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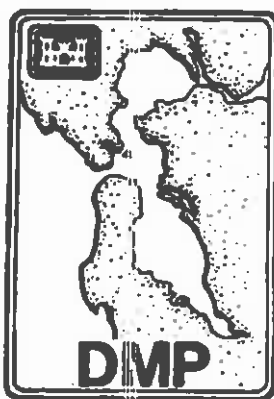
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- FINAL REPORT -

OCEANOGRAPHIC INVESTIGATION
at the
ALCATRAZ DISPOSAL SITE,
SAN FRANCISCO BAY, CALIFORNIA

for the
U.S. ARMY CORPS OF ENGINEERS
SAN FRANCISCO DISTRICT

11 SEPTEMBER 1985



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APPENDICES EXCLUDED

PREFACE

The San Francisco District of the Corps of Engineers has recently begun a program to review and evaluate existing dredging and disposal operations in San Francisco Bay. The program, called the Disposal Management Program (DMP) will address the following issues:

1. Material accumulation at the Alcatraz disposal site (SF-11).
2. Periodic bathymetric monitoring of the two north bay disposal sites: Carquinez Straits (SF-9), and San Pablo Bay (SF-10).
3. Availability and feasibility of potential alternate disposal options.
4. Fate of dredged material as a result of open-water disposal.
5. Ocean disposal site designation.

Completion of the program is scheduled for July 1988.

The following report, "Oceanographic Investigation at the Alcatraz Disposal Site, San Francisco Bay, California" documents work conducted during July 1985 to monitor currents in and around the Alcatraz disposal site.

For more information regarding this study or the DMP in general, contact Mr. Les Tong at (415) 974-0439 or ((FTS) 454-0439, or Ms. Jody Zaitlin at (415) 974-0442 or (FTS) 454-0442, Environmental Branch, San Francisco District Corps of Engineers, 211 Main St., San Francisco, California 94105-1905.

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1.0 INTRODUCTION

The Alcatraz dredged material disposal site is an active disposal area in San Francisco Bay (Figure 1) that has been filled more rapidly than anticipated; the expected natural dispersion of spoil has not occurred and the site has required redistribution of disposed material. The U.S. Army Corps of Engineers is investigating the processes of spoil deposition, resuspension, and transport at the site through application of numerical modeling methods. Calibration and verification of the model requires field data on current velocities, tidal elevation, wave characteristics, seawater temperature and salinity, and suspended solids concentrations.

The Corps of Engineers, through award of Solicitation Number DACW07-85-R-0025 dated 21 May 85, contracted Winzler & Kelly to collect, reduce, and present required field data. The Scope of Work included the collection, over a five-day period between 14 and 19 July 85, of the following field measurements:

- ° Time-series measurements of current speed and direction at six stations (A-F, Figure 2) located in and near the disposal site, using a total of 17 recording current meters.
- ° Time-series of tidal elevations at three sites in San Francisco Bay.
- ° Time-series data on water elevation, current speed and direction, wave height and period, direction of wave approach, and seawater temperature from a bottom-mounted gauge located within the disposal site.

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- B-1 Wave and Orbital Velocity Data from PUV Gauge.
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- ° Collection of water samples at three depths once each hour over a 12-hour tidal cycle at a location in the center of the site; the samples were subsequently analyzed for salinity and total suspended solids concentration.

The Alcatraz dredged material disposal site is a circular area of 2000-foot diameter located immediately south of Alcatraz Island (Figure 2); geographic coordinates for the center of the site are 34°49'17" North and 122°25'23" West. Water depths within the area vary widely depending upon the extent of spoil disposal, but ranged in June 1985 from 36 to 111 feet.

Previous current measurements near the disposal site had been reported by Dames & Moore (1971), Rubin and McCulloch (1979), and Goddard et al. (1984); all describe a tidally dominated, oscillatory current regime with maximum speeds reaching 150 cm/sec (2.9 knots) and principle flow directions of east and west.

2.0 MATERIALS AND METHODS

2.1 Instrumentation

Three principal types of in-situ, self-recording instruments were used during this study: (1) tide gauges, (2) current meters, and (3) a multi-function pressure, current, and temperature gauge (termed a PUV gauge).

2.1.1 Tide Gauges

The tide gauges were model TDR-2 temperature/depth recorders, manufactured by Sea Data Corporation, which use YSI precision thermistors for temperature measurement and Sensometrics strain gauges for pressure measurements. Manufacture's specifications for the TDR-2 instruments are as follows:

Temperature -

Range: -5° to 35 °C
Resolution: 0.01 °C
Accuracy: 0.15 °C

Tide -

Range: 0-20 meters
Resolution: 0.4 cm
Accuracy: 1.5 cm

The TDR-2 gauges were set to record temperature and tide values every 3 minutes; data were logged in digital format on endless-loop microcassettes.

2.1.2 Current Meters

ENDECO Type 105 tethered current meters were used to measure and record current speed and direction data. These meters employ a ducted impeller speed sensor that is specifically designed to minimize the influence of surface wave contamination of the current signal; current direction is measured by an internal compass which senses the orientation of the pressure housing. The Type 105 is a neutrally-buoyant instrument that is attached to the mooring line with a flexible tether; this unique design effectively decouples the instrument from wave-induced motions of the mooring line, and from errors induced by tilt of the mooring line.

The current meters were selected to sample once every 15 minutes, and recorded the speed and direction data on 16 mm photographic film cartridges. Some of the manufacturer's specifications for the ENDECO 105 meters are as follows:

Current Speed -

Range: 0 - 360 cm/sec at 1 recording
each 15 minutes
Threshold: Less than 2.6 cm/sec
Resolution: 2.6 cm/sec
Accuracy: ± 10 cm/sec

Current Direction -

Resolution: ± 1 degree
Accuracy: ± 7 degrees (above meter threshold
and referenced to computer
calibration)

Data Recording -

Rate: Selectable, 1 reading per 15, 30, or
60 minutes
Method: Photographic time exposure of sensor
outputs

Housing -

Material: PVC plastic
Finish: Anti-foulant paint
Weight: 27 lbs in air, neutral in water
Dimensions: 30" long x 16" diameter

2.1.3 Directional Wave, Tide, and Temperature Gauge

A single, multi-sensor instrument, a model 635-12 directional wave and tide recorder manufactured by Sea Data Corporation, was used to measure bottom pressure, water temperature, and orthogonal velocity components (commonly called u and v) of current flow. The 635-12 as deployed sampled and recorded tide data every 3.75 minutes, mean current velocity every 30 minutes, seawater temperature every 30 minutes, and collected a wave burst sample every 60 minutes. The wave bursts were series of high-frequency sampling; 2056 readings, at 0.5 second intervals, occurred once per hour. The instrument uses a highly accurate DigiQuartz pressure transducer which senses pressure changes as frequency changes of an oscillating quartz crystal; an integral thermistor senses water temperature. Current flows are sensed with a Marsh-McBirney two-axis electromagnetic current sensor. Some of the specifications for the 635-12 PUV gauge follow:

Currents -

Mean speed range: ± 300 cm/sec
Mean speed resolution: 0.2 cm/sec
Speed accuracy: 2% of signal + 2 cm/sec
Direction accuracy: ± 15 degrees

Depth -

Range: 0 - 20 meters
Resolution: 0.05 cm (tides)
0.045 cm (waves)
Accuracy: 0.4 cm

Temperature -

Range: -4 to 34 °C
Resolution: 0.002° C

2.2 Field Operations

Spoiling operations at the Alcatraz site were suspended between 10 and 19 July to prevent conflicts with a preceding sediment coring operation and with this oceanographic investigation. The latter study was constrained to occur between 14 and 19 July. The period between receipt of the Notice to Proceed on 8 July and the nominal beginning of the field measurement program on 14 July was used to ship and prepare the instruments, fabricate mooring arrays and marker buoys, and contract and outfit vessels.

The three tide gauges were deployed at Hyde Street Pier (TG1), Alcatraz Island dock (TG2), and at a piling about 150 m south of Brooks Island (TG3); all were emplaced on 12 July 85 (see Table 1 for a complete listing of instrument deployment data). Survey diagrams for each of the three locations are given

in Appendix A; each of the three tide gauges was accurately levelled to an established shoreside datum.

The six current meter arrays (including the PUV gauge) were deployed without incident prior to 1430 PDT on 14 July at locations fixed with LORAN-C positioning. Each array comprised a deadweight anchor clump weighing approximately 275 kg, a taut-moored 1/4" steel cable, a pair of submerged buoys for flotation, and a tethered spar buoy as a surface marker. Current meters were attached at depths 4 m below MLLW, at mid-depth, and 1 m above bottom; 3 current meters were attached to each array A through E, while array F had only near-surface and near-bottom meters. Figure 3 shows schematically the arrangement of instruments on each of the six arrays.

The array deployment and retrieval operations, and the water sampling task, used LORAN-C as the primary means of station location and positioning. The LORAN-C console unit was calibrated by checking the readings against known latitude and longitude locations in Richmond Marina, at the Point Blunt (Angel Island) and Alcatraz Island docks, and at the Hyde Street Pier. Calibrations were checked at the start and end of each field day, and were generally found to agree within 0.01 minutes of latitude and longitude. The estimated accuracy of the reported positions (Table 1) is approximately 18 meters.

The water sampling operation occurred as planned on 17 July; thirteen sets of three water samples, collected at depths of -4, -7, and -11m MLLW, were obtained between 0844 and 1829. The water samples were labeled and stored on board for subsequent laboratory analyses.

Retrieval of the current meter arrays and tide gauges took place on 19 and 20 July (see table 1). Array B, comprising three current meters, was not recovered; the upper meter on array F was recovered in a damaged condition (the forward half of the instrument, including the film pack was recovered, but was flooded and the film was unreadable).

2.3 Data Reduction and Analysis

Field data and samples comprised (1) film packs from the ENDECO 105 current meters, (2) magnetic tape microcassettes from the Sea Data TDR gauges, (3) a magnetic tape cassette from the Sea Data 635-12 PUV, (4) seawater samples, (5) and field observation logs. The film and magnetic media were processed, read and digitized, and converted to engineering units; calibration corrections unique to each instrument were applied. Correction factors for the pressure port depth of each of the three TDR tide gauges were applied to relate the three data sets to MLLW datum. The tide readings from the PUV gauge, which was not levelled to a shoreside datum, were related to an approximate MLLW level by the following procedure:

1. A mean water surface level was calculated for the PUV data during the measurement period.
2. A mean water surface elevation was calculated from tidal predictions during the measurement period.
3. The difference between (1) & (2) above provides an estimate of the depth of the pressure sensor below MLLW.
4. This difference was subtracted from each water level value to obtain a tidal curve referenced to an approximate MLLW datum.

Data recovery was virtually 100 per cent for each recovered instrument; no instrument malfunctions occurred. Note, however, that the current meters at locations D-Middle, E-Middle, and E-Bottom were slightly fouled with drift seagrass which had wrapped around the impeller shaft. The formatted data sets were used in various analytical and plotting applications; these results are presented in the following section:

3.0 RESULTS

3.1 Tides

Tidal curves are shown on Figure 4 for predicted tides at Alcatraz (based on NOAA corrections for Golden Gate predictions), and measured data at Hyde Street Pier, Alcatraz Island dock, Brooks Island, and the Alcatraz disposal site (PUV gauge). A spring tidal range of 2.25 m occurred during the measurement period on 18 July, coincident with the new moon.

Tabulations of the measured tidal data for Hyde Street Pier, Alcatraz Island, and Brooks Island locations are given in Appendices B-1, B-2, and B-3. Corresponding data for the PUV gauge is listed in Appendix C along with the mean current and water temperature data that were also collected by the PUV gauge.

3.2 Currents

The current speed and direction data obtained from the 13 recovered and undamaged film packs, and also from the PUV gauge, are presented in five different formats:

- 1) Time-series plots showing the time history of current speed and direction (Figures 5 through 10).
- 2) Rectangular histograms showing the percent frequency of occurrence of current speeds (Figures 11 through 16).
- 3) Polar histograms showing the percent frequency of occurrence of current direction (Figures 17 through 22).

- 4) Joint frequency distribution diagrams showing the percent frequency of occurrence of pairs of speed and direction classes (Figure 23 through 36), and
- 5) Tabulations of velocity data (Appendix C for the PUV gauge, and Appendix D for the ENDECO 105 current meters).

Table 2 presents mean speed and mean direction statistics for all current meters. The statistics are reported for flood and ebb tidal conditions and also lists the number of observations comprising the mean for each current meter.

The time-series plots of current speed and direction derived from the ENDECO 105 meters (Figures 5 through 9) are referenced to Julian dates. The correspondence between the Julian and Gegorian days of interest is:

JD 195 =	14 July
JD 196 =	15 July
JD 197 =	16 July
JD 198 =	17 July
JD 199 =	18 July
JD 200 =	19 July
JD 201 =	20 July
JD 202 =	21 July

Inspection and comparison of the time series plots reveal a number of relationships governing the flow regime.

1. The magnitude of current speed is strongly correlated with tidal range; the greater the range, the higher the maximum speed.

2. Midwater current speeds are generally within about 10 percent of surface values, while bottom currents are considerably more diminished; the diminution is least for stations A and C (atop the shoal spoil mound) and greatest at the deeper stations D and E.
3. Peak speeds occur about 60-90 minutes before high and low tides; minimum speeds occur about 60-90 minutes after the highs and lows.
4. Flow directions at all stations are roughly aligned with the east-west axis of the channel between Alcatraz Island and San Francisco; the direction changes generally occur in a progressive and rotary clockwise fashion. Directions change rapidly (reversing within a 30 minute time period) about 60-90 minutes after high and low waters.

The rectangular histograms of current speed (Figures 11 through 16) show that the highest near-surface speed encountered was 142 cm/sec at Station C, the highest mid-depth speed was 147 cm/sec at Station D, and the highest near-bottom speed was 109 cm/sec at Station C. The distributions for Station E, top meter (Figure 14), and Station F, bottom meter (Figure 15), both have unusually high occurrences of zero speeds and probably represent fouling of the current meter rotor with drift seagrasses over some part of the measurement period.

The polar coordinate histograms of current direction (Figures 17 through 22) show clearly the bimodal distribution of direction data and the generally low variance about the mean flood and ebb directions.

The joint-frequency of occurrence diagrams (Figures 23 through 36) again demonstrate the narrow directional bands within which most of the data fall. It is also evident that the highest current speeds at all stations and depths occur during ebb tide conditions when currents flow in a westerly direction.

3.3 Waves

Wave data were collected with a Sea Data 635-12 directional wave, tide, temperature and current meter. The meter was mounted on a tripod in a water depth of 13.7 meters below mean lower low water (MLLW). Tabular results of significant wave height, wave period, mean velocity and direction are provided in Appendix B. Time series plots of significant wave height and period of maximum energy are provided on Figure 37. Significant wave heights measured ranged from 0.02 to 0.17 meters with periods of maximum energy characteristically in the range of 7 to 9 seconds. Figures 38 and 39 present examples of energy density vs. frequency for measurement time periods of 10:35 am and 01:35 pm on July 16, 1985, respectively.

The peak energy period plot, Figure 37, shows several peak periods at 2.5 seconds. These periods are believed to be numerical processing artifacts since the pressure response to a 2.5 second wave in a water depth of 13 meters below MLLW is small and below the ability of the pressure sensor to distinguish the transmitted wave pressure signal from other pressure noise. In fact, the depth of deployment of the pressure sensor effectively filtered out waves with periods of 5 seconds or less based on pressure attenuation of approximately 85 percent of the surface pressure signal. Therefore, what the meter measured and is presented in Figure 37 represents the "non-filtered" residual wave energy associated with waves having periods greater than about 5 seconds. Residual wave components are characterized as

low in height with relatively long periods. These waves are probably refracted and diffracted ocean swell which propagate through the Golden Gate.

Waves observed during field operations were local wind generated waves associated with the typical summer wind regime in central San Francisco Bay. Winds were light in the evening and mornings, progressively increasing to about 7 to 10 m/sec in the late afternoon. Wind direction was typically from the west, generating waves with heights observed in the range of 0.45 to 0.90 meters with periods of 2 to 4 seconds in the afternoon. Vessel wakes were also frequent in the study area and were generated by the passage of large ships, ferries, commercial fishing boats, pleasure craft, etc. Wakes were characteristically short duration with heights observed in the range of 0.30 to 0.60 meters and periods ranging from 2 to 3 seconds. None of the above observed wave trains were sensed at the depth of the Sea Data 635-12 pressure sensor.

Observed wind and vessel generated waves were influenced by tidal stage. Ebbing tidal currents increased wave heights and shortened wave periods. Flooding tides decreased wave heights and lengthened wave periods. The wave data shown on Figure 37 may reflect this tidal influence, although a consistent tidal signal is not obvious.

The mean orbital velocity presented in Appendix B is numerically the vector sum of the U-V components of current speed sensed by the Sea Data 635-12. Thus, it more accurately represents the dominant tidal component of current rather than a mean wave induced orbital velocity.

The relatively large mean (tidal) current component, compared to the small orbital velocities associated with the low

energy long period waves that were sensed during the measurement period, preclude the ability to accurately calculate wave induced orbital velocities and resulting directional wave energy spectrum. Residual wave orbital velocities, after subtraction of the mean current component, are the same order of magnitude as fluctuations in the mean current. Orbital velocities would thus be superimposed on mean current fluctuations at magnitudes that we estimate to be in the range of 2.5 to 5.0 cm/sec. Directional wave energy plots were not prepared and we do not believe meaningful directional wave spectrum can be derived from the data set.

Wave induced orbital velocities at a water depth of 13 meters MLLW were not a significant portion of maximum current velocities. Longer period waves, with greater wave heights than occurred during the field program, might generate orbital velocities at a water depth of 13 meters MLLW that are significant compared to current velocities at various tidal stages. These waves would likely be the result of winter storms generating large swell that would propagate through the Golden Gate. However, it is unlikely, due to frequency of occurrence and duration of such wave conditions, that wave induced orbital velocities would have any significant impact on resuspension of bottom material at a water depth of 13 meters below MLLW.

3.4 Seawater Analyses

The seawater samples that were collected hourly at three depth over a 12-hour tidal cycle on 17 July were analyzed by Kennedy/Jenks Engineers for salinity and total suspended solids (TSS) concentration. Salinity was determined using standard methods procedure 210 C, Argentometric Method, and TSS was determined using EPA Method 160.2, Non-filterable Residue. Those

data are listed in Table 3 and are plotted, along with tidal height and current speed and direction, on Figure 41.

Salinities ranged from 31.9 parts per thousand (ppt) to 34.6 ppt. There is no clear relationship between the current flow regime and salinity. Surface salinities do show a slight depression at the beginning of the series and a slight elevation at the ends but the depressed values occur on flood tide (normally when higher salinity coastal waters enter the bay) and the elevated values on ebb tide (usually when fresher bay waters exit the bay). Mid-depth and near bottom values do not show any regular variations.

The total suspended solids data show a decreasing trend over the thirteen-hour period that is independent of the variations in current speed. The fact that the last two-thirds of the sampling period has little change in tidal elevation suggests that turbid bay waters which exited the bay on the preceding large falling tide re-entered the bay early in the measurement period and were followed by less turbid coastal water; the low tide range later in the period was not sufficient to bring turbid bay waters back into the sampling area.

