ANNUAL SUMMARY R.PORT

FOR 1977 .YDROGRAPHIC STUDIES

OFF HAMPTON BEACH, NEW HAMPSHIRE

TECHNICAL REPORT X-1

PREOPERATIONAL ECOLOGICAL MONITORING STUDIES

FOR SEABROOK STATION

Conducted for

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
Manchester, New Hampshire

By

NORMANDEAU ASSOCIATES, INC.
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1.0 INTRODUCTION

This report contains the results of the 1977 baseline hydrographic and meteorological studies conducted as part of the ecological monitoring program for Public Service Company of New Hampshire's (PSC) Seabrook Station Project. These studies of the coastal waters off Hampton Beach, New Hampshire, the estuarine waters of Hampton Harbor, and the oceanic waters of the western Gulf of Maine characterize general preoperational hydrographic conditions. Seabrook Station will take in coastal water from about 1 n mi (1.9 km) off Hampton Beach for once through condenser cooling and release the heated water back into the ocean through a submerged multiport diffuser, again about 1 n mi offshore.

The 1977 program was designed to: (1) document existing conditions for the year; (2) characterize ambient conditions at particular locations such as the diffuser site, the intake site, far-field reference sites, the Sunk Rocks, and Hampton Harbor estuary; (3) help understand important processes, such as stratification formation, estuarine-oceanic interaction, wind stress effects, coastal boundary layer dynamics, upwelling and downwelling; and (4) compare results to historical information. This year's program focused on continuous monitoring of water currents, temperature, tides, and wind. Supplemental spatial surveys delineated tidal and seasonal variations in local and regional distributions of water temperature, salinity, density and dissolved oxygen. This report summarizes the latest findings and compares them with Normandeau Associates, Inc. (NAI) baseline hydrographic and sedimentological studies listed in Figure 1.0-1 starting in September 1972 (NAI 1975a, 1976b, 1977a, 1977b, and 1979).

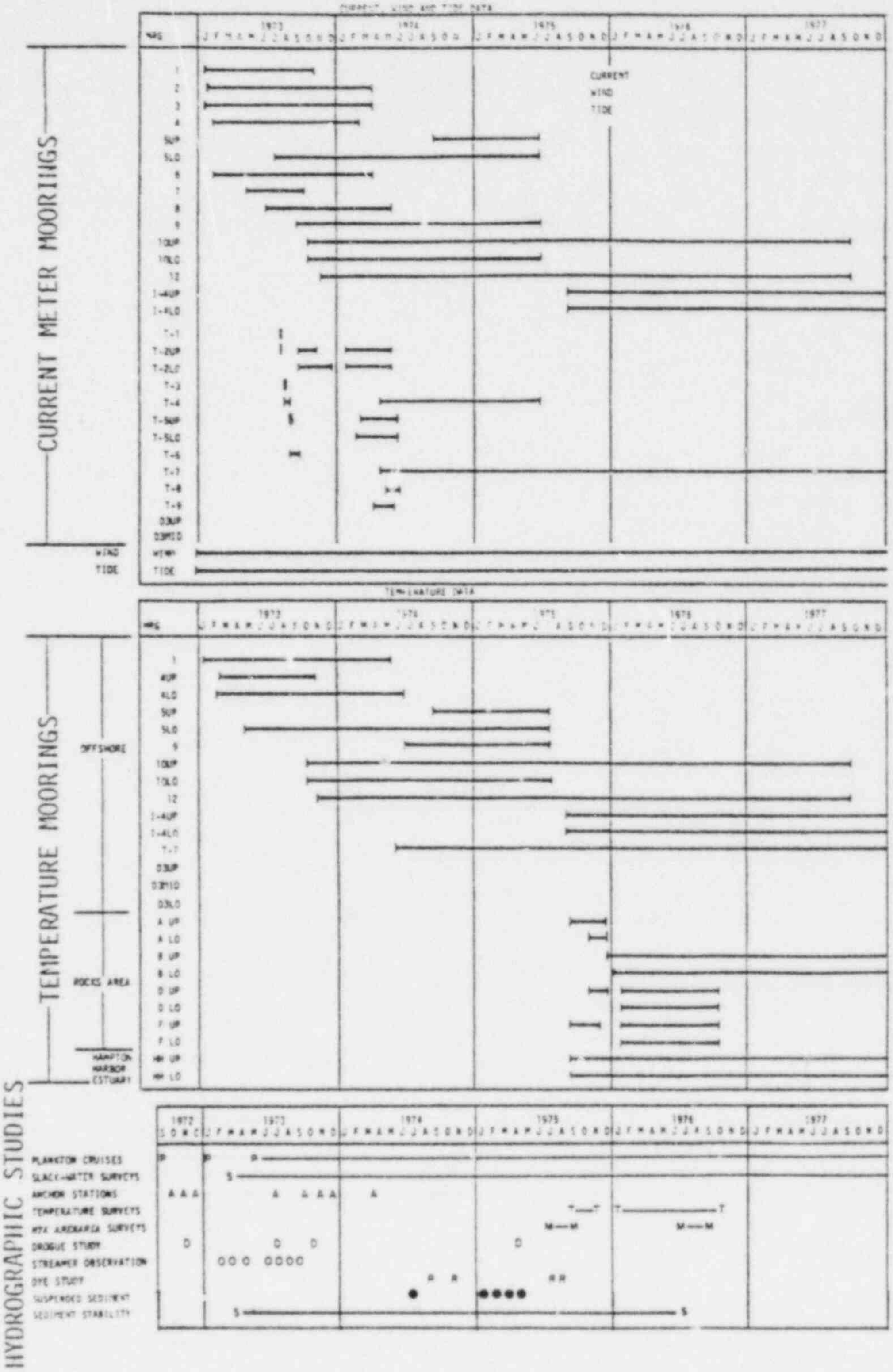

Figure 1.0-1. Diagram showing hydrographic studies which have been conducted off Hampton Beach, New Hampshire, from 1972 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

2.0 MATERIALS AND METHODS

2.1 STUDY DESIGN

The overall design for the 1977 studies focuses on continuous measurement of key parameters and monthly measurements of other parameters (Table 2.1-1). The key parameters (currents, wind, tide, and water temperature) are those which: (1) exhibit greatest spatial and seasonal variability, (2) describe the natural environment and dominant oceanographic and meteorological processes, (3) describe existing conditions affecting local biota and (4) may be affected by plant operation. These parameters must be measured continuously because they fluctuate so rapidly. Sampling locations were selected as representative critical sites where plant effects might be observed and where long-term historical information has been obtained.

In contrast, the other parameters such as salinity, density, dissolved oxygen, and runoff fluctuate more slowly and continuous data are not as critical in order to characterize their seasonal variation. The slack-water surveys emphasize tidal variations; whereas plankton cruises emphasize spatial variations and set the hydrographic framework for biological events.

2.2 FIELD METHODS

2.2.1 Temporal Monitoring

Continuously recording instruments mounted on taut moorings or platforms were deployed to monitor water currents, temperature, tide elevation and local winds in the study area (Figure 2.2-1 and Table 2.2-1). Configurations of surface following and fixed subsurface moorings are described in detail in NAI (1977a). The three-point moored, surface following buoy systems minimized mooring watch circle and held instruments at fixed depths below the instantaneous water surface throughout the

TABLE 2.1-1. OPERATIONAL DATES AND SAMPLING DEPTHS FOR 1977 NAI CURRENT METERS AND TEMPERATURE MONITORS OFF HAMPTON BEACH, NEW HAMPSHIRE. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

MOORING DESIGNATION	MOORING LOCATION LATITUDE N	LONGITUDE W	WATER DEPTH AT MLW, FT	(M)	DATES OPERATIONAL, 1977	SENSOR DEPTHS BELOW INSTANTANEOUS SEA SURFACE: CURRENT METERS FT	(M)	TEMPERATURE MONITORS FT	(M)
	Reference Site								
T-7	42°55'15"	70°46'46"	60.0	(18.3)	Jan 1 to Dec 31	5.7	(1.7)	2.0	(0.6)
	Diffuser Site								
12	42°53'43"	70°47'23"	60.0	(18.3)	Jan 1 to Sep 15	5.2	(1.6)	2.0	(0.6)
10 Upper						20.0*	(6.1)	23.0	(7.0)
	Offshore Intake Site								
I-4 Upper	42°54'20"	70°47'09"	55.0	(16.8)	Jan 1 to Dec 31	5.2	(1.6)	2.2	(0.7)
I-4 Lower						44.0*	(13.4)	48.6*	(14.8)
	Rocks Area								
B Upper	42°53'49"	70°48'00"	15.0	(4.6)	Jan 1 to Dec 31	N/A		1.0	(0.3)
B lower								13.0	(4.0)
	Hampton Harbor Estuary								
HH Upper	42°53'59"	70°49'09"	4.0	(1.2)	Jan 1 to Dec 31	N/A		1.0	(0.3)
HH Lower								4.0*	(1.2)
	Hampton Beach State Park								
Wind	42°53'58"	70°48'46"			Jan 1 to Dec 31	35.5	(10.8)+		
	Hampton Beach Marina								
Tide	42°54'08"	70°49'06"			Jan 1 to Dec 31				

*Depths below mean low water (MLW)

+Height above mean sea level

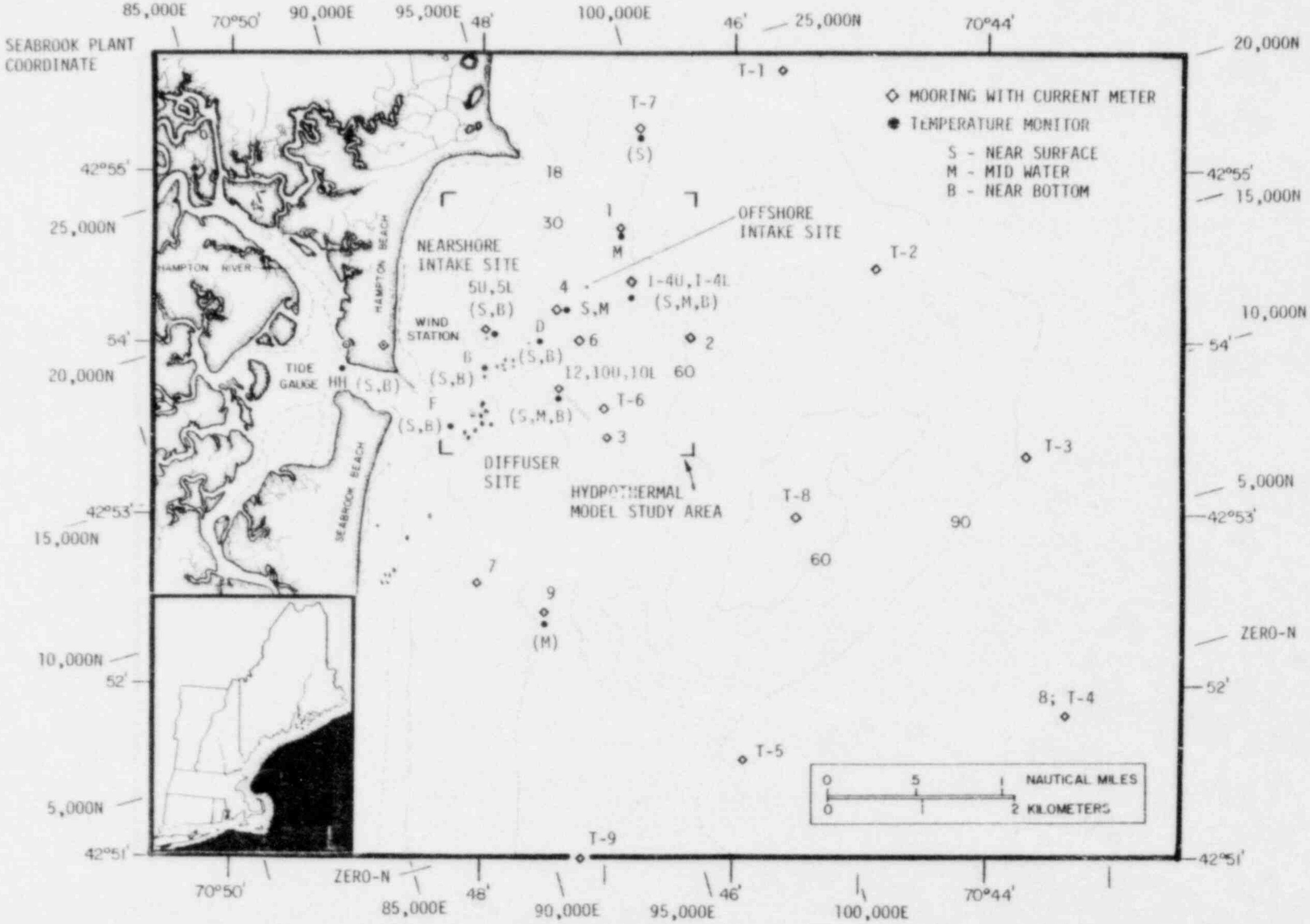

Figure 2.2-1. Location map showing study area and historical NAI current and temperature moorings in coastal waters off Hampton Beach, New Hampshire, from 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

TABLE 2.2-1. SPECIFICATIONS FOR PRIMARY INSTRUMENTATION UTILIZED IN THE NAI MONITORING STUDIES OFF HAMPTON BEACH, NEW HAMPSHIRE. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

SENSOR/RECORDER				SPECIFICATIONS			RECORDING			
MANUFACTURER	MODEL	PARAMETER MEASURED	TYPE OF SENSOR	MEASUREMENT THRESHOLD	RANGE	ACCURACY	MEDIUM	SAMPLING PERIOD	SAMPLING FORMAT	REMARKS
CURRENT VELOCITY										
BENDIX	Q-15, Q-15E and Q-16	Speed	Ducted Impeller	0.04 kns	0 to 1 kn 0 to 5 kns switch selectable	± 3% or ± 0.05 kn whichever is greater	Strip chart	16 days	Continuous	Rustrak Model 291 DC recorder
	Current Sensors/ 270 Recorder	Direction	Vane with potentiometric direction transducer and compass (Q-16 only No compass)		0° to 360°	± 12°				
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day			3-hr cycling switch	3-hr event marks
TEMPERATURE										
[illegible]	1001-T Temperature Monitor	Temperature	Fenwall H72/00A123 Mod.Fast TC; SS Housing		Single channel 50°F(25 to 75°) Dual channel 20°F(variable)	± 1.0 F or ± 0.46 C	Strip chart	16 days	Continuous	Rustrak Model 2133 DC recorder
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/	± 2 sec/day			3-hr cycling switch	3-hr event marks
TIDE LEVEL										
MARSH McBIRNEY Water-level Gauge	100	Tide Elevation	Gradient wire		17 ft	± 0.2 ft	Strip chart	16 days	Continuous	Rustrak Model 288 DC recorder
		Time	Bulova Model TE-11 Accutron Cycle Timer	N/A	N/A	± 2 sec/day			3-hr cycling switch	3-hr event marks
WIND										
R.M Young Field recording Wind set	6405	Speed	3 cup anemometer	1.5 kns	0 to 50 kns	± 1.0 kn	Strip chart	16 days	Continuous	Rustrak DC recorder built into unit
		Direction	Vane with potentiometer	N/A	0° to 360°	± 7°				
		Time	Bulova Model TE-11 Accutron Cycle Timer			± 2 sec/day			3-hr cycling switch	3-hr event marks
HYDROGRAPHIC PROFILES										
BECKMAN	RS5-3	Temperature	Thermistor		0 to 40 C	± 1.0 C			Instantaneous readings	Field readings entered onto data sheets
		Conductivity	Inductive		0 to 60 mmhos/cm	± 1.0 mmhos/cm				
		Salinity	D.C. Wheatstone Bridge Circuit utilizing temperature and conductivity input		0 to 40 °/oo	± 0.1 °/oo			3-hr cycling switch	
SALINITY										
Beckman	RS7-C	Salinity	Inductive		0 to 40 °/oo	±0.003 equivalent salinity	Digital Readout			Instrument measures the conductivity ratio of the sample reference to standard seawater

tidal cycle as, for example, Moorings T-7, 12, and I-4 upper. The subsurface moorings held instruments at depth, minimizing and absorbing induced deflections from open ocean waves as, for example, Moorings 10 upper, 10 lower and I4 lower,

Currents were measured with Bendix Model Q15 or Q15 (R)[+] geomagnetic, bidirectional, ducted current sensors with 10-ft (3-m) directional vanes and Bendix Model 270 recorder/power supply units. The Bendix system has an accuracy of ±0.05 kn (±2.6 cm/sec) for speed and ±12° for direction (Table 2.2-1). The data from these current sensors were recorded on dual channel Rustrak Model 291 DC recorders within the Bendix Model 270 housing. Bulova Model TE-11 Accutron cycle timers were installed in all recorders to provide time marks every 3 hrs on the strip charts. Electrical power was supplied with 14-day rechargeable battery packs. Instrument specifications are listed in Table 2.2-1.

Water temperature was measured at selected sites with NAI Model 1000 and 1001 Temperature Monitors consisting of Rustrak Model 2133 DC recorders with matched Model 1332 thermistor probes (Table 2.2-1).

Tide elevation in the Hampton Harbor estuary was measured continuously at the Hampton Beach Marina (Figure 2.2-1) using a Marsh-McBirney Model 100 water-level gauge and a Rustrak Model 288 single-channel, DC strip-chart recorder. The accuracy of this system was about ±0.2 ft or 5.0 cm (Table 2.2-1). All measurements were referenced to mean low water (MLW) from surveyed bench marks keyed to the U.S. Army Corps of Engineers 1929 geodetic elevation datum.

[+] One mooring (5 lower) used Q-16 current meters; these are identical to Q-15's but lack a compass and must be mounted on a rigid bottom structure.

Local wind speed and direction were measured continuously from a telephone pole located in the Hampton Beach State Park using an R.M. Young Model 6405 Field Recording wind set. The accuracy of the unit was about ±1.0 kn (51.5 cm/sec) speed and ±7° direction (Table 2.2-1).

Moorings were serviced by SCUBA divers every 2 weeks, depending upon weather conditions. During each servicing period, detailed electronic tests were conducted on each *in situ* in[illegible]ment to check its functioning and to detect possible instrument failure before the data were affected. Every three months, sensors and recorders were returned to NAI's Engineering Department instrumentation laboratory for routine maintenance, calibration, and repairs as necessary, in accordance with NAI Technical Procedures Manuals and manufacturers' specifications.

The locations of all historical offshore buoy systems from 1973 through 1977 are shown in Figure 2.2-1. The approximate latitude and longitude, water depth, sensor depths, and operational dates for all 1977 moorings are summarized in Table 2.1-1. Data collection for earlier years is summarized in Figure 1.0-1. Operational performance for each mooring is summarized in Appendix 7.1-1.

2.2.2 Spatial Surveys

Monthly hydrographic surveys were conducted to measure seasonal and tidal variations in the ambient oceanographic parameters at selected stations in the coastal waters off Hampton Beach, and in the Hampton-Seabrook estuary. These surveys were designed to examine typical monthly conditions, and to alternate with each other for maximum data coverage each month.

Slack-water surveys consisted of two sampling runs: one keyed to high-water slack and the other keyed to low-water slack. Each generally took about 1.5 to 2.0 hrs, centered around National Oceanic and Atmospheric Administration - National Ocean Survey (NOAA-NOS) predicted

high water or low-water; a fast boat was used to minimize cruising time for each run. At each sampling station (Figure 2.2-2), vertical profiles of temperature, conductivity and salinity were made with a Beckman RS5-3 salinometer (see Table 2.2-1 for instrument specifications). Sampling depths were: surface, 3.3 ft (1 m), 6.6 ft (2 m) and thereafter every 6.6 ft (2 m) to bottom. Duplicate water samples from near surface and near bottom were obtained at selected stations using Kemmerer or Niskin wate- sam 1- -. These samples were used for laboratory determination of di s... .d oxygen by azide modification of the Winkler method (U.S. Er vironmental Protection Agency, 1974), and of salinity with a Beckman Model RS7C Induction Salinometer referenced to standard seawater samples. Actual sampling dates were as follows:

1977: January 24, February 22 (low-water only due to bad weather), March 30, April 27, May 23, June 13, July 27, August 19, September 29, October 19, November 16, and December 30.

Plankton cruises were conducted similarly, except without regard for any specific tide stage. Both biological and non-biological stations (Figure 2.2-2) were generally done within the same day. Field methods were the same as for slack-water surveys. Actual sampling dates were as follows:

1977: January 3, February 8, March 21, April 13, May 4, June 9, July 6, August 3, September 7, October 4, November 1 and 2, and December 15.

2.3 LABORATORY AND DATA PROCESSING METHODS

2.3.1 Temporal Monitoring Data

Current, temperature, tide elevation and wind data strip charts were each handled in the same general manner (for detailed description see NAI, 1977a). First each strip chart was checked for correct start

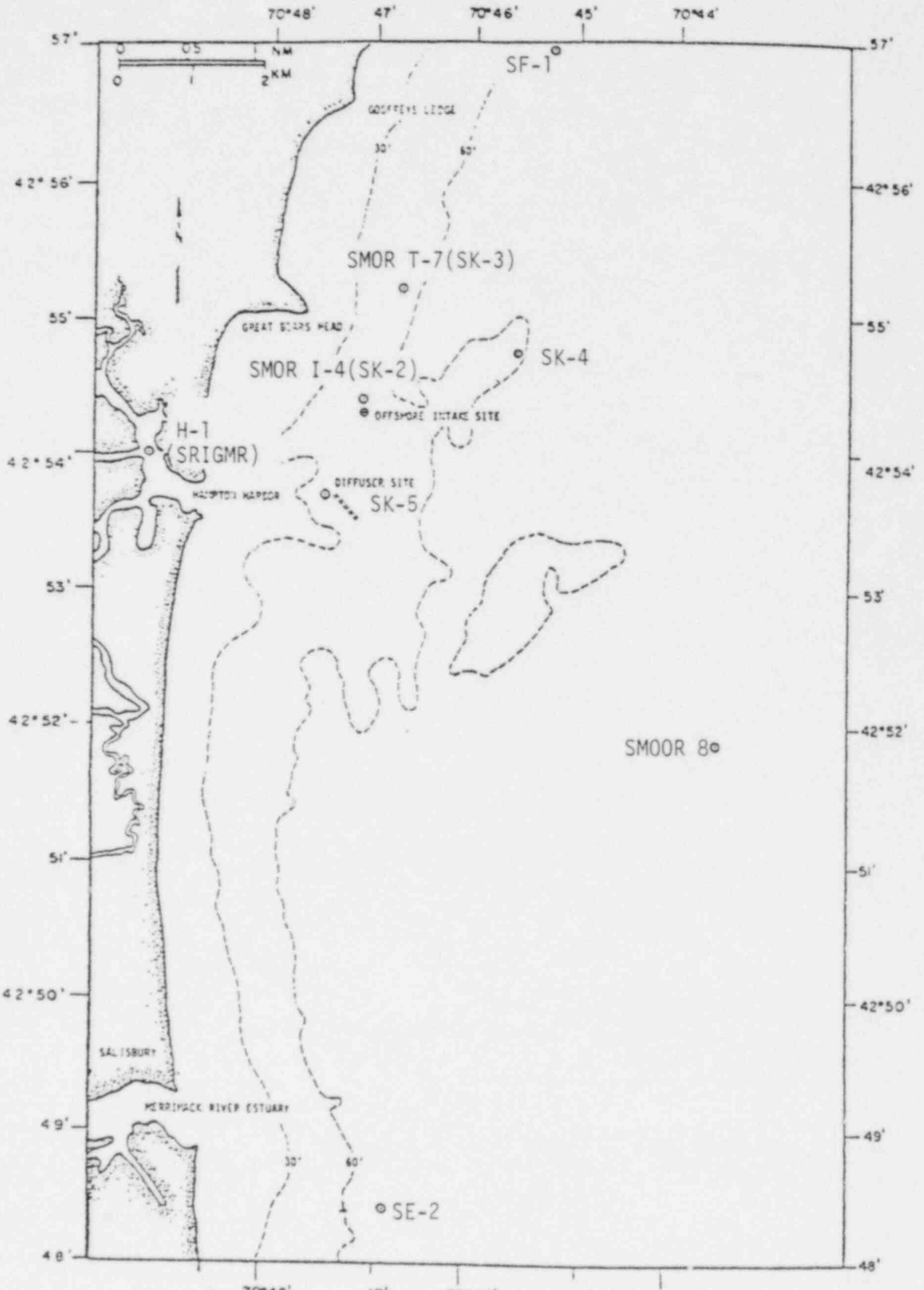

Figure 2.2-2. Location map for NAI plankton cruise and slack-water survey sampling stations off Hampton Beach, New Hampshire, for 1977 Ecological Study Program. Seabrook 1977 Annual Hydrographic Report, 1979.

and end times, agreement with field check measurements, possible instrument malfunctions, and overall reliability. Then each strip chart was time based using the known start and end times and the 3-hr time marks. Next current and wind were reduced to 20-min visual averages of speed and direction using standard conversion tables. The time and height of each high and low water were also determined and entered onto the current and wind data sheets. Finally, data were keypunched, listed by computer, and checked for possible errors.

Temperature strip charts were digitized onto magnetic cassette tapes using a Numonics Model 274-133 Electronic Graphics Calculator, a Numonics Model 310 Interface and a Techtron Model 8400 Read/Write Unit. Then tapes were loaded onto NAI's IBM System 3 Model 12 computer for listing and editing. Data were tabulated and hourly average values punched onto cards.

Punched card data were processed by PSC's Engineering Department computer staff, using a standard series of plot and tabulation programs developed for their twin General Automation Model 18/30 computers.

2.3.2 Spatial Survey Data

First, field hydrographic data sheets from slack-water surveys and plankton cruises were checked for accuracy and completeness. Dissolved oxygen samples were processed in the laboratory using standard procedures (EPA, 1974) and results entered onto the field sheets. These data were keypunched and listed to check for accuracy and completeness.

Data were processed at PSC, using program "HYDS2" for the following: (1) converts depths to both ft and m, regardless of which were input; (2) transforms temperature readings, based on instrument correction factors derived from annual laboratory calibration (NAI, 1977c); (3) converts resulting temperatures to both C and F; (4) transforms conductivity readings, based on instrument correction factors

derived from annual laboratory calibration (NAI, 1977c); (5) calculates salinity from transformed temperature and conductivity; (6) calculates density or sigma-t from corrected temperature and salinity, using the Woods Hole Oceanographic Institution (WHOI) subroutine "SIGMA"; and (7) calculates the percent saturation of observed dissolved oxygen values using the equation of Gilbert *et al.* (1968). Finally, calculated salinity values were compared to results of reference salinity measurements obtained with the Beckman laboratory salinometer.

2.4 OTHER DATA

Air temperature data from U.S. Weather Bureau stations at Portland, Maine and Boston, Massachusetts for 1973 through 1977 were obtained from NOAA-Environmental Data Service (NOAA-EDS) summaries (1973 to 1977). From this information, monthly means of daily maximum and daily minimum temperatures were calculated.

Mean daily and monthly average runoff data for 1973 through 1976 from the Merrimack River, the Piscataqua River basin, and the Saco River basin were obtained from the U.S. Geological Survey (1973 to 1977). From this information, the approximate runoff into the western Gulf of Maine was determined.

3.0 RESULTS

3.1 CIRCULATION

3.1.1 Tidal Conditions

During 1977 tide height was measured continuously at the Hampton Beach Marina (location map, Figure 2.2-1) to determine actual times and heights of high and low water in the study area and to document periods of abnormally high tides which frequently accompany major storms. These tides are of the mixed, semi-diurnal type with a small (1 to 2 ft or 0.3 to 0.6 m) diurnal inequality which is most pronounced during spring tides (Figure 3.1-1). In the summer months, the highest spring tides occur with the full moon, whereas in the winter months the highest spring tides occur with the new moon. The NAI tide observations showed close agreement with the NOAA-NOS tide table predictions for Hampton Harbor (NOAA-NOS, 1977); time within 10 to 20 min and height within 0.1 to 0.2 ft. In general, the mean tide range was about 8.3 ft (2.5 m). Spring tides ranged as high as 12.5 ft (3.8 m), whereas neap tides ranged as low as 6.0 ft (1.8 m).

The change in tide height (high or low water) and tidal current direction generally occurs 15 to 30 min earlier offshore than inside Hampton Harbor. Measurements of tide heights and times of high and low water at the mouth of the estuary in August 1974 showed that recorded heights at the Hampton Beach Marina were as much as 6 in (15.2 cm) higher and occurred 3 to 10 min later (NAI, 1975a).

In the absence of meteorological forcing functions, tidal forces dominate the coastal circulation. At such times current-meter vectors demonstrate periodic changes in flow pattern such as flood-and ebb-tidal reversals (generally on a 6- to 7-hr basis) or a variable weak tidal flow with periodic shifts of speed and direction. Offshore tidal currents tend toward rotary motion, with northward flood and southward ebb along the coast. Mean speeds rarely exceed 0.1 to 0.2 kn (5.1 to 10.3 cm/sec).

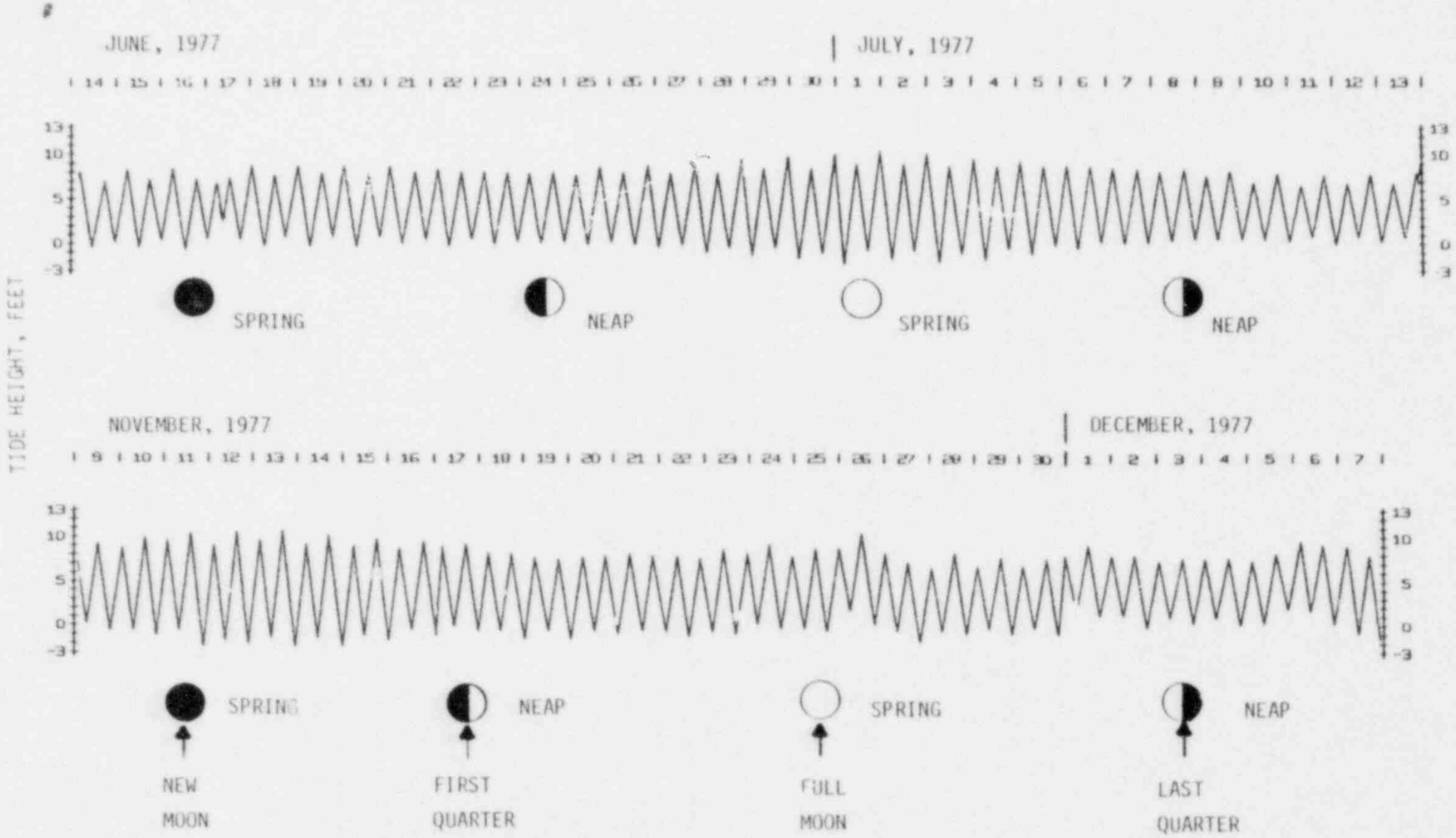

Figure 3.1-1. Plot of high-water and low-water tide heights in the Hampton Harbor Estuary during typical 1977 summertime and wintertime lunar months. Seabrook 1977 Annual Hydrographic Report, 1979.

Weak tidal flow has a tendency toward periodic 180° reversals in direction. A 24-hr sequential-vector plot from July 2, 1977 illustrates this type of flow (Figure 3.1-2). This plot sho · the observed 20-min average vectors of current speed and direction . each current meter for the day, referenced to Eastern Standard Time (EST). Vectors are plotted as direction toward which current was flowing.

Reversing flood- and ebb-tidal currents are strong, rhythmic sinusoidal reversals of current direction (generally at 6- to 7-hr intervals) made up of a northward-flowing, flood-tidal current and a southward-flowing, ebb-tidal current. As the flows reverse, a short period of "slack" currents frequently occurs. Occasionally the currents demonstrate a more rotary character with little speed loss as direction changes. A 24-hr sequential-vector plot from August 3, 1977 illustrates this type of flow (Figure 3.1-2). Tidal flows are usually more evident during the summer months when winds are weaker and more variable. During the autumn and winter months, storm influence is so great that tidal effects are usually masked (see vector plots in Appendix 7.5).

3.1.2 Wind Effects

Winds play an important role in the movement of coastal waters in the study area. As a general rule, local winds push near surface waters downwind. Such influence first affects the topmost water, then can gradually deepen as the winds persist. Because of New Hampshire's geography and gently sloping sea-floor bathymetry, the greatest wind influence is longshore when winds blow from the north-northeast (northeaster storm) or from the south-southwest. When winds are blowing seaward, near-surface waters are typically pushed offshore and a compensatory flow at depth moves landward. The strongest wind effects always accompany northeast storms because of the large fetch across the Gulf of Maine. During such storms, near-surface waters are often carried southwestward at speeds of 1.0 kn (51.5 cm/sec) or more (NAI, 1975a).

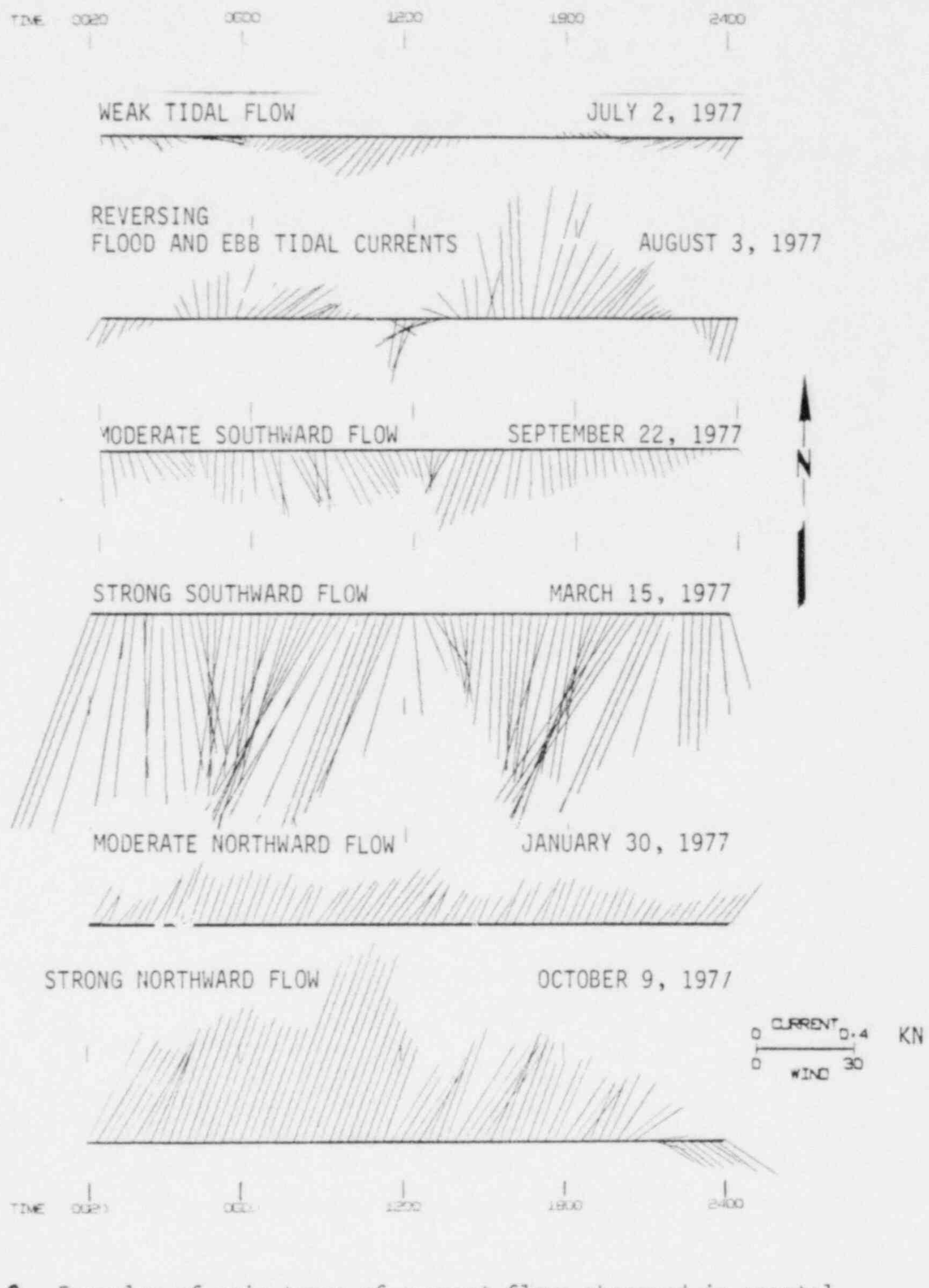

Figure 3.1-2. Examples of main types of current flows observed in coastal waters off Hampton Beach, New Hampshire (examples from 1977). Seabrook 1977 Annual Hydrographic Report, 1979.

Annual wind variations over the period from December 20, 1976 through December 7, 1977 show considerable seasonal variation (Figure 3.1-3). During the winter months predominant winds (about 42 percent) were from the west+ at mean speeds of 10.7 kns (5.5 m/sec). Strong winds from the southwest and northwest occurred about 13 to 18 percent of the time. Strong winds from the east and northeast were the result of northeastern storms (mean speeds of 10.0 to 10.6 kns or 5.1 to 5.4 m/sec). In the spring, predominant winds were from the northwest and west (about 24 percent), but strongest winds were from the northeast (mean speed of 15.0 kns (7.7 m/sec). Summer winds were much calmer (mean speeds of 4.9 to 7.9 kns or 2.5 to 4.1 m/sec) and predominant winds were from the southwest and west. In the fall, winds picked up again with slightly higher mean speeds. Predominant winds were still from the west and southwest, but strongest winds were from the northwest and east (mean speeds of 15.0 and 12.7 kns or 7.7 to 6.5 m/sec, respectively).

From the 1977 wind measurements, net monthly transport or displacement (referenced toward where the wind was blowing) was determined. Results were resolved into onshore/offshore or east/west components and longshore or north/south components (Figure 3.1-4). The 1977 data show a total domination of offshore winds, with peaks occurring in January to April, July, August and November - December. Greatest wind transport was observed in January. The longshore components showed a more complex pattern during 1977. Winter months showed northward drift, spring months showed southward, summer months showed northward again, and fall showed both types (Figure 3.1-4).

+Note that rose diagrams show direction <u>toward</u> which wind is blowing and current is flowing.

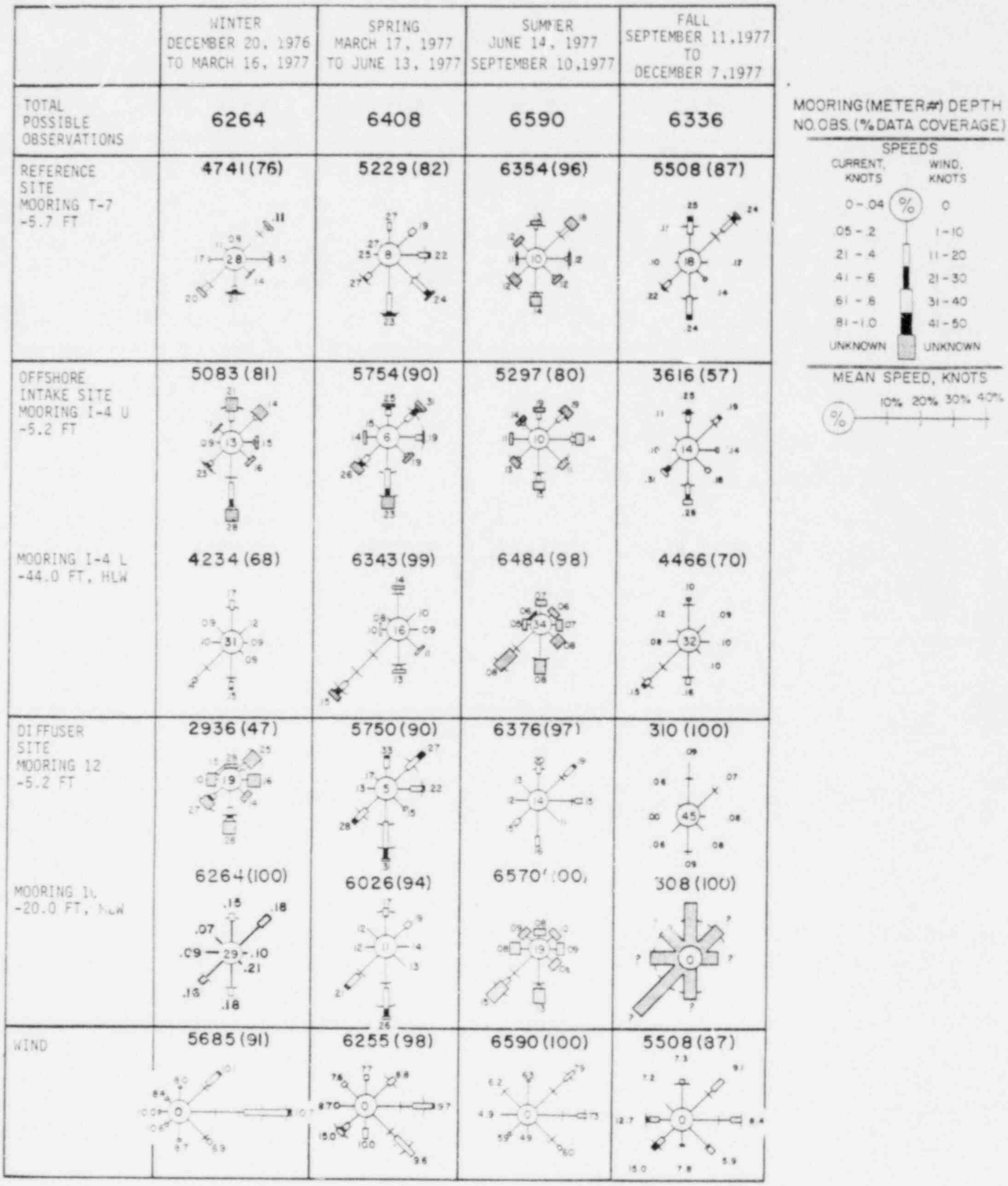

Figure 3.1-3. Rose diagrams of currents and local winds off Hampton Beach, New Hampshire, for the winter, spring, summer and fall seasons of 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

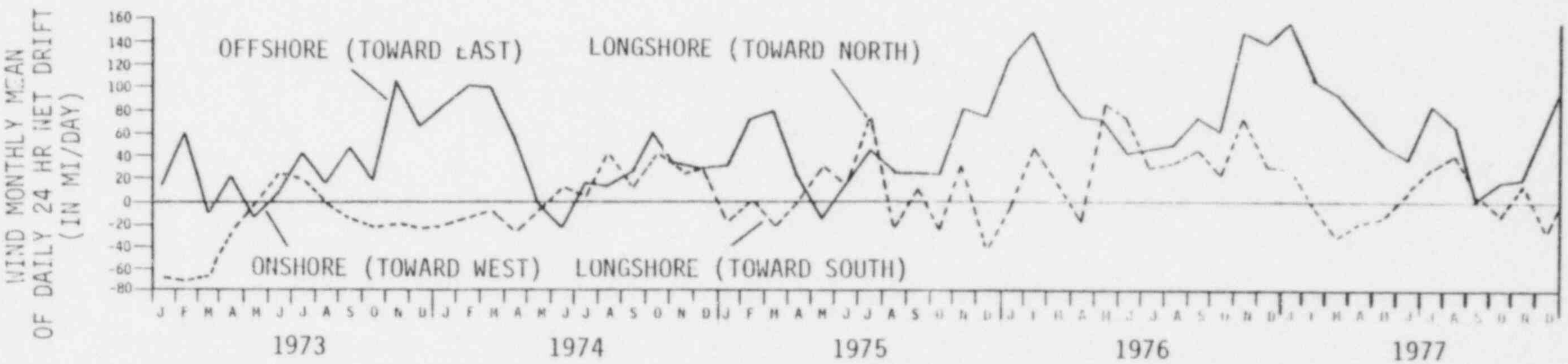

Figure 3.1-4. Plot of monthly mean onshore/offshore and longshore components of daily 24-hour wind net drift for 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

Seasonal trends at Hampton Beach have been consistent from year to year (Figure 7.2-1). West, northwest, and southwest winds have been prevalent during the winter months. Spring has generally been a transition period into the calmer, more variable winds of summer. Fall winds have generally returned back to southwest and coast. Note that strongest winds have usually been from the northeast, in association with northeastern storms.

Five years of summary wind data from January 24, 1973 through January 1, 1978 (Figure 3.1-5) illustrate that predominant winds (about 24 percent of the time) have been from the west at a mean speed of 8.1 kns (4.2 m/sec). Winds from the southwest and from the northwest each occurred about 17 percent of the time, with mean speeds of 8.3 to 7.0 kns (4.3 and 3.6 m/sec) respectively. Highest mean speed (9.6 kn or 4.9 m/sec) has been from the northeast (in conjunction with northeaster storms), but such winds are not prevalent (about 8.5 percent of the time, Table 7.3-1).

Calculations of net monthly wind displacement or net drift from 1973 through 1977 show that the offshore component (wind toward the east) is prevalent (Figure 3.1-4). Greatest wind transport was observed in the fall and winter months (up to 150 n mi or 278 kn per day in February 1976 and January 1977). During the late spring of the first three years of studies, there was a short period of onshore net transport, up to about 25 n mi or 46.3 km/day in June 1974; this pattern was not observed during 1976 and 1977.

The longshore or north/south transport components show a more complex pattern (Figure 3.1-4). During the winter months, wind transport has been generally southward (up to 69 n mi or 127.8 km/day in February 1973), except for February and March of 1976 when it was northward. The spring and early summer months have generally shown a northward component of longshore wind transport (up to 85 n mi or 157.5 km/day in May 1976). During the fall and early winter, conditions have varied from year to year. That is, 1973 showed southward transports (up to 25 n mi or 46.3 km/day);1974 and 1976 showed northward transports (up

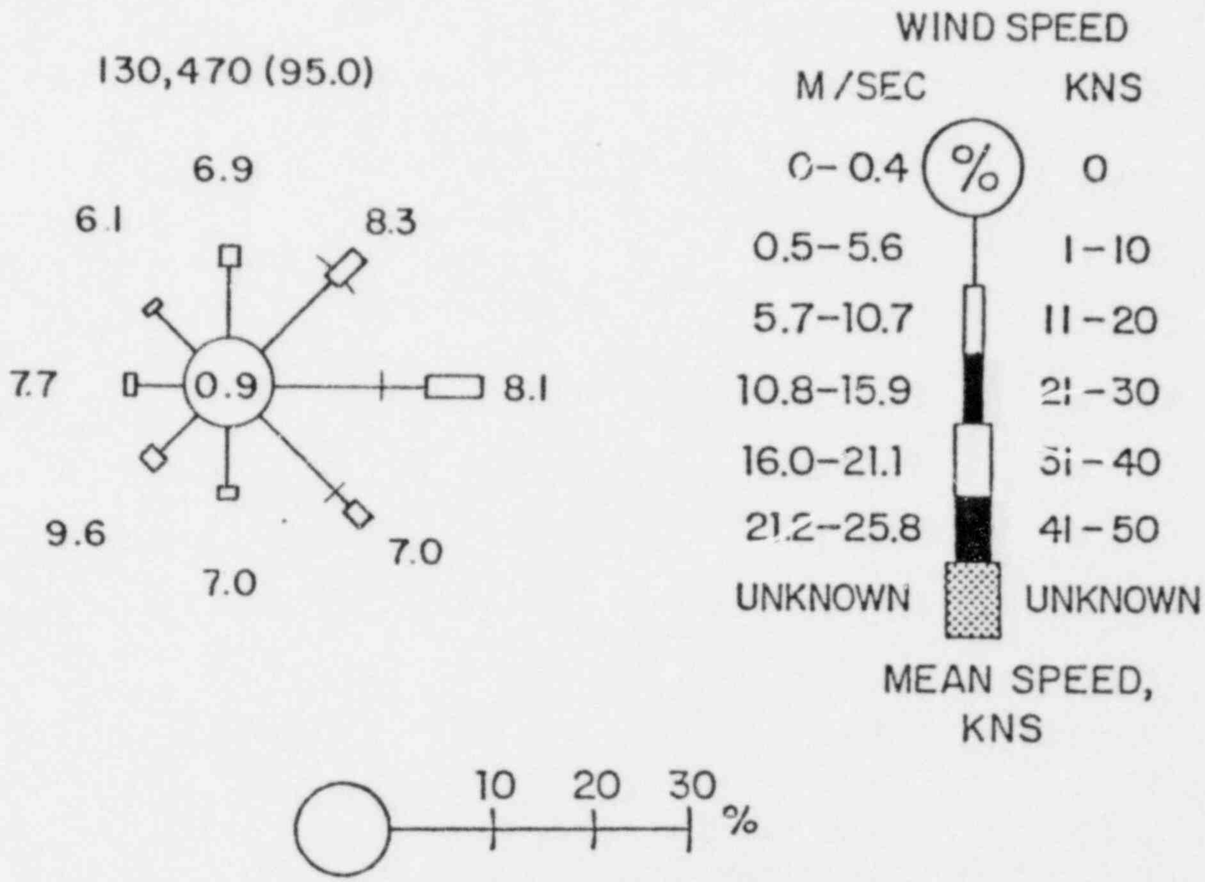

Figure 3.1-5. Rose diagram showing percentage-frequency of wind (direction toward which wind was blowing) measured by NAI at Hampton Beach, New Hampshire from January 24, 1973 to January 5, 1978. Total possible 20-min observations for period = 130,470. Seabrook 1977 Annual Hydrographic Report, 1979.

to 75 n mi or 139 km/day); and 1975 and 1977 showed both northward and southward transports.

