Tidal Hydraulics, Flushing Characteristics and Water Quality of Netarts Bay

by

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Final Report

TIDAL HYDRAULICS, FLUSHING CHARACTERISTICS AND WATER QUALITY IN NETARTS BAY, OREGON

submitted to

Louis W. and Maud Hill Family Foundation

by

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January, 1971

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I. Introduction

A. Purpose of Project

This project was undertaken to provide basic data on physical characteristics, tidal hydraulics, flushing characteristics and present water quality of Netarts Bay, Oregon. These basic data are for use by biologists for assessment of productive capabilities of Netarts Bay, by engineers for decision making about disposal of domestic wastes originating from areas adjacent to the Bay, by local planners to preserve and protect Netarts Bay and by persons interested in basic processes of tidal flat embayments.

B. Conduct of Project

Under the guidance of Dr. Bard Glenne and Professor Fred J. Burgess, Charles F. Glanzman, a civil engineering graduate student, performed many of the analyses. Mr. Glanzman was assisted by students Eric W. Emmett, Scott Boley, Carl Goodwin and others. Dr. David A. Bella and Dr. Donald C. Phillips were frequently consulted on water quality problems. Dr. Wesley P. James conducted the aerial photography for present topographic conditions.

Dr. W. J. McNeil, Head, Pacific Fisheries Laboratory, and his staff at the OSU Netarts Bay Fisheries Laboratory have helped monitor Whiskey Creek discharge and stage and local meteorological conditions.

During the summer of 1969, tidal hydraulics, physical characteristics and water quality of Netarts Bay were investigated. Winter and Spring activities focused on water quality, sediment analysis, hydrologic measurement and topographic data analysis. Activities during the Summer of 1970 centered on sediment analysis, water quality measurements, tidal hydraulics modeling, dispersion studies and data reduction. An attempt to mathematically model the transport of pollutants and calculate dispersion coefficients in Netarts Bay is being made as a subsequent study.

Possible use of Netarts Bay for domestic waste water disposal has been considered with respect to tidal hydraulics, constituent transport processes, biological balances and sediment characteristic changes. Recommendations regarding the most desirable means of waste disposal, based on the findings of this study are also offered in the conclusions.

C. Acknowledgements

The study leading to this report was funded generously by the Louis W. and Maud Hill Family Foundation. The investigators wish to thank the Hill Family Foundation for its support of this basic study since the data obtained is needed for rational decisions about the management of this estuary

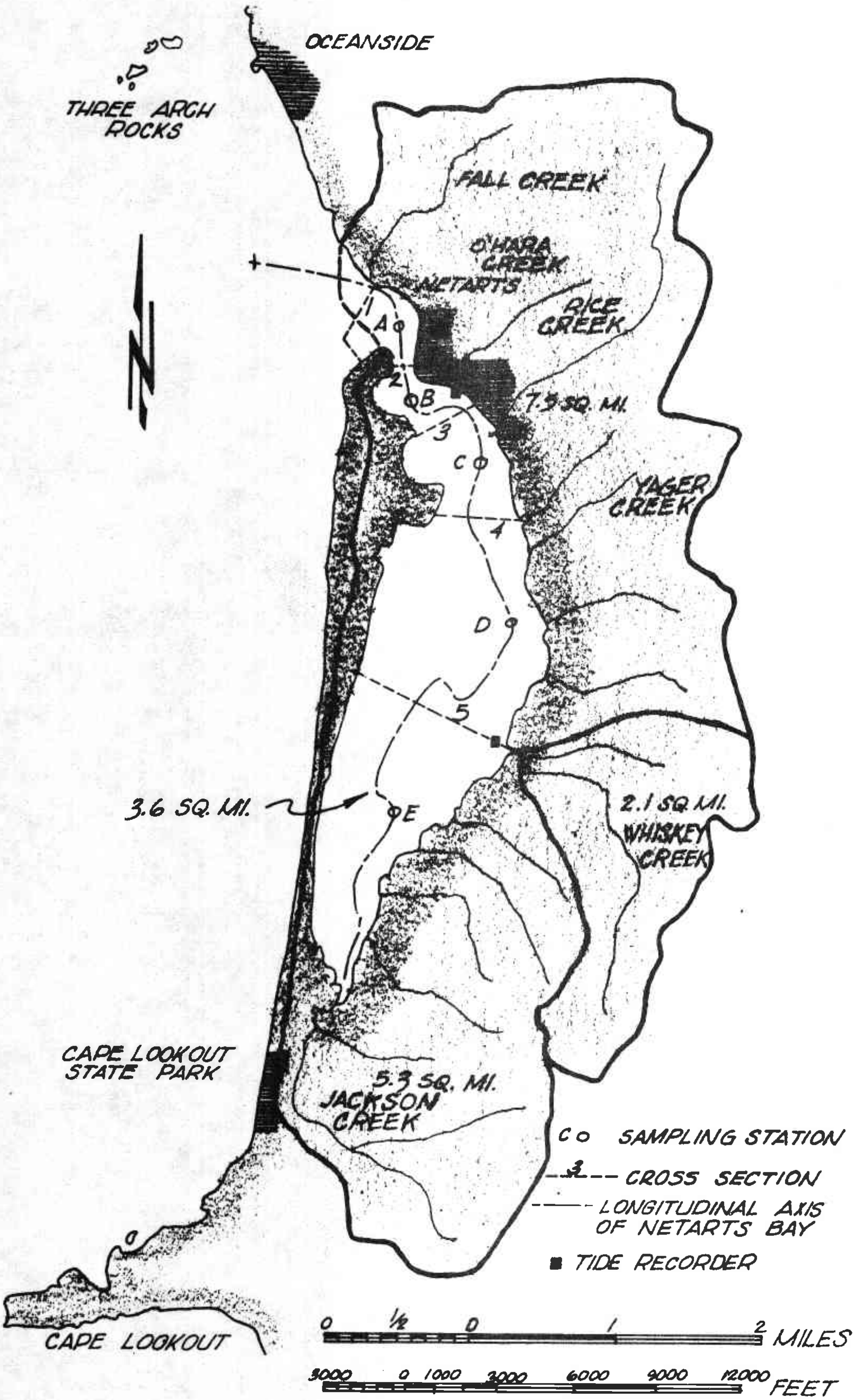
Appreciation is also expressed to Dr. W. J. McNeil, the State Department of Environmental Quality and to Mr. Steven Zimmerman for their aid and advice throughout the project.

II. Physical Characteristics of Netarts Bay

A. Topography

1. Drainage Area

Netarts Bay is one of Oregon's very few undeveloped estuaries. The Bay encompasses a body of water of 3.65 square miles at mean higher high water (MHHW). Drainage area surrounding the Bay is approximately 14.9 square miles and is characterized by timbered areas many of which have been logged and are in a stage of reforestation. The principal drainage areas of the Bay are the Jackson, Whiskey, Yager, O'Hara, Rice and Fall Creek watersheds. Water supply records from the various drainage basins are nonexistent except for Whiskey Creek which has a short-term record. A vicinity map of the Bay is shown in Figure 1.



VICINITY MAP OF NETARTS BAY, OREGON
SHOWING DRAINAGE AREAS AND STUDY CROSS-SECTIONS

FIGURE 1.

2. Bottom Characteristics

The only known hydrographic survey conducted on Netarts Bay prior to this study is summarized on the 1957 "NETARTS BAY & ENTRANCE" Hydrographic Survey map No. 8372 by the U. S. Coast and Geodetic Survey. A contour map of the Bay based on this data is shown in Figure 2.

An inspection of Netarts Bay indicated that the meander pattern of channels in the Bay had changed since 1957. Because of these changes it was necessary to obtain accurate surface and cross sectional areas as well as tidal volumes by infrared aerial photographs which were taken of the Bay at various tidal heights on 2 August, 1969. The tidal heights ranged from 0 feet above MLLW to 6.67 feet above MLLW.[1/] [2/] From these photographs the current topographic map shown in Figure 3 was prepared.

The areas of most significant change from the 1957 map are:

a. North End of the sand spit: A realignment of the meander near the Tillamook County small boat harbor has turned scouring tidal flows against the Northern 3000 foot section of this spit. There is accretion seaward of the spit and erosion bayward. The MHHW line has moved as much as 800 feet seaward in some places since 1957. The volume of the spit appears about equal to that observed in the 1957 USC & GS Study.

b. Main channel between cross-sections 2 and 3: The main channel in this reach appears to be establishing a less tortuous alignment. This is occurring in the form of a braided channel around a large sand bar.

1/ For purposes of this report the following descriptions of tidal height are used: MHHW - Mean higher high water describes the average of the highest daily tidal heights; MHW - Mean high water; MLW - Mean low water; MLLW - Mean lower low water describes the average of the lowest daily tidal heights.

2/ Unless otherwise noted, all tidal heights refer to the Schooner tide recorder at the Tillamook County Boat Landing.

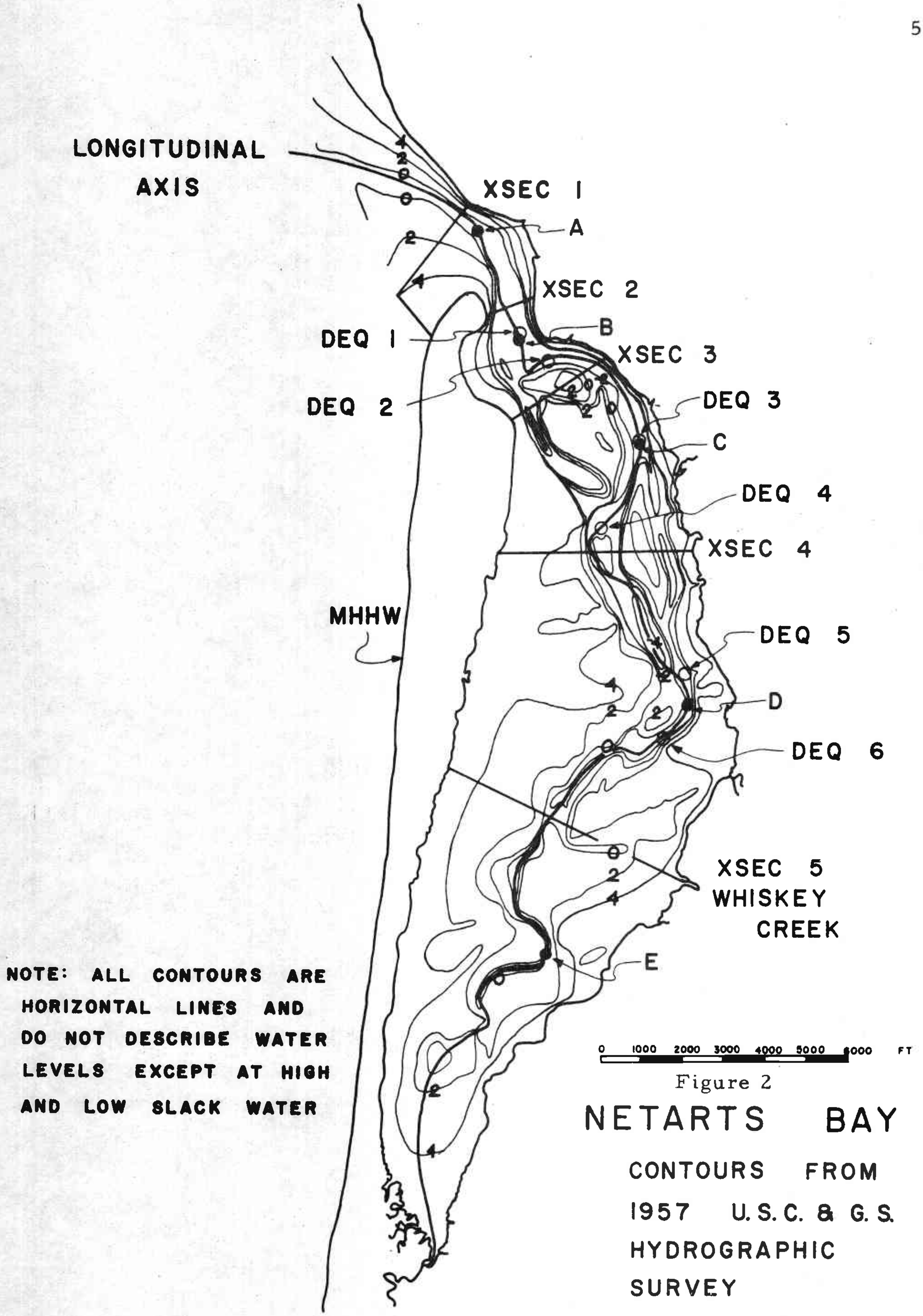
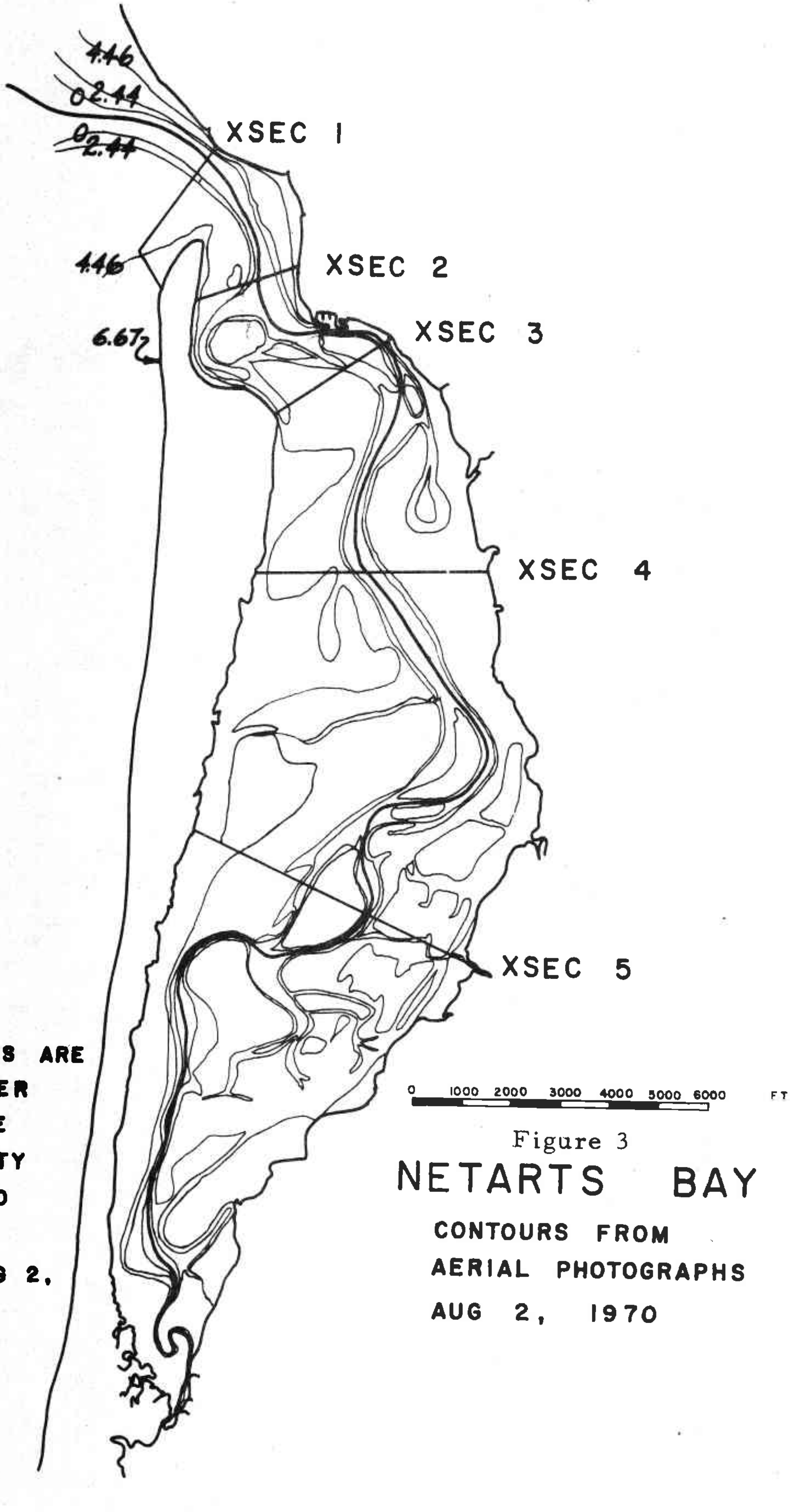


Figure 2

NETARTS BAY

CONTOURS FROM 1957 U.S.C. & G.S. HYDROGRAPHIC SURVEY



NOTE: ALL CONTOURS ARE INSTANTANEOUS WATER LEVELS WHEN TIDE RECORDER AT COUNTY BOAT LANDING READ STATED HEIGHT ON INCOMING TIDE, AUG 2, 1970

Figure 3
NETARTS BAY
CONTOURS FROM AERIAL PHOTOGRAPHS
AUG 2, 1970

c. Main channel between cross-sections 3 and 4: This channel has moved seaward and reversed curvature. A large sand bar has been scoured through and significant accretion of the sand flats adjacent sample station C has occurred.

d. Main channel landward of cross section 5: A change in orientation of this channel has occurred. The channel also appears to be deepending.

In addition to the above locations a few cross sections have been sounded.[1/] These are the minimum width cross section very near cross section 1 and the current velocity measurement cross section approximately 200 feet south of cross section 2. These sections are shown in Fjgures 4 and 5.

Distances from the various points in the Bay to the mouth (section 0) have been measured along the path of the main channel as shown on the 1957 map. This line has been called the longitudinal axis of Netarts Bay. This longitudinal axis has changed slightly in orientation from its 1957 location. However, for simplicity the axis and distances are regarded as unchanged in all graphs that follow. Thus, those persons possessing the 1957 hydrographic survey map have a reference for information presented in this study. Distances from the mouth are tabulated in Table 1.

3. Cross Sectional Areas

Cross sectional areas were determined from the hydrographic survey map from maximum depth to MHHW. From the airphotos, cross sectional areas above MLLW were also determined. Figures 6 and 7 show the variations of cross sectional area with respect to depth or tidal height from the 1957 chart and airphotos respectively. Sounded[1/] sections 1 and 2 were used to verify the

[1/] Sounded refers to the nautical measurement of water depth and is used as an abbreviation for this description.

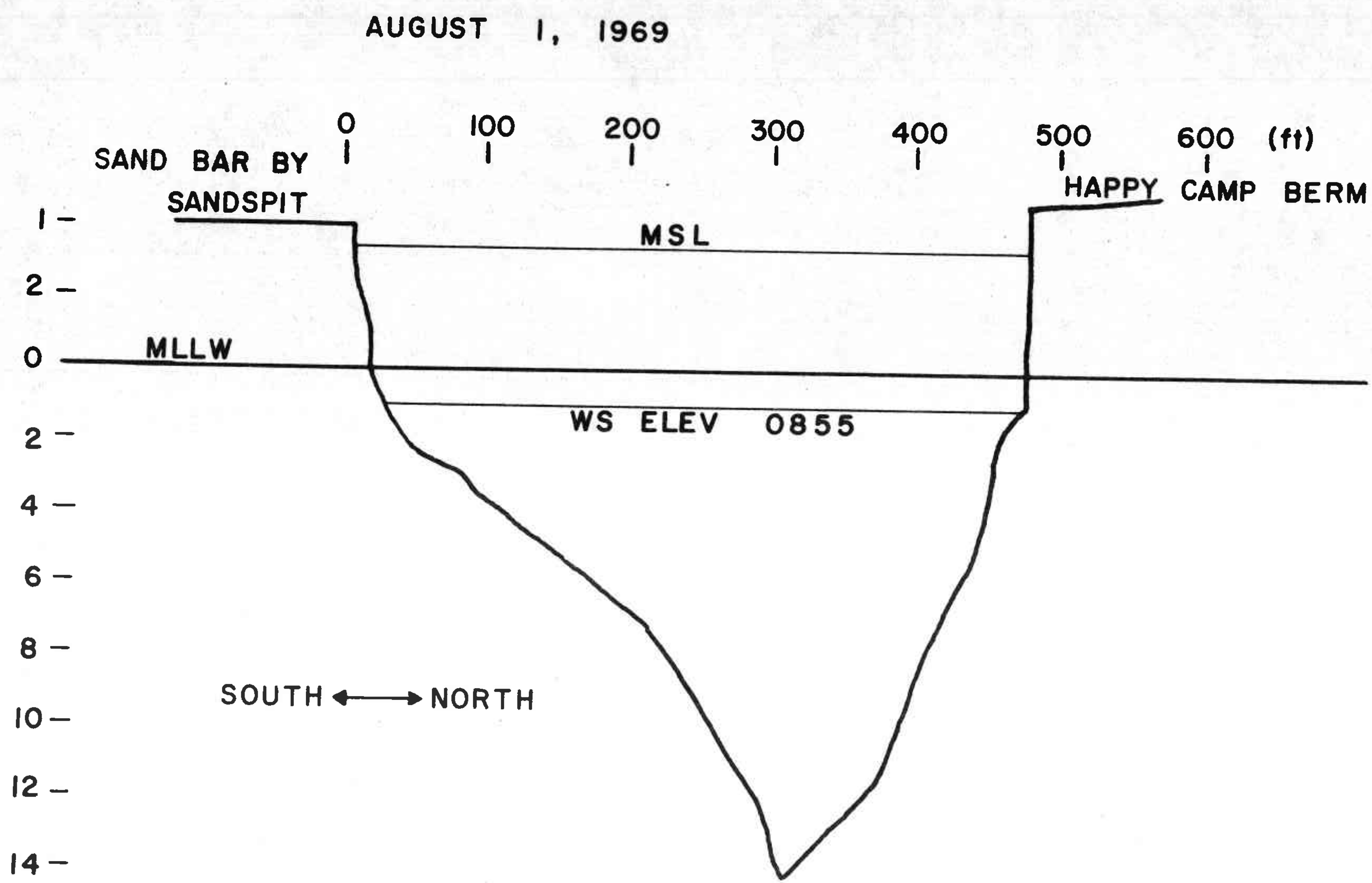


FIGURE 4. MINIMUM WIDTH CROSS SECTION

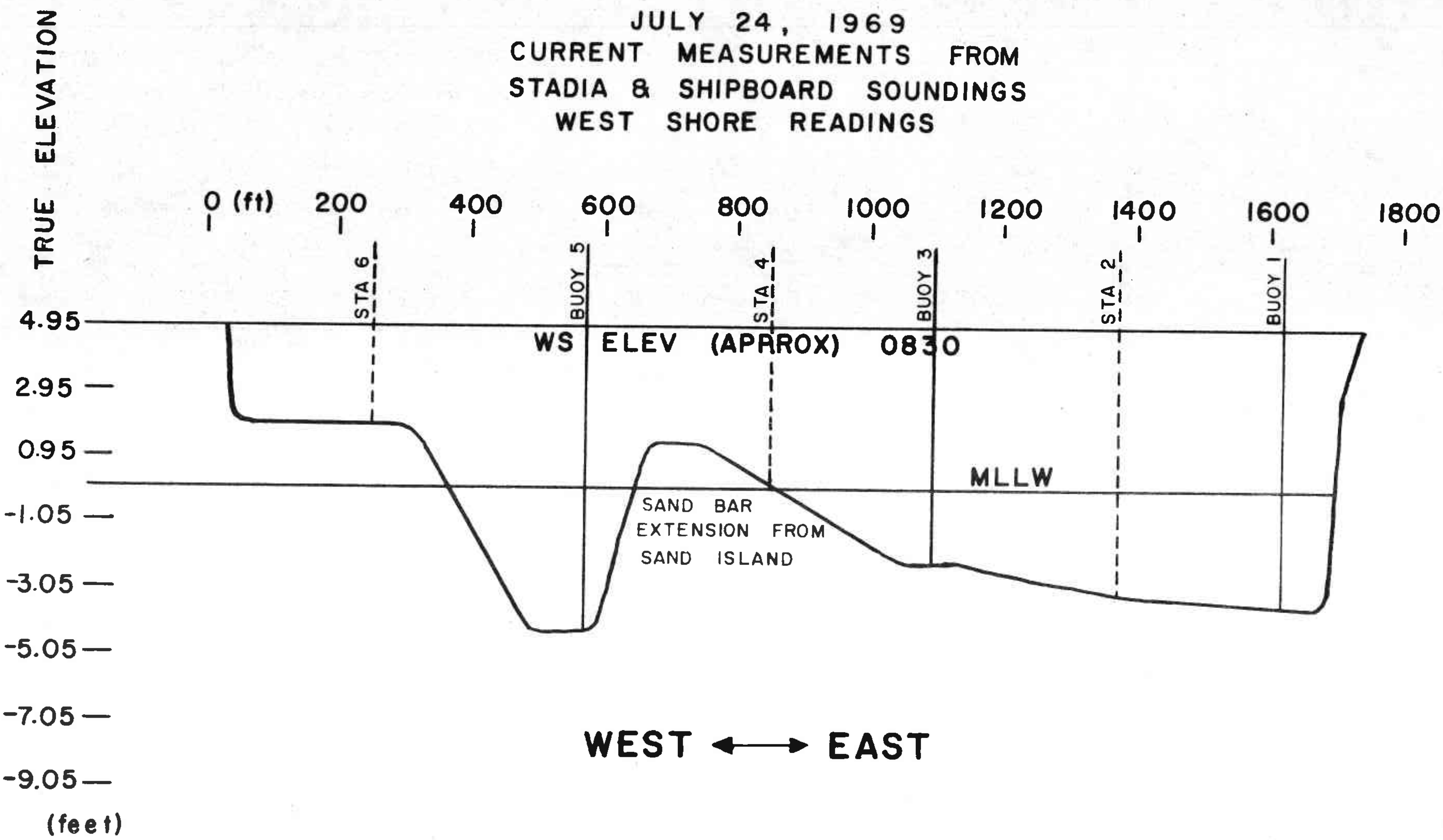


FIGURE 5. CROSS SECTION 200 FT. SOUTH OF SECTION 2

Table 1. Station and Cross Section Identification

Station	X Section	Latitude	Longitude	Distance From Mouth	Description
O				0	Start of offshore bar
	1			4,670	Across mouth approx. 420 yards NW of Station A
A		45°26'27"N	123°57'18"W	5,105	Channel adjacent Happy Camp Store
	2			7,132	
B, DEQ 1		45°25'53"N	123°57'00"W	7,969	Channel 0.4 miles NW of Tillamook County boat launching site (Chucks Boats)
DEQ 2		45°25'46"N	123°56'46"W	9,664	Channel opposite boat ramp mouth at pilings
	3			11,032	
Proposed Sewage Treatment Plant				12,582	Rice Creek
C, DEQ 3		45°25'25"N	123°56'20"W	13,276	Channel 0.4 miles So. Wilson Beach
DEQ 4		45°25'07"N	123°56'35"W	16,057	Channel 600 yards SW of DEQ 3
	4			16,492	
DEQ 5		45°24'32"N	123°56'07"W	20,512	Channel 300 yards west of highway junction (Cape Lookout-Netarts Bay Highway)
D		45°24'25"N	123°56'03"W		Eastern bend in channel 1570 yards N of Whiskey Creek Lab
DEQ 6		45°24'15"N	123°56'27"W	25,433	Channel 0.6 miles SW of Station DEQ 5
	5			28,012	Across from Whiskey Creek
E		45°23'24"N	123°56'54"W	32,199	Channel 1230 yards west southwest of Whiskey Creek Lab
END				41,012	End of the Bay

