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W. E. Wrather, Director

NANTUCKET HARBOR AND THE PROPOSED CUT AT CHATHAM BEND

by

W. H. Bradley and Joshua I. Tracey, Jr.
U. S. Geological Survey

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TABLE OF CONTENTS

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Introduction

This study of Nantucket Harbor was undertaken in response to a request General Hale made of L. W. Currier, U. S. Geological Survey, as part of the cooperative agreement between the Commonwealth of Massachusetts and the U.S. Geological Survey. The purpose of the study was twofold: (1) to determine, if possible, whether a channel cut through the Coatue Beach at the Chatham Bend (between Wyer's and Bass Points) would have beneficial or adverse effects on navigation in the harbor and through the Nantucket ship channel, and (2) to determine, if possible, what effect such a cut in the Coatue Beach would have on flushing out the easternmost part of the harbor (Head of the Harbor) and thereby perhaps improving the shellfish productivity. The problem was attacked first by determining the existing characteristics of the harbor and then by constructing a model in which these characteristics could be approximated. In the model a cut-through at the Chatham Bend was made so as to observe what effect that channel would have on the hydrography of the harbor.

The location, physical features, geology, and history of Nantucket Harbor have been effectively treated in two earlier reports - "Report on Nantucket Harbor and its Improvement" by William F. Jones, consulting shoreline engineer of Nantucket, March 15, 1938; and "Shore Protection Board Report on Nantucket Harbor, Mass.", by A. C. Lieber, Jr., Major, Corps of Engineers, U. S. Army, June 7, 1939 - and will not be repeated here. Both these reports considered only the possibility of a channel being cut through the Haulover Beach to the open ocean at the extreme eastern end of Nantucket Harbor. Both reports conclude that an opening at that place would probably not be economically sound. We found no evidence in this study that leads us to question in any way their conclusions.

Conclusions and Recommendations

Current velocities measured between Pocomo and Bass Points, observation of the movement of stick buoys, and the chemical and thermal properties of the water all indicate that tidal currents ensure a continuous, though comparatively small, replacement of water in the Head of the Harbor (east of Pocomo and Bass Points) by water from Nantucket Sound that enters the harbor through the Nantucket ship channel. This continuous freshening of the water in the Head of the Harbor was confirmed by observation of the tidal circulation in the model of the harbor constructed for this investigation.

Tidal currents determine the major circulation pattern of the harbor as a whole. Direct observation and model study show that tidal circulation in the Head of the Harbor is not at all uniform and that in the vicinity of Coskata and Wauwinit the circulation is distinctly feeble. Wind generated surface currents probably provide some circulation in those areas and certainly accelerate, retard, or deflect tidal currents in all parts of the harbor, depending upon their direction.

Vertical temperature profiles of the water in the Head of the Harbor indicate that the circulation is not good, or continuous, in the deeper holes. The observations made, however, are not adequate to evaluate either the extent or duration of water stagnation in the deeper parts.

Observation of the harbor model shows that much better tidal circulation in the Head of the Harbor could be established by cutting a channel about 300 feet wide and 6 feet deep (at low tide) across Coatue Beach between Bass and Wyer's Points at what is known locally as the Chatham Bend. The phases of the tide in the Head of the Harbor, and in Nantucket Sound in the vicinity of Coskata are sufficiently different to ensure a large exchange of water between Nantucket Sound and the Head of the Harbor. It should be emphasized, however, that the vigorous circulation thus established in the Head of the Harbor is, to an appreciable degree, obtained at the expense of the tidal circulation in the rest of the harbor. The velocity of both flood and ebb tide currents in the Nantucket ship channel are appreciably diminished. The tidal currents that flow back and forth over the generally shoal area between Pocomo Point and Coatue Beach in the vicinity of Bass and Five Finger Points (see Fig. 1) are markedly slowed. It seems probable from the action of the model that if a cut were made through Coatue at the Chatham Bend the velocity of the tidal currents in the Nantucket ship channel would be reduced enough to cause considerable accumulation of sand in the channel. Systematic dredging of the ship channel would probably thereafter be required but at what intervals we are unable to say. Almost certainly the area between Pocomo Point and Coatue Beach would become appreciably shoaler. To maintain a channel having a minimum depth of 6 feet through this area would surely require dredging.

In the model, eddies developed within the Head of the Harbor on each side of the cut through Coatue Beach during the influx of flood tides. These eddies were eliminated by building short jetties out into the harbor on each side of the cut. Presumably comparable jetties would have to be built on the harbor side if the cut at Chatham Bend is made.

About 650 new soundings showed that the area northwest of Pocomo Point has shoaled since 1938 and that the spits at the ends of Five Finger Point and, particularly, Bass Point have lengthened appreciably. Plane table measurements made along parts of the shore in the bays between Five Finger and Bass Points and between Bass and Wyer's Points show that in the crescentic bay facing the harbor between Five Finger and Bass Points the shore has been cut back northwestward about 80 feet since 1938. It is now only about 210 feet across Coatue Beach between the high tide line in this bay and the high tide line on the Nantucket Sound side. The northern side of the bay between Bass and Wyer's Points has been cut back a similar amount since 1938.

This investigation has turned up only two observations on the ecology of harbor scallops that may be significant. One is that the scallops that grow in the Head of the Harbor near Coskata and Wauwinit where the tidal circulation is very feeble and have exceptionally large shells but smaller than usual "eyes" (i.e. the adductor muscle, which is the commercially valuable part). The other observation was that the best scallops come from the "hard" bottom in the vicinity of Wyer's Point where the tidal circulation appears to be only a little more vigorous than in the vicinity of Coskata and Wauwinit.

One other observation was made that may be of significance in the ecology of scallops and other shell fish; namely that eel grass is reestablishing itself at different rates in different parts of the Nantucket area. Near Maddaket, at the southwestern end of the Island, eel grass is so abundant that it is becoming a nuisance. In the western end of Nantucket Harbor eel grass is becoming fairly plentiful but in the Head of the Harbor it exists now only in small patches that, according to casual observations of local residents, do not appear to be expanding.

Discussions with biologists at Woods Hole Oceanographic Institution lead us to the conclusion that so little is known about the ecology of the harbor scallop in general, and about the harbor scallop in the hydrographically complex Nantucket Harbor in particular, that it is quite impossible to predict whether a channel through Coatue Beach connecting the Head of the Harbor and Nantucket Sound would improve the yield and quality of scallops or whether it would have no effect upon them. Conceivably it could have an adverse effect on the scallop yield from the Head of the Harbor. For example, it may be that the drainage from the land and swamps from the Polpis Harbor area may bring into the harbor beneficial additions of dissolved phosphate and nitrogen - important nutrients for all aquatic organisms. At present, drainage from the Polpis area almost certainly gets into the Head of the Harbor. Observations of the harbor model suggest that if the Chatham Bend cut is made it is likely that much less of this land and swamp drainage could get into the Head of the Harbor. It would stay in the lower part of the harbor or be swept out into Nantucket Sound. Also, the reported fact that the best scallops now come from the Head of the Harbor (near Wyer's Point), where the circulation is not at all vigorous seems to cast some doubt on the desirability of a frequent large exchange of harbor and Nantucket Sound water.

