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May 1999

US Army Corps of Engineers
Waterways Experiment Station

Ashtabula River, Ohio, Sedimentation Study

Report 2
Field Data Collection

by Timothy L. Fagerburg

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Prepared for U.S. Army Engineer District, Buffalo

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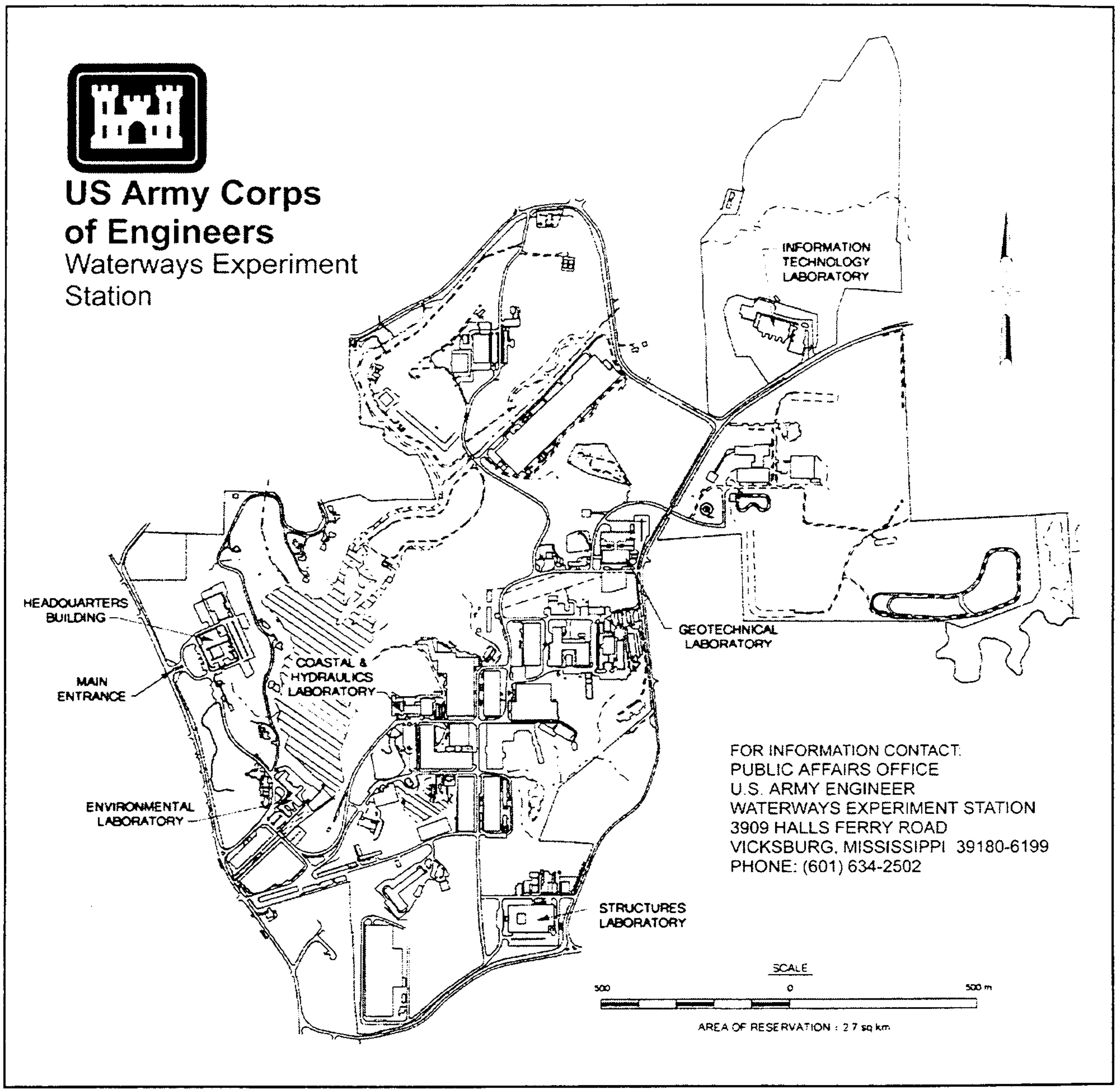
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Report 2 of a series

Prepared for U.S. Army Engineer District, Buffalo
Buffalo, NY 14207-3199



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Contents

Preface

The field investigation reported herein was conducted by the U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, from 4 June 1994 through 12 November 1995, to provide the necessary data for model verification in support of a river water quality study project proposed by the U.S. Army Engineer District, Buffalo. This effort was funded by the Buffalo District under the management of Mr. S. Goalyski. The WES liaison was Mr. R. Heath of the Waterways and Estuaries Division (WED), Coastal and Hydraulics Laboratory (CHL). The CHL was formed in October 1996 with the merger of the WES Coastal Engineering Research Center and Hydraulics Laboratory. Dr. James R. Houston is the Director of the CHL.

Personnel of the CHL Prototype and Field Studies Group (PFSG), performed their work under the general supervision of Mr. W. H. McAnally, Jr., Chief, WED. The data collection program was designed by Messrs. T. L. Fagerburg, H. A. Benson, J. W. Parman, and T. C. Pratt, PFSG. Data reduction was performed by Mrs. C. J. Coleman and Mr. Fagerburg, PFSG. Laboratory analyses of water samples were performed by Mrs. Coleman and Mr. Parman. This report was prepared by Mr. Fagerburg.

At the time of publication of this report, Commander of WES was COL Robin R. Cababa, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
inches	25.4	millimeters
miles (U.S. statute)	1.609347	kilometers
square miles	2.589998	square kilometers
cubic feet per second	0.2831685	cubic meters
degrees (angle)	0.01745329	radians
knots	0.5144444	meters per second
ounces	28.34952	grams
pounds	0.4535924	kilograms

1 Introduction

Background

The study of circulation and sediments in the Ashtabula River system is a complex issue. 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, astronomical and meteorological induced currents, wind-induced circulation, density variations and resulting gravitational induced currents, and freshwater inflow are major factors determining river-wide circulation and suspended sediment patterns. In addition, the proposed deepening and widening of the Ashtabula River Entrance Channel and the navigation channel could affect both circulation and suspended sediment concentrations throughout the river system.

The Ashtabula River Basin is located in northeast Ohio. The river enters Lake Erie at the city of Ashtabula, which is about 55 miles[1] east of Cleveland, OH, and 40 miles west of Erie, PA. The river extends about 18 miles from the river mouth to the confluence of the east and west branches, which are 12 miles long. The river drainage area consists of about 136 square miles and an average flow of 150 cfs. Major tributaries to the river include Fields Brook, East and West Branch Hubbard Run, Ashtabula Creek, and Strong Brook. The Ashtabula River navigation channel extends from the entrance at Lake Erie to a point approximately 3.5 miles upstream. The harbor and approximately the lower 3,000 ft of waterway (to the 5th Street Bridge) are routinely dredged to maintain commercial navigation depths. The navigation channel from the 5th Street Bridge through the turning basin is approximately 200 ft wide with a project depth of 16 ft at low water referenced to International Great Lakes Datum 1985. Upstream of the turning basin the remainder of the Federal Navigation Project averages approximately 11 ft depth.

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page v.

Purpose

The purpose of the overall Ashtabula River monitoring program was to provide the necessary boundary condition, initial condition, and verification data for a comprehensive numerical simulation of Ashtabula River. 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 Ashtabula River system from June 1994 through November 1995.'Measurements consisted of the following:

a. Short-term.

1. Current speed and direction at five ranges for one river discharge.

2. Suspended sediment samples at each of the ranges.

3. Bottom sediment samples at 12 locations.

b. Long-term.

1. Water level monitoring at four locations.

2. Suspended sediment measurements at three locations.

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 Equipment and Program

Data were collected in the Ashtabula River on 4-8 June 1994, as part of the short-term data collection program, and were concurrent with the long-term data collection program that began on 4 June 1994 and extended to 13 November 1995. During the data collection periods, water level recorders and stage-actuated water samplers were in place continuously. As part of the short-term programs, profile measurements of current speed, direction, and suspended sediment concentrations were obtained. The short- and long-term data collection efforts are described in further detail in subsequent sections of this report.

Water Level Measurements

During the Ashtabula River field investigation, instruments were deployed for monitoring of water levels. These instruments are identified on the location map, Figure 1, as locations WL-1, WL-2, WL-3, and WL-4. Water-surface elevations were monitored using Environmental Devices Corporation (ENDECO) model 1029 electronic water level recorders, as described in Appendix A.

Suspended Sediment Sample Measurements

Suspended sediment samples for determination of concentrations at three of the water level recorders were obtained with a stage-activated American Sigma Automatic Water sampler , as described in Appendix A. These instruments were deployed in areas relatively close to the navigation channel and in water depths ranging from 3-12 ft. Intakes for the samplers were positioned at a depth of 2 ft above the bottom. They are designated as stations WS-2, WS-3, and WS-4, as shown in Figure 1. For safety and security of the instruments, the deployment sites were located on private property with the property owners' permission. The sampling interval for these suspended sediment concentrations recorders was 30 min between samples once the float was activated by rising water levels.

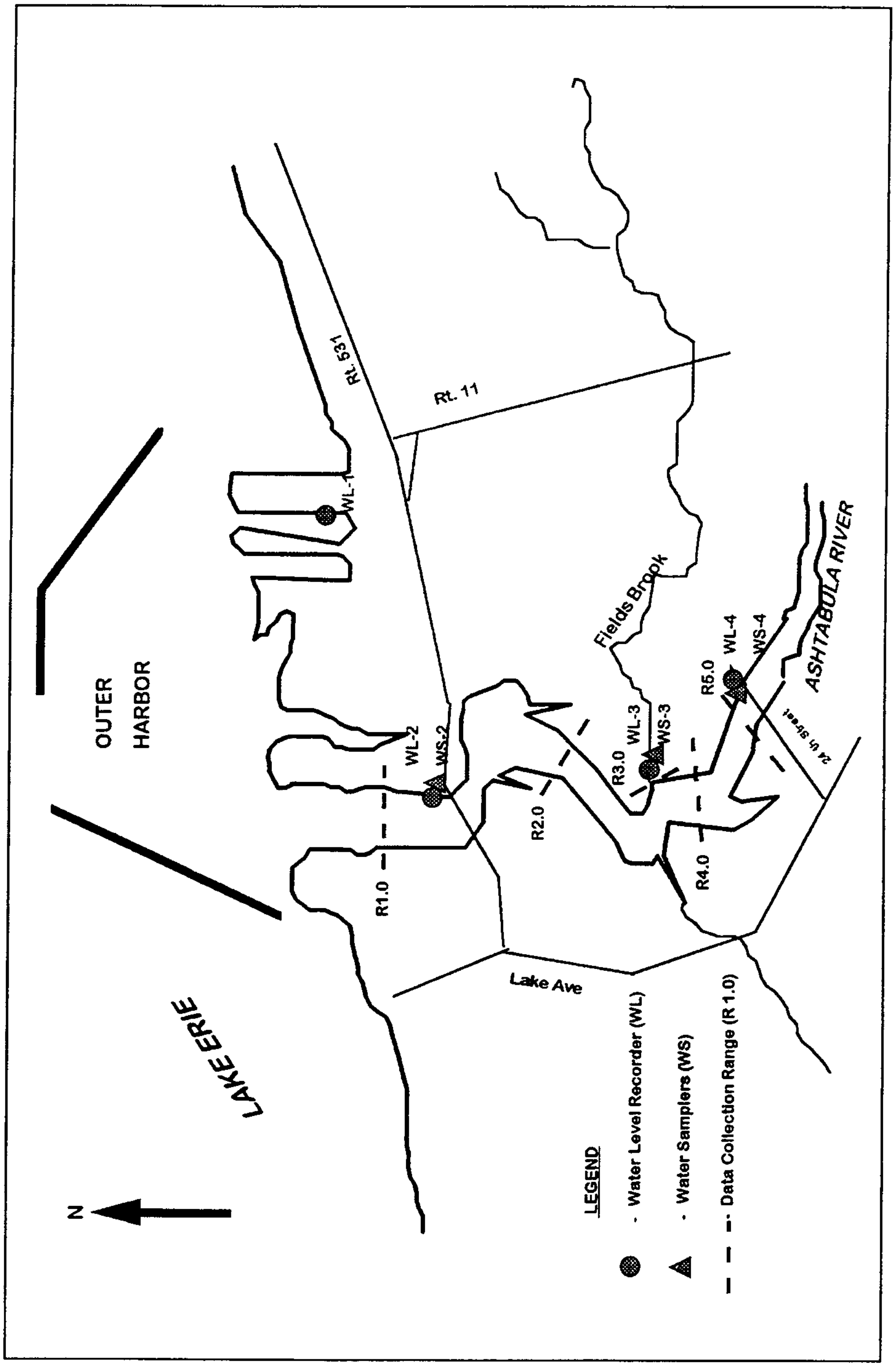


Figure 1. Project location and field data monitoring locations

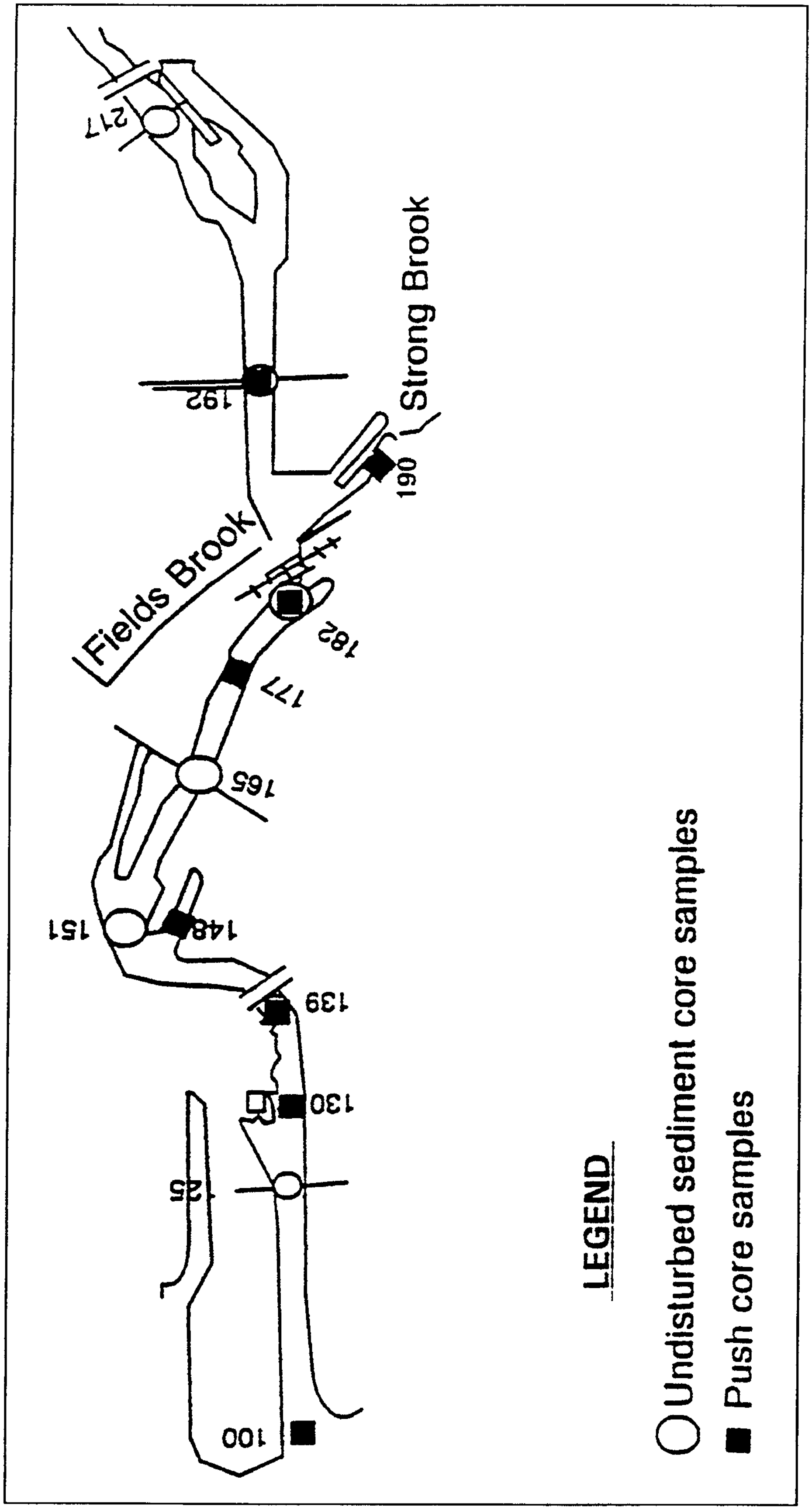


Figure 2. Bottom sediment sampling locations

When the water level receded and the float deactivated, the sampler would take a final sample and await the next rise in water level.

Current Speed and Direction Measurements

During the intensive data collection efforts, two boats employed Acoustic Doppler Current Profiler (ADCP) instruments to collect current speed and direction. Water samples were obtained at various depths at each data collection range throughout the data collection period for determination of sediment concentration profiles. Portable water sampling equipment, as described in Appendix A, was used to collect water samples during the current speed data collection for the suspended sediment concentration determination.

Data Collection Range Locations

For the intensive data collection survey, the data collection ranges were selected to yield the information most applicable to the numerical model study. The general locations of these ranges are shown in Figure 1. Range 1 was located in the Ashtabula River Entrance Channel between the entrance and the Coast Guard Station. Range 2 was located midway between the turning basin and the railroad bridge at approximately river mile 1.5. Range 3 was located at the confluence of Fields Brook with the Ashtabula River. Range 4 and Range 5 were located near the end of the Federal Channel limits and near the 24th Street Bridge, respectively.

Boat Procedures

The boat moved into position at each of the data collection ranges, using the same starting point, initialized the ADCP and completed the transect. Data at each station were obtained hourly whenever possible. At each station, the current speed, direction, and depth data were recorded electronically on a computer, and water samples were obtained for later analysis of suspended sediment concentrations.

Suspended Sediment Concentration Water Samples

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 2 ft above the actual bottom. The middepth sample was obtained at the actual middepth measurement. The surface sample was obtained approximately 3 ft below the water surface. These water samples provided a means of determining the suspended sediment concentrations from laboratory analysis. 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 samples section of Appendix A.

Individual water samples collected during the intensive survey 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.

River Bottom Sediment Sampling

Sediments from the river bottom were obtained during the short-term field investigation in June 1994. Figure 2 illustrates where the samples were obtained. Additional samples were obtained following the spring thaw in June 1995. Samples were obtained by using a push core sampler as described in Appendix A. During the June 1995 period, the U.S. Environmental Protection Agency (EPA) conducted an intensive bottom core sampling effort in the Ashtabula River study area. Core samples at depths of 4-6 ft below the invert of the river bottom were obtained at the same locations as the previous sampling. These corings were obtained using the EPA vibracore sampler equipment deployed from the R/V *Mudpuppy*.

Laboratory Analysis of Bottom Sediment Samples for Sediment Characterization

The individual bottom material samples collected during the data collection period by WES and EPA personnel 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.

Long-Term Field Investigation Equipment Service Procedures

To ensure proper operation and data collection of the long-term equipment, regularly scheduled visits to the study area were conducted. At approximately 30-day intervals, all water level recorders and suspended sediment samplers were cleaned and checked for proper operation, new batteries were installed, stored data were retrieved, and new recording media were installed where applicable.

Quality Control/Data Quality Assurance

During the scheduled instrument maintenance intervals, techniques were employed to provide information on the quality of the data being obtained. The data collected included calibration verification of the water level recorders using onsite physical measurements of sensor depth versus the recorder indication. The information provided a determination of the changes to the relative accuracy of the instruments due to the effects of biological growth on the depth sensors.

3 Data Presentation

Short-Term Data Collection

ADCP Velocity Profile Measurements

Plates 1-20 are time-history plots of the ADCP current speed data obtained during the June 1994 data collection period at all the velocity data collection ranges. The orientation of the directions of flow in the plots is 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.

The maximum velocity observed at the lower range, Range 1, was 1.2 fps. The maximum velocity observed at Range 2 was a surface measurement of 0.7 fps. Range 3, at the confluence of Fields Brook with the Ashtabula River, was observed to have surface velocities of 0.50 fps. The maximum velocities observed at the upper ranges, Ranges 4 and 5, in the Ashtabula River, were surface measurements of 0.40 and 0.60 fps, respectively.

No significant storms occurred prior to the initiation of or during the June 1994 data collection effort. No significant eddies or unusual flow circulation patterns were observed at any data collection ranges. No well-defined velocity gradients were evident at any of the data collection ranges due to the low discharge during the data collection period.

Water surface measurements

Variations of water-surface elevation data observed during the intensive data collection effort are shown in the time-history plots of the water-level fluctuation data during the month of June 1994 (see Plate 21).

Data from location WL-2 were used as a reference for comparison with data from the other river stations in order to estimate water-level phase and range differences between the entrance and the upper reaches of Ashtabula River. This comparison illustrated that ranges observed were small, with the maximum water-level fluctuation observed from 4-8 June 1994 at 0.25 ft. The comparison also showed a phase difference of 0.67 hr between WL-1 and WL-4 at the time of maximum water-level fluctuations.

Suspended sediment concentration measurements

General observations on the suspended sediment concentration data indicated significant differences in the suspended sediment concentration values. The observed maximum suspended sediment concentrations for data collection Ranges 1 and 4 were 0.167 g/ℓ and 0.180 g/ℓ, respectively. Likewise, the minimum suspended sediment concentration values were 0.018 g/ℓ and 0.020 g/ℓ for Ranges 1 and 4, respectively. Suspended sediment concentration values at the profile locations within Ashtabula River indicate that flows within Ranges 1-4 were not significant in greatly increasing the suspended sediment concentrations.

Long-Term Field Investigation

Water level measurements

Water level elevation data for the long-term field investigation are plotted in Plates 21-68. All recorders functioned properly during most of the data collection period. The percent of time in service over the investigation period for these instruments ranged from 90-100 percent. The data display the water-level fluctuations for the system during the entire period of the study. The zero datum indicated in the plots is an arbitrary datum and is not referenced to any geodetic datum. The maximum water level fluctuation range observed at all locations was 2 ft and occurred between 11-12 November 1995. However, these water-level fluctuation ranges involve not only occasional boat traffic and astronomical effects but meteorological forces from strong frontal passages. This is evidenced in many of the plots of the water level data. No sustained and substantial rise in water level was evidenced during the entire data collection period.

Suspended sediment concentration measurements

Suspended sediment concentrations were sampled at the locations of three water level recorders. Suspended sediment concentrations measured from the fixed depth sampler deployments at WS-2, WS-3, WS-4 are shown in Tables 1-12.

Very little biological fouling of the water sampler intakes and water level sensors occurred during the study period.

Suspended sediment concentrations in the lower part of Ashtabula River ranged from 0.007-0.180 g/ℓ. In the mid-area of Ashtabula River, suspended sediment concentrations ranged from 0.014-0.570 g/ℓ. The upper area of the river at WS-4 had the highest level of suspended sediment concentrations, 0.965 g/ℓ.

The effect on suspended sediment concentrations resulting from an extremely large influx of freshwater inflow into the Ashtabula River could not be determined from the long-term data due to lack of significant storm events during the study period. Several of the suspended sediment concentration recorders also developed mechanical problems and failed to collect any samples during certain portions of the deployment period.

4 Summary

The data presented herein were collected from only one intensive data collection survey and a 1-year long-term sampling effort within Ashtabula River. The following observations were made:

a. During the short-term data collection period (June 1994), the maximum range of water levels that occurred at all locations was 2 ft. The maximum range of water levels from the Lake Erie monitoring station WL-1 was 2 ft.

b. Maximum velocity observed for the short-term data collection period occurred at Range 1. The maximum recorded velocity was 1.2 fps.

c. The effect on suspended sediment concentrations resulting from an extremely large influx of freshwater inflow into the Ashtabula River could not be determined from the long-term data due to lack of significant storm events during the study period.

Table 1
Suspended Sediment Concentrations, 6 June to 5 July 1994

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
6/29/94	1	0.020
Pump Sampler: Station WS-3		
6/29/94	1	0.096
6/29/94	2	0.030
6/29/94	3	0.079
6/29/94	4	0.059
Pump Sampler: Station WS-4		
6/29/94	1	0.020
6/29/94	2	0.037
6/29/94	3	0.082
6/29/94	4	0.106
6/29/94	5	0.072
6/30/94	6	0.043
6/30/94	7	0.036
6/30/94	8	0.025
7/1/94	9	0.042
7/1/94	10	0.036
7/2/94	11	0.032
7/3/94	12	0.033
7/3/94	13	0.036
7/4/94	14	0.025
7/4/94	15	0.037
7/4/94	16	0.041

Table 2
Suspended Sediment Concentrations, 6 July to 8 August 1994

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
No samples obtained during period		
Pump Sampler: Station WS-3		
7/7/94	1	0.023
7/25/94	2	0.080
8/4/94	3	0.105
8/4/94	4	0.104
8/4/94	5	0.181
Pump Sampler: Station WS-4		
7/7/94	1	0.018
7/7/94	2	0.054
7/7/94	3	0.042
7/7/94	4	0.032
7/7/94	5	0.033
7/22/94	6	0.056
7/25/94	7	0.039
8/4/94	8	0.052
8/4/94	9	0.044
8/4/94	10	0.037

Table 3
Suspended Sediment Concentrations, 8 August to 8 September 1994

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
No samples obtained during period		
Pump Sampler: Station WS-3		
8/13/94	1	0.570
8/14/94	2	0.532
8/14/94	3	0.400
8/4/94	4	0.326
Pump Sampler: Station WS-4		
8/13/94	1	0.353
8/14/94	2	0.965
8/14/94	3	0.903
8/14/94	4	0.708
8/14/94	5	0.723
8/14/94	6	0.423
8/14/94	7	0.362
8/28/94	8	0.047
8/24/94	9	0.034

Table 4
Suspended Sediment Concentrations, 8 September to 4 October 1994

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
No samples obtained during period		
Pump Sampler: Station WS-3		
No samples obtained during period		
Pump Sampler: Station WS-4		
9/28/94	1	0.095

Table 5
Suspended Sediment Concentrations, 4 October to 6 December 1994[1]

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
No samples obtained during period		
Pump Sampler: Station WS-3		
No samples obtained during period		
Pump Sampler: Station WS-4		
No samples obtained during period		

[1] Equipment removed from recording locations during the winter months to prevent ice damage to instruments.

Table 6
Suspended Sediment Concentrations, 4 April to 26 April 1995

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
4/4/95	1	0.048
4/4/95	2	0.023
4/4/95	3	0.058
4/4/95	4	0.056
4/12/95	5	0.068
4/21/95	6	0.007
Pump Sampler: Station WS-3		
4/4/95	1	0.028
4/4/95	2	0.014
4/12/95	3	0.067
4/26/95	4	0.197
Pump Sampler: Station WS-4		
4/4/95	1	0.090
4/4/95	2	0.040
4/9/95	3	0.195
4/9/95	4	0.158
4/10/95	5	0.122
4/10/95	6	0.070
4/11/95	7	0.076
4/12/95	8	0.058
4/12/95	9	0.032
4/13/95	10	0.059
4/13/95	11	0.195
4/21/95	12	0.122
4/21/95	13	0.088
4/21/95	14	0.083
4/21/95	15	0.061
4/21/95	16	0.056
4/21/95	17	0.057

Table 7
Suspended Sediment Concentrations, 27 April to 30 May 1995

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
4/27/95	1	0.029
5/10/95	2	0.078
5/14/95	3	0.043
5/28/95	4	0.089
5/28/95	5	0.029
5/29/95	6	0.069
5/29/95	7	0.043
Pump Sampler: Station WS-3		
5/28/95	1	0.030
5/29/95	2	0.028
Pump Sampler: Station WS-4		
4/27/95	1	0.018
4/27/95	2	0.009
4/27/95	3	0.014

Table 8
Suspended Sediment Concentrations, 30 May to 29 July 1995

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
No samples obtained during period		
Pump Sampler: Station WS-3		
No samples obtained during period		
Pump Sampler: Station WS-4		
6/7/95	1	0.023
6/8/95	2	0.016
6/8/95	3	0.052
6/8/95	4	0.024
6/8/95	5	0.015
6/9/95	6	0.018
6/9/95	7	0.012
6/9/95	8	0.014
6/9/95	9	0.006
6/10/95	10	0.016

Table 9
Suspended Sediment Concentrations, 26 June to 28 July 1995

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
6/27/95	1	0.076
6/27/95	2	0.018
6/28/95	3	0.039
7/7/95	4	0.016
7/7/95	5	0.015
7/7/95	6	0.005
7/7/95	7	0.014
7/13/95	8	0.043
7/13/95	9	0.066
7/14/95	10	0.101
7/14/95	11	0.018
7/14/95	12	0.018
7/15/95	13	0.015
7/15/95	14	0.050
7/15/95	15	0.051
7/15/95	16	0.018
7/15/95	17	0.025
7/16/95	18	0.038
7/16/95	19	0.084
7/16/95	20	0.031
7/16/95	21	0.013
7/17/95	22	0.097
7/18/95	23	0.167
7/18/95	24	0.052
Pump Sampler: Station WS-3		
6/27/95	1	0.104
6/28/95	2	0.044
7/13/95	3	0.167
7/14/95	4	0.108
7/14/95	5	0.063
7/14/95	6	0.057
7/15/95	7	0.024

(Continued)

Table 9 (Concluded)

Date	Sample	Concentration, g/ℓ
Pump Sampler: Station WS-2		
7/15/95	8	0.032
7/16/95	9	0.035
7/17/95	10	0.035
7/17/95	11	0.040
7/17/95	12	0.040
7/17/95	13	0.033
7/18/95	14	0.031
Pump Sampler: Station WS-4		
6/27/95	1	0.028
6/27/95	2	0.020
6/27/95	3	0.024
6/27/95	4	0.023
6/28/95	5	0.025
6/28/95	6	0.029
6/28/95	7	0.036
6/29/95	8	0.026
6/29/95	9	0.040
6/29/95	10	0.062
6/29/95	11	0.035
6/29/95	12	0.028
6/29/95	13	0.051
6/29/95	14	0.055
7/5/95	15	0.031
7/6/95	16	0.036
7/6/95	17	0.027
7/7/95	18	0.017
7/7/95	19	0.029
7/7/95	20	0.024
7/8/95	21	0.038
7/13/95	22	0.037
7/13/95	23	0.081
7/13/95	24	

Table 10
Suspended Sediment Concentrations, 28 July to 7 September 1995

Date	Sample	Concentration, g/ℓ
	Pump Sampler: Station WS-2	
No samples obtained during period		
	Pump Sampler: Station WS-3	
No samples obtained during period		
	Pump Sampler: Station WS-4	
No samples obtained during period		

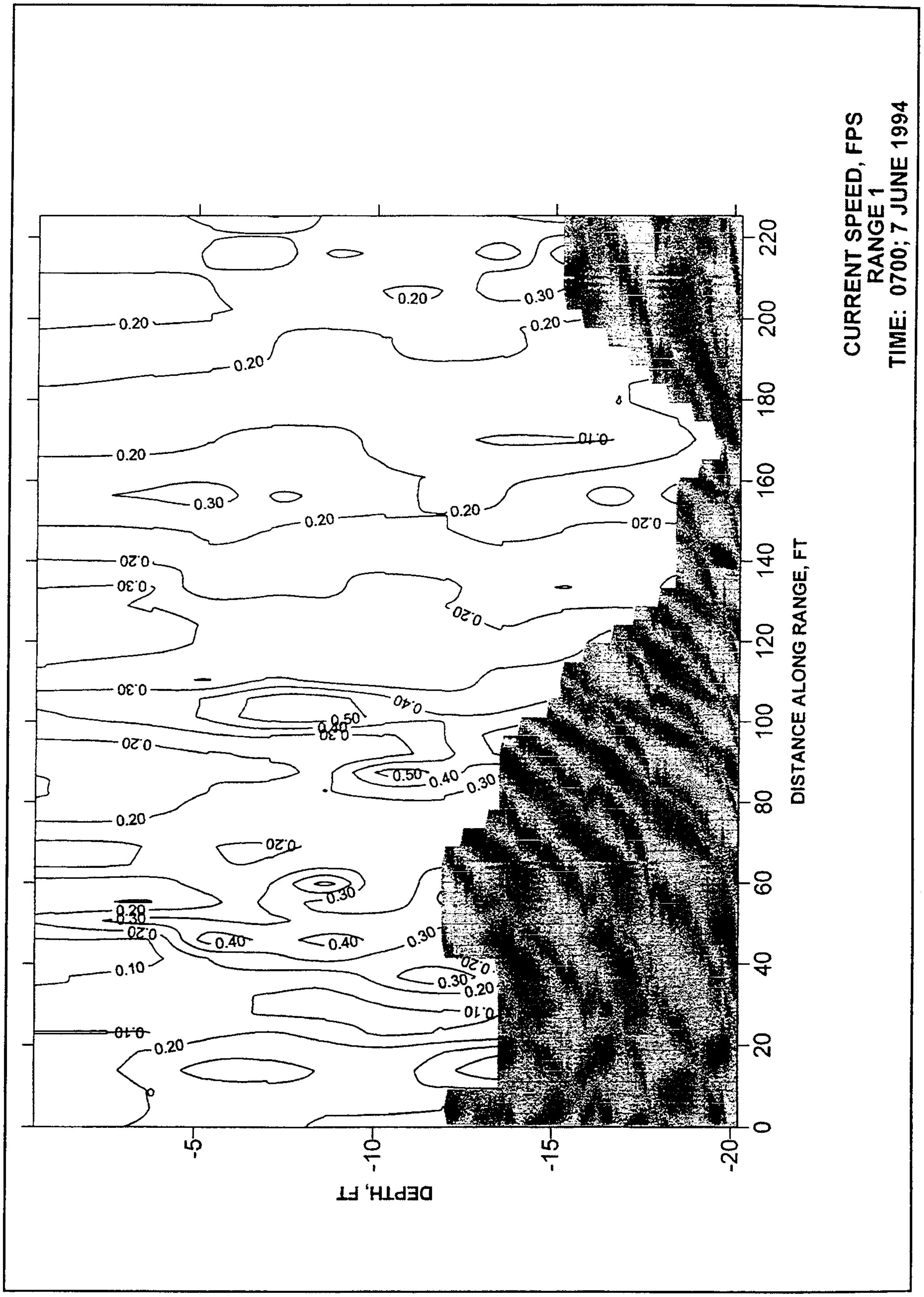
Table 11
Suspended Sediment Concentrations, 7 September to 23 October 1995

Date	Sample	Concentration, g/ℓ
	Pump Sampler: Station WS-2	
No samples obtained during period		
	Pump Sampler: Station WS-3	
No samples obtained during period		
	Pump Sampler: Station WS-4	
No samples obtained during period		

Table 12
Suspended Sediment Concentrations, 23 October to 29 November 1995[1]

Date	Sample	Concentration, g/ℓ
	Pump Sampler: Station WS-2	
No samples obtained during period		
	Pump Sampler: Station WS-3	
No samples obtained during period		
	Pump Sampler: Station WS-4	
No samples obtained during period		

[1] Equipment removed from recording locations during the winter months to prevent ice damage to instruments.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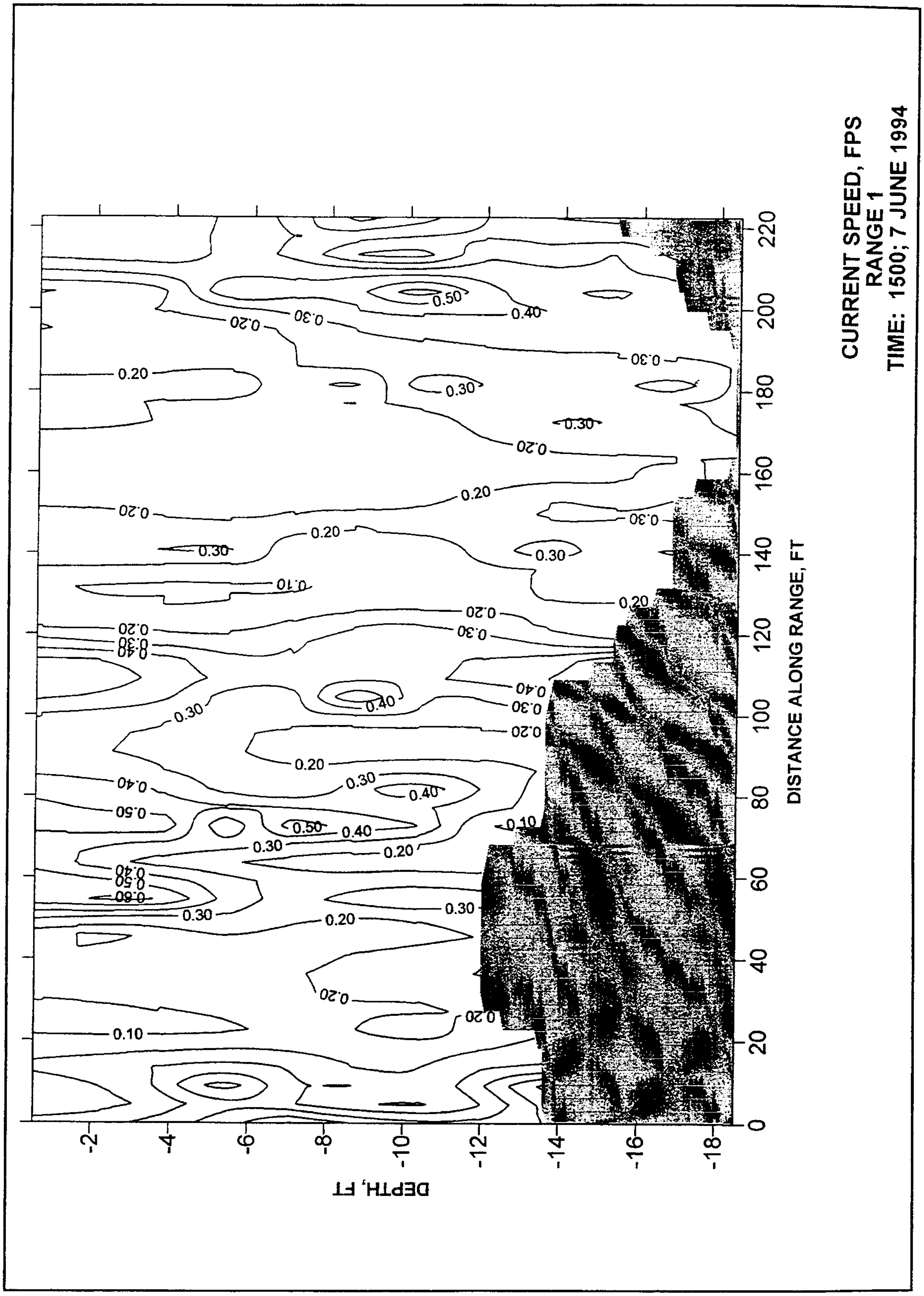
DISTANCE ALONG RANGE, FT
DEPTH, FT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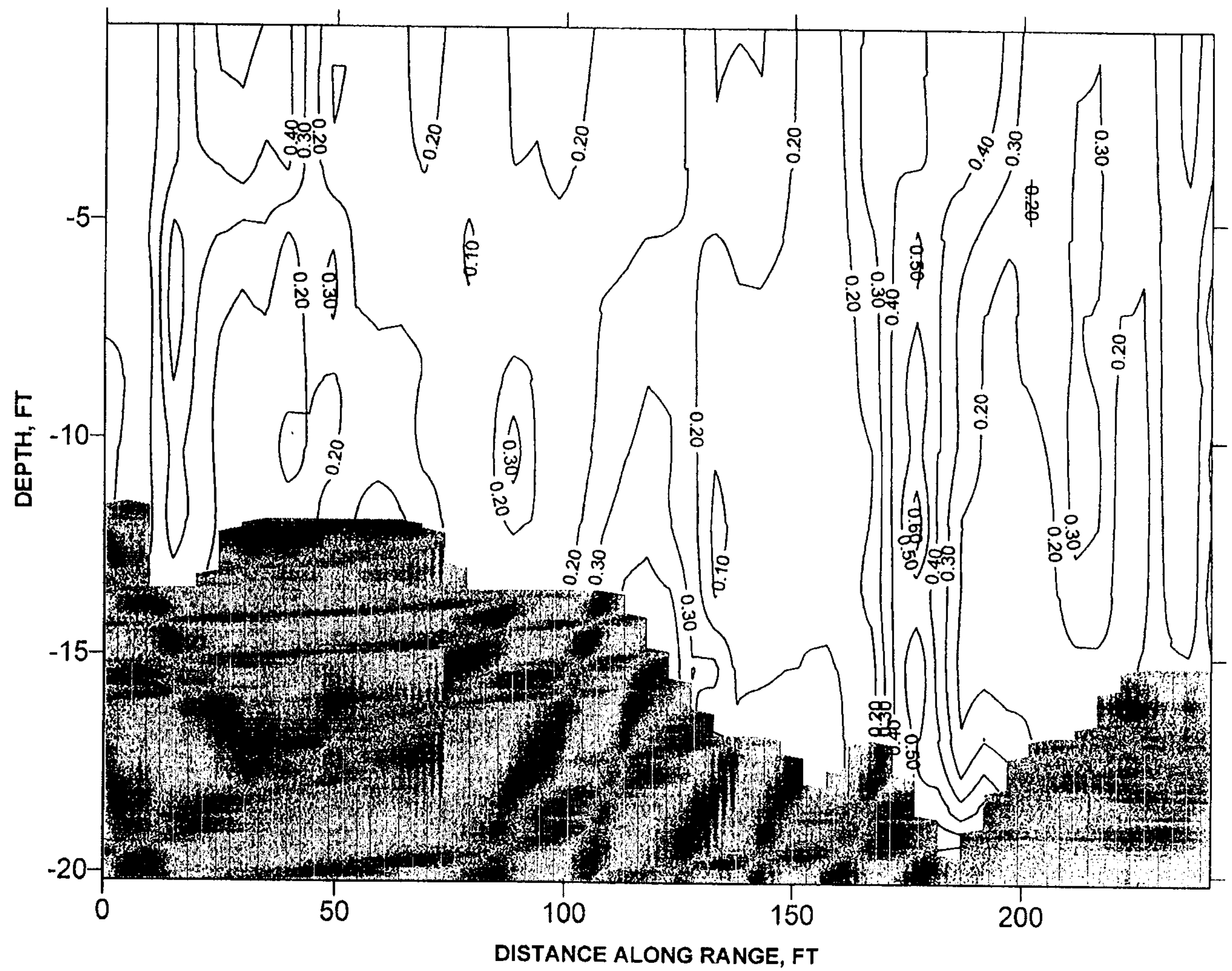
RANGE 1
TIME: 1500; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT

