WIDS

(WATERBORNE INTRUSION DETECTION SYSTEM)

ENVIRONMENTAL SUMMARY FOR THE NAVAL SUBMARINE BASE, BANGOR, WASHINGTON

FPO-1-78 (1)
OCTOBER 1977

OCEAN ENGINEERING
AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C. 20374

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

3. DISTRIBUTION AVAILABILITY OF REP.
Approved for public release; distribution is unlimited

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER
FPO 7801

5. MONITORING ORGANIZATION REPORT #

6a. NAME OF PERFORM. ORG.
Ocean Engineering
& Construction
Project Office
CHESNAVFACENGCOM

6b. OFFICE SYM

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and Zip Code)
BLDG. 212, Washington Navy Yard
Washington, D.C. 20374-2121

7b. ADDRESS (City, State, and Zip)

8a. NAME OF FUNDING ORG.

8b. OFFICE SYM

9. PROCUREMENT INSTRUMENT INDENT #

8c. ADDRESS (City, State & Zip)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT #	PROJECT #	TASK #	WORK UNIT ACCESS #

11. TITLE (Including Security Classification)
WIDS (Waterborne Intrusio Detection Syetem) Environmental Summary for the Naval Submarine Base, Bangor, Washington

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT

13b. TIME COVERED FROM TO

14. DATE OF REP. (YYMMDD) 10/77

15. PAGES 28

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if nec.)
WIDS, Waterborne Intrusion Detection System, Naval Submarine Base, Bangor, WA;

19. ABSTRACT (Continue on reverse if necessary & identify by block number)
Presented herein is a summary of environmental information for the TRIDENT Refit Facility (TRF), at the Naval Submarine Base (NSB), Bangor, Washington. The base is located on the Hood Canal, which is part of the Puget Sound estuary system. An effort is made to present quantitative information (Con't)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
SAME AS RPT.

21. ABSTRACT SECURITY CLASSIFICATIOI

22a. NAME OF RESPONSIBLE INDIVIDUAL
Jacqueline B. Riley

22b. TELEPHONE
202-433-3881

22c. OFFICE SYMBOI

DD FORM 1473, 84MAR

SECURITY CLASSIFICATION OF THIS PAGI

BLOCK 19 (Con't)

in a concise fashion regarding a variety of environmental factors. Some developmental history or explanation is provided only when it is necessary to clarify a particular phenomenon. In general, this summary is intended to be a reference handbook rather than a detailed narrative or environmental phenomena.

ILLUSTRATIONS

TABLES

I. INTRODUCTION

Presented herein is a summary of environmental information for the TRIDENT Refit Facility (TRF), at the Naval Submarine Base (NSB), Bangor, WA ~~Washington (Figure 1)~~. The base is located on the Hood Canal, which is part of the Puget Sound estuary system. An effort is made to present quantitative information in a concise fashion regarding a variety of environmental factors. Some developmental history or explanation is provided only when it is necessary to clarify a particular phenomenon. In general, this summary is intended to be a reference handbook rather than a detailed narrative on environmental phenomena. Keywords: WIDS (Waterborne Intrusion Detection System).

II. DAILY CURRENT PREDICTIONS

In estuaries dominated by tidal flow, it is possible to predict accurately the general tenor of currents as a function of time. This can be done for the TRF on the Hood Canal. For the Bangor area of Hood Canal, tidal currents are referenced to specific predictions for Admiralty Inlet. These predictions appear annually in the Tidal Current Tables (Pacific Coast of North America and Asia), published by the U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA).

Factors can be given so that the Admiralty Inlet predictions can be adjusted to make them applicable to the TRIDENT site. The tidal current at Bangor, both ebb and flood, will appear 45 minutes earlier and will be 35 percent of the values predicted for Admiralty Inlet. The average values for the Bangor area based on theoretical predictions are 0.5 knot for flood tide and 0.9 knot for ebb tide. The current direction (mid-channel) for full flowing flood will be 205 degrees true and for ebb 025 degrees true. These values are comparable with the results of the TRF Current Survey conducted by the Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM (Code FPO-1)) during the 1976 to 1977 time period.

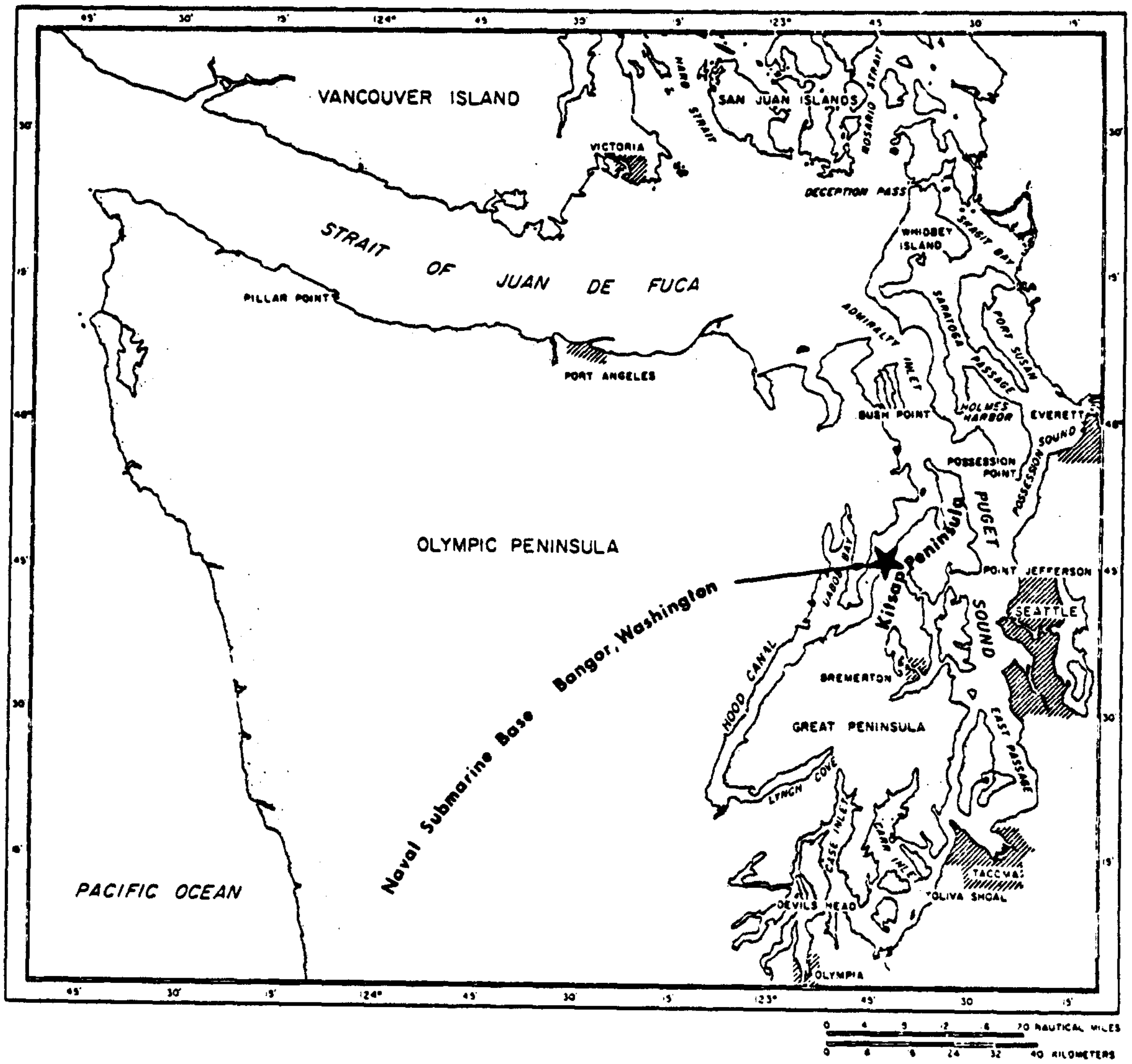


Figure 1. Location of Naval Submarine Base (NSB), Bangor, Washington

III. METEOROLOGY AND CLIMATOLOGY

The NSB is located on the northwestern side of the Kitsap Peninsula (Figure 1). Air flow patterns in this region are affected by the Olympic Mountains, which prevent direct air flow from the Pacific Ocean. Although this region has occasionally severe weather, the area winds are generally light.

The prevailing winds are from the northeast, creating a marine air flow regime where air is channeled through the Puget Sound and down the Hood Canal to the Bangor area, as seen in Figure 2. Nighttime summer winds are light and tend to be southerly. The primary driving force for the evening summer circulation is the nocturnal air drainage off local land masses (Figure 3). In winter, the temperature differential between land and water is reduced, there is a continuous supply of cold air from the snow fields, and a nearly continuous downslope air flow.

Unfortunately, no continuous meteorological data base is available. Therefore, a statistical summary for the Hood Canal (Bangor area) cannot be provided. In spite of this, some documentation is available for a severe weather event. On February 16 and 17, 1972, there was a 7-hour period, from 2100 on the 16th to 0400 on the 17th, when the lowest recorded wind speed was 40.2 km/hr (25 mph). During this period, the lowest mean hourly wind was 64.4 km/hr (40 mph). Between 0000 and 0100, winds averaged more than 96.5 km/hr (60 mph). Gusts were in excess of 128.7 km/hr (80 mph), and a few gusts exceeded 144.8 km/hr (90 mph). This appears to have been one of the longest intense windy periods recorded in inland Washington.

