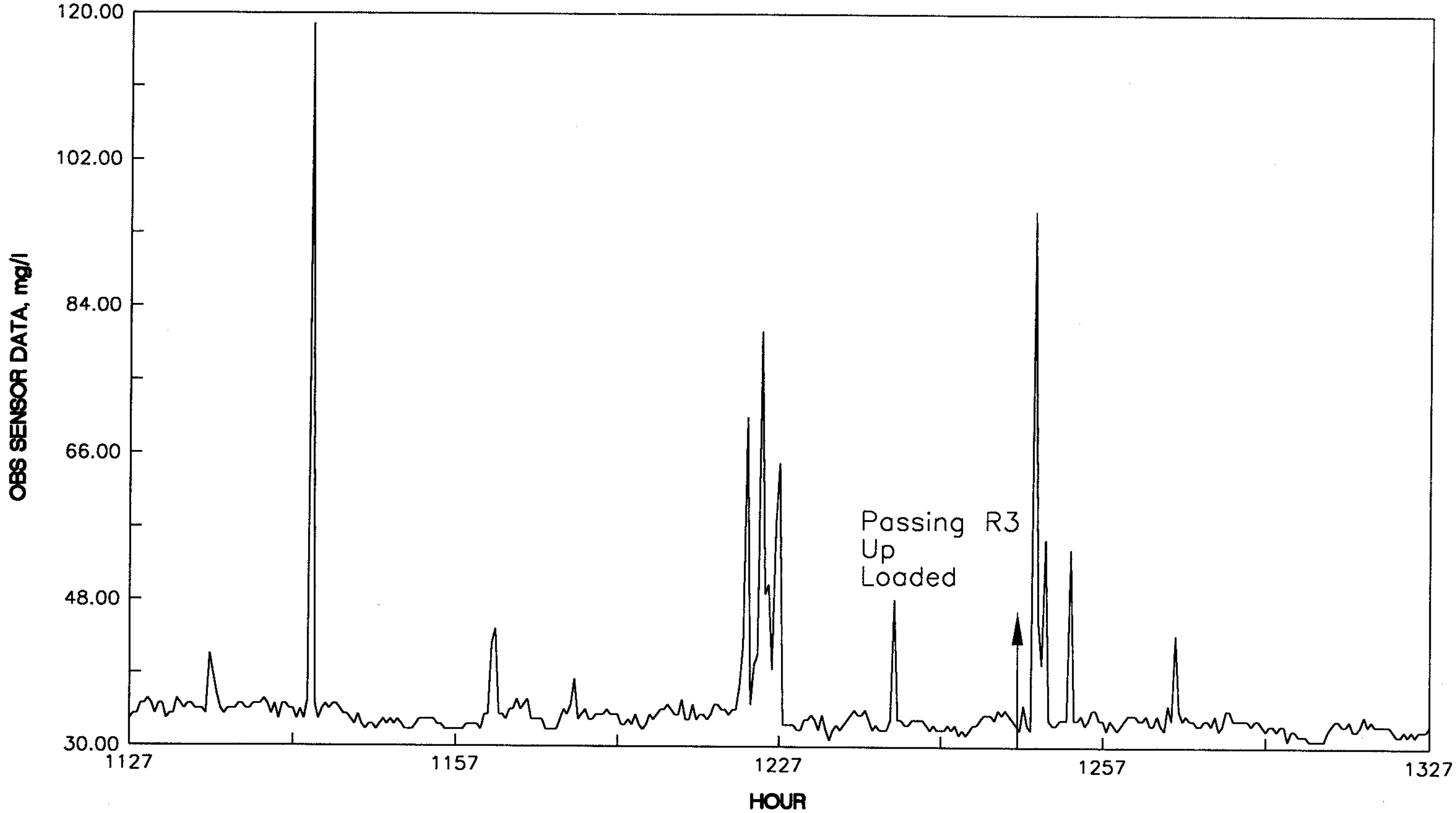
OBS SENSOR AT 15 FT
RANGE 4 POOL 26 BOAT 05
9/6/96-9/6/96



MEAN IS 34.7000 mg/l

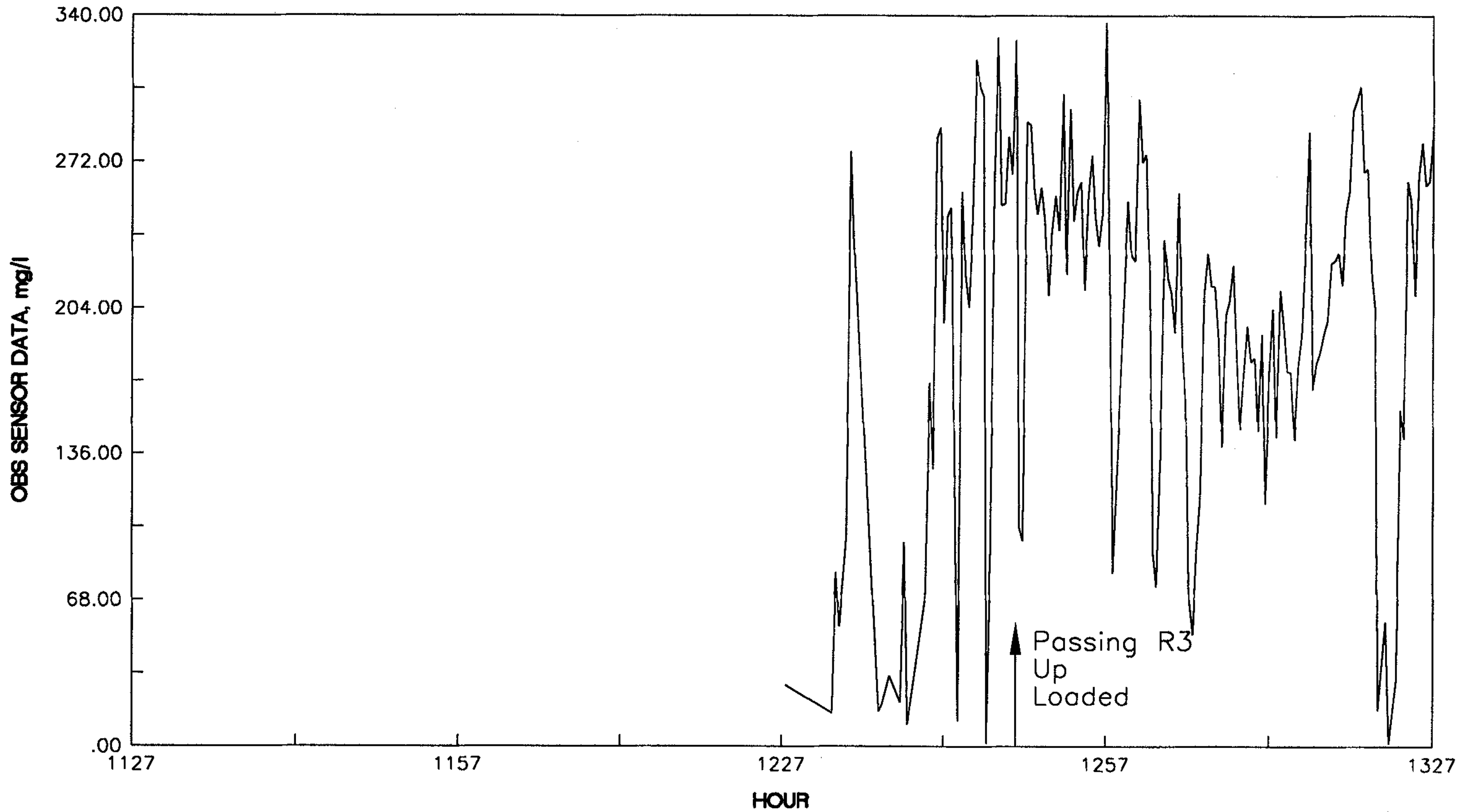
OBS SENSOR AT 3 FT
RANGE 4 POOL 26 BOAT 07
9/6/96-9/6/96

Plate 72



MEAN IS 34.7001 mg/l

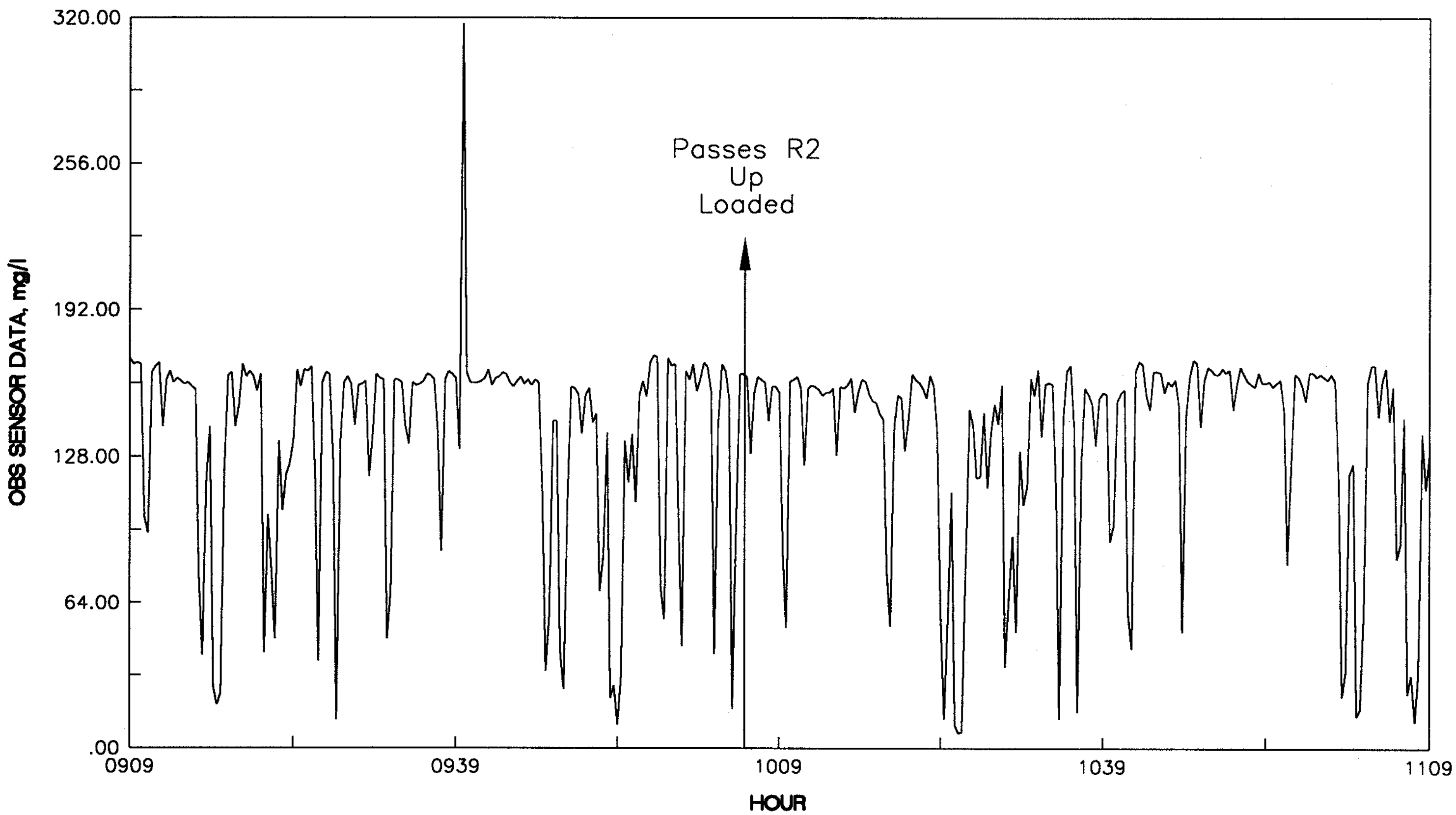
OBS SENSOR AT 14 FT
RANGE 4 POOL 26 BOAT 07
9/6/96-9/6/96



MEAN IS 196.5870 mg/l

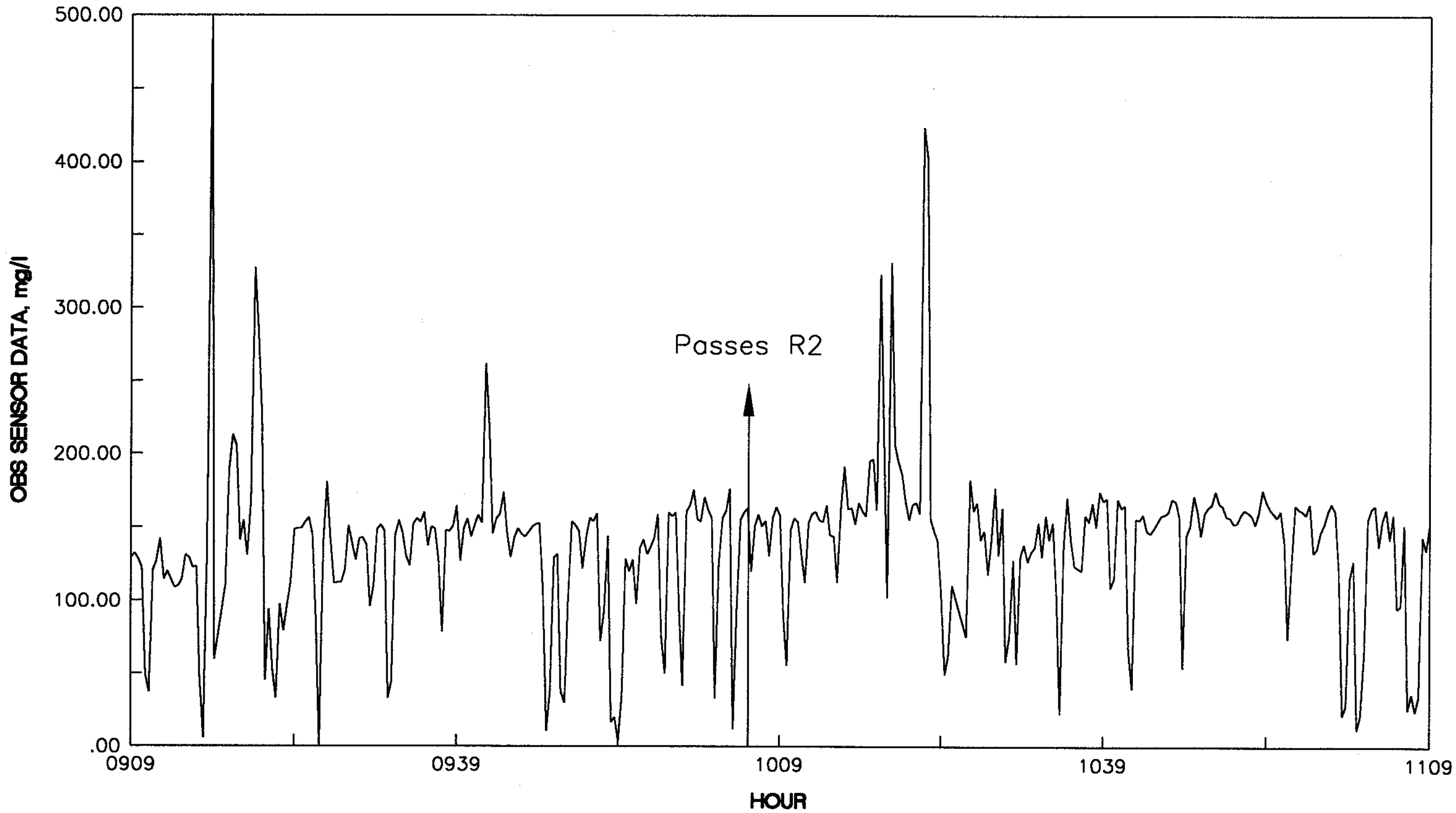
OBS SENSOR AT 15 FT
RANGE 4 POOL 26 BOAT 07
9/6/96-9/6/96