The information and ideas developed during the course of this investigation lead us to recommend:

1) An engineering study of the harbor model and the harbor itself to determine how much the tidal currents in the Nantucket ship channel would be reduced by the changes in the hydrography of the upper harbor brought about by an opening at the Chatham Bend. This would be necessary to assess the economic consequences in terms of required dredging in the ship channel;

2) A systematic biological study of the ecology of the harbor scallop in Nantucket Harbor as a whole to determine the probable economic effects of the proposed Chatham Bend cut on yield and quality of the scallops. This study, should, and probably would normally, include many more determinations of the chemical and thermal characteristics of the harbor water, particularly in the Head of the Harbor. Such additional data are necessary to make sure whether or not the deep parts of that basin contain enough stagnant water during any part of the year, to have an adverse effect on shell fish. Such a study also should include an assessment of the relationship of the kind of bottom (clay, cobble, loose sand, etc.) to the best production of scallops. Biologists at the Woods Hole Oceanographic Institution, for example, showed quite convincingly that there is an extraordinarily close dependence on the particle size and grain size distribution of the bottom deposits and the setting of seed clams. If scallop spat requires anything like as fine grained sediment as seed clams do then a vigorous circulation is something to be shunned like a plague. Perhaps on the other hand their requirements are utterly different. But they certainly should be known before making so drastic a change in the hydrography of the harbor as the Chatham Bend cut would produce; and

3) That, if the Chatham Bend cut is made, the channel to be dredged through the area between Pocomo Point and Coatue Beach be sinuous and follow the present course of the deepest channel up along the west side of Pocomo Point, deep into the bay between Five Finger and Bass Points, thence southeastward along, and close to, the Bass Point spit toward the site of the temporary tide gauge shown on Fig. 1. That sinuous channel would be easier to maintain and would require much less frequent dredging than a straight channel through the area. It would make use of, rather than fight, the natural processes going on there.

Hydrography of Nantucket Harbor

In 1934 the Corps of Engineers took a great many soundings when they made a systematic survey of the bathymetry of Nantucket Harbor. Subsequently William F. Jones of Nantucket made additional soundings and compiled a useful and informative bathymetric chart of the harbor. Apparently that chart was never submitted to either the State or Federal governments. Through the kindness of Mr. Bassett Jones, brother of the late William F. Jones, we have traced that bathymetric chart and transmit it with this report. (Figure 1). It has been modified, however, in the area around Five Finger, Pocomo, Bass, and Wyer's Points to accord with about 650 new soundings taken by the U. S. Geological Survey in July and August, 1948. Soundings were taken in that area because it appears to be the most critical, both for navigation through the harbor and for the exchange of water between the upper (eastern) end or Head of the Harbor and the middle of the harbor. The smallest cross-section (wetted perimeter) inside the harbor is between Pocomo Point and Bass Point.

The new soundings showed that the spits at the end of Five Finger and Bass Points have lengthened since 1938, particularly the one on Bass Point. The shoals off both these points have not altered significantly, but the shoal off Pocomo Point has broadened considerably. The narrow but rather deep channel along the southwest side of the Bass Point spit is apparently either a new feature or one that has been accentuated since Mr. Jones made his map.

Coast line changes. Plane table surveys were made along parts of the shore in the bays between Five Finger and Bass Points and between Bass and Wyer's Points. These show that in the crescentic bay facing the harbor between Five Finger and Bass Points the shore has been cut back northwestward about 80 feet since 1938. It is now only about 210 feet across Coatue Beach between the high tide line in this bay and the high tide line on the Nantuckt Sound side. This narrow neck of the Coatue Beach is made up of low beach ridges that parallel the outer shore. Most of the ridges rise 3 or 4 feet above high tide line, but two have crests of windblown sand and rise 6 and 7 feet respectively above the high tide line. The neck is covered by a sparse growth of beach grass, poison ivy, lichens, and a very few plants of vetch. It is clear that the neck is not commonly, if ever, washed over by storm waves. Winds have made many small blow outs along the old beach ridges, however, and particularly near the Sound shore. The northern side of the Bay between Bass and Wyer's Points has been cut back a similar amount since 1938.

Recently Mr. Bassett Jones suggested to us that the slow progressive subsidence of the Atlantic Coast reported by Marmer (Geographical Review, p. 652, October 1948) may account for the progressive erosion of the harbor side of Coatue that he has observed over the past 50 or more years. Marmer reports an average annual subsidence of 0.02 foot since 1930 along the Atlantic Coast. We interpret this, from other considerations, to be a eustatic rise of sea level rather than coastal subsidence. By either interpretation, however, the sea should theoretically have gained erosive power with respect to the shore. Whether the increase of erosive power gained by such a change in sea level is quantitatively adequate to account for the observed erosion of Coatue we do not know. Nevertheless, the trend is certainly worthy of further analysis and careful consideration in any long range plans for the utilization of Nantucket Harbor. Such a trend is likely to be significant in terms of changes in the configuration - or even the continued existence of Coatue Beach.

Tidal observations. In order to construct a model and in order to correct the soundings and evaluate a series of detailed current measurements made between Pocomo and Bass Points, a temporary tide gauge was established on the south shore of the Head of the Harbor. (See Fig. 1.) The gauge was made of 3-inch galvanized down-spout containing a metal float to which was soldered a vertical brass rod. The top of the rod was read against a scale fixed on the same upright as the pipe. The lower end of the gauge pipe was closed except for a hole about 1/8 inch in diameter to damp out the effect of the waves. The gauge was attached to the temporary pier owned by John Mendonca.

Only 8 complete tide ranges were observed, which is far too few to determine a reliable mean but must suffice for the present purposes. The readings given are from the arbitrarily set scale whose zero has not been related exactly to mean low tide. From these few observations the zero of the scale appears to be between 0.3 and 0.4 feet above mean low tide.

Date		Time	High	Low	Range
Aug.	6	14:20	3.99		
		20.40		0.12	3.87
	7	9:45		0.06	4.17
		15:05	4.23		
		21:25		0.25	3.98
	8	10:10		0.06	
		15:50	4.58		4.52
	9	11:05		0.16	
		16:50	4.20		4.04
	11	12:40		0.33	
		18:40	4.25		3.92
	13	8:20	3.51		2.56
		14:20		0.95	
		20:30	4.48		3.53
	21	14:35	3.11		
		20:50		0.56	2.55

Maximum range 4.52 feet
Minimum range 2.55 feet
Average range 3.68 feet

According to the Atlantic Ocean tide tables, Coast and Geodetic Survey, the mean range of tide at Nantucket is 3.0 feet and the spring range 3.6. Local residents report that at rare intervals (measured in years or tens of years) there are extreme low tides in the Head of the Harbor when the water level is about 2 feet below the lowest recorded above. No exceptionally high tides were noticed or reported. We infer from the variability of the tides observed in the Head of the Harbor that there may be in the harbor as a whole a complex regimen of tidal surges, perhaps modified by seiches.

On August 13 the tide gauge was read at 15 minute intervals from 8:30 A.M. to 10:00 P.M. and at 10 minute intervals during the turns. These observations are plotted in Fig. 4. On that day the second high observed is a foot higher than the first high.

Current observations and measurements. Observation of stick buoys and measurements of currents with a Price water meter were used to determine the characteristics of the tidal currents in the upper part of the harbor.

The stick buoys were hastily improvised and consisted of 1-inch round spruce poles 4 feet long weighted with a short length of pipe so they floated upright with 6 inches to a foot above water. That the wind affected those that stood high out of water is shown by the difference in the two long tracks shown in Figure 2. The one making the smaller loop in the Head of the Harbor projected about one foot above water and was clearly held back by the light easterly wind in its march up the harbor and aided by the wind on its travel back with the ebb tide. Vanes on the underwater weights would have been helpful.

Drift of the stick buoys shows a strong flood tide current along the southwest flank of Pocomo Head, over the shoals and well into the Head of the Harbor. This current turned back toward Bass Point well before the tide began to ebb. Slow reverse eddy currents appear in the bays of the Coatue Beach as might be inferred. They are much too weak, however, to serve by themselves as significant erosive agents for the medium to coarse grained sand that makes up Coatue. The flood tide current evidently splits in the northeastern part of the cove between Bass and Five Finger Points and the stronger current runs up into the Head of the Harbor. Observations of the ebb tide currents are inadequate to define the patterns. It is inferred that clockwise eddy currents run in the coves along Coatue and that a relatively weak northerly current flows along the southwest flank of Pocomo Point.

At times the stick buoys moved against a light wind at an average rate of nearly 1 foot per second.