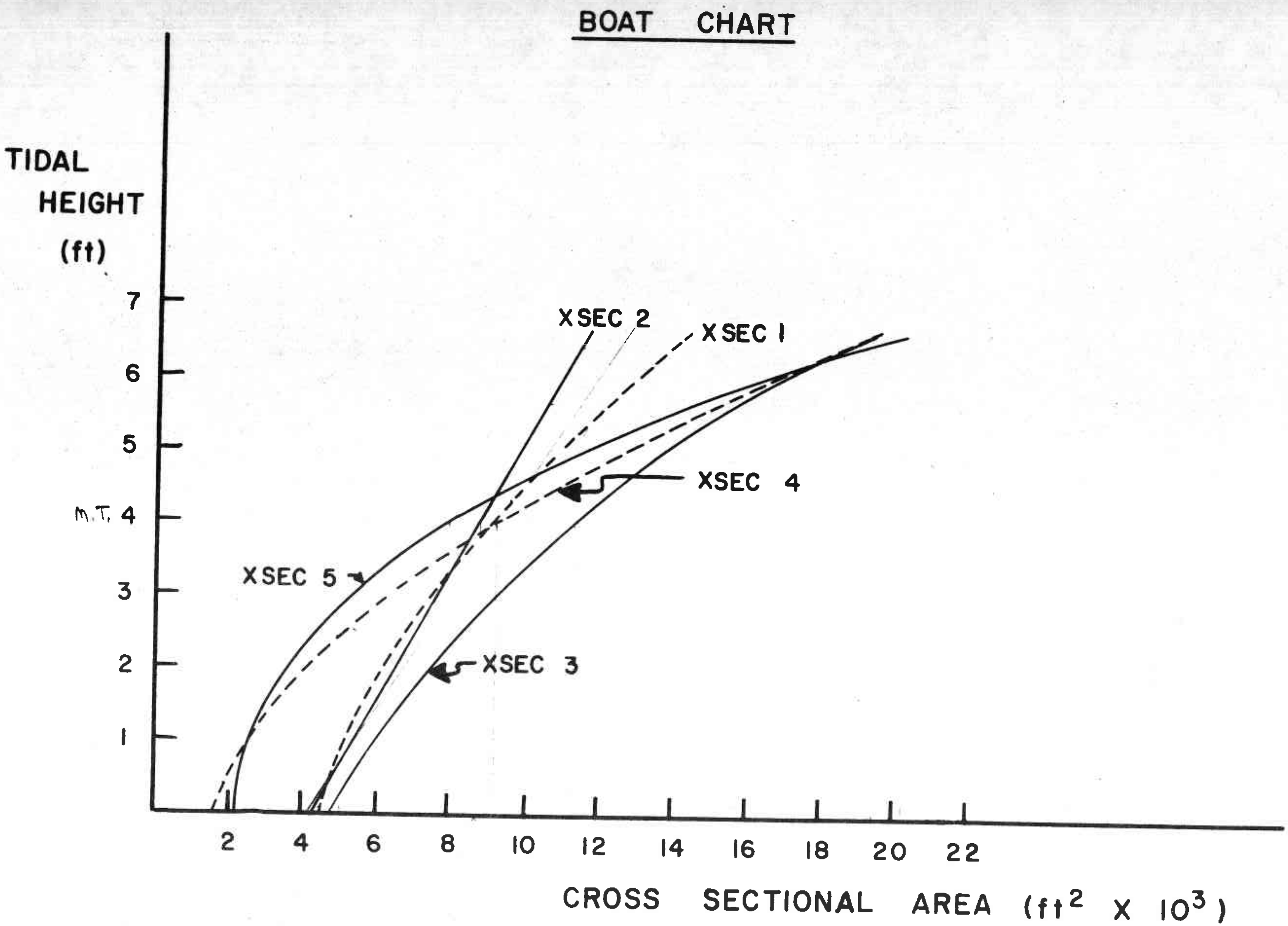


FIGURE 6. CROSS SECTIONAL AREA VS TIDAL HEIGHT

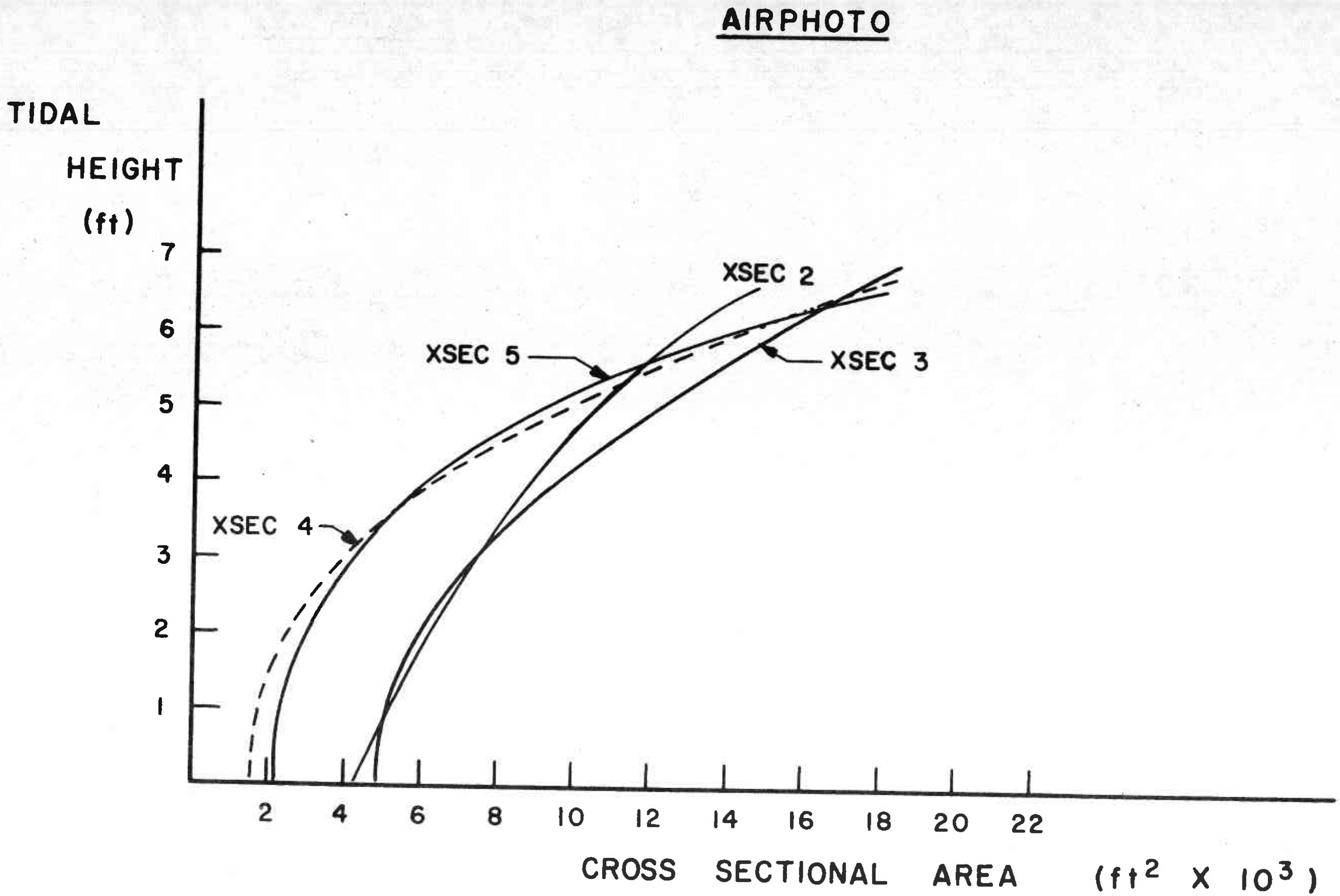


FIGURE 7. CROSS SECTIONAL AREA VS TIDAL HEIGHT

analysis obtained from airphotos. The agreement obtained was satisfactory and verified the use of this method.

Figure 8 shows the 1957 hydrographic survey chart and airphoto analyses of the variation of cross sectional area with tidal height and distance from the mouth.

When these results are interpreted, one should keep in mind that some error is not unlikely in such analyses. It appears, however, that approximately a 10% decrease in bay cross-sectional areas at MHHW may have taken place since 1957.

4. Tidal and Total Volumes

Total volumes of the Bay were determined using the 1957 USC & GS hydrographic survey chart assuming the water surface to be horizontal. Such an analysis gives correct tidal volumes only at high and low slack waters when the bay water surface is almost horizontal. A more complete analysis would have to consider that water surface slopes are different for each possible tide. Such accuracy is unnecessary.

An alternative analysis was made using airphotos which show the bay water surface as it varies during any particular tide. The analysis performed on the airphotos is most accurate for an incoming tide ranging from 0 to 7 feet with respect to MLLW. The tidal heights are referred to the tide recorder at Schooner, as shown on "VICINITY MAP OF NETARTS BAY, OREGON," Figure 1.

Surface areas were obtained to calculate volumes in both cases. Surface area as a function of distance and tidal height is given for the 1957 chart and for the airphoto analysis in Figure 9. The total surface area at MLW (approx. $22 \times 10^6 ft^2$) can be seen to be approximately 20% of the surface area at MHW (approx. $108 \times 10^6 ft^2$).

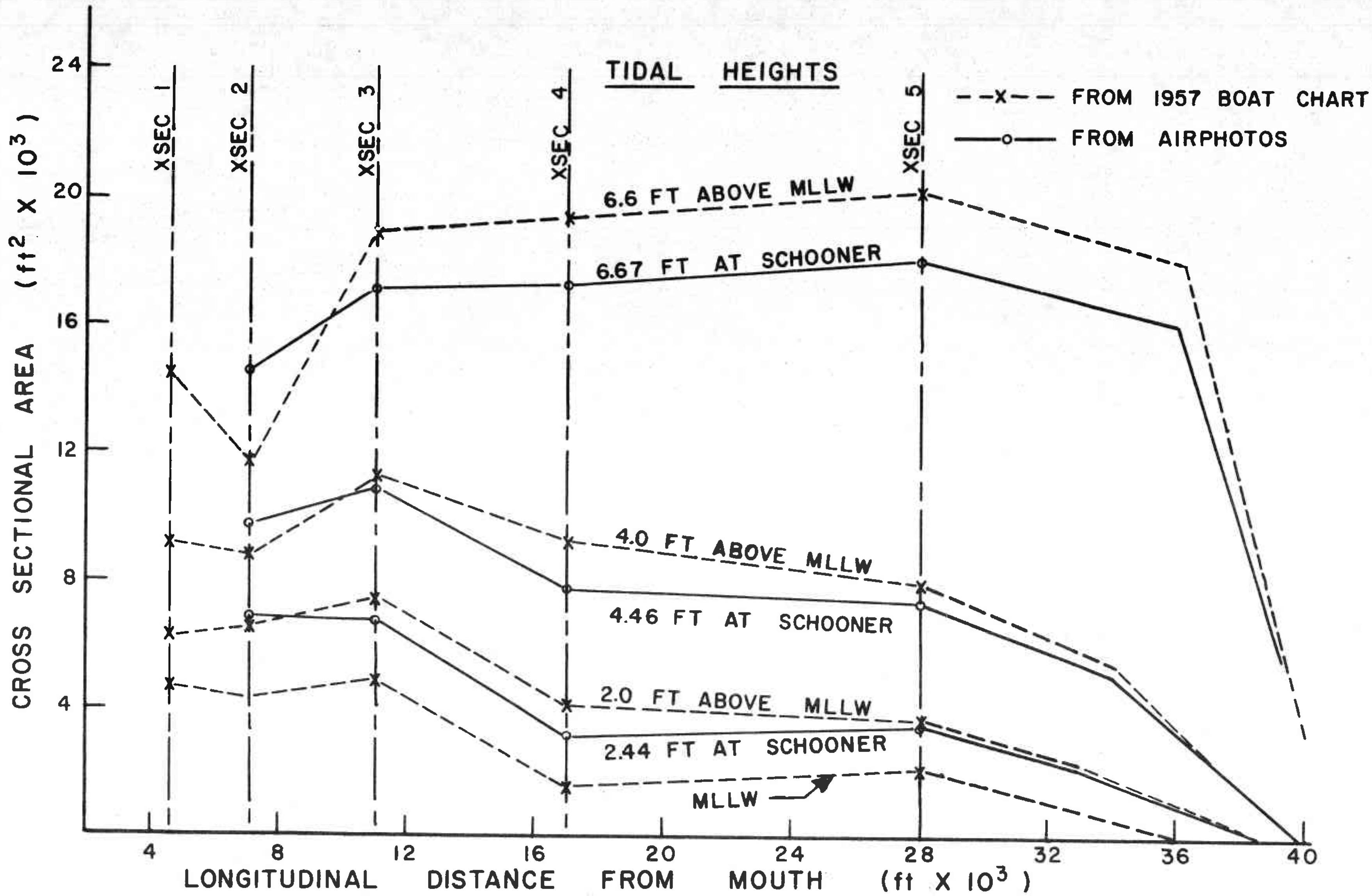


FIGURE 8. CROSS SECTIONAL AREA VS DISTANCE FROM MOUTH

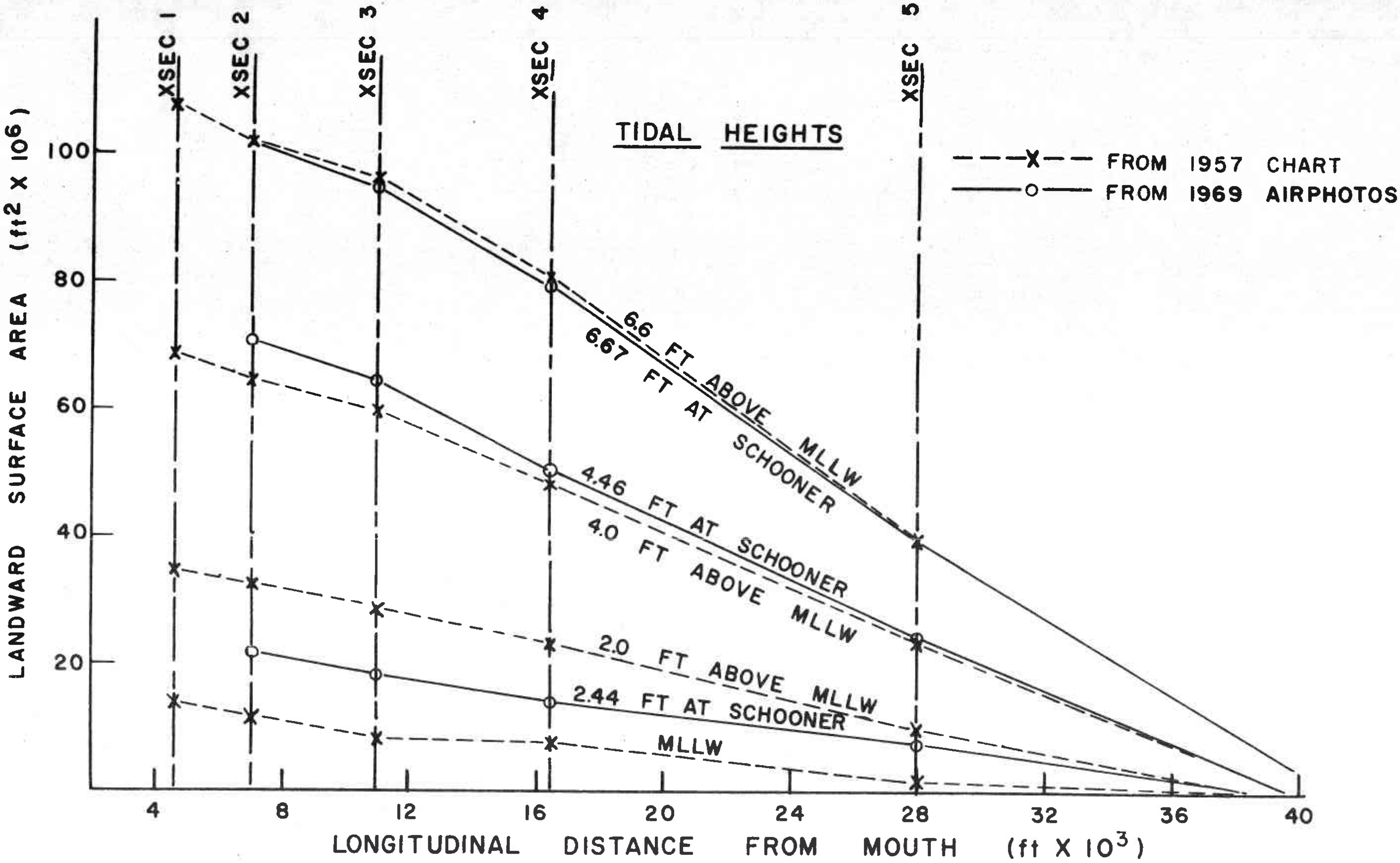


FIGURE 9. SURFACE AREA VS DISTANCE FROM MOUTH

Volumes were computed using the surface areas plotted as functions of distance and tidal height (Figure 10). The Bay's total landward water volume (at X SEC 1) at MLW is approximately 11.3×10^7 cu. ft. (ie: about 2600 acre feet). This is about 25% of the total water volume contained in the bay (landward of X SEC 1) at MHW which is approximately 44.5×10^7 cu. ft. Assuming that these data are correct, a 10% decrease in total MHW volume is indicated from 1957 to 1969.

The water volume contained in a bay between MHW and MLW is termed the bay's tidal prism. On Figure 11, the Netarts Bay tidal prism taken between MHW and MLW is given. If the total tidal prism is taken as approximately 33×10^7 cu. ft. it can be said that on the average about 75% of the total water volume contained in the bay leaves the bay each tidal cycle. This figure will, of course, vary from about 40% on a very small tide range to about 90% on a very large tide range.

In Figure 12 the relationship between tidal prism and cross-sectional area is plotted for Netarts Bay and compared with O'Brien's curve (O'Brien, 1931).[1/] The point of the minimum entrance area lying to the left of the curve agrees with the relationship found in other similar "choked" Oregon estuaries such as the Siletz (Glenne, Goodwin, Emmett, 1970).

Table 2 contains a summary of the physical dimensions discussed in this chapter.

[1/] O'Brien's relationship competes cross sectional area at the estuary mouth to tidal prism by $A_c = 1000\, P_t^{0.85}$ where A_c is cross sectional area and P_t is tidal prism from MHW to MLW.

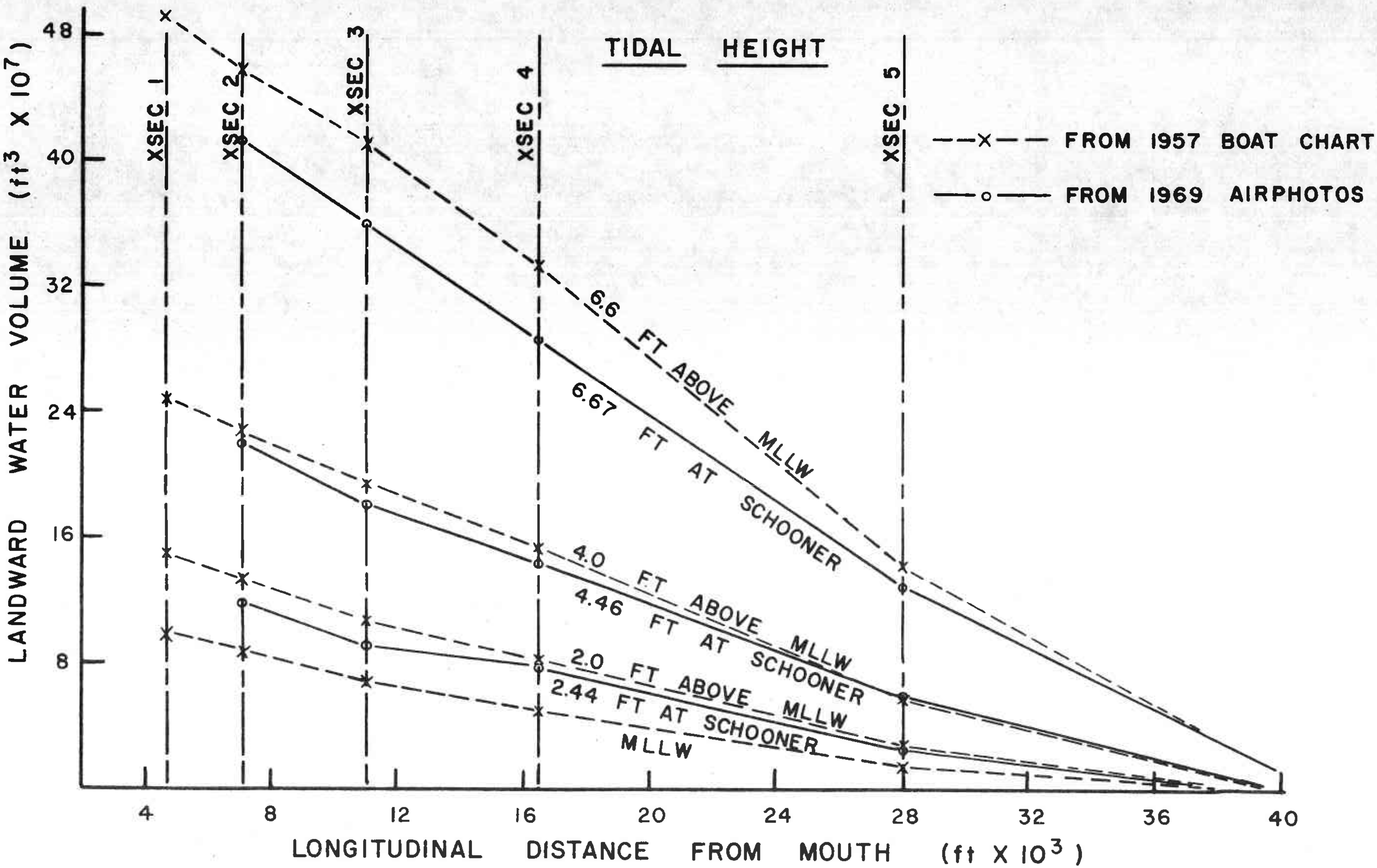


FIGURE 10. WATER VOLUME VS DISTANCE FROM MOUTH

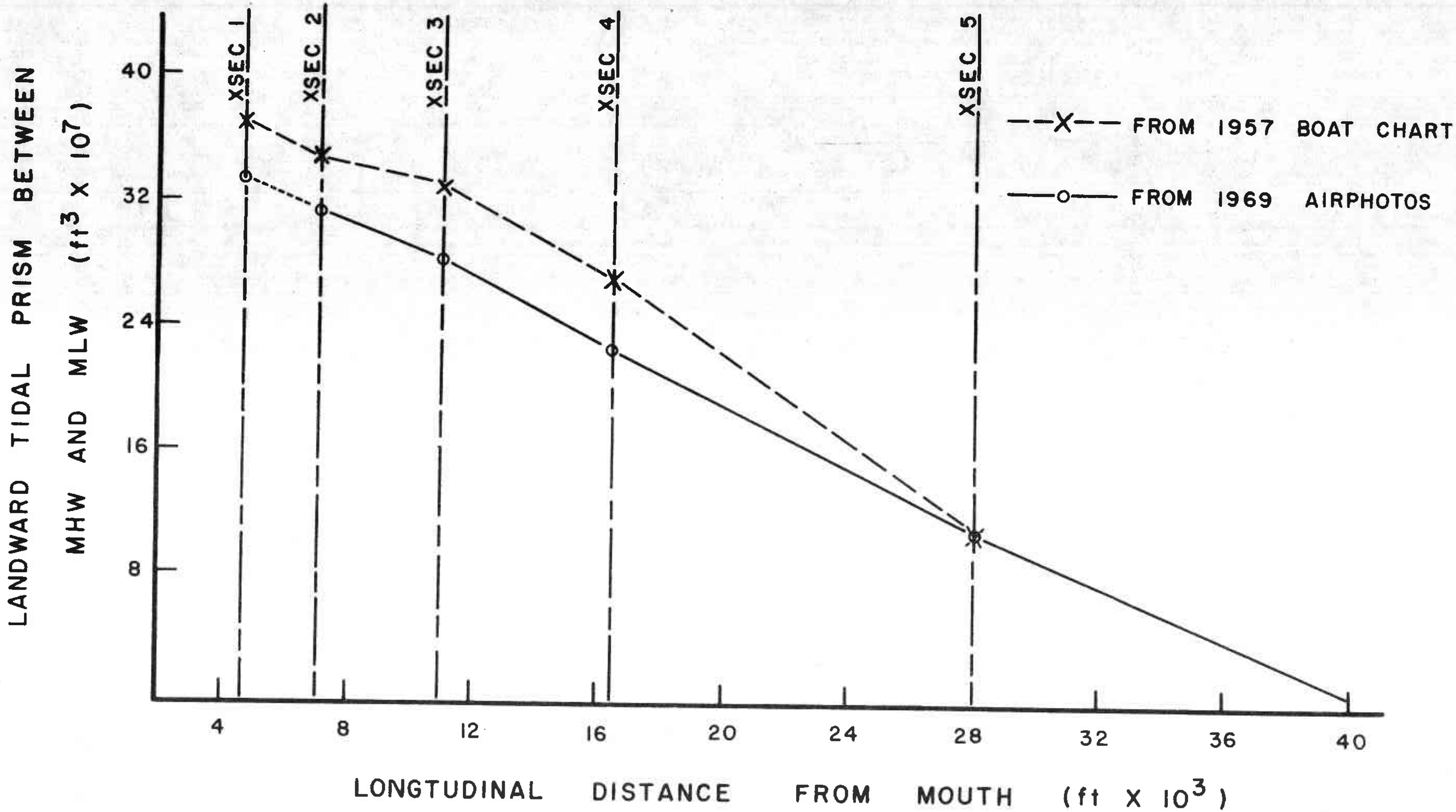


FIGURE II. TIDAL PRISM FOR NETARTS BAY

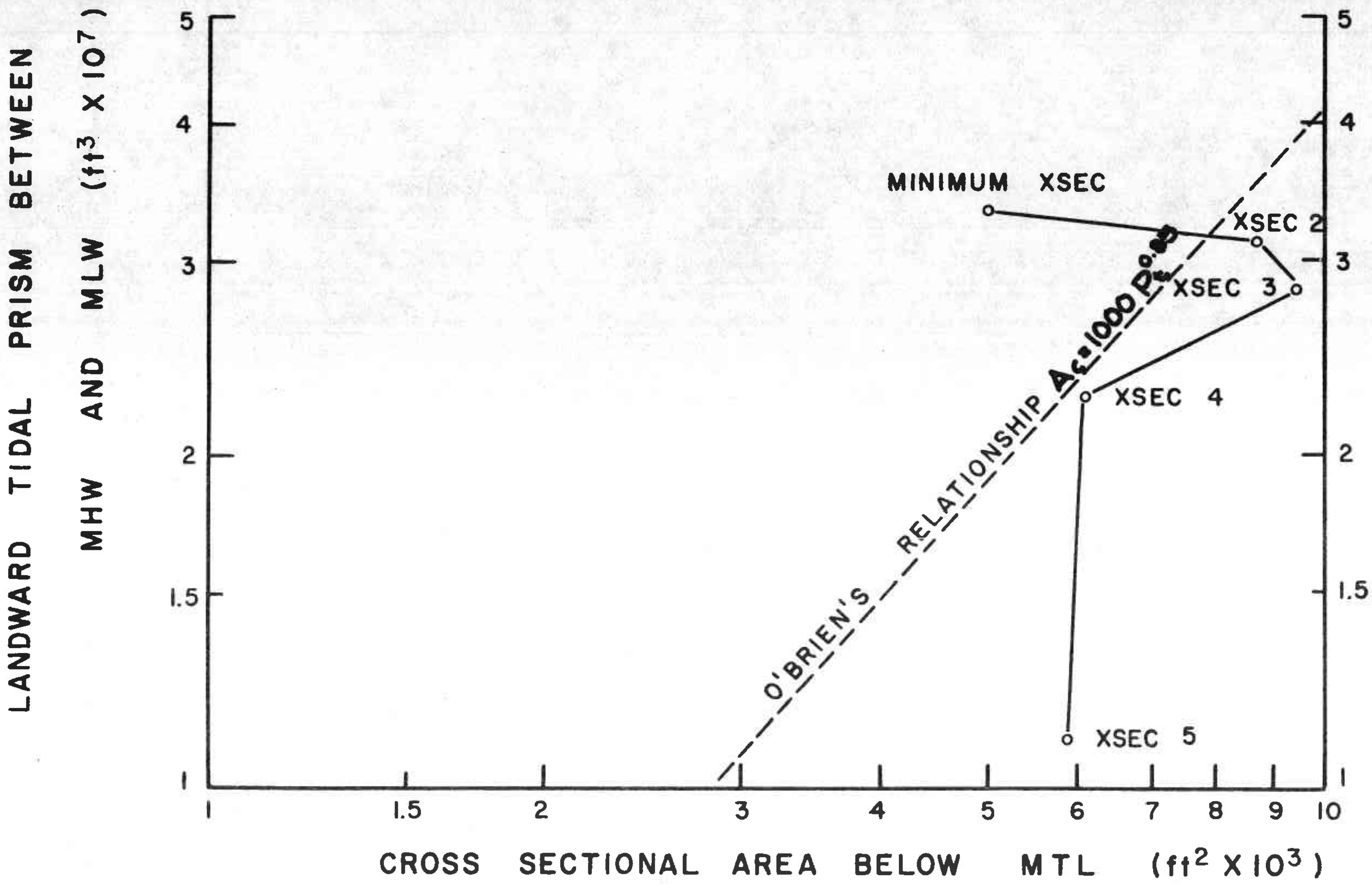


FIGURE 12. NETARTS TIDAL PRISM COMPARED TO O'BRIEN'S RELATIONSHIP

Table 2. Summary of Netarts Bay Dimensions

	Entire Bay	Landward of x sec e	Landward of x sec 5
Surface Areas			
- at MLW	$2.2 \cdot 10^7$ ft^2	$1.3 \cdot 10^7$ ft^2	$0.5 \cdot 17^7$ ft^2
- at MTL	$6.0 \cdot 10^7$ ft^3	$5.0 \cdot 10^7$ ft^2	$2.4 \cdot 10^7$ ft^2
- at MHW	$10.8 \cdot 10^8$ ft^2	$9.45 \cdot 10^8$ ft^2	$3.95 \cdot 10^8$ ft^2
Water Volumes			
- at MLW	$11.3 \cdot 10^7$ ft^3	$7.8 \cdot 10^7$ ft^3	$1.9 \cdot 10^7$ ft^3
- at MTL	$24 \cdot 10^7$ ft^3	$18 \cdot 10^7$ ft^3	$6.0 \cdot 10^7$ ft^3
- at MHW	$44.5 \cdot 10^7$ ft^3	$36 \cdot 10^7$ ft^3	$12.9 \cdot 10^7$ ft^3
Tidal Volume between MLW and MHW	$33.2 \cdot 10^7$ ft^3	$28.2 \cdot 10^7$ ft^3	$11 \cdot 10^7$ ft^3
Cross-sectional Area at MTL			
- minimum	4980 ft^2		
- maximum	8250 ft^2		

B. Hydrography

1. Tidal Observations

During part of the 1969 Summer, tide recorders were installed and operated at Tillamook County Boat Landing (Schooner) and Whiskey Creek. Two Leupold-Stevens Type F recorders were used with stilling wells and operated on a 24 hour cycle. The recorders were levelled into existing bench marks and the recorded heights were registered with respect to Mean Lower Low Water (MLLW) at Tillamook, which is given as 3.41 feet below Mean Sea Level (MSL). MSL is a relatively constant elevation along the Oregon Coast.