In Figure 4, the annual march of air temperature is shown for monthly means, maximums, and minimums. The mean temperature for the year is 10° C (50.1° F). Fog probability is presented in Figure 5a. Maximum fog occurs in the September-to-February period; October is the worst month for fog formation. Fog is often prefrontal in nature, but

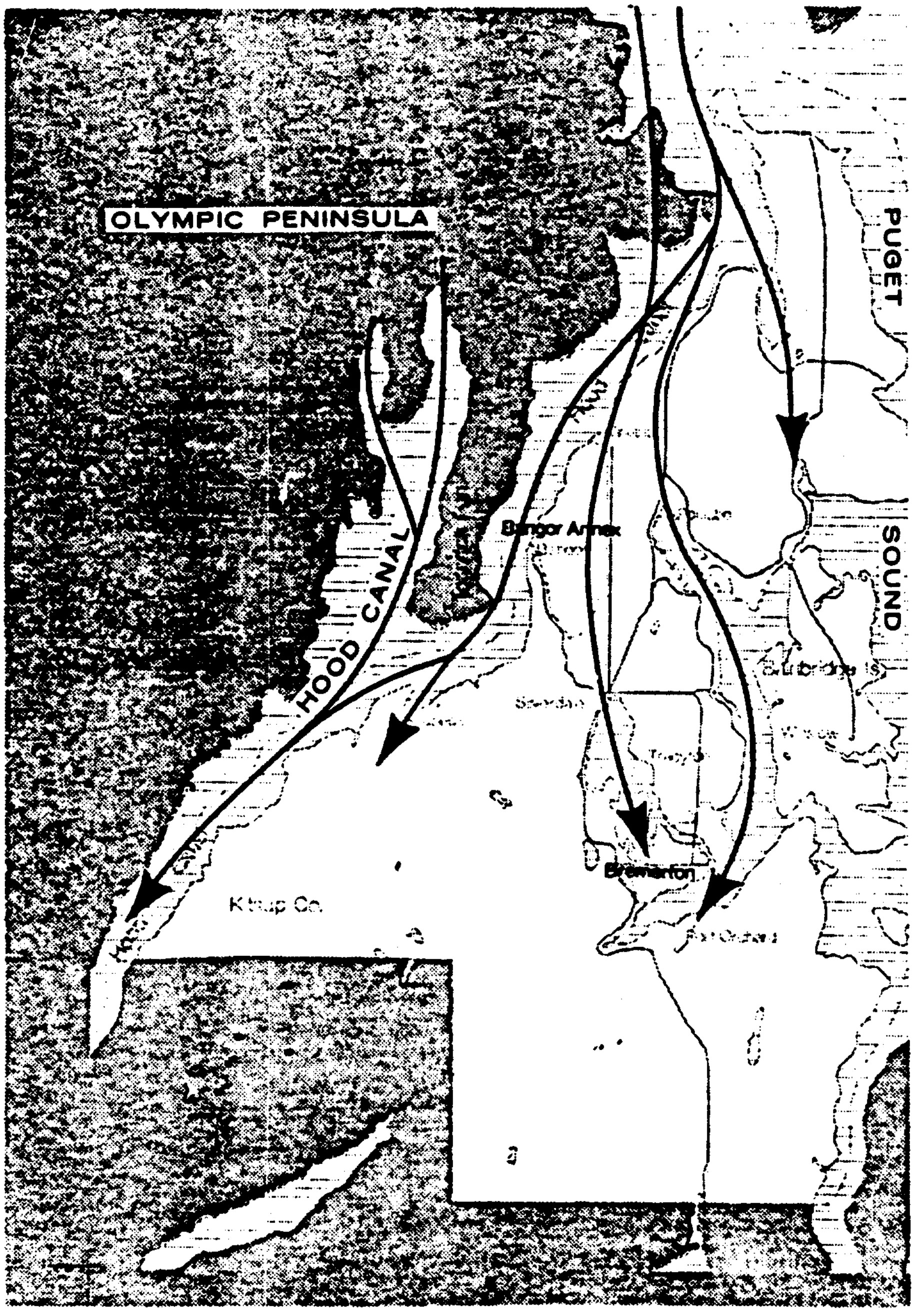


Figure 2. Daytime Streamlines Under Fully-Developed Marine Air Flow Regime

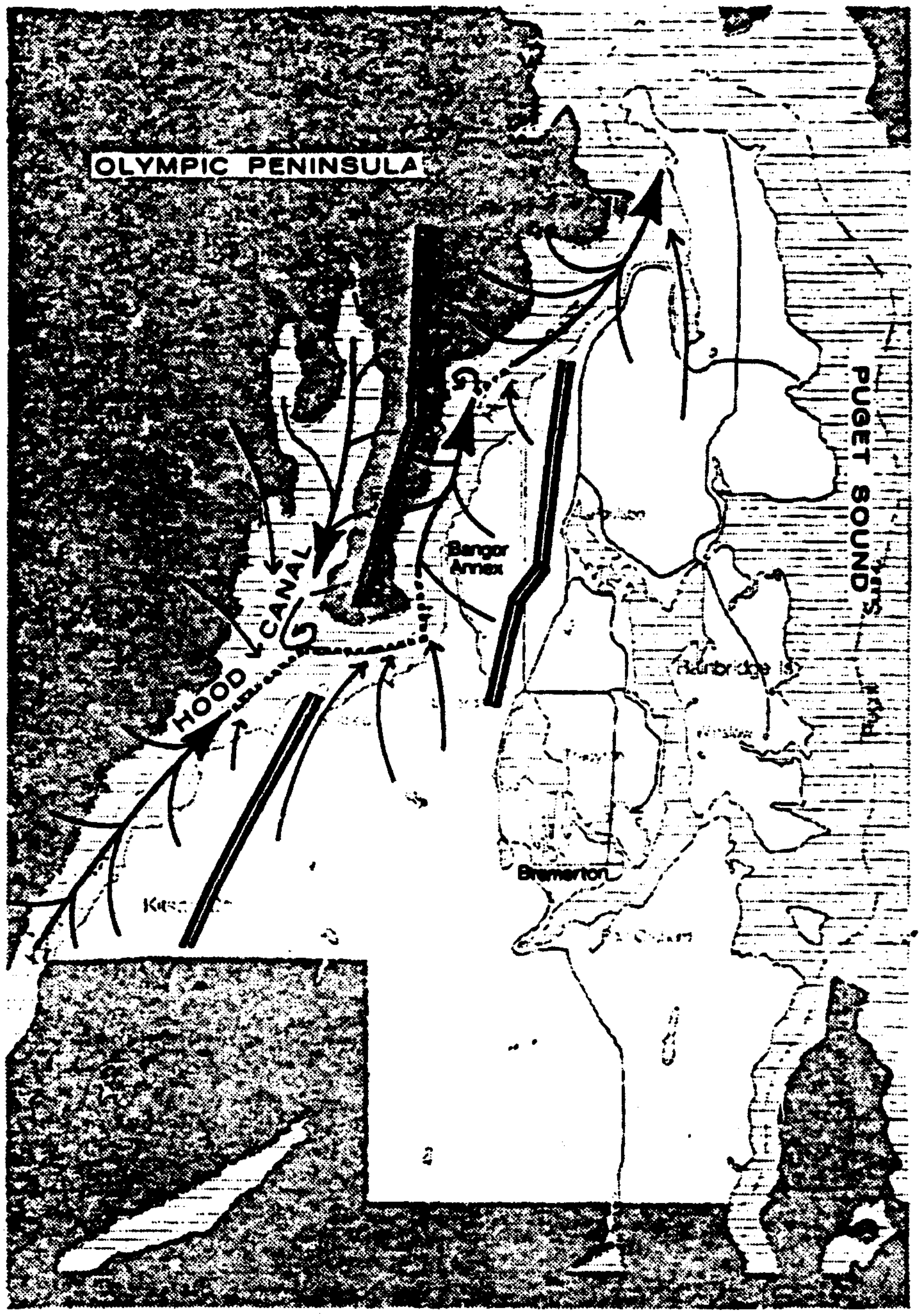


Figure 3. Nighttime Streamlines Under Fully-Developed Drainage Wind Regime

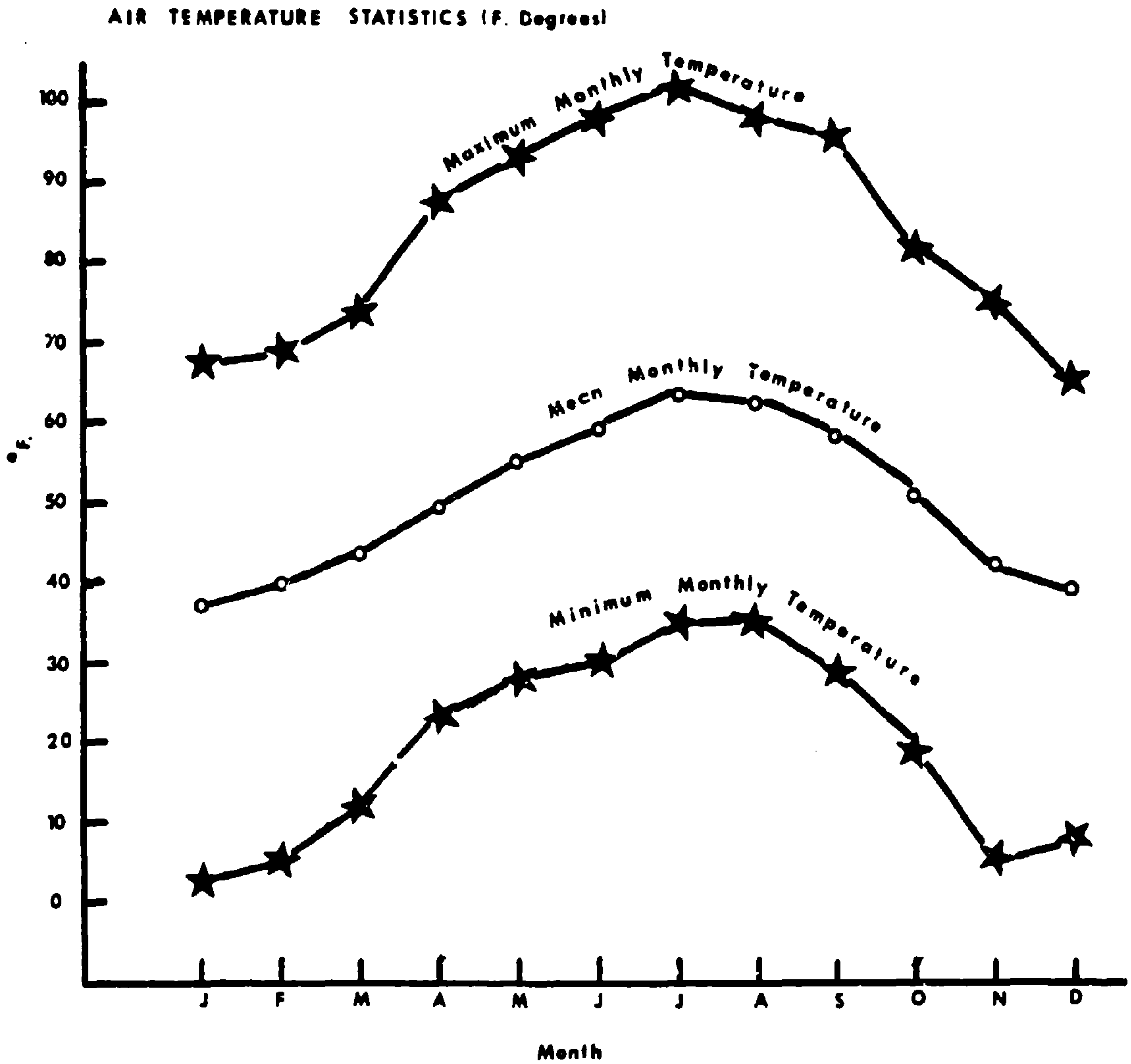
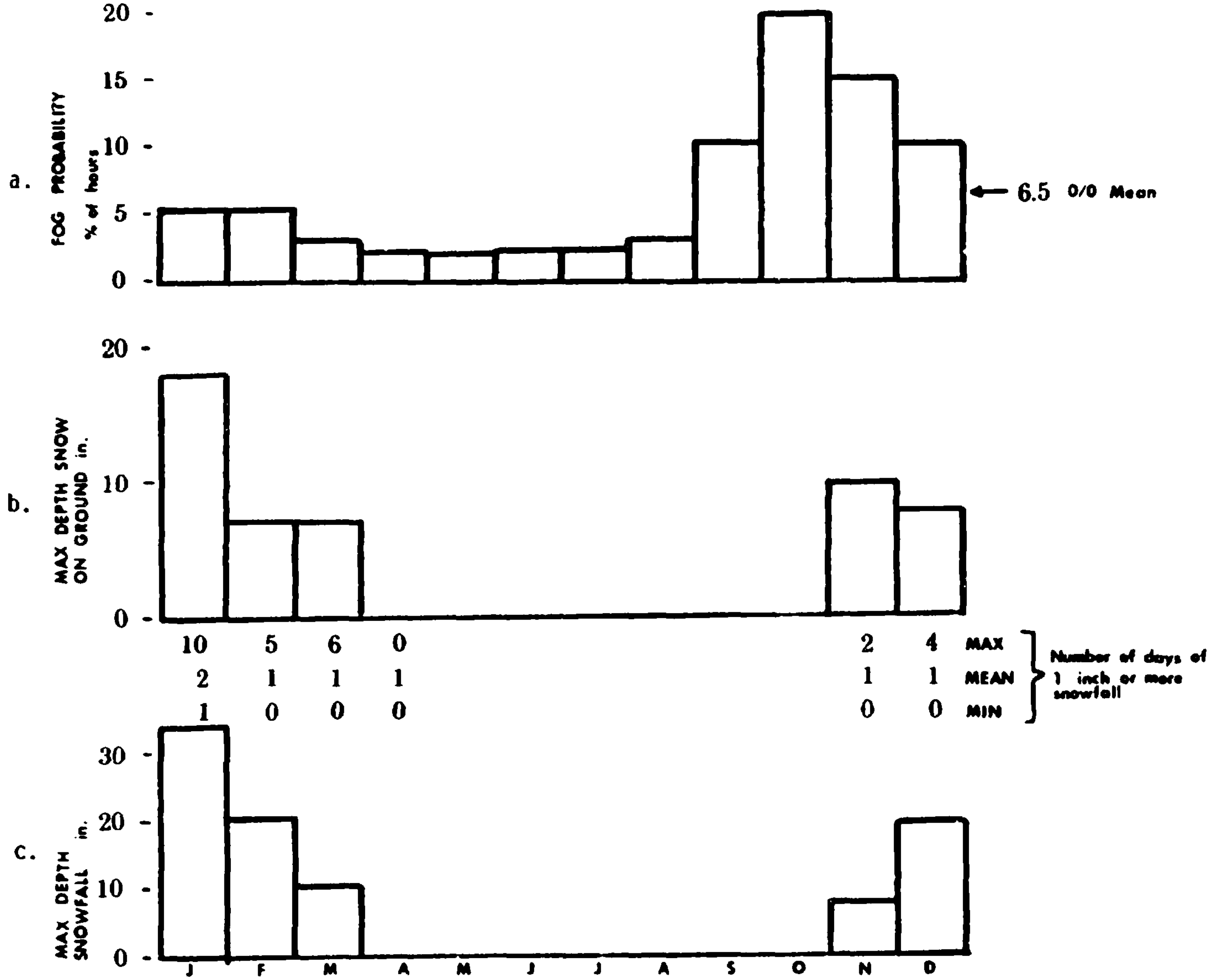