Mean wind stress data for 1973 through 1975 have showed that the strongest wind stresses generally occur in the late winter to early spring, with a secondary peak in the fall (NAI, 1977a). This pattern corresponds closely to the onshore/offshore net drift pattern, wherein the periods of strong wind stress seem to have a predominantly offshore component (Figure 3.1-4).

3.1.3 Storm Conditions

During 1977, the region was subjected to a series of major northeaster storms which caused periodic surges in coastal flows, large waves and some beach erosion events (Figure 3.1-6). Numerous weaker storms also occurred (Table 3.1-1). February, March and April were the stormiest months, but at least one northeaster occurred every month of the year.

3.1.4 Currents

3.1.4.1 Temporal Variations

Temporal variations in local currents are primarily due to tides and winds. The weaker tidal circulation features are often masked by stronger, more variable wind driven currents on a day-to-day basis. Such flows may be drastically altered for weeks at a time with sustained periods of strong winds.

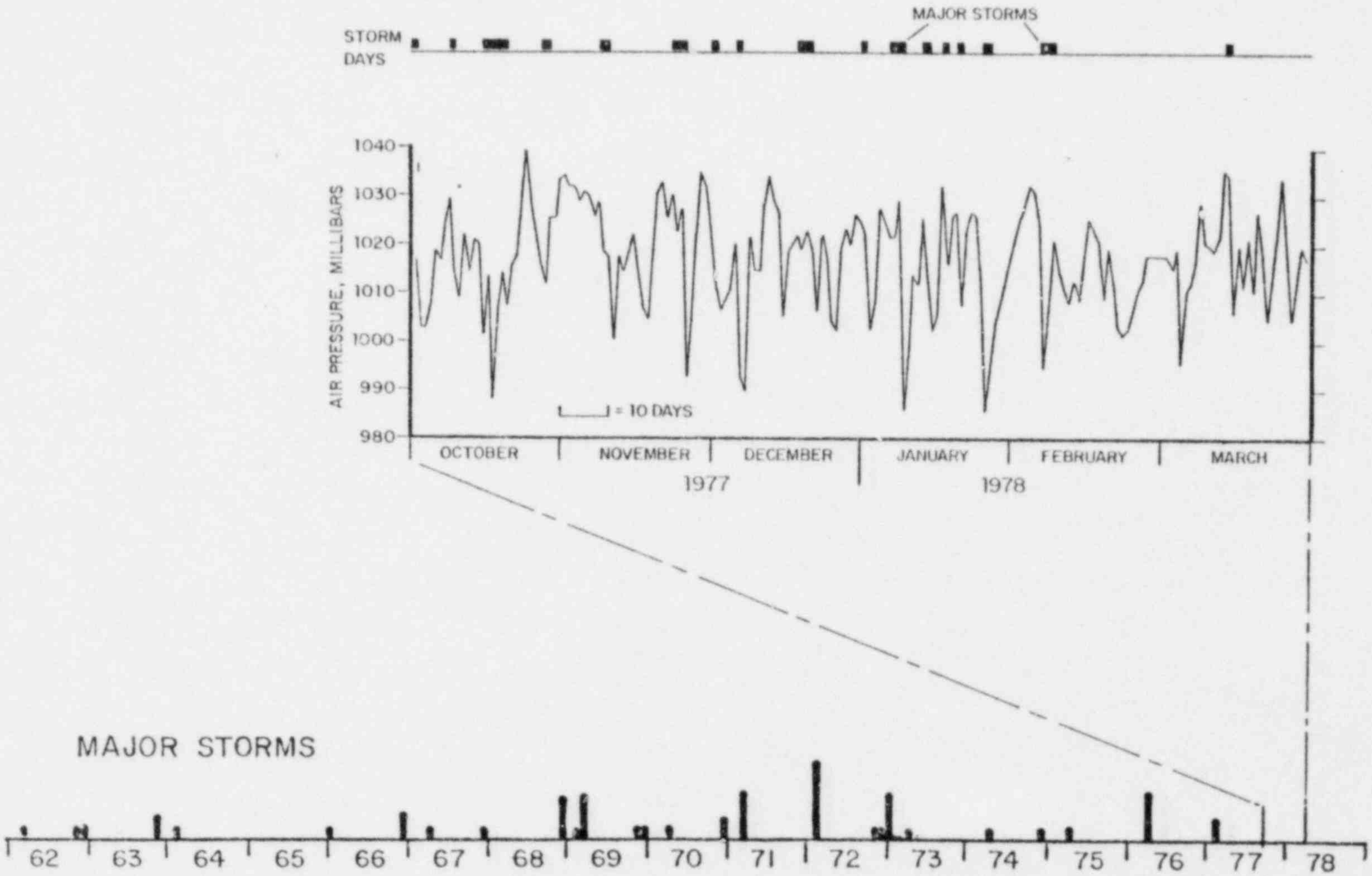

Figure 3.1-6. Major storms which caused coastal erosion in Massachusetts and New Hampshire from 1962 to 1977 (from Richardson, 1977) along with atmospheric pressure and storm activity for the winter of 1978. Seabrook 1977 Annual Hydrographic Report, 1979.

TABLE 3.1-1. DATES OF MAJOR AND LESS IMPORTANT STORMS DURING 1977. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

1977	MAJOR STORMS	LESS IMPORTANT STORMS
January	7-9, 27-31	1-2, 11-12, 18-19
February	5-8	17, 20-21, 23-24, 27-28
March	4-6, 11-13, 14-16, 29-31	18, 22-23
April	5-6, 17-20, 23-27	3-4, 8, 14-16
May	1-3, 9-11	17-18, 26-27, 28-29
June	1-3, 6-8, 10-12	17-18, 25-27
July		6-11, 22-23
August		22
September	20-23	15-16, 30
October	7-9, 14-17, 19-21, 25-27	1-2, 29-31
November	3-10, 17-19, 20-22	11-1], 15-16
December	13-14, 18-20, 28-29	1-2, 6-7

The most common type c˜ flow in waters seaward of the Outer Sunk Rocks was transient or t· \ flow, which comprised from 31.8 to 48.4 percent for 1973 to 1977 or ɾ' out 41.2 percent overall (roughly one half) of the 5-year (1,802 -day) study period from January 24, 1973 to December 31, 1977 (Tabl 3.1-2 and Figure 3.1-7). The most frequent flows of this type were weak tidal flows comprising from 11.9 to 27.0 percent for 1973 to 1977 or 21.2 percent overall. Reversing flood and ebb-tidal currents made up the remaining 6.6 to 34.2 percent for 1973 to 1977 or 20.0 percent overall.

The steady-state flows toward the south and the north were about equally distributed, being 25.5 to 35.5 percent or 30 0 percent overall for the former and 20.0 to 40.6 percent or 28.8 percent overall for the latter (Table 3.1-2 and Figure 3.1-7). The southerly flows, which occurred roughly one fourth of the year, were generally the result of northeasterly storms and occasional periods of north to northwesterly winds. Such flows essentially masked out the tidal currents and frequently persisted unabated for days at a time. Moderate southward flows comprised about 15.2 to 29.5 percent for 1973 to 1977 or 21.7 percent overall. Correspondingly, the northward flows generally occurred during the remaining one-fourth of the year in conjunction with strong south-to-southwesterly winds or as possible seiching in the western Gulf of Maine following storm surges. Moderate northward flows comprised about 15.5 to 35.9 percent or 24.2 percent overall whereas strong flows were observed about 2.9 to 7.6 percent or 4.6 percent overall (Table 3.1-2).

As during previous years, transient flows in 1977 were most prevalent during summer months, when meteorological conditions tend to be fairly stable (Figure 3.1-7). Northerly flows were less common than during previous years, occurring mostly during spring and autumn months. During 1977, the southerly flows occurred about equally during most months of year, reflecting the periodic passage of eastward-moving low-pressure systems and associated northeasterly wind events.

TABLE 3.1-2. TABULATION OF CURRENT FLOW TYPES IN COASTAL WATERS SEAWARD OF THE OUTER SUNK ROCKS OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1973 THROUGH 1976. SEABROOK 1976 ANNUAL HYDROGRAPHIC REPORT, 1979.

MONTH	NO. OF DAYS IN MONTH	WEAK TIDAL FLOW	REVERSING FLOOD AND EBB TIDAL CURRENTS	MODERATE ABOUT 0.2-0.3 KN	STRONG GENERALLY >0.3 KN	MODERATE ABOUT 0.2-0.3 KN	STRONG GENERALLY >0.3 KN
		NUMBER OF DAYS PER MONTH (PERCENTAGE)					
		TRANSIENT FLOW		STEADY-STATE FLOW			
		TIDAL EFFECTS		FLOW TOWARD THE SOUTH		FLOW TOWARD THE NORTH	
1973							
January	7	2.0 (28.6)	0.0 (0.0)	3.0 (42.8)	2.0 (28.6)	0.0 (0.0)	0.0 (0.0)
February	28	2.0 (7.1)	8.0 (28.6)	9.0 (32.1)	8.0 (28.6)	1.0 (3.6)	0.0 (0.0)
March	31	8.0 (25.8)	6.0 (19.4)	3.5 (11.3)	10.0 (32.2)	3.5 (11.3)	0.0 (0.0)
April	30	3.0 (10.0)	9.0 (30.0)	2.0 (6.7)	5.5 (18.3)	4.0 (13.3)	6.5 (21.7)
May	31	4.0 (12.9)	16.5 (53.2)	6.0 (19.4)	4.0 (12.9)	0.5 (1.6)	0.0 (0.0)
June	30	6.0 (20.0)	12.0 (40.0)	5.5 (18.3)	4.0 (13.3)	2.5 (8.3)	0.0 (0.0)
July	31	4.5 (14.5)	20.0 (64.5)	6.0 (19.4)	0.0 (0.0)	0.5 (1.6)	0.0 (0.0)
August	31	4.5 (14.5)	13.0 (41.9)	9.0 (29.0)	3.0 (9.7)	1.5 (4.8)	0.0 (0.0)
September	30	8.5 (28.3)	16.0 (53.3)	0.0 (0.0)	2.0 (6.7)	2.5 (8.3)	1.0 (3.3)
October	31	3.0 (9.7)	9.5 (30.6)	2.0 (6.4)	4.0 (12.9)	7.5 (24.2)	5.0 (16.1)
November	30	0.5 (1.7)	3.5 (11.7)	0.5 (1.7)	0.0 (0.0)	15.5 (51.7)	10.0 (33.3)
December	31	2.5 (8.1)	3.0 (9.7)	5.5 (17.7)	2.5 (8.1)	14.0 (45.2)	3.5 (11.3)
TOTAL DAYS	341	48.5 (14.2)	116.5 (34.2)	52.0 (15.2)	45.0 (13.2)	53.0 (15.5)	26.0 (7.6)
PERCENT BY TYPE		(48.4)		(28.4)		(23.2)	
1974							
January	31	4.0 (12.9)	3.5 (11.3)	2.5 (8.1)	3.5 (11.3)	14.5 (46.8)	3.0 (9.7)
February	28	0.0 (0.0)	5.0 (17.8)	7.0 (25.0)	4.0 (14.3)	11.0 (39.3)	1.0 (3.6)
March	31	0.5 (1.6)	10.0 (32.3)	4.5 (14.5)	2.5 (8.1)	9.5 (30.6)	4.0 (12.9)
April	30	2.0 (6.7)	12.5 (41.7)	8.5 (28.3)	3.0 (10.0)	4.0 (13.3)	0.0 (0.0)
May	31	5.5 (17.7)	8.0 (25.8)	7.5 (24.2)	3.0 (9.7)	6.0 (19.4)	1.0 (3.2)
June	30	2.5 (8.3)	14.5 (48.3)	10.5 (35.0)	2.0 (6.7)	0.5 (1.7)	0.0 (0.0)
July	31	5.0 (16.1)	17.0 (54.8)	7.0 (22.6)	0.0 (0.0)	2.0 (6.4)	0.0 (0.0)
August	31	5.5 (17.7)	16.5 (53.2)	5.5 (17.7)	0.0 (0.0)	3.5 (11.3)	0.0 (0.0)
September	30	[illegible]	[illegible] (25.0)	4.5 (15.0)	0.0 (0.0)	10.5 (35.0)	0.0 (0.0)
October	31	2.0 (6.4)	6.5 (21.0)	1.0 (3.2)	0.0 (0.0)	14.5 (46.8)	7.0 (22.6)
November	30	4.0 (13.3)	4.5 (15.0)	9.5 (31.7)	0.0 (0.0)	11.0 (36.7)	1.0 (3.3)
December	31	6.5 (21.0)	4.5 (14.5)	3.5 (11.3)	3.5 (11.3)	13.0 (41.9)	0.0 (0.0)
TOTAL DAYS	365	43.5 (11.9)	111.5 (30.5)	71.5 (19.6)	21.5 (5.9)	100.0 (27.4)	17.0 (4.6)
PERCENT BY TYPE		(42.5)		(25.5)		(32.0)	
1975							
January	31	3.0 (9.7)	3.5 (11.3)	10.0 (32.2)	1.0 (3.2)	12.5 (40.3)	1.0 (3.2)
February	28	5.5 (19.6)	3.0 (10.7)	6.0 (21.4)	3.0 (10.7)	10.5 (37.5)	0.0 (0.0)
March	31	7.0 (22.6)	9.0 (29.0)	4.0 (12.9)	5.5 (17.7)	4.5 (14.5)	1.0 (3.2)
April	30	9.0 (30.0)	2.0 (6.7)	8.5 (28.3)	4.0 (13.3)	5.5 (18.3)	1.0 (3.3)
May	31	9.5 (30.6)	1.0 (3.2)	15.5 (50.0)	3.0 (9.7)	1.0 (3.2)	1.0 (3.2)
June	30	9.5 (31.7)	5.0 (16.7)	8.0 (26.7)	5.5 (18.3)	2.0 (6.7)	0.0 (0.0)
July	31	12.5 (40.3)	4.0 (12.9)	7.0 (22.6)	3.5 (11.3)	4.5 (14.5)	0.0 (0.0)
August	31	12.0 (38.7)	4.0 (12.9)	7.0 (22.6)	3.5 (11.3)	4.5 (14.5)	0.0 (0.0)
September	30	4.5 (15.0)	2.5 (8.3)	3.0 (10.0)	0.0 (0.0)	15.0 (50.0)	5.0 (16.7)
October	31	9.5 (30.6)	0.0 (0.0)	3.5 (11.3)	6.0 (19.4)	11.0 (35.5)	1.0 (3.2)
November	30	5.5 (18.3)	3.0 (10.0)	4.0 (13.3)	1.0 (3.3)	13.0 (43.3)	3.5 (11.7)
December	31	10.5 (33.9)	1.0 (3.2)	10.5 (33.9)	3.0 (9.7)	5.5 (17.7)	0.5 (1.6)
TOTAL DAYS	365	98.5 (27.0)	45.0 (12.3)	84.5 (23.2)	35.5 (9.7)	88.0 (24.1)	14.0 (3.8)
PERCENT BY TYPE		(39.3)		(32.7)		(28.0)	
1976							
January	31	7.5 (24.2)	0.0 (0.0)	9.5 (30.6)	6.5 (21.0)	7.5 (24.2)	0.0 (0.0)
February	29	6.5 (22.4)	0.0 (0.0)	5.5 (19.0)	5.5 (19.0)	9.5 (32.8)	2.0 (6.9)
March	31	5.5 (17.7)	0.0 (0.0)	7.5 (24.2)	5.5 (17.7)	11.5 (37.1)	1.0 (3.2)
April	30	8.5 (28.3)	0.0 (0.0)	9.5 (31.7)	2.5 (8.3)	8.5 (28.3)	1.0 (3.3)
May	31	10.0 (32.2)	4.0 (12.9)	3.5 (11.3)	2.0 (6.4)	9.5 (30.6)	2.0 (6.4)
June	30	14.5 (48.3)	4.0 (13.3)	4.5 (15.0)	0.5 (1.7)	6.5 (21.7)	0.0 (0.0)
July	31	12.5 (40.3)	6.5 (21.0)	2.5 (8.1)	1.5 (4.8)	6.0 (19.4)	2.0 (6.4)
August	31	9.0 (29.0)	5.0 (16.1)	5.5 (17.7)	0.5 (1.6)	9.5 (30.6)	1.5 (4.8)
September	30	8.5 (28.3)	1.0 (3.3)	11.0 (36.7)	0.5 (1.7)	7.5 (25.0)	1.5 (5.0)
October	31	2.5 (8.1)	2.0 (6.4)	7.5 (24.2)	0.0 (0.0)	15.5 (50.0)	3.5 (11.3)
November	30	1.5 (5.0)	0.0 (0.0)	4.0 (13.3)	0.0 (0.0)	24.5 (81.7)	0.0 (0.0)
December	31	6.0 (19.4)	1.5 (4.8)	5.5 (17.7)	0.0 (0.0)	15.5 (50.0)	2.5 (8.1)
TOTAL DAYS	366	92.5 (25.3)	24.0 (6.6)	76.0 (20.8)	25.0 (6.8)	131.5 (35.9)	17.0 (4.6)
PERCENT BY TYPE		(31.9)		(27.6)		(40.6)	
1977							
January	31	4.5 (14.5)	8.0 (25.8)	6.5 (21.0)	0.5 (1.6)	10.5 (33.9)	1.0 (3.2)
February	28	5.0 (17.4)	8.0 (28.6)	10.0 (35.7)	0.5 (1.8)	4.5 (16.1)	0.0 (0.0)
March	31	10.0 (32.3)	3.0 (9.7)	11.0 (35.5)	3.5 (11.3)	3.0 (9.7)	0.5 (1.6)
April	30	5.0 (16.7)	3.0 (10.0)	10.5 (35.0)	4.0 (13.3)	5.0 (16.7)	2.5 (8.3)
May	31	13.0 (41.9)	2.0 (6.4)	6.5 (21.0)	2.0 (6.4)	6.0 (19.4)	1.5 (4.8)
June	30	8.5 (28.3)	1.0 (3.3)	10.0 (33.3)	2.5 (8.3)	6.5 (21.7)	1.5 (5.0)
July	31	14.5 (46.8)	4.0 (12.9)	9.5 (30.6)	0.0 (0.0)	3.0 (9.7)	0.0 (0.0)
August	31	9.0 (29.0)	11.0 (35.5)	10.5 (33.9)	0.0 (0.0)	0.5 (1.6)	0.0 (0.0)
September	30	9.0 (30.0)	8. (26.7)	8.0 (26.7)	2.5 (8.3)	2.0 (6.7)	0.5 (1.7)
October	31	8.0 (25.8)	4 (12.9)	5.5 (17.7)	3.5 (11.3)	8.0 (25.8)	2.0 (6.4)
November	30	6.0 (20.0)	[illegible] (30.0)	9.0 (30.0)	0.0 (0.0)	5.0 (16.7)	1.0 (3.3)
December	31	6.0 (19.4)	[illegible] (9.7)	10.5 (33.9)	3.0 (9.7)	8.5 (27.4)	0.0 (0.0)
TOTAL DAYS	365	98.5 (27.0)	[illegible]	107.5 (29.5)	22.5 (6.2)	62.5 (17.1)	10.5 (2.9)
PERCENT BY TYPE		(44.5)		(35.5)		(20.0)	
SUMMARY 1973 to 1977							
TOTAL DAYS = 1802		381.5	361.0	31.0	149.0	436.0	81.5
PERCENT		(21.2)	(20.0)	(1.7)	(8.3)	(24.2)	(4.5)
PERCENT BY TYPE		(41.2)		(30.0)		(28.8)	
SUMMARY: 1973 TO 1976							
TOTAL DAYS = 1437		283.0	297.0	283.5	127.0	373.5	73.0
PERCENT		(19.7)	(20.7)	(19.7)	(8.8)	(26.2)	(5.1)
PERCENT BY TYPE		(40.4)		(28.6)		(31.0)	

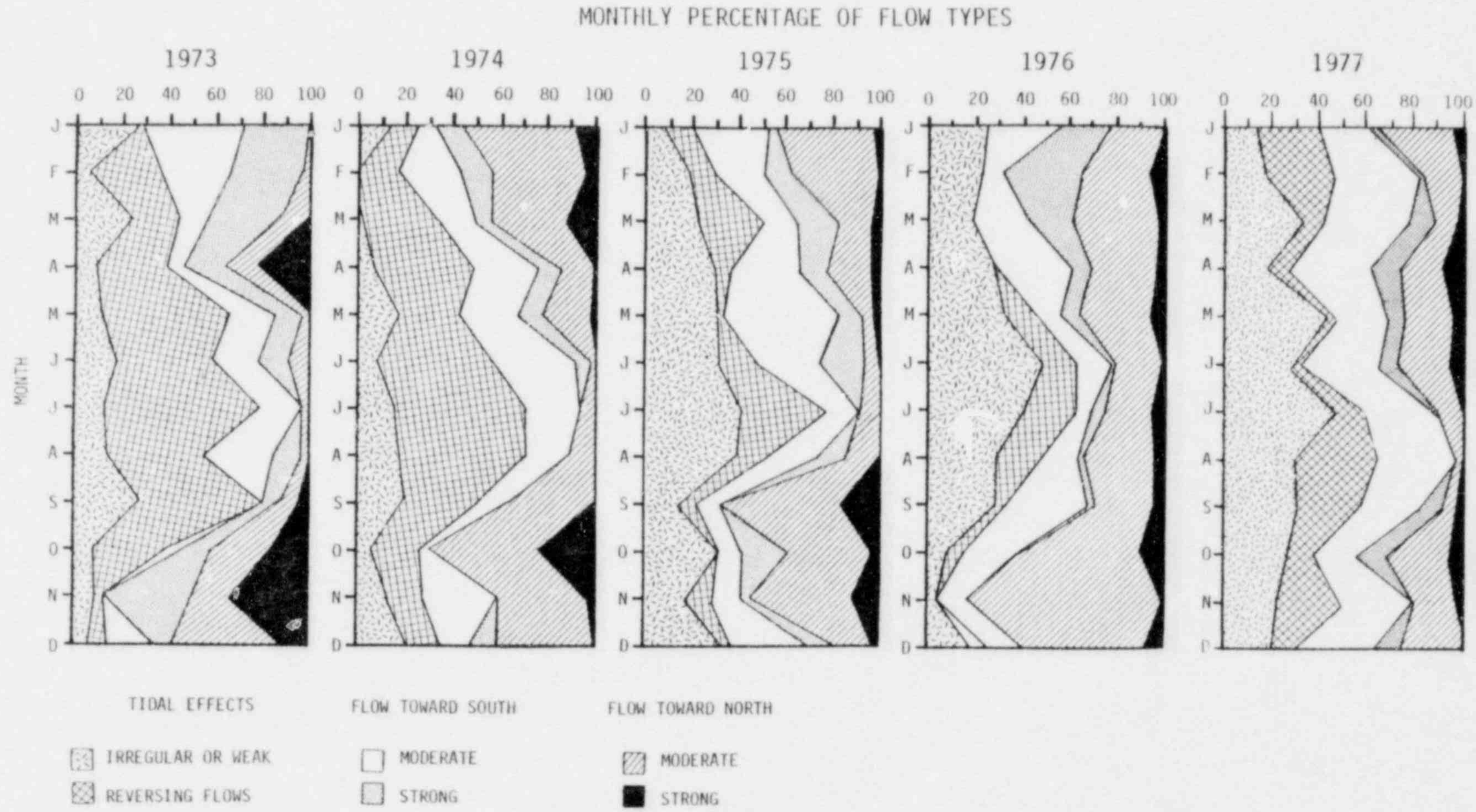

Figure 3.1-7. Distribution of monthly percentage of observed current flow types for coastal waters off Hampton Beach, New Hampshire, from 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

During the winter months, winds and storms generally play a dominant role in coastal circulation in the waters off Hampton Beach, New Hampshire and in the western Gulf of Maine. The current patterns observed during the winter months of 1977 (lunar months December 20, 1976 to March 16, 1977; Figure 3.1-3) were quite similar to those observed during the winters of 1973 through 1976 (NAI, 1975a)*. Dominant winds were from the west at a mean speed of 10.7 kns. Winds from the northeast and east were also strong, with mean speeds of 10.6 kn (6.4 m/sec) and 10.0 kn (6.9 m/sec), respectively. This distribution was similar to wintertime wind conditions of previous years (Figure 7.2-1).

During the spring months, storms generally continue to play an important role in coastal circulation with the tides beginning to show more of an influence, especially during periods of calm weather. Dominant winds are still from the western quadrant, but stronger components from the northeast and southeast observed (Figure 7.2-1 and PSC, 1973). During 1977 (lunar months of March 28 to June 7, 1976; Figure 3.1-3) winds from the northwest and west averaged 9.6 to 9.7 kns (4.9 to 5.0 m/sec), while winds from the northeast averaged 15.0 kns (7.7 m/sec). Near-surface currents are generally toward the south and southwest quadrants, at about the same mean speeds as equivalent flows during the preceding winter months. Northeastward currents were nearly as common as in the winter, but their mean speeds were greater (up to 0.33 kn or 17.0 cm/sec). This bimodal pattern was primarily the result of combined effects of northeasterly and southwesterly storm winds, which pushed nearshore waters either southward or northward along the coast. The annual peak in development of the southerly flow of the counterclockwise Gulf of Maine gyre also typically occurs during the late spring (largely as a consequence of spring runoff). This phenomenon reinforced the southward net drift of coastal waters at this time of year. The influence of tides during the calmer atmospheric periods between storms was apparent from the more equal flow distributions in the various direction classes (for example Figure 7.2-2).

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* Note that rose diagrams represent direction <u>toward which</u> current was flowing or wind was blowing. See figure legends for additional details.

Storms begin to intensify during the autumn season, with dominant winds generally from the northwest and secondary components from the northeast and southwest (Figure 7.2-1 and PSC, 1973). During the autumn of 1977 (lunar months September 11 to December 7, 1977) both the predominant and the strongest winds were from the west and southwest at mean speeds of 8.4 to 9.1 kns (4.3 to 4.7 m/sec; Figure 3.1-3). Currents were somewhat different from those observed during other seasons, apparently as a result of southwest winds and breakdown in the flow of the Gulf of Maine gyre.

Daily (24-hr) net-drift data (longshore or north-south components* averaged over 3-day periods for ease in presentation) collected from mid-depth current meters off Hampton Beach during 1973 through 1977 are summarized in Figure 3.1-8. Data from the summer season show typical net drift rates of at least 1 to 2 n mi per day and numerous periods of much greater net drift. Periods of large net drift are in apparent response to storm effects.

Although conditions from year to year have varied slightly, a general summertime pattern has been observed all 5 years. During both June and July of all 5 years, predominant net drift was southward except for about 4 to 5 days of northward drift. In August 1973 there was very little northward drift, in August 1974 about 5 to 6 days, and in August 1975 through 1977 about 10 to 12 days. During September 1973, 1976 and 1977, there was about 6 to 8 days of northward net drift, in 1974 about 21 days, and in 1975 about 27 days. These data show that periods of relatively small net drift lasting several days at a time occur periodically during the summer season. However, such quiescent periods alternate with periods of strong flow, lasting for days at a time and resulting in large-scale net displacement of nearshore waters.

During the summer months, storms are less frequent and less intense, enabling tidal effects to become more apparent. The wind

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* In calculating the longshore components of net drift, the directional axis was rotated 10° east of north to approximate the orientation of the New Hampshire coastline.

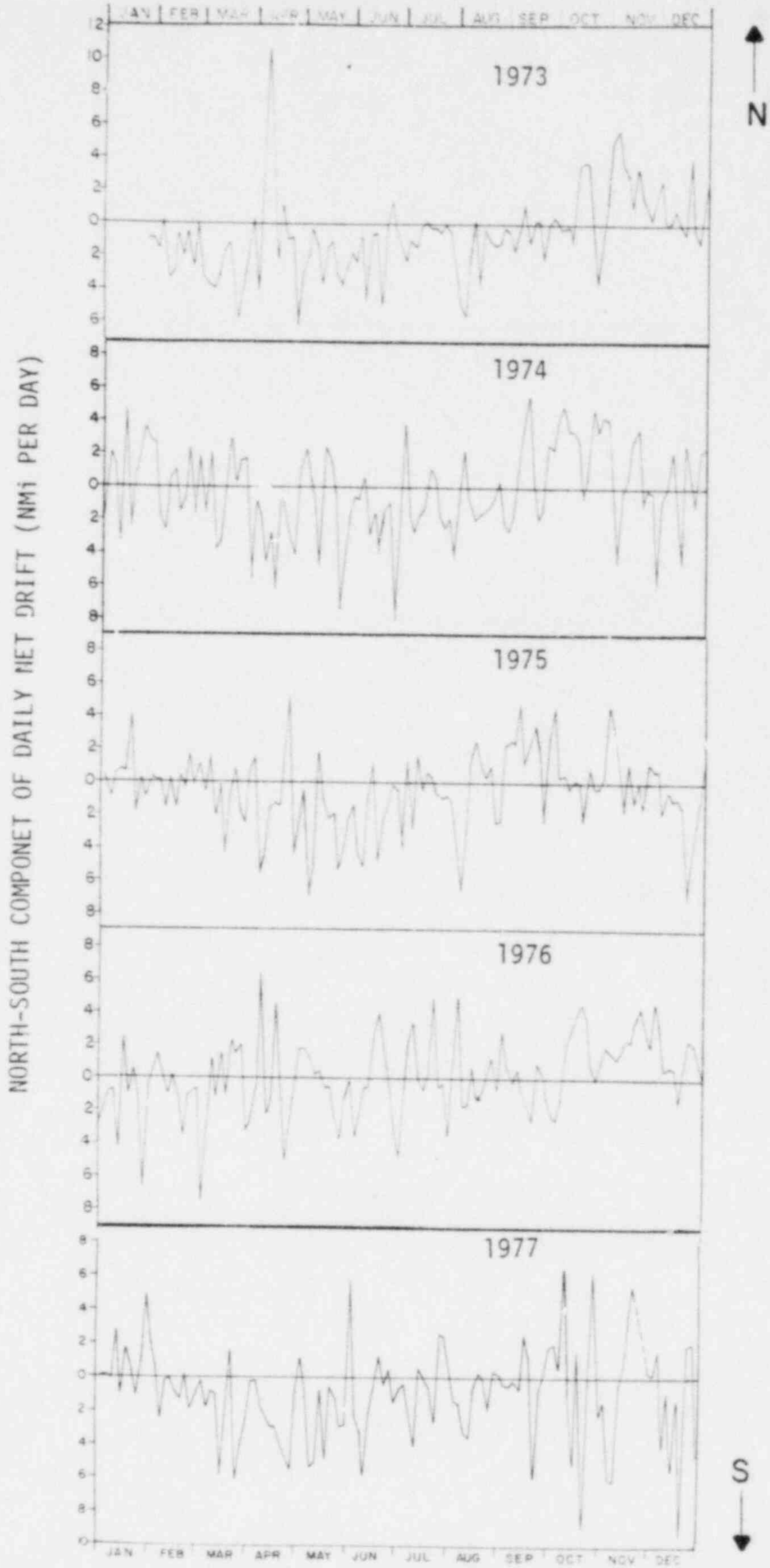

Figure 3.1-8. Plot of daily net drifts of longshore (north-south) components averaged over 3-day periods from mid-depth current meters off Hampton Beach, New Hampshire, 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

pattern also becomes quite different, with most of the winds either from the southwest, northwest or the southeast at relatively slow speeds (Figure 7.2-1 and PSC, 1973). Typically, winds blow onshore during the day and offshore at night under the influence of the thermal differential between the land and the sea. During the summer months of 1977 (lunar months of June 14 to September 10, 1977; Figure 3.1-3), near-surface flows were generally weak and variable in all directions, reflecting increased tidal influence. Occasional summer storms caused pulses of strong current. At this time of year, current speeds weaker than 0.05 kn (2.6 cm/sec) occur more frequently. During periods of tidal flow alternating between northward flood and southward ebb, there was generally at least 2 to 3 n mi (4 to 6 km) per day of southward net residual drift along the coast (as part of the counterclockwise Gulf of Maine gyre). This tidal oscillation was evident from July 25 to 31, 1977 (Figure 7.5-14). Nevertheless, note that strong winds can quickly mask the tidal influence, causing strong northward or southward flows (Appendix 7.5).

3.1.4.2 Spatial Variations

Regional current flow patterns northward or southward along the coast tend to be consistent from site to site for any particular depth (Appendices 7.2 and 7.5). Because of wind influence, strongest flows always occur closest to the surface.

Coastal flows at the diffuser site and the intake site, both located about 1 n mi (2 km) off Hampton Beach (Figure 2.2-1) have shown pronounced variations with season and with depth. Near-surface flows at Moorings 12, I-4 upper, and T-7 have been generally strong, with a pronounced bimodality toward the northeast and south. At Mooring 10 upper, located about mid-depth, currents have been somewhat weaker, but overall patterns have been similar to Mooring 12. Near bottom at Mooring 10 lower and I4 lower, flows have been quite weak, generally toward the southwest and west due to local topography and compensatory landward flows.

The near-surface moorings showed strong currents toward both the south and the north at mean speeds of up to 0.28 kn (14.4 cm/sec); there was relatively little onshore/offshore flow (Figure 3.1-3). Mid-depth flows were weaker with mean speeds of 0.07 to 0.21 kn (3.6 to 10.8 cm/sec) and a higher percentage (29%) of calm flows below threshold of the current meters. Near-bottom flows were even weaker with 31 percent calm and mean speeds of 0.09 to 0.17 kn (4.6 to 8.7 cm/sec).

Flows showed considerable variation from one depth to another at these moorings. At the near-surface moorings, northeasterly and southerly flows were nearly balanced. Speeds were below 0.05 kn (2.6 cm/sec) about 10 to 14 percent of the summer. Mid-depth flows were more southerly and about 19 percent of the speeds were below 0.05 kn (2.6 cm/sec). Near-bottom flows were even weaker (34 percent below threshold) but showed predominantly southwestward transport.

Pronounced vertical shearing at both the diffuser site and the intake site was observed. Both Mooring 10 upper and I-4 lower exhibited weaker mean speeds and higher percentage calm (Figure 3.1-3); but predominant flows were still toward the south and southwest. Distinct shearing along the halocline and thermocline separating the upper and lower portions of the water column was observed, especially during the early autumn as the Gulf of Maine began to cool. Near-surface currents tended to follow the wind, whereas flows at depth were more influenced by the tides and occasional compensatory flows during stormy periods. Near-surface flows were more northward in autumn than during other seasons, whereas mid-depth and near-bottom flows still showed predominantly southwestward transport (Figure 3.1-3).

Summary tabulations of all available data from selected moorings document some interesting relationships (Appendix 7.3). The three near-surface moorings (12, I-4 upper and T-7) all showed low percentages of flows below current meter threshold (0.04 kn or 2.0 cm/sec), ranging from 9.8 to 14.0 percent. Speeds of 0.05 to 0.2 kn (2.6 to 10.3 cm/sec) ranged from 47.5 to 55.5 percent. Percentages from 0.21 to 0.4 kn (10.8

to 20.6 cm/sec) were 23.3 to 30.6 percent and from 0.41 to 0.6 kn (21.1 to 30.8 cm/sec) were 5.2 to 9.1 percent. The higher speeds were less common - 1.4 to 2.2 percent for 0.61 to 0.8 kn (31.4 to 41.1 cm/sec) and 0.6 to 1.0 percent for 0.81 to 1.0 kn (41.6 to 51.4 cm/sec). These three moorings all showed the prevalence of longshore flows; southward flows ranged from 17.2 to 21.3 percent and northeastward flows ranged from 18.8 to 24.3 percent. Flows toward the southwest and the north were a little less common, ranging from 12.2 to 16.6 percent.

Mid-depth flows at Mooring 10 upper were somewhat weaker showing higher percentages of calm flows (18.6 percent) and 0.05 to 0.2 kn (2.6 to 10.3 cm/sec) speeds (59.7 percent). Higher speeds were proportionately rarer with only 0.1 percent from 0.81 to 1.0 kn (41.7 to 51.4 cm/sec). Flows toward the northeast and southwest were most common (17.9 and 18.1 percent respectively).

Mooring I-4 lower showed near bottom flows of 35.0 percent calm, 57.6 percent from 0.05 to 0.2 kn (2.6 to 10.3 cm/sec), 6.4 percent from 0.21 to 0.4 kn (10.8 to 20.6 cm/sec), and 1.0 percent from 0.41 to 0.8 kn (21.1 to 41.1 cm/sec). In only 4 instances were speeds higher than those observed (Table 7.3-5). Flows were predominantly toward the southwest (29.8 percent) and the south (18.6 percent), with a secondary northward peak (15.5 percent). This pattern appeared to be due to effects of local bottom topography and compensatory landward flows similar to the trajectory data from sea-bed drifters (NAI, 1975a and 1975b).

3.2 TEMPERATURE

3.2.1 Air Temperature

Air temperature plays a major role in heating estuarine and coastal waters during the summer and cooling them during the winter.

Air temperature data from the closest U.S. Weather Bureau stations at Boston, Massachusetts and Portland, Maine bracket local conditions in the Hampton Beach area. Monthly means of the daily maximum and minimum air temperatures from these stations for 1977 obtained from NOAA-EDS show that July was the warmest month and January was the coldest (Figure 3.2-1). At Boston the monthly mean of the daily maxima was 84 F (28.9 C) in July whereas the monthly mean of the daily minima was 17 F (-8.3 C) in January; at Portland corresponding values were 79.5 F (26.4 C) and 4.0 F (-15.6 C). Monthly differences between stations were consistent during the year (Figure 3.2-1).

Total monthly heating and cooling degree days (based on 60F or 15.5 C) from Boston and Portland in 1977 were determined from NOAA-EDS (1977). These data showed a winter peak of 1280 heating degree days in January and a summer peak of 310 cooling degree days in July (Figure 3.2-1).

Seasonal patterns have varied somewhat from year to year for each station (Figure 3.2-1). For example in the summertime at Boston, 1975 appears to have been the warmest summer with a mean of daily maxima of 85 F (29.4 C) and a mean of daily minima of 68 F (20 C) in July. Peak temperatures other years occurred in June (1976), July (1973, 1975 and 1977), and August (1974). To the north at Portland, the warmest summer appears to have been 1973 with a mean of daily maxima of 80 F (26.7 C) and a mean of daily minima of 62 F (16.7 C) in July. Peak temperatures other years occurred in June (1976) and July (1973, 1974, 1975, and 1977). The most anomalous year was 1976 when peak minimum values occurred in June and peak minimum values occurred in August.

Wintertime temperature patterns have been more consistent. At both Portland and Boston, January 1977 was the coldest month. Monthly means of daily minima were 4 F (-15.6 C) and 17 F (-8.3 C), respectively; whereas daily maxima were 25 F (-3.9 C) and 30 F (-1.1 C), respectively. The unusually cold winter of 1977 was attributed to persistent southward flow of the cold Polar Continental air mass from

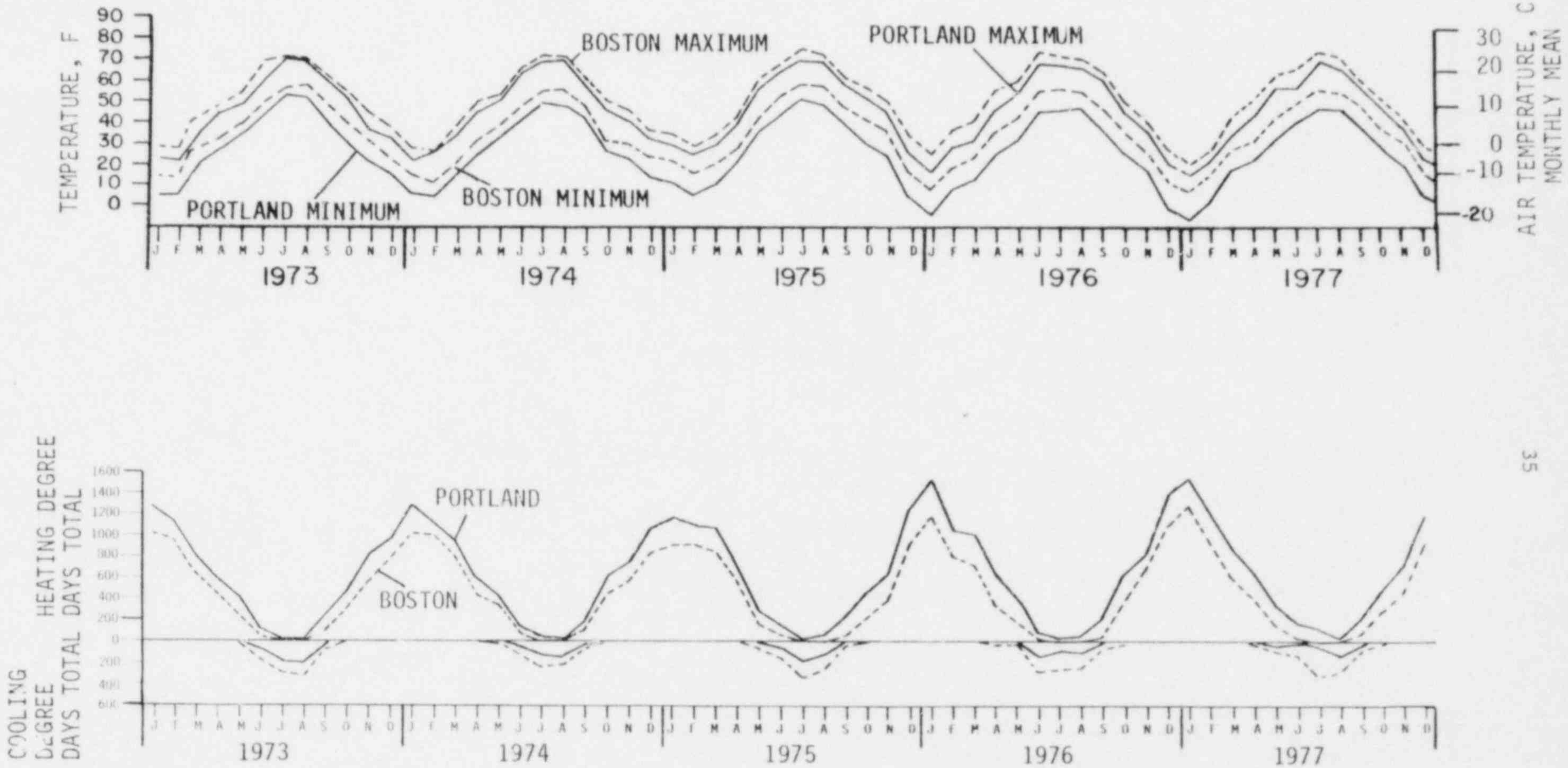

Figure 3.2-1. Monthly mean of daily maximum and minimum air temperatures, and heating and cooling degree days measured at U.S. Weather Bureau stations at Boston, Mass., and Portland, Maine from 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

northwest Canada deep into the U.S. mid-section and then spreading across the eastern two-thirds of the country. This pattern resulted in record low temperatures in much of New England and the rest of the Nation. For all the other years under discussion, February was consistently the coldest month (Figure 3.2-1).

Comparing the two stations during the summer months, the monthly means of the daily maxima at Boston were 1 to 6 F (0.6 to 3.3 C) warmer than those at Portland, whereas the monthly means of the daily minima were up to 10 F (5.5 C) warmer. During the winter months Boston's monthly means of the daily maxima were up to 8 F (4.4 C) warmer than Portland's; the minima were up to 13 F (7.2 C) warmer (Figure 3.2-1).

Total monthly heating and cooling degree days (based on 60 F or 15.5 C) for Boston and Portland show that the highest total degree days have occurred during January of all five years; 1977 has been the coldest winter (Figure 3.2-1). The pattern of cooling degree days has been somewhat variable, with peak cooling degree days having occurred during June of 1976; July of 1974, 1975 and 1977 (Boston) and August 1973 and 1977 (Portland).

3.2.2 Water Temperature

Water temperature and associated thermal stratification are controlled primarily by air temperature and solar insolation. Local temperature stratification can be strongly affected by winds, coastal currents, precipitation, estuarine discharge, vertical mixing, upwelling and downwelling.

3.2.2.1 Temporal Variations

Variations in hourly average temperatures document the dynamic nature of these waters. Ambient daily variability within the Hampton

Harbor estuary has ranged from 3.0 to more than 12.0 F (1.7 to 6.7 C) in the winter; and from 5.0 to more than 12.0 F (2.8 to 6.7 C) in the summer. Examples of typical summertime and wintertime conditions are illustrated in Figure 3.2-2. Lowest temperatures each day occur near high tide, whereas highest temperatures typically occur around low tide, under the influence of the ebbing tide. Typical mid-summer data from offshore moorings, moorings in the Rocks area, and moorings in the Hampton Harbor estuary show changes of at least 2 to 6 F (1.1 to 3.3 C) within 1 hr, 5 to 12 F (2.8 to 6.7 C) within a tidal cycle (12.8 hr) and 5 to 13 F (2.8 to 7.2 C) over a day.

These waters also show pronounced seasonal and annual variability. Mean monthly near-surface temperatures from selected moorings during 1977 showed that lowest temperatures occurred in February, typically lagging about 30 days behind the coldest air temperatures (Figures 3.2-1 and 3.2-3). During April, May and June, temperatures rose rapidly with highest temperatures generally being reached during August. During late September and early October, temperatures began to decrease. Overall summary data are presented in Appendix 7.4.*

Temperature measurements from the monthly slack water surveys provide an additional framework for the continuous data observations. Measurements made at Mooring 12 during 1977 for near surface and near bottom at both high and low water showed that late January was the coldest part of the year (note: no high water survey in February) and that peak temperatures occurred in August and September (Figure 3.2-4). No distinct pattern of temperature differences between high water and low water was evident. However, surveys did show a tendency for colder near-surface temperatures to occur at low water during the winter months (November-February). It appears that on the flooding tide during the

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* These figures summarize the overall monthly means of the daily maxima and daily minima and indicate the maximum and minimum temperatures ever observed during each month of any year. Mean monthly temperatures for 1977 are also shown.