The gage at Schooner was operated satisfactorily for about two weeks while the gage at Whiskey Creek only gave about one week of record due to the difficulty of measuring very low waters at this location. The times and heights of observed high and low waters at Schooner and Whiskey Creek are given in Table 3.

2. Comparison With Newport Tides

The tide recorder at Newport (operated by the Oregon State University Marine Science Center) has proven to be fairly representative of true coastal conditions (not masked by excessive estuary influences) (Goodwin, Glenne, Emmett, 1970). It is therefore significant to compare the results of the tide recorder at Schooner with those of the Newport gage for the same observation period. Corresponding elevations of high and low waters for Newport and Schooner are shown in Figure 13. This figure shows that if the elevation of high or low water at Newport is known, it is possible to predict the corresponding elevation of high or low water at Schooner. One should note that the elevations at Newport are with respect to MLLW at Newport (4.16 feet below MSL) while the elevations at Schooner are with respect to MLLW at Tillamook (3.41 feet below MSL).

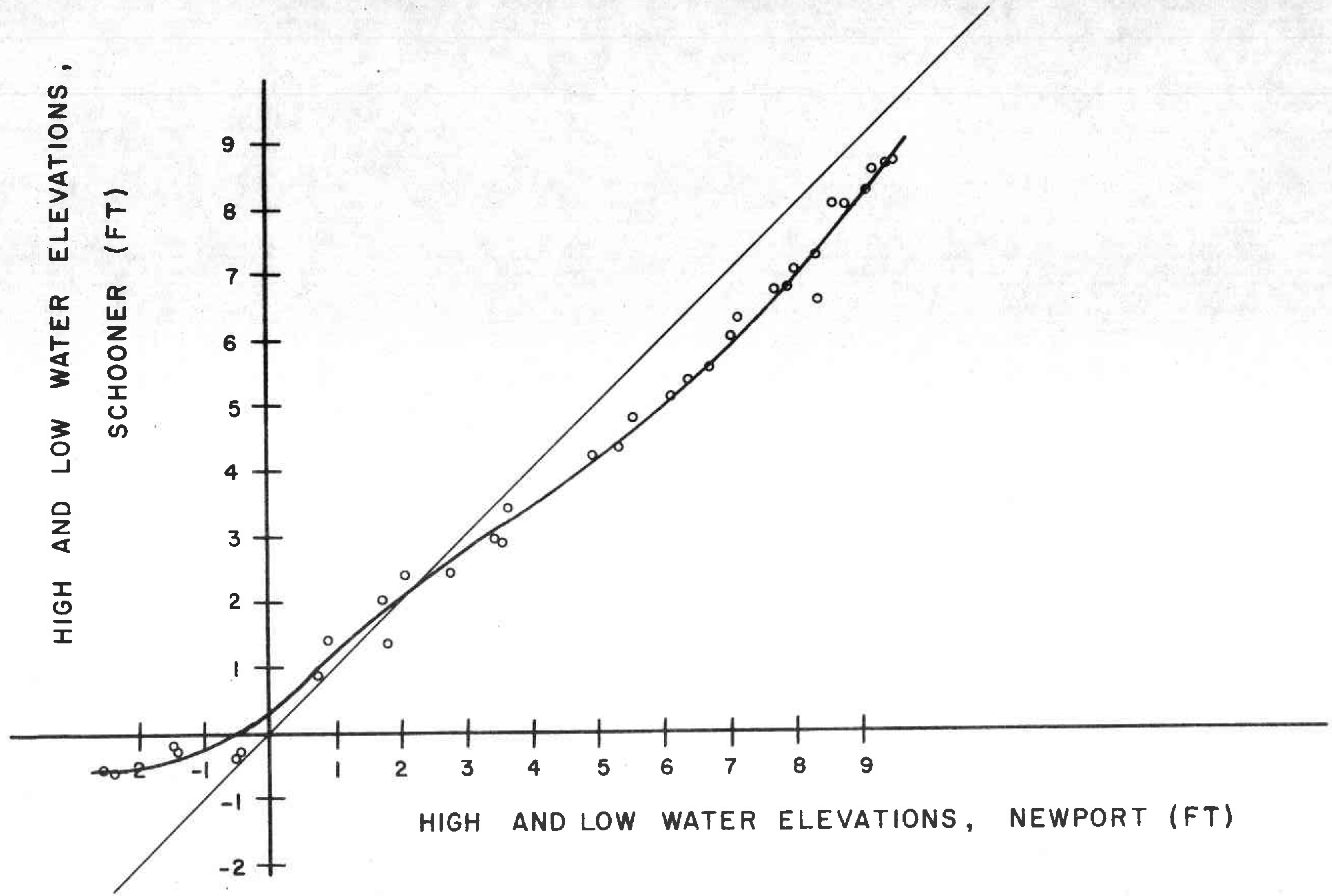


FIGURE 13. SCHOONER TIDAL HEIGHT VS NEWPORT TIDAL HEIGHT

Table 3. Tidal Observations

Date	Time	Schooner Elev.	Range	Whiskey Creek Time	Whiskey Creek Elev.	Whiskey Creek Range	Time Lag (min.)	Choking coeff.
16 Jul	1050	-0.42	5.92					
	1625	5.50	2.84					
	2150	2.66	4.04					
17 Jul	0345	6.70						
22 Jul	1225	1.39	5.20					
	1915	6.59	5.69	1952	6.74		37	
23 Jul	0245	0.90	3.33	-	-		-	
	0800	4.23	1.77	0917	4.05	1.79	77	100%
	1310	2.46	-	1355	2.26		45	
	-	-	-	-	-		-	
24 Jul	-	-		-	-		-	
	0938	4.37	1.47	1045	4.27	1.22	67	83%
	1410	2.40	4.36	1520	3.05	4.49	70	99%
	2050	7.26	7.62	2105	7.54		15	
25 Jul	0512	0.36	5.16	-	-		-	
	1105	4.80	1.38	1205	4.49	1.07	60	78%
	1520	3.42	4.65	1625	3.42	4.51	65	98%
	2145	8.07	8.33	2158	7.93		13	
26 Jul	0623	-0.26	5.39	-	-		-	
	1205	5.13	1.84	1317	4.99	1.65	72	90%
	1658	3.29	4.97	1748	3.34	5.00	50	100%
	2250	8.26	-	2300	8.31		10	
27 Jul	-	-	-	-	-		-	
	1225	5.56	2.60	1405	5.19	1.93	90	74%
	1802	2.96	5.73	1845	3.26	5.05	43	88%
	2350	8.69	9.22	0015	8.31		25	
28 Jul	0820	-0.53	6.54	-	-		-	
	1335	6.01	3.27	1503	5.28	2.31	92	70%
	1905	2.74	5.90	2022	2.97	5.03	77	85%
29 Jul	-	8.64	-	0155	8.00		25	
	-	-	-	-	-		-	
	-	-	-	-	-		-	
	2010	2.42	6.15	2102	2.99	4.76	52	77%
30 Jul	0150	8.57	9.05	0210	7.75		20	
	0955	-0.48	7.22	-	-		-	
	1515	6.74	4.70	1558	6.61	3.99	43	87%
	2110	2.04	5.99	2205	2.62	5.27	55	88%
31 Jul	0245	8.03	-	0300	7.89		15	
	-	-	-	-	-		-	
	1515	6.72	-	1630	6.67		41	
	-	-	-					
1 Aug	-	-	-					
	1103	-0.18	7.22					
	1640	7.04	5.62					
	2320	1.42	4.92					ave. 86%
2 Aug	0428	6.34	6.56					
	1120	-0.22	7.01					
	1705	6.79	5.83					
3 Aug	0010	0.94	4.43					
	0505	5.39						

Table 4. Summary of Tidal Observations (16 July - 3 August, 1970)

	Schooner	Whiskey Creek	Schooner to Whiskey Creek
MHHW elevation*	7.66 ft	7.81 ft	
MHW	6.59 ft	6.50 ft	
MTL	3.78 ft	4.09 ft	
MLW	0.97 ft	1.67 ft	
MLLW	-0.25 ft	-	
Mean Tidal Range	5.62 ft	4.83 ft	
Ebbing Period for Mean Tidal Range	405 min.	410 min.	
Flooding Period for Mean Tidal Range	340 min.	335 min.	
Avg. Time Lag of High or Low Water			47 min.
Avg. Choking Coefficient			86%

* MHHW - Mean Higher High Water

MHW - Mean High Water

MTL - Mean Tide Level

MLW - Mean Low Water

MLLW - Mean Lower Low Water

Elevations are expressed above MLLW at Tillamook which is 3.41 feet below Mean Sea Level.

Note that observation periods are not the same for Schooner and Whiskey Creek elevations.

A comparison of the tidal observations at Schooner with those from Newport shows that, in the observation period the average tidal range at Schooner was 5.62 feet or approximately 81% of the average tidal range of 6.92 feet at Newport. Most of this "choking" occurs in the Netarts Bay entrance channel. The elevation of Mean High Water (MHW) at Schooner was 3.18 feet above MSL as compared with 3.39 feet above MSL at Newport. The elevation of Mean Low Water (MLW) at Schooner was 2.44 feet below MSL as compared with 3.54 feet below MSL at Newport.

To facilitate prediction of times of high and low waters in Netarts Bay the observed time lags of high and low waters between Newport and Schooner have been plotted in Figure 14. The major part of the time lag is due to the friction in the Netarts Bay entrance channel since indications are that a tidal wave requires only about 8 minutes to travel the distance from Newport to Oceanside. The observed longer time lags for low waters also bear this observation out. The major part of the tidal amplitude choking observed at Schooner also takes place during times of low water characterized by high frictional effects. To accurately predict high and low waters at Schooner, one should use Figure 14 and the ESSA tide predictions for Newport, obtainable at the Marine Science Center.

3. Tidal Heights and Times in Netarts Bay

The data listed in Table 3 have been analyzed and reduced as shown in Table 4. Average MHHW, MHW, MTL, MLW and MLLW elevations have been calculated for a 14 day period at Schooner and a 9 day period at Whiskey Creek. Due to the difficulty of measuring Lower Low Water at Whiskey Creek there is no elevation given for MLLW. This difficulty of measurement is due to the fact that the Whiskey Creek channel has virtually no water during most low water periods.

For the tide ranges measured at both Schooner and Whiskey Creek, choking coefficients have been calculated (Table 3). The choking coefficient is defined as the tide range at Whiskey Creek divided by the tide range at Schooner. An average value of 86% choking coefficient is found for tidal ranges between Schooner and Whiskey Creek. Thus since a Mean Tide Range of 5.62 ft. was measured at Schooner a corresponding Mean Tide Range at Whiskey Creek would be 0.86 x 5.62 ft. = 4.83 ft.

Two separate attempts were also made to measure a tide range on the coast outside Netarts Bay. The tide ranges at Schooner were found to be 80% and 91% of those measured on the outside of the Netarts sandspit for tide ranges of respectively 7.2 ft. and 1.5 ft. at Schooner. These limited data indicate that, on the average, approximately 76% of the ocean tide range can be expected in Netarts Bay at Whiskey Creek. Attempts to obtain more than two observations were not made due to the difficulty of measuring the ranges in the surf zone.

In Figure 14 the times required for high and low waters to travel from Newport to Schooner have been plotted for a 14 day observation period. The major part of these time lags (except about 8 minutes) can be attributed to the time taken for the tidal wave to travel from the seaward side of the Netarts sandspit to Schooner. Separate measurements conducted on two tides at the outside of the sandspit indicate an average travel time of about 45 minutes for high and low waters from the seaward side of the sandspit through the Netarts Bay entrance channel to the site of the Schooner gage (approx. 9600 feet).

Table 3 contains the calculated time lags between times of high and low waters at Schooner and Whiskey Creek. The

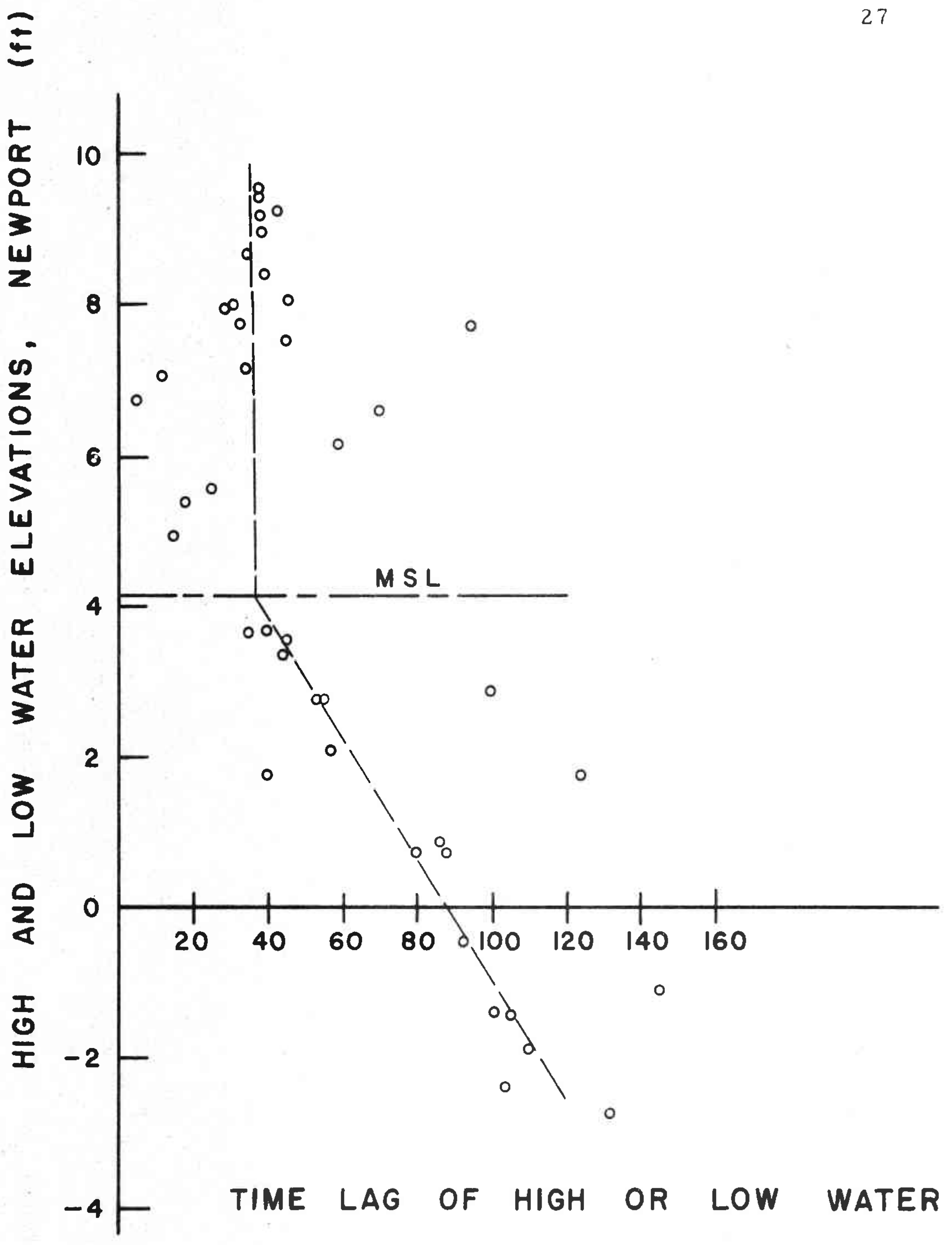


FIGURE 14. TIDAL TIME LAG FROM NEWPORT TO SCHOONER

average time lag or time taken to travel the distance between the two gaging stations (approx. 18,400 feet) is shown in Table 4 as 47 minutes. This time lag of 47 minutes does not include any time lags for Mean Lwer Low Waters since they could not be measured at the Whiskey Creek gaging station.

A total time lag for high and low waters to proceed from the ocean through Netarts Bay to Whiskey Creek of about 45 + 47 = 92 minutes is fairly representative of existing conditions.

4. Tidal Currents in Netarts Bay

Ideally all the tidal currents in Netarts Bay should have been mapped simultaneously with respect to location, depth and tidal time. Unfortunately, due to the very large requirement for manpower and equipment, such an undertaking is not practical. An alternate method of conducting point measurements using a specially equipped boat and area measurements using special drift cards was utilized.

The results of the current measurements conducted by boat on 24 July, 1970, are shown in Figure 15. The measurements seem to indicate a 25% smaller current near the bottom at 80% depth than near the top at 20% depth. This absence of a strong vertical velocity gradient has also been noticed in other parts of Netarts Bay. These data indicate that the bay is well mixed in the vertical direction and is not subject to gradients in current velocity due to stratification. This characteristic has also been observed during water quality sampling and dye studies.

Strong horizontal velocity gradients are observed with higher velocities. Most of the water is transported in the deeper channels. Flow along the tidal flats and shoreline is

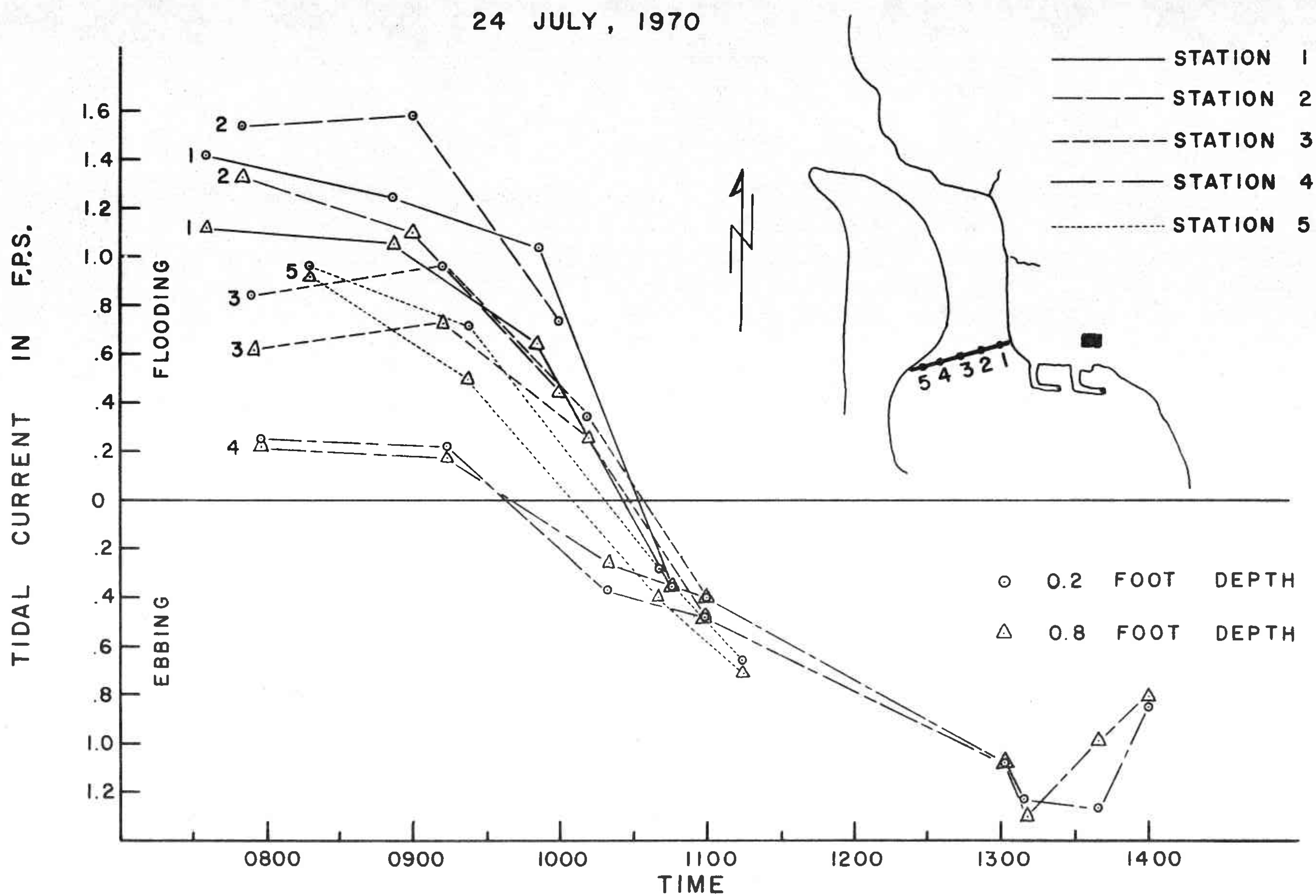


FIGURE 15. BOAT MEASURED CURRENTS AT STATION B

secondary to the main channel flow. Flows onto and off of the tidal flats are sometimes almost perpendicular to the flow in the main channel.

Slack Water (zero current velocity) can be seen from Figure 15 to occur at approximately 1030 hours on 24 July, 1969. This compares with high water on 24 July at Schooner at 0938 hours and at Whiskey Creek at 1045 hours. Other measurements have also shown that slack waters occur at a location fairly soon after times of high and low water occur at the same location. Such a phase lag of nearly 90^o between tidal heights and currents is fairly typical of estuaries and bays with the physical characteristics of Netarts Bay, i. e. low fresh water inflow and an integrating type basin. On the Oregon coast, for example, the Yaquina, Alsea and Siletz exhibit similar phase lag characteristics. By subtracting the time of low water from the following time of high water at a location, the approximate period during which flooding occurs at the location can be calculated. Similarly, by subtracting the time of high water from the following time of low water at a location the approximate period during which ebbing occurs can be located. The flooding and ebbing periods at Schooner and Whiskey Creek have been calculated from the times of high and low waters shown in Table 4. When averaged to represent Mean Tidal Range conditions at the two gaging stations, the flooding and ebbing periods given in Table 4 result. As can be seen, the ebbing periods are longer than the flooding periods. The sum of the flooding and ebbing periods must, on the average, total approximately 745 minutes, the average tidal period. During the winter when a significant quantity of fresh water flows into the bay, longer ebbing periods and shorter flooding periods would be expected.

On 11 July, 1970 drift card measurements were performed on an ebbing tide (tidal range: 2.8 ft.). The drift cards were released approximately 1850 feet south of the Tillamook County Boat Landing in the deep channel immediately west of the proposed sewage treatment plant site (Figure 16). The cards which penetrated to a depth of approximately 3 ft., were released at 0800, approximately one hour after Lower High Water at Schooner. Calm winds and low surf conditions existed until Noon. The positions of the drift cards at every one-half hour after release are given in Figure 16. The drift card velocities varied from approximately 1 ft./sec. to 1.5 ft./sec. except from position 3 to position 4 where the velocity was about 2.1 ft./sec. These velocities are essentially representative surface velocities (magnitude and direction) except between position 1 and position 3 where secondary currents due to flow around bends tended to deposit the cards on the shore of the outside of the bend (East shore between Schooner and the release point). The velocities agree with those measured using current meters (Figure 15).

All the cards, except two that were destroyed by the surf, proceeded South toward Cape Lookout after leaving the Netarts Bay entrance channel. The travel time from the point of release to the mouth of the Bay was approximately 100 minutes. This travel time varies with the tidal range. High afternoon wind and surf made it impossible to observe the paths of the cards on the following flood tide.

