AN ASSESSMENT OF THE WATER QUALITY CHARACTERISTICS OF GREAT SOUTH BAY AND CONTIGUOUS STREAMS

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Introduction

Numerous problems arise in the utilization of estuarine areas. Most noticable are those related to pollution, but many others related to shellfish culture, sport fishing, recreation, and urban development are also involved. The Great South Bay system is presently experiencing the effect of all of these diverse forces and the question of its survival in its present state hinges on the intelligent planning used to reconcile such varied uses. Decision making requires a knowledge of alternative actions and the consequences of these alternatives. It follows therefore, that some baseline or norm must be available against which comparisons may be made.

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With recent completion of the Nassau-Suffolk Bi-County Master Plan and the increased awareness of the water supply needs of Suffolk County as outlined in the Holzmacher reports (Holzmacher, McLendon and Murrell), there are increased requirements for a more detailed understanding of the general impact of proposed development on the water quality of the bay systems of Long Island. Before the consequences of decreased ground-water levels, point-source outfalls, or single point recharge can be evaluated, the characteristics of the receiving body of water must

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be known. At present most proposals either deal with discharge via streams or outfalls or attempts at single point recharge. These actions immediately raise questions as to effects on the salinity of the receiving body (increases due to stream elimination or decreases due to increased freshwater input from large outfalls) and changes in nutrient levels (increases at point sources from outfalls or decreases due to elimination of surface water runoff.

There are few studies available on the water quality of Great South Bay and adjacent waters. Several were completed more than fifteen years ago by the Woods Hole Oceanographic Institution (WHOI)(Redfield,1950,1952; Bumpus, et al,1954; Ryther et al, 1956,1957,1958; Guillard, et al, 1960) and even these were limited by the length of time samplings were carried out. Several other agencies have or are presently monitoring various parameters(Foehrenbach, 1968; Koetzner,1966; Ryther,1954; Wilson and Brenowitz, 1966). However, these are restricted to specific goals such as shellfish analyses, coliform counts, hydraulics, or small geographical areas. With the exception of a three year sampling program initiated by the Adelphi University Institute of Marine Science(AIMS) in 1968, there are no long-term, bay-wide studies available on Great South Bay.

A general literature review of the existing data base related to the physical and chemical characteristics of Long Island waters has been completed by the Center for Environment and Man (Cheney, P.B., 1970) and the New York Ocean Science Laboratory (Anon.,1971). In general these reports indicate a general paucity of information on the physical and chemical properties of the south shore bay waters.

Several investigations have shown that nitrogen is the main limiting factor in the growth of excessive plant material in Long Island waters and the adjacent continental shelf (Ryther et al, 1958; Ryther & Dunstan,1971). The nitrogen/phosphorus (N/P) ratios are especially important in characterizing the potential for eutrophication in these cases. Ryther et al(1958) pointed out that dissolved inorganic phosphorus (DIP) could also be used as an index of pollution by duck farms and other sources.

It is recognized that, in addition to spatial variations in these parameters, significant seasonal fluctuations also exist, necessitating long-term studies to provide valid baseline data. This author (Hair, 1968,1970) has shown pronounced seasonal variations in dissolved and particulate nutrients in Goose Creek, Long Island and dramatic long-term changes in these nutrients in Great South Bay and Moriches Bay. If the fact of seasonal fluctuations further modified by long-term variations, is realized, then the requirement for periodic updating of baseline data must be accepted. Without periodic monitoring on a bay-wide basis, questions as to water quality standards, effluent standards, and sources of potential eutrophication cannot be answered.

A complete study of all sources of nutrient additions and their effects on the receiving body of water would require prodigious sums of money and untold man-hours of effort. While this may be ideal, much can be gained by selective monitoring of fewer, more important parameters. The present study was designed to determine on a first-cut basis, the general concentrations and distribution of essential plant nutrients in the bays and those areas which may act as sources of possible eutrophication. It is not intended to be the definitive work on the nutrient chemistry of Great South Bay but rather to point the way for future intensive investigations.

AREA OF STUDY

Great South Bay and Moriches Bay are located along the south shore of Long Island and separated from the Atlantic Ocean by the Fire Island Barrier Beach (Fig. 1). Great South Bay is approximately 47 miles in length (92 square miles) while Moriches Bay is 10 miles long (15 square miles). There are approximately 36 creeks flowing into the two bays, the largest being the Carll's and Connetquot Rivers in Great South Bay and the Forge and Terrell Rivers in Moriches Bay (see Table 1 for a list of gaged streams and approximate rates of flow). Although not measured directly, Pluhowski and Kantrowitz (1964) have estimated that 25-30 percent of total stream flow reaches the bay as horizontal subsurface flow.

There are only two direct openings to the ocean - Fire Island Inlet in Great South Bay and Moriches Inlet in Moriches Bay. A single restricted channel connects the eastern end of Great South Bay with western Moriches Bay.

The average depth of the bays is approximately 1.3 meters except in areas of dredged channels. Tidal changes vary from one meter at Fire Island Inlet to less than 0.2 meters at the Connetquot River. There are extensive eel grass (<u>Zostera</u> <u>marina</u>) beds throughout both systems.

METHODS

Based on previous work (Hair,1970), a network of 39 stations was established. Many of these stations duplicated earlier sites set up by WHOI. A complete list of all stations with their locations is given in Table 2 and shown in Figure 1. Of the 39 stations, 25 can be

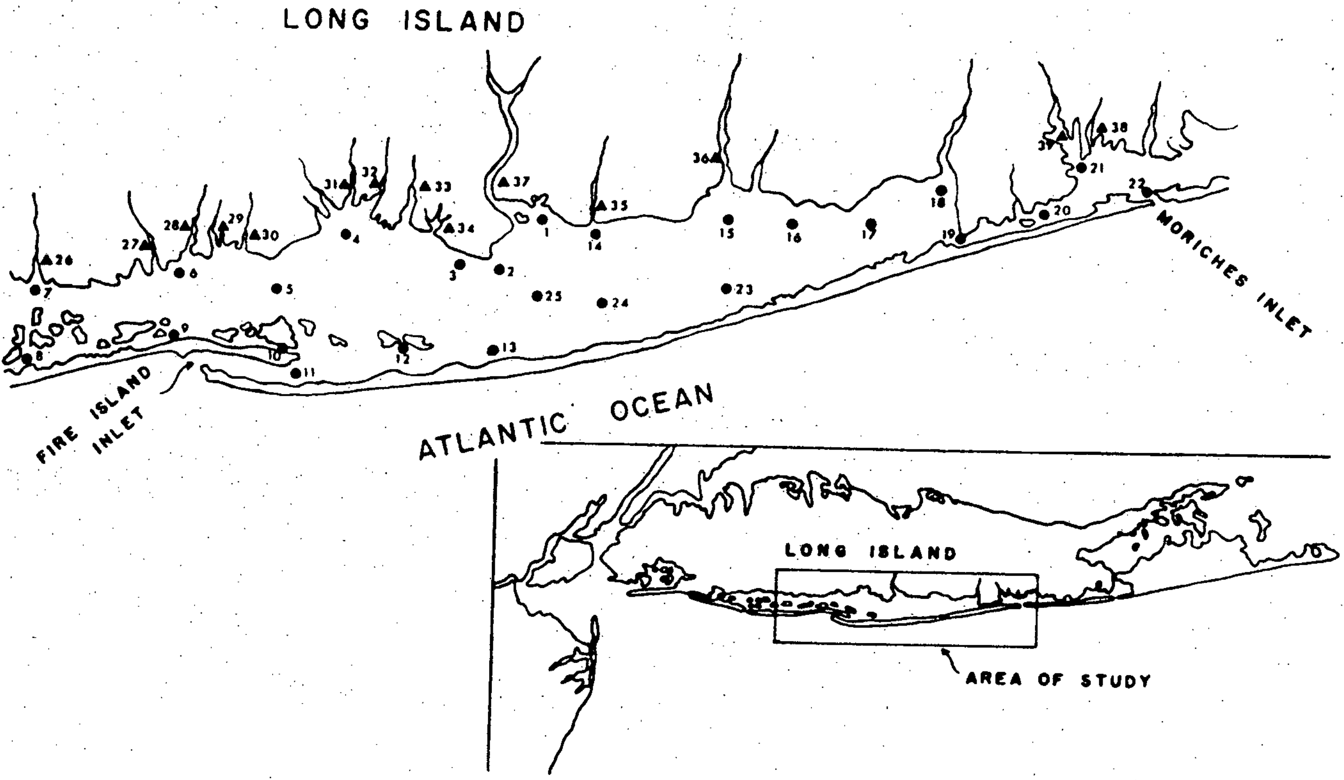

Fig. 1: General location of Great South Bay showing sampling station. Circles = bay stations; triangles = river stations.

Table 1

	Mean Annual Discharge (cfs)
Carman Creek, Amityville	4.3
Woods Creek, Amityville	0.5
Amityville Creek, Amityville	3.6
Great Neck Creek, Copiaque	2.4
Strong Creek, Lindenhurst	1.7
Neguntatoque Creek, Lindenhurst	3.7
*Santapoque River, Lindenhurst	9.5
W. Babylon Creek, Babylon	0.7
*Carlls River, Babylon	36.0
*Sampawams Creek, Babylon	12.5
Skookwams Creek, Babylon	1.1
Willetts Creek, W. Islip	2.6
*Penataquit Creek, Bayshore	6.2
Trues Creek, W. Islip	1.9
Thompsons Creek, Brightwaters	0.7
Cascade Lake Outlet, Brightwaters	2.5
Lawrence Creek, Brightwaters	0.7
Awixa Creek, Islip	2.1
W. Branch Orowoc Creek, Islip	5.9
E. Branch Orowoc Creek, Islip	2.7
*Champlin Creek, Islip	10.3
West Brook, Great River	4.5
*Connetquot River, Oakdale	40.2
Rattlesnake Brook, Oakdale	10.0
Greene Creek, W. Sayville	4.5
W. Branch Brown Creek, Sayville	5.1
E. Branch Brown Creek, Sayville	3.0
*Tuthills Creek, Patchogue	6.0
*Patchogue River, Patchogue	21.2
*Swan River, Patchogue	13.0
*Carmens River, Bellport	24.2

Table 2

List of stations and locations

Station No.	Location
1	Great South Bay Connetquot River at Timber Island
2	Great South Bay Nicoll Point Bouy N5
3	Great South Bay Hecksher Park bouy C3
4	Great Cove Bayshore NYSDEC clam bouys
5	Great South Bay Captree Bridge in main channel
6	Great South Bay Santapoque Point at Fl G bouy
7	Great South Bay Amityville Creek at Fl G bouy
8	Intercoastal waterway at Gilgo Island
9	Intercoastal waterway at Cedar Island
10	Intercoastal waterway at Captree Island
11	Fire Island Inlet at bouy N20
12	Great South Bay West Fire Island at bouy N6
13	Great South Bay Point O' Woods at bouy C15
14	Great South Bay off Brown Point at bouy C1
15	Great South Bay off Patchogue River at bouy N2
16	Great South Bay off Bellport at bouy C33
17	Great South Bay off Bellport at bouy N2
18	Great South Bay Carmens River at bouy C1
19	Smith Point Bridge at bouy C13
20	Narrow Bay at bouy C21
21	Moriches Bay Forge River at bouy C1
22	Moriches Bay at bouy R6
23	Great South Bay at Watch Hill bouy C1
24	Great South Bay at Barrett Beach C1
25	Great South Bay East Channel at bouy N22
26	Amityville Creek
27	Santapoque River
28	Carll River
29	Sampawams Creek
30	Willet Creek
31	Awixa Creek
32	Orowoc Creek
33	Champlin Creek
34	Quintuck Creek
35	Brown Creek
36	Patchogue River
37	Connetquot River
38	Senix Creek
39	Forge River

considered open bay stations while the remainder characterize tributory streams and rivers. All stations were sampled on the same day once every two weeks from May through November, 1972.