Plate 74



MEAN IS 135.0000 mg/l

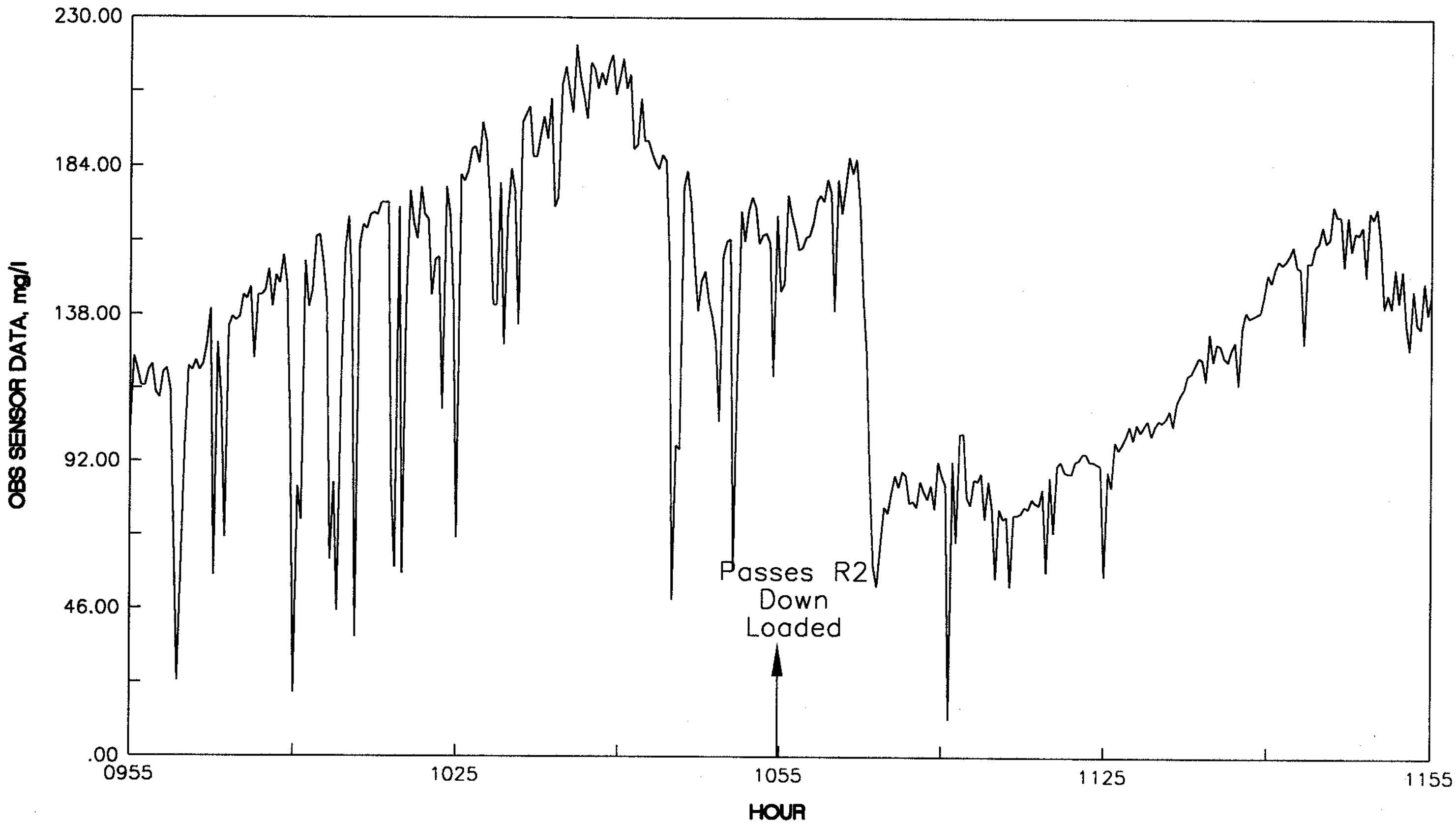
OBS SENSOR AT 0.5 FT
RANGE 1 LA GRANGE BOAT 03
9/9/96 - 0/9/96



MEAN IS 137.8637 mg/l

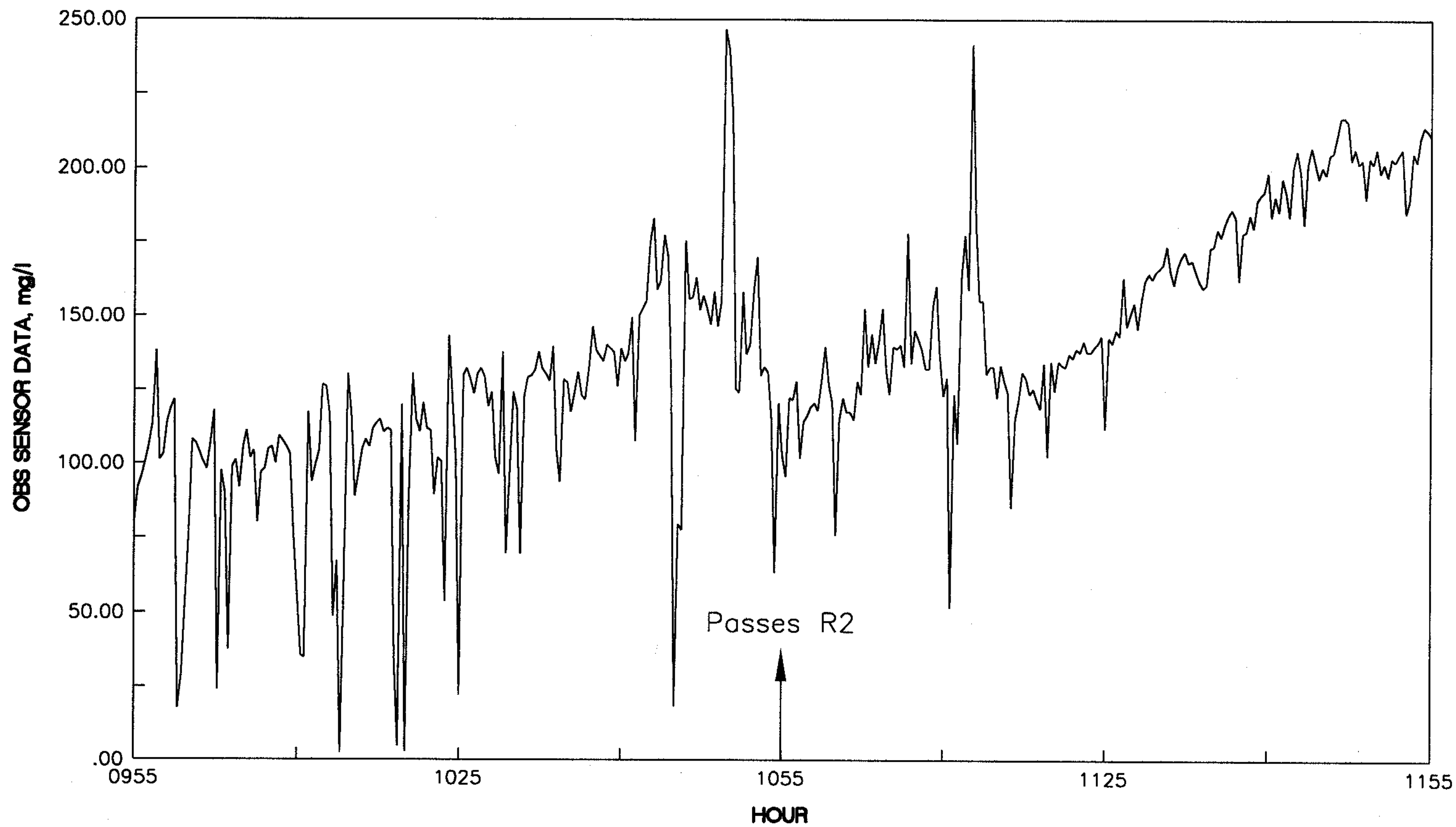
OBS SENSOR AT 3.5 FT
RANGE 1 LA GRANGE BOAT 03
9/9/96 - 9/9/96

Plate 76



MEAN IS 135.7631 mg/l

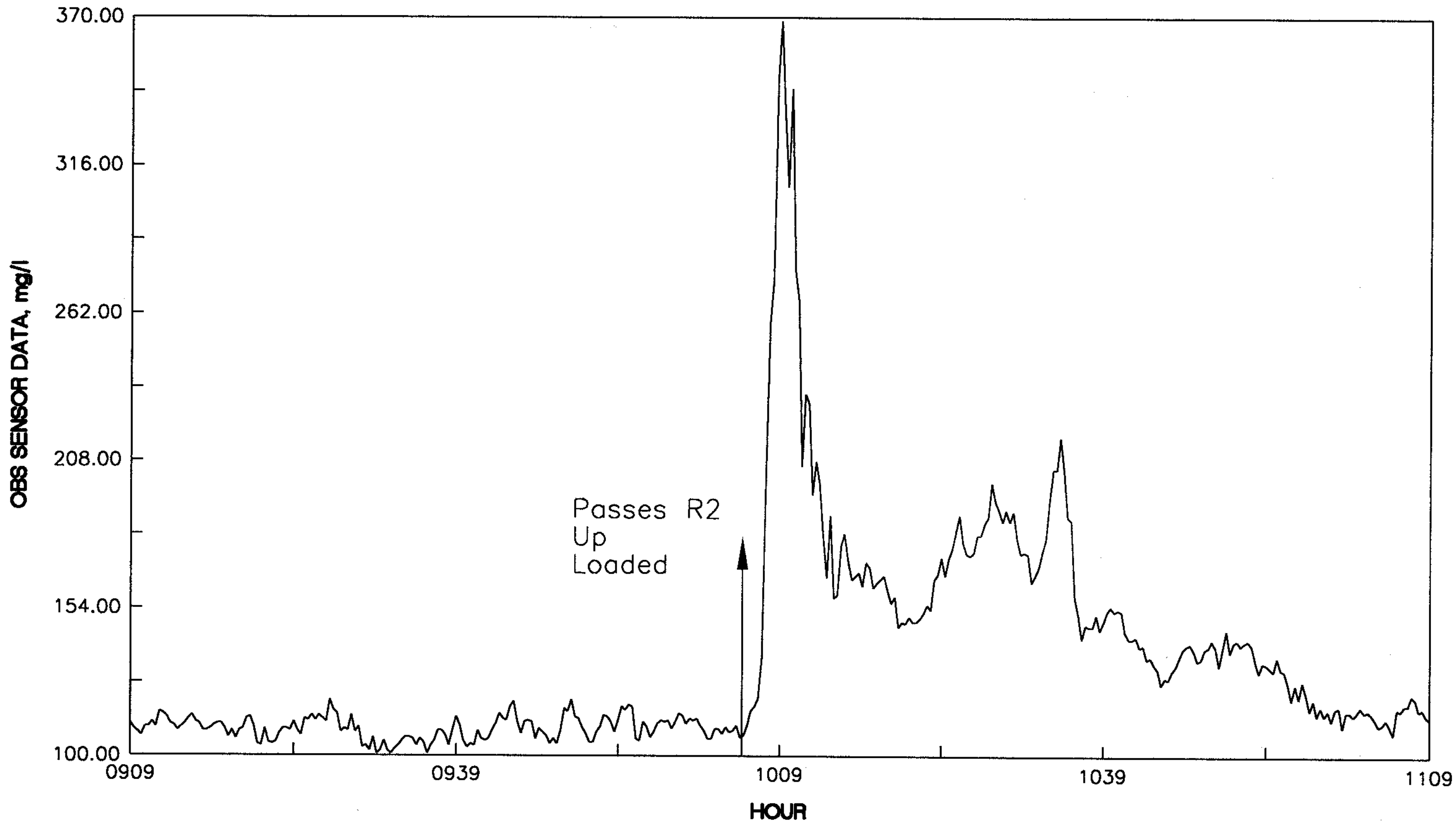
OBS SENSOR AT 0.5 FT
RANGE 1 LA GRANGE BOAT 10
9/10/96 - 9/10/96



MEAN IS 136.3450 mg/l

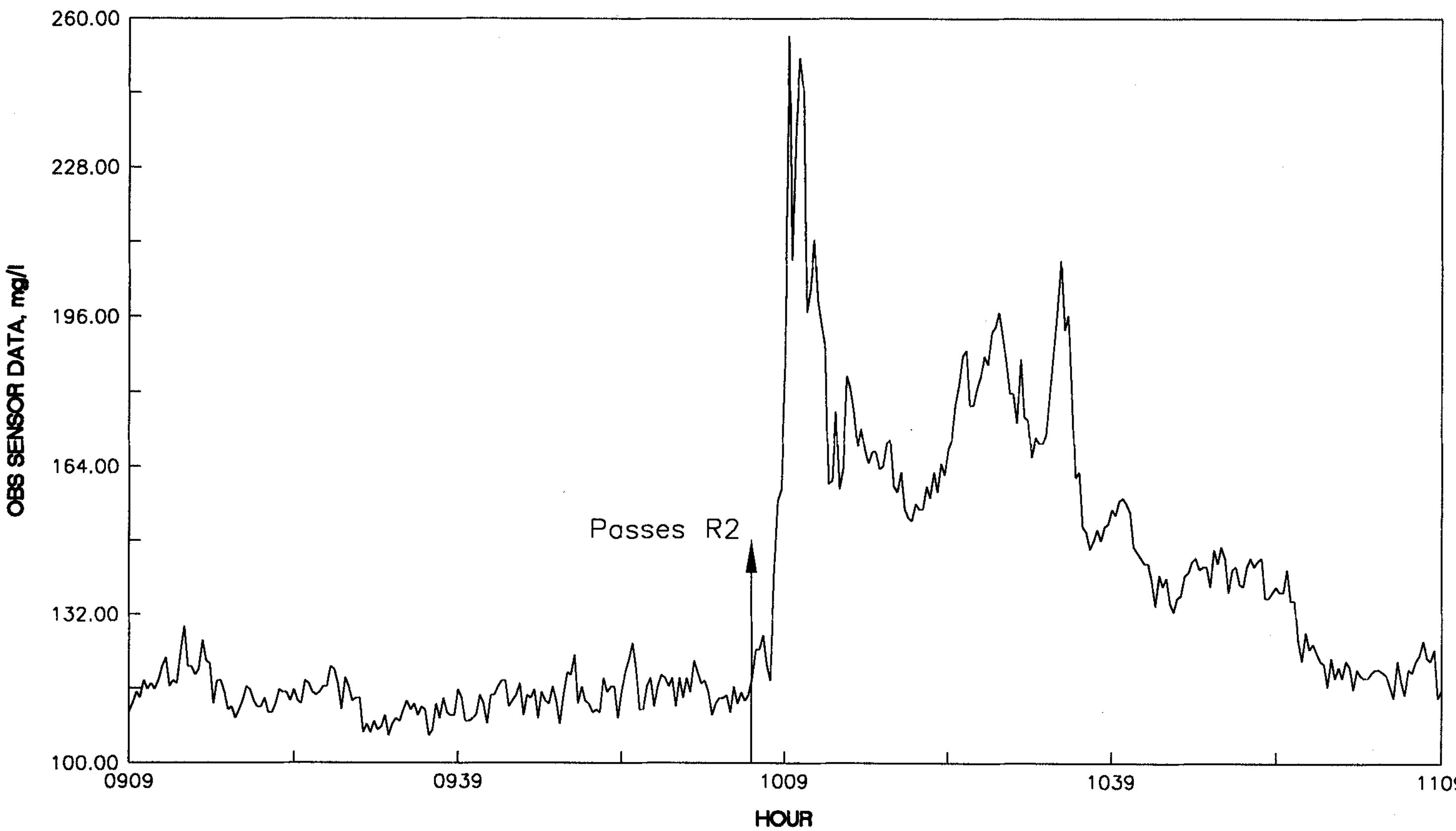
OBS SENSOR AT 3.5 FT
RANGE 1 LA GRANGE BOAT 10
9/10/96 - 9/10/96