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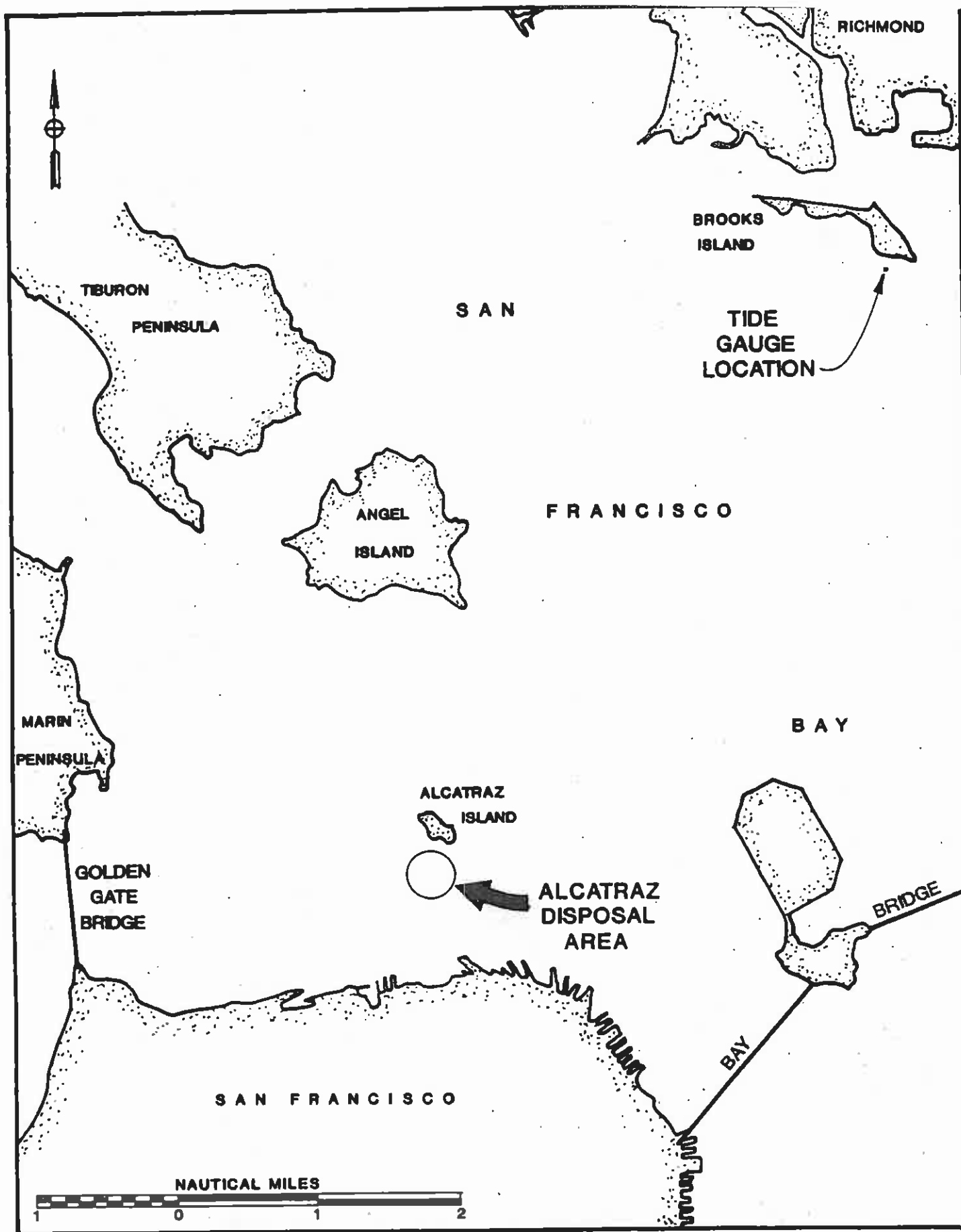


Figure 1. Location of the Alcatraz Disposal Site.

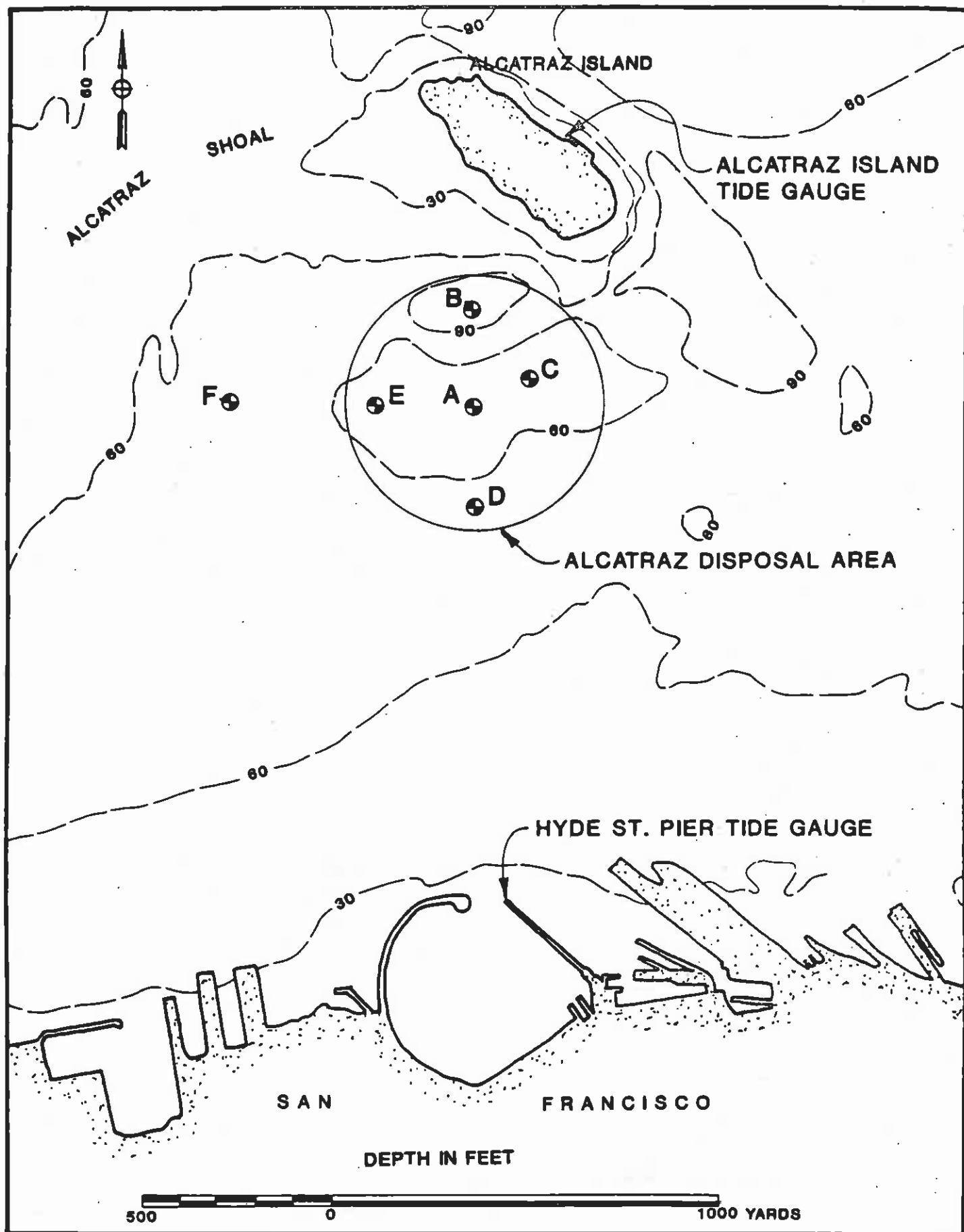


Figure 2. Locations of Current Meter Arrays and Tide Gauges.

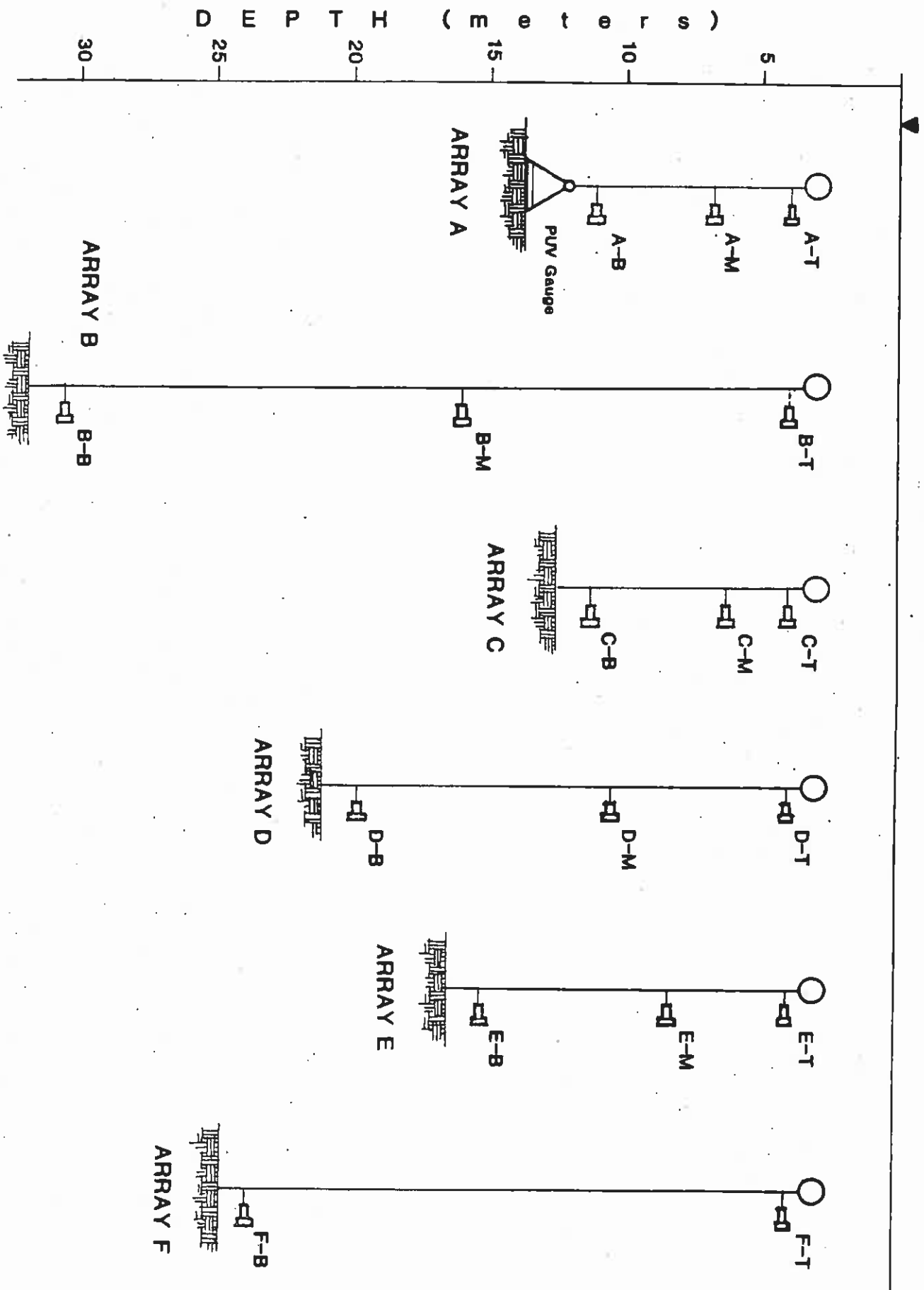


Figure 3. Schematic Diagram of Instrumented Arrays.

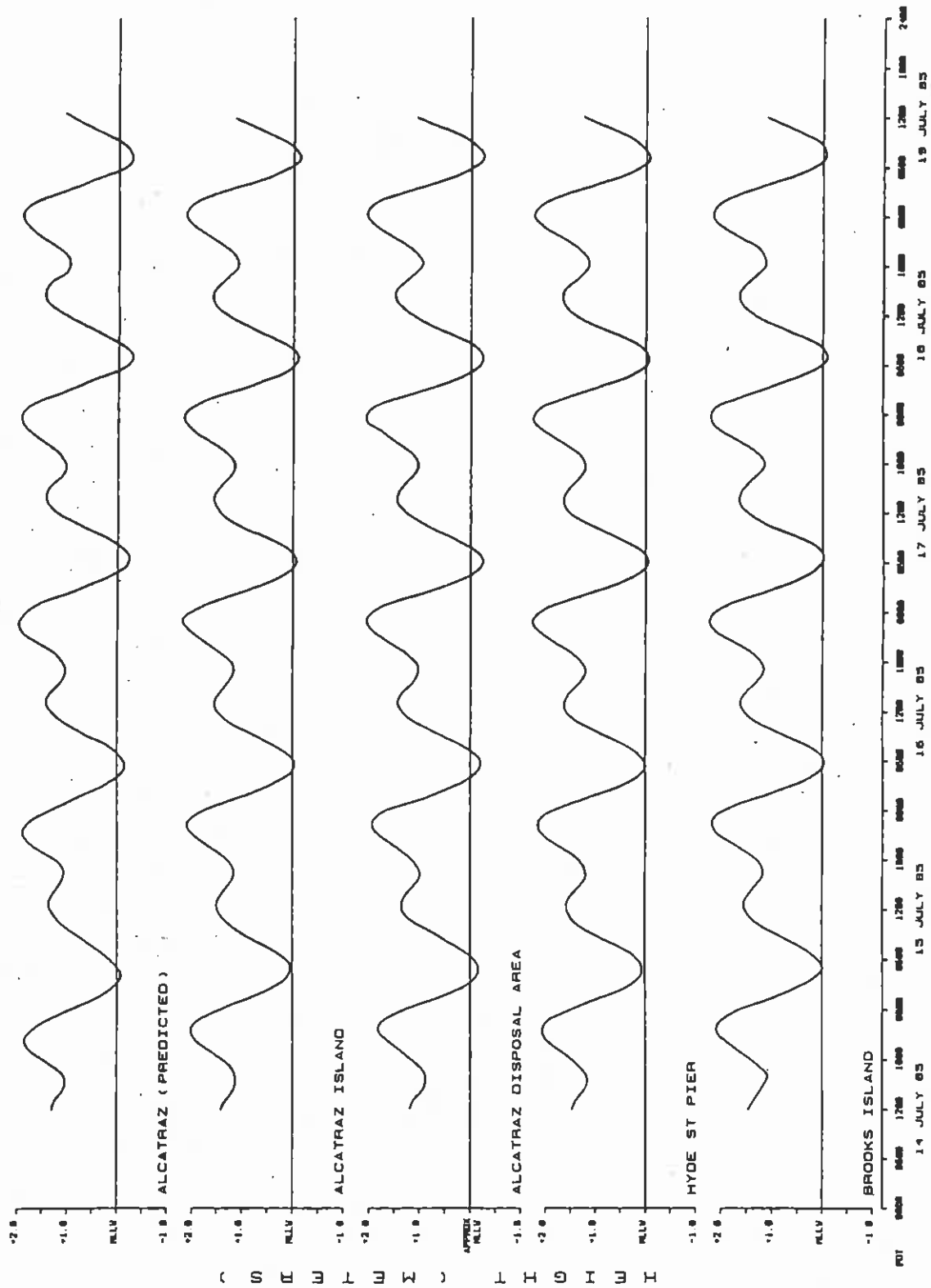


Figure 4. Predicted and Measured Tide Curves, 14 - 19 July 1985.

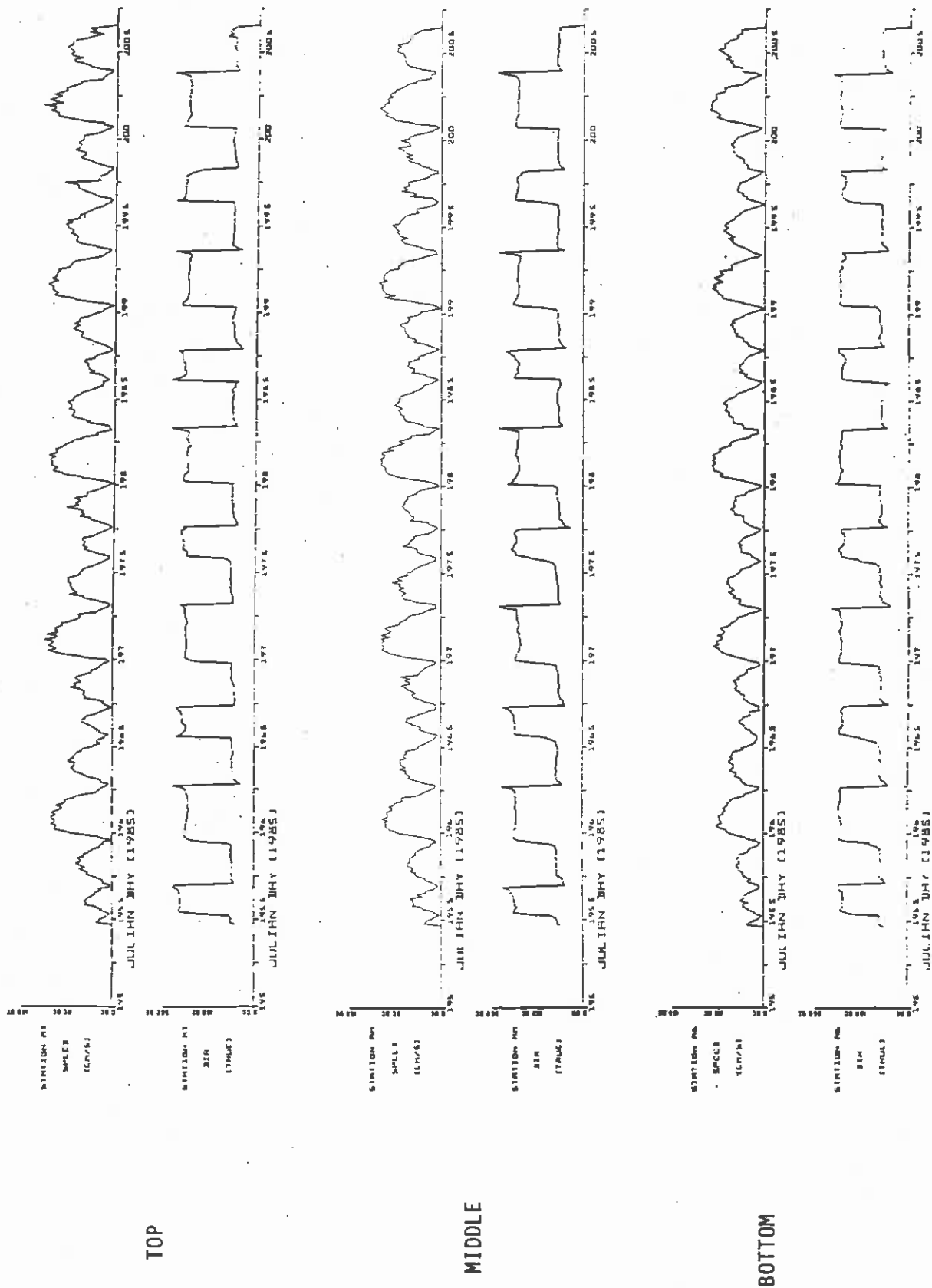


Figure 5. Current Speed and Direction Time-Series Plots, Station A.