Water samples for chemical analysis were obtained by means of a flow system through the hull of the research vessel at a point 0.5 meters below the surface. All water samples were filtered immediately using Whatman GF/C glass fiber filters and the pads and filtrate aliquots immediately stored on ice for return to AIMS. All samples were stored in the lab at -4°C until analyzed.

Temperature and salinity were measured using a Beckman Model R5-S induction salinometer. Oxygen measurements were made with a Cambridge Instruments Model 15A dissolved oxygen meter. The pH values were obtained from the flow system on the vessel using an Orion Model 404 Ionanalyzer.

Dissolved inorganic phosphorous, nitrite, ammonia, and chlorophyll pigments were performed as per Strickland and Parsons(1968). Nitrate was determined as per Strickland and Parsons(1965).

All data was punched on standard 80-column IBM cards with data processing and reduction performed on a CDC 3300 computer. Input/output formats and complete data listings are given in Appendices A and B.

Data are presented as average values for each station for the study period or as monthly averages for all stations. There are two reasons for this: (1) averages would have less tendencies to emphasize atypical conditions, and (2) past studies by WHOI and others were usually restricted to summer months providing a limited baseline for comparison. This approach may obscure short-term changes at a particular station but is adequate for a first-cut characterization of general conditions.

RESULTS

Average monthly values of each parameter for bay and river stations are given in Table 3. Average values for each parameter are listed by station in Table 4.

Salinity

Average bay-wide surface salinity values during the period of study varied from a low in June of 24.75‰ to high of 26.96‰ in September with a mean of 25.85‰.

Surface waters in the bay averaged 0.15‰ lower than bottom stations. Average surface salinity values for all river stations ranged from a low of 18.02‰ in June to a high of 23.80‰ with a mean of 21.65‰. However since instrumental accuracy is ±0.05‰, no significant differences exist between surface and bottom waters in the open bay.

Values for bottom river salinities varied from 23.31 °/oo in June to 27.48°/oo in September with a mean of 25.11°/oo. The mean salinity for surface stations in the bay averaged 4.20°/oo higher than those of the river stations. There is a close agreement between mean surface bay salinity (25.85°/oo) and mean bottom river salinities (25.11°/oo). The low surface river values and the close agreement between bay salinities and bottom river waters illustrates the salt-wedge character of the rivers where higher salinity water moves upstream along the bottom and fresh river water moves downstream on the surface. A prime example of this is the Connetquot River (Fig.2). Modifications of this type of flow pattern exist where dredging has altered the natural flow characteristics of the streams such as Brick Kiln Creek (Fig. 3) where near fjord-type conditions are obtained.

Figure 4 shows isohalines for the bay system based on the average for each station during the period of study. As can be seen, there is a general decrease in salinity values from west to east until reaching the Smith Point Bridge, at which point, salinity values begin increasing. The higher salinities in the western end of the bay can be due to two factors: (1) ocean water entering Jones Inlet and moving eastward or (2) ocean water entering Fire Island Inlet and moving westward. Previous studies (Foehrenback,

Table 3

Monthly averages for each parameter for all bay and river stations. Stations 1-25 are considered bay stations. Stations 26-39 constitute river stations.

		Salinity		Temperature		Diss. Phos.		Part. Phos.	
		Bay	Riv.	Bay	Riv.	Bay	Riv.	Bay	Riv.
		o/oo		°C		µg-atP/L		µg-atP/L	
May	T	25.71		17.30		0.25		0.83	
	B	25.78		17.21					
June	T	24.75	18.02	20.24	20.43	0.21	0.37	0.97	1.52
	B	24.86	23.31	19.96	19.78				
July	T	25.51	22.77	24.75	25.52	0.55	0.56	1.52	1.80
	B	25.54	23.98	24.66	25.27				
August	T	25.55	20.51	24.00	24.81	0.71	0.91	1.15	1.87
	B	25.61	24.79	23.93	24.49				
September	T	26.96	23.67	20.81	21.96	1.15	1.46	0.94	1.96
	B	27.16	27.48	20.85	24.82				
October	T	26.80	23.80	13.57	13.92	1.71	2.32	0.79	1.00
	B	26.88	25.95	13.64	13.88				
November	T	25.73	21.10	7.71	8.08	0.23	0.46	1.13	1.30
	B	26.20	25.12	7.79	8.04				
Average	T	25.83	21.65	18.34	19.12	0.69	1.01	1.05	1.58
	B	26.00	25.11	18.29	19.38				

Table 3 continued

		Nitrate		Nitrite		Ammonia		Chloro.		Phaeo.		N/P Ratio	
		Bay	Riv.	Bay	Riv.	Bay	Riv.	Bay	Riv.	Bay	Riv.	Bay	Riv.
		µg-atNO_3-N/L		µg-atNO_2-N/L		µg-atNH_4-N/L		µg Chl					
May	T			0.09				2.8		0.7		0.4	
June	T	6.58	20.80	0.16	1.09	3.11	7.31	4.4	46.5	1.8	2.1	46.4	79.2
July	T	0.91	5.92	0.05	0.33	0.17	0.16	7.0	18.1	2.7	3.5	2.1	11.5
August	T	1.90	3.09	0.09	0.24	1.51	0.97	5.7	17.7	3.8	6.2	4.9	4.7
September	T	1.82	10.16	0.08	0.24	1.71	0.54	5.9	25.0	3.2	8.3	3.1	7.5
October	T	7.23	15.39	0.32	0.58	5.44	2.35	7.4	10.8	11.8	0.7	7.6	7.9
November	T	6.04	17.77	0.38	0.58	2.69	1.08	12.0	15.6	4.9	6.1	40.3	40.6
Average	T	4.08	12.09	0.17	0.51	2.44	2.07	6.5	23.4	4.1	4.4	9.7	14.5

Table 4

Average values for each parameter by station.

Station	Salinity	Temp.	Oxygen	pH	DIP	Part.P.	Nitrate	Nitrite	Ammonia	N/P	Chloro.	Phaeo.
	(°/oo)	(°C)	(%Sat.)		ug-atP/L		ug-atN/L			$\frac{NO_3+NO_2+NH_4}{DIP}$	ug/l	
1	24.73	18.53	109	7.9	0.44	1.20	10.65	0.21	2.23	29.56	7.3	2.4
2	25.19	18.39	110	7.9	0.55	1.23	2.86	0.19	3.24	11.54	4.8	7.5
3	25.35	17.90	109	8.0	0.54	1.09	3.79	0.22	3.29	13.59	6.5	6.1
4	25.36	18.33	107	8.2	0.32	1.26	3.92	0.27	2.45	21.23	11.4	4.7
5	26.11	18.57	102	8.2	0.57	1.08	4.07	0.20	2.55	12.03	9.9	6.3
6	26.86	18.41	102	8.1	0.97	1.19	9.57	0.54	4.23	14.76	7.8	9.5
7	28.60	18.04	90	8.6	1.47	0.86	4.00	0.26	2.01	4.27	5.3	7.5
8	29.24	18.83	89	8.6	1.66	0.87	2.36	0.18	1.80	2.61	7.0	8.7
9	28.66	18.25	106	8.5	1.10	0.89	1.90	0.16	3.39	4.96	8.2	6.1
10	28.04	17.94	90	8.4	0.72	0.93	1.85	0.16	1.75	5.23	4.8	10.7
11	28.08	18.20	95	8.4	0.85	.94	1.99	0.20	1.75	4.60	5.5	6.4
12	27.70	17.82	88	8.1	0.71	1.01	2.88	0.14	1.60	6.48	4.5	8.7
13	26.56	17.94	88	8.2	0.39	0.91	1.44	0.15	1.08	6.86	7.1	1.4

Table 4 continued

Station	Salinity (°/oo)	Temp. (°C)	Oxygen (%Sat.)	pH	DIP ug-atP/L	Part.P. ug-atP/L	Nitrate ug-atN/L	Nitrite ug-atN/L	Ammonia ug-atN/L	N/P $\frac{NO_3+NO_2+NH_4}{DIP}$	Chloro. ug/l	Phaeo. ug/l
14	24.49	18.46	111	7.8	0.44	1.24	6.92	0.23	3.21	21.90	7.3	2.0
15	23.78	18.31	111	7.8	0.28	1.29	5.88	0.22	2.69	29.55	8.8	4.7
16	23.89	18.21	108	7.9	0.36	1.13	3.17	0.18	2.95	17.31	9.0	2.0
17	24.57	18.23	92	8.0	0.17	1.19	2.35	0.06	1.23	20.45	11.3	1.7
18	24.10	18.38	98	8.0	0.51	1.53	3.46	0.06	1.27	8.82	7.6	4.2
19	24.66	18.01	103	8.0	0.58	1.07	6.25	0.11	1.71	12.95	7.2	1.6
20	26.20	18.16	99	8.3	1.08	0.84	5.07	0.09	2.54	10.67	2.5	2.1
21	25.36	17.78	108	8.1	1.04	0.82	2.31	0.13	2.31	3.45	3.9	1.9
22	29.62	15.22	96	7.9	1.00	0.68	3.36	0.14	3.47	5.26	2.5	2.1
23	24.18	18.36	105	7.8	0.33	1.31	2.50	0.15	3.21	18.00	5.2	3.4
24	24.71	18.39	106	7.7	0.34	1.28	4.32	0.18	2.15	19.68	7.0	1.6
25	25.84	18.77	84	7.9	0.57	1.17	3.17	0.17	2.25	9.8	6.4	1.3
26	27.71	18.49	90	8.4	1.55	1.00	9.33	0.44	4.30	9.09	9.3	1.5