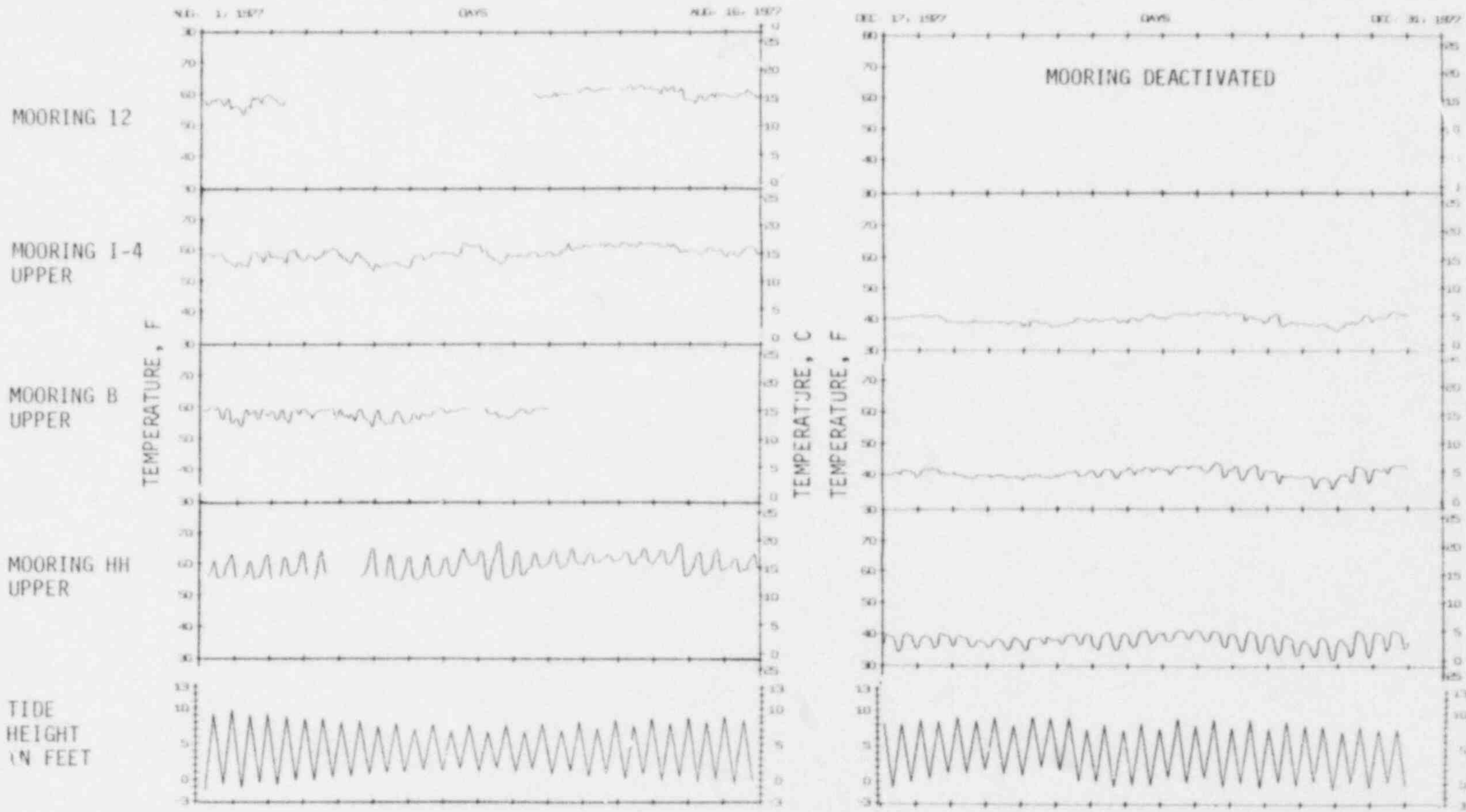

Figure 3.2-2. Representative summertime(August 1 to 16, 1977) and wintertime (December 17 to 31, 1977) plots of hourly average near-surface temperature data from diffuser site (Mooring 12), intake site (Mooring I-4 Upper), Rocks area (Mooring B), and Hampton Harbor estuary (Mooring HH Upper), tide heights shown along bottom. Seabook 1977 Annual Hydrographic Report, 1979.

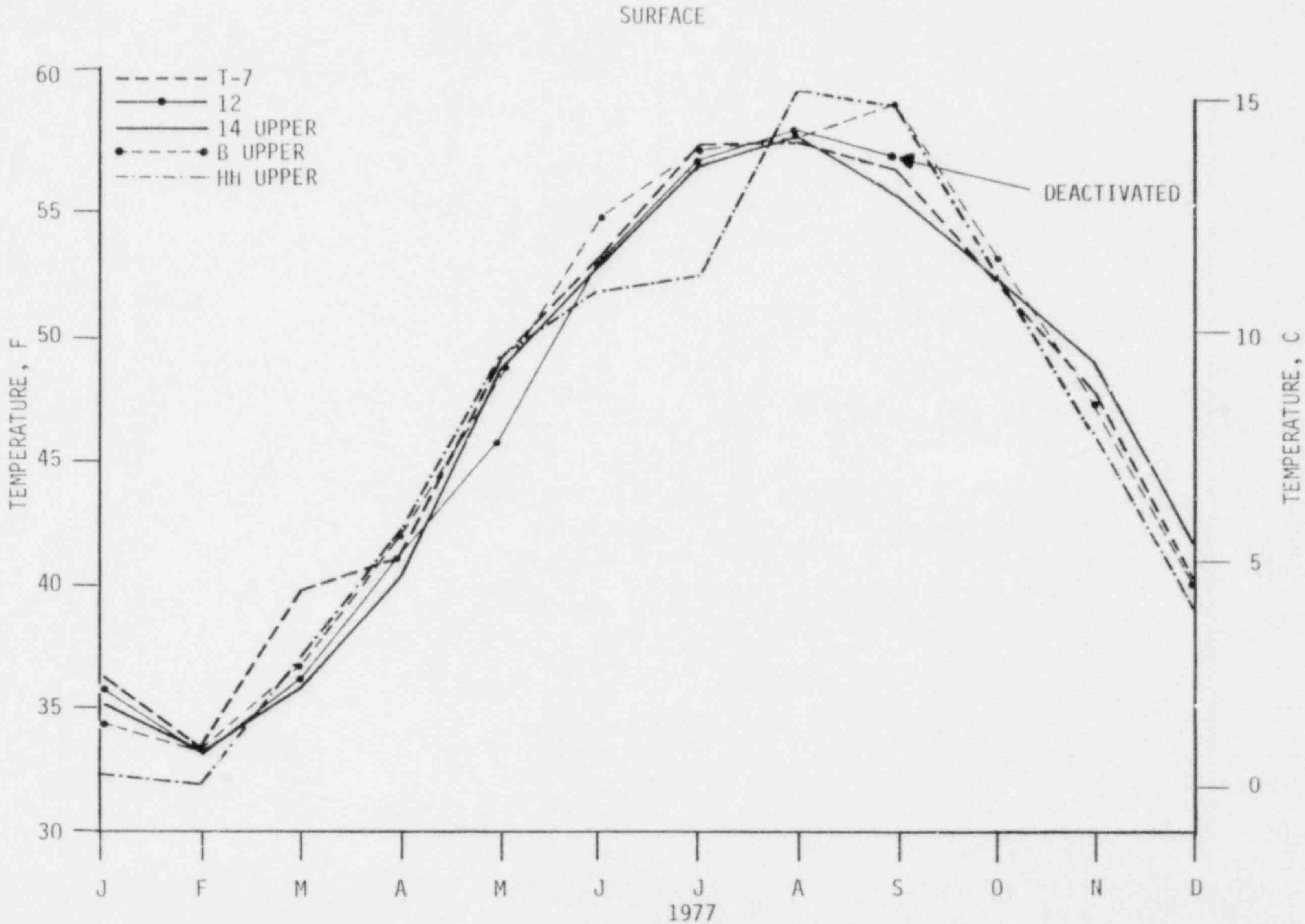

Figure 3.2-3. Monthly mean near-surface water temperature for selected moorings off Hampton Beach, New Hampshire, during 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

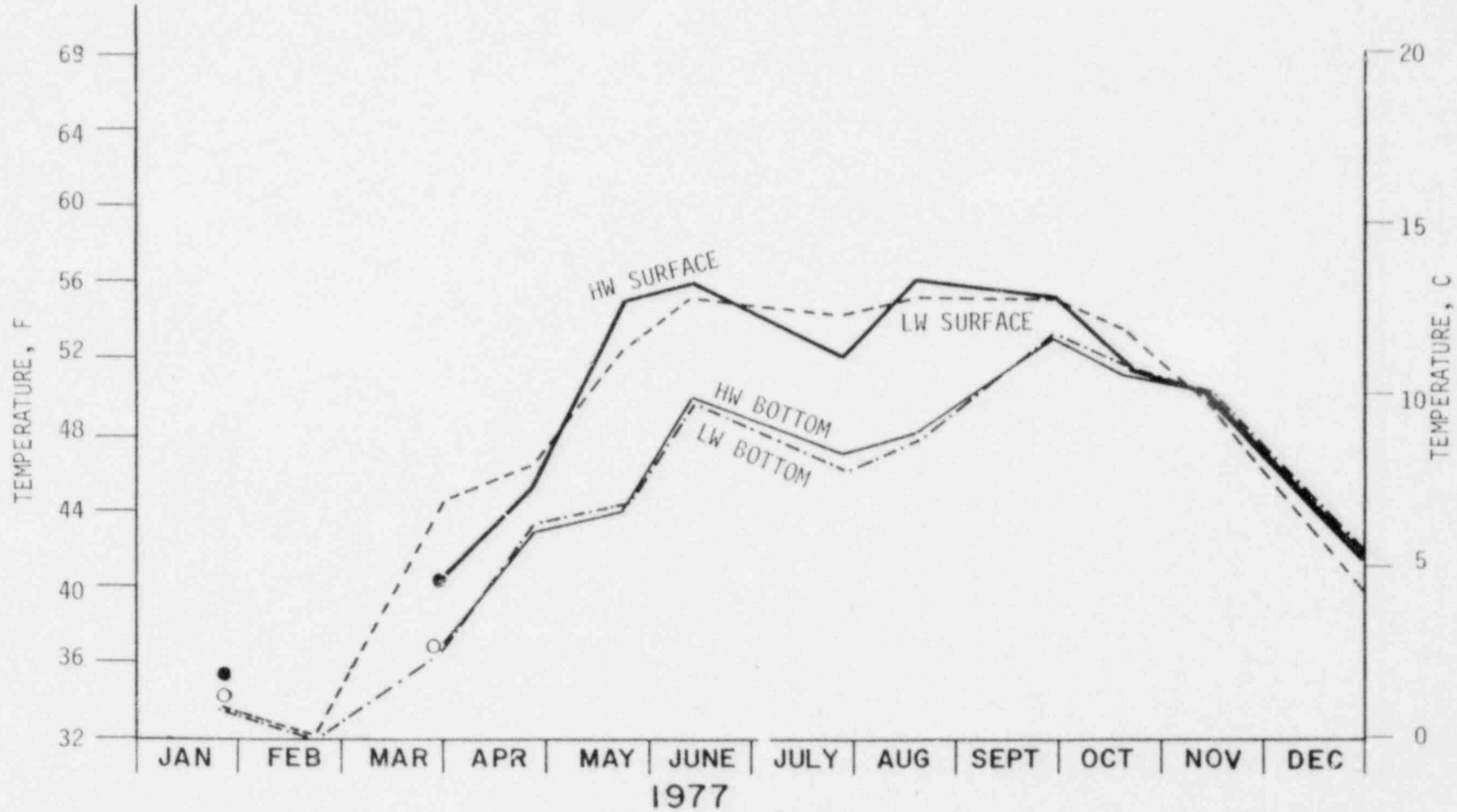

Figure 3.2-4. Monthly temperature observations at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1977 slack-water surveys (both low water, LW and high water, HW). (No high water data in February due to weather problems). Seabrook 1977 Annual Hydrographic Report, 1979.

winter, near-surface waters tend to become warmer and during the summer they tend to become colder, as water from offshore displaces water closer to shore. Near-bottom waters showed less variability (Figure 3.2-4).

Mean monthly temperature profiles from high-water slack for all of the offshore stations during 1977 are shown in Figure 3.2-5. The annual cycle begins in November with vertically homogeneous temperatures averaging about 50 F (10 C). In the early winter, temperatures dropped sharply with coldest values during late February (as observed at the continuous temperature monitoring stations) about 30 days behind the minimum atmospheric temperature observed during the year.

Starting with isothermal conditions in January and February, the water column showed a gradual warming trend as the spring season progressed (Figure 3.2-5). By May and June, the development of the seasonal thermocline was well along. By mid-summer the coastal waters showed a strong thermal stratification with a variation of up to 5 C between near-surface and near-bottom depths. Maximum near-surface temperatures occurred during August, lagging about 30 days behind the maximum atmospheric temperatures observed during the year. During September and early October, the stratification broke down rapidly and temperatures became isothermal.

Summary plots of the monthly mean of the daily mean and standard deviation of near surface temperatures (Moorings 12 and I-4 upper) and near bottom temperatures (Moorings 10 lower and I-4 lower) from April 1973 through December 1977 show consistent trends from year to year (Figure 3.2-6). Highest temperatures occurred during September 1973 and lowest temperatures occurred during February 1977. During 1975, peak temperatures at both near surface and near bottom were observed in August, whereas during other years near-bottom temperatures tended to lag 1 to 2 months behind (such as in 1974). Mean annual near-surface water temperatures* have remained fairly constant over this period:

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* Average of mean monthly values weighted by the number of days for which data were actually acquired.

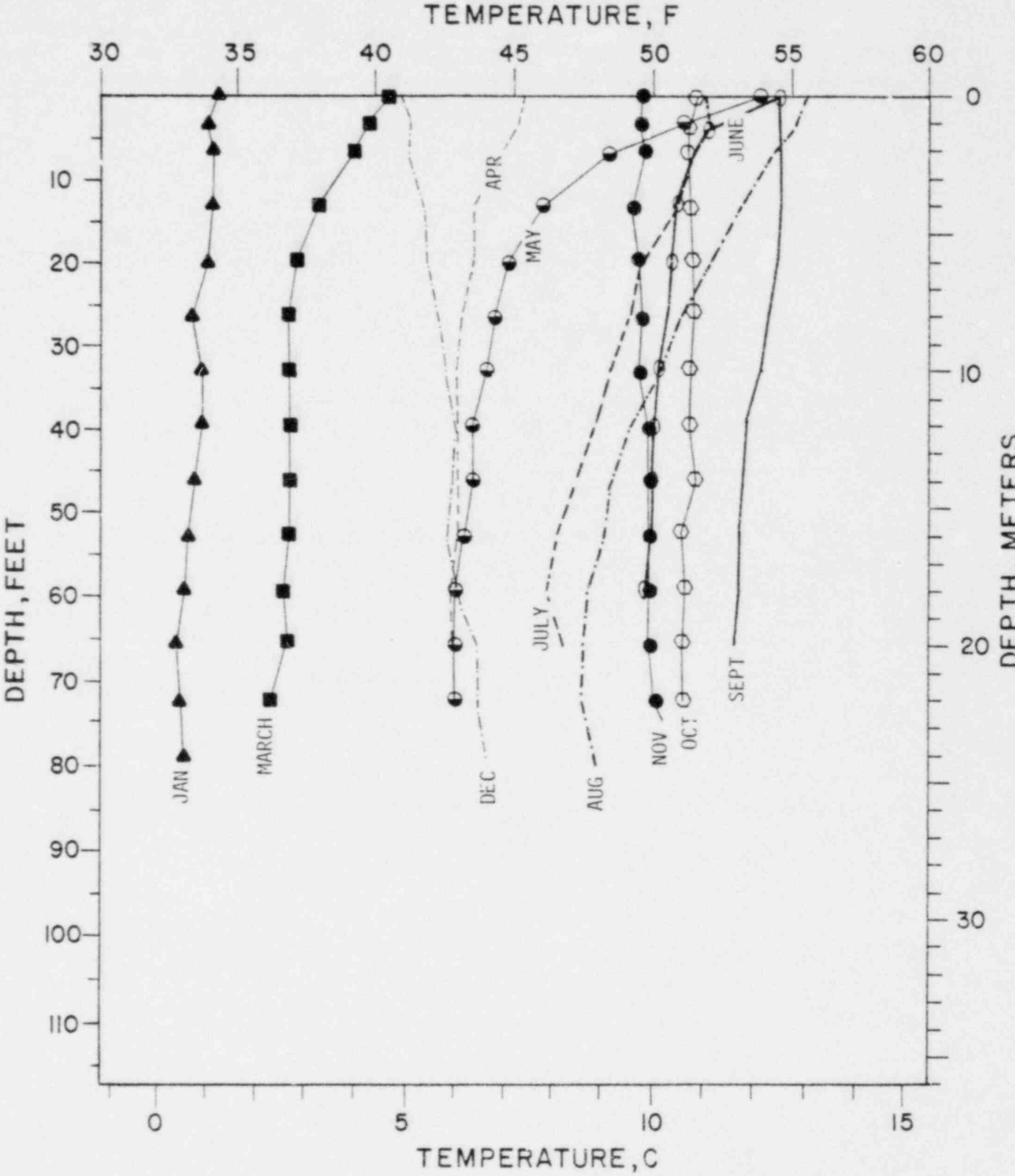

Figure 3.2-5. Mean high-water slack temperature profiles from coastal waters off Hampton Beach, New Hampshire, during 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

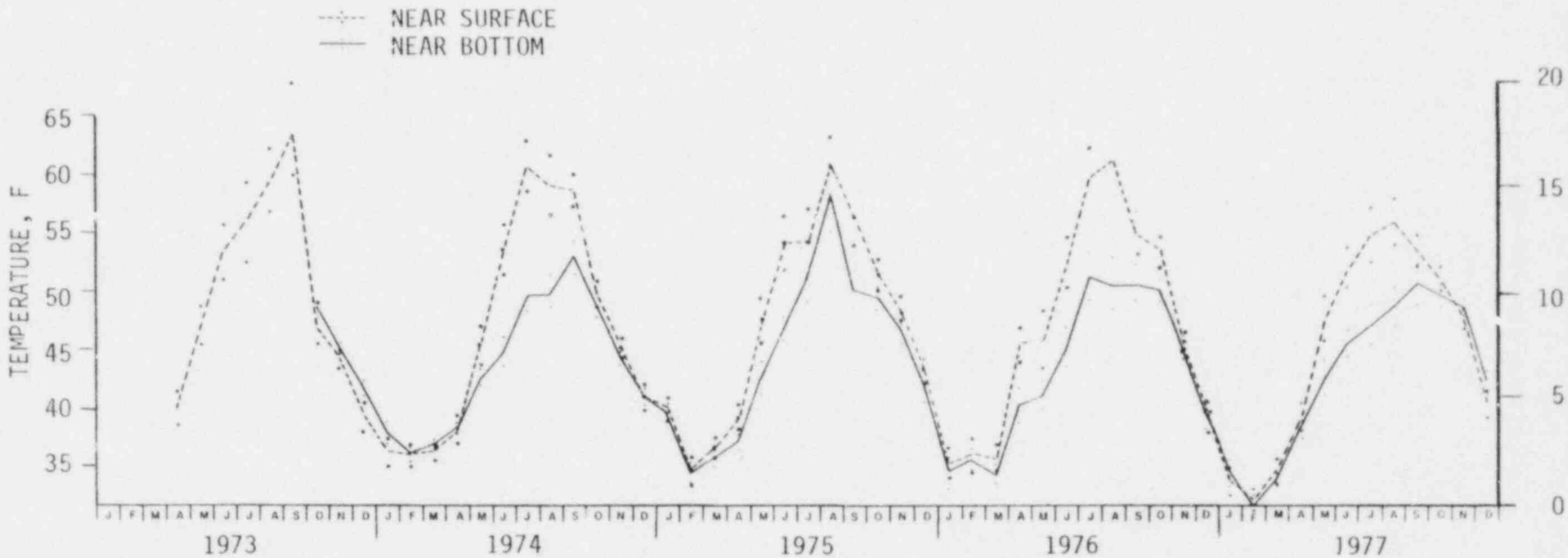

Figure 3.2-6. Monthly mean temperature and standard deviation for near-surface waters (Moorings 12 and I-4 upper) ar l near-bottom waters (Moorings 10 lower and I-4 lower) off Hampton Beach, New Hampshire, from 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

51.5 F or 10.8 C for 1973 (incomplete year as data began in early April), 48.5 F or 9.2 C for both 1974 and 1975, and 49.4 F or 9.7 C for 1976. The record cold winter of 1977 lowered the mean down to 45.8 F or 7.7 C (Figure 3.2-6).

Near-surface data from Mooring B upper, located west of the Outer Sunk Rocks, showed daily ranges of from 2.0 to more than 12.0 F (1.1 to 6.7 C) in the summer and 1.0 to 5.9 F (0.6 to 3.3 C) in the winter. Plots of typical summertime and wintertime data are shown in Figure 3.2-2. Mean monthly of daily mean near-surface measurements from Mooring B upper showed lowest values in February 1977 and peak values in August 1976 (Figure 3.2-7).

Near-bottom temperatures at Mooring B lower closely followed near surface temperatures (Figure 3.2-7). Wintertime temperatures averaged about 1.0 F (0.6 C) warmer on the bottom than near the surface, whereas summertime temperatures averaged about 3.0 F (1.7 C) colder on the bottom. Autumn temperatures were essentially isothermal.

The waters of the Hampton Harbor estuary show the most temporal variation of any location in the study area. Mean monthly near-surface measurements from Mooring HH upper showed lowest values in February 1977 and highest values in August 1976 (Figure 3.2-8). Note that temperatures at this mooring were lower than at all other near surface moorings during the winter months but warmer than at all the others during the summertime. Near-bottom measurements from Mooring HH lower closely parallel those from Mooring HH upper because estuarine waters are vertically well mixed most of the year. At the wintertime extreme, near-surface waters average about 0.3 F (0.2 C) colder than near bottom, whereas in the summer they average about 0.7 F (0.4 C) warmer than near bottom (Figure 3.2-8). Observed temperatures have ranged from a low of 27.0 F (-2.8 C) to a high of 72.5 F (22.5 C).

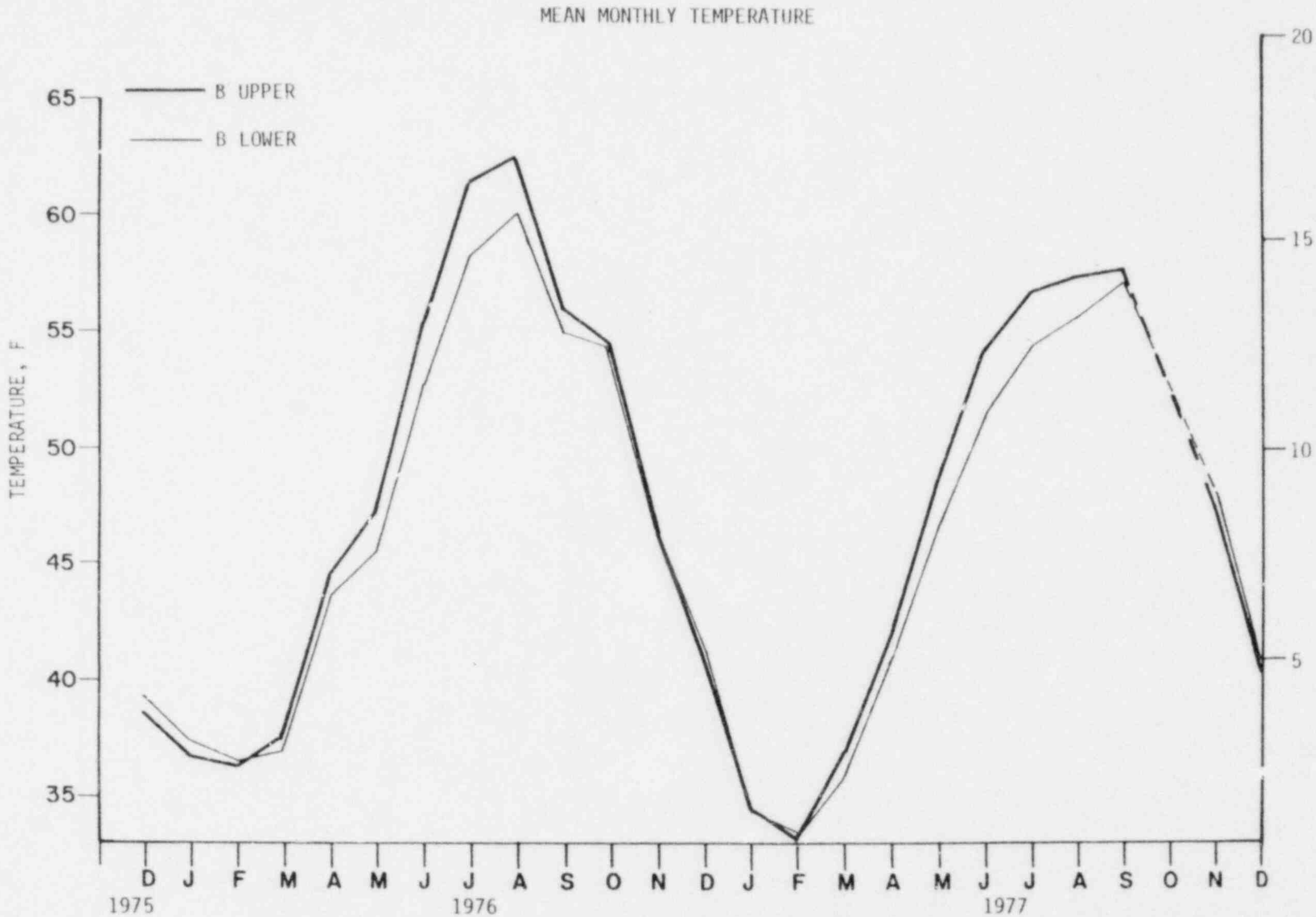

Figure 3.2-7. Monthly mean near-surface and mid-depth water temperatures from the Sunk Rocks (Mooring B) off Hampton Beach, New Hampshire, from 1975 to 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

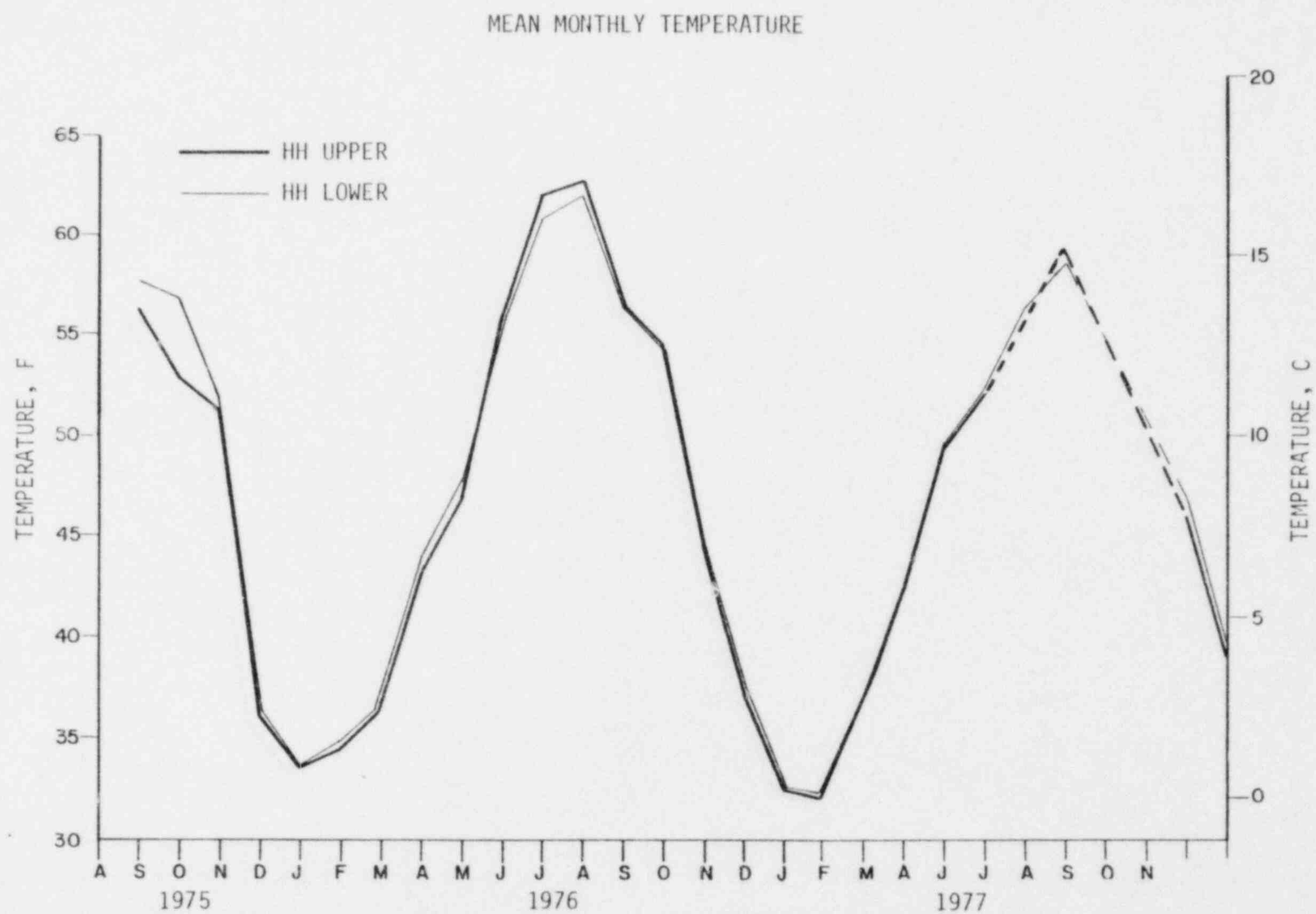

Figure 3.2-8. Monthly mean of the daily mean near-surface and near-bottom water temperatures from the Hampton Harbor estuary (Mooring HH) for 1975 to 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

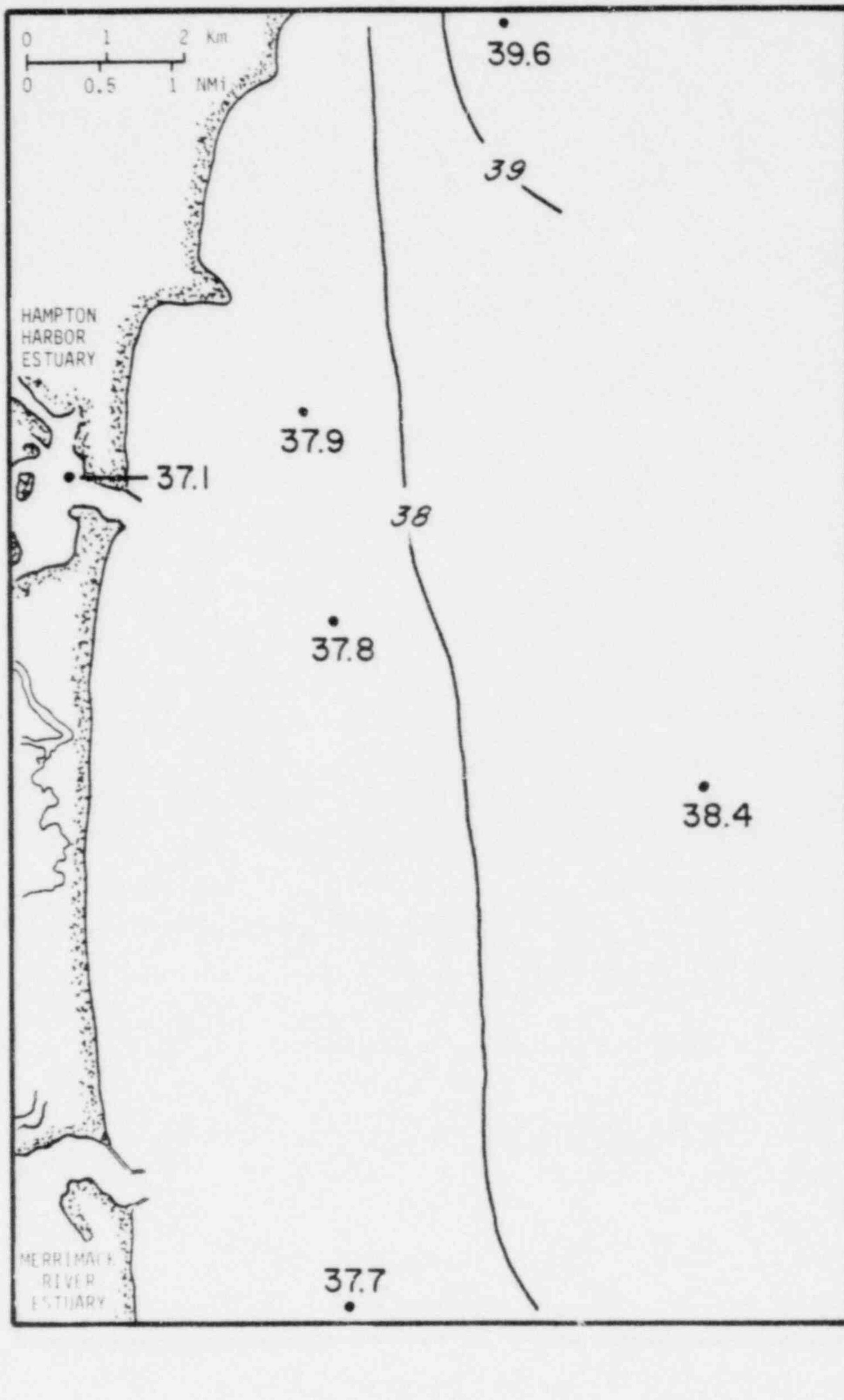

Figure 3.2-9. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on January 3, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

3.2.2.2 Spatial Variations

Near-surface temperature measurements obtained from slack-water surveys and plankton cruises further document the dynamic nature of these waters. Data from the former highlight the variability between tidal cycles, whereas the latter emphasizes the variability along the coast from Rye Harbor southward to the Merrimack River.

Selected surveys since 1976 illustrate the variability of near-surface waters over a typical year. The plankton cruise of January 3, 1977 (Figure 3.2-9) showed homogeneous temperature near shore (37.1 to 37.9 F or 2.8 to 3.3 C) and slightly warmer temperatures offshore (38.4 to 39.6 F or 3.6 to 4.2 C). In the spring estuarine and offshore waters gradually warm up. The plankton cruise of May 4, 1977 (Figure 3.2-10) showed warm water off the Merrimack River (49.7 F or 9.8 C) and somewhat colder waters off Hampton Beach. The slack-water survey of May 23, 1977 illustrates how variable estuarine and offshore waters can be (Figure 3.2-11). Harbor waters ranged from 49.8 to 53.0 F (9.9 to 11.7 C) at high water and from 54.0 to 62.6 F (12.2 to 17.0 C) at low water. Offshore temperatures were much less variable, the temperature differences ranging about 1.4 to 4.7 F (0.8 to 2.6 C) over the tidal cycle. Mid-summer data from August 19, 1977 (Figure 3.2-12) showed comparable variability and the influence of the ebb tidal prism discharging south of the Sunk Rocks. By the late summer plankton cruise of September 7, 1977 (Figure 3.2-13) peak seasonal temperatures had been attained, but there was a tendency for slightly cooler conditions along the coast (possibly due to vertical mixing and wave effects). Near-surface waters cooled down during the fall and by early winter (slack water survey of December 30, 1977; Figure 3.2-14) estuarine waters were averaging about 5 to 8 F (2.8 to 4.4 C) colder than offshore.

Continuous temperature data from offshore moorings show little horizontal variation among near-surface moorings, there is vertical variations with temperature getting progressively colder at depth (Figures 3.2-15 and 16; Appendix 7.4). For example, summary data from Mooring 12

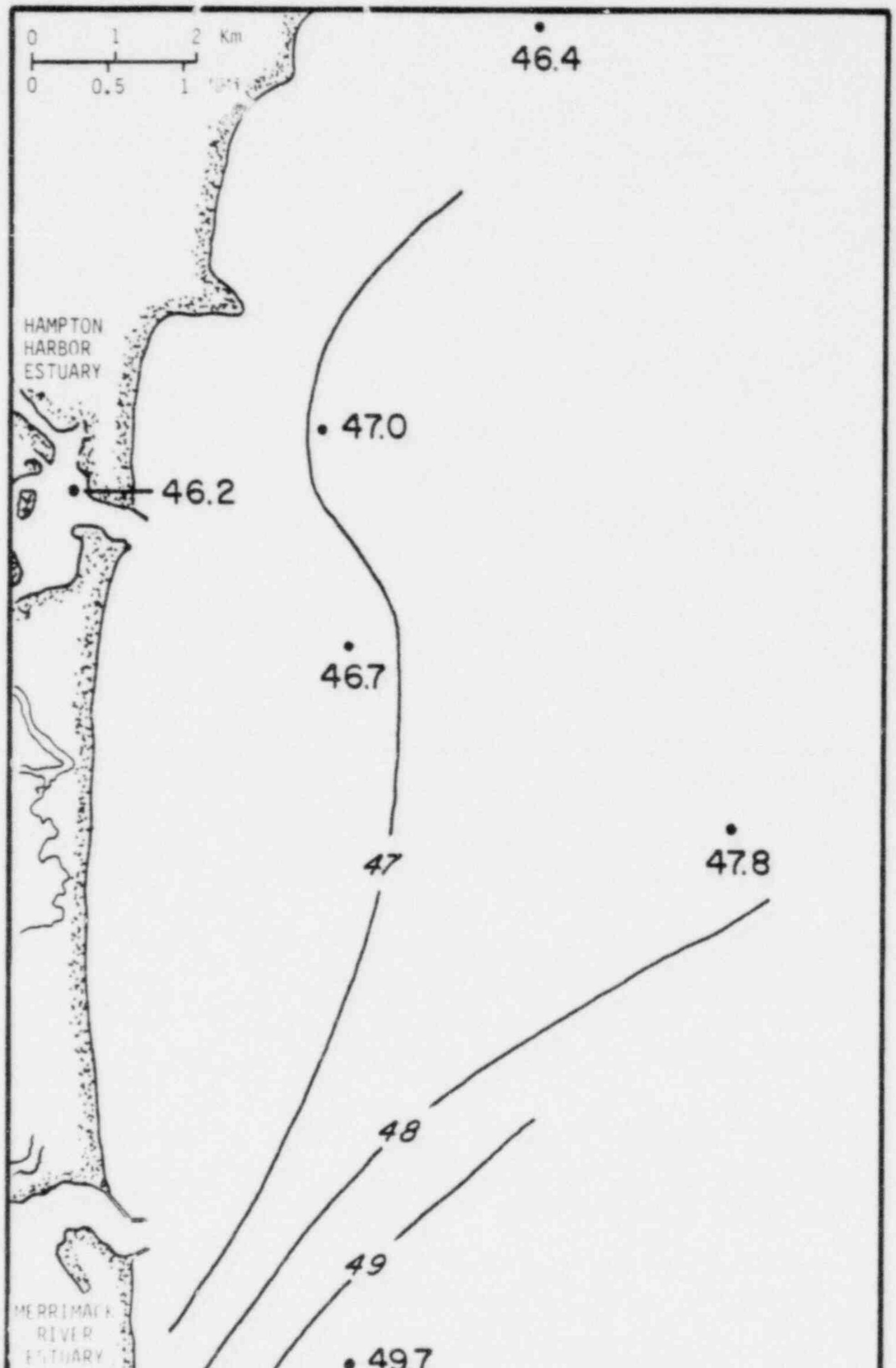

Figure 3.2-10. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on May 4, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

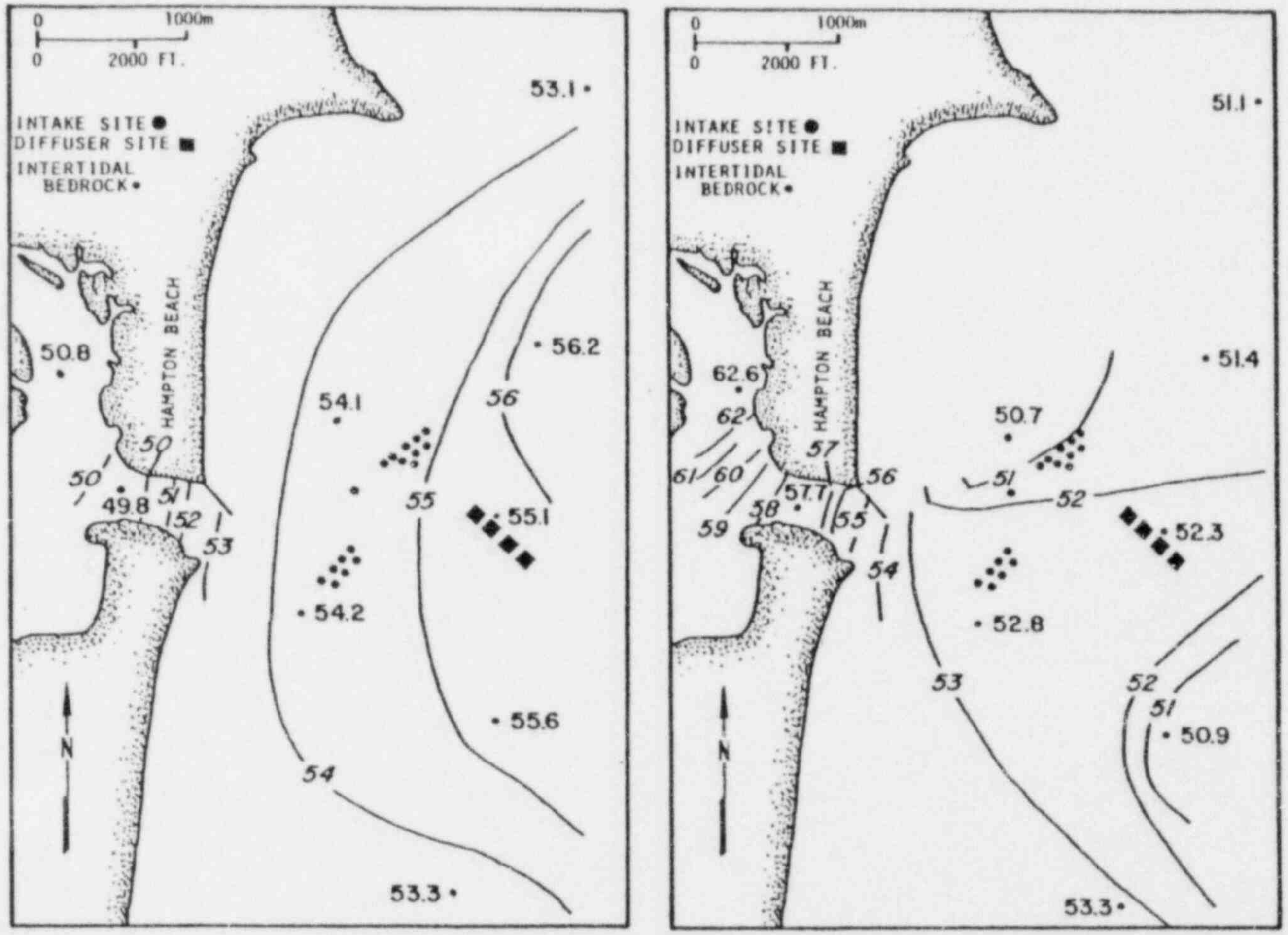

Figure 3.2-11. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on May 23, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

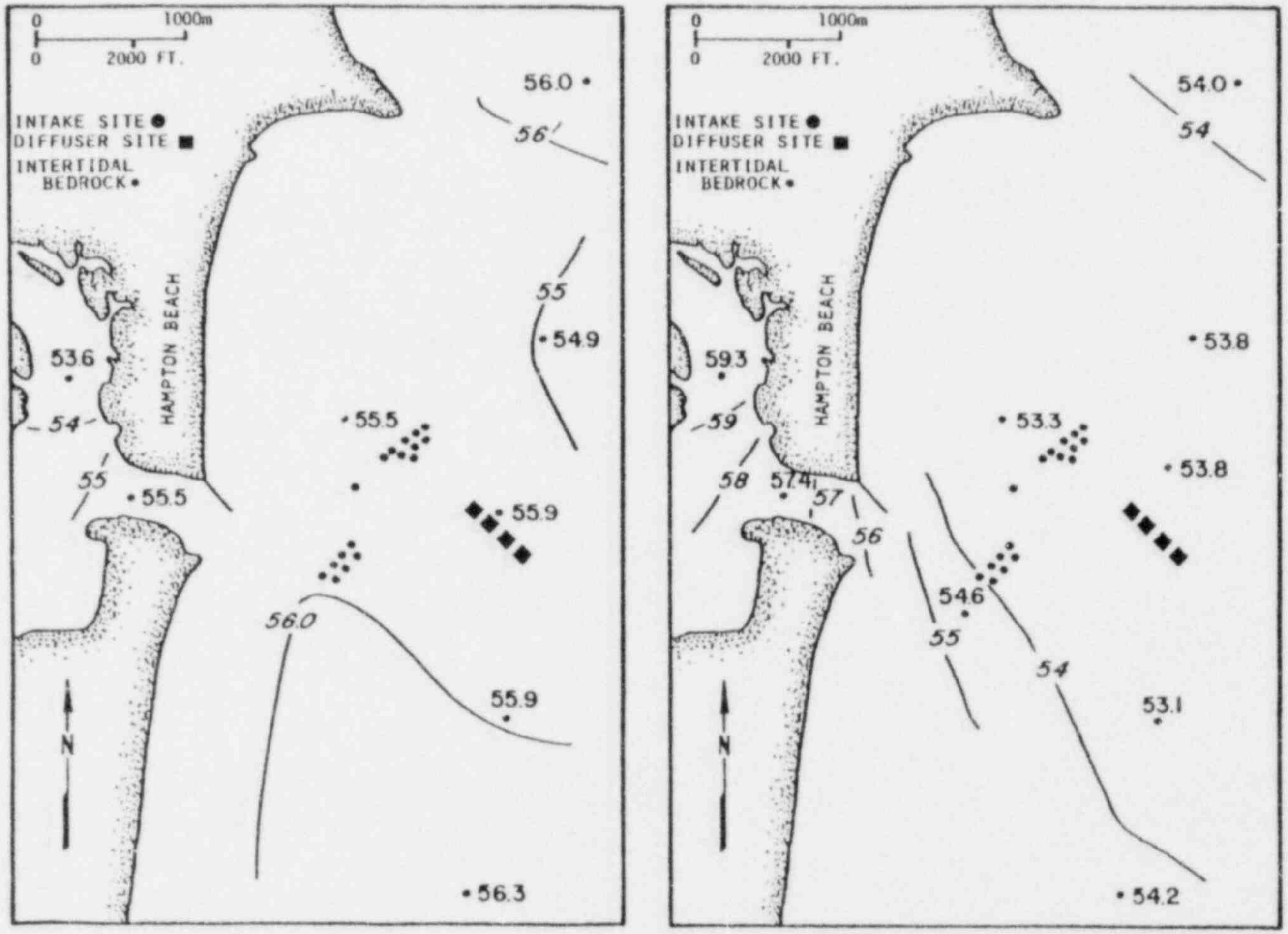

Figure 3.2-12. Surface water temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on August 19, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

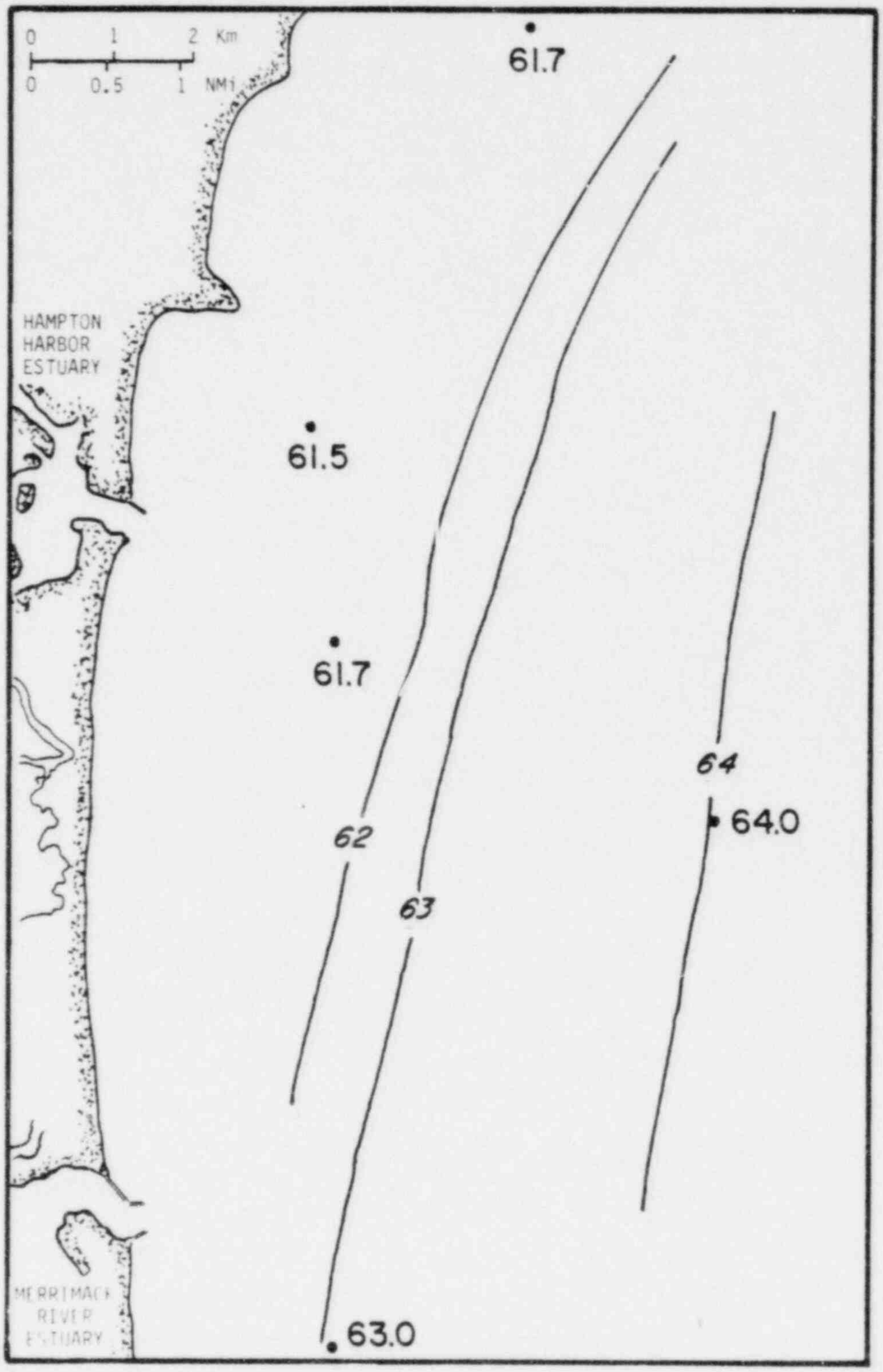

Figure 3.2-13. Surface temperatures (F) in Hampton Harbor estuary and adjacent coastal waters on September 7, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