Through the kindness of Mr. H. B. Kinnison of the Geological Survey's Boston office, Mr. C. E. Knox came to Nantucket and made a detailed series of current measurements with a Price current meter. We selected a line between the Pocomo Point spit and the Bass Point spit as it marks about the smallest cross-section through which the tidal currents run in and out of the Head of the Harbor. (See Figs. 1 and 3). At the stations indicated Mr. Knox measured current velocities at 0.2 and 0.8 depth and also took a series of readings from top to bottom so as to get velocities at 6 inch intervals. (See Figure 5.) The next day we occupied a position at, or close to, station 165 from 9 a.m. to 9 p.m. where Mr. Knox measured velocities at 0.2 and and 0.8 of the depth at 10 minute intervals and made detailed vertical profiles of the current velocities at half hour intervals.

Mr. Knox's computations of tidal current velocities and flow in and out of the Head of the Harbor are summarized graphically in Figures 4 and 5 and in the following tables. His discussion of the results were given me in a personal letter from which the following statements are quoted.

"The vertical velocity curves . . . indicate definite trends. The curves for 10:30 a.m. through 2 p.m. are on the ebb tide with the wind blowing against the current. Note that the general shape of each curve below 0.4 depth is about the same. Above 0.4 depth the curves are quite different. The 10:30, 11:00, and 11:30 curves show maximum velocity at 0.25 depth with velocities decreasing towards the surface. Velocities above 0.4 depth increase progressively by time until the top velocities are maximum.

"The 2:30 vertical velocity curve was taken at the change in tide. Flow at this time was parallel to the section. It is interesting to note that the shape is about the same as a combination of the 2 and 3 p.m. curves.

"The 3:00 p.m. to 8:00 p.m. curves are for the flood tide. The 3:30 is one that we plotted in the boat. I can't explain why the velocities should change so rapidly. The 6 p.m. curve is not similar to any other. The 0.1 velocities for the 7:30 and 8:00 p.m. curves seem high. With the exception of the above, in general the vertical velocity curves indicate that at the start of the flood tide the surface velocities are the highest and velocities decrease fairly constantly to the bottom. As the time progresses the bottom velocities increase until they are about equal to the velocities at the surface and the curve is practically a vertical straight line.

"The graph (Fig. 3) showing the horizontal distribution of the velocities shows that we were around the point of maximum velocity across the section. For this reason our observed velocities should be higher than the computed mean velocity for the section. However, due to the angularity of the velocity, the actual velocity at any point is higher than the mean velocity multiplied by the horizontal distribution factor.

"We measured velocities over two feet a second on August 12, 1948. These are actual velocities while velocities computed from the computed mean velocity would be lower due to the fact that the velocity computed would be the component normal to the section.

"The changing velocities from top to bottom and from side to side insure that the water is being mixed constantly. This fact alone could account for the fact that the salinity is practically the same throughout the harbor. In this connection, 198 million cubic feet of water moved past our measuring section from the head of the harbor during the ebb tide and 274 million cubic feet of water moved into the head of the harbor during the flood tide. With the low mean velocities present it is unlikely that any of the water that was in the head of the harbor reached the sound during the ebb tide. However, all water from the head of the harbor mixed with water from lower in the harbor and it is likely that little of the water that came from the head of the harbor on the ebb tide returned on the flood tide."

Winds and Erosion

Waves and currents produced by strong winds are probably much more effective in changing the configuration of the coast line than are the tidal currents. Obviously, however, where the two coincide the effects are enhanced. Nevertheless, to judge from the configuration of the harbor bottom, tidal currents are effective in sweeping channels out and maintaining them.

Probably also the tidal currents were responsible for determining the crescentic pattern of the harbor side of the ancestral Coatue Beach as William F. Jones pointed out in his report. Initially the south side of Coatue Beach was a smooth curve nearly concentric with the present Nantucket Sound shore of Coatue Beach. Also the south side of Coatue was at that time much closer to Pocomo Point and consequently much of the main tidal stream may have impinged on the Coatue Beach after being deflected northward by Pocomo Point.

Major Lieber, in the Shore Protection Board Report on Nantucket Harbor, Mass., June 7, 1939, prepared a diagram showing how dominant, year after year, are the prevailing southwest winds. But it is the sustained high winds of the big storms that are the most significant as erosive agents.

The distribution of these large storms by compass direction and intensity are plotted in Figure 6. The dominance of northeast storms is striking. Sustained strong winds from the southwest are next most numerous, though fewer of them rise to the high velocities of the northeast storms. Nantucket Harbor is oriented with its long axis northeast-southwest so it catches the full effect of the most numerous large storms. Waves driven before a northeast gale have crests that are essentially normal to the harbor axis. According to the general principle of the refraction of waves they tend to curve in and parallel the shore as they break. If the angle of refraction is large this results in the waves striking a curving beach with a "wiping" action. (See Figure 7). This is very effective in translating sand along a beach for each wave throws sand into suspension and then the swash of the wave moves the suspended, and rolled, material up the beach at an angle to the slope of the beach and in the general direction of the forward-moving wave crests. The returning swash carries the material still farther in the same direction. Long shore currents driven by the wind aid the translation of the material. Where supplemented by tidal currents they are, of course, that much more effective. Sand thus eroded from the crescentic beaches moves outward along the spits and comes to rest near the outer ends adding to their length. It appears that this general process is gradually deepening the arcuate bays along the southeast side of Coatue Beach. All strong winds except those blowing generally southeastward would contribute to this pattern of erosion. It should be emphasized, however, that for most of the time these crescentic beaches are essentially in a state of equilibrium as storms of opposing directions alternately move sand along the curving beach in opposite directions.

Sand spits in Nantucket Harbor, particularly those off Five Finger, Pocomo, and Bass Points, are continually shifting a few feet, or perhaps tens of feet, up harbor or down harbor with each persistent strong wind that blows approximately along the axis of the harbor.

Chemical and Biological Considerations

One part of the problem was to determine if possible whether there is a significant exchange of water in the large basin known locally as the Head of the Harbor and the water in the middle and lower parts of the harbor. It is fairly evident that the water in the lower and middle harbor is continually, or periodically, refreshed by exchange with water from Nantucket Sound.

If the water in the Head of the Harbor is stagnant, or even partially stagnant, as has frequently been claimed, and if it stagnates long enough to be harmful to scallops, the chemical and thermal characteristics of the water there should differ appreciably from the water entering the harbor from Nantucket Sound. For example, water trapped there during the summer when evaporation rates are high should become more saline. Water samples were accordingly taken from near the surface of the center of the Head of the Harbor and from a corresponding shallow depth off Brant Point on a flood tide. The salinities of these two samples were kindly determined for me by the staff at the Woods Hole Oceanographic Institution and found to be virtually identical.

	Brant Point	Head of the Harbor
Salinity	31.22	31.29

These two determinations of salinity are too few to be definitive. Salinity determinations of both the surface and deep water at 10 or more stations in the head of the harbor would be needed to determine possible increases in salinity due to evaporation. It may well be, for example, that in the fairly sheltered bay near Coskata surface water becomes more saline and therefore more dense and sinks down into the deep holes in the bottom of the Head of the Harbor. (See discussion of vertical water temperature profiles on the following pages).

Water that stagnates enough to be harmful to scallops would probably have a dissolved oxygen content of the order of 50% of the saturation value (oral communication Dr. John Ayers, Woods Hole Oceanographic Institution). Accordingly, three water samples were taken from the deep basin near the center of the Head of the Harbor. Two of these were taken from 2 feet above the bottom and the other, at the same station, from about 12 feet above the bottom. At this station the water at that stage of the tide was 25 feet deep. As soon as taken reagents were added to fix the dissolved oxygen. They were taken to Woods Hole where Dr. W. T. Edmondson of Harvard and the Woods Hole Oceanographic Institution titrated the samples with the following results:

Sample	Oxygen Content milligrams/liter	Assumed Temp.	Assumed Salinity
A - 2 ft. above bottom	13.1	20° C. (68° F.)	30.1
B - 2 feet above bottom	11.1		
C - 12 ft. above bottom	14.2		

At the same temperature and salinity the saturation value is 7.9 milligrams/liter. Obviously they are much over saturated. Dr. Edmondson examined some of the water taken at the same station and found that it contained a very large content of living microscopic organisms; mostly diatoms. These would account for the abnormally high oxygen content of the water.