Plate 78



MEAN IS 135.0002 mg/l

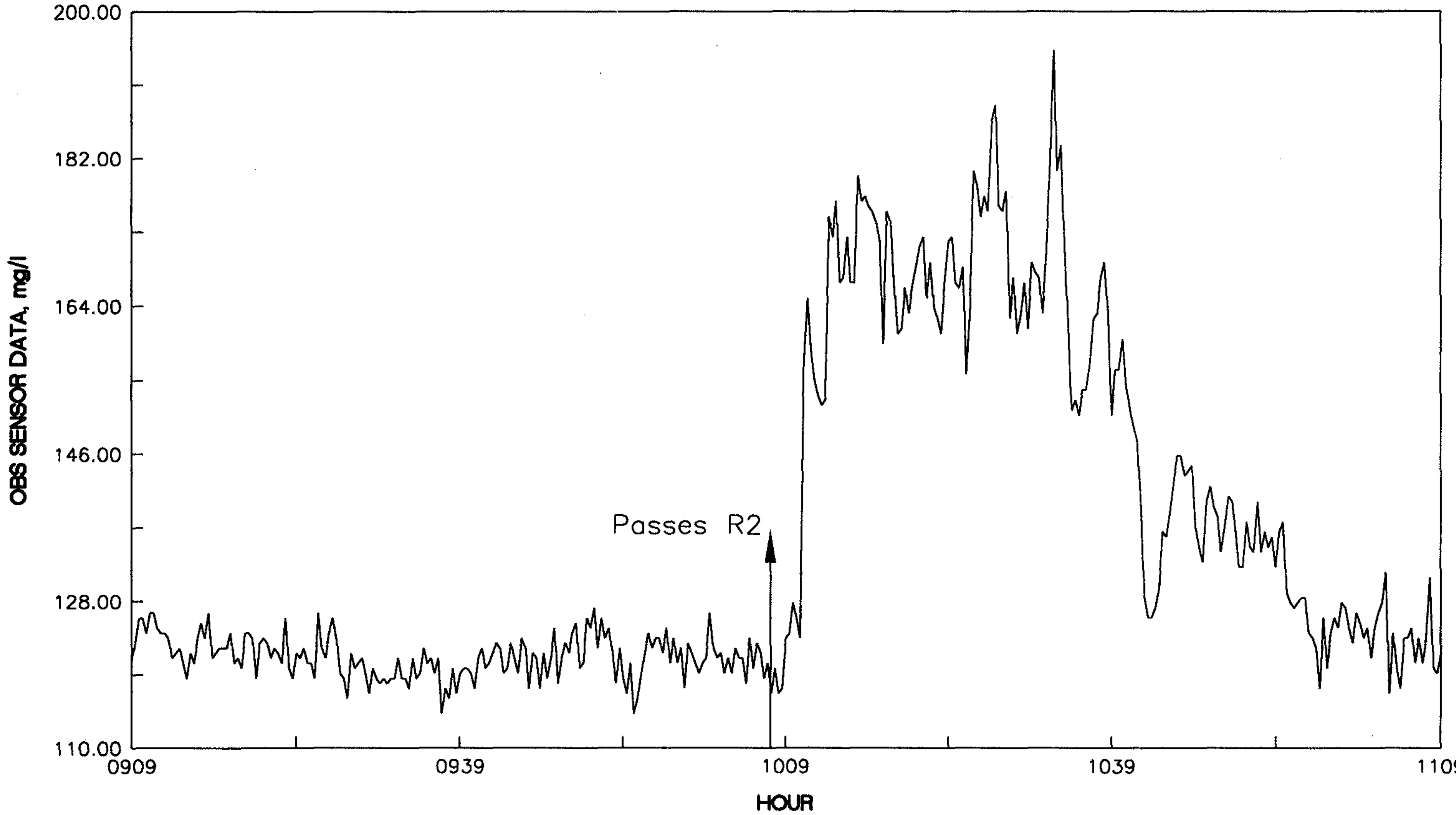
OBS SENSOR AT 1.5 FT
RANGE 2 LA GRANGE BOAT 03
9/9/96 - 9/9/96



MEAN IS 135.0000 mg/l

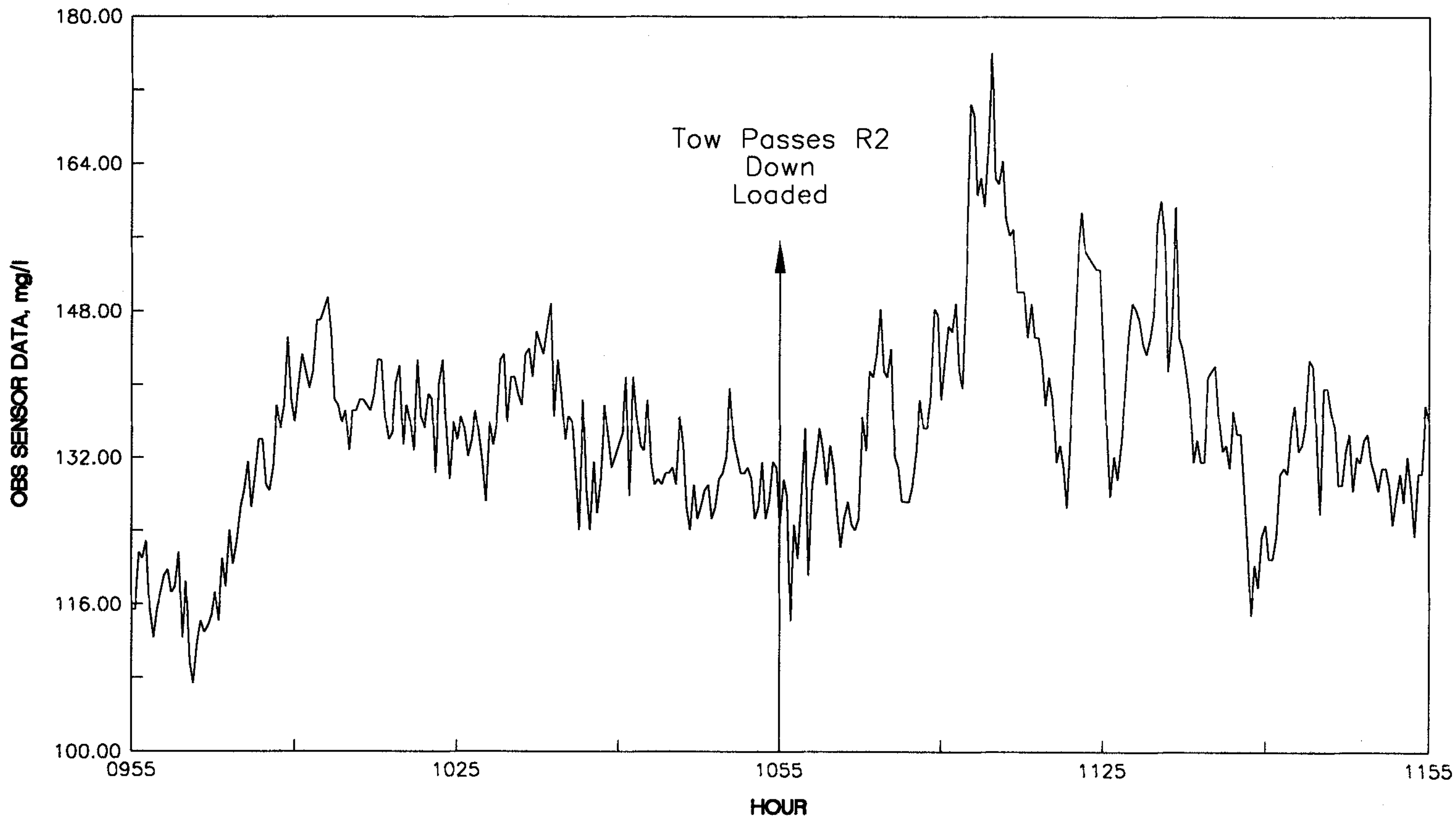
OBS SENSOR AT 7.0 FT
RANGE 2 LA GRANGE BOAT 03
9/9/96 - 9/9/96