Plate 2



CURRENT SPEED, FPS
RANGE 1
TIME: 0800; 8 JUNE 1994

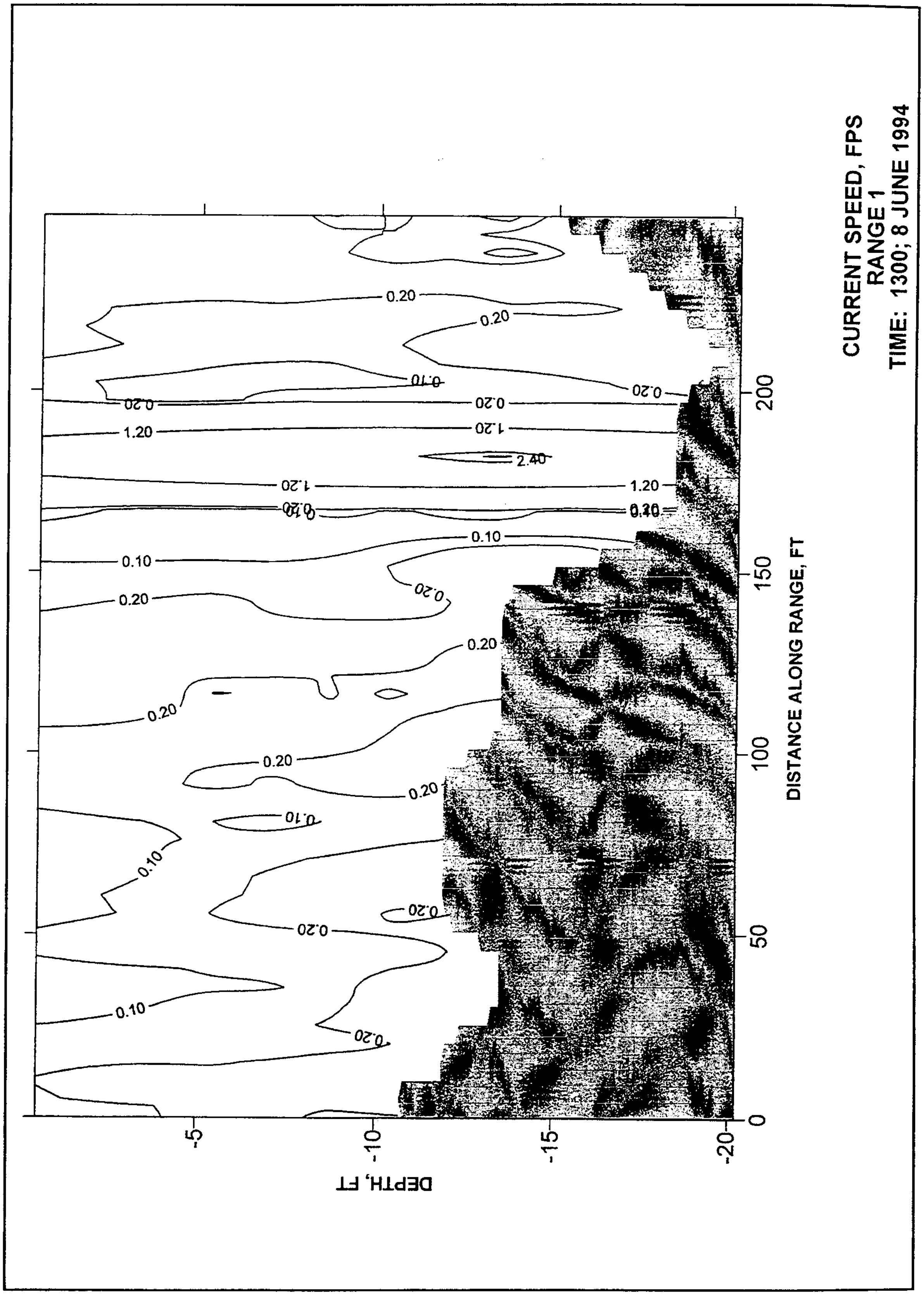
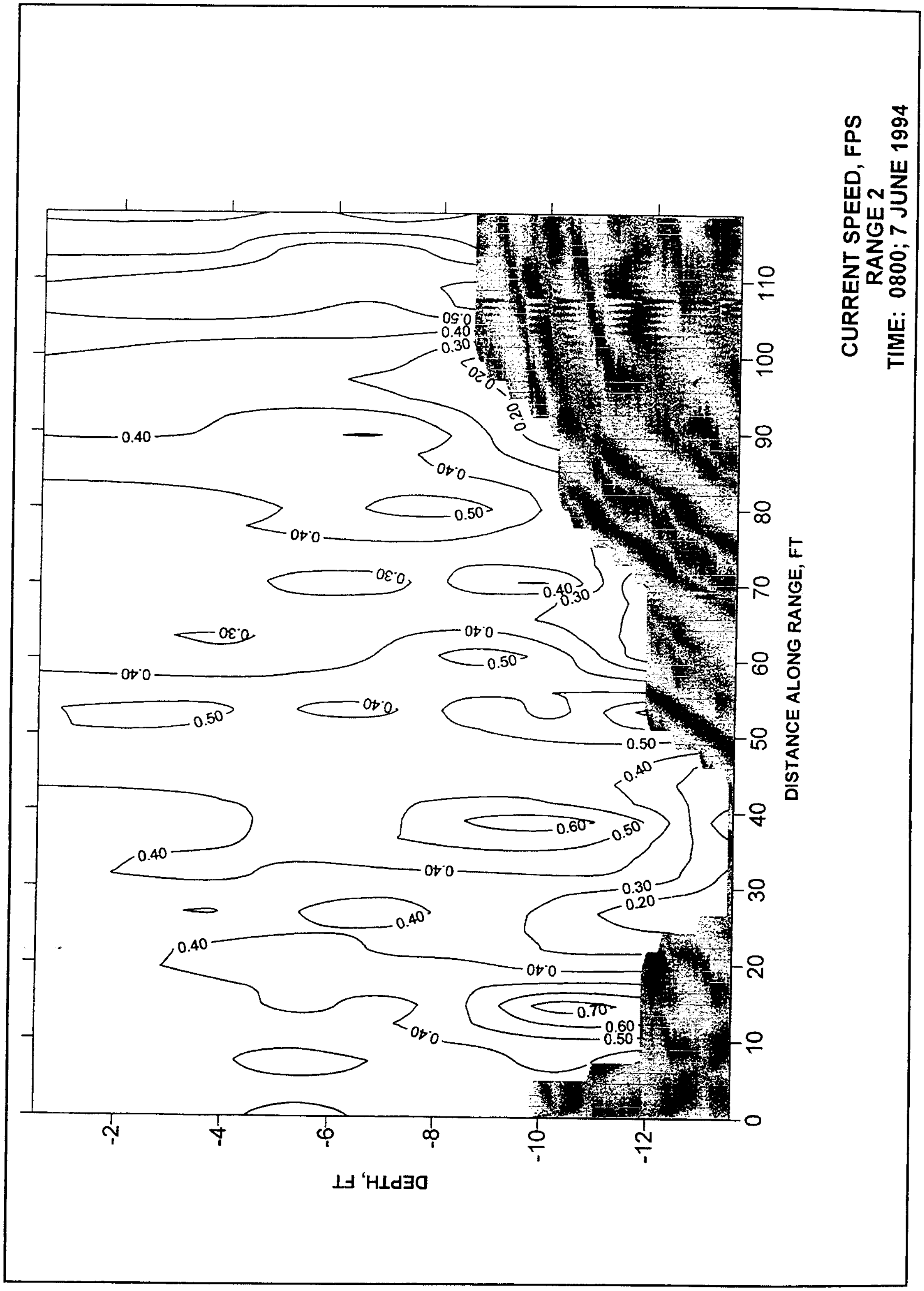
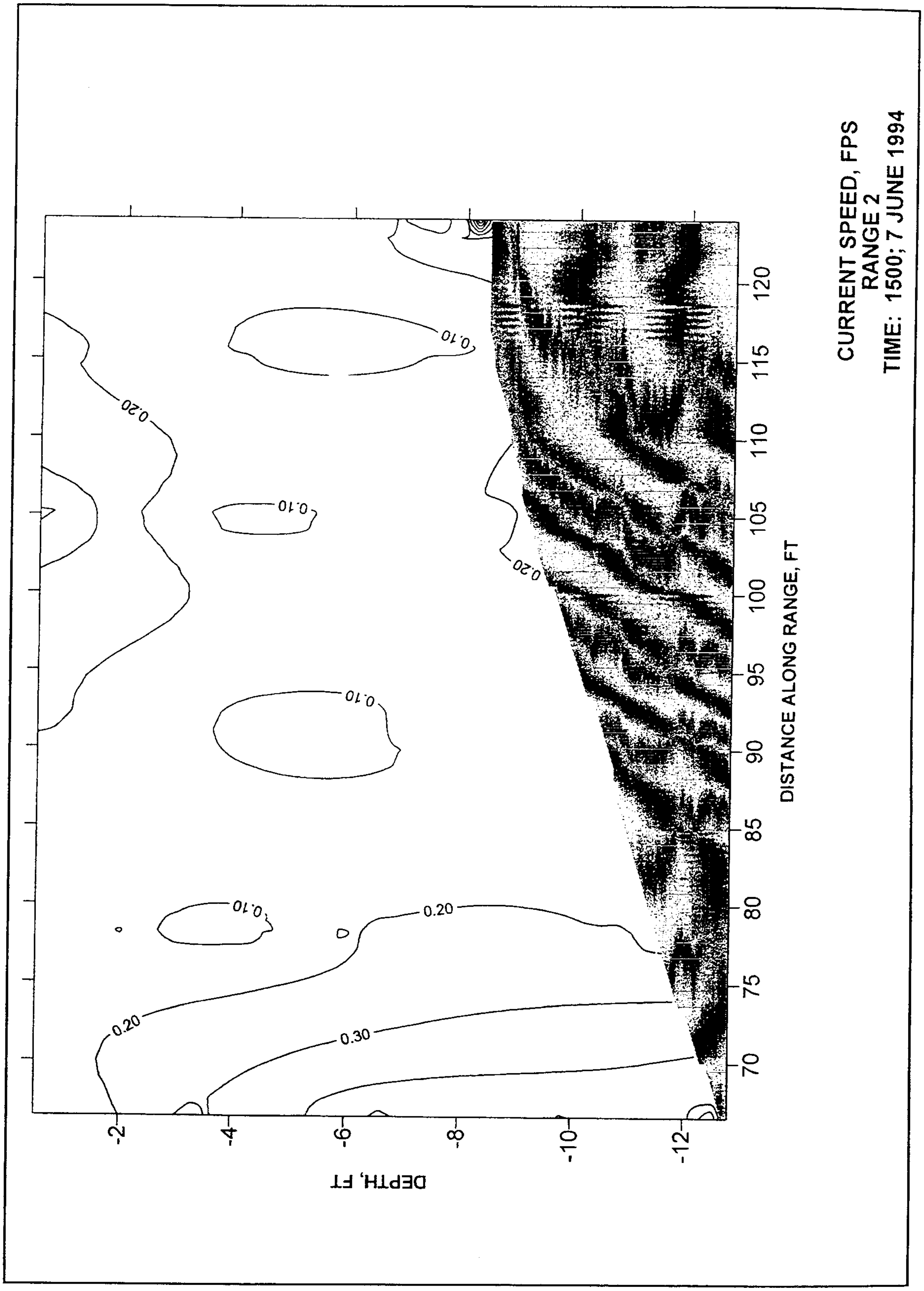

CURRENT SPEED, FPS
RANGE 1
TIME: 1300; 8 JUNE 1994
DEPTH, FT
-5
-10
-15
-20
DISTANCE ALONG RANGE, FT
0
50
100
150
200
0.10
0.20
1.20
2.40

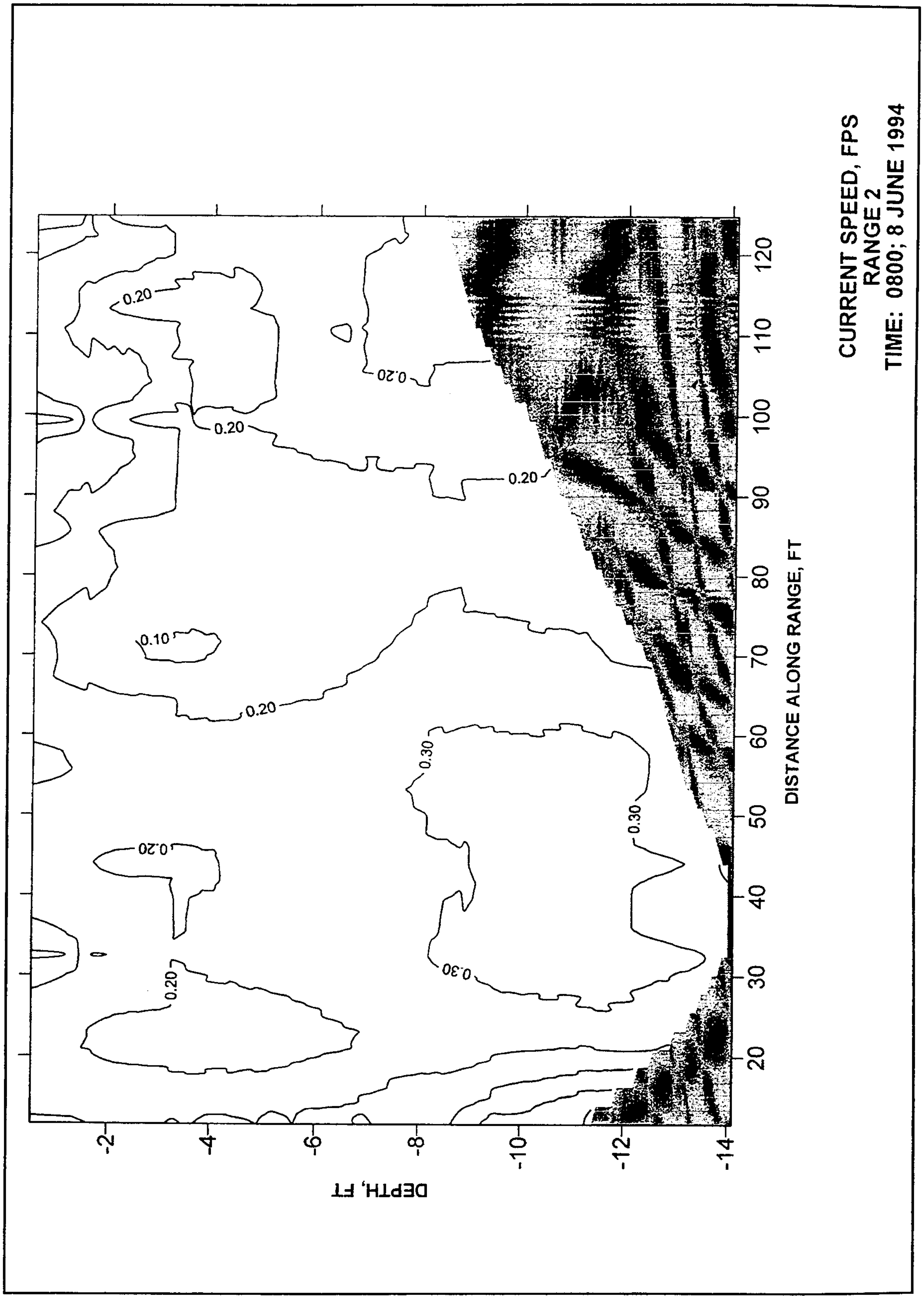
Plate 4


CURRENT SPEED, FPS
RANGE 2
TIME: 0800; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0
10
20
30
40
50
60
70
80
90
100
110
-2
-4
-6
-8
-10
-12
0.20
0.30
0.40
0.50
0.60
0.70



CURRENT SPEED, FPS
RANGE 2
TIME: 1500; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
70
75
80
85
90
95
100
105
110
115
120
-2
-4
-6
-8
-10
-12
0.10
0.20
0.30

Plate 6


CURRENT SPEED, FPS
RANGE 2
TIME: 0800; 8 JUNE 1994
DEPTH, FT
DISTANCE ALONG RANGE, FT
-2
-4
-6
-8
-10
-12
-14
20
30
40
50
60
70
80
90
100
110
120
0.10
0.20
0.30

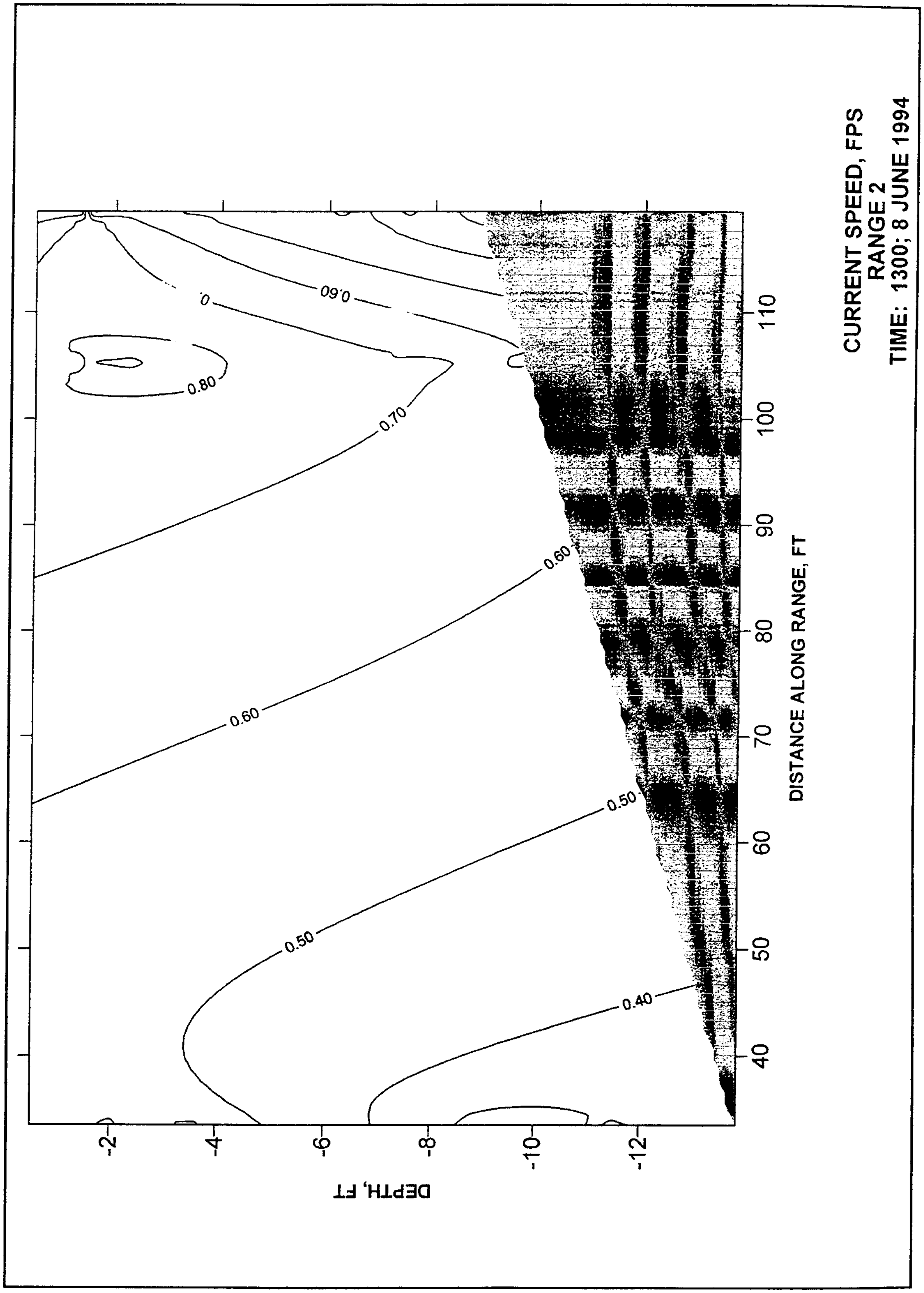
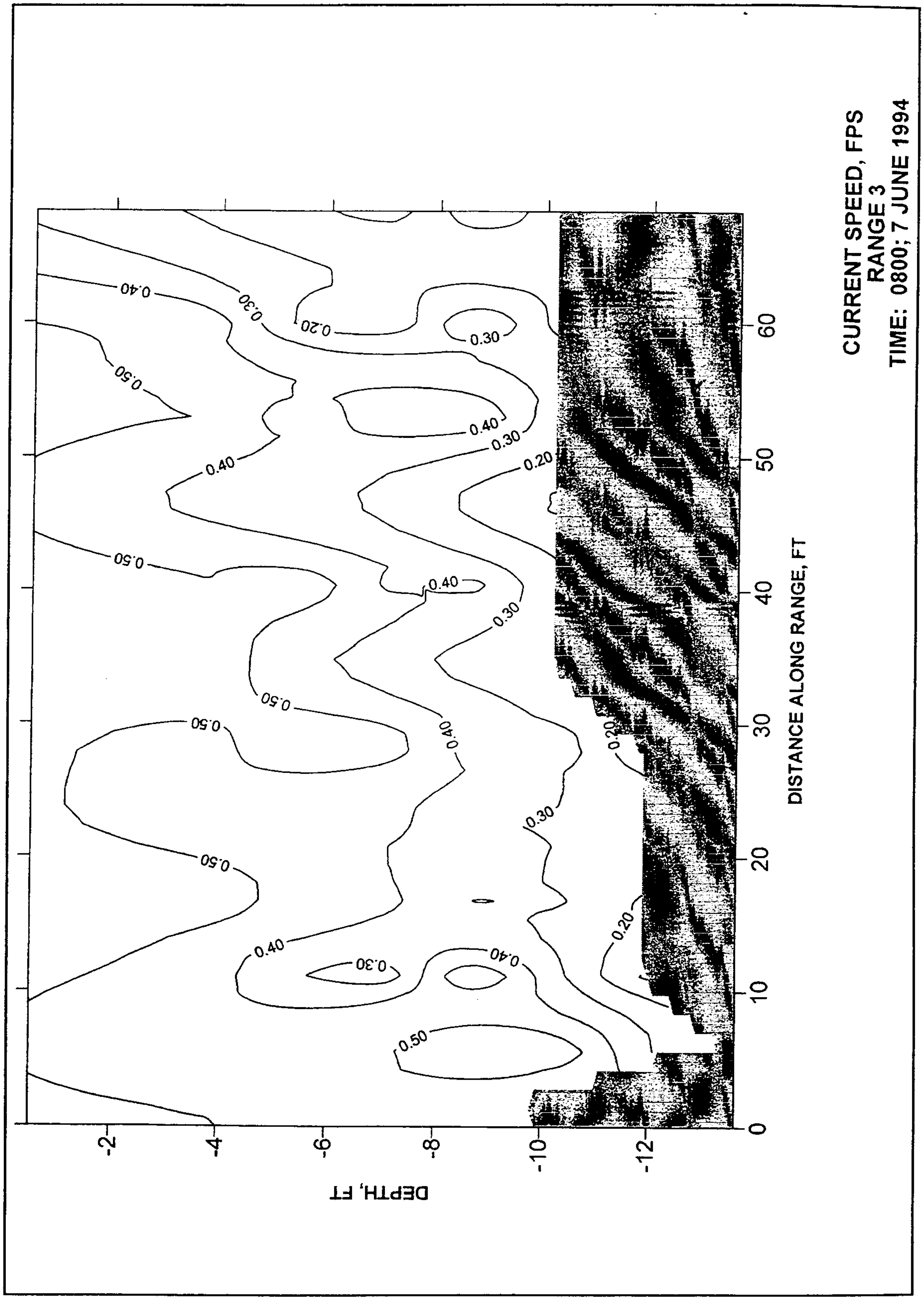

CURRENT SPEED, FPS
RANGE 2
TIME: 1300; 8 JUNE 1994
DEPTH, FT
DISTANCE ALONG RANGE, FT
-2
-4
-6
-8
-10
-12
40
50
60
70
80
90
100
110
0.40
0.50
0.50
0.60
0.60
0.60
0.70
0.80

Plate 8


CURRENT SPEED, FPS
RANGE 3
TIME: 0800; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0
10
20
30
40
50
60
-2
-4
-6
-8
-10
-12
0.20
0.30
0.40
0.50

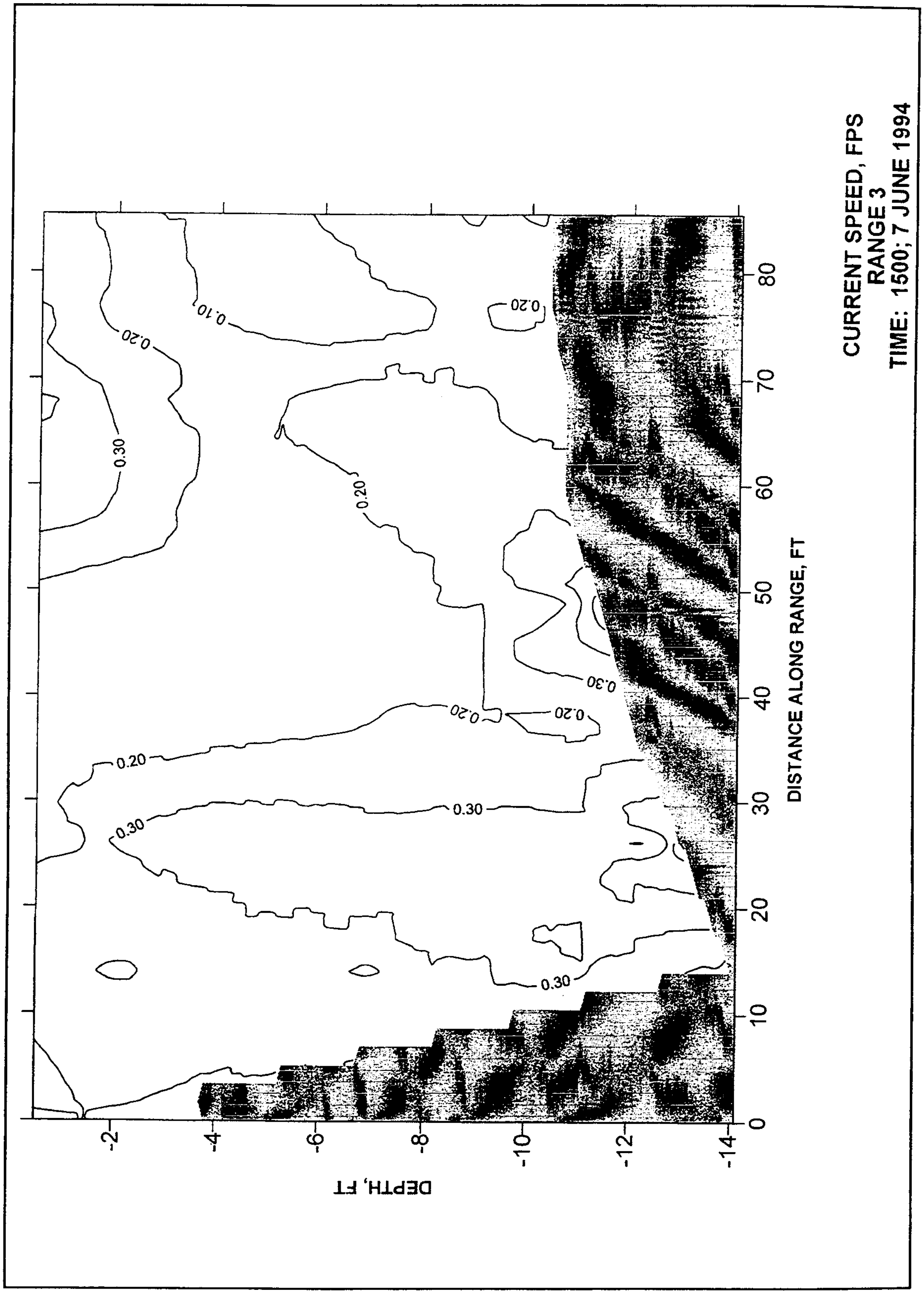
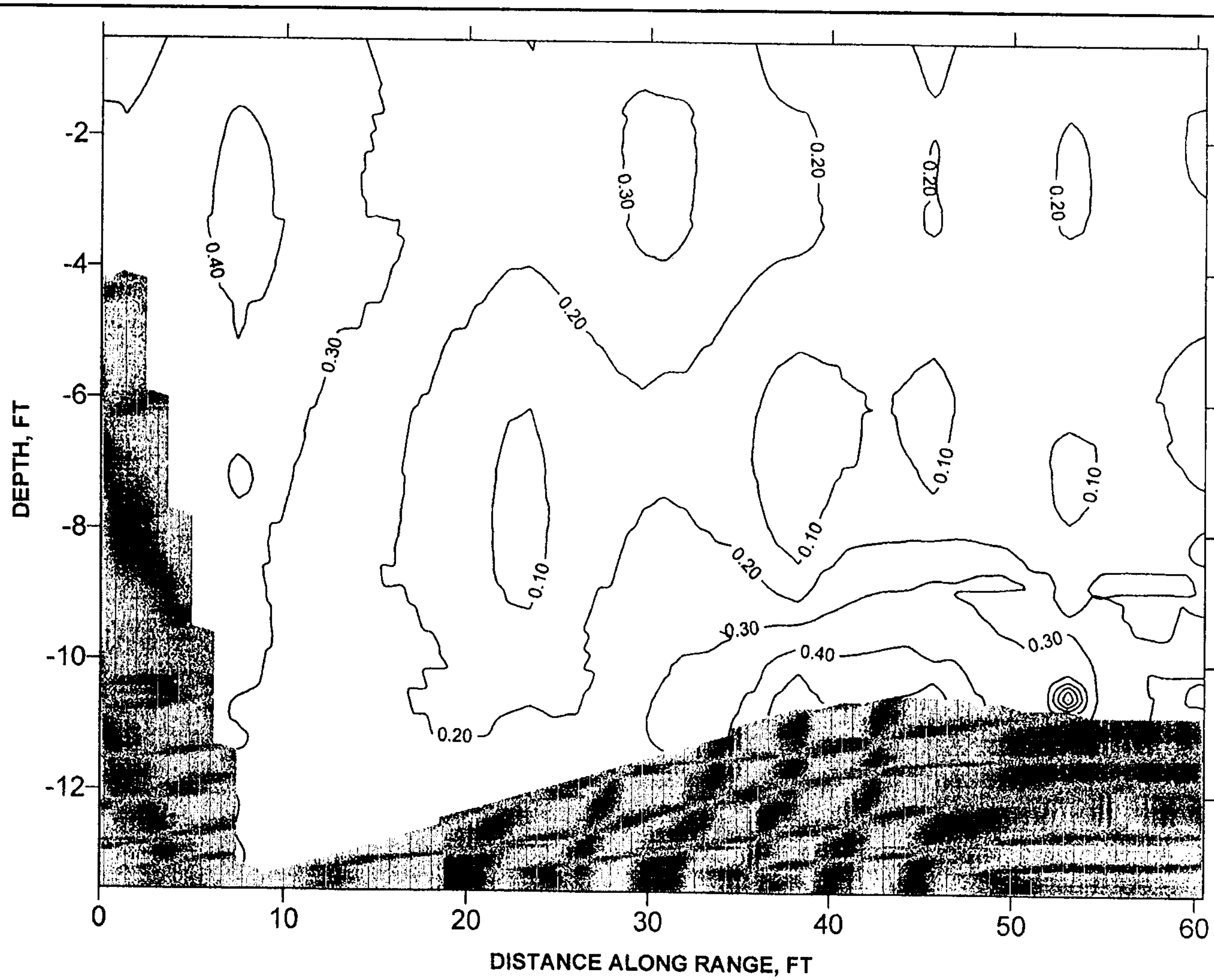
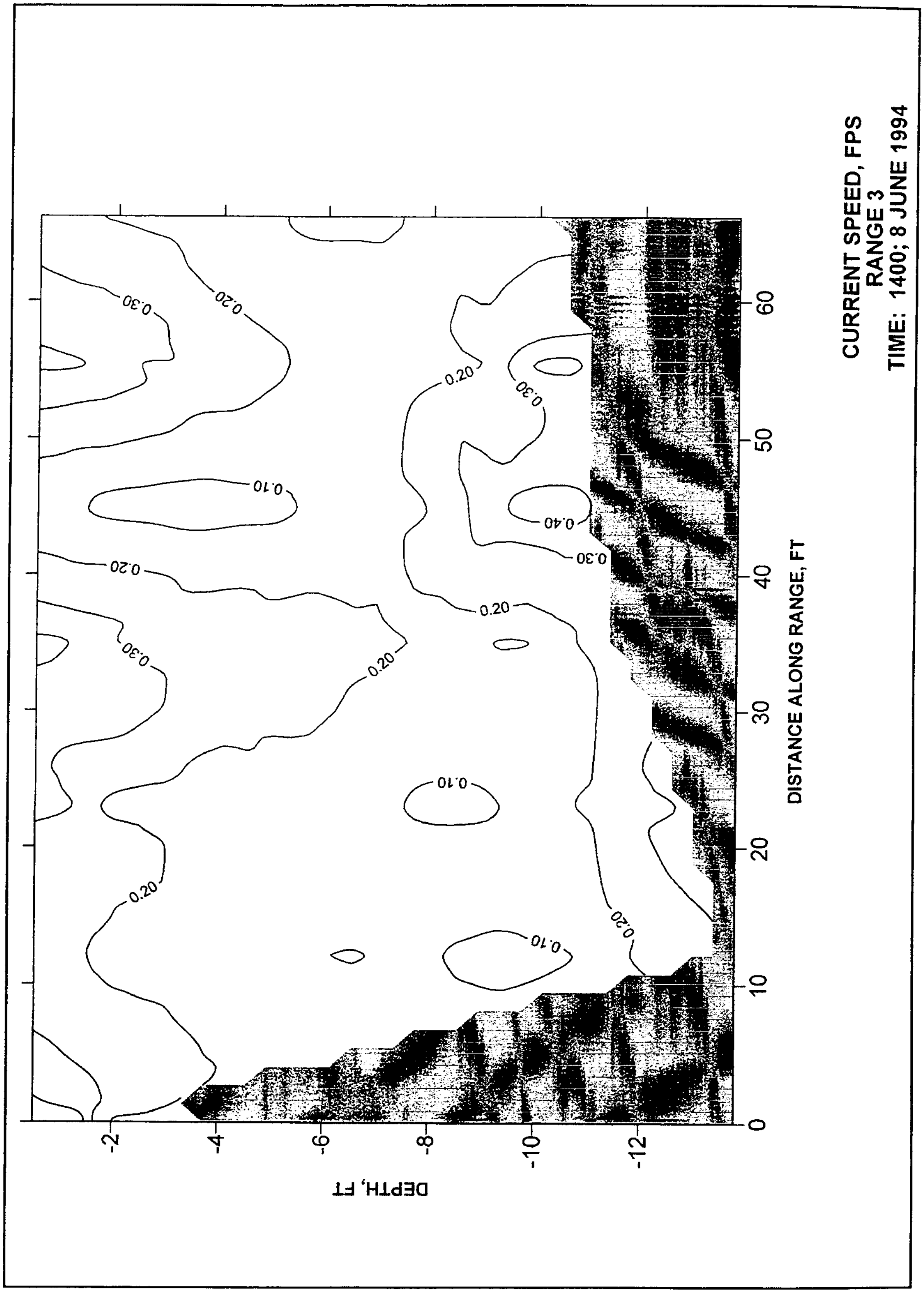
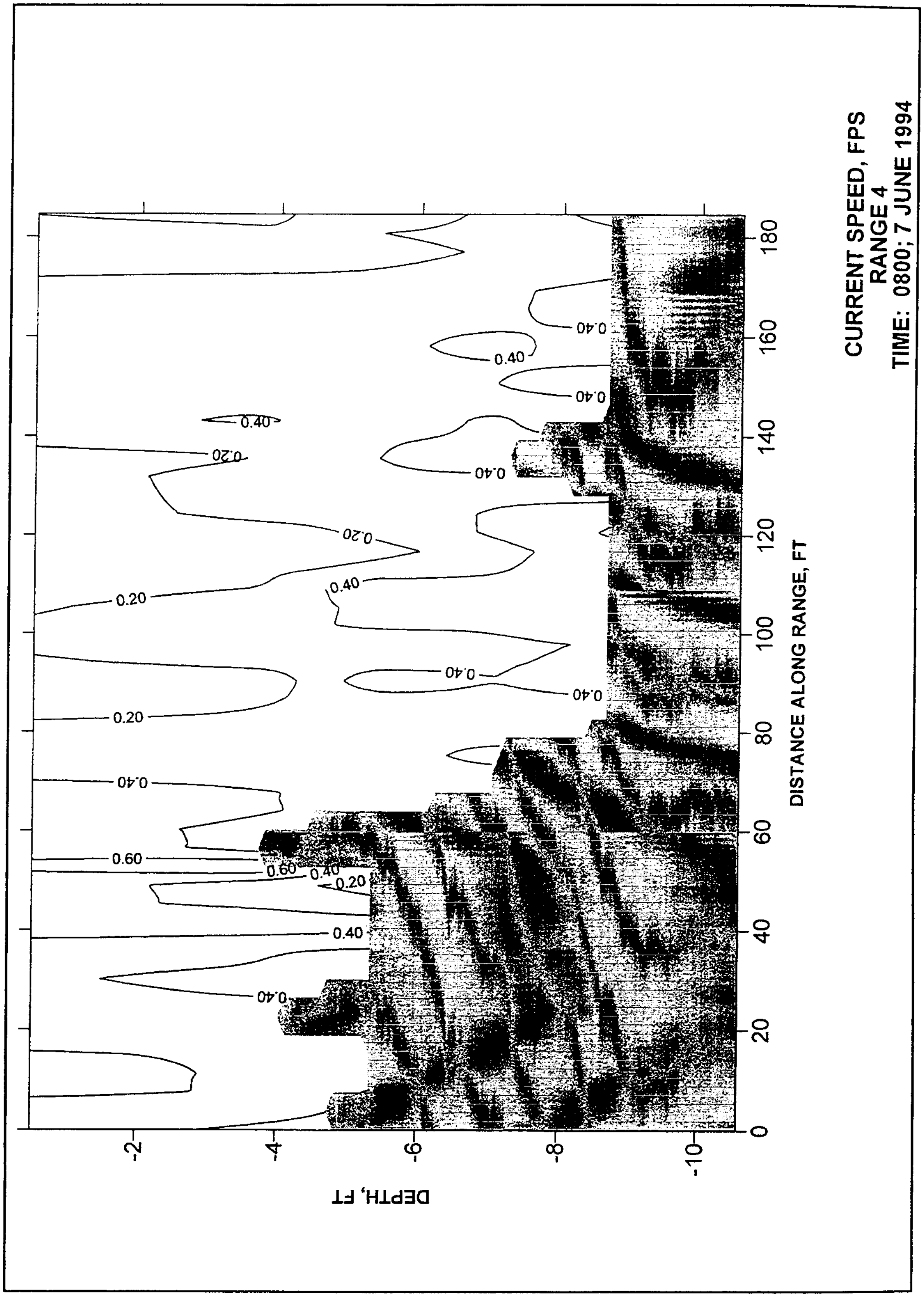

CURRENT SPEED, FPS
RANGE 3
TIME: 1500; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0 10 20 30 40 50 60 70 80
-2 -4 -6 -8 -10 -12 -14
0.10
0.20
0.30

Plate 10

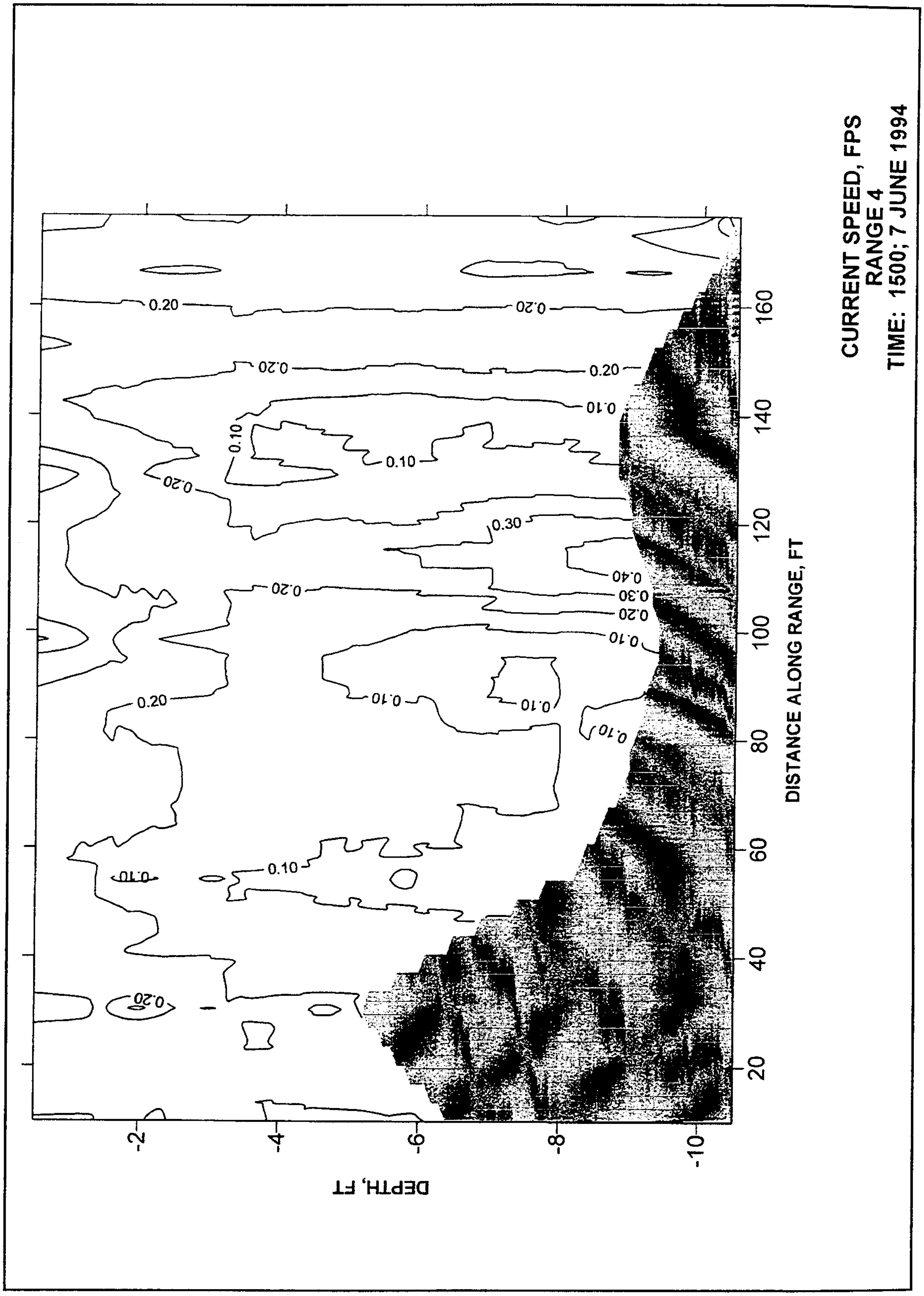


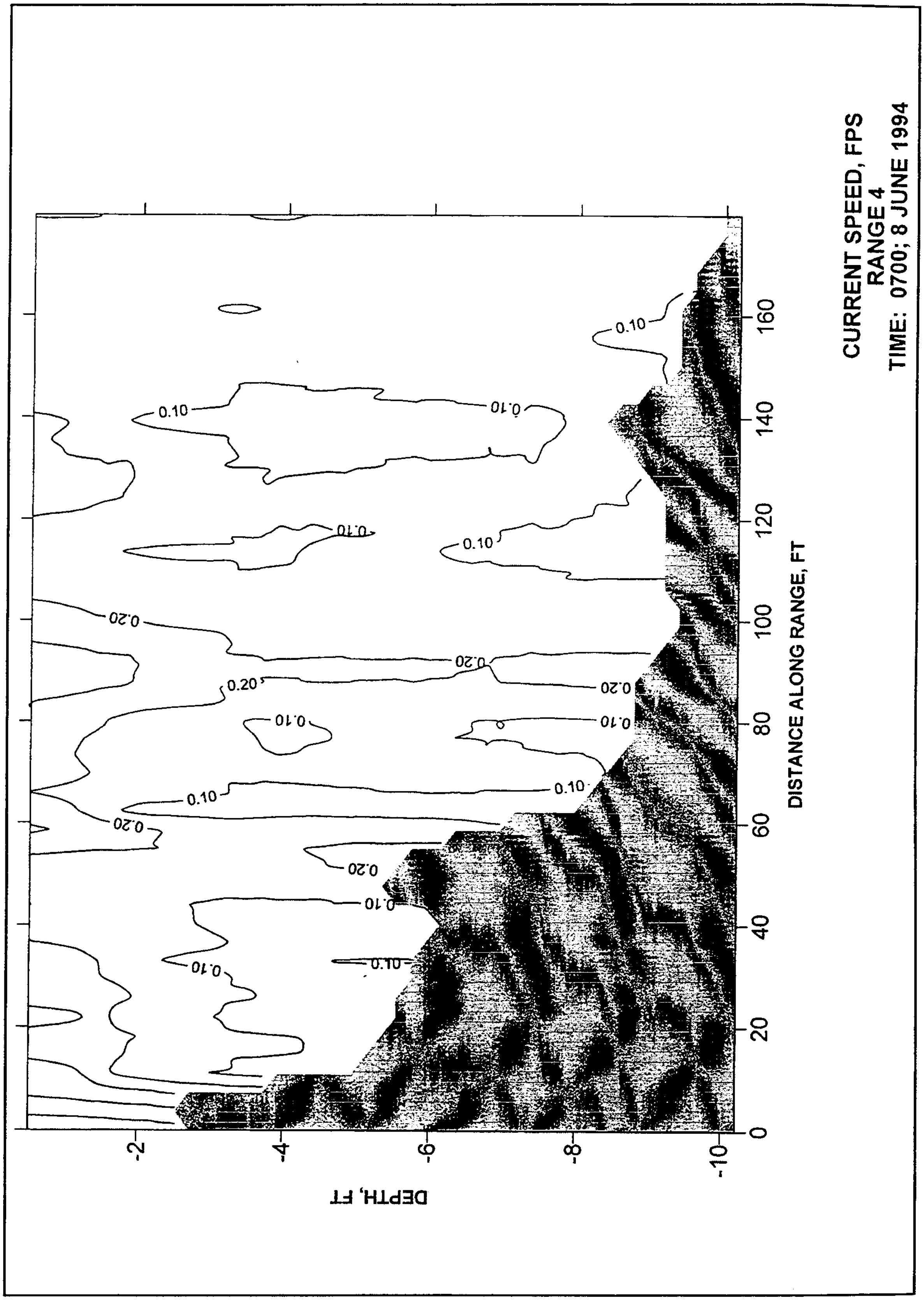
CURRENT SPEED, FPS
RANGE 3
TIME: 0700; 8 JUNE 1994