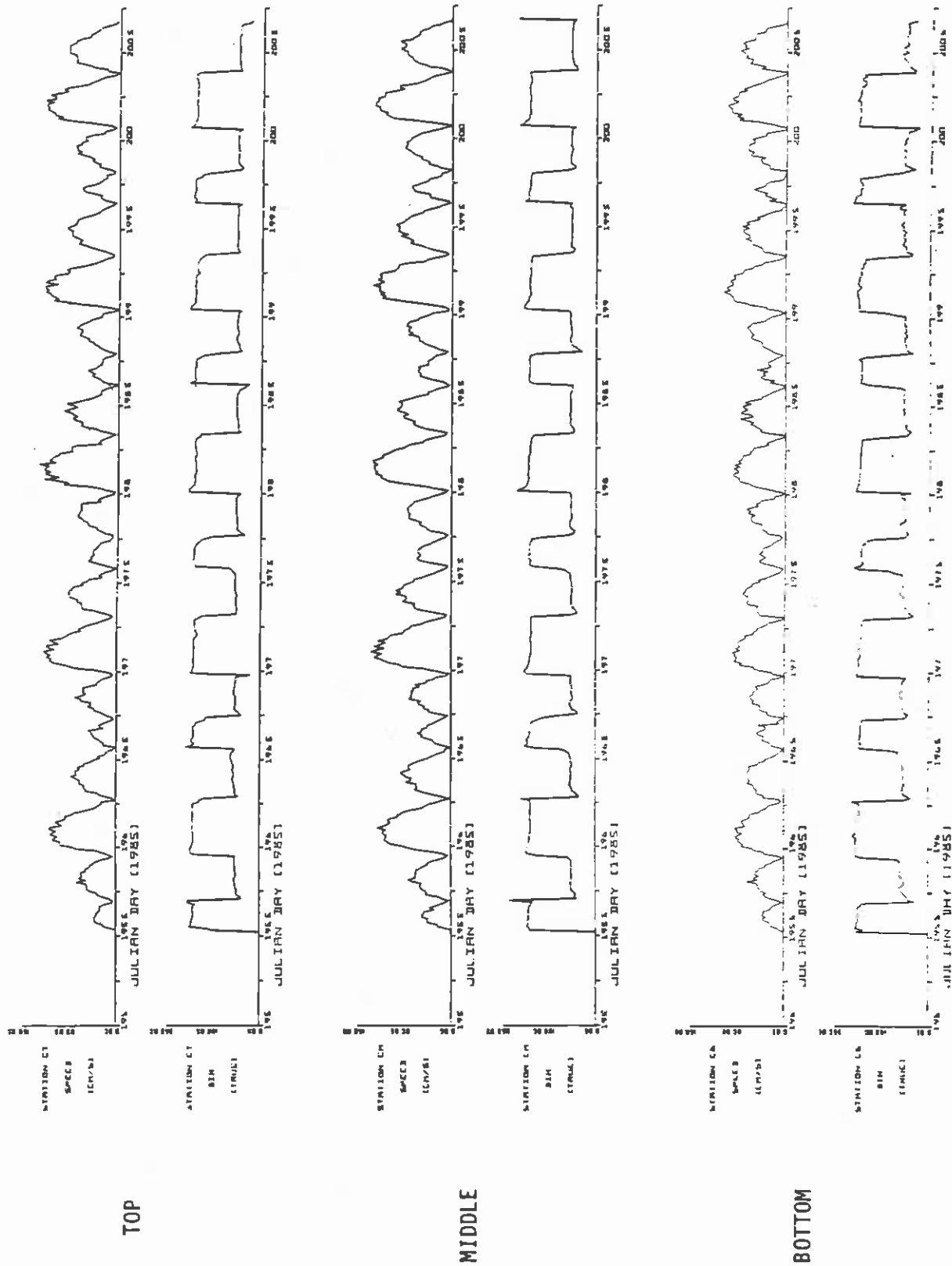


Figure 6. Current Speed and Direction Time-Series Plots, Station C.

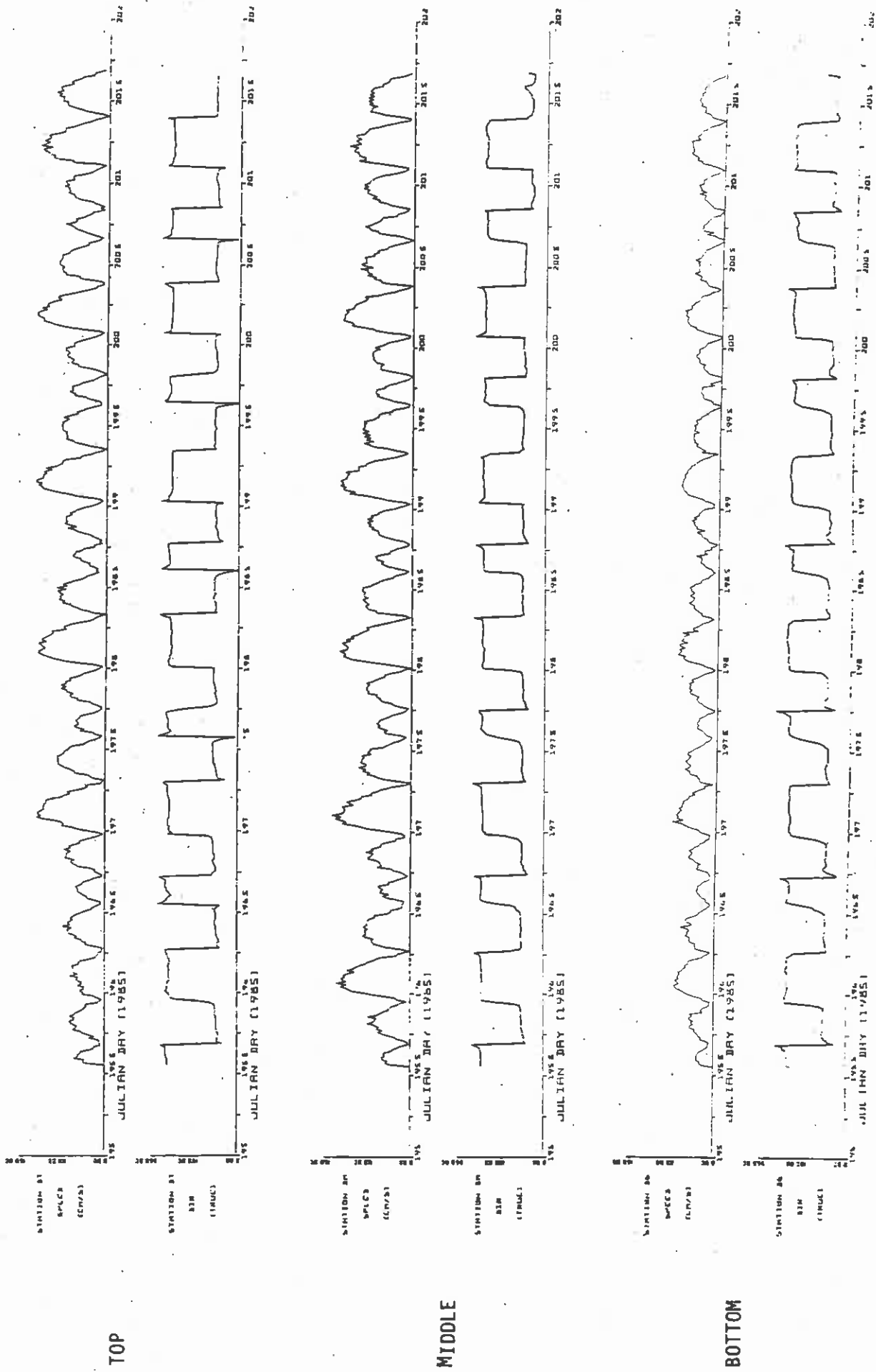


Figure 7. Current Speed and Direction Time-Series Plots, Station D.

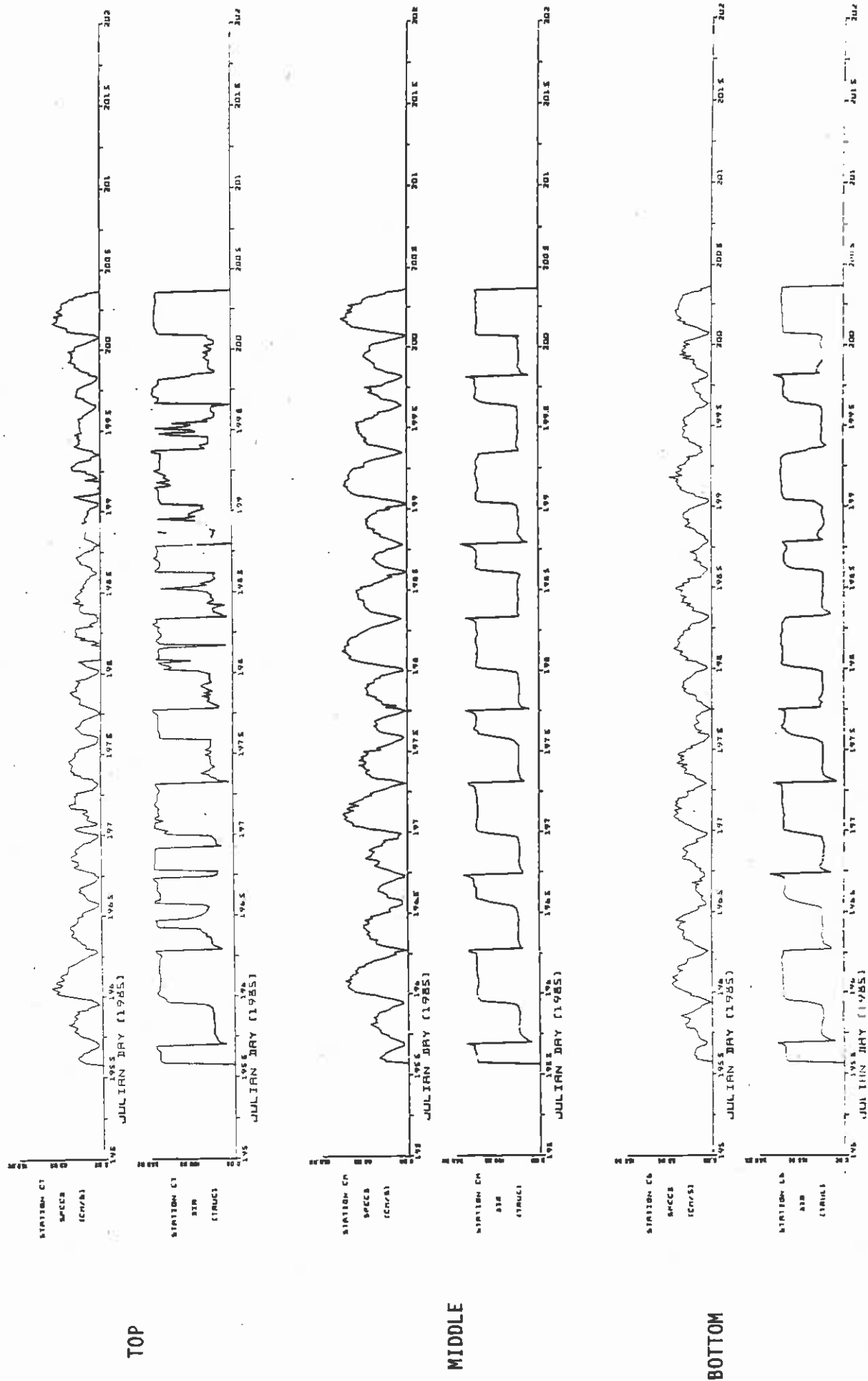


Figure 8. Current Speed and Direction Time - Series Plots, Station E.

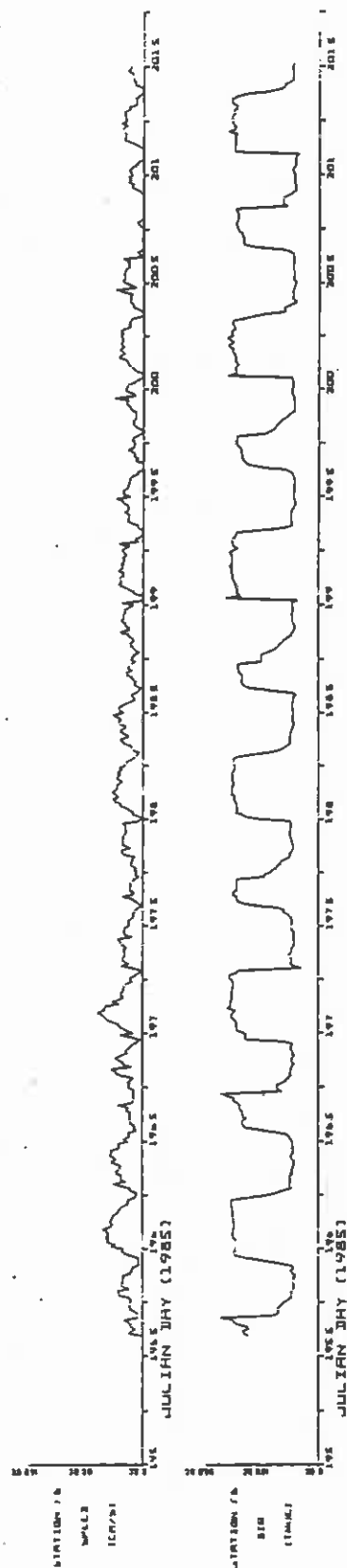


Figure 9. Current Speed and Direction Time-Series Plots, Station F.

ALCATRAZ DISPOSAL SITE

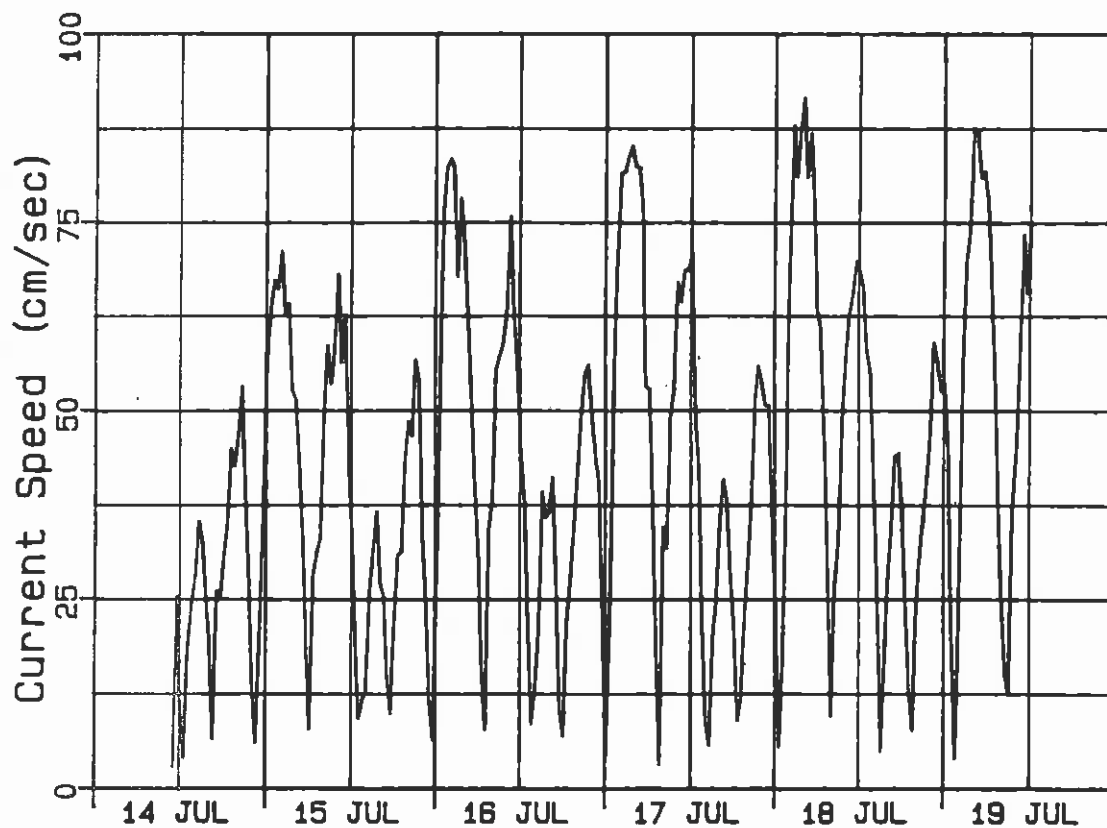
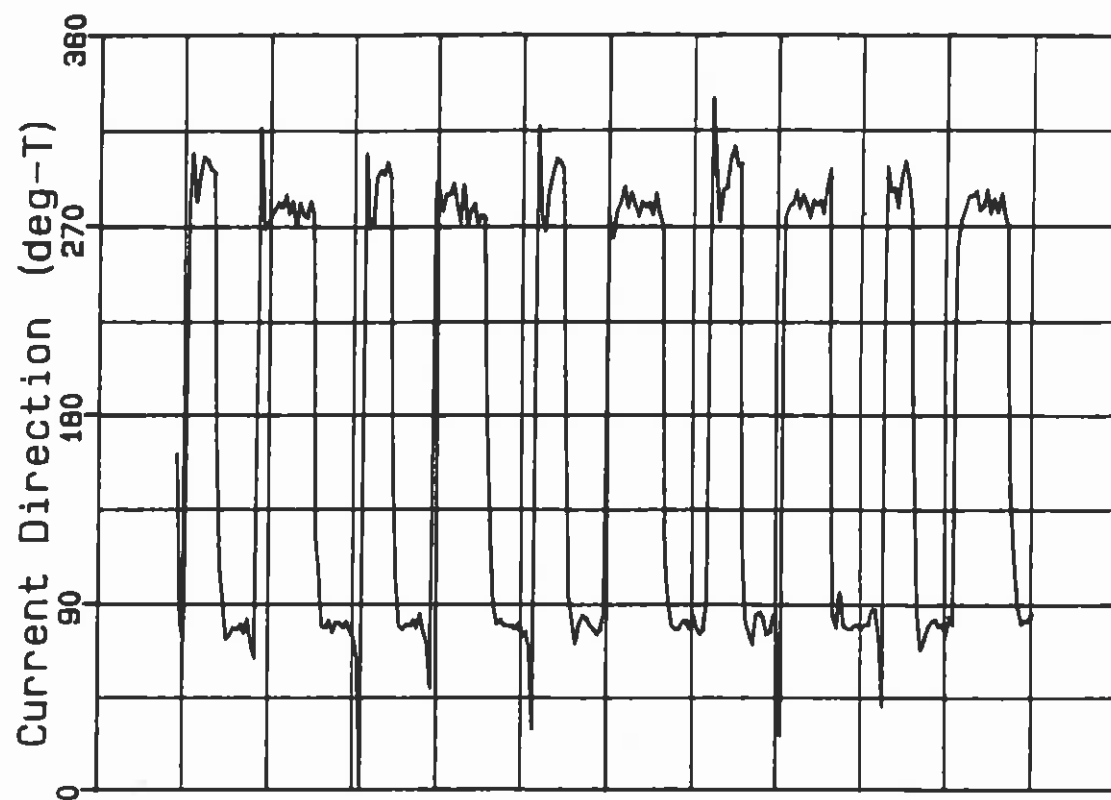
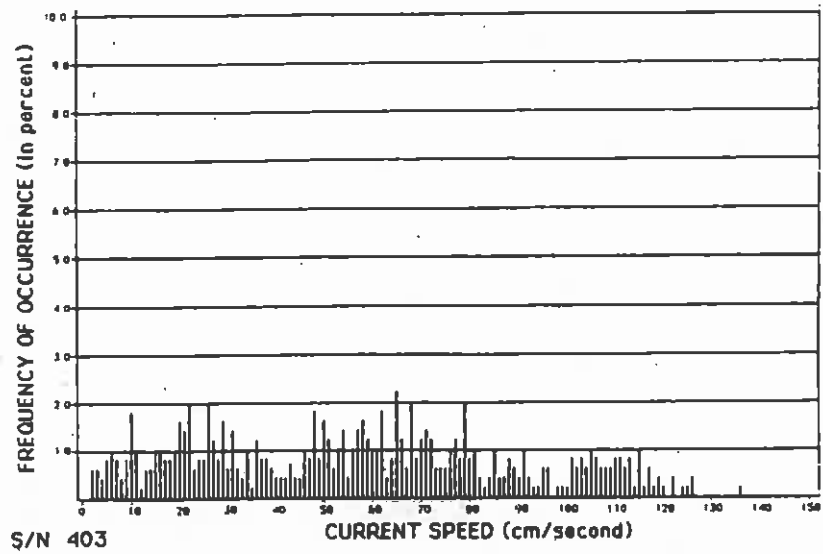
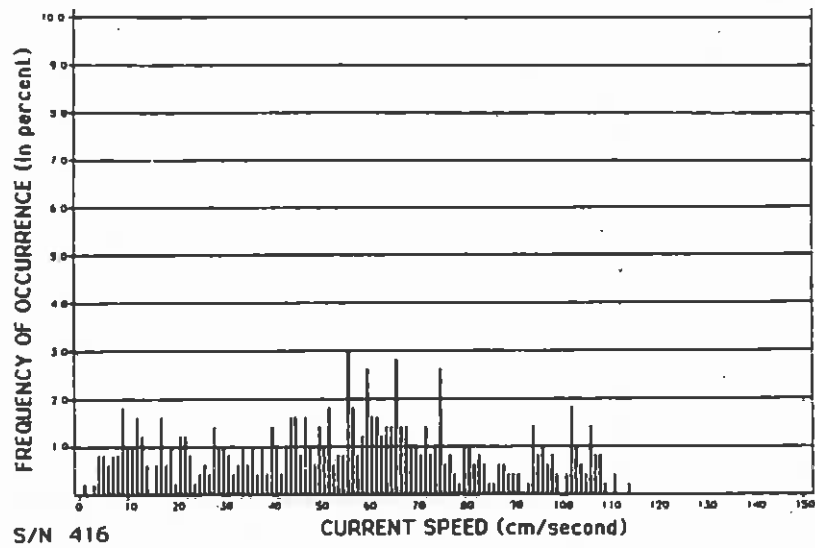


Figure 10. Current Speed and Direction Time-Series, PUV Gauge.