5. Wave Information

Data on wave direction, height and period on the Oregon coast are very sparse. The data obtained by National Marine

JULY 11, 1970

POSITION	TIME
1.	0800
2.	0830
3.	0900
4.	0930
5.	1000
6.	1030
7.	1100

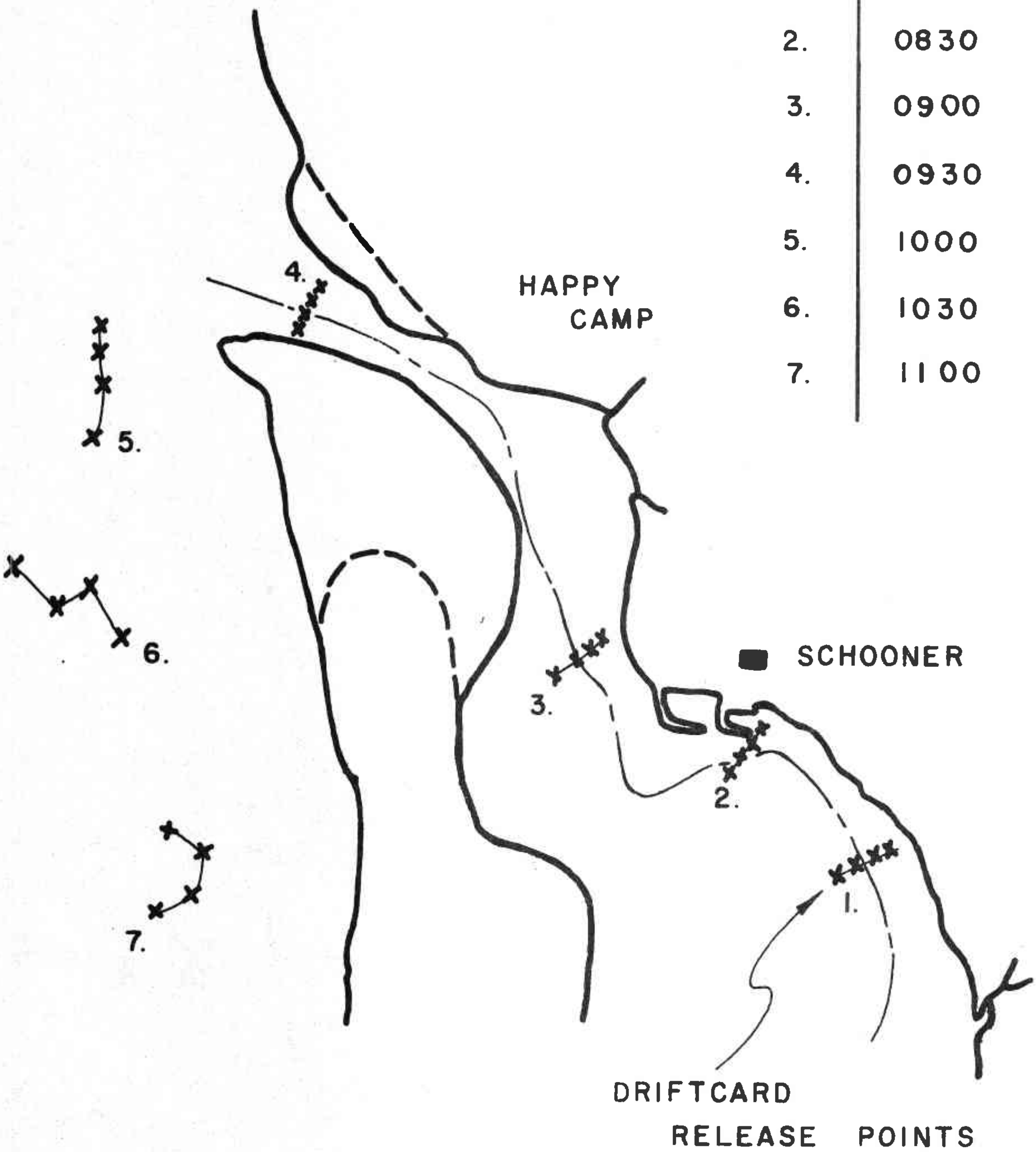


FIGURE 16. DRIFT CARD RELEASE

Consultants using hindcast techniques are generally used, but these data are open to considerable criticism. A summary of the data is given in Table 5. The most frequently occurring summer conditions are swell from NW-W and sea from N-NW[1/]. In the winter the swell comes mainly from NW-W while the sea mainly comes from SW-SSE. The highest average waves hindcasted were the winter seas from SW-SSE (7.9 ft. wave height), while the longest average waves hindcasted were the autumn swell from NW-W (10.8 sec. wave period). Against the predominant swell from NW-W and N-NW Three Arch Rocks offers considerable protection for the Oceanside shore and the Netarts Bay entrance.

The dominant swell direction from NW-W would indicate a most frequent (but not necessarily greatest intensity) longshore coastal transport from the North to the South due to wave currents. Such a transport was observed on an ebbing tide 11 July, 1970 from drift card release (see Figure 16).

Inside Netarts Bay the most significant waves would occur near Schooner at high tide with a strong SSW wind. Using a fetch of 4 miles and a wind strength of 60 mph in empirical formulas by Bretschneider and Saville, a significant wave height of 5 feet and a significant wave period of about 4.4 seconds result. In order to achieve these wave conditions the 60 mph wind would have to blow for at least 45 minutes. To have a 60 mph wind from the S-SW blowing for 45 minutes is a very rare circumstance certainly, but not completely unlikely.

[1/] Swell should be thought of as the long, uniform waves reaching shore from midocean storms. Sea is used to describe choppiness resulting from storms and winds in the observation area.

Table 5. Hindcast Deep Water Wave Heights and Periods on the Oregon Coast (from National Marine Consultant Data)

		N - NW			NW - W			W - SW			SW - SSE			Calm
		H_o	T	%	H_o	T	%	H_o	T	%	H_o	T	%	%
Winter	Swell	4.5	10.0	10.1	5.4	10.7	52.2	5.2	10.2	24.7	5.6	9.4	13.0	30.1
	Sea	5.6	6.8	7.5	5.9	7.3	10.8	6.2	7.3	14.5	7.9	7.9	37.0	
Spring	Swell	3.3	10.3	15.1	4.4	10.7	65.7	4.1	10.5	12.4	4.5	9.1	6.2	29.7
	Sea	4.0	6.3	32.8	3.9	6.2	9.6	4.6	6.6	10.4	5.3	6.8	17.4	
Summer	Swell	2.9	9.4	33.3	3.3	10.4	59.5	3.2	8.9	4.4	3.5	8.6	2.8	29.5
	Sea	3.8	6.2	51.4	2.7	5.4	4.8	3.2	5.8	5.6	4.2	6.0	8.6	
Autumn	Swell	4.8	10.3	17.8	5.1	10.8	68.4	3.7	10.0	7.1	3.8	9.6	6.7	35.3
	Sea	4.2	6.2	17.4	5.1	6.8	7.1	4.7	6.5	15.7	5.9	7.1	25.1	
Annual	Swell	3.6	9.8	18.8	4.6	10.5	60.5	4.6	10.4	13.2	4.8	9.4	7.5	31.0
	Sea	4.0	6.3	30.0	4.7	6.6	7.8	5.0	6.8	10.6	6.5	7.3	20.6	

H_o - deep water wave height in feet

T - wave period in seconds

% - % of time waves approach from particular direction

The more common 13-31 mph summer winds from the NW (see next section) will, in general, cause a maximum significant wave height of approximately 1.3 feet inside Netarts Bay.

C. Hydrology

1. Climatological Data

The climatological data available and pertinent to this study have been tabulated in Tables 6 and 7. Since no long period records are available for Netarts or Oceanside, data from Tillamook and Astoria are shown. The wind data shows a predominant wind direction from the Northwest in the Summer and from the South in the Winter. There appears to be more periods of calm during the Winter than during the Summer.

To arrive at a net water balance from a water surface, the Astoria pan evaporation data has been multiplied by 0.7 to approximate actual evaporation in nature based upon accepted hydrologic techniques . This value has been subtracted from the Tillamook or Netarts precipitation. A net normal annual water surplus of 72.4 inches results (i.e. precipitation minus evaporation).

Table 8 shows climatological data for the 1969-70 observation period. The Netarts Bay data have been collected by the OSU Netarts Bay Fisheries Laboratory personnel. From the collected data it appears that the precipitation at Whiskey Creek does not significantly differ from that indicated for Tillamook.

Comparison of the annual values in Table 8 with those in Table 6 indicates that the 1969-70 observation year was a very typical year as far as weather is concerned.

2. Runoff

Of the approximately 18.5 square miles in the Netarts Bay basin, about 2.5 square miles represent the Netarts Bay

Table 6. Normal Climatological Data

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Tillamook													
- air temp., °F (1936-1951)	42.5	44.3	45.7	48.4	52.0	55.8	58.8	58.9	56.4	52.9	47.9	44.0	50.6
- precipitation, in. (1940-1955)	13.48	11.59	10.74	6.36	5.17	3.16	1.33	1.48	3.48	7.28	13.51	15.26	93.50
- avg. wind direction (1943-1945)	S	SSW	NW	SSW	NW	NW	NW	NW	NW	S	S	S	
Astoria													
- air temp., °F (1953-1968)	41.7	42.8	44.5	49.0	53.3	57.3	60.6	61.0	58.0	52.9	46.3	43.1	50.8
- precipitation, in. (1953-1968)	11.71	9.89	8.98	5.18	2.62	3.02	1.27	1.49	3.13	7.70	11.20	13.65	80.44
- pan evap., in. (1965 + 1969 avg.)	0.55	1.09	2.30	1.90	3.76	3.69	4.77	3.96	2.93	1.50	0.86	1.61	28.92
- avg. wind direction	E	ESE	SE	WNW	NE	NW	NW	NW	SE	SE	SE	ESE	
- wind speed, mph (11 year record)	8.9	8.7	8.7	8.5	8.2	8.2	8.5	7.7	7.2	7.6	8.5	8.8	8.3
(Tillamook precip.) - (actual evap.) (in)	13.1	10.8	9.1	5.0	2.5	0.6	-2.0	-1.3	1.4	6.2	12.9	14.1	72.4

Actual evaporation = 0.7 x pan evaporation

Stations - Astoria USWB at Astoria airport for air temperature, precipitation and wind
Astoria Experiment Station for evaporation
Tillamook (IW) KTIL radio transmitter for air temperature and precipitation
Tillamook airport for wind

Table 7. Tillamook Airport Normal Wind Data

Wind Direction	Percentage of time wind blows					
	Calm	January 4-12 mph	January 13-31 mph	Calm	July 4-12 mph	July 13-31 mph
North	49%	1%	0%	39%	6%	2%
Northeast		2%	2%		1%	0%
East		9%	4%		1%	0%
Southeast		4%	1%		1%	0%
South		13%	4%		2%	1%
Southwest		3%	2%		2%	1%
West		3%	1%		7%	2%
Northwest		2%	2%		23%	13%

Table 8. 1969-1970 Climatological Data

	1969								1970								Annual
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
Tillamook (KTIL)																	
- avg. air temp. (°F)	53.7	59.8	57.1	57.1	56.9	51.3	46.6	44.7	43.4	47.6	45.1	45.5					50.7
- precipitation (in.)	4.77	6.08	0.64	0.61	5.44	7.80	7.80	16.19	19.39	7.07	6.21	9.77					91.8
Astoria																	
- total wind (miles/month)	869	590	743	729	827	862	713	1215	1573	1091	952	1093					938
- max. wind (miles/day)	76.0	77.5	80.4	79.3	72.9	61.9	52.5	47.3	45.6	54.9	61.0	62.7					80.4
- pan evaporation (in.)	3.96	2.98	4.71	4.04	2.50	1.81	1.12	0.80	0.40	1.08	2.03	1.51					26.9
Netarts Grocery																	
- precipitation (in.)						6.55	6.94	13.01	16.90	5.7	5.1						
Whiskey Creek																	
- precipitation (in.)						7.37	8.03	14.85	22.30	7.0	6.6	9.8	3.2				
- avg. air temp. (°F)									44	49	46	47	52				
- creek water temp. (°F)									44.5	48.5	50	52	58				
(Precipitation) - (actual evaporation) (in.)	2.0	4.0	-2.7	-2.2	3.7	6.1	7.3	14.3	22.0	6.2	5.2	8.7					74.6

Actual evaporation = 0.7 x Pan evaporation

Table 9. Approximate Normal Runoff

	Inflow to water surface	Normal runoff from land	Fresh water inflow to Netarts Bay
Jan	29 ft^3/sec	171 ft^3/sec	200 ft^3/sec
Feb	26 "	148 "	174 "
Mar	20 "	127 "	147 "
Apr	11 "	81 "	91 "
May	5.5 "	45 "	50 "
June	1.3 "	24 "	25 "
July	-4.4 "	12 "	8 "
Aug	-2.8 "	8 "	5 "
Sept	3.2 "	10 "	13 "
Oct	13.5 "	45 "	59 "
Nov	29 "	123 "	152 "
Dec	31 "	198 "	229 "
Annual	13.5 "	90 "	104 "

water surface area at MTL (see Table 2). It seems safe to assume that the net freshwater inflow to this water surface is represented by the last lines in Tables 6 and 8. In Table 9 these inflows have been calculated for the 2.5 square mile water surface as monthly average flows in cubic feet per second.

The runoff into Netarts Bay from the approximately 16 square miles of land area is difficult to determine because there are no stream gaging station records for the area. However, when the average annual discharge of small rivers (drainage area less than 200 square miles) on the North Pacific slope in Oregon is plotted against drainage area, a relationship is found between average annual discharge and drainage area. This relationship has been used to estimate the average annual discharge at about 90 ft^3/sec from Netarts Bay's drainage area. The same procedure gives an average annual flow of about 10 ft^3/sec in Whiskey Creek. The relationship between Whiskey Creek precipitation and stage is shown on Figure 17.

The estimated monthly fresh water inflows to Netarts Bay are given in Table 9 using the monthly flow distribution from Tillamook River (State Water Resources Board, 1961). The peak fresh water inflow (229 ft^3/sec during December) represents a volume inflow of approximately 5×10^6 ft^3 during one-half tidal cycle (6.22 hours) or about 1.5% of an average tidal volume which enters Netarts Bay in the same time period (see Table 2).

One may conclude that during times of heavy rainfall the fresh water inflow to Netarts Bay is large enough to affect the water quality in the upper bay and cause a small flushing action. During the Summer, however, the fresh water inflow

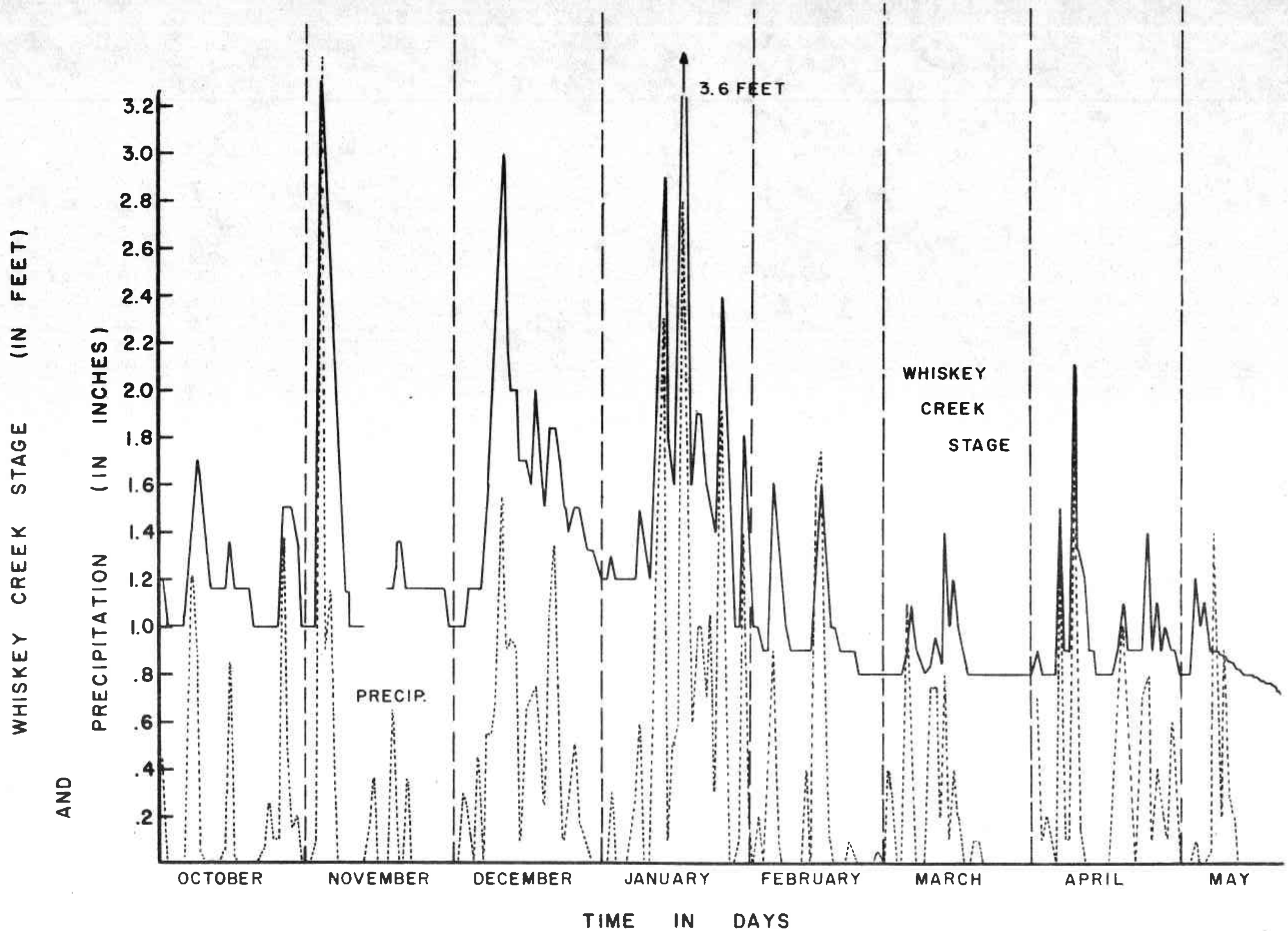


FIGURE 17. WHISKEY CREEK PRECIPITATION AND STAGE 1969–1970

to Netarts Bay is too small to affect the flushing of the Bay.

No account has been taken of groundwater flow into Netarts Bay. Ground water geology maps of Netarts Bay (State Water Resources Board, 1961) show the Netarts Bay drainage area to consist of a Columbia River Basalt mantle over Cape Lookout stretching north almost to Whiskey Creek. The sandspit and the east shore consist of an alluvium while the higher eastern drainage area consists of sandstones and shales with very low permeabilities. Two wells near Whiskey Creek (in the aluvium) report pumping rates of 0.01 gal/min and 1.8 gal/min per foot of drawdown.

The alluvium on the sandspit and eastern shore indicate a possibility of salt water intrusions into groundwater aquifers.

D. Sediments

1. Data

Sediments have been sampled at 20 locations in Netarts Bay (Figure 18). One series of samples was collected on 30 October, 1969 the other on 18 June, 1970. It was thought that the conditions on these two sampling dates would reflect typical Winter and Summer conditions respectively.

Soil gradation curves have been plotted for the analyzed samples and the essential results are given in Table 10. Specific gravities are given for the D_{50} size particles. Sediment descriptions apply to Winter and Summer samples.

2. Seasonal Variation

The average D_{50} (see Table 10) during the October run was 0.26 mm while the average D_{50} for corresponding locations in June was 0.21 mm. Thus, a 22% coarser sediment size was found in October than in June. This may, in part, be explained by the large tides experienced in the week

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[1/] 50% of the particles would be smaller than the D_{50} size.

preceding 30 October. The October sediments were also more uniform (average difference between D_{20} and D_{80} was 0.11 mm) than the sediments sampled in June (average difference between D_{20} and D_{80} was 0.17 mm).

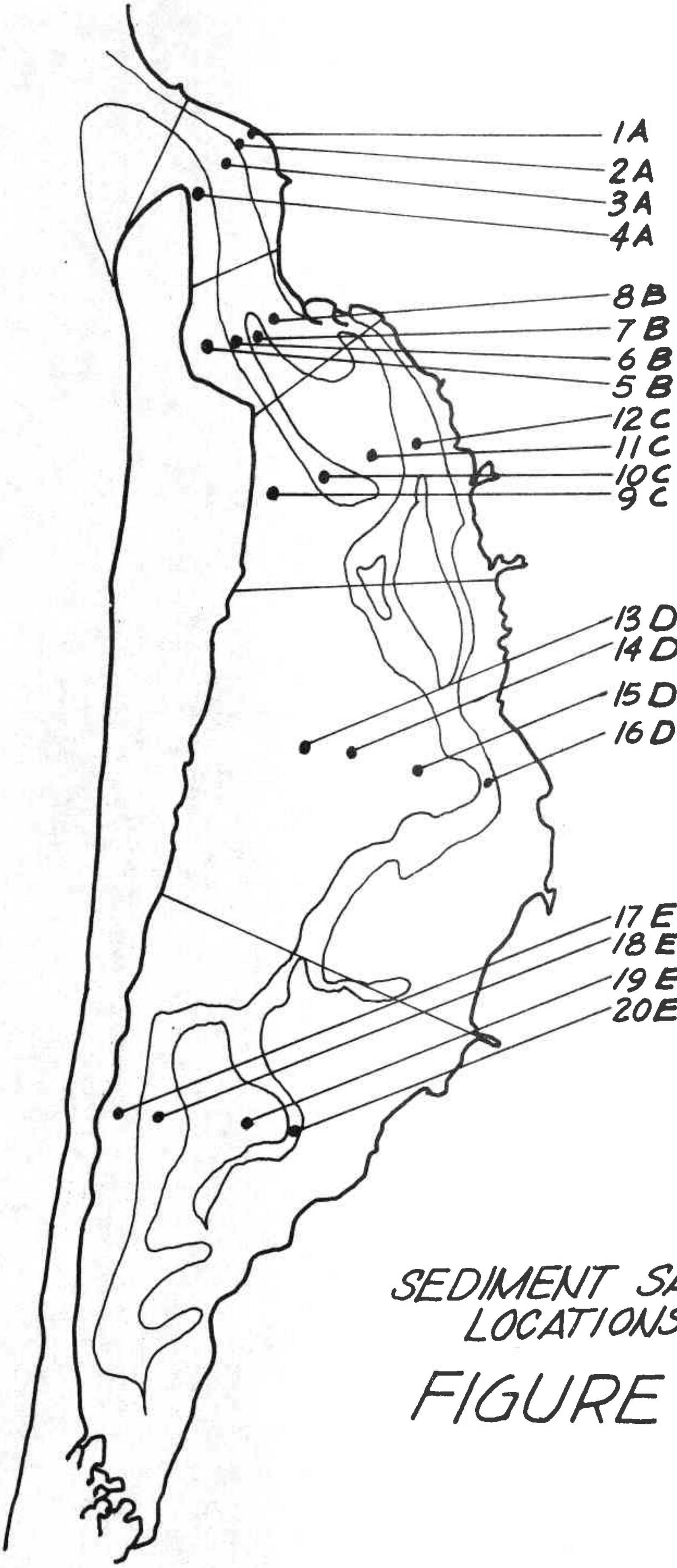
Samples at stations 8B and 18E showed cobbles, sands and silts in June. The cobbles were covered with sand in October. At station 8B the layer of sand on top of the cobbles was 6-10 inches thick in October.

3. Variation with Location

The sediment sizes found in the channel show a slight decrease toward the head of the Bay. Table 10 also shows that larger sediment sizes exist where strong currents are present as may be expected since strong currents tend to carry away fine particles such as silt and clay.

The sediments found near the mouth of the Bay are typical fine silica sands, with small silt and clay contents. At station 18E a silt and clay content of 13% by weight was found in the June sample. This content was 2% in the October sample at the same location. Samples from stations 15, 16, 17 and 20 were found to have a high organic content. The sediments were black, and odorous muds. Primary constituents of the volatile organic gases were hydrogen sulfide (H_2S) and to a lesser extent, ammonia (NH_3). These gases are usually indicators of anaerobic biological processes.

The sources of the basaltic sands, clays and silts are the various streams emptying into Netarts Bay. Most of the silica sands in Netarts Bay are thought to have come via water or wind from the coast. On the outside of bends of the east channel between cross sections 3 and 5 evidence of the original alluvium mentioned in section 3 of this report have been found by divers. Such a scarp can be taken as an



SEDIMENT SAMPLE LOCATIONS

FIGURE 18.

Table 10. Sediment Data

Station	Summer Condition D_{20} mm	D_{50} mm	D_{80} mm	Specific Gravity	Description	Winter Condition D_{20} mm	D_{50} mm	D_{80} mm	Specific Gravity
1A - North Bank	0.28	0.22	0.18	2.97	uniform fine	0.29	0.24	0.195	----
2A - North Berm	----	----	----	----	silica sand	0.29	0.265	0.24	----
3A - Channel	0.28	0.22	0.195	2.77	"	0.36	0.29	0.24	----
4A - South Berm	----	----	----	----	"	0.37	0.28	0.21	2.72
5B - West Bank	----	----	----	----	"	0.295	0.25	0.205	2.66
6B - West Channel	----	----	----	----	"	0.29	0.27	0.24	----
7B - Bar	----	----	----	----	"	0.35	0.27	0.24	----
8B - East Channel	0.28	0.22	0.18	2.73	"	0.28	0.24	0.20	----
					(variable composition)	0.295	0.27	0.24	----
9C - Bank	----	----	----	----	uniform fine silica sand	0.35	0.295	0.25	----
10C - West Channel	0.45	0.22	0.20	2.73, 2.69	uniform silica sand	0.34	0.29	0.25	----
11C - Bar	0.45	0.22	0.20	2.79, 2.68	"	0.295	0.27	0.23	----
12C - East Channel	----	----	----	----	uniform fine silica sand	0.29	0.27	0.23	----
13D - West Bank	----	----	----	----	"	0.28	0.27	0.25	----
14D - Bar	----	----	----	----	"	0.36	0.28	0.25	----
15D - Channel	0.39	0.22	0.12	2.75	organic clayey silica sand	0.29	0.26	0.19	----
16D - East Bank	0.36	0.21	0.108	2.67	organic clayey uniform silica sand	0.29	0.25	0.19	----
17E - West Flat	0.205	0.185	0.11	2.71	organic clayey uniform basalitic sand	0.28	0.22	0.18	----
18E - West Channel Grass Slope	0.30	0.21	0.18	2.81	clayey uniform basaltic sand	0.36	0.29	0.14	----
19E - Sand Bar	0.26	0.20	0.18	2.73	uniform fine silica sand	----	----	----	----
20E - East Channel	----	----	----	----	organic uniform fine basaltic sand	0.305	0.25	0.20	2.77

D_{20}: The particle size in millimeters which 20% by weight of the particles are no larger (coarser) than.
D_{50} " " " " " 50% " " " " " " " .
D_{80} " " " " " 80% " " " " " " " .

indication of meandering activity in this part of the Bay.

Dicken (1966) notes the activity of the foredune border and stability of other features of Netarts Bay. Dicken states that Netarts Bay is "gradually filling with sediment." This conclusion is supported by the observed 10% decrease in bay volume between 1957 and 1969 which was previously mentioned.

III. Water Quality

A. General Discussion

Salinity is defined as the total amount of solid material, in grams, contained in one kilogram of water when all carbonate, bromide, iodine and organic matter are fully oxidized. Salinity is a crude measure of the total salt content, in grams, of mineral salts in a kilogram of water.

Seawater salinity is generally above 32 parts per thousand (grams per kilogram, or ppt). Fresh water salinity is usually near zero ppt. Dilution of seawater by freshwater is indicated by salinities below 32 ppt.

The density of water is related to salinity and temperature. Estuarine stratifications are therefore indicated by differences between top and bottom water salinities and temperatures. Bays without such stratifications are called homogeneous with respect to depth. If the homogeneity is due to turbulent tidal and wave mixing, the bay is called well mixed.

Most marine organisms prefer rather narrow ranges of salinity. Since salinity of coastal and bay waters changes with season, biological conditions of Netarts Bay are partly determined by season.

Water expands as its temperature increases. Dense or cool waters tend to sink. Temperature differences between top and bottom waters indicate thermal stratifications. Homogeneous or well mixed bays do not generally exhibit thermal stratifications.

Chemical processes, biological metabolism and biological reproduction are temperature dependent. Such processes generally accelerate with increasing temperature.