CURRENT SPEED, FPS
RANGE 3
TIME: 1400; 8 JUNE 1994
DEPTH, FT
-2
-4
-6
-8
-10
-12
DISTANCE ALONG RANGE, FT
0
10
20
30
40
50
60
0.10
0.20
0.30
0.40



CURRENT SPEED, FPS
RANGE 4
TIME: 0800; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0.20
0.40
0.60


CURRENT SPEED, FPS
RANGE 4
TIME: 1500; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
20
40
60
80
100
120
140
160
DEPTH, FT
-2
-4
-6
-8
-10
0.10
0.20
0.30
0.40


CURRENT SPEED, FPS
RANGE 4
TIME: 0700; 8 JUNE 1994
DEPTH, FT
DISTANCE ALONG RANGE, FT
-2
-4
-6
-8
-10
0
20
40
60
80
100
120
140
160
0.10
0.20

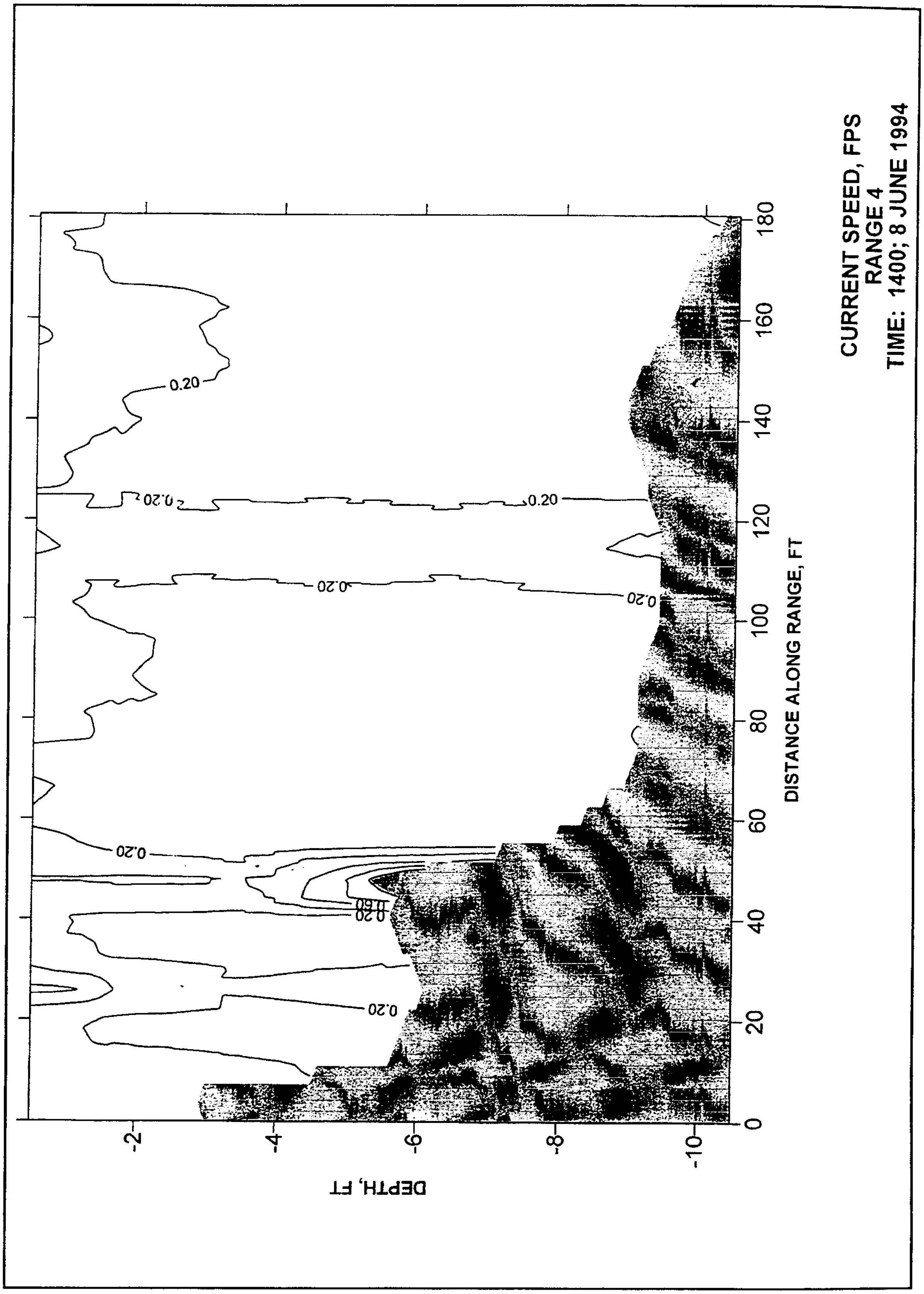
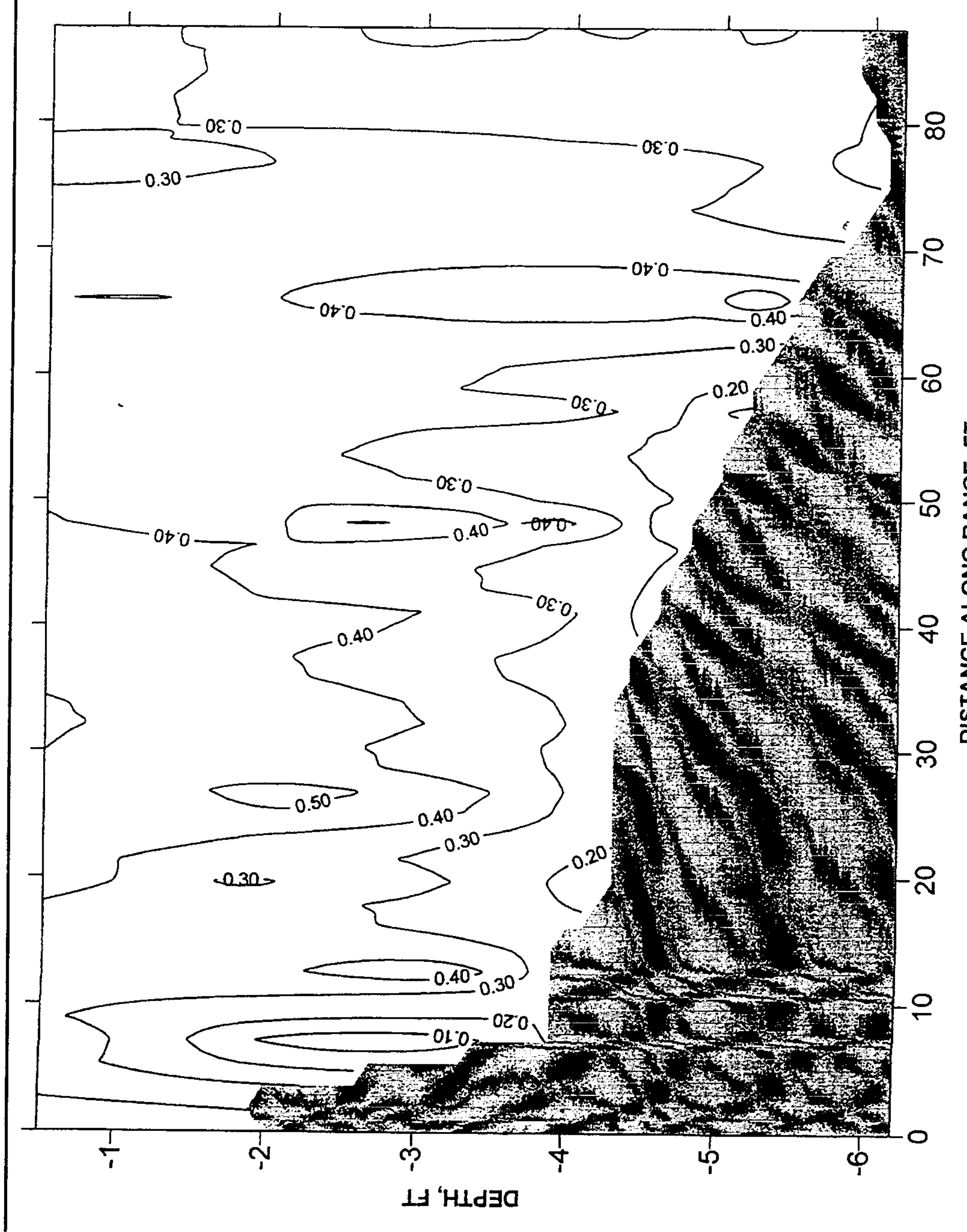
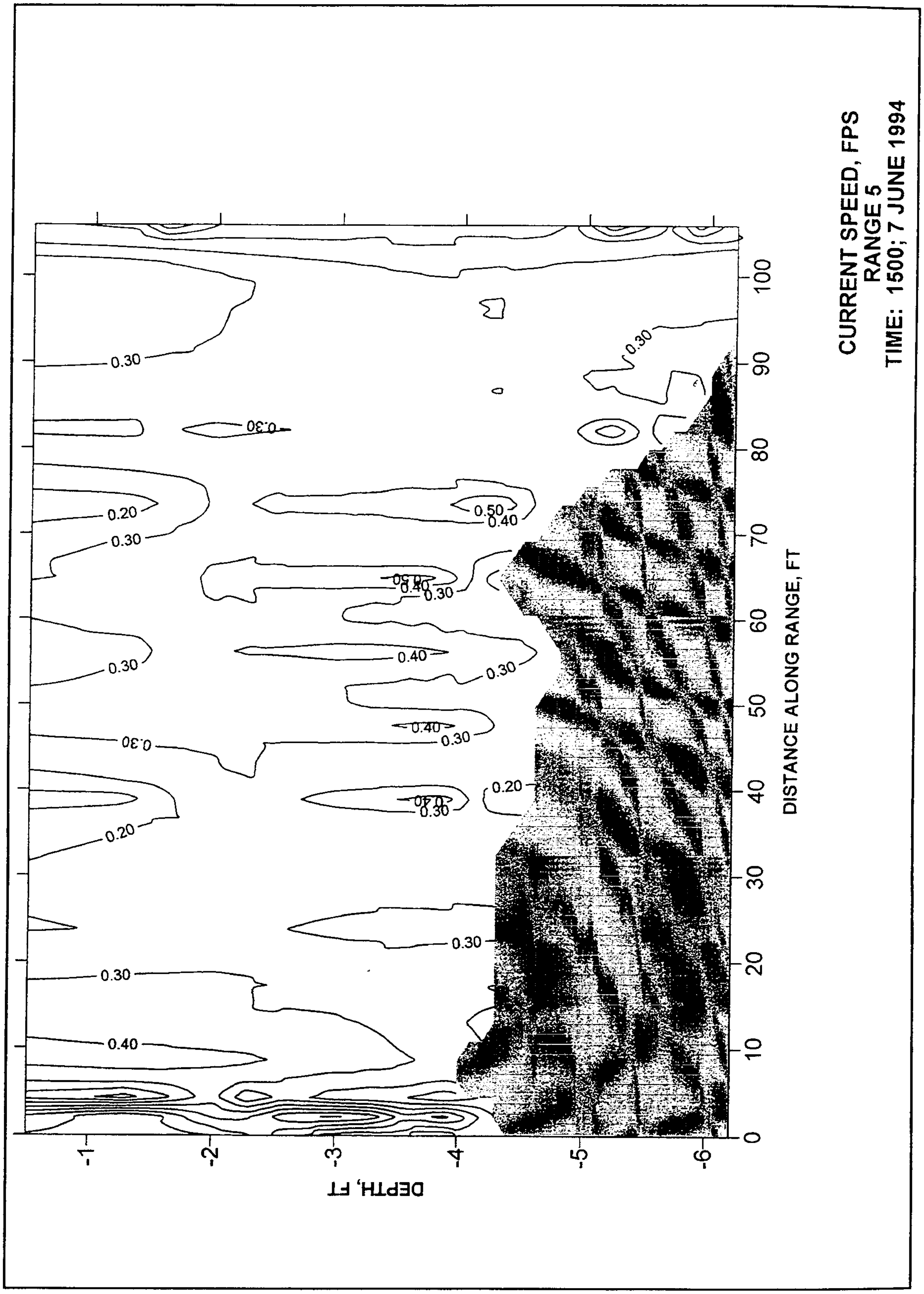
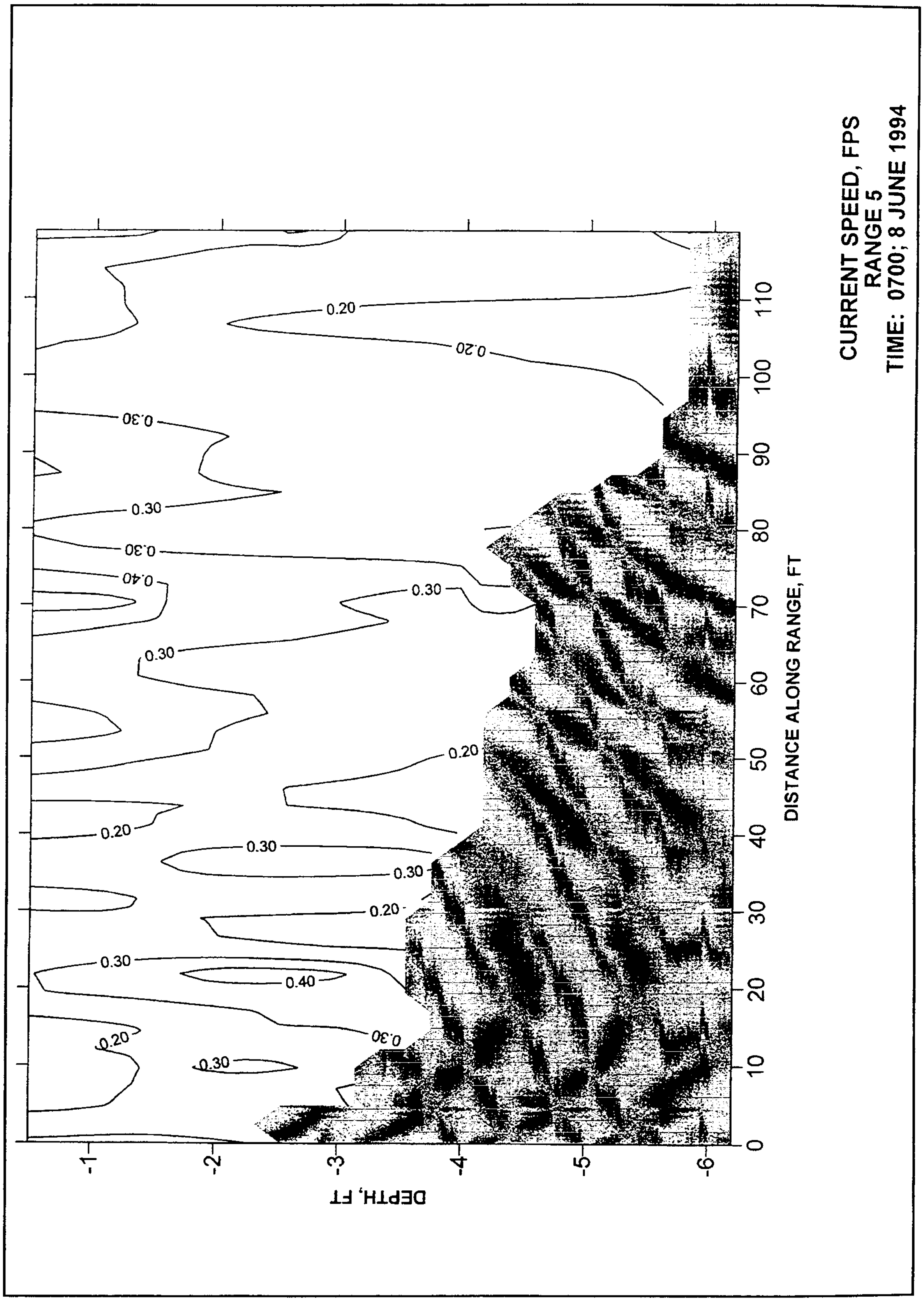

CURRENT SPEED, FPS
RANGE 4
TIME: 1400; 8 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0
20
40
60
80
100
120
140
160
180
-2
-4
-6
-8
-10
0.20
0.60

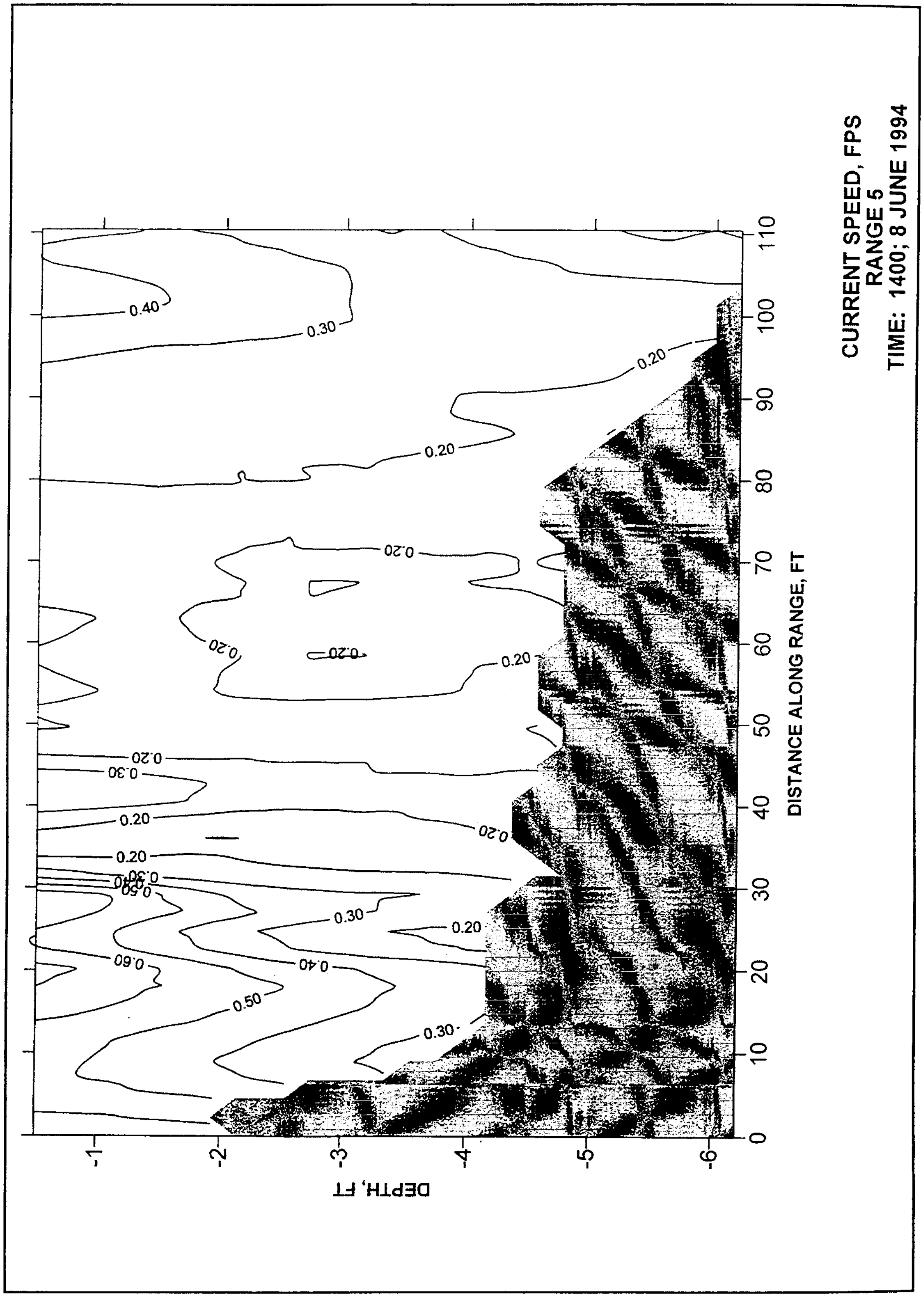
Plate 16

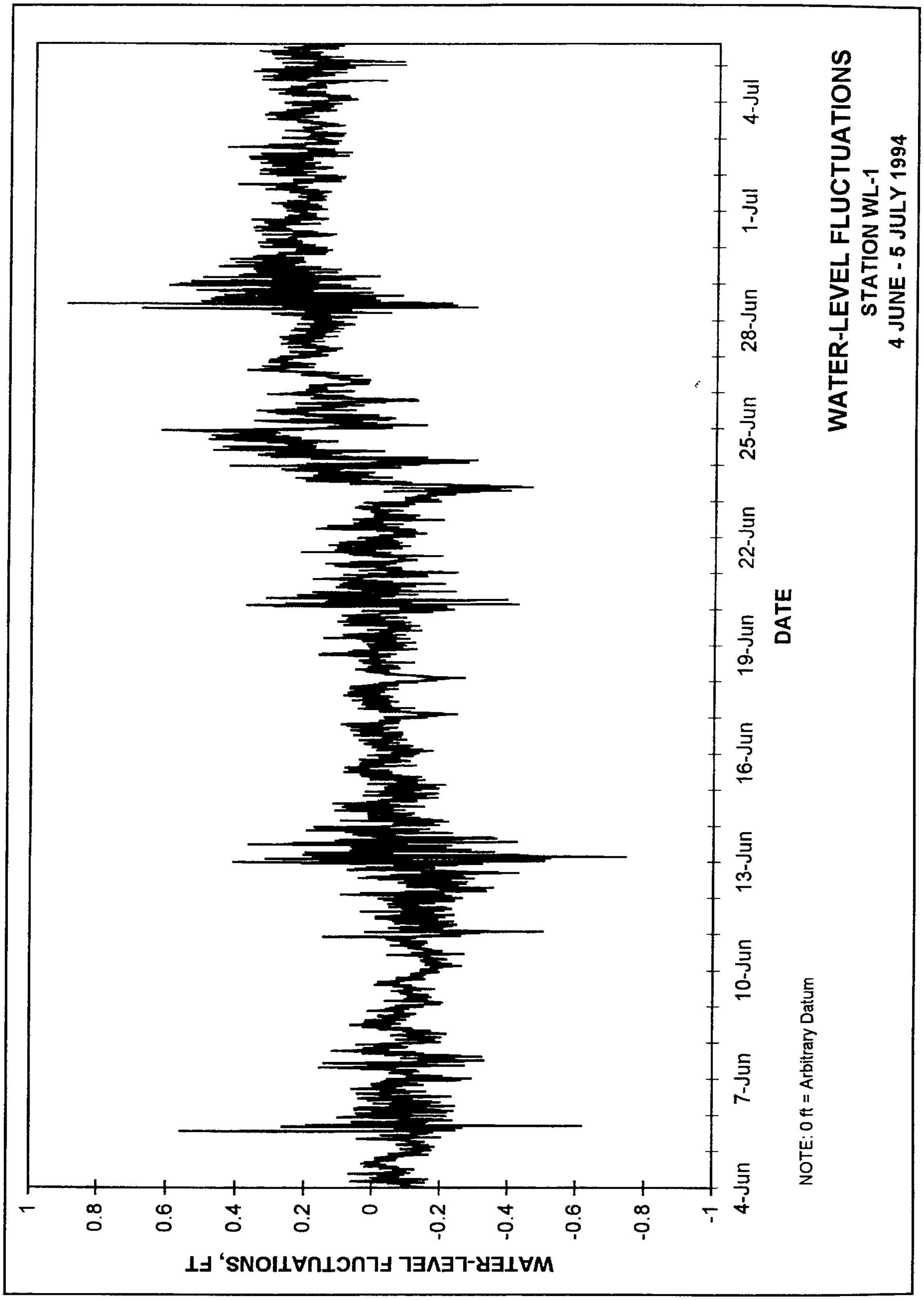


CURRENT SPEED, FPS
RANGE 5
TIME: 0800; 7 JUNE 1994


CURRENT SPEED, FPS
RANGE 5
TIME: 1500; 7 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0
10
20
30
40
50
60
70
80
90
100
-1
-2
-3
-4
-5
-6
0.20
0.30
0.40
0.50


CURRENT SPEED, FPS
RANGE 5
TIME: 0700; 8 JUNE 1994
DEPTH, FT
DISTANCE ALONG RANGE, FT
-1
-2
-3
-4
-5
-6
0
10
20
30
40
50
60
70
80
90
100
110
0.20
0.30
0.40


CURRENT SPEED, FPS
RANGE 5
TIME: 1400; 8 JUNE 1994
DISTANCE ALONG RANGE, FT
DEPTH, FT
0
10
20
30
40
50
60
70
80
90
100
110
-1
-2
-3
-4
-5
-6
0.40
0.30
0.20
0.50
0.60


WATER-LEVEL FLUCTUATIONS
STATION WL-1
4 JUNE - 5 JULY 1994
WATER-LEVEL FLUCTUATIONS, FT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
4-Jun
7-Jun
10-Jun
13-Jun
16-Jun
19-Jun
22-Jun
25-Jun
28-Jun
1-Jul
4-Jul
DATE
NOTE: 0 ft = Arbitrary Datum

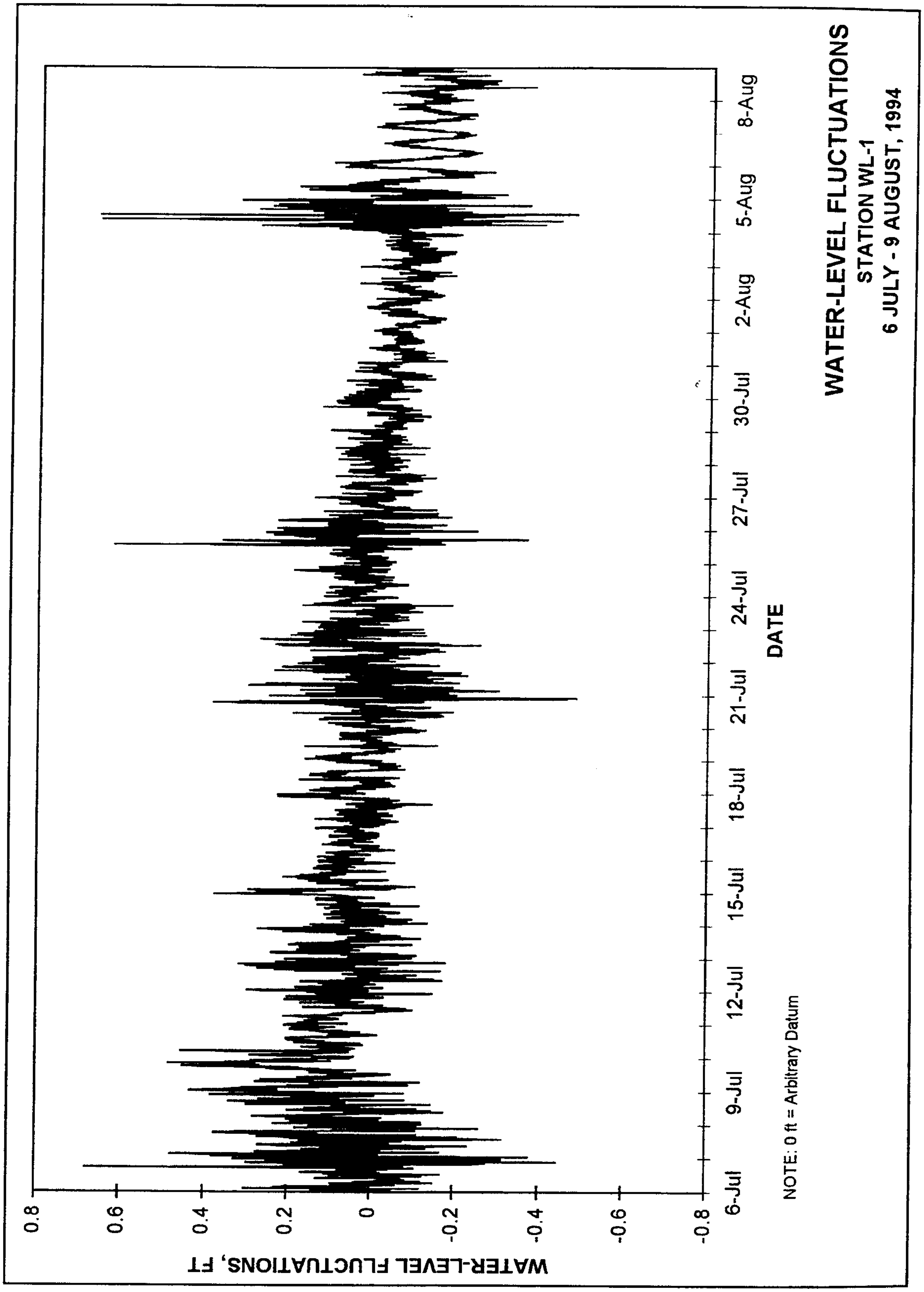
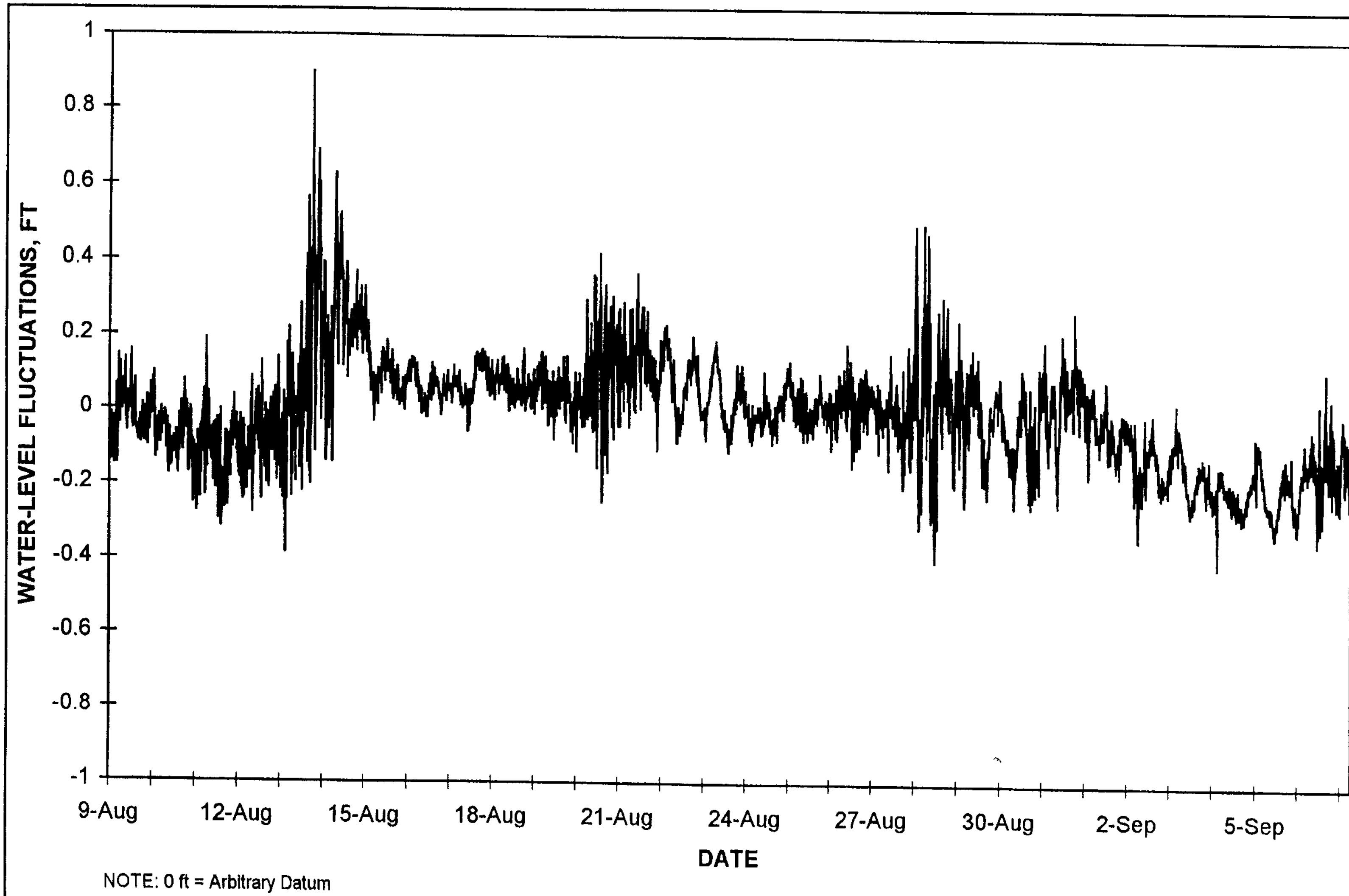
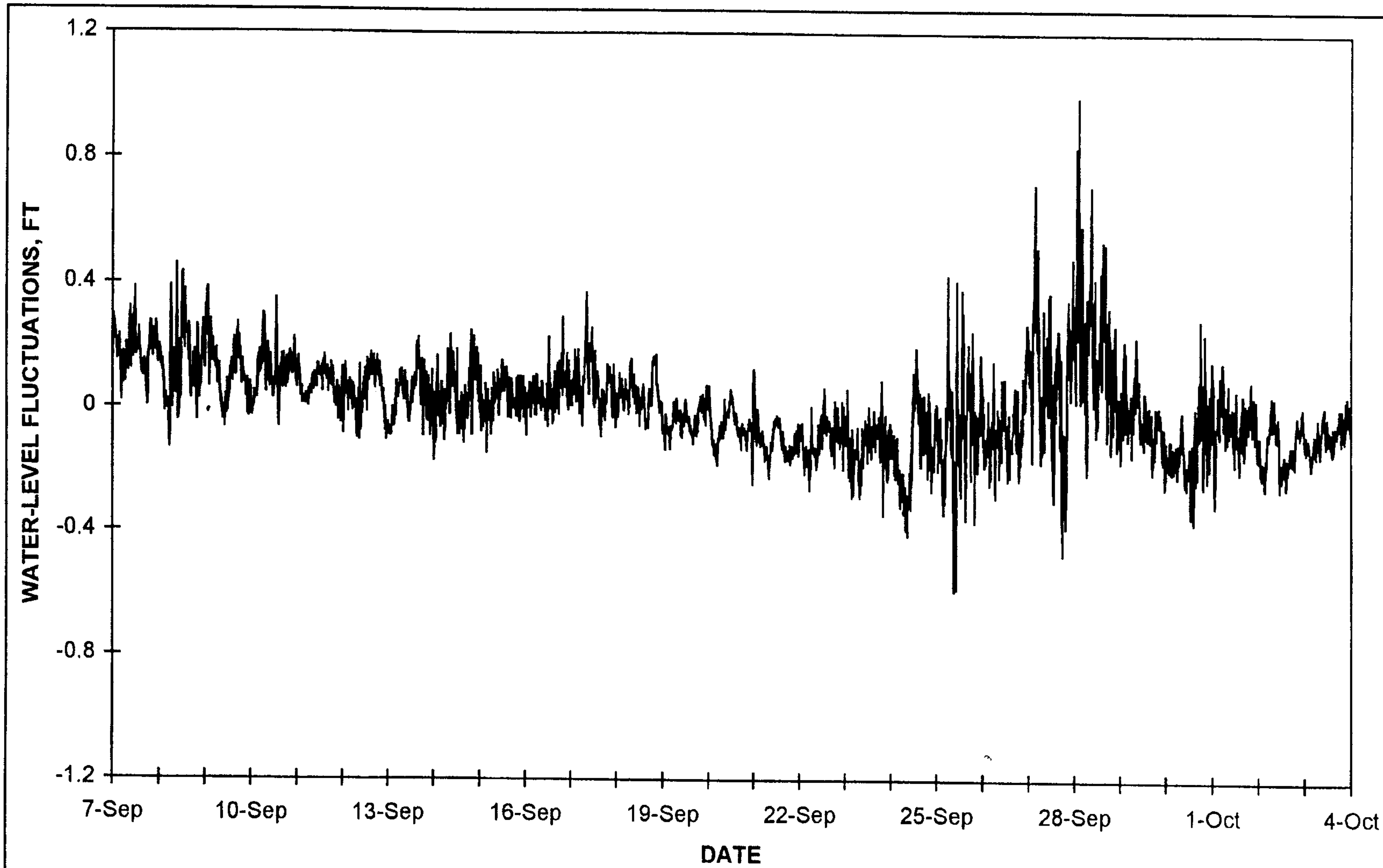

WATER-LEVEL FLUCTUATIONS
STATION WL-1
6 JULY - 9 AUGUST, 1994
WATER-LEVEL FLUCTUATIONS, FT
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
6-Jul
9-Jul
12-Jul
15-Jul
18-Jul
21-Jul
24-Jul
27-Jul
30-Jul
2-Aug
5-Aug
8-Aug
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 22

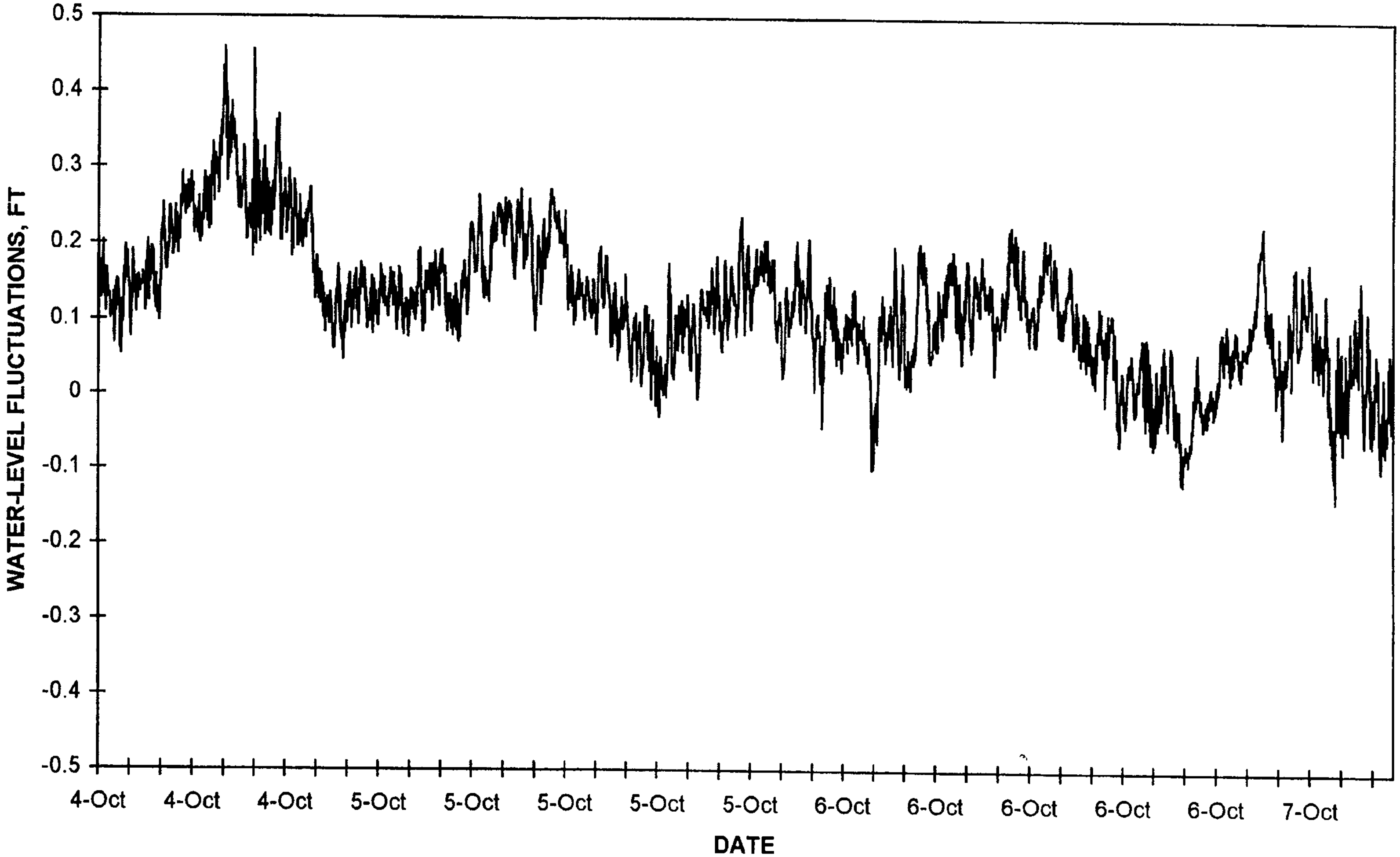


WATER-LEVEL FLUCTUATIONS
STATION WL-1
9 AUGUST - 7 SEPTEMBER, 1994



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-1
7 SEPTEMBER - 4 OCTOBER, 1994