Figure 4. Annual March of Monthly Air Temperature Statistics



Figures 5a. Fog Probability Histogram (By Month)
5b. Maximum Depth of Snow on Ground (Monthly)
5c. Maximum Depth of Snowfall (By Month)

is also caused by the local driving forces. In the late fall and winter, air will increase in temperature during the day, pick up moisture from the Hood Canal, suffer radiative cooling at night, and form fog. Snow cover and snowfall statistics are given in Figures 5b and 5c. Snowfalls never exceed 3 feet and snow accumulation never exceeds 2 feet.

IV. HOOD CANAL SURFACE TEMPERATURE AT NSB, BANGOR

The annual march of Hood Canal surface temperature has a range from 6.5° C in March to 15° C in August, a difference of 8.5° C (Figure 6). Historical data indicate that the variance around the monthly means is greater during the warmer months of June, July, and August. This is indicated by the increased separation of the maximum and minimum extreme lines. The smallest variation in surface temperature appears in the month of November, when temperatures are between 9.5° C and 10.0° C. The mean monthly surface temperatures are:

Month	J	F	M	A	M	J	J	A	S
Temp ° C	8.03	7.60	7.73	8.94	10.38	12.90	13.43	13.68	12.80

	O	N	D
	11.37	9.70	8.71

The mean temperature for the year is 10.43° C.

V. HOOD CANAL VERTICAL TEMPERATURE STRUCTURE AT NSB, BANGOR

The vertical temperature structure at NSB, Bangor, varies during the year. In the spring and summer, the water is well-stratified with as much as 5° C difference between the surface and deep water (Figure 7). The water column during the fall, winter, and early spring ranges from quasi-homogeneous in temperature to a vertically-inverted temperature structure. Inversions do not exceed 1° C.