Vertical temperature profiles of the water off Coatue Point, Second Point, and in the center of the Head of the Harbor were measured with a bathythermograph, which was loaned by the Woods Hole Oceanographic Institution. The temperature profiles were measured to determine if the water were thermally uniform and therefore frequently and thoroughly mixed by tidal and wind-driven currents. Bodies of colder, and therefore denser, water accumulate in the deeper parts of some basins where circulation is feeble. The following temperature profiles indicate that the water off Coatue and Second Points is thermally almost homogeneous and therefore continuously and effectively circulated and oxygenated. On the contrary the water in at least a part of the center of the Head of the Harbor is thermally stratified.

Temperature profiles of water in Nantucket Harbor

Readings taken from bathythermograph records made August 21, 1948.

Off Coatue Point

Depth in feet below surface	Temperature (F°)
2-8	73.2°
8-10	73.1°
10-21	73.0°

Off Second Point

1.5	72.8 (Linear; surface to bottom)
17.0	72.9

Head of the Harbor in elongate hole 22+ feet deep between Wyer's Point and Wauwinit (3 samples)

	Depth	Temperature
A	2-10	75.2
	10-14	75.1
	16	75.0
	18	74.7
	19	74.5
	20	74.3
	22	74.0
	23	74.0
B	2-14	75.2
	16	75.1
	18	74.8
	20	74.5
	22	74.3
	23	74.2
C	2-6	75.1
	8	75.1
	10-14	75.2
	16	75.1
	18	74.8
	20	74.5
	21	74.1
	22	74.1
	23	74.0

A layer of water about 6 feet thick at the bottom of the elongate depression 22+ feet deep between Wyer's Point and Wauwinit is significantly cooler than the water above, which is thermally homogeneous. Such bottom layers of cooler, denser water may become quite stable and persist for weeks, months, or even years, as in certain Norwegian fjords. If they persist they gradually become depleted of oxygen by respiration of bottom-dwelling organisms and by decay of organic matter on and in, the bottom sediments. When such layers or bodies of water become wholly depleted of dissolved oxygen they become toxic to all organisms except anaerobic bacteria. The bottoms below such water bodies become veritable deserts upon which no shell fish or water plants can live.

Unfortunately these temperature measurements were made late in the investigation. Consequently the presence and extent of this cooler water body were not verified by determinations of the salinity. It is possible that the salinity is greater than that of the surface water. If so the stagnant body of water would be even more dense than its coolness alone would determine. Clearly also the more dense the water the more persistent the stagnation. It is certain, however, that if the observed stratification is due solely to temperature difference it will not persist through a winter because the bottom water at about 74°F would be distinctly less dense than the overlying body of water, which surely cools well below 74° during the winter. Only a considerably higher salinity, therefore, could continue to hold water of temperature 74° at the bottom throughout a winter.

The determination of excessive amounts of dissolved oxygen in two water samples taken from 2 feet above the bottom of this same depression in the Head of the Harbor suggests that the cooler layer of water is only a transient feature. Indeed, this cooler water may simply be part of the tongue of cooler (ca 73° F) Nantucket Sound water which the tide projects past Second and Third Points and into the Head of the Harbor - water which, by reason of its coolness and greater density, spreads out under the relatively warm (75°F) and therefore less dense surface water in the Head of the Harbor. Waters of that general temperature show a perceptible tendency not to mix if their temperatures differ by even a few degrees. Additional determinations of temperature, oxygen content, and salinity of this deeper water should be made at intervals of a week or two through the su summer months in order to determine how persistent a feature the stratification is. If it is a transient feature it may be disregarded as far as the scallop yield is concerned.

Eel grass, which may have a bearing on the scallop and other fisheries of the Harbor is coming back again after virtually complete disappearance for more than a decade In the lower part of the Harbor, near the town of Nantucket and around the jetties it is becoming fairly abundant. (In the vicinity of Madaket at the southwestern end of Nantucket Island eel grass is now so abundant that it is becoming something of a nuisance.) In the middle part of the Harbor it is plentiful enough so that moderate storms wash up windrows of it on Pocomo Point. In the Head of the Harbor small patches of eel grass have established themselves but local residents say that the patches seem not be be spreading as is the habit of the plant where it is healthy and prosperous.

Model of Nantucket Harbor

The observations recorded above and the evident complexity of the tidal circulation in the Harbor led to the decision to construct a small model. Through the kindness of Mr. C. O'D. Iselin, Director of the Woods Hole Oceanographic Institution this was undertaken at the Institution under the guidance of Mr. Wm.

Von Arx. Joshua I. Tracey, geologist of the U. S. Geological Survey made the model and ran the experiments in collaboration with Mr. Von Arx. The data shown on Fig. 1 of this report provided the basis for the model, which was routed out of plywood. The wood surface was coated and smoothed with putty and painted. The tidal surges were made by a relatively large, partly submerged block that rose and fell through the action of an eccentric operated by a small synchronous motor.

The horizontal scale is 1 inch equals 1,000 feet (1:12,000) and the vertical scale 1 inch equals 48 feet. (1:576). The tidal motion (i.e. rise and fall of water surface) of 1/16 inch in the model corresponds to a 3 foot tide.

Theoretically on a distorted model, velocities should be in the ratio of the square root of the vertical scale and time should be proportional to the linear horizontal scale divided by the root of the vertical scale. On this model the theoretical time scale is 1/500, the velocity scale is 1/24. Actually the telechron motor revolving once a minute represents a tidal cycle of 12 hours. This gives a time scale of 1/720 which results in a velocity scale of about 1/17. Five seconds in the model represents 1 hour in the harbor; one second corresponds to 12 minutes. Therefore a current moving 1 inch in 1 second corresponds to a current in the harbor moving 1000 feet in 12 minutes; six inches in five seconds represents a current of one knot.

It should be noted that both time and velocity scales used differ considerably from the theoretical. The scales used, however, gave current patterns throughout the tidal cycle that corresponded rather closely to those in the harbor wherever we were able to observe them. Moreover, velocities measured in the model approximated velocities measured in one part of the harbor. Therefore, if a cut is made at the Chatham Bend we expect that the pattern of currents in the Harbor to be approximately the same as that already observed in the model.

Patterns of currents in the model (Figs. 8 and 9) correspond rather closely to observations on the harbor itself although exact paths of floats are not reproducible. This is so for two reasons; first, in the harbor a series of identical stick buoys released at the same time would trace out a gradually widening path whereas one stick buoy will trace a single path somewhere within this pattern; and second, in the model exact duplication of velocities, or magnitudes of forces are not reproducible. Furthermore, we were not able to reproduce wind conditions satisfactorily, and they had an important effect on the buoys.

The current pattern of the harbor model followed almost exactly that expected from position and curvature of bars seen in the airphotos taken in 1938. This is especially true in the channel and bars between Pocomo and Bass Points. The main current follows the channel up to Pocomo Point on the flood tide, and near high tide a tongue of this current goes into the Head of the Harbor. Currents along the shores are in the same direction as the main current as it develops; as it reaches a maximum at mid-tide, countercurrents develop along concave beaches and points. Because of the eddy developed in the Head of the Harbor the high water starts receding over Bass Point bar while the main tongue of water is still pouring into the bay. (see Figs. 2 and 8). On the outgoing tide the main current again sets up shore counter-currents as it increases. The eddy developed off the town of Nantucket is interesting as it is always in the same clockwise direction. On flood tide it is a counter-current centered in the deep part of the pool. On the ebb tide the main current splits over Hussey shoal, and the southern stream forms the eddy, now centered over the shoal.