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-1
4 -7 OCTOBER, 1994

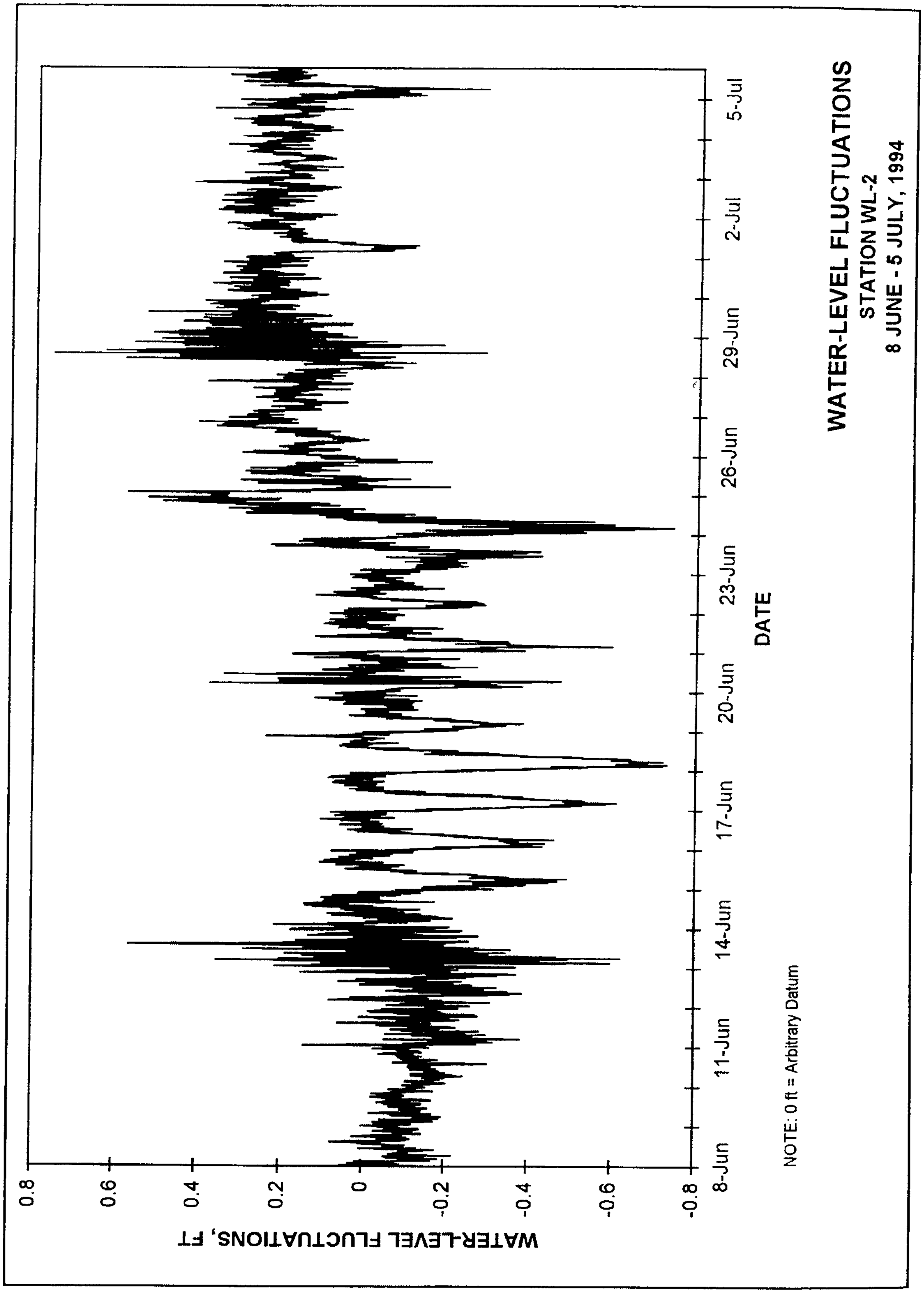
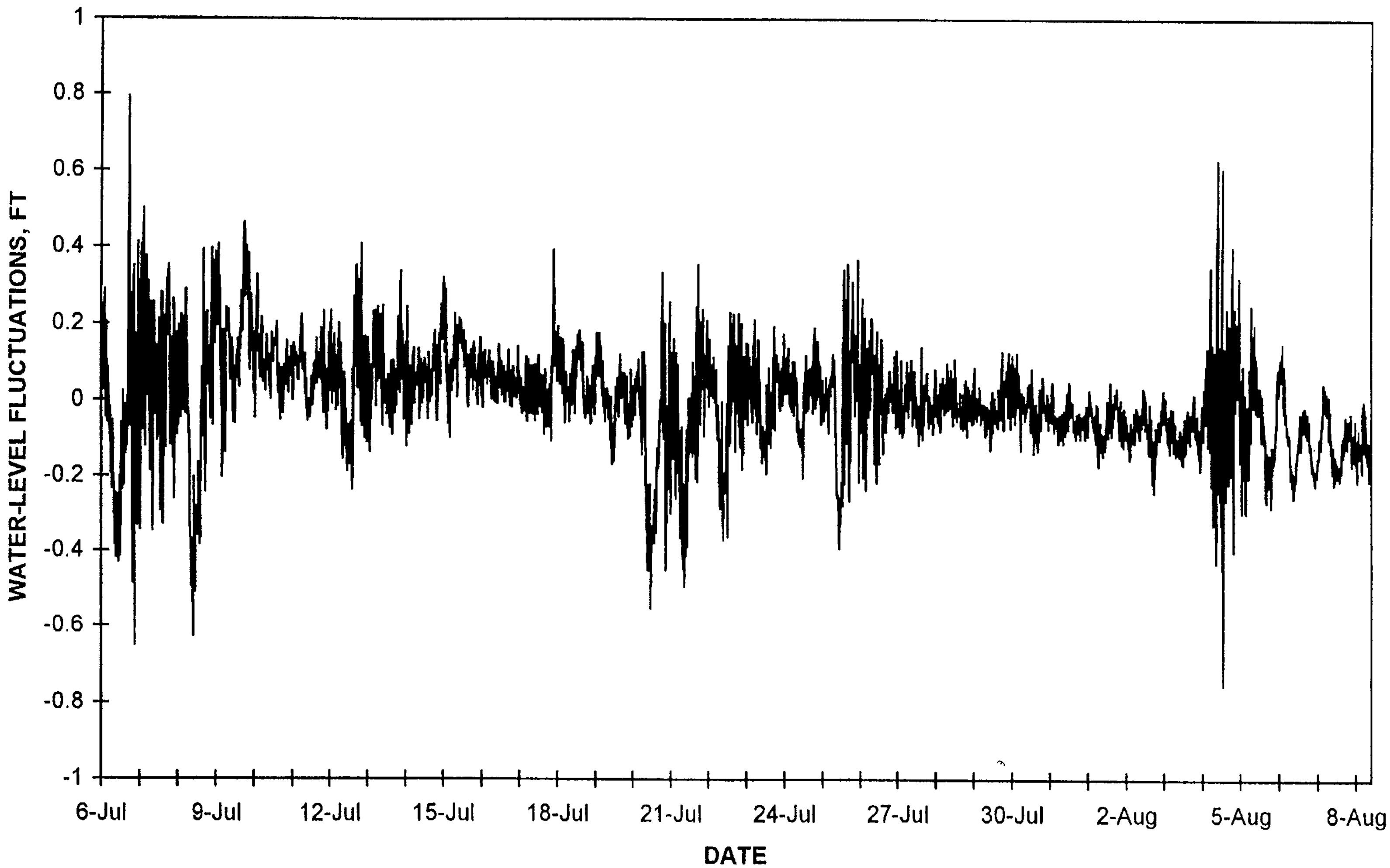
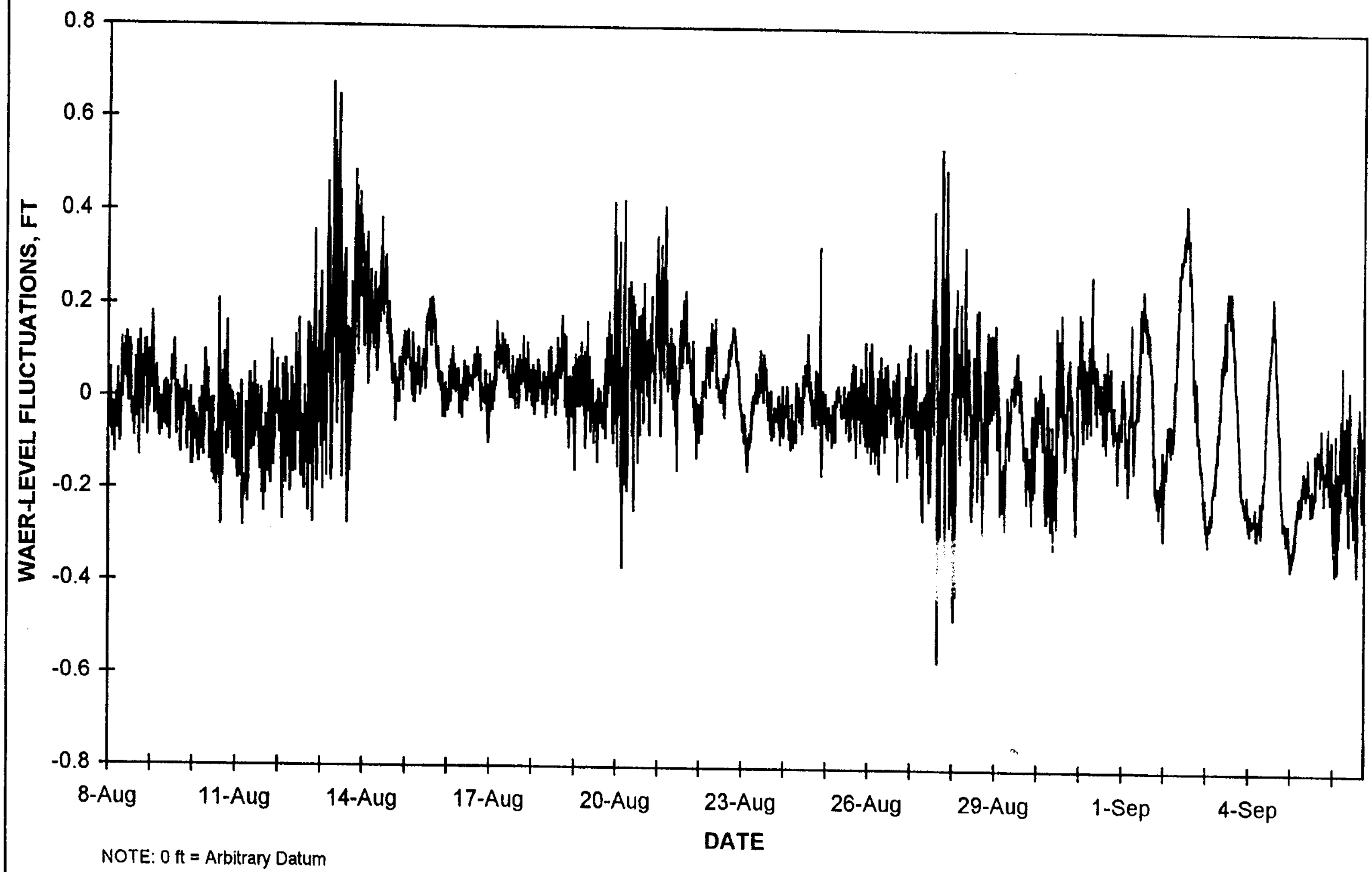

WATER-LEVEL FLUCTUATIONS
STATION WL-2
8 JUNE - 5 JULY, 1994
WATER-LEVEL FLUCTUATIONS, FT
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
8-Jun
11-Jun
14-Jun
17-Jun
20-Jun
23-Jun
26-Jun
29-Jun
2-Jul
5-Jul
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 26



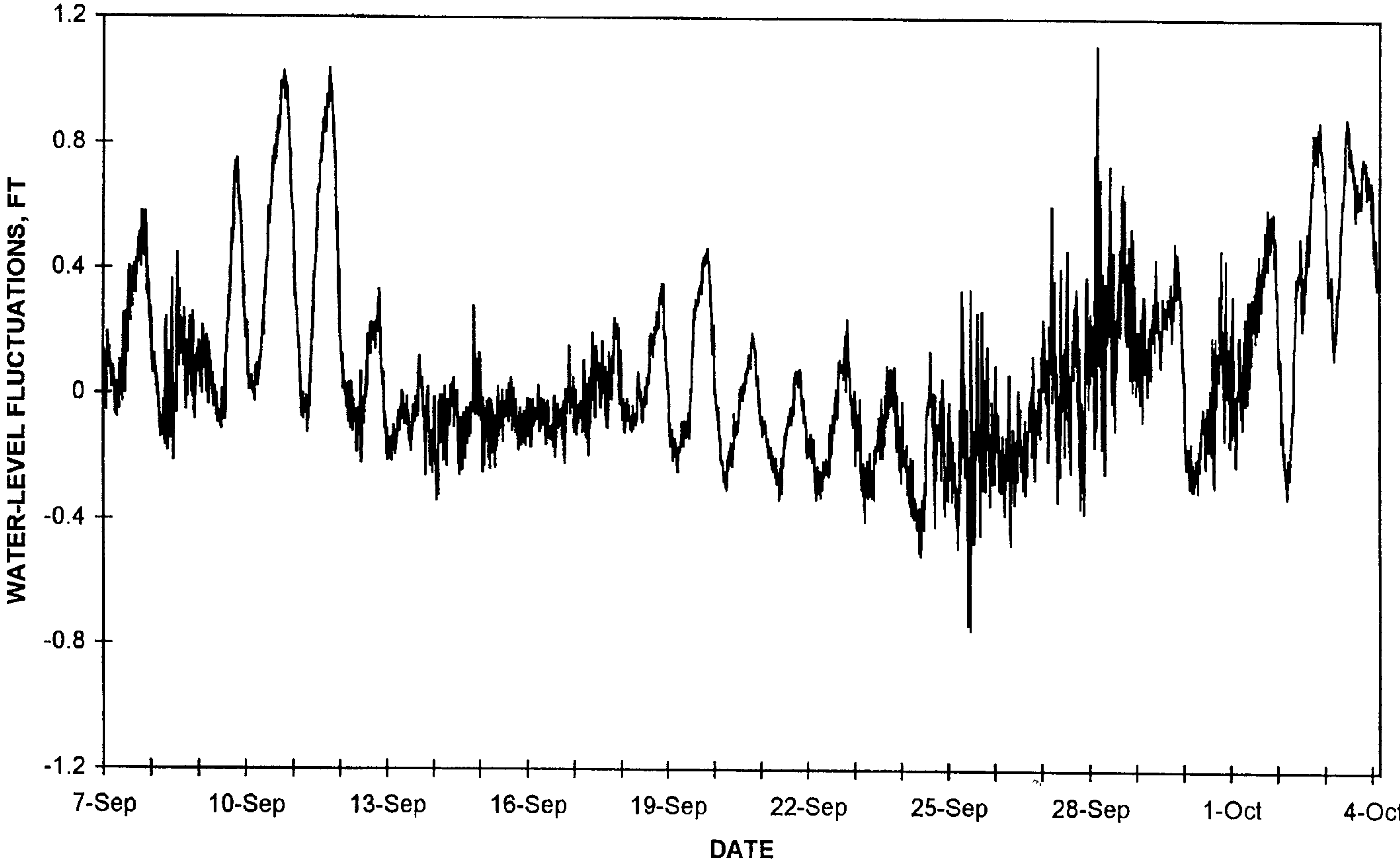
NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-2
6 JULY - 8 AUGUST, 1994



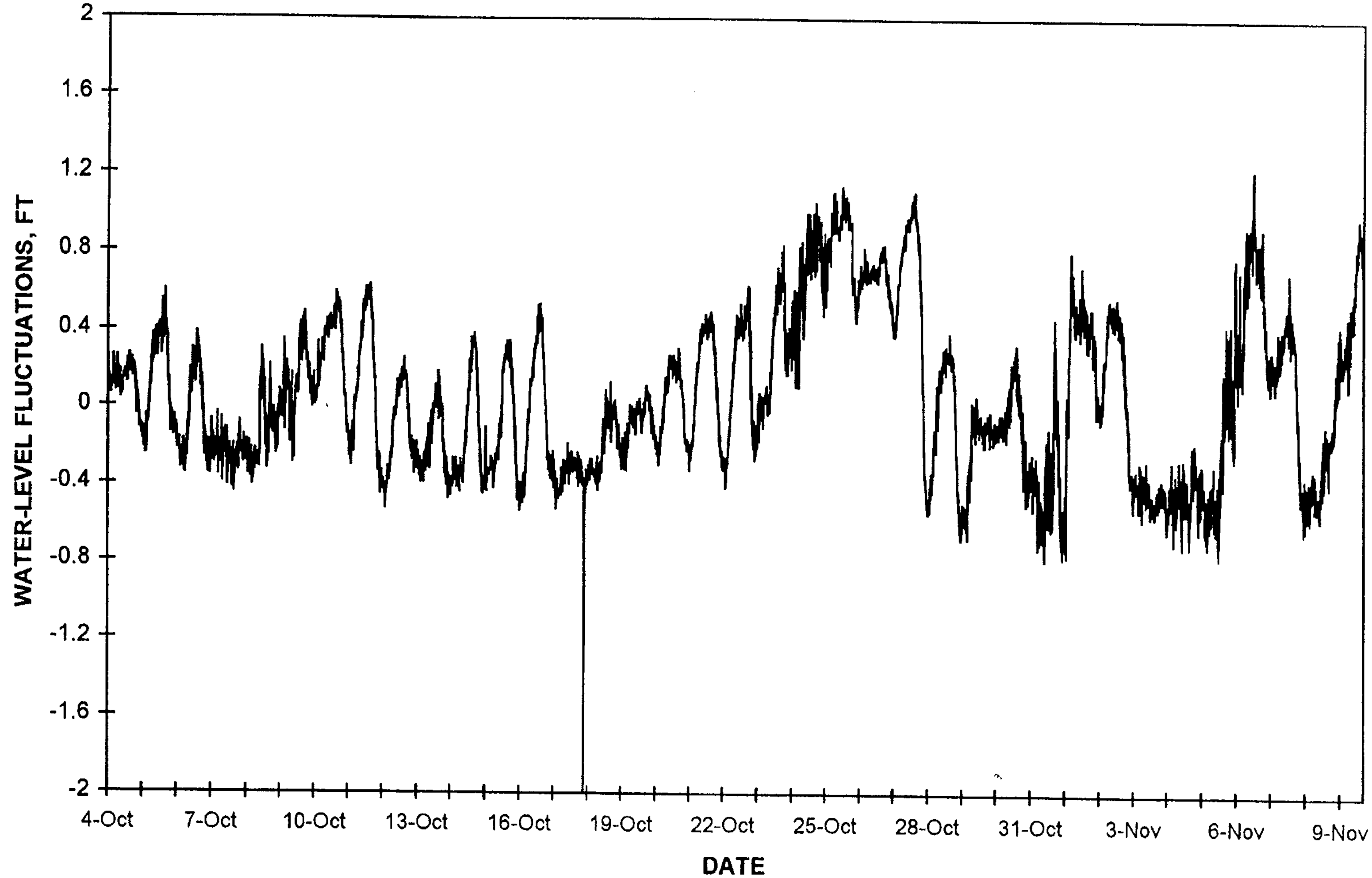
WATER-LEVEL FLUCTUATIONS
STATION WL-2
8 AUGUST - 7 SEPTEMBER, 1994

Plate 28



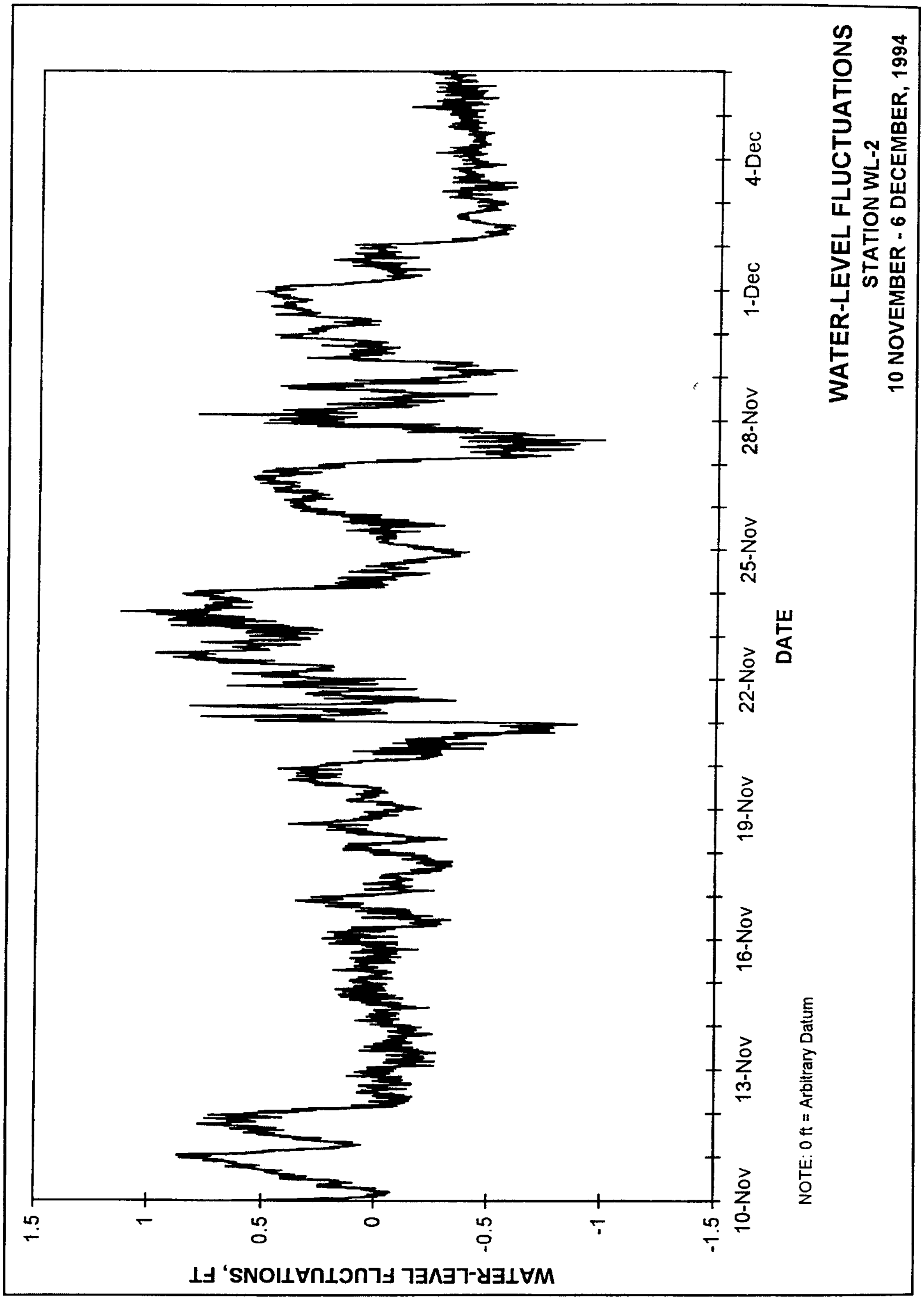
NOTE: 0 ft = Arbitrary Datum

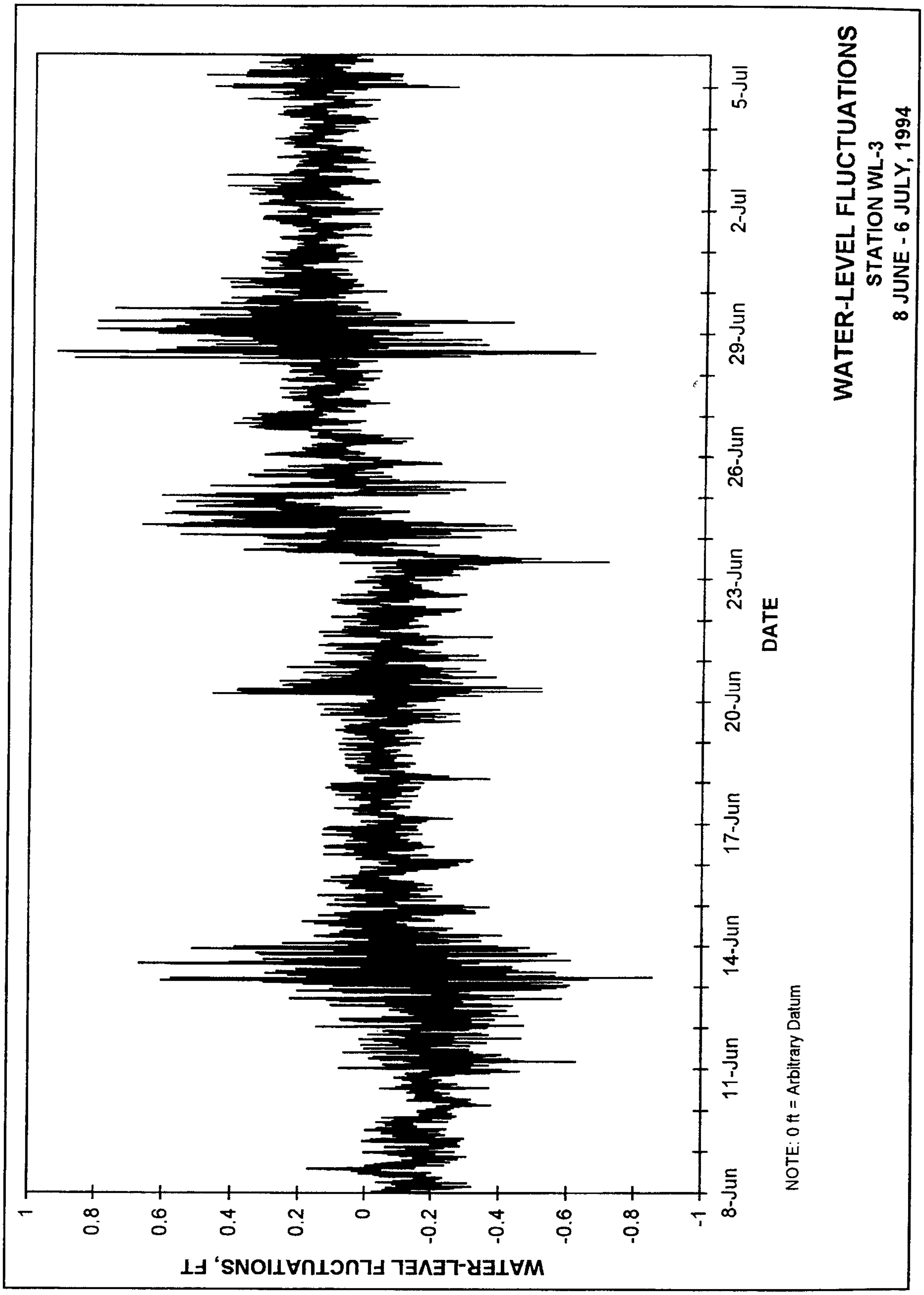
WATER-LEVEL FLUCTUATIONS
STATION WL-2
7 SEPTEMBER - 4 OCTOBER, 1994

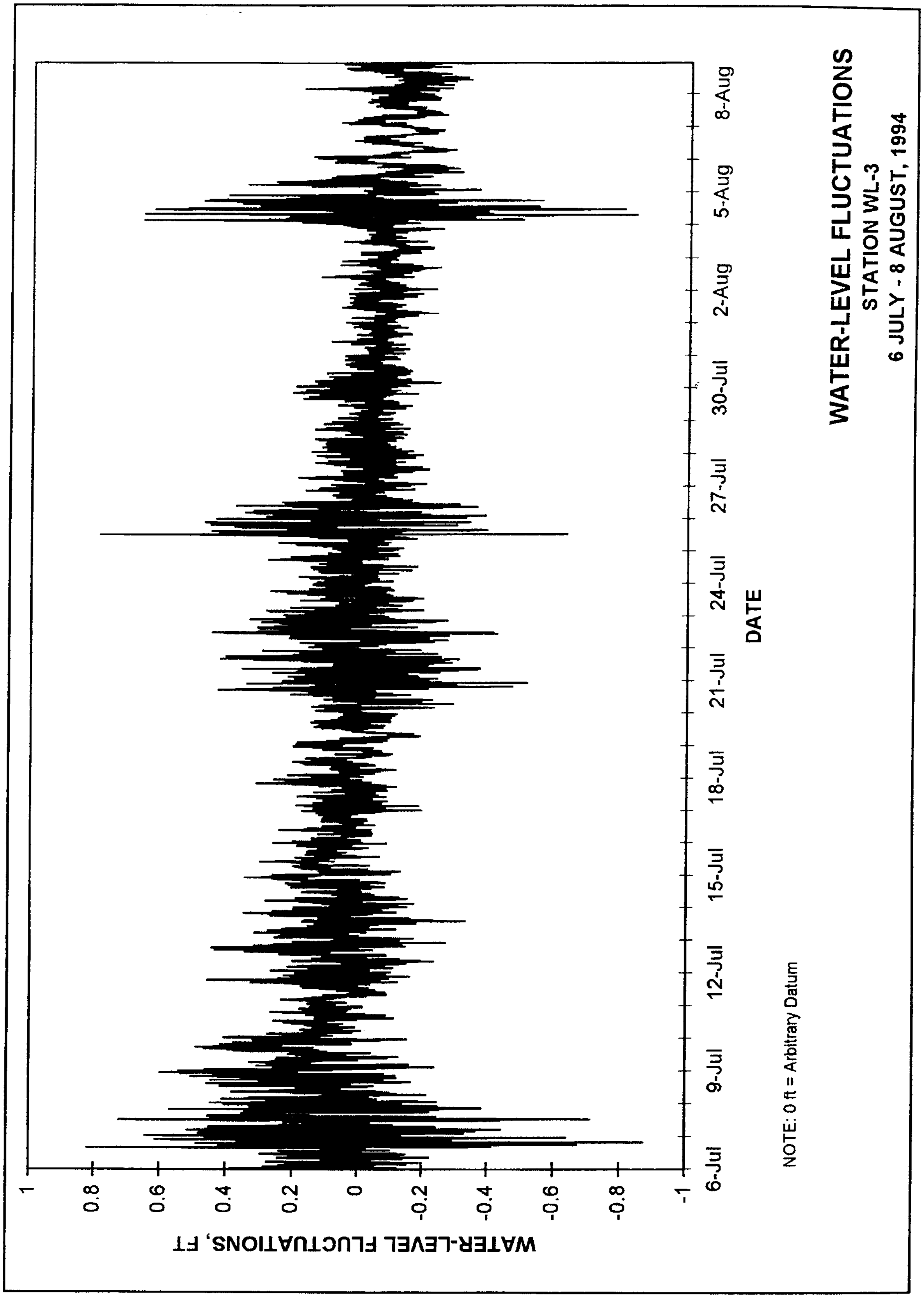


NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-2
4 OCTOBER - 10 NOVEMBER, 1994


WATER-LEVEL FLUCTUATIONS
STATION WL-2
10 NOVEMBER - 6 DECEMBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
DATE
1.5
1
0.5
0
-0.5
-1
-1.5
10-Nov
13-Nov
16-Nov
19-Nov
22-Nov
25-Nov
28-Nov
1-Dec
4-Dec
NOTE: 0 ft = Arbitrary Datum


WATER-LEVEL FLUCTUATIONS
STATION WL-3
8 JUNE - 6 JULY, 1994
WATER-LEVEL FLUCTUATIONS, FT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
8-Jun
11-Jun
14-Jun
17-Jun
20-Jun
23-Jun
26-Jun
29-Jun
2-Jul
5-Jul
DATE
NOTE: 0 ft = Arbitrary Datum


WATER-LEVEL FLUCTUATIONS
STATION WL-3
6 JULY - 8 AUGUST, 1994
WATER-LEVEL FLUCTUATIONS, FT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
6-Jul
9-Jul
12-Jul
15-Jul
18-Jul
21-Jul
24-Jul
27-Jul
30-Jul
2-Aug
5-Aug
8-Aug
DATE
NOTE: 0 ft = Arbitrary Datum

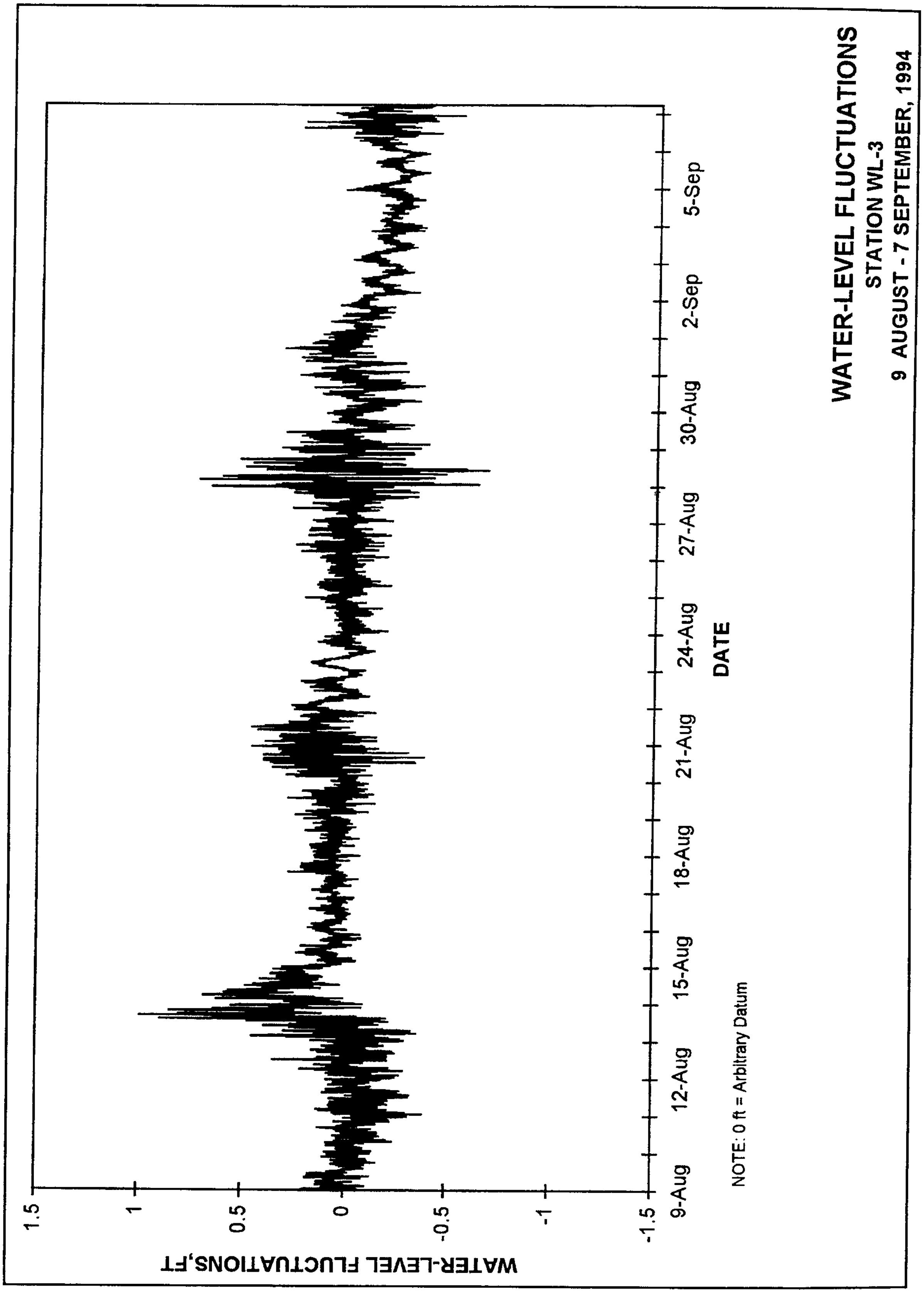
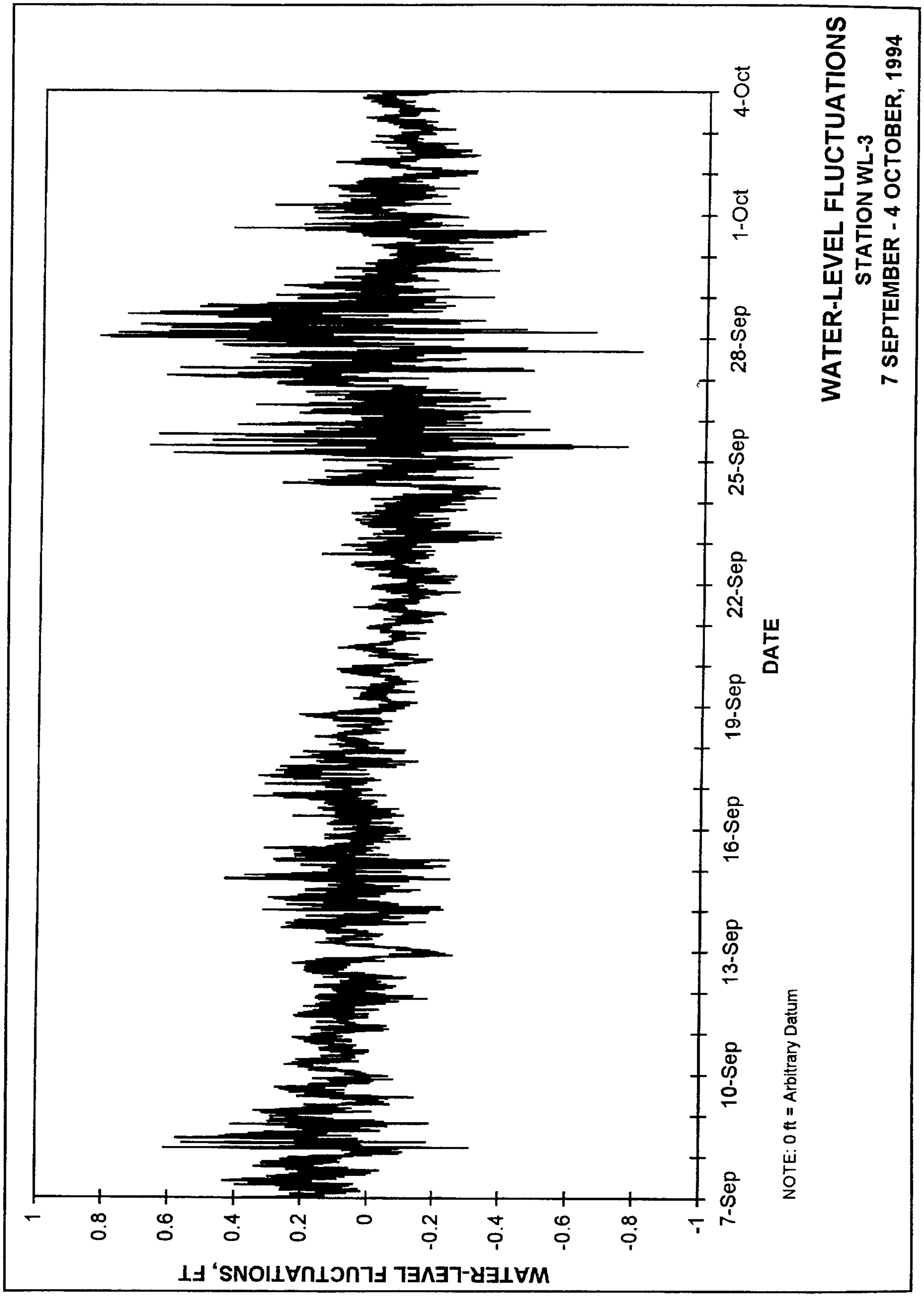

WATER-LEVEL FLUCTUATIONS
STATION WL-3
9 AUGUST - 7 SEPTEMBER, 1994
WATER-LEVEL FLUCTUATIONS,FT
1.5
1
0.5
0
-0.5
-1
-1.5
9-Aug
12-Aug
15-Aug
18-Aug
21-Aug
24-Aug
27-Aug
30-Aug
2-Sep
5-Sep
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 34


WATER-LEVEL FLUCTUATIONS
STATION WL-3
7 SEPTEMBER - 4 OCTOBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
7-Sep
10-Sep
13-Sep
16-Sep
19-Sep
22-Sep
25-Sep
28-Sep
1-Oct
4-Oct
DATE
NOTE: 0 ft = Arbitrary Datum

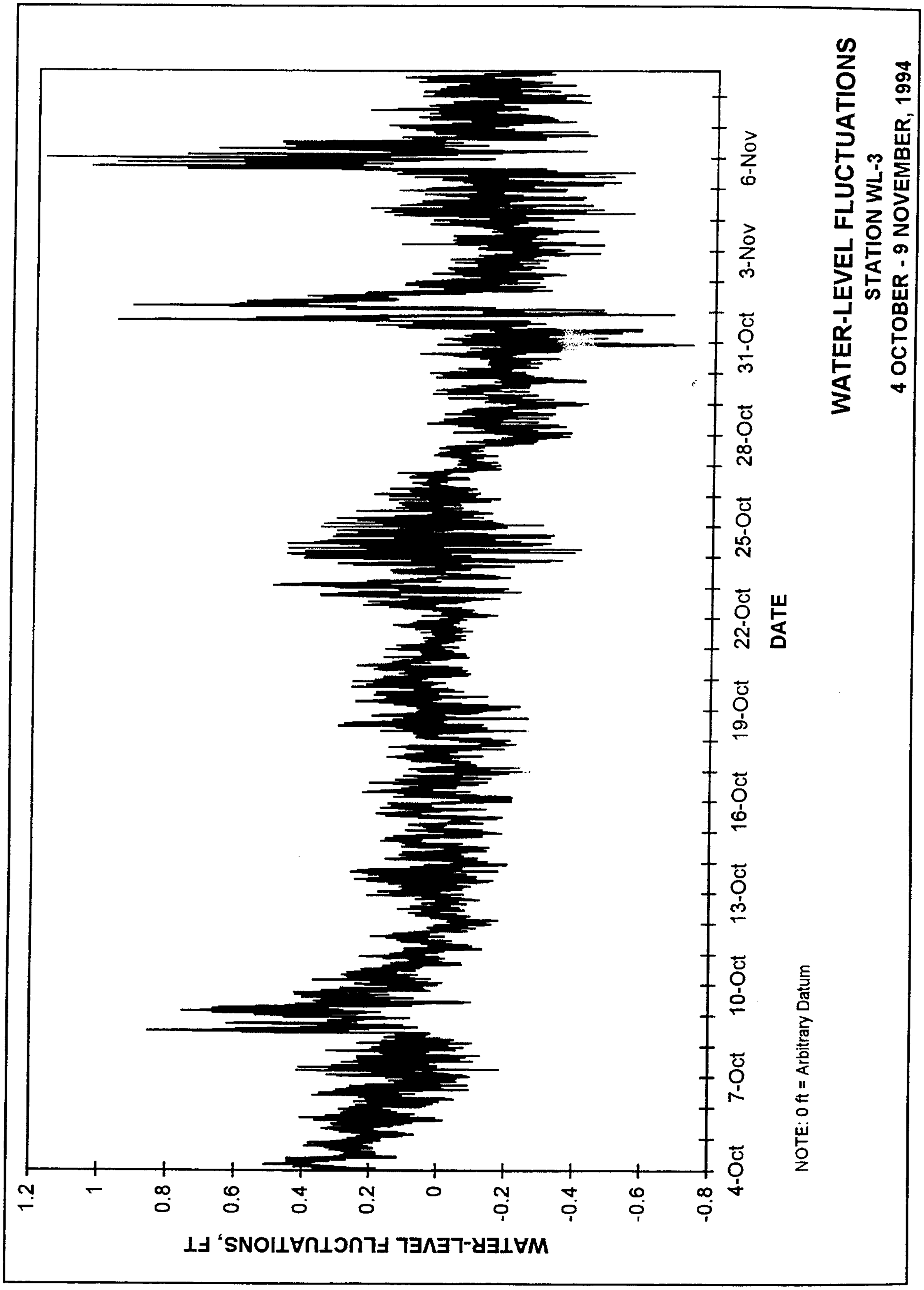
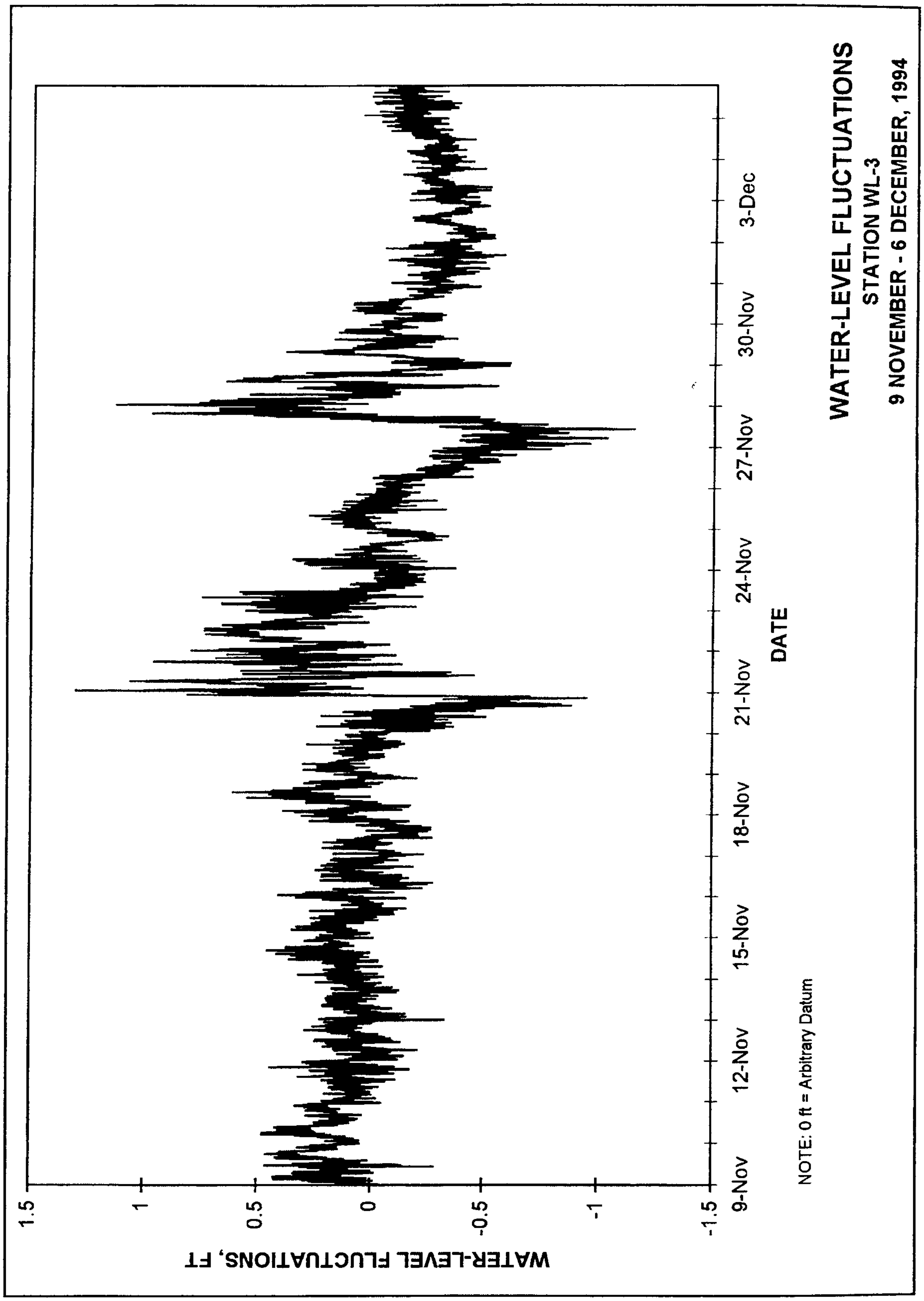