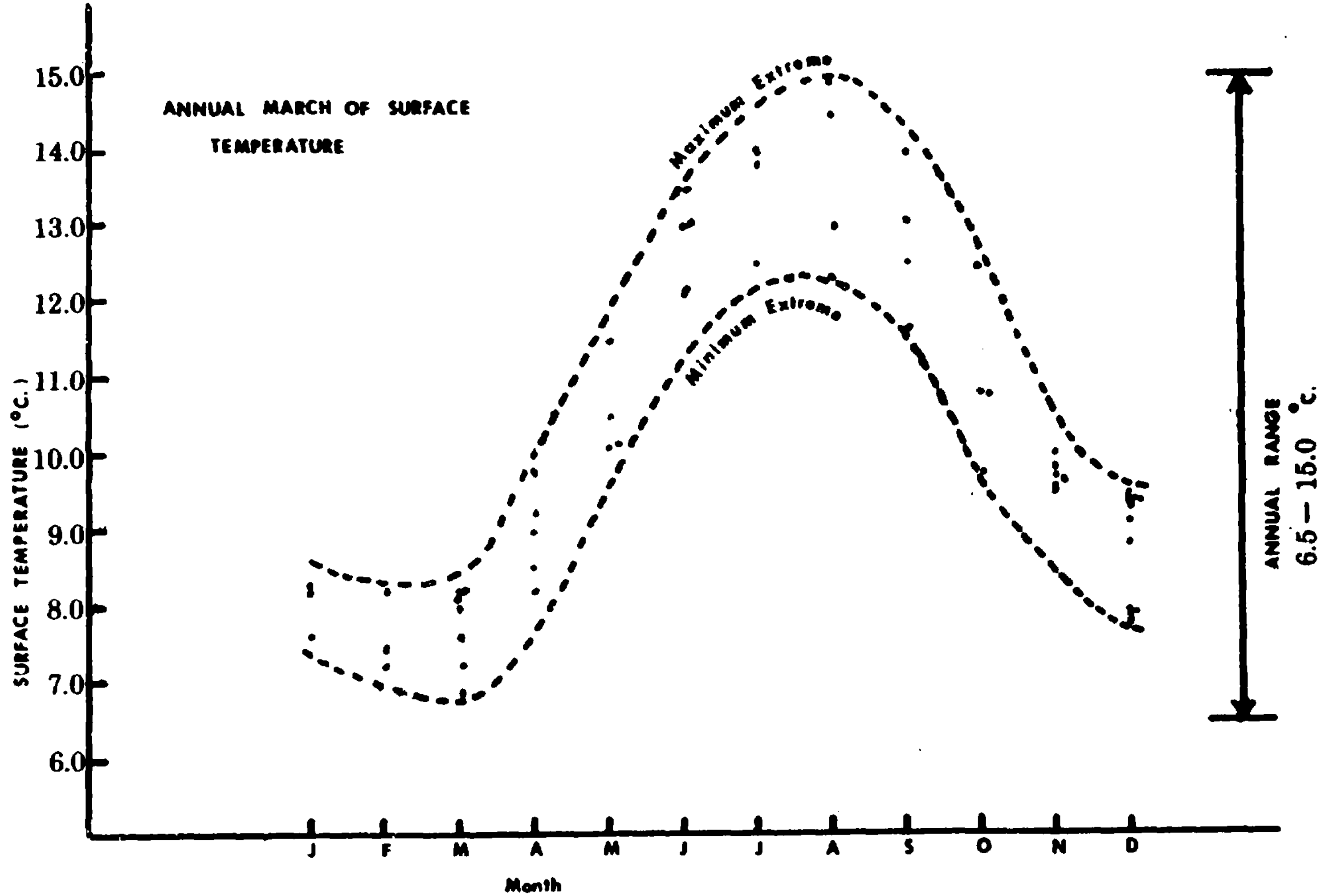


Figure 6. Annual March of Hood Canal Surface Temperature at NSB, Bangor

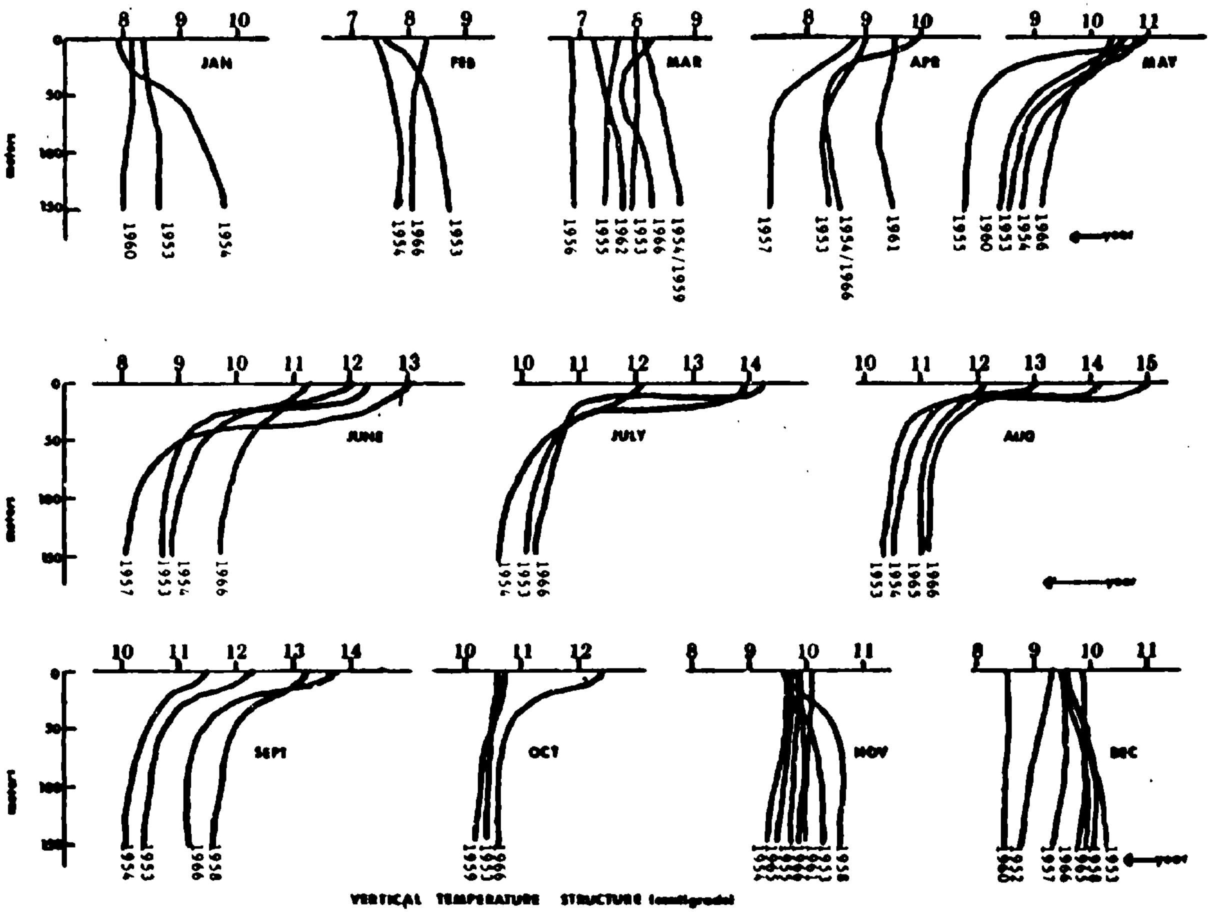


Figure 7. Vertical Temperature Structure of the Hood Canal at NSB, Bangor (Historical Traces by Month)

VI. HOOD CANAL OXYGEN AND INORGANIC PHOSPHATE CHARACTERISTICS AT NSB, BANGOR

The variation of dissolved oxygen is characterized by a simple annual march. Maximum oxygen values appear in the May-to-July time period, whereas the minimum seems to fall consistently in October (Figure 8). The annual range is 0.37 milligram atoms/liter with the expected minimum being 0.37 milligram atoms/liter and the maximum 0.74 milligram atoms/liter. The comparison of the oxygen concentration with the ability of the water to hold oxygen, percent saturation, shows an in-phase relationship. The annual march of the percent saturation (Figure 9) shows that during the warm months, April through August, the water is supersaturated.

The annual march of inorganic phosphate (Figure 10) is in direct opposition to the time variation of oxygen. This is expected because the spring bloom of plant life consumes the phosphate while providing oxygen to solution. The approximate annual range of inorganic phosphate is from a low of 0.45 milligram atoms/liter in June to 2.90 milligram atoms/liter in November-December.

VII. SURFACE SALINITY OF THE HOOD CANAL AT NSB, BANGOR

The time variation of surface salinity (Figure 11) shows a dominant second harmonic effect over a 1-year period. During the December-to-January and June-to-July time periods, it is likely to observe extremely low salinities. This produces a possible annual range of up to 30 parts per thousand. Superimposed on the second harmonic is a reasonably strong fundamental. The effect of the fundamental can be seen in the increased amplitude of the maximum extreme in the fall (approximately 30.3 $^{o}/oo$) over the spring value (approximately 29.6 $^{o}/oo$).