Plate 80



MEAN IS 135.0001 mg/l

OBS SENSOR AT 8.0 FT
RANGE 2 LA GRANGE BOAT 03
9/9/96 - 9/9/96



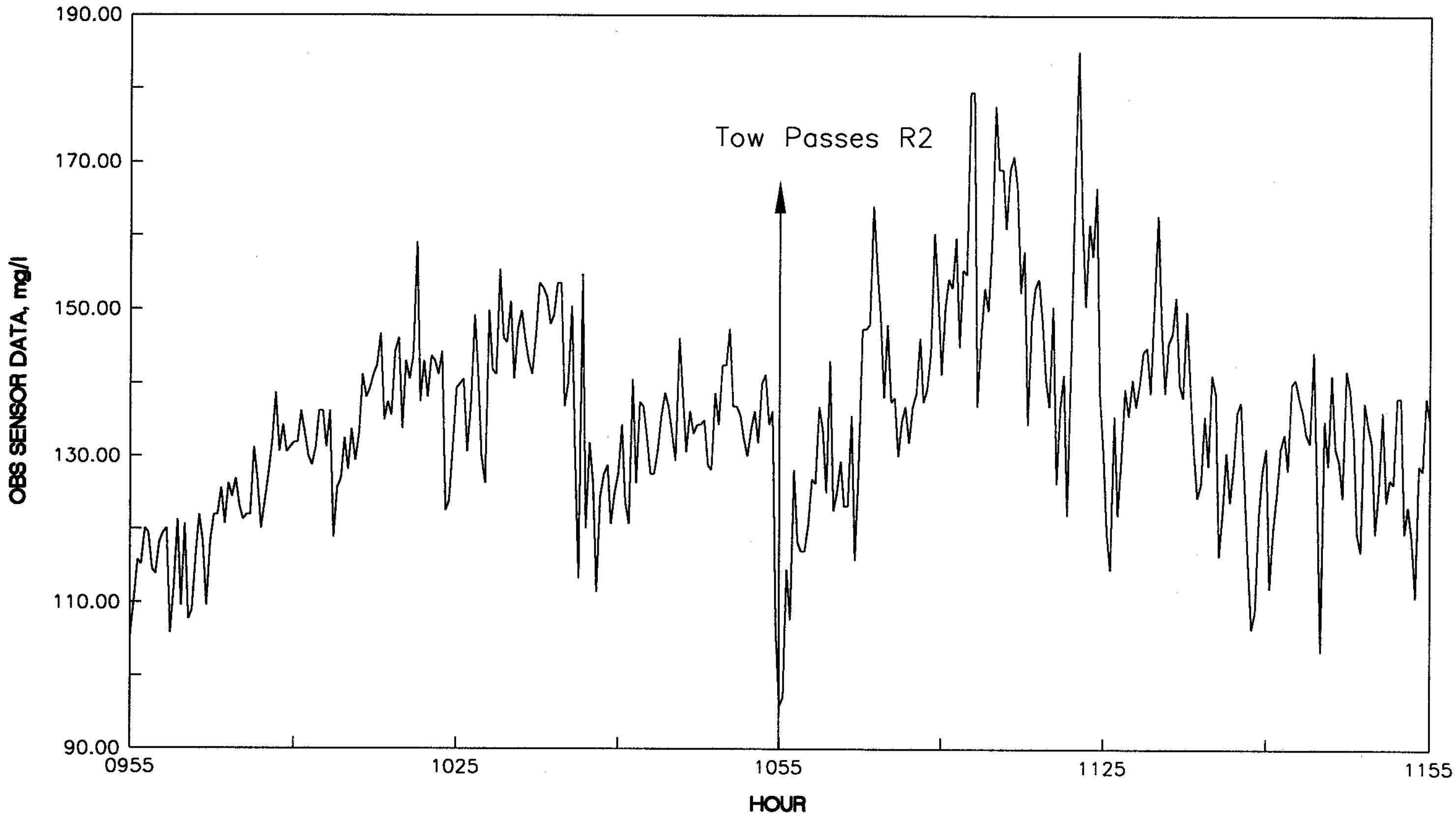
MEAN IS 134.9999 mg/l

OBS SENSOR AT 1.5 FT

RANGE 2 LA GRANGE BOAT 10

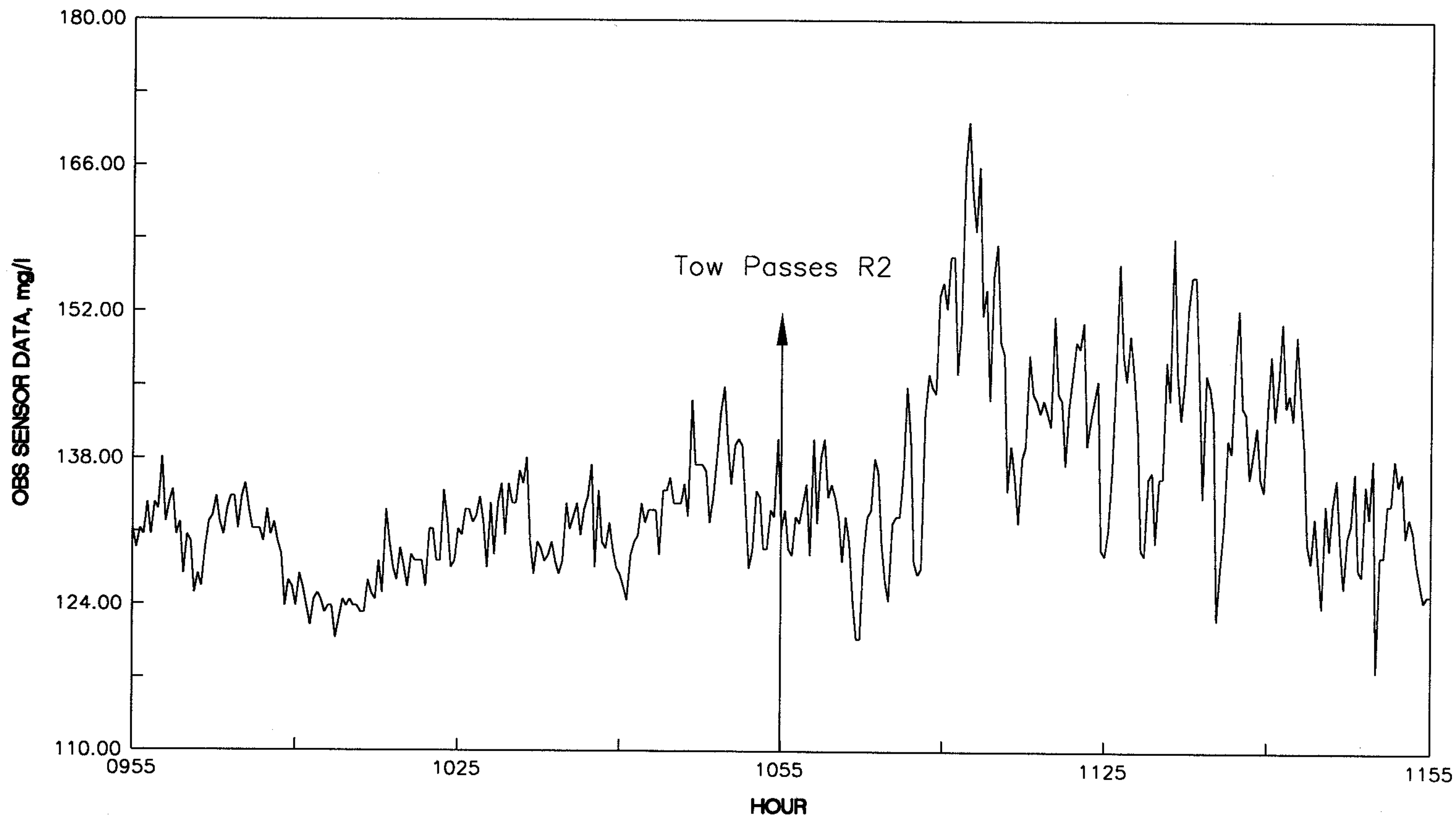
9/10/96 - 9/10/96

Plate 82



MEAN IS 135.0000 mg/l

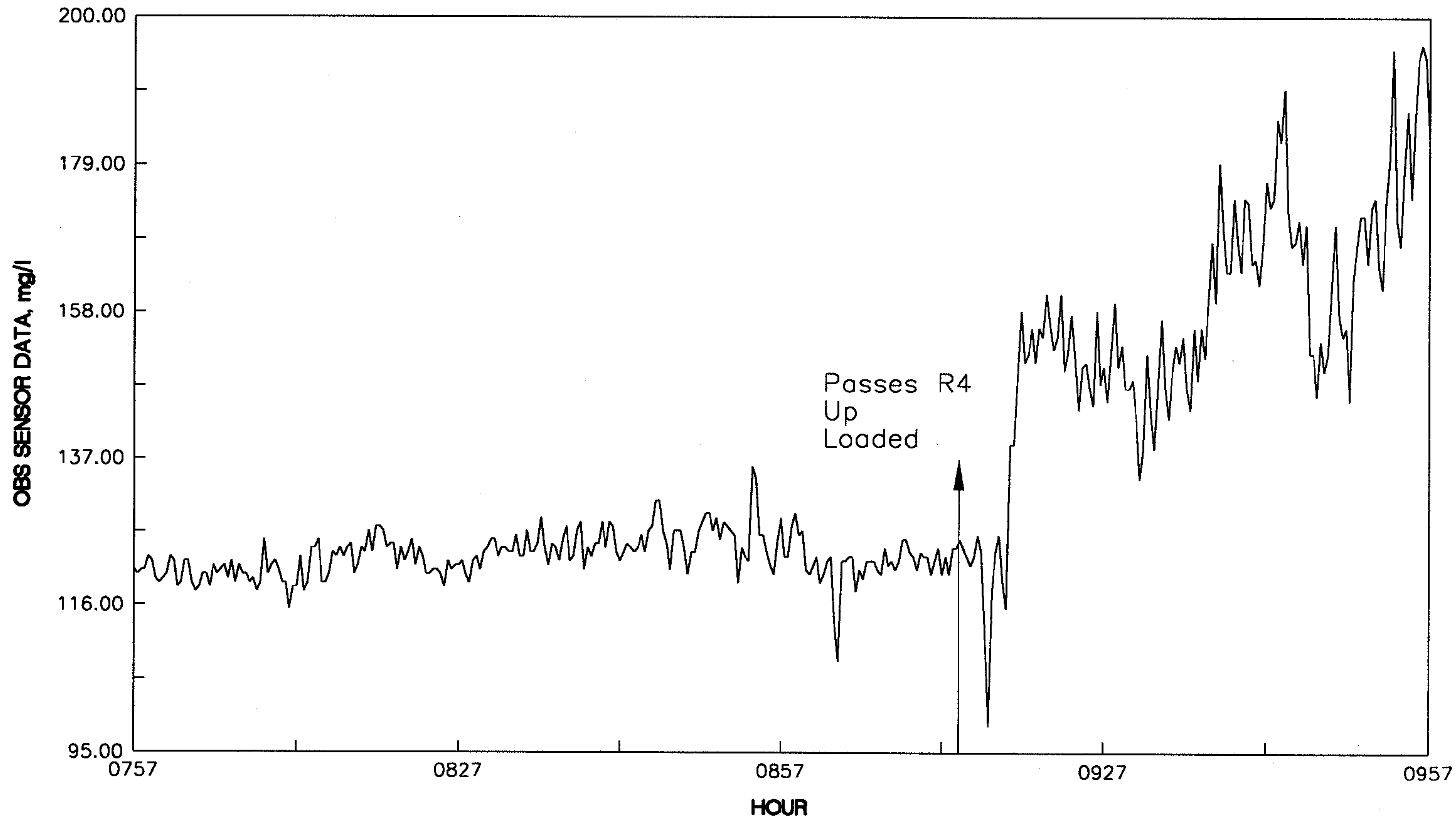
OBS SENSOR AT 7.0 FT
RANGE 2 LA GRANGE BOAT 10
9/10/96 - 9/10/96