WATER-LEVEL FLUCTUATIONS
STATION WL-3
4 OCTOBER - 9 NOVEMBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
4-Oct
7-Oct
10-Oct
13-Oct
16-Oct
19-Oct
22-Oct
25-Oct
28-Oct
31-Oct
3-Nov
6-Nov
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 36


WATER-LEVEL FLUCTUATIONS
STATION WL-3
9 NOVEMBER - 6 DECEMBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
1.5
1
0.5
0
-0.5
-1
-1.5
9-Nov
12-Nov
15-Nov
18-Nov
21-Nov
24-Nov
27-Nov
30-Nov
3-Dec
DATE
NOTE: 0 ft = Arbitrary Datum

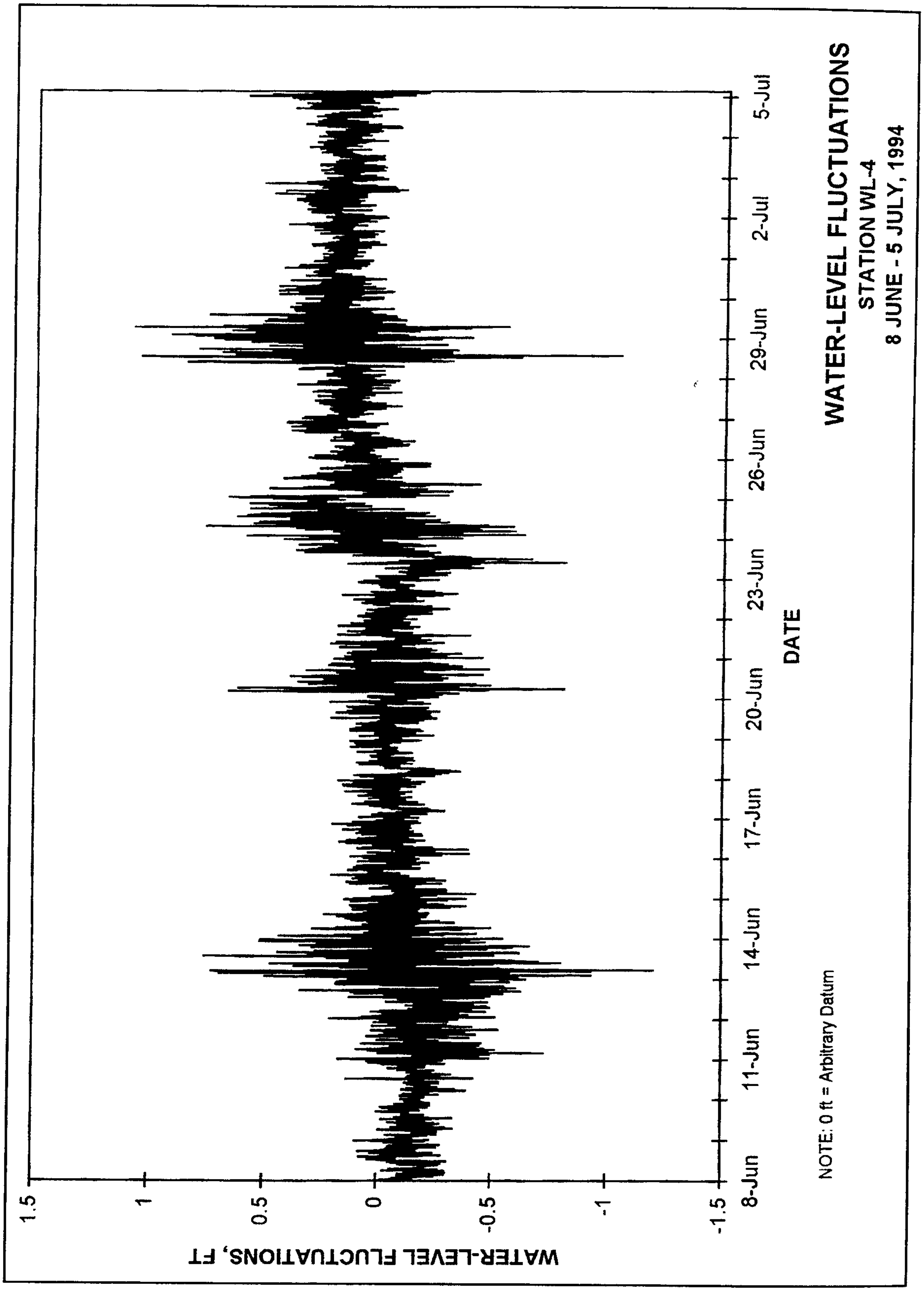
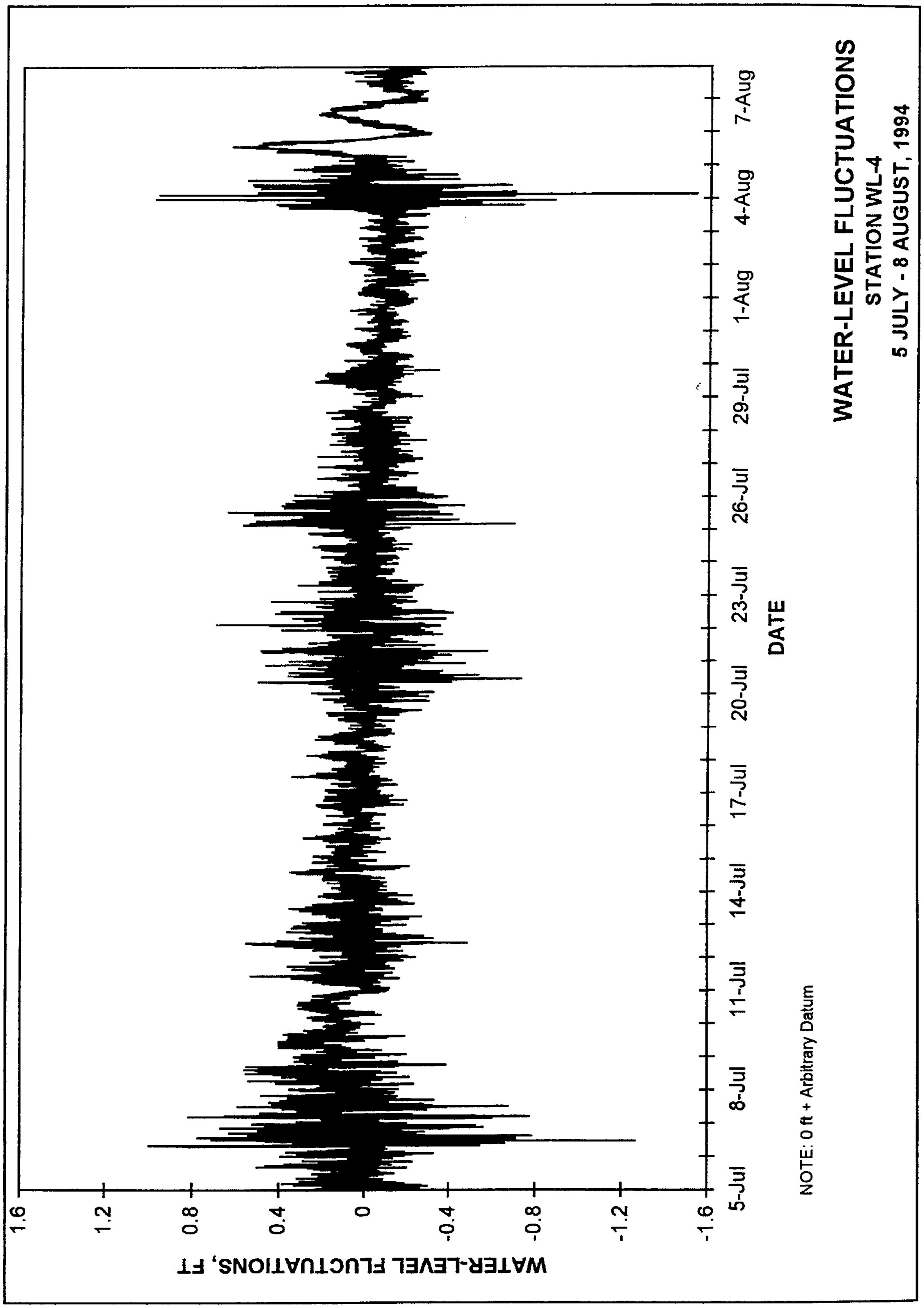

WATER-LEVEL FLUCTUATIONS
STATION WL-4
8 JUNE - 5 JULY, 1994
WATER-LEVEL FLUCTUATIONS, FT
DATE
NOTE: 0 ft = Arbitrary Datum
1.5
1
0.5
0
-0.5
-1
-1.5
8-Jun
11-Jun
14-Jun
17-Jun
20-Jun
23-Jun
26-Jun
29-Jun
2-Jul
5-Jul

Plate 38



WATER-LEVEL FLUCTUATIONS
STATION WL-4
5 JULY - 8 AUGUST, 1994
WATER-LEVEL FLUCTUATIONS, FT
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
DATE
5-Jul
8-Jul
11-Jul
14-Jul
17-Jul
20-Jul
23-Jul
26-Jul
29-Jul
1-Aug
4-Aug
7-Aug
NOTE: 0 ft + Arbitrary Datum

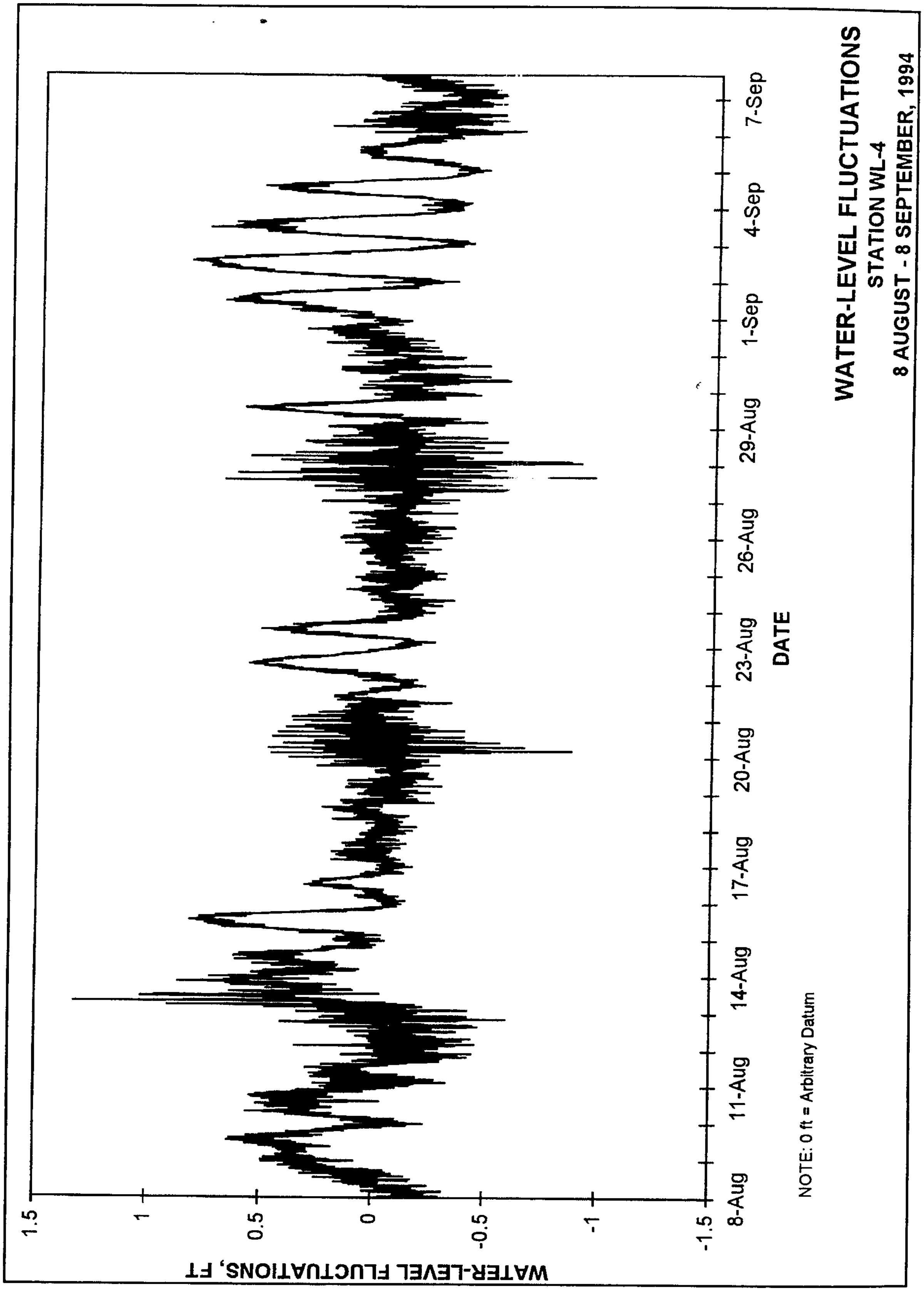
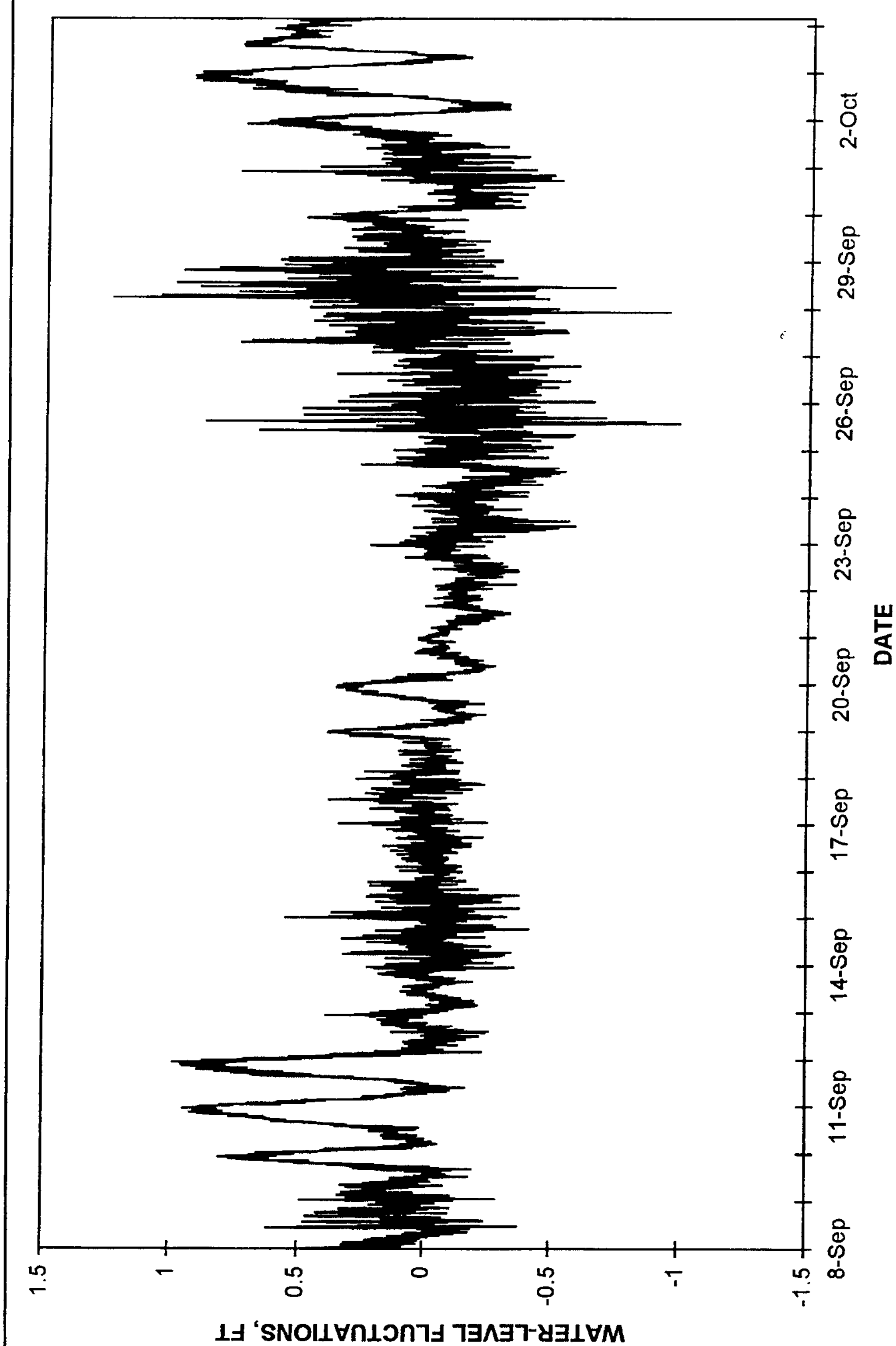
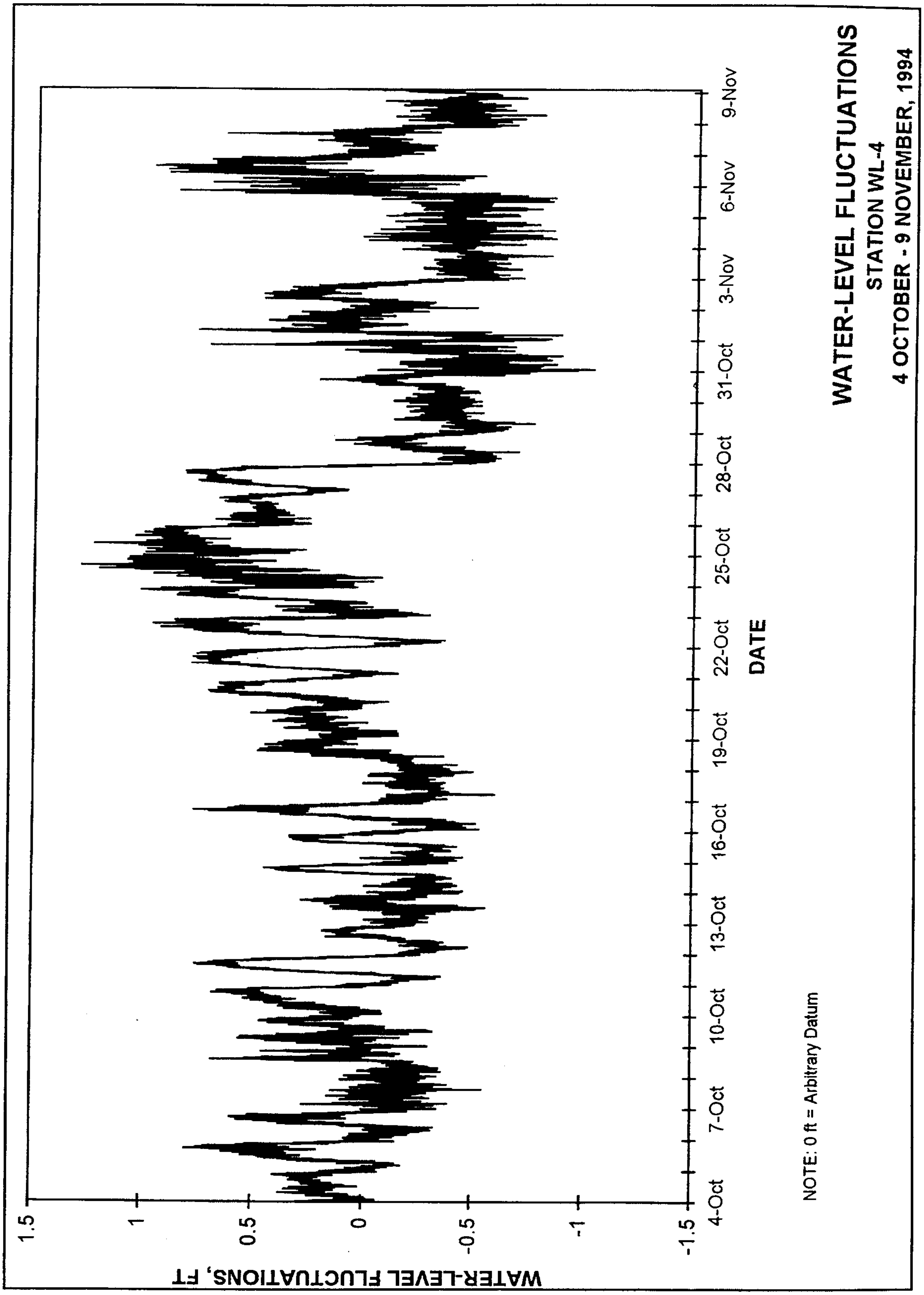

WATER-LEVEL FLUCTUATIONS
STATION WL-4
8 AUGUST - 8 SEPTEMBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
1.5
1
0.5
0
-0.5
-1
-1.5
8-Aug
11-Aug
14-Aug
17-Aug
20-Aug
23-Aug
26-Aug
29-Aug
1-Sep
4-Sep
7-Sep
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 40

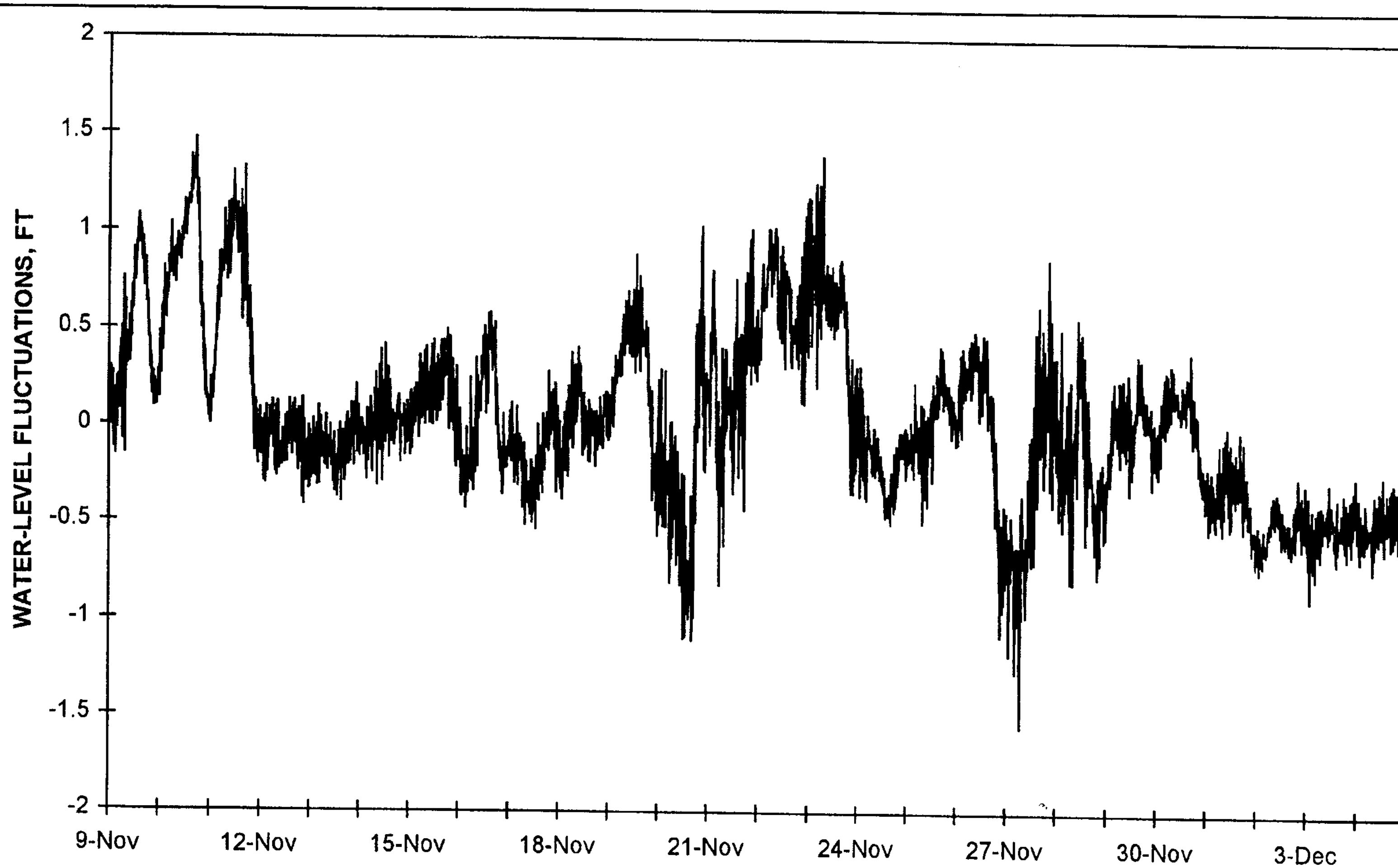


WATER-LEVEL FLUCTUATIONS
STATION WL-4
8 SEPTEMBER - 4 OCTOBER, 1994



WATER-LEVEL FLUCTUATIONS
STATION WL-4
4 OCTOBER - 9 NOVEMBER, 1994
WATER-LEVEL FLUCTUATIONS, FT
1.5
1
0.5
0
-0.5
-1
-1.5
4-Oct
7-Oct
10-Oct
13-Oct
16-Oct
19-Oct
22-Oct
25-Oct
28-Oct
31-Oct
3-Nov
6-Nov
9-Nov
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 42



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-4
9 NOVEMBER - 5 DECEMBER, 1994

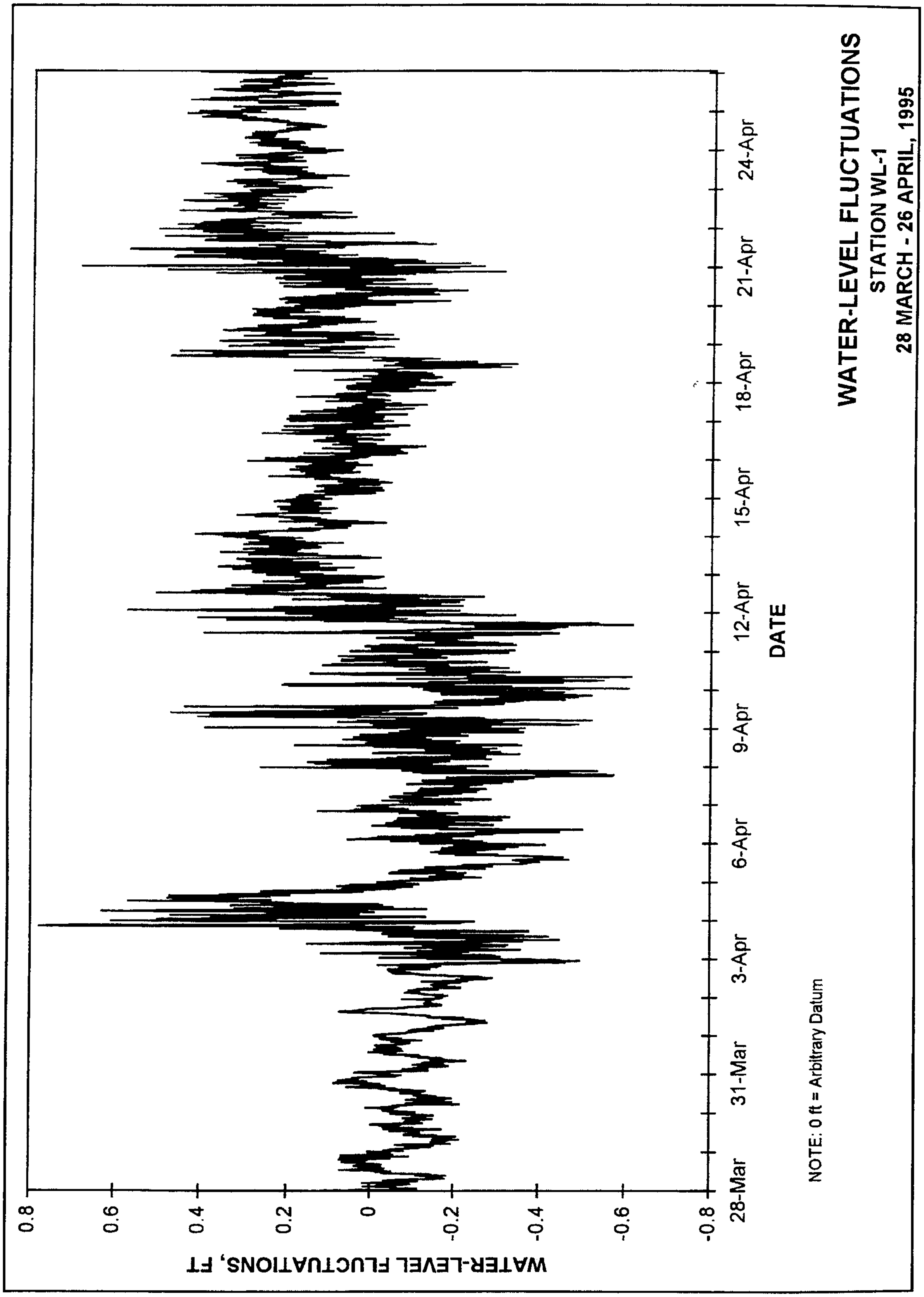
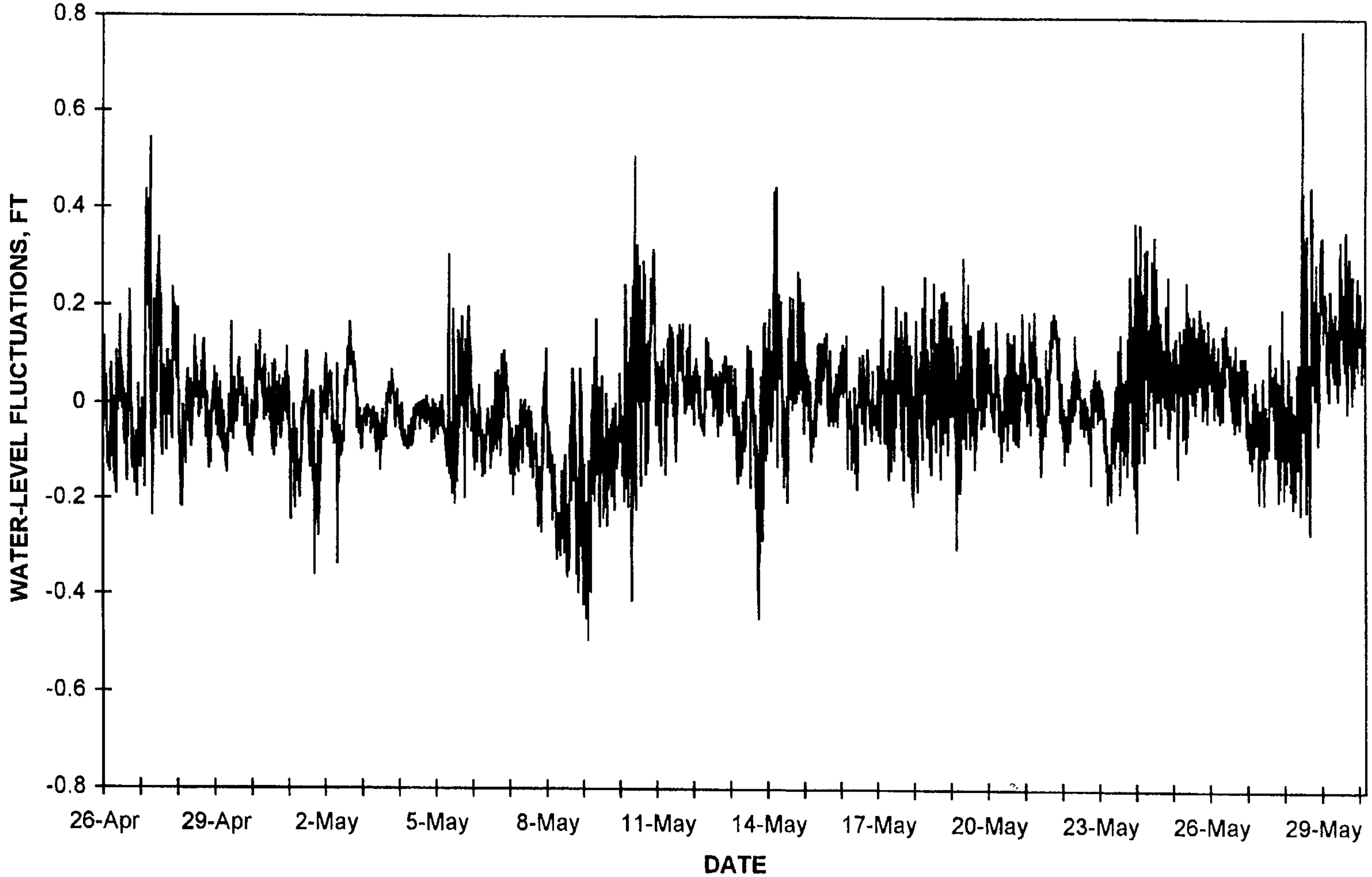
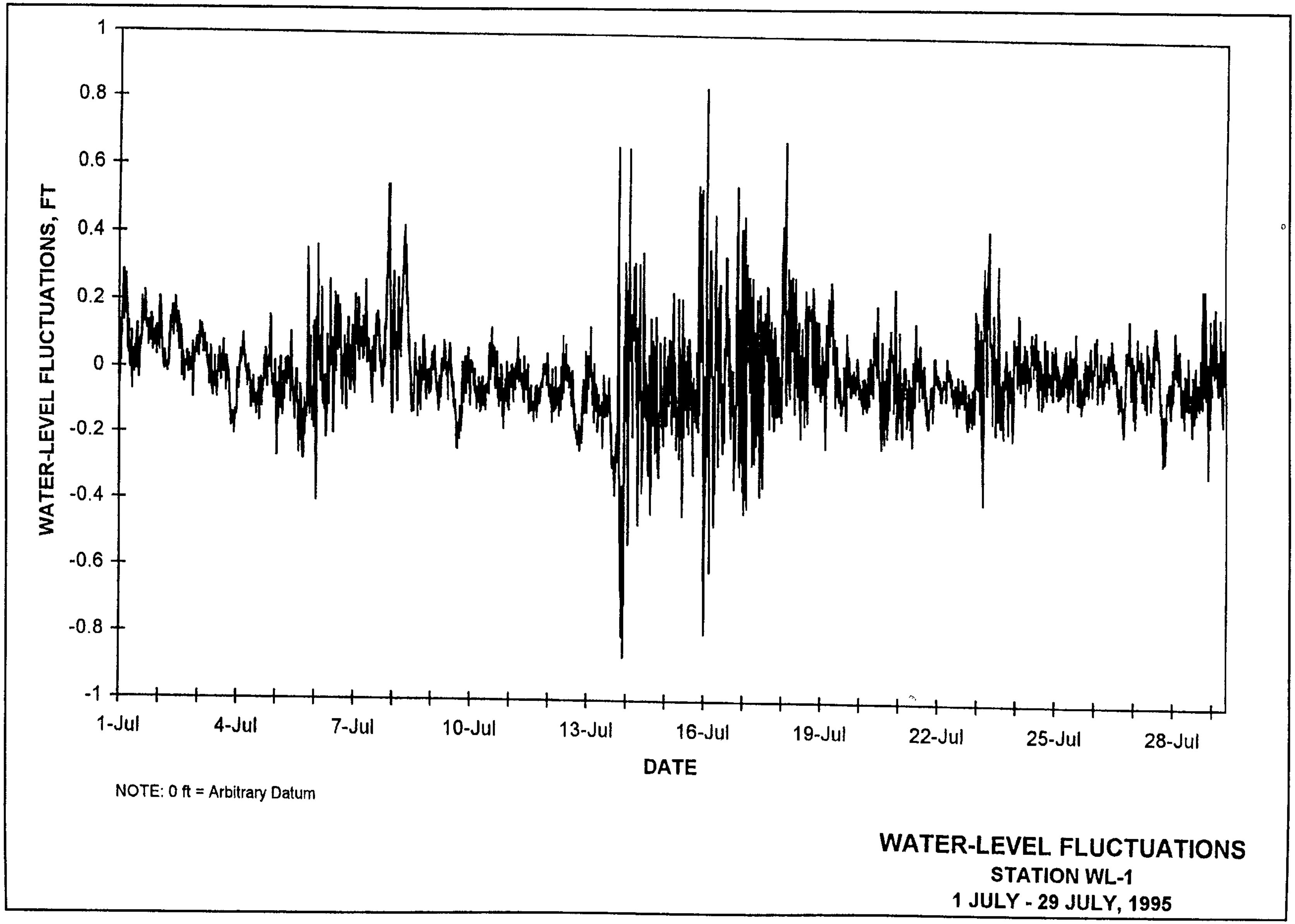

WATER-LEVEL FLUCTUATIONS
STATION WL-1
28 MARCH - 26 APRIL, 1995
WATER-LEVEL FLUCTUATIONS, FT
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
28-Mar
31-Mar
3-Apr
6-Apr
9-Apr
12-Apr
15-Apr
18-Apr
21-Apr
24-Apr
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 44

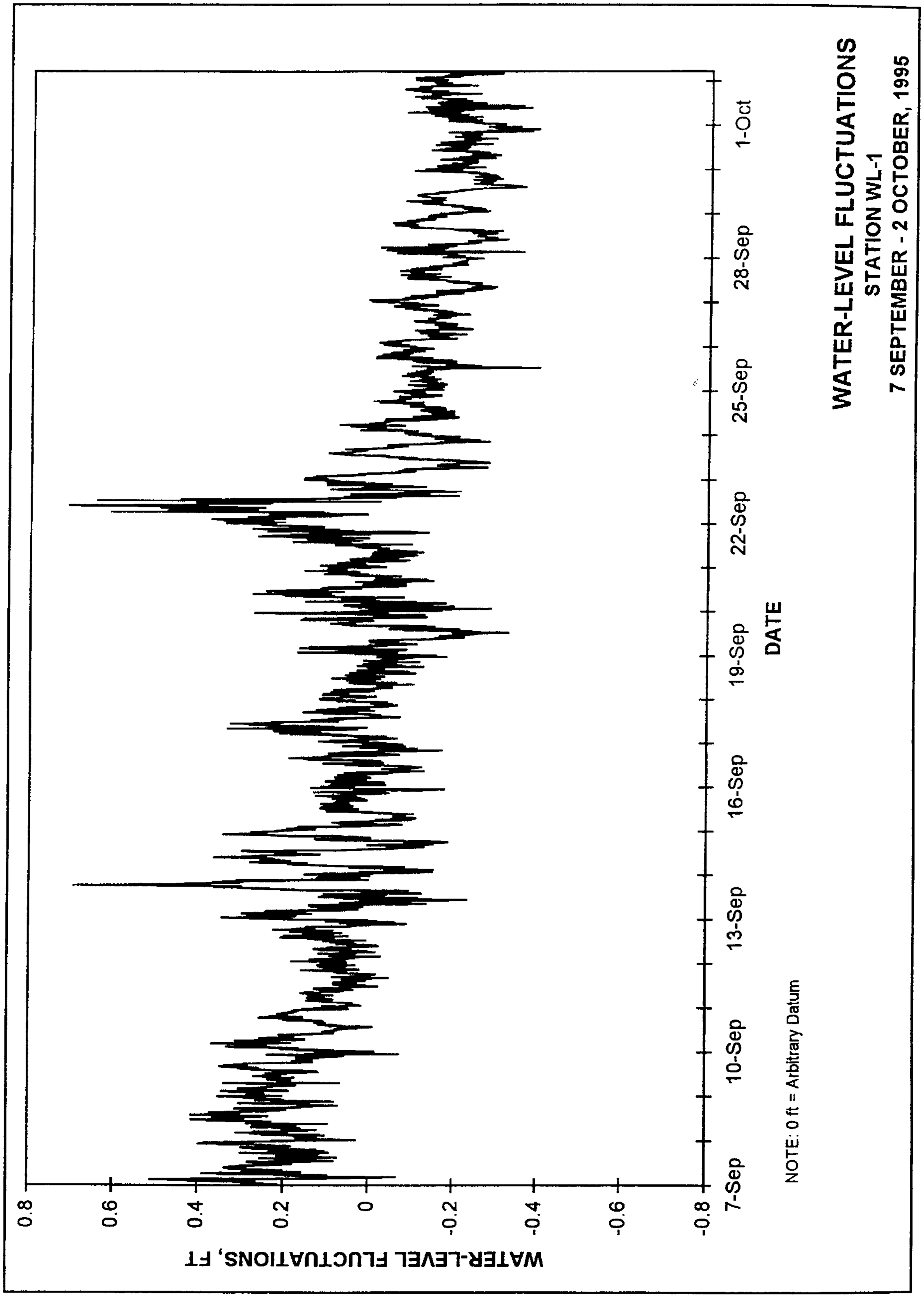


NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-1
26 APRIL - 30 MAY, 1995



WATER-LEVEL FLUCTUATIONS, FT
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1-Jul
4-Jul
7-Jul
10-Jul
13-Jul
16-Jul
19-Jul
22-Jul
25-Jul
28-Jul
DATE
NOTE: 0 ft = Arbitrary Datum
WATER-LEVEL FLUCTUATIONS
STATION WL-1
1 JULY - 29 JULY, 1995


WATER-LEVEL FLUCTUATIONS
STATION WL-1
7 SEPTEMBER - 2 OCTOBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
7-Sep
10-Sep
13-Sep
16-Sep
19-Sep
22-Sep
25-Sep
28-Sep
1-Oct
DATE
NOTE: 0 ft = Arbitrary Datum