The model suggests the following pattern of water circulation for the Head of the Harbor:

1st flood tide: A tongue of Nantucket Sound water runs through the harbor channel, floods the middle Harbor, and extends across Bass Point bar into the Head of the Harbor.

1st ebb tide: This tongue completely withdraws from the Head of the Harbor, but an appreciable amount of it remains in the middle Harbor. Relatively old (several to many (?) tidal cycles) water from Head of the Harbor follows out through the channel to Harbor mouth.

2nd flood tide: Tongue from deep pool in the middle Harbor crosses Bass Point bar into the Head of the Harbor. Old water now at Harbor mouth returns nearly to middle of Harbor (i.e. between Third and Five Finger Points.)

2nd ebb tide: Part of the tongue of Nantucket Sound water remains in Head of the Harbor; an appreciable amount of the old water now in the middle Harbor passes out through the Harbor or ship channel.

These conclusions result from a composite of two experiments - one putting dye in at the Harbor entrance - the Nantucket Sound water - and observing it through several cycles, the other putting dye in the Head of the Harbor, "old" water, and tracing its course through several cycles. A definite, though small, exchange of water in the Head of the Harbor with that entering the ship channel is indicated. Velocities measured to scale in the model represent, but do not faithfully duplicate, the following velocities in the prototype:

1) Channel between Pocomo and Bass Points.
   Flood tide, average 1.37 ft./sec. for 5 tides.
   Ebb tide, average 0.81 ft./sec. for 4 tides.

These velocities correspond roughly to the average velocities measured in the prototype with a Price current meter.

Ship channel: flood tide, 1.58 ft. sec. for 5/ tides.
ebb tide, 1.4 ft./sec. for 7 tides.

No velocities were measured in the ship channel but we estimate that the velocities observed in the model are appreciably lower than the actual tidal currents in the ship channel.

Observations of the model through several tidal cycles after a cut equivalent to 300 feet wide and 6 feet deep had been made through Coatue Beach (See Figs. 10 and 11) at the Chatham Bend (between Bass and Wyer's Points) led to the following generalizations:

1) The velocities of currents in the Nantucket ship channel at the Harbor entrances are appreciably decreased on both flood and ebb tides.

2) Currents having velocities apparently greater than those that now prevail in the ship channel flowed through the Chatham Bend opening on both flood and ebb tides.

3) A large stream of Nantucket Sound water flows across the Head of the Harbor and **impinges** on the shore at Pocomo settlement, the site of the temporary tide gauge.

4) Vigorous circulation was established in the greater part of the Head of the Harbor.

5) On flood tides eddies develop in the Head of the Harbor on either side of the cut. Experimental jetties on each (Harbor) side of the cut eliminated these eddies.

6) Exchange of water between the Head of the Harbor and the middle Harbor was markedly diminished.

It is worthy of note that the model study reveals that before the cut was made in Coatue Beach the tidal circulation of water was slow or absent in the northeastern part of the Head of the Harbor near Coskata, and in the southeastern part of the Head of the Harbor near Wauwinit. It is perhaps significant that in those areas the scallops have larger shells than in the rest of the whole harbor but the "eyes" (adductor muscles) are smaller than the average harbor scallop. This is the observation of Mr. Clinton Andrews, a fisherman of Nantucket, whose powers of observation and keen intellectual interest we have good reason to respect. When the cut through Coatue Beach was made the water in the Coskata area circulated only feebly but near Wauwinit it was increased but not vigorous. Mr. Andrews' brother George, who has dredged for scallops in Nantucket Harbor for the past 15 years reports that the best scallops come from the Head of the Harbor in the general vicinity of Wyer's Point where the bottom is "hard" (i.e. clayey and firm). Surprisingly enough, the tidal circulation in that area is apparently not much more vigorous than it is near Coskata.

The apparent high velocities through the artificial cut suggests that scour would soon enlarge the channel very appreciably. According to the thorough studies of Coatue Beach made by the late William F. Jones a bed of tough clay underlies that part of Coatue Beach at a depth of about 6 or 8 feet below mean low water. That tough clay with its associated layers of iron oxide cemented sand and cobbles should provide an effective curb against deep scour.

Before the cut was made it was impossible to determine from the model the time relationships of the high and low tides in the Head of the Harbor with respect to those at the harbor entrance at Nantucket. With the artificial cut open, however, the change of tide was 5 seconds (corresponding to 1 hour in the prototype) earlier at the cut than at the harbor entrance at high tide and 2 to 3 seconds (corresponding approximately to ½ hour in the prototype) earlier at low tide.

When a putty dam was made from Pocomo Point to Bass Point the change of tide, at flood, was 6 seconds later at the Chatham Bend cut and 4 seconds later at the ebb tide. This suggests that a small channel (e.g. 300 feet wide and 6 feet deep) probably would be subject to even greater scour in the unlikely event that the area between Pocomo, Five Finger, and Bass Points should silt up so as to prevent exchange of an appreciable volume of water between the Head of the Harbor and the middle part of the harbor.