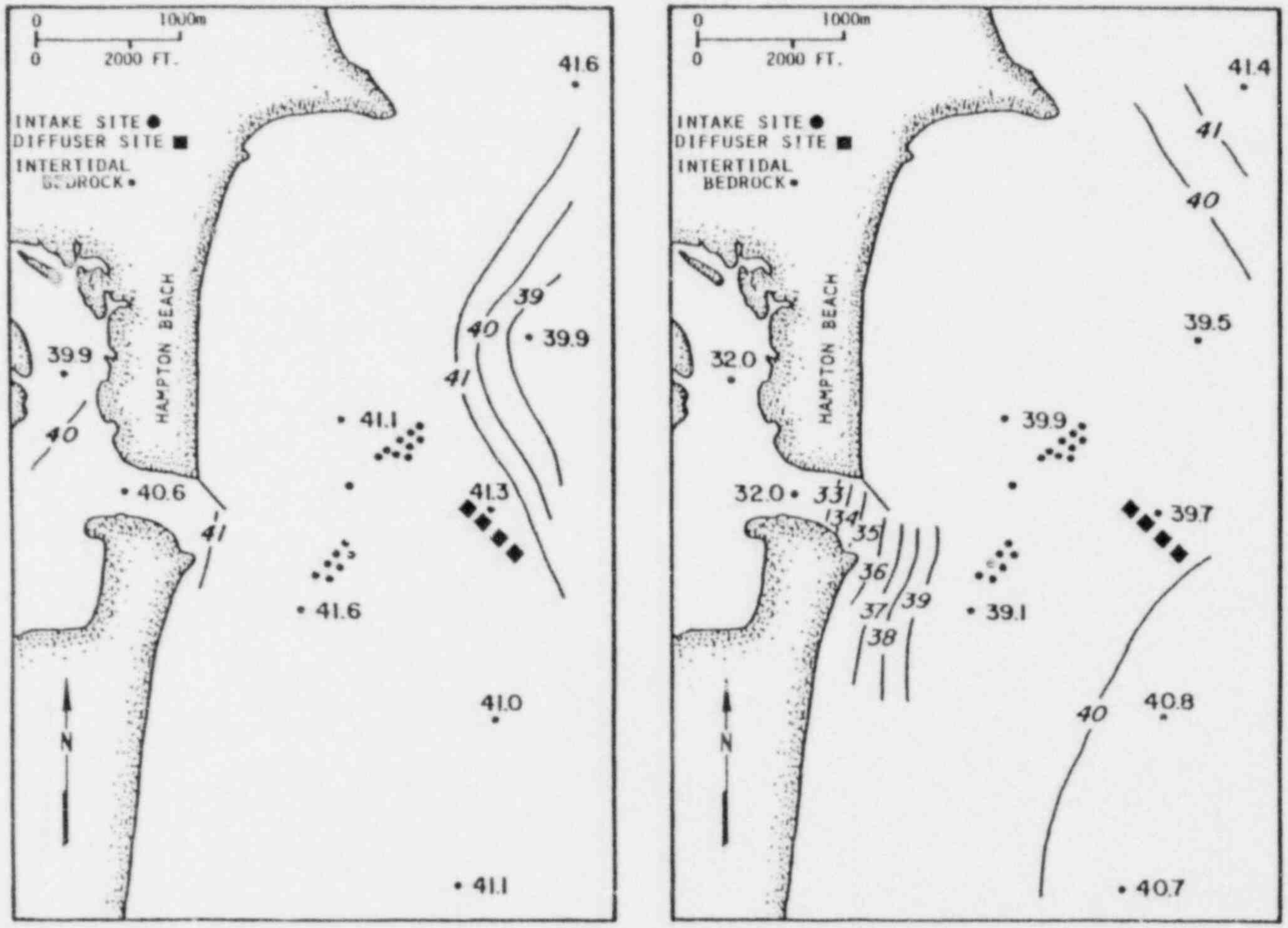

Figure 3.2-14. Surface water temperatures (⊦) in Hampton Harbor estuary and adjacent coastal waters on December 30, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

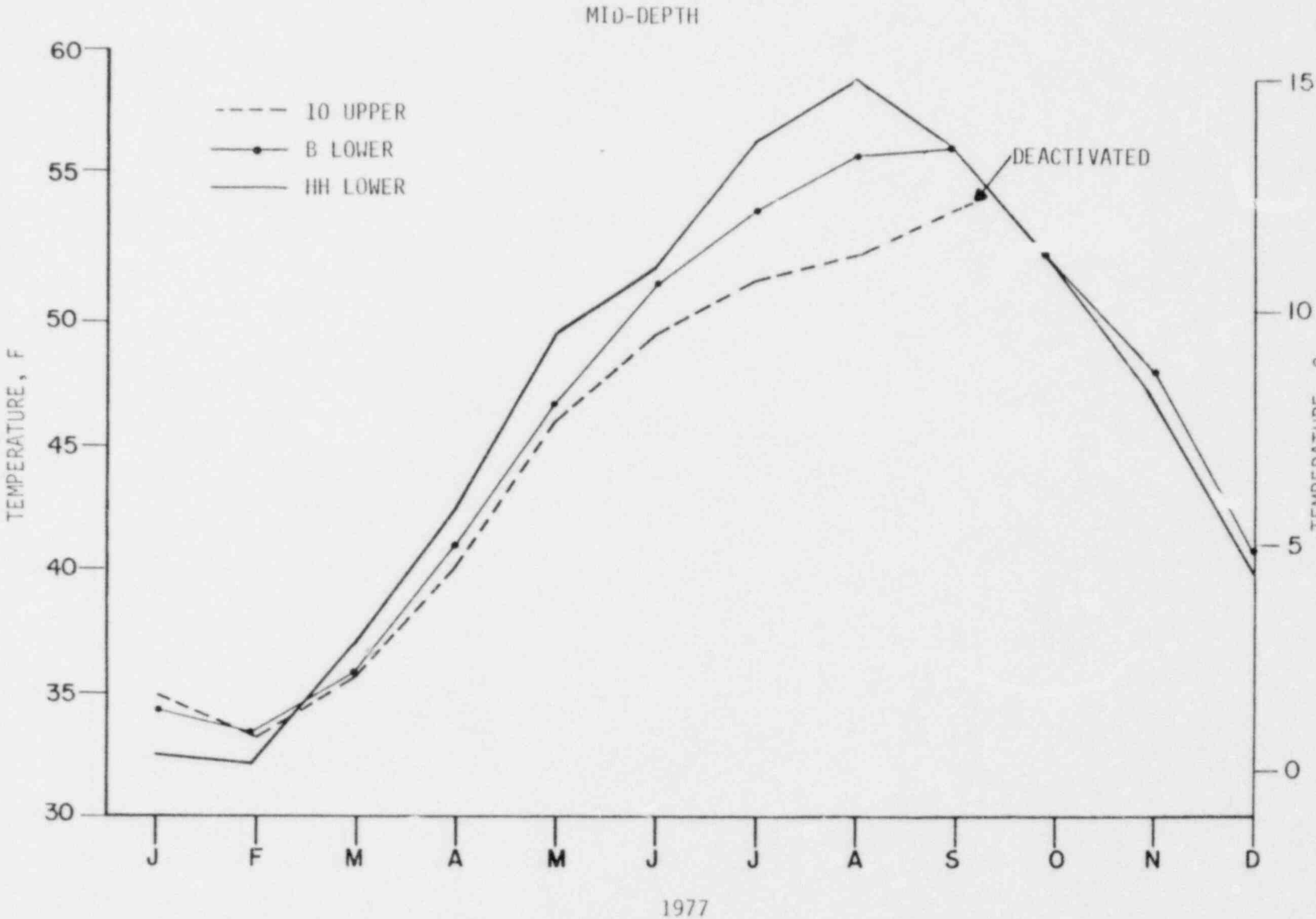

Figure 3.2-15. Monthly mean mid-depth water temperature for selected moorings off Hampton Beach, New Hampshire, during 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

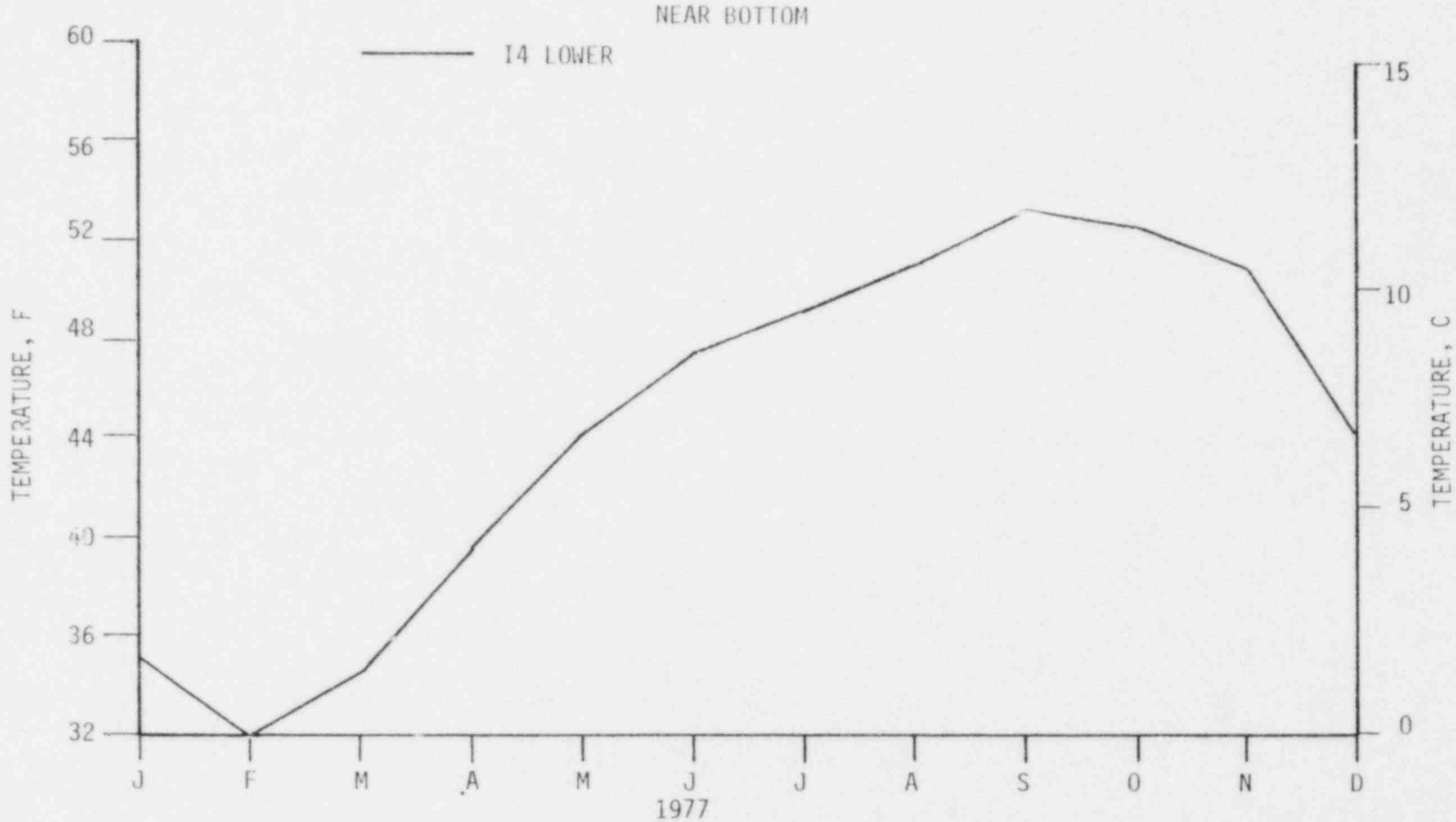

Figure 3.2-16. Monthly mean near-bottom water temperature from Mooring I-4 lower off Hampton Beach, New Hampshire, during 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

from November 9, 1973 through September 14, 1977 (Figure 7.4-1) show that lowest temperatures occur in February, but February 1977 was much colder than average. August was the warmest month. Data from Moorings I-4 upper and T-7 showed very similar patterns (Figure 7.4-4 and 7.4-6).

Mooring B upper which was closer to shore and subject to greater estuarine influence showed similar wintertime temperatures but warmer temperatures in September th[illegible]e offshore locations (Figure 7.4-7). Mooring B lower showed little vertical variation during the winter, but was about 2 to 4 F (1.1 to 2.2 C) colder in summer (Figure 7.4-8).

Mooring HH upper had the warmest temperatures of all during the summer and coldest during the winter (Figure 7.4-9). Near bottom temperatures (Mooring HH lower) were about the same as near surface in the winter but slightly colder by 1 to 2 F (0.6 to 1.1 C) in the summer (Figure 7.4-10).

3.3 RUNOFF AND SALINITY

3.3.1 Precipitation and Runoff

Precipitation (rain or snow) and subsequent runoff or discharge into local rivers and estuaries greatly affect salinities of coastal waters in the western Gulf of Maine (Graham, 1970b and NAI, 1979). For the region from Cape Ann, Massachusetts northward to Cape Elizabeth, Maine, about 90 percent of the drainage basin is comprised of the Merrimack River, Piscataqua River and Saco River systems. Mean monthly discharge data from the most downstream U.S. Geological Survey gauging stations on each basin were compiled to determine approximate runoff into the coastal waters for 1977 (Figure 3.3-1). These data show a close relationship to NAI's mean near-surface and mean near-bottom

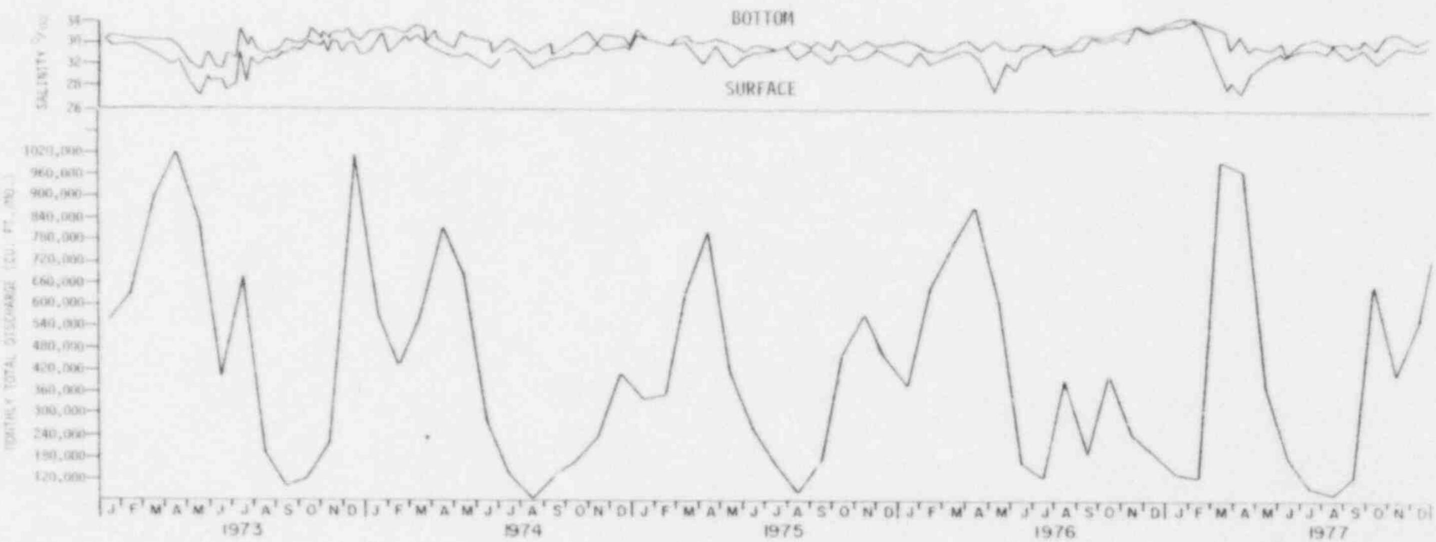

Figure 3.3-1. Plots of mean near-surface and near-bottom salinities from hydrographic surveys of coastal waters off Hampton Beach, New Hampshire, and mean monthly discharge from the Merrimack, Piscataqua and Saco Rivers combined for 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

salinities* observed during each hydrographic cruise over the same period.

During 1977 peak discharge, which occurred in March and April caused a dramatic lowering of salinities with near surface values down to 27.2 °/oo and near bottom values down to 31.3 °/oo. The freshening appeared to lag about 2 weeks behind the peak runoff (Figure 3.3-1). Highest salinities occurred in January and February (33.5 to 34.4 °/oo). From June through December, salinities remained fairly consistent when near surface averaged about 31.5 °/oo and near bottom about 32.5 °/oo.

3.3.2 Salinity

3.3.2.1 Temporal Variations

Near surface and near bottom measurements made at Mooring 12 during 1977 for both high and low water show a gradual rise through the year (Figure 3.3-2). The winter and spring data showed considerable variability. From June through December, salinities became less variable and rose from around 31.0 °/oo up to about 32.0 °/oo. Lowest mean near surface values were about 28.0 °/oo in late March. Near bottom salinities were slightly higher and much less variable. In general, lowest salinities were observed at low water, reflecting the influence from estuary discharge.

Mean monthly salinity profiles from high-water slack for all of the offshore stations during 1977 are shown in Figure 3.3-3. In January with a mean salinity of around 33.5 °/oo was observed. During March surface salinities dropped to 28.9 °/oo, as a pronounced halocline resulted from spring run-off into the western Gulf of Maine. During the summer months, salinities increased again and the halocline was less evident. In September, October and November, increased runoff reestablished

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*Mean of all available data from each given day including both high water and low water measurements from slack-water surveys.

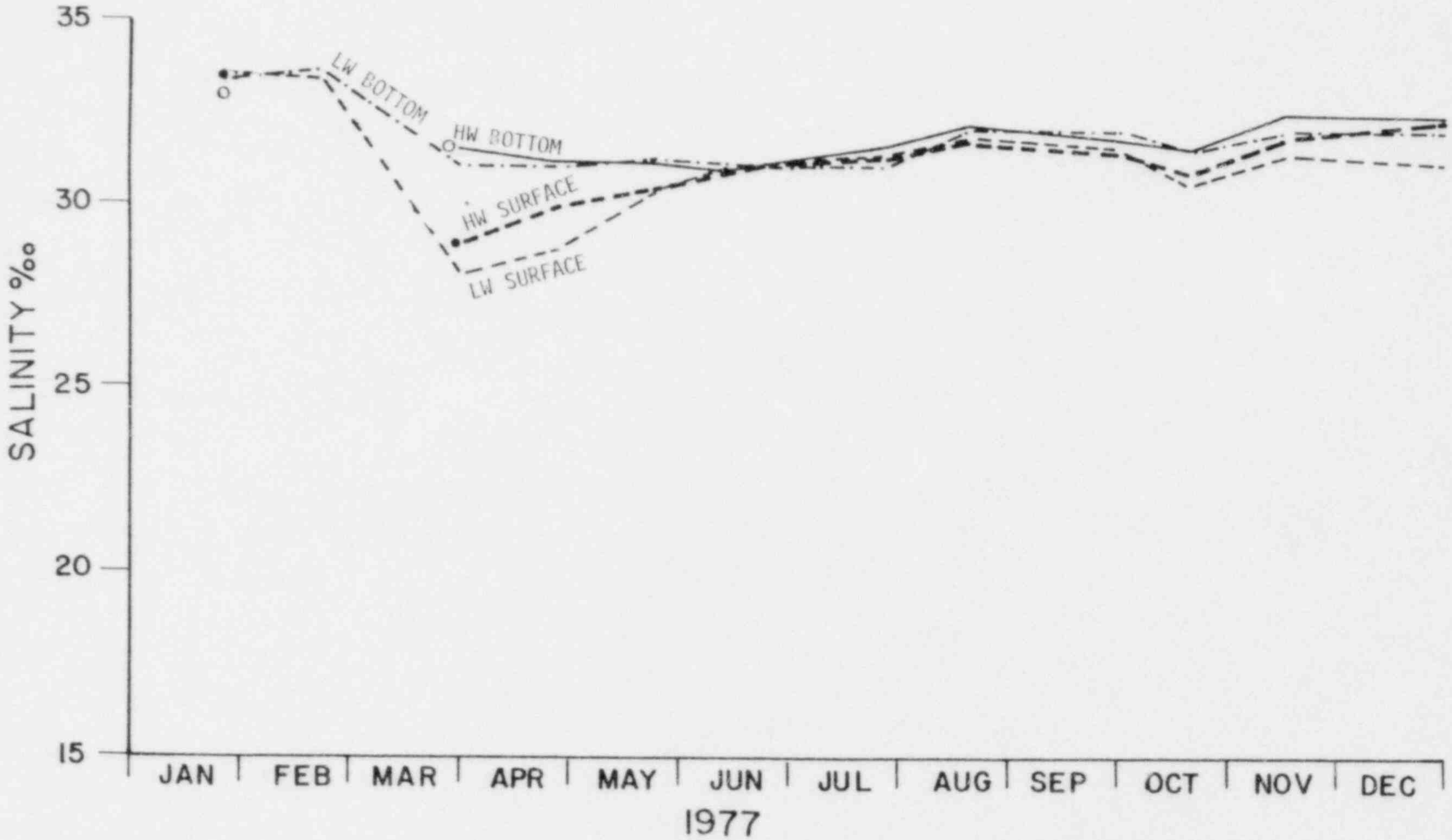

Figure 3.3-2. Monthly salinity observations (^{o}/oo) at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1977 slack-water surveys (both low water, LW and high water, HW). (No high water data in February due to weather problems). Seabrook 1977 Annual Hydrographic Report, 1979.

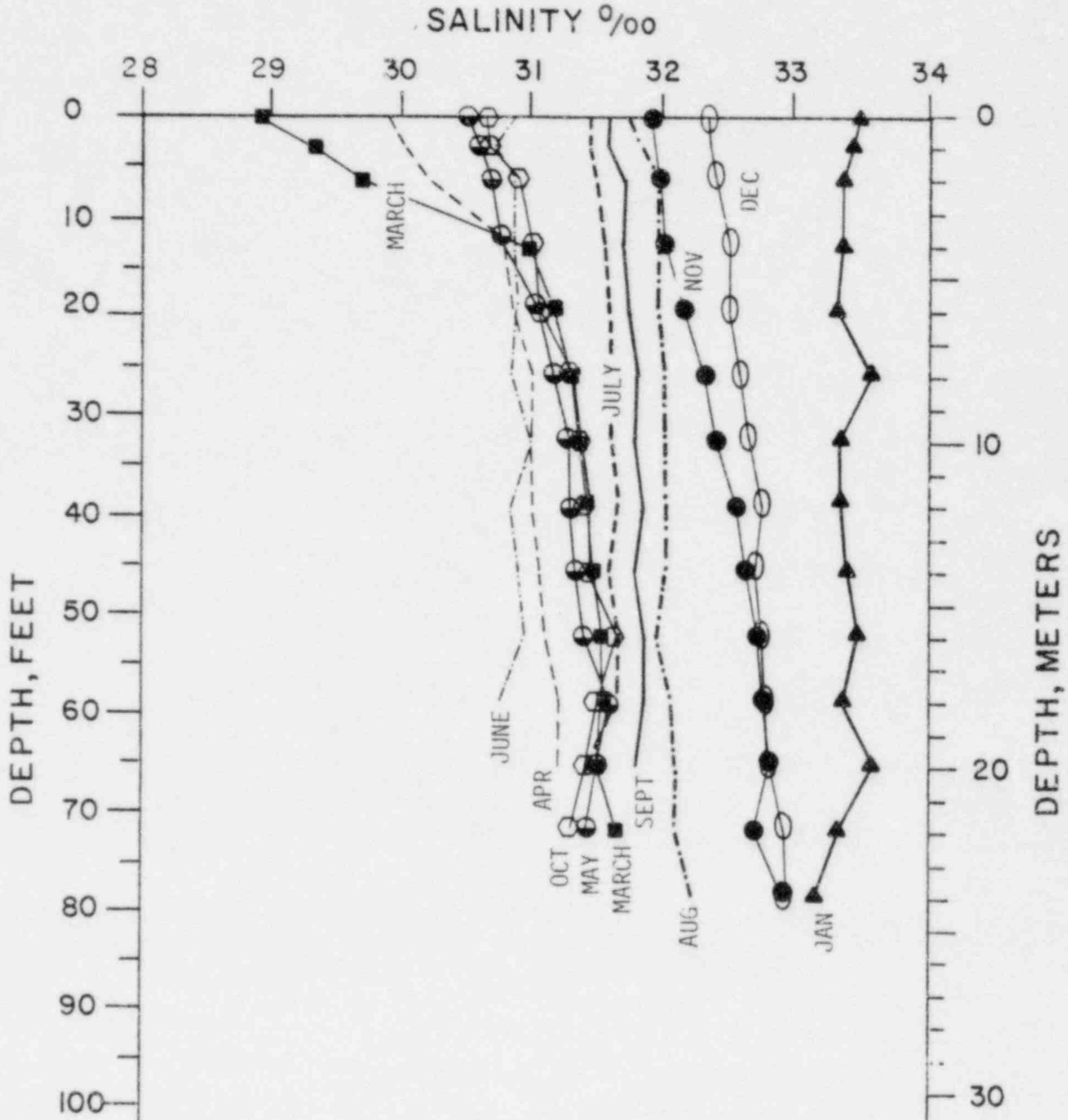

Figure 3.3-3. Mean salinity profiles taken at high-water slack from coastal waters off Hampton Beach, New Hampshire, during 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

a slight halocline, showing surface-to-bottom variations of up to 0.5 °/oo (Figure 3.3-3). In the late fall, the onset of more intense winter storms (in the absence of the seasonal thermocline and decreased runoff) brought increased vertical mixing and return to the more uniform conditions of December (which averaged 32.7 °/oo.

3.3.2.2 Spatial Variations

Near-surface salinity measurements obtained from slack-water surveys and plankton cruises further document the dynamic nature of these waters Salinity data from the slack-water surveys emphasize the variability between tidal cycles, whereas the plankton cruise data highlight the variability along the coast from Rye Harbor southward to the Merrimack River.

Selected surveys from 1977 illustrate the variability of near-surface waters over a typical year. The early spring plankton cruise of April 13, 1977 (Figure 3.3-4) showed the regional effect from the Merrimack River (17.1 °/oo near the mouth). Some freshened water was apparently transported northward but conditions off Hampton Beach were quite uniform (30.5 to 30.8°/oo). Similarly the slack-water survey of April 27, 1977 shows a dramatic lowering of ebb-tidal salinities (down to 18.9 °/oo) and discharge of freshened water offshore (Figure 3.3-5). By mid summer salinities increase again and show little tidal variation (Figure 3.3-6). A rainy period in early September sharply reduced estuarine salinities again off the mouth of the Merrimack (down to 27.4 °/oo; Figure 3.3-7). The slack-water survey of December 30, 1977 showed reduced salinities from the December 15, 1977 plankton cruise (Figure 3.3-8) in the estuary resulting from local runoff (Figure 3.3-9).

The slack water surveys documented salinity variations of as much as 10.8 °/oo at one station within the estuary over a single tidal cycle (April 27, 1977); more typical variations were 2.0 to 4.0 °/oo between tidal cycles. Monthly plankton cruise data showed lowest salinities were generally in Hampton Harbor or off the mouth of the Merrimack River estuary (down to 17.1 °/oo on April 13, 1977).

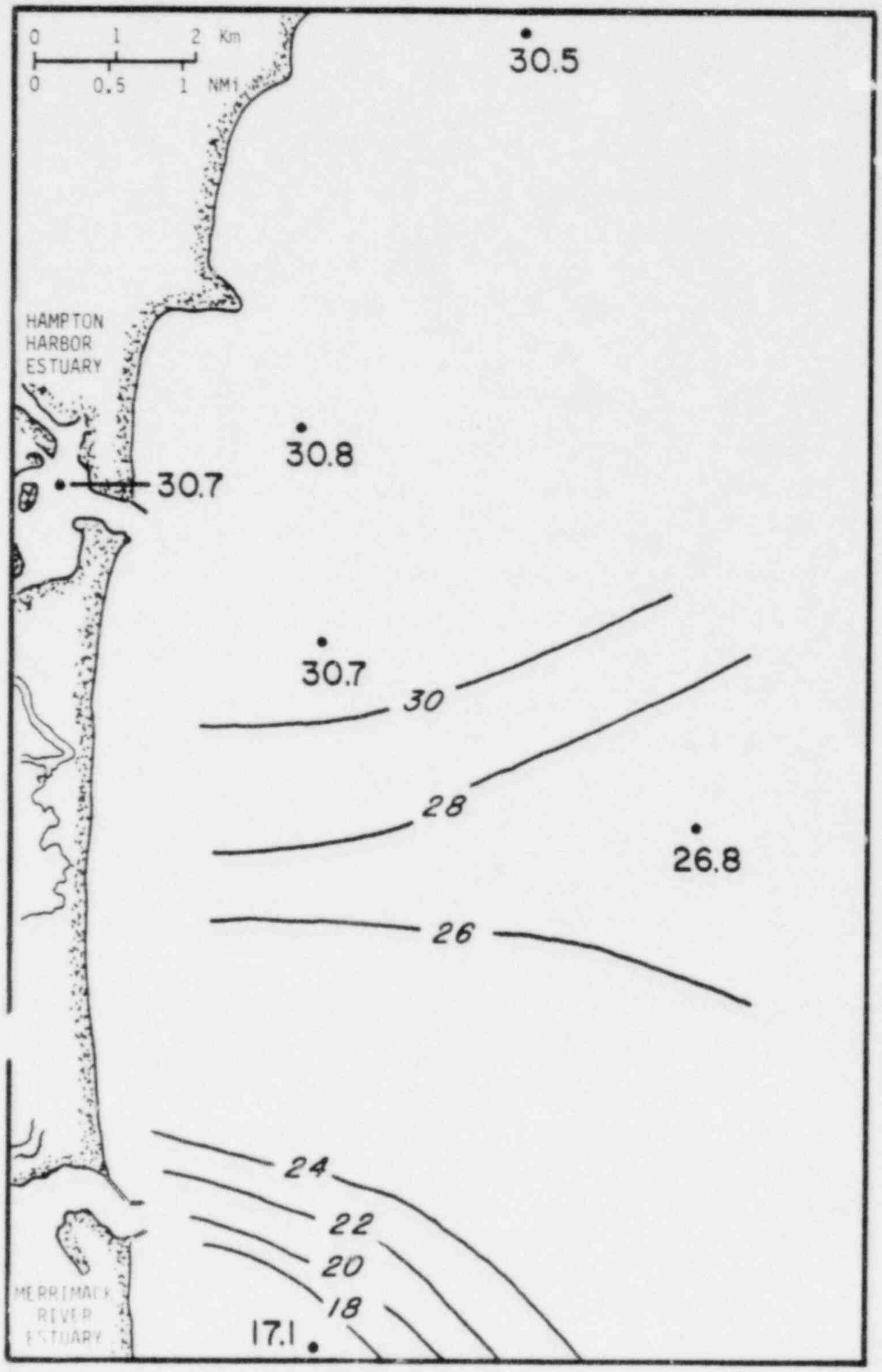

Figure 3.3-4. Surface salinity (°/oo) in Hampton Harbor estuary and adjacent coastal waters on April 13, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

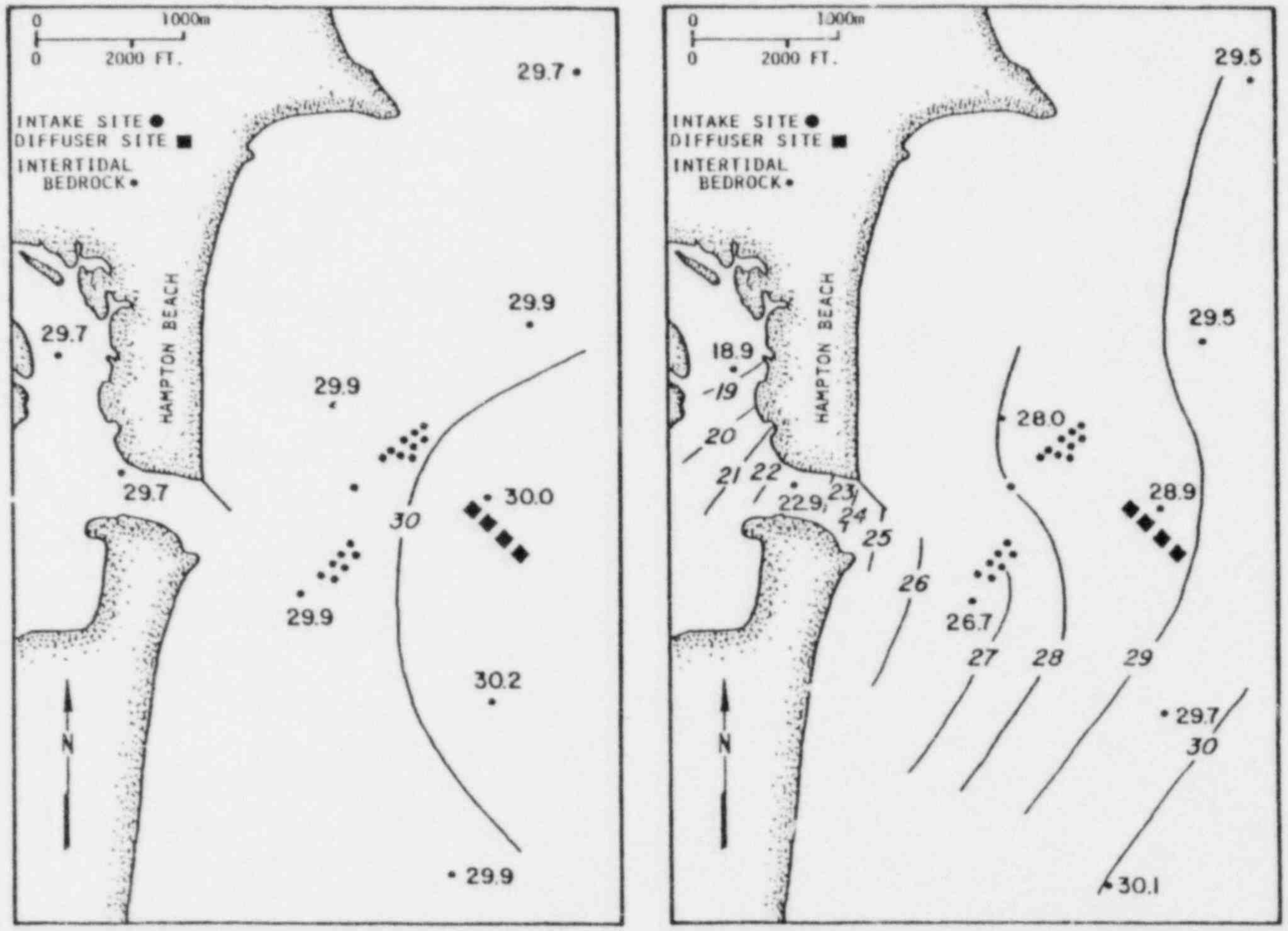

Figure 3.3-5. Surface salinities ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on April 27, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

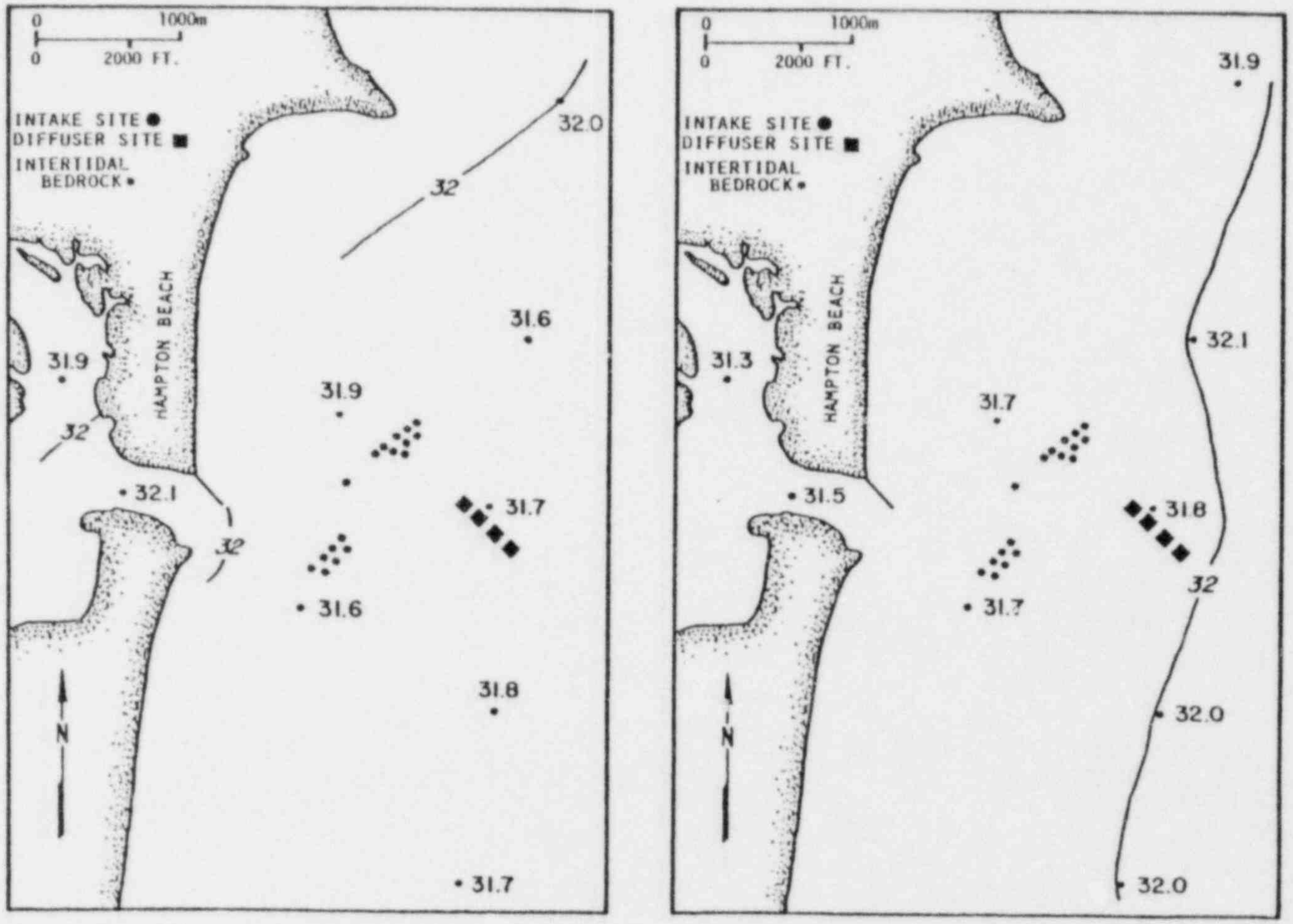

Figure 3.3-6. Surface salinities ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on August 19, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

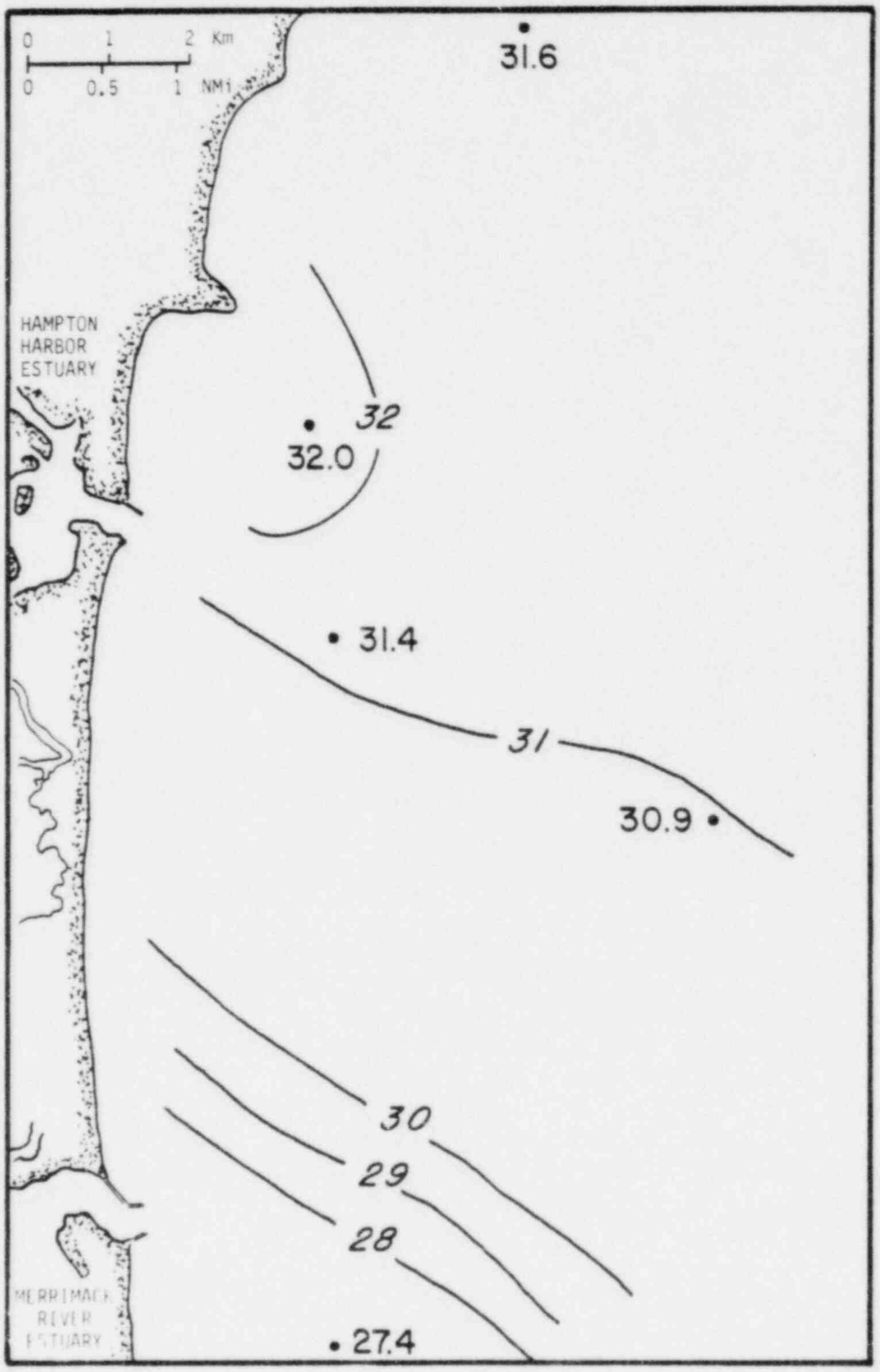

Figure 3.3-7. Surface salinity ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on September 7, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

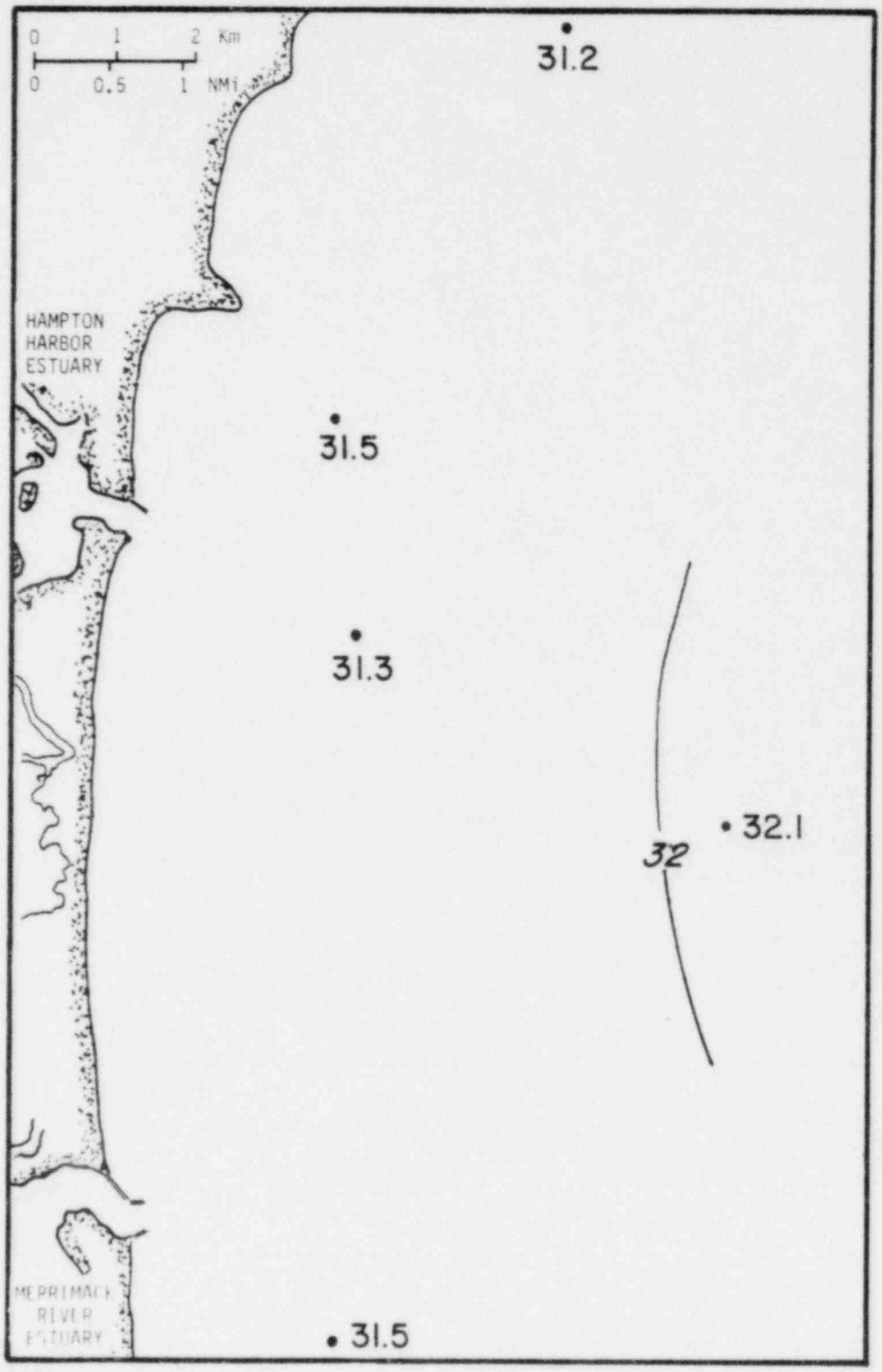

Figure 3.3-8. Surface salinity ($^{o}/oo$) in Hampton Harbor estuary and adjacent coastal waters on December 15, 1977 from plankton cruise measurements. Seabrook 1977 Annual Hydrographic Report, 1979.

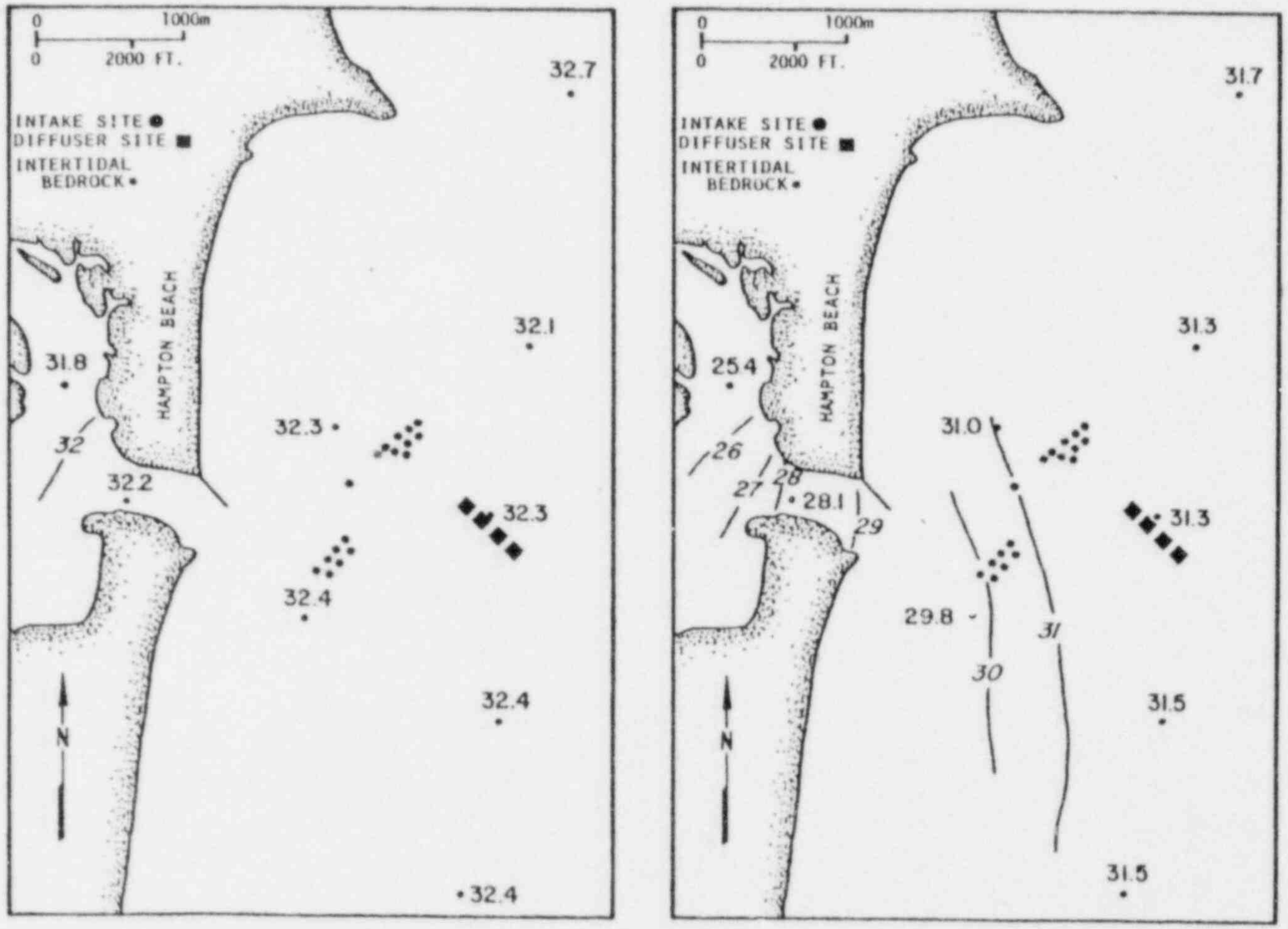

Figure 3.3-9. Surface salinities ($^{0}/oo$) in Hampton Harbor estuary and adjacent coastal waters on December 30, 1977, from slack-water survey at high water (left) and low water (right). Seabrook 1977 Annual Hydrographic Report, 1979.