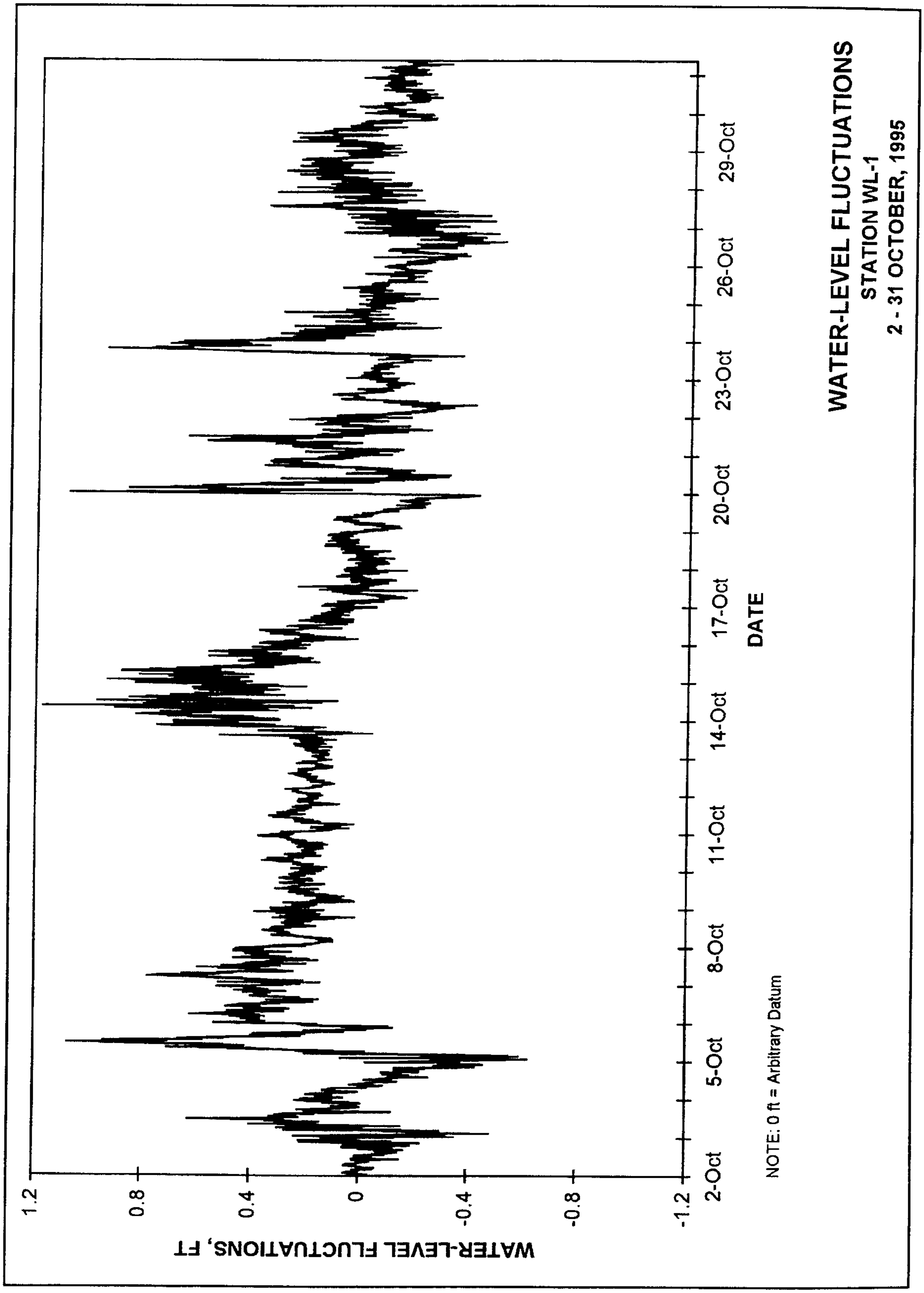
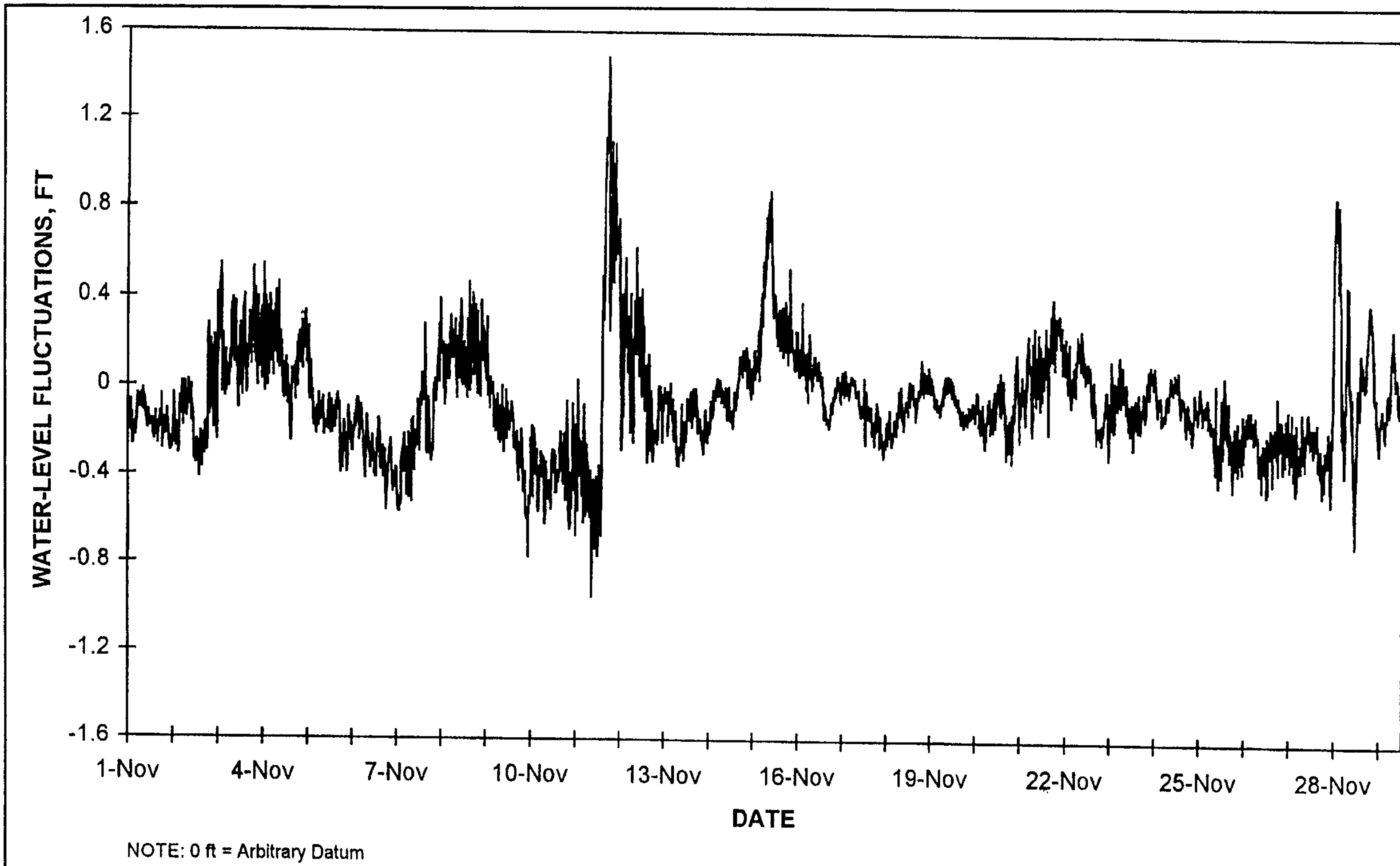
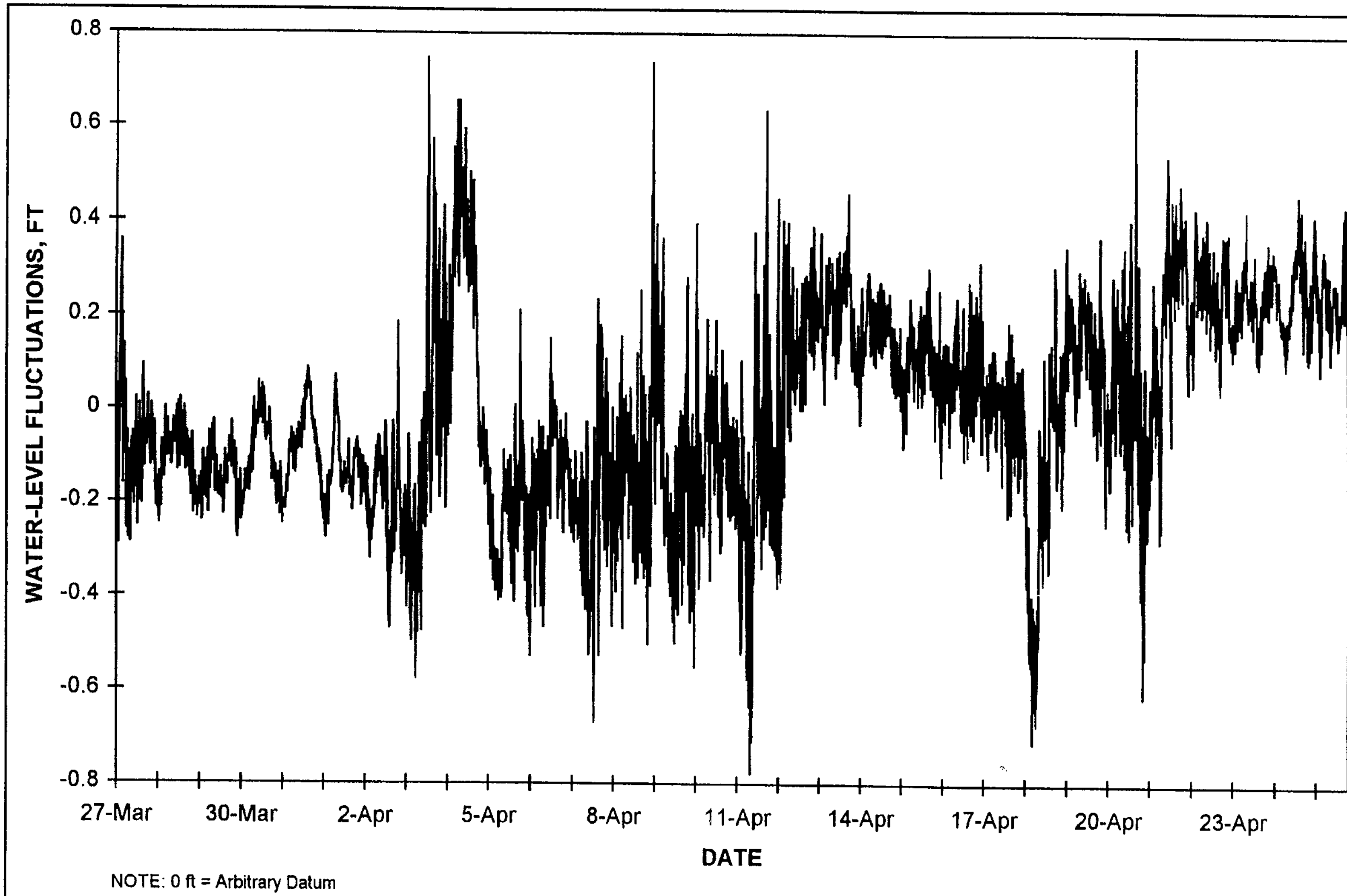

WATER-LEVEL FLUCTUATIONS
STATION WL-1
2 - 31 OCTOBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
2-Oct
5-Oct
8-Oct
11-Oct
14-Oct
17-Oct
20-Oct
23-Oct
26-Oct
29-Oct
DATE
NOTE: 0 ft = Arbitrary Datum

Plate 48

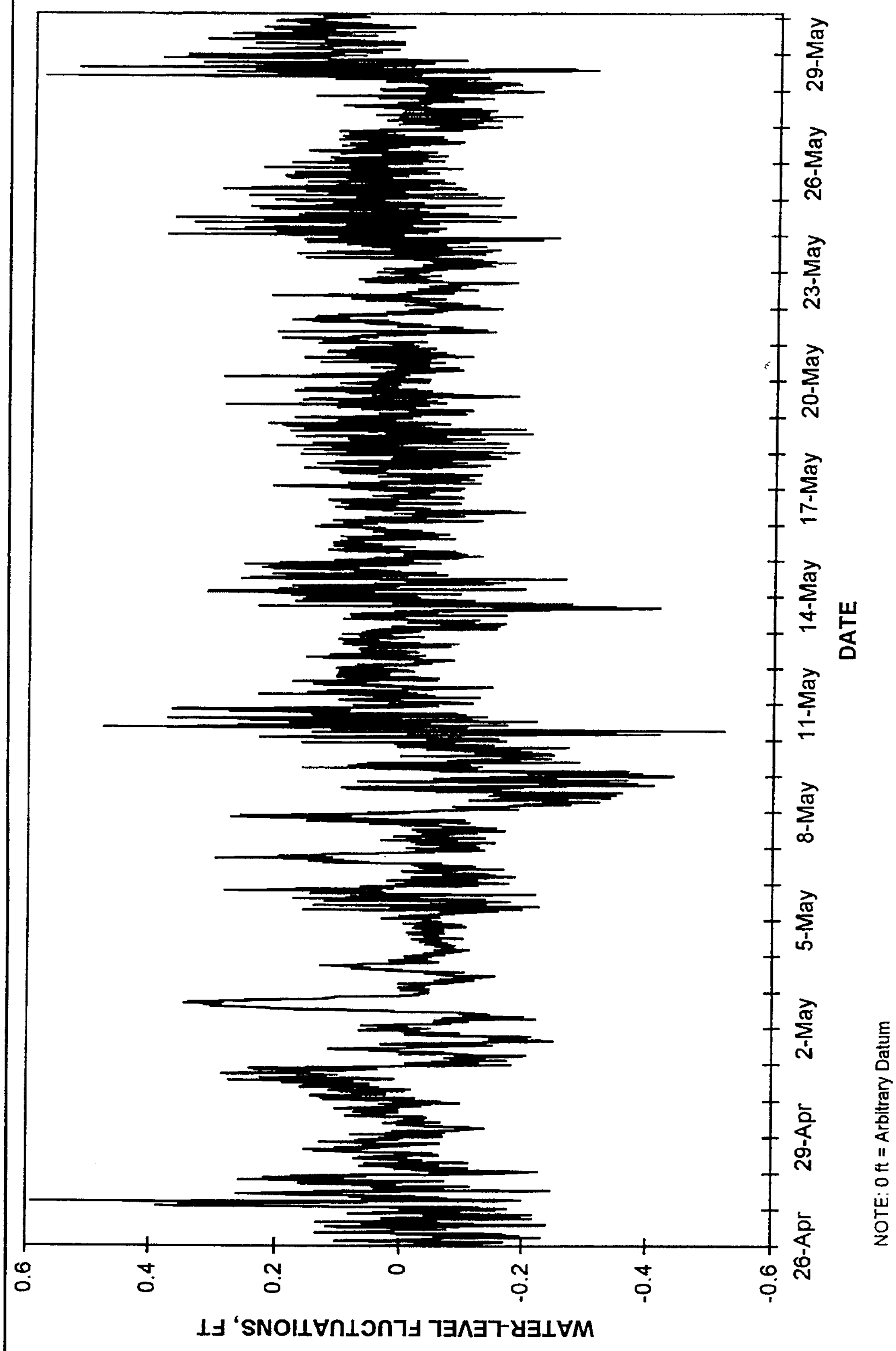


WATER-LEVEL FLUCTUATIONS
STATION WL-1
1 - 29 NOVEMBER, 1995



WATER-LEVEL FLUCTUATIONS
STATION WL-2
27 MARCH - 26 APRIL, 1995

Plate 50



WATER-LEVEL FLUCTUATIONS
STATION WL-2
26 APRIL - 30 MAY, 1995

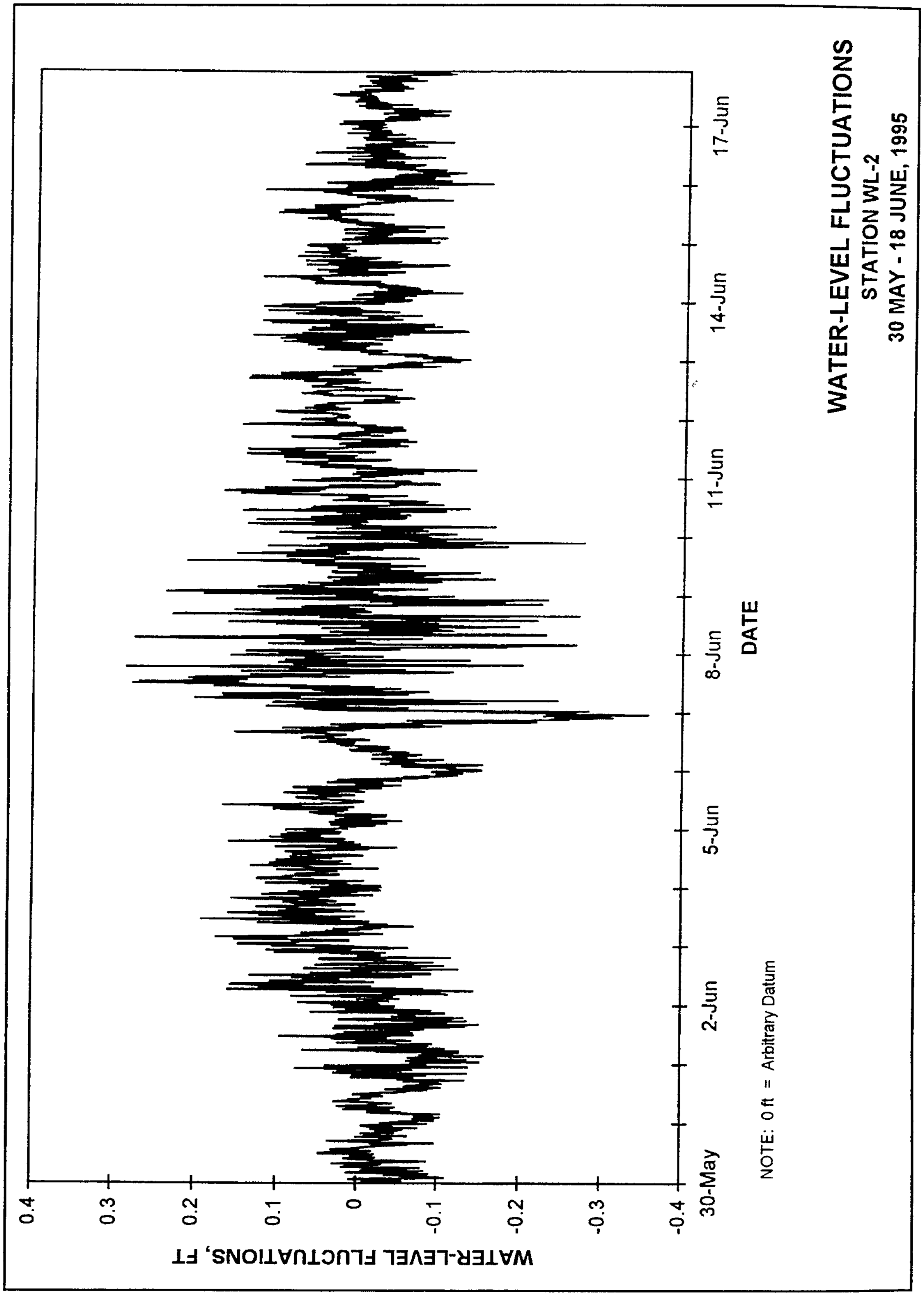
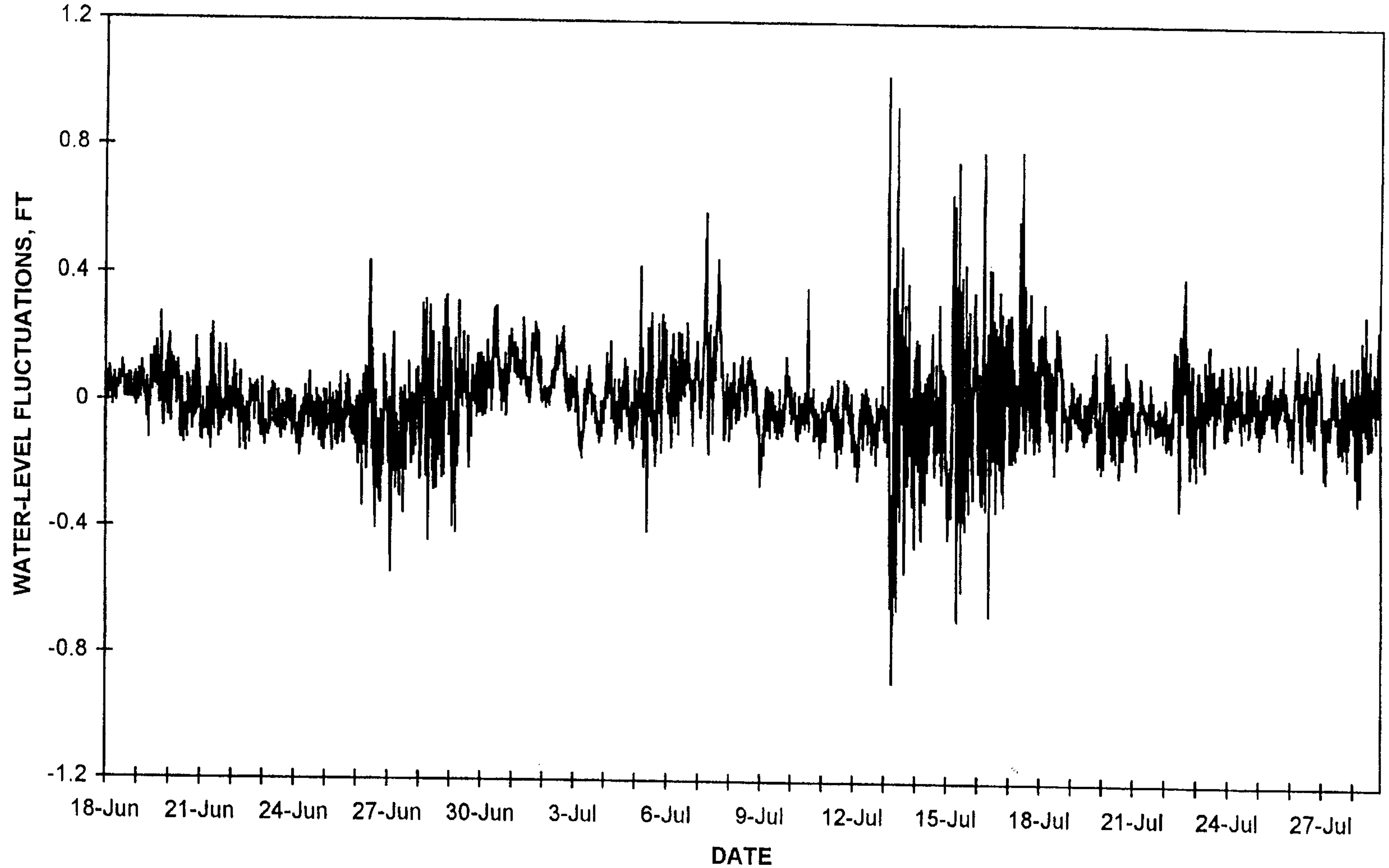
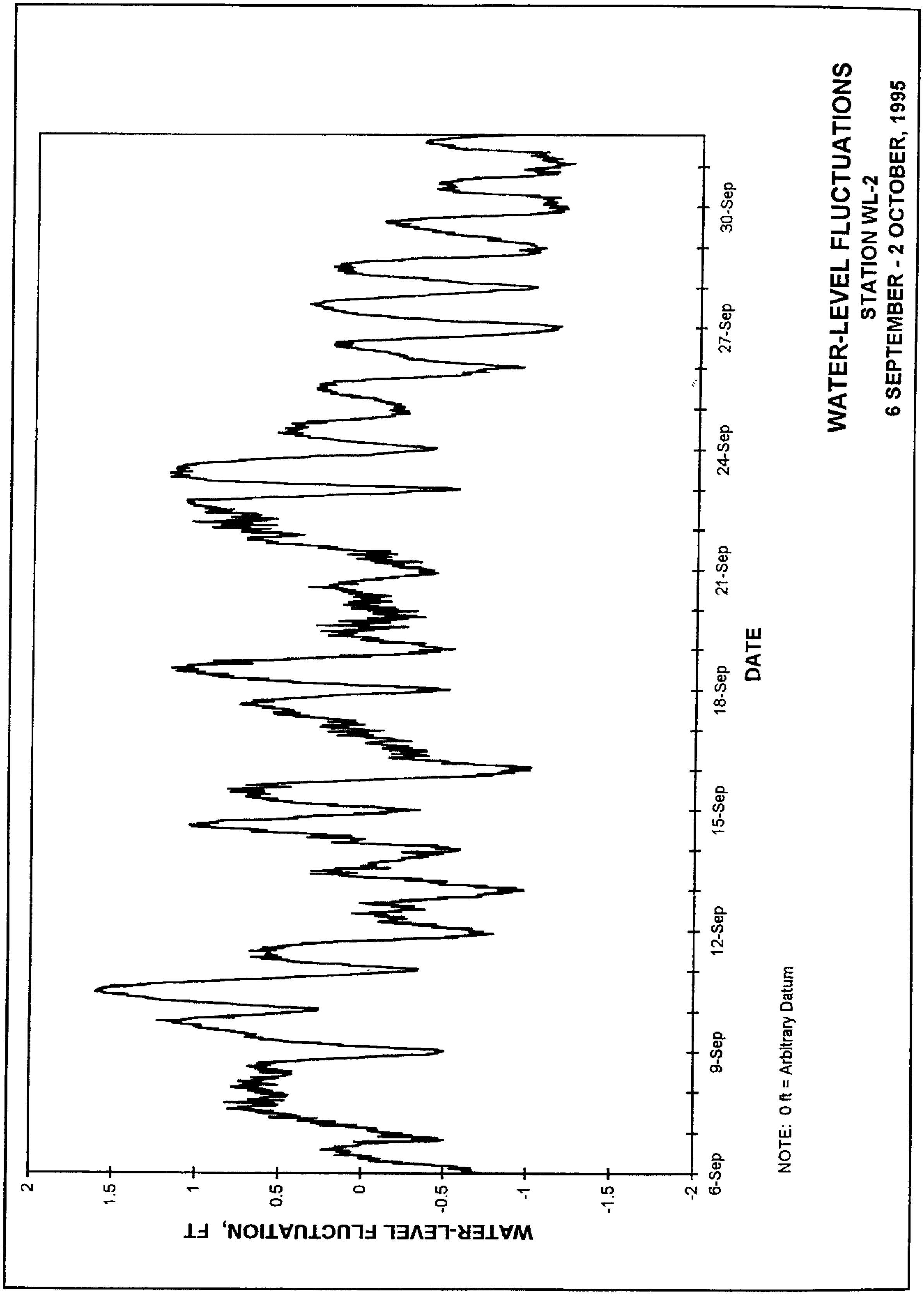

WATER-LEVEL FLUCTUATIONS
STATION WL-2
30 MAY - 18 JUNE, 1995
WATER-LEVEL FLUCTUATIONS, FT
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
30-May
2-Jun
5-Jun
8-Jun
11-Jun
14-Jun
17-Jun
DATE
NOTE: 0 ft = Arbitrary Datum

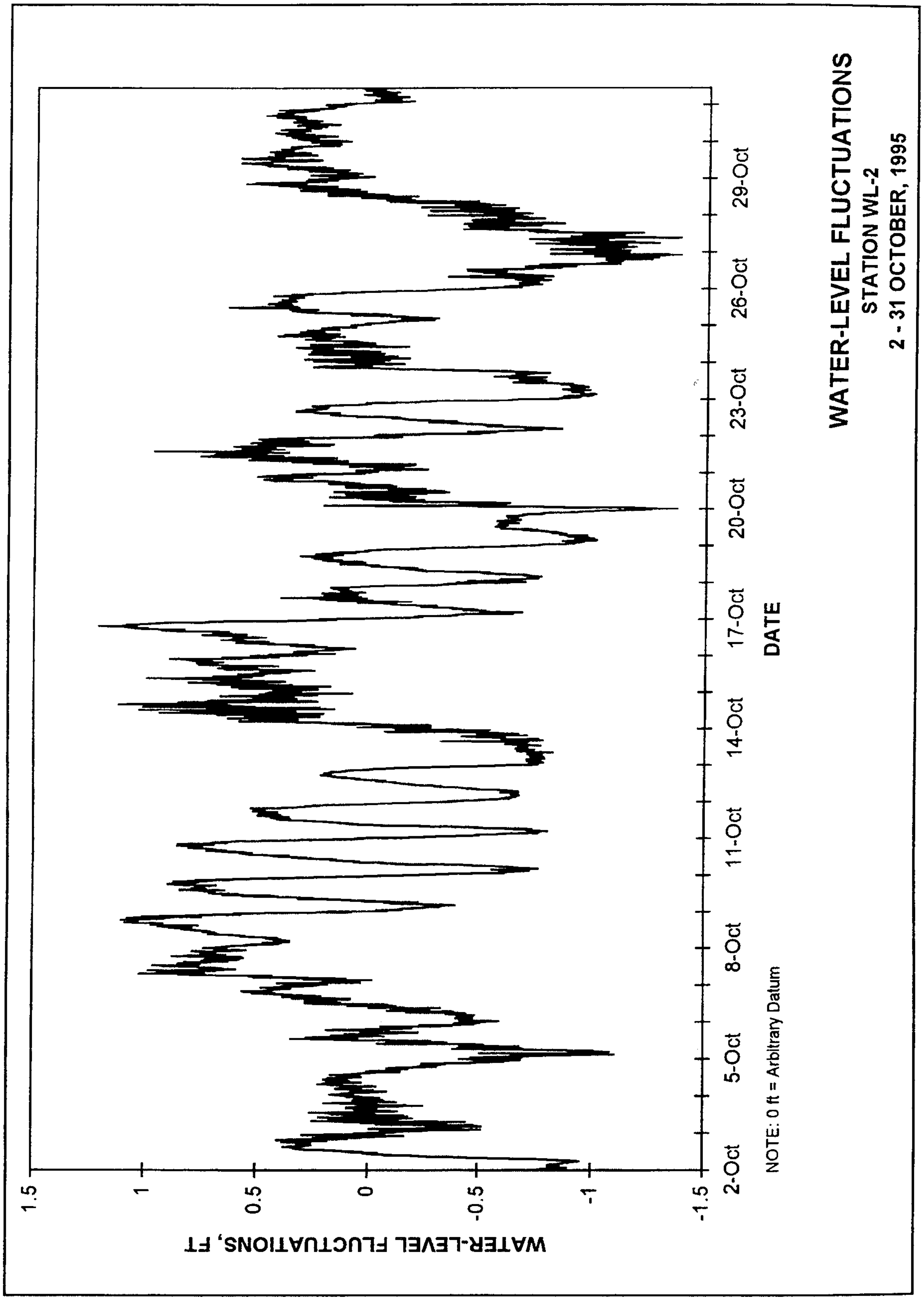
Plate 52



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-2
18 JUNE - 29 JULY, 1995


WATER-LEVEL FLUCTUATIONS
STATION WL-2
6 SEPTEMBER - 2 OCTOBER, 1995
WATER-LEVEL FLUCTUATION, FT
DATE
6-Sep
9-Sep
12-Sep
15-Sep
18-Sep
21-Sep
24-Sep
27-Sep
30-Sep
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
NOTE: 0 ft = Arbitrary Datum


WATER-LEVEL FLUCTUATIONS
STATION WL-2
2 - 31 OCTOBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
1.5
1
0.5
0
-0.5
-1
-1.5
2-Oct
5-Oct
8-Oct
11-Oct
14-Oct
17-Oct
20-Oct
23-Oct
26-Oct
29-Oct
DATE
NOTE: 0 ft = Arbitrary Datum

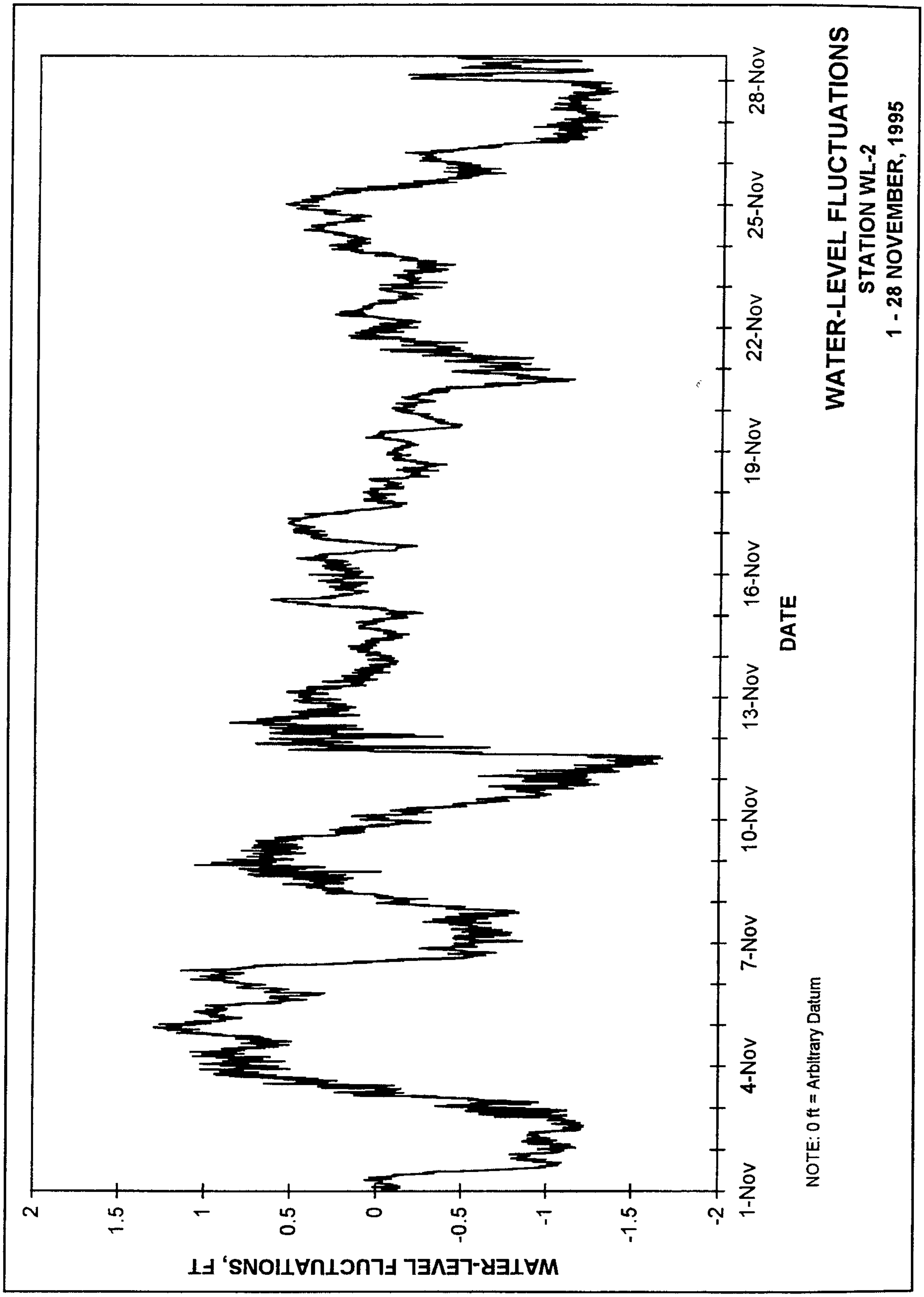
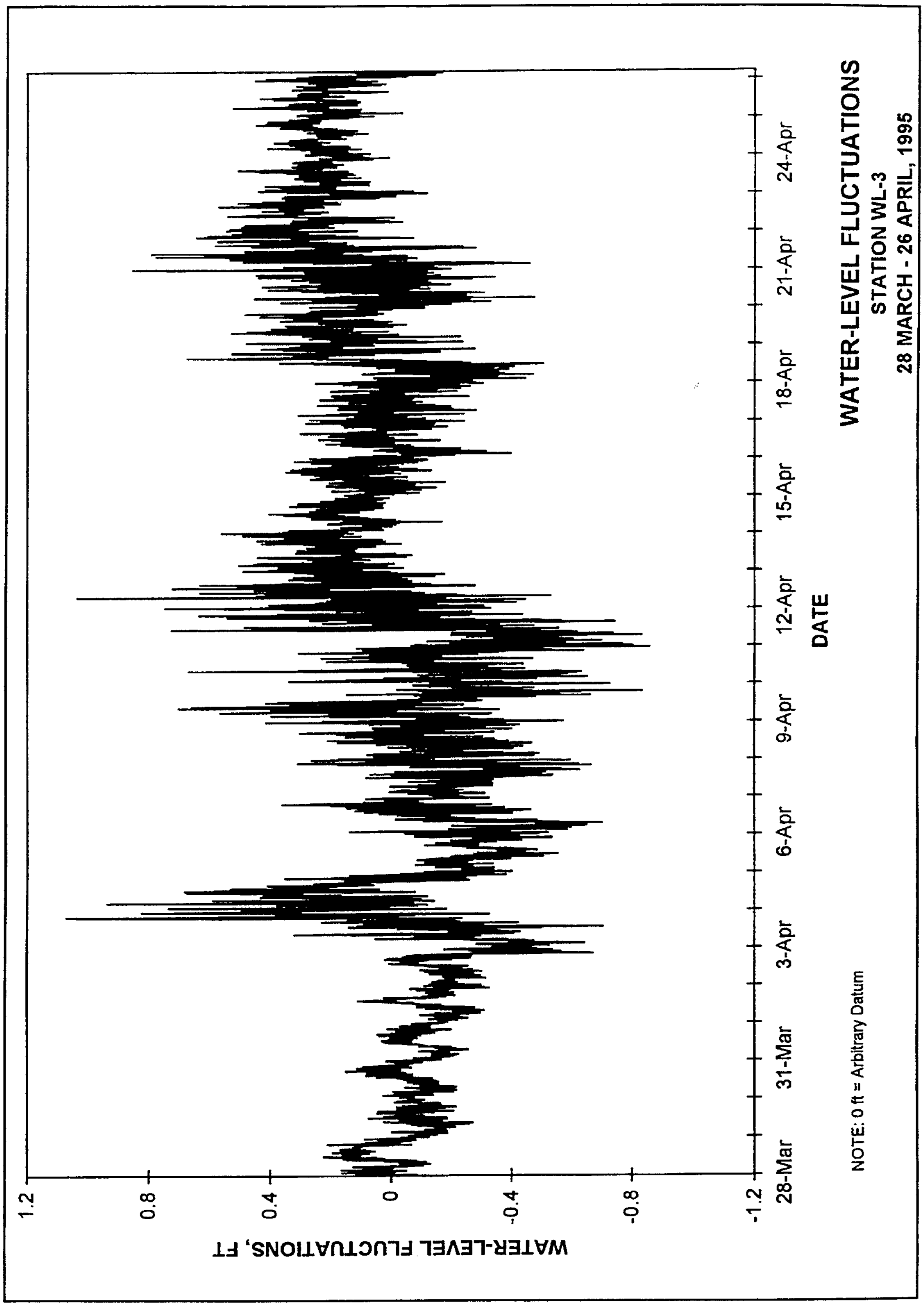
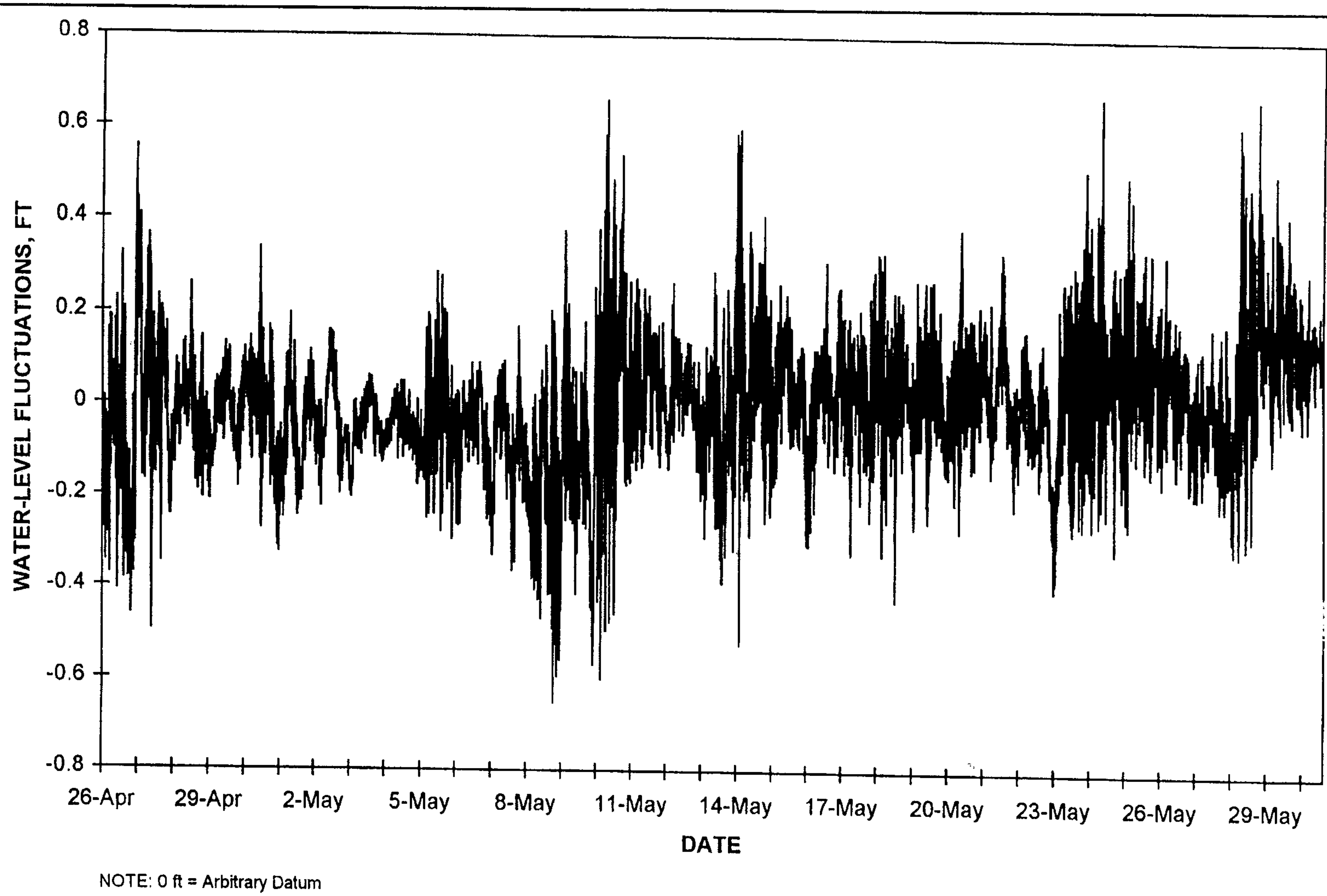
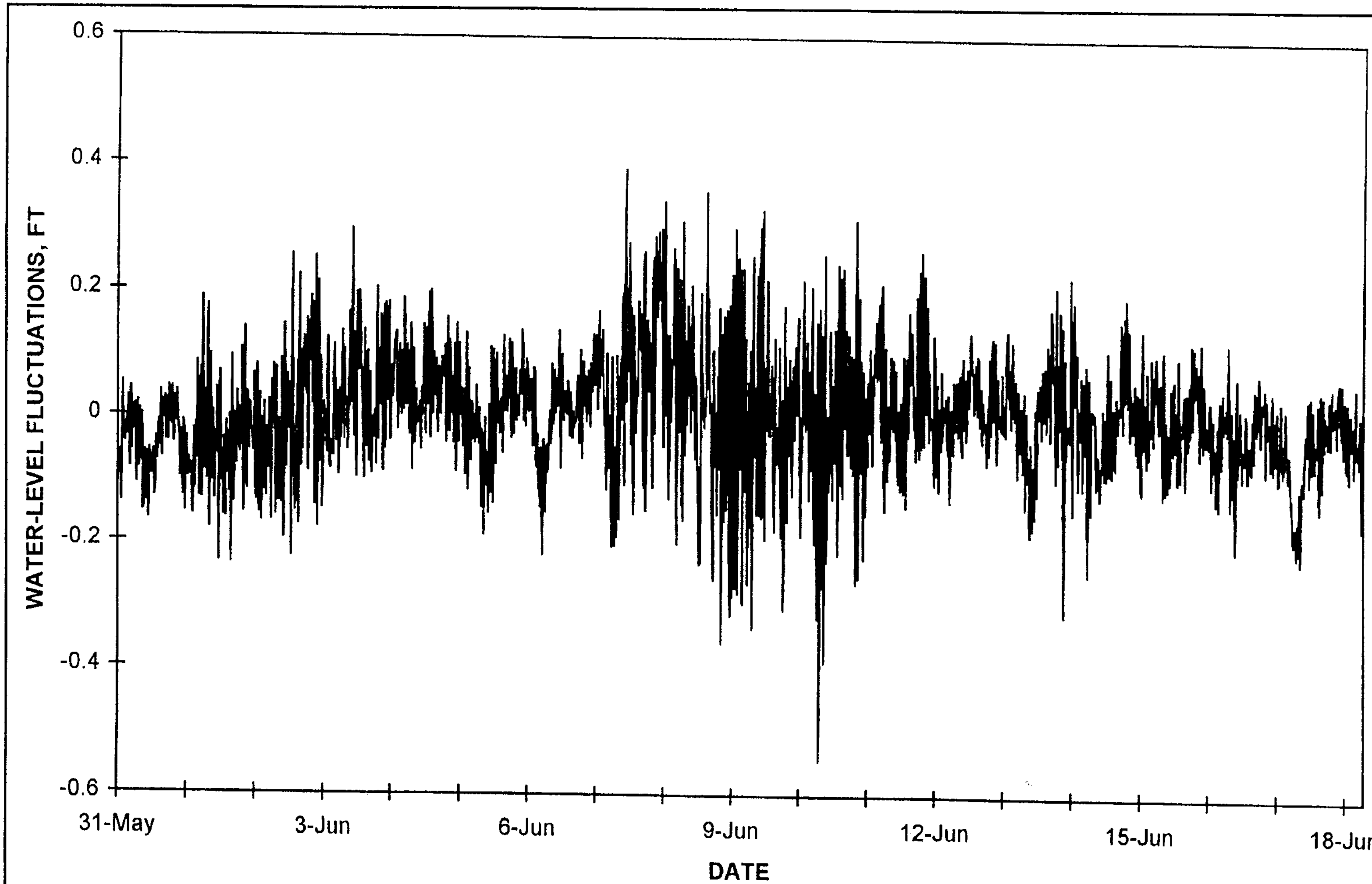

WATER-LEVEL FLUCTUATIONS
STATION WL-2
1 - 28 NOVEMBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
DATE
NOTE: 0 ft = Arbitrary Datum
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1-Nov
4-Nov
7-Nov
10-Nov
13-Nov
16-Nov
19-Nov
22-Nov
25-Nov
28-Nov

Plate 56


WATER-LEVEL FLUCTUATIONS
STATION WL-3
28 MARCH - 26 APRIL, 1995
WATER-LEVEL FLUCTUATIONS, FT
DATE
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
28-Mar
31-Mar
3-Apr
6-Apr
9-Apr
12-Apr
15-Apr
18-Apr
21-Apr
24-Apr
NOTE: 0 ft = Arbitrary Datum