Since a bay is shallower than the ocean, one would expect bay waters to exhibit diurnal temperature fluctuations of greater magnitude than ocean waters. In Netarts Bay, one finds in general that variations of water temperatures are determined by the tidal inflows and outflows.

Dissolved oxygen (DO) is required for most important biological processes in an estuarine environment, the exception being the anaerobic activity present in the bay muds. Photosynthetic plants (phytoplankton and others) produce oxygen in the presence of sunlight. Also oxygen may pass across the air-water interface by molecular diffusion and turbulent entrainment. Dissolved oxygen is consumed by biological respiration and by certain chemical reactions. Oxygen consumption is not limited to materials suspended in the water. Crook (1970) found that organisms and chemicals in tidal flat sediments may consume oxygen at an approximate rate of 2 grams O_2/meter^2/day depending on the particular sediment and degree of disturbance by water motion.

There exists a saturation value of DO for each salinity and temperature. The saturation value for DO decreases with increasing salinity and temperature. Depletion of DO below saturation often indicates a serious water pollution problem.

Biochemical oxygen demand (BOD_5)[1/] is the amount of oxygen utilized in the biologically stabilizing action of organic material. The total oxygen demand consists of the biochemical oxygen demand plus the oxygen required to stabilize reduced chemical compounds such as hydrogen sulfide gas produced in the bay muds. High BOD_5

[1/] Generally defined in terms of the oxygen required to satisfy biochemical degradation of wastes in a water sample over a 5 day period at 20°C.

in water is generally accepted as evidence or organic pollution while a low BOD_5 usually indicates a water body is not seriously polluted with organic matter or that previous pollution has been stabilized by natural processes. It is important to note that BOD_5 is only one measurement of pollution and does not indicate other types of serious water quality problems that may exist such as pollution from toxic materials.

Oxygen from atmospheric and water sources is needed for stabilization of organic materials found on or trapped in sediments. Of importance in determining oxygen demand of sediments are:

1. amounts of oxidizable materials disturbed by normal bay currents.
2. amounts of oxidizable materials in the aerobic (oxygen available) zone of the sediments.
3. rates of oxygen uptake by sediments exposed to various states of submergence.

Sediments demanding large amounts of oxygen may be called highly productive or over-burdened, depending upon the ability of oxygen sources to maintain an adequate supply of oxygen. Small oxygen demands are associated with low productivity or clean sediments.

pH measurements indicate acidity or basicity of water. pH units greater than 7.0 indicate basic waters. pH numbers less than 7.0 indicate acidity. Many chemical reactions and chemical solubilities are dependent on pH. As pH rises, dissolved carbon dioxide (CO_2), dissolved silicon, reactive silicate ion, nitrate ion and phosphate ion tend to decrease (Horne, 1969). Water will normally be acidic if hydrogen sulfide (H_2S) is produced; a situation typical of anearobic (absence of oxygen) conditions.

Turbidity is a measure of the concentration of suspended particles in water. Turbidity can be caused by blooms of plankton (algae and small aquatic animals) and suspended silt and clay particles. Turbidity is a measure of how far light will penetrate to initiate photosynthesis by phytoplankton. High turbidity often occurs when rains erode soil into a bay.

Coliform bacteria are used as indicator organisms since large numbers of these are present in human feces. The presence of fecal coliforms indicates that the water has been contaminated and that there is a possibility that pathogenic bacteria capable of causing disease in humans may also be present.

B. Salinity

1. Other Data

The Department of Environmental Quality has collected salinity data on Netarts Bay from 1960 to the present. These data were collected one foot above bottom at various times for periods of one day. The data have been analyzed by the investigators with respect to precipitation, runoff and time of year.

Nearshore salinity variations of ocean waters appear to be affected primarily by the location of the Columbia River plume and to a lesser extent by fresh water streams. Coastal nearshore salinities can vary widely in the Netarts area. For example, on 11 July, 1967, surface salinity near Tillamook Bay was 25.98 ppt and on 9 July, 1959, it was in excess of 33 ppt (Dept. of Oceanography, 1967, 1959). Netarts Bay salinities remain close to ocean salinities throughout the year due to the very limited inflow of fresh water into the bay.

During winter periods of high freshwater flow into

Table 11. Salinity and Temperature Data (Burt, 1956)

Location	Time	Temperature °C	Salinity ppt	Depth ft
Tide: unknown Date: 28 April, 1955				
0.0 miles - Oceanside Surf	1200	-	31.1	0
0.2 - Happy Camp	1415	8.9	31.4	0
		8.9	31.9	6
0.6 - Chuck's Boats	1725	9.3	30.6	0
	1800	-	31.0	0
1.0 - First Bend	1430	9.2	29.8	0
		8.8	31.6	8
1.5 - Wilson Beach	1815	19.2	-	0
1.8 - Smith Landing	1445	8.8	29.4	0
		9.2	29.1	9
3.6 - Whiskey Creek Bridge	1300	8.8	0.3	0
		-	9.9	0
3.6 - Whiskey Creek Channel	1315	16.5	-	0
	1615	26.7	8.9	0
5.5 - Head of Bay	1230	8.8	0.3	0
Tide: Morning low Afternoon high Date: 3 August, 1955				
0.2 miles - Happy Camp	0655	16.2	28.8	0
		16.4	29.3	5
		16.2	29.3	9
	1240	11.2	32.8	0
		12.1	32.8	9
0.6 - Chuck's Boats	0710	16.4	28.6	0
		17.0	28.8	8
	1250	11.5	32.5	0
		11.1	32.5	8
		11.6	32.5	15
1.8 - Channel	0720	16.8	28.2	0
		17.0	28.4	6
		17.0	28.5	12
	1255	12.7	32.5	0
		12.3	32.5	10
		12.2	32.5	25
3.0 - Channel	0740	17.0	27.7	0
		17.3	28.0	6
	1305	11.9	32.5	0
		12.2	32.5	8
4.0 - Channel	0700	17.0	26.4	0
	1320	11.8	32.5	0
		12.3	32.5	5

Source: Hydrography of Oregon Estuarires Prior to June, 1956; W. V. Burt; School of Science, Oregon State College, 1956.

Table 12. Salinity and Temperature Data (Hunger)

January 5, 1958							
Kilometers*	0.3	1.8	4.0	6.3	9.0		
Temp. °C	9.8	--	9.6	8.5	6.8		
Sal.	--	31.6	31.6	29.5	13.9		
Depth in meters	0	0	0	0	0		

July 24, 1958							
Kilometers*	1.8	1.8	1.8	1.8	4.0	5.1	6.3
Temp. °C	10.4	10.4	10.3	10.3	13.5	10.9	12.4
Sal	34.2	34.2	34.2	34.2	33.7	33.8	33.7
Depth in meters	0	1.5	3.0	3.7[B]	0	0	0

* Distance up the main channel from the mouth of Netarts Bay

[B] Sample taken at the bay bottom

Source: From Hunger, 1966

Table 13. Mean Monthly Salinity and Temperature Data[1/]

Mean monthly salinity and temperature of Netarts Bay in channel by Tillamook County Board Landing from January 1960 to December 1963. Compiled from Kujala and Wyatt (1961), Oliphant and Wyatt (1962), Still and Wyatt (1963), and Wyatt, Still and Haag (1965).

Year	Mean monthly salinity in											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1960	30.93	30.55	29.53	30.11	29.23	31.11	32.66	31.84	32.45	32.19	31.55	--
1961	30.96	29.33	28.74	30.36	30.26	31.96	--	--	32.20	31.90	31.79	31.31
1962	30.16	30.72	29.85	28.11	28.29	31.26	31.66	30.53	32.46	29.86	30.40	30.57
1963	31.25	30.41	31.11	27.42	29.76	28.91	28.60	27.74	31.74	30.54	30.09	30.35

Year	Mean monthly temperature in °C											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1960	10.0	9.8	9.3	12.1	12.9	13.7	11.9	14.4	11.4	10.6	10.4	--
1961	9.5	10.5	10.2	10.8	14.1	14.8	--	--	13.0	12.4	10.5	8.6
1962	7.9	9.0	8.8	11.5	13.1	12.8	14.4	15.8	12.1	13.5	12.0	10.2
1963	8.2	10.3	8.7	11.2	13.4	15.4	17.0	14.6	15.5	13.9	12.1	11.5

1/ From Hunger, 1966

Netarts Bay the difference of salinity from mouth to head will generally be about 2.5 ppt. Salinity in Netarts Bay ranges from 13 ppt to 35 ppt. Mr. Steven Zimmerman of the Oregon State University Oceanography Department has studied salinity and temperature in Netarts Bay during the project period. This study is part of a Zooplankton study of the bay. The data will be published as part of Zimmerman's Ph.D. thesis. W. V. Burt (1956) reported salinities collected in a random fashion. These data are similar to the Department of Environmental Quality data. The data are shown in Table 11.

2. Project Data

Summer and Winter conditions (low and high freshwater inflow) have been investigated. During Summer conditions, salinity varied from 29.0 ppt to 34.0 ppt. Salinity generally decreased from mouth to head of the bay during Summer 1969 and increased during Summer 1970. The difference between stations A and E was never more than 1.6 ppt. The reason for the change in variation is unknown.

During Winter conditions salinity varied from 13.9 ppt to 30.1 ppt. A large gradient from mouth to head was observed on 31 December, 1969. Whiskey Creek was gaged at 6.68 cfs, much less than the 19.4 cfs on 19 February, a day with a much smaller salinity gradient. From the data, one may conclude that Netarts Bay is well mixed, with no significant vertical variations in salinity.

On 24 July, 1969, the investigators monitored salinity over a tidal cycle. The sampling was performed on a section 200 ft. South of Cross Section 3. Six sampling points were established across this section. Salinities of all surface and bottom samples were essentially the same at any time, however, salinity rose from 33.25 ppt at midtide to 33.45 ppt at high slack and then dropped to 33.05 at low tide. Surface and bottom salinities were roughly the same. Thus, salinity across the cross section was constant at any time, but varies slightly during any tidal cycle.

C. Temperature

Data from the State Department of Environmental Quality show that temperatures in Netarts Bay vary from 9.0°C to 18.0°C near the bottom at various channel stations. The data have been examined for trends. None seems apparent except that on warm days and high tides, the bay waters appear to heat as time progresses and the warmest water is found in the shallow headlands. During June through September, one may expect the bay waters to rise to about 16°C while, during Winter conditions, October through April, bay temperatures generally stay below 11°C.

Burt (1956) reported temperatures taken at Netarts Bay in a random manner which are in general agreement with Dept. of Environmental Quality data. These data are tabulated in Table 11. Data collected from shore stations during preliminary investigations are reported in Table 12. These data were collected from shore stations.

Data on temperature distributions with respect to distance from the mouth were collected at high or low tide at dawn and high or low tide in the late evening. These data show that ocean water temperature is generally in the range 8.0° to 8.9°C. During daylight hours, incoming waters are heated to as much as 18°C in some of the shallow areas of the bay. The temperature increase is dependent on time of residence in the bay and intensity of solar insolation. Highest temperature elevations occur in shallow waters at the head of the bay. The shore sampling data reported in Table 12 shows a maximum shoreline temperature in the head of the bay to be 19°C. Summer night water temperatures remain close throughout the day. During the Winter bay water temperatures remain rather constant at near the ocean water temperature because of decreased solar insolation. One may expect Winter temperature variations from 8.0°C to 11.0°C.

On 24 July, 1969, temperature was observed at a cross section 200 feet South of cross section 3 during most of a tidal cycle. At each of the six sampling points across this section, the temperatures varied by only ± 0.1°C at any time.. The temperatures rose from 9.3°C at 0900 to 12.2°C at 1500. The tide was high at 0900. Top and bottom temperatures varied only by ± 0.1°C.

The project data indicate that Netarts Bay is well mixed and that thermal stratifications occur only at the mouth (Station A) and there very rarely. This well mixed behavior is exhibited throughout the year.

D. Dissolved Oxygen (D.O.)

Dissolved oxygen data reported by the State Department of Environmental Quality show values that are above the saturation concentration at the reported temperature and salinity. The DEQ data, collected in mid-day hours, appear to reflect a relatively high photosynthetic activity wherein marine algae are producing oxygen in excess of demands by the process of photosynthesis.

The diurnal variation of dissolved oxygen was measured at shore stations by project personnel and found to be as much as 2.5 mg/l below saturation at dawn and to be above saturation values by midafternoon.

Samples collected from the bay channels indicated that the dissolved oxygen concentration was near saturation at both dawn and dusk. Dissolved oxygen values near the bottom are consistently lower than those at the surface. With the exception of shallow tide flat areas, Netarts Bay is able to maintain a high dissolved oxygen level near saturation under the present conditions of organic loading.

E. Biochemical Oxygen Demand (BOD_5)

The Department of Environmental Quality has analyzed BOD_5 since 8 May, 1967 in its surveillance program. The highest value recorded is 3.2 mg/l, the lowest is 0.0. These very low values indicate that the bay water is unpolluted from organic matter. Generally, BOD_5 increases slightly from the mouth to the head of the bay. Values may vary $\pm$ 0.5 mg/l but the variations are too random to be significant.

Samples for BOD_5 analysis were obtained by project personnel at dawn and dusk at both high and low tide to determine variations. The BOD_5 was defined as the change in DO after incubating the undiluted sample in the dark at 20°C for 5 days. No nutrients were added as preliminary investigations showed this did not alter values obtained. Reported values are averages of two replicate samples. Replicates showed rather large variations, with no particular reason for such behavior other than experimental error.

BOD_5 values determined by project personnel are in the same range as the DEQ data. The BOD_5 does not systematically vary with time of day or height of tide. Generally, bottom BOD_5 is greater than top BOD_5 in the headlands (stations D and E). The BOD_5 usually increases from mouth to head of the bay. The data do not allow generalization about BOD_5 variations with respect to time during tidal cycles.

The samples collected on 30 June - 1 July and 10 July, 1970, appear to yield higher BOD_5 than 1969 studies. Without measurements of biomass to support the statement, the investigators believe that the algal bloom evident on both runs was greater than any 1969 run.

F. Productivity Measurements

Two types of quantitative measurements of oxygen production capabilities were performed. A "light and dark bottle analysis" was performed on the samples collected on 22, 23 August, 1969. The light bottle test performed at 20°C for 5 days with continuous diffused light from a 100 watt incandescent light bulb in the incubator. The production ranged from 0.1 to 4.9 mg/1 (per day). As some algae migrate to the surface in weak light, the morning bottom values were generally substantially lower than top values. Unfortunately the measurements are qualitatively, but not quantitatively useful because the conditions do not simulate the actual environment.

The second productivity tests conducted were in-situ (in natural environment) tests. Measurements of dissolved oxygen changes under natural conditions should indicate true photosynthetic rates. Net photosynthesis is defined as the increase in DO of an illuminated sample in the natural temperature and illumination conditions. A "light and dark bottle analysis" was conducted on water samples suspended from an anchored buoy at one foot depth for samples collected at the surface and on bottom samples lowered to the channel bottom on the buoy tether. This buoy was placed at station C after dusk samples were collected and the dawn samples were added to the containers. Samples were retrieved after the 1800 hour the same day. These analyses were conducted on runs 1, 2 and 3 (8-9 August, 16-17 August and 22-23 August, 1969).

Martin (1968) defined photosynthetic quotient

$PQ = \dfrac{\text{moles oxygen generated}}{\text{moles carbon dioxide used}}$. PQ ranges from 1.05 to 1.60

depending on nitrogen sources. Since PQ was not measured, no attempt was made to quantify total daily biomass production. Martin also defined net primary production as the true rate of photosynthesis corrected for respiration. Thus,

$$\text{net primary production} = -BOD_{isd} - BOD_{isl}$$

where

BOD_{isd} = in-situ dark bottle BOD and

BOD_{isl} = in-situ light bottle BOD.

Net primary production is tabulated in Table 14.

Table 14. Net Primary Production (mg/l as O_2 per 24 hour day)

Run	Sample	Station A	B	C	D	E
1 - dusk	top	1.1	1.4	0.4	1.2	1.9
	bottom	0.8	0.4	2.1	1.8	0.9
- dawn	top	-0.5	-0.1	0.7	3.1	0.7
	bottom	0.8	0.3	1.9	-	-
2 - dusk	top	0.2	0.0	0.7	0.2	1.9
	bottom	-0.1	0.5	0.1	0.1	0.5
- dawn	top	-0.1	-0.4	-0.4	0.0	0.0
	bottom	-0.6	1.0	0.4	0.7	0.7
3 - dusk	top	0.5	-1.5	-1.0	-0.3	-0.3
	bottom	8.2*	-2.2	-1.5	-1.9	-1.5
- dawn	top	-	-1.5	-0.5	-3.3	-1.9
	bottom	-	0.6	-1.5	-0.8	-

* high concentration of green algae

In attempting to interpret these findings one must consider the precision of the above measurements. The azide modification of the Winkler DO test has an expected error ± 0.05 mg/l. With three such tests, the maximum expected error should be ± 0.15. Round-off errors bring the maximum expected variation to ± 0.20 mg/l. There were no replicate samples, so this expected maximum error is in the range of most of the net productivity measurements thereby making positive trends difficult to identify. However, the data show a trend toward higher respiration than net photosynthesis on cloudy days during late summer months.

The first type of productivity test is a measure of the algal activity and reproductive capability. The second (in-situ) type of test is a measure of photosynthetic activity and algal mass present during the day of sampling. Differences between dusk and dawn values of the in-situ test measure the changes in activity and biomass over one tidal cycle.

G. pH

Department of Environmental Quality data show that Netarts Bay remains slightly alkaline.

H. Coliform Bacteria

1. DEQ Data

The Department of Environmental Quality data on coliform bacteria have been analyzed with respect to distance from mouth and time of tide. No general mode of variation seems to be evident. On 22 April, 1968, no significant number of coliforms were found at any time in the tidal cycle, at any point except the mouth (station DEQ 1). Taking means of all reported values at each station, the investigators observed the trend of coliform data. The mean at station DEQ 1 was 5 times that of stations DEQ 2, 3 and DEQ5, 2.5 times that of station DEQ 4 and 7 times that of station DEQ 6.

Although the coliform data show considerable scatter some general trends are indicated:

1. The coliform concentrations are small with respect to other Oregon estuaries.

2. Values found during Summer conditions are less than Winter condition values for all points in the bay
3. Highest concentrations were found at the mouth of Netarts Bay.
4. Fecal coliforms are below detection levels during the Summer but may be found after late summer rains. Their concentrations are small with respect to values in other Oregon estuaries.

2. Project Data

The investigators used the membrane filter analysis method rather than the fermentation tube method employed by the Department of Environmental Quality (Standard Methods, 1965). The membrane filter technique was chosen since this method was better suited to field laboratory use. In addition, samples could be filtered and incubated immediately after collection. The investigators chose to sample during typical Summer conditions and typical Winter conditions. Two analyses were made, the Winter sampling being by boat on channel stations and the Summer sampling on the East bay shoreline. The Summer sampling was one day after the first Fall storm. The Winter sampling was two days after the last Spring storm. Creek flows on both runs were moderate. These conditions were expected to produce the highest concentrations of coliform bacteria since the primary source appears to be from land drainage. Data are shown in Table 15.

These data reinforce the conclusions that were based on Department of Environmental Quality data.

The survival of sewage-borne bacteria and the coliform group of indicator bacteria is of considerable interest in assessing the health hazards of a water body. Pearson (1956) reported

Table 15. Project Coliform Analyses

Sampling Station	22 September, 1969 Time	Total Coliforms #/100 ml	Fecal Coliforms #/100 ml	30 June, 1970 Time	Total	Fecal	30 June, 1970 Time	Total	Fecal	1 July, 1970 Time	Total	Fecal
A top	1100	20	0	1130	0	0	1530	6	0	0500	-	0
A bottom	-	-			4	0		18			-	2
B top	1130	26	0		8	2		8	0		-	2
B bottom	-	-			12	2		6	2		-	0
C top	1230	11	0		4	0		6	2		-	2
C bottom	-	-			12	0		4	2		-	4
D top	1300	4	2		18	1		16	2		-	2
D bottom	-	-			7	3		12	2		-	0
E top	1350	13	2		5	3		18	0		-	1
E bottom	1350	18	3	1300	16	1		12	0		-	0
upper end	-	-		1330	16	4	1700	20	1	0724	-	2
A top	1430	10	4		-	-		-	-		-	-
B top	1500	100 (approx.)	0		-	-		-	-		-	-
C top	1600	2	0		-	-		-	-		-	-

Conditions

Date - 22 September, 1969
Tide - high 10:56, 7.50 ft low 16:00, 3.24 ft
Weather - clear, with heavy rain during two previous days, 50°F.
Sampling - on shore adjacent established water quality stations

Date - 30 June, 1970
Tide - high 12:20, 5.4 ft low 17:00, 3.1 ft
Weather - clear, with light rain two days prior, 60°F
Sampling - established channel sampling stations

Date - 1 July, 1970
Tide - low 06:34, 1.5 ft
Weather - clear, with light rain three days prior, 65°F.

an exponential decrease of E. coli and E. typhosa in San Francisco Bay water. It has been generally found that about 2% of the E. coli will last 13 days. During one tidal cycle (about 12 hours), between 50% and 90% of the organisms are expected to survive. Pearson also reports that some investigators have found bacteria to multiply in seawater for a day or two after introduction.

The very low level but relatively constant counts of coliform bacteria suggest that there may be small concentrations of coliform bacteria present in the near shore ocean water in addition to possible small sources originating in the bay. In any event the fecal coliform data do not indicate significant contamination of the bay at this time.

I. General Biological Information

Hunger (1966) studied Netarts Bay foraminifera (small unicellular animals) distribution. Among his findings are the following:

a. Organic carbon of sediments varied from 0.1 to 3.5% by weight. The organic carbon content of sediments increases from the mouth to the southern periphery of Netarts Bay.

b. The large salt marsh at the head of Netarts Bay consists of two regions. The low marsh is frequently inundated by high tides. It consists of soft muds and recent deposits of foraminiferal remains. The high marsh is an older deposit with marsh grasses and peat-like soil. The high marsh is inundated only by the highest tides.

c. Marsh sediment pH varies from 7.0 to 5.7, decreasing from low to high marsh.

d. The salt marsh standing crop of foraminifers is approximately $80/cm^2$. Tidal flat standing crop is approximately $8/cm^2$. Tidal channel standing crop is approximately $0.8/cm^2$. The standing crop shows a biomodal distribution, the maxima occurring in January and July. The peaks are attributed to stable food supplies.

e. Netarts Bay has 51 benthic foraminiferal species. The bay has 4 foraminiferal groups. Elphidiella fauna is found mostly in channels. Elphidium fauna is found on the central bay flats. Ammonia fauna is found on mud flats and inner bay sand flats. Miliammina fauna is found in the salt marsh. Planktonic foraminifera are rare in Netarts Bay because of high tidal currents.

J. Sediment Oxygen Uptake

Sediments of a bay are inhabited by several levels of life. The primary producers are the attached algae and phytoplankton. They produce biomass by photosynthesis using carbon dioxide in the presence of sunlight and nutrients. Phytoplankton may die, settle to the sediments and be decomposed by bacteria. The decaying biomass (detritus) will be trapped in sediments. The phytoplankton may also be eaten by zooplankton (small, often unicellular animals).

There is a complicated set of reactions and interactions called the food web, which must be understood before the ecological importance of organic detritus may be assessed. Some of the most elementary associations of the sediment-water food web are shown on Figure 22.

One characteristic of a food web is that, when one factor is changed, be it nutrients, food, biomass or an externality such as temperature or salinity, all members of the food web react. Such reactions are usually deleterious to the stability of the food web. The most common estuarine reaction to nutrient and organic enrichment is rapid eutrophication, a dramatic imbalance, where only the phytoplankters and decomposers thrive. Normally desirable species cease to inhabit the sediments and overlying waters. Thus, the desirability of leaving the water body in its natural state is easily seen.

The level of reduced organic materials in Netarts Bay sediments was measured by a rather crude, but useful test. A large carboy was filled with bay water and agitated to remove supersaturation of dissolved oxygen. An initial DO sample was siphoned from the carboy. Sediment samples were gathered to a depth of 3 inches using a can thrust into the sediment. The full sample was placed into the carboy, which was then filled to the brim with water and covered. The carboy was vigorously agitated, allowed to set 10 minutes, shaken again and allowed to set 5 minutes. A final DO sample was obtained. The change in DO per gram dry weight of introduced sediment was termed the instantaneous oxygen uptake.

The test has significance because the organic level is directly related to hydrogen sulfide and ammonia in the anaerobic region of a sediment (usually all sediment below one centimeter depth). In this reaction hydrogen sulfide is oxidized to sulfuric acid in the presence of water and oxygen.

$$H_2S + 2O_2 \rightarrow 2H^+ + SO_4^=$$

This test is useful in assessing changes in sediment conditions when the organic load on the bay is increased by waste discharges or other processes. Results are shown in Table 15.

Table 16. Sediment Oxygen Uptake Test

Station	No. Samples	Max. Uptake	Min. Uptake	Average Uptake
1	6	0.106 mg/g	0.0353 mg/g	0.0633 mg/g
2	5	0.1590	0.0277	0.0759
3	5	0.1951	0.1532	0.1751

Station descriptions:

1. Midbay adjacent Maxwell Point; east side of channel. Eel grass over silty sand.

2. Midbay, west side of channel 1000 ft. North of station 1,100 ft east of three 9 inch diam. oyster stakes. Low productive clean sands with faint H_2S smell. Red attached algae cover.

3. South bank of Whiskey Creek 200 ft west of bank at shoreline. Highly anaerobic silty mud penetrated by many worm holes.