Table 4 continued

Station	Salinity	Temp.	Oxygen	pH	DIP	Part.P.	Nitrate	Nitrite	Ammonia	N/P	Chloro.	Phaeo.
	(°/oo)	(°C)	(%Sat.)		ug-atN/L		ug-atN/L			$\frac{NO_3+NO_2+NH_4}{DIP}$	ug/l	
27	26.00	17.94		8.3	1.19	1.40	17.53	0.88	13.05	26.36	13.0	3.8
28	24.57	18.25		8.3	0.67	1.68	18.02	0.55	8.77	40.68	19.4	10.0
29	22.74	18.34		8.3	0.63	2.07	12.11	0.67	5.38	29.01	35.5	8.2
30	25.47	18.06		8.4	0.83	1.51	7.94	0.58	4.26	15.38	18.7	4.8
31	24.86	18.21	90	8.2	0.56	1.69	7.69	1.03	3.96	22.53	11.9	4.4
32	22.73	18.52	90	8.1	0.47	1.83	9.98	0.65	4.20	31.61	24.2	4.6
33	24.68	18.59	100	8.1	0.47	1.39	5.62	0.26	3.18	19.09	10.6	2.7
34	24.36	18.79	106	8.1	0.99	1.40	3.37	0.26	3.88	7.59	12.6	2.0
35	15.88	18.30	94	7.6	0.49	1.18	23.66	0.61	6.61	62.67	10.5	2.4
36	14.56	19.03	93	7.6	0.97	2.10	29.87	0.75	6.02	37.82	15.2	5.2
37	21.68	19.58	136	8.2	0.53	1.55	6.95	0.31	1.88	15.73	21.85	7.2
38	24.70	18.01	98	7.8	1.72	1.18	7.65	0.24	3.95	6.65	7.6	2.3
39	25.43	18.08	99	7.9	2.55	1.51	6.41	0.16	2.99	3.55	10.1	2.1

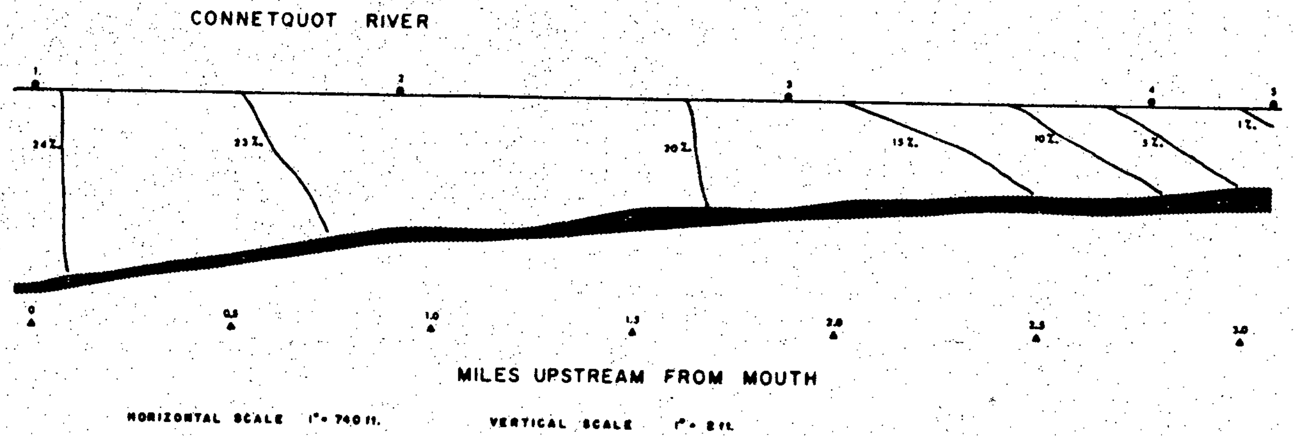

Fig. 2: Isohalines for Connetquot River illustrating the typical salt wedge flow patterns.

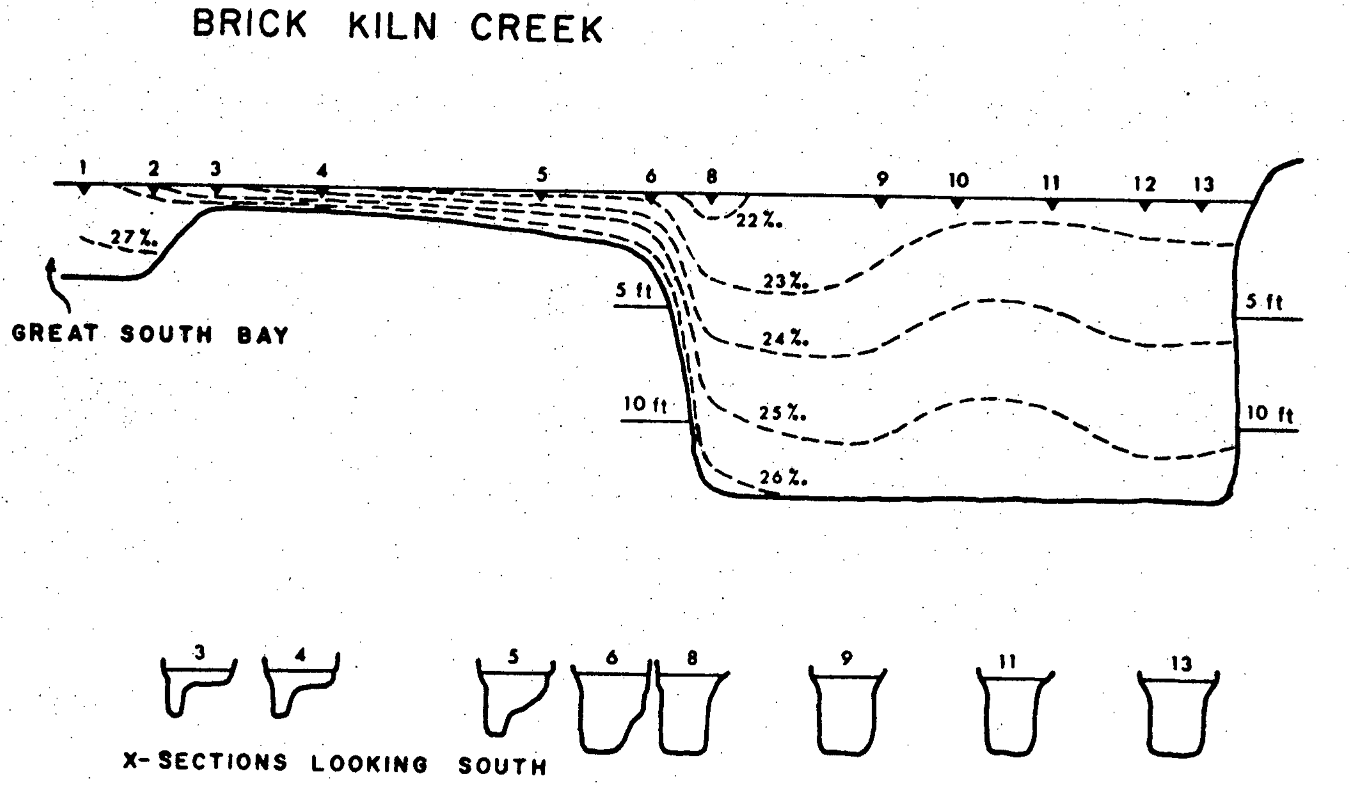

Fig. 3: Isohalines for Brick Kiln Creek illustrating fjord-type hydrography of dredged canals.

1968; Jamieson,1968; Ichiye,1966) have shown a net eastward movement of water from South Oyster Bay into Great South Bay. Highest transport volumes were obtained along the south shore of the bay, that is, between Stations 8 and 9. A significant amount of this eastward moving waters is carried out Fire Island Inlet on the ebb tide. Maximum tidal excursion during the flood tide at Fire Island Inlet (Anon.,1962) reaches a northern boundary delineated by the 27% isohaline in the vicinity of Sexton and East-West Fire Islands. The lower salinities along the north shore of the Bay reflect the addition of stream and subsurface groundwater inflow. Because the bay is not stratified, values shown represent both surface and near bottom conditions. Where significant horizontal differences exist, such as near the mouth of the Patchogue River, Vertical differences are slight until one actually enters the mouth of the river. The main reason for this is the extremely shallow nature of the bay and the marked influence of wind direction and velocity on the system.

Temperature

Average monthly temperature for surface bay stations ranged from 7.7°C in November to 24.8°C in July with a mean of 18.34°C. Bottom bay stations average only 0.05°C less than surface stations. The difference is not significant