3.3.3 Density

Density or sigma-t measurements from slackwater surveys and plankton cruises provide additional framework for the data discussed in preceding sections. Measurements made at Mooring 12 during 1977 for near surface and near bottom at high water and at low water are presented in Figure 3.3-10. Near-surface waters showed considerable variability, ranging from 22.1 in late March to 26.9 in January. Near-bottom waters ranged from about 24.0 to 27.0; they followed a trend similar to the near-surface waters. Both showed a gradual rise from June, through December.

3.4 DISSOLVED OXYGEN

The monthly slack water surveys and plankton cruises have documented dissolved oxygen conditions in coastal waters. Measurements made at Mooring 12 during 1977 for near surface and near bottom at both high and low water are presented in Figure 3.4-1. Highest values were observed during the late winter and early spring (about 10.5 to 11.3 mg/l), whereas lowest values occurred during the late summer (down to 7.8 mg/l in September). No consistent relationship was observed between tidal stage or water depth. During the winter and spring, it was essentially homogeneous horizontally with vertical gradient. Near-surface waters had higher concentrations than near bottom during the summer.

The percent saturation of dissolved oxygen for Mooring 12 over the same time period is summarized in Figure 3.4-2. During the winter and spring, concentrations gradually rose from about 95 percent to around 110 percent. In the summer near-surface waters were highly supersaturated (up to 115 percent), whereas near-bottom waters were generally below saturation (down to 90 percent). Lowest saturations occurred in the fall and winter (mean of about 95 percent). No consistent variation between tidal stage was observed. Saturation levels were consistently lower at depth except in the winter when surface and bottom values were similar

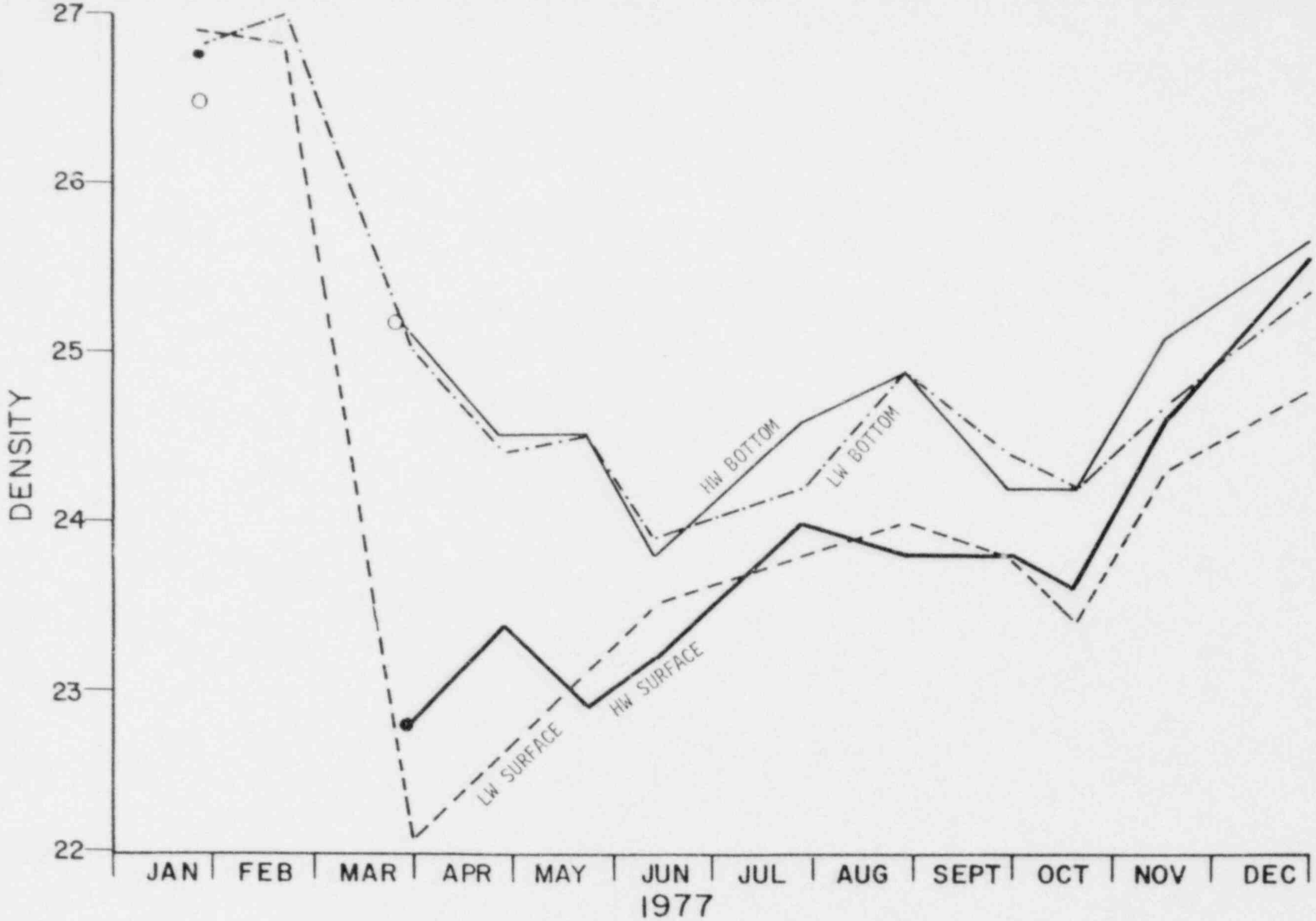

Figure 3.3-10. Monthly density of sigma-t observations at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1977 slack-water surveys (both low water, LW and high water, HW). (No high water data in February due to weather problems). Seabrook 1977 Annual Hydrographic Report, 1979.

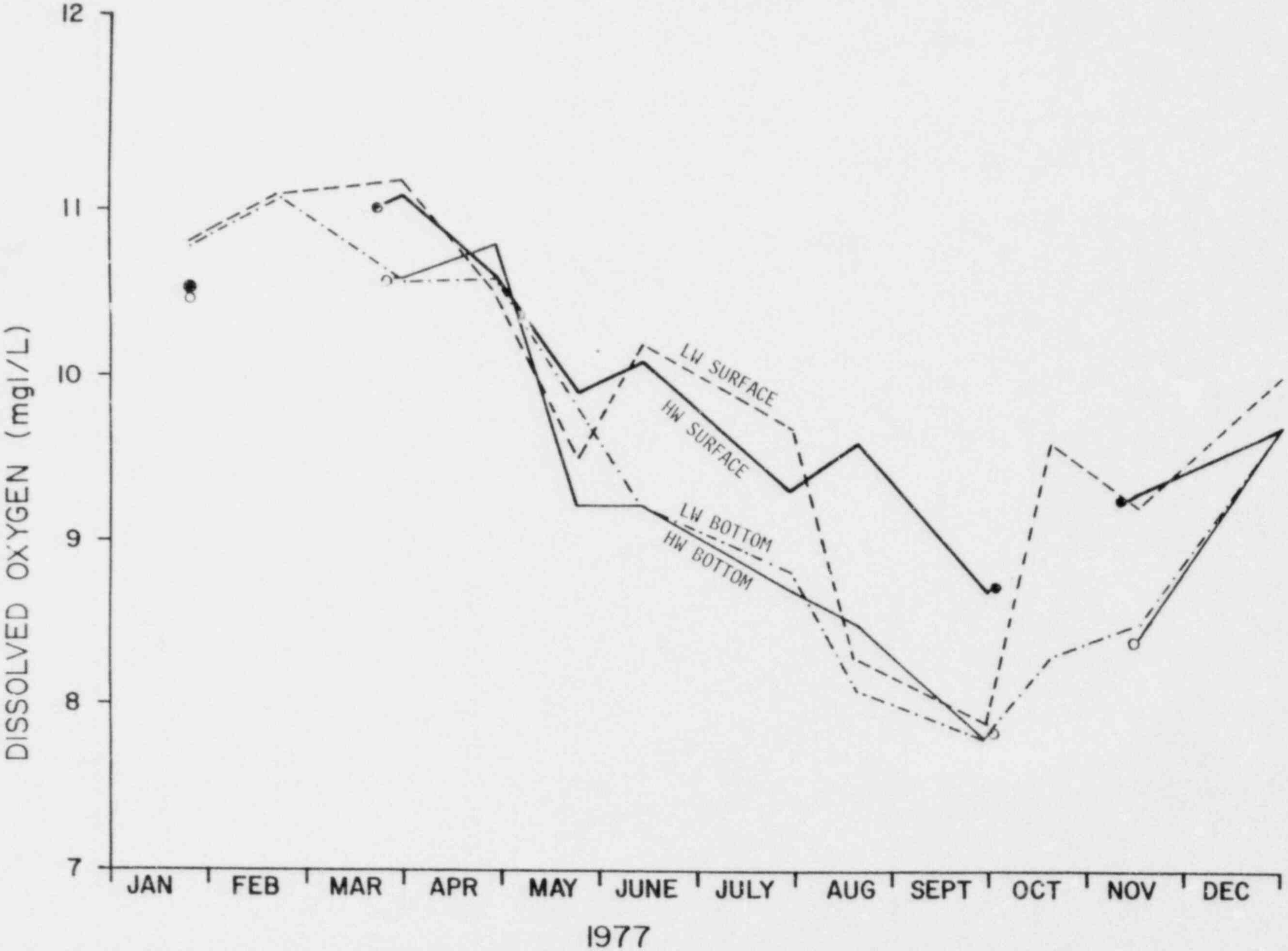

Figure 3.4-1. Monthly dissolved oxygen observations (mg/l) at the diffuser site (Mooring 12) for near-surface and near-bottom waters from 1976 slack water surveys (both low water LW and high water HW). Seabrook 1977 Annual Hydrographic Report, 1979.

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4.0 DISCUSSION

4.1 TEMPORAL VARIATIONS IN WATER MASS DYNAMICS

The coastal waters off Hampton Beach and in the western Gulf of Maine, out to at least 9 n mi (17 km) offshore, undergo an annual cycle which is representative of the natural variability of temperate coastal seas, caused by factors such as: tides, winds, solar radiation, waves, storms, regional circulation patterns, rainfall, evaporation, and estuarine exchange. The Gulf of Maine waters can be grouped into four water masses: surface (MSW), intermediate (MIW), bottom (MBW) and Georges Bank (GBW), based on Hopkins and Garfield (1978). The Seabrook study area is primarily within the MSW mass (NAI, 1979).

In the portion of the MSW which NAI has been studying, the freshwater input is either mixed with salt water in estuaries before it reaches the Gulf of Maine proper or falls as rain across the Gulf. The salinity of the estuarine input varies considerably, depending primarily upon the size of the drainage basin. The largest source of freshwater runoff in this portion of the western Gulf of Maine is the Merrimack River (Manohar-Maharaj and Beardsley, 1973). Other sources include the Great Bay System (including the Piscataqua River), the Hampton Harbor estuary, Parker River estuary and Essex River estuary. These estuaries typically release freshened waters, causing a well-defined coastal halocline during much of the year. As these waters are transported offshore, they become diluted with higher salinity waters

Seasonal variations in nearshore water temperatures are primarily the result of air-sea heat transfer and circulation patterns. The circulation affects temperature by: (1) lateral displacement of water masses and (2) vertical motion such as upwelling or turbulent mixing by storms and waves (Sverdrup *et al.*, 1942 and Smith, 1973).

This annual cycle is primarily manifested in the ambient variations in temperature and salinity which may be used to subdivide MSW into six distinct water masses over the course of the year. This cycle, documented by the NAI hydrographic data from 1972 through 1975, consists of the following: December Water Mass, Winter Water Mass, Spring Transitional Water Mass, Summer Surface Water Mass, Bottom Water Mass, and Fall Transitional Water Mass (Figure 4.1-1). Over the year each of the primary hydrographic and meteorological factors vary in a cyclical manner (Table 4.1-1).

4.1.1 Winter

During January, February and March, storms are frequent with strong winds and coastal currents. Air and water temperatures drop down to minimal levels and runoff is generally low. Surface temperatures are sometimes colder than near bottom. Salinity, density and dissolved oxygen are all quite high. Because of strong vertical mixing, each parameter tends to be fairly homogeneous from surface to bottom.

4.1.2 Spring

During April and May, conditions begin a rapid series of changes. Storms become less frequent and winds weaken. Coastal currents show a strong southward drift as the counterclockwise Gulf of Maine gyre becomes well established. Air and water temperatures gradually rise and the seasonal thermocline begins to develop. Maximal annual runoff generally occurs, resulting in a sharp drop in near surface salinity with creation of a strong seasonal halocline and pycnoline. Dissolved oxygen concentrations drop but waters become supersaturated as temperatures increase and biological activity intensifies.

TABLE 4.1-1. SEASONAL CHARACTERISTICS AND VARIABILITY OF SELECTED OCEANOGRAPHIC AND METEOROLOGICAL PARAMETERS, WESTERN GULF OF MAINE. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

SEASON	WIND	AIR TEMPERATURE	PRECIPITATION AND RUNOFF	STORMS	CURRENTS	WATER TEMPERATURE	SALINITY	DENSITY	DISSOLVED OXYGEN
Winter (January, February, and March)	Strong winds; predominant from the west (about 42 percent), northwest (about 18 percent), and southwest (about 13 percent); strong winds also from northwest and east.	Minimum values occur. January or February generally the coldest month; typical monthly average temperatures = January 23F (-5C) February are 24F (-5 C), March 32F (0 C).	Monthly average precipitation is 3.4 to 4.2 in; runoff generally low unless weather is warm; typical regional monthly total discharge about 442,000 ft^3/mo.	Very common; occur every 1 to 2 weeks in conjunction with passing low pressure systems; northeasters are most severe.	Generally strong, storm domination; flows southward about 40 percent of the time (in association with northeasters); northward about 29 percent; tidal dominated about 32%.	Minimum values occur; February generally the coldest month; water column generally isothermal; surface sometimes slightly colder than near bottom; typical values for both near surface and near bottom is 36.0 to 41.5 F (2.2 to 5.3 C).	Generally increase in salinity; typical near-surface values are 31.1 to 32.7 ‰; near-bottom are 32.0 to 33.5 ‰.	Generally isopycnal typical value is 24 to 26 sigma t units	Very high; typical value is 10.0 to 115 mg/l; generally 90 to 100 percent saturated.
Spring (April and May)	Weaker winds; prodominantly from the northwest and west (both about 24 percent); strongest winds from northeast.	Gradually increase; typical monthly average temperature is 43 F (6.1 C) in April; 54 F (12.2 C) in May.	Monthly average precipitation is 2.8 to 3.6 in; maximum annual runoff generally occurs; typical regional monthly total discharge about 622,000 ft^3/mo. maximum observed during study period is 1,022,230 ft^3/mo. (April 1973).	Less common and less intense than winter.	Southward flows fairly strong (about 36 percent as Gulf of Maine Gyre becomes well established; flows northward about 22 percent; tidal about 42 percent.	Rapid near surface warming leading to development of seasonal thermocline; typical near surface values = 39 to 51 F (3.9 to 10.6 C); near bottom = 39 to 43 F (3.9 to 6.1 C).	Regional runoff creates strong seasonal halocline; typical near surface values = 27.7 to 31.0 ‰; near bottom = 29.9 to 32.2 ‰	Salinity stratification creates distinct seasonal pycnocline; typical near surface values = 23 to 25; near bottom = 24.5 to 26	High then drop sharply; typical values begin at 10.0 to 11.0 mg/l; decrease to 9.0 to 10.0 mg/l; generally saturated to slightly supersaturated (about 90 to 115 percent).

TABLE 4.1-1. (Continued)

SEASON	WIND	AIR TEMPERATURE	PRECIPITATION AND RUNOFF	STORMS	CURRENTS	WATER TEMPERATURE	SALINITY	DENSITY	DISSOLVED OXYGEN
Summer (June, July, and August	Typically weak; sea-land breezes are common; predominant winds from southwest and west (both about 22 percent).	Maximum values occur; July generally the warmest month; typical monthly average temperatures = June 63F (17.2C) July 68F (20C) August 66F (18.9 C).	Monthly average precipitation = 2.7 to 3.4 in; minimum annual runoff generally occurs; typical regional monthly total discharge about 172,000 ft^3; minimum observed during study period = 70,954 ft^3 (August 1974).	Generally rare.	Generally fairly weak; minimal storm influence; shearing common between warm near-surface wind driven layer and cold near-bottom layer; flows tidal dominated (about 58 percent); southward about 29 percent; northward about 13 percent.	Maximum values occur; August generally the warmest month; strong seasonal thermocline present; typical near surface values = 53 to 69F (11.7 to 20.6C); near bottom = 44 to 53 F (6.7 to 11.7C).	Stratification weakens and return to more isohaline conditions; typical near surface values = 28.0 to 32.0 °/oo; near bottom = 31.0 to 32.2 °/oo.	Seasonal thermocline creates distinct vertical pycnoline; typical near surface values = 23 to 24; near bottom = 24.5 to 26.	Near surface values generally 1.0 mg/l higher than near bottom; typical range = 8 to 10 mg/l; near surface supersaturated (100 to 120 percent); near bottom saturated (80 to 100 percent).
Autumn (September and October	Generally become stronger; perdominantly from west and southwest (both about 20 percent); occasionally strong northwest winds.	Gradually decrease, typical monthly average temperatures = September 58F (14.4C), October 49F (9.4 C).	Monthly average precipitation = 3.8-4.1 in; typical regional monthly total discharge abou 324,500 ft^3.	Frequency of northeasters gradually increases; hurricane potential exists.	Generally weak; increasing storm influence and vertical mixing; flows about 39 percent northward; about 21 percent southward.	Rapid cooling; seasonal thermocline broken down by autumn storms; water column becomes isothermal; typical near surface values = 51 to 64F (10.6 to 17.8C); near bottom = 46 to 51 F (7.8 to 10.6C).	Regional runoff creates seasonal stratification; typical near surface values = 30.7 to 31.5 °/oo; near bottom = 31.5 to 32.5 °/oo.	Salinity stratification creates distinct pycnocline; typical near surface values = 21 to 24; near bottom = 23.5 to 25.	Generally lowest values of the year; about 7 to 9 mg/l; generally saturated (80 to 100 percent).

TABLE 4.1-1. (Continued)

SEASON	WIND	AIR TEMPERATURE	PRECIPITATION AND RUNOFF	STORMS	CURRENTS	WATER TEMPERATURE	SALINITY	DENSITY	DISSOLVED OXYGEN
Early Winter (November and December)	Stronger winds; predominantly from west and southwest (both about 20 percent); strong northeast winds are common.	Continue to decrease; December often very cold; typical monthly average temperatures = November 39F 3.9C), December 25F(-3.9C).	Monthly average precipitation = 3.5 to 4.6 in; typical regional monthly total discharge about 518, 500 ft^3/mo.	Increasing frequency and intensity of northeasters and major storms.	Become stronger as storms become more intense; typical flows are northward; about 48 percent; southward about 25 percent; tidal about 27 percent.	Tendency toward isothermal conditions; typical near surface values = 41 to 51 F (5.0 to 10.6C); near bottom = 43 to 48 (6.1 to 8.9C).	Generally vertically homogeneous; typical near surface values [illegible] 30.9 to 32.0 °/oo near bottom = 32.0 to 33.0 °/oo.	Generally verti[illegible]ly homog[illegible]eous; typical values [illegible] 24 to 25.	Values rise sharply; typically 7.5 to 10 mg/l[illegible] generally slightly unsaturated (9.0 to 100 percent[illegible].

4.1.3 Summer

During June, July and August storms are rare and winds light and variable. Air and water temperatures attain maximum values with a strong seasonal thermocline, whereas precipitation and runoff are typically at minimal levels. Tidal currents are usually predominant, but shearing between the warm near surface layer and the cold near bottom layer is often pronounced. Salinities are typically isohaline because of the weak runoff, but a strong density pynocline is evident. Dissolved oxygen levels are moderate with supersaturation near the surface and undersaturation near the bottom.

4.1.4 Autumn

During September and October storms occur more frequently and hydrographic conditions change dramatically. Stronger winds and currents increase the vertical mixing and the seasonal thermocline rapidly breaks down, often within a week or less. Air and water temperature start dropping. With increased precipitation, a second seasonal halocline and pycnoline is created, but it is not as pronounced as the spring one (Figure 4.1-1). Dissolved oxygen values drop down to lowest of the year.

4.1.5 Early Winter

During November and December winds and storms become more intense. Air temperature continues to drop and coastal waters become isohaline, forming the December Water Mass (Figure 4.1-1). Currents become wind and storm dominated. With the weak regional runoff, vertical salinities and densities become homogeneous. Dissolved oxygen levels begin to rise sharply and the seasonal cycle is completed.

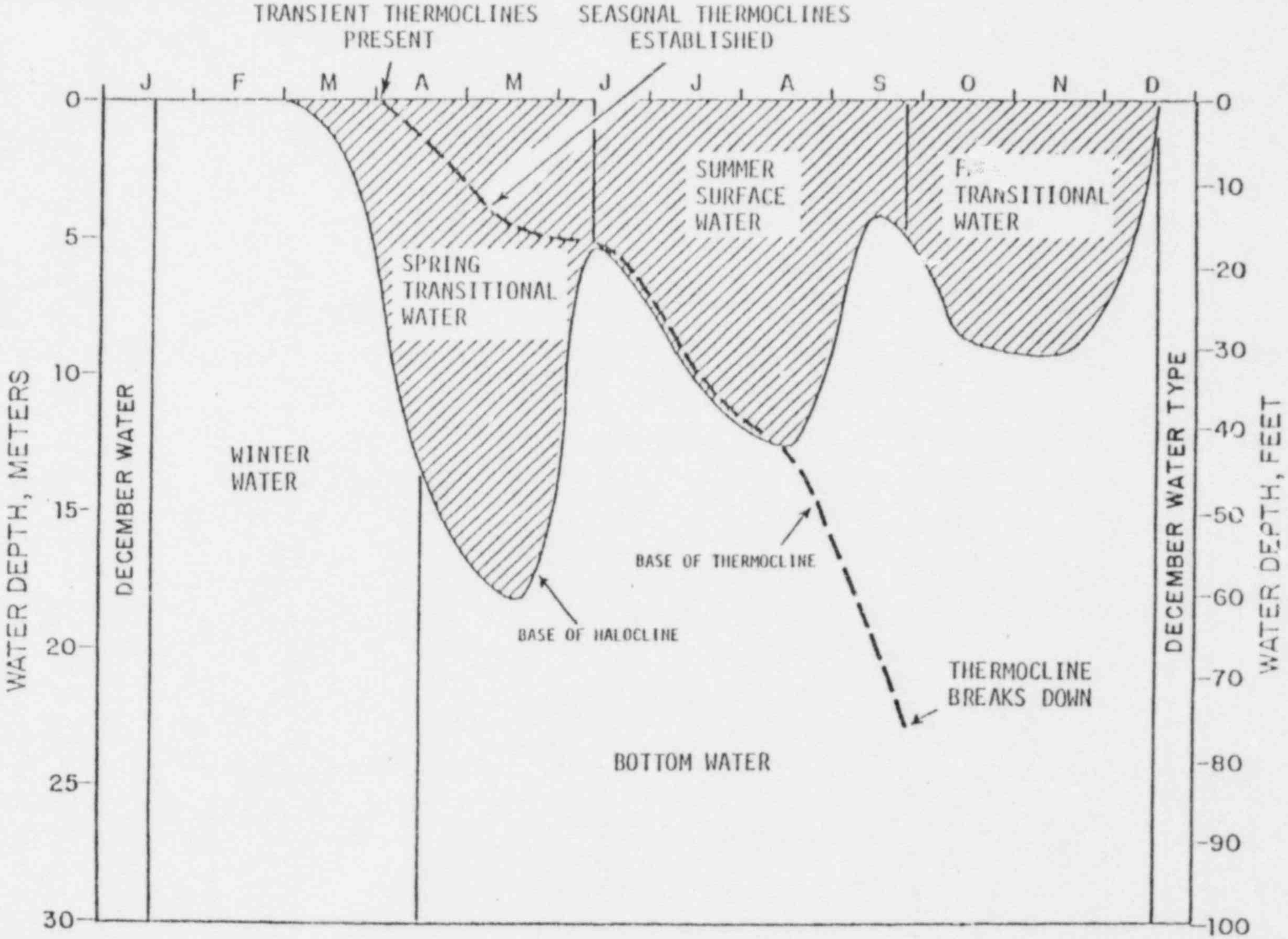

Figure 4.1-1. Annual cycle of water mass based on temperature and salinity variations in waters off the New Hampshire coast and in the western Gulf of Maine. Seabrook 1977 Annual Hydrographic Report, 1979.

4.2 SPATIAL VARIATIONS

4.2.1 Storm Conditions

Winds have a major influence in near-surface water mass transport, especially in areas close to shore. When prevailing winds move near-surface waters away from the coast, subsurface waters move upward to replace them, a process called "upwelling", which is responsible for bringing nutrients into the more productive nearshore areas. Upwelling has been documented in the western Gulf of Maine by Hartwell (1975 and 1976), Kangas and Rufford (1974), Graham (1970a) and Longard and Banks, (1952). Conversely, when winds are onshore, the opposite process of "downwelling", or plunging of coastal waters seaward along the bottom, can occur (NAI, 1975a). Strongest wind effects always accompany northeast storms. During these storms, near-surface waters often flow southward at speeds of 1.0 kn (51.5 cm/sec) or more.

Based on the NAI current-meter data and results of concurrent drifter releases (NAI, 1975a and 1975b), it appears that storms and associated winds play a key role in the large scale water mass displacement of the western Gulf of Maine and appear to help drive the general counterclockwise circulation of the Gulf of Maine gyre, as described by the work of Bumpus (1973), Graham (1970a), Bumpus and Lauzier (1965), Day (1958), and Bigelow (1927). In general, low pressure systems moving across the region cause the stormiest conditions ard the most significant wind stress effects in nearshore waters (Beardsley and Butman, 1974). Lows which come up along the coast and pass northeastward over Georges Bank ("northeasters") cause southward flows; inland lows which move down the St. Lawrence River valley cause northward flows.

Under the influence of the first type of meteorological forcing function (winds from the north and northeast), southward flows are manifested by southward current vectors which show a sustained steady-state flow along the coast. Such flow essentially masks out the weaker tidal currents, frequently persisting for days at a time.

Moderate southward flows (about 0.2 to 0.3 kn or 10.3 to 15.4 cm/sec are generally stronger than typical mean tidal current speeds. A 24-hr sequential-vector plot from September 22, 1977 illustrates this type of flow (Figure 3.1-2). Strong southward flows (greater than about 0.3 kn or 15.4 cm/sec) are faster than typical mean tidal current speeds. Such flows average 0.4 to 0.6 kn or 20.5 to 30.9 cm/sec and may occasionally exceed 1.0 kn (51.5 cm/sec). A 24-hr sequential-vector plot from March 15, 1977 illustrates this type of flow (Figure 3.1-2).

Under the influence of the second type of meteorological forcing function (winds from the south and southwest), northward flows are manifested by northward current vectors which show a sustained steady-state flow along the coast. Such flow essentially masks out the weaker tidal currents, frequently persisting for days at a time.

Moderate northward flows (about 0.2 kn to 0.3 kn or 15.4 cm/sec) are generally stronger than typical mean tidal current speeds. A 24-hr sequential vector plot from January 20, 1977 illustrates this type of flow (Figure 3.1-2). Strong northward flows (greater than about 0.3 kn or 15.4 cm/sec) are faster than typical mean tidal current speeds. Such flows average 0.3 to 0.5 kn or 15.4 to 25.7 cm/sec and may occasionally exceed 1.0 kn (51.5 cm/sec). A 24-hr sequential vector plot from October 9, 1977 illustrates this type of flow (Figure 2.1-2).

In terms of actual current directions, it should be noted that the "flow toward the south" and the "flow toward the north" categories are essentially the same as the ebb or flood portions, respectively, of a reversing tidal flow. The only difference is that they have persisted as a steady-state condition for a longer period.

There was no indication that any of the 1977 storms set any U.S. Weather Bureau records. Storm intensity and frequency were similar to observations of previous years. Other studies in the western Gulf of Maine (for example, NAI, 1974 in Casco Bay, Maine; Cox, 1975 in Massachusetts Bay; Kangas and Hufford, 1974 in Massachusetts Bay; and EG&G, 1976

off Salisbury Beach and Plymouth, Massachusetts) have also showed that periodic storm events drive coastal currents southward or northward along the coast, depending upon wind direction. Such events typically affect the entire coastal region from Cape Elizabeth to Cape Cod, resulting in major displacements of large volumes of water.

Since 1962 a number of major storms causing severe beach erosion have hit Massachusetts and New Hampshire (Figure 3.1-6). The most severe was February 19-20, 1972 (Richardson, 1977). According to Richardson's research, moderate damage was caused by storms of November 11-13, 1968; March 2-3, 1969; March 3-5, 1971; January 28-29, 1973; and March 17, 1976. Other erosion periods with lesser damage have been November 29-30, 1963; December 29, 1966; December 16 to 17, 1970; and February 24-25, 1977 (Figure 3.1-6).

4.2.2 Coastal Boundary Layer Dynamics

In analyzing current meter and hydrographic data obtained during more than 100 northeasterly storms since 1973, Hartwell (1976) developed a simple model for the typical pattern of coastal boundary layer dynamics, storm buildup, and dissipation. In the "storm phase", ambient temperatures and salinity often create a stratified condition comprising an upper layer and a lower layer in the offshore zone. Shallow waters along the coast, which are especially susceptible to wind shear effects, constitute the "nearshore" zone; waters further seaward are called the "offshore" zone (Figure 4.2-1). In the absence of storm or wind-driven currents, transient or tidal effects predominate.

In the "early storm phase", wind stress effects begin, waves start building up, mixing near shore is initiated, with upper momentum transfer from the upper to lower layer. The nearshore zone exhibits southward flow; whereas the offshore zone continues to show residual tidal effects (Figure 4.2-1).

In the "intense storm phase", the momentum transfer is both vertically (upper to lower layer) and horizontally (nearshore to offshore zones). Strong southward currents predominate (Figure 4.2-1).

Finally, with the "post storm phase", currents have shifted with potential for downwelling along the coast; however, residual longshore transport persists, especially in the offshore zone. This phase is characterized by minimal horizontal momentum transfer between the nearshore and offshore zones. The nearshore zone returns to tidal flows, whereas the residual storm-driven flows in the offshore zone may persist for several more days.

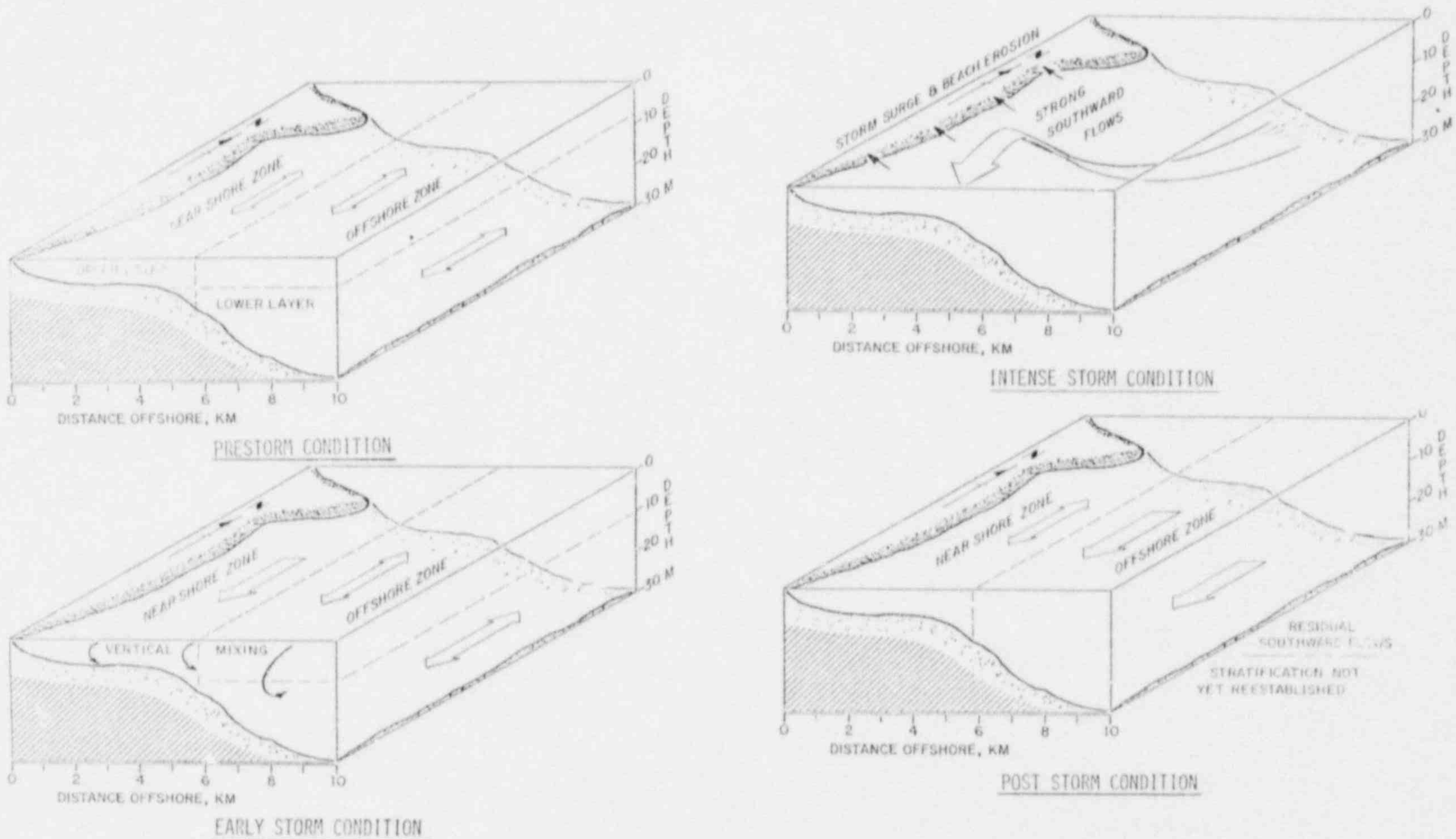

Figure 4.2-1. Diagram illustrating coastal boundary layer dynamics and the four phases of northeasterly storm buildup and dissipation in the western Gulf of Maine. Seabrook 1977 Annual Hydrographic Report, 1979.

5.0 SUMMARY

The results of the hydrographic studies off Hampton Beach, New Hampshire, from September 1972 through December 1977 can be summarized as follows:

5.1 CURRENTS

These coastal waters are very dynamic and some flow is always evident. Tidal flows are prevalent in the absence of wind. These flows occur either as flood- and ebb-tidal reversals (generally on a 6- to 7-hr basis) or as a variable, weak tidal flow with periodic shifts in speed and direction. Mean speeds average 0.1 to 0.2 kn (5.1 to 10.3 cm/sec). Such flows have comprised about 41 percent overall for the 5 years of study. Wind-driven currents can easily overpower tidal flows, causing either southward or northward currents which often persist for days at a time. Mean speeds average 0.3 to 0.6 kn (15.4 to 30.9 cm/sec), but can exceed 1.0 kn (51.5 cm/sec) during storms. For the 5-year study period such flows have comprised 30 percent and 29 percent overall for southward and northward, respectively.

5.2 WIND

Wind and associated storms which accompany passage of low-pressure systems play an important role in driving coastal water flows either southward or northward. Over the 5-year study period, predominant winds have been from the west. The next most common directions are northwest and southwest. Highest mean speeds have been from the northeast (9.6 kn or 4.9 m/sec).

Storms and associated winds play a key role in large scale water mass displacement in the western Gulf of Maine and help drive the general counterclockwise circulation of the Gulf of Maine gyre. In

general, low-pressure systems moving across the region cause the stormiest conditions and the most significant wind stress effects in nearshore waters. Typical northeaster storms show a pattern which has been divided into the following phases: prestorm, early storm, intense storm and post storm. Although January to April 1977 was the stormiest period, at least one northeaster occurred every month of the year.

5.3 TEMPERATURE

Water temperatures show pronounced daily, seasonal and annual variability. Coldest temperatures typically occur in February, lagging about 30 days behind the coldest air temperatures; the winter of 1977 was the coldest observed to date. During the spring months temperatures gradually rise and the seasonal thermocline becomes established. By midsummer the thermocline may be 30 to 40 ft (9 to 12 m) thick. Highest temperatures are generally reached during August. Temperature data show daily variations of 1 to 11 F (0.5 to 6 C) during the summertime and 1 to 7 F (0.5 to 4 C) during the wintertime.

5.4 SALINITY

Near-surface values always being less than those at depth, the mean salinity from about 33.0 $^{o}/oo$ in January decreased during the winter. From February through May, seasonal runoff lowered salinities sharply and a pronounced halocline formed. By early summer the halocline weakened and salinities started rising again. In September, October and November, increased runoff reestablished the halocline, showing vertical variations of at least 0.5 $^{o}/oo$. In the late fall intense storms and vertical mixing brought a return to isohaline conditions averaging 3.3 $^{o}/oo$. Field data show that the Merrimack River plays an important role in regional salinity distributions.

5.5 DENSITY

Near-surface waters showed considerable variability, sigma-t units of density ranging from 22.1 in late March to 27.0 in January and February. Near bottom waters were more uniform, averaging from 24.0 to about 27.0 and following a similar trend. Both showed a gradual rise from October through December.

5.6 DISSOLVED OXYGEN

Highest values were observed during the winter and spring (about 10.5 to 11.2 mg/l), whereas lowest values occurred during the late summer and autumn (down to 8.0 mg/l in September). No consistent pattern was observed between tidal stage or water depth, suggesting that dissolved oxygen follows a seasonal cycle related to planktonic photosynthesis, temperature and salinity. During the winter and spring, dissolved oxygen distributions were homogeneous, but near-surface waters had higher concentrations during the summer. Winter and spring percentage saturation ranged from 95 to 112 percent. In the summertime, near-surface waters became highly supersaturated (up to 115 percent) whereas near-bottom waters were generally undersaturated (down to 88 percent).

5.7 TIDES

Tides in Hampton Harbor are of the mixed, semi-diurnal type with a small (1 to 2 ft or 0.3 to 0.6 m) diurnal inequality which is most pronounced during spring tides. The mean tide range was about 8.3 ft (2.5 m). Spring tides ranged as high as 12.5 ft (3.8 m); neap tides ranged as low as 6.0 ft (1.8 m). In the summer months, the highest spring tides occur with the full moon; in the winter months the highest spring tides occur with the new moon.

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APPENDIX 7.1

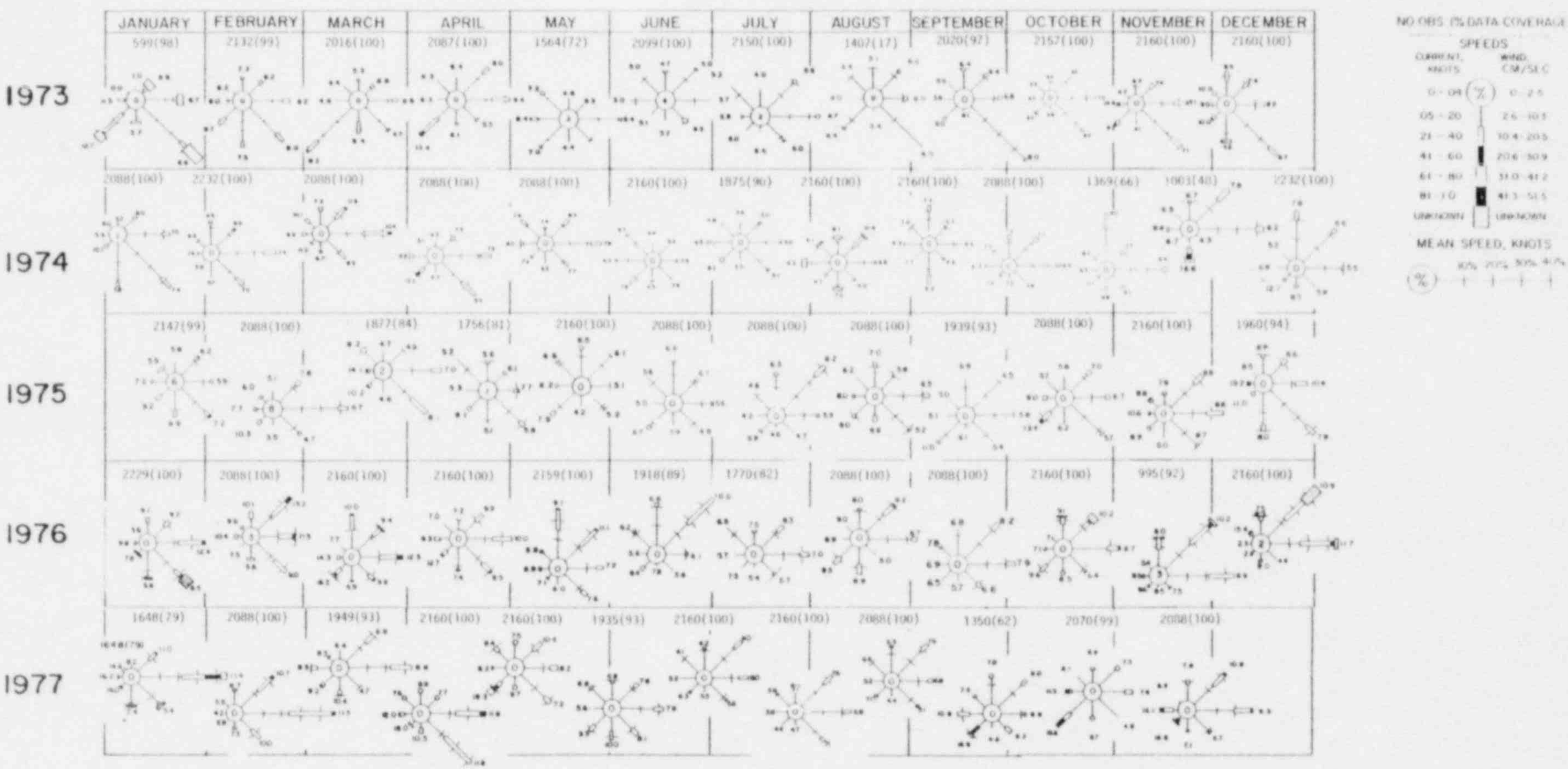
APPENDIX TABLE 7.1-1. OPERATIONAL PERFORMANCE OF NAI CURRENT METERS AND WIND STATION OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1977. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

DESIGNATION	DATES OPERATIONAL 1977	TOTAL POSSIBLE OBSERVATIONS	ACTUAL VECTOR OBSERVATIONS	DIRECTION ONLY OBSERVATIONS	SPEED ONLY OBSERVATIONS	NO DATA
T-7	Jan 1 to Dec 31	26280	21130	1936	1106	2108
12	Jan 1 to Sept 15	18526	14189	573	1780	1984
10 upper	Jan 1 to Sept 15	18525	15552	2590	1	382
I-4 Upper	Jan 1 to Dec 31	26280	17683	3173	2318	3106
I-4 Lower	Jan 1 to Dec 31	28280	19765	2440	1068	3007
Current Meter Total		115891	88319	10712	6273	10587
Percentage Recovery			76.2%	9.2%	5.5%	9.1%
Wind Total	Jan 1 to Dec 31	26280	24781	76	0	1423
Percentage Recovery			94.3%	0.3%	0%	5.4%

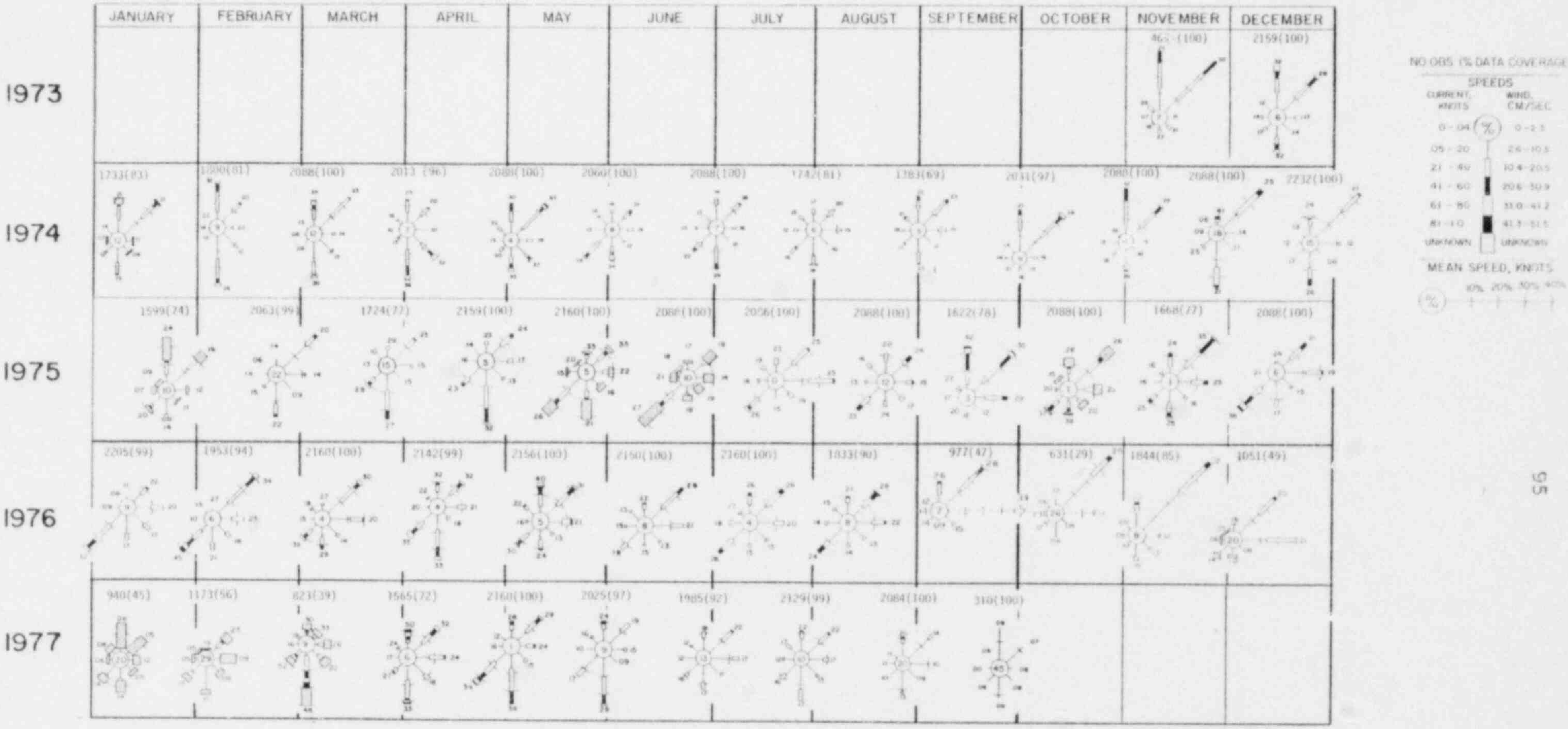
APPENDIX TABLE 7.1-2. OPERATIONAL PERFORMANCE OF NAI TEMPERATURE MONITORS OFF HAMPTON BEACH, NEW HAMPSHIRE, FOR 1977. SEABROOK 1977 ANNUAL HYDROGRAPHIC REPORT, 1979.