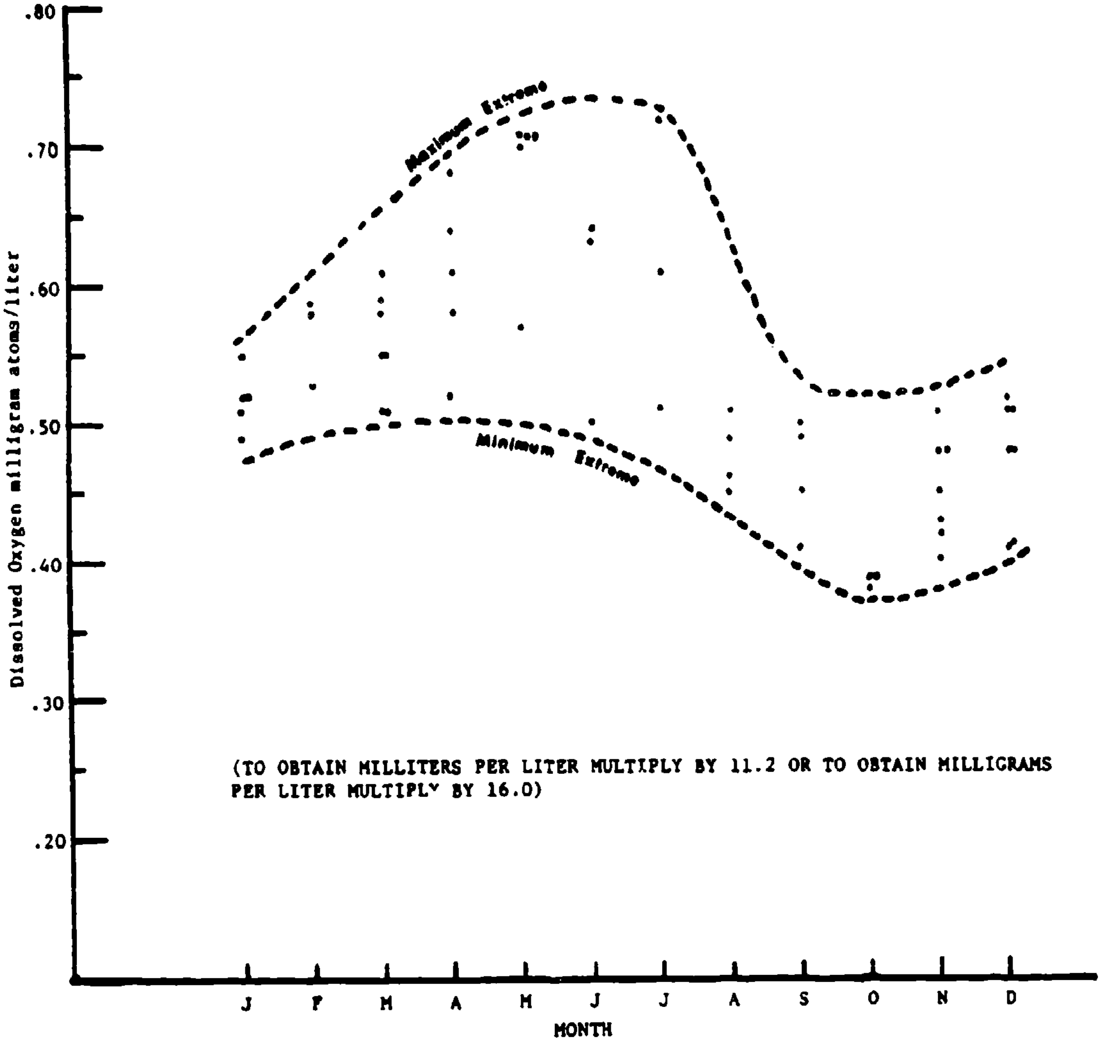


Figure 8. Annual March of Dissolved Oxygen at NSB, Bangor

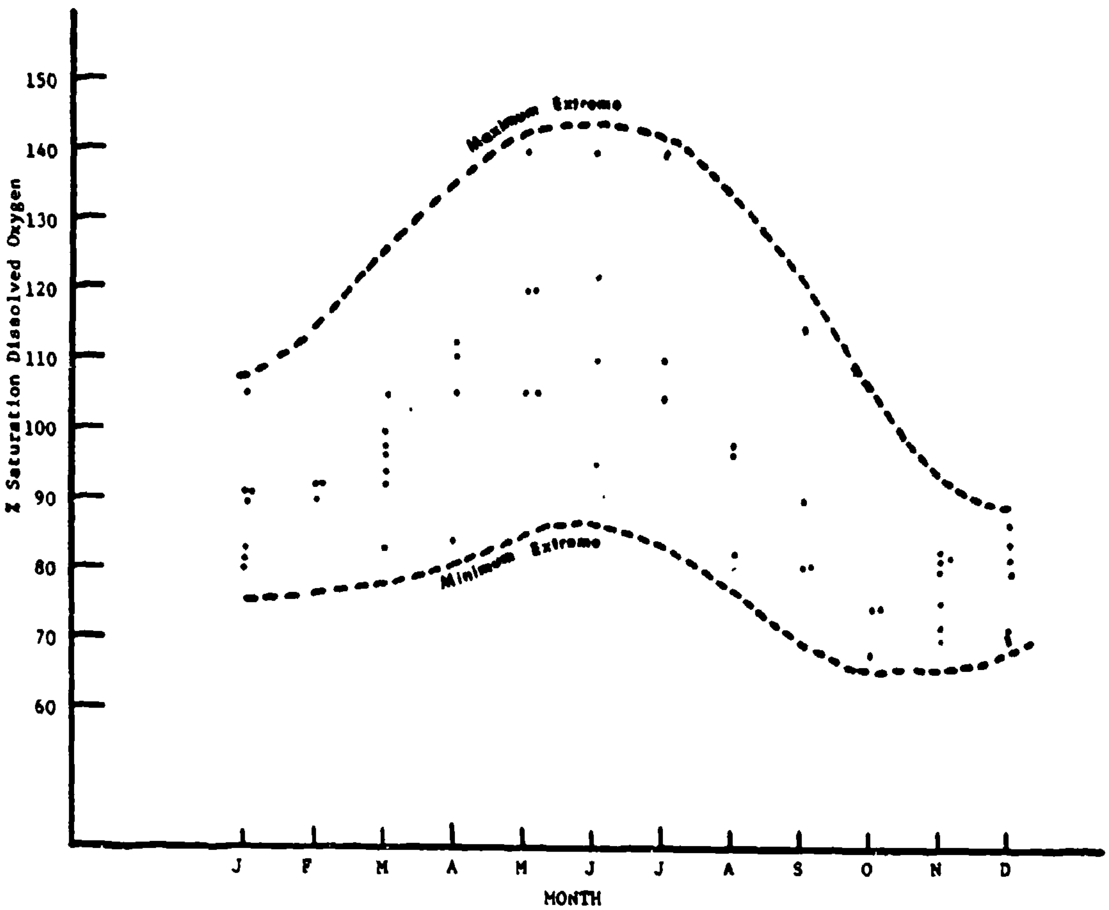


Figure 9. Annual March of Percent Saturation of Dissolved Oxygen at NSB, Bangor

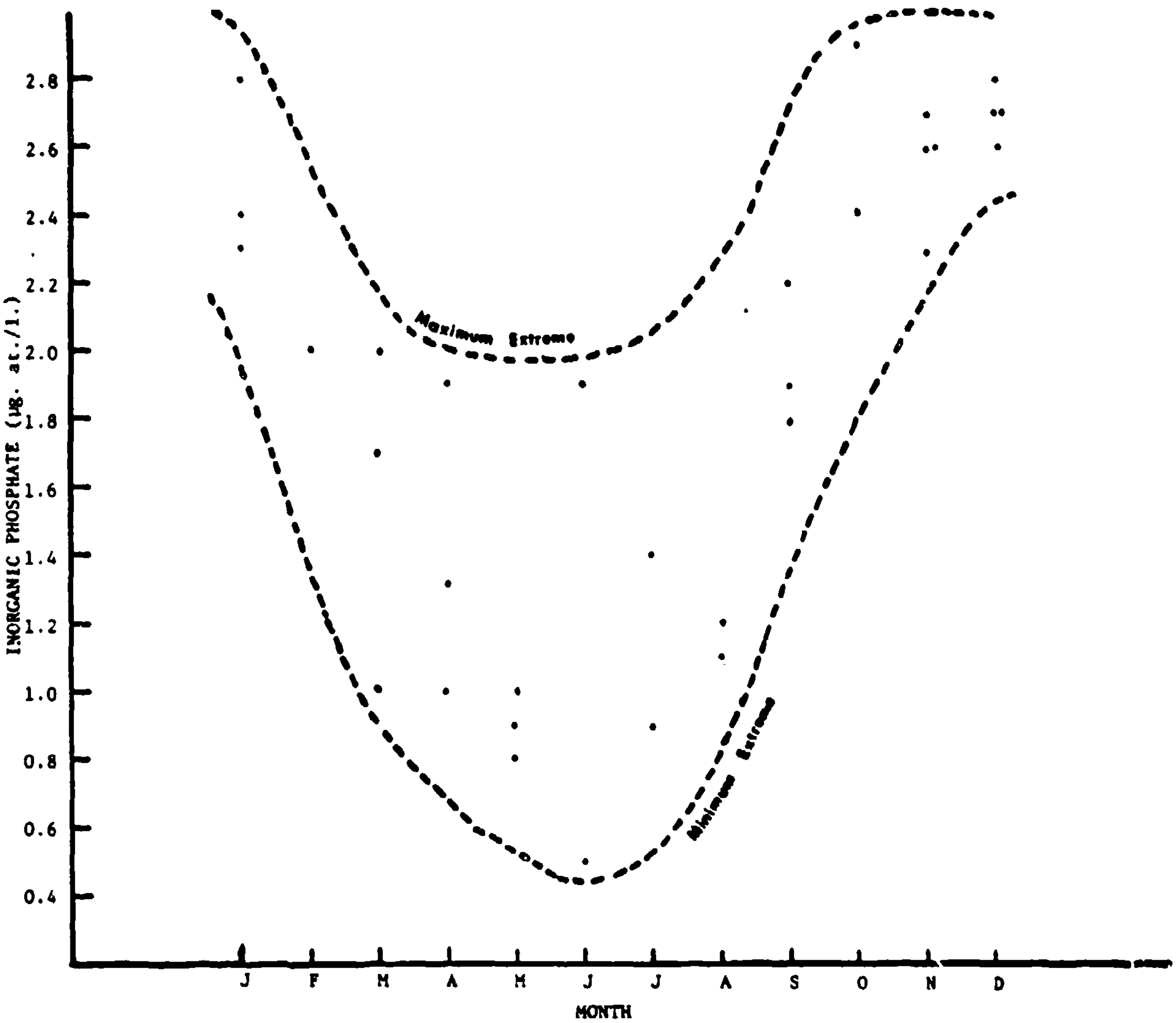


Figure 10. Annual March of Inorganic Phosphate at NSB, Bangor

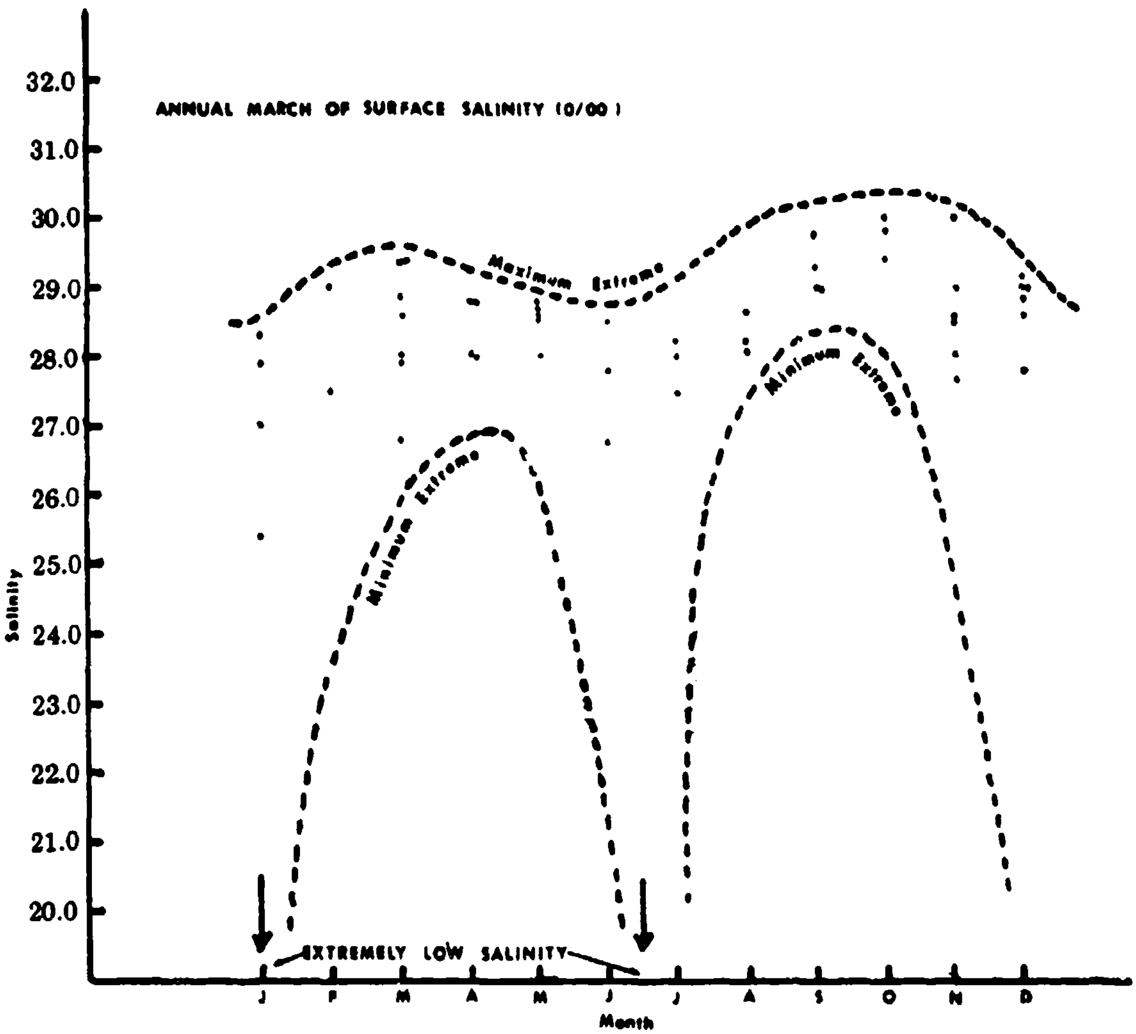


Figure 11. Annual March of Surface Salinity at NSB, Bangor

VIII. TRANSMISSION OF LIGHT IN HOOD CANAL

In 1971, measurements were made in Dabob Bay and Hood Canal with a transmissometer (Oceanographic Engineering Corporation, Model 412-T), which consists of a sensor and a Model 410-BR deck readout unit. The sensor unit contains a light source and a photocell separated by 1 meter. Some of the light is absorbed in the medium and the rest impinges upon the photocell, except for spherical spreading and subsequent absorption. Baffles in the unit exclude outside light while admitting water. A meter indicates the amount of light transmitted through the in-situ sample of water. An optical absorption coefficient can be calculated for a 1-meter path length from the relation:

$$\alpha = \ln \frac{1}{T} \quad \text{or} \quad Te^{\alpha} = 1$$

where T is transmissibility expressed in percent.

Measurements were made in the vertical every 10 feet, down to 100 feet, at each station. Positions of the stations in Dabob Bay and Hood Canal are shown in Figure 12. In Tables 1 and 2, data for Dabob Bay and Hood Canal are presented in tabular form. The lowest transmission value measured in Dabob Bay was 45, whereas the lowest value for the Hood Canal was 53. Average values are given for each measurement depth. Lowest transmission values were observed in the upper part of the water column. The user of this information is cautioned because the averages were derived from measurements made at different times of the day. It is likely that the migration of biological material in the vertical and tidal variations may produce spurious effects on averaging.

Plots of the vertical variation of light transmission for the Hood Canal stations (Figures 13 to 15) show that there is little horizontal variation. It is expected that this situation will vary and will show some seasonal influence. Average curves for the vertical variation of light transmission for Hood Canal and Dabob Bay are given in Figure 16. Dabob Day shows a greater vertical variation. Dabob surface water tends