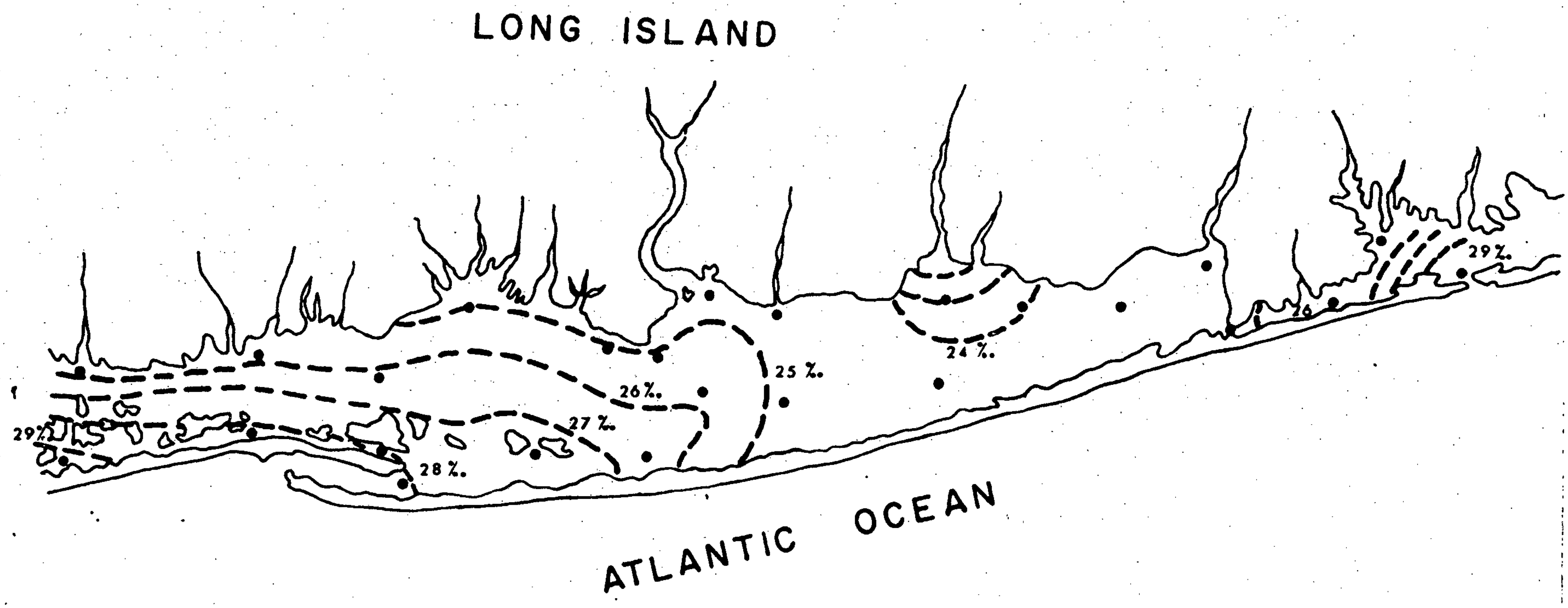

Fig. 4: Isohalines for Great South Bay based on station averages for period May-November, 1972.

since instrumental accuracy is ± 0.05°C. River stations averaged approximately 1°C higher than the bay stations, reflecting the more rapid equilibration of the streams with ambient air temperature.

Oxygen

Dissolved oxygen concentrations were measured on only four occassions during this survey due to instrument failure. The number of stations and time required to obtain valid samples prohibited the use of Winkler determinations. However, when oxygen was measured during this survey and during the three preceeding years, concentrations were consistently near or above 100% saturation. This is to be expected in a shallow, wind-driven system such as Great South Bay.

Phosphorus

Because of previous analyses of vertical stratification and salinity values obtained in this study indicating vertical homogeneity, only surface samples were taken for nutrient analyses. Dissolved inorganic phosphorus (DIP) in the bay varied from monthly low of 0.21 in June to a high of 1.71 in October with a mean of 0.69 ug-at.P/l. Average DIP values for all river stations ranged from a low of 0.37 in June to a high of 2.32 in October with a mean of 1.01

ug-at.P/l. Instantaneous phosphate values for river stations were approximately double that of the bay throughout the study. Phosphorus isopleths for the bay are shown in Figure 5.

In general isopleths for DIP show the same pattern as seen with salinity; that is, decreasing values from west to east until reaching the Smith Point Bridge. Again the influence of point sources can be seen as demonstrated by values near the Patchogue River. Obviously, had smaller increments been selected for plotting, additional detail would become evident. However, for purposes of this report, values outlined here are adequate.

Particulate phosphorus, used as an indicator of plankton concentrations and detritus, ranged from 0.79 in October to 1.52 in July with a mean of 1.05 ug-at.P/l for the bay stations. River stations varied from a low of 1.00 in October to a high of 1.96 in September with a mean of 1.58 ug-at.P/l. In general, rivers were approximately 48% higher than open bay stations.

Isopleths for particulate phosphorus are shown in Figure 6. In general, they indicate water having lower concentrations moving along the southwest side of the bay with higher values in the central bay. The general counterclockwise circulation pattern is again evident with material

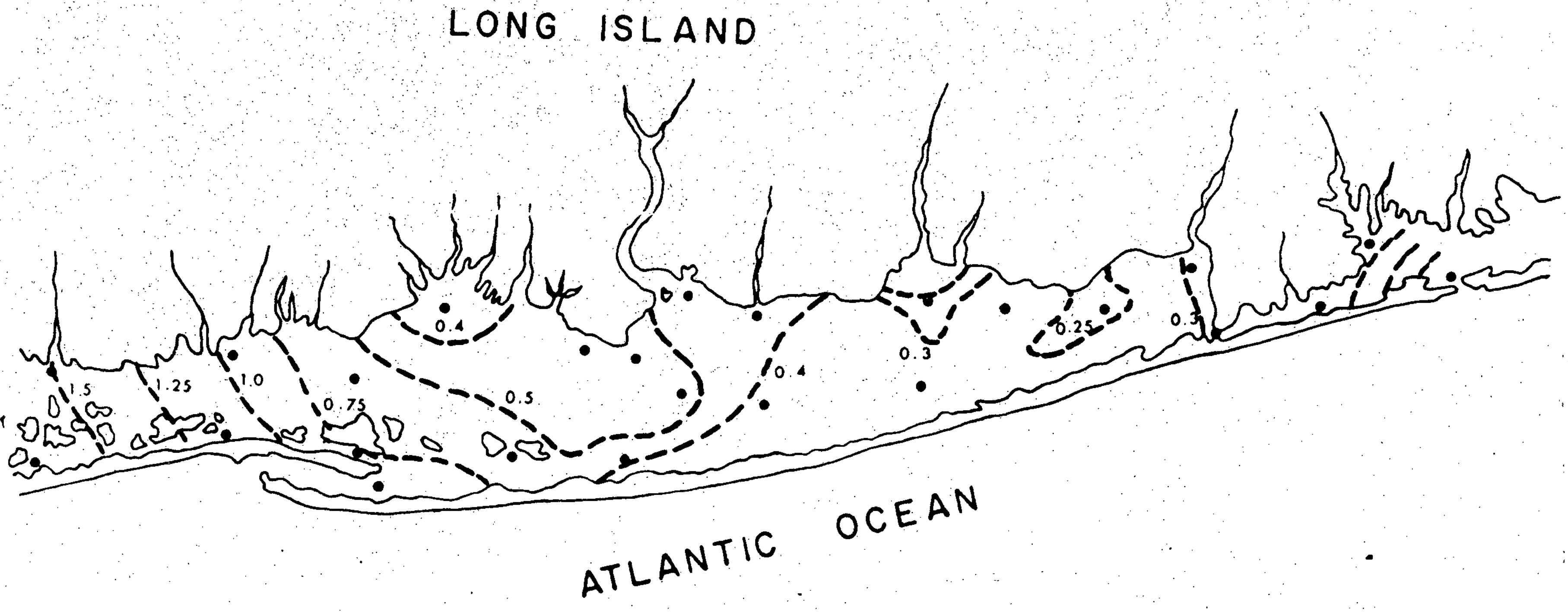

Fig. 5: Dissolved inorganic phosphorus isopleths for Great South Bay based on average station values for the period May-November 1972 - All values are in ug-at P/L.

moving eastward along the south shore and westward along the north shore. The use of the word "moving" may be misleading in some cases since particulate phosphorus cannot be used as an indicator of water mass movement *per se*. Unlike salinity, particulate phosphorus can arise *de novo* due to uptake of DIP and subsequent growth of phytoplankton and zooplankton. Therefore, isopleths could merely be indicating areas where phytoplankton growth is taking place in the absence of any movement of the water mass. It should be noted that,as expected, particulate phosphorus levels are inversly related to DIP values in this study. For example, the central gyre in the bay contains the highest particulate phosphorus values and lowest DIP values. In this particular case, hydrographic data supports the general pattern of water movement as delineated by particulate phosphorus.

Nitrate

Nitrate values for bay stations varied from a low of 0.91 in July to a high of 7.23 in October with a mean of 4.08 ug+at.NO_3-N/L. River stations ranged from a low of 3.09 in August to a high of 20.80 in June with a mean of 12.09 ug-at.NO_3-N/L and averaged approximately three times the values for the bay.

Figure 7 shows the nitrate isopleths for the bay system. Again, the eastward movement of water from South Oyster Bay is seen in the 3.0 ug-at. isopleths while the opposing flow from Moriches Bay through Smith Point can be seen extending westward towards Patchogue Bay. The marked effect of stream additions can be seen in the high values found along the north shore of the bay near stations 1 and 6. These stations are greatly influenced by inflow from Connetquot River, Santopoque River, Carll River, and Sampawams Creek. Each of these streams consistently ranked in the six highest nitrate values throughout the study period with the Brown River and Patchogue River ranking first and second respectively. The 4.0 ug-at. isopleth extends from Bellport westward to Nicoll Point. It is probable that the westward flow of water along the north shore combined with wind driven water currents restricts the distribution of water from these streams to the north shore of the bay, especially during summer months when prevailing winds are from the south-southwest. It is obvious that the major nitrate contribution to the bay is derived from the streams along the north shore. The ultimate source of the nitrate-nitrogen cannot be traced to individual outfalls, surface runoff, or subsurface groundwater movements at this time. However, the highest values were consistently obtained at the mouths of the most heavily developed streams. It is also interesting

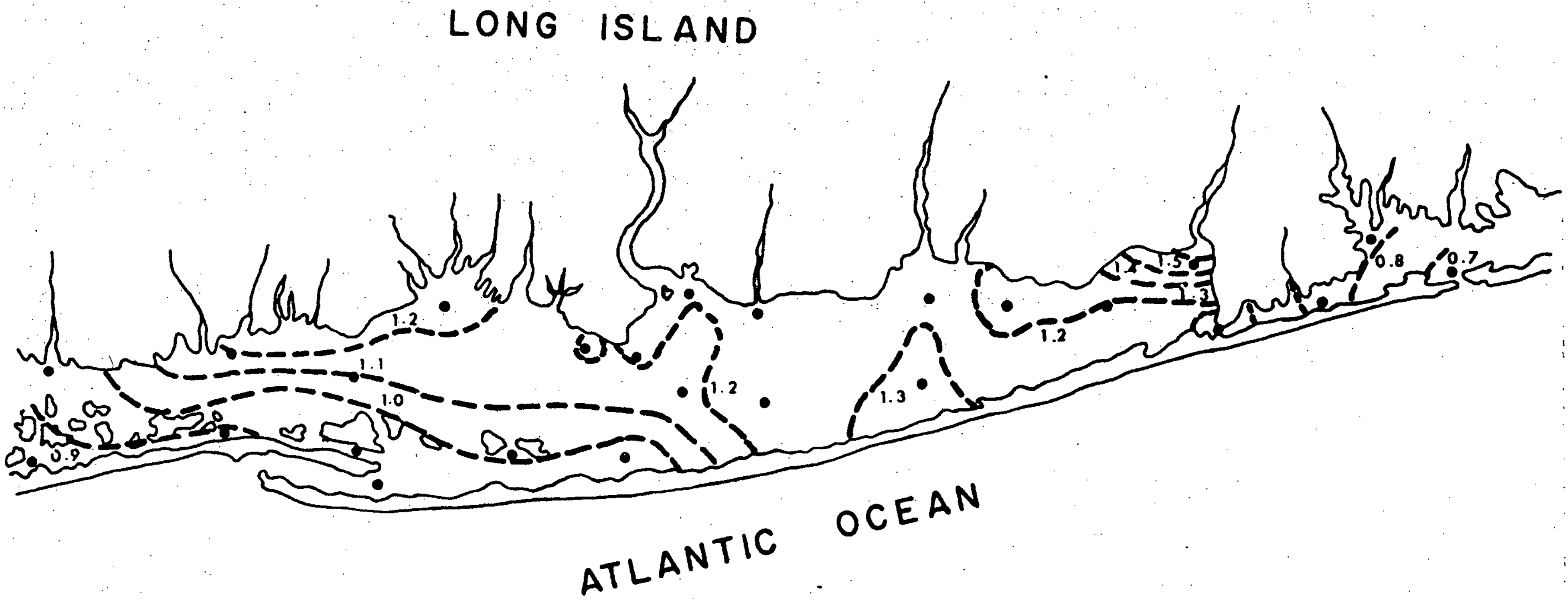

Fig. 6: Particulate phosphorus isopleths for Great South Bay based on average station values for the period May-November, 1972. All values are ug-at P/L.