DESIGNATION	DATES OPERATIONAL 1977	TOTAL POSSIBLE DAYS	DAYS DATA OBTAINED	DAYS NO DATA OBTAINED
T-7	Jan 1 to Dec 31	365	268	97
12	Jan 1 to Sept 14	257	232	25
10 Upper	Jan 1 to Sept 15	258	222	36
I-4 Upper	Jan 1 to Dec 31	365	360	5
I-4 Lower	Jan 1 to Dec 31	365	355	10
B Upper	Jan 1 to Dec 31	365	247	118
B Lower	Jan 1 to Dec 31	365	233	132
HH Upper	Jan 1 to Dec 31	365	255	110
HH Lower	Jan 1 to Dec 31	365	267	98
Total		3070	2439	631
Percentage			79.4%	20.6%

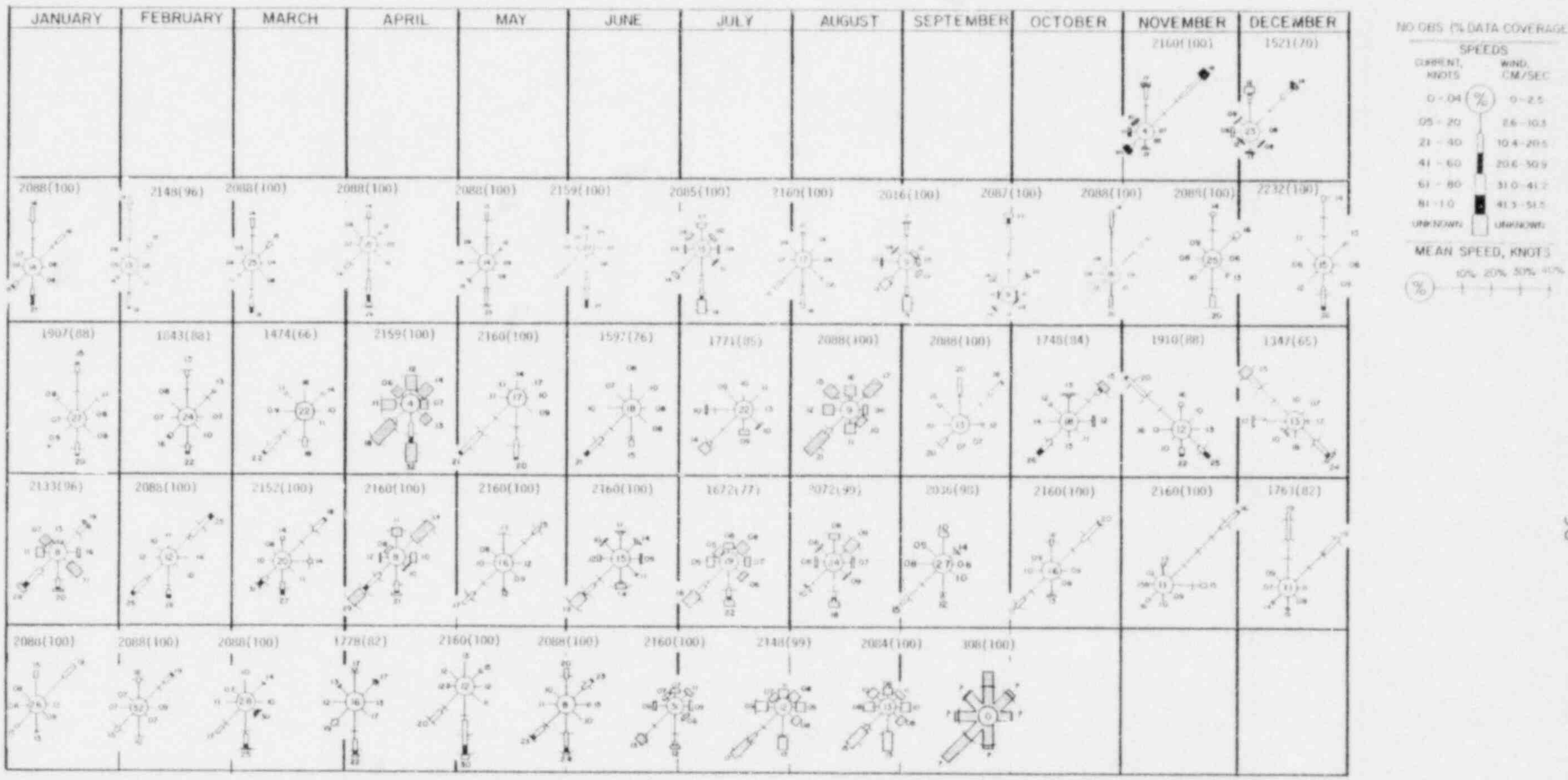
APPENDIX 7.2



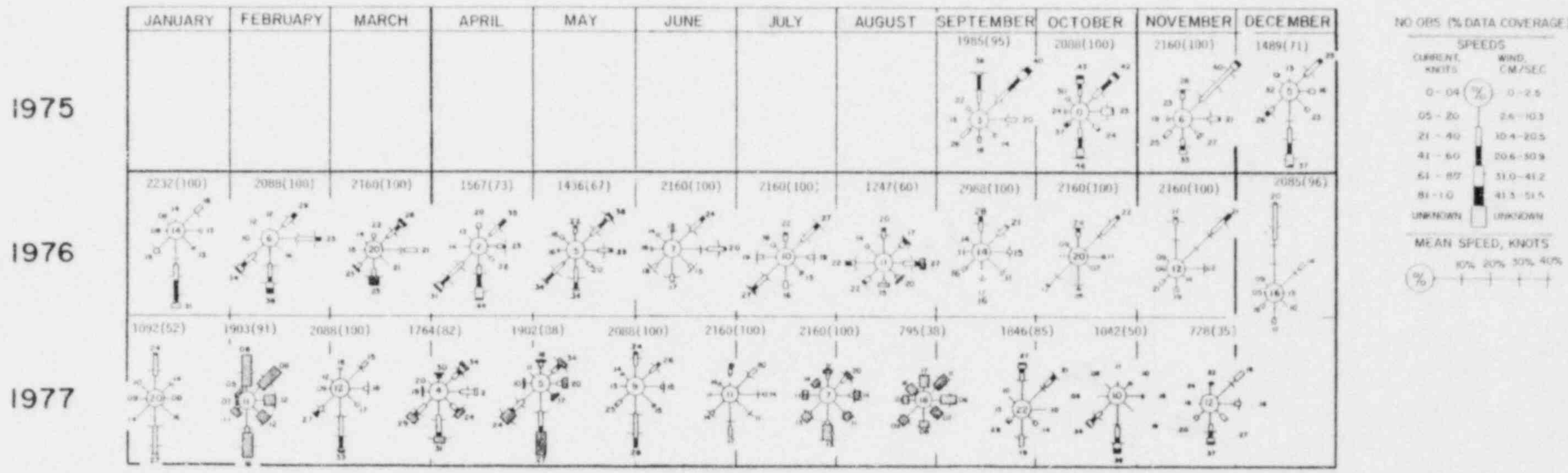
Appendix Figure 7.2-1. Summary rose diagrams of wind data measured by NAI at Hampton Beach, New Hampshire, from 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



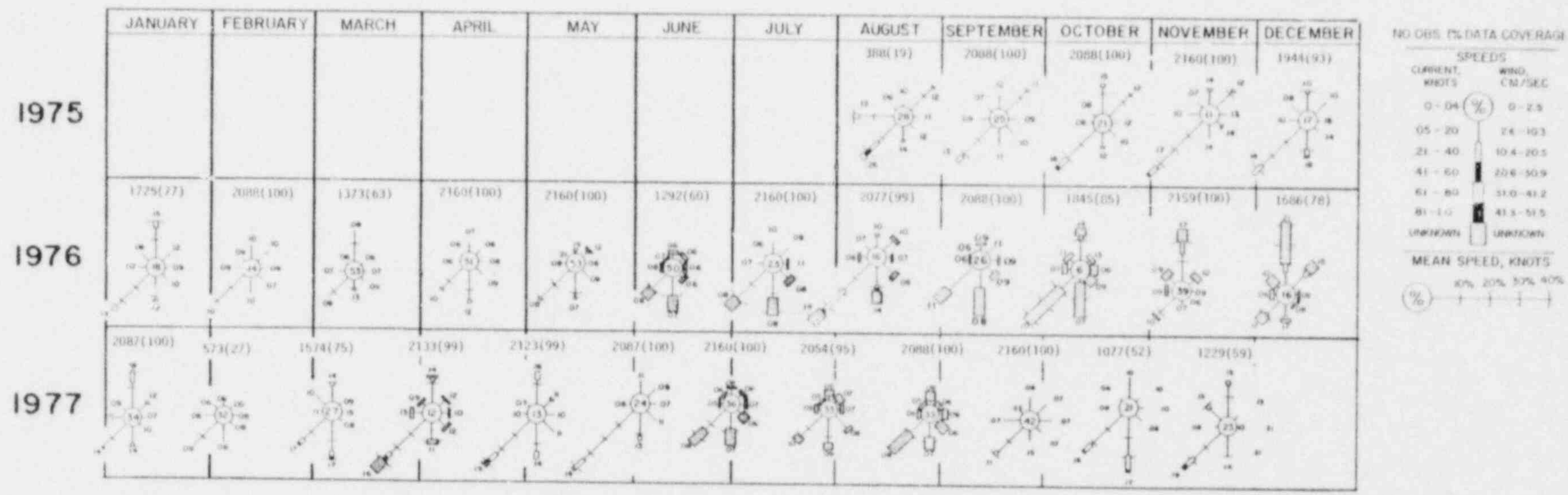
Appendix Figure 7.2-2. Summary rose diagrams of near-surface currents at NAI Mooring 12 off Hampton Beach, New Hampshire for 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



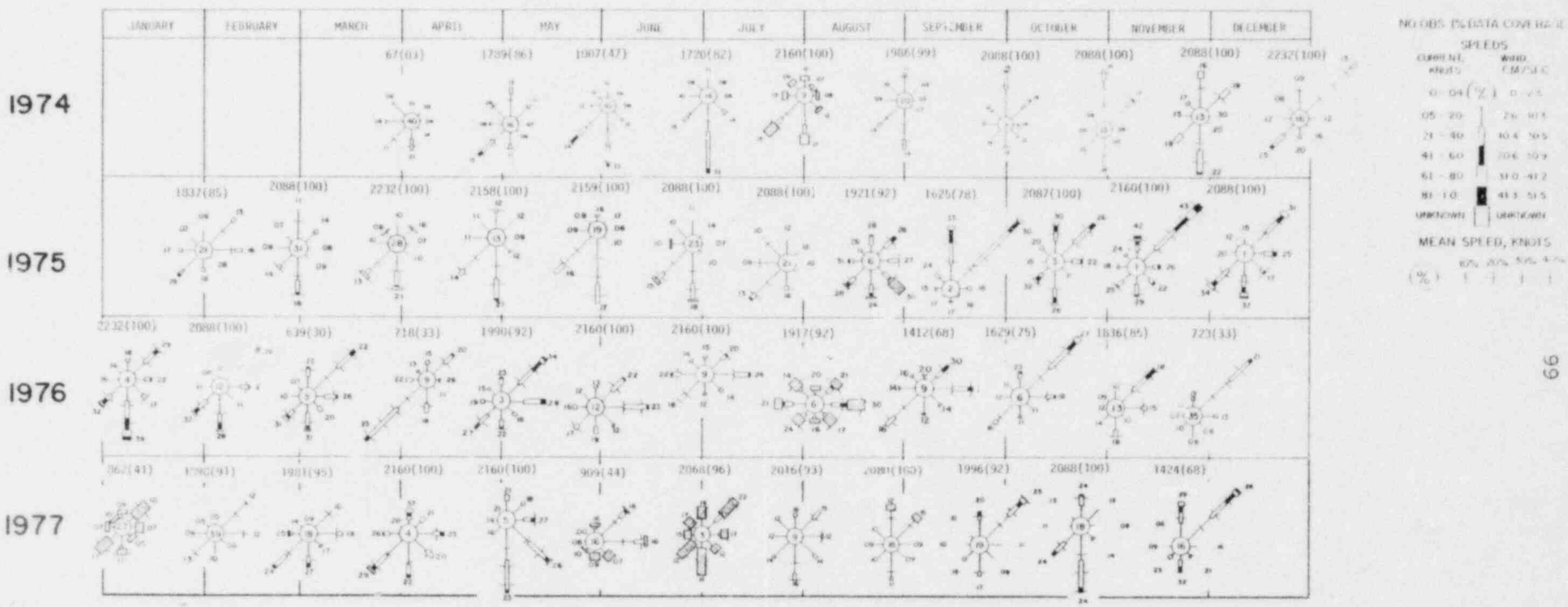
Appendix Figure 7.2-3. Summary rose diagrams of near-surface currents at NAI Mooring 10 upper off Hampton Beach, New Hampshire for 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix Figure 7.2-4. Summary rose diagrams of near-surface currents at NAI Mooring I-4 upper off Hampton Beach, New Hampshire for 1973 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix Figure 7.2-5. Summary rose diagrams of near-surface currents at NAI Mooring I-4 lower off Hampton Beach, New Hampshire for 1975 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix Figure 7.2-6. Monthly rose diagrams of near-surface currents at NAI Mooring T-7 for 1974 through 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

APPENDIX 7.3

OVERALL DATA TABULATIONS

APPENDIX TABLE 7.3-1. PERCENTAGE-FREQUENCY TABULATION OF WIND DATA FROM WIND STATION AT HAMPTON BEACH NEW HAMPSHIRE. DATA ARE FROM 1-24-73 TO 1-5-78.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS.

DIRECTION WIND IS BLOWING TOWARD, DEGREES TRUE

SPEED. KN	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
<1	132	218	271	205	107	56	69	55	1	1114	.9
1-10	10813	14823	21242	17070	7765	6885	6280	8421	0	93299	76.2
11-20	2167	5749	7321	3717	1568	2673	1257	883	2	25337	20.7
21-30	104	406	608	106	82	731	349	67	0	2453	2.0
31-40	1	11	22	5	18	132	22	3	0	214	.2
41-50	0	0	0	0	2	10	2	0	0	14	0
DIRECTION ONLY	159	402	103	296	151	84	60	62	0	1317	0
TOTAL	13376	21609	29567	21399	9693	10571	8039	9491	3	123748	100
PERCENT FREQUENCY	10.8	17.5	23.9	17.3	7.8	8.5	6.5	7.7	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 130470

VECTOR OBSERVATIONS = 122428 (93.8%)

DIRECTION ONLY OBSERVATIONS = 1317 (1.0%)

SPEED ONLY OBSERVATIONS = 3 (0%)

NO DATA = 6722 (5.2%)

APPENDIX TABLE 7.3-2. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING 12 OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM 11-16-73 TO 9-15-77.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

SPEED, KNOTS	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
	DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE										
0.0-0.04	714	1118	1186	1189	1136	953	818	779	562	8455	9.8
0.05-0.2	4204	8287	6334	4763	6471	4842	2458	2369	1085	40813	47.5
0.21-0.4	3692	7995	3530	1139	4544	3493	581	737	627	26338	30.6
0.41-0.6	1545	2441	326	150	1618	1517	42	113	117	7869	9.1
0.61-0.8	343	483	10	75	485	423	0	27	22	1868	2.2
0.81-1.0	178	116	4	30	149	179	0	3	3	662	.8
DIRECTION ONLY	531	852	573	370	640	678	197	217	0	4058	0
TOTAL	11207	21292	11963	7716	15043	12085	4096	4245	2416	90063	100
PERCENT FREQUENCY	12.8	24.3	13.6	8.8	17.2	13.8	4.7	4.8	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 100934

VECTOR OBSERVATIONS = 83589 (82.8%)

DIRECTION ONLY OBSERVATIONS = 4058 (4.0%)

SPEED ONLY OBSERVATIONS = 2416 (2.4%)

NO DATA = 10871 (10.8%)

APPENDIX TABLE 7.3-31. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING 10 UPPER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM 10-12-73 TO 9-15-77.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

	DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE										
SPEED, KNOTS	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.0-0.04	2564	2616	1739	1648	1704	1857	1868	2283	9	16288	18.6
0.05-0.2	9594	9346	3321	3849	8262	8972	3999	4822	3	52168	59.7
0.21-0.4	2944	3555	301	387	4140	3939	244	556	1	16067	18.4
0.41-0.6	210	321	10	102	1089	601	18	36	0	2387	2.7
0.61-0.8	16	21	0	5	293	105	1	6	0	447	.5
0.81-1.0	5	1	0	20	53	20	0	0	0	99	.1
DIRECTION ONLY	1250	1688	752	849	1537	2245	1040	1016	0	10377	0
TOTAL	16583	17548	6123	6860	17078	17739	7170	8719	13	97833	100
PERCENT FREQUENCY	17.0	17.9	6.3	7.0	17.5	18.1	7.3	8.9	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 103452

VECTOR OBSERVATIONS = 87443 (84.5%)

DIRECTION ONLY OBSERVATIONS = 10377 (10.1%)

SPEED ONLY OBSERVATIONS = 13 (0)

NO DATA = 5619 (5.4%)

APPENDIX TABLE 7.3-4. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING I-4 UPPER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM 12-29-75 TO 1-5-78.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

	DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE										
SPEED, KNOTS	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.0-0.04	580	846	793	758	845	668	516	543	125	5674	12.9
0.05-0.2	2595	3704	3272	2518	3717	2905	1283	1185	692	21871	49.7
0.21-0.4	1457	2482	1449	524	2621	1684	241	243	954	11655	26.4
0.41-0.6	343	747	179	75	958	621	51	14	393	3381	7.7
0.61-0.8	57	127	20	24	389	225	4	0	183	1029	2.3
0.81-1.0	16	52	3	12	167	94	0	0	96	440	1.0
DIRECTION ONLY	470	529	415	359	882	457	169	175	0	3456	0
TOTAL	5518	8487	6131	4270	9579	6654	2264	2160	2443	47506	100
PERCENT FREQUENCY	12.2	18.8	13.6	9.5	21.3	14.8	5.0	4.8	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 53390

VECTOR OBSERVATIONS =41607 (77.9%)

DIRECTION ONLY OBSERVATIONS = 3456 (6.5%)

SPEED ONLY OBSERVATIONS = 2443 (4.6%)

NO DATA = 5884 (11.0%)

APPENDIX TABLE 7.3-5. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING I-4 LOWER OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM 12-29-75 TO 1-5-78.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

	DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE										
SPEED, KNOTS	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.0-0.04	1805	1671	1268	1426	1974	2589	1563	1351	531	14178	35.0
0.05-0.2	3654	1854	935	1708	4214	7932	1004	1056	956	23313	57.6
0.21-0.4	728	119	38	75	554	879	23	63	106	2585	6.4
0.41-0.6	23	2	0	5	108	234	1	0	0	373	.9
0.61-0.8	0	0	0	0	2	46	3	0	0	51	.1
0.81-1.0	0	0	0	0	0	4	0	0	0	4	0
DIRECTION ONLY	889	550	393	699	1668	1950	402	364	0	6915	0
TOTAL	7099	4196	2634	3913	8520	13634	2996	2834	1593	40504	100
PERCENT FREQUENCY	15.5	9.2	5.7	8.5	18.6	29.8	6.5	6.2	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 53390

VECTOR OBSERVATIONS = 38911 (72.9%)

DIRECTION ONLY OBSERVATIONS = 6915 (12.9%)

SPEED ONLY OBSERVATIONS = 1593 (3.0%)

NO DATA = 5971 (11.2%)

APPENDIX TABLE 7.3-6. PERCENTAGE-FREQUENCY TABULATION OF CURRENT METER DATA FROM MOORING T-7 OFF HAMPTON BEACH, NEW HAMPSHIRE. DATA ARE FROM 4-16-74 TO 1-5-78.

PERCENTAGES ARE BASED ON THE TOTAL VECTOR, DIRECTION ONLY AND SPEED ONLY OBSERVATIONS

	DIRECTION CURRENT IS FLOWING TOWARD, DEGREES TRUE										
SPEED, KNOTS	N 388-22	NE 23-67	E 68-112	SE 113-157	S 158-202	SW 203-247	W 248-292	NW 293-337	SPEED ONLY	TOTAL	PERCENT FREQUENCY
0.0-0.04	1517	1797	1220	1282	1363	1346	1181	1397	423	11526	14.0
0.05-0.2	5800	8550	4159	3555	7876	7501	3682	3311	1186	45620	55.5
0.21-0.4	1927	4451	2216	1106	4648	3314	702	467	364	19195	23.3
0.41-0.6	466	1278	492	137	939	760	144	52	10	4278	5.2
0.61-0.8	148	421	53	51	229	218	30	12	0	1162	1.4
0.81-1.0	61	183	3	6	101	103	17	3	0	477	.6
DIRECTION ONLY	319	515	401	518	678	721	287	369	0	3808	0
TOTAL	10238	17195	8544	6655	15834	13963	6043	5611	1983	86066	100
PERCENT FREQUENCY	12.2	20.4	10.2	7.9	18.8	16.6	7.2	6.7	0	0	100

TOTAL POSSIBLE 20-MINUTE OBSERVATIONS = 98141

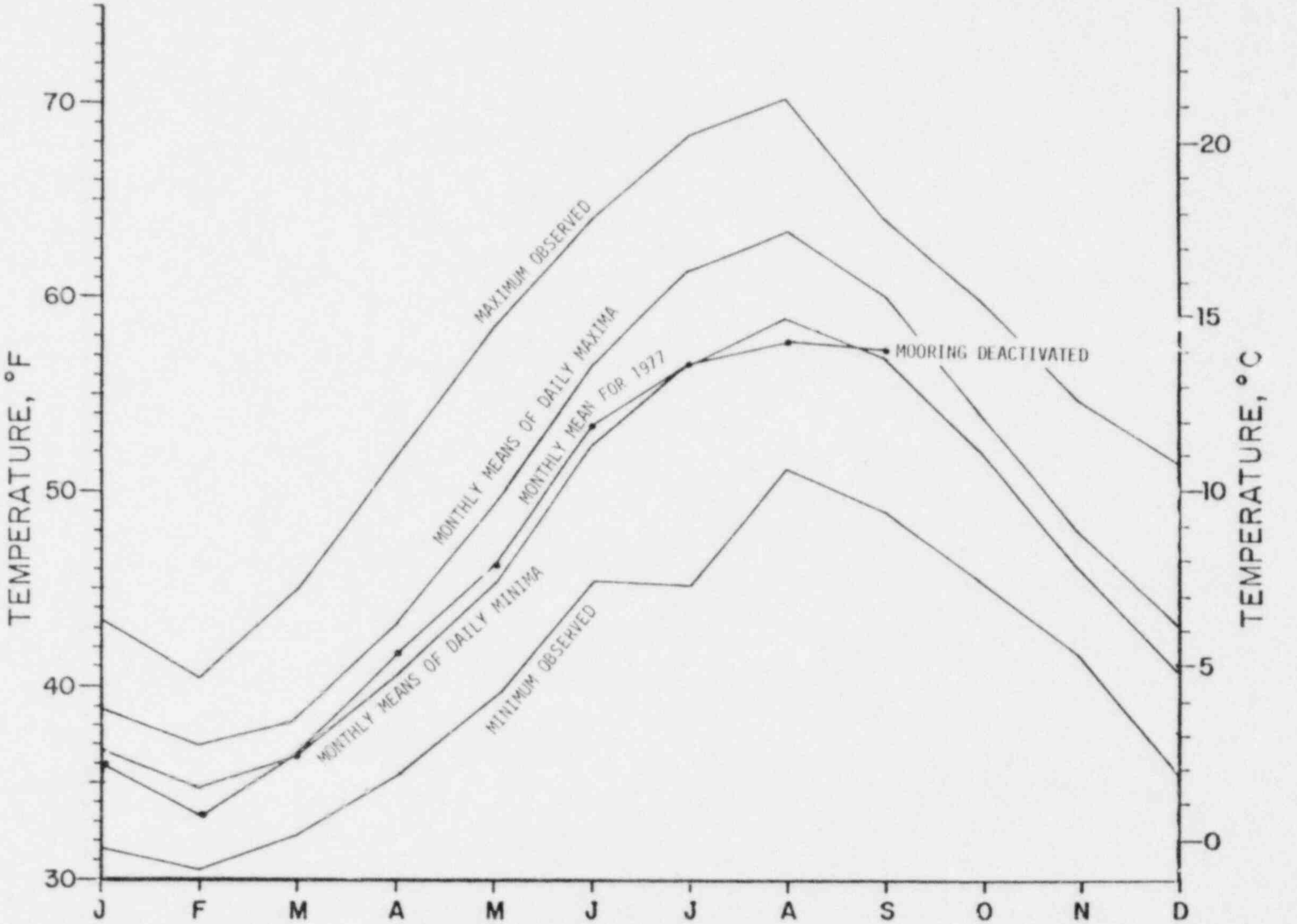
VECTOR OBSERVATIONS = 80275 (81.8%)

DIRECTION ONLY OBSERVATIONS = 3808 (3.9%)

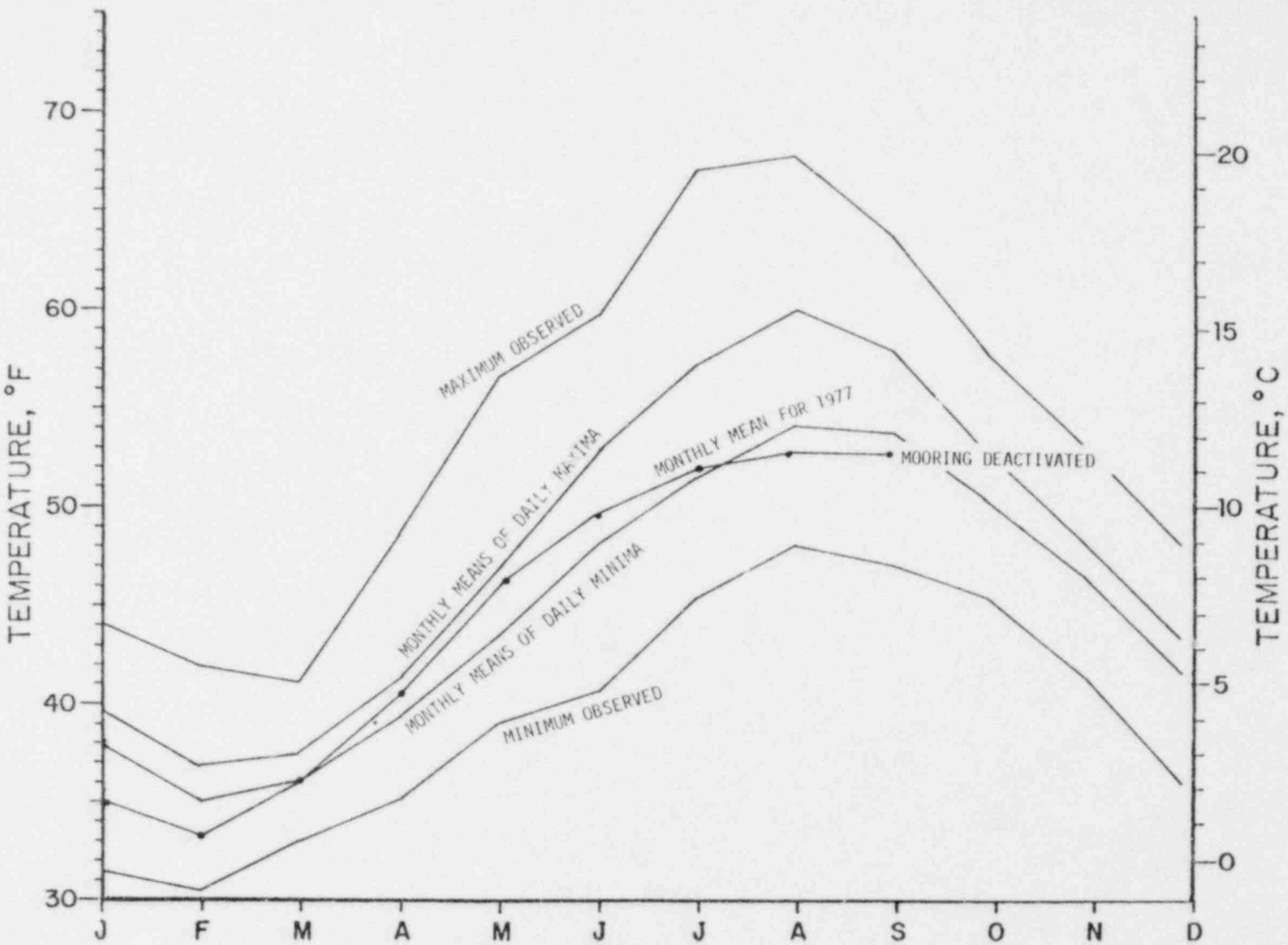
SPEED ONLY OBSERVATIONS = 1983 (2.0%)

NO DATA = 12075 (12.3%)

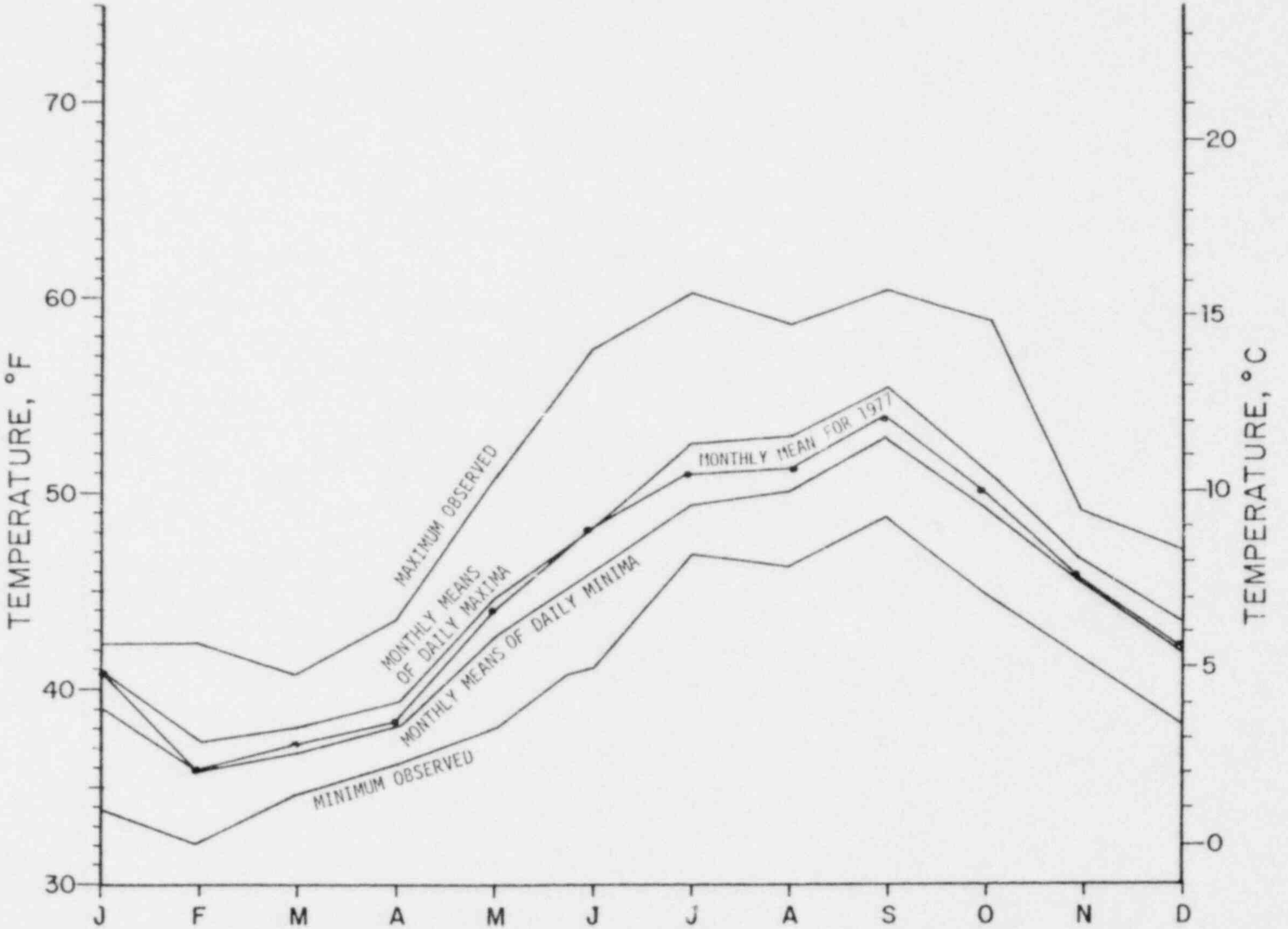
APPENDIX 7.4



Appendix Figure 7.4-1. Monthly summary temperature data from Mooring 12 showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed from November 9, 1973 to September 14, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix Figure 7.4-2. Monthly summary temperature data from Mooring 10 Upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed from October 19, 1973 to September 15, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



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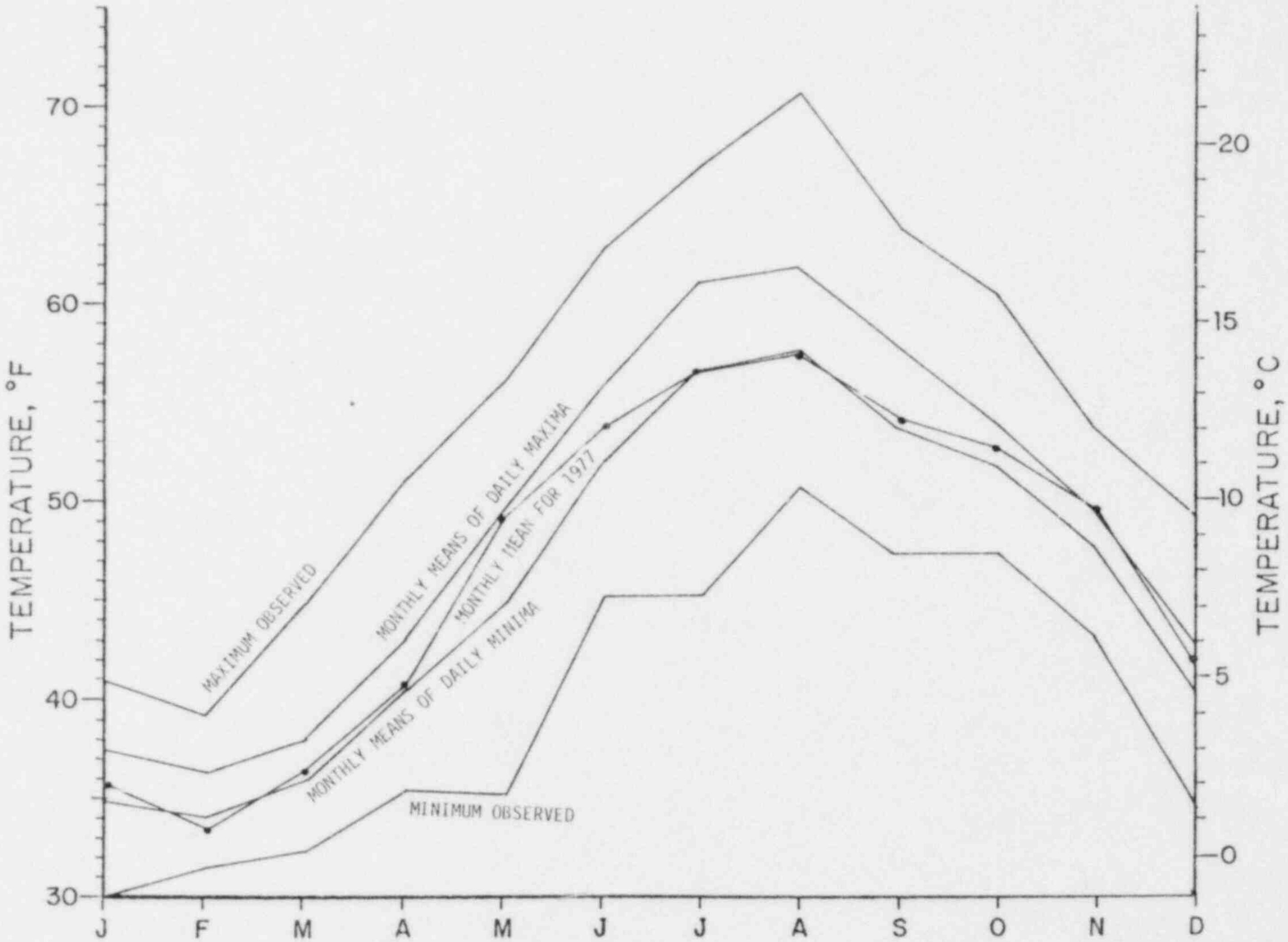
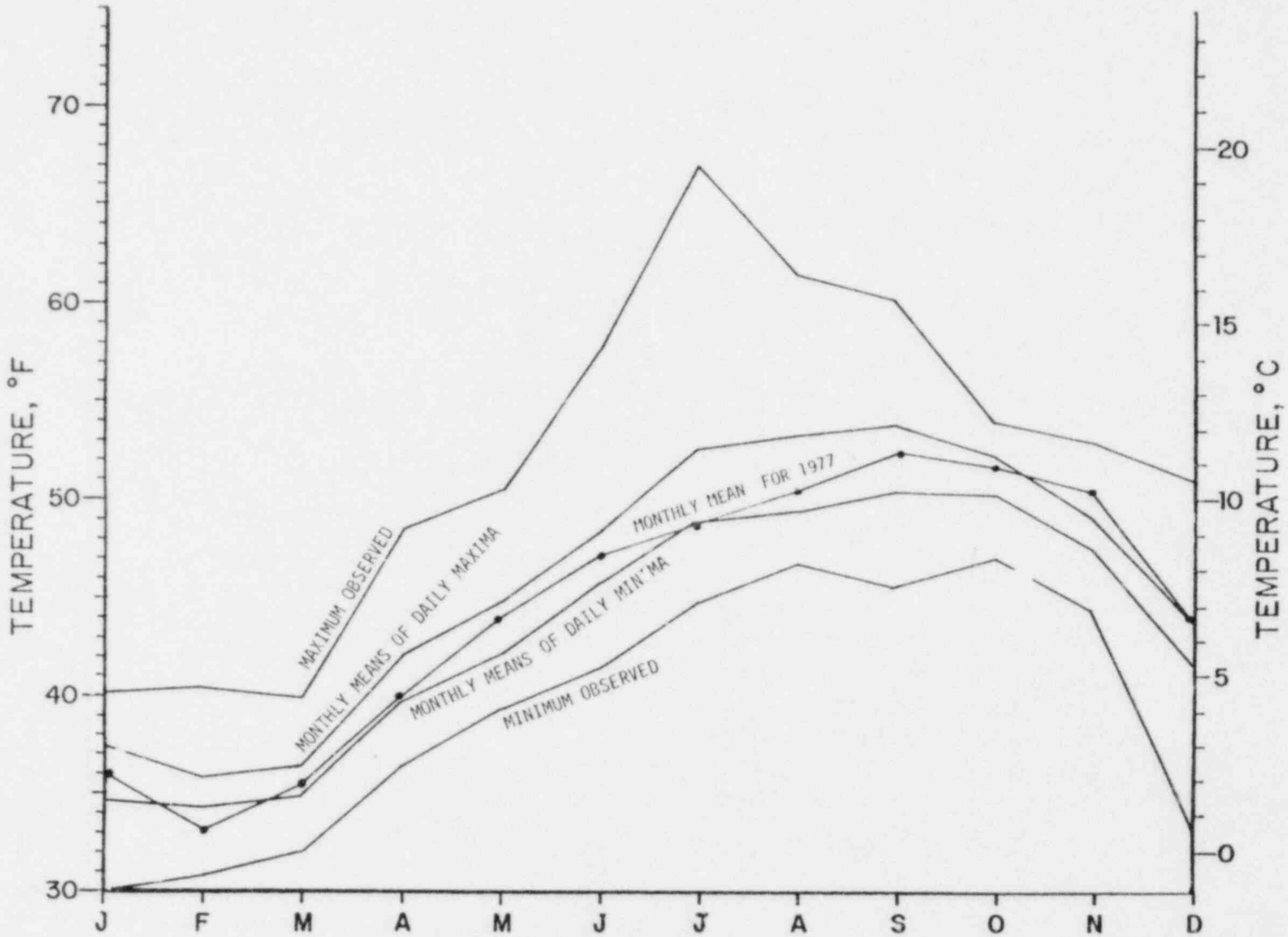
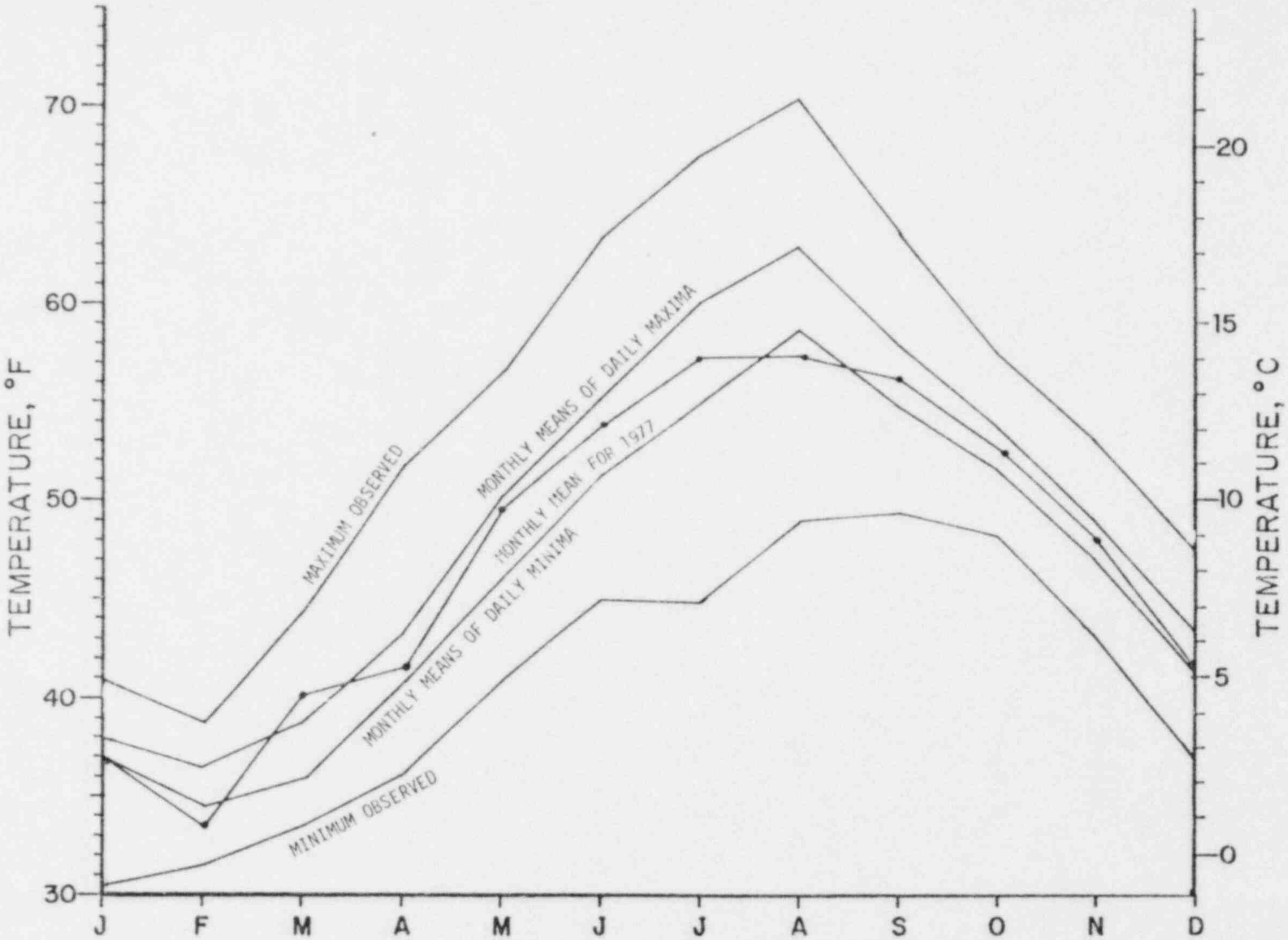
Appendix Figure 7.4-3. Monthly summary temperature data from Mooring 10 Lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed from October 20, 1973 to June 24, 1975. Seabrook 1977 Annual Hydrographic Report, 1979.