MEAN IS 135.0000 mg/l

OBS SENSOR AT 8.0 FT
RANGE 2 LA GRANGE BOAT 10
9/10/96 - 9/10/96

Plate 84

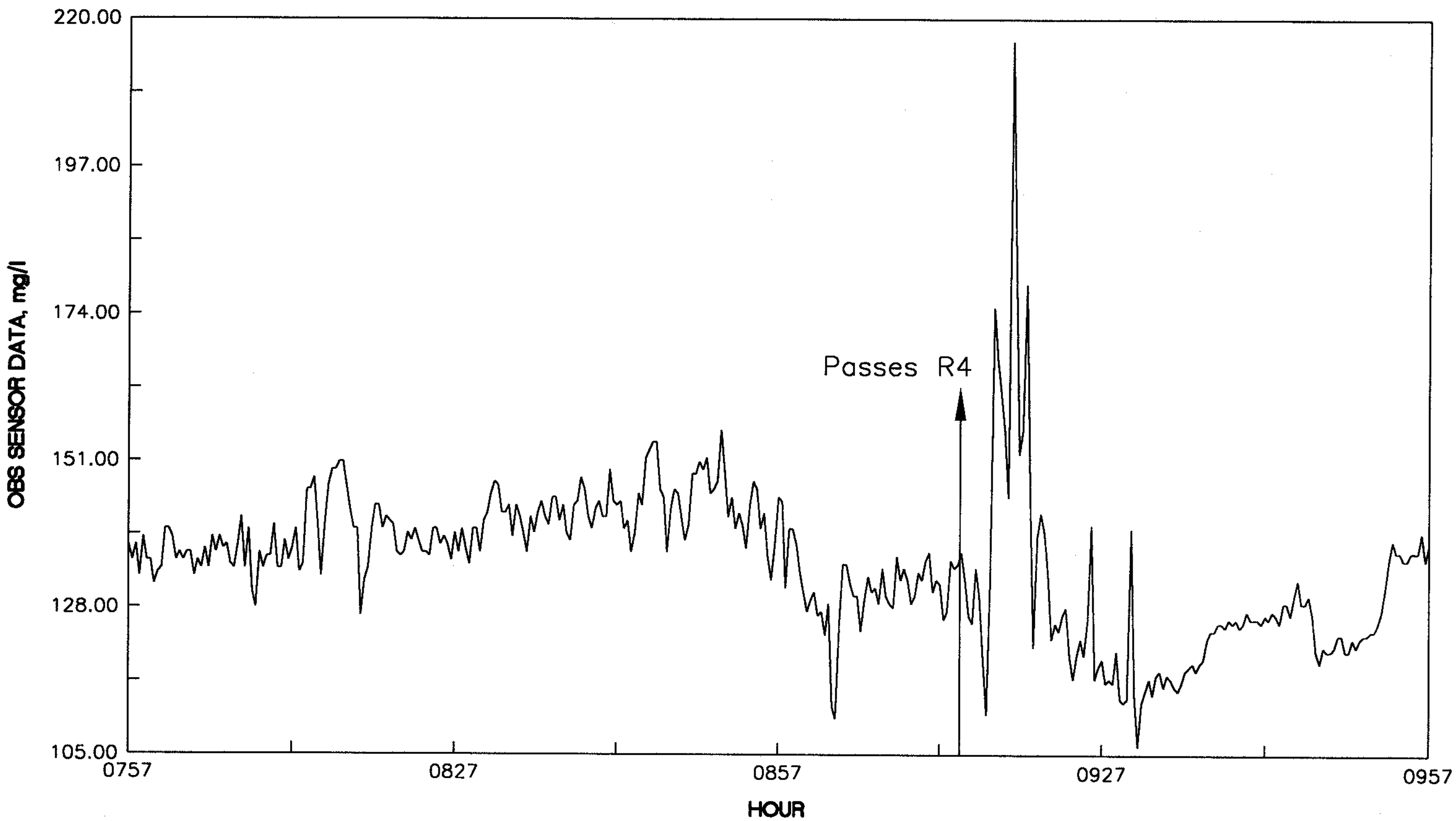


MEAN IS 134.9999 mg/l

OBS SENSOR AT 3.5 FT

RANGE 4 LA GRANGE BOAT 02

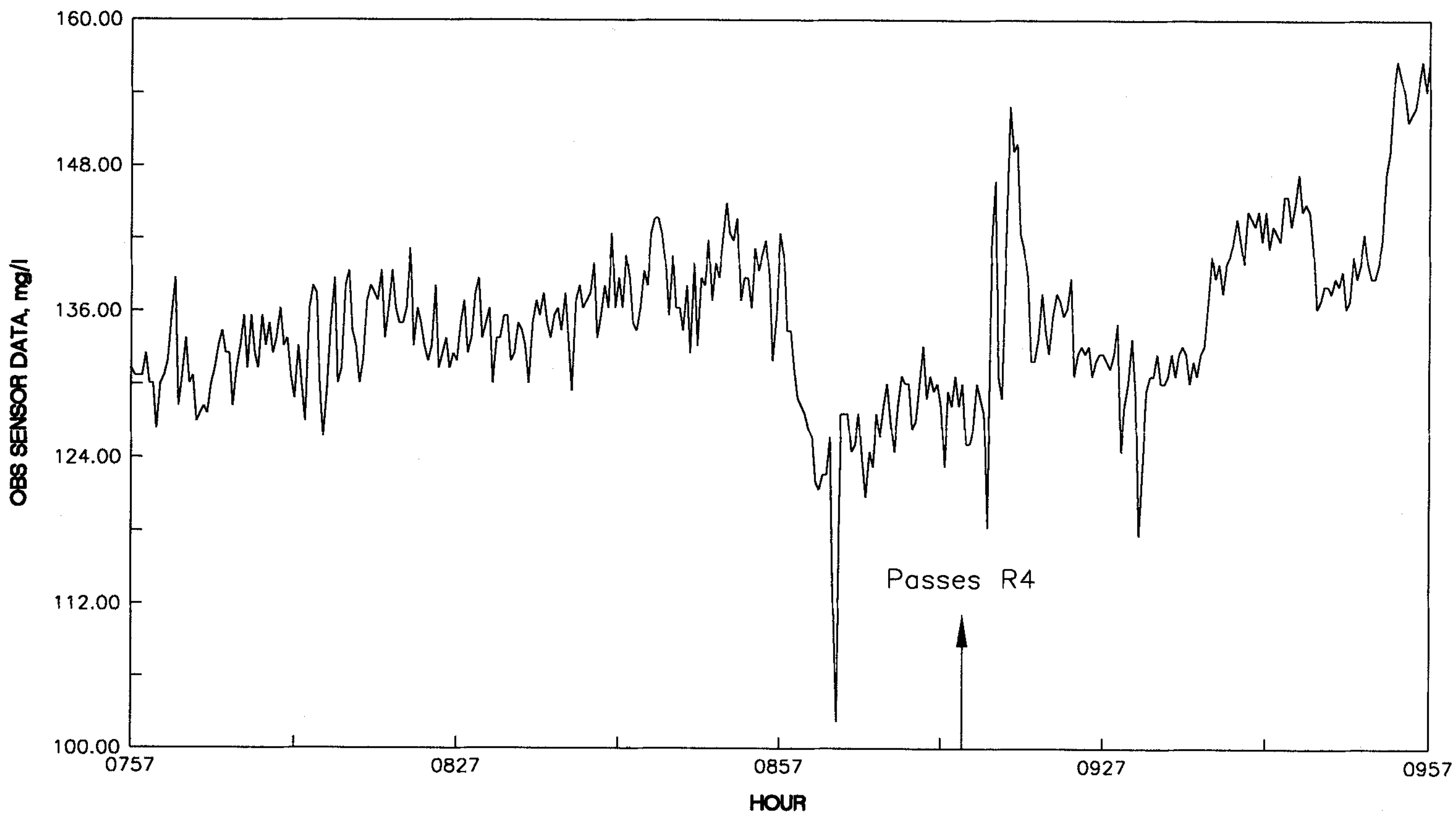
9/9/96 - 9/9/96



MEAN IS 135.0001 mg/l

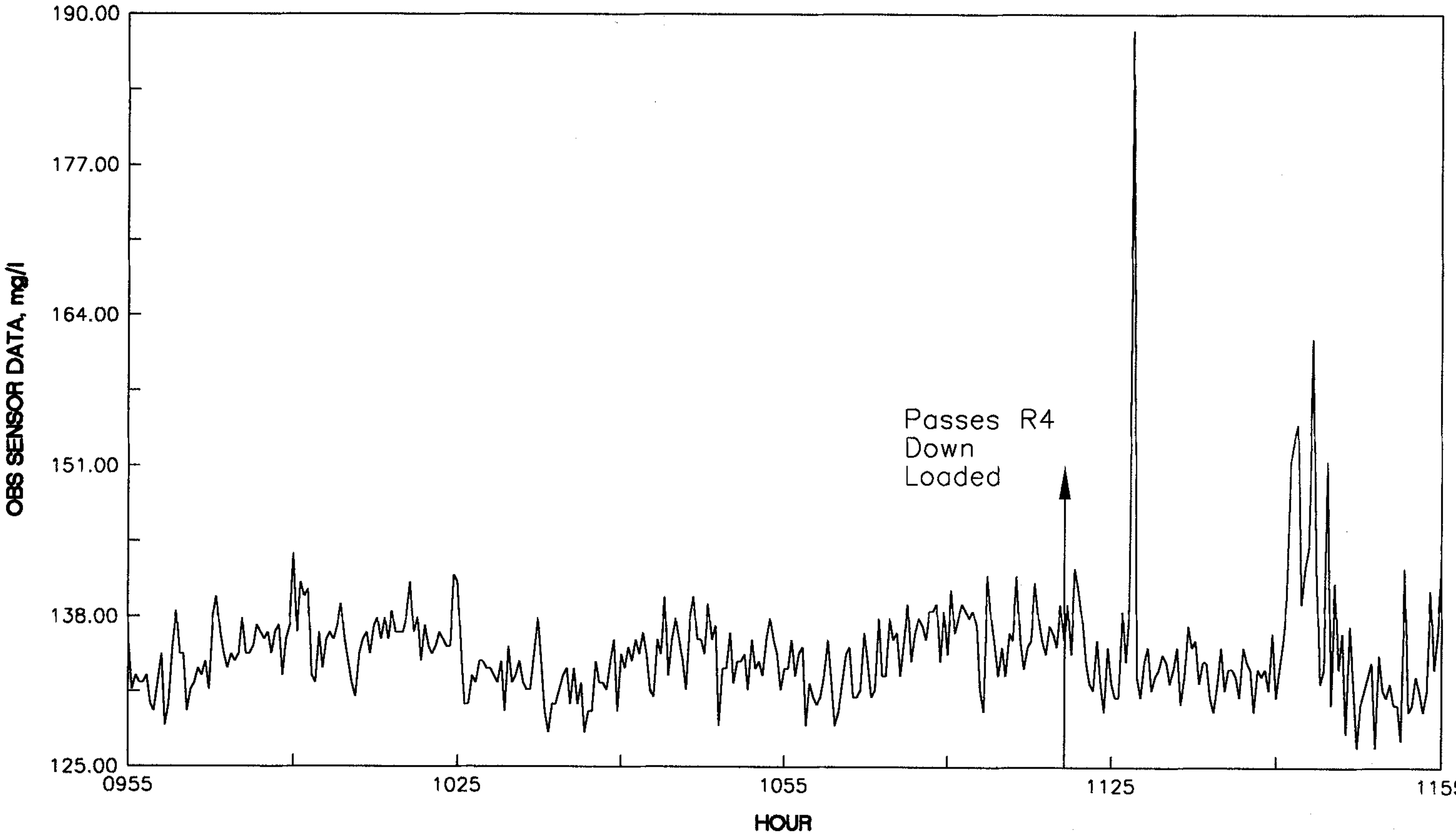
OBS SENSOR AT 7.5 FT
RANGE 4 LA GRANGE BOAT 02
9/9/96 - 9/9/96

Plate 86



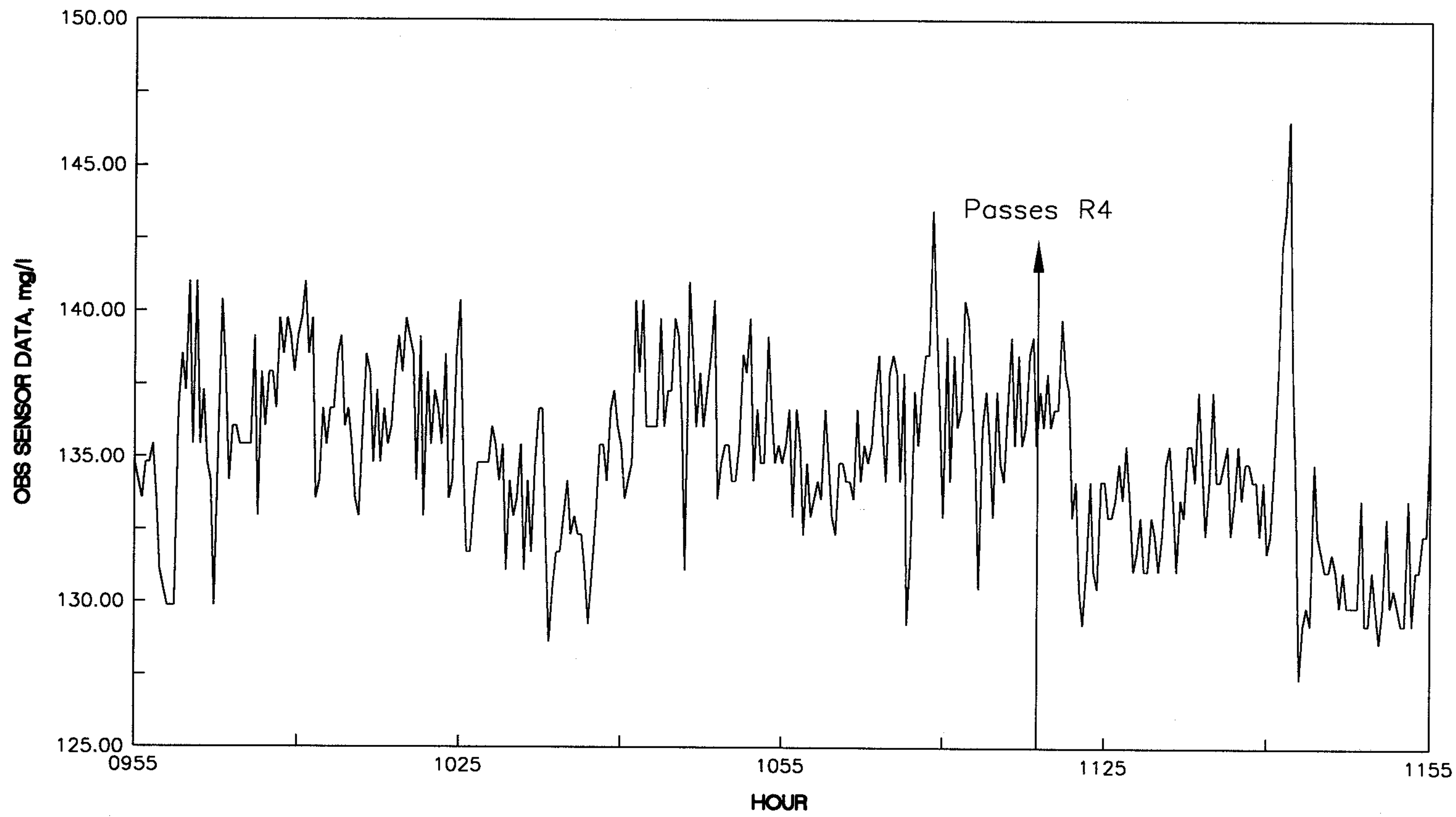
MEAN IS 135.0001 mg/l

OBS SENSOR AT 8.5 FT
RANGE 4 LA GRANGE BOAT 02
9/9/96 - 9/9/96



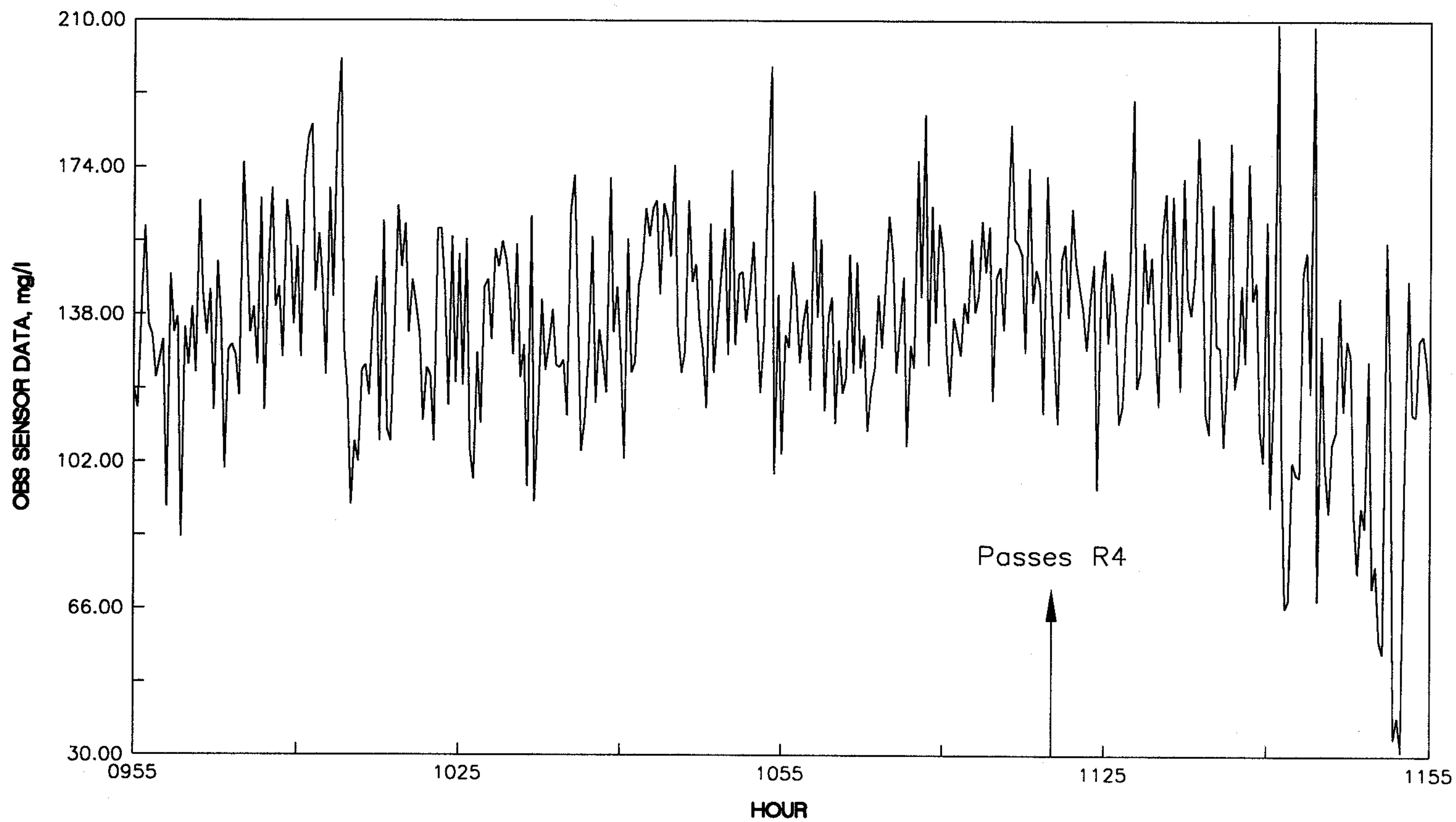
MEAN IS 135.0000 mg/l

OBS SENSOR AT 3.5 FT
RANGE 4 LA GRANGE BOAT 10
9/10/96 - 9/10/96



MEAN IS 134.9999 mg/l

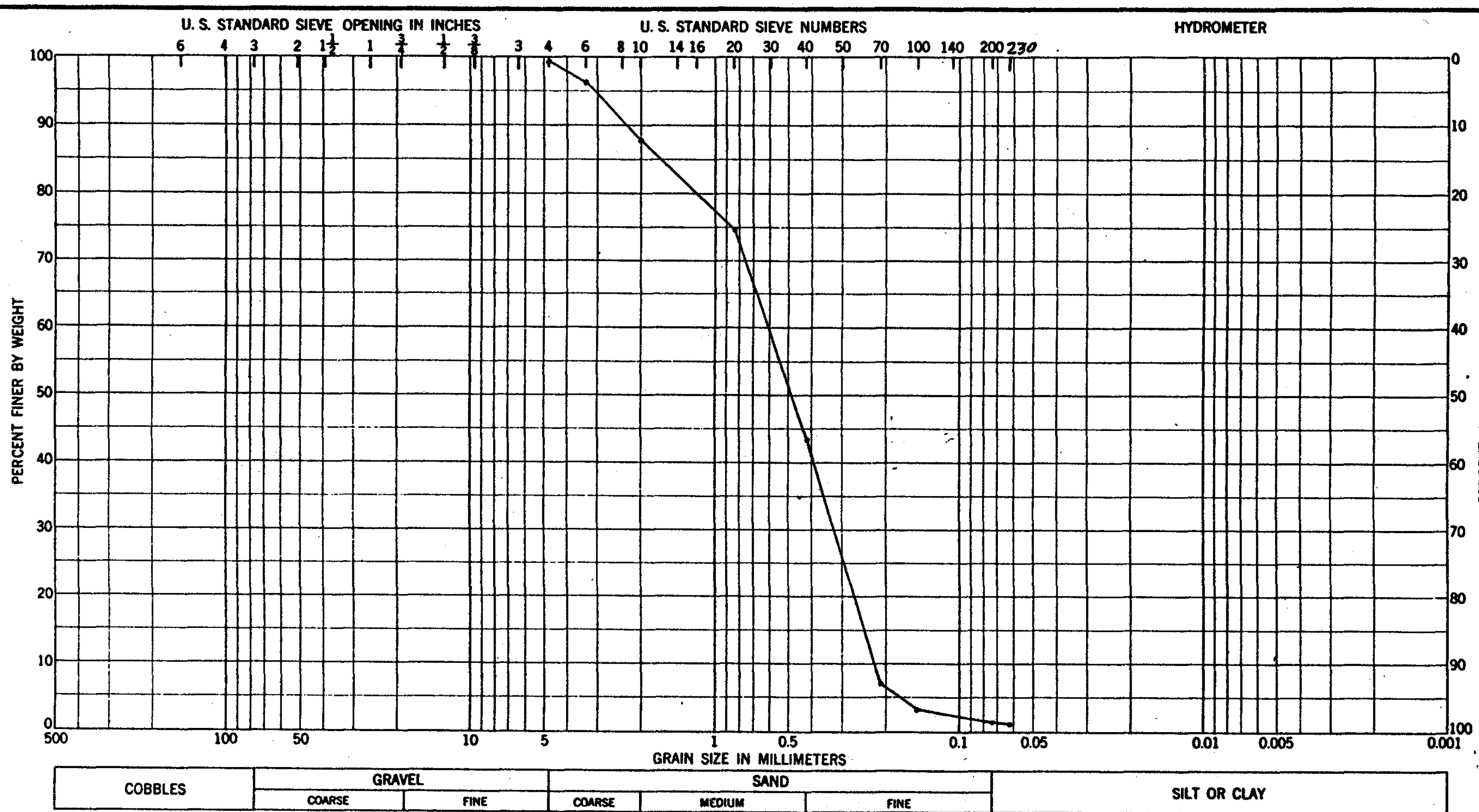
OBS SENSOR AT 7.5 FT
RANGE 4 LA GRANGE BOAT 10
9/10/96 - 9/10/96