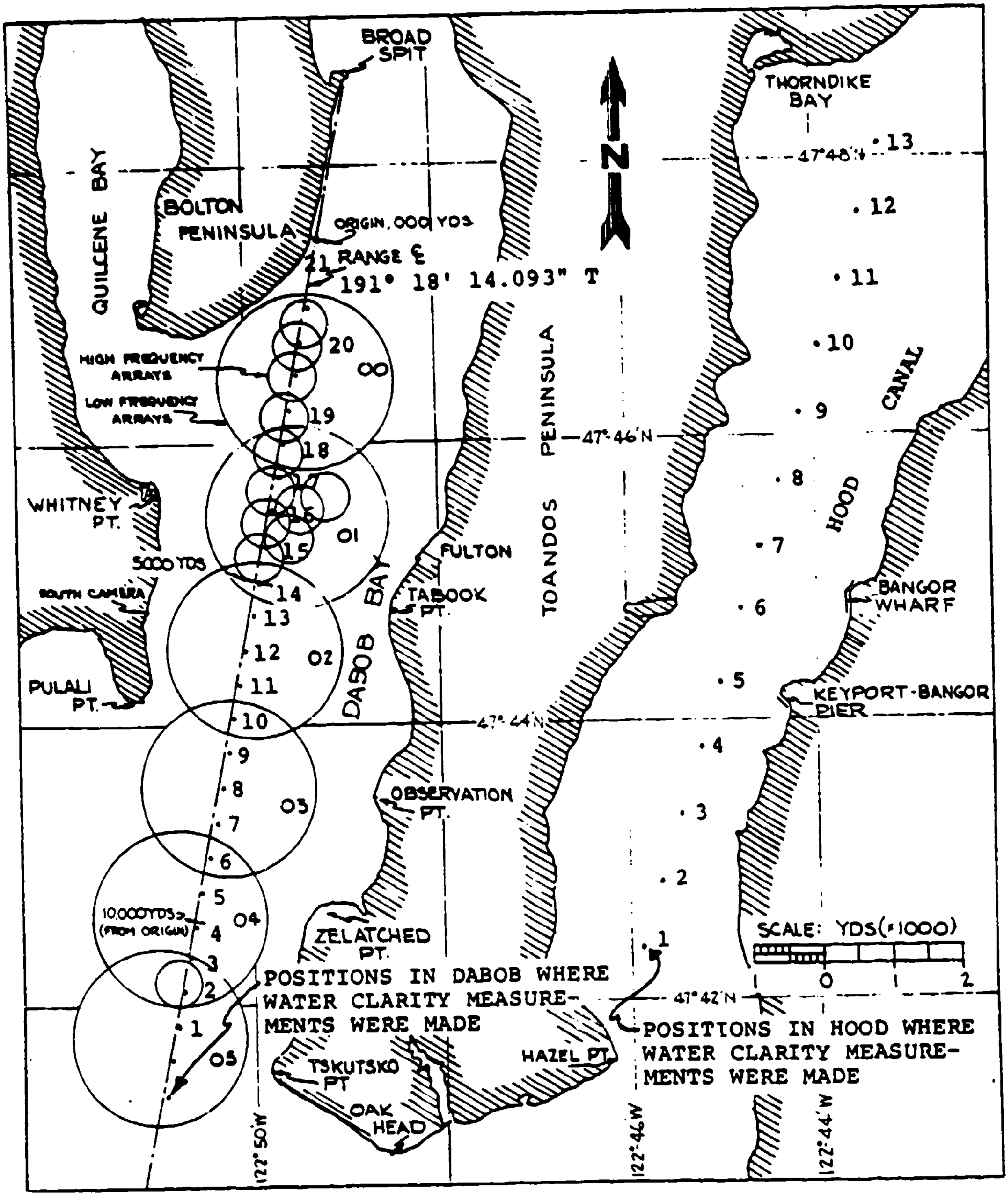


Figure 12. Location of Dabob Bay and Hood Canal Transmission of Light Measurement Sites

TABLE 1. LIGHT TRANSMISSION VERSUS DEPTH IN DABOB BAY

LIGHT TRANSMISSION VERSUS DEPTH IN DABOB BAY, 4 and 5 March 1971											
		DEPTH (feet)									
		10	20	30	40	50	60	70	80	90	100
POSITION	TIME	TRANSMISSION (%)									
1	0938	45	56	60	63	65	65	65	63	63	59
2	0945	59	62	65	66	66	67	67	65	62	59
3	0951	58	61	63	65	67	69	71	71	66	64
4	0958	57	61	63	65	66	67	68	68	68	67
5	1007	57	60	63	65	67	69	70	70	70	69
6	1014	57	61	62	63	64	65	67	67	67	68
7	1022	59	61	63	64	65	66	67	67	68	68
8	1033	56	58	61	64	65	66	67	67	67	67
9	1040	56	58	61	63	65	66	67	68	66	66
10	1049	55	57	61	64	64	65	67	68	68	67
11	0855	49	52	53	56	60	63	66	64	63	61
12	1040	50	53	56	58	63	66	67	68	68	68
13	1045	51	54	58	61	64	66	67	68	67	66
14	1053	52	54	56	57	59	63	64	65	66	65
15	1102	51	54	57	60	64	65	67	68	69	68
16	1107	50	53	55	60	64	66	67	67	68	68
17	1114	49	52	54	57	63	64	65	66	67	68
18	1124	53	54	55	56	58	60	64	65	66	66
19	1135	50	52	53	55	56	58	62	65	66	66
20	1145	54	56	57	58	60	64	67	68	68	68
21	1151	55	56	56	57	58	60	61	64	67	68
	TOTAL	1123	1185	1232	1277	1323	1360	1393	1402	1400	1386
	AVG	53.4	56.4	58.6	60.8	63.0	64.7	66.3	66.7	66.6	66.0

NOTE: Dates of measurement were:
Positions 1 through 10 -- 4 March 1971
Positions 11 through 21 -- 5 March 1971

TABLE 2. LIGHT TRANSMISSION VERSUS DEPTH IN HOOD CANAL

LIGHT TRANSMISSION VERSUS DEPTH IN HOOD CANAL, 5 March 1971											
		DEPTH (feet)									
		10	20	30	40	50	60	70	80	90	100
POSITION	TIME	TRANSMISSION (%)									
1	1330	53	55	57	58	59	58	57	57	57	57
2	1337	55	57	58	59	60	60	59	58	57	57
3	1340	58	60	61	62	62	61	59	59	57	57
4	1345	57	59	60	62	63	61	62	63	62	62
5	1350	57	58	59	60	59	60	60	60	59	59
6	1356	55	56	57	57	58	58	59	59	59	58
7	1403	56	58	59	60	61	61	60	59	57	56
8	1409	58	59	60	59	59	59	58	58	59	59
9	1416	57	58	58	59	59	60	60	59	58	57
10	1423	58	59	60	61	62	62	61	61	60	60
11	1429	54	56	57	58	59	60	60	59	59	59
12	1436	55	57	59	61	63	64	66	67	67	67
	TOTAL	673	692	705	716	724	724	721	719	711	708
	AVG	56.1	57.7	58.8	59.7	60.3	60.3	60.1	59.9	59.3	59.0

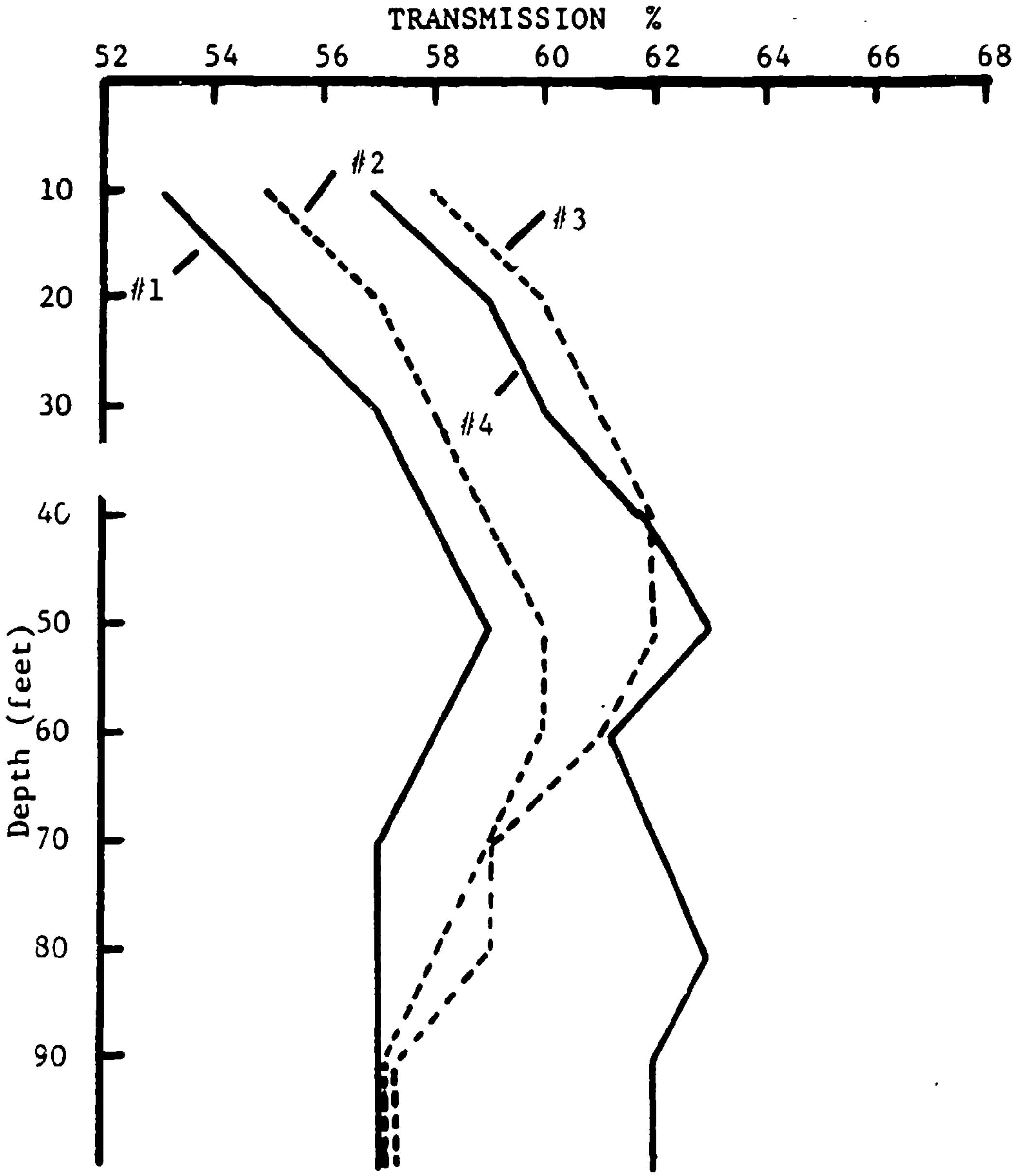


Figure 13. Variation of Light Transmission in the Vertical, Hood Canal Stations 1 to 4