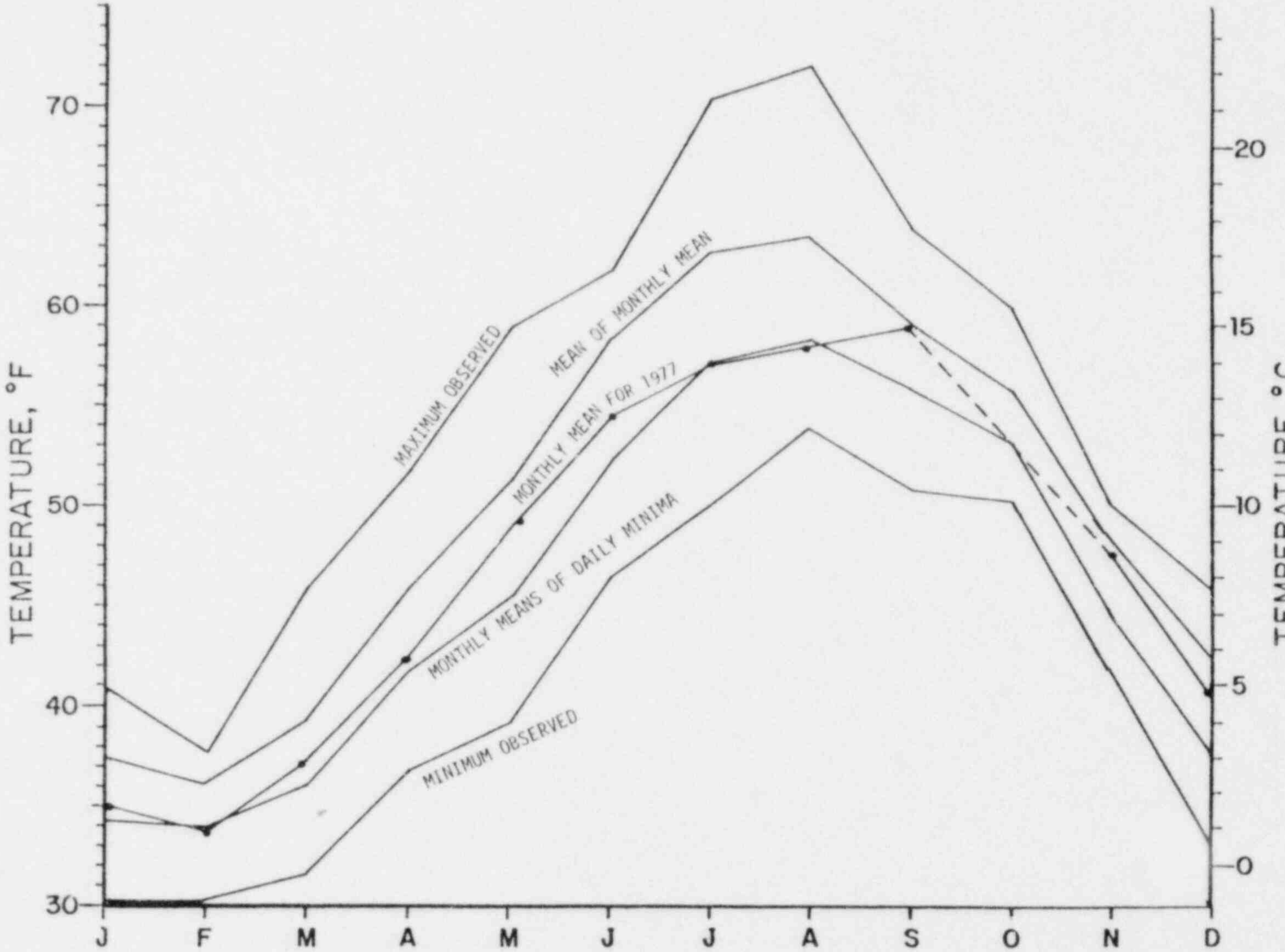
Appendix Figure 7.4-4. Monthly summary temperature data from Mooring I-4 Upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed from September 5, 1975 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



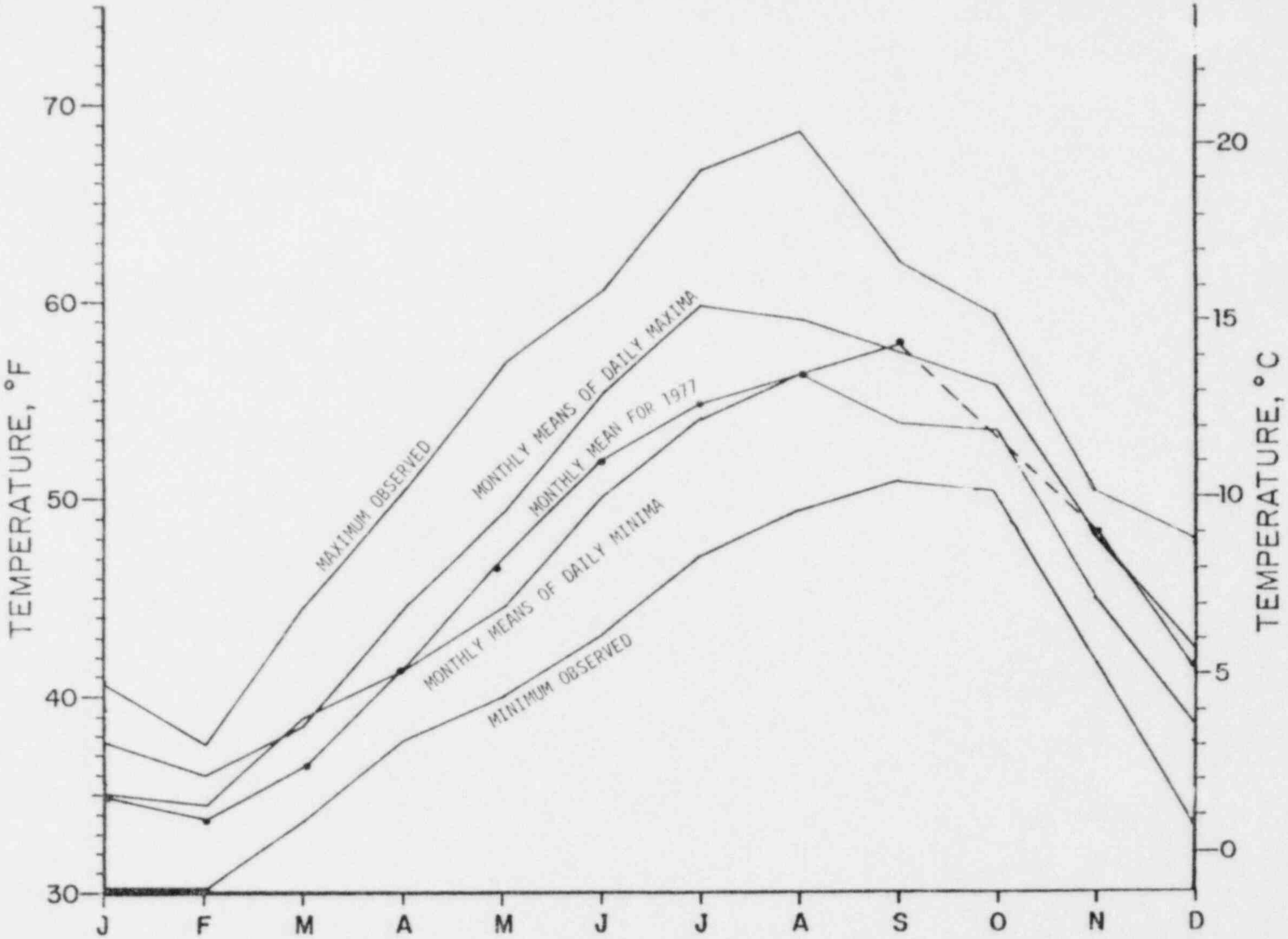
Appendix Figure 7.4-5. Monthly summary temperature data from Mooring I-4 Lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed from September 5, 1975 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



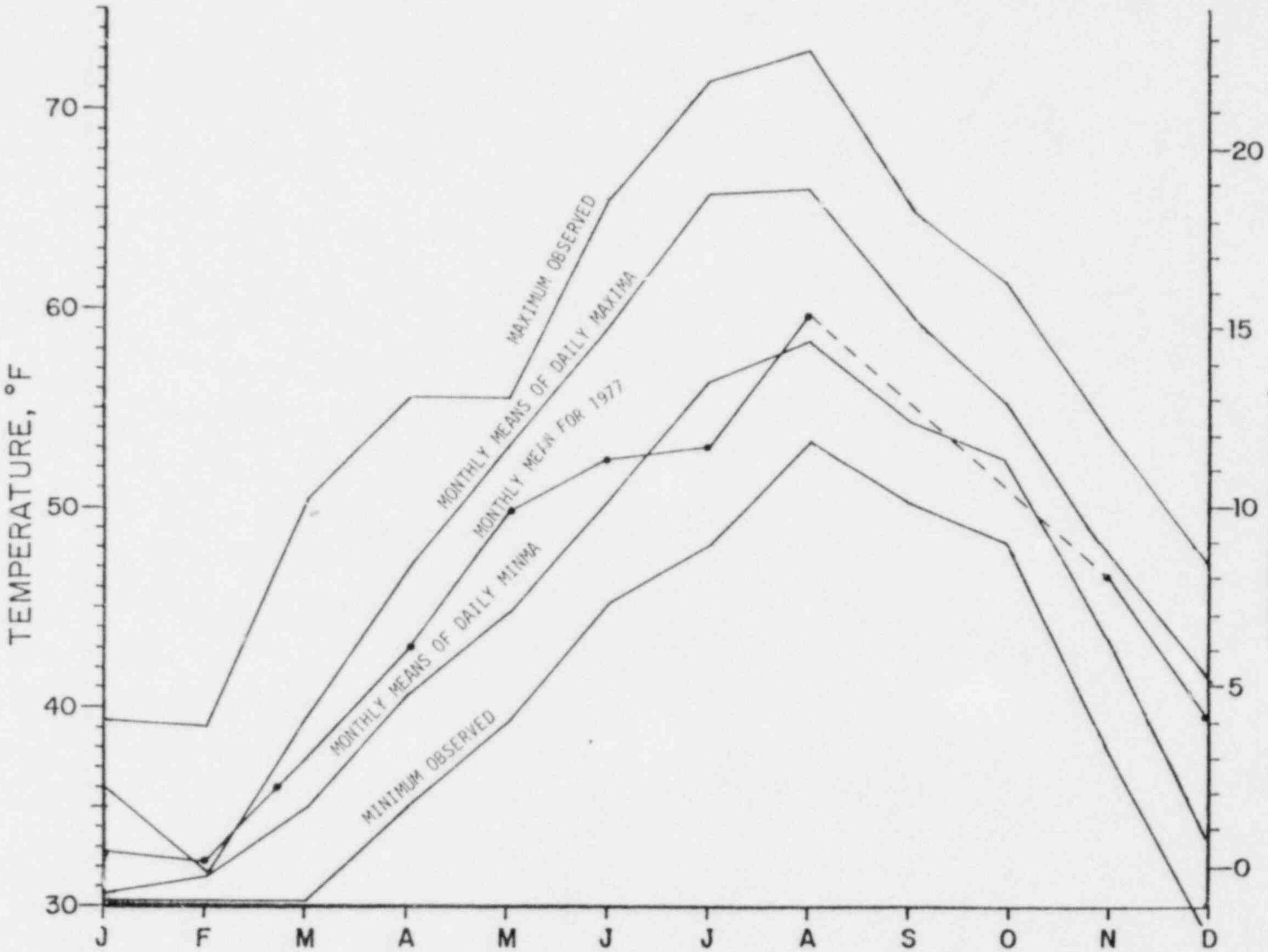
Appendix Figure 7.4-6. Monthly summary temperature data from Mooring T-7 showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed July 1, 1975 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



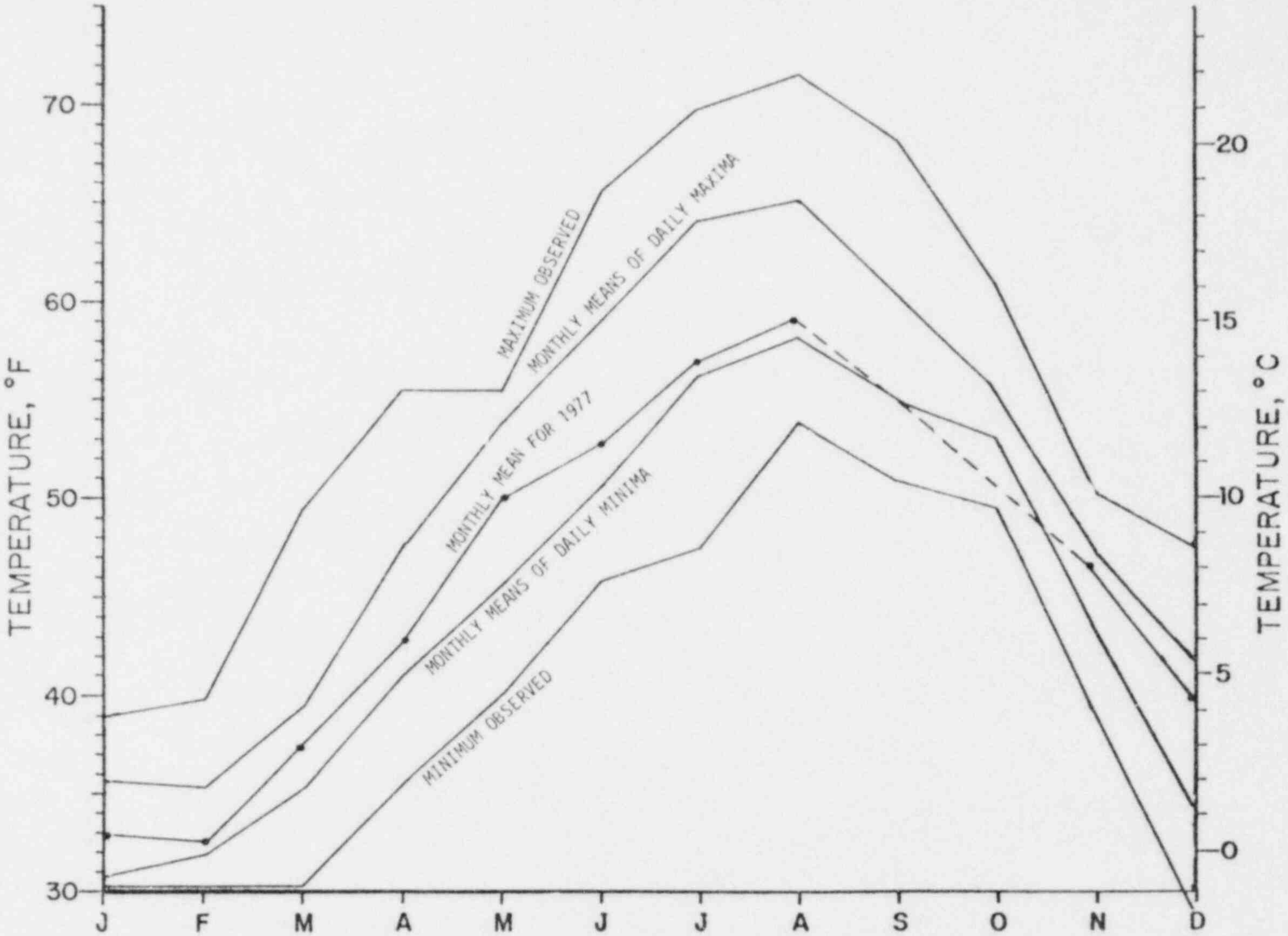
Appendix Figure 7.4-7. Monthly summary temperature data from Mooring B Upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed January 1, 1976 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix Figure 7.4-8. Monthly summary temperature data from Mooring B Lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed January 1, 1976 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

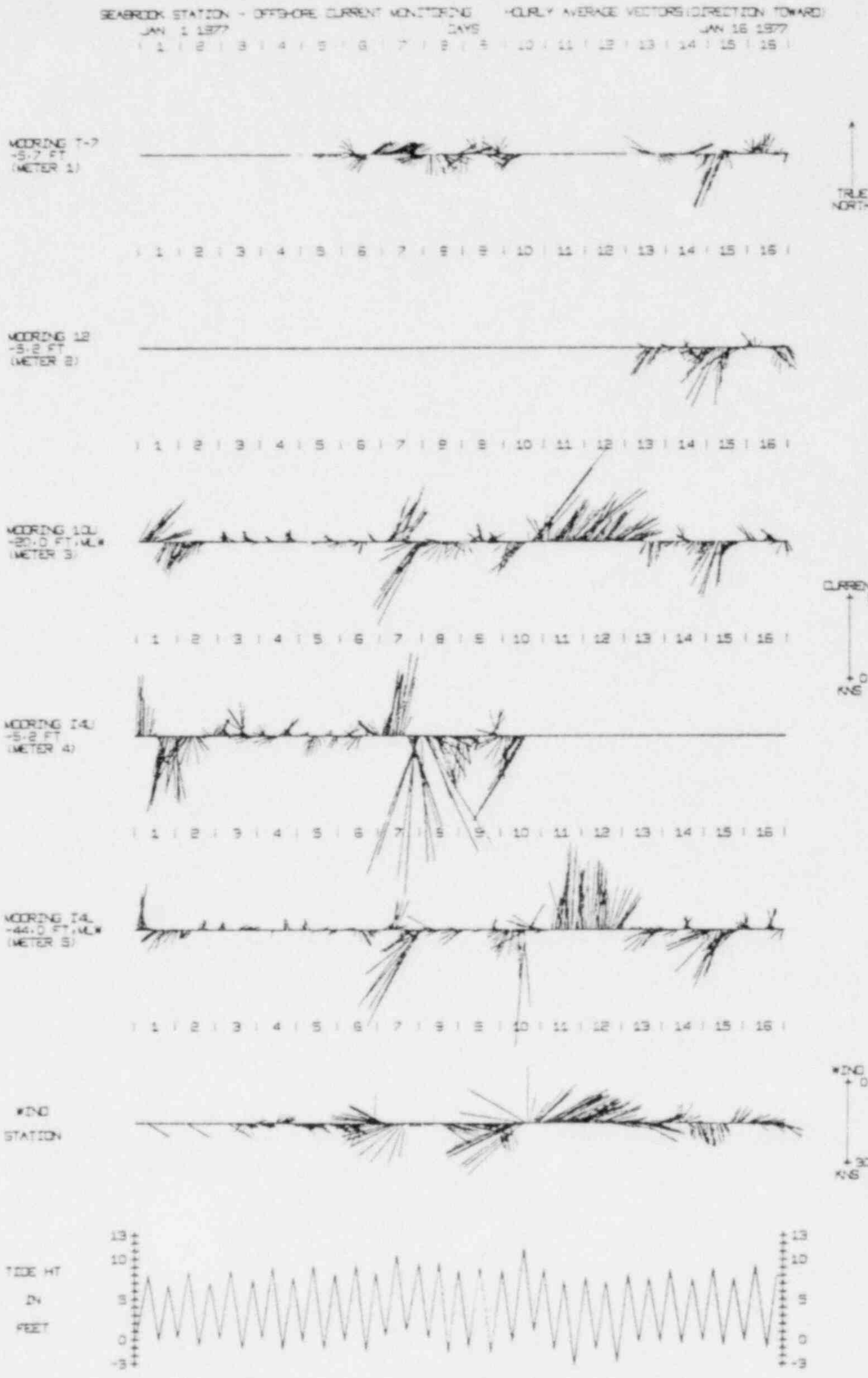


Appendix Figure 7.4-9. Monthly summary temperature data from Mooring HH Upper showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed January 1, 1976 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



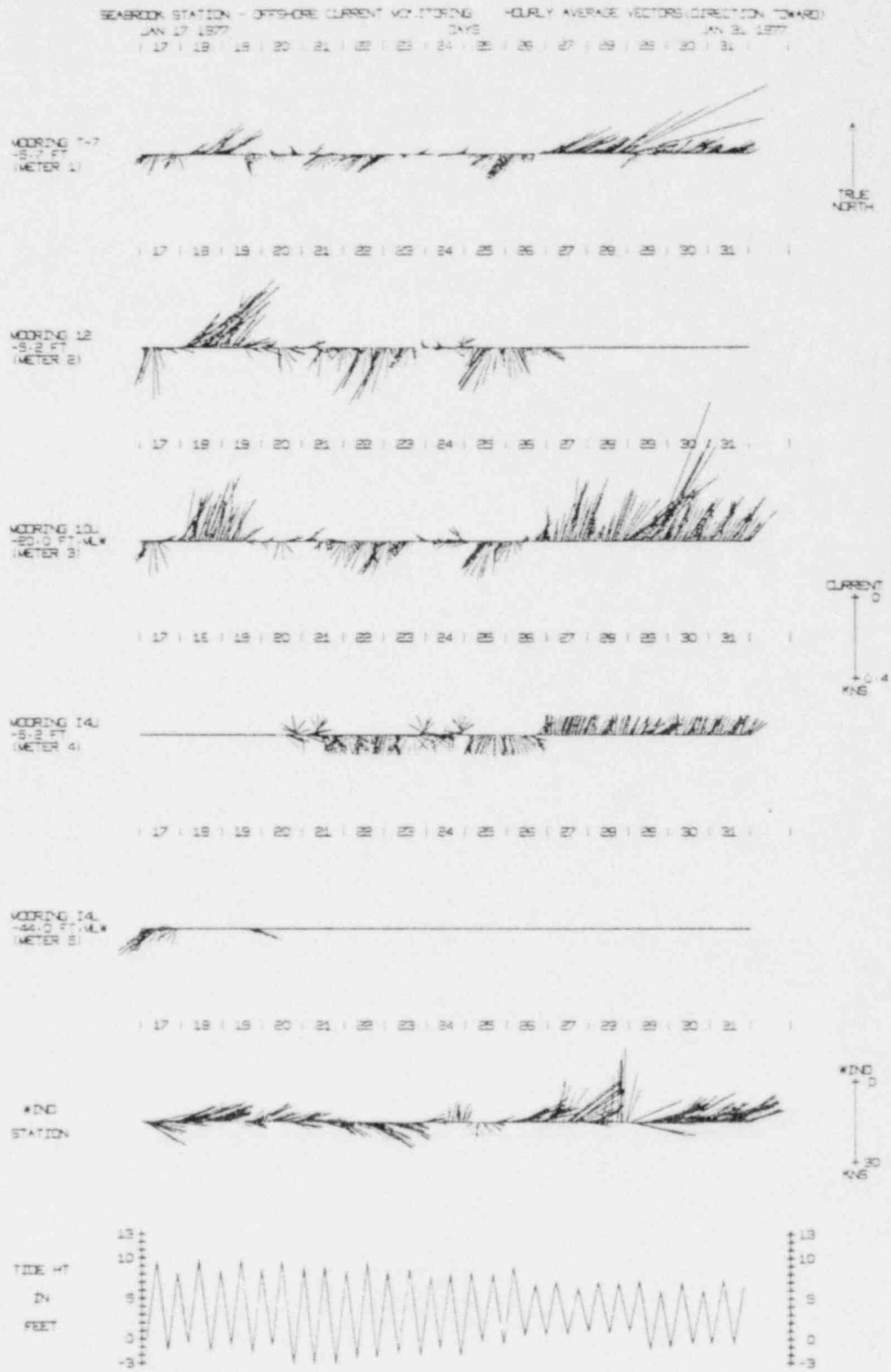
Appendix Figure 7.4-10. Monthly summary temperature data from Mooring HH Lower showing maximum ever observed, monthly mean of daily maxima, monthly mean for latest year (1977), monthly mean of daily minima, and minimum ever observed January 1, 1976 to December 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

APPENDIX 7.5

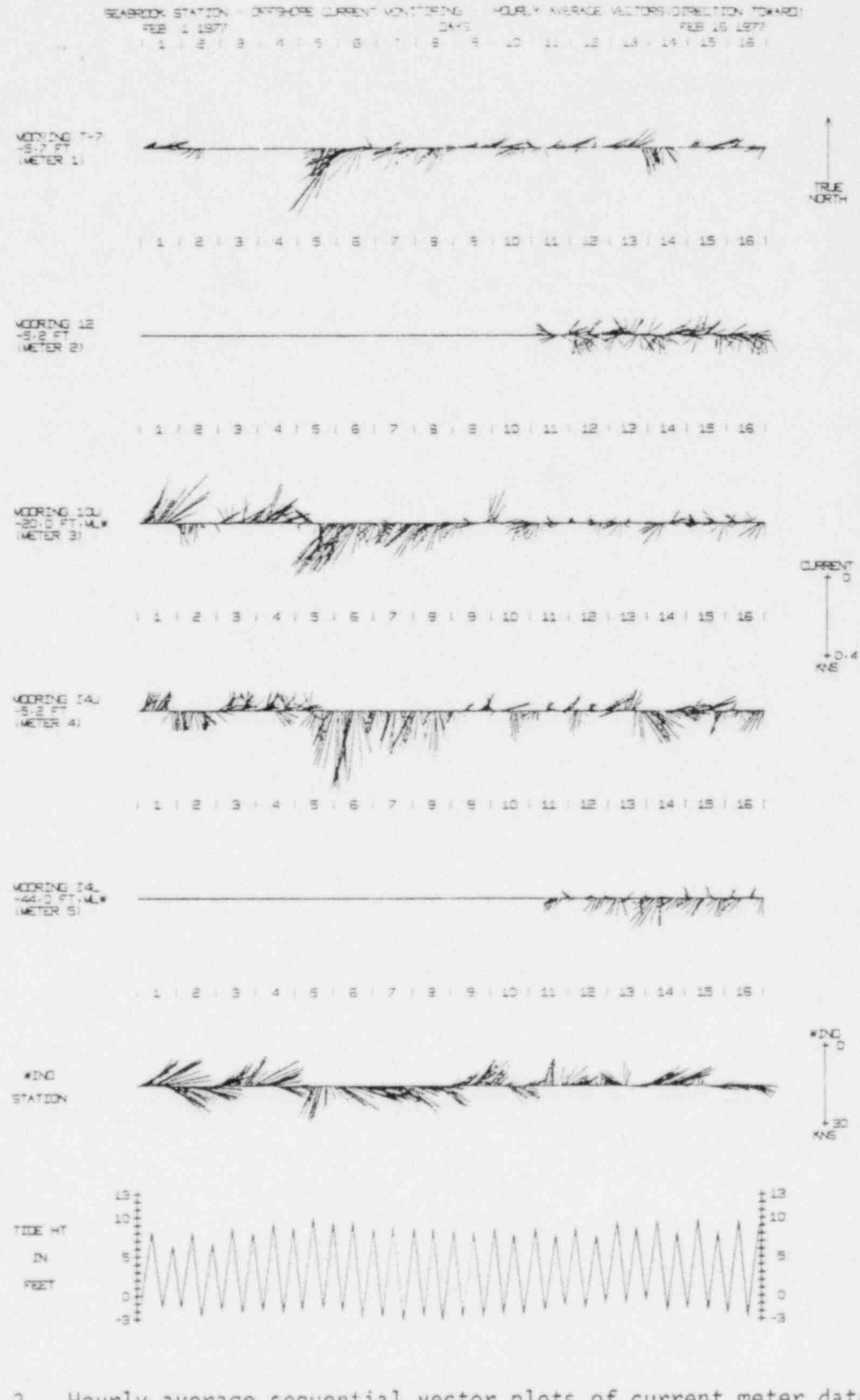


Appendix

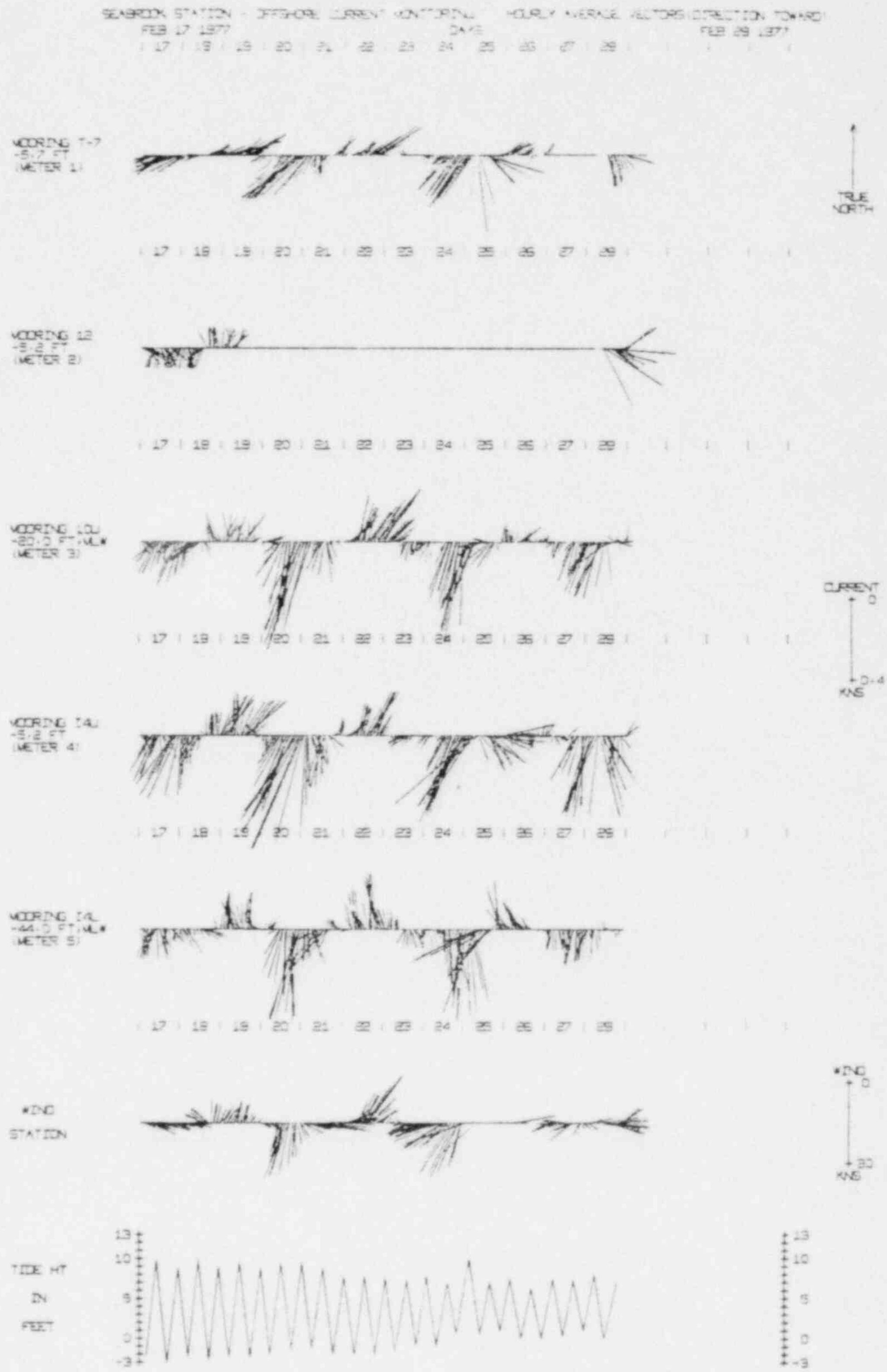
Figure 7.5-1. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for January 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-2. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for January 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-3. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for February 1 to 16, 1977.
Seabrook 1977 Annual Hydrographic Report, 1979.



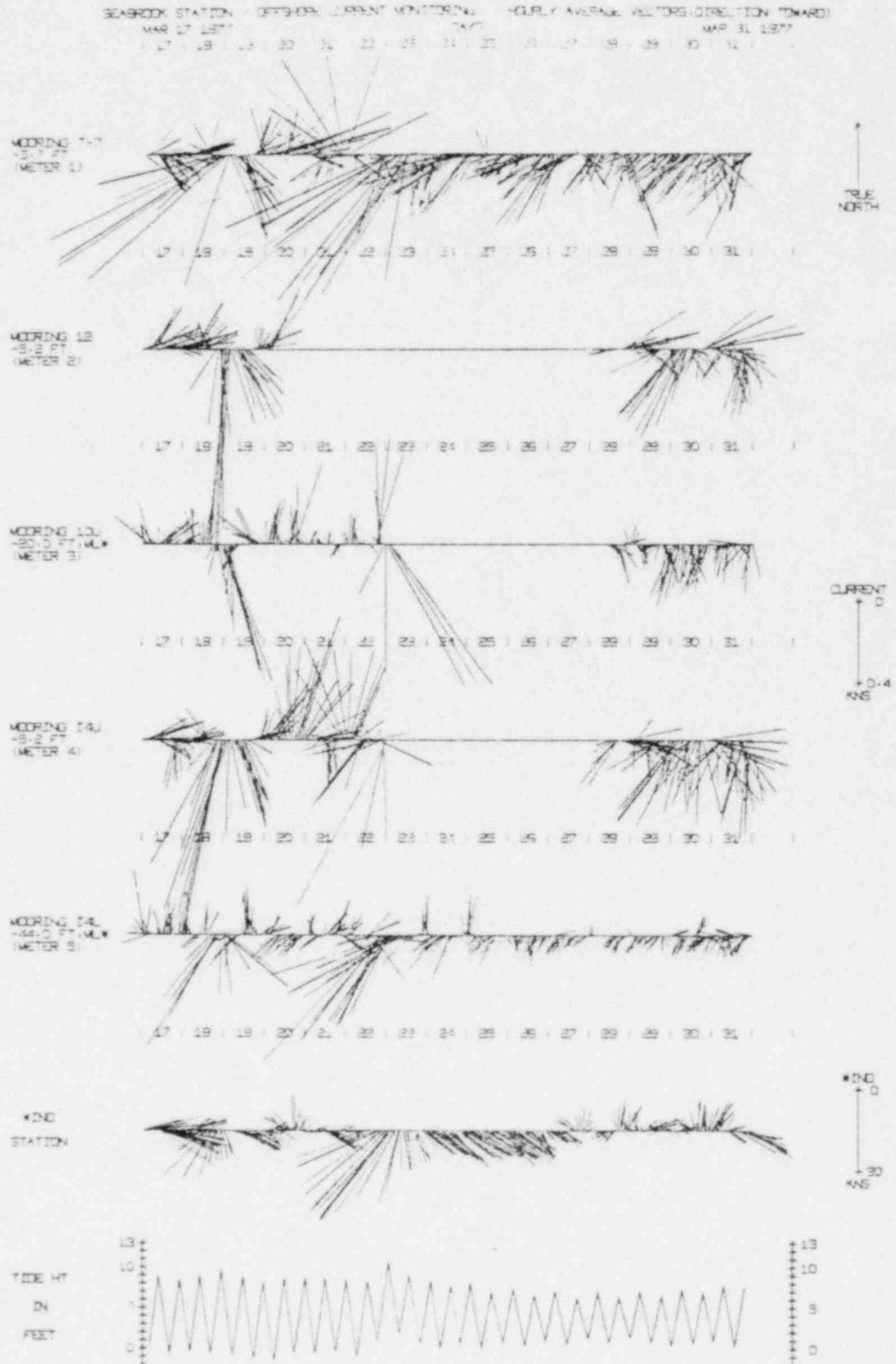
Appendix

Figure 7.5-4. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for February 17 to 28, 1977. Seabrook 1977 Annual Hydrographic Report, 1979

Appendix

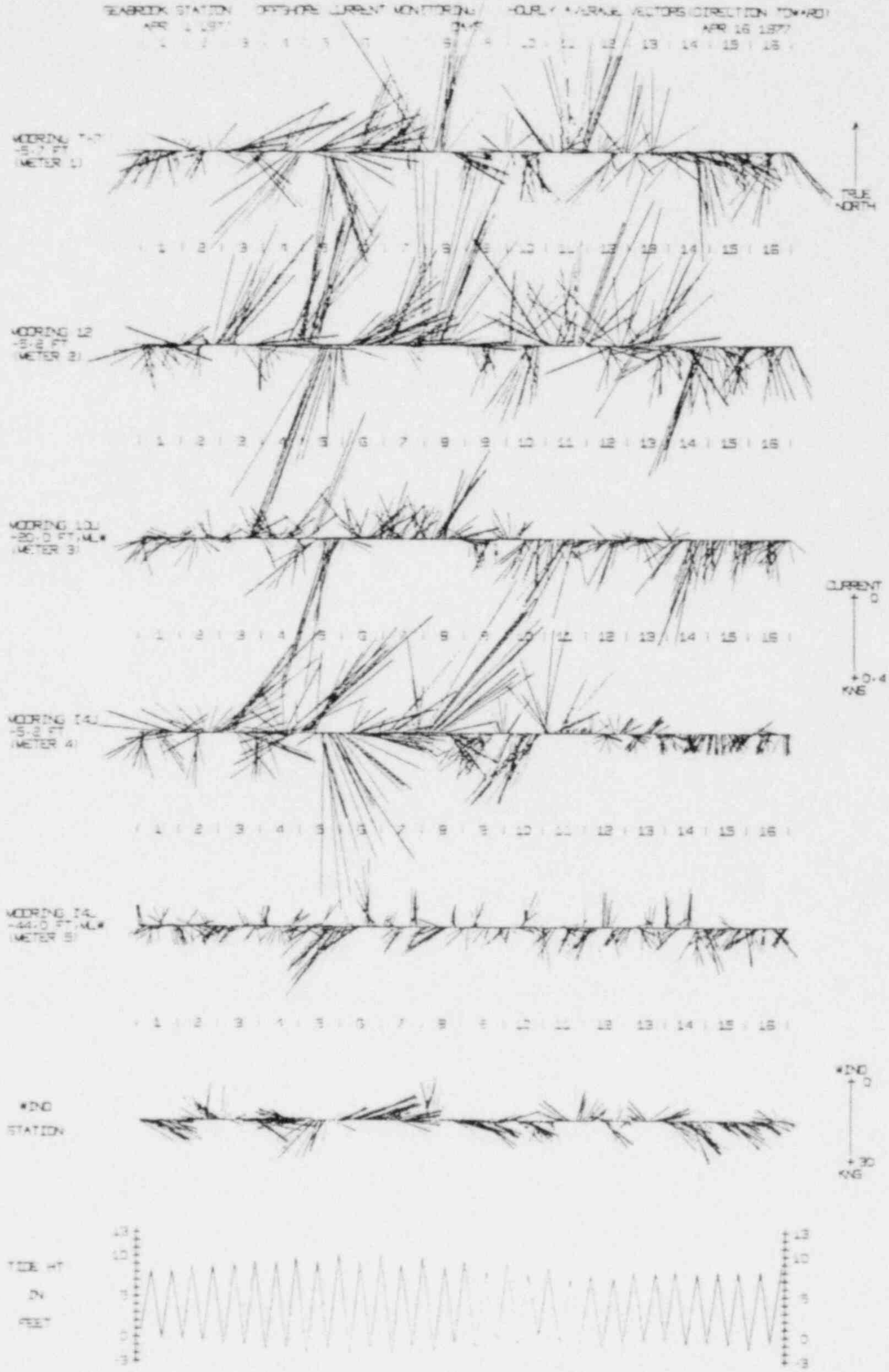
Figure 7.5-5. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for March 1 to 16, 1977.

Seabrook 1977 Annual Hydrographic Report, 1979.



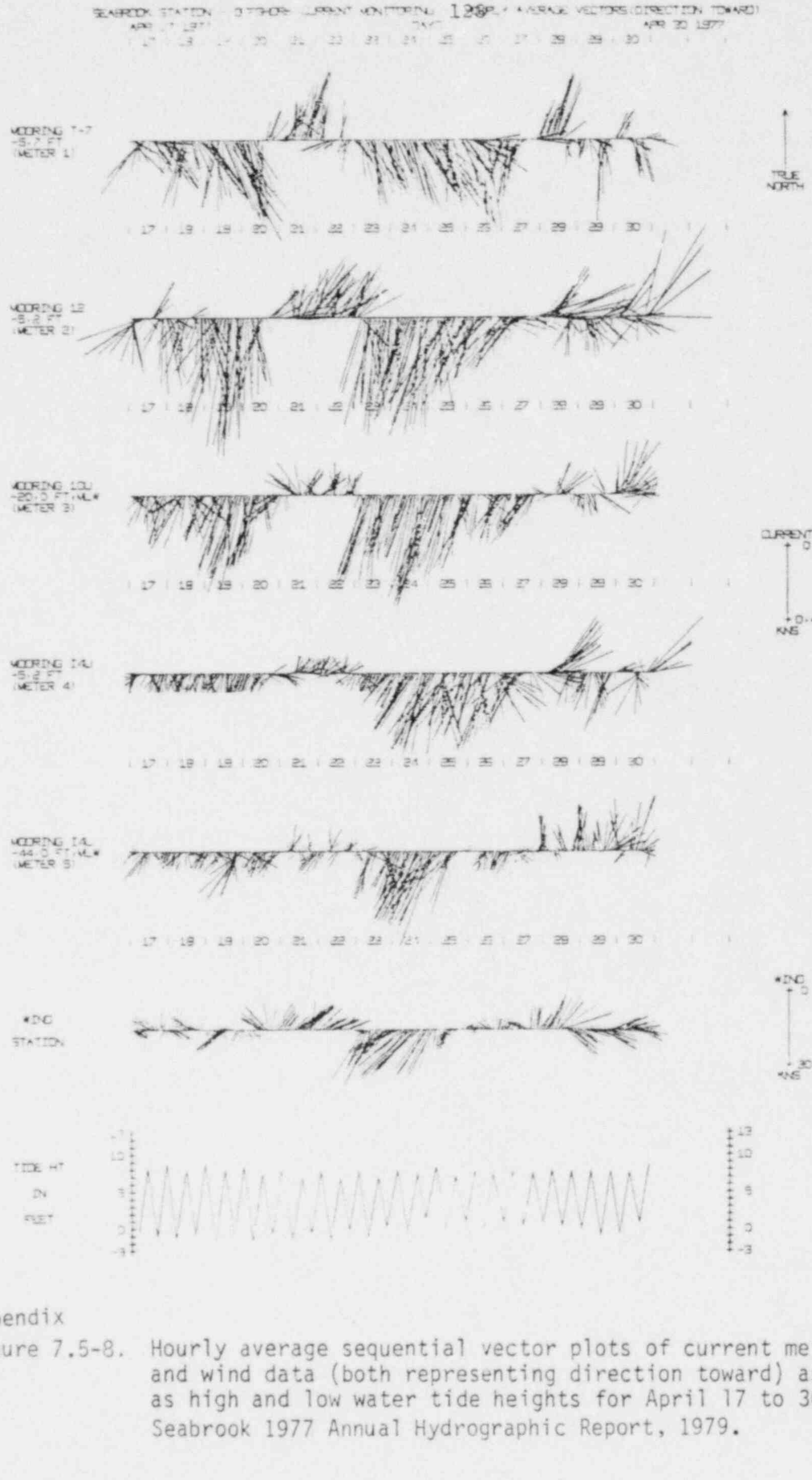
Appendix

Figure 7.5-6. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for March 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



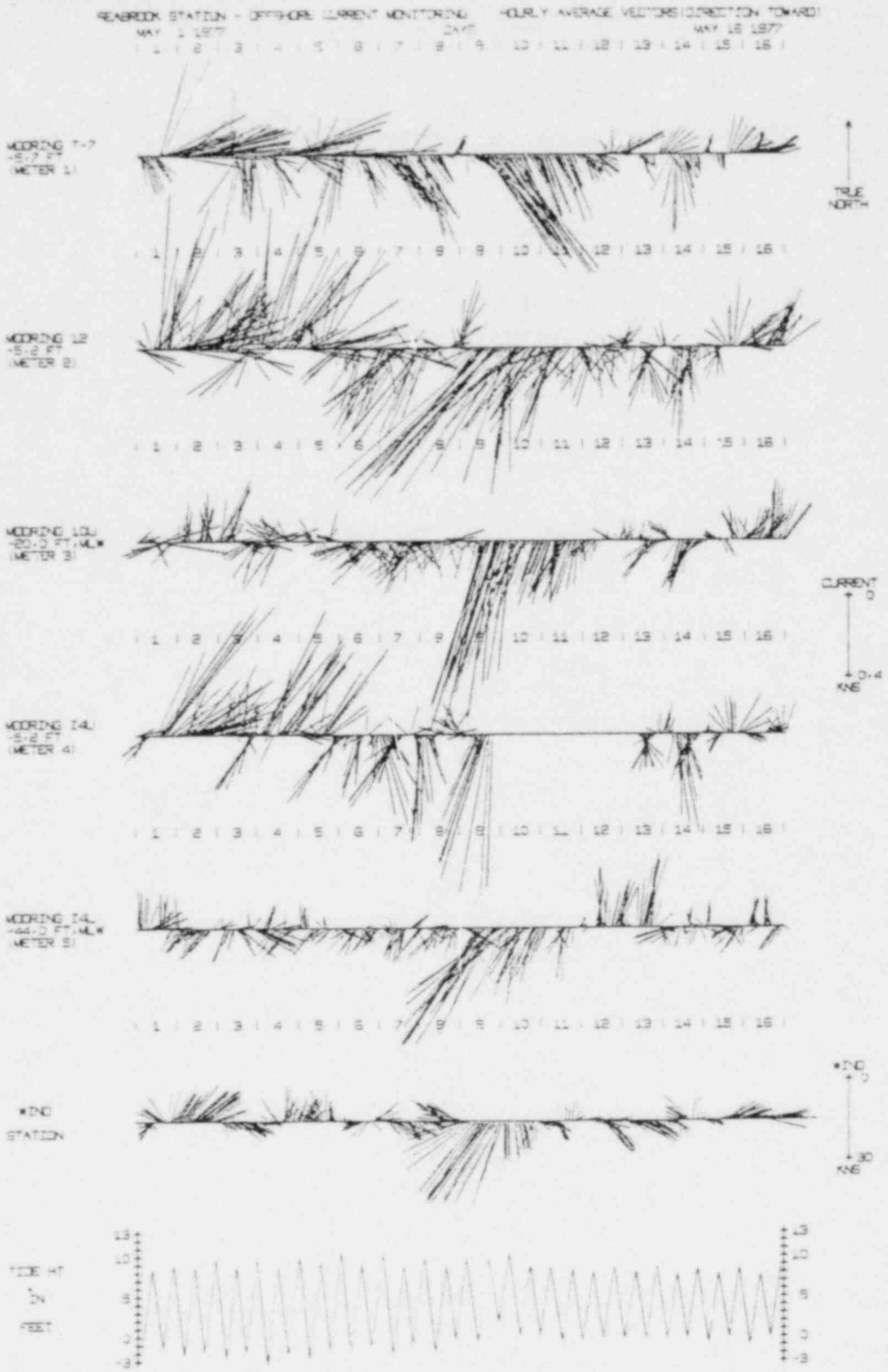
Appendix

Figure 7.5-7. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for April 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

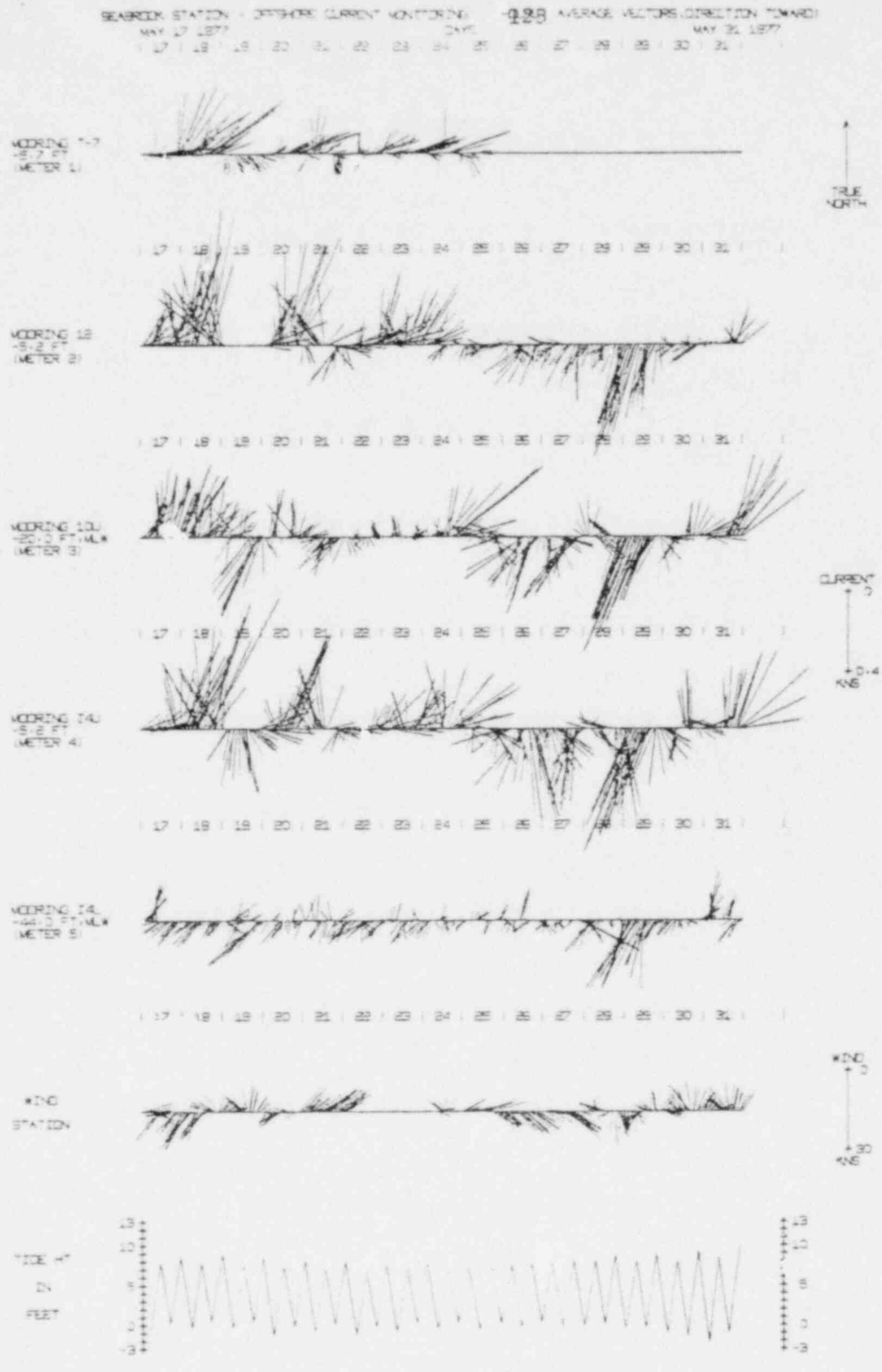


Appendix

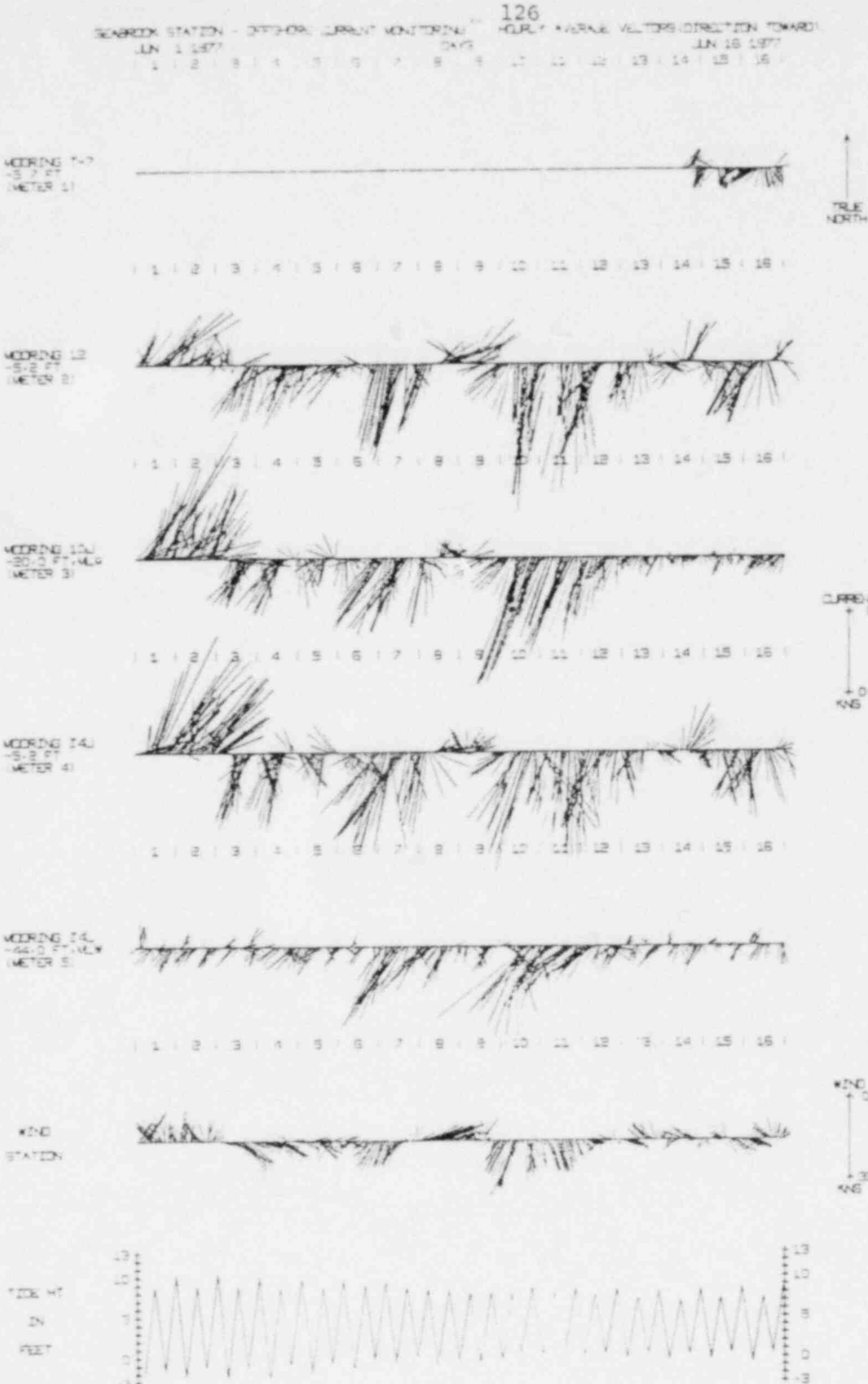
Figure 7.5-8. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for April 17 to 30, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-9. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for May 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