MEAN IS 135.0000 mg/l

OBS SENSOR AT 8.5 FT
RANGE 4 LA GRANGE BOAT 10
9/10/96 - 9/10/96

Plate 90



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project UPPER MISS. RIVER

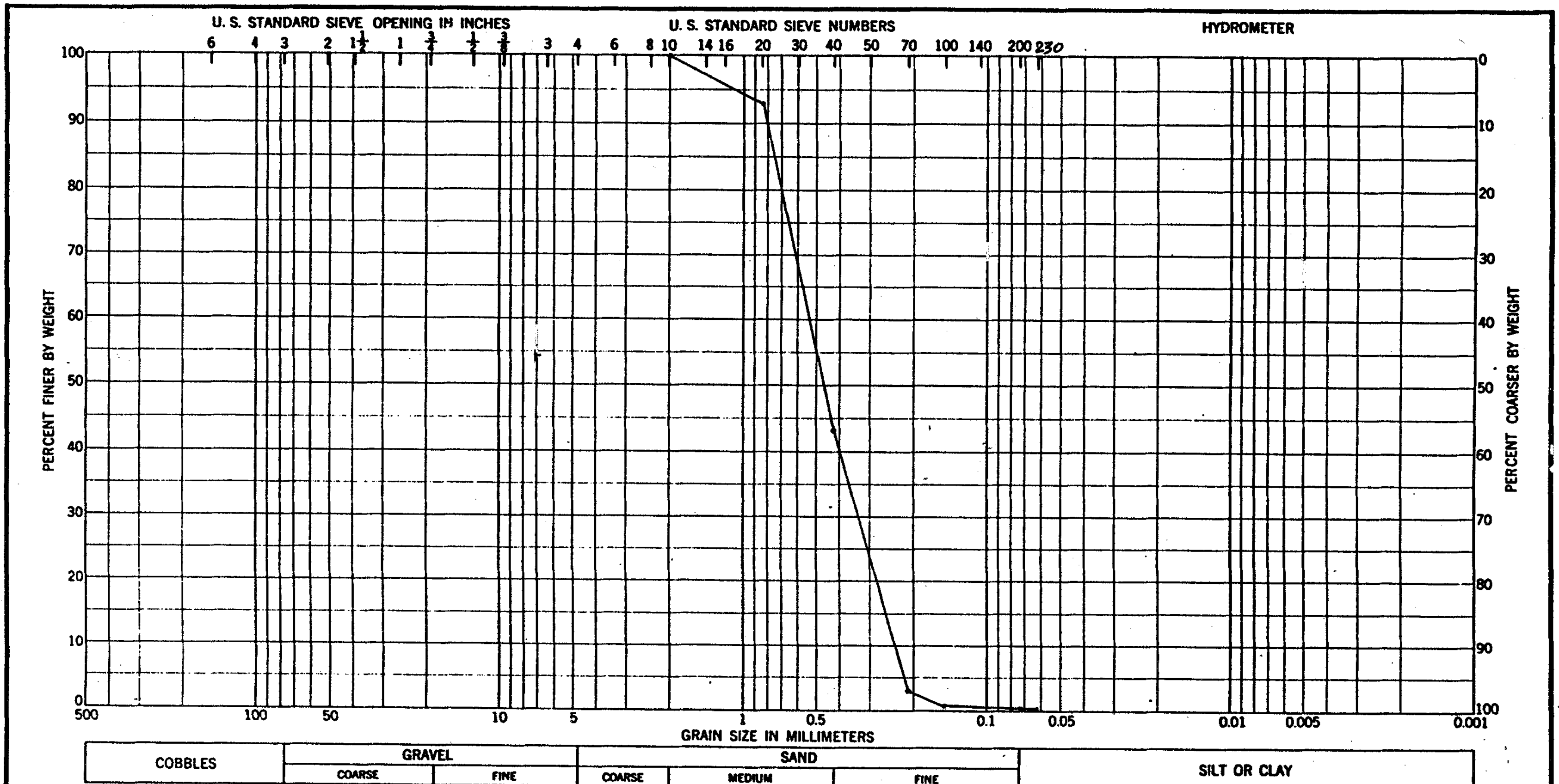
Area POOL 8 RANGE 1

Boring No. d50 = 0.48 MM

Date 10-16-96

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project *UPPER MISS. RIVER*

Area *POOL 8 RANGE 5*

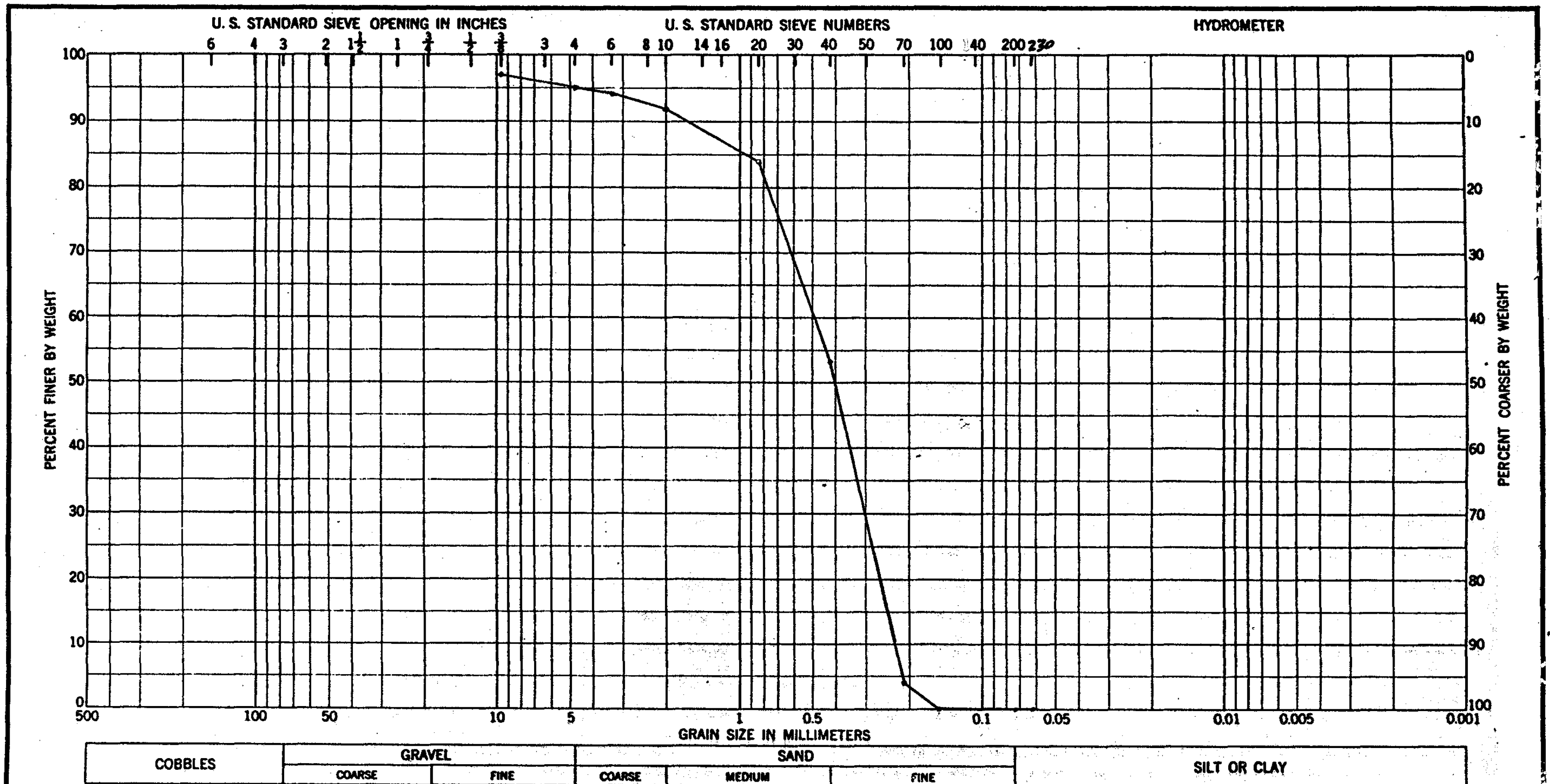
Boring No. *d50 = 0.46 mm*

Date *10-16-96*

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Plate 92



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project UPPER MISS. RIVER

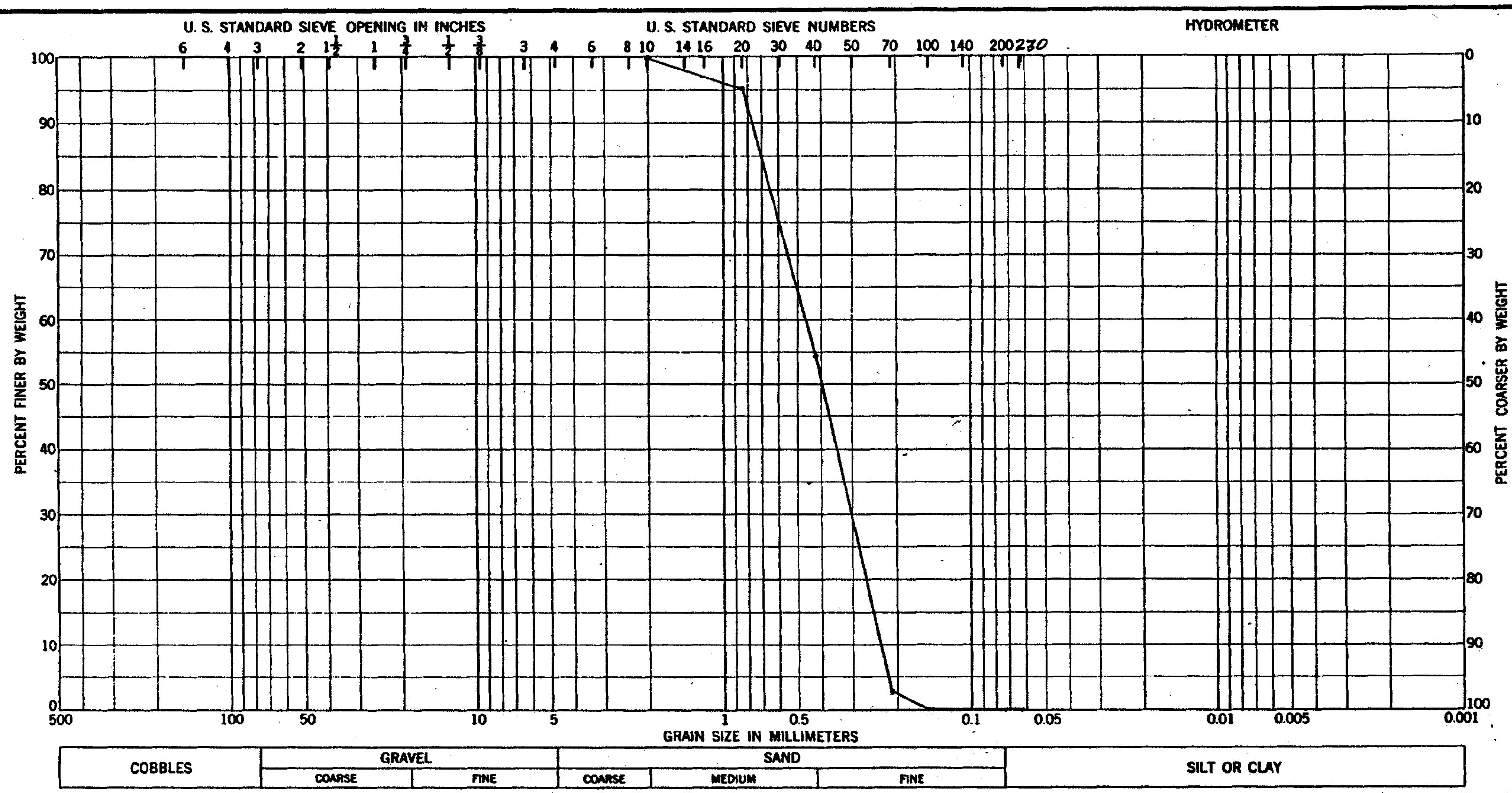
Area POOL 26 RANGE 5

Boring No. d50=0.40 MM

Date 10-23-96

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project *UPPER MISS. RIVER*

Area *POOL 26 RANGE 7*

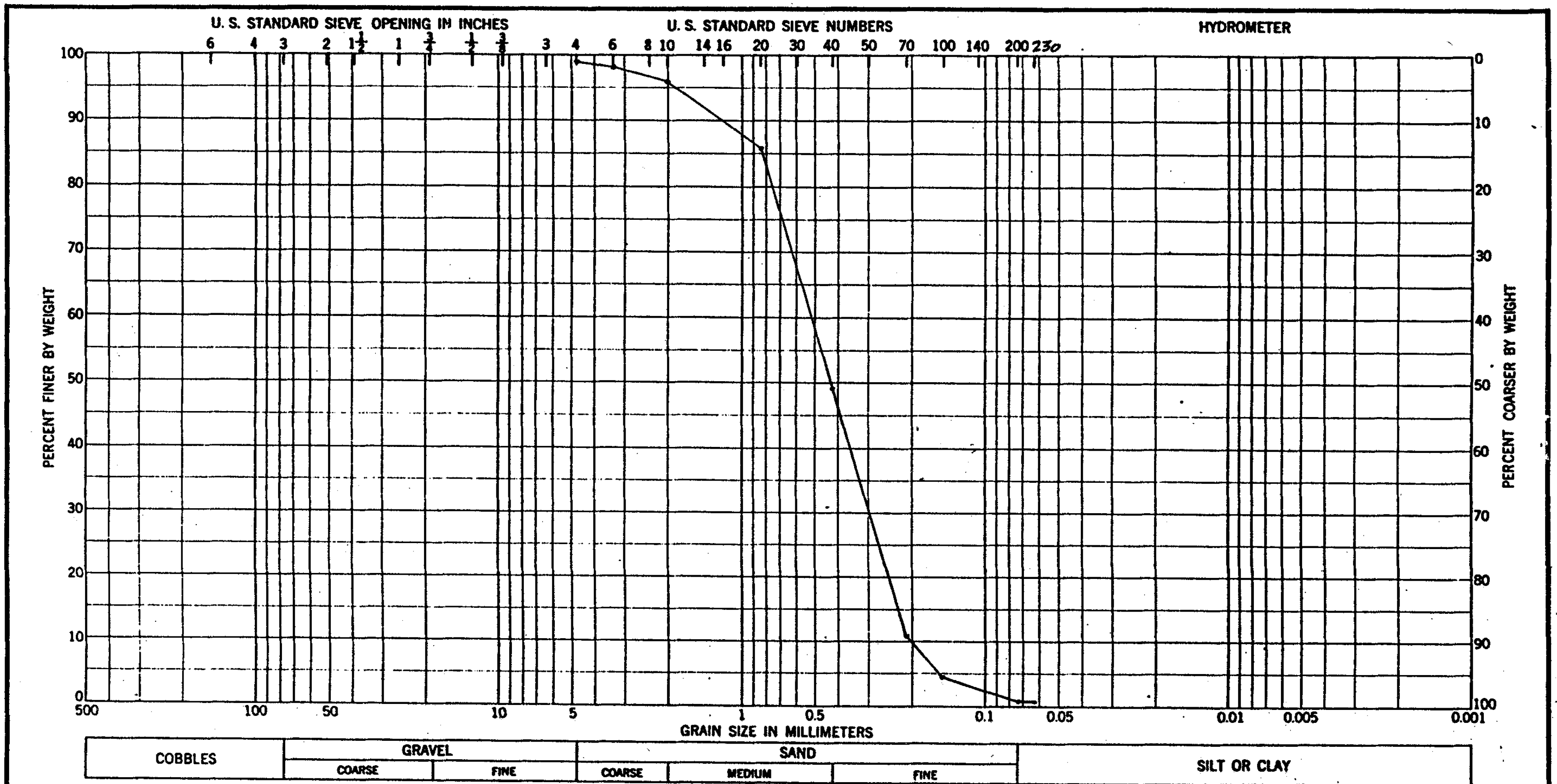
Boring No. *d50 = 0.40 mm*

Date *10-23-96*

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Plate 94



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project UPPER MISS. RIVER

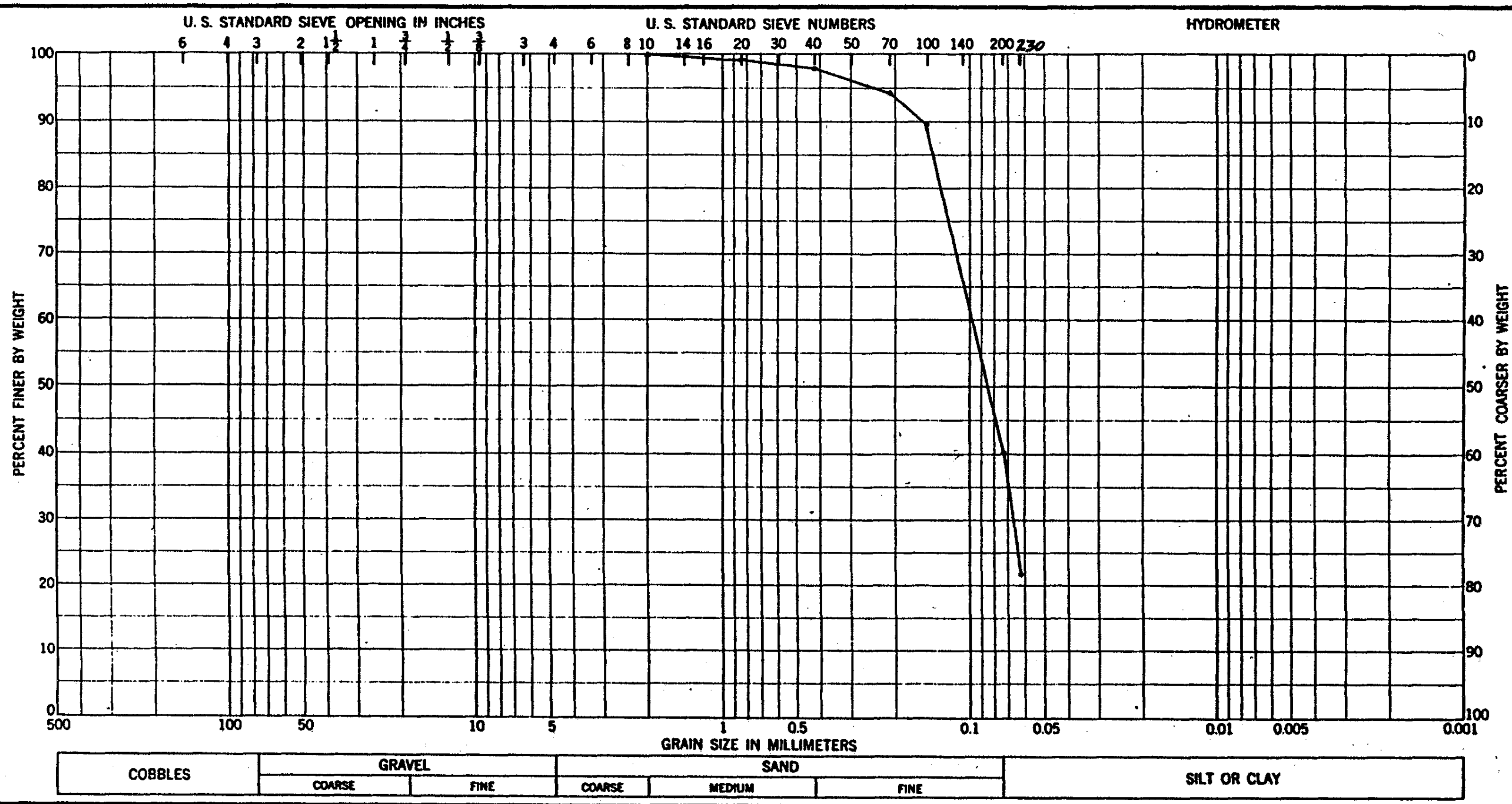
Area LAGRANGE RANGE 3

Boring No. d50=0.42 mm

Date 10-23-96

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project *UPPER MISS. RIVER*

Area *LAGRANGE RANGE 1*

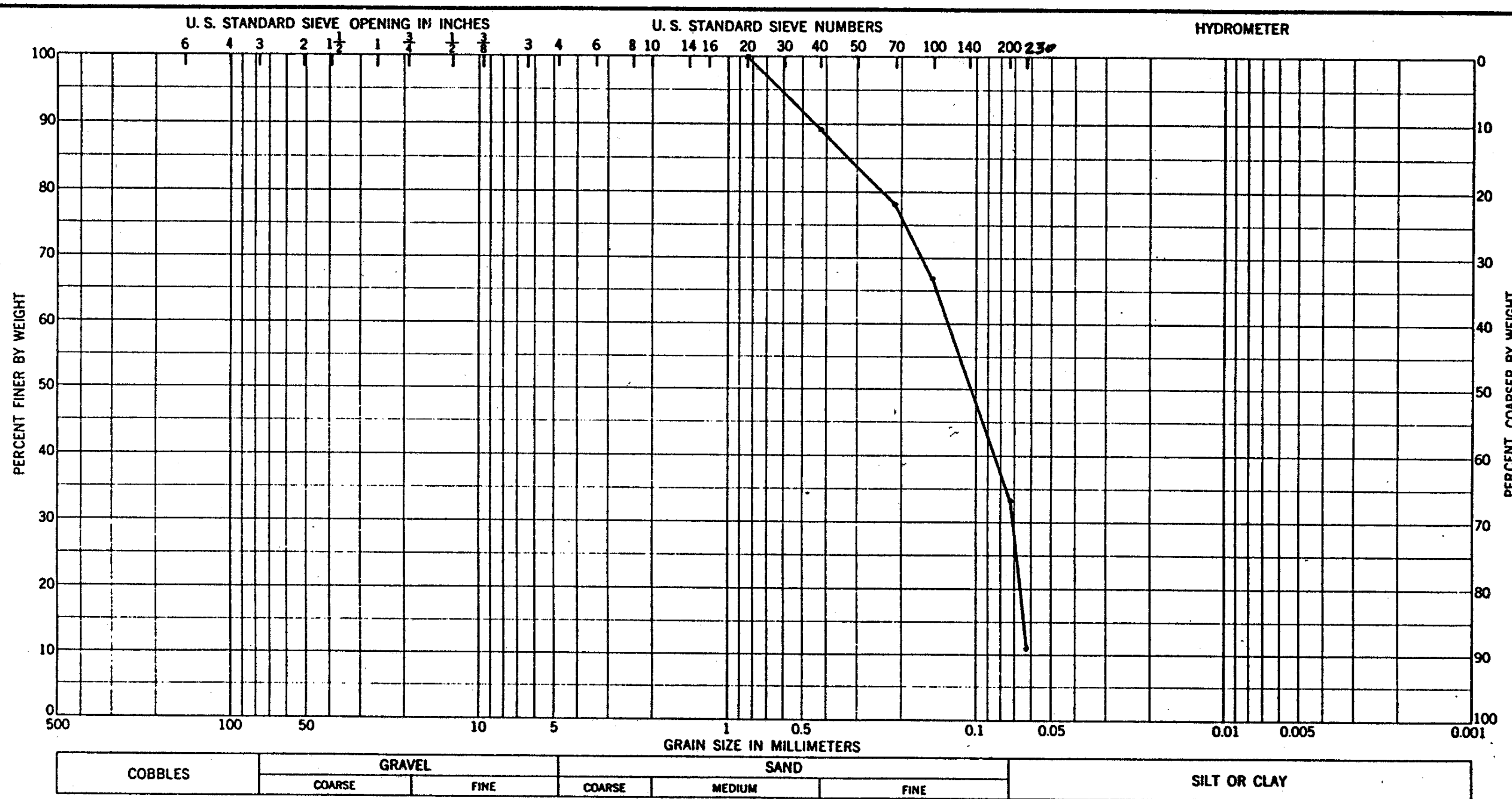
Boring No. *d50 = 0.084 mm*

Date *10-25-96*

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Plate 96



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project UPPER MISS. RIVER

Area LAGRANGE RANGE 4 0742

Boring No. d50 = 0.11 mm

Date 10-25-96

GRADATION CURVES

ENG FORM 1 MAY 63 2087

Appendix A
Prototype and Field Studies Group Data Collection Equipment and Laboratory Analysis Procedures

The contents of this appendix are to provide detailed information on the types of data collection and laboratory equipment used in a majority of the field investigations performed by the Prototype and Field Studies Group, Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Waterways Experiment Station (WES). The following table is provided to identify the parameters most commonly measured and the types of instruments that can provide these measurements.

Table A1
Current Velocity and Direction Measurements
Recording Velocity Meter Acoustic Doppler Current Profiler System
Suspended Sediment Sampling
Pumped Water Sample Optical Backscatterance Sensors
Water-Level Measurements
Wave-Height Measurements Electronic Water-Level Recorders
Bottom-Sediment Sampling
Push Core
Meteorological Measurements
Digital Recording Station
Laboratory Equipment and Sample Analysis
Laboratory Analysis for Suspended-Sediment Concentrations Laboratory Analysis for Total Suspended Material Density Analysis

Current Velocity and Direction Measurements

Recording velocity meters