Figure 2

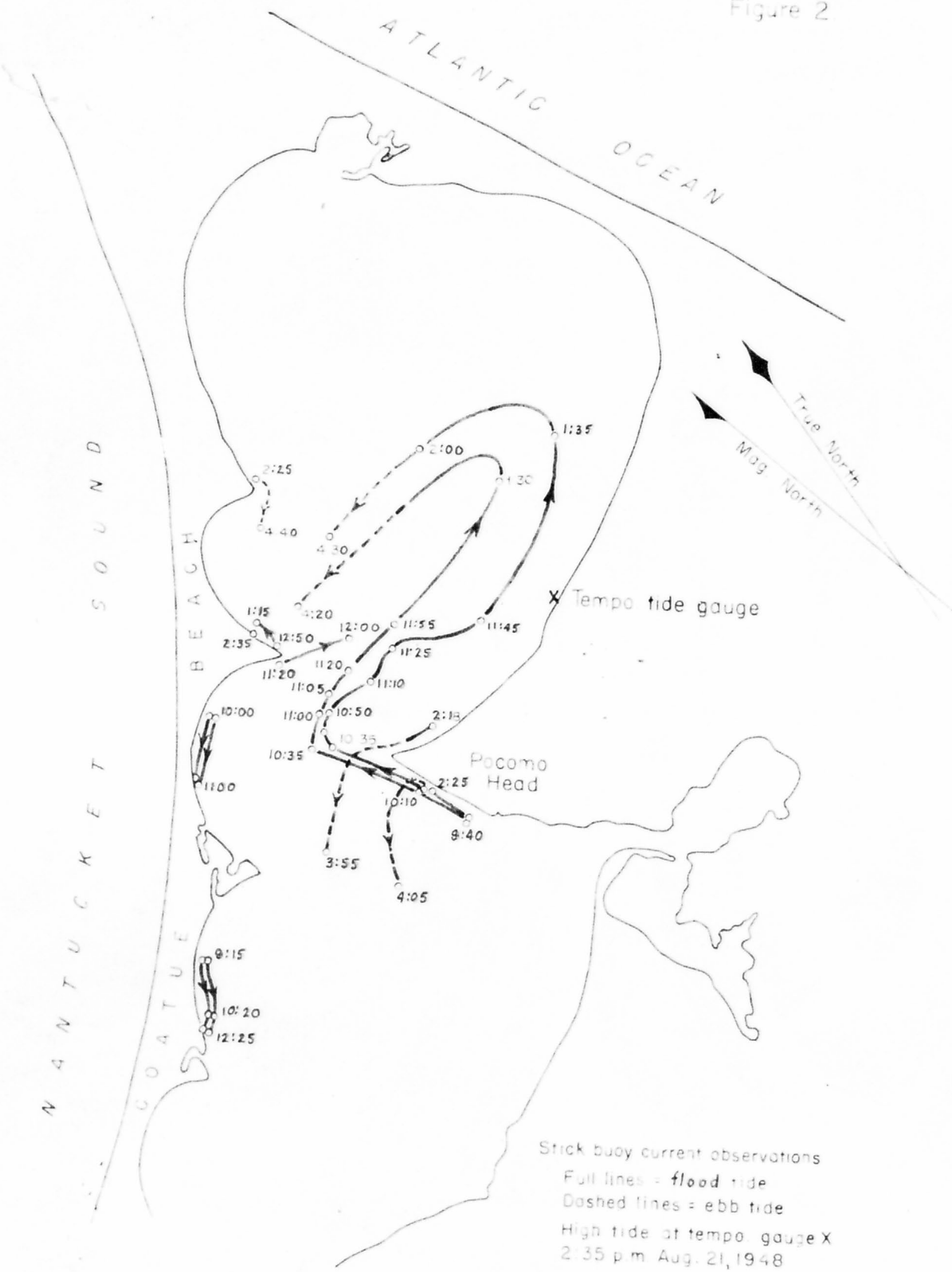
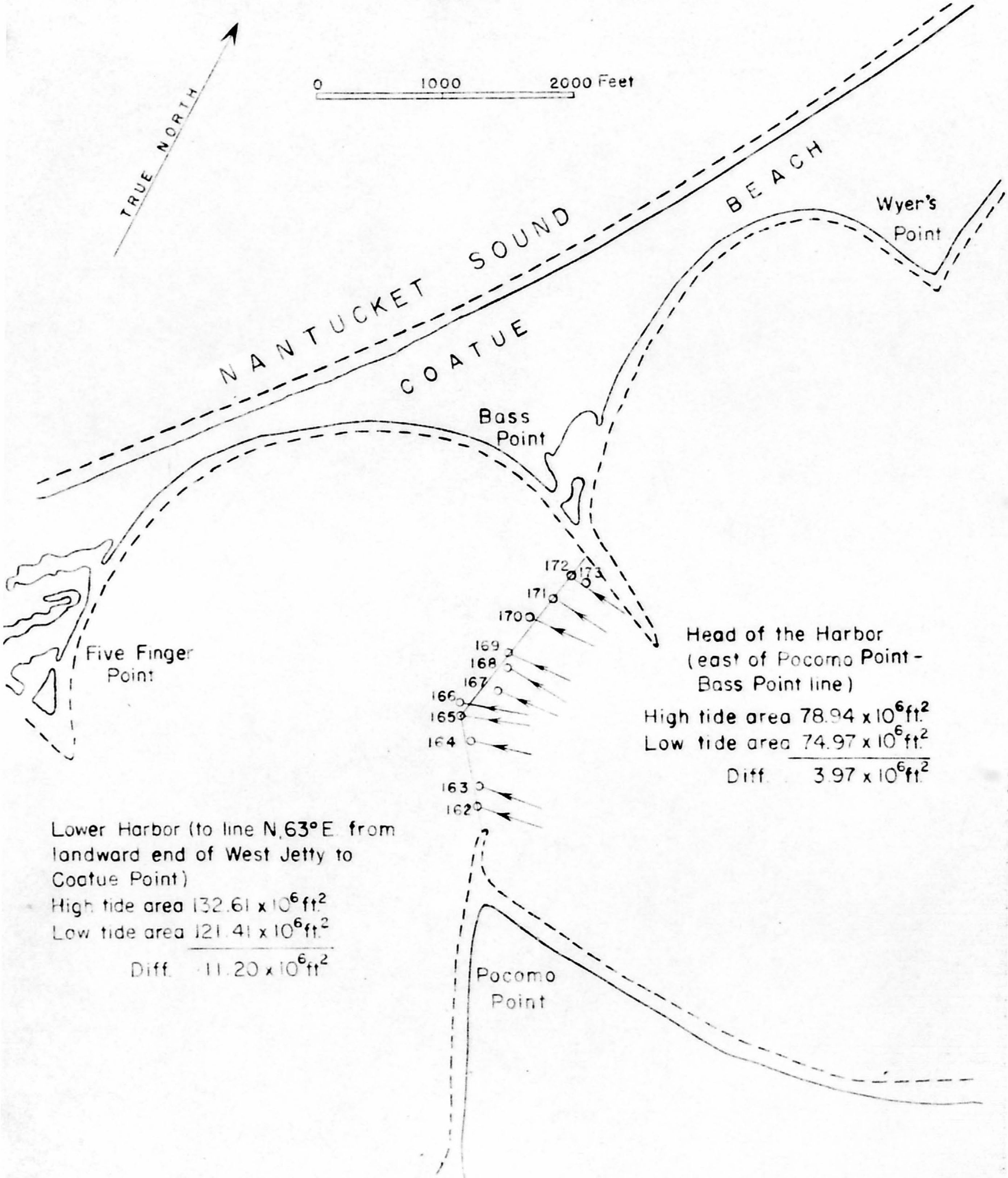
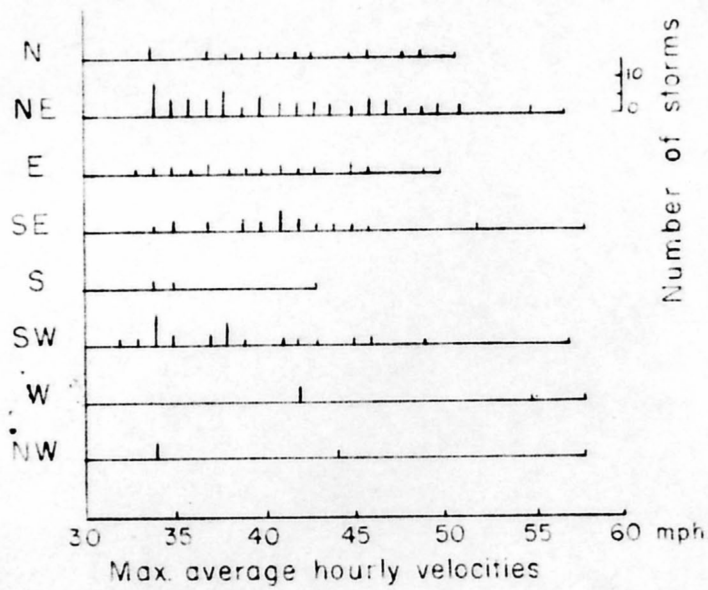

ATLANTIC OCEAN
NANTUCKET SOUND
BEACH
COATUE
True North
Mag. North
Tempo tide gauge
Pocomo Head
1:35
2:00
1:30
2:25
4:40
4:30
4:20
1:15
2:35
12:50
12:00
11:55
11:45
11:20
11:25
11:20
11:10
11:05
11:00
10:50
10:00
2:18
10:35
10:35
11:00
2:25
10:10
9:40
3:55
4:05
9:15
10:20
12:25
Stick buoy current observations
Full lines = flood tide
Dashed lines = ebb tide
High tide at tempo. gauge X
2:35 p.m. Aug. 21, 1948

Figure 3.