TOP



MIDDLE



BOTTOM

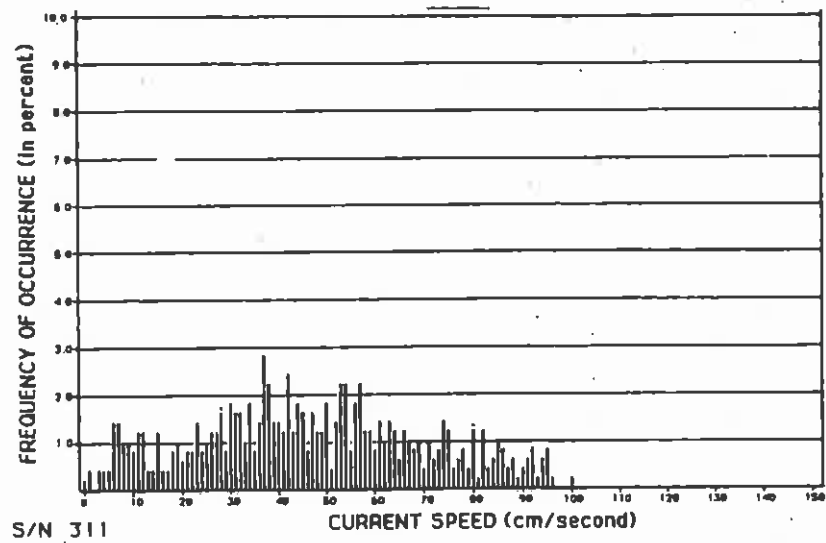
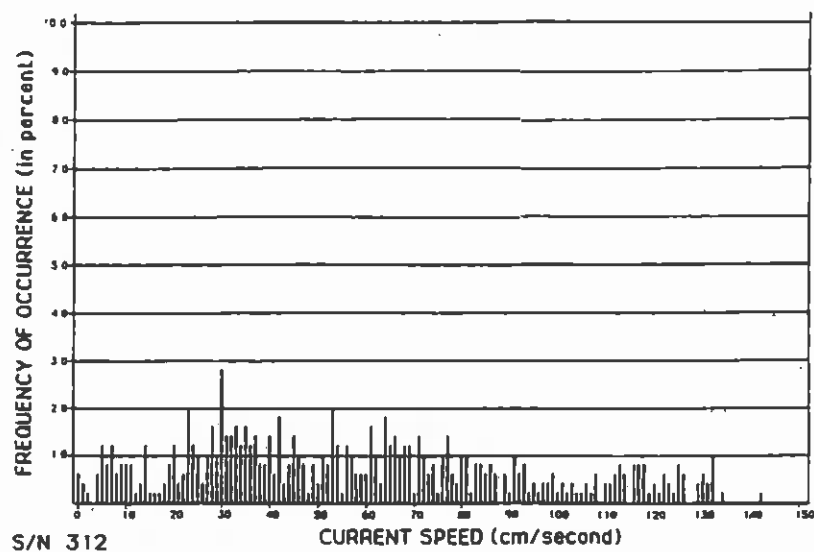
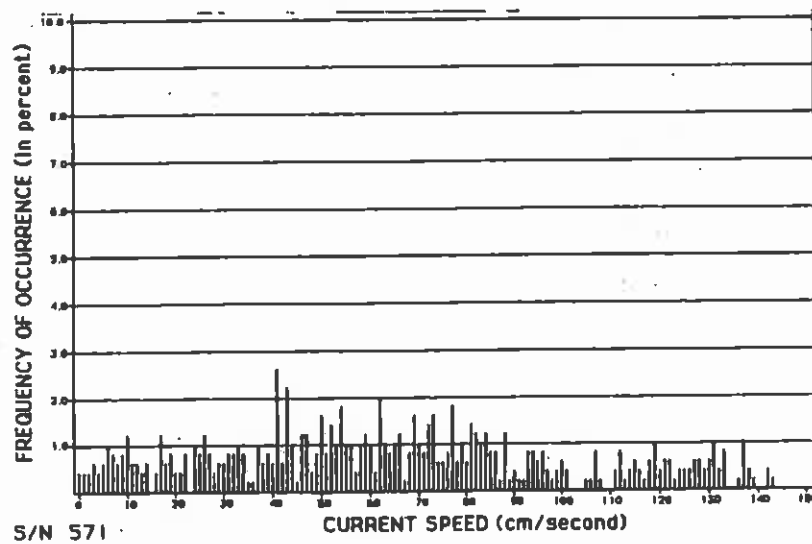


Figure 11. Current Speed Histograms, Station A.

TOP



MIDDLE



BOTTOM

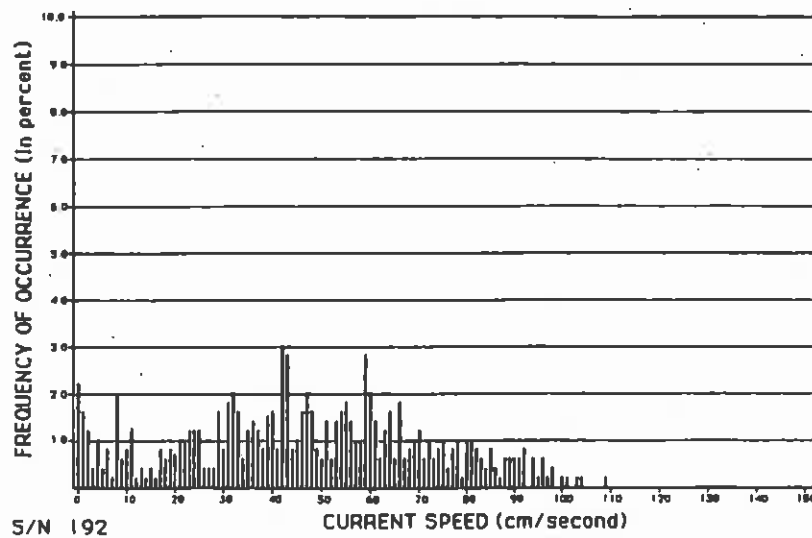
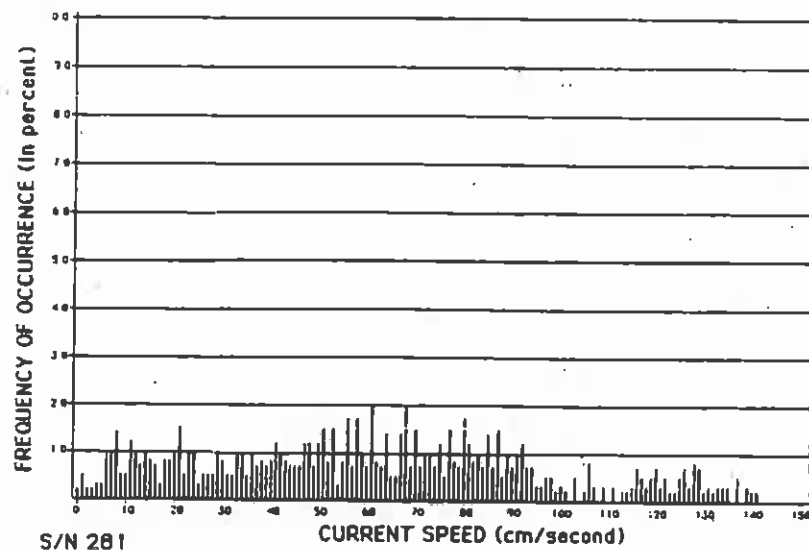
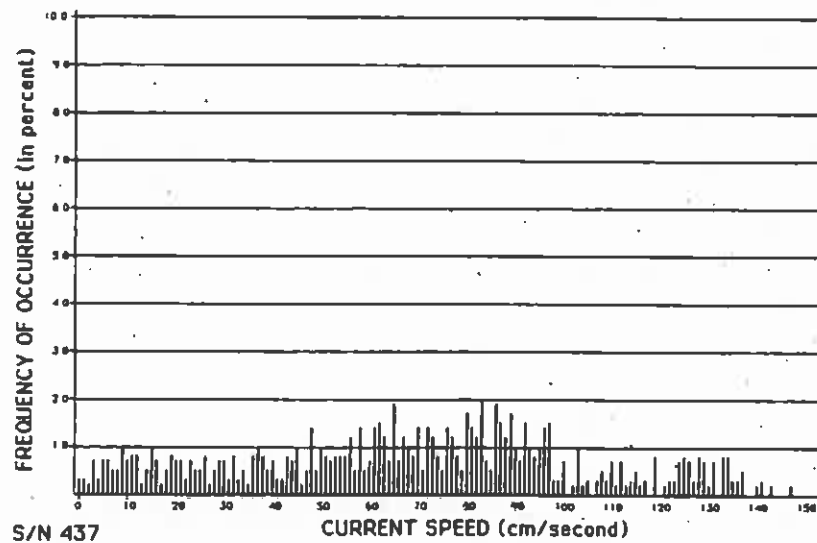


Figure 12. Current Speed Histograms, Station C.

TOP



MIDDLE



BOTTOM

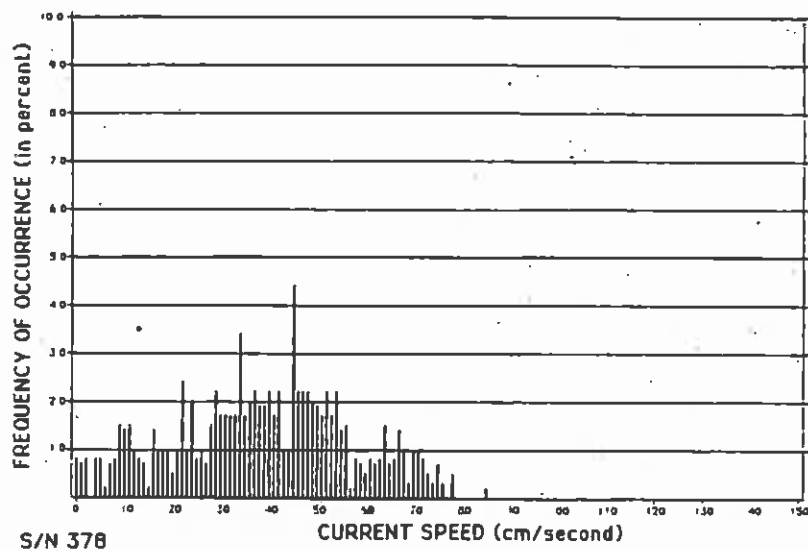
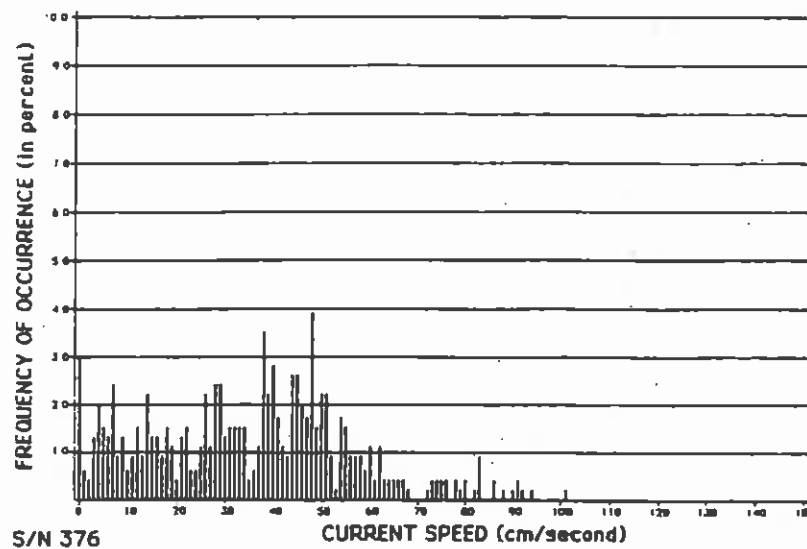
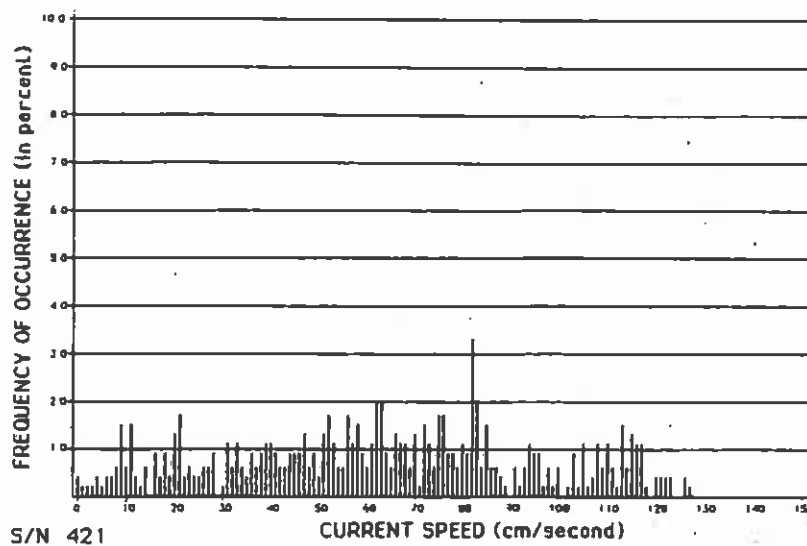


Figure 13. Current Speed Histograms, Station D.

TOP



MIDDLE



BOTTOM

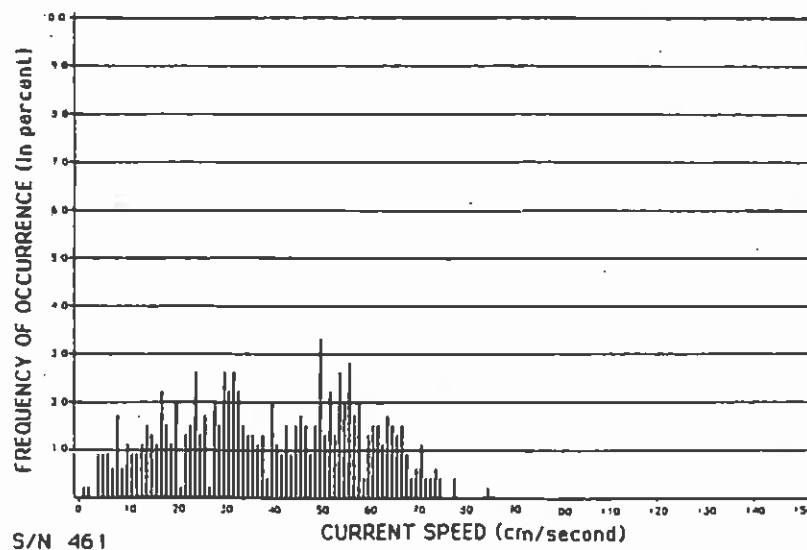


Figure 14. Current Speed Histograms, Station E.

BOTTOM

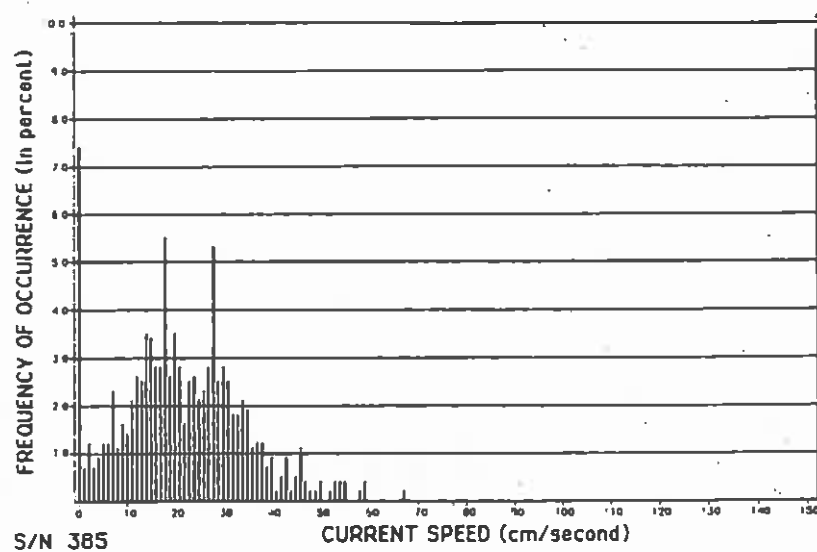


Figure 15. Current Speed Histogram, Station F.

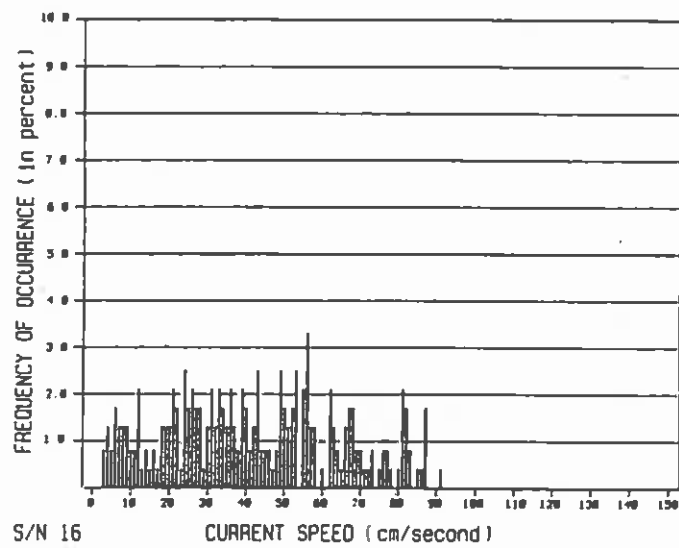


Figure 16. Current Speed Histogram, PUV Gauge.