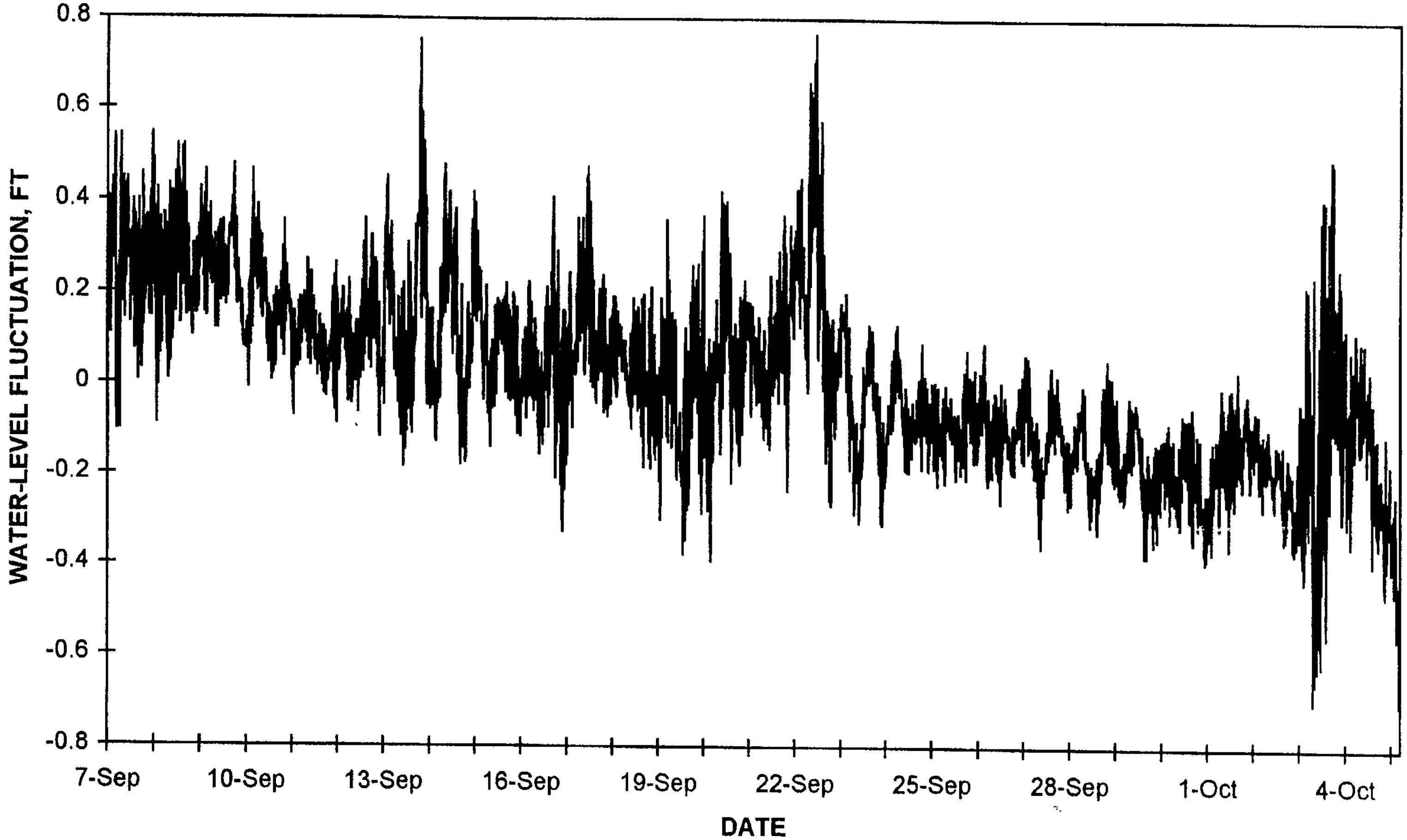


WATER-LEVEL FLUCTUATIONS
STATION WL-3
26 APRIL - 31 MAY, 1995



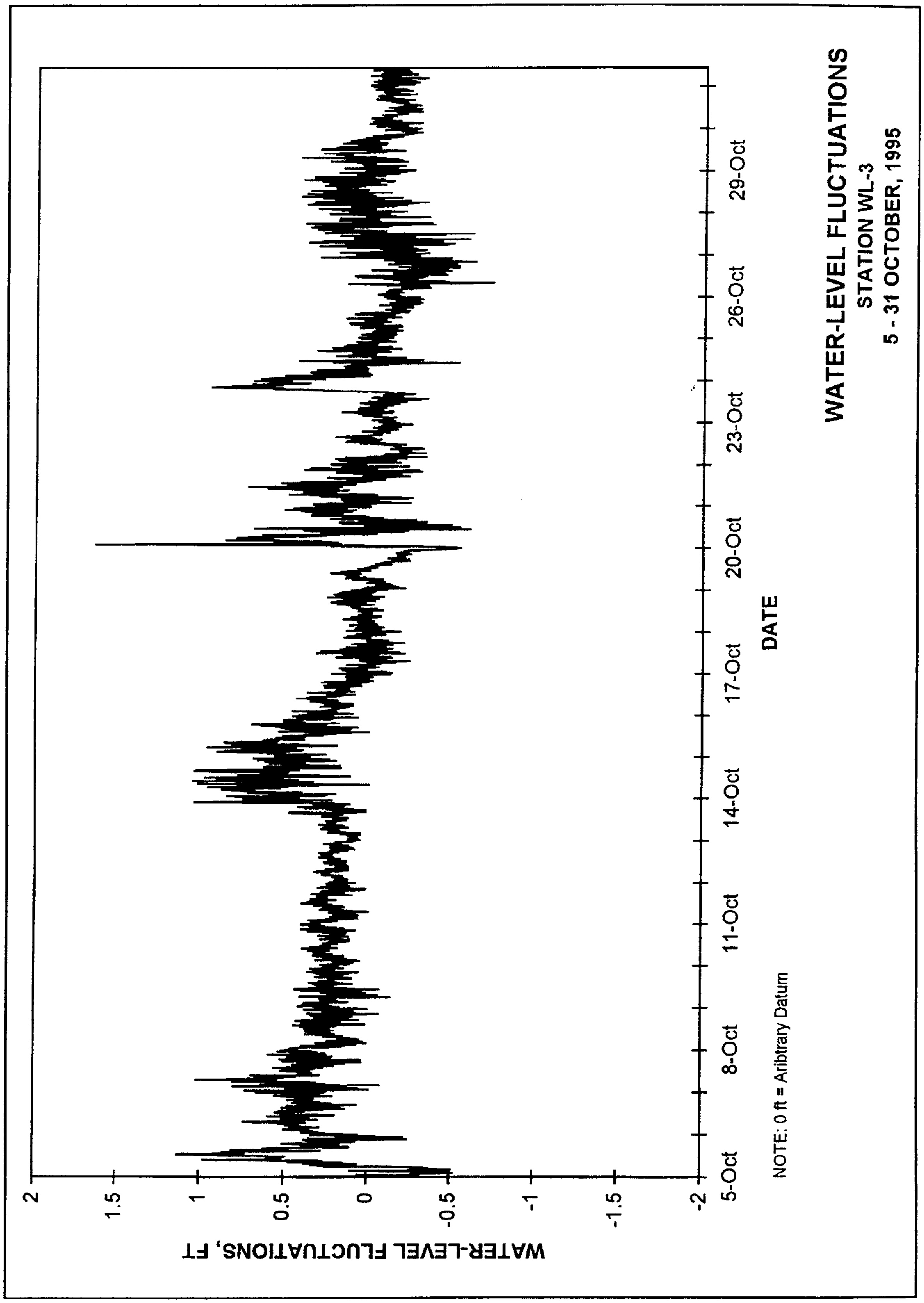
NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-3
31 MAY - 18 JUNE, 1995



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-3
7 SEPTEMBER - 5 OCTOBER, 1995



WATER-LEVEL FLUCTUATIONS
STATION WL-3
5 - 31 OCTOBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
DATE
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
5-Oct
8-Oct
11-Oct
14-Oct
17-Oct
20-Oct
23-Oct
26-Oct
29-Oct
NOTE: 0 ft = Aribtrary Datum

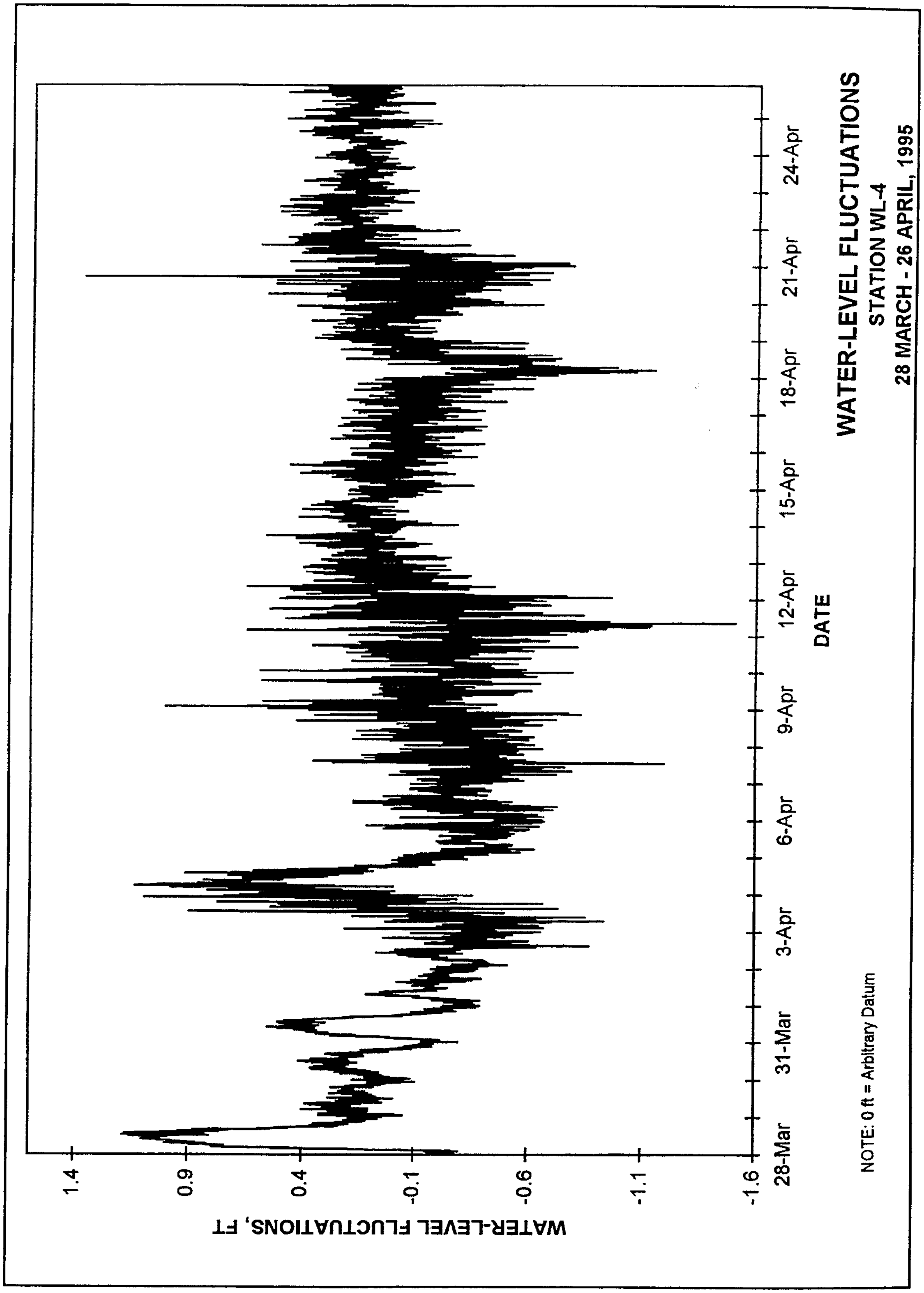
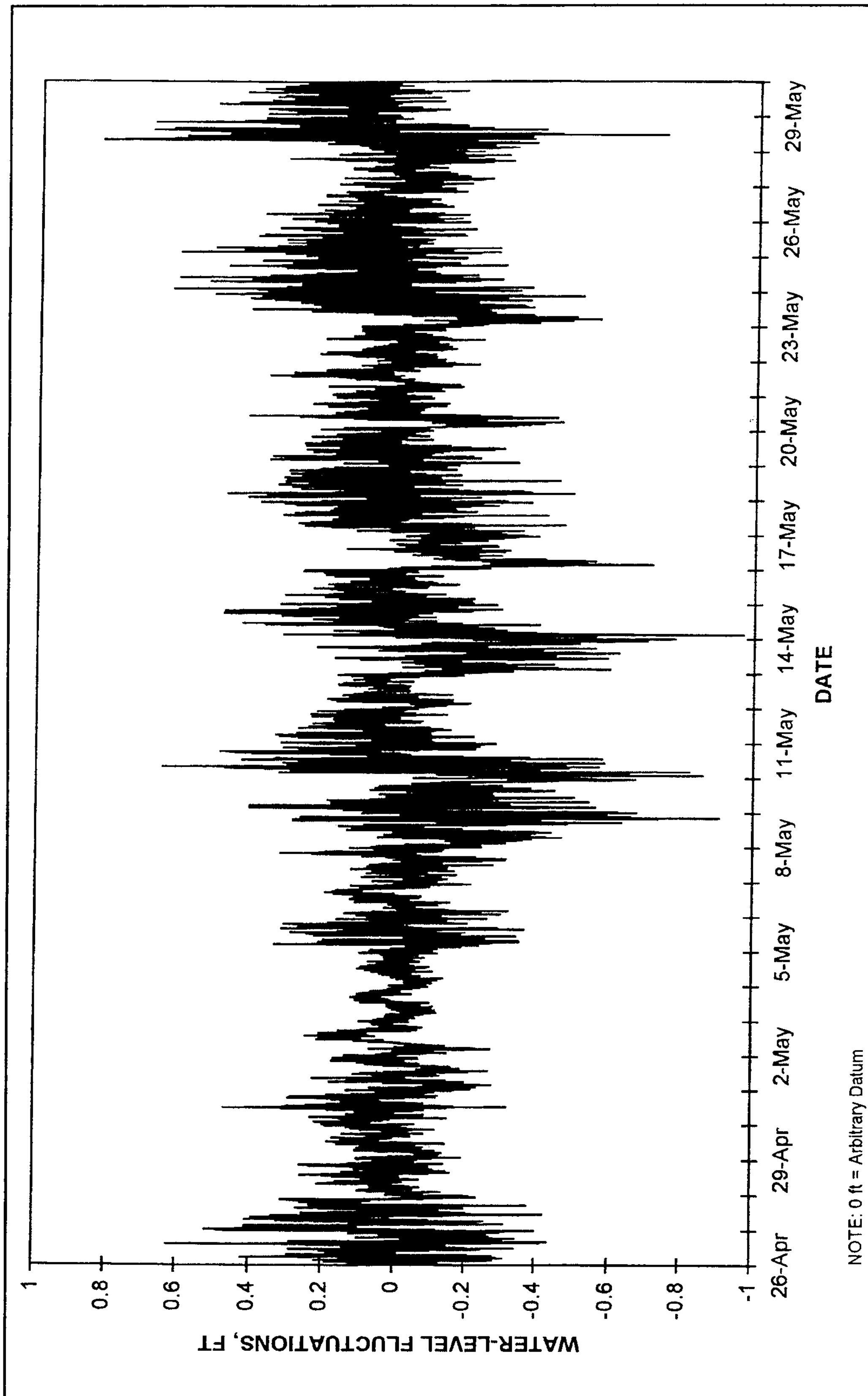
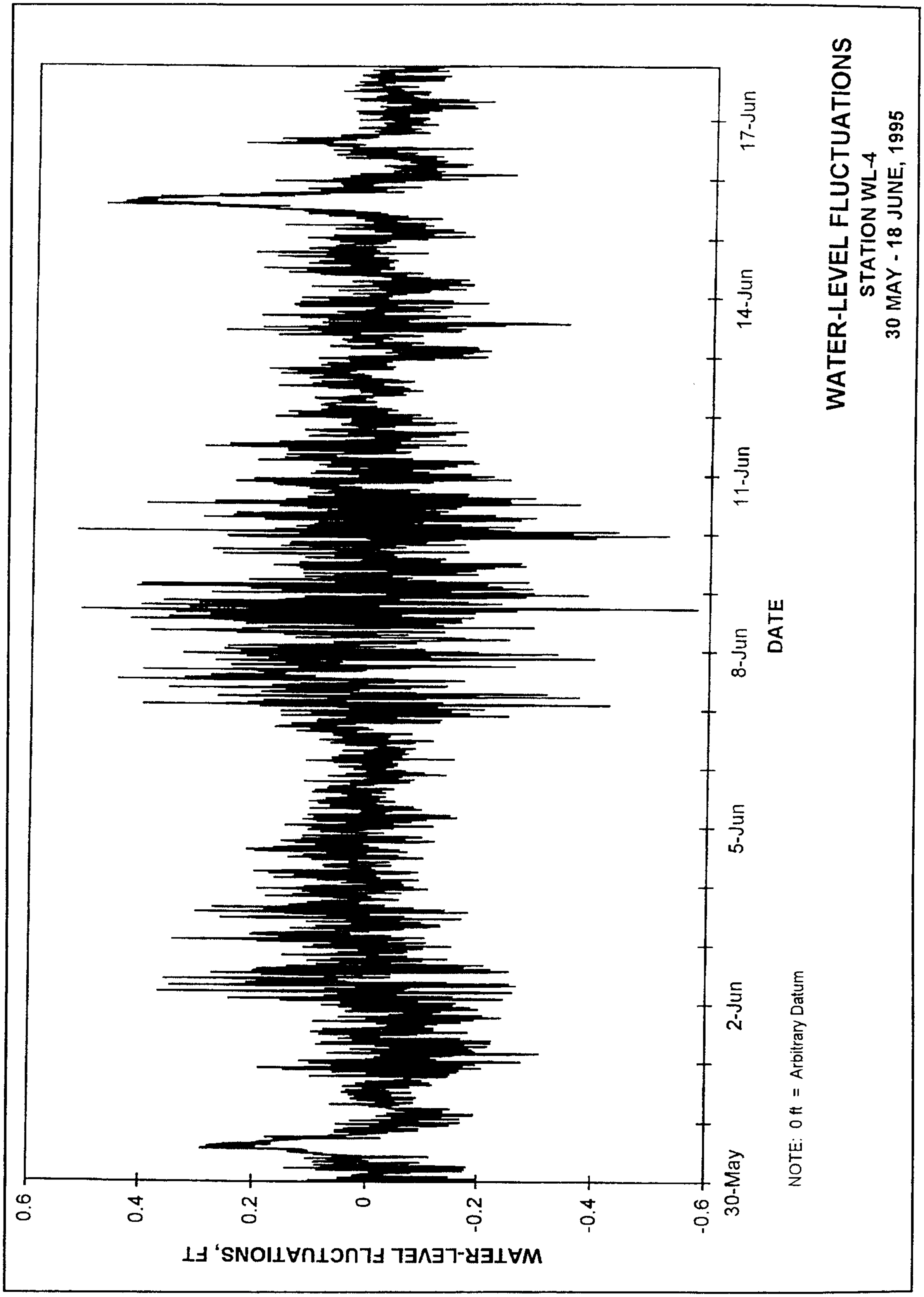

WATER-LEVEL FLUCTUATIONS
STATION WL-4
28 MARCH - 26 APRIL, 1995
WATER-LEVEL FLUCTUATIONS, FT
DATE
1.4
0.9
0.4
-0.1
-0.6
-1.1
-1.6
28-Mar
31-Mar
3-Apr
6-Apr
9-Apr
12-Apr
15-Apr
18-Apr
21-Apr
24-Apr
NOTE: 0 ft = Arbitrary Datum

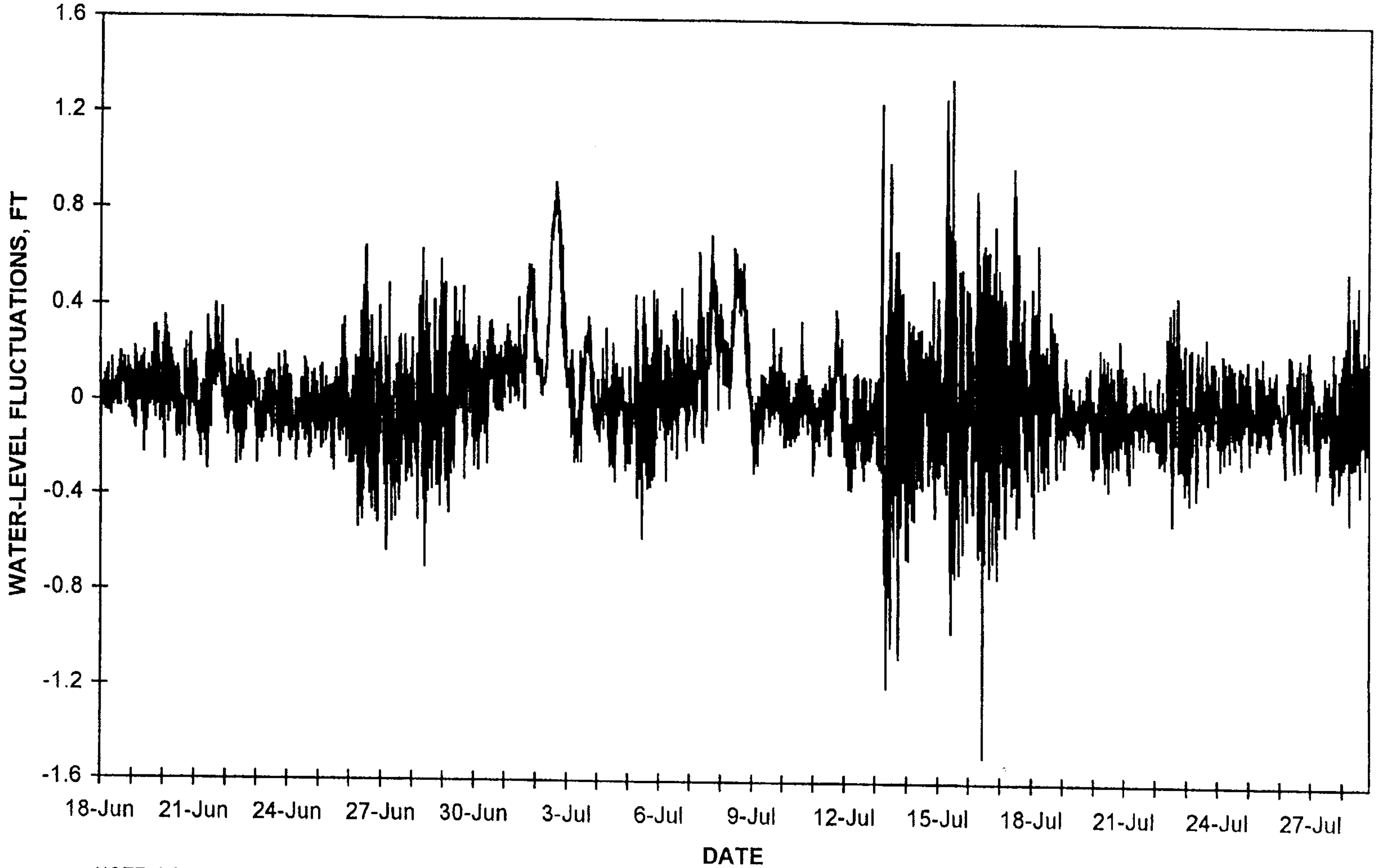
Plate 62



WATER-LEVEL FLUCTUATIONS
STATION WL-4
26 APRIL - 30 MAY, 1995

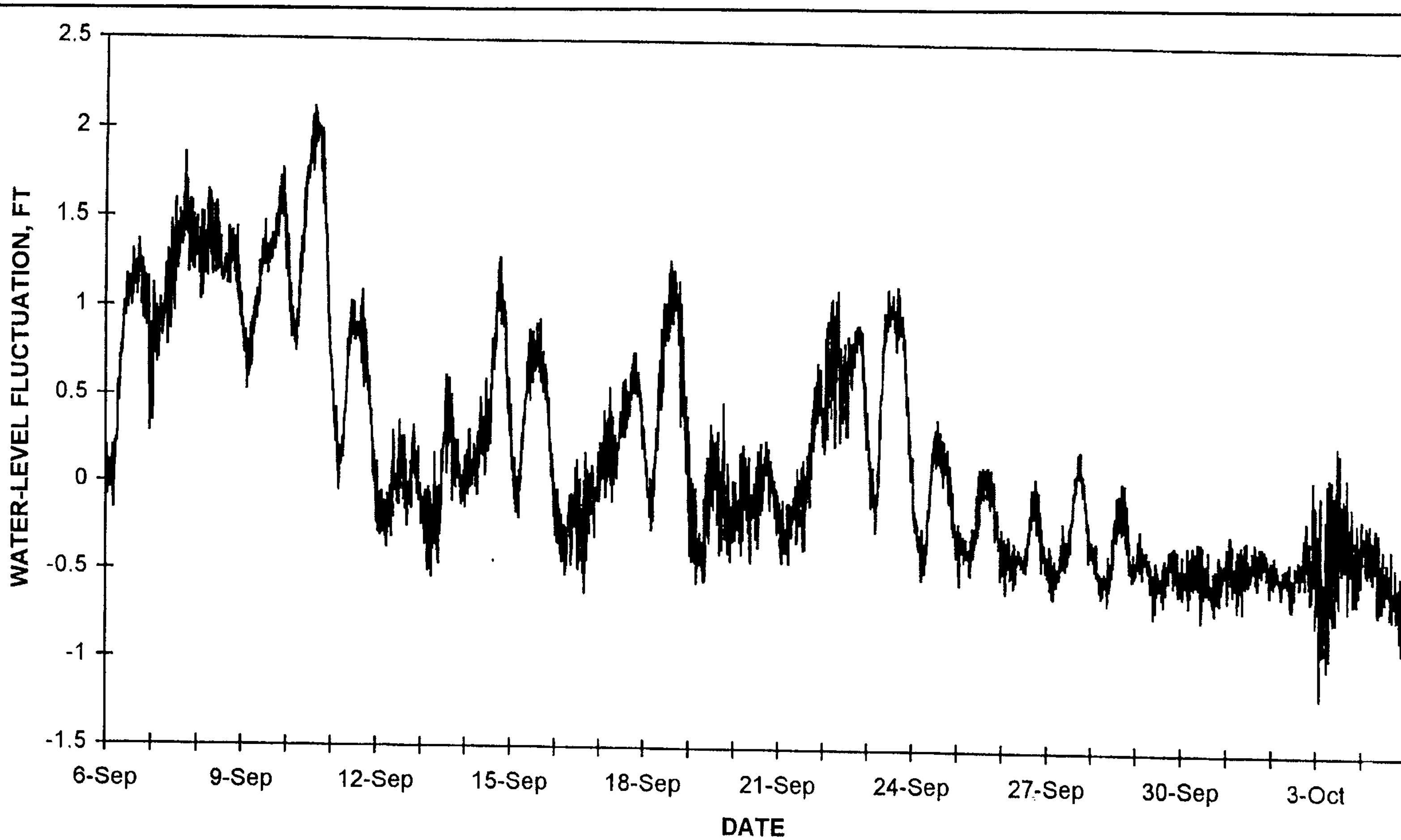


WATER-LEVEL FLUCTUATIONS
STATION WL-4
30 MAY - 18 JUNE, 1995
WATER-LEVEL FLUCTUATIONS, FT
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
30-May
2-Jun
5-Jun
8-Jun
11-Jun
14-Jun
17-Jun
DATE
NOTE: 0 ft = Arbitrary Datum



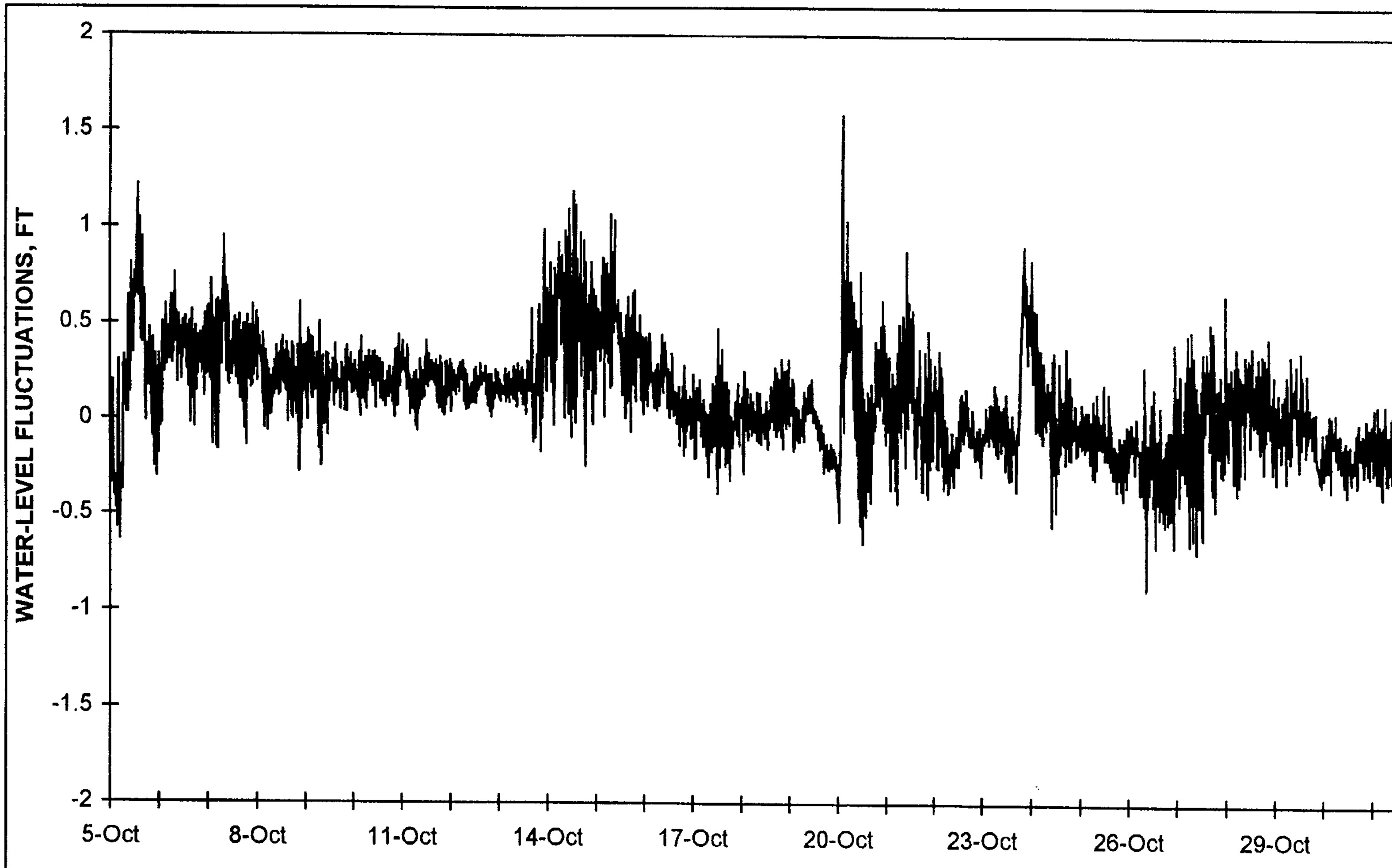
NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-4
18 JUNE - 28 JULY, 1995



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-4
6 SEPTEMBER - 5 OCTOBER, 1995



NOTE: 0 ft = Arbitrary Datum

WATER-LEVEL FLUCTUATIONS
STATION WL-4
5 - 31 OCTOBER, 1995

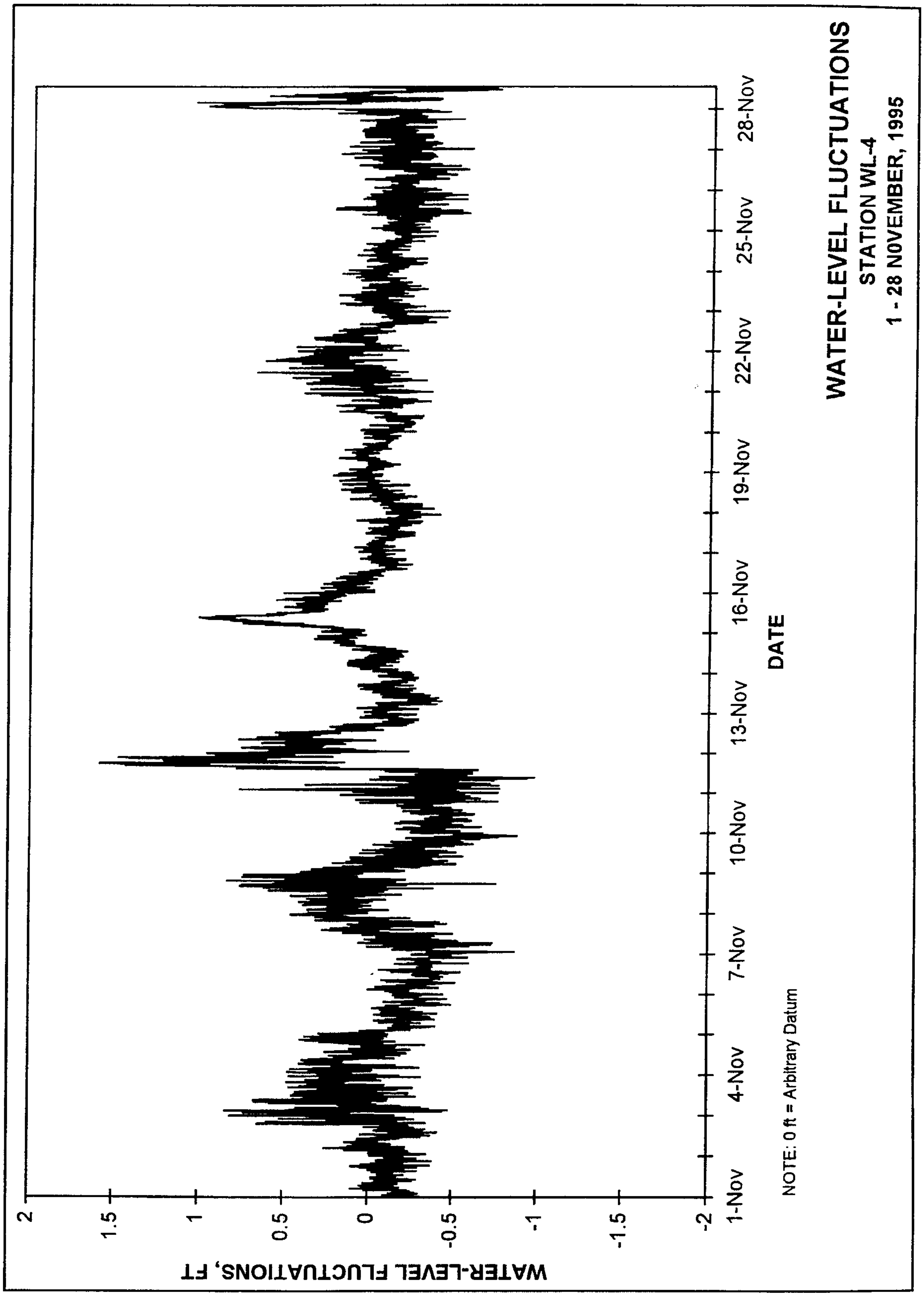

WATER-LEVEL FLUCTUATIONS
STATION WL-4
1 - 28 N0VEMBER, 1995
WATER-LEVEL FLUCTUATIONS, FT
DATE
NOTE: 0 ft = Arbitrary Datum
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1-Nov
4-Nov
7-Nov
10-Nov
13-Nov
16-Nov
19-Nov
22-Nov
25-Nov
28-Nov

Plate 68

Appendix A
Hydraulic Analysis Group Data Collection Equipment and Laboratory Analysis Procedures

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

Current Velocity and Direction Measurements

Acoustic Doppler current meters

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 BroadBand Acoustic Doppler Current Profilers (ADCPs) and SonTek Acoustic Doppler Profilers (ADPs), as shown in Figures A1 and A2, respectively. The RDI instruments vary in operating frequency ranges from 150-1200 kHz, whereas the SonTek instruments have frequency ranges from 75-3,000 kHz. The equipment can be mounted over the side of boat with the acoustic transducers submerged, and data are collected while the vessel is under way, as shown in Figure A3. It can also be mounted on a stable platform and placed on the riverbed or seabed as shown in Figure A4.

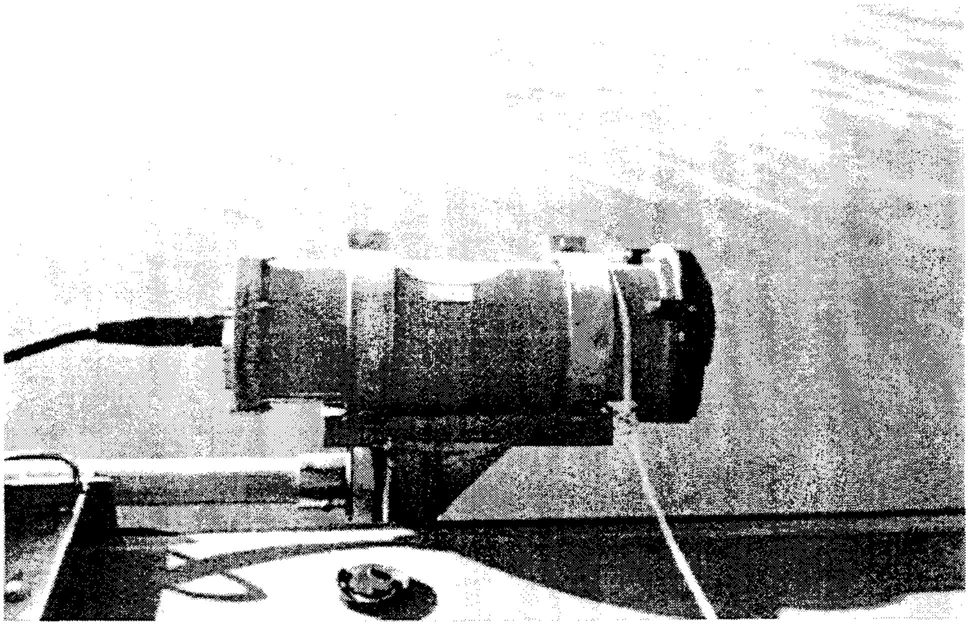


Figure A1. Acoustic Doppler current profiler (ADCP)

The ADCP and ADP transmit sound bursts into the water column. The sound bursts are scattered back to the instrument by particulate matter suspended in the flowing water. The ADCP and ADP sensors listen for the returning signal and assign depth and velocity to the received signal based on the change in 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 is performed with a portable computer using manufacturer-supplied software, hardware, and communication cables. The manufacturer-stated accuracies are ±0.2 cm/sec for current speed measurement; ±2 deg for vessel direction; and ±5 °F for temperature.

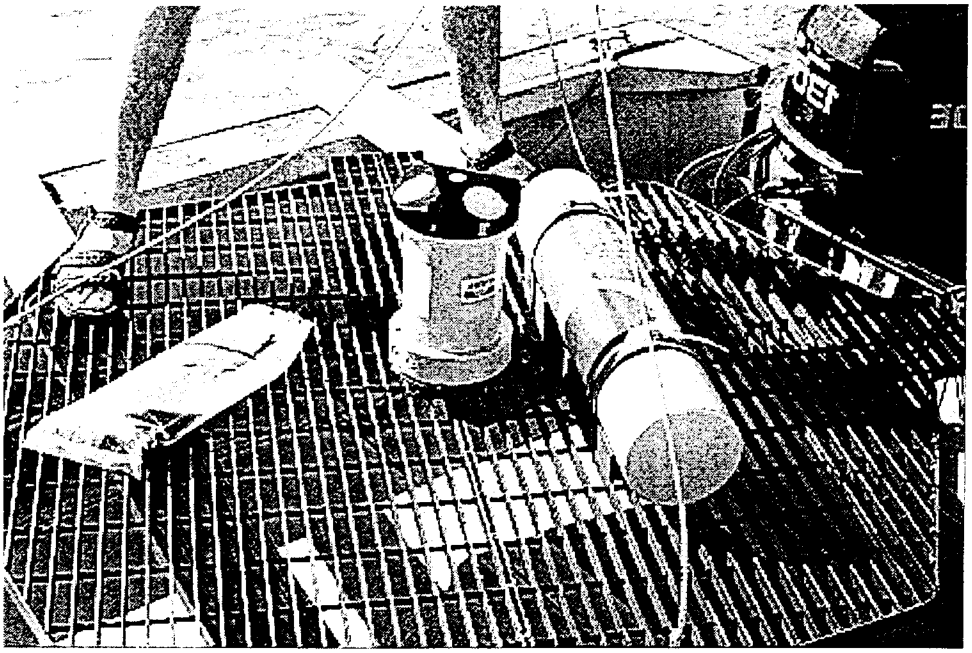


Figure A2. Acoustic doppler profiler (ADP)

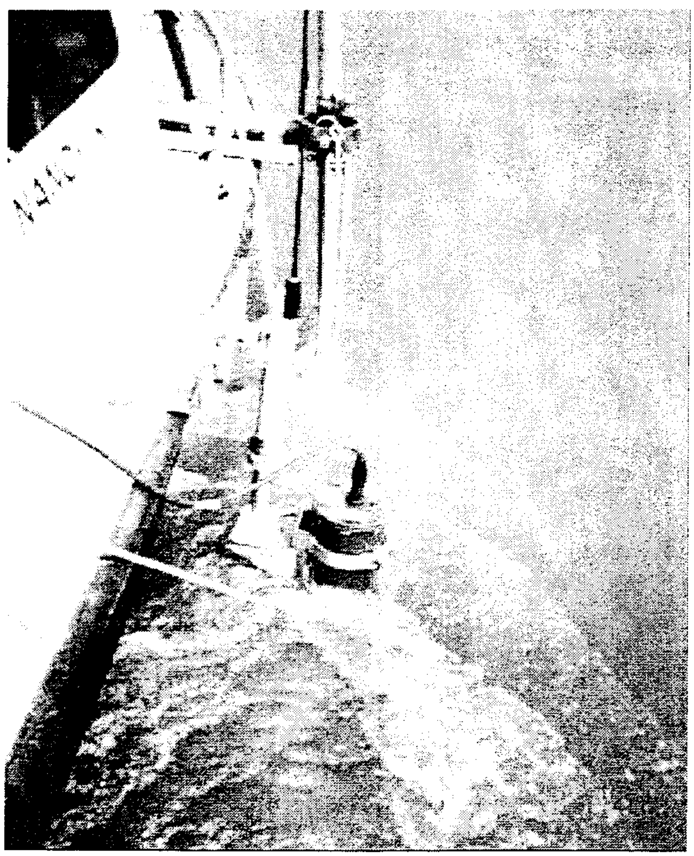


Figure A3. Vessel-mounted ADCP

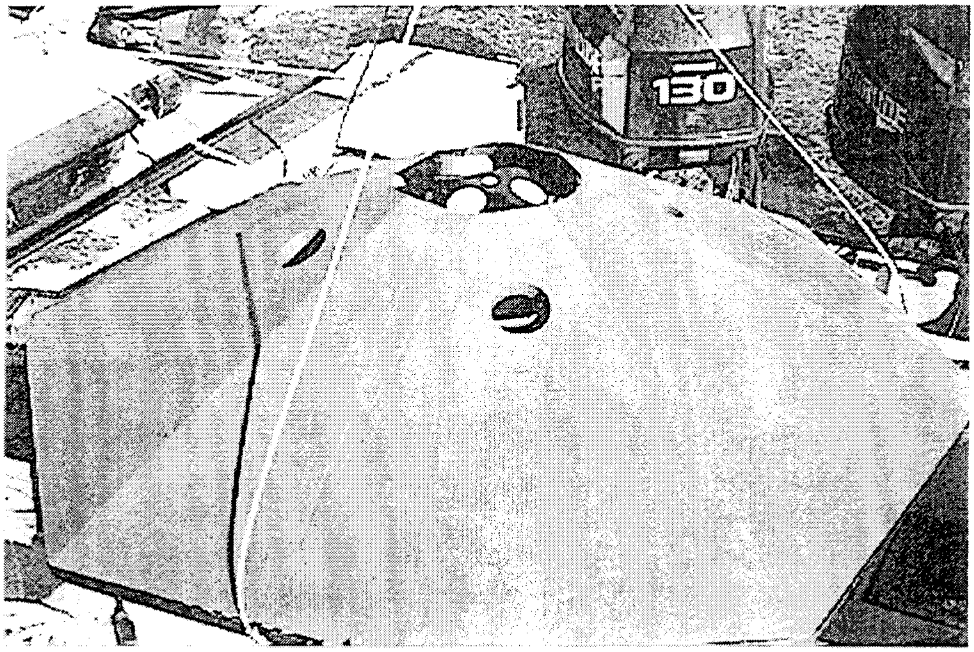


Figure A4. Bottom-mounted ADP unit

Fixed-depth recording current 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 Environmental Device Corporation (ENDECO) Type 174 SSM current meter, shown in Figure A5, is tethered to a stationary line or structure and floats in a horizontal position at the end of the tether (as shown in Figure A6). It measures current speed with a ducted impeller and current direction with an internal compass. It 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 between the meter and a computer. The threshold speed is less than 2.5 cm/sec, maximum speed of the unit is about 2.5 m/sec (10 knots), and stated speed accuracy is ±2 percent of full scale. The manufacturer states that direction accuracy is ±7.2 deg above 2.5 cm/sec. Time accuracy is ±4 sec/day.