Table 17. Preliminary Project Water Quality Investigations

Date	Sampling Point	Time	Tide	D. O. mg/l	Salinity ppt	Temperature °C
24 July, 1969	Moorage - top	21:16	high peak	7.0	28.73	13.0
	bottom			3.2	33.21	11.0
26 July, 1969	Whiskey Creek	20:38	mid-tide	11.1	7.10	14.3
	Cape Lookout Store - top	21:56	mid-tide	5.4; 5.4	16.41	18.16
	bottom			6.1; 6.3	30.96	18.19
30 July, 1969	Cape Lookout Store	20:40	mid-tide	2.5	7.87	14
	Whiskey Creek top	20.15	mid-tide	3.9	30.17	17
	bottom	20.09		3.0	30.21	16
31 July, 1969	Moorage - top	06:26	mid-tide	7.0	33.39	10.1
	bottom	20.09		7.3; 7.0	33.70	10.0; 10.0
	Whiskey Creek top	06:50	outgoing high	8,0; 8.4	17.04	10.2; 10.1
	bottom			4.5; 4.0	17.84	10.5; 11.0
	Cape Lookout Store - top	07:20	mid-tide	6.0	negligible	14.0
	bottom			3.3	"	15.2

Table 18. Project Water Quality Data Summary

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #1 8 - 9 August, 1969 Clear 70°F					
EVENING HIGH (7. 0 ft)					
Top Temp. °C	11. 1	11. 2	11. 1	11. 3	13. 0
Top Salinity ppt	33. 1	33. 2	32. 8	32. 9	31. 7
Top DO mg/1 (avg.)	10. 1	8. 3	10. 2	10. 3	9. 6
Top BOD_5 mg/1 (avg.)	0. 6	0. 2	1. 3	1. 8	1. 4
Top BOD in situ (light)	-1. 3	-1. 4	-0. 7	-2. 3	-3. 1
Top BOD in situ (dark)	0. 2	0. 0	0. 3	1. 1	0. 8
Bottom Temp.	11. 1	10. 9	11. 0	11. 1	12. 7
Bottom Salinity	33. 3	33. 5	33. 0	33. 1	32. 0
Bottom DO	10. 6	8. 1	8. 8	9. 1	8. 0
Bottom BOD_5	0. 4	0. 0	0. 0	1. 1	0. 9
Bottom BOD in situ (light)	-0. 8	-0. 4	-2. 1	-2. 0	-1. 8
Bottom BOD in siut (dark)	0. 0	0. 0	0. 0	0. 2	0. 9
MORNING LOW (0. 8 ft)					
Top Temp.	10. 3	10. 1	10. 2	9. 8	10. 0
Top Salinity	32. 8	32. 7	31. 9	32. 1	31. 2
Top DO	10. 3	9. 6	8. 5	7. 6	7. 0
Top BOD_5	0. 0	-0. 2	0. 0	0. 7	0. 9
Top BOD in situ (light)	-0. 1	-0. 3	-0. 9	-3. 1	-1. 5
Top BOD in situ (dark)	0. 6	0. 4	0. 2	0. 0	0. 8
Bottom Temp.	10. 3	10. 1	10. 1	9. 8	9. 9
Bottom Salinity	33. 0	32. 9	32. 4	32. 9	31. 5
Bottom DO	10. 3	9. 7	8. 1	-	-
Bottom BOD_5	0. 0	0. 3	0. 0	-	-
Bottom BOD in situ (light)	-0. 7	-0. 6	-2. 1	-	-
Bottom BOD in situ (dark)	-0. 1	0. 3	0. 2	-	-

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #2 16-17 August, 1969 Clear 65°F					
EVENING LOW (1.3 ft) 10:35					
Top Temp. °C	14.3	14.6	15.0	15.6	16.2
Top Salinity ppt	33.05	33.04	33.04	32.82	32.87
Top DO mg/1 (avg.)	12.0	12.2	10.1	9.4	9.3
Top BOD_5 mg/1 (avg.)	2.7	2.4	-0.1	0.2	0.1
Top BOD in situ (light)	-0.2	-0.1	-0.7	-0.3	-2.1
Top BOD in situ (dark)	0.0	0.1	0.0	0.1	0.2
Bottom Temp.	14.1	14.3	15.0	15.3	15.9
Bottom Salinity	33.11	33.11	33.08	33.04	32.91
Bottom DO	8.9	8.7	8.9	9.1	10.0
Bottom BOD_5	0.0	0.1	0.5	0.3	0.1
Bottom BOD in situ (light)	0.1	-0.3	-0.2	-0.4	-1.3
Bottom BOD in situ (dark)	0.0	-0.2	0.1	0.3	0.8
MORNING HIGH (6.8 ft) 04:00					
Top Temp.	8.9	8.9	8.9	8.8	8.9
Top Salinity	33.61	33.57	33.51	33.50	33.32
Top DO	8.9	8.9	8.9	9.0	8.7
Top BOD_5	0.2	0.1	-0.3	0.2	0.6
Top BOD in situ (light)	-1.0	-0.7	-0.6	-0.8	-1.2
Top BOD in situ (dark)	1.1	1.1	1.0	0.8	1.2
Bottom Temp.	8.9	8.9	8.9	8.8	8.7
Bottom Salinity	33.48	33.41	33.49	33.50	33.20
Bottom DO	9.3	11.6	9.1	9.0	9.1
Bottom BOD_5	0.3	0.2	0.9	0.8	1.3
Bottom BOD in situ (light)	0.0	-1.1	-0.8	-0.9	-1.3
Bottom BOD in situ (dark)	0.6	0.1	0.4	0.2	0.6

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #3 22-23 August, 1969 Cloudy, 55°F					
EVENING HIGH (7.0 ft)					
Top Temp. °C	11.0	11.0	11.4	12.0	13.6
Top DO (avg.)	9.3	9.8	9.9	10.1	9.4
Top BOD_5 (avg.)	0.1	2.3	1.2	-0.1	0.9
Top BOD in situ (light)	-0.7	-0.2	0.7	0.0	-0.1
Top BOD in situ (dark)	0.2	1.7	1.7	0.3	0.4
Top BOD_5 (light)	-0.5	-0.6	-0.8	-0.5	-0.4
Bottom Temp.	11.1	11.1	11.2	12.2	14.0
Bottom DO (avg.)	9.3*	10.6	10.4	9.6	9.6
Bottom BOD_5 (avg.)	0.1*	0.2	0.3	0.2	0.4
Bottom BOD in situ (light)	-7.5*	-0.9	-0.7	-0.8	-0.7
Bottom BOD in situ (dark)	-0.7*	3.7	2.2	2.7	2.2
Bottom BOD_5 (light)	-0.1*	-0.2	-0.6	-0.3	-0.8
MORNING LOW (0.1 ft) 05:40					
Top Temp.	-	11.0	12.2	12.8	18.0
Top DO	-	12.8	13.4	10.4	11.5
Top BOD_5	-	3.1	0.8	1.1	1.1
Top BOD in situ (light)	-	-0.5	-0.7	-0.3	-3.0
Top BOD in situ (dark)	-	2.0	1.2	3.6	4.9
Top BOD_5 (light)	-	-3.0	-3.1	-4.1	-3.7
Bottom Temp.	-	11.0	12.1	12.7	-
Bottom DO	-	10.4	8.2	10.5	-
Bottom BOD_5	-	0.8	0.6	0.6	-
Bottom BOD in situ (light)	-	-1.4	-0.6	-1.7	-
Bottom BOD in situ (dark)	-	0.8	2.1	2.5	-
Bottom BOD_5 (light)	-	-0.2	-0.3	-4.9	-

* high concentration of green algae

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #4 31 December, 1969 Clear 55° F					
NOON LOW 12:00					
Top Temp. °C	9.3	9.3	9.5	9.4	9.6
Top Salinity ppt	26.6	26.4	25.0	24.7	23.5
Bottom Temp.	9.4	9.2	9.4	9.5	9.5
Bottom Salinity	25.5	26.0	24.6	24.3	21.9
AFTERNOON HIGH 16:00					
Top Temp.	10.1	10.2	10.4	10.6	10.5
Top Salinity	25.9	25.5	24.2	23.6	21.1
Bottom Temp.	10.0	10.0	10.5	10.5	10.6
Bottom Salinity	26.2	25.2	24.0	22.8	13.9

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #5 19 February, 1970 Cloudy, morning rain, clearing afternoon 50°F					
MORNING HIGH (6 ft) 10:30					
Top Temp. °C	10.0	10.0	10.0	11.0	9.0
Top Salinity	30.12	30.14	29.73	27.60	25.21
Top DO mg/l	9.1	9.2	9.0	9.6	9.1
Top BOD_5 mg/l	0.2	0.9	0.5	1.1	0
Top BOD_5 mg/l	0.7	0.3	0.3	0.7	0.2
Top BOD_5 (avg.)	0.45	0.6	0.4	0.9	0.1
Bottom Temp.	10.0	10.0	10.3	11.0	9.0
Bottom Salinity	30.15	30.10	29.77	27.68	26.28
Bottom DO	9.3	9.0	9.2	9.0	9.1
Bottom BOD_5 in situ (light)	0.5	0	0.3	0.2	1.4
Bottom BOD_5 in situ (dark)	0.7	0	0.6	0.6	0.9
Bottom BOD_5 (avg.)	0.6	0	0.45	0.4	1.15
AFTERNOON MIDTIDE (2.5 ft) 14:30					
Top Temp.	11.0	10.3	10.2	10.0	10.0
Top Salinity	27.14	27.62	25.43	22.18	21.76
Top DO	9.3	9.4	9.7	9.6	9.6
Top BOD_5 in situ (light)	0.5	0.8	0.8	0.6	0.7
Top BOD_5 in situ (dark)	0.4	0.4	0.6	0.7	0.7
Top BOD_5 (avg.)	0.45	0.6	0.7	0.65	0.7
Bottom Temp.	10.0	10.2	10.1	10.0	-
Bottom Salinity	28.70	27.71	25.51	22.21	-
Bottom DO	10.0	9.5	9.5	9.3	-
Bottom BOD_5 in situ (light)	0.9	0.3	0.3	0.3	-
Bottom BOD_5 in situ (dark)	0.2	0.6	0.3	0.4	-
Bottom BOD_5 (avg.)	0.55	0.45	0.3	0.35	-

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E	Upper End
Run #6 June 30, 1970 Clear, 65° F						
EVENING HIGH (8.2 ft) 20:00						
Top Temp. °C	12.0	12.0	12.0	12.5	14.5	17.0
Top Salinity 0/00	33.02	32.97	33.08	33.36	33.59	33.48
Top DO mg/l	10.1	11.5	10.9	12.3	12.3	9.6
Top BOD_5 mg/l	3.6	4.2	3.0	4.1	3.0	1.2
Top BOD_5 mg/l	3.8	4.1	-	4.6	2.8	1.1
Top BOD_5 avg.	3.7	4.15	3.0	4.35	2.9	1.15
Bottom Temp.	12.0	12.0	12.0	12.5	15.0	-
Bottom Salinity	33.02	32.91	32.96	33.57	33.17	-
Bottom DO	10.5	11.0	10.7	12.6	11.9	-
Bottom BOD_5	4.2	3.7	5.0	4.3	3.0	-
Bottom BOD_5	4.3	-	-	3.6	3.0	-
Bottom BOD_5 avg.	4.25	3.7	5.0	3.95	3.0	-
July 1, 1970 Clear 55°F						
MORNING HIGH (+5.1) 10:30						
Top Temp.	12.0	12.8	12.3	14.7	16.3	17.0
Top Salinity	32.89	33.20	33.16	33.45	33.45	-
Top DO	9.5	9.5	10.2	8.5	7.4	7.5
Top BOD_5	2.3	0.6	0.9	1.0	1.8	1.7
Top BOD_5	2.4	1.4	3.2	-	0.9	2.3
Top BOD_5 avg.	2.35	1.0	2.1	1.0	1.35	2.0
Bottom Temp.	12.0	12.0	13.1	15.0	16.0	-
Bottom Salinity	33.01	33.22	33.19	33.57	33.50	-
Bottom DO	9.7	9.7	9.8	8.4	7.4	-
Bottom BOD_5	2.2	1.9	0.9	0.9	0.5	-
Bottom BOD_5	2.6	-	-	1.1	0.6	-
Bottom BOD_5 avg.	2.4	1.9	0.9	1.0	0.55	-

Table 18. (continued)

	Sta A	Sta B	Sta C	Sta D	Sta E
Run #7 July 10, 1970 Clear, 60°F					
MORNING HIGH (5.5 ft) 05:00					
Top Temp °C	8.0	7.9	8.9	11.0	12.0
Top Salinity 0/00	34.32	34.28	34.18	34.18	34.16
Top DO mg/l	10.1	10.1	10.0	9.6	9.5
Top BOD_5 mg/l	1.9	2.0	2.9	1.1	1.5
Bottom Temp.	8.0	7.8	9.0	11.6	-
Bottom Salinity	34.24	34.30	34.35	34.16	-
Bottom DO	10.2	10.4	9.9	10.3	-
Bottom BOD_5	2.1	2.8	1.9	2.1	-
EVENING HIGH (6.8 ft) 18:00					
Top Temp.	10.1	9.3	9.4	9.1	10.8
Top Salinity	34.08	34.19	34..15	34.27	34.24
Top DO	9.8	9.7	10.2	10.5	11.4
Top BOD_5	3.3	3.2	2.6	2.4	2.5
Bottom Temp.	10.3	9.1	9.3	9.8	11.0
Bottom Salinity	34.12	34.18	34.22	34.68	34.40
Bottom DO	9.2	9.7	11.0	9.9	11.4
Bottom BOD_5	3.8	3.4	4.4	2.3	2.8

IV. Other Considerations

A. Mathematical Model of Tidal Flows

The main mechanisms controlling the volume of water entering or leaving Netarts Bay are the ocean tidal ranges and the frictional characteristics of the entrance constriction. Generally only about 75% of the outside tidal range can be observed at Whiskey Creek due to choking and channel friction. The inside tidal range attentuation is accompanied by a delay in times of high and low waters from the outside times (see Tables 3 and 4 and Figure 20).

In order to predict entrance channel flows and tidal conditions at Schooner (Tillamook County Boat Landing) a mathematical model has been developed. This model can, when the outside tidal range and time of high water is known, predict channel flows and tidal heights at Schooner. In using this model it is assumed that the outside tidal range and time of high water can be extrapolated from tide tables for Newport or Astoria (see Section II-2-b of this report).

The mathematical model is based on a method outlined in a paper by Glenne, Goodwin, Glanzman (in printing, 1971).[1/] The coefficient, K, has been evaluated for Netarts Bay and found to vary from 3×10^6 sec^2/ft at low waters on a rising tide to 20×10^6 sec^2/ft at high waters on a falling tide. This relatively large variation in K is mainly due to the intertidal changes in bay surface area and channel cross-sectional area. The variation in average channel cross-sectional area with tidal height is shown in Figure 19. From tidal measurements on 1 August, 1969 an average channel Chezy "C" (frictional coefficient) of 64 was calculated.

A four step variation in the coefficient "K" was incorporated and the tidal heights at Schooner and channel flows were calculated using

1/ Familiarity with the "OS-3" Fortran IV computer of the Oregon State University computer is assumed.

a digital computer program developed by Glenne, Goodwin and Glanzman (see Table 18). Calculated results are shown in Figure 20 for outside tidal ranges of 5. 0 ft and 9. 0 ft. For the 5.0 ? ~~9.0~~ ft ocean range a high water choking coefficient of 96% with a 32 minute time lag and a low water choking coefficient of 95% with a 38 minute time lag are calculated. For the 9. 0 ft ocean range a high water choking of 90% with a time lag of 52 minutes and a low water choking coefficient of 82% with a time lag of 72 minutes are calculated.

Flows in the entrance channel as calculated by the mathematical model using a form of Chezy's equation are also shown in Figure 20. For the 9. 0 ft ocean range maximum ebbing and flooding channel flows of respectively 30, 000 ft^3/sec and 36, 000 ft^3/sec are calculated. The ebbing period is about 390 minutes and the flooding period is about 355 minutes in the channel. For the 5. 0 ft ocean range the model gives maximum ebbing and flooding channel flows of respectively 17, 000 ft^3/sec and 19, 000 ft^3/sec. For this range the ebbing period is about 380 minutes and the flooding period is about 365 minutes in the channel.

The tidal prism for the 9. 0 ft ocean range is approximately $43 \cdot 10^7$ ft^3 and for the 5. 0 ft ocean range approximately $25 \cdot 10^7$ ft^3. These values seem to agree closely with the tidal prism calculated in Table 2. Fresh water inflow has been ignored in these examples since it has little quantitative effect during the dry season. However the program listed in Table 19 is designed to include freshwater or other inflows if they are significant.

In order to compare the results of the mathematical model with observed data, choking coefficients between Schooner and the ocean have been calculated and plotted in Figure 21. The ocean tidal ranges outside Netarts have been calculated as 91. 4% of the measured Newport tidal ranges. Two field measurements, on 24 July 1969 and 1 August 1969, are the basis for this explantion. The

exterpolation ?

Table 19. Mathematical Model for Tidal Flows

DATA INPUT

```
      PROGRAM TIDEN
      REAL N,M,K
    4 WRITE(61,300)
  300 FORMAT (' ' /////)
      HO=TTYIN(4HHO=  )
      IF(HO.EQ.O.) GO TO 3
      AS=TTYIN(4HAS=  )
      QL=TTYIN(4HQL=  )
      DST=TTYIN(4HDST=)
      CYC=TTYIN(4HCYCL,4HES=  )
      STM=CYC*360.
      DSTO=TTYIN(4HDSTO,4H=      )
      DT=DST*44700./360.
      J=0
```

INITIALIZATION AND HEADING OF OUTPUT

```
      HHH=1.
      HC=1.
      ST=-DST/2.
      SST=-DST
      WRITE(61,200)
  200 FORMAT(' '//' SIGMA T        HO        HI        Q'/)
      HA=HO
      HAV=HA
      HH=0.
```

ASSIGNING VALUES OF K AS A FUNCTION OF TIDAL HEIGHT AND TYPE OF TIDAL FLOW

```
    1 ST=ST+DST/2.
      DH=HC-HHH
      IF(HC.LT.O.) GO TO 10
      IF(DH.GT.O.) K=12.E06
      IF(DH.LE.O.) K=20.E06
      GO TO 11
   10 IF(DH.GT.O.) K=3.E06
      IF(DH.LE.O.) K=12.E06
```

COMPUTATION OF BAY WATER SURFACE ELEVATION

```
   11 G=K*HO
      M=(DT*DT)/(4.*G)
      N=HA/HO
      HHH=HC
      QR=(QL*DT)/(AS*HO)
      P=M*M+4.*M*(COS(6.2832*ST/360.)-N-QR/2.)
      HC=0.5*(2.*N-M+QR+SQRT(ABS(P))*M/ABS(M))
      IF(ST.EQ.(STT+DST/2.)) GO TO 9
```

OUTPUT

```
      IF(ABS(HH-HC).LT.ABS(HH)) GO TO 8
      HH=0.
    9 IF(ABS(HC).LE.ABS(HH)) GO TO 6
      HH=HC
      STT=ST
      GO TO 8
    6 IF(ST.GT.(STT+DST/2.)) GO TO 7
      AA=COS(6.2832*STT/360.)
      WRITE(61,400) STT,AA,HH
  400 FORMAT(' ',F7.1,2F8.3,'M')
      GO TO 8
```

Table 19. (continued)

```
    7 CONTINUE
    8 HA=HO*HC
      A=COS(6.2832*ST/360.)
      HAV=HO*(HC+A)/2.
      IF(ST.EQ.J*DSTO) GO TO 2
      GO TO 1
    2 J=J+1
      L=8320.
      HAC=HAV+3.68
      DDH=HO*(A-HC)
      ADH=ABS(DDH)
      R=3.5*HAC*.5
      BA=4.E03+HAC*1.56E03
      Q=-QL+64.*BA*((R*ADH/L)**.5)*DDH/ADH
      IF(ST.GE.(STM-360.)) GO TO 5
      GO TO 1
    5 WRITE(61,100) ST,A,HC,Q,K
  100 FORMAT(' ',F7.1,2F8.3,2E11.2)
      HA=HO*HC
      IF(ST.GE.STM) GO TO 4
      GO TO 1
    3 CONTINUE
      END
```

OUTPUT

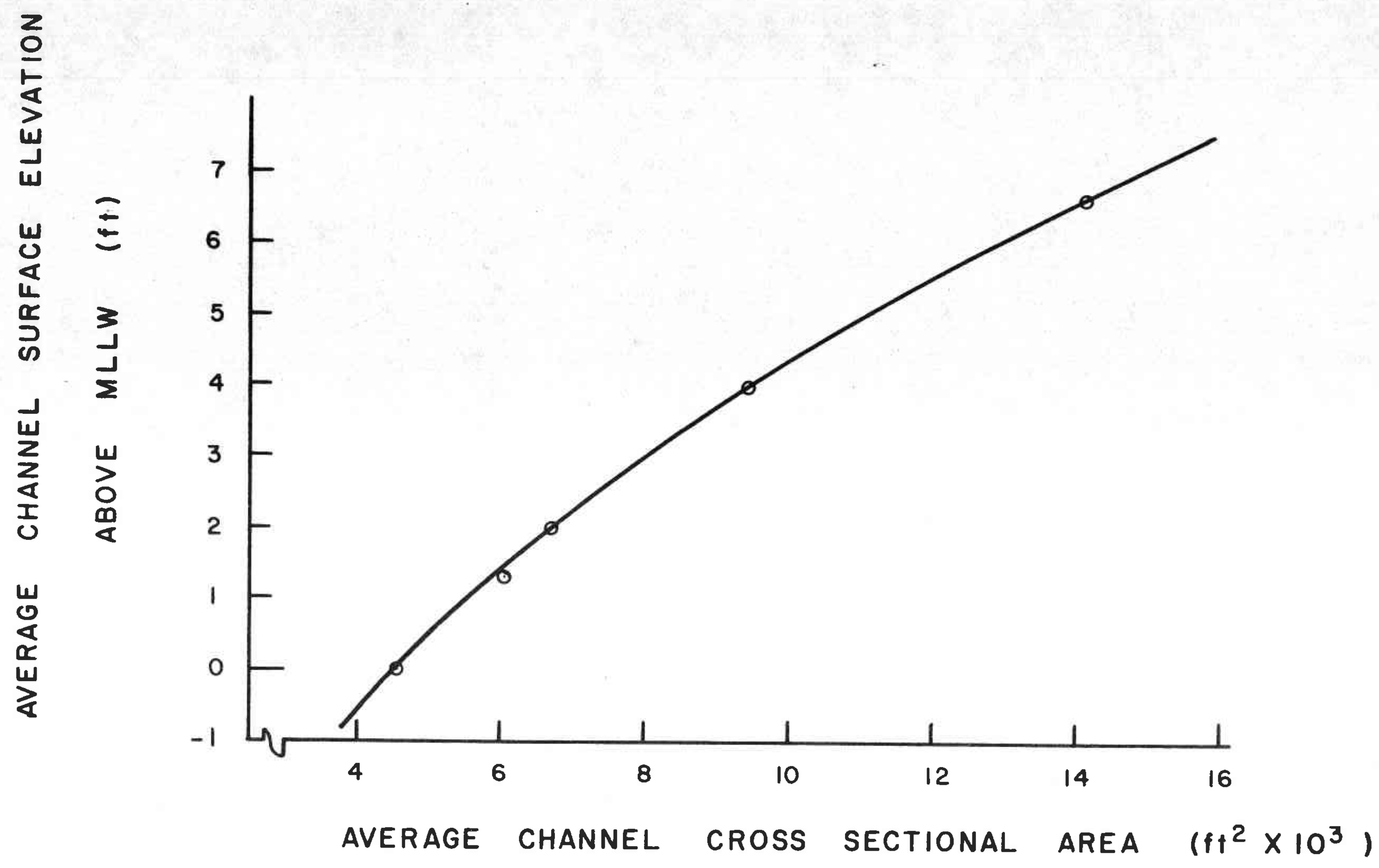


FIGURE 19. CROSS SECTIONAL AREA OF ENTRANCE

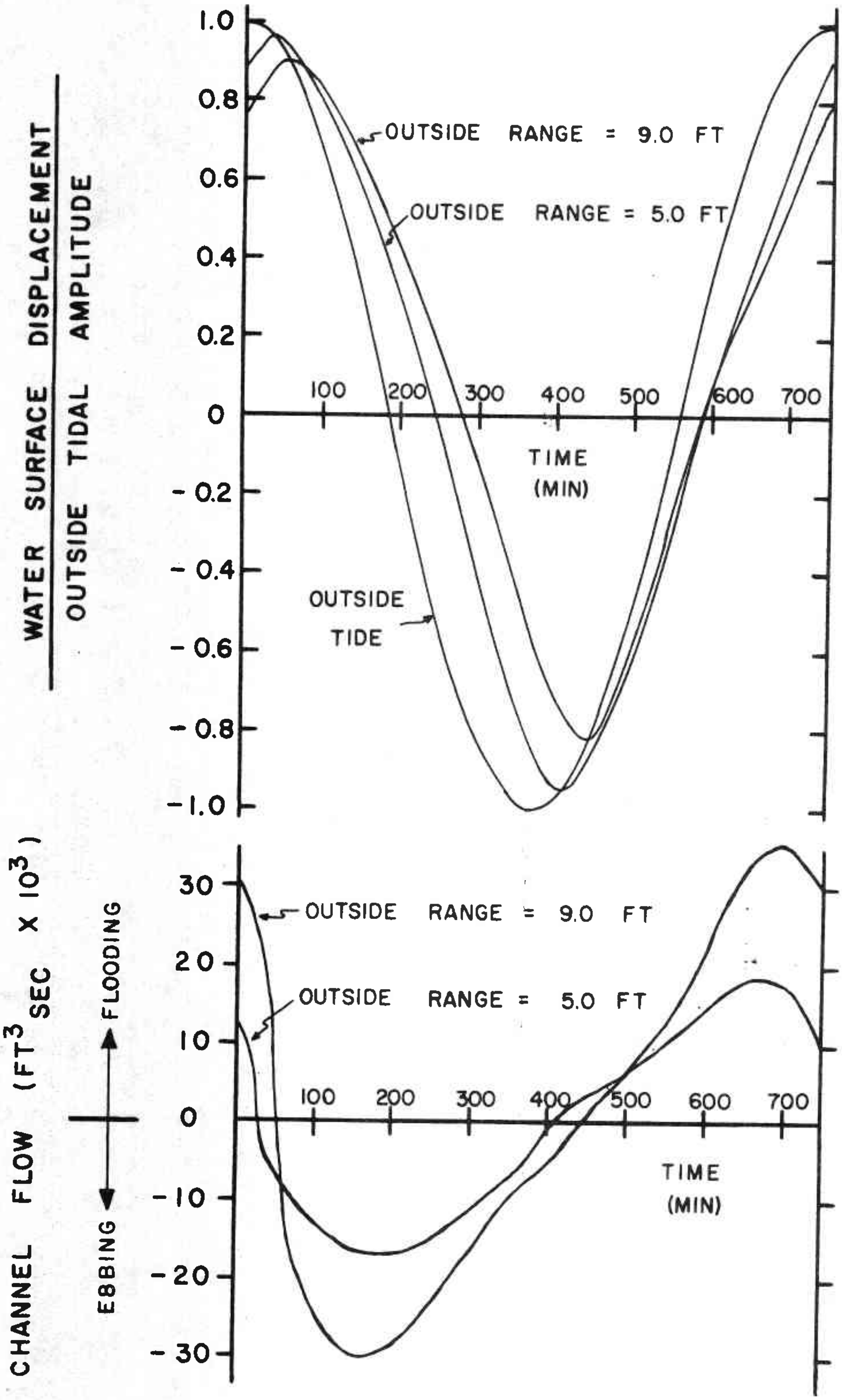


FIGURE 20. MATHEMATICAL MODEL RESULTS

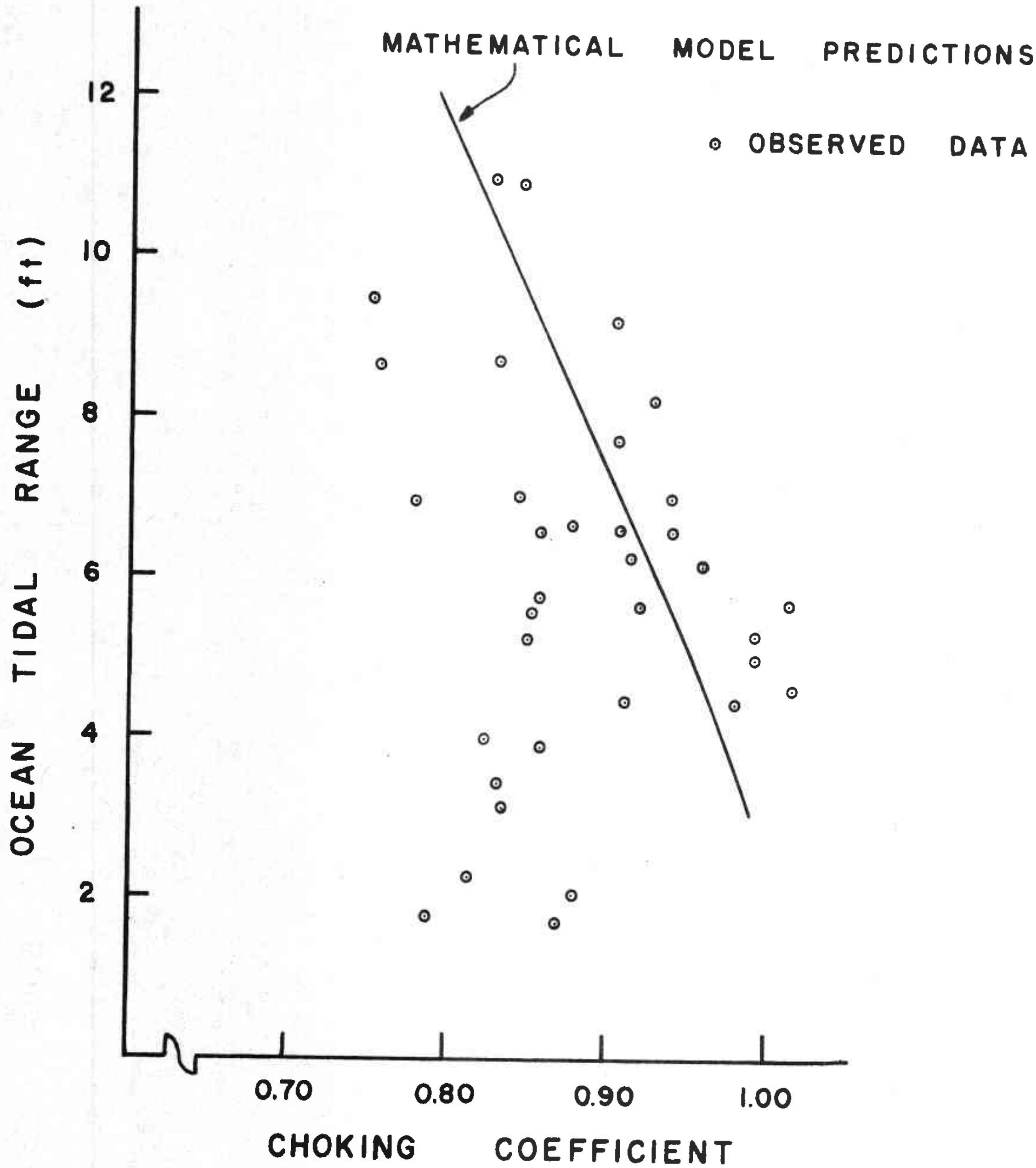


FIGURE 21.