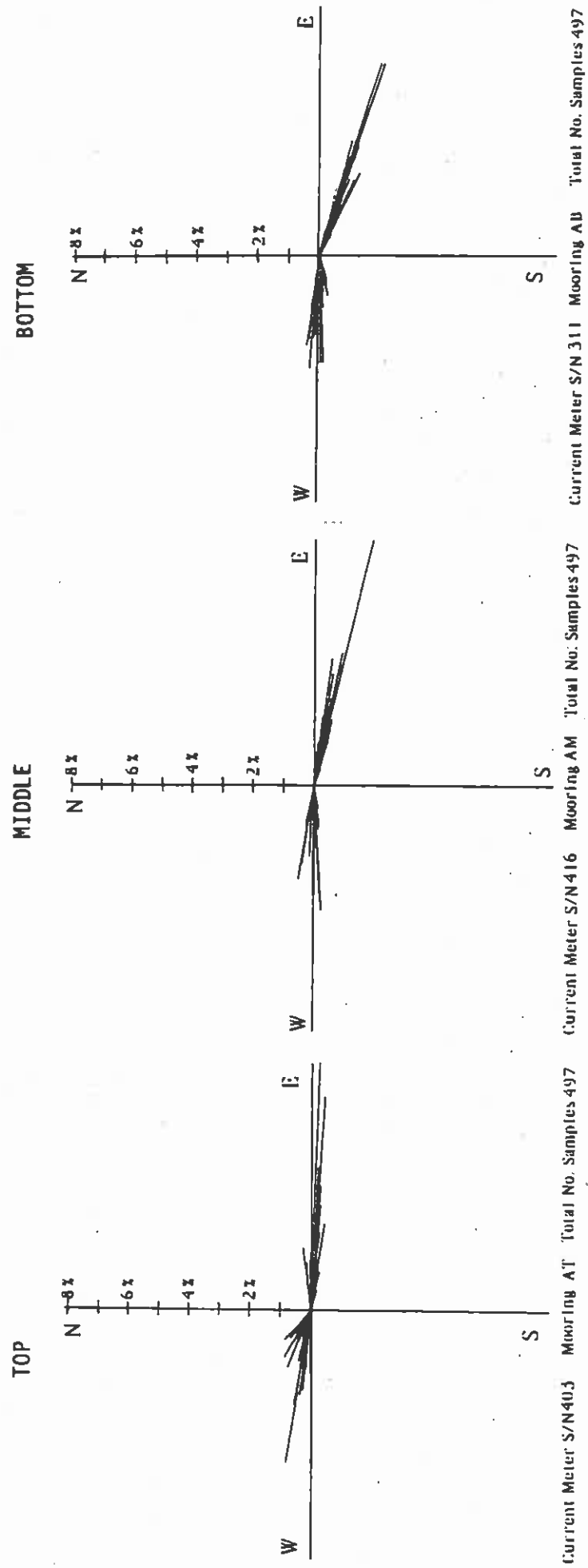


Figure 17. Current Direction Histograms, Station A.

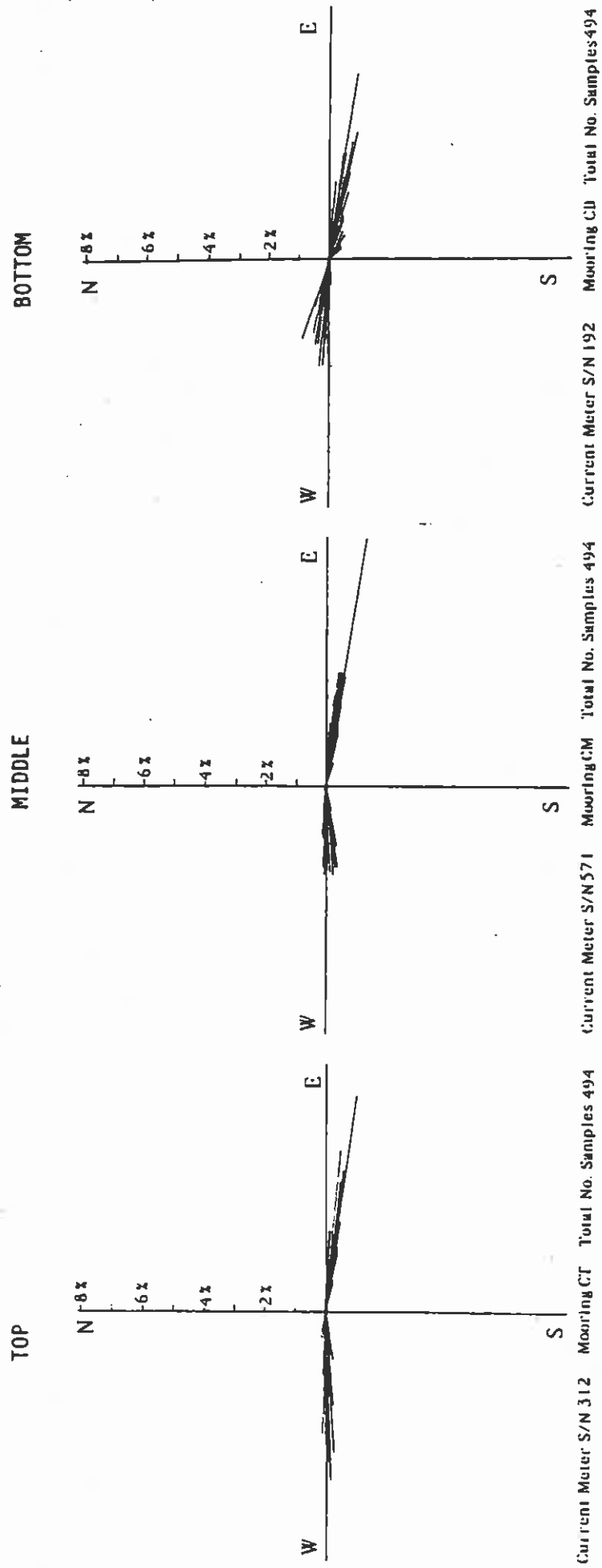


Figure 18. Current Direction Histograms, Station C.

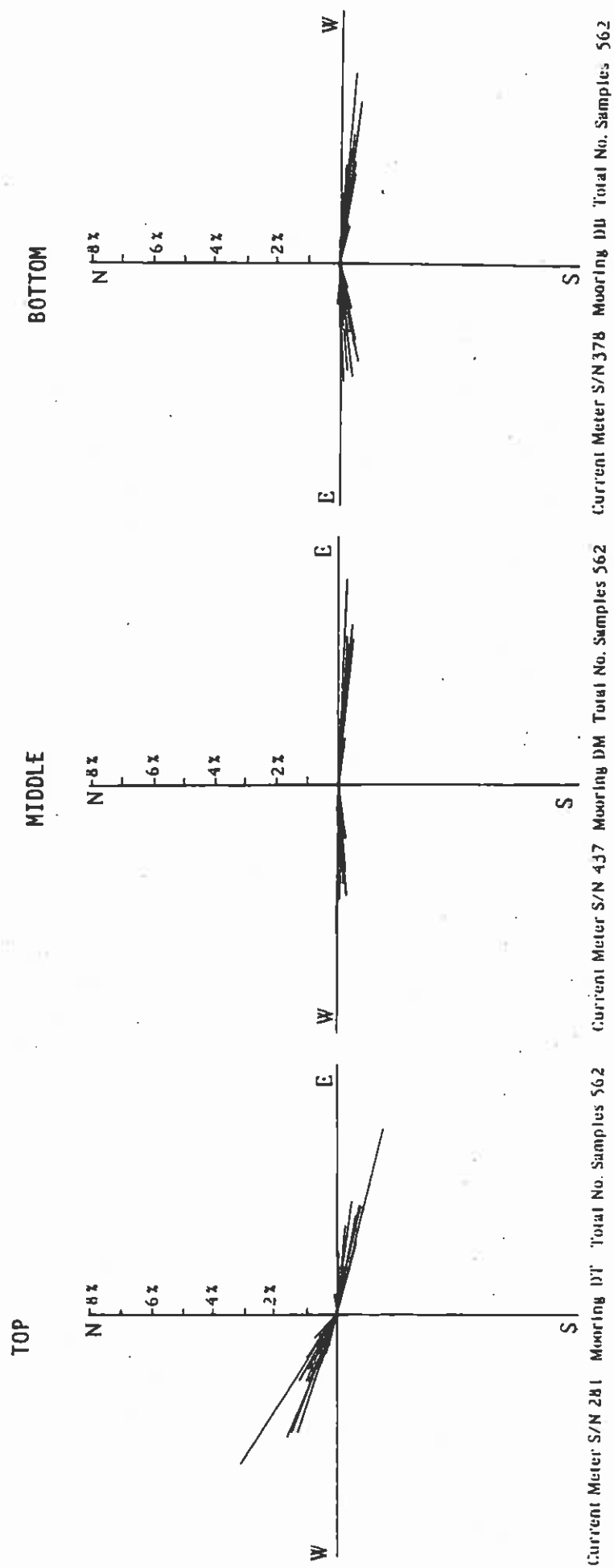


Figure 19. Current Direction Histograms, Station D.

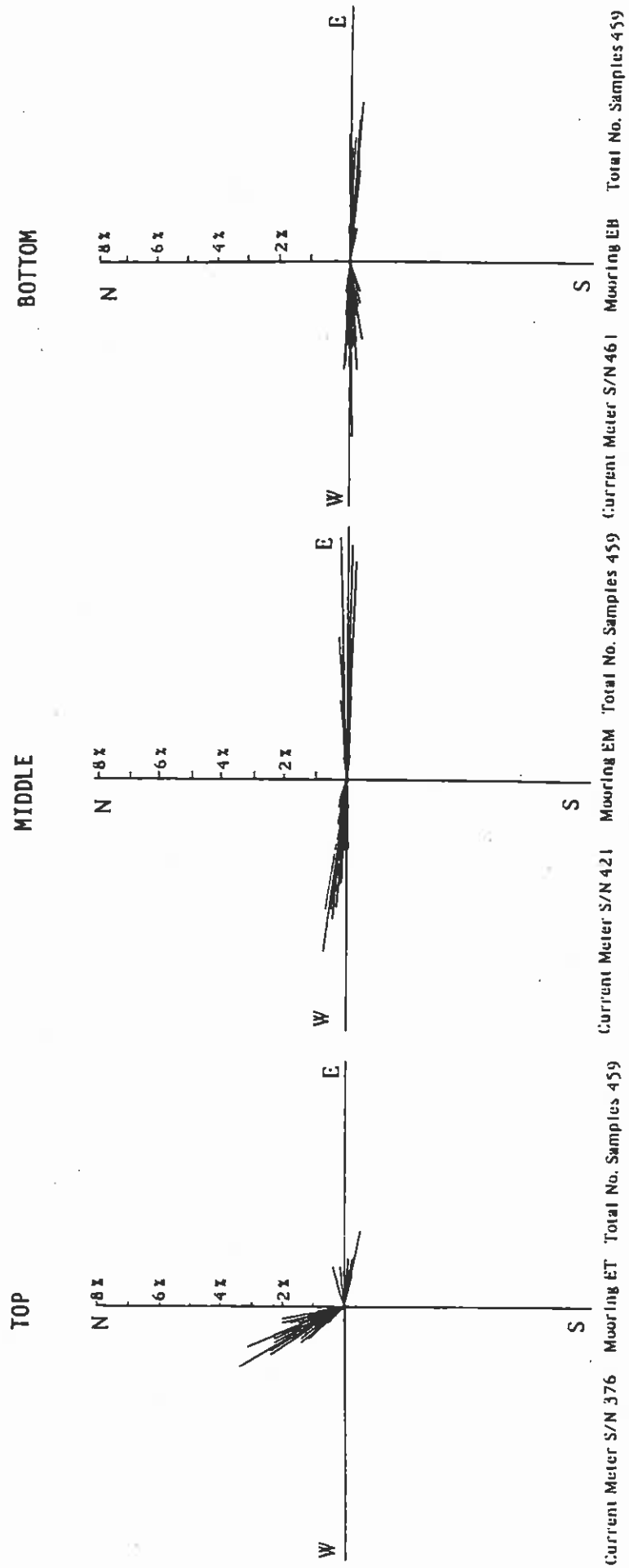


Figure 20. Current Direction Histograms, Station E.

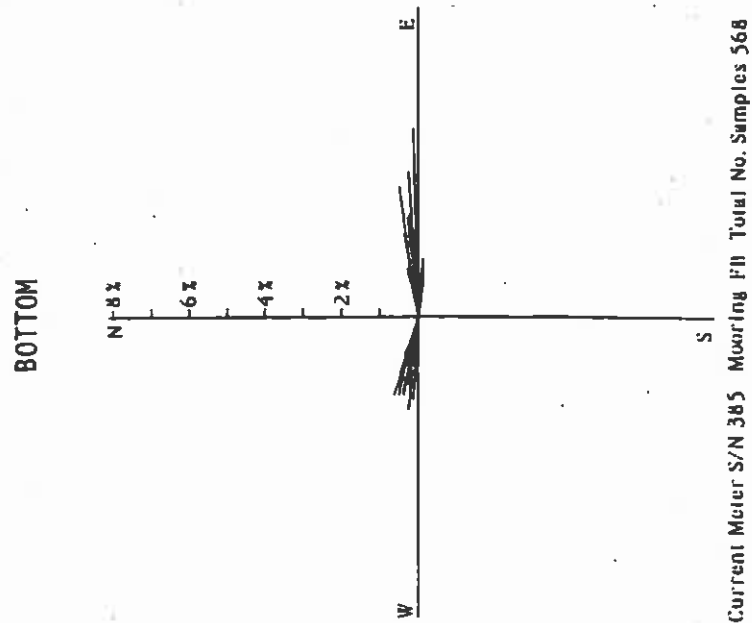


Figure 21. Current Direction Histogram, Station F.

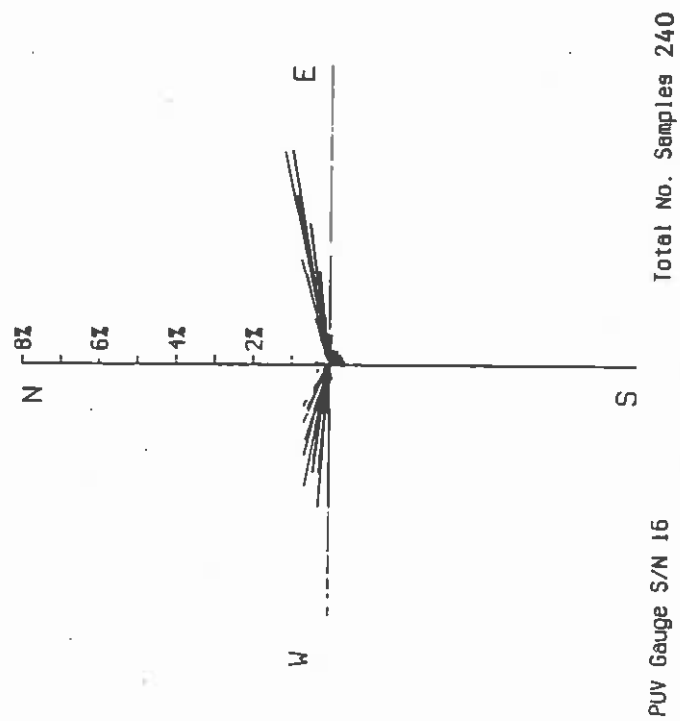


Figure 22. Current Direction Polar Histogram, PUV Gauge.

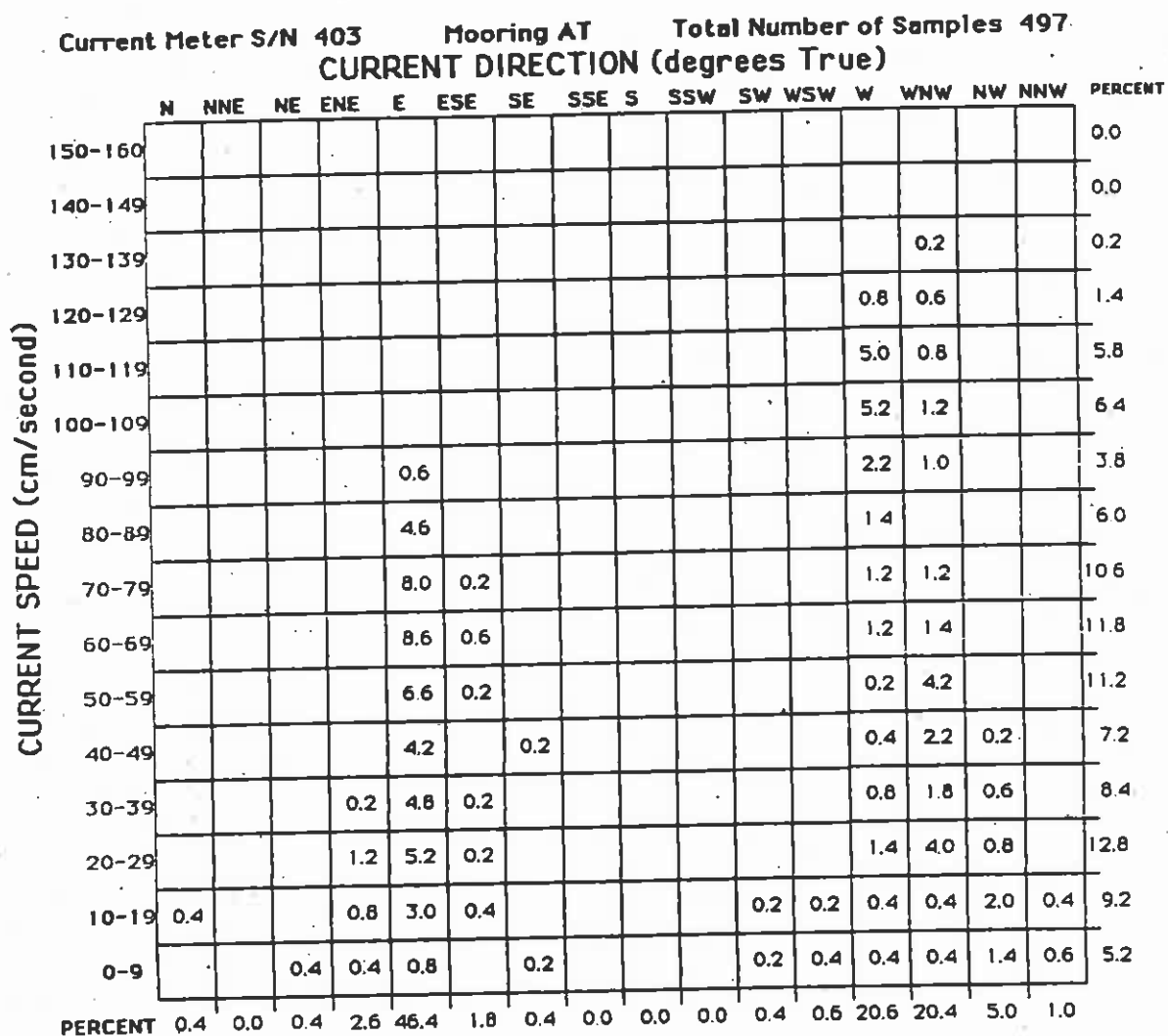


Figure 23. Joint Frequency Diagram for Currents, Station A, Top Meter.