The InterOcean Model S4 electromagnetic current meter, shown in Figure A7, can continuously record current velocity and direction at fixed depths or can be used to profile the water column for current velocity and direction. The S4 meter is a 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 A8. The S4 meter measures the current velocity using an electromagnetic microprocessor coupled with an internal flux-gate compass and computes the velocity

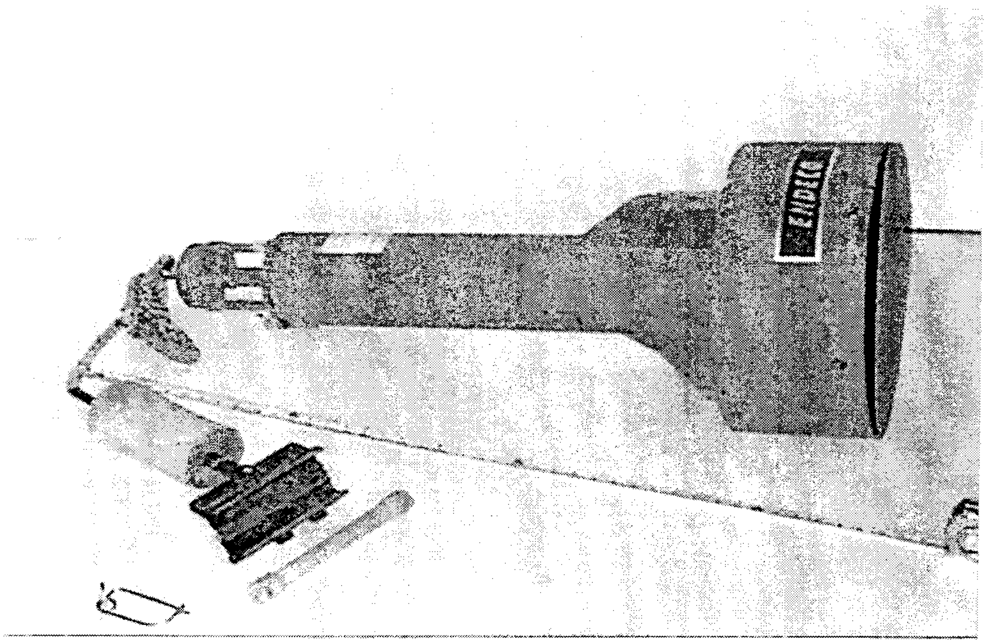


Figure A5. ENDECO Type 174 SSM current meter

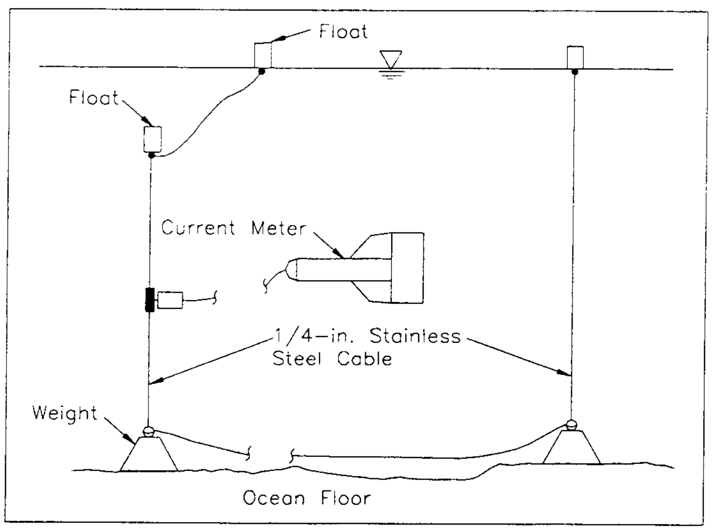


Figure A6. ENDECO 174 SSM current meter as deployed in the field

vectors, which are then stored in the solid-state memory. The accuracy of the S4 meter current speed is ±0.2 cm/sec.

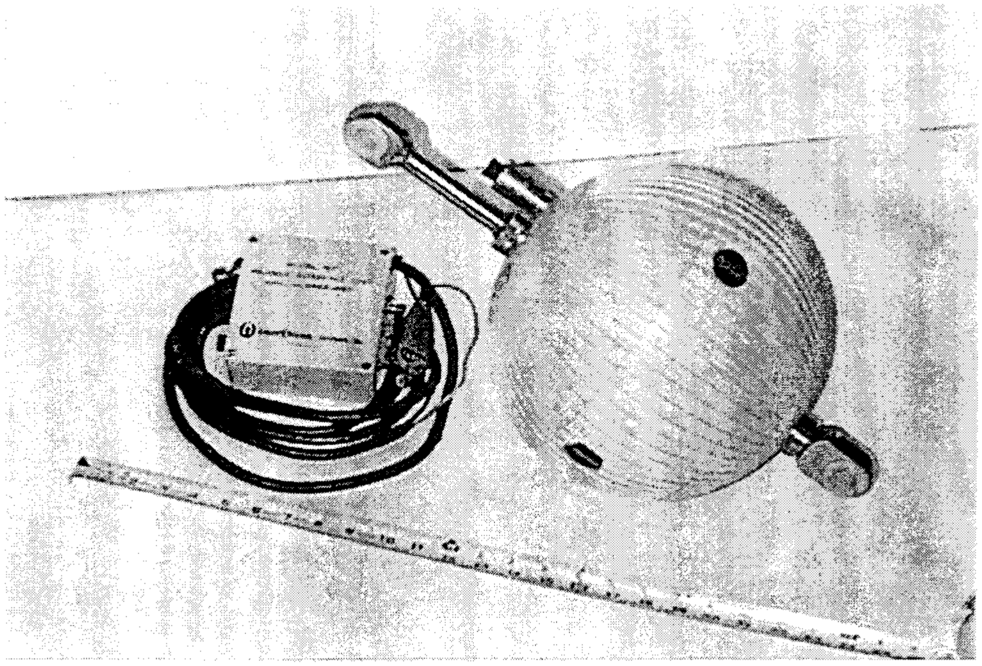


Figure A7. InterOcean S4 electromagnetic current meter

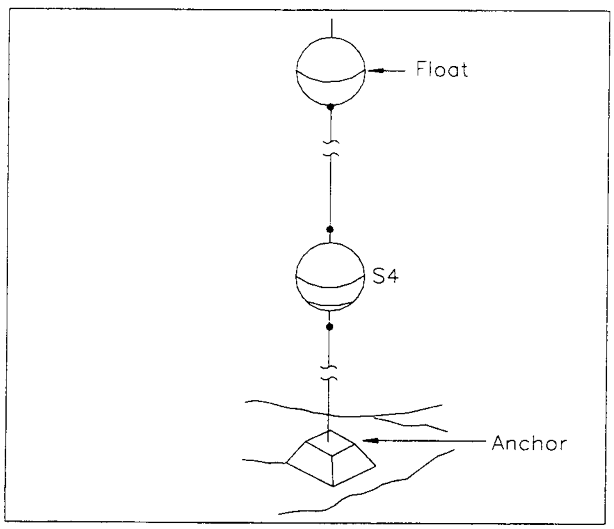


Figure A8. Electromagnetic current meter deployment technique

Suspended Sediment Sampling

Pumped water samples

In combination with the over-the-side velocity measuring equipment, water samples for analysis 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 1/4-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-V dc pump is used to pump the water through the tubing to the deck of the boat where each sample is then collected in individual 8-oz. plastic bottles. The pump and tubing are flushed for approximately 1 min at each depth before collecting the sample.

Automatic water sampler

The ISCO Model 6700 automatic water sampler, shown in Figure A9, and the American Sigma Models 700 and 2000 are employed to provide unattended sampling. A typical field installation of these water samplers is shown in Figure A10. Discrete water samples are collected in 1-ℓ plastic bottles located inside the sampler. The samplers are fully programmable, operating from a 12-V DC power source, for obtaining any volume of sample desired up to the maximum size of the bottle, for obtaining composite samples, for setting different intervals between samples, and for setting times to begin the sampling routine. During servicing, the sample bottles are replaced with empty bottles to begin a new sampling period.

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 infrared light from suspended matter. It consists of a high-intensity infrared emitting diode (IRED), a series of silicon photodiodes as detectors, 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 A11. Scattering by particles is a strong function of the angle between the path of radiation from the sensor 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.

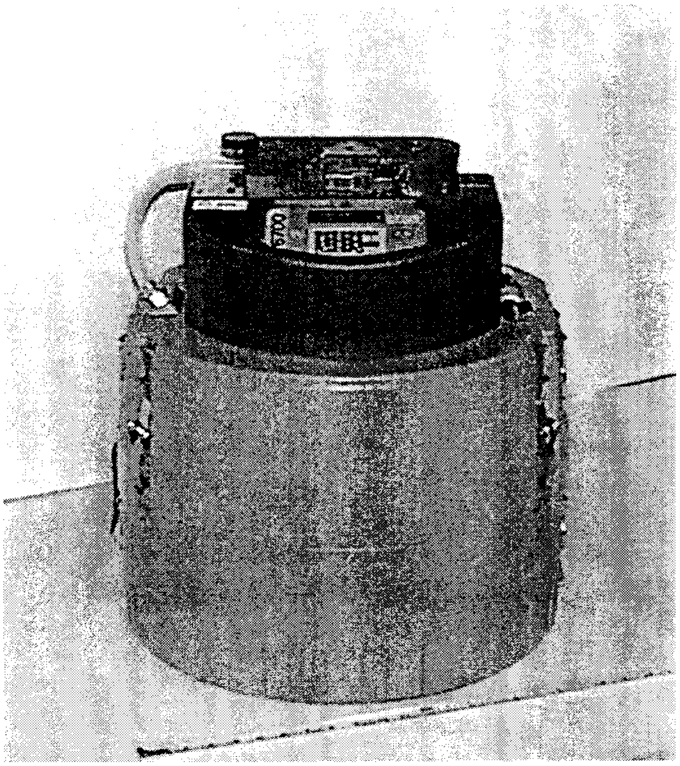


Figure A9. ISCO Model 6700 automatic water sampler

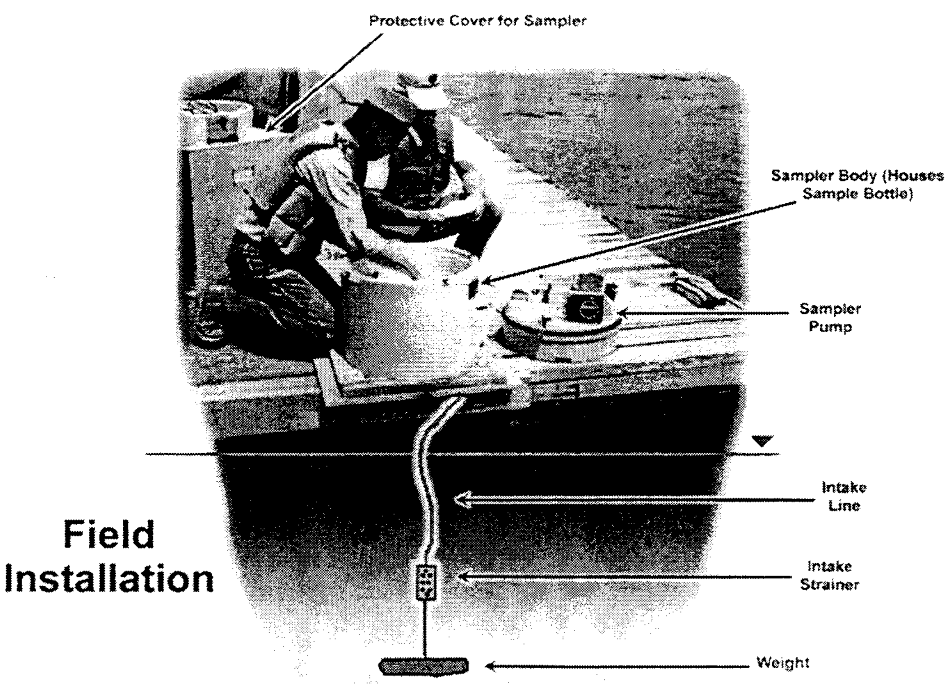


Figure A10. Typical field installation of automatic water samplers

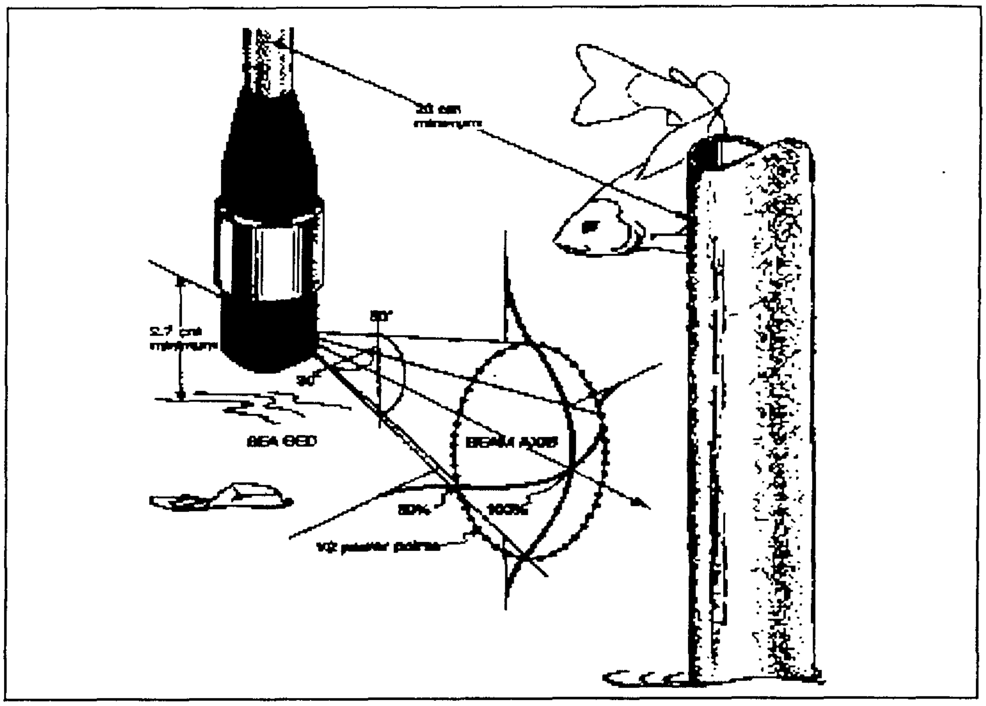


Figure A11. OBS sensor beam pattern

Salinity Measurements (Hydrolab DataSonde 3 Water Quality Data Loggers)

The Hydrolab Datasonde 3 water quality data logger, shown in Figure A12, provides conductivity and temperature with a computed salinity concentration measurement corrected to a known calibration standard at 25 °C. The recorder housing is a high-density PVC case with a specific conductance cell and temperature sensor. The specific conductance probe is a six-electrode cell having a measurement range of 0.0 to 100 mS/cm with an accuracy of ±1 mS/cm. The salinity concentration range is from 0.0 to 40 ppt with an accuracy of ±0.2 ppt (calculated from the conductivity). The temperature probe is a thermistor type sensor with a measurement range of -5 ° to 50 °C with an accuracy of ±0.15 °C. Data sampling intervals range from 1-59 sec, 1-59 min, or 1-23 hr. Data are stored on nonvolatile EPROM chips. Internal or external batteries provide the power requirements for sensor operation and data storage. Data are offloaded from the instrument via an industry standard RS-232 port to a portable computer using standard communication software.

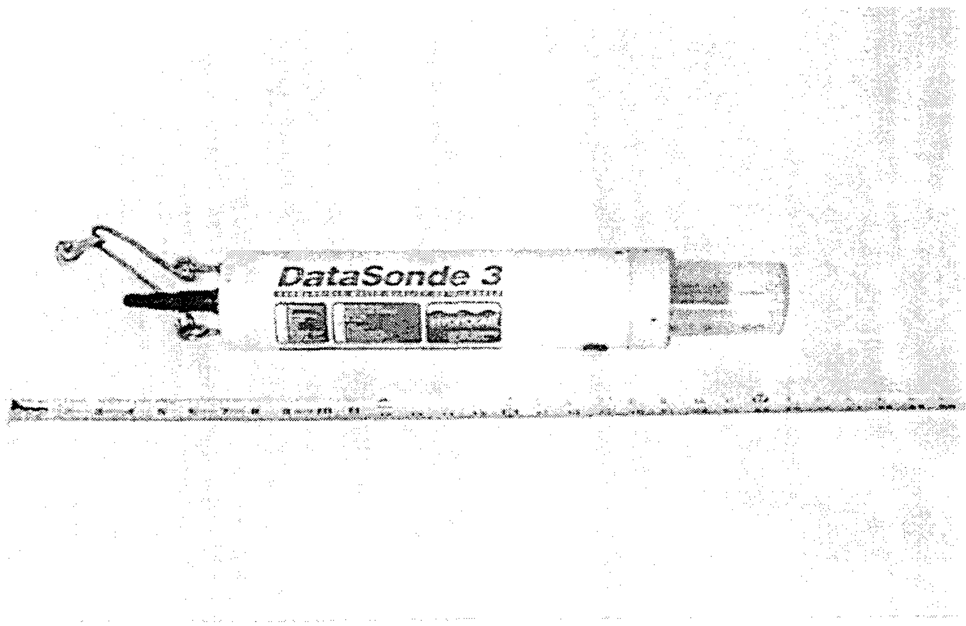


Figure A12. Hydrolab Datasonde 3 water quality data logger

Wave Height Measurements (Electronic Wave Height Recorders)

The Microtide water level recorders, shown in Figure A13, 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 ±0.6 cm. The sampling time interval can be set from 0.25 sec to 24 hr. The Microtide also measures temperature by means of a Yellow Springs Instruments (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. Data from each recorder are stored on an accessible RAM located in the waterproof subsurface unit, which also contains the DC power supply.

Water Level Measurements (Electronic Water Level Recorders)

Water level elevation measurements can also be recorded using solid-state electronic recorders, such as Microtide, YSI, and ENDECO water level recorders. Water level elevations, temperature, conductivity, salinity, and dissolved oxygen (DO) concentrations are recorded using YSI Model 6000 water

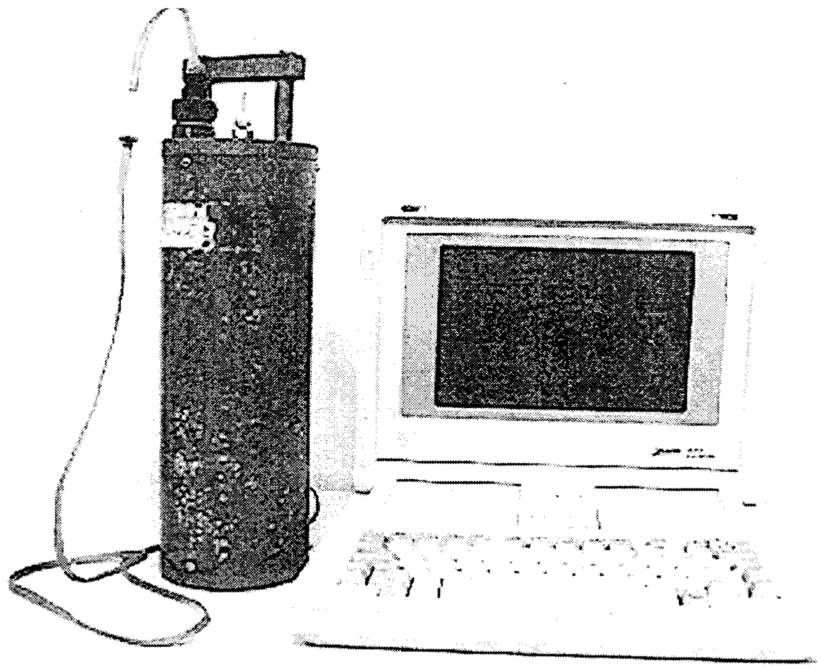


Figure A13. Microtide electronic wave height recorder

level recorders and ENDECO Models 1152 and 1029 SSM (solid-state measurement) water level recorders (excluding the DO measurements). The ENDECO Model 1152 SSM, shown in Figure A14, and Model 1029 SSM 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 ±1.5 cm. The sampling time interval can be set from 1 min to 1 hr. Models 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 Model 1152 measures conductivity by an inductively coupled probe installed on the meter. These measurements and the measurements of temperature are used to calculate salinity concentrations in units of parts per thousand (ppt). The salinity 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 which also contains the DC power supply.

The YSI/ENDECO Model 6000 recorder (Figure A15) also uses a strain-gauge type pressure transducer located in a subsurface case and records the absolute pressure of the water column above the case. The Model 6000 is not vented

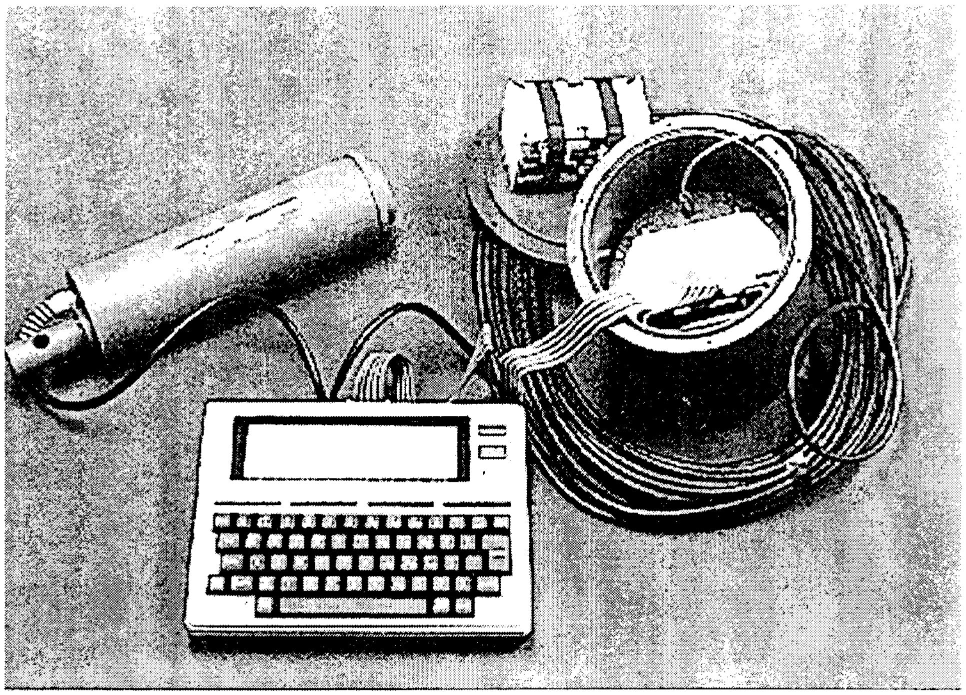


Figure A14. ENDECO Model 1152 SSM water level recorder

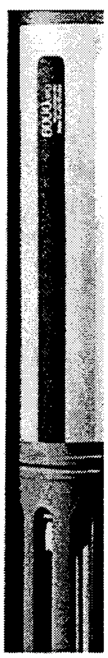


Figure A15. YSI/ENDECO Model 6000 water level recorder

to compensate for atmospheric pressure; therefore, after the sensor is initially calibrated, any changes in barometric pressure will appear as changes in depth. This is particularly significant in shallow water. For example, a change of 1 mm of Hg in barometric pressure will change the apparent depth by approximately

1.37 cm. The range of 0-9.14 m of water has an accuracy of ±1.83 cm and a resolution of 0.03 cm. The Model 6000 utilizes a thermistor of sintered metallic oxide, which changes predictably in resistance with temperature variations. The thermistor has a range of -5 ° to +45 °C, with an accuracy of ±0.15 °C and a resolution of 0.01 °C. The Model 6000 measures conductivity using a four-nickel-electrode cell in the range of 0-100 mS/cm with an accuracy of ±0.5 percent and a four-digit resolution. Salinity is calculated based on conductivity and temperature measurements in the range of 0-70 ppt with an accuracy of ±0.1 ppt and a resolution of 0.01 ppt. The Model 6000 uses a dissolved oxygen (DO) sensor that employs a patented "Rapid-Pulse" measuring technique. Its range is 0-20 mg/ℓ with an accuracy of ±0.2 mg/ℓ and 0- to 200-percent saturation with an accuracy of ±2 percent.

Bottom Sediment Sampling

Push-core sampler

Bottom sediments are obtained using a push-core type sampler. The sampler consists of a 1.5-in.-diam PVC pipe, 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. The push-core sampler is displayed in Figure A16.

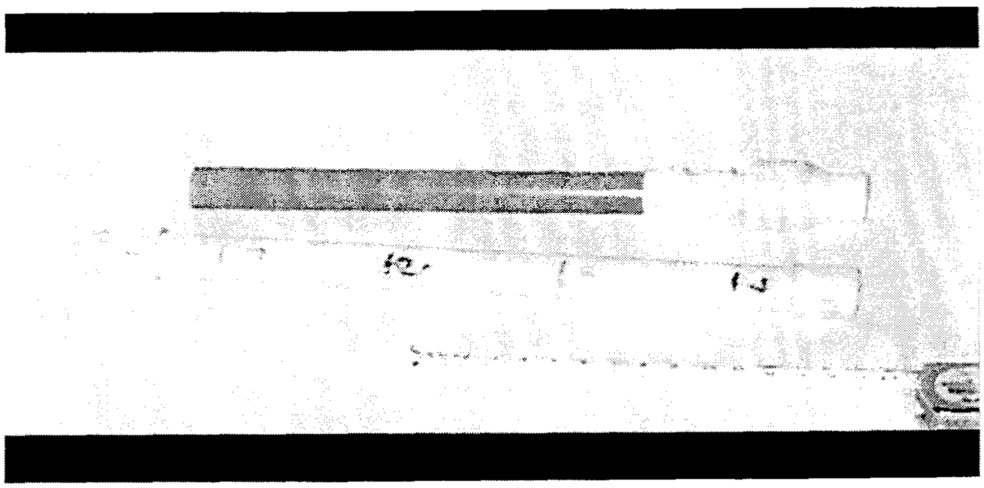


Figure A16. Push-core sampler

Box- core sampler

The box-core sampler is very similar to the petite Ponar in its triggering mechanism and sampling technique. The main difference in the two samplers is where the sample is trapped. The box-core has clam-shell jaws that scoop the sediment into a clear plastic square tube. When the sampler is opened at the surface, the sample is visible from a top door on the sampler. From this top door, the trapped sample can be sub-sampled for more detailed analysis. Figure A17 shows the box-core sampler.

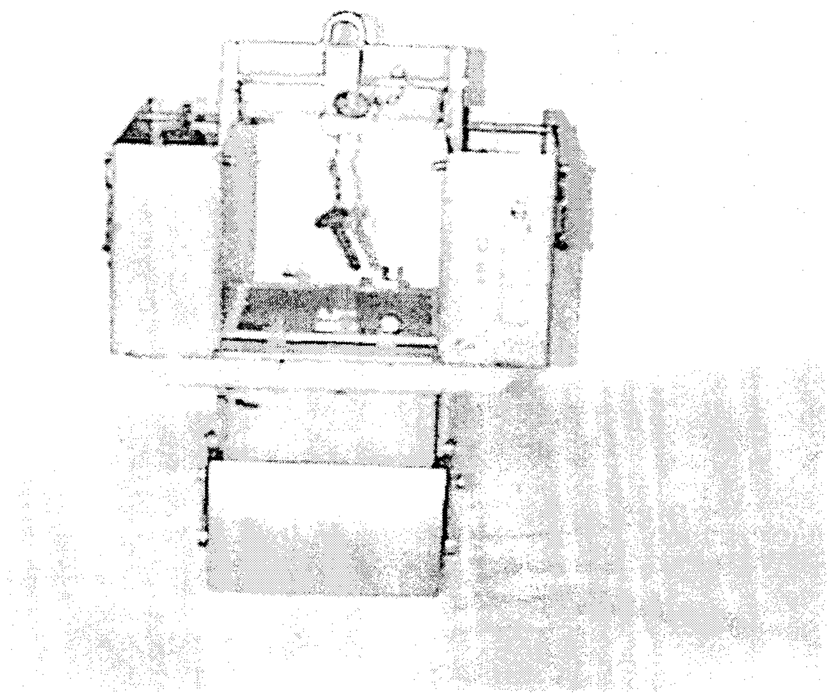


Figure A17. Box-core sampler

Petite Ponar sampler

The petite Ponar sampler is basically a clam-shell type sampler. The sampler is cocked on the surface before lowering to the bottom. When the sampler makes contact with the bottom, the trigger pin releases allowing the sampler to close. As the sampler is raised to the surface, it closes around the captured sediment until it is opened at the surface. Samples are removed, inspected, and packaged in plastic bags or jars for further analysis once returned to WES. The petite Ponar is displayed in Figure A18.

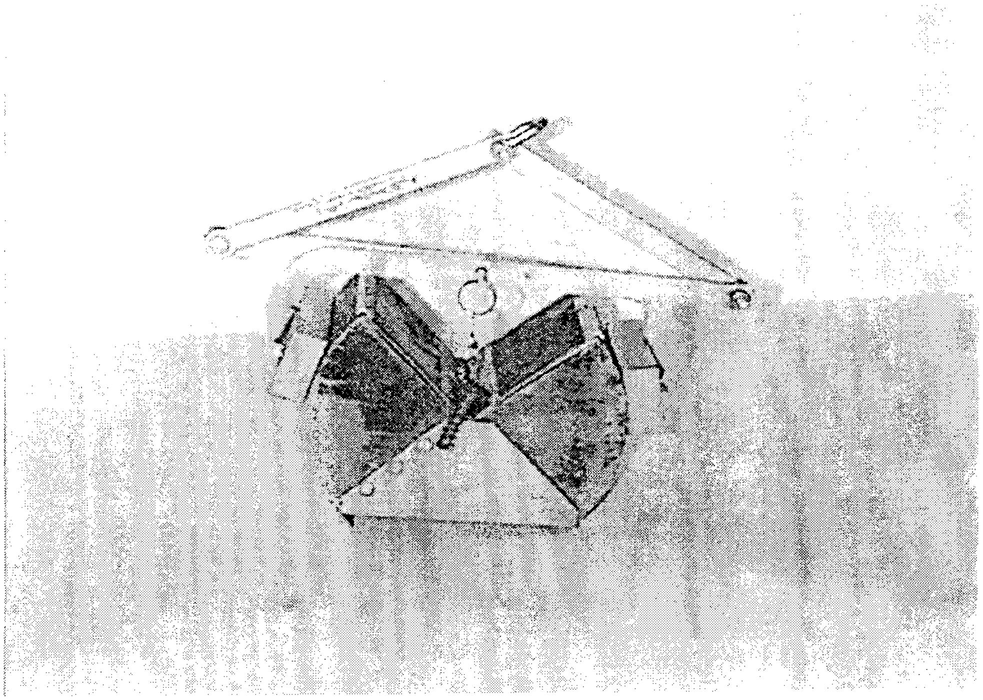


Figure A18. Petite Ponar sampler

Tethered-drag sampler

The tethered-drag sampler is basically a 3-in.-diam pipe cut on a 45-deg angle with a shackle mounted on one side. The sampler is thrown over the side and dragged along the bottom. The sample accumulates inside the pipe. Samples are removed, inspected, and packaged in plastic bags or jars for further analysis once returned to WES. The tethered-drag sampler is displayed in Figure A19.

Digital Data Acquisition of Meteorological Data

Wind speed and direction measurements are recorded continuously with a Campbell Scientific Model W2000 Data Acquisition system (see Figure A20). The data collection platform is typically located at some central location in the study area and mounted approximately 5 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.

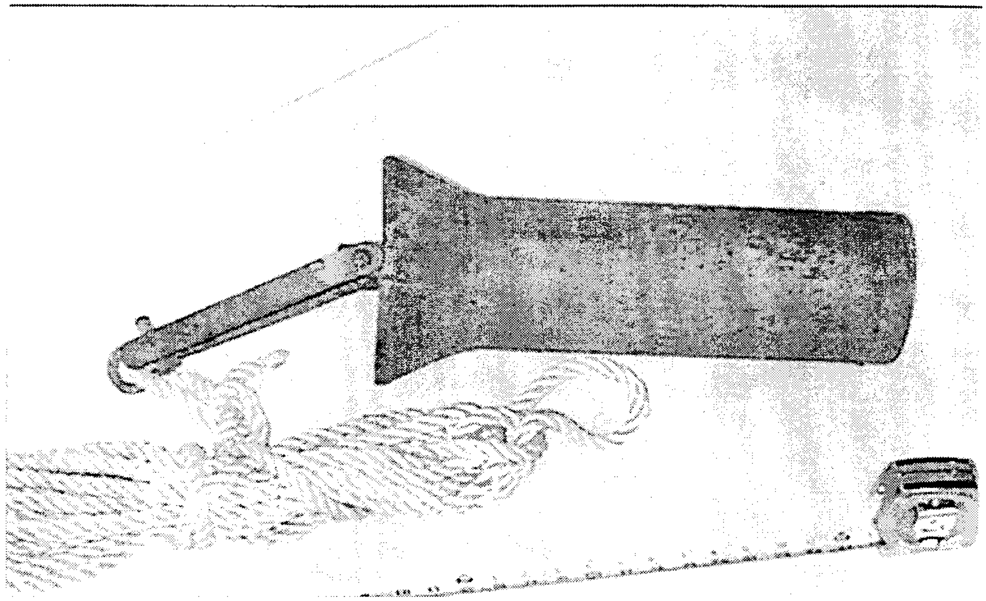


Figure A19. Tethered-drag sampler

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 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 is ±1.0 mph and ±3.0 deg, respectively. The barometric pressure sensor, Model CS105, has an accuracy of ±0.5 mb for a range from 600-1,060 mb. The tipping bucket rain gauge has a resolution of 0.01 in. for each tip. The calibrated accuracy is ±1 tip or 1 percent at 2 in./hr or less. The relative humidity sensor has an accuracy of ±2-percent RH within the range of 0-90 percent and ±3-percent RH within the range of 90-100 percent.

Laboratory Equipment and Sample Analysis

Laboratory analysis for salinity concentrations

An AGE Instruments Incorporated Model 2100 MINISAL salinometer (Figure A21) with automatic temperature compensation is used for the determination of suspended sediment concentrations in the individual samples. The salinometer is a fully automated system, calibrated with standard seawater, and the manufacturer's stated accuracy is ±0.003 ppt on samples ranging from 2 to 42 ppt.

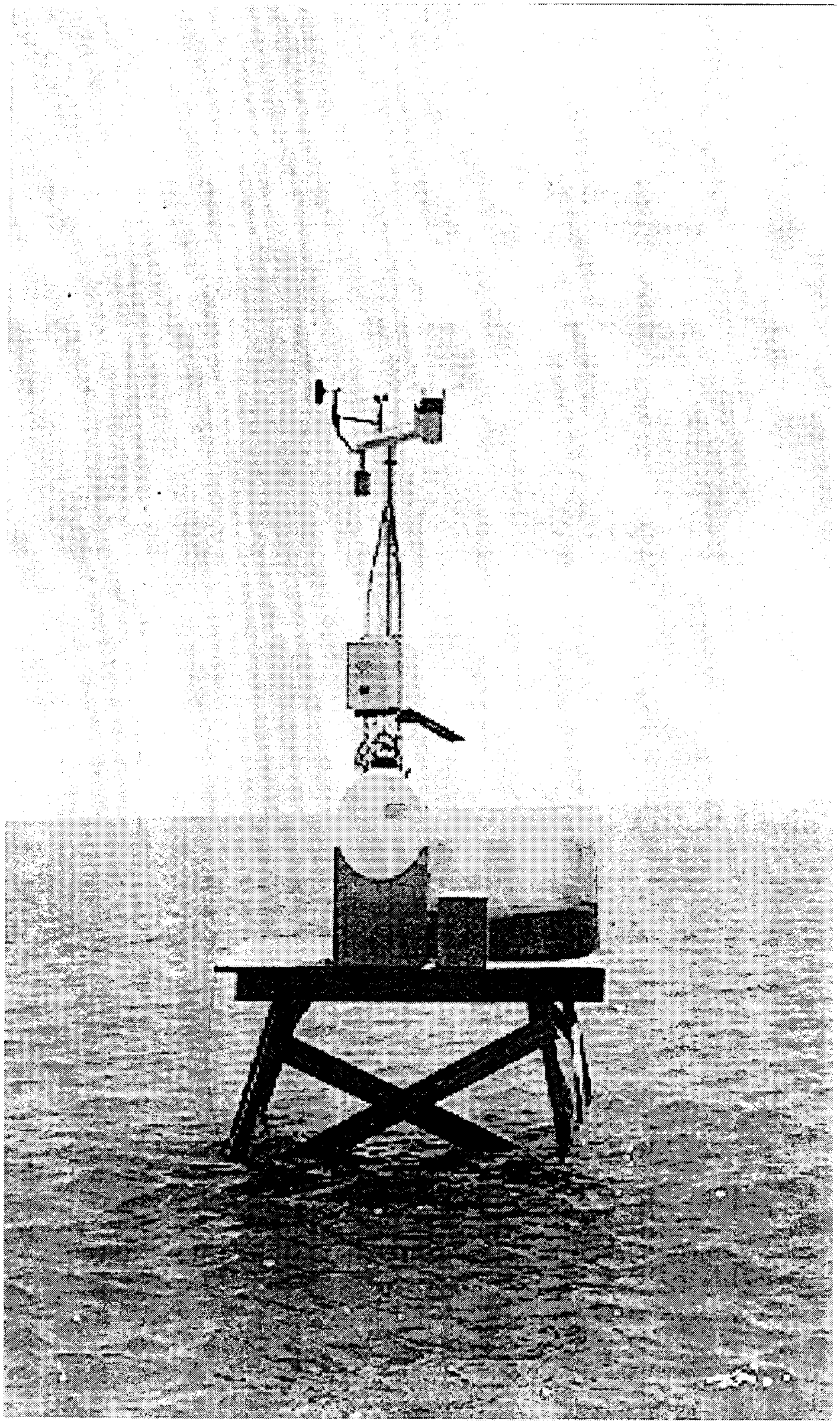


Figure A20. Weather Station Model W2000

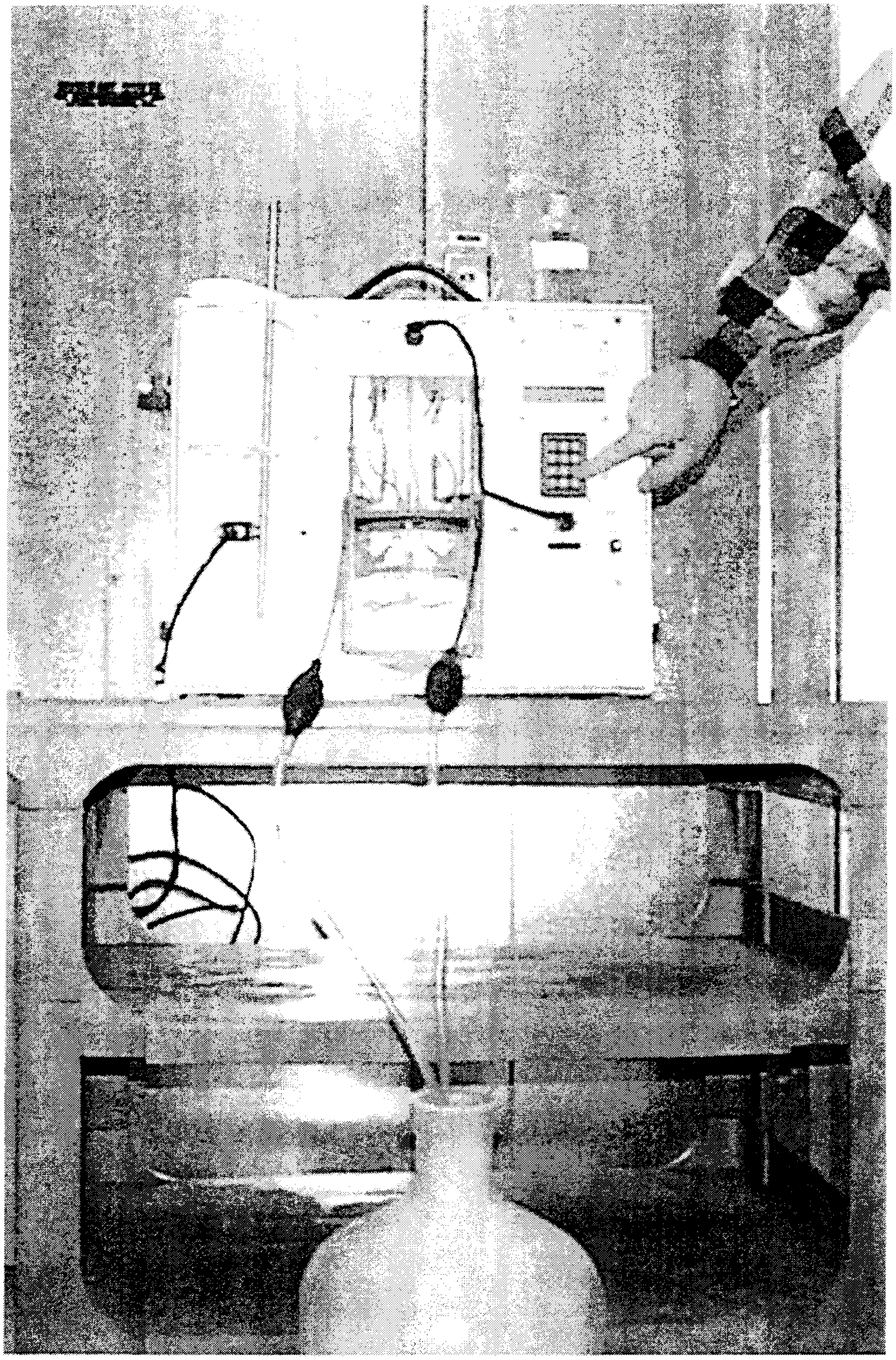


Figure A21. AGE MINISAL salinometer

Laboratory analysis for total suspended materials

Total suspended materials (TSM) are determined by filtration of samples. Nuclepore (Registered Trademark) polycarbonate filters with 0.40-micron 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:

$$BSG = \frac{(\rho)\ (sed\ wt\ -\ tare\ wt)}{(\rho)\ (vol\ pyc)\ +\ (sed\ wt)\ -\ (sed\ +\ water\ wt)} \tag{A1}$$

where

ρ = density of water at temperature of analysis

sed wt = Total weight of pycnometer and sediment

tare wt = tare weight of pycnometer

vol pyc = volume of pycnometer

sed + water wt = total weight of pycnometer, sediment, and water

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13.ABSTRACT *(Maximum 200 words)*

The Ashtabula River Basin is located in northeast Ohio. The river enters Lake Erie at the city of Ashtabula, which is about 55 miles east of Cleveland, OH, and 40 miles west of Erie, PA. The purpose of the overall Ashtabula River monitoring program was to provide the necessary boundary condition, initial condition, and verification data for a comprehensive numerical simulation of Ashtabula River. This report provides a permanent record of the instrumentation and techniques employed during the field investigation and makes the data collected available for use.

Representative results of the field investigation of the Ashtabula River system from June 1994 through November 1995 are presented. Measurements consist of current speed and direction at five ranges for one river discharge, suspended sediment samples at each of the ranges, bottom sediment samples at twelve locations, water-level monitoring at four locations, and suspended sediment measurements at three locations. Field investigation equipment and methods used to collect the data are described, representative results of the data reduction efforts are shown, and the results of these efforts are summarized.

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