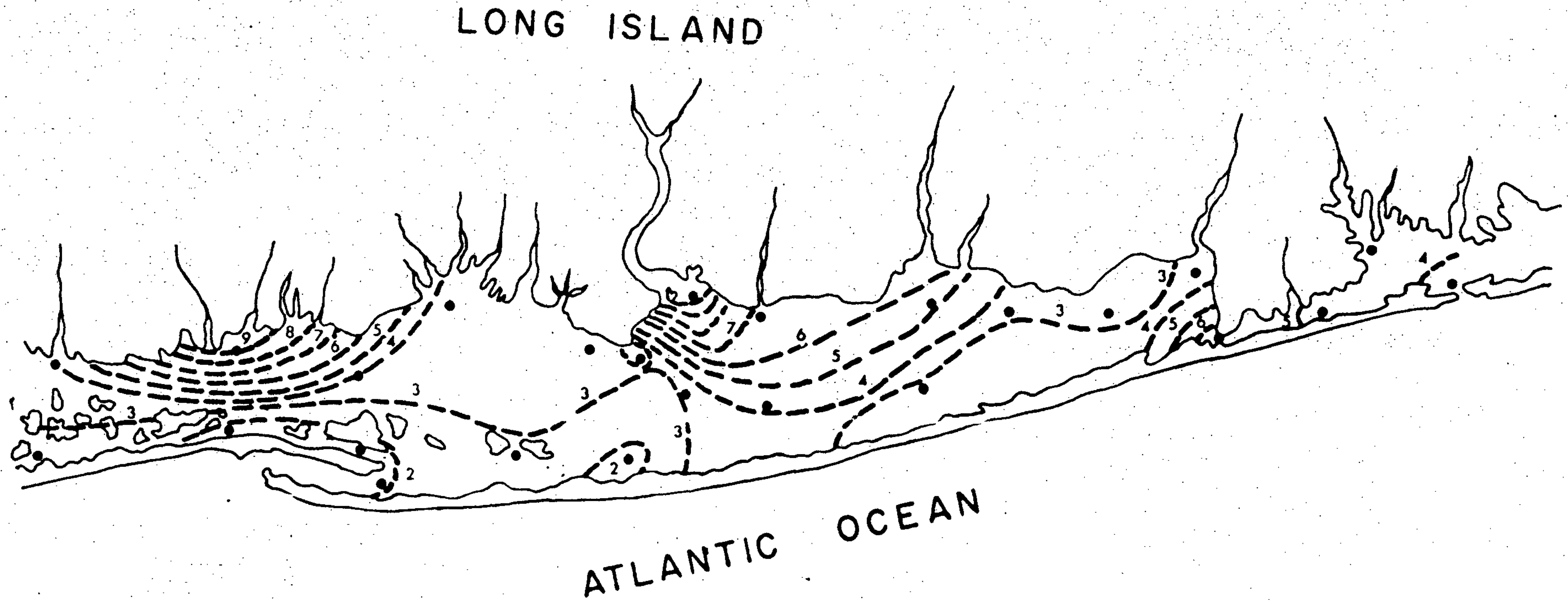

Fig. 7: Nitrate isopleths for Great South Bay based on average station values for the period May-November, 1972. All values are ug-at NO_3-N/L.

to note that the only elevated nitrate value along the south shore occurs between Ocean Beach and Point O' Woods at station 13 - the location of a sewage treatment plant on the barrier beach which discharges into the bay.

Nitrite

Nitrite values for the bay ranged from a low of 0.05 in July to a high of 0.38 in November with a mean of 0.17 ug-at.NO_2-N/L. River stations averaged approximately twice as high as the bay ranging from a low of 0.24 in August-September to a high of 1.09 in June with a mean of 0.51 ug-at.NO_2-N/L.

Nitrite isopleths (Fig.8) show similar patterns as DIP and nitrate, that is, higher values along the north shore of the bay with the lowest values associated with water moving east along the state boat channel and entering from Fire Island Inlet. The central and eastern portions of the bay show little variations in nitrite values as does Moriches Bay. As with nitrate values, the highest nitrite concentrations were consistently found in the vicinity of Santapogue River, Carll's River and Sampawams Creek.

Ammonia

Concentrations of ammonia in the bay ranged from a low of 0.17 in July to a high of 5.44 in October with a mean of 2.44 ug-at.NH_4-N/L. Average concentrations for

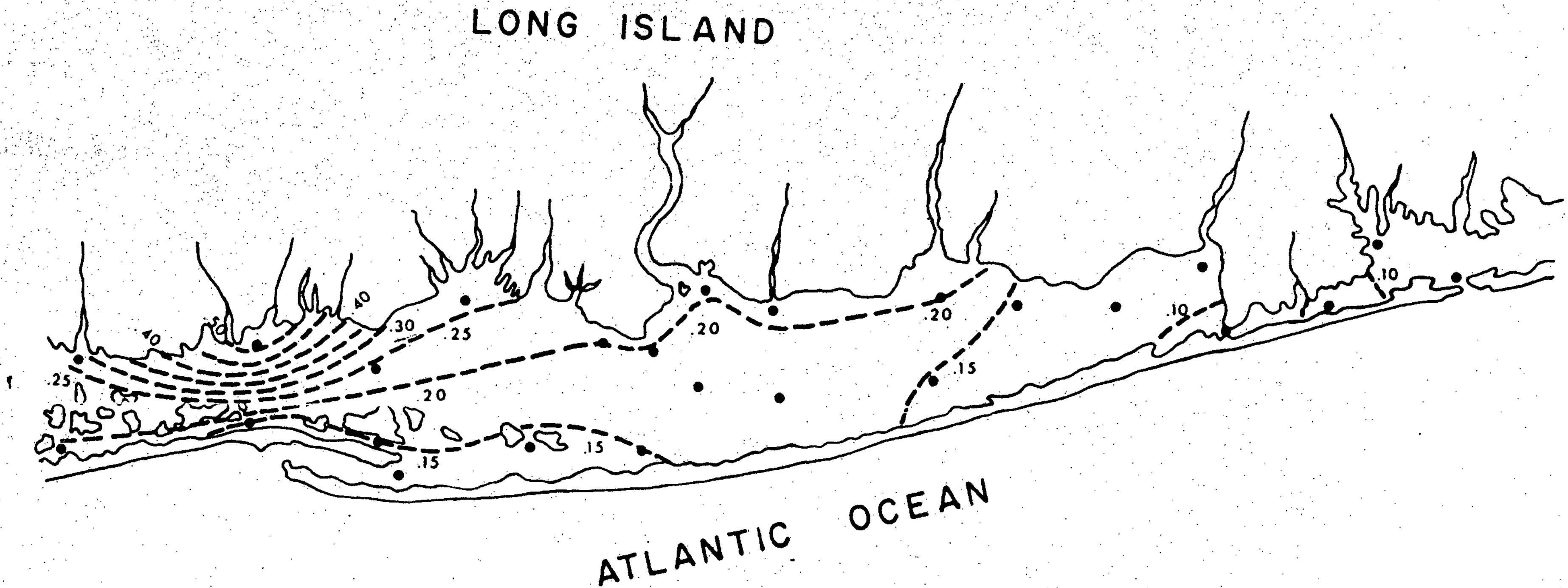

Fig. 8: Nitrite isopleths for Great South Bay based on average station values for the period May-November, 1972. All values are in ug-at. NO_2-N/L.

river stations varied from 0.16 in July to 7.31 in June with a mean of 2.07 ug-at.NH_4-N/L. Although average river values were lower than average bay levels, the highest ammonia concentrations were consistently found along the north shore of the bay (Fig.9), with highest values generally found in the western portions. Again there is the indication of eastward movement of water along the south shore and a westward movement along the north shore. As with nitrate and nitrite, it is the westward movement of water that carries the highest concentrations of ammonia. The influence of river stations is easily seen in the vicinity of Carll's River, Santapogue River, Brown River, Patchogue River, and Forge River.

Pigments

Chlorophyll a values, used as an index of phytoplankton abundance, varied from a low of 2.71 in May to a high of 12.0 in November with a mean of 6.4 ug Chl a/L. Concentrations for river stations ranged from 10.8 in October to 46.5 in June with a mean of 22.3 ug Chl a/L. Lowest values were consistently found along the south shore of the bay while high values were found along the north shore (Fig.10). In general chlorophyll values are highest in areas of highest nutrient concentrations with the exception of elevated values just west of the Carmens River(station 16 & 17).