COMPARISON OF CALCULATED WITH OBSERVED CHOKING mathematical model appears to calculate somewhat high choking coefficients, but in general the agreement is satisfactory. The scatter in observed data is normal and indicates the amount of variation due to local and unsteady conditions.

B. Inflow Estimates

1. Runoff

Table 9 in Chapter II lists the maximum monthly freshwater inflow to Netarts Bay as 229 ft^3/sec in December. During an average tidal cycle (12.42 hours) this represents a freshwater inflow of 10,200,000 cubic feet. The minimum monthly freshwater inflow is listed as 5 ft^3/sec in August or a tidal cycle freshwater volume of 233,000 cubic feet.

2. Sewage Flow

In the 1968 report to the Netarts-Oceanside Sanitary District (CH2M, 1968) the engineering firm of "Cornell, Howland, Hayes & Merryfield" based its suggested sewage treatment plant design on a future summer population of 1000 in Oceanside and 1400 in Netarts. The company assumed a sewage flow of 100 gallons per capita per day with a biochemical oxygen demand (BOD) production of 0.17 pounds per capita per day. These figures are realistic and will be used in this report.

Based on these estimates the communities of Netarts and Oceanside can be expected to produce a Summer sewage flow of about 0.24 million gallons per day or 0.37 ft^3/sec or 16,600 cubic feet per tidal cycle. During the Summer months Cape Lookout State Park also produces sewage. This effluent is presently discharged into the southern end of Netarts Bay via subsurface drain fields and an oxidation pond. In 1970 Cape Lookout State Park had approximately 250 tent and trailer spaces. Assuming 4.5 people per space and a consumptive use of 30 gallons per capita per day gives a sewage yield of 34,000 gallons per day or about 2,300 cubic feet per tidal cycle on a maximum use day.[1/] There is no data available on the amount of this flow that ultimately reaches the bay.

At the present time essentially no sewage is discharged into Netarts Bay by industry or from the Oregon State University Aquaculture Laboratory. Present method of domestic sewage disposal is septic tank and drain field, although several bayfront homeowners now discharge directly into creeks emptying into the bay.

3. Organic Load

Sewage and other wastes contain organic material which requires oxygen for its decomposition (usually termed biochemical oxygen demand or BOD_5). The organic and inorganic nutrients (nitrates, phosphates, etc.) present in sewage and wastes may also have the effect of serving as fertilizer for algae or bottom growths which also add to the organic load. This fertilization effect with its resulting bloom is termed eutrophication.

From the communities of Oceanside and Netarts a summer organic contribution of 0.17 pounds of BOD per capita per day gives 408 pounds of BOD produced per day or 211 pounds of BOD per tidal cycle assuming no treatment. The yield of organic material from Cape Lookout State Park is estimated at 170 pounds per day BOD_5 prior to treatment. Since no information is available on the effectiveness of the treatment system employed it is not possible to predict the amount of this load that reaches the bay.

1/ Federal Water Quality Administration Data (30 gpcd).

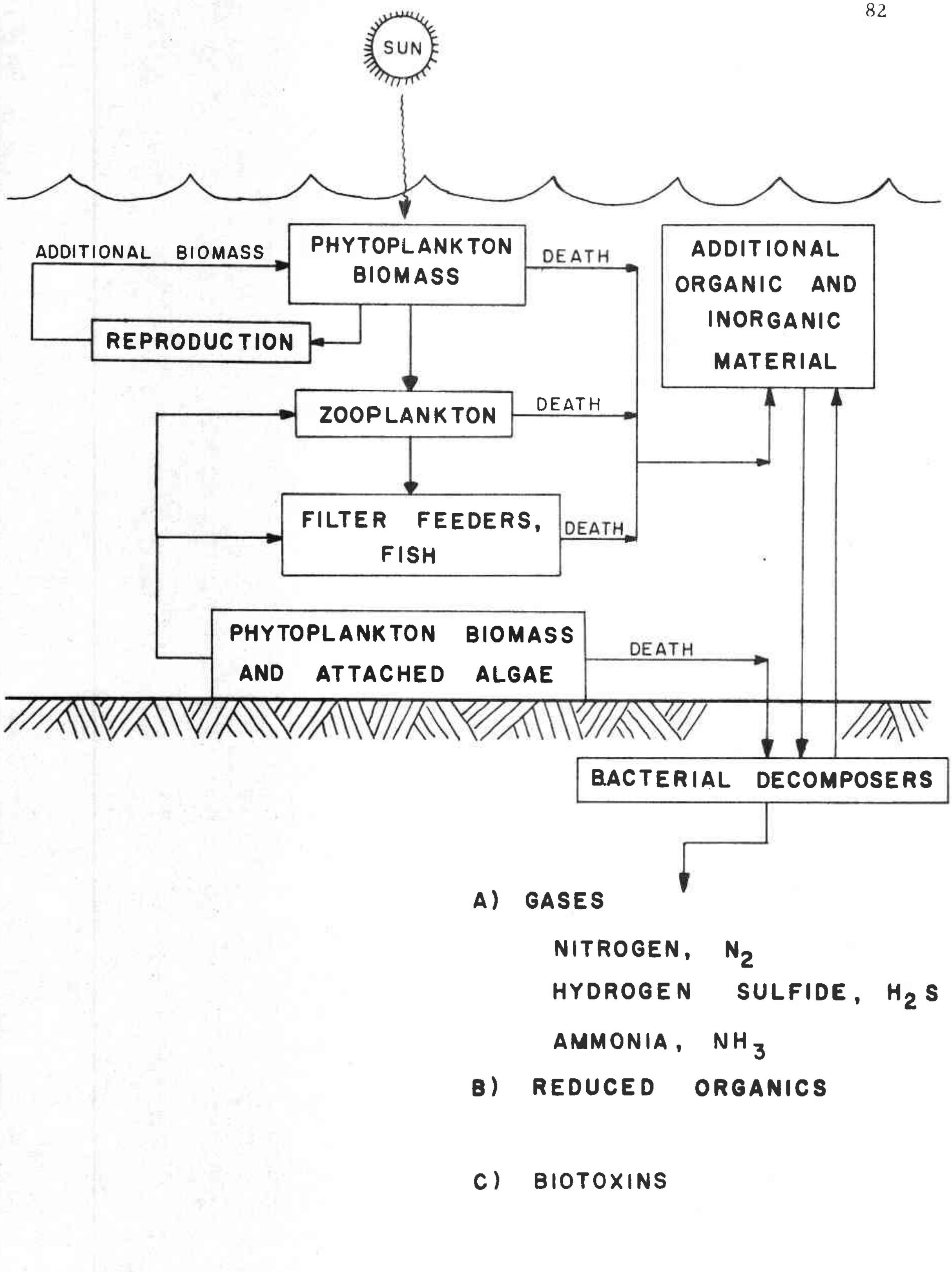


FIGURE 22. SIMPLIFIED SEDIMENT FOOD WEB

Table 20. Estimated Inflows to Netarts Bay

	Volume (ft^3/tidal cycle)
Ocean water	
- 5 ft tidal range	250,000,000
- between MLW and MHW	330,000,000
- 9 ft tidal range	430,000,000
Runoff	
- August	223,000
- December	10,200,000
Sewage (Summer flows)	
- Netarts and Oceanside	16,600
- Cape Lookout State Park	2,300

C. Dyes Study Results

Four dye studies of water mass movements have been conducted at Netarts Bay. Since the methods were refined with successive dye studies, each study will be considered in its entirety.

<u>24 July, 1970</u>

Description:

Dye dumped . . . 1.085 liters Rhodamine WT (20%) at 5% concentration. Time of dump - 0630. Dumped at proposed sewage treatment plant site.

Sampling stations . . . Water quality station B, sampling points across channel - 3, recovery = 84.6%. Water quality station A, sampling points across channel - 2, recovery = 102%.

The dye was spread across the cross section perpendicular to the bays longitudinal axis by discharging dye slowly through a boat propellor as the boat traversed the cross section. This achieves vertical distribution of the dye. A drift card placed at the west end of the patch moved due west, rather than down the channel with the main body of dye and the other drift cards.

Three points at station B were sampled at both top and bottom.

Top and bottom samples show fair consistency of concentration and time of peak concentration. However, each sampling point had different dye concentrations and remarkably different times of peak concentration. This is probably due to lateral differences in velocities of water rounding the two severe bends at Schooner.

Two points were sampled at station A. Sampling may have been discontinued accidentally before all dye had passed or perhaps an eddy current at the mouth recirculated the dye. Times of peak concentration varied, due to the vastly different velocities between the north and south points, as evidenced by drift card passage.

Samples were collected into well cleaned bottles, thermally stablized and stored out of the light until processed. A fluorometer was used to measure dye concentration in each sample. No more than two hours storage time was allowed because of the surface adsorptive properties of Rhodamine WT dye.

Recovery was calculated using

$$\Delta V = \Sigma \Delta P_t \left(\frac{\overline{A}_c}{\overline{A}_{CT}}\right) \overline{C}$$

where ΔV is the increment of dye passing on sampling interval Δt, ΔP_t is the incremental tidal prism passing during Δt, $\overline{A}_c$ is the portion of the total channel allocated to the sampling point midway in Δt, $\overline{A}_{CT}$ is the total cross section area and $\overline{C}$ is the average of the average of top and bottom concentrations during Δt.

$$\text{Recovery} = \frac{\Sigma_o^t (\Delta V)}{\text{volume of dye dumped}} \ (100\%) .$$

As the dye cloud passes through the bay, it disperses longitudinally. The time of peak concentrations gives an indication of the modal time of travel of a dye particle. The times of 50% and 95% dye travel past the point are given as a statistical measure of particle residence times. Since recovered dye volume will deviate somewhat from the actual dumped volume, 50% and 95% passage times are reported based on recovered dye volume, as the elapsed times from the time of dump. The results are shown in Table 21.

For a 4.79 foot tidal range (at Schooner), with discharge of dye 45 minutes after high tide at the sewage treatment plant site, 95% of the recovered dye passed station A in 2 hours and 45 minutes. Drift cards which were released with the dye, reached the hypothetical mouth of Netarts Bay about one hour after the main dye body passed station A. If no waters would return to Netarts Bay, these data would suggest a safe discharge time (95% pollutant removal) of 2 hours 2 minutes. However, the suggested correction based on the dye study of 22 September yields a safe discharge time of 1 hour and 2 minutes for this day and tide.

22 August, 1970

Description:

Dye dumped . . . 3 liters Rhodamine WT (20%) at 4% concentration. Time of dump - 1205. Dumped at mouth, cross section 0.

Sampling stations . . . Water quality station A, recovery = 24%.
Station 300 ft. South of boat landing, recovery = 158%.
Whiskey Creek west channel, recovery = 94% of total dump.
Whiskey Creek east channel, recovery = 127% of total dump.

This dye dump was performed on an incoming tide to gather data for a mathematical model of constituent transport in Netarts Bay. The dump was only partially successful due to large eddy current at the mouth, at the time of dumping. Because of this eddy current a long, narrow patch, clearly not one dimensional, was formed. This eddy phenomenon is important because, while the tide level had begun to rise at the mouth, the momentum current outgoing on the North side of the channel still existed. Bay waters are often caught in a low-slack water eddy at the mouth and channeled partially back into Netarts Bay on the next flooding tide.

The two Whiskey Creek stations were located on an east-west line from the creek. Peak concentrations were 15 minutes apart and T_{95} times were 29 minutes apart, displaying the effects of channelization in Netarts Bay. The east channel carried most of the dye.

30 August, 1970

Description:

Dye dumped . . . 3 liters Rhodamine WT (20%) were dumped about 3,500 ft. south of the proposed sewage treatment plant site, at 1415.

Sampling stations . . . Sewage treatment plant site, in channel, recovery = 195%.
Station 200 ft. south of boat landing, recovery = 66.5%.
Water quality station A, recovery = 126%.

This was another outgoing tide dye dump designed to eliminate some of the difficulties of the 24 July dye dump. A one-dimensional Gaussian distribution of dye concentration was observed at all three stations.

Considering the T_{50} at the sewage treatment plant site as a base time, the time of residence in Netarts Bay for this tide would be 2 hours 9 minutes, and the safe discharge time would be 2 hours and 20 minutes.

Comparing this safe discharge time with that of 24 July, 1970, one notes that safe discharge time is a function of high tide level and tide range. At higher tides, bay volumes increase dramatically, as do tidal velocities.

As the safe discharge times for the 24 July and 30 August dye studies differed significantly for nearly similar tides, it is pertinent to question the reliability of the safe discharge time analyses. The investigators feel that the 24 July dye study results are more

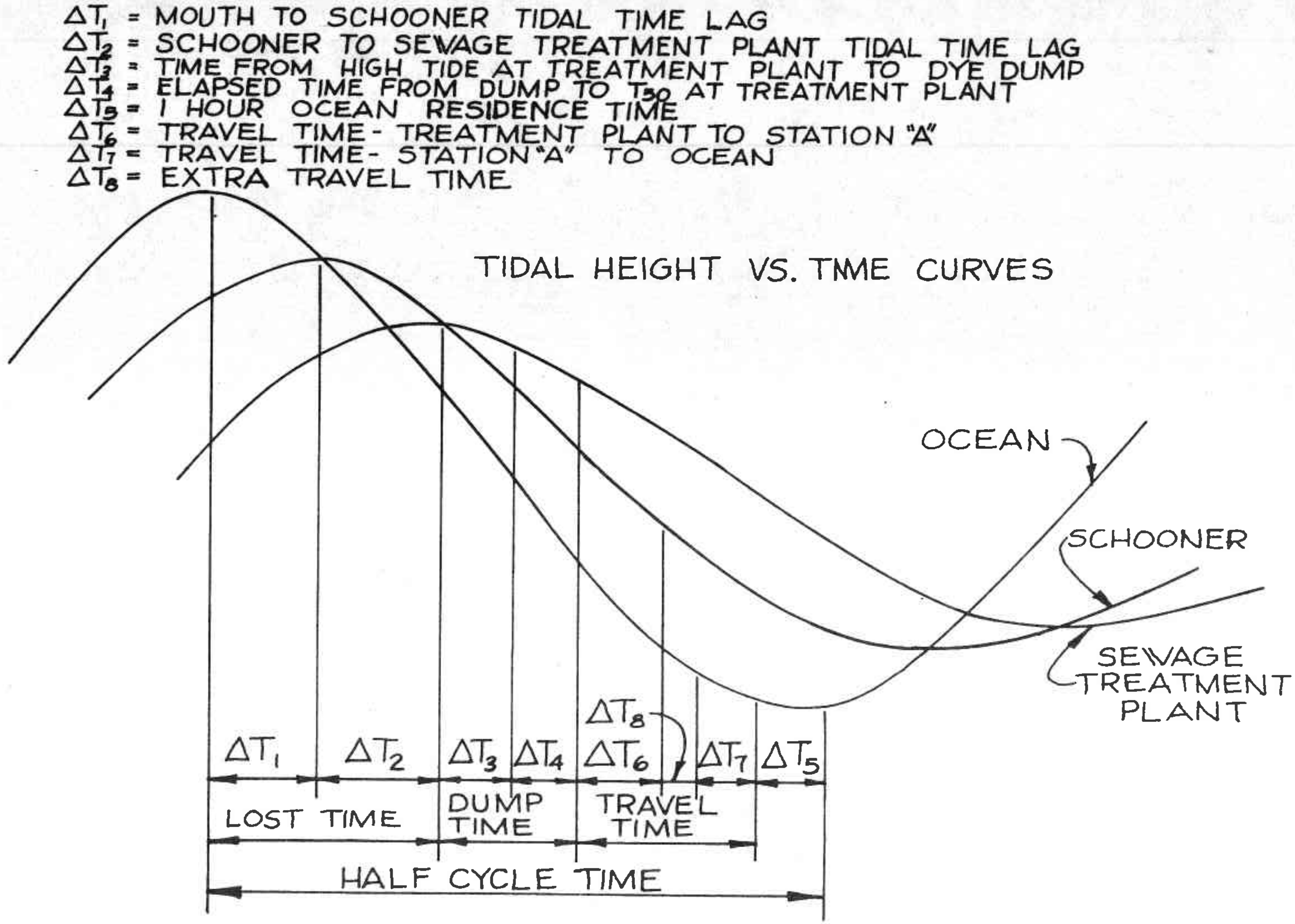


FIGURE 23. SAFE DISCHARGE TIME ANALYSIS

Table 21. Dye Study Results

Date	Tides (ft)			Type of Tide	Station	Distance from Dump (ft)	T_{50} (hrs:min)	T_{95} (hrs:min)	Safe Discharge Time (hrs:min)
	High	Low	Range						
24 July, 1970	4.49	-0.30	4.79	outgoing	Sewage Treatment Plant	0	0	0	
					W. Q. B.	4,507	1:27	2:25	
					W. Q. A.	7,301	1:50	2:45	1:02
22 August, 1970	7.63	0.76	6.87	incoming	Mouth	0	0	0	
					W. Q. A.	5,105	0:30	0:37	
					300 ft South of boat landing	11,000	1:36	2:03	
					Whiskey Creek West	28,500	3:23	3:55	
					Whiskey Creek East	28,012	3:33	4:24	
30 August, 1970	5.12	1.20	3.92	outgoing	King Realty	0	0	0	
					Sewage Treatment Plant	3,524	1:06	1:16	
					200 ft south of boat landing	4,168	1:31	1:46	
					W. Q. A.	10,895	2:01	2:15	2:20

accurate. The multiple sampling points at each station more adequately describe the motion of a dispersing waste water mass than one point at each station. Remarkably different velocities and times of passage are observed at most of the cross sections of Netarts Bay.

For most tides, one may conclude that discharging for one hour immediately after high slack water at the proposed sewage treatment plant site would approach 95% permanent removal of sewage effluent from Netarts Bay.

22 September, 1970

Description:

Dye dumped . . . 2 liters Rhodamine WT (20%) at 8% at water quality station A, at 1110.

Sampling station A occupied as tide returned.

This dye dump was at station A slmost one hour before low slack. The dye was observed to pass out the mouth completely. Throughout the subsequent flood tide, dye was observed to reenter Netarts Bay. The total calculated recovery was 16.8%. One may assume that from 10% to 25% of any constituent leaving Netarts Bay in the last hour of an outgoing tide will return, based on experimental accuracies.

To approach 95% pollutant removal from Netarts Bay, at least one hour should be subtracted from the safe discharge times inferred from other dye studies.

V. Conclusions

This report has presented the basic data on physical characteristics, water quality and flushing behavior of Netarts Bay. Although the analysis of hydraulic characteristics and transport phenomena in the bay and nearshore ocean waters are continuing, data of this report provides a basis upon which to plan future development of the Netarts Bay area. Conclusions based upon the findings of this report follow.

1. The volume of Netarts Bay appears to be decreasing. The bay volume for mean high water appears to have decreased approximately 10% from 1957 to 1969. The relative roles that erosion caused by uses of adjacent lands, including logging, marina and road construction, and land fill operations play in this filling process are not fully understood. The meander patterns of the channels are changing with time in an unpredictable manner. The long term rate of bay filling is not known and should be a subject of continuing study.
2. At mean low water (MLW) approximately 25% of the total mean high water (MHW) bay volume is contained landward of the entrance channel. At extreme low tides the bay is substantially drained.
3. Tidal phenomena in Netarts Bay are governed by the frictional characteristics of the entrance channel. The tidal wave is choked as it enters Netarts Bay. Approximately 81% of the ocean tidal range is observed at the Tillamook County boat landing and 75% at Whiskey Creek. Tidal velocities and tidal heights are nearly 90 degrees out of phase in the bay.
4. Tidal currents in Netarts Bay show no density stratification and no appreciable vertical velocity gradient. Netarts Bay is vertically well mixed.
5. Waters leaving the mouth of Netarts Bay during Summer conditions move primarily to the south toward Cape Lookout and along the beach littoral zone (surf zone). Information on the direction of wave attack and ocean currents near the mouth for all times throughout the year are inadequate for a detailed analysis of offshore movement of water masses.
6. Netarts Bay has a high level of water quality at the present time. Dissolved oxygen levels in the main water body are near saturation. Some diurnal variation in dissolved oxygen

is observed particularly in shallow areas. The level of dissolved organic material in the bay measured by a biochemical oxygen demand is very low. There is evidence of a very low level of bacteriological contamination of the bay as indicated by the presence of fecal coliforms. However, bacteriological quality of the bay is high when compared to other Oregon estuaries.

7. Sediments of the upper reaches of Netarts Bay near Whiskey Creek have high levels of organic carbon and decomposition byproducts, including hydrogen sulfide. Addition of nutrient materials to the bay which accelerate eutrophication will increase the anaerobic decomposition process in these headland sediments. Eutrophication of the sediments by nutrients from inadequately treated wastes or from land drainage including septic tank effluents may produce undesirable changes in the tidal flat areas of the bay.
8. Current studies utilizing dye and drift cards indicate that a portion of any effluent that is discharged continuously during outgoing tides at the proposed sewage treatment plant site may return on the next flood tide, depending on nearshore currents and other conditions of discharge. A 16% return was observed on one tide.
9. The mixing characteristics of Netarts Bay to the south of the Tillamook County boat landing depend, not only on tidal currents, but also on wind currents and secondary currents. Studies indicate that effluents discharged into Netarts Bay on a continuous basis will eventually spread over the entire bay.
10. The attractiveness of Netarts Bay as a recreational area has resulted in substantial development of housing and other

facilities in the area. The unique characteristics of this unspoiled bay together with improved transportation to the area make substantial additional growth of recreational facilities and housing a certainty. In addition to its recreational assets Netarts Bay also has a high potential for shellfish and fish production. It is essential that developments attracted to the bay do not destroy the very qualities they seek, by pollution of the bay. Protection of the bay requires a high degree of water quality and a high degree of reliability for any waste treatment system that is installed.

11. Increasing recreational use and residential development on Netarts Bay is resulting in the generation of domestic sewage loads that cannot be satisfactorily handled by conventional septic tanks and drainage fields in many areas adjacent to the bay. Seepage from septic tank effluents poses a hazard to the quality of water and sediments of the bay in addition to any local health hazards that may also be involved. These considerations indicate that a community sewer system and adequate waste treatment system are required for satisfactory development of the Netarts Bay area. The areas of immediate concern are the communities of Oceanside and Netarts, other lands encompassed by the Netarts Bay sanitary district and Cape Lookout State Park.

12. To assure permanent discharge of waste materials from the bay it would be most desirable to have effluents discharged either directly to the ocean or into the tidal channel north of the Tillamook County boat landing. Discharge into the bay should occur during ebb tides with a time of discharge sufficient to prevent significant re-entry into Netarts Bay. Studies indicate that at the proposed Rice Creek site

(Cornell, Howland, Hayes, Merryfield, 1968) the period of discharge should be during the first one to two hours of each ebbing tide period. Discharge points close to the bay mouth can utilize longer discharge periods.

13. Observations of oceanic conditions and circulation patterns from the bay indicate that an ocean outfall for the discharge of wastes generated in the bay drainage area should be located South of the bay mouth to provide maximum protection of the Summertime water quality of Netarts Bay. Although the predominant ocean currents are from North to South in the Summer, knowledge of the year round current conditions in the vicinity of the bay outlet are not known at this time.

14. Based upon the potential growth of the area, the requirement for any sewage treatment system and the uncertainty of the effects of residual wastes that are discharged into the bay, maximum protection of the bay's water quality may be gained by discharging the treated waste from a highly efficient secondary sewage treatment plant into the bay on an outgoing tide. If the proposed sewage treatment plant site is utilized, discharges should occur within a one to two hour period after high tide in order to prevent significant return of residual waste to the bay.

VI. References

Baumgartner, D. J., D. S. Trent. Ocean Outfall Design. Part One. U. S. Department of the Interior, Federal Water Quality Administration. April, 1970.

Burt, W. V. Hydrography of Oregon Estuaries Prior to June 1956. Department of Oceanography, School of Science, Oregon State University. 1956.

Cornell, Howland, Hayes and Merryfield, Inc. A Sewerage Study: Netarts-Oceanside Sanitary District, Tillamook County, Oregon. 1968.

Crook, Gene R. In-Situ Measurement of the Benthal Oxygen Requirement of Tidal Flat Deposits. M. S. Thesis. Oregon State University, Department of Civil Engineering. 1970.

Dicken, Samuel N. Some Recent Physical Changes of the Oregon Coast. University of Oregon, Department of Geography. 1961.

Glenne, Bard, C. Goodwin, C. Glanzman. Tidal Choking. Journal of the International Association for Hydraulic Research (IAHR). In printing.

Goodwin, C. R., E. W. Emmett, B. Glenne. Tidal Study of Three Oregon Estuaries. Bulletin No. 45, May 1970. Oregon State University, Engineering Experiment Station, Corvallis, Oregon. 1970.

Horne, R. A. Marine Chemistry. John Wiley & Sons. New York. 1969.

Hunger, A. A. Distribution of Foraminifera, Netarts Bay, Oregon. M. S. Thesis. Oregon State University, Department of Oceanography. 1966.

Martin, R. F. Marine Chemistry. Vol. 1. Marcel Dekker Inc. New York. 1968.

O'Brien, Morrough P. Equilibrium Flow of Inlets on Sandy Coasts. Journal of the Waterways and Harbors Division. Vol. 95, No. WWI. American Society of Civil Engineers. 1969.

Oregon State Department of Environmental Quality. Estuarine Water Quality Data (computerized summary of water quality observations at Netarts Bay).

Oregon State University, Department of Oceanography. Oceanographic Data Observations. Annual Publication.

Oregon State University Marine Science Center. Tide Tables. Newport, Oregon. Annual Publication.

Pearson, Erman A. An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge. California State Water Pollution Control Boards. 1956.