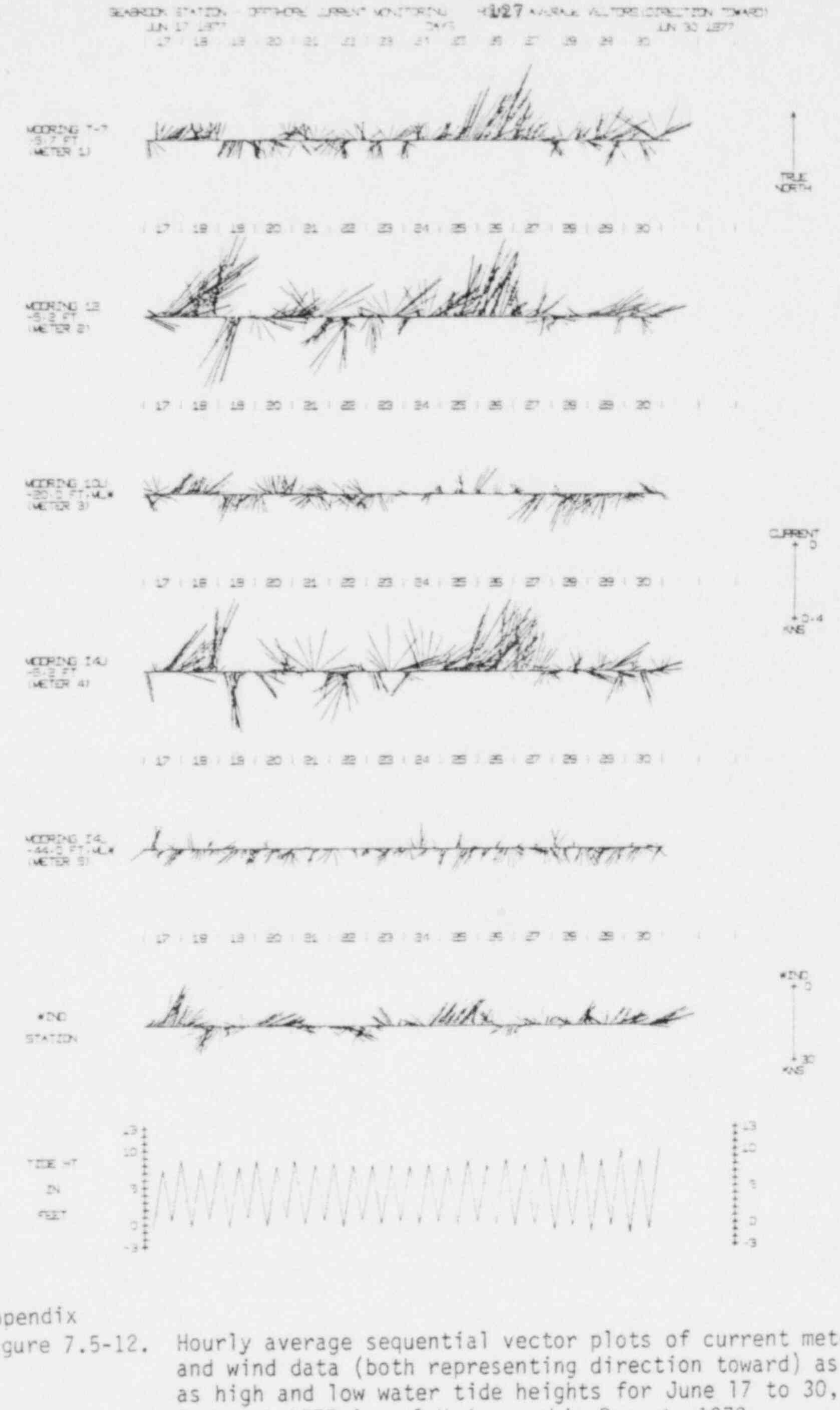


Appendix
Figure 7.5-10. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for May 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

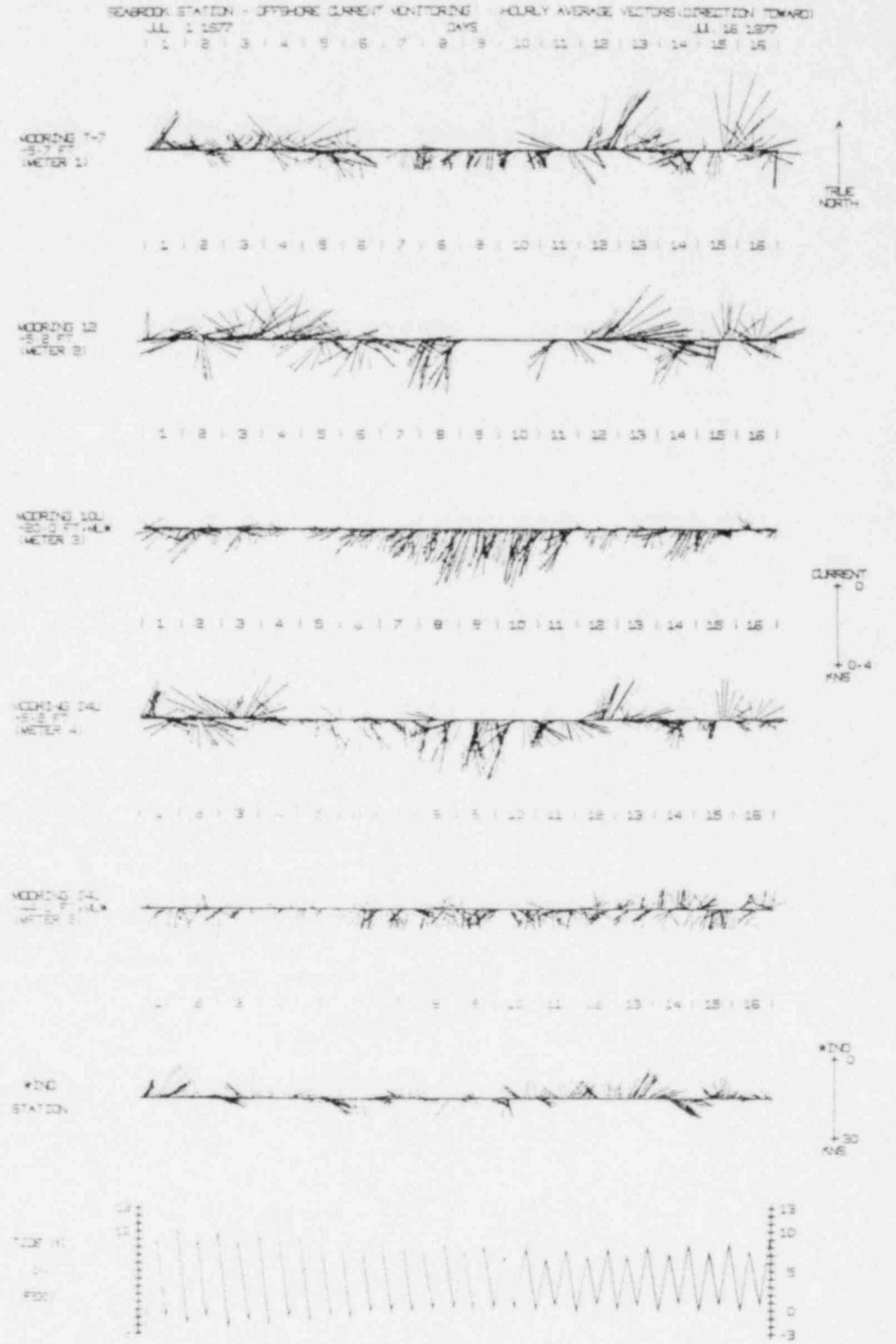


Appendix

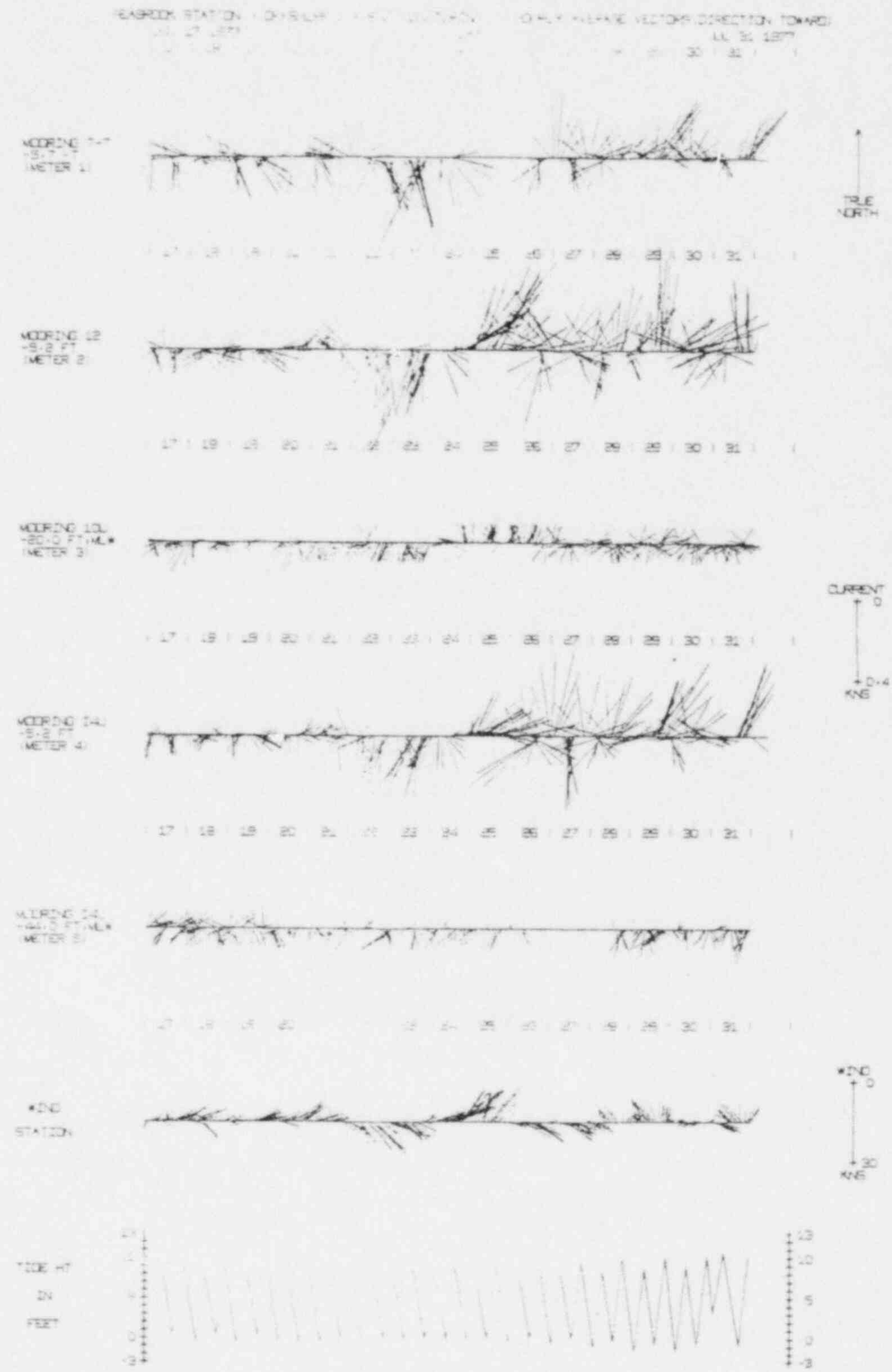
Figure 7.5-11. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for June 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



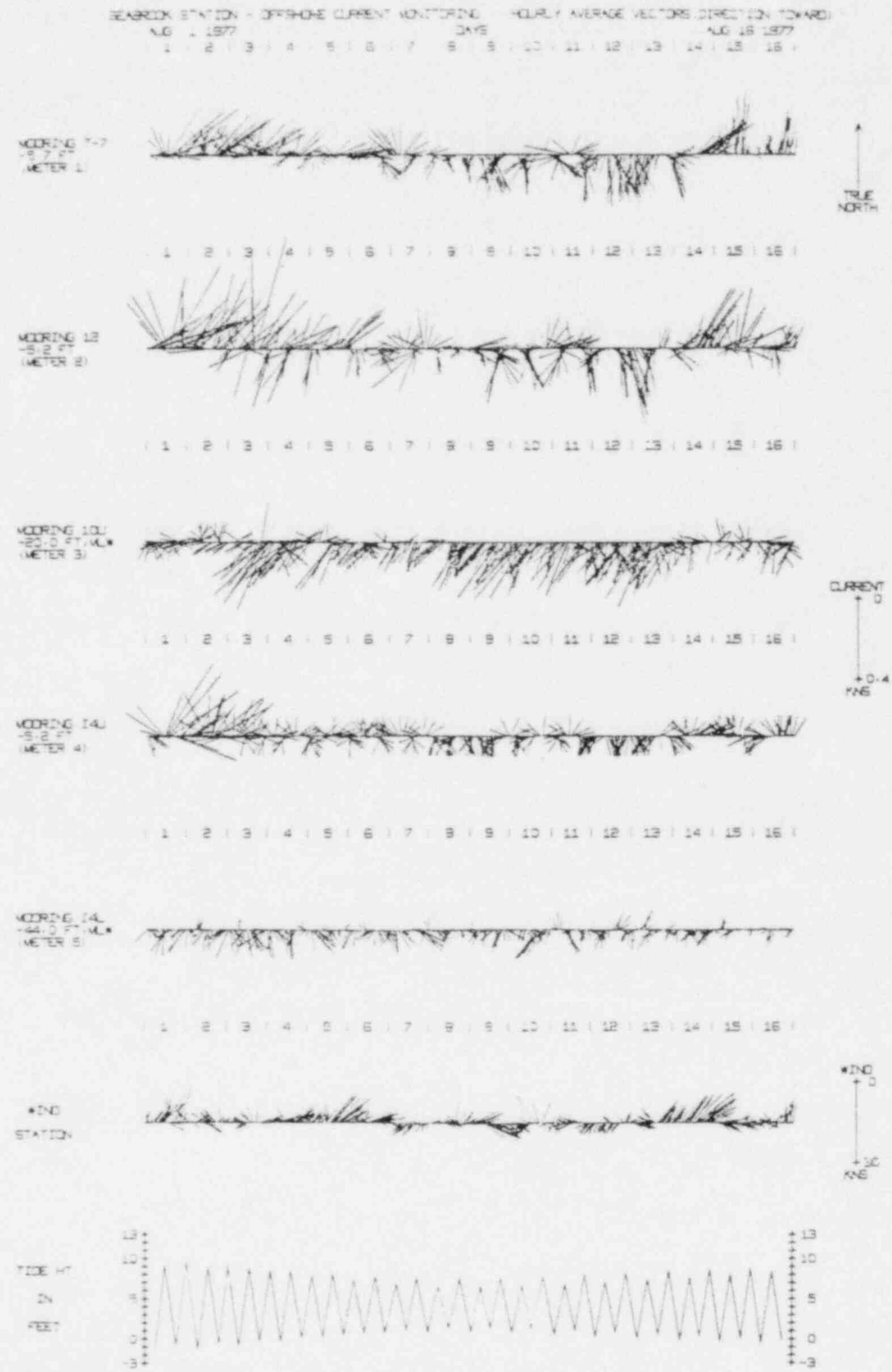
Appendix
Figure 7.5-12. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for June 17 to 30, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-13. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for July 1 to 16, 1977.
Seabrook 1977 Annual Hydrographic Report, 1979.

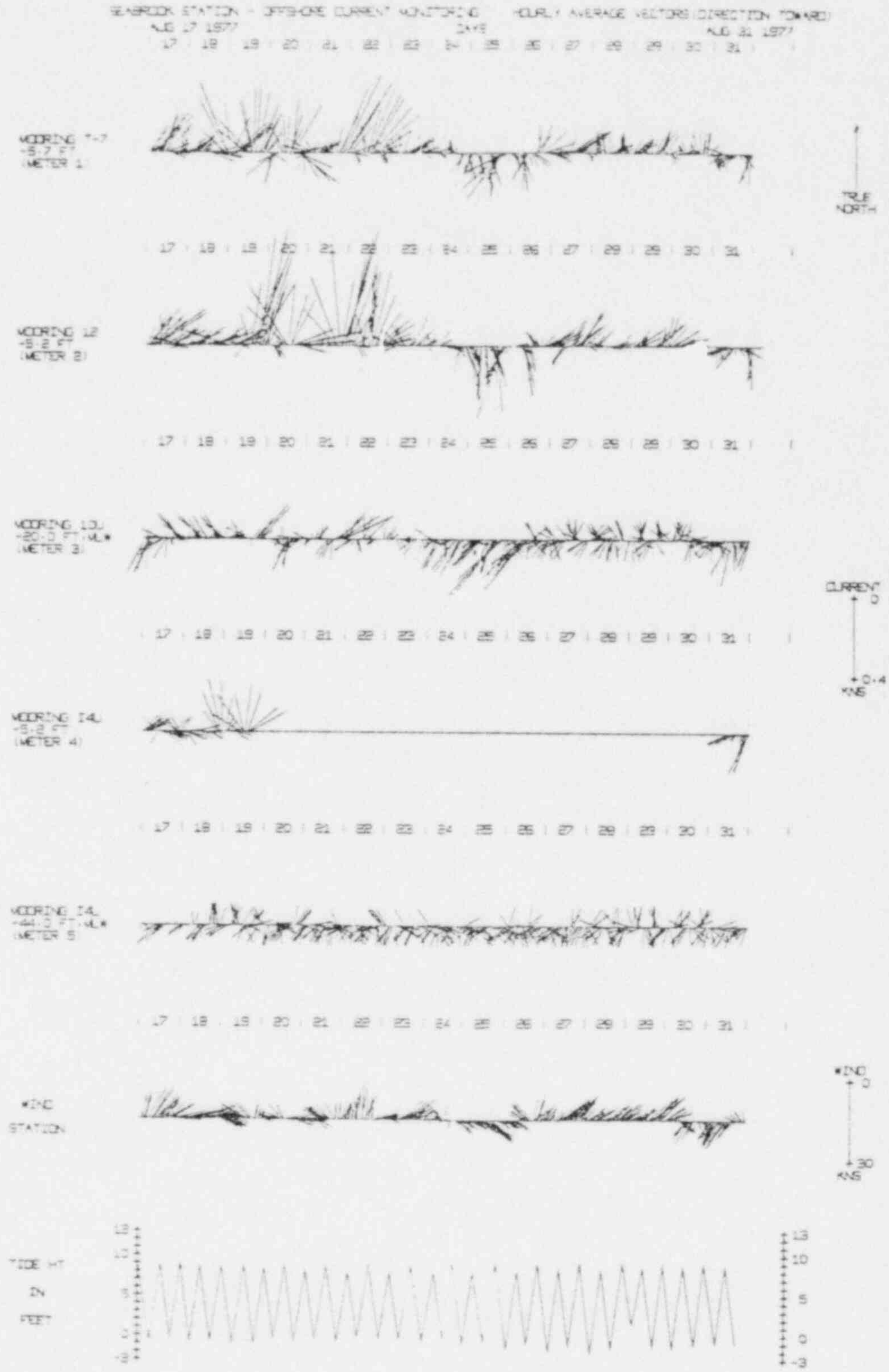


Appendix
Figure 7.5-14. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for July 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

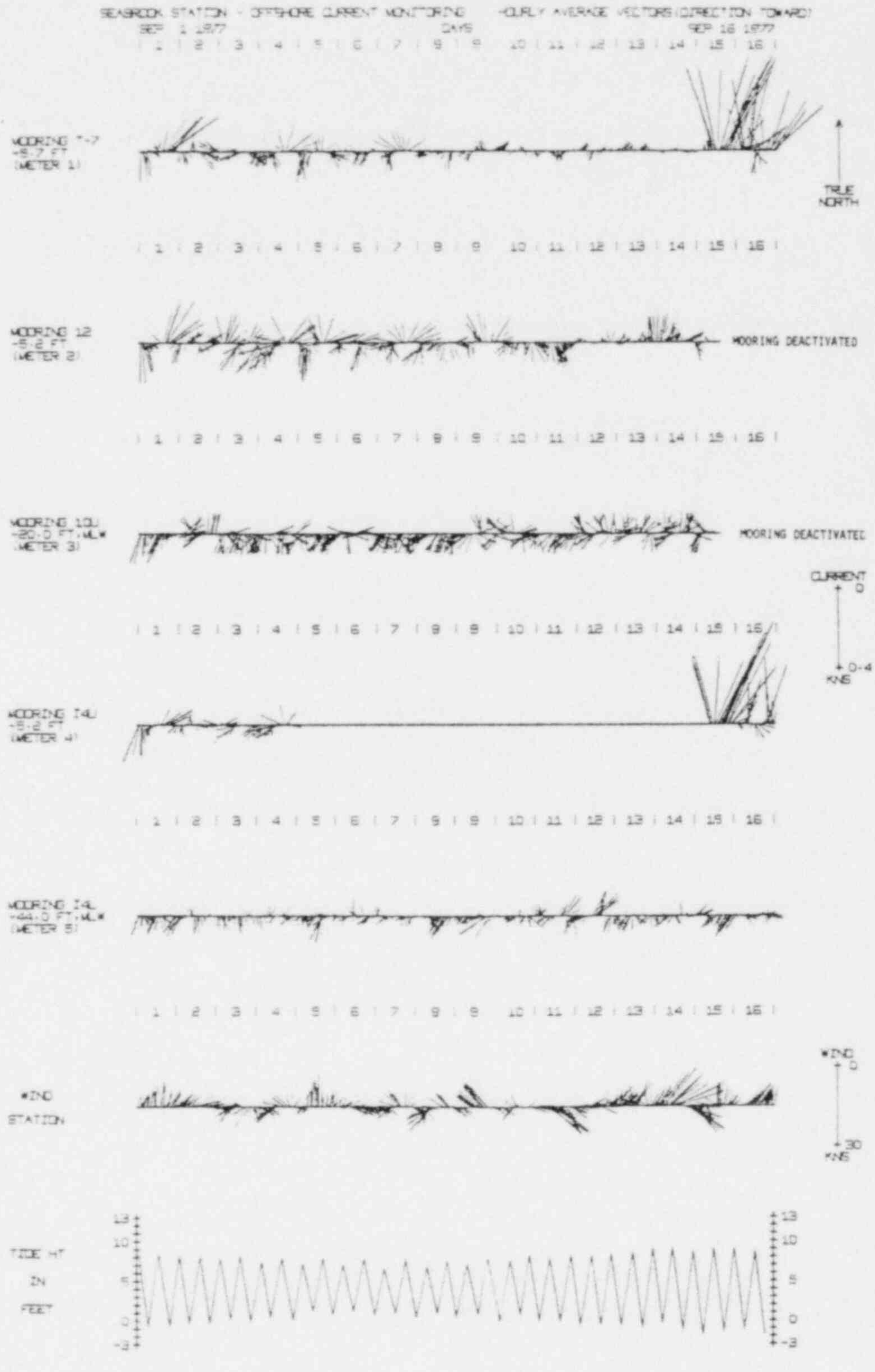


Appendix

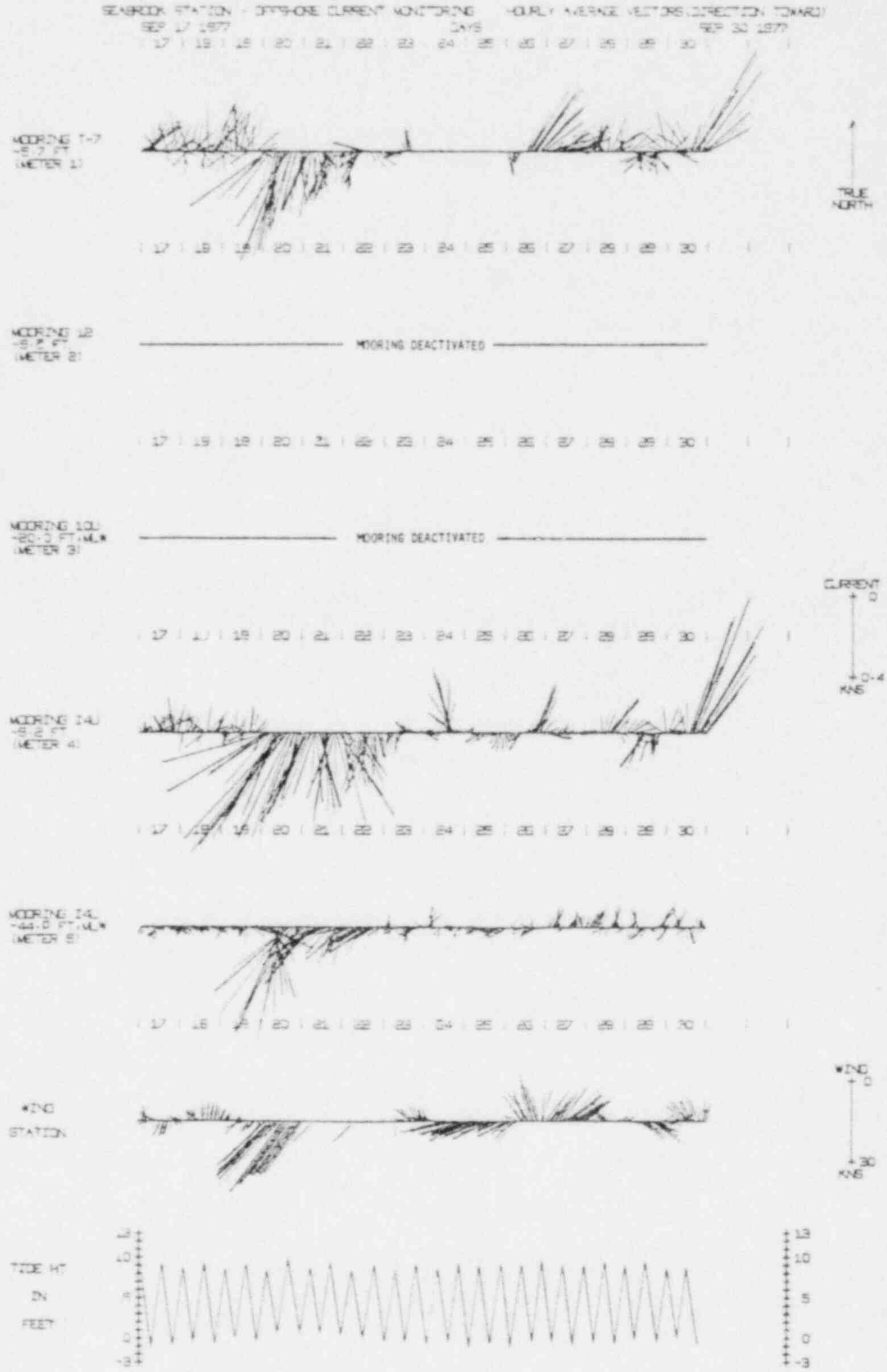
Figure 7.5-15. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for August 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



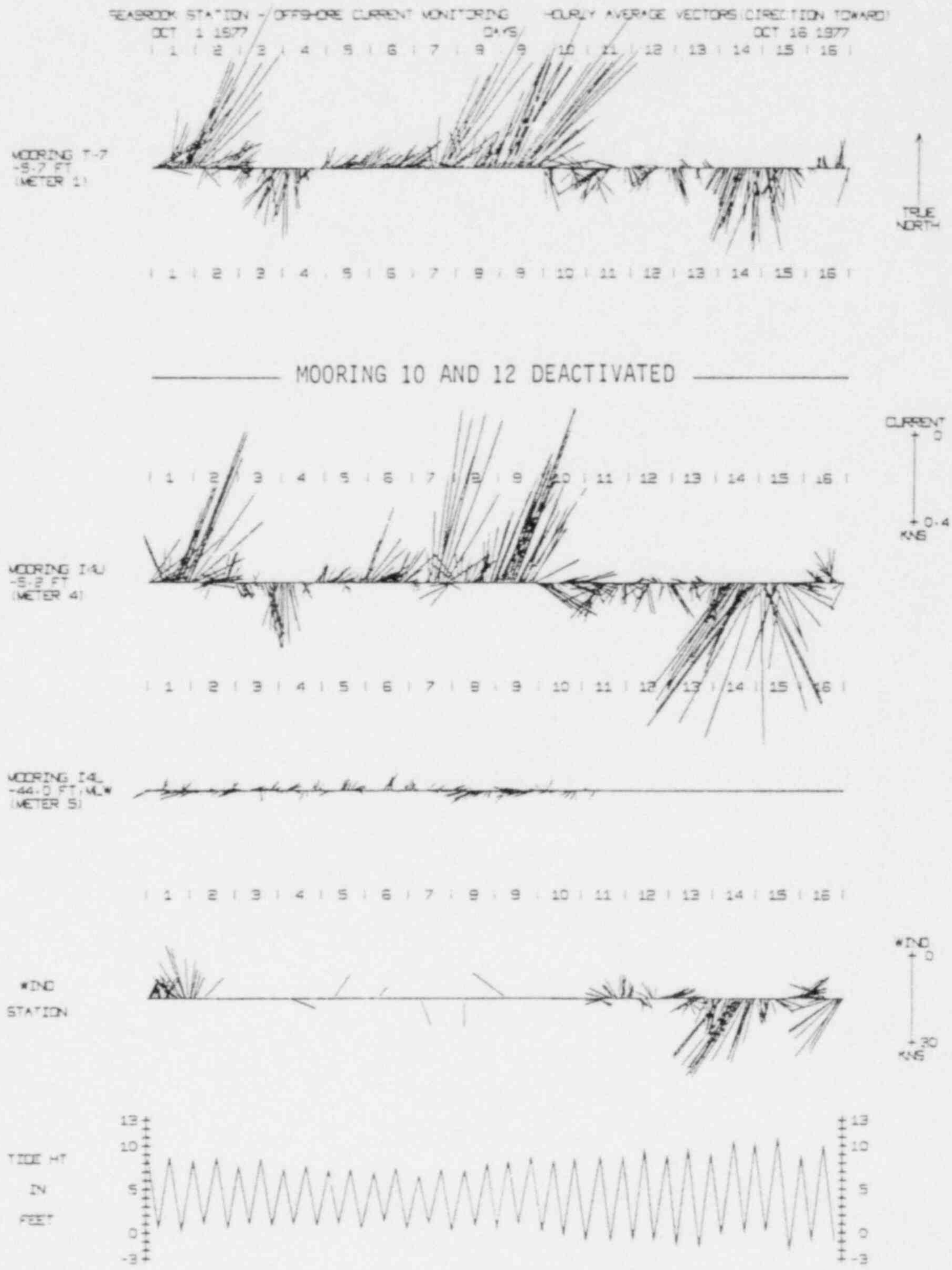
Appendix
Figure 7.5-16. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for August 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



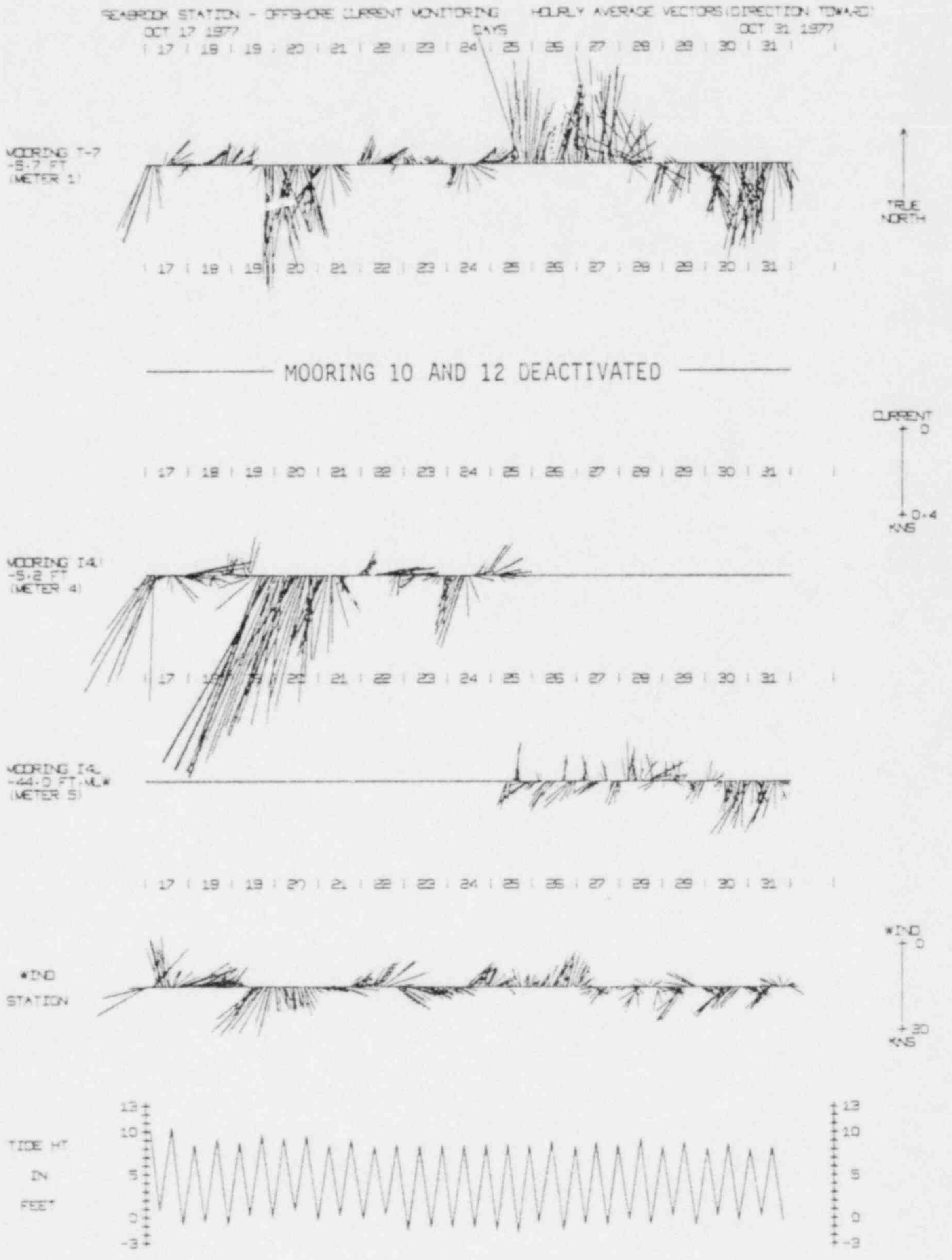
Appendix
Figure 7.5-17. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for September 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-18. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low water tide heights for September 17 to 30, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

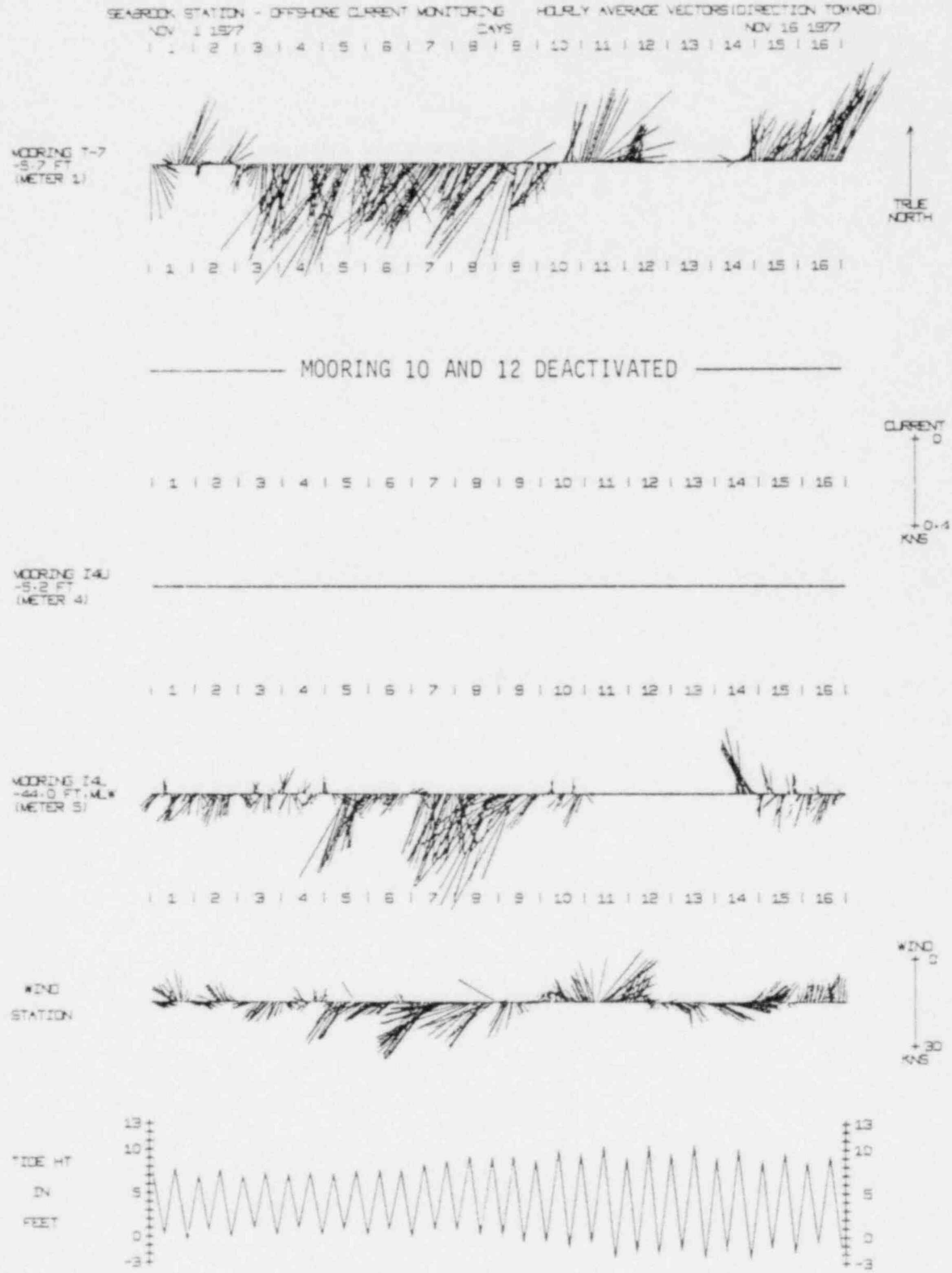


Appendix
Figure 7.5-19. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for October 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



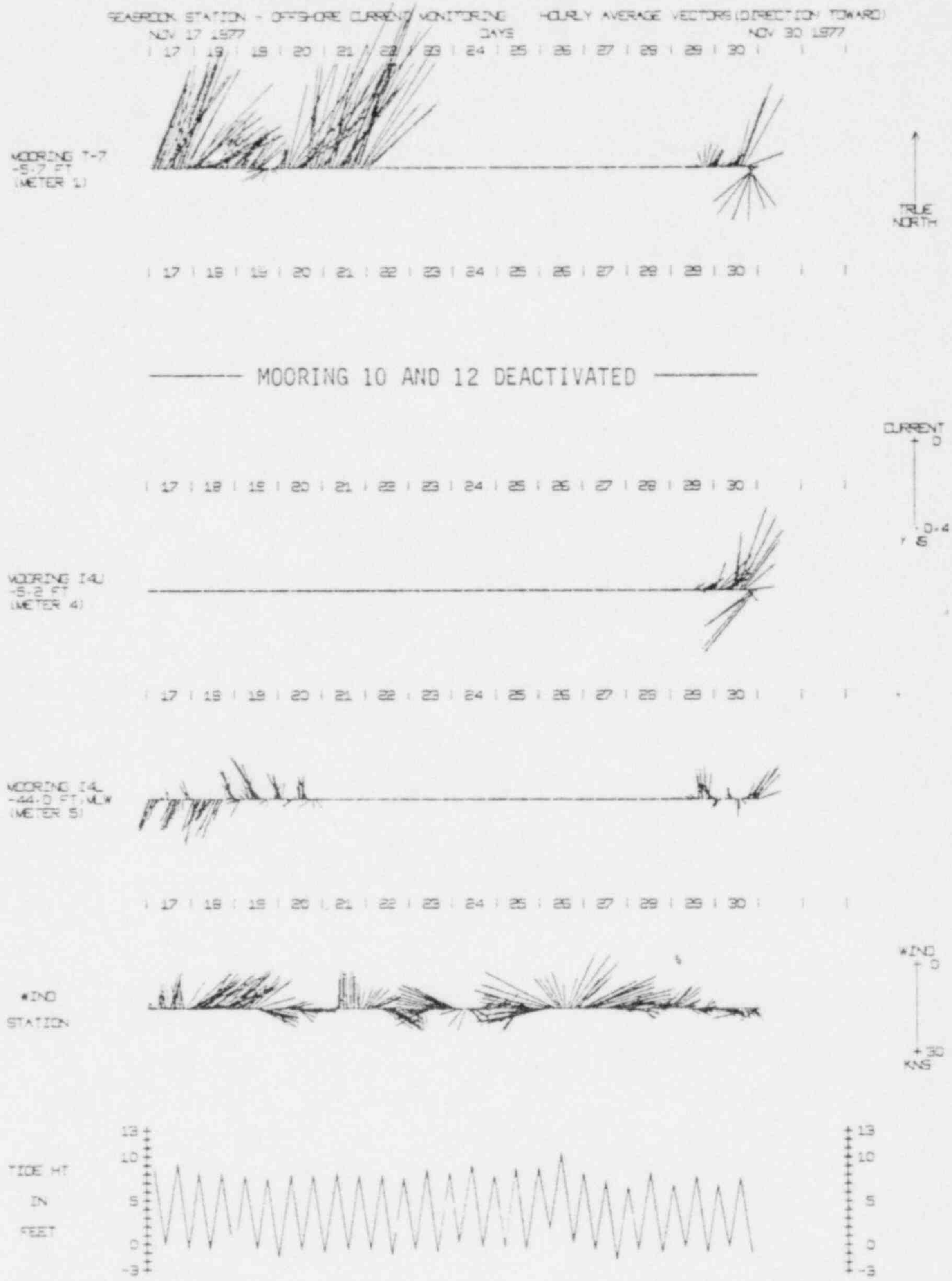
Appendix

Figure 7.5-20. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for October 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.

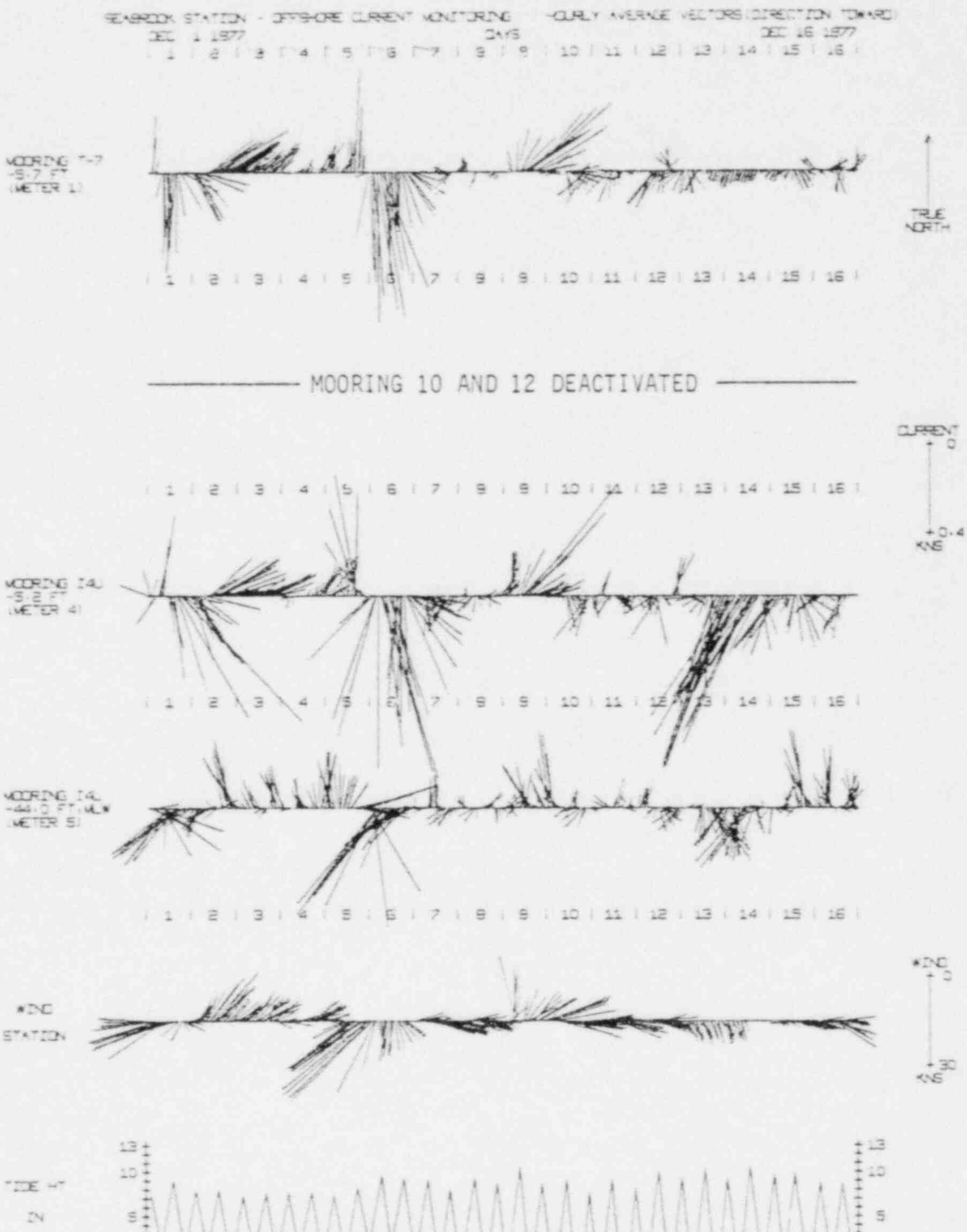


Appendix

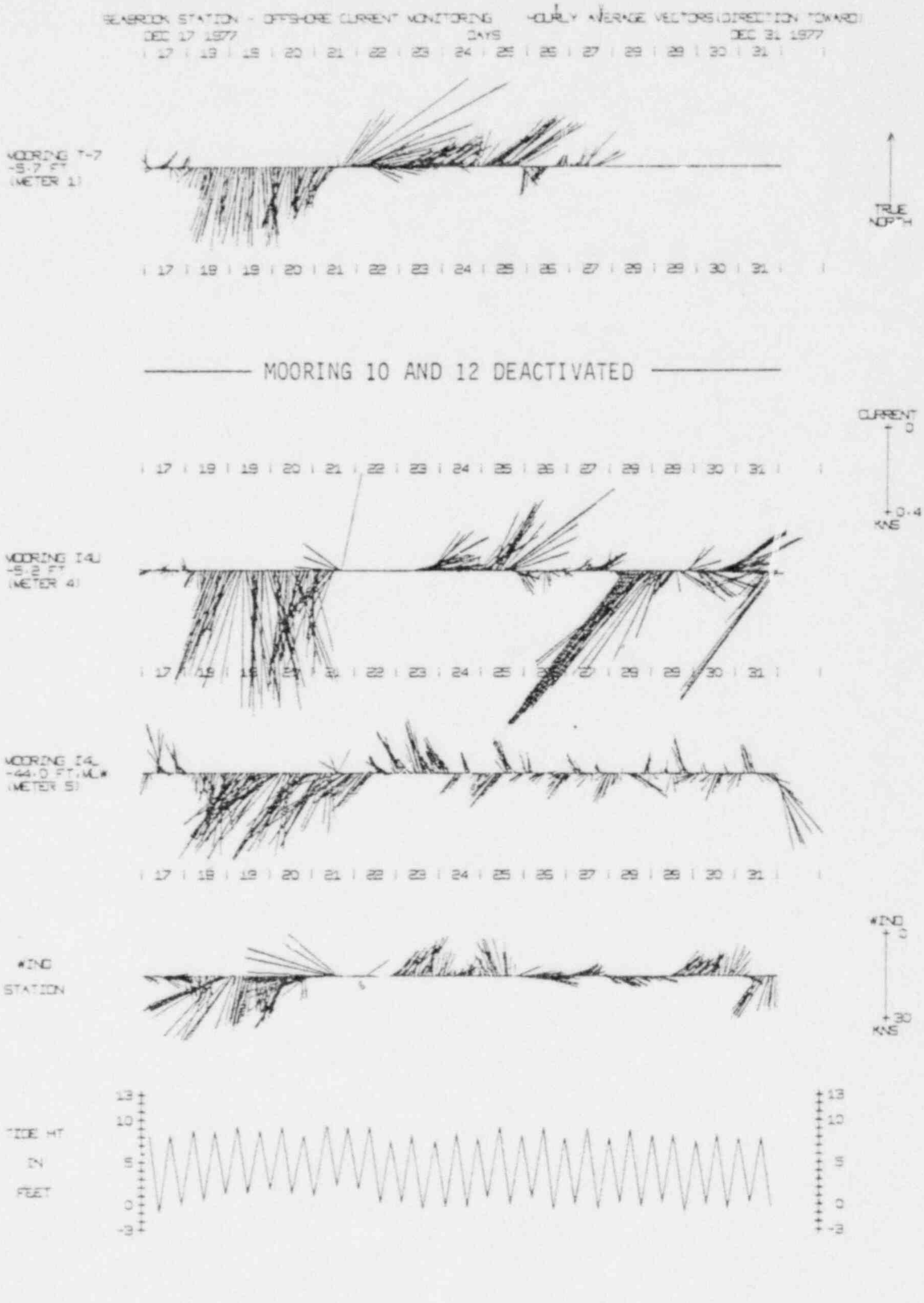
Figure 7.5-21. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for November 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-22. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for November 17 to 30, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-23. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for December 1 to 16, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.



Appendix
Figure 7.5-24. Hourly average sequential vector plots of current meter data and wind data (both representing direction toward) as well as high and low tide heights for December 17 to 31, 1977. Seabrook 1977 Annual Hydrographic Report, 1979.