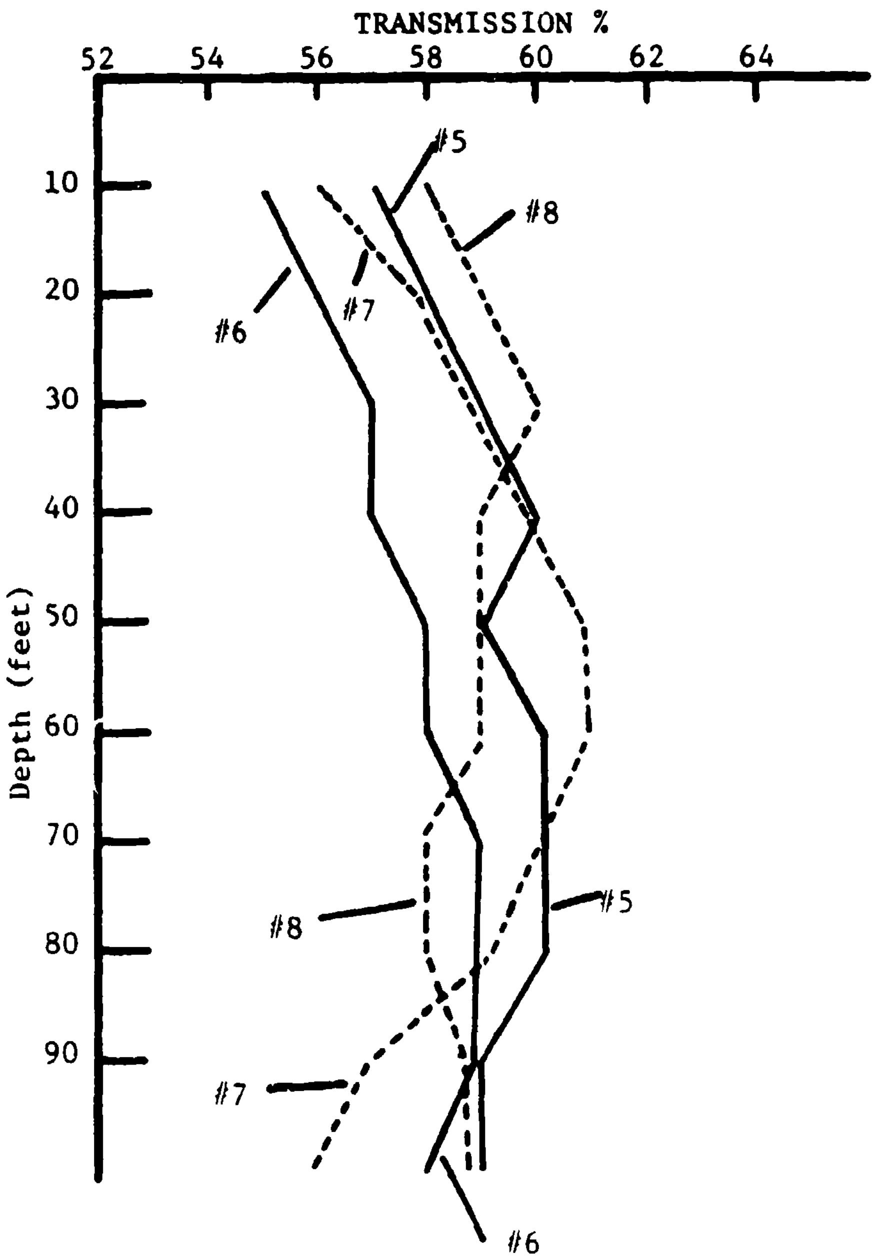


Figure 14. Variation of Light Transmission in the Vertical, Hood Canal Stations 5 to 8

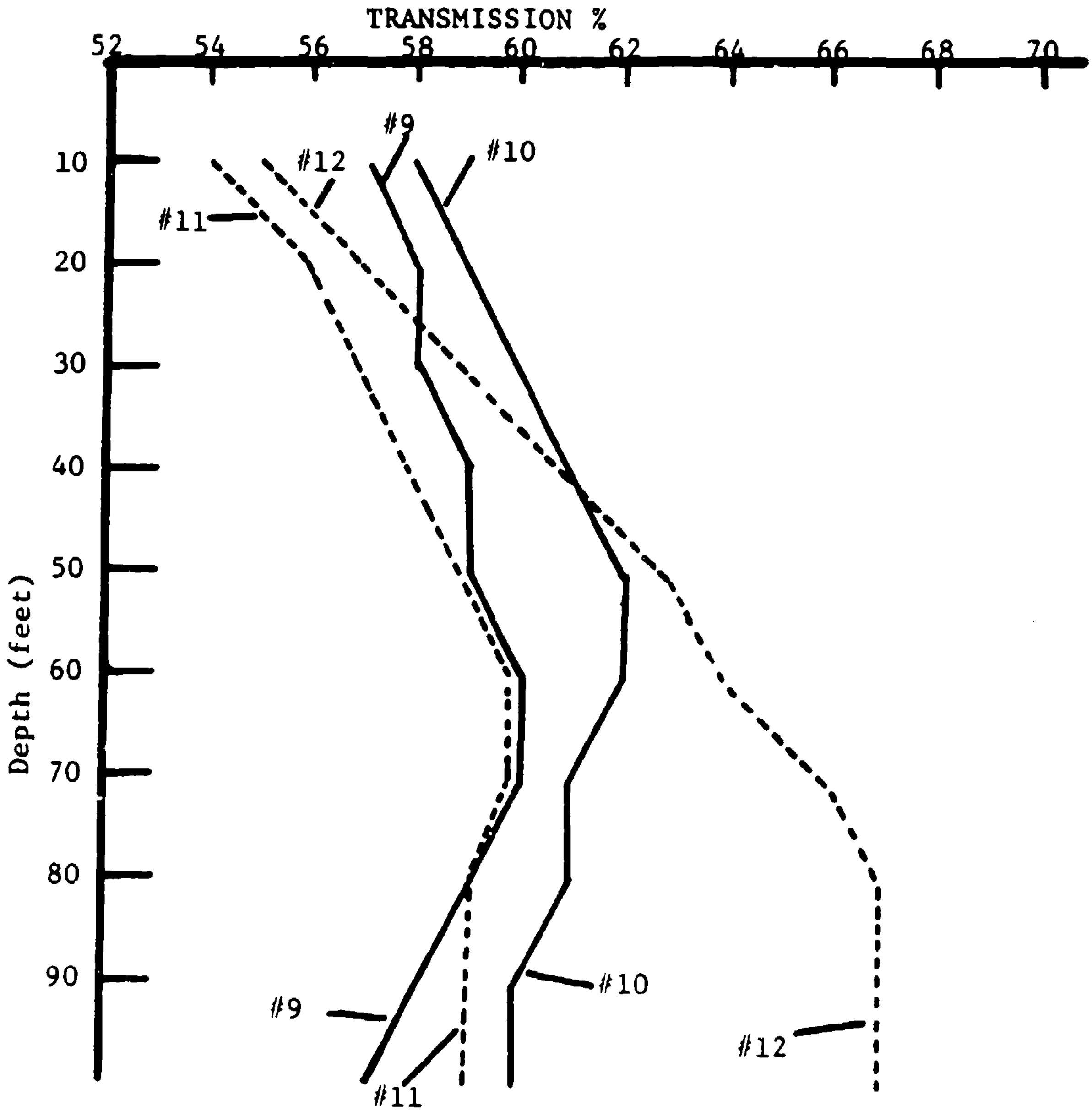


Figure 15. Variation of Light Transmission in the Vertical, Hood Canal Stations 9 to 12

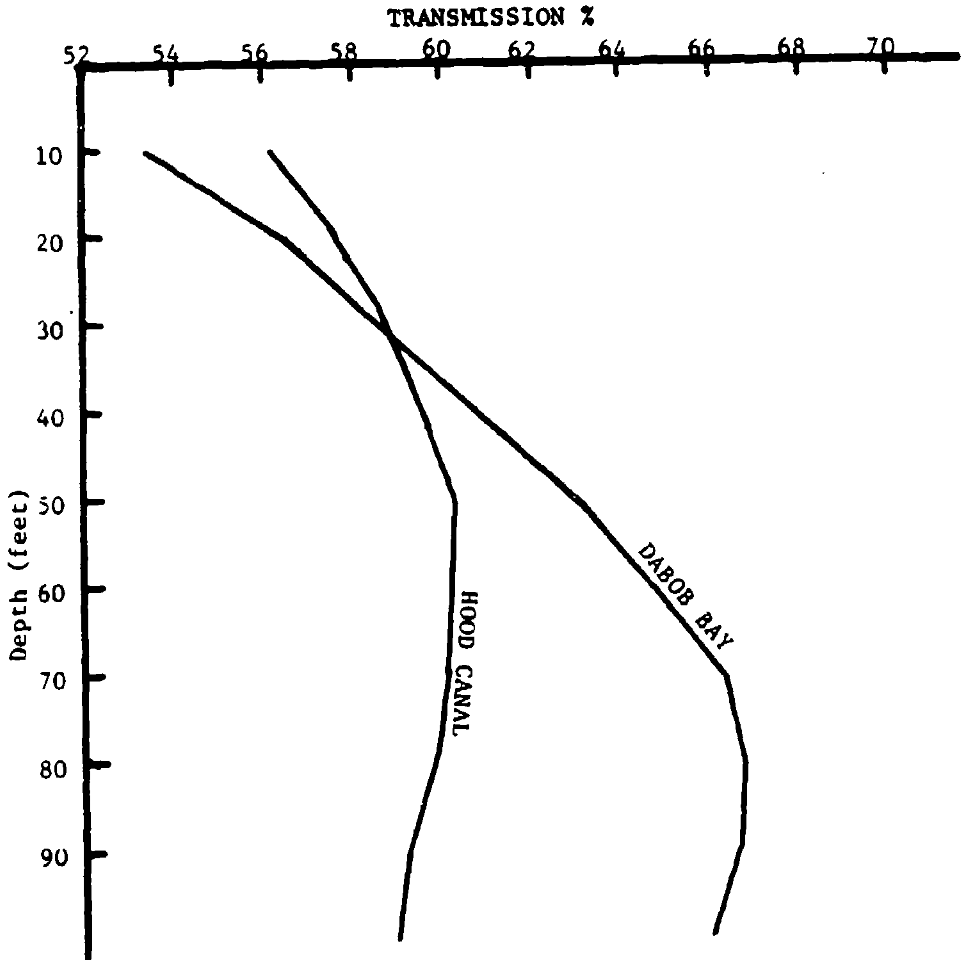


Figure 16. Average Variation of Light Transmission in the Vertical for Hood Canal and Dabob Bay

to have lower transmission than Hood Canal, but the deeper water in Dabob is clearer.

IX. OBSERVATIONS OF CURRENT

The observations of current were made on the mooring farthest away from the shore in a water depth of 40 meters (125 feet), and the current meter was at a depth of 5 meters. These data are representative of the conditions.

Figure 17 presents a series of current measurements made by CHESNAVFACENGCOM which provide a good data base from which to extract information from currents at the sites. From this 1-year series of measurements, Figure 17 shows an excerpt from a period in March 1976 when the currents were high. Figure 17 presents smoothed current data with the high frequencies extracted. It is presented in u and v components. The u component is oriented along the axis of the canal which is a 30 degree positive rotation from true north; thus, the v component becomes the shoreward component.

Figure 18 is the spectra for the current record for this period. The u and v components are shown as solid and dashed lines, respectively. Figure 18 also shows large spikes which indicate tidal periodicity.

Figure 19 is the residual current after low-pass filtering for the major part of March 1976. The portion of the record shown in Figure 17 is indicated. Figure 19 shows a slight residual current ranging from 0 to 10 cm/sec downstream.

Figure 20 is a component representation of the wind for March 1976. The u component of the wind is oriented the same as the u component of the current; thus, the coordinate systems become congruent except for magnitude. The wind is in meters/second. It should also be noted that in comparing the u component of the wind with the u component of the current, there is some degree of correlation, as would be expected when wind stress increases.