Self-contained recording current meters are used to obtain current velocity and direction measurements for both profiling and for long-term fixed-depth deployment. The two types of equipment commonly utilized are the Environmental Devices Corporation (ENDECO) Type 174 SSM current meters as shown in Figure A1 and the InterOcean S4 electromagnetic current meter shown in Figure A2.

The ENDECO 174 SSM meter is tethered to a stationary line or structure and floats in a horizontal position at the end of the tether (as shown in Figure A3). It measures current speed with a ducted impeller and current direction with an internal compass. The ENDECO 174 SSM also measures temperature with a thermilinear thermistor and conductivity with an induction-type probe. Data are recorded on an internal solid-state memory data logger. Data are offloaded from the meter data logger by means of a communication cable connected between the meter and a computer. The threshold speed is less than 0.024 mps (0.08 fps); maximum speed of the unit used is 2.57 mps (8.44 fps) (10 knots); and stated speed accuracy is ±3 percent of full scale. The manufacturer states that direction accuracy is ±7.2 deg above 0.024 mps (0.08 fps). Time accuracy is ±4 sec per day.

The InterOcean Model S-4 electromagnetic current meter can obtain continuous recording of current velocity and direction at fixed depths or can be used to profile the water column for current velocity and directions. The S-4 meter, shown in Figure A2, is a 25.4-cm-diam (10-in.-diam) sphere that is suspended vertically in the water column with a submerged flotation device and anchored to the bottom by a heavy block and anchor arrangement. This deployment technique is illustrated in Figure A4. The S-4 meter measures the current velocity using an electromagnetic field to sense current induced by the movement of water through the field. An internal microprocessor coupled with an internal flux-gate compass computes the velocity vectors, which are then stored in the solid-state memory. The accuracy of the S-4 meter current speed is ±0.2 cm/sec.

Acoustic Doppler Current Profiler

Acoustic techniques are used to obtain current velocity and direction measurements for fast and accurate profiling in the field. The equipment used is RD instruments Acoustic Doppler Current Profiler (ADCP)-BroadBand as shown in Figure A5. These instruments use a 1,200-kHz operating frequency. The equipment is mounted over the side of boat with the acoustic transducers submerged, and data are collected while the vessel is underway as shown in Figure A6.

Figure A1. ENDECO 174SSM recording current meter

Figure A2. InterOcean S-4 current meter

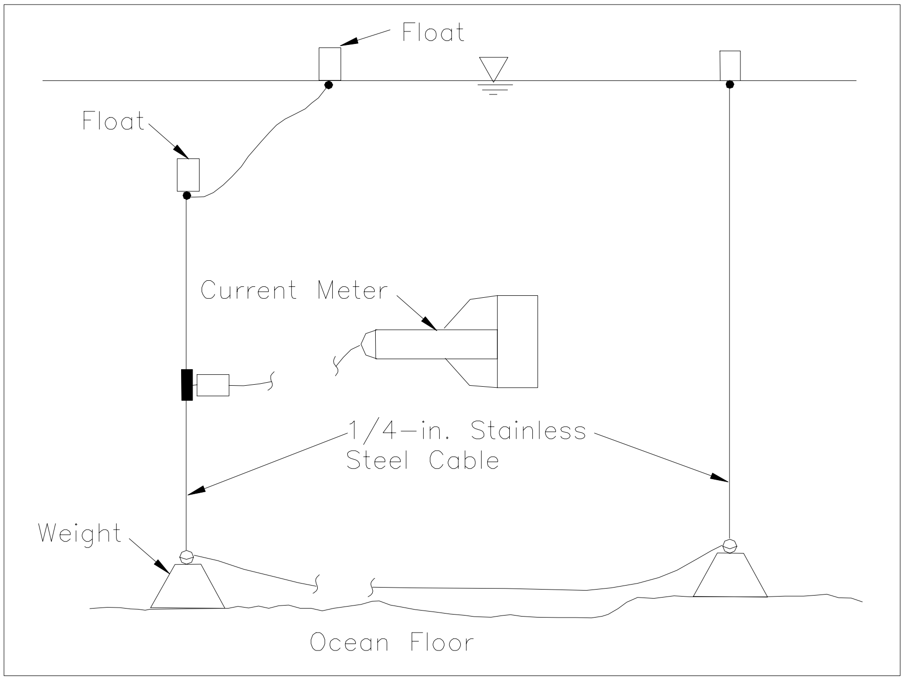


Figure A3. Typical deployment technique for fixed-depth velocity meter

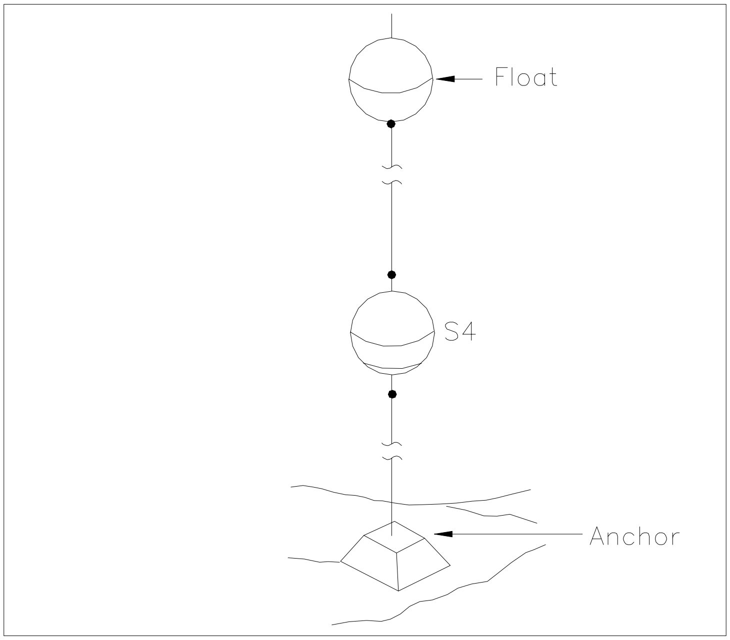


Figure A4. S-4 current meter deployment method

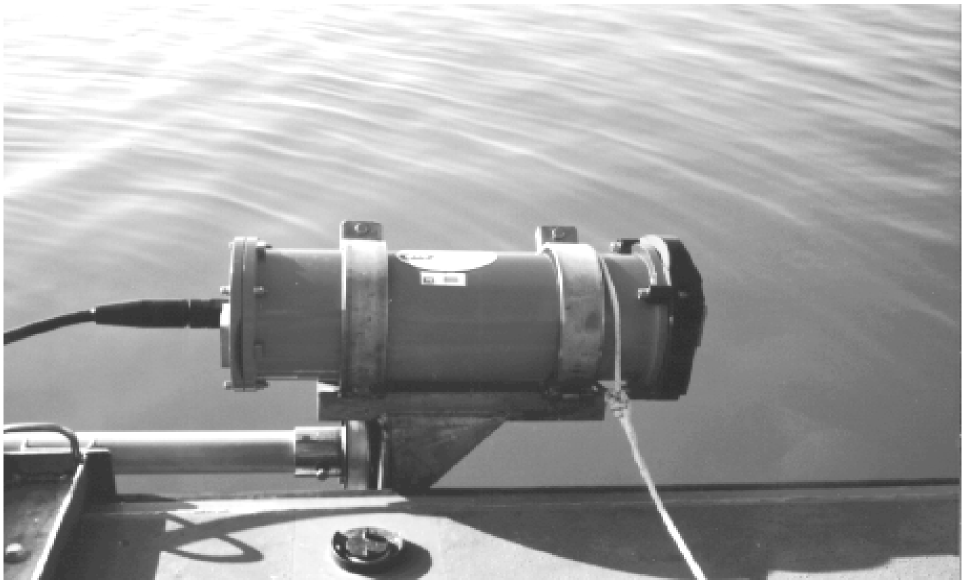


Figure A5. Acoustic Doppler Current Profiler (ADCP)