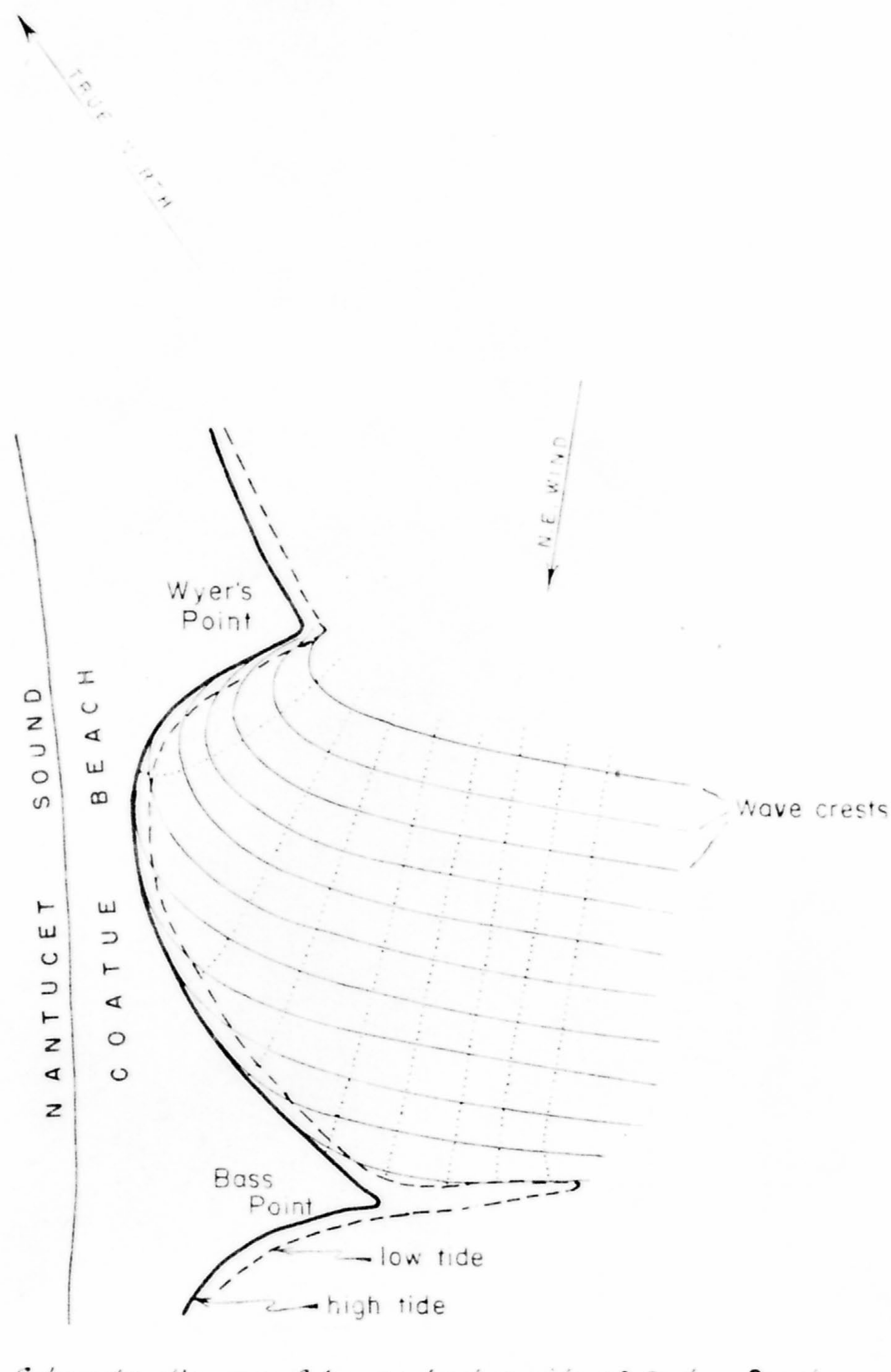
Area of Pocomo and Bass Points, Upper Nantucket Harbor showing line of stations at which current velocities were measured. Arrows indicate direction of flow during ebb tide.

Figure 6.



Wind velocities in storms whose maximum average hourly velocities exceed 30 miles per hour at Nantucket, Mass., 1936 to June 1948 incl. Data by U.S. Weather Bur.

Figure 7



Schematic diagram of bay on harbor side of Coatue Beach showing the inferred refraction pattern of waves driven by a N. E. wind. Dotted lines normal to the wave crests are orthaganals. The wider the spacing of the orthaganals the less the wave energy at the beach.

Fig. 8

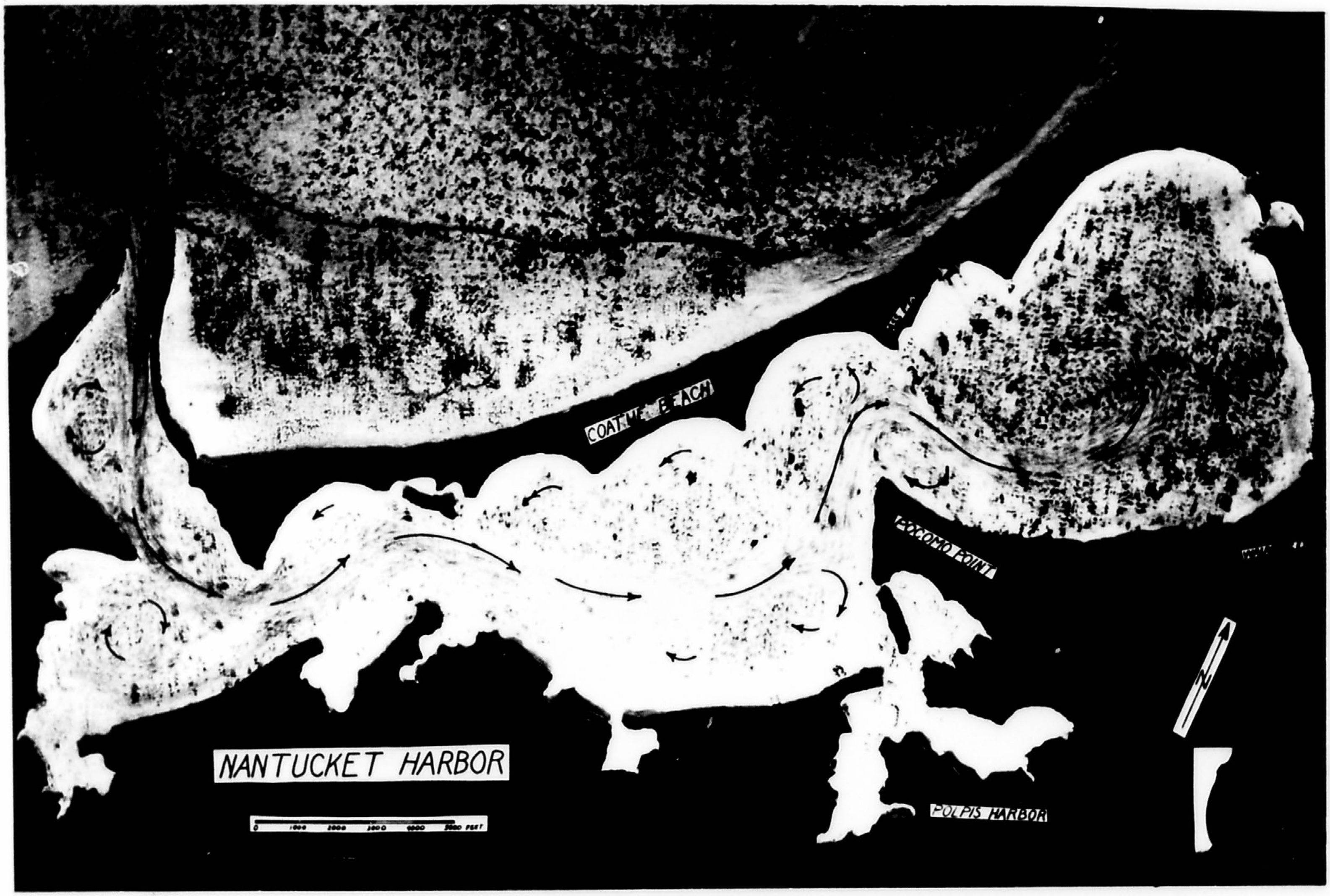


Figure 8

Photograph of model of Nantucket Harbor showing the circulation pattern induced by the flood tide.

Fig. 9

Figure 9

Photograph of model of Nantucket Harbor showing the circulation pattern induced by the ebb tide.