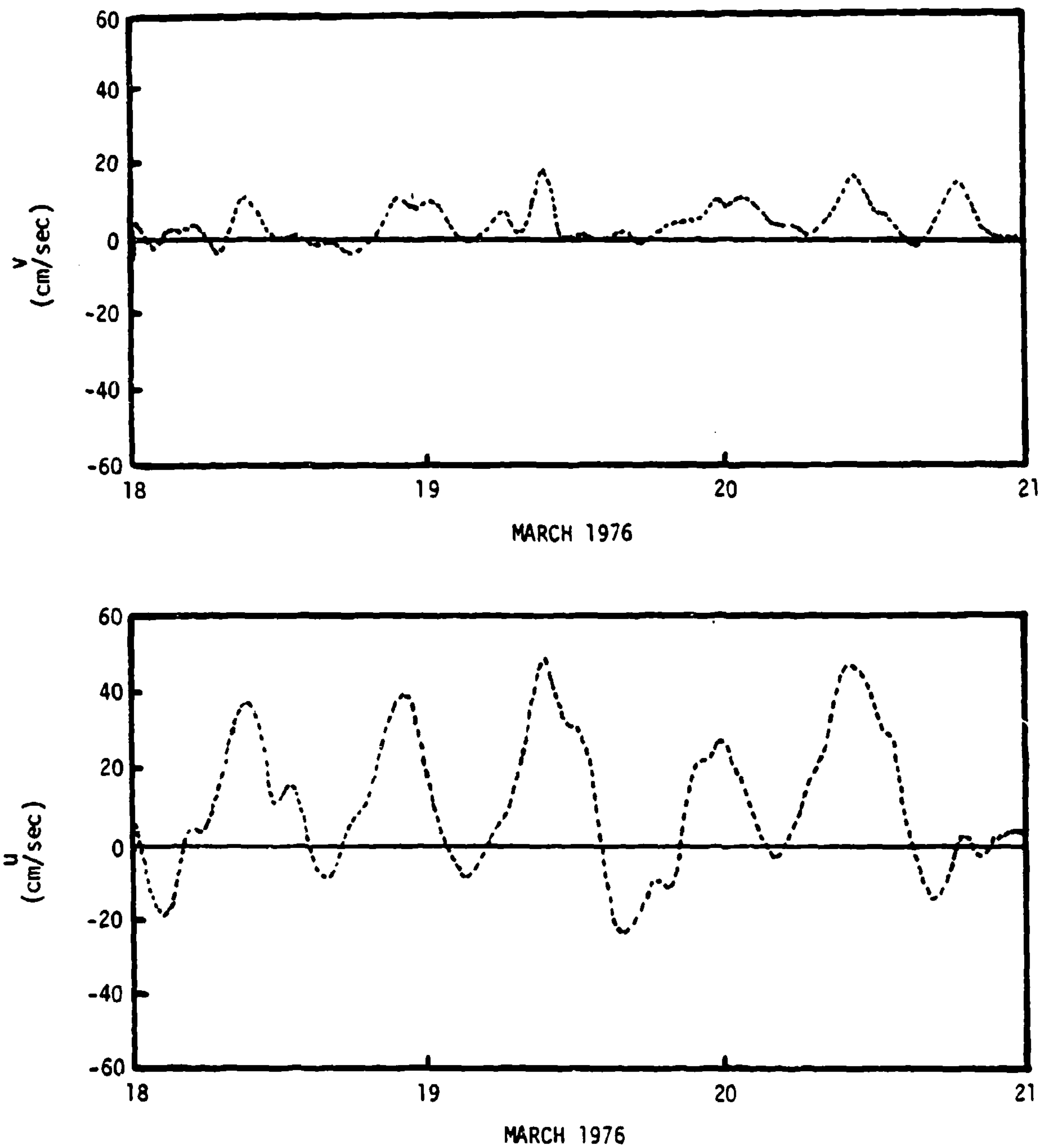


Figure 17. U and V Components of Current in Hood Canal at NSB, Bangor (Smoothed)

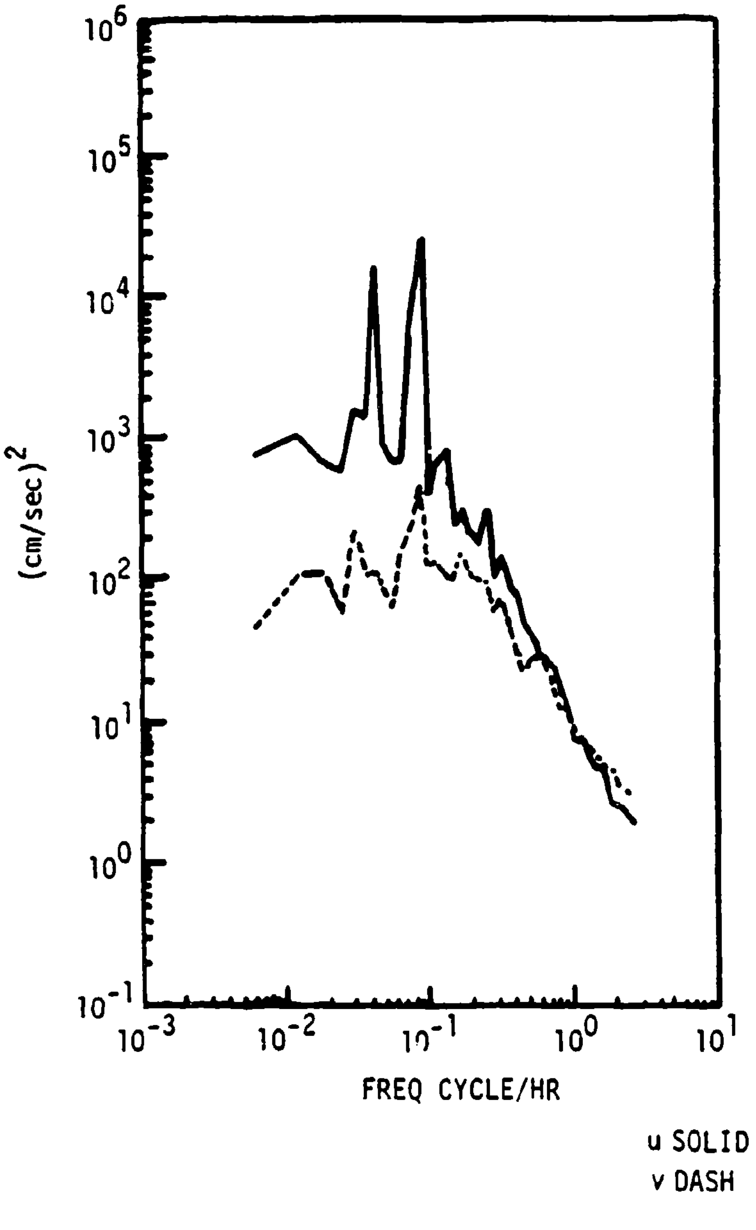


Figure 18. Energy Density Spectra for Figure 17 Current Record

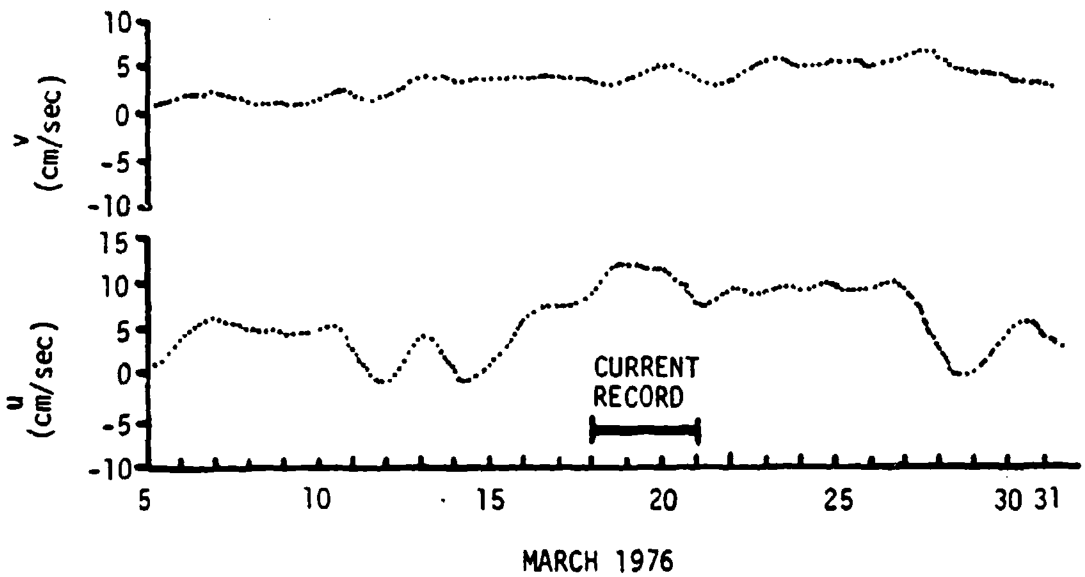


Figure 19. Residual Current for March 1976 in Hood Canal at NSB, Bangor (Low Pass Filtering)

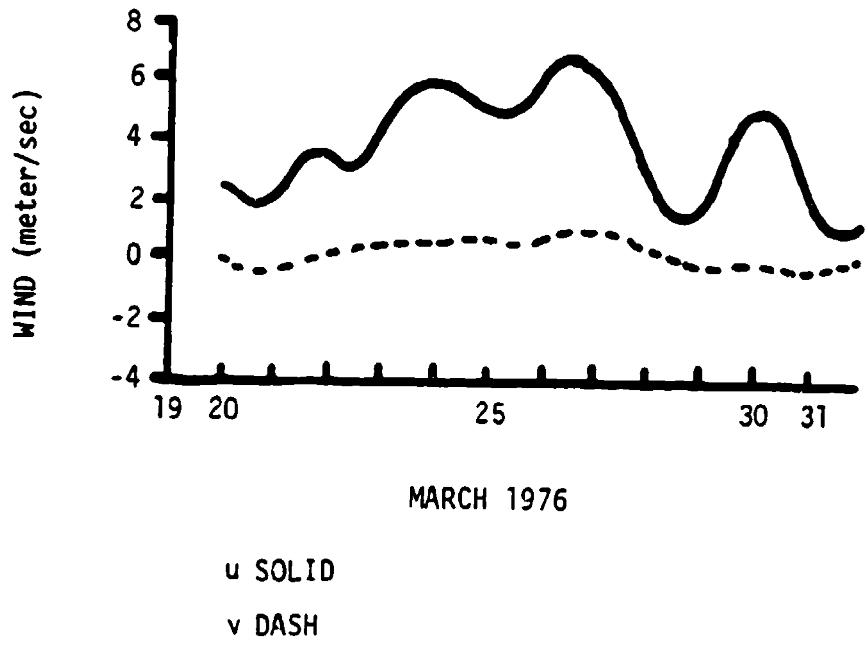


Figure 20. Wind Velocity (U and V Components)