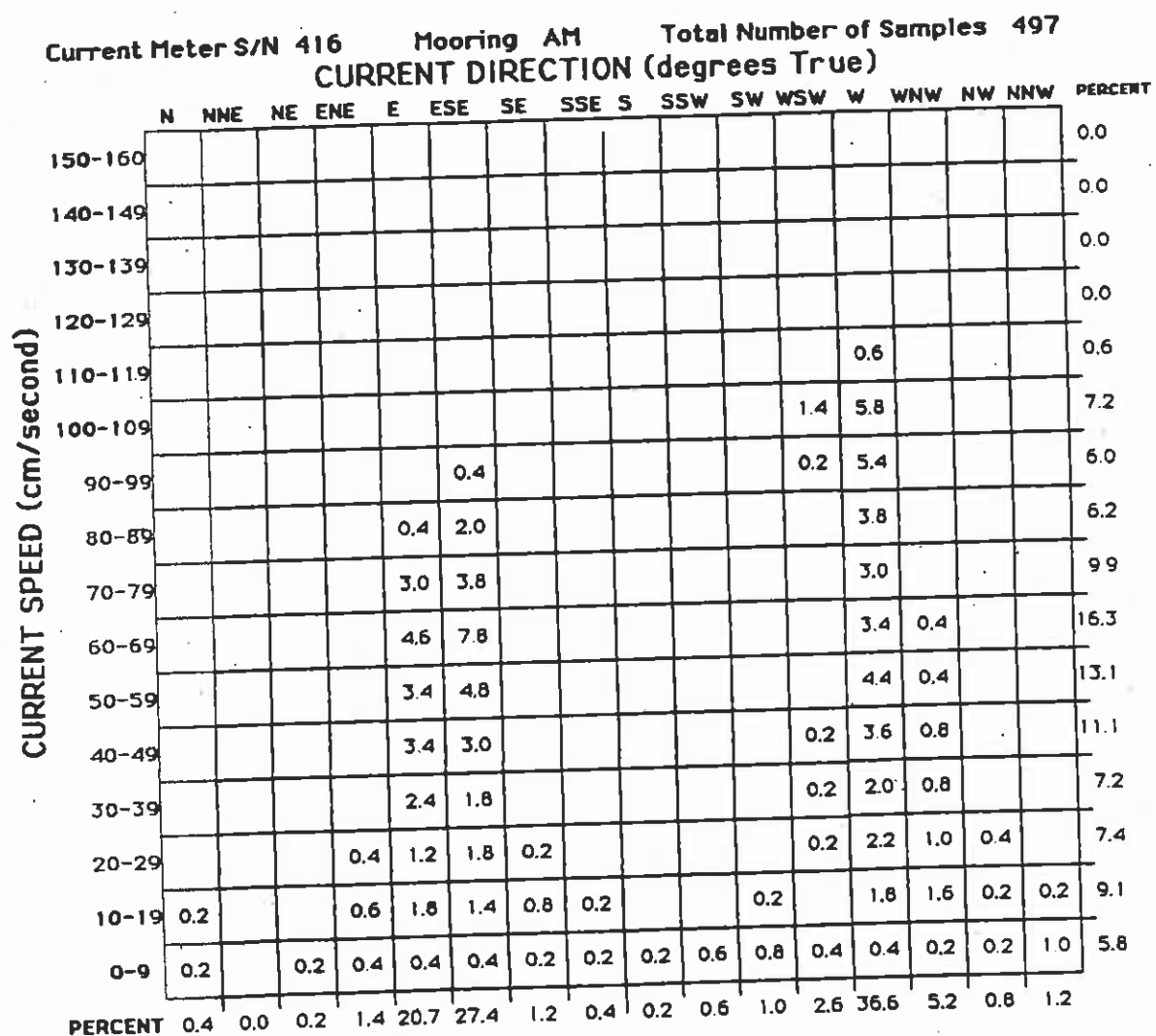


Figure 24. Joint Frequency Diagram for Currents, Station A, Middle Meter.

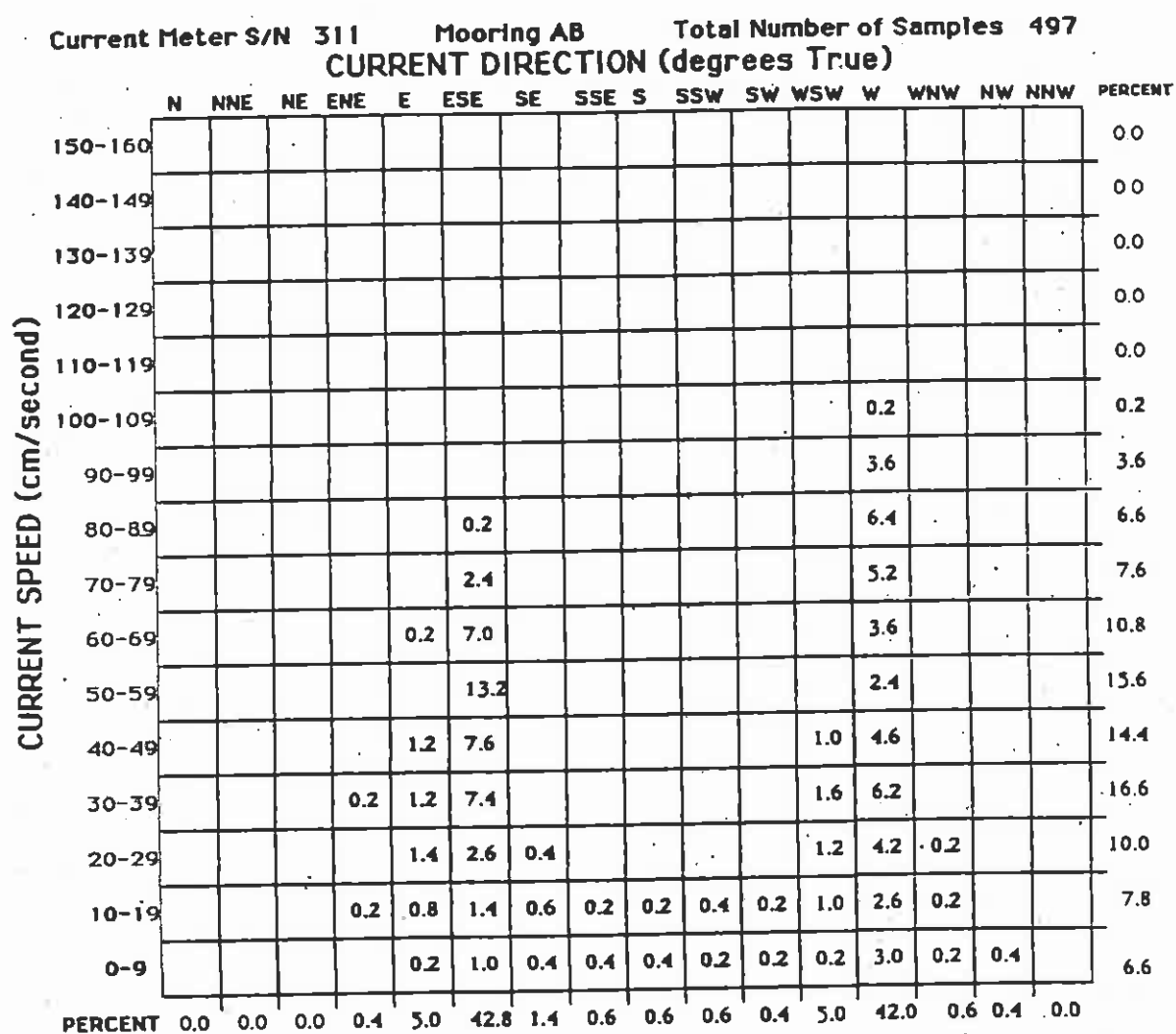


Figure 25. Joint Frequency Diagram for Currents, Station A, Bottom Meter.

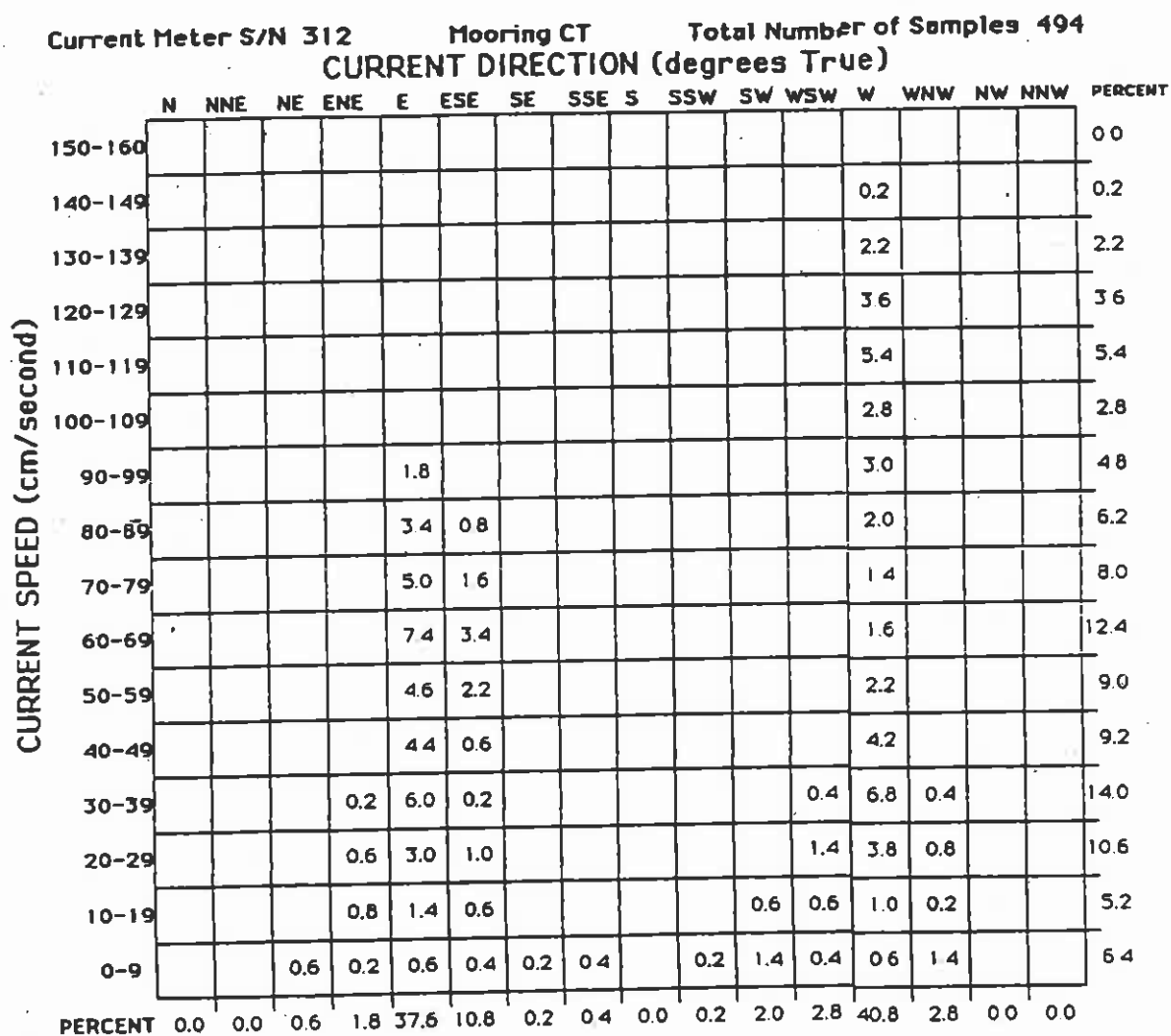


Figure 26. Joint Frequency Diagram for Currents, Station C, Top Meter.

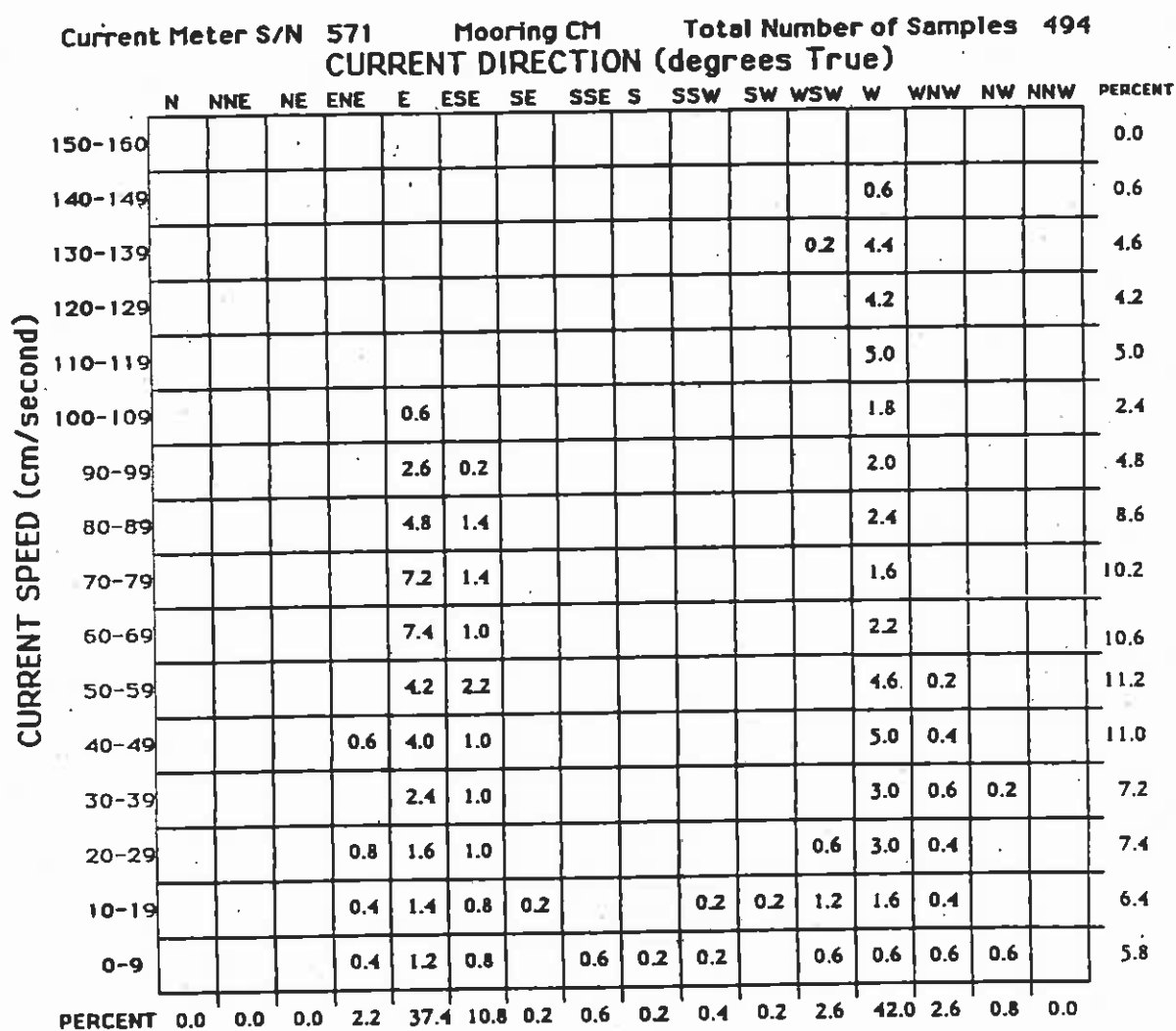


Figure 27. Joint Frequency Diagram for Currents, Station C, Middle Meter.

Current Meter S/N 192 Mooring CB Total Number of Samples 494
CURRENT DIRECTION (degrees True)

	CURRENT DIRECTION (degrees True)																PERCENT
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
150-160																	0.0
140-149																	0.0
130-139																	0.0
120-129																	0.0
110-119																	0.0
100-109													0.4	0.6			1.0
90-99													0.8	3.2			4.0
80-89					0.2	0.2							2.8	3.0	0.2		6.4
70-79					1.4	2.2							2.6	2.4			8.6
60-69					4.8	5.0							0.8	1.8			12.4
50-59					4.4	5.4							2.2	1.6			13.6
40-49				0.6	3.8	6.4							4.8	0.8			16.4
30-39				0.4	3.2	2.0						0.2	5.2	1.4	0.2		12.6
20-29				0.4	2.2	1.6						0.2	3.2	1.2			8.8
10-19				0.2	1.0	1.0						0.8	1.2	1.4	0.2		5.8
0-9			0.4	1.0	2.2	1.2	0.4	0.6	0.8	0.6	0.2	0.6	0.8	1.2	0.4		10.4
PERCENT	0.0	0.0	0.4	2.6	23.2	25.0	0.4	0.6	0.8	0.6	0.2	1.8	24.8	18.6	1.0	0.0	

Figure 28. Joint Frequency Diagram for Currents, Station C, Bottom Meter.

Current Meter S/N 281 Mooring DT Total Number of Samples 589

CURRENT DIRECTION (degrees True)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	PERCENT
CURRENT SPEED (cm/second)																	
150-160																	0.0
140-149														0.3			0.3
130-139														2.6			2.6
120-129														5.1			5.1
110-119														3.1			3.1
100-109						0.3								2.4			2.7
90-99					0.5	4.4								1.2			6.1
80-89					3.2	4.8								2.6			10.5
70-79					4.1	3.4								2.0	0.2		9.7
60-69					3.7	2.7								3.9	0.3		10.7
50-59					4.2	1.5								4.2	1.4		11.4
40-49				0.2	2.2	1.9								2.6	2.0		8.8
30-39					3.2	1.4								2.2	0.9		7.6
20-29	0.2				2.9	0.5								2.0	2.2		7.8
10-19	0.5		0.2	1.0	1.2	1.5	0.2		0.2					1.5	1.0	0.7	8.0
0-9			0.2	0.3	0.7	0.5	0.2				0.3		0.2	0.3	1.5	1.4	5.6
PERCENT	0.7	0.0	0.3	1.5	26.0	22.9	0.3	0.0	0.2	0.0	0.3	0.0	0.2	36.0	9.5	2.1	

Figure 29. Joint Frequency Diagram for Currents, Station D, Top Meter.

Current Meter S/N 437 Mooring DM Total Number of Samples 589

		CURRENT DIRECTION (degrees True)																	PERCENT
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		
CURRENT SPEED (cm/second)	150-160													0.2				0.2	
	140-149													0.9				0.9	
	130-139													3.7				3.7	
	120-129													5.1				5.1	
	110-119													3.9				3.9	
	100-109				0.2	0.7							0.2	2.6				3.6	
	90-99				1.2	5.3	0.3							3.1				9.9	
	80-89			0.2	2.0	8.8	0.3							2.2				13.6	
	70-79				0.7	6.0	0.2							2.9				9.7	
	60-69				0.9	6.3	0.2							3.7				11.1	
	50-59				0.9	4.0								3.9				8.7	
	40-49				0.3	2.0	0.3						0.2	3.4	0.2			6.5	
	30-39				0.2	2.4	0.5						0.2	2.9				6.1	
	20-29				0.3	1.0	1.5					0.2	0.3	2.0	0.2			5.6	
	10-19				1.0	0.7	0.9	0.7	0.3	0.2	0.2		0.5	1.2	0.7			6.3	
	0-9				0.5	1.0	0.2	0.2			0.2	0.3	0.7	0.7	0.7	1.0		5.4	
PERCENT		0.0	0.0	0.2	8.2	38.1	4.4	0.9	0.3	0.2	0.3	0.5	2.0	42.3	1.7	1.0	0.0		

Figure 30. Joint Frequency Diagram for Currents, Station D, Middle Meter.

Current Meter S/N 378 Mooring DB Total Number of Samples 589
CURRENT DIRECTION (degrees True)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	PERCENT
CURRENT SPEED (cm/second)																	
150-160																	0.0
140-149																	0.0
130-139																	0.0
120-129																	0.0
110-119																	0.0
100-109																	0.0
90-99																	0.0
80-89												0.2					0.2
70-79												1.2	4.1				5.3
60-69					0.3	0.2						0.3	7.8				8.7
50-59					8.5	1.0						0.3	4.4				14.3
40-49					14.6	2.0						0.5	4.1				21.2
30-39					7.5	3.7						3.7	4.9				20.0
20-29				0.2	4.9	1.5	0.2					2.0	4.4				13.2
10-19			0.3	0.5	1.0	1.2	0.7	0.5	0.2	0.2	0.7	2.0	2.5		0.2		10.0
0-9			0.3	0.3	0.5	0.5	0.7	0.3	0.7		0.5	0.8	1.7	0.7	0.2		7.3
PERCENT	0.0	0.0	0.7	1.0	37.4	10.2	1.5	0.8	0.8	0.2	1.2	11.2	34.0	0.7	0.3	0.0	

Figure 31. Joint Frequency Diagram for Currents, Station D, Bottom Meter.