Strickland, J. D. H., T. R. Parsons. A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada. Ottawa. 1968.

American Public Health Assn. Standard Methods for the Examination of Water and Wastewater. 12th edition. 1965.

APPENDIX A

Department of Environmental Quality Data

Estuary Coding Information

Station # refers to the station number shown in table 1. and on figure 1.

Date refers to the date of collection of samples

Time indicates time of day in hours and minutes.

High indicates the corrected high tide and low the corrected low tide. All tidal information has been obtained from Tide Tables, high and low water predictions for the West Coast, North and South America, published by U. S. Department of Commerce, Environmental Science Services Administration, Coast and Geodetic Survey. All tidal information has been corrected from the reference tides listed under Humboldt Bay, California.

Stage refers to the stage of tide as follows:

An "0" in column 25 refers to low tide.

A "1" in column 25 refers to high tide.

Read an "0" in column 26 as -- before the --.

Read a "1" in column 26 as -- after the --.

Read column 27 in hours and columns 28 and 29 in minutes.

Depth refers to the depth of the water (in feet) at the point of sampling, as determined by The Ross Sportsman Depth Indicator Model P-100 (Ross Laboratories, Inc., Seattle, Washington). All samples were taken approximately one foot from the bottom.

Temp: Water temperature in °C.

pH: pH.

Salinity refers to salinity which was calculated from hydrometer - specific gravity field recordings and the use of the following publication: Sea Water Temperature and Density Reduction Tables by W. B. Zerbe and C. B. Taylor, Special Publication 298, U. S. Dept. of Commerce, Coast and Geodetic Survey, 1953.

<u>Cond:</u> Conductance in micro mhos/cm at 25°C as measured in the field by use of a conductivity bridge.

<u>DO:</u> Dissolved oxygen (DO) expressed in mg/1 and determined in the laboratory by the Winkler Test.

<u>BOD:</u> Biochemical oxygen demand (5-day BOD @ 20 C).

<u>Turb:</u> Turbidity in parts per million silicon dioxide (SiO_2).

<u>MPN:</u> Most probable number (MPN) of total coliforms per 100 ml sample, from multiple dilution fermentation tubes.

<u>Fecal:</u> MPN of fecal coliforms (*E. coli*) per 100 ml sample.

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
1	05/25/70	01:05	-	-	-	4.0	15.0	8.1	34.4	41000	8.8	0.7	-	3.0E	-
1	08/11/69	11:15	-	-	-	-	12.0	8.2	35.7	-	10.0	1.8	0.2	3.0E	3.0E
1	02/25/69	01:02	-	-	-	5.0	8.0	8.3	31.0	-	10.3	2.2	6.5	4.0E	3.0E
1	08/19/68	-	1035	1450	52	10.0	15.4	8.4	30.3	38000	8.7	1.0	3.0	9.3E1	4.3E1
1	08/19/68	-	1035	1450	155	12.7	15.0	8.4	30.6	40000	8.9	1.4	4.0	4.3E1	4.3E1
1	08/19/68	-	1035	1450	11050	10.0	14.4	8.3	30.3	39000	8.8	2.0	7.0	4.6E2	4.6E2
1	08/19/68	-	1035	1450	10005	9.5	14.4	8.4	30.6	39000	8.6	1.3	4.0	3.6E	3.6E
1	04/22/68	-	817	1508	1016	6.0	10.5	8.3	29.4	38000	9.6	0.6	6.0	-3.0E	3.0E
1	04/22/68	-	817	1508	121	7.0	11.0	8.1	30.4	39000	9.7	0.6	3.0	1.5E2	3.6E
1	04/22/68	-	817	1508	226	7.0	10.0	8.3	31.4	40000	9.6	0.3	2.5	9.3E1	-3.0E
1	04/22/68	-	817	1508	11238	9.0	9.4	8.4	31.1	39000	9.4	1.0	11.5	2.3E1	-3.0E
1	09/25/67	-	453	944	1008	9.2	9.4	7.8	32.9	44000	8.8	0.6	6.0	2.3E1	-3.0E
1	09/25/67	-	453	944	1128	8.0	9.4	7.8	32.9	47500	9.5	0.7	5.5	2.3E1	-3.0E
1	09/25/67	-	453	944	1208	10.0	9.3	7.8	33.2	46000	9.2	0.6	6.5	9.1E	3.6E
1	09/25/67	-	453	944	1234	6.5	9.8	7.8	32.7	46000	9.3	0.6	6.0	-3.0E	3.0E
1	05/08/67	-	1211	602	10141	9.0	9.4	8.2	32.1	42000	9.4	0.4	7.5	-3.0E	3.0E
1	05/08/67	-	1211	602	10011	10.0	9.1	8.2	31.9	43000	9.3	0.5	7.0	-3.0E	3.0E
1	05/08/67	-	1211	602	11152	9.0	9.3	8.2	31.9	41000	9.4	0.4	6.0	3.6E	3.0E
1	05/08/67	-	1211	602	238	10.0	9.4	8.1	31.6	42000	9.6	0.4	8.0	-3.0E	3.0E
1	07/22/63	-	1400	738	231	9.9	16.0	8.3	26.7	-	-	-	-	2.3E1	2.3E1
1	07/22/63	-	1400	738	10010	5.8	17.0	8.4	26.5	-	-	-	-	3.6E	3.6E
1	07/22/63	-	1400	738	10205	8.0	16.0	8.3	29.0	-	-	-	-	9.3E1	2.3E1
1	07/22/63	-	1400	738	11125	14.0	16.0	8.3	26.9	-	-	-	-	3.6E	3.6E
1	09/12/60	-	535	1112	49	7.1	15.0	-	33.2	-	-	-	-	3.6E	3.0E
1	09/12/60	-	535	1112	11215	4.5	13.0	-	32.7	-	-	-	-	3.6E	3.6E
1	09/12/60	-	535	1112	1212	9.6	16.5	-	33.8	-	-	-	-	-3.0E	3.0E
1	09/12/60	-	535	1112	10141	8.8	14.5	-	32.5	-	-	-	-	3.6E	3.0E
1	05/16/60	-	1728	1050	329	3.5	12.5	7.6	29.7	-	-	-	-	3.0E	3.0E
1	05/16/60	-	1728	1050	1106	3.1	14.5	8.4	28.2	-	-	-	-	9.1E	9.1E
1	05/16/60	-	1728	1050	10158	2.4	14.8	8.4	28.8	-	-	-	-	3.0E	3.0E
2	05/25/70	01:01	-	-	-	4.0	15.0	8.2	34.4	42000	9.0	1.1	-	9.0E	-
2	08/11/69	11:20	-	-	-	-	12.0	8.2	32.5	-	10.4	2.7	0.3	3.0E	3.0E

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
2	02/25/69	01:04	-	-	-	8.0	8.0	8.3	28.5	-	10.5	2.0	5.0	3.0E	3.0E
2	08/19/68	-	1035	1450	45	10.0	15.4	8.4	30.1	38000	8.9	1.3	3.0	1.5E1	9.1E
2	08/19/68	-	1035	1450	147	11.0	15.0	8.4	30.6	39000	9.0	1.4	4.0	2.3E1	9.1E
2	08/19/68	-	1035	1450	11057	12.5	14.8	8.3	30.1	38000	8.7	1.5	6.0	7.5E1	2.0E1
2	08/19/68	-	1035	1450	11005	11.5	14.6	8.3	30.1	40000	8.7	1.3	10.0	2.8E1	3.6E
2	04/22/68	-	817	1508	1027	11.8	10.5	8.3	28.9	38000	9.6	1.0	6.0	-3.0E	3.0E
2	04/22/68	-	817	1508	113	11.0	11.0	8.3	29.7	38000	9.3	0.3	2.0	-3.0E	3.0E
2	04/22/68	-	817	1508	215	9.5	10.0	8.3	31.4	39000	9.6	2.2	1.5	3.6E	3.0E
2	04/22/68	-	817	1508	11251	7.5	9.1	8.3	31.4	40000	9.4	0.7	4.0	-3.0E	3.0E
2	09/25/67	-	453	944	1020	18.7	9.4	7.8	32.9	46000	8.6	0.5	5.5	3.6E	3.6E
2	09/25/67	-	453	944	1133	10.0	9.4	7.7	32.7	46000	8.9	0.7	6.0	3.6E	3.0E
2	09/25/67	-	453	944	1213	11.2	9.4	7.8	32.7	46000	9.1	0.5	6.0	-3.0E	3.0E
2	09/25/67	-	453	944	1250	11.0	9.4	7.9	32.4	45000	9.3	-	6.0	9.1E	3.6E
2	05/08/67	-	1211	602	10131	10.0	9.2	8.2	32.1	40000	9.4	0.5	7.0	3.6E	3.6E
2	05/08/67	-	1211	602	10004	9.0	9.0	8.2	31.9	42000	9.1	0.1	7.0	-3.0E	3.0E
2	05/08/67	-	1211	602	11159	9.0	9.2	8.2	31.6	41000	9.4	0.3	7.0	-3.0E	3.0E
2	05/08/67	-	1211	602	229	9.0	9.4	8.1	31.6	40000	9.5	0.5	7.0	-3.0E	3.0E
2	07/22/63	-	1400	738	10200	12.1	16.0	8.3	28.8	-	-	-	-	2.3E1	2.3E1
2	07/22/63	-	1400	738	10006	9.0	16.0	8.4	26.7	-	-	-	-	-3.0E	3.0E
2	07/22/63	-	1400	738	11138	17.2	16.0	8.4	26.9	-	-	-	-	3.6E	3.6E
2	07/22/63	-	1400	738	218	18.0	16.0	8.4	26.7	-	-	-	-	-3.0E	3.0E
2	09/12/60	-	535	1112	11235	13.8	14.0	-	32.7	-	-	-	-	-3.0E	3.0E
2	09/12/60	-	535	1112	35	11.4	16.0	-	33.2	-	-	-	-	-3.0E	3.0E
2	09/12/60	-	535	1112	1224	12.1	16.5	-	33.6	-	-	-	-	-3.0E	3.0E
2	09/12/60	-	535	1112	10130	16.0	15.0	-	33.5	-	-	-	-	-3.0E	3.0E
2	05/16/60	-	1728	1050	307	2.0	12.2	7.7	30.3	-	-	-	-	3.6E	3.0E
2	05/16/60	-	1728	1050	48	3.5	13.5	8.3	30.7	-	-	-	-	3.6E	3.0E
2	05/16/60	-	1728	1050	10138	1.0	14.5	8.5	29.1	-	-	-	-	3.6E	3.6E
2	05/16/60	-	1728	1050	1123	3.5	14.5	8.3	28.6	-	-	-	-	9.1E	3.0E
3	05/25/70	01:02	-	-	-	4.0	16.0	8.3	31.4	42000	8.8	0.3	-	9.0E	-
3	08/11/69	11:21	-	-	-	-	12.0	8.2	32.3	-	10.2	2.7	0.2	3.0E	3.0E
3	02/25/69	01:10	-	-	-	10.0	8.0	8.3	27.4	-	10.5	0.1	6.0	3.0E	3.0E

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
3	08/19/68	-	1035	1450	33	10.0	15.8	8.4	30.3	39000	8.9	1.1	3.0	9.1E	9.1E
3	08/19/68	-	1035	1450	140	10.5	15.2	8.4	30.1	39000	9.0	3.2	5.0	2.1E1	1.5E1
3	08/19/68	-	1035	1450	11113	14.0	14.6	8.4	30.6	38000	8.9	3.2	6.0	4.3E1	9.1E
3	08/19/68	-	1035	1450	11011	10.0	14.6	8.3	30.8	40000	8.8	1.6	9.0	2.3E1	9.1E
3	04/22/68	-	817	1508	1052	8.3	10.5	8.3	28.6	37500	9.6	1.2	5.5	-3.0E	3.0E
3	04/22/68	-	817	1508	106	8.4	11.0	8.4	29.9	39000	9.3	0.5	6.0	-3.0E	3.0E
3	04/22/68	-	817	1508	207	8.2	10.5	8.3	31.5	40000	9.3	0.6	2.0	3.6E	3.0E
3	04/22/68	-	817	1508	11302	12.3	9.4	8.4	31.5	40000	9.6	1.1	5.0	-3.0E	3.0E
3	09/25/67	-	453	944	1024	14.5	9.7	7.7	32.7	46000	8.6	-	5.5	9.1E	3.0E
3	09/25/67	-	453	944	1137	9.3	10.0	7.9	32.7	48000	8.6	0.6	6.0	2.3E1	3.6E
3	09/25/67	-	453	944	1217	9.1	9.4	7.8	32.4	46000	9.0	0.6	6.0	3.6E	3.0E
3	09/25/67	-	453	944	1255	10.5	9.6	7.8	32.7	45000	9.3	1.2	6.5	-3.0E	3.0E
3	05/08/67	-	1211	602	10121	17.0	9.0	8.2	31.9	42000	9.3	0.3	7.0	-3.0E	3.0E
3	05/08/67	-	1211	602	11005	12.0	9.7	8.2	31.9	41000	9.3	0.5	7.0	3.6E	3.0E
3	05/08/67	-	1211	602	11206	12.6	9.6	8.1	31.9	40000	9.3	0.2	7.0	2.3E1	-3.0E
3	05/08/67	-	1211	602	223	12.0	9.4	8.1	31.6	41000	9.3	0.6	8.0	3.6E	3.0E
3	07/22/63	-	1400	738	10153	13.5	16.0	8.2	29.3	-	-	-	-	2.1E1	1.5E1
3	07/22/63	-	1400	738	11013	8.1	16.0	8.5	26.9	-	-	-	-	-3.0E	3.0E
3	07/22/63	-	1400	738	11145	8.6	16.0	8.4	26.9	-	-	-	-	7.3E	7.3E
3	07/22/63	-	1400	738	211	9.1	16.5	8.4	27.2	-	-	-	-	3.6E	3.6E
3	09/12/60	-	535	1112	17	9.1	17.0	-	33.5	-	-	-	-	-3.0E	3.0E
3	09/12/60	-	535	1112	11253	7.9	14.5	-	33.2	-	-	-	-	9.1E	3.0E
3	09/12/60	-	535	1112	10113	9.8	15.0	-	33.2	-	-	-	-	-3.0E	3.0E
3	09/12/60	-	535	1112	1235	11.9	17.5	-	33.3	-	-	-	-	3.6E	3.0E
3	05/16/60	-	1728	1050	31	1.0	13.8	-	30.3	-	-	-	-	3.6E	3.0E
3	05/16/60	-	1728	1050	245	2.5	12.2	-	30.3	-	-	-	-	3.6E	3.0E
3	05/16/60	-	1728	1050	1136	5.4	14.5	8.2	28.4	-	-	-	-	-3.0E	3.0E
3	05/16/60	-	1728	1050	10121	1.5	14.0	8.4	28.8	-	-	-	-	-3.0E	3.0E
4	05/25/70	01:03	-	-	-	4.0	16.0	8.2	31.1	40000	9.1	1.5	-	3.0E	-
4	08/11/69	11:22	-	-	-	-	14.0	8.3	32.1	-	10.8	2.6	0.2	3.0E	3.0E
4	02/25/69	01:12	-	-	-	9.0	8.0	8.4	27.2	-	10.4	0.7	5.0	3.0E	3.0E

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
4	08/19/68	-	1035	1450	25	18.2	16.2	8.4	30.1	39000	8.6	0.9	4.0	7.5E1	4.3E1
4	08/19/68	-	1035	1450	132	12.5	15.5	8.4	30.3	40000	9.0	1.9	5.0	1.5E1	1.5E1
4	08/19/68	-	1035	1450	11122	16.2	14.6	8.3	30.8	39000	8.6	1.9	6.0	2.3E1	2.3E1
4	08/19/68	-	1035	1450	11019	11.5	14.6	8.3	30.6	39000	8.5	1.6	8.0	2.3E1	3.6E
4	04/22/68	-	817	1508	1059	9.7	10.5	8.3	27.7	38000	9.6	1.0	9.0	-3.0E	3.0E
4	04/22/68	-	817	1508	101	9.2	11.0	8.4	28.9	38000	9.5	0.8	6.0	3.6E	3.0E
4	04/22/68	-	817	1508	158	10.0	11.0	8.3	30.2	40000	9.7	2.7	2.0	-3.0E	3.0E
4	04/22/68	-	817	1508	11308	14.2	9.7	8.3	31.6	39000	9.8	0.8	5.0	-3.0E	3.0E
4	09/25/67	-	453	944	1030	9.5	10.0	7.8	32.4	46000	8.4	0.5	5.5	7.3E	3.0E
4	09/25/67	-	453	944	1143	10.6	11.1	7.8	32.5	46000	8.4	0.7	6.0	9.1E	3.6E
4	09/25/67	-	453	944	1222	19.0	10.1	7.9	32.7	46000	8.8	0.3	6.5	9.1E	3.6E
4	09/25/67	-	453	944	1300	14.3	9.7	7.8	32.7	47000	9.0	0.6	5.5	-3.0E	3.0E
4	05/08/67	-	1211	602	10116	13.0	9.0	8.1	31.9	41000	9.1	0.2	8.0	-3.0E	3.0E
4	05/08/67	-	1211	602	11010	6.0	9.4	8.2	31.6	42000	9.3	0.5	7.5	9.1E	3.6E
4	05/08/67	-	1211	602	11211	6.6	9.4	8.1	31.6	41000	9.4	0.3	7.0	7.3E	3.6E
4	05/08/67	-	1211	602	215	6.0	9.6	8.1	31.6	42000	8.5	-	8.0	-3.0E	3.0E
4	07/22/63	-	1400	738	10137	10.4	17.0	8.2	29.3	-	-	-	-	2.4E2	4.3E1
4	07/22/63	-	1400	738	11020	12.1	16.0	8.4	26.7	-	-	-	-	3.6E	3.6E
4	07/22/63	-	1400	738	11150	12.6	16.0	8.4	26.9	-	-	-	-	3.6E	3.0E
4	07/22/63	-	1400	738	204	10.1	16.5	8.5	26.9	-	-	-	-	9.1E	3.6E
4	09/12/60	-	535	1112	202	5.2	16.0	-	33.5	-	-	-	-	3.6E	3.0E
4	09/12/60	-	535	1112	1022	4.5	17.5	-	33.3	-	-	-	-	-3.0E	3.0E
4	09/12/60	-	535	1112	10248	4.1	18.0	-	33.7	-	-	-	-	-3.0E	3.0E
4	09/12/60	-	535	1112	10101	13.1	15.5	-	33.6	-	-	-	-	-3.0E	3.0E
4	05/16/60	-	1728	1050	224	5.5	12.8	7.8	29.7	-	-	-	-	-3.0E	3.0E
4	05/16/60	-	1728	1050	10	4.5	13.4	8.1	29.4	-	-	-	-	2.3E1	-3.0E
4	05/16/60	-	1728	1050	10113	5.2	13.0	8.2	29.7	-	-	-	-	-3.0E	3.0E
4	05/16/60	-	1728	1050	1147	9.1	14.5	8.2	28.4	-	-	-	-	3.6E	3.0E
5	05/25/70	01:03	-	-	-	4.0	16.0	8.3	30.6	42000	9.3	1.2	-	3.0E	-
5	08/11/69	11:23	-	-	-	-	13.0	8.3	38.4	-	10.0	2.6	0.2	3.0E	3.0E
5	02/25/69	01:14	-	-	-	8.0	8.0	8.2	27.0	-	10.5	1.1	3.5	3.0E	3.0E

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
5	08/19/68	-	1035	1450	15	11.0	16.2	8.4	30.1	39000	8.9	0.9	6.0	4.3E1	2.3E1
5	08/19/68	-	1035	1450	122	11.0	15.4	8.4	30.1	40000	8.9	1.4	3.0	2.3E1	9.1E
5	08/19/68	-	1035	1450	11131	11.0	14.6	8.3	30.3	40000	8.7	2.0	4.0	7.3E	7.3E
5	08/19/68	-	1035	1450	11028	12.5	14.6	8.4	30.8	40000	8.7	3.1	6.0	9.3E1	2.3E1
5	04/22/68	-	817	1508	1107	7.5	10.5	8.3	27.7	38000	9.6	1.1	5.0	-3.0E	3.0E
5	04/22/68	-	817	1508	53	8.0	11.0	8.4	28.6	38000	9.7	1.2	5.0	-3.0E	3.0E
5	04/22/68	-	817	1508	151	9.0	11.0	8.3	30.2	39000	9.6	0.4	4.0	-3.0E	3.0E
5	04/22/68	-	817	1508	11316	7.5	9.6	8.3	31.4	40000	9.6	1.4	4.0	-3.0E	3.0E
5	09/25/67	-	453	944	1036	6.0	11.2	7.9	32.5	46000	8.1	0.6	6.5	2.3E1	2.3E1
5	09/25/67	-	453	944	1149	10.5	11.7	7.7	32.8	46000	8.1	0.6	6.0	2.3E1	2.3E1
5	09/25/67	-	453	944	1227	11.4	11.2	7.8	32.5	45000	8.3	0.6	6.5	2.3E1	3.6E
5	09/25/67	-	453	944	1306	10.0	10.8	7.8	32.8	45000	8.7	0.6	6.0	2.3E1	3.6E
5	05/08/67	-	1211	602	10056	7.0	9.0	8.2	31.9	42000	9.0	0.7	8.0	-3.0E	3.0E
5	05/08/67	-	1211	602	11015	22.0	9.4	8.2	31.6	42000	9.3	0.5	8.5	-3.0E	3.0E
5	05/08/67	-	1211	602	11216	5.0	9.4	8.1	31.8	40000	9.4	2.1	7.0	3.6E	3.0E
5	05/08/67	-	1211	602	208	16.0	9.6	8.1	31.4	42000	9.6	0.3	6.5	-3.0E	3.0E
5	07/22/63	-	1400	738	10129	1.1	16.5	8.1	29.3	-	-	-	-	7.5E1	4.3E1
5	07/22/63	-	1400	738	11026	16.5	16.0	8.4	26.1	-	-	-	-	9.1E	3.0E
5	07/22/63	-	1400	738	11156	9.7	16.0	8.4	27.5	-	-	-	-	9.1E	3.6E
5	07/22/63	-	1400	738	153	9.0	16.5	8.5	26.4	-	-	-	-	-3.0E	3.0E
5	09/12/60	-	535	1112	152	2.6	16.5	-	33.3	-	-	-	-	-3.0E	3.0E
5	09/12/60	-	535	1112	1038	5.1	18.0	-	33.2	-	-	-	-	-3.0E	3.0E
5	09/12/60	-	535	1112	10231	5.5	18.0	-	33.7	-	-	-	-	-3.0E	3.0E
5	09/12/60	-	535	1112	10049	4.0	15.5	-	33.3	-	-	-	-	3.6E	3.0E
5	05/16/60	-	1728	1050	157	3.2	12.5	7.8	29.7	-	-	-	-	-3.0E	3.0E
5	05/16/60	-	1728	1050	1006	10.1	13.8	8.3	29.5	-	-	-	-	3.6E	3.6E
5	05/16/60	-	1728	1050	1203	10.1	14.2	8.3	28.9	-	-	-	-	3.0E	3.0E
5	05/16/60	-	1728	1050	10059	5.5	12.5	8.3	32.7	-	-	-	-	-3.0E	E
6	08/11/69	11:24	-	-	-	-	13.0	8.3	31.9	-	10.0	2.3	0.2	3.0E	3.0E
6	02/25/69	01:15	-	-	-	6.0	8.0	8.3	26.8	-	10.5	1.2	1.5	3.0E	3.0E

Station #	Date mo./day/yr	Time	High	Low	Stage	Depth	Temp.	pH	Salinity	Cond.	D.O.	B.O.D.	Turb.	M.P.N.	Fecal
6	08/19/68	-	1035	1450	1003	10.6	16.2	8.4	30.1	40000	8.8	1.2	4.0	2.4E2	3.6E
6	08/19/68	-	1035	1450	113	12.5	15.8	8.4	30.1	38000	8.9	1.5	7.0	1.5E1	1.5E1
6	08/19/68	-	1035	1450	11140	10.3	15.2	8.4	30.1	40000	8.8	3.1	6.0	2.9E1	2.1E1
6	08/19/68	-	1035	1450	11040	13.0	14.6	8.3	30.3	39000	8.5	1.7	5.0	9.3E1	2.1E1
6	04/22/68	-	817	1508	1123	6.0	10.5	8.3	26.4	35000	9.7	1.3	8.0	-3.0E	3.0E
6	04/22/68	-	817	1508	46	9.5	10.5	8.4	27.7	38000	9.5	1.0	6.5	-3.0E	3.0E
6	04/22/68	-	817	1508	143	5.0	11.5	8.3	29.1	37000	9.3	0.6	5.0	-3.0E	3.0E
6	04/22/68	-	817	1508	11328	10.0	10.2	8.3	31.1	38500	9.4	0.5	3.0	-3.0E	3.0E
6	09/25/67	-	453	944	1048	9.5	12.5	7.9	32.7	46000	7.7	1.0	6.0	2.3E1	3.6E
6	09/25/67	-	453	944	1156	10.8	13.1	7.8	32.4	46000	7.4	0.8	6.0	7.3E	3.0E
6	09/25/67	-	453	944	1232	10.3	12.4	7.9	32.8	46000	7.9	0.6	6.0	3.6E	3.6E
6	09/25/67	-	453	944	1317	9.0	11.2	7.8	32.8	45000	8.5	0.6	6.5	1.5E1	-3.0E
6	05/08/67	-	1211	602	10049	10.0	9.0	8.2	31.9	42000	9.0	0.3	7.0	-3.0E	3.0E
6	05/08/67	-	1211	602	11024	10.0	9.4	8.1	31.8	43000	8.9	0.8	7.0	-3.0E	3.0E
6	05/08/67	-	1211	602	11228	11.6	9.4	8.1	31.6	41000	8.9	0.3	6.0	-3.0E	3.0E
6	05/08/67	-	1211	602	138	11.0	9.6	8.2	31.4	41000	8.7	-	6.0	-3.0E	3.0E
6	07/22/63	-	1400	738	141	9.5	16.0	8.5	26.4	-	-	-	-	-3.0E	3.0E
6	07/22/63	-	1400	738	11205	14.3	16.0	8.4	26.7	-	-	-	-	3.6E	3.6E
6	07/22/63	-	1400	738	11035	13.7	16.0	8.4	26.9	-	-	-	-	9.1E	3.6E
6	07/22/63	-	1400	738	10100	1.1	17.5	8.1	29.5	-	-	-	-	4.3E1	2.3E1
6	09/12/60	-	535	1112	122	2.0	16.5	-	33.6	-	-	-	-	-3.0E	3.0E
6	09/12/60	-	535	1112	10027	5.1	15.5	-	33.3	-	-	-	-	-3.0E	3.0E
6	09/12/60	-	535	1112	10216	5.0	18.0	-	33.3	-	-	-	-	-3.0E	3.0E
6	09/12/60	-	535	1112	1111	3.7	18.5	-	33.3	-	-	-	-	-3.0E	3.0E
6	05/16/60	-	1728	1050	137	2.1	12.4	7.9	29.7	-	-	-	-	-3.0E	E
6	05/16/60	-	1728	1050	10044	2.6	12.5	8.3	31.6	-	-	-	-	-3.0E	3.0E
6	05/16/60	-	1728	1050	1020	6.6	14.0	8.2	29.3	-	-	-	-	-3.0E	E
6	05/16/60	-	1728	1050	1212	4.0	14.0	8.4	28.5	-	-	-	-	3.6E	3.0E

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- Marine Science Center at Newport (1965)
- Radiation Center (1964)

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- Genetics Institute (1963)
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- Nutrition Research Institute (1964)
- Science Research Institute (1952)
- Transportation Research Institute (1960)
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