Figure A6. Vessel-mounted ADCP

The ADCP transmits sound bursts into the water column that are scattered back to the instrument by particulate matter suspended in the flowing water. The ADCP listens for the returning signal and assigns depths and velocity to the received signal based on the change in the frequency caused by the moving particles. This change in frequency is referred to as a Doppler shift. The ADCP is also capable of measuring vessel direction, current direction, water temperature, and bottom depth. Communication with the instrument for setup and data recording are performed with a portable computer using manufacturer-supplied software, hardware, and communication cables. The manufacturer stated accuracies for current speed measurement ±0.2 cm/sec; for vessel direction ±2 deg; and temperature ±5 °C.

Suspended-Sediment Sampling

Pumped water samples

In combination with the over-the-side velocity measuring equipment, water samples for analyses of suspended-sediment concentrations and total suspended solids are obtained by pumping the sample from the desired depth to the surface collection point. The pumping system consists of a 0.64-cm (0.25-in.) ID plastic tubing attached to the current meter signal cables for support. The opening of the sampling tubing is attached to the solid suspension bar at the same elevation as the current meter and is pointed into the flow. A 12 Vdc pump is used to pump the water through 15.24 m (50 ft) of the tubing to the deck of the boat where each sample is then collected in individual 226.80-g (8-oz) plastic bottles. The pump and tubing are flushed for approximately 1 min at each depth before collecting the sample.

Optical backscatterance (OBS) sensors

The OBS sensor, a product of D&A Instruments and Engineering, is a type of nephelometer for measuring turbidity and solids concentrations by detecting scattered radiation from suspended matter. It consists of a high-intensity infrared emitting diode (IRED), a series of silicon photodiodes as detector, and a linear solid-state temperature transducer. The IRED emits a beam at angles 50 deg in the axial plane and 30 deg in the radial plane to detect suspended particles by sensing the radiation they scatter, as shown in Figure A7. Scattering by particles is a strong function of the angle between the path of radiation from the sensors through the water and the signal return to the detector. OBS sensors detect only radiation scattered at angles greater than 140 deg. As with other optical turbidity sensors, the response of the OBS sensor depends on the size distribution, composition, and shape of particles suspended in the medium being monitored. For this reason, sensors must be calibrated with suspended solids from the waters being monitored. The OBS sensor can be interfaced with “smart” data loggers that are capable of powering the sensor during sampling intervals.

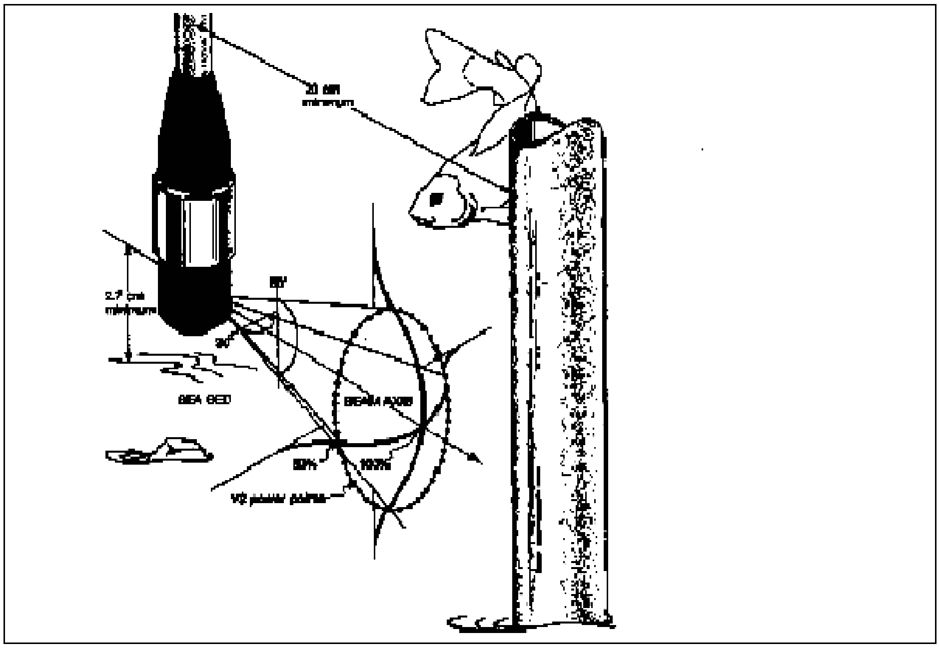


Figure A7. OBS sensor beam pattern

Wave-Height Measurements–Electronic Wave-Height Recorders

The Microtide water-level recorders, shown in Figure A8, contain a strain-gauge-type pressure transducer in a subsurface case that records the absolute pressure of the column of water above the case. The pressure transducer is not vented to the atmosphere; therefore, an extra unit is positioned in the study area to record atmospheric pressure changes. Water pressure is measured for the desired sample interval, and an average value is computed and stored on the internal RAM data logger. The stated accuracy is ±0.006 m (±0.02 ft). The sampling time interval can be set from 1 min to 24 hr. The Microtide also measures temperature by means of a YSI thermilinear thermistor built into the water-level recorder. The thermistor has a range of -5 to +45 °C, with a stated accuracy of ±0.1 °C. The data from each recorder are stored on an accessible RAM located in the waterproof subsurface unit that also contains the DC power supply.

Wave-Level Measurements–Electronic Water-Level Recorders

Water-level elevation measurements can also be recorded using solid-state electronic recorders, such as Microtide and ENDECO water-level recorders.

Figure A8. Microtide electronic wave-height recorder

Water-level elevations, temperature, conductivity, and suspended-sediment concentration measurements are recorded using ENDECO models 1152 SSM and 1029 (solid-state measurement) water-level recorders shown in Figure A9. The ENDECO model 1152 SSM and 1029 recorders contain a strain-gauge-type pressure transducer located in a subsurface case that records the absolute pressure of the column of water above the case. The pressure transducer is vented to the atmosphere by a small tube in the signal cable to compensate for atmospheric pressure. The pressure is measured for 49 sec of each minute of the recording interval with a frequency of 5-55 kHz to filter out surface waves, therefore eliminating the need for a stilling well. The accuracy is (±0.15 m) (±0.05 ft). The sampling time interval can be set from 1 min to 1 hr. The 1152 and 1029 also measure temperatures by means of a thermilinear thermistor built into the recorders. The thermistor has a range of -5° to +45° C, with an accuracy of ±0.2 C. The 1152 measures conductivity by an inductively coupled probe installed on the meter. These measurements and the measurements of temperature are used to calculate water-suspended sediment concentrations in units of parts per thousand. The water-suspended sediment concentrations are computed with an accuracy of ±0.2 ppt.

The sampling time interval for conductivity and temperature cannot be set independently from the water-level measurements. The data from each recorder are stored on a removable EPROM solid-state memory cartridge located in a waterproof surface unit that also contains the DC power supply.

Figure A9. Water-level recorder

Bottom-Sediment Sampling–Push Core Sampler

Bottom sediment is obtained using a push-core-type sampler. The sampler consists of a 3.81-cm-diam (1.5-in.-diam) PVC pipe, 45.72 cm (18 in.) in length. Attached to this is a smaller section of pipe with a valve attached at the upper end. The purpose of the valve is to create a reduced pressure holding the sample in the larger diameter pipe. The samples are then brought to the surface and classified by visual inspection or transported back to WES for more detailed analysis.

Meteorological Measurements–Digital Data Acquisition of Meteorological Data

Continuous wind speed and direction measurements are recorded using a HANDAR Model No. 540-A Data Acquisition system (see Figure A10). The data collection platform is typically located at some central location in the study area and mounted approximately 10 m above the water. The data acquisition system is a battery-powered microcomputer with a real-time clock, a serial data interface, and programmable analog-to-digital converter. The battery is constantly charged using a solar panel charging system located near the system.

Various programming options are available for setting the sampling interval of the system for the input signals from the wind speed and direction sensors. The system can be programmed to sample the input signals each second over a set period of time to determine the mean wind speed, mean direction, maximum

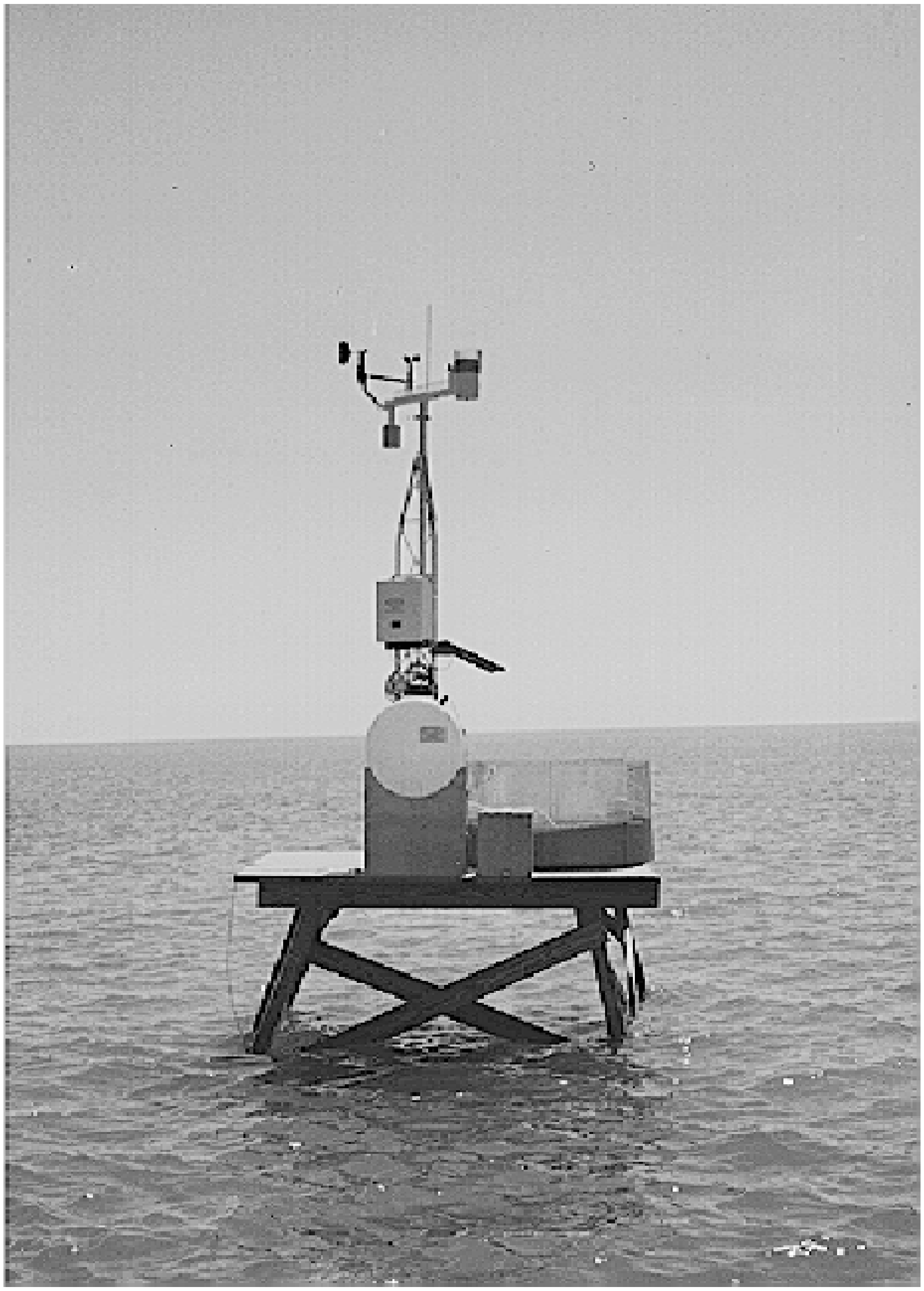


Figure A10. HANDAR meteorological data-acquisition system

wind-gust speed, and maximum wind-gust direction. The data are processed internally and stored in formats specified in a user-entered output table. The accuracy of the analog input of the wind speed and direction sensors are ± 1.0 mph and ± 3.0 deg, respectively.

Laboratory Equipment and Sample Analysis

Total suspended materials (TSM) are determined by filtration of samples. Nuclepore (Registered Trademark) polycarbonate filters with 0.40-μm pore size are used. They are desiccated and preweighed, then a vacuum system (8-lb vacuum maximum) is used to draw the sample through the filter. After the filters and holders are washed with distilled water, the filters are dried at 105 °C for 1 hr and reweighed. The TSM are calculated based on the weight of the filter and the volume of the filtered sample.

Density Analysis

A density analysis is done using wide-mouth, 25-cm, constant-volume pycnometers. They are calibrated for tare weight and volume. A pycnometer is partially filled with sediment and weighed, then topped off with distilled water. Care is taken to remove any bubbles before the pycnometer is reweighed. The bulk density (BSG) of the sediment is then calculated by the equation:

$$BSG = \frac{(p)(sedwt - tarewt)}{(p)(volpyc) + (sedwt) - (sed + waterwt)}$$

where

p =density of water at temperature of analysis

$sedwt$ = weight of pycnometer with sediment

$tarewt$ = tare weight of pycnometer

$volpyc$ = volume of pycnometer

$sed + waterwt$ = weight of pycnometer with sediment and water