Current Meter S/N 376 Mooring ET Total Number of Samples 459
CURRENT DIRECTION (degrees True)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	PERCENT
CURRENT SPEED (cm/second)																	
150-160																	0.0
140-149																	0.0
130-139																	0.0
120-129																	0.0
110-119																	0.0
100-109																0.2	0.2
90-99																1.1	1.1
80-89															0.2	2.0	2.2
70-79																2.6	2.6
60-69					1.3	0.2										3.5	5.0
50-59	0.4			0.2	3.7	0.9	2.0	0.4							1.3	4.0	12.9
40-49	1.3	0.2	0.2	0.2	4.8	3.3	0.9	0.2	0.4	0.2			0.4		2.4	5.9	20.4
30-39	0.2			1.3	2.0	2.2	1.1	0.9	0.4	0.2				0.4	2.8	3.7	15.2
20-29	0.4		0.2	1.7	2.4	1.5		0.4	0.7	0.2				0.4	2.4	3.1	13.4
10-19	0.7		0.4	2.2	1.5	0.9	0.2						0.2	0.2	2.4	3.5	12.2
0-9	1.7	0.7	0.7	0.4	1.5	0.2	0.7	0.4	0.2		0.2		0.7	0.9	2.8	3.7	14.8
PERCENT	4.7	0.9	1.5	6.0	17.2	9.2	4.9	2.3	1.7	0.6	0.2	0.0	1.3	1.9	14.3	33.3	

Figure 32. Joint Frequency Diagram for Currents, Station E, Top Meter.

Current Meter S/N 421 Mooring EM Total Number of Samples 459
CURRENT DIRECTION (degrees True)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	PERCENT
CURRENT SPEED (cm/second)																	
150-160																	0.0
140-149																	0.0
130-139																	0.0
120-129												2.4					2.4
110-119												7.8					7.8
100-109					0.2							5.2					5.4
90-99					3.5							2.0					5.5
80-89					7.4							3.9					11.3
70-79					8.9							1.7					10.6
60-69					7.0							4.1	0.2				11.3
50-59					6.1							0.2	3.9	0.9			11.1
40-49				0.9	3.7								3.5	0.7			8.8
30-39				0.9	2.8	0.2							2.2	1.3			7.4
20-29				1.1	1.3	0.7						0.2	2.6	1.1	0.4		7.4
10-19			0.9	0.4	1.4	0.4	0.2	0.4			0.7	0.2	0.7	0.7	0.2	0.2	6.4
0-9	0.2		0.2		0.4	0.2	0.4	0.2	0.4	0.2	0.2	0.4	0.2		0.9	0.7	4.6
PERCENT	0.2	0.0	1.1	3.3	42.7	1.5	0.6	0.6	0.4	0.2	0.9	1.0	40.2	4.9	1.5	0.9	

Figure 33. Joint Frequency Diagram for Currents, Station E, Middle Meter.

Current Meter S/N 461 Mooring EB Total Number of Samples 459

CURRENT DIRECTION (degrees True)

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	PERCENT
150-160																	0.0
140-149																	0.0
130-139																	0.0
120-129																	0.0
110-119																	0.0
100-109																	0.0
90-99																	0.0
80-89													0.4				0.4
70-79					0.9								3.5				4.4
60-69					3.8								9.8				13.6
50-59					12.4								5.8				18.2
40-49				0.2	8.3								5.4				13.9
30-39				0.4	6.5	1.7						2.4	5.5				16.5
20-29			0.4	0.7	3.7	1.1		0.2				2.2	6.1				14.4
10-19			0.7	0.4	1.7	2.2	0.4	0.4	0.4	0.4	0.4	1.5	3.3	0.4	0.4		12.6
0-9					0.7	0.9	0.2	0.7	0.4	0.4	0.4	0.7	1.1	0.2	0.2		5.9
PERCENT	0.0	0.0	1.1	1.7	38.0	5.9	0.6	1.3	0.8	0.8	0.8	6.8	40.9	0.6	0.6	0.0	

Figure 34. Joint Frequency Diagram for Currents, Station E, Bottom Meter.

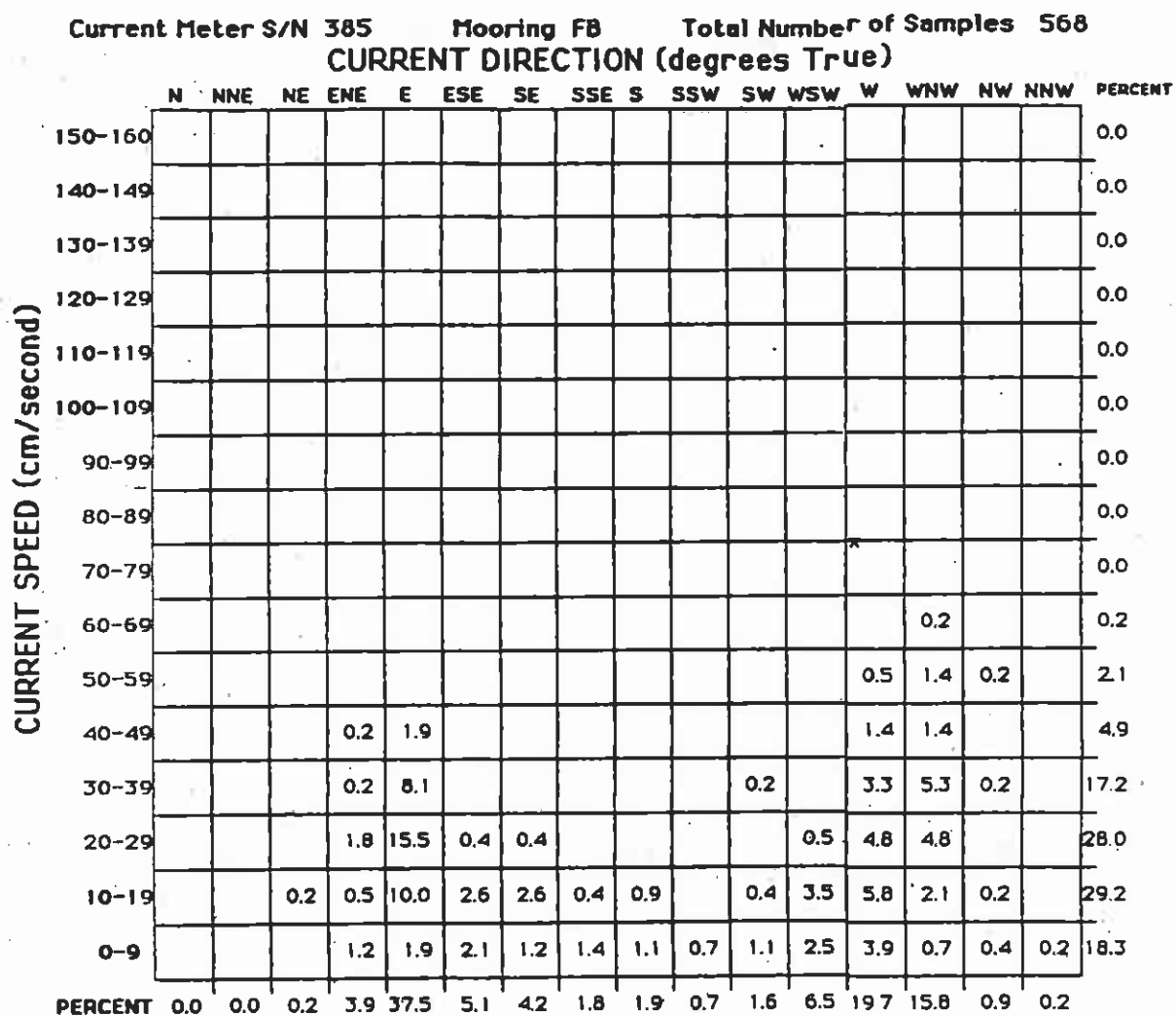


Figure 35. Joint Frequency Diagram for Currents, Station F, Bottom Meter.

PUV Gauge S/N 16

Total Number of Samples 240

CURRENT DIRECTION (degrees True)

CURRENT SPEED (cm/second)	CURRENT DIRECTION (degrees True)																PERCENT
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
150-160																	
140-149																	
130-139																	
120-129																	
110-119																	
100-109																	
90-99													0.4				0.4
80-89													2.9	4.6			7.5
70-79				0.4	1.3								1.7	1.7			5.1
60-69				2.5	2.5								0.4	3.8	1.3		10.5
50-59				4.2	7.1								0.4	3.3			15.0
40-49				5.8	3.8								1.3	1.7			12.6
30-39				4.2	2.5	1.7							0.4	2.1	4.6	0.4	15.9
20-29				3.3	3.8	0.8								2.5	3.3	1.7	15.4
10-19			0.4	1.3		0.4	0.4						0.4	2.9	2.5	0.8	9.1
0-9	0.4	0.8	0.4		0.8			1.3	0.4	0.4			0.4	1.7	0.8	0.4	8.2
PERCENT	0.4	0.8	0.8	21.7	21.8	2.9	0.4	1.3	0.4	0.4	0.0	2.0	22.6	20.5	3.3	0.4	

Figure 36. Joint Frequency Diagram for Currents, PUV Gauge.

ALCATRAZ DISPOSAL SITE

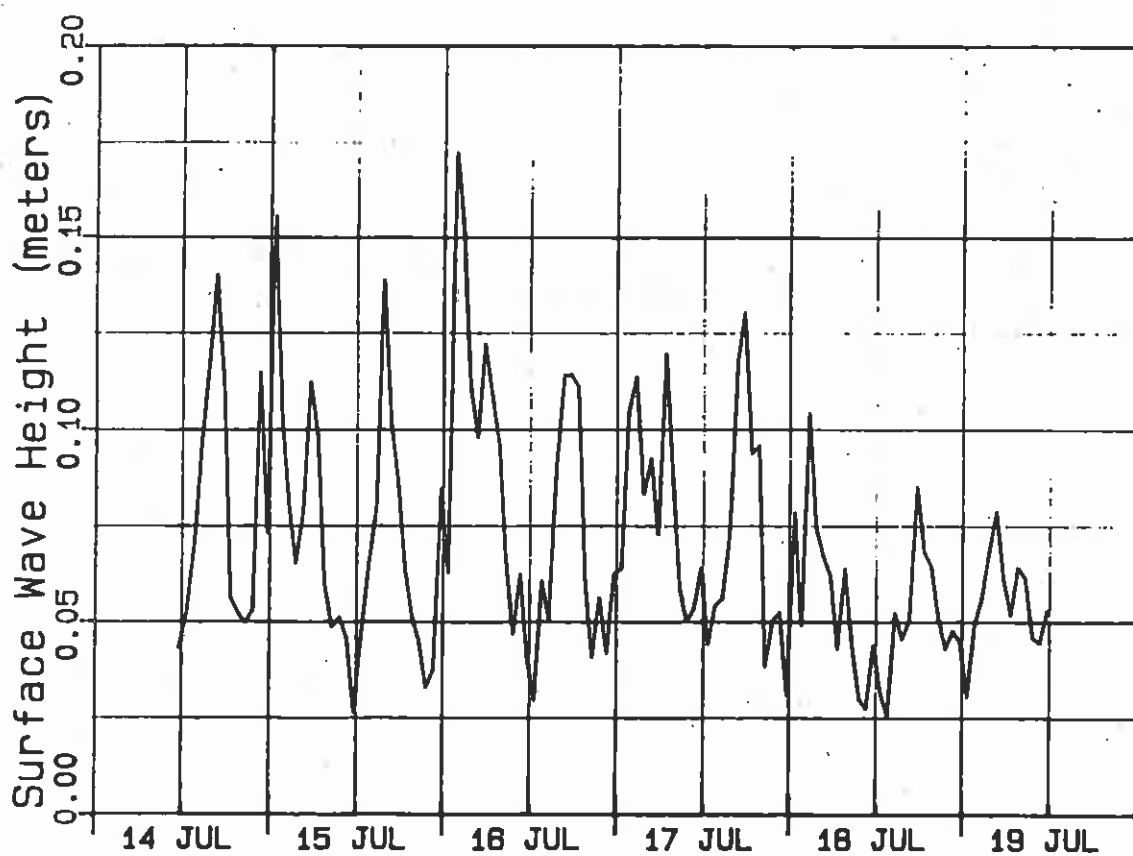
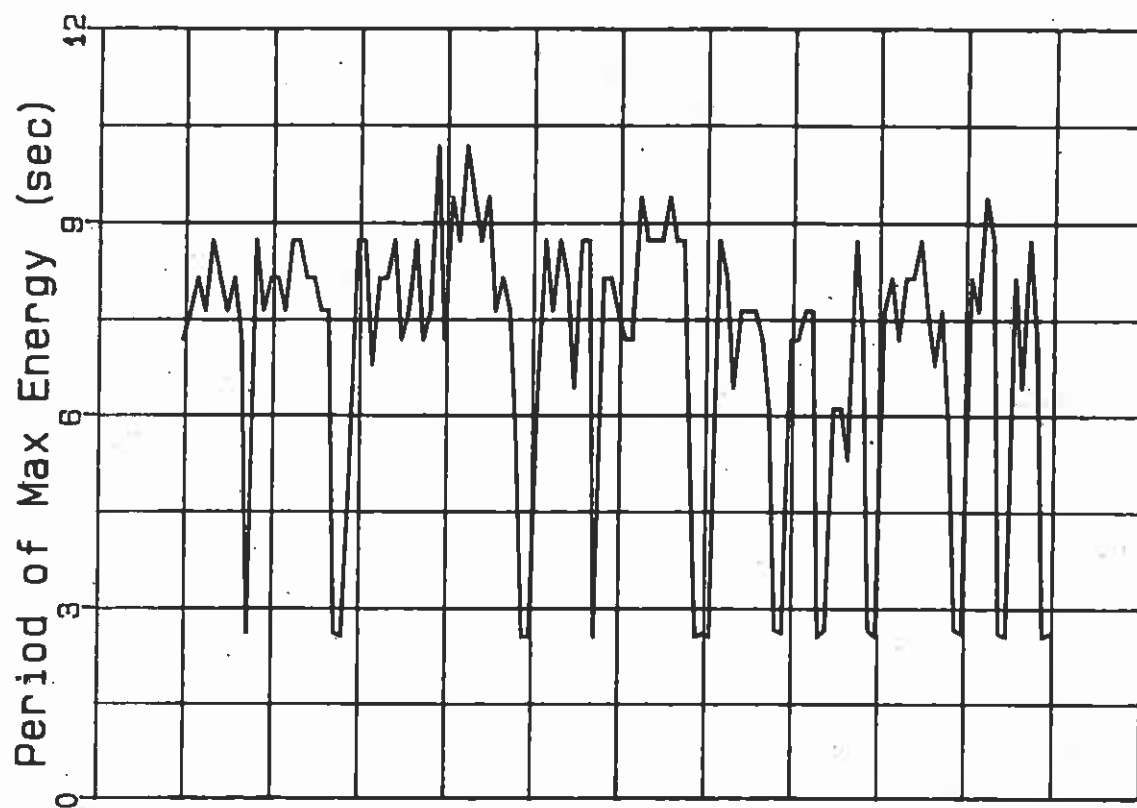


Figure 37. Wave Height and Period, PUV Gauge.

ALCATRAZ DISPOSAL SITE
Surface Wave Spectrum
16 July 10:35

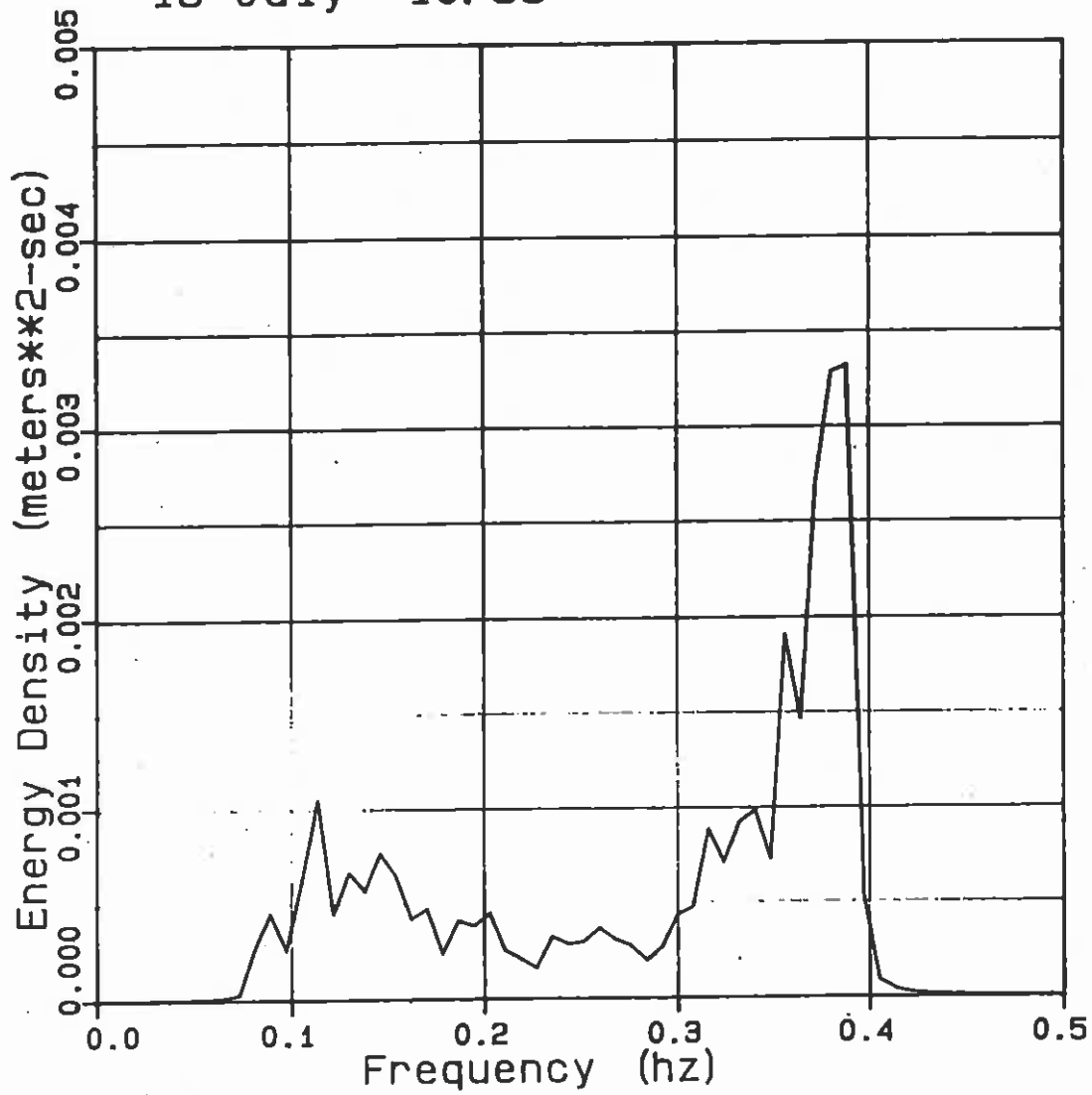


Figure 38. Surface Wave Spectrum, 16 July 85, 1035 h.