Fig. 10

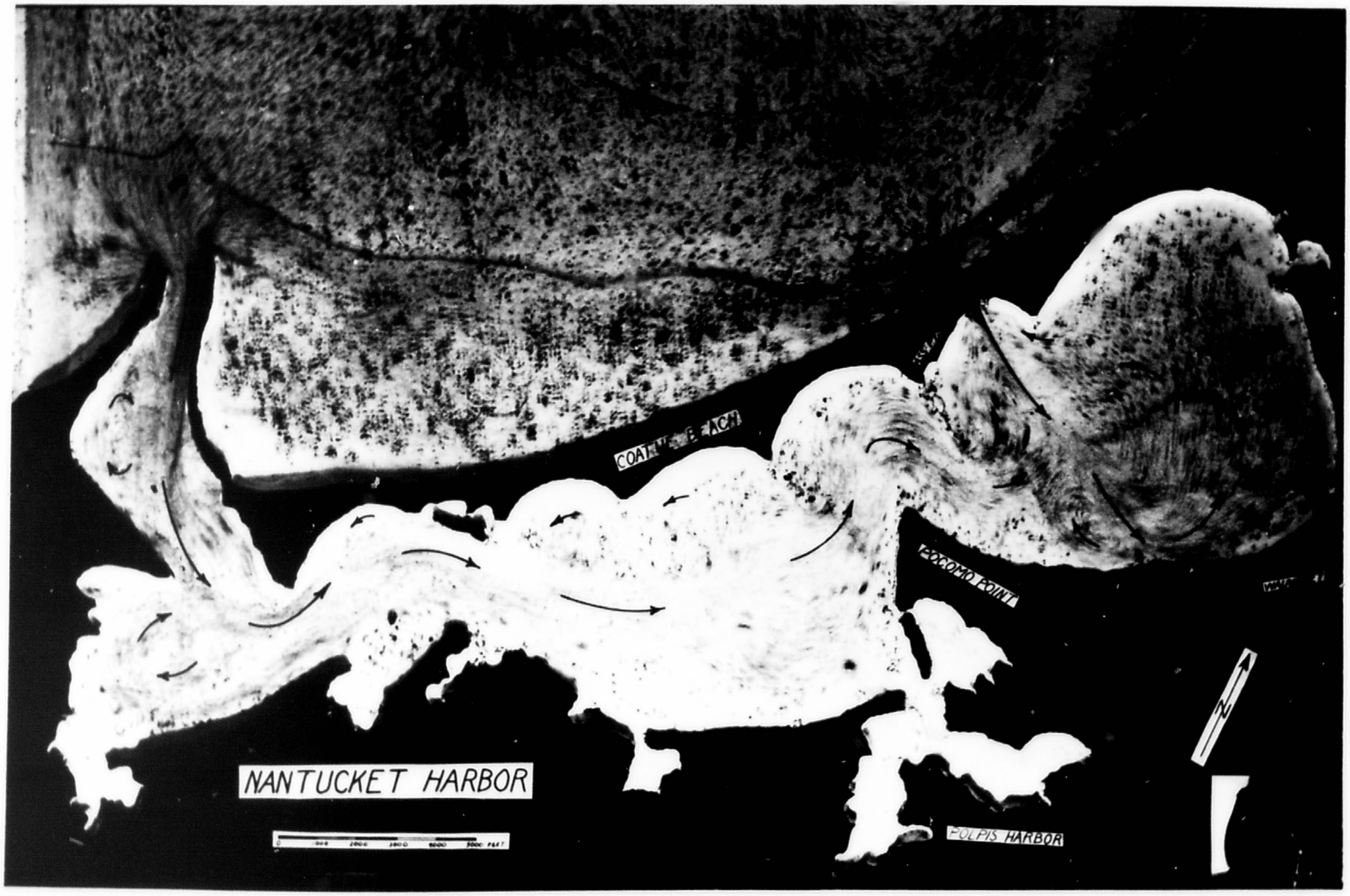


Figure 10

Photograph of model of Nantucket Harbor showing the circulation pattern induced by flood tide entering through the Nantucket ship channel and also through a cut across Coatue Beach into the Head of the Harbor.

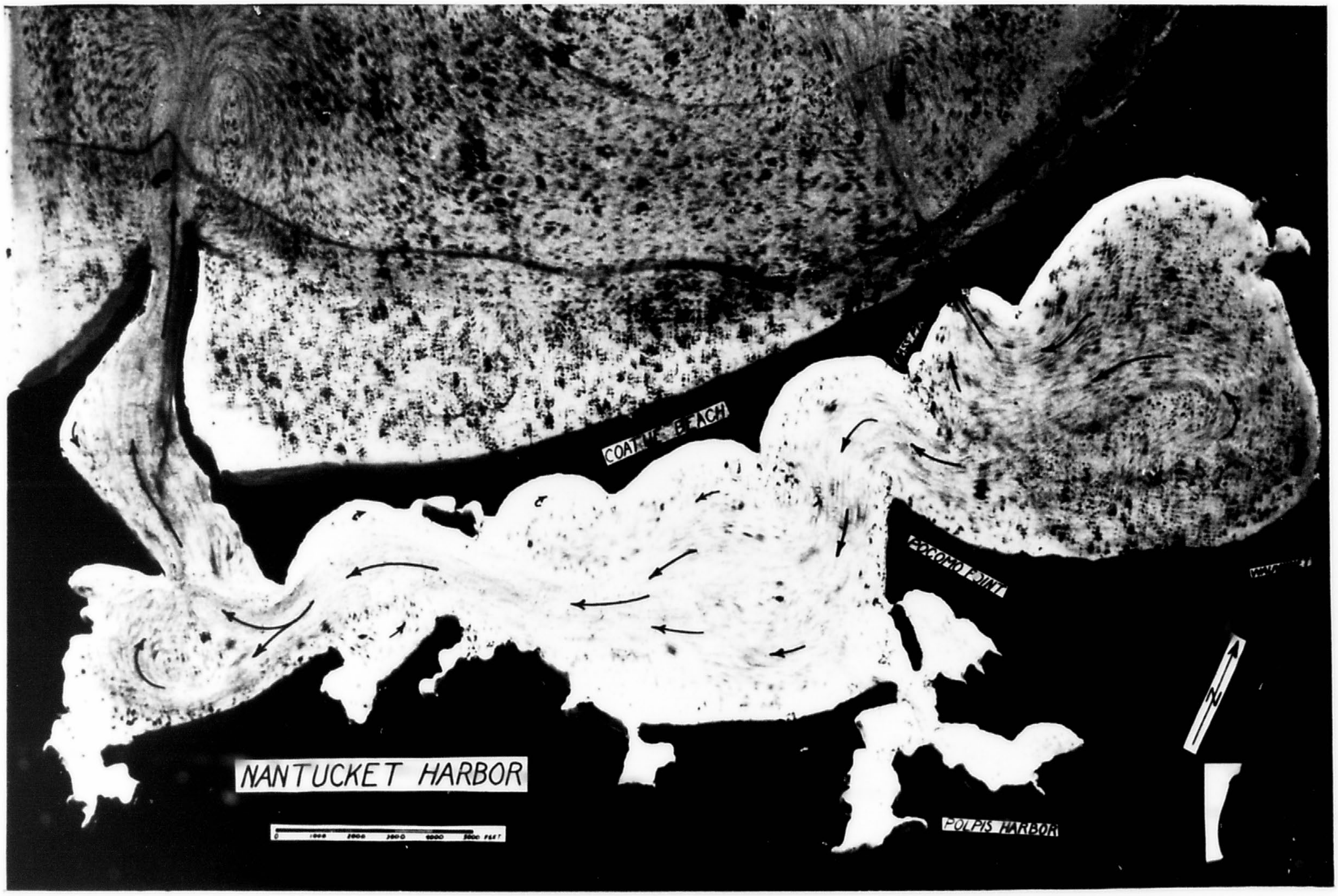


Figure 11

Photograph of model of Nantucket Harbor showing the circulation pattern induced by ebb tide entering through the Nantucket ship channel and also through a cut across Coatue Beach into the Head of the Harbor.