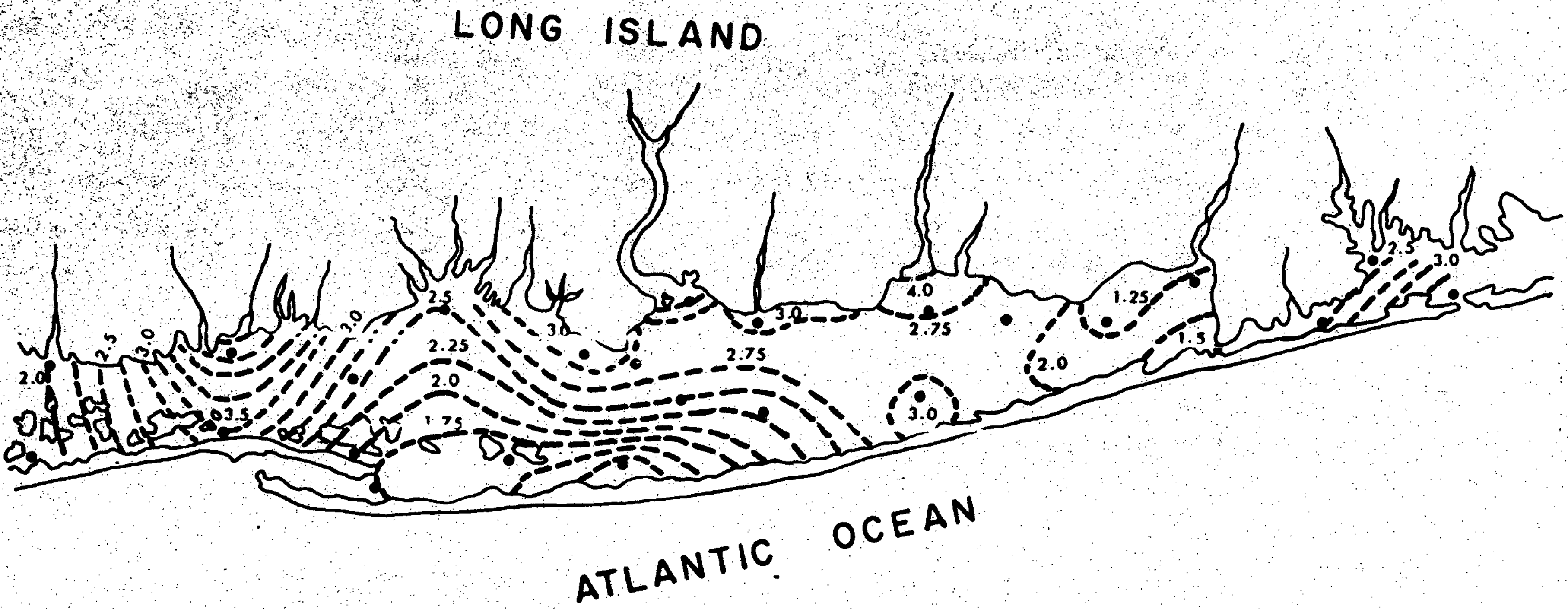

Fig. 9: Ammonia isopleths for Great South Bay based on average station values for the period May-November, 1972. All values are in ug-at. NH_4 -N/L.

Phaeophytin, used as an indicator of algal decomposition, ranged from 0.7 in May to 11.8 in October with a baywide mean of 4.1 ug/l. Average river concentrations varied from 0.7 in October to 8.3 in September with a mean of 4.5 ug/l. Since phaeophytin concentrations are a function of the abundance of phytoplankton, rates of decomposition, and physiological state of the algae, no isopleths were constructed. They are utilized here merely as supportive evidence for decomposition and release of micronutrients. For example, highest phaeophytin concentrations in the bay were recorded in October - the same period of maximum nutrient concentrations. This peak occurred immediatdy after the death of a massive *Cladophora gracilis* bloom which involved the entire western and central portion of the bay system. Maximum phaeophytin values for river stations occurred in September - coinciding with the accumulation of *Cladophora* in almost all of the rivers and canals along the north shore of the bay due to prevailing southerly winds. The picture in the rivers is not as clear-cut as in the bay due to the fact that nutrient concentrations here are modified by input from upstream, loss to the bay, and *in situ* production of a higher standing crop as evidenced by higher chlorophyll *a* values.

N/P Ratios

Nitrogen/phosphorus ratios (by atoms) represent the

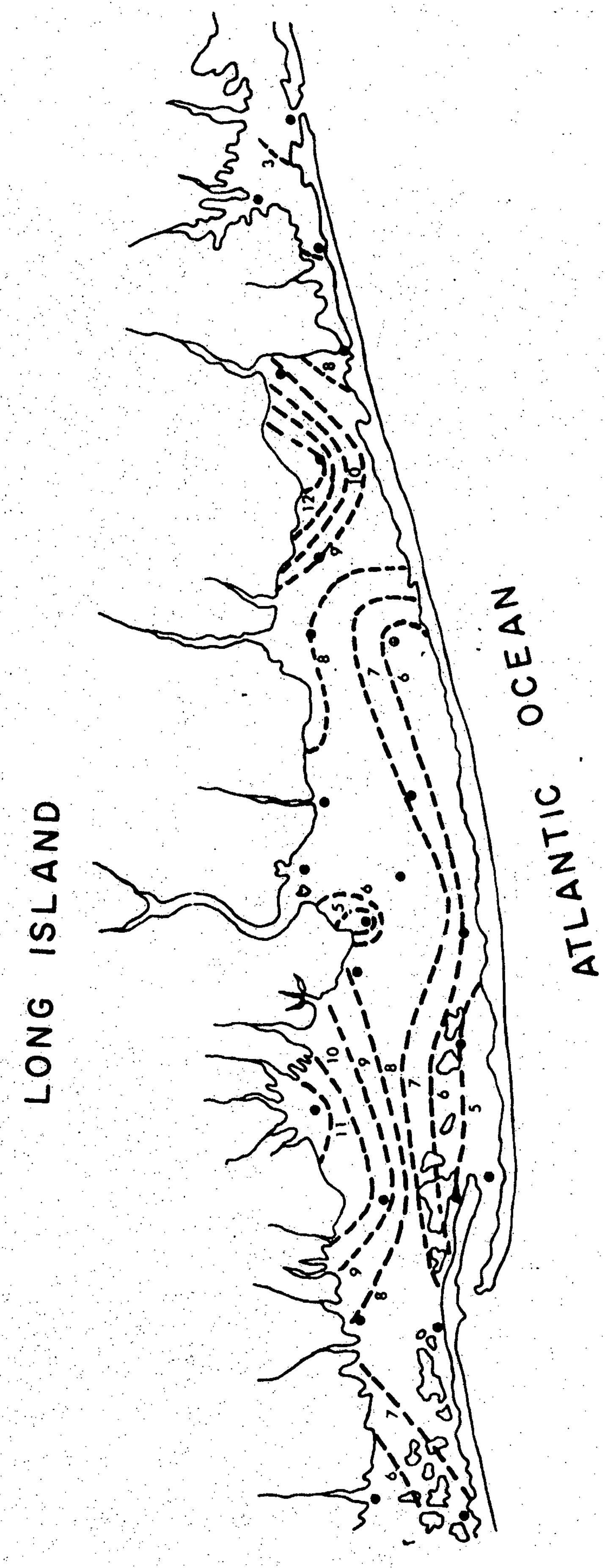

Fig. 10: Chlorophyll isopleths for Great South Bay based on average station values for the period May-November, 1972. All values are in ug. Chl a/L.

bility of the present study in planning decisions since it is precisely during this period when the "worst possible conditions" are obtained due to increased utilization by summer visitors and residents and unusual meterological conditions.

Table 6 is a compendium of all data available to date as either technical papers or personal obsdrvations. The major portion of this data is drawn from the series of reports by the Woods Hole Oceanographic Institute earried out during the period 1950-1958. Since some of these reports contain data derived from several sources cumulative effects of individual nutrient additions, relative rates of removal of each nutrient specie by phytoplankton, relative rates of release from decomposing plankton, and losses due to dilution. Nitrogen:phosphorus ratios in the bay varied from a low of 0.4:1 in May to a high of 46.4:1 in June with a mean baywide ratio of 9.7:1. Average monthly values for river stations ranged from a low of 4.7:1 in August to a high of 79.2:1 in June with a mean value of 14.5:1. Highest N/P ratios were

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and/or previous unpublished reports by the same organization, they will be referenced as "WHOI" and the reader is directed to the original reports listed in the reference section of the present study for more detailed information. As far as has been possible, values taken from these reports are limited to those areas which coincide with the station network shown in Figure 1 and are averages for either all values for an individual station or all stations for the time period under discussion. Values referenced as "AIMS" were obtained by this author while at the Adelphi Institute of Marine Science during the period 1968 to the present. Values for salinity and nutrients are not available on a bay-wide basis for the period 1960-1965. However, the Blue Point Oyster Company has maintained a record of salinity for the central portions of the bay. It is fortunate and coincidental that average salinities for this area are extremely close to the actual mathematical average for all stations in the bay. Data from this source are referenced as "BP". Precipitation values were obtained from the U.S. Department of Commerce and are based on the 28-year mean of 43.9 inches measured at Patchogue, New York.

The most obvious pnenomenon is the long-term changes in salinity levels in the bay. No baywide records are available before 1950. However, reports by baymen and some unpublished data indicate levels prior to 1938 of approximately 13.0^{o}/oo. Values estimated from WHOI data indicate average baywide values of approximately 24-26^{o}/oo in 1951 prior to the closing of Moriches Inlet. After the spontaneous closing of the inlet in 1951, salinity levels dropped to 15.4‰ (Ryther, et al, 1956). Note that upon closing of the inlet phosphorus values rose from 2.28 to 12.54 ug-at.DIP/L. Upon reopening of the inlet in 1954, salinities and phosphorus returned to preclosure levels of 25.7^{o}/oo and 2.07 ug-at.DIP/L. The same phenomenon can be seen to a lesser extent when exchange through the inlet was restricted in 1957 due to shoaling whereupon phosphorus values almost doubled. However, precipitation during this period was below normal resulting in elevated phosphorus values and high salinities, presumably due to evaporation. Upon reopening of the inlet in 1958, salinity decreased approximately 4^{o}/oo while phosphorus values dropped by a factor of three (Ryther, et al.,1958). A significant factor in the decrease of salinity and phosphorus during this period was the abnormally high amount of rainfall (11.88" above normal). It should be remembered that the period encompassed by the WHOI reports was characterized by changing inlet conditions and a highly vigorous duck farm industry.

Data from the Blue Point Company show marked increases in salinity levels in the bay for the period 1960 through 1964. This coincided with a severe drought period in the northeast as evidenced by rainfall records. It is interesting to note that even at the end of the drought in 1967, salinity values continued to increase presumably due to the lag between rainfall and rates of groundwater recharge. Salinity values returned to 25^{o}/oo in 1968 and have remained so to the present. Ambient ocean salinities off Long Island are approximately 30.5^{o}/oo. Accordingly, average bay salinities are presently approximately 85% of ambient ocean levels(Chase,1969).