ALCATRAZ DISPOSAL SITE
Surface Wave Spectrum
16 July 1985 01:35

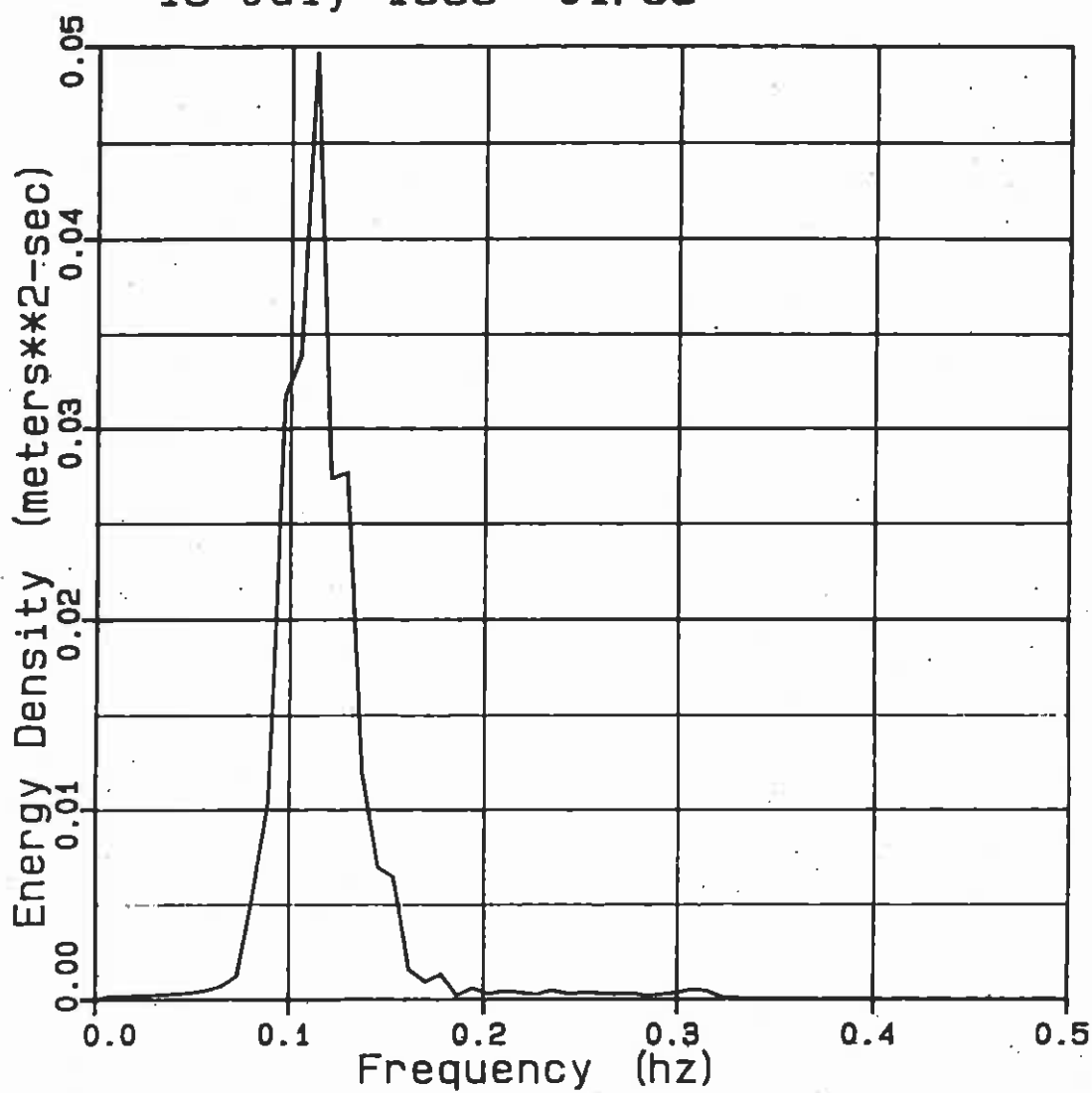


Figure 39. Surface Wave Spectrum, 16 July 85, 0135 h.

ALCATRAZ DISPOSAL SITE

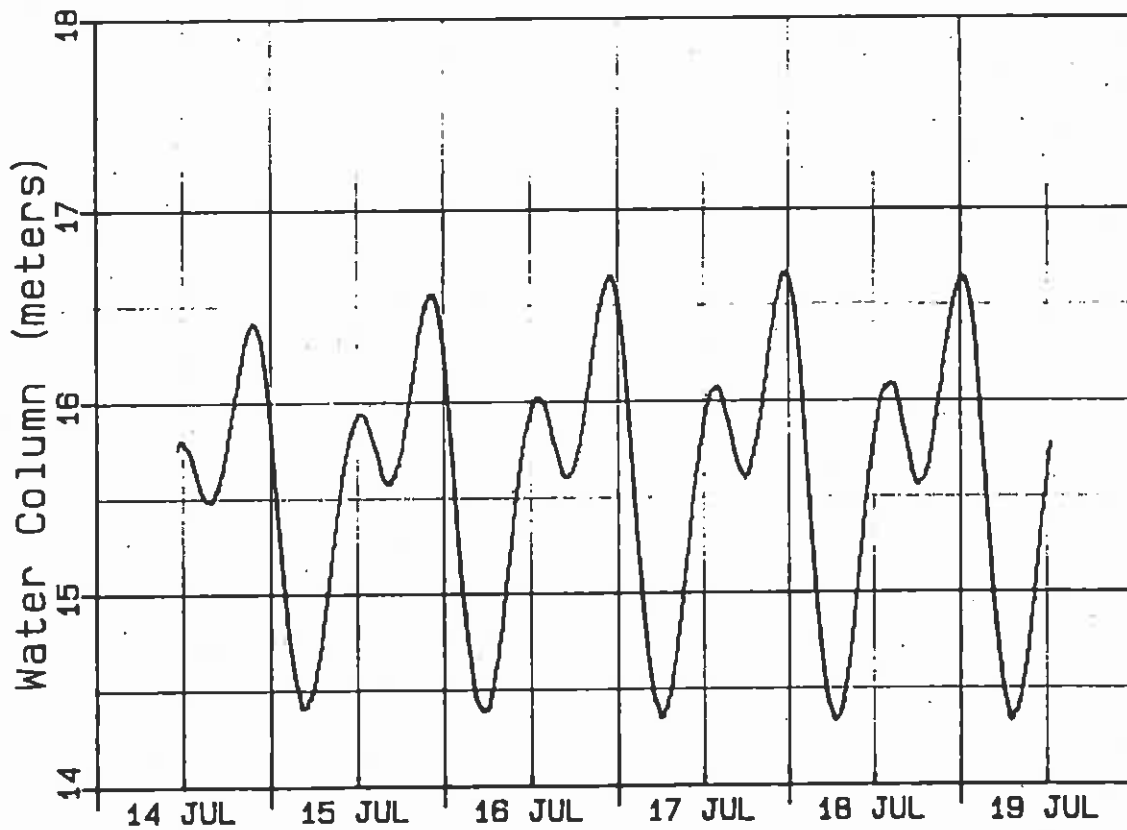
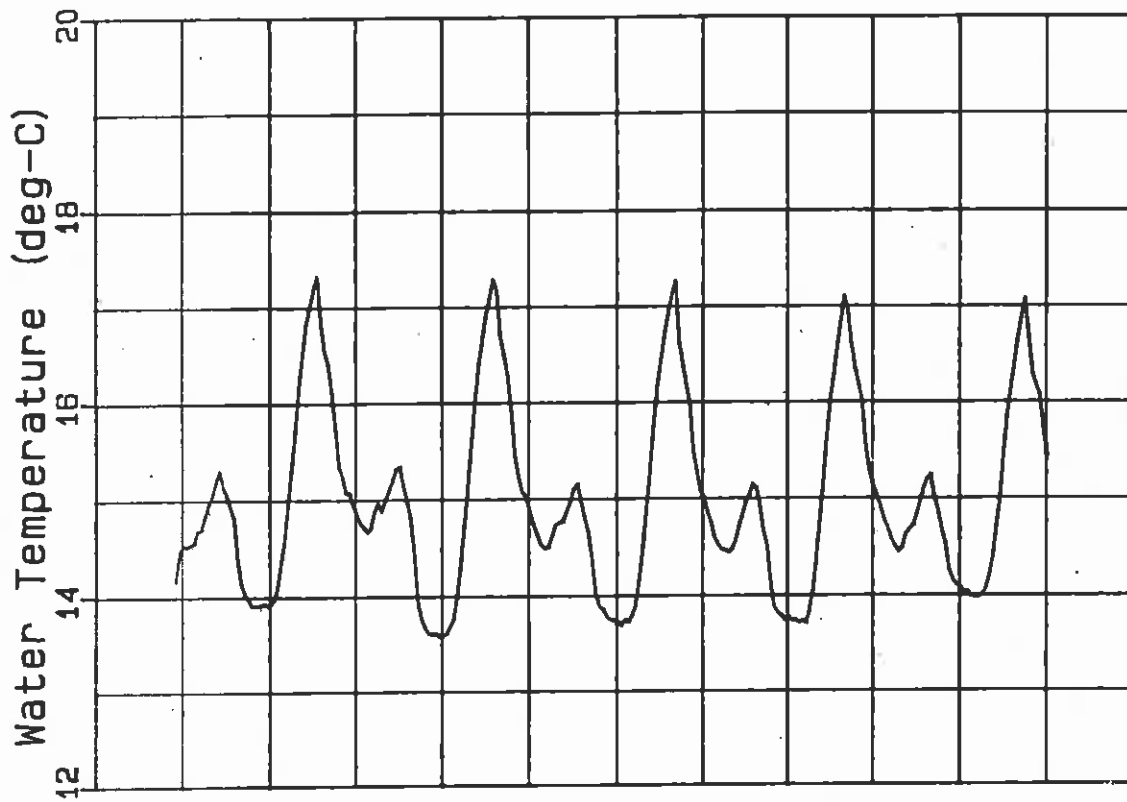


Figure 40. Water Temperature and Water Column Elevation, PUV Gauge.

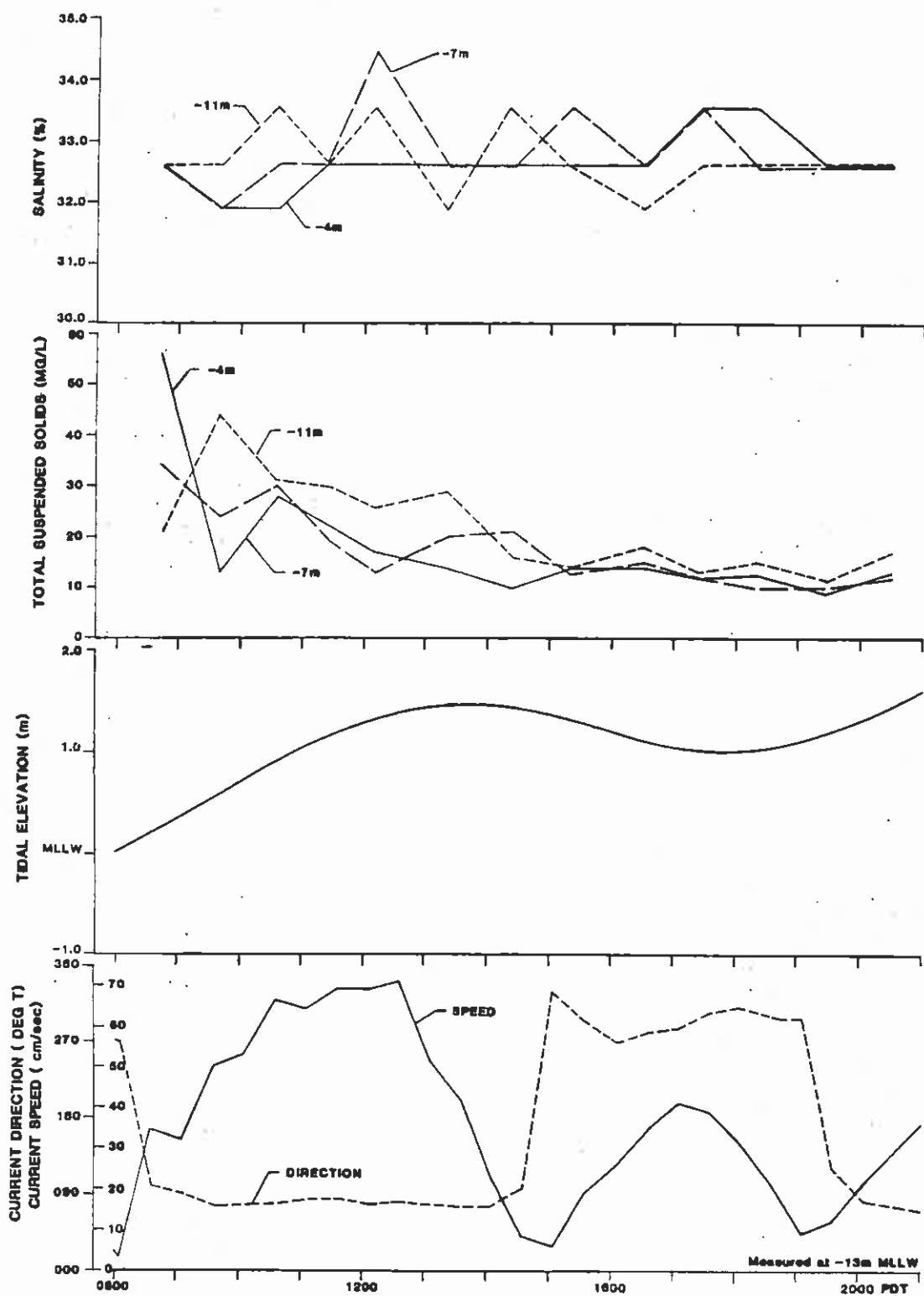


Figure 41. Plotted Results of Sea Water Sampling at Station A.

TABLE 1.

INSTRUMENT TYPES, LOCATIONS, AND DEPLOYMENT DATES

STATION	INSTRUMENT DESIGNATION	INSTRUMENT TYPE	WATER DEPTH	INSTRUMENT DEPTH	LATITUDE/ LONGITUDE	DATE/TIME (a)	
						IN-SITU	EX-SITU
TG-1	HYDE	SEA DATA TDR-2	5 m	3.07 m	37° 48.61' N 122° 25.28' W	07.12.85., 1430	07.19.85., 1815
TG-2	ALCATRAZ	SEA DATA TDR-2	7 m	1.42 m	37° 49.62' N 122° 25.26' W	07.12.85., 1540	07.19.85., 1755
TG-3	BROOKS	SEA DATA TDR-2	3 m	1.33 m	37° 53.76' N 122° 21.30' W	07.12.85., 1640	07.20.85., 2000
A	A-T	ENDECO 105	13.7 m	4 m	37° 49.28' N 122° 25.38' W	07.14.85., 1108	07.19.85., 1530
A	A-M	ENDECO 105	13.7 m	6 m	37° 49.28' N 122° 25.38' W	07.14.85., 1108	07.19.85., 1530
A	A-B	ENDECO 105	13.7 m	12 m	37° 49.28' N 122° 25.38' W	07.14.85., 1108	07.19.85., 1530
A	PUV	SEA DATA 635-12	13.7 m	13 m	37° 49.28' N 122° 25.38' W	07.14.85., 1108	07.19.85., 1530
B	B-T	ENDECO 105	32.0 m	4 m	37° 49.42' N 122° 25.38' W	07.14.85., 1207	(b)
B	B-M	ENDECO 105	32.0 m	16 m	37° 49.42' N 122° 25.38' W	07.14.85., 1207	(b)
B	B-B	ENDECO 105	32.0 m	32 m	37° 49.42' N 122° 25.38' W	07.14.85., 1207	(b)
C	C-T	ENDECO 105	12.5 m	4 m	37° 49.33' N 122° 25.30' W	07.14.85., 1240	07.19.85., 1625
C	C-M	ENDECO 150	12.5 m	6 m	37° 49.33' N 122° 25.30' W	07.14.85., 1240	07.19.85., 1625
C	C-B	ENDECO 105	12.5 m	11 m	37° 49.33' N 122° 25.30' W	07.14.85., 1240	07.19.85., 1625
D	D-T	ENDECO 105	21.0 m	4 m	37° 49.15' N 122° 25.38' W	07.14.85., 1310	07.20.85., 1630
D	D-M	ENDECO 105	21.0 m	10 m	37° 49.15' N 122° 25.38' W	07.14.85., 1310	07.20.85., 1630
D	D-B	ENDECO 105	21.0 m	20 m	37° 49.15' N 122° 25.38' W	07.14.85., 1310	07.20.85., 1630

TABLE 1. (con't)

INSTRUMENT TYPES, LOCATIONS, AND DEPLOYMENT DATES

STATION	INSTRUMENT DESIGNATION	INSTRUMENT TYPE	WATER DEPTH	INSTRUMENT DEPTH	LATITUDE/ LONGITUDE	DATE/TIME (a)	
						IN-SITU	EX-SITU
E	E-T	ENDECO 105	16.5 m	4 m	37° 49.28' N 122° 25.54' W	07.14.85., 1343	07.19.85., 0830
E	E-M	ENDECO 105	16.5 m	8 m	37° 49.28' N 122° 25.54' W	07.14.85., 1343	07.19.85., 0830
E	E-B	ENDECO 105	16.5 m	15 m	37° 49.28' N 122° 25.54' W	07.14.85., 1343	07.19.85., 0830
F	F-T	ENDECO 105	24.7 m	4 m	37° 49.28' N 122° 25.78' W	07.14.85., 1406	(c)
F	F-B	ENDECO 105	24.7 m	23 m	37° 49.28' N 122° 25.78' W	07.14.85., 1406	07.20.85., 2140

(a) All times are Pacific Daylight Time.

(b) Instrument not recovered.

(c) Instrument damaged and data lost.

TABLE 2

STATISTICS OF EBB AND FLOOD CURRENTS, ALCATRAZ DISPOSAL SITE
14 - 19 JUNE 1985

STATION	--- FLOOD (001-180 DEG) ---			--- EBB (181-360 DEG) ---		
	n	MEAN DIRECTION (DEG T)	MEAN SPEED (cm/sec)	n	MEAN DIRECTION (DEG T)	MEAN SPEED (cm/sec)
A-T	254	92	51	243	287	62
A-M	255	102	50	242	273	59
A-B	252	110	43	244	268	48
PUV	122	82	40	118	281	44
C-T	253	97	51	241	265	64
C-M	254	98	56	240	267	71
C-B	259	100	43	235	276	50
D-T	306	97	57	283	299	65
D-M	308	91	63	281	267	74
D-B	304	99	37	285	262	40
E-T	200	99	33	259	326	36
E-M	229	89	57	230	276	67
E-B	230	94	38	229	264	40
F-B	304	95	20	264	271	21

TABLE 3

RESULTS OF SEAWATER ANALYSES
WATER SAMPLES FROM STATION A

JULY 17, 1985

<u>Time (PDT)</u>	<u>Depth (M)</u>	<u>Salinity (PPT)</u>	<u>Total Suspended Solids (mg/l)</u>
0844	4	32.77	56
	7	32.77	34
	11	32.77	21
0940	4	31.88	13
	7	31.88	24
	11	32.77	44
1035	4	31.88	28
	7	32.77	30
	11	33.65	31
1123	4	32.77	22
	7	32.77	19
	11	32.77	30
1210	4	32.77	17
	7	34.54	13
	11	33.65	26
1320	4	32.77	14
	7	32.77	20
	11	31.88	29
1422	4	32.77	10
	7	32.77	21
	11	33.65	16
1520	4	32.77	14
	7	33.65	13
	11	32.77	14
1630	4	32.77	14
	7	32.77	15
	11	31.88	18
1725	4	33.65	12
	7	33.65	12
	11	32.77	13
1817	4	33.65	13
	7	32.77	10
	11	32.77	15
1927	4	32.77	9
	7	32.77	10
	11	32.77	11
2029	4	32.77	13
	7	32.77	12
	11	32.77	17