There are three main points to be considered in relation to the present and past salinity regime of the bay: 1) the opening and closing of natural or artifical inlets can have marked effects on the salt balance of the bay system. 2) natural, long-term changes such as drought or rainy periods can significantly affect salinity levels in the bay. 3) the combined effects of changes in hydrography due to channel or inlet dredging and changes in freshwater imput due to increases or decreased groundwater levels can drastically affect salinities.

Because of the above factors, any development which will affect exchange of bay water with the ocean or alter the freshwater input to the bay from changing stream runoff or groundwater levels must be evaluated using the most sophisticated methods until all factors are fully understood.

As evidenced by the long-term changes in salinity, actions based on results from a few samples taken during one relatively short period of time may often indicate the atypical rather than typical condition. Alterations due to artificial manipulation of the system may not become evident for several years by which time they may have already caused irreversible changes. Only continuous updating of the data record will allow intelligent decision making.

It appears that once Moriches Inlet was reopened and stabilized in 1958, phosphorus levels began decreasing to levels found at the present time as evidenced by DIP values from 1959 to the present. Whether this decrease in phosphorus is due to increased flushing rates, a change in the biological character of the system, or much improved housekeeping on the part of duck farms cannot be answered definitively at this time.

Present phosphate values are similar to those found for the summer months by Koetzner (1966). His values for the western end of the bay vary from 0.63 to 1.25 ug-at.PO_4-P/L with a mean of 0.96 ug-at. Values for the same area in this study varied from 0.32 to 1.66 with a mean of 0.82 ug-at.PO_4-P/L. Values for DIP in Goose Creek, New York varied from 0.22 to 1.54 ug-at.PO_4-P/L with a mean of 0.81 (Hair,1968). This small embayment receives no direct industrial or domestic wastes and is probably representative of relatively undeveloped embayments on Long Island. It appears, therefore, that the phosphorus levels in the bay proper are typical for inshore waters of Long Island and have remained essentially stable since 1968. However, several rivers are contributing excess phosphate to the bay. If the ambient concentrations are taken as 0.69 ug-at. PO_4-P/L, then seven rivers are supplying phosphorus at levels in excess of bay values. Table 7 gives the ratios of station values to ambient bay levels. Values above 1.0 indicate the river is acting as a source of phosphorus for the bay. Ratios below 1.0 indicate either an *in situ* loss of phosphorus or lower concentrations entering from the watershed. The main loss of DIP is in the conversion to particulate phosphorus by phytoplankton uptake. If ratios below 1.0 are due to this uptake, particulate phosphorus and chlorophyll ratios should be elevated. In fact, there appears to be some correlation between low river/bay phosphate ratios and elevated particulate phosphorus and chlorophyll values. For example, Carll's River, Sampawams Creek, Awixia Creek, Orowoc Creek, and the Connetquot River have DIP ratios below 1.0 and particulate phosphorus and/or chlorophyll ratios higher than the mean value for all rivers. It appears, therefore, that those streams with decreased phosphate values are not necessarily carrying a lower phosphate load but that it is being trapped in the estuary as particulate phosphorus and may be released at a later time from the sediments. This situation has been pointed out in detail by McGraime (1969) for the Connetquot River.

Some estimates of the amount of phosphorus entering the bay via rivers can be obtained by summing the concentrations of dissolved and particulate phosphorus and multiplying these by the estimated discharge rates of streams entering the bay. This method assumes that all the material present in the river will reach the bay without loss to the sediments or trapping by phytoplankton uptake and that it will arrive in the form utilizable by plants. This obviously is not the case since some of the material moving out into the bay, may move back into the river on the next flood tide or settle out as detritus. However, since most of the streams have a salt wedge circulation pattern, the amount returned to the river should be quite small in relation to the total moving downstream. There have been reports (McRoy and Barsdate, 1970; Reimold, 1972) showing that material lost to sediments is often returned to the water column within short periods of time.

Table 8 shows the calculations of inputs of phosphorus and nitrogen to the system. Dissolved organic phosphorus was not measured during this study. However, values for organic phosphorus usually run approximately 60-70%

of DIP values (Hair,1968) so that calculations of the phosphorus content of the bay and the amount contributed by streams are shown corrected upward by this value. Values for rainfall are based on total phosphorus concentration and groundwater contains little or no organic phosphorus.

Since DIP values for Great South Bay have remained relatively constant since 1968, it follows that the total input of phosphorus(streamflow + groundwater + rainfall) should be equalled by losses from the water column. If, on the average, approximately 3.99 kg-at.(123 kg) is added to the bay daily, then it follows that this quantity must be lost to the ocean, trapped in bottom sediments, and/or incorporated into animal and plant biomass. No doubt all three mechanisms are active but their individual impacts cannot be fully evaluated at this time. However, some estimate of the potential amount of plant material that could be produced given this amount of phosphorus can be made. It should be remembered that these estimates are based on an instantaneous fixation. Phosphorus once incorporated into plants or animals may become available for uptake subsequently through decomposition and recycling. Therefore, these are minimum estimates.

The photosynthetic mechanism requires carbon, nitrogen, and phosphorus in an atomic ratio of 106:16:1 (Sverdrup, et al,1942; Odum, 1959). Studies have also shown that phytoplankton will assimilate these elements in this ratio (Redfield,1958; Eppley, et al, 1971). The 3.99 kg-at. of phosphorus added daily would result in the fixation of 423 kg-at. of carbon. In addition, uptake of phosphorus in the water column would result in 135 x 10^3 kg-at. of carbon fixed. As mentioned above these are estimates of potential instantaneous uptake of the phosphorus present in the water column and added from external sources.

Similar analyses can be carried out for nitrogen. However, the picture here is much more complicated due to the more numerous forms of nitrogen and the large reservoir of this element in the atmosphere. It is felt by some workers that the fixation of elemental nitrogen by epiphytes (attached algae) on sea grasses (e.g. Zostera) may be a significant source of this nutrient in estuarine areas (Goering and Parker, 1972). We have no estimate of the magnitude of this input for nitrogen in Great South Bay.

Particulate nitrogen:particulate phosphorus ratios for plankton have been found to average 6.5:1 (Strickland, 1966). Some preliminary work on these ratios for Great South Bay confirms this. Table 8 shows the calculated nitrogen content of the bay. Average particulate phosphorus values for the bay were 1.05 ug-at/L while the rivers

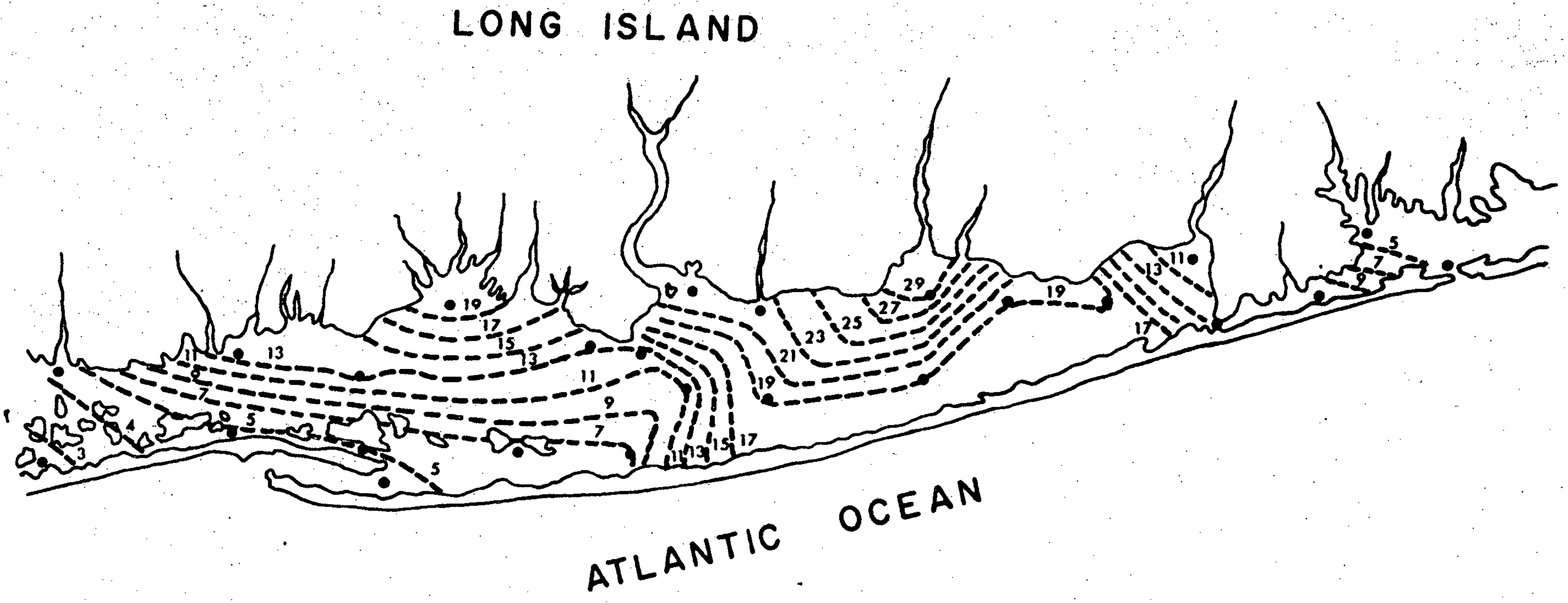

Fig. 11: N/P ratio isopleths for Great South Bay for the period May-November, 1972. All values are ug-at. NO_3+ NO_2+ NH_4 N/ug-at. DIP.

Table 5

Multiple correlation coefficients (significant at the 95% level) for each variable based on average values for each station for the study period.

	Sal.	Temp.	DIP	PP	NO_3	NO_2	NH_4	Chl a	Phaeo	N/P
Salinity	1.0000	-.4501	.3023	-.6582	-.7333	-.4372	-.2978	-.4372	.1550	-.7684
Temp.		1.0000	-.2263	.4481	.1799	.1574	-.0454	.3388	.1324	.2167
DIP			1.0000	-.1619	.0381	.0006	.1415	-.1415	-.0003	-.4380
Part.Phos.				1.0000	.5834	.6485	.4163	.8054	.1356	.5518
NO_3					1.0000	.7116	.7254	.4492	.0559	.7868
NO_2						1.0000	.7224	.6012	.2031	.5762
NH_4							1.0000	.3967	.0954	.5479
Chl a								1.0000	.2385	.4715
Phaeo									1.0000	- .0186
N/P										1.0000

Table 6

Average values for all stations in Great South Bay and Moriches Bay - Salinity is in ppt.; precipitation is inches above or below 28 year mean of 43.83 inches; DIP is ug-atP/L; Nitrate, Nitrite, and Ammonia are ug-atN/L; N/P ratio is by atoms; and, chlorophyll is in ug/L.

Year	Inlet Cond.	Sal.	Precip.	Phos.	NO_3	NO_2	NH_4	N/P	Chloro.
1950WHOI	Both open	~13°/oo	-5.77	1.60					
1951WHOI	M.I. closed	~25	+0.21	2.28					
1952WHOI	M.I. closed	15.4	-2.89	12.54	0.89	0.05		~10:1	
1953	M.I. closed		+6.85						
1954WHOI	M.I. open	25.7	+9.34	2.07	1.30	0.06			
1955	M.I. open		+2.21						
1956WHOI	M.I. open	25.3	-0.72	2.09	0.32	0.22	4.40	2.36	4.7
1957WHOI	M.I. prt.closed	25.0	-7.18	4.55		2.51		0.55	25.3
1958WHOI	M.I. open	21.5	+11.88	1.34		2.10		1.57	11.4
1959SHOI	M.I. open	23.2	+0.93	2.27		0.98			8.4
1960BP	M.I. open	21.9	-1.84						
1961BP	M.I. open	22.1	+3.16						
1962BP	M.I. open	23.1	-2.39						
1963BP	M.I. open	24.4	-12.41						
1964BP	M.I. open	26.2	-3.82						
1965AIMS	M.I. open	27.3	-18.77	1.23					
1966	M.I. open		-10.57						
1967	M.I. open		+2.52						
1968AIMS	M.I. open	27.1	-2.14	0.60					
1969AIMS	M.I. open	25.5	+4.71	0.86					
1970AIMS	M.I. open	25.7		0.82					
1971AIMS	M.I. open			0.65					
1972AIMS	M.I. open	25.7	>20"	0.66	4.08	0.17	2.44	9.7	5.7

Table 7

Ratios for dissolved phosphorus, particulate phosphorus, and chlorophyll a values to ambient bay values.

Station	DIP river/DIP Bay	PP river/PP Bay	Chl river / Chl Bay
26-Amityville Creek	2.25	0.95	1.43
27-Santapogue River	1.72	1.33	2.00
28-Carll River	0.97	1.60	2.98
29-Sampawams Creek	0.91	1.97	5.47
30-Willet Creek	1.20	1.43	2.88
31-Awixa Creek	0.81	1.61	1.84
32-Orowoc Creek	0.68	1.74	3.73
33-Champlin Creek	0.68	1.32	1.64
34-Quintuck Creek	1.43	1.33	1.94
35-Brown River	0.71	1.12	1.61
36-Patchogue River	1.41	2.00	2.34
37-Connetquot River	0.84	1.48	3.37
38-Senix Creek	2.58	1.12	1.17
39-Forge River	3.90	1.44	1.55
Average	1.43	1.46	2.43

Table 8

Estimates of phosphorus and nitrogen inputs to Great South Bay

	Phosphorus Conc.	Nitrogen Conc.	N/P
Volume of Great South Bay[1]	@1.74ug-atP/L[3]	@6.69ug-atN/L[6]	
580×10^{9} liters	$=1.01\times10^{3}$ kg-at	$=3.88\times10^{3}$ kg-at	3.84
Volume of streamflow[1]	@2.59ug-atP/L[3]	@14.67ug-atN/L[7]	
680×10^{6} liters/day	=1.76kg-at/day	=9.98kg-at/day	5.67
Volume of subsurface flow[1]	@0.029mg/L[4]	@0.54mgNO_2-N/L[4]	
792×10^{6} liters/day	=0.74kg-at/day	=30.6kg-at/day	41.35
Volume of rainfall[2]	@0.034mg/L[5]	=0.35tons/yr/sq.km.[8]	
266×10^{9} liters/Yr.	=.80kg-at/day	=5.73kg-at/day	7.16
Corrected for DOP and	@65% of DIP	@6.83ug-at.part.N/L	
Part. N. in Bay	$=1.27\times10^{3}$ kg-at	$=7.84\times10^{3}$ kg-at	6.17
Corrected for DOP and	@65% of DIP	@24.94ug-at.part.N/L	
Part. N. in streams	=2.45kg-at/day	=16.96kg-at/day	6.92
Total daily increment[9]	=3.99 kg-at/day	=53.29kg-at/day	13.36
Total yearly increment	=1,456kg-at/yr.	=19,450kg-at/yr.	13.36

Table 8 cont'd

	Phosphorus Conc.	Nitrogen Conc.	N/P
Potential carbon fixation[10]			
Total Bay	$=135\times10^3$kg-at	$=51.9\times10^3$kg-at	
Total from daily increment	=423kg-at/d	=353kg-at/d.	

1 - Values from Foehrenback, 1968.
2 - Estimated from U.S. Dept. Commerce, U.S. Weather Bureau, Patchogue, New York.
3 - Includes DIP and Part. P.
4 - U.S. Dept. Interior, U.S. Geological Survey Water Supply Paper 2091(1968)
5 - U.S. Dept. Interior, Geological Survey, Water Resource Data for New York, 1968-1969.
6 - Includes average values for NO_3-, NO_2-, and NH_4-nitrogen.
7 - Based on average nitrate, nitrite, and ammonia nitrogen for all streams
8 - Pearson, F.J. and D. Fisher, 1971. Chemical composition of atmospheric precipitation in the Northeastern United States. U.S. Geol. Surv. Water Supply Paper 1535-P.
9 - Includes streamflow, subsurface flow and rainfall
10- Based on corrected values for bay and daily increment.

Table 9

Ranking of rivers by N/P ratios compared to average bay ratio of 9.7:1

Station	Name	Ratio	% Difference from 9.7:1
35	Brown River	62.7	646
28	Carll's River	40.7	419
36	Patchogue River	37.8	389
32	Orowoc Creek	31.6	325
29	Sampawams Creek	29.0	299
27	Santapogue River	26.4	272
31	Awixa Creek	22.5	232
33	Champlin Creek	19.1	197
37	Connetquot River	15.7	162
30	Willet Creek	15.4	159
26	Amityville Creek	9.1	94
34	Quintuck Creek	7.6	78
38	Senix Creek	6.7	69
39	Forge River	3.6	37

averaged 1.58. Using 6.5 as the conversion factor, particulate nitrogen in the bay would be approximately 6.83 ug-at. N/L and 10.27 ug-at. N/L in the rivers. These values are used as correction factors for the nitrogen content of the bay and streams. An additional source of nitrogen not accounted for is dissolved organic nitrogen(DON).

Daily nitrogen additions to the bay are 53.29 kg-at. which would result in the potential fixation (if all nitrogen were available for uptake by phytoplankton) of 353 kg-at. C/day. This estimate would be increased by inclusion of DON.

N/P ratios based on inorganic nitrogen factions and DIP averaged 9.7:1 for the bay during the study period whereas calculations based on total daily inputs of phosphorus and nitrogen (minus DON and N_2 fixation) to the bay system have an average ratio of 13.4:1. This is highly significant, for nitrogen and phosphorus are being added to the bay at approximately the ratio that Ryther and Dunstan (1971) indicate as requirec by inshore plankton. Several rivers are supplying nitrogen and phosphorus at ratios greater than the 10:1 ratio and, therefore, are potential sources of eutrophication for the bay. This is especially true when the absolute concentrations of the individual nutrients are considered.

Table 9 ranks each river in relation to the ambient bay ratio of 9.7:1. The low ratio found in the Forge River and Senix Creek are not due as much to the presence of low levels of nitrogen as to the elevated levels of phosphorus. These two creeks still support large duck farms, the effluent from which is characterized by low N/P ratios and high amounts of phosphorus. Notice that Quintuck Creek, the only stream almost completely surrounded by salt marsh and with little domestic development has the lowest N/P ratio of all other rivers studied.

It should be noted that N/P ratios and absolute concentrations of inorganic nitrogen have increased since the WHOI surveys in the 1950's (Table 6). At that time nitrogen was the limiting factor in the bay system. Since then, inorganic nitrogen levels have risen to the point where they are now close to or above limiting concentrations.

It appears, therefore, that total nitrogen and phosphorus are present in the bay system in approximately a 13:4 ratio by atoms. By additions and remineralization, the N/P ratio of inorganic nitrogen and phosphorus in the water column is maintained at approximately 9.7:1. Since inshore plankton generally require these elements in a ratio of approximately 10:1, it would appear the system as a whole is slightly enriched. However, since the elevated ratios in the bay can be traced directly to rivers and streams emptying into the bay, the continued enrichment of the bay can be controlled by limiting the additions of nitrogen to the bay via rivers and streams. The addition of secondary sewage effluent to the bay either by covert sources or overt additions from treatment plants can only cause to further aggrevate the problem. Effluent standards for these sources should be set with the requirements of nutrient limitation in mind. Since phosphorus is almost always found in excess in this and other inshore areas, limitations of this nutrient without concurrent nitrogen control will not result in any significant decrease in the rates of eutrophication.

In general, the Great South Bay system is in a rather precarious state from a nutrient standpoint especially considering the intensive development of its shoreline and pressures from recreational and commercial interests. The continued health of the bay depends on the intelligent establishment of controls to prevent further degradation.

SUMMARY AND RECOMMENDATIONS

1. Alterations in the freshwater input or changes in flushing ratio of the bay will have significant effects on the salinity regime of the system. The magnitude of the effects cannot be determined at this time without updated hydrologic and hydrographic studies. These should be initiated as soon as possible and before major projects are undertaken which could cause these alterations.
2. Phosphorus levels in the bay have remained essentially stable since 1968. However, certain rivers, notably the Amityville Creek, Santapogue River, Senix Creek, and Forge River are contributing excess phosphate to the bay system.
3. Nitrogen levels in the bay as a whole are approaching non-limiting concentrations. Any attempt to control increasing enrichment of the system should include provisions for reducing the nitrogen additions to the bay. This is particularly true for additions such as secondary sewage effluent which is normally high in nitrogen.
4. Due to general circulation patterns, increased development along the north shore of the bay, resulting in increased nutrient additions, will cause

accumulation of these materials along the north shore especially in the western portions. This condition could further exaccerbate the problem of summer blooms of macroalgae.

5. Additional studies on the phosphorus and nitrogen budgets of the system should be initiated to determine the maximum load of these nutrients which can be allowed to enter the bay.
6. Due to the increased pressures on the system, updating of data on an annual basis is essential for intelligent